



## APPLICATION FOR VDOT MATERIALS TECHNICIAN CERTIFICATION

This is to affirm that \_\_\_\_\_ (Technician's Name), hereinafter "Technician," desires to be certified by the VDOT as an **Concrete Plant Technician**. By making this Application, Technician acknowledges and agrees that Certification carries inherent rights and responsibilities. The rights include being exclusively sanctioned, along with others so certified by VDOT, to perform sampling, testing, and reporting of test results for quality acceptance, quality control and assurance programs. The responsibilities include performing and reporting tests with the accuracy and precision expected of the Technician in accordance with the required test procedures.

By signing this Application, Technician agrees to strive to maintain compliance with all rules, regulations, specifications, industry standards, procedures and policies, applicable to any work performed under the Certification. A violation of the above as determined by the VDOT Technician Certification Review Board may result in a suspension or revocation of the rights and responsibilities conferred on the Technician. Revocation or suspension of one Certification may be considered a revocation or suspension of all Certifications held by the Technician. Further, any suspension or revocation of Technician's Certification in any other jurisdiction may result in the VDOT Technician Certification Review Board taking the same or other action, against Technician's Certification in Virginia.

By signing below, Technician also affirms that he/she is aware that both State and Federal laws may govern construction projects in Virginia, including Title 18, United States Code, Section 1020, that states, in pertinent part, that anyone making falsifications on Federal-aid projects,

**"Shall be fined not more than \$10,000 or imprisoned not more than five years, or both."**

I, \_\_\_\_\_ (Print Name), affirm that I have read and fully understand the foregoing "APPLICATION FOR VDOT TECHNICIAN CERTIFICATION," and I agree to be bound by these terms.

\_\_\_\_\_  
Technician's Signature

\_\_\_\_\_  
Date



**Virginia Department of Transportation  
Concrete Plant Certification**

**First Day**

7:30 am - 8:00 am	Registration
8:00 am - 10:00 am	Chapter 1 – Components of Concrete
10:00 am – 11:30 am	Chapter 2 - Sieve Analysis, Fineness Modulus
11:30 am - 12:30 pm	Lunch
12:30 pm - 5:00 pm	Chapter 3 - ACI Concrete Mix Design Allowable Field Adjustments

**Second Day**

8:00 am - 9:00 am	Chapter 4 - Moisture Content and Batch Weight Calculations
9:00 am – 9:30 am	Chapter 5 – Inspection of Plant and Equipment
9:30 am – 10:00 am	Chapter 6 - Responsibilities of Producer and VDOT Materials Technician
10:00 am - 11:30 am	Chapter 7 - Automated Data Processing
11:30 am – 12:30 pm	Lunch
12:30 pm - 3:30 pm	Exam

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**Test:** Open Book: 50 multiple choice

**Proficiency:** 6 Math problems (35 questions)- given on same day as test

**Grading:** Must score a 70% or better on test and proficiency to pass

**Exam Results:** Exam results will be visible at the completion of the test. Exam results can be found on VDOTU. Non-VDOT personnel can find their results at the following website: <https://virtualcampus.vdot.virginia.gov/external> . If you do not know your login and password, DO NOT create a new account, call (804)328-3158 or [MaterialsCertification@vdot.virginia.gov](mailto:MaterialsCertification@vdot.virginia.gov) or [VDOTUniversity@vdot.virginia.gov](mailto:VDOTUniversity@vdot.virginia.gov) for login information and any questions.

All exams must be completed by **November 30, 2021**

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# 1

## Components of Concrete

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Concrete is made up of two components, aggregates and paste. Aggregates are generally classified into two groups, fine and coarse, and occupy about 60 to 80 percent of the volume of concrete. The paste is composed of cement, water, and entrained air and ordinarily constitutes 20 to 40 percent of the total volume.

In properly made concrete, the aggregate should consist of particles having adequate strength and weather resistance and should not contain materials having injurious effects. A well graded aggregate with low void content is desired for efficient use of paste. Each aggregate particle is completely coated with paste, and the space between the aggregate particles is completely filled with paste. The quality of the concrete is greatly dependent upon the quality of paste, which in turn, is dependent upon the ratio of water to cement content used, and the extent of curing. The cement and water combine chemically in a reaction, called hydration, which takes place very rapidly at first and then more and more slowly for a long period of time in favorable moisture conditions. More water is used in mixing concrete than is required for complete hydration of the cement. This is required to make the concrete plastic and more workable; however, as the paste is thinned with water, its quality is lowered, it has less strength, and it is less resistant to weather. For quality concrete, a proper proportion of water to cement is essential.

### Desirable Properties of Concrete

**Durability:** Ability of hardened concrete to resist deterioration caused by weathering, chemicals, and abrasion

**Workability:** Ease of placing, handling, and finishing

<b>Weather Resistance:</b>	Resistance to deterioration caused by freezing and thawing, wetting and drying, and heating and cooling
<b>Erosion Resistance:</b>	Resistance to deterioration caused by water flow, traffic, and wind blasting
<b>Chemical Resistance:</b>	Resistance to deterioration caused by de-icing salts, salt water, sulfate salts
<b>Water Tightness:</b>	Resistance to water infiltration
<b>Strength:</b>	Capacity to resist loading - Compressive strength refers to resistance of compressive loads (being pushed together), as compared to Tensile strength which refers to resistance to tension forces (pulling apart)
<b>Economy:</b>	Cost of the mix (including materials/components, batching, transportation, placement, and finishing) as compared to the effectiveness of the mix

## Ingredients in Concrete

### Hydraulic Cement

Portland Cements and Blended Cements are hydraulic, since they set and harden to form a stone-like mass by reacting with water. The term Hydraulic Cement is all inclusive and is the newer term to be used for both Portland Cement and Blended Cement.

The invention of Portland Cement is credited to Joseph Aspdin, an English mason, in 1824. He named his product Portland Cement, because it produced a concrete which resembled a natural limestone quarried on the Isle of Portland.

The raw materials used in the manufacturing of cement consist of combinations of limestone, marl or oyster shells, shale, clay and iron ore. The raw materials must contain appropriate proportions of lime, silica, alumina, and iron components. Selected raw materials are pulverized and proportioned in such a way that the resulting mixture has the desired chemical composition. This is done in a dry process by grinding and blending dry materials, or in a wet process by utilizing a wet slurry. In the manufacturing process, analyses of the materials are made frequently to ensure a uniform high quality Portland Cement.

After blending, the prepared mix is fed into the upper end of a kiln while burning fuel, producing temperatures of 2600 °F to 3000 °F, is forced into the lower end of the kiln. During the process, several reactions occur which result in the formation of Portland Cement clinker. The clinker is cooled and then pulverized. During this operation gypsum is added as needed to control the setting time of the cement. The pulverized finished product is Portland Cement. It is ground so fine that nearly all of it passes a sieve having 40,000 openings per sq. inch.

There are five types of Portland Cement (Types I, II, III, IV, V) and two types of Blended Cement (Types I-P, I-S). Each type is manufactured to meet certain physical and chemical requirements for specific purposes.

**Type I** is a general-purpose cement. It is suitable for all uses when the special properties of the other types are not required.

**Type II** cement is used when sulfate concentrations in ground water are higher than normal. Type II will usually generate less heat at a slower rate than Type I or Normal cement. Therefore, it may be used in structures of considerable mass, such as large piers, heavy abutments, and heavy retaining walls. Its use will minimize temperature rise, which is especially important in warm weather pours.

**Type III** is a high-early-strength cement which will develop higher strength at an earlier age. It is used when early form removal is desired. Richer mixes (higher cement content) of Types I and II may be used to gain early strength.

**Type IV** cement is used in massive structures, such as dams. This type of cement is used where the heat generated during hardening is critical.

**Type V** cement is used in concrete exposed to severe sulfate action, and is used mainly in the western section of the United States.

**Type I-P** blended cement is a combination of Portland Cement and a pozzolan. A pozzolan, such as fly ash, by itself has no cementing qualities, but when combined with moisture and calcium hydroxide (in the Portland Cement) it produces a cementing effect.

**Type I-S** blended cement is a combination of Portland Cement and blast-furnace slag. The slag constitutes between 25 and 65 percent of the weight of the blended cement.

Basically, Hydraulic Cements may be considered as being composed of the following compounds:

- Tricalcium Silicate (C<sub>3</sub>S)
- Dicalcium Silicate (C<sub>2</sub>S)
- Tricalcium Aluminate (C<sub>3</sub>A)
- Tetracalcium Aluminoferrite (C<sub>4</sub>AF)

It is not necessary to memorize these chemical formulas; however, do become familiar with the contribution each compound makes to the concrete.

**Tricalcium Silicate** hydrates and hardens rapidly and is largely responsible for initial set and early strength. **Dicalcium Silicate** hydrates and hardens slowly and contributes to strength increases at ages beyond one week. **Tricalcium Aluminate** causes the concrete to liberate heat during the first few days of hardening and it contributes slightly to early strength. Cement with low percentages of this compound are especially resistant to sulfates (Types II and Type V). **Tetracalcium Aluminoferrite** formation reduces the clinkering temperature, thereby assisting in the manufacture of cement. It hydrates rapidly but contributes very little to strength.

**Table 1. Chemical and Compound Composition and Fineness of Some Typical Cements**

Types of Portland Cement		Potential Compound Composition %*				Blaine Fineness m <sup>2</sup> /kg
ASTM	CSA	C <sub>3</sub> S	C <sub>2</sub> S	C <sub>3</sub> A	C <sub>4</sub> AF	
I	Normal	55	19	10	7	370
II		51	24	6	11	370
III	High-Early Strength	56	19	10	7	540
IV		28	49	4	12	380
V	Sulfate-Resisting	38	43	4	9	380

\* "Potential Compound Composition" refers to the maximum compound composition allowable by ASTM C150 calculations using the chemical composition of the cement. The actual compound composition may be less due to incomplete or altered chemical reactions.

## Properties of Hydraulic Cement

**Fineness:** Fineness of cement affects heat released and the rate of hydration. Greater cement fineness increases the rate at which cement hydrates and thus accelerates strength development.

**Setting Time:** Initial set of cement paste must not occur too early; final set must not occur too late. The setting times indicate that the paste is or is not undergoing normal hydration reactions. Setting time is also affected by cement fineness, water-cement ratio, admixtures and gypsum. Setting times of concrete do not correlate directly with setting times of pastes because of water loss to air or substrate, and because of temperature differences in the field as contrasted with the controlled temperature in the testing lab.

**False Set:** False set is evidenced by a significant loss of plasticity without the evolution of much heat shortly after mixing. Further mixing without the addition of water or mixing for a longer time than usual can restore plasticity.

**Heat of Hydration:** Heat of hydration is the heat generated when cement and water react. The amount of heat generated is dependent chiefly upon the chemical composition of the cement. The water-cement ratio, fineness of the cement, and temperature of curing also are factors.

**Specific Gravity:** Specific gravity of Portland Cement is generally about 3.15. The specific gravity of a cement is not an indication of the cement's quality; its principal use is in mixture proportioning calculations.

## Shipping and Storage of Cement

Cement shall be measured by weight. Cement in standard packages need not have its weight determined, but bulk cement and fractional packages shall have their weight determined within an accuracy of 1 percent.

## Mixing Water for Concrete

Almost any natural water that is drinkable is satisfactory as mixing water for making or curing concrete. However, water suitable for making concrete may not necessarily be fit for drinking.

The acceptance of acidic or alkaline waters is based on the pH scale which ranges from 0 to 14. The pH of neutral water is 7.0. A pH below 7.0 indicates acidity, and a pH above 7.0 indicates alkalinity. The pH of mixing water shall be between 4.5 and 8.5.

Unless approved by tests and the Engineer, water that has not been approved for drinking shall not be used. Water from the following sources should not be used:

1. Water containing inorganic salts such as manganese, tin, zinc, copper, or lead;
2. Industrial waste waters from tanneries, paint and paper factories, coke plants, chemical and galvanizing plants, etc.;
3. Waters carrying sanitary sewage or organic silt; and
4. Waters containing small amounts of sugar, oil, or algae.

Wash water can be reused in the concrete mixture provided it is metered and is 25 percent or less of the total water. A uniform amount of wash water must be used in consecutive batches, with subsequent admixture rates adjusted accordingly to produce a workable concrete that conforms to the specifications. The total water must conform to the acceptance criteria of ASTM C1602, Tables 1 and 2.

## Aggregates for Concrete

Aggregates must conform to certain requirements and should consist of clean, hard, strong, and durable particles free of chemicals, coatings of clay, or other fine materials that may affect the hydration and bond of the cement paste. The characteristics of the aggregates influence the properties of the concrete.

Weak, friable, or laminated aggregate particles are undesirable. Aggregates containing natural shale or shale like particles, soft and porous particles, and certain types of chert (hard, fine-grained sedimentary rock composed of crystals of quartz (silica) that are very small) should be especially avoided since they have poor resistance to weathering.

## Characteristics of Aggregates

**Resistance to Freeze Thaw:** (Important in structures subjected to weathering) – The freeze-thaw resistance of an aggregate is related to its porosity, absorption, and pore structure. Specifications require that resistance to weathering be demonstrated by the magnesium sulfate test (AASHTO T103 or T104).

**Abrasion Resistance:** (Important in pavements, loading plat-forms, floors, etc.) - Abrasion resistance is the ability to withstand loads without excessive wear or deterioration of the aggregate.

**Chemical Stability:** (Important to strength and durability of all types of structures) - Aggregates must not be reactive with cement alkalis. This reaction may cause abnormal expansion and map-cracking of concrete.

**Particle Shape and Surface Texture:** (Important to the workability of fresh concrete) - Rough textured or flat and elongated particles, due to their high surface area, require more water to produce workable concrete than do rounded or cubical aggregates

**Grading:** (Important to the workability, and the amount of water and cement required of fresh concrete, see Fig. 1) - The grading or particle size distribution of an aggregate is determined by sieve analysis.

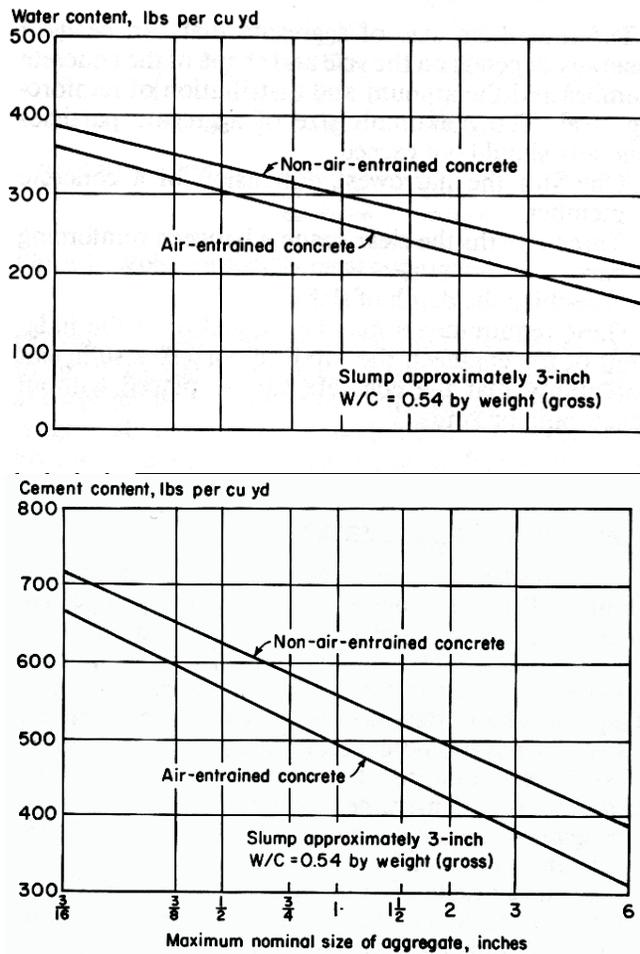


Fig. 1. Cement and water contents in relation to maximum size of aggregates, for air-entrained and non-air-entrained concrete. Less cement and water are required in mixes having large, coarse aggregate.

**Specific Gravity (Density):**

The specific gravity of an aggregate is the ratio of its weight to the weight of an equal volume of water at a given temperature. Most normal weight aggregates have a specific gravity ranging from 2.4 to 2.9. It is not a measure of aggregate quality. It is used for certain computations in a mix design.

## Absorption and Surface Moisture:

The moisture conditions of aggregates are shown in Fig. 2. They are designated as:

- a. **Oven-Dry:** fully absorbent
- b. **Air-Dry:** dry at the surface but containing some interior moisture, thus somewhat absorbent
- c. **Saturated Surface-Dry:** neither absorbing water from, nor contributing water to, the concrete mix
- d. **Wet with Free Moisture:** containing an excess of moisture on the surface

Batch weights of materials must be adjusted for moisture conditions of the aggregates.

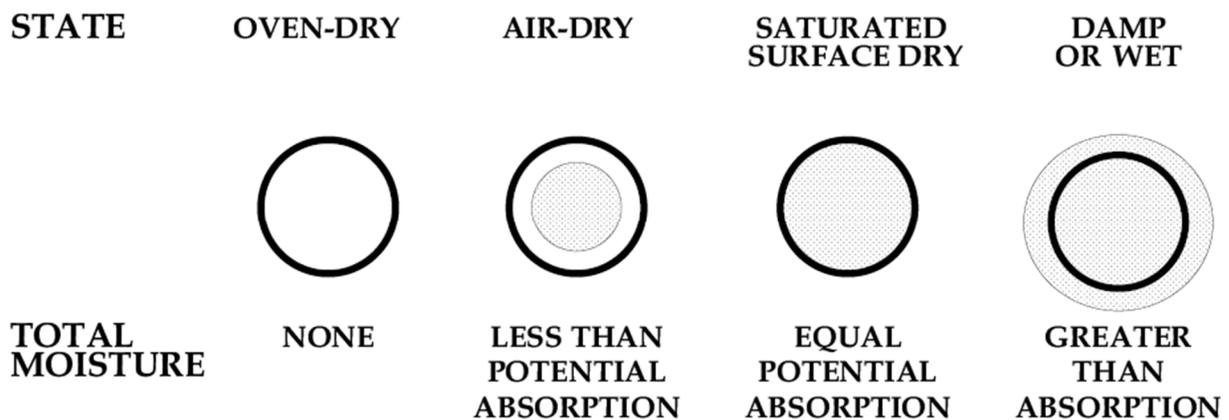


Fig. 2. Moisture conditions of aggregates

## Dry-rodded Unit Weight:

Dry-rodded unit weight is the mass (weight) of one cubic meter (foot) of dry coarse aggregate that is compacted, by rodding in three equal layers, in a standard container. For any one aggregate, the dry-rodded unit weight varies with the size and gradation.

## Deleterious Substances in Aggregates

Harmful substances and their effect on concrete include the following:

1. **Organic Impurities:** affect setting time and hardening, and may cause deterioration
2. **Material finer than the #200 (75 $\mu$ m) sieve:** affect bond and increases water demand
3. **Lightweight Materials** (coal, lignite): affect durability, and may cause popouts and stains
4. **Soft Particles:** affect durability and wear resistance
5. **Friable Particles:** affect workability and durability, break up in mixing, and increase water demand
6. **Clay Lumps:** absorb mixing water or cause popouts

## Admixtures for Concrete

Admixtures include all materials other than cement, water and aggregates that are added to concrete. Admixtures can be broadly classified as follows:

1. Air-entraining admixtures
2. Retarding admixtures
3. Water-reducing admixtures
4. Accelerating admixtures (Used only in special circumstances)
5. Pozzolans
6. Workability agents
7. Miscellaneous, such as permeability-reducing agents, gas forming agents, and grouting agents
8. Water reducing and retarding admixtures
9. Water reducing and accelerating admixtures (Used only in special circumstances)

Concrete should be workable, finishable, strong, durable, watertight, and wear-resistant. These qualities can often be obtained by proper design of the mix using suitable materials without resorting to admixtures (except air-entraining admixtures). There may be instances, however, when special properties such as extended time of set, acceleration of strength, or a reduction in shrinkage may be desired. These may be obtained by the use of admixtures. However, no admixture of any type or amount should be considered as a substitute for good concreting practices.

The effectiveness of an admixture depends upon such factors as the type and amount of cement, water content, aggregate shape, gradation and proportions, mixing time, slump, and the temperature of the concrete and air. Trial mixes should be made to observe the compatibility of the admixture with other admixtures and job materials as well as the properties of the fresh or hardened concrete.

## Air-Entraining Admixtures

An air-entrained concrete contains microscopic air bubbles that are distributed, but not interconnected, through the cement paste. The air bubbles are small and invisible to the naked eye. Visible entrapped air voids occur in all concrete and the amount of entrapped air is largely a function of aggregate characteristics. Variations in air content can be expected with variations in aggregate proportion and gradation, mixing time, temperature and slump. Adequate control is required to ensure the proper air content at all times. Since the amount of air-entraining agent per batch is small [3 to 8 oz. (110 to 300 ml) per cubic yard (meter) of concrete], it is important to disperse the agent in the plastic concrete to insure proper spacing and size of air voids, which are significant factors contributing to the effectiveness of air-entrainment in concrete.

## Effect of Entrained Air on Concrete

<b>Workability:</b>	Air-entrainment improves workability. Sand and water contents are reduced. The plastic mass is more cohesive and looks and feels “fatty” or “workable”. Segregation and bleeding of the mix are reduced.
<b>Freeze-Thaw Resistance:</b>	Freeze-thaw resistance is improved as the air voids act as reservoirs to relieve the pressure as water freezes. This prevents damage to the concrete.
<b>Resistance to De-icing:</b>	Surface scaling is reduced.
<b>Sulfate Resistance:</b>	Air-entrainment improves sulfate resistance.

**Strength:**

Reduction in strength is minimized because the improved workability allows a lower water-cement ratio. Strength depends upon the voids-cement ratio. "Voids" is defined as the total volume of water plus air (entrained and entrapped).

**Abrasion Resistance:**

About the same as non-air-entrained concrete of the same compressive strength.

**Watertightness:**

Watertightness of air-entrained concrete is superior to that of non-air-entrained concrete. Low water-cement ratio makes the concrete more impermeable.

## Factors Affecting Air Content

### Coarse Aggregate Gradation:

There is little change in air content when the maximum size of aggregate is increased above 1½ in. (37.5 mm). For aggregate sizes smaller than 1½ in. (37.5 mm), the air content increases sharply as the size decreases because of the increase in mortar volume. (See Fig. 3.)

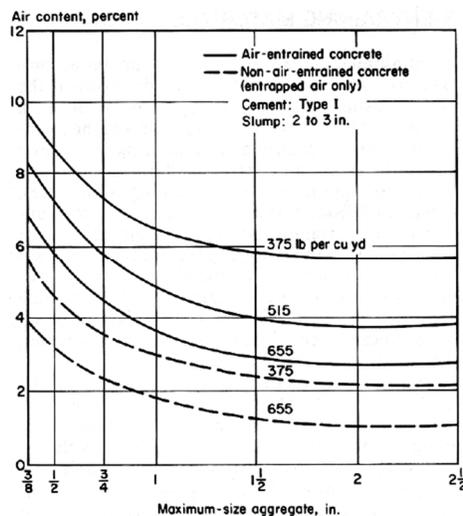


Fig. 3. Relationship between aggregate size, cement content, and air content of concrete. The air-entraining admixture dosage per unit of cement was constant for air-entrained concrete.

**Fine Aggregate Content:** An increase in the amount of fine aggregate causes an increase in air content with a given amount of air-entraining agent. (See Fig. 4.)

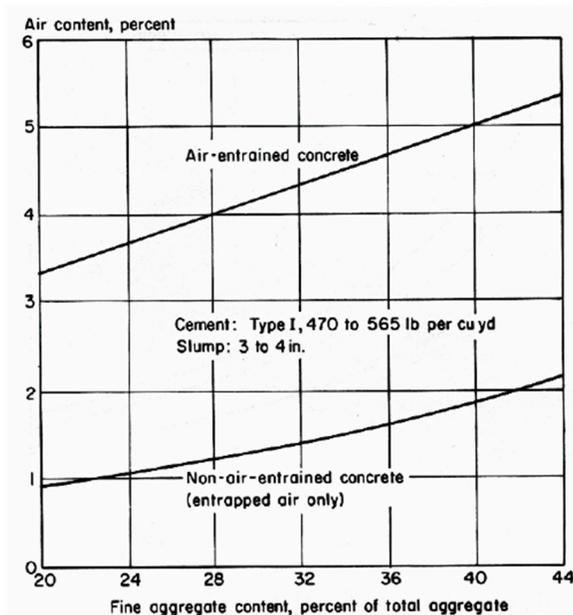


Fig. 4. Relationship between percentage of fine aggregate and air content of concrete.

**Cement Content:** As the cement content increases, the air content decreases.

**Consistency:** The air content increases as the slump increases up to about 7" (175 mm), and decreases with further increases in slump.

**Vibration:** Prolonged vibration should be avoided. Regardless of the slump, 15 seconds of vibration causes a considerable reduction in air content. If vibration is properly applied, little of the intentionally entrained air is lost. Air lost during handling and vibration consists mostly of large bubbles (entrapped air) which are usually undesirable from a standpoint of strength and durability.

**Temperature:**

Less air is entrained as the temperature of the concrete increases. (See Fig. 5)

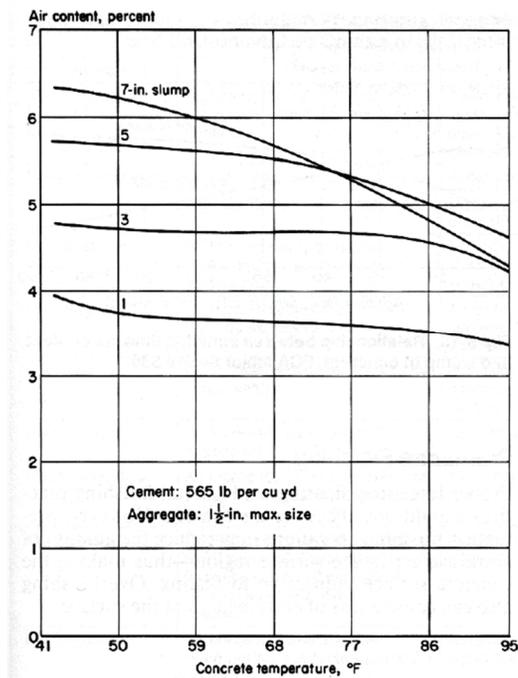


Fig. 5 Relationship between temperature, slump, and air content of concrete.

**Mixing Action:**

The amount of entrained air varies with the type and condition of the mixer, the amount of concrete being mixed, and the rate of mixing. Fig. 6 shows the effect of mixing speed and mixing time in a transit mixer. Fig. 7 shows the effect on air content as agitating time is increased.

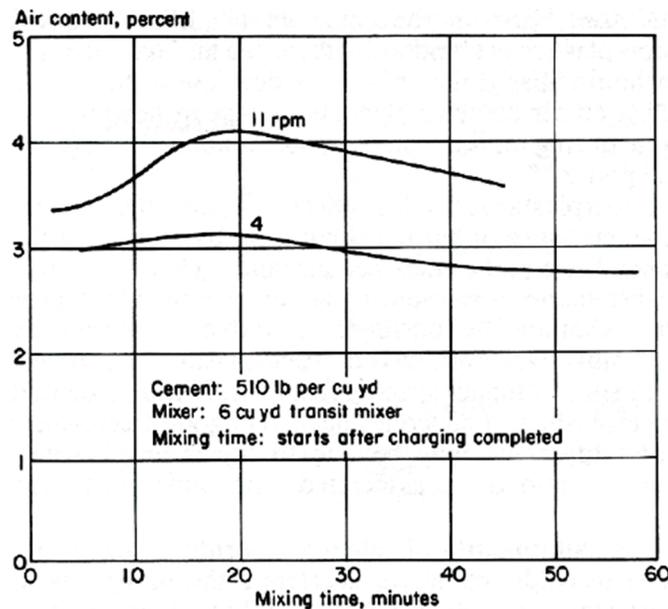


Fig. 6. Relationship between mixing time and air content of concrete.

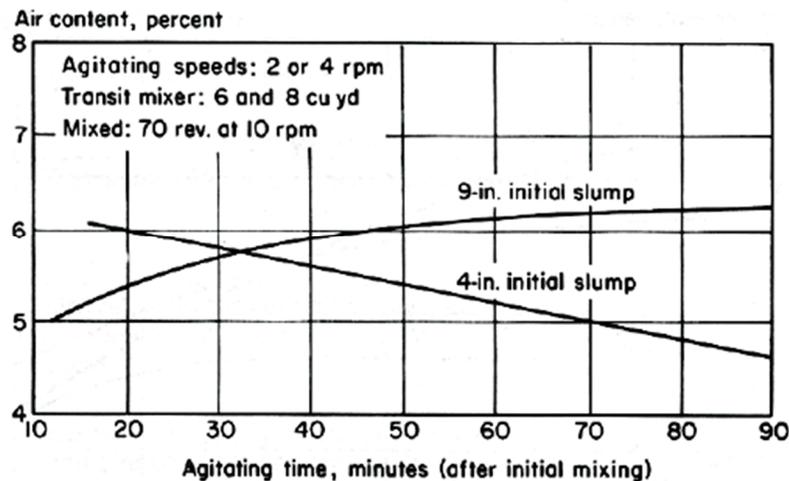


Fig. 7. Typical relationship between agitating time, air content and slump of concrete.

The amount of air specified in air-entrained concrete depends on the type of structure and the extent of exposure to de-icing chemicals, freeze-thaw cycles, and chemically reactive soil or water.

## Retarding Admixtures

A retarding admixture is a material that is used for the purpose of delaying the setting time of concrete. Retarders are used in concrete to:

1. Offset the accelerating effect of hot weather on the setting of concrete.
2. Provide time for difficult placing or finishing in such items as bridge decks or large piers.

Most retarders also function as water reducers. They are frequently called “water-reducing retarders.” Some retarders also entrain air in concrete. A retarded concrete may lose slump faster than a non-retarded concrete. Because some retarders react with certain air-entraining agents, they are introduced into the mixing water separately.

Acceptance tests of retarders with cements for each design mix and cement content are necessary to determine whether the materials are compatible.

## Water Reducing Admixtures

A water-reducing admixture is a material used for the purpose of reducing the quantity of mixing water required to produce concrete of a given consistency. These materials increase the slump of concrete for a given water content. For a given slump, the water reduction possibly amounts to about 5%.

Many water-reducing admixtures may also retard the setting time of concrete. Some also entrain air in concrete. An increase in strength can generally be obtained with water-reducing admixtures if the water content is reduced and if the cement content and slump are kept the same. A rapid loss in slump and a significant increase in drying shrinkage can result from the use of some of these admixtures. Therefore, trial batch tests should be made with job materials.

## Accelerating Admixtures

An accelerating admixture is used to accelerate the setting and the strength development of concrete. The development of strength of concrete can also be accelerated by:

1. Using Type III Cement (high-early-strength cement);
2. Lowering the water cement ratio, or increasing the cement content; and
3. Curing at higher temperatures.

Most of the commonly used accelerators cause an increase in the drying shrinkage of concrete. Calcium chloride is the most commonly used accelerating admixture. Calcium chloride and other materials used as accelerators are not antifreeze agents. When used in normal amounts, they will not reduce the freezing point of concrete by more than a few degrees.

Calcium chloride should be added in solution form as part of the mixing water in amounts not to exceed two percent by weight of cement. A greater amount can result in placement problems and can be detrimental to concrete, since it may cause rapid stiffening, increase drying shrinkage, and corrode reinforcement steel. The addition of no more than two percent of calcium chloride has no significant corrosive effect on ordinary steel reinforcement provided the concrete is of high quality.

Most commercial admixtures contain calcium chloride and are not recommended for use in items such as:

1. Prestressed concrete,
2. Concrete with steel reinforcement, or
3. Concrete subject to alkali-aggregate reaction.

However, there are more and more admixtures available without calcium chloride, which overcome the concerns with these items.

Virginia Specifications do not allow the use of an accelerator except in special circumstances.

## Mineral Admixtures

Fly Ash and Granulated Iron Blast-Furnace Slag are two of the mineral admixtures available for use in concrete.

They may be used to replace a portion of the cement in a concrete mix. This replacement is usually made for economic reasons, but the quality of the mix can be maintained if certain precautions are taken. Actually, some properties such as sulfate resistance and cement-alkali reactions may be improved when mineral admixtures are used.

The fly ash approved for use as an admixture for concrete must meet certain chemical and physical requirements. The type of fly ash available in this area has pozzolanic properties. Pozzolans are siliceous materials which themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide to form compounds having cementitious properties. Fly ash is a residue collected from the exhaust gases of a coal burning boiler (usually from an electrical power plant). Coal has in it certain minerals which cannot be burned, and the very fine ash that goes up the exhaust stack is termed fly ash.

A portion of the residue is unburnt carbon, which tends to filter out the air entraining agent. This reduction in air content can be further increased because of the fineness of fly ash when compared to cement, and it is not uncommon for the air content to be very low if the air entraining admixture dosage is not increased. The properties listed above and the effect on air content make it necessary to monitor air contents more frequently.

Granulated iron blast-furnace slag is a glassy, granular material formed when molten blast-furnace slag is rapidly chilled. The slag is composed of various silicates and oxides similar to those in Portland Cement, and as such it has some cementitious properties of its own. It also has the finely divided silica, associated with pozzolans, thereby functioning similar to the fly ash. It is permitted to replace a much higher percentage of cement.

## High Range Water Reducers

High range water reducing and retarding admixtures are water reducers which permit large reductions in the water cement ratio, or provide large increases in the consistency. This can be accomplished with relatively small dosages of the admixture. It is possible to make no-slump concrete and produce a workable concrete. It is also possible to take a normal specification concrete and increase the consistency to the flowable range of greater than 8 inches (200 mm) of a slump. Because the slump cone is limited in its ability to measure high slumps, the maximum slump should be about 7 inches (175 mm).

These admixtures have a very limited time duration before the benefits of increased consistency have been lost, which can create finishing problems. Caution should be exercised in the use of these admixtures and the selection of applications where they will provide a benefit. Trial batching is recommended prior to use.

The Contractor shall use only admixtures (air-entraining, water-reducing and retarding, water-reducing, accelerating, high-range water-reducing, and high-range water-reducing and retarding) that appear on the Materials Division Approved Products List.

## Bridge Deck HCC (HCC = hydraulic cement concrete)

Virginia Road and Bridge Specifications (VRBS) reference: Section 217.12

In an effort to reduce concrete cracking on bridge decks, VDOT specifies a Low shrinkage Class A4 modified HCC using either shrinkage reducing admixture (maximum cementitious materials is 600 pounds per cubic yard) or lightweight coarse aggregate (maximum cementitious materials is 650 pounds per cubic yard and a maximum density of 120 lbs./ft<sup>3</sup> unless specified otherwise).

## Precast HCC

VRBS reference: Section 302

At times HCC precast producers submit precast mix designs with the nominal maximum size coarse aggregate smaller than the specified in Table II-17 for the specified class in order to achieve better consolidation. This is acceptable for precast concrete provided all other aspects of contract specifications governing the acceptance of HCC are met.

## Pavement HCC

VRBS reference: Section 316

HCC pavement may be opened to traffic if

1. the modulus of rupture strength tested on a beam in accordance with ASTM C78 (third point loading) has reached a minimum of 600 psi or,
2. the pavement is at least 14 days old.

The Maturity Test Method (ASTM C1074) may be used to determine the opening to traffic strength. However, the acceptance test for pavement HCC is the compressive strength in accordance with ASTM C39 (Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens) for the specified class of HCC. In addition, air content, consistency, and other tests are performed.

HCC pavement will also be checked for depth in accordance with VTM 26, by drilling cores from the completed pavement. Drilling cores for depth check will be performed by the District Materials Section.

## Overlay HCC

VRBS reference: Section 217.13 and 217.14

HCC for bridge deck or pavement overlays may use one or more mineral admixtures (silica fume, latex, Class F fly ash, ground-granulated blast furnace slag or a combination of these) in the mix design. Generally, No. 67, No. 78 or No. 8 grade coarse aggregate is used and determined by the depth of the overlay in conjunction with the presence of reinforcing steel.

## Specialty Concretes (including Self-Consolidating, Lightweight, Drilled Shaft, Mass and Roller-Compacted Hydraulic Cement Concrete)

Depending upon project conditions, some HCC mixes must meet additional requirements for special applications. Special Provisions may be inserted into contracts that place additional specifications on the HCC supplied to a project and override the VDOT Road and Bridge Specification book. Special Provisions must be reviewed carefully to ensure all requirements are met. An example of not reading a Special Provision is as follows:

A contractor obtains a bid price on a particular class of HCC from the producer. Unless the contractor informs the producer that the HCC must meet additional contract

requirements, the HCC producer will submit a bid based upon the price of a generically approved mix design. However, the Special Provision may dictate the following:

- Additional ingredients such as more or less cementitious materials and/or admixtures
- Placement procedures such as pumping or use of high-density pavers have supplemental testing requirements such as the use of the maturity meter or temperature-matched curing for the HCC before the mix design is approved and during construction.

For this reason, the producer should be informed of the contract requirements for the HCC specified as far in advance as possible. Specialty HCCs may include SCC, lightweight, drilled shaft, mass and roller-compacted HCC. These specialty concretes are considered separately below.

## Self-Consolidating Concrete (SCC)

VRBS reference: Section 217.11

SCC is often made by using a higher cementitious content, decreasing the coarse aggregate content, increasing the fine aggregate content, using viscosity modifying admixtures and additional high-range water reducers. Adding excess water above the maximum permitted water cement ratio is not acceptable to achieve increased flow. Water/cementitious material ratios for SCC mixes are generally less than 0.4. The chemical admixture manufacturer/supplier's technical representative is a good source for mix design information. SCC mixes do not follow the ACI 211 mix design process, but rely more on plant/field experience. SCC is more susceptible to segregation than most typical VDOT HCC mixes. Instead of performing the slump test (ASTM C143), the slump flow (ASTM C1611) and the J-ring (ASTM C1621) tests are performed. The slump flow test evaluates the ability of the SCC to flow and rates the SCC on its tendency to segregate based upon a visual stability index. Typical contract acceptance values for the visual stability index test are "0" or "1". The J-ring test evaluates the ability of the SCC to flow around steel. A typical value of the slump flow test is 20 to 29 inches depending on the application. The value for the J-ring test is generally no more than 2 inches less than the slump flow test value. If segregation is seen in the HCC mix, generally the moisture content of the sand is inconsistent or there is not enough fine material. Cylinders for strength and permeability are cast in accordance with ASTM C1758. The best application for SCC is where:

- there is heavy congestion of steel,
- there is little room for internal vibration and
- the resulting HCC surface is relatively flat and smooth.

## Lightweight Concrete (LWC)

VRBS reference: Section 206 (Lightweight Aggregate)

VDOT uses LWC in prestressed bridge beams and concrete decks. When a structure is designed with LWC, the elements are of less weight per unit volume than normal weight HCC. There are three types of LWC:

- All lightweight HCC consists of both lightweight coarse and fine aggregates.
- Sand lightweight HCC consists of normal weight fine (sand) and lightweight coarse aggregates. This is the LWC that VDOT typically specifies.
- Specified density lightweight HCC which is a blend of normal weight and lightweight aggregates designed to achieve a specified density.

The preferred method of accepting LWC based upon density is by performing ASTM C138 (Unit Weight) on the fresh HCC. Typical values of fresh HCC density for normal weight HCC is about 145 pcf, whereas all or sand LWC is less than 120 pcf. ACI 211 defines the mix design process for lightweight HCC. Common problems with LWC include:

- Inconsistency in the mix due to variation in the moisture content of the aggregate; which draws attention to the importance of proper pre-wetting of the LW aggregates.
- Over-vibrating during placement resulting in segregation

## Drilled Shaft SCC (DSC)

The drilled shaft HCC Special Provision requires SCC. The special provision also requires the Contractor to supply details of the DSC placement, including proposed operational procedures for free fall, tremie or pumping methods. The proposed Concrete Placement Plan shall ensure that sufficient DSC is at the job site or in transit to the job site so that the entire placement can be accomplished without delay. The Concrete Placement Plan shall also include the following:

- The location of the HCC plant, number of trucks, estimated delivery times, estimated time between trucks, and number of trucks at the site before placement begins.
- Indicate the use of tremie or HCC pump, de-airing lines, details of the seal to be used at the bottom end of the tremie or HCC pump line.
- Breakdowns of HCC plants, trucks, or traffic problems shall be considered under this Concrete Placement Plan.
- Include an estimate of the HCC placement and over-placement time per drilled shaft.

If required on the plans, a trial shaft is constructed. Testing of DSC is as described under “SCC or Self-Consolidating Concrete”. Tremie or pumped DSC for drilled shafts has an additional requirement for the slump test (ASTM C143) to ensure that the first load placed is still as workable as the last load is placed since the first load rises to the top as HCC is continuously placed. Typically, a DSC trial batch is required. If the DSC is to be tremied or pumped, the Contractor shall demonstrate that the DSC mix can maintain at least a 4-inch slump throughout

the anticipated time of DSC placement. As the DSC is tremied and moves to the surface of the drilled shaft, the DSC must remain in a plastic state, otherwise the HCC will freeze, lock or plug the shaft to the point where no additional DSC can be pumped into the shaft. On some projects a steel sleeve is placed into the drilled shaft. If a 4-inch slump is not maintained throughout the entire DSC placement, the HCC can bond to the steel sleeve. If this occurs and the steel sleeve is specified to be removed after the DSC placement, it may not be possible to remove the steel sleeve. Furthermore, DSC has a low permeability specification where the trial batch permeability value must be 500 coulombs below the specification maximum. Free fall is discouraged and is allowed only if approved by the Engineer because during the fall, especially when the HCC hits the reinforcement cage, segregation is possible.

## Mass HCC or Mass Concrete (MC)

MC is defined by the American Concrete Institute (ACI) 116R as: any volume of concrete with dimensions large enough to require that measures be taken to cope with the generation of heat from hydration of the cement and attendant volume change, to minimize cracking. Given this definition, the question, “What is MC” will still arise. Some references may designate MC as any HCC with a minimum dimension of 3 feet; others may stipulate 5 feet. The uncertainty is due to many factors such as:

- the geometry of the element,
- the ingredients, especially the amount of portland cement,
- the initial HCC temperature, and
- the environment

will affect the generation of heat.

However, VDOT will identify on the contract plans what structure or what part of a structure is MC or specify a minimum dimension in the special provision. When referring to that part of a structure identified as MC, the MC must meet the contract requirements found in the “Mass Concrete Special Provision.” The special provision requires that temperature sensors be placed into the structure at designated locations. The temperature during the MC curing process must not exceed a specified temperature maximum for any given sensor. Also, the maximum temperature differential between any two sensors is defined. To meet these requirements, the MC mix design allows for more of the Portland cement be replaced with a mineral admixture than is normally permitted. Class F Fly ash contents in excess of 30% and slag contents in excess of 50% are common. Additionally, some HCC producers will take into consideration the structural design and use computer programs to optimize their MC mix design. ACI 211 provides guidance to develop MC mix designs. Some design engineers will specify the addition of cooling tubes to the structure. The cooling tubes (if specified) remove trapped heat from within the HCC element by circulating water through the cooling tubes during the MC curing process. The critical MC curing period is generally the first 5 days where excess heat is generated, potentially resulting in thermal cracking. Note that excess steel may be added to the structure to prevent or control these cracks. Some studies indicate that the cooling tubes produce inconsistency in the curing process – that is, hot and cold spots resulting in differential

strength gain within the HCC element. Frequently, VDOT does not permit the use of cooling tubes in recognition of this potential condition as well as the cost associated with the materials/installation of the cooling tubes. A well-designed MC mix can minimize the need for cooling tubes.

The reasons for the two temperature criteria are:

- the maximum temperature is set to prevent the future formation of ettringite (calcium trisulfoaluminate), and
- the maximum temperature differential is established to minimize thermal cracking where the inside of the structure due to heat generation expands more than the outside of the structure, and thus produces a crack during the period of cement hydration. Cracks occur when the tensile forces in the HCC exceed the tensile strength of the HCC.

## **Roller-Compacted Concrete (RCC)**

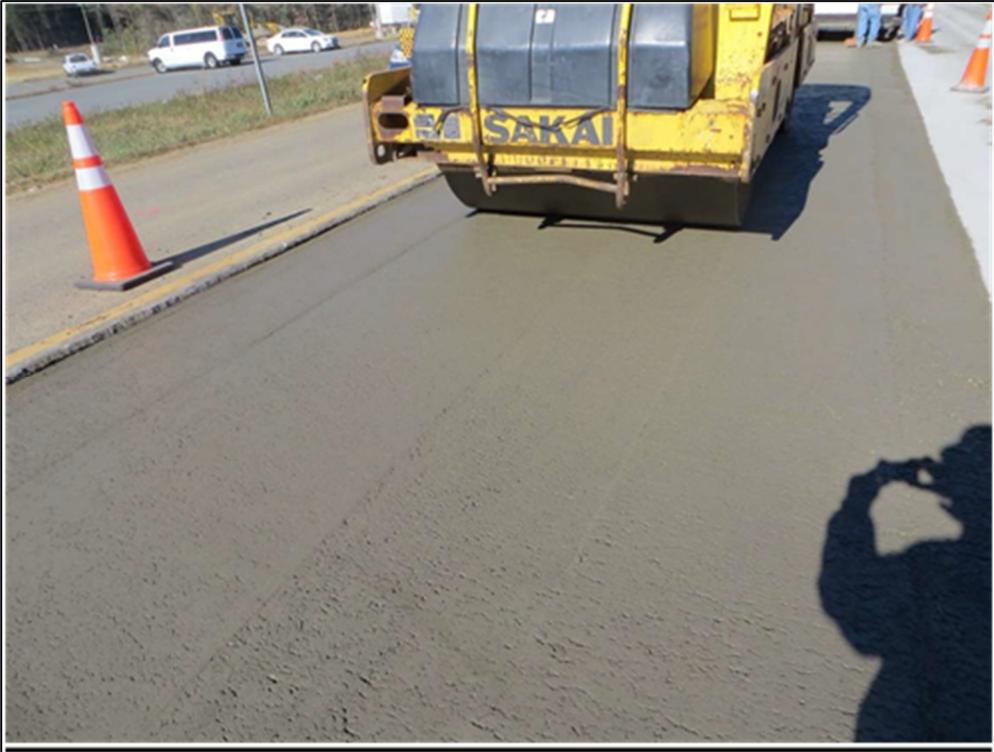
RCC is used by VDOT in paving low-volume HCC roads. RCC mixes have very low water/cementitious material ratios, usually less than 0.35. ACI 207 provides guidance in designing RCC mixes in addition to methods of handling and placement. Often, test sections will be specified in order to optimize RCC mix designs and placement methods. Typically, the same equipment used to place asphalt concrete is used to place RCC with the exception that a high-density paver and a vibratory steel roller are recommended to achieve adequate compaction. The percent compaction varies, but generally is about the same as when compacting asphalt or at least above 90% compaction after the paver. A good goal for adequate compaction is 98% or greater after the final finish typically with the roller.



RCC placed with a high-density paver.



RCC looks dry.



RCC is compacted using a vibratory steel roller.



The density or compaction is checked with a nuclear density gauge.



The concrete is kept moist during curing.



Joints are saw-cut.

## Shotcrete

Reference: VRBS Sections 412.03(g)

Shotcrete will be permitted only when specified for repairs or approved in writing in lieu of conventional hydraulic cement concrete or self-consolidating concrete.

## Hydraulic Cement Mortar and Grout (not to be confused with cable grout)

Reference: VDOT Materials Division Manual of Instructions (MOI), Chapter II, Section 204.11(a) for the acceptance of high strength mortar and grout.

Reference: VRBS Section 218.03 for hydraulic cement mortar and grout.

On some projects grouts are specified. The grout is tested in accordance with ASTM C939 to determine the time of efflux of a specified volume of fluid hydraulic cement grout through a standardized flow cone. Once the water content for the determined flow is set, this becomes the maximum amount of mixing water permitted.

## HCC Repair and Coating Materials

Pre-packaged Repair Materials: HCC repair materials shall be tested in accordance with VTM-132. Manufacturers submit independent laboratory data on each HCC repair material to the Central Office, Materials Division's Physical Laboratory for evaluation. Products meeting the requirements in VTM-132 will be added to Approved List No. 31.

Coating Materials: HCC Sealants, Stains, and Coatings are contained on Approved List No. 30.

## Chapter 1

### Study Questions

1. \_\_\_\_\_ is the chemical reaction between water and cement.
2. \_\_\_\_\_ is the property of freshly mixed concrete which is the ease of difficulty in the placing and finishing of concrete.
3. A chemical, such as calcium chloride used to “speed up” the setting time of concrete is \_\_\_\_\_.
4. \_\_\_\_\_ is a significant loss of plasticity shortly after the concrete is mixed.
5. The time it takes a cement paste to begin hardening is known as \_\_\_\_\_.
6. A condition at which an aggregate will neither absorb moisture from concrete nor contribute moisture to the mix is \_\_\_\_\_.
7. \_\_\_\_\_ is a material used for the purpose of delaying the setting time of concrete.
8. \_\_\_\_\_ is a condition of plastic concrete which relates to its cohesion, wetness, or to flow.
9. \_\_\_\_\_ is the bonding agent used in a concrete mix.
10. The ability of hardened concrete to resist the deterioration caused by weathering, chemicals, and abrasion is known as \_\_\_\_\_.
11. The pH value of water used with cement shall be between \_\_\_\_\_ and \_\_\_\_\_ as found in Section \_\_\_\_\_.
12. Gypsum is added to cement to control \_\_\_\_\_.
13. List two desirable qualities of hardened concrete: \_\_\_\_\_ and \_\_\_\_\_.
14. The primary effect of air entrainment in concrete is to improve \_\_\_\_\_.
15. List two desirable properties of an aggregate: \_\_\_\_\_ and \_\_\_\_\_.

16. How should admixtures be dispensed? \_\_\_\_\_.
17. List two principal raw components in the manufacture of cement \_\_\_\_\_ and \_\_\_\_\_.
18. The type of cement which has the highest fineness reading and the highest tricalcium silicate (C<sub>3</sub>S) composition, both factors in accelerated strength, is \_\_\_\_\_.
19. The void content of identically graded fine aggregates will vary with \_\_\_\_\_.
20. \_\_\_\_\_ is the specific gravity of Portland Cement.
21. \_\_\_\_\_ has the greatest affect on the strength, durability and water tightness of concrete.
22. If the amount of admixture is constant and the concrete temperature is increased, the entrained air content will \_\_\_\_\_.
23. A pH value of 6.0 indicates \_\_\_\_\_ and a pH value of 7.5 indicates \_\_\_\_\_.
24. The strength requirements for High Early Strength Portland Cement Concrete shall be obtained in \_\_\_\_\_ days as stated in Section \_\_\_\_\_.
25. In no case shall a vibrator be operated longer than \_\_\_\_\_ seconds in any one location as stated in Section \_\_\_\_\_.
26. The specification requirements for the approval to use admixtures in Hydraulic Cement Concrete are found in Section \_\_\_\_\_.
27. Each batch of concrete shall be delivered to the site of work and discharged within \_\_\_\_\_ of the time the cement is introduced into the mixture unless otherwise approved by the Engineer as found in Section \_\_\_\_\_.
28. According to Section \_\_\_\_\_, in cold weather, \_\_\_\_\_ and \_\_\_\_\_ may be heated; however, \_\_\_\_\_ is not to be heated.
29. Is wash water from hydraulic cement concrete mixer operations permitted to be reused in the concrete mix? \_\_\_\_\_.

**STUDENT NOTES:**

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# 2

## Sieve Analysis, Fineness Modulus

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### Sampling

Since the reason for sampling aggregates is to determine the gradation (particle size) of the aggregate, it is necessary that they be sampled correctly.

The results of testing will reflect the condition and characteristics of the aggregate from which the sample is obtained. Therefore, when sampling, it is important to obtain a representative sample that is representative of the source being tested. Unless it is truly representative, the test results apply to the sample only and not to the entire aggregate shipment or stockpile. Without accuracy in sampling, test results are worthless.

In many cases, representative sampling cannot be achieved by a single sample. It may be necessary to take a number of samples to obtain a true picture of the properties of a stockpile or source of material. Also, as the maximum particle size in the aggregate increases, the size of the sample must increase to maintain accuracy in testing.

### How to Take a Sample

There are three principal aggregate sampling points that are of concern at a concrete plant. These are:

- 1) source of material, (quarry, gravel pit, etc.)
- 2) the stockpile, and
- 3) the storage bin.

The first two will be discussed in this section and the third in the section on moisture content and batch weight adjustments.

When sampling at the source of materials, it would be well to remember one general rule. It is easier to obtain a representative sample from the production stream, such as from the conveyor belt, than from trucks, storage bins or stockpiles. If the sample is taken from the conveyor belt, take the entire cross-section of the belt. The same is true when sampling from the chutes or bins.

Getting a sample from a stockpile is not easy, and great care must be taken to obtain a truly representative sample. Segregation usually occurs when the material is stockpiled, because the coarse particles will roll to the base of the pile while the fine particles stay on top. When sampling coarse aggregates from stockpiles, samples should be taken at or near the top and base, and at some intermediate point. To prevent further segregation while sampling, a board may be shoved into the pile just above the sampling area. A second method of sampling coarse materials would be to expose the face of the stockpile from the top to the bottom, with a front end loader. The samples could then be taken from the exposed face. A third method would be to have the overhead loader take a scoop from bottom to top and dump the material in a convenient location for sampling. The sample bag could then be filled from various locations around the scoop of material. Fine aggregate may be sampled with a sampling tube approximately 1 ¼ inches (30 mm) in diameter and 6 feet (1.8 meters) in length. Or if sampling a stockpile of sand, or fine aggregate, it is usually necessary to remove the dry layers where the segregation occurs and sample the damp material below.

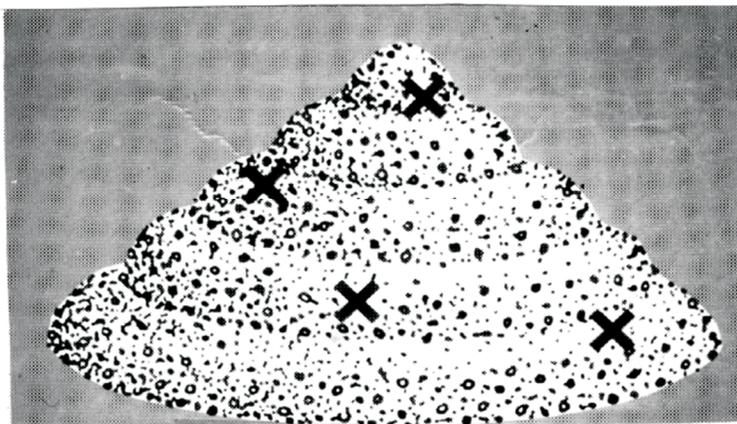


Figure 1. Sampling locations

## Sieve Analysis

Aggregate gradation (sieve analysis) is the distribution of particle sizes expressed as a percent of the total dry weight. Gradation is determined by passing the material through a series of sieves stacked with progressively smaller openings from top to bottom and weighing the material retained on each sieve. Sieve numbers and sizes most often used in grading aggregates for Hydraulic Concrete paving mixtures are as follows:

### Nominal Dimensions of U.S. Standard Sieves - AASHTO M 92

Sieve Designation		Nominal sieve Openings	
metric	Standard	Metric	inches
50.0 mm	2	50.0 mm	2.00
37.5 mm	1 ½	37.5 mm	1.50
25.0 mm	1	25.0 mm	1.00
19.0 mm	¾	19.0 mm	0.750
12.5 mm	½	12.5 mm	0.500
9.5 mm	3/8	9.5 mm	0.375
4.75 mm	No. 4	4.75 mm	0.187
2.36 mm	No. 8	2.36 mm	0.093
1.18 mm	No. 16	1.18 mm	0.0469
600 µm	No. 30	0.600 mm	0.0234
300 µm	No. 50	0.300 mm	0.0117
150 µm	No. 100	0.150 mm	0.0059
75 µm	No. 200	0.075 mm	0.0029

Sieve sizes to be used for the various mixtures are designated in the Road and Bridge Specifications. Gradations are expressed on the basis of total percent dry weight passing, which indicates the total percent of aggregate by weight that will pass a given size sieve.

Some of the descriptive terms used in referring to aggregate gradations are:

**Coarse Aggregate:** All the materials retained on and above the No. 8 (2.36 mm) sieve

**Fine Aggregate:** All the material passing the No. 8 (2.36 mm) sieve.

## Procedure for Sieve Analysis

Dry sieve analysis and washed sieve analysis are two methods of determining proportions of various particle sizes in a mineral aggregate. In Virginia, however, the **WASHED SIEVE ANALYSIS** is used, and will be discussed in this section. Standard procedures for running the sieve analysis are given in AASHTO T 27 and AASHTO T 11, and as amended by VTM-25.

Regardless of the size of the aggregate, the procedure for running a sieve analysis is basically the same. The steps for this procedure are outlined as follows:

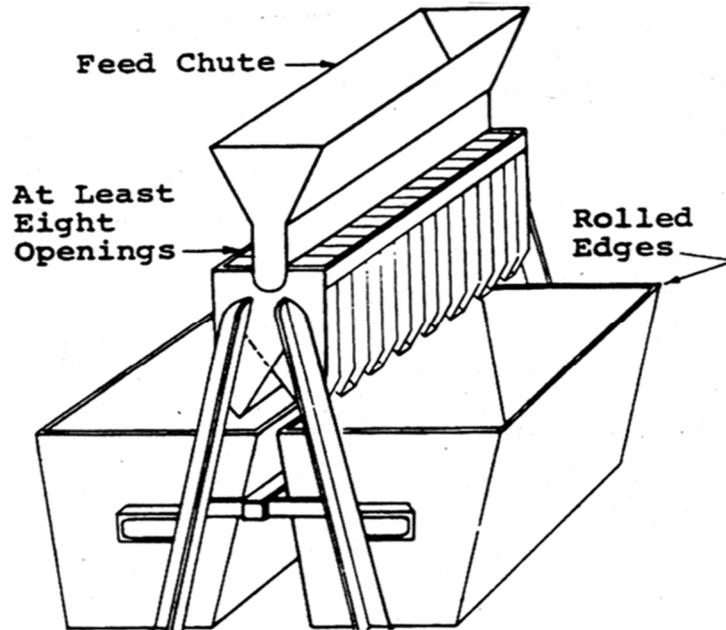
1. Obtain a **representative sample** of the material from the original sample by either a sample splitter or the quartering method. (See paragraphs a and b below.) Reduce to a size that can be handled on the balance and sieves, also, according to maximum stone size. Reference AASHTO T 27.
  - a. **Sample Splitter** - Sample splitters shall have even number of equal width chutes, but not less than a total of eight for coarse aggregates, or twelve for fine aggregates, which discharge alternately to each side of the splitter. The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall be equipped with a hopper or straightedge pan which has a width of the assembly of chutes, by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material. Place the field sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the

intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

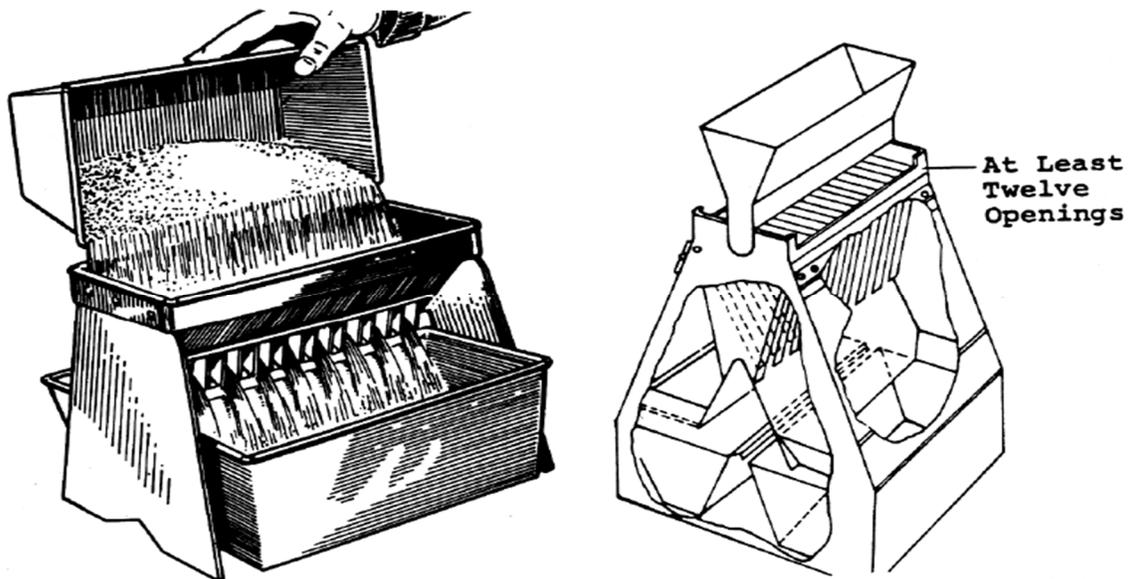
b. **Quartering Method** - The following method for size reduction by quartering is outlined for use when a conventional sample splitter is not available.

1. Distribute a shovel full of the aggregate as uniformly as possible over a wide, flat area on a tight weave canvas or other smooth surface. Continue to distribute shovels full of material in layers until all the sample is used to make a wide, flat pile that is reasonably uniform in thickness and diameter. Do not permit coning of the aggregate.
  2. Divide the pile cleanly into equal quarters with a square-ended shovel or straight piece of sheet metal. When a canvas is used, the division may be conveniently made by inserting a thin stick (or rod) under the canvas and raising it to divide the sample equally, first into halves, then into quarters.
  3. Remove two opposite quarters, including all fine materials, and set aside.
  4. Repeat the foregoing procedure with the remaining portion of the aggregate until test sample of desired size is obtained.
  5. If desired, store the portion that has been set aside for possible check testing.
2. **Dry aggregate sample thoroughly.** The samples are dried to constant weight on a hot plate or in an oven at a temperature of 230°F.
3. **Accurately weigh the dried sample.** When weighing and handling the sample, extreme care must be taken to avoid any loss of the material, as this will affect the accuracy of the results. Also, do not adjust the weight of the split sample to an even figure, such as 500 grams, 1000 grams, etc. Use the entire reduced and dried sample.
4. **Record the total dry weight** on the worksheet. For example, assume the total dry weight of the sample is 506.4 grams.
5. **Wash the sample over a nest of two sieves**, the upper or top sieve being the No. 16 mesh sieve and the lower or the bottom sieve being the No. 200 mesh sieve. Doing this, you would take your sample, add water, to cover the material completely, add a drop of soap and wash it thoroughly being careful not to lose any of the material. Pour the water and material over the nest of sieves, the No. 16 and No. 200, being careful not to lose any of the material, then repeat the procedure until the water is clear.

### Sample Splitter

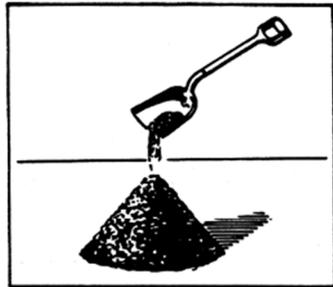


(a) Large Riffle Samplers for Coarse Aggregate

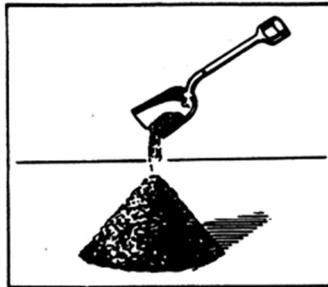


(b) Small Riffle Sampler for fine aggregate

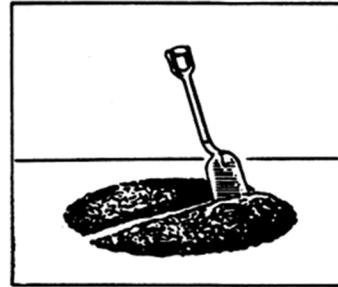
### Quartering Method



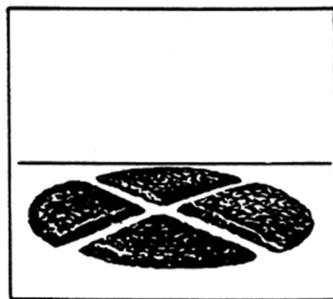
Cone Sample on Hard Clean Surface



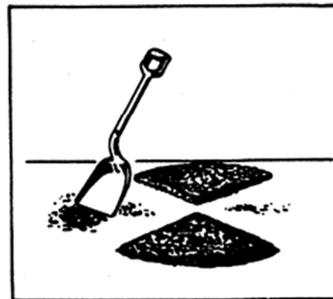
Mix by Forming New Cone



Quarter After Flattening Cone

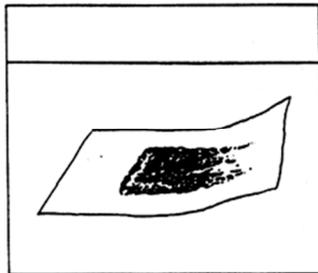


Sample Divided into Quarters

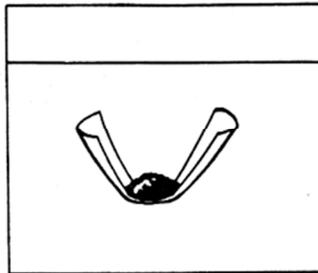


Retain Opposite Quarters  
Reject the Other Two Quarters

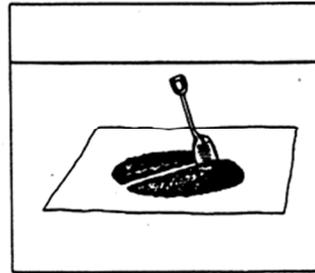
#### Quartering on a Hard, Clean Level Surface



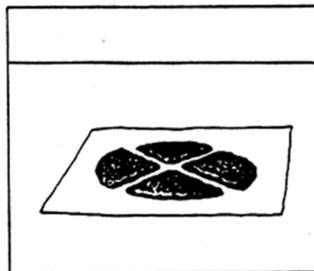
Mix by Rolling on Blanket



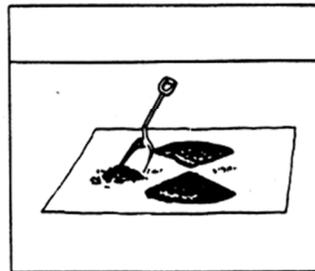
Form Cone after Mixing



Quarter After Flattening Cone



Sample Divided into Quarters



Retain Opposite Quarters  
Reject the Other Two Quarters

#### Quartering on a Canvas Blanket

6. **Dry the sample again** to a constant weight on a hot plate or in an oven at a temperature of 230°F, then accurately weigh and record.
7. **Separate the sample into individual sizes** using the proper sieves. The sieves normally used are the standard 8-inch sieves. With Fine Aggregate the coarse sieve or the 3/8" sieve at the top; each sieve below is finer; and the finest sieve, a No. 200 is at the bottom. A pan is placed below to retain any fine material that may pass this sieve.

The dried sample is placed on the top sieve, and the entire nest of sieves is placed in a shaker that produces a circular and tapping motion, or in other approved shaking devices. This motion assists gravity in settling the individual aggregate particles on the sieve which will properly identify the size of that particular particle. It will take approximately 7 to 10 minutes of shaking to separate the material. Always refer to the AASHTO T-27 procedure to assure shaking for the proper amount of time.

8. **Weigh and record the weights retained on each sieve cumulatively**, increasing by successive additions to the nearest 0.1 grams. For example, suppose a particular gradation required a maximum size of 3/8". Upon examination of this sieve no material was retained. This would then be recorded in the "Cumulative Grams Retained" column of the worksheet, as "0" for this sieve. The No. 4 sieve is then checked, the material carefully removed, placed on the balance and a weight of 14.8 grams is recorded. The No. 8 sieve is removed from the nest of sieves, the material is emptied into the pan with the No. 4 material and the cumulative weight is recorded on the worksheet beside the No. 8 sieve, example 47.6 grams. Repeat the procedure until all of the sieves are weighed and recorded cumulatively. (Note: In a fine aggregate sieve analysis, the test sample is washed over the No. 200 sieve and the portion retained on the No. 200 sieve is dried and the loss recorded.)

## Sieve Analysis - Example

The following sieve analysis is for a sample of natural sand for use in concrete subject to abrasion and meets Virginia Department of Transportation requirements for Grading "A" Sand.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0	0.0	100.0	100.0
No. 4	14.8	2.9	97.1	95-100
No. 8	47.6	9.4	90.6	80-100
No. 16	117.3	23.2	76.8	50-85
No. 30	274.2	54.1	45.9	25-60
No. 50	418.8	82.7	17.3	5-30
No. 100	467.4	92.3	7.7	0-10
No. 200	494.2	97.6	2.4	0-3
PAN	506.4	100.0	0.0	

In this example, the cumulative grams retained on each sieve was determined in the sieve analysis.

9. **Calculate the cumulative percent retained on each sieve.** (Answer to the nearest 0.1%) This is determined by the following formula:

$$\text{Cumulative \% Retained} = \frac{\text{Cumulative Grams Retained}}{\text{Total Weight of Sample}} \times 100$$

For Example: Weight on the No. 4 sieve = 14.8 grams

Total Dry Weight of Sample = 506.4 grams

$$\% \text{Retained} = \frac{14.8}{506.4} \times 100 = 2.9\%$$

This is performed for each sieve size and the end figures entered in the "Cumulative % Retained" column of the worksheet.

10. **Calculate the percent passing each sieve.** (Answer to the nearest 0.1%). To determine this figure, subtract the percent retained on each sieve from 100.

Example: This is performed for each sieve and entered in the % Passing Column of the worksheet. Check to see if the % Passing complies with the Virginia Department of Transportation Specifications *for Grade A Sand* (Table II-1).

- 1.) % Retained on 3/8 inch sieve = 0  
 $100 - 0 = 100.0\%$  passing 3/8 inch sieve (Pass)
- 2.) % Retained on No. 4 sieve = 2.9  
 $100 - 2.9 = 97.1\%$  passing No. 4 sieve (Pass)
- 3.) % Retained on No. 8 sieve = 9.4  
 $100 - 9.4 = 90.6\%$  passing No. 8 sieve (Pass)

**TABLE II-3**  
**Sizes of Open Graded Coarse Aggregates**

Amounts Finer Than Each Laboratory Sieve (Square Openings) (% by Mass)

Va. Size No.	4 in	3 ½ in	3 in	2 ½ in	2 in	1 ½ in	1 in	¾ in
1	Min. 100	90-100		25-60		Max. 15		Max .5
2			Min. 100	90-100	35-70	Max. 15		Max. 5
3				Min. 100	90-100	35-70	0-15	
357				Min. 100	95-100		35-70	
5						Min. 100	90-100	20-55
56						Min. 100	90-100	40-85
57						Min. 100	95-100	
67							Min. 100	90-100
68							Min. 100	90-100
7								90-100
78								90-100
8								
8P								
9								
10								

(Continued)

**TABLE II-3 (Continued)**

Va. Size No.	½ in	3/8 in.	No. 4	No. 8	No. 16	No. 50	No. 100
1							
2							
3	Max. 5						
357	10-30		Max. 5				
5	Max. 10	Max. 5					
56	10-40	Max. 15	Max. 5				
57	25-60		Max. 10	Max. 5			
67		20-55	Max. 10	Max. 5			
68		30-65	5-25	Max. 10	Max. 5		
7	90-100	40-75	Max. 15	Max. 5			
78	90-100	40-75	5-25	Max. 10	Max. 5		
8	Min. 100	85-100	10-30	Max. 10	Max. 5		
8P	Min. 100	75-100	5-30	Max. 5			
9		Min. 100	85-100	10-40	Max. 10	Max. 5	
10		Min. 100	85-100				10-30

**TABLE II-1**  
**Fine Aggregate**

Grading	Amounts Finer Than Each Laboratory Sieve (Square Openings) ( % by Mass)							
	3/8 in	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200
A	Min. 100	95-100	80-100	50-85	25-60	5-30	Max. 10	
B	Min. 100	94-100					Max. 10	
C	Min. 100	94-100				Max. 25		

Section 202.03(e) Deleterious Material: The amount of deleterious material in sands shall be not more than the following:

Material	% by Mass	AASHTO Test Method
Clay Lumps	0.25	T112
Shale, mica, coated grains, soft or flaky particles	1.0	T113
Organic material	0	T21
Total material passing No. 200 sieve by washing <sup>1</sup>		T11 and T27
For use in concrete subject to abrasion	3	
For other concrete	5	

<sup>1</sup>In the case of stone sand, if the material passing the No. 200 sieve is dust of fracture, essentially free from clay or shale, the percentages shown for use in concrete subject to abrasion and in other concrete may be increased to 5.0% and 7.0%, respectively.

## Fineness Modulus

Fineness Modulus is defined as an index to the particle size, not to the gradation. Fineness Modulus is calculated from the sieve analysis. It is defined mathematically as the sum of the cumulative percentages retained on the standard sieves divided by 100. The standard size sieves are 6", 3", 1 ½ ", ¾", 3/8", No. 4, No. 8 , No. 16, No. 30, No. 50, and No. 100. Always report the fineness modulus to the nearest 0.01. In fineness modulus, the finer the material the more the water demand is. It is used for the purpose of estimating the quantity of coarse aggregate to be used in the concrete mix design. The F.M. of fine aggregates should not be less than 2.3 or more than 3.1, or vary by more than 0.20 from batch to batch. When the fineness modulus of the fine aggregate changes more than 0.2 from the original design and the concrete does not have the desired properties, the concrete mixture shall be redesigned.

The American Concrete Institute (ACI) has developed Table A1.5.3.6. (Chapter 3) which for various sizes of coarse aggregate, gives the volume of dry rodded coarse aggregate per unit volume of concrete for different fineness moduli of sand. If the maximum size of the coarse aggregate and the fineness modulus of the Fine Aggregate are known, the volume of the dry rodded coarse aggregate can be obtained from this table.

The volume relationship in the ACI Table actually relates to the total surface area of the aggregates, or water demand of the aggregate. For example, if the Fineness Modulus is constant, the volume of coarse aggregate increases with the size of the aggregate, or with the decrease in surface area of the coarse aggregate. Likewise, as the fine aggregate decreases for any one size of coarse aggregate, the volume of the coarse aggregate increases. As the particle size of the fine aggregate decreases, the surface area increases. Thus, more coarse aggregate and less fine aggregate is used in the mix proportions. Therefore, the volume of the coarse aggregate, as determined in the ACI Table, increases or decreases to maintain a constant total surface area, or constant water demand, with the variable fineness moduli, coarseness or fineness, of the sand.

## Procedure for Determining the Fineness Modulus

Add the Cumulative % Retained on all of the sieves *except the No. 200* and the Pan. Then divide by 100. Remember to report answer to the nearest 0.01.

Example:

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 in	0.0	0.0	100.0	100.0
No. 4	14.8	2.9	97.1	95-100
No. 8	47.6	9.4	90.6	80-100
No. 16	117.3	23.2	76.8	50-85
No. 30	274.2	54.1	45.9	25-60
No. 50	418.8	82.7	17.3	5-30
No. 100	467.4	92.3	7.7	0-10
No. 200	494.2	97.6	2.4	0-3
PAN	506.4	100.0	0.0	

$$\frac{0.0 + 2.9 + 9.4 + 23.2 + 54.1 + 82.7 + 92.3}{100.0} = \frac{264.6}{100.0} = 2.65$$

Once this result is obtained the average size particle in a mix can be determined by looking at the scale and placing a mark where it fits in the best. If for example the F.M. is 2.65, then you would place the mark between the No. 50 and the No. 30 sieve.

#100	#50	#30	#16	#8	#4	3/8"	3/4"	etc
1	2	X 3	4	5	6	7	8	

## “Recommended Practice For Selecting Proportions For Concrete”

(ACI 211) Proportions shall be computed on the absolute volume basis and that the 10 percent adjustment allowed in Table A1.5.3.6 will not be permitted. The actual quantities used, as determined by the methods described herein, shall not deviate more than 5 percent from such quantities.

### ACI TABLE 5.3.6 - VOLUME OF COARSE AGGREGATE PER UNIT VOLUME OF CONCRETE (SI)

Maximum size Volume of dry-rodded coarse aggregate* per unit aggregate volume of concrete for different fineness moduli** of fine aggregate				
	2.40	2.60	2.80	3.00
3/8 inch	0.50	0.48	0.46	0.44
1/2 inch	0.59	0.57	0.55	0.53
3/4 inch	0.66	0.64	0.62	0.60
1 inch	0.71	0.69	0.67	0.65
1 1/2 inch	0.75	0.73	0.71	0.69
2 inch	0.78	0.76	0.74	0.72
3 inch	0.82	0.80	0.78	0.76
6 inch	0.87	0.85	0.83	0.81

\*Volumes are based on aggregates in dry-rodded condition as described in ASTM C29

These volumes are selected from empirical relationships to produce concrete with a degree of workability suitable for usual reinforced construction. For less workable concrete such as required for concrete pavement construction they may be increased up to 10 percent. For more workable concrete, they may be reduced up to 10 percent.

\*\*See ASTM Method 136 for calculation of fineness modulus



## CHAPTER 2 STUDY PROBLEMS

### Sieve Analysis - No. 1

Check the following sieve analysis of a sample of natural sand for use in concrete subject to abrasion and determine if it meets Virginia Department of Transportation requirements for Grading "A" Sand. Circle the sieve not passing, if any.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0			
No. 4	16.6			
No. 8	64.5			
No. 16	214.1			
No. 30	389.2			
No. 50	483.0			
No. 100	543.4			
No. 200	565.0			
Total Wt.	573.0			

Does it meet specification? Yes \_\_\_\_\_ No \_\_\_\_\_.

What is the Fineness Modulus? \_\_\_\_\_ .



## Sieve Analysis - No. 2

Check the following sieve analysis of a sample of natural sand for use in concrete subject to abrasion and determine if it meets Virginia Department of Transportation requirements for Grading "A" Sand. Circle the sieve not passing, if any.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0			
No. 4	6.9			
No. 8	28.3			
No. 16	34.9			
No. 30	219.2			
No. 50	398.8			
No. 100	482.9			
No. 200	498.1			
Total Wt.	503.0			

Does it meet specification? Yes \_\_\_\_\_ No \_\_\_\_\_ .

What is the Fineness Modulus? \_\_\_\_\_ .



## Sieve Analysis - No. 3

Check the following sieve analysis of a sample of natural sand for use in concrete not subject to abrasion and determine if it meets Virginia Department of Transportation requirements for Grading "A" Sand. Circle the sieve not passing, if any.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0			
No. 4	6.7			
No. 8	54.0			
No. 16	168.6			
No. 30	340.5			
No. 50	407.7			
No. 100	459.1			
No. 200	468.1			
Total Wt.	480.0			

Does it meet specification? Yes \_\_\_\_\_ No \_\_\_\_\_ .

What is the Fineness Modulus? \_\_\_\_\_ .

## **STUDENT NOTES:**

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# 3

## ACI Concrete Mix Design and Allowable Field Adjustments

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### ACI Concrete Mix Design

In 1963 the Virginia Department of Transportation realized that a definite need existed to adopt a standard method of concrete design. Contractors, Producers, and the Department itself had used many varying methods of concrete designs.

The Department has adopted the ACI absolute volume method of design, and requires that this method be used in the design of all normal weight concrete mixes.

$$\text{Example: Absolute Volume} = \frac{\text{Weight}}{(\text{Sp. Gr.}) \times 62.4 \text{ lb/ft}^3}$$

For purposes of establishing concrete proportions and calculating yields, we will not concern ourselves with bulk yield or bulk volumes of aggregate, cement, etc., but with the **Absolute Volume** of these materials. This means the volume of material is solid and without voids.

For example: 94 lbs. of cement in a bulk state occupies approximately 1 cubic foot of volume; however, the Absolute Volume of 94 lbs. of cement is only approximately 0.48 cubic feet. (This means the cement is consolidated without voids.) It is the latter volume which 94 lbs. of cement actually occupies in a batch of concrete.

As a further explanation, we will calculate the absolute volume occupied by cement in a cubic yard of concrete which contains 588 lbs. of cement.

EXAMPLE: The weight of cement is: 588 lbs. **Cement has a specific gravity of 3.15** (this means cement is 3.15 times heavier than an equal volume of water)

A solid cubic foot of cement then weighs  $3.15 \times 62.4 \text{ lb/ft}^3$  of water =  $196.56 \text{ lb/ft}^3$

So the Absolute Volume, or the space occupied by 588 lbs. of cement, will be:

$$\frac{588 \text{ lb.}}{196.56 \text{ lb/ft}^3} = 2.99 \text{ ft}^3$$

Before calculations can be started for a concrete design, there are certain items that must be known or available to the person doing the design work. Those items are as follows:

1. Class of concrete to be designed.
2. Fine aggregate:
  - a. Specific gravity
  - b. Fineness modulus
3. Coarse aggregate:
  - a. Maximum size aggregate
  - b. Specific Gravity
  - c. Unit Weight (dry rodded unit weight)
4. From VDOT Specifications:
  - a. Cement factor (minimum cement content)
  - b. W.C. ratio (maximum W/C ratio)
  - c. Air content (mean air content)
  - d. Nominal Maximum size aggregate
5. Other information:
  - a. ACI Table A1.5.3.6 (volume of coarse aggregate per unit of volume of concrete) (Page 3-5)
  - b. Type of cement and alkali content
  - c. TL-27 (Concrete Mix Design Form)
  - d. ACI Mix design work sheet may be used (Page 3-3)
  - e. Source of all materials going into the mix

(For example purposes, the Fineness Modulus and Specific Gravity for all design problems in this study guide are taken from the Aggregate Data Sheets on Pages 3-27 and 3-28. For an updated list, please see the Aggregate Quality List, which is published annually in the Materials Division Manual of Instruction.)

#### HELPFUL CONVERSION FACTORS

**One cubic foot of water = 7.5 gallons = 62.4 lbs.**

**One bag of cement = 94 lbs. (42.6 kg)**

**Specific gravity of cement is 3.15**

**Specific gravity x 62.4 = Absolute Volume**

**1 gallon of water = 8.33 lbs.**

**One cubic yard = 27 cubic feet**

**One bag of cement = one cubic foot (loose volume)**

**One bag of cement = 0.48 cubic feet (absolute volume)**



217.06

**TABLE II-17**  
**Requirements for Hydraulic Cement Concrete**

Class of Concrete	Design Min. Laboratory Compressive Strength at 28 Days (f'c) (psi)	Aggregate Size No. <sup>6</sup>	Design Max. Laboratory Permeability at 28 Days (Coulombs) <sup>5</sup>	Design Max. Laboratory Permeability Over tidal water (Coulombs) <sup>5</sup>	Nominal Max. Aggregate Size (in)	Min. Grade Aggregate	Min. Cementitious Content (lb./cu yd)	Max. Water /Cementitious Mat. (lb. Water /lb. Cement)	Consistency (in of slump)	Air Content (percent) <sup>1</sup>
A5 Prestressed and other special designs <sup>2</sup>	5,000 or as specified on the plans	57, 68, 78, or 7	1,500	1,500	1	A	635	0.40	0-4	4 1/2 ± 1 1/2
A4 General	4,000	56 or 57	2,500	2,000	1	A	635	0.45	2-4	6 1/2 ± 1 1/2
Low Shrinkage A4 Mod.	4,000	56 or 57	2,500	2,000	1	A	N.A.	0.45	2-4	6 1/2 ± 1 1/2
A4 Post & rails	4,000	7, 8 or 78	2,500	2,000	0.5	A	635	0.45	2-5	7 ± 2
A3 General	3,000	56 or 57	3,500	2,000	1	A	588	0.49	1-5	6 ± 2
A3a Paving	3,000	56 or 57	3,500	3,500	1	A	564	0.49	0-3	6 ± 2
A3b Paving	3,000	357	3,500	3,500	2	A	N.A.	0.49	0-3	6 ± 2
B2 Massive or lightly Reinforced	2,200	57	N.A.	N.A.	1	B	494	0.58	0-4	4 ± 2
C1 Massive Unreinforced	1,500	57	N.A.	N.A.	1	B	423	0.71	0-3	4 ± 2
T3 Tremie seal	3,000	56 or 57	N.A.	N.A.	1	A	635	0.49	3-6	4 ± 2
Latex hydraulic cement concrete overlay <sup>3</sup>	3,500	7, 8 or 78	1,500	1,500	0.5	A	658	0.40	4-6	5 ± 2
Silica fume, silica fume / Class F Fly Ash or silica fume / slag concrete overlay <sup>4</sup>	5,000	7, 8 or 78	1,500	1,500	0.5	A	658	0.40	4-7	6 ± 2
Class F Fly Ash or slag overlay	4,000	7, 8 or 78	1,500	1,500	0.5	A	658	0.40	4-7	6 ± 2

**TABLE A1.5.3.6 VOLUME OF COARSE AGGREGATE  
PER UNIT OF VOLUME OF CONCRETE (SI)**

Nominal Maximum size of Aggregate		Volume of dry-rodded coarse aggregate * per unit volume of concrete for different fineness moduli** of fine aggregate						
Metric	English	2.40	2.50	2.60	2.70	2.80	2.90	3.00
9.5 mm	3/8	0.50	0.49	0.48	0.47	0.46	0.45	0.44
12.5 mm	1/2	0.59	0.58	0.57	0.56	0.55	0.54	0.53
19.0 mm	3/4	0.66	0.65	0.64	0.63	0.62	0.61	0.60
25.0 mm	1	0.71	0.70	0.69	0.68	0.67	0.66	0.65
37.5 mm	1 1/2	0.75	0.74	0.73	0.72	0.71	0.70	0.69
50 mm	2	0.78	0.77	0.76	0.75	0.74	0.73	0.72
75 mm	3	0.82	0.81	0.80	0.79	0.78	0.77	0.76
150 mm	6	0.87	0.86	0.85	0.84	0.83	0.82	0.81

\* Volumes are based on aggregates in dry-rodded condition as described in ASTM C 29

\*\* See ASTM Method 136 for calculation of fineness modulus

**ACI WORKSHEET**

CLASS A3- General MIX DESIGN

**MODIFIED WITH:**

FINE AGGREGATE

COARSE AGGREGATE

F.M. 2.70

DRY RODDED UNIT WT. 104

SP. GR. 2.66

SP. GR. 2.61

NOMINAL MAX. SIZE C.A. 1"

TABLE 5.3.6 FACTOR 0.68

OTHER DATA NEEDED FOR SPECIAL DESIGNS Sp. Gr. of IS 3.05

**QUANTITY OF COARSE AGGREGATE**

TABLE 5.3.6 0.68 X 27 ft<sup>3</sup> X UNIT WT. 104 lb/ft<sup>3</sup> = 1909 lbs.

**ABSOLUTE VOLUMES**

~~PORTLAND- IS CEMENT~~ 588 = 3.09 ft<sup>3</sup>  
 $\frac{\quad}{3.05 \times 62.4}$

WATER 588 x 0.49 = 288 lbs. = 4.62 ft<sup>3</sup>  
 $\frac{\quad}{1.00 \times 62.4}$

AIR 6 % x 27 = 1.62 ft<sup>3</sup>  
 $\frac{\quad}{100}$

C. AGGR. 1909 lbs. = 11.72 ft<sup>3</sup>  
 SP. GR. 2.61 X 62.4

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = 21.05 ft<sup>3</sup>

27.00 ft<sup>3</sup>

- 21.05 ft<sup>3</sup>

F.A. 5.95 ft<sup>3</sup> X 2.66 SP.GR. X 62.4 = 988 lbs.

**SUGGESTED QUANTITIES** \_\_\_\_\_ ± 5% TOLERANCE

CEMENT 588 lbs.

WATER 288 lbs. or 34.6 gals.

AIR 6 %

C. AGGR. 1909 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. 988 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ = \_\_\_\_\_ lbs.

\_\_\_\_\_ =

## GRANULATED IRON BLAST FURNACE SLAG

### **Specification:**

Shall conform to ASTM C989, Grade 100 or 120

Replaces up to 50% of the cement (percentages vary – based on the alkali content of the Portland Cement in the mix, see 217.02)

### **Reaction:**

Reactive within itself and also reacts with the free lime in the cement

### **Advantages:**

Cheaper than cement

Utilization of a waste product

Reduces heat of hydration (less cement)

Improves sulfate resistance

Reduces alkali-silica reaction

Gives higher strength at later ages

### **Disadvantages:**

Another mixture

Scaling and drying shrinkage may be increased

Early strengths retarded, particularly in cool weather

**Note:** When forms are stripped, the concrete will be discolored with greens, blues, and blacks, like ink blots, but will bleach fairly rapidly.

## ACI Concrete Mix Design Utilizing Ground Granulated Iron Blast-Furnace Slag

When Ground Granulated Blast-Furnace Slag is utilized as an additive in concrete, it must conform to the requirements of ASTM C 989, Grade 100 or 120.

Ground Granulated Blast-Furnace Slag shall not exceed 50 percent of the total design cement weight specified in Table II-17. The method of design is very similar to that used in the previous mix design in this section.

**EXAMPLE:** Using the ACI worksheet provided, let us design a VDOT A3 general use mix with slag.

Conditions:

Minimum Portland Cement Content:	588 lbs. (Table II-17)
Alkali Content of Cement:	0.82 (from supplier)
Maximum Water Cement Ratio:	0.49 lb water per lbs. Cement (Table II-17)
Nominal maximum size aggregate:	1 inch (Table II-17)
Air Content:	6% ± 2% (Table II-17)
Sp. Gr. of Slag:	2.90 (Specific gravity of slag will vary; therefore, the most current gravity should be obtained from the District Materials Section)
Fineness Modulus of Sand:	2.70 (fine aggr. data sheet)
Sp. Gr. of Fine Aggregate:	2.66 (fine aggr. data sheet)
Sp. Gr. of Coarse Aggregate:	2.61 (coarse aggr. data sheet)
Dry rodded unit weight of C.A.:	104 lb/ft <sup>3</sup> (Lab Results)
Sp. Gr. of Cement:	3.15 (from supplier)

Let us now solve for the absolute volume of each material, remembering the total must be 1 yd<sup>3</sup> (27 ft<sup>3</sup>) for all materials.

The minimum cement content is 588 lbs.; however, a portion of the cement will be replaced with slag. We need to refer to Section 217.02(a) Table 1 of the Specifications. The alkali content of the cement is 0.82%; therefore, 50% of the cement will be replaced by slag.

1. **Cement:** 294 lbs. (this is equal to 50% of 588 lbs., which is the design weight for cement on Class A3 General Use mixes.)

$$\frac{294 \text{ lbs.}}{3.15 (\text{sp.gr. of port. cem.}) \times 62.4 (\text{weight of } 1 \text{ ft}^3 \text{ of water})}$$

To find absolute volume:

$$\frac{294}{3.15 \times 62.4} = 1.50 \text{ ft}^3 (\text{absolute volume})$$

2. **Slag:** 294 lbs. (this is equal to 50% of 588 lbs., which is design weight for cement on Class A3 General use mixes.)

To find absolute volume:

$$\frac{294 \text{ lbs.}}{2.90 (\text{sp.gr. for this slag}) \times 62.4 (\text{weight of } 1 \text{ ft}^3 \text{ of water})} = 1.62 \text{ ft}^3$$

3. **Water:** By specifications, the maximum water is 0.49 lb water per lb. cementitious material. For this mix, you would consider the cementitious weight to be: 294 lbs. Cement + 294 lbs. Slag = 588 lbs.

$$588 \times 0.49 = 288 \text{ lbs.}$$

To find absolute volume:

$$\frac{288}{1.00 \times 62.4} = 4.62 \text{ ft}^3 = \text{Absolute Volume}$$

$$4.62 \text{ ft}^3 \times 7.5 (\text{gallons of water in } 1 \text{ ft}^3) = 34.6 \text{ gallons}$$

4. **Air:** The target air content is 6%. To find the absolute volume of air:

$$0.06 \times 27 \text{ ft}^3 = 1.62 \text{ ft}^3 = \text{Absolute Volume}$$

As air will not weigh anything, it will not have a specific gravity, so we have solved for the 6% volume displaced by the air in a cubic yard.

5. **Coarse Aggregate:** A factor of 0.68 is obtained from Table A1.5.3.6 of ACI by using the Fineness Modulus of the sand and the nominal maximum size of the coarse aggregate. To convert this to volume, we say  $0.68 \times 27 \text{ ft}^3 = 18.36 \text{ ft}^3$  (this volume is dry rodded). With the dry rodded unit weight given as  $104 \text{ lb/ft}^3$ , determine the weight of coarse aggregate going into the mix by the following:

$$18.36 \text{ ft}^3 \times 104 \text{ lb/ft}^3 = 1909 \text{ lbs. (design wt. of C.A.)}$$

The specific gravity of the coarse aggregate was 2.61. The absolute volume is determined by the following:

$$\frac{1909 \text{ lbs.}}{2.61 \times 62.4 \text{ (wt. of ft}^3 \text{ of water)}} = 11.72 \text{ ft}^3 = \text{Absolute Volume}$$

6. **Fine Aggregate:** To solve for the amount of fine aggregate, work the problem in reverse as compared to the other materials. First, total the absolute volume of the other five materials:

	<u>Design</u>	<u>Absolute Volume</u>
Cement	294 lbs.	1.50 ft <sup>3</sup>
Slag	294 lbs.	1.62 ft <sup>3</sup>
Water	288 lbs.	4.62 ft <sup>3</sup>
Air	6 %	1.62 ft <sup>3</sup>
Coarse Aggr.	1909 lbs.	<u>11.72 ft<sup>3</sup></u>
TOTAL		21.08 ft <sup>3</sup>

If the five materials total  $21.08 \text{ ft}^3$ , it is proper to assume that the fine aggregate will fill the remaining volume of a cubic yard ( $27 \text{ ft}^3$ ). To find the volume the fine aggregate will occupy, solve the following:

$$27 \text{ ft}^3 - 21.08 \text{ ft}^3 = 5.92 \text{ ft}^3$$

Now, multiply the volume of fine aggregate times the specific gravity of fine aggregate times 62.4 (unit weight of water):

$$5.92 \text{ ft}^3 \times 2.66 \times 62.4 = 983 \text{ lbs. (design weight of fine aggregate)}$$

The Class A3 general use concrete mix utilizing slag will be shown on the TL-27 as follows:

Cement	-	294 lbs.
Slag	-	294 lbs.
Water	-	288 lbs.
Air	-	6 %
Coarse Aggregate	-	1909 lbs.
Fine Aggregate	-	983 lbs.

**ACI WORKSHEET**

CLASS A3 General MIX DESIGN  
 MODIFIED WITH 50% blast furnace slag

FINE AGGREGATE

COARSE AGGREGATE

F.M. 2.70

DRY RODDED UNIT WT. 104 lb/ft<sup>3</sup>

SP. GR. 2.66

SP. GR. 2.61

NOMINAL MAX. SIZE C.A. 1"

TABLE 5.3.6 FACTOR 0.68

OTHER DATA NEEDED FOR SPECIAL DESIGNS Sp.Gr. of Blast Furnace Slag = 2.90

QUANTITY OF COARSE AGGREGATE

TABLE 5.3.6 0.68 X 27 ft<sup>3</sup> X UNIT WT. 104 = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT  $\frac{.50 \times 588 = 294 \text{ lbs.}}{3.15 \times 62.4} = \underline{1.50} \text{ ft}^3$

WATER  $\frac{.49 \times 588 = 288 \text{ lbs.}}{1.00 \times 62.4} = \underline{4.62} \text{ ft}^3$

AIR  $\frac{6}{100} \% \times 27 = \underline{1.62} \text{ ft}^3$

C. AGGR.  $\frac{1909 \text{ lbs.}}{\text{SP. GR. } \underline{2.61} \times 62.4} = \underline{11.72} \text{ ft}^3$

ADDITIONAL MATERIALS  $\frac{\text{slag}}{588 - 294 = 294 \text{ lbs.}} = \underline{\hspace{2cm}} \text{ ft}^3$   
 $\frac{294 \text{ lbs.}}{2.90 \times 62.4} = \underline{1.62} \text{ ft}^3$

TOTAL = 21.08 ft<sup>3</sup>

27.00 ft<sup>3</sup>  
 - 21.08 ft<sup>3</sup>  
 F.A. 5.92 ft<sup>3</sup> X 2.66 SP.GR. X 62.4 = 983 lbs.

SUGGESTED QUANTITIES

±5% TOLERANCE

CEMENT 294 lbs.  
 WATER 288 lbs. or 34.6 gals.  
 AIR 6 %  
 C. AGGR. 1909 lbs. - [ ] + [ ]  
 F. AGGR. 983 lbs. - [ ] + [ ]  
 ADDL. MATLS. slag = 294 lbs.

## FLY ASH

### **Production:**

Waste product of coal fired electrical utility

### **Specifications:**

Must meet ASTM C618 Class F with maximum loss on ignition of 6%  
Replaces up to 30% of the cement (percentages vary – based on the alkali content of the Portland Cement in the mix, see 217.02)

### **Reaction:**

Reacts with the free lime (calcium hydroxide) given off by cement during hydration, and water to produce cementitious material.

### **Advantages:**

Utilization of a waste product  
Reduces energy for production of cement  
Reduces heat of hydration  
Improves workability  
Improves sulfate resistance  
Reduces alkali-silica aggregate reaction  
Costs less than cement

### **Disadvantages:**

Another admixture  
Scaling and drying shrinkage may be increased  
Slower strength gain  
Air content difficult to control

1. Finer than cement
2. Unburned carbon

## ACI Concrete Mix Design Utilizing Fly Ash

When fly ash is utilized as an additive in concrete, it must conform to the requirements of ASTM C618 Class F or Class C, except that the Loss on Ignition shall be limited to a maximum of 6%. Class F, fly ash shall replace 20 to 30% by weight of the design cement depending on the alkali content of the cement used. The minimum total cementitious materials are specified in Table II-17. The method of design is very similar to that used in the previous mix designs in this chapter.

EXAMPLE: Using the ACI worksheet provided, let us design a VDOT Class A3 General mix using fly ash.

Conditions:

Minimum Cement Content:	588 lbs. (Table II-17)
Alkali Content of Cement:	0.65% (from supplier)
Maximum Water-Cement ratio:	0.49 lbs. water per lb. cement (Table II-17)
Nominal Maximum Size Aggregate:	1 inch (Table II-17)
Air Content :	6% ± 2% (Table II-17)
Sp. Gr. of fly ash:	2.25 (Specific gravity of fly ash will vary. The most current gravity from the manufacturer/supplier should be used).
Fineness Modulus of Sand:	2.70 (fine aggr. data sheet)
Sp. Gr. of Fine Aggregate:	2.66 (fine aggr. data sheet)
Sp. Gr. of Coarse Aggregate:	2.61 (coarse aggr. data sheet)
Dry-rodded Unit Weight of C.A.:	104 lb/ft <sup>3</sup> (lab results)
Sp.Gr. of Cement:	3.15 (from supplier)

Let us now solve the absolute volume of each material, remembering the total must be 27ft<sup>3</sup> (1 CY) for all materials.

The minimum cement content is 588 lbs.; however, a portion of the cement will be replaced with fly ash. We need to refer to Section 217.02(a). The alkali content of the cement is 0.65%; therefore, 20% of the cement will be replaced by fly ash.

1. **Cement:** 470 lbs. (this is equal to 80% of 588 lbs., which is the design wt. of cement of a Class A3 General Mix).

$$\frac{470 \text{ lbs. (this is design weight for 1 yd}^3)}{3.15 \text{ (sp.gr. of cement)} \times 62.4 \text{ (weight of 1 ft}^3 \text{ of water)}}$$

$$\frac{470 \text{ lbs.}}{3.15 \times 62.4} = 2.39 \text{ ft}^3 \text{ Absolute volume}$$

2. **Fly ash:** 118 lbs. (this is equal to 20% of 588 lbs., which is design wt. for cement of a Class A3 General use mix).

To find absolute volume:

$$\frac{118 \text{ lbs.}}{2.25(\text{sp.gr. for this fly ash}) \times 62.4(\text{weight of } 1 \text{ ft}^3 \text{ of water})} = 0.84 \text{ ft}^3$$

3. **Water:** By specification, the maximum water is 0.49 lbs. water per lb. cementitious material. For this mix, you would consider the cementitious weight to be 588 lbs. Cement + Fly Ash (470 lbs. + 118 lbs.).

$$588 \times 0.49 = 288 \text{ lbs.}$$

To find absolute volume:

$$\frac{288}{1.00 \times 62.4} = 4.62 \text{ ft}^3 = \text{Absolute volume}$$

$$4.62 \text{ ft}^3 \times 7.5 \text{ (gallons of water in } 1 \text{ ft}^3) = 34.6 \text{ gallons}$$

4. **Air:** The target air content is 6%. To find the absolute volume of air:

$$0.06 \times 27 \text{ ft}^3 = 1.62 \text{ ft}^3 = \text{Absolute Volume}$$

As air will not weigh anything, it will not have a specific gravity, so we have solved for the 6% volume displaced by the air a cubic yard.

5. **Coarse Aggregate:** A factor of 0.68 is obtained from Table A1.5.3.6 of ACI by using the Fineness Modulus of the sand and the nominal maximum size of the coarse aggregate. To convert this to volume,  $0.68 \times 27 \text{ ft}^3 = 18.36 \text{ ft}^3$  (this volume is dry rodded). With the dry rodded unit weight given as  $104 \text{ lb/ft}^3$ , determine the weight of coarse aggregate going into the mix by the following:

$$18.36 \text{ ft}^3 \times 104 \text{ lb/ft}^3 = 1909 \text{ lbs. (this is the design mass of C.A.)}$$

The specific gravity of the coarse aggregate was 2.61. The absolute volume is determined by the following:

$$\frac{1909}{2.61 \times 62.4 \text{ (wt. of ft}^3 \text{ of water)}} = 11.72 \text{ ft}^3 = \text{Absolute Volume}$$

6. **Fine Aggregate:** To solve for the amount of fine aggregate, we will work the problem in reverse as compared to the other materials. First, we must total the absolute volume of the other five materials:

	<u>Design</u>	<u>Absolute Volume</u>
Cement	470 lbs.	2.39 ft <sup>3</sup>
Fly Ash	118 lbs.	0.84 ft <sup>3</sup>
Water	288 lbs.	4.62 ft <sup>3</sup>
Air	6 %	1.62 ft <sup>3</sup>
Coarse Aggr.	1909 lbs.	<u>11.72 ft<sup>3</sup></u>
TOTAL		21.19 ft <sup>3</sup>

If the five materials total 21.19 ft<sup>3</sup>, it is proper to assume that the fine aggregate will fill the remaining volume of a cubic yard. To find the volume the fine aggregate will occupy, solve the following:

$$27.00 \text{ ft}^3 - 21.19 \text{ ft}^3 = 5.81 \text{ ft}^3$$

Now, multiply the volume of fine aggregate times the specific gravity of fine aggregate times 62.4 (unit weight of water):

$$5.81 \text{ ft}^3 \times 2.66 \times 62.4 = 964 \text{ lbs. (design mass of fine aggregate)}$$

The Class A3 general use concrete mix utilizing fly ash will be shown on the TL-27 as follows:

Cement	- 470 lbs.
Fly Ash	- 118 lbs.
Water	- 288 lbs.
Air	- 6 %
Coarse Aggregate	- 1909 lbs.
Fine Aggregate	- 964 lbs.

## ACI WORKSHEET

CLASS A3 General MIX DESIGNMODIFIED WITH 20% Fly Ash

FINE AGGREGATE

COARSE AGGREGATE

F.M. 2.70DRY RODDED UNIT WT. 104 lb/ft<sup>3</sup>SP. GR. 2.66SP. GR. 2.61NOMINAL MAX. SIZE C.A. 1 inchTABLE 5.3.6 FACTOR 0.68

OTHER DATA NEEDED FOR SPECIAL DESIGNS

Sp.Gr. of Fly Ash = 2.25

QUANTITY OF COARSE AGGREGATE

TABLE 5.3.6 0.68 X 27 ft<sup>3</sup> X UNIT WT. 104 lb/ft<sup>3</sup> = 1909 lbs.

ABSOLUTE VOLUMES

PORTLAND CEMENT  $\frac{588 \times .80}{3.15 \times 62.4} = 470$  lbs. = 2.39 ft<sup>3</sup>

WATER {470 + 118 = 588}  $\frac{588 \times 0.49}{1.00 \times 62.4} = 288$  lbs. = 4.62 ft<sup>3</sup>

AIR  $\frac{6}{100} \% \times 27 = 1.62$  ft<sup>3</sup>

C. AGGR.  $\frac{1909}{\text{SP. GR. } 2.61 \times 62.4} = 11.72$  ft<sup>3</sup>

ADDITIONAL MATERIALS fly ash = 0.84 ft<sup>3</sup>  
 $\frac{588 \times 0.20}{2.25 \times 62.4} = 118$  lbs. = 0.84 ft<sup>3</sup>

TOTAL = 21.19 ft<sup>3</sup>27.00 ft<sup>3</sup>- 21.19 ft<sup>3</sup>F.A. 5.81 ft<sup>3</sup> X 2.66 SP.GR. X 62.4 = 964 lbs.

SUGGESTED QUANTITIES

±5% TOLERANCE

CEMENT 470 lbs.WATER 288 lbs. or 34.6 gals.AIR 6 %C.A. AGGR. 1909 lbs. - [ ] + [ ]F. AGGR. 964 lbs. - [ ] + [ ]ADDL. MATLS. Flyash = 118 lbs.

**ACI Design Example Problem No.1**

Design a Class A4 Post and Rail concrete mix with slag to be used in footing, using coarse and fine aggregate from Lone Star Industries, Dock Street. Dry rodded unit weight of coarse aggregate is 101 lb/ft<sup>3</sup>. Alkali Content of Cement is 0.67%. Specific gravity of slag is 2.94. Use data sheets page 3-27 and 3-28.

CLASS A4 Post & Rail MIX DESIGN  
 MODIFIED WITH Slag

<u>FINE AGGREGATE</u>	<u>COARSE AGGREGATE</u>
F.M. <u>2.80</u>	DRY RODDED UNIT WT. <u>101 lb/ft<sup>3</sup></u>
SP. GR. <u>2.64</u>	SP. GR. <u>2.63</u>
NOMINAL MAX. SIZE C.A. <u>1/2</u>	TABLE A1.5.3.6 FACTOR <u>0.55</u>
OTHER DATA NEEDED FOR SPECIAL DESIGNS	<u>Slag 40%</u>
	<u>Sp. Gravity 2.94</u>

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.55 X 27 ft<sup>3</sup> X UNIT WT. 101 = 1500 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT {(.40)(635)=254} 635 - 254 = 381 lbs. = 1.94 ft<sup>3</sup>  
 3.15 x 62.4

WATER .45 x 635 = 286 bs. = 4.58 ft<sup>3</sup>  
 1.00 x 62.4

AIR 7.0 % x 27 = 1.89 ft<sup>3</sup>  
 100

C. AGGR. 1500 lbs. = 9.14 ft<sup>3</sup>  
 SP.GR. 2.63 X 62.4

ADDITIONAL MATERIALS .40 x 635 = 254 = 1.38 ft<sup>3</sup>  
 2.94 x 62.4

TOTAL = 18.93 ft<sup>3</sup>

27.00 ft<sup>3</sup>  
 - 18.93 ft<sup>3</sup>  
 F.A. 8.07 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1329 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE  
 CEMENT 381 lbs.  
 WATER 286 lbs. or 34.3 gals.  
 AIR 7.0 %  
 C. AGGR. 1500 lbs. - [          ] + [          ]  
 F. AGGR. 1329 lbs. - [          ] + [          ]  
 ADDL. MATLS. Slag = 254 lbs.

**ACI Design Example Problem No.2**

Design a Class A4 General Use mix to be used in a bridge deck. Coarse and fine aggregate will be obtained from Sadler Materials, Richmond, Va. Make no adjustments for retarder. Dry rodded unit weight of the coarse aggregate is 102 lb/ft<sup>3</sup>. Alkali content of the cement is 0.72%. Fly ash can be obtained from JTM Industries with a Specific Gravity of 2.35. Use aggregate data sheets page 3-27 and 3-28.

CLASS A4 General MIX DESIGNMODIFIED WITH Fly AshFINE AGGREGATEF.M. 3.00SP. GR. 2.64NOMINAL MAX. SIZE C.A. 1"

OTHER DATA NEEDED FOR SPECIAL DESIGNS

COARSE AGGREGATEDRY RODDED UNIT WT. 102 lb/ft<sup>3</sup>SP. GR. 2.62TABLE A1.5.3.6 FACTOR 0.65Fly Ash 20% ReplacementSp. Gravity 2.35

## QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 0.65 X 27 ft<sup>3</sup> X UNIT WT. 102 = 1790 lbs.**ABSOLUTE VOLUMES**

PORTLAND CEMENT  $\{(.20)(635)=127\}$   $\frac{635 - 127 = 508 \text{ lbs.}}{3.15 \times 62.4} = \underline{2.58} \text{ ft}^3$

WATER  $\frac{.45 \times 635 = 286 \text{ lbs.}}{1.00 \times 62.4} = \underline{4.58} \text{ ft}^3$

AIR  $\frac{6.5}{100} \% \times 27 = \underline{1.76} \text{ ft}^3$

C. AGGR.  $\frac{1790 \text{ lbs.}}{\text{SP.GR. } 2.62 \times 62.4} = \underline{10.95} \text{ ft}^3$

ADDITIONAL MATERIALS  $\frac{.20 \times 635 = 127}{2.35 \times 62.4} = \underline{0.87} \text{ ft}^3$

TOTAL = 20.74 ft<sup>3</sup>

27.00 ft<sup>3</sup>- 20.74 ft<sup>3</sup>F.A. 6.26 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1031 lbs.

## SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT 508 lbs.WATER 286 lbs. or 34.3 gals.AIR 6.5 %C. AGGR. 1790 lbs. - [          ] + [          ]F. AGGR. 1031 lbs. - [          ] + [          ]ADDL. MATLS. Fly Ash = 127 lbs.

**ACI Design Example Problem No. 3**

Design a Class A4 Post and Rail Concrete modified with slag. Fine aggregate will come from Chickahominy, Inc., Charles City, VA. and coarse aggregate will come from Virginia Traprock, Inc., Leesburg, VA. Dry rodded unit weight of the coarse aggregate is 100 lb/ft<sup>3</sup>. Alkali content of the cement is 0.85%. Specific gravity of slag is 2.94. Use aggregate data sheets on page 3-27 and 3-28.

CLASS A4 Post and Rail MIX DESIGNMODIFIED WITH 50% Slag

<u>FINE AGGREGATE</u>	<u>COARSE AGGREGATE</u>
F.M. <u>2.70</u>	DRY RODDED UNIT WT. <u>100 lb/ft<sup>3</sup></u>
SP. GR. <u>2.62</u>	SP. GR. <u>3.04</u>
NOMINAL MAX. SIZE C.A. <u>1/2"</u>	TABLE A1.5.3.6 FACTOR <u>.56</u>
OTHER DATA NEEDED FOR SPECIAL DESIGNS	<u>50% Slag (Sp. Gr. = 2.94)</u>

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 .56 X 27 ft<sup>3</sup> X UNIT WT. 100 = 1512 lbs.**ABSOLUTE VOLUMES**

PORTLAND CEMENT  $\{(.50)(635)=318\}$   $\frac{635 - 318 = 317 \text{ lbs.}}{3.15 \times 62.4} = \underline{1.61} \text{ ft}^3$

WATER  $\frac{.45 \times 635 = 286 \text{ lbs.}}{1.00 \times 62.4} = \underline{4.58} \text{ ft}^3$

AIR  $\frac{7}{100} \% \times 27 = \underline{1.89} \text{ ft}^3$

C. AGGR.  $\frac{1512 \text{ lbs.}}{\text{SP.GR. } 3.04 \times 62.4} = \underline{7.97} \text{ ft}^3$

ADDITIONAL MATERIALS  $\frac{.50 \times 635 = 318}{2.94 \times 62.4} = \underline{1.73} \text{ ft}^3$

TOTAL = 17.78 ft<sup>3</sup>27.00 ft<sup>3</sup>- 17.78 ft<sup>3</sup>F.A. 9.22 ft<sup>3</sup> X 2.62 SP.GR. X 62.4 = 1507 lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT 317 lbs.WATER 286 lbs. or 34.3 gals.AIR 7 %C. AGGR. 1512 lbs. - [            ] + [            ]F. AGGR. 1507 lbs. - [            ] + [            ]ADDL. MATLS. 50% Slag = 318 lbs.

### ACI Design Example Problem No.4

Design a Class A4 General Use mix to be used in a box culvert using fine and coarse aggregate from West Sand and Gravel, Richmond, Va. Alkali content of the Type I cement is 0.59%. Dry rodded unit weight of the coarse aggregate is 104 lb/ft<sup>3</sup>. Fly Ash is available from Monex with a specific gravity of 2.25. Use aggregate data sheets on page 3-27 and 3-28.

CLASS A4 General MIX DESIGN

MODIFIED WITH Fly Ash

FINE AGGREGATE

F.M. 2.70

SP. GR. 2.64

NOMINAL MAX. SIZE C.A. 1"

OTHER DATA NEEDED FOR SPECIAL DESIGNS

COARSE AGGREGATE

DRY RODDED UNIT WT. 104 lb/ft<sup>3</sup>

SP. GR. 2.60

TABLE A1.5.3.6 FACTOR 0.68

Fly Ash 20% Replacement

Sp. Gravity 2.25

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 0.68 X 27 ft<sup>3</sup> X UNIT WT. 104 = 1909 lbs.

### ABSOLUTE VOLUMES

PORTLAND CEMENT {(.20)(635)=127      $\frac{635 - 127 = 508 \text{ lbs.}}{3.15 \times 62.4}$      = 2.58 ft<sup>3</sup>

WATER      $\frac{.45 \times 635 = 286 \text{ lbs.}}{1.00 \times 62.4}$      = 4.58 ft<sup>3</sup>

AIR      $\frac{6.5 \% \times 27}{100}$      = 1.76 ft<sup>3</sup>

C. AGGR.      $\frac{1909 \text{ lbs.}}{\text{SP.GR. } 2.60 \times 62.4}$      = 11.77 ft<sup>3</sup>

ADDITIONAL MATERIALS      $\frac{.20 \times 635 = 127}{2.25 \times 62.4}$      = 0.90 ft<sup>3</sup>

TOTAL     = 21.59 ft<sup>3</sup>

27.00     ft<sup>3</sup>

- 21.59     ft<sup>3</sup>

F.A. 5.41 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 891 lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT 508 lbs.

WATER 286 lbs. or 34.3 gals.

AIR 6.5 %

C. AGGR. 1909 lbs. - [          ] + [          ]

F. AGGR. 891 lbs. - [          ] + [          ]

ADDL. MATLS. Fly Ash = 127 lbs.

## Allowable Field Adjustments

If the quantities calculated by ACI absolute volume method do not give the required workability and consistency in the field, the mix can be adjusted by an allowable interchange of coarse aggregate and fine aggregate. The interchange of coarse aggregate and fine aggregate may vary up to 5 percent (by weight), but neither may be changed more than 5 percent. When an interchange of aggregate is needed, the fine aggregate, normally being of less weight than coarse aggregate, is increased or decreased 5 percent and then the coarse aggregate is changed by an equal volume so the design will be 27 ft<sup>3</sup>.

For example, when the first load of concrete using the Class A3 general use design (as shown below) arrived on the project, the slump was 2 inches. The contractor desired a higher slump. In order to accomplish this, the surface areas of the aggregate must be decreased as much as is allowable, which will make the mix as coarse as possible and remain within the specification requirements.

Class A3 General Mix Design:

IP Cement	- 588 lbs.	Sp. gr. F.A. = 2.67
Water	- 288 lbs.	Sp. gr. C.A. = 2.61
Air	- 6 %	F.M. of F.A. = 2.70
#57	- 1965 lbs.	Unit wt. of C.A. = 107 lbs/ft <sup>3</sup>
F.A.	- 930 lbs.	Sp. gr. Cement = 3.03

The F.A., being of less weight than the C.A., will be decreased by 5% as follows:

$$\text{F.A.} = 930 \times 5\% = 930 \times 0.05 = 47 \text{ lbs.}$$

Original Wt. of F.A. =	930 lbs.
Less 5% =	<u>- 47 lbs.</u>
New Wt. of F.A.	883 lbs.

The C.A. must then be increased the same volume that the F.A. is decreased so the design will remain 27 ft<sup>3</sup>. This is accomplished as follows:

$$\frac{47 \text{ lbs. F.A.}}{[2.67(\text{F.A. Sp. Gr.}) \times 62.4]} = 0.28 \text{ ft}^3$$

$$0.28 \times [2.61 (\text{C.A. Sp. Gr.}) \times 62.4] = 46 \text{ lbs. of C.A. to be added}$$

Original wt. of C.A. #57	1965 lbs.
Plus wt. C.A. to be increased	<u>+ 46</u> lbs.
Net wt. of C.A.	2011 lbs.

The adjusted design quantities are:

Cement	588 lbs.
Air	6 %
Water	288 lbs.
#57	2011 lbs.
F.A.	883 lbs.

After these adjustments are made, the design should be checked to make sure it yields 27.00 ft<sup>3</sup>

		Absolute Volume (ft <sup>3</sup> )
IP Cement - 588 lbs.	$\frac{588}{3.03 \times 62.4}$	= 3.11
Air - 6%	$0.06 \times 27$	= 1.62
Water – 288 lbs.	$\frac{288}{1.00 \times 62.4}$	= 4.62
C. A. - #57 = 2011 lbs.	$\frac{2011}{2.61 \times 62.4}$	= 12.35
F. A. - 883 lbs.	$\frac{883}{2.67 \times 62.4}$	= 5.30
TOTAL		27.00

**Allowable Field Adjustment Example Problem No. 1**

The following Class A3 General mix design produced a harsh mix. The contractor desires to reduce the harshness (reduce the C.A.). Show the aggregate adjustments that may be made within the specification requirements.

IP Cement	- 588 lbs.	F. A. Sp. Gr.	- 2.64
Air	- 6.0%	F. A. F. M.	- 3.00
Water	- 288 lbs.	C. A. Sp. Gr.	- 2.62
F. A.	- 998 lbs.	C. A. Unit Wt.-	108 lb/ft <sup>3</sup>
C. A. No. 57	- 1895 lbs.	Cement Sp. Gr.	- 3.03

**SOLUTION:**

$998 \times 0.05 = 50$  lbs. (This weight must be added to the weight of sand)

$998 + 50 = 1048$  lbs. (Total weight of sand)

$$\frac{50}{2.64 \times 62.4} = 0.30 \text{ ft}^3$$

$$2.64 \times 62.4$$

$$0.30 \times 2.62 \times 62.4 = 49 \text{ lbs.}$$

(The weight of C.A. must be decreased by this amount)

$1895 - 49 = 1846$  lbs. (Total weight of C.A. due to increase in the sand)

**ADJUSTED MIX DESIGN**

Cement	- 588 lbs.
Air	- 6.0%
Water	- 288 lbs.
F. A.	- 1048 lbs.
C. A. - No. 57	- 1846 lbs.

**Allowable Field Adjustment Example Problem No. 2**

The following Class A3 General mix design produced a slump of 3 inches. The contractor desires a 4" slump (increase slump by increasing C.A.). Show the aggregate adjustments that may be made within the specification requirements.

Cement	-	470 lbs.	F. A. Sp. Gr.	-	2.62
Air	-	6%	F. A. F. M.	-	2.70
Water	-	288 lbs.	C. A. Sp. Gr.	-	3.04
F. A.	-	1189 lbs.	C. A. Unit Wt.-		106 lb/ft <sup>3</sup>
C. A. No. 57	-	1946 lbs.	Cement Alkali Content	-	0.65%
Flyash	-	118 lbs.	Flyash Sp. Gr.	-	2.25

**SOLUTION:**

$1189 \times 0.05 = 59$  lbs. (This weight must be subtracted from the weight of sand)

$1189 - 59 = 1130$  lbs. (Total weight of sand)

$$\frac{59}{2.62 \times 62.4} = 0.36 \text{ ft}^3$$

$$0.36 \times 3.04 \times 62.4 = 68 \text{ lbs.}$$

(This weight must be added to C.A. weight)

$1946 + 68 = 2014$  lbs. (Total weight of C. A.)

**ADJUSTED MIX DESIGN**

Cement	-	470 lbs.
Air	-	6%
Water	-	288 lbs.
F. A.	-	1130 lbs.
C. A. - No. 57	-	2014 lbs.
Flyash	-	118 lbs.

**Allowable Field Adjustment Example Problem No. 3**

The following Class A4 General mix design produced a harsh mix. The contractor desires to reduce the harshness. Show the aggregate adjustments that may be made within the specification requirements.

Cement	-	381 lbs.	F. A. Sp. Gr.	-	2.60
Air	-	6.5%	F. A. F. M.	-	2.93
Water	-	286 lbs.	C. A. Sp. Gr.	-	2.67
F. A.	-	1063 lbs.	C. A. Unit Wt.	-	96.5 lbs/ft <sup>3</sup>
C. A. No. 57	-	1798 lbs.	Cement Alkali Content	-	0.70%
Slag	-	254 lbs.			

**SOLUTION:**

$1063 \times 0.05 = 53 \text{ lbs.}$  (This weight must be added to the weight of sand)

$1063 + 53 = 1116 \text{ lbs.}$  (Total weight of sand)

$$\frac{53}{2.60 \times 62.4} = 0.33 \text{ ft}^3$$

$$0.33 \times 2.67 \times 62.4 = 55.0 \text{ lbs.}$$

(The weight of C. A. must be decreased by this amount)

$1798 - 55 = 1743 \text{ lbs.}$  (Total weight of C. A. due to increase in the sand)

**ADJUSTED MIX DESIGN**

Cement	-	381 lbs.
Air	-	6.5%
Water	-	286 lbs.
F. A.	-	1116 lbs.
C. A. - No. 57	-	1743 lbs.
Slag	-	254 lbs.

**VIRGINIA DEPARTMENT OF TRANSPORTATION  
RESULTS OF QUALITY TEST ON  
COMMERCIALY PRODUCED  
COARSE AGGREGATES**

(THE VALUES THAT FOLLOW ARE TO BE USED FOR TRAINING PURPOSES ONLY. FOR ACTUAL VALUES, REFER TO THE LATEST PUBLISHED LIST.)

PRODUCER AND LOCATION	SP. GR.	ABS.(%)	L. A. ABRASION LOSS		
			A	B	C
Sadler Materials Richmond, VA	2.62	0.9	37.6	38.0	----
Lone Star Industries Dock St., Richmond, VA	2.63	0.8	39.2	38.0	34.0
Fredericksburg Sand & Gravel Fredericksburg, VA	2.64	0.3	37.5	35.5	----
Virginia Traprock, Inc. Leesburg, VA	3.04	0.4	----	19.1	26.7
West Sand and Gravel Richmond, VA	2.60	1.0	----	39.3	37.1
Bull Run Stone Co. Manassas, VA	2.67	1.5	----	14.3	----
Dillon, E & Co. Swords Creek, VA	2.83	0.4	23.1	----	----
Lone Jack Glasgow, A	2.81	0.3	----	18.9	21.8
Shenandoah Asphalt Vesuvius, VA	2.59	1.0	----	30.3	39.3

**VIRGINIA DEPARTMENT OF TRANSPORTATION**

**FINE AGGREGATE DATA**

(THE VALUES THAT FOLLOW ARE TO BE USED FOR TRAINING PURPOSES ONLY. FOR ACTUAL VALUES, REFER TO THE LATEST PUBLISHED LIST.)

<u>PRODUCER AND LOCATION</u>	<u>SP. GR.</u>	<u>ABS.(%)</u>	<u>SOUNDNESS</u>	
			<u>F.M.</u>	<u>LOSS</u>
Chickahominy, Inc. Charles City, VA	2.62	1.0	2.7	7.9
Sadler Materials Richmond, VA	2.64	0.5	3.0	7.0
Fredericksburg Sand & Gravel Fredericksburg, VA	2.62	0.8	2.7	11.9
Lone Star Industries Dock St., Richmond, VA	2.64	0.6	2.8	5.8
West Sand and Gravel Richmond, VA	2.64	0.9	2.7	6.7
Aylett Sand & Gravel Aylett, VA	2.62	0.2	2.9	4.6
Dillon E. & Co. Swords Creek, VA	2.80	1.1	3.1	13.8
Stuart M. Perry, Inc. Winchester, VA	2.67	1.0	2.8	9.1
Wilson Quarries Horsepasture, VA	2.83	0.5	2.8	6.8

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## Chapter 3

### Study Problems

#### ACI Mix Design Problem No. 1

Design a Class A4 general mix using a Type II cement from Giant Cement Co. with an alkali content of 0.19. Fly Ash, Specific Gravity of 2.35, is available if necessary from Monex Resources, Inc. Coarse aggregate will come from Lone Star Industries, Richmond, VA. Dry rodded unit weight of coarse aggregate is 103 lb/ft<sup>3</sup>. Fine aggregate will come from West Sand and Gravel, Richmond, VA. Use aggregate data sheets found on page 3-27 and 3-28.



**ACI Mix Design Problem No. 2**

Design a Class A4 general use mix using IP cement from Roanoke. Coarse aggregate will come from Dillon Company, Swords Creek, VA. Fine aggregate will come from Sadler Materials, Richmond, VA. Dry rodded unit weight of the coarse aggregate is 105 lb/ft<sup>3</sup>. Specific gravity of the IP cement from Roanoke is 3.02. Use aggregate data sheets found on page 3-27 and 3-28.



**ACI Mix Design Problem No. 3**

Design a Class A4 Post and rail concrete mix using a Type II cement from Lehigh Cement Co. with an alkali content of 0.57. Design the mix with a water cement ratio of 0.43 and the minimum amount of slag required. Coarse aggregate will come from Sadler Materials, Richmond, VA. Dry rodded unit weight of coarse aggregate is 101 lb/ft<sup>3</sup>. Fine aggregate will come from Chickahominy Inc., Charles City, VA. Specific gravity of the slag is 2.94. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $3.15 \times 62.4$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $1.00 \times 62.4$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  
 100

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 SP.GR. \_\_\_\_\_ X 62.4

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Problem No. 4**

Design a Class A4 general concrete mix using Type I cement from Blue Circle Atlantic with an alkali content of 0.32. Fly ash with a specific gravity of 2.35 is available from Monex Resources, Inc. Coarse aggregate will come from Virginia Traprock, Inc. Dry rodded unit weight of the coarse aggregate is 105 lb/ft<sup>3</sup>. Fine aggregate will come from Sadler Materials. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 3.15 x 62.4

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 1.00 x 62.4

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  
 100

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 SP.GR. \_\_\_\_\_ X 62.4

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Problem No. 5**

Design a Class A4 General mix using Type IS cement from Roanoke with a specific gravity of 3.05. Coarse aggregate will come from Virginia Traprock, Leesburg, VA and fine aggregate will come from Lone Star Industries, Dock St., Richmond, VA. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 100 lb/ft<sup>3</sup>. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $3.15 \times 62.4$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $1.00 \times 62.4$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  
 100

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 SP.GR. \_\_\_\_\_ X 62.4

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Problem No. 6**

Design a slag modified Class A3 General use mix. Coarse and fine aggregate will come from Sadler Materials, Richmond, Va. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 99 lb/ft<sup>3</sup>. Alkali content of the Type II cement is 0.28%. Specific gravity of the slag is 2.94. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{3.15 \times 62.4}$$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{1.00 \times 62.4}$$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{100}$$

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{\text{SP.GR.} \times 62.4}$$

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =

\_\_\_\_\_ =

**ACI Mix Design Problem No. 7**

Design a Class A3 Paving mix, modified with slag. Coarse and fine aggregate will come from West Sand and Gravel, Richmond, Va. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 104 lb/ft<sup>3</sup>. Specific Gravity of slag is 2.94. Alkali content of the cement is 0.81%. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{3.15 \times 62.4}$$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{1.00 \times 62.4}$$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{100}$$

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{\text{SP.GR.} \times 62.4}$$

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Problem No. 8 - Modified With Fly Ash**

Design a fly ash modified Class A3 General Use mix. Coarse and fine aggregate will come from Lone Star Industries, Dock St., Richmond, VA. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 105 lb/ft<sup>3</sup>. Specific gravity of fly ash is 2.22. Alkali content of the cement is 0.65%. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $\frac{\quad}{3.15 \times 62.4}$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $\frac{\quad}{1.00 \times 62.4}$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  
 $\frac{\quad}{100}$

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $\frac{\quad}{\text{SP.GR.} \times 62.4}$

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Problem No. 9 - Modified With Fly Ash**

Design a fly ash modified Class A4 General Use mix. Coarse and fine aggregate will come from Sadler Materials, Richmond, VA. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 98 lb/ft<sup>3</sup>. Fly ash has a specific gravity of 2.30. Alkali content of the cement is 0.76%. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{3.15 \times 62.4}$$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{1.00 \times 62.4}$$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{100}$$

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  

$$\frac{\quad}{\text{SP.GR.} \times 62.4}$$

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Problem No. 10 - Modified With Slag**

Design a slag modified Class A4 Post & Rail mix. Coarse aggregate will come from Lone Jack, Glasgow, and fine aggregate will come from Wilson Quarries, Horsepasture. Make no adjustment for retarder. Dry rodded unit weight of the coarse aggregate is 102 lb/ft<sup>3</sup>. Specific Gravity of the Slag is 2.85. Alkali content of the cement is 0.95%. Use aggregate data sheets found on page 3-27 and 3-28.

CLASS \_\_\_\_\_ MIX DESIGN / MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE

COARSE AGGREGATE

F.M. \_\_\_\_\_

DRY RODDED UNIT WT. \_\_\_\_\_

SP. GR. \_\_\_\_\_

SP. GR. \_\_\_\_\_

NOMINAL MAX. SIZE C.A. \_\_\_\_\_

TABLE A1.5.3.6 FACTOR \_\_\_\_\_

OTHER DATA NEEDED FOR SPECIAL DESIGNS \_\_\_\_\_

QUANTITY OF COARSE AGGREGATE:

TABLE A1.5.3.6 \_\_\_\_\_ X 27 ft<sup>3</sup> X UNIT WT. \_\_\_\_\_ = \_\_\_\_\_ lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $3.15 \times 62.4$

WATER \_\_\_\_\_ lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 $1.00 \times 62.4$

AIR \_\_\_\_\_ % x 27 = \_\_\_\_\_ ft<sup>3</sup>  
 $100$

C. AGGR. \_\_\_\_\_ Lbs. = \_\_\_\_\_ ft<sup>3</sup>  
 SP.GR. \_\_\_\_\_ X 62.4

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

\_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>

- \_\_\_\_\_ ft<sup>3</sup>

F.A. \_\_\_\_\_ ft<sup>3</sup> X \_\_\_\_\_ SP.GR. X 62.4 = \_\_\_\_\_ lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT \_\_\_\_\_ lbs.

WATER \_\_\_\_\_ lbs. or \_\_\_\_\_ gals.

AIR \_\_\_\_\_ %

C. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. \_\_\_\_\_ Lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

**ACI Mix Design Adjustment Problem No. 1**

The following Class A4 General Use mix design produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One yd<sup>3</sup>.

Based on SSD Condition

IP Cement	635 lbs.	Sand - F. M.	2.80
Sand	1150 lbs.	Sand - Sp. Gr.	2.64
No. 57	1954 lbs.	CA - Sp. Gr.	3.04
Water	288 lbs.	CA - Unit Weight	108 lb/ft <sup>3</sup>
Air	6.5 %	IP Cement - Sp. Gr.	3.05

ANSWER

Cement \_\_\_\_\_ lbs.

Sand \_\_\_\_\_ lbs.

No. 57 \_\_\_\_\_ lbs.

Water \_\_\_\_\_ lbs.

Air \_\_\_\_\_ %

**ACI Mix Design Adjustment Problem No. 2**

The following Class A3 General Use mix design produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One yd<sup>3</sup>.

Based on SSD Condition

IS Cement	588 lbs.	Sand - F. M.	2.70
Sand	983 lbs.	Sand - Sp. Gr.	2.66
No. 57	1909 lbs.	CA - Sp. Gr.	2.61
Water	288 lbs.	CA - Unit Weight	104 lb/ft <sup>3</sup>
Air	6.0 %	IS Cement - Sp. Gr.	3.02

ANSWER

Cement \_\_\_\_\_ lbs.

Sand \_\_\_\_\_ lbs.

No. 57 \_\_\_\_\_ lbs.

Water \_\_\_\_\_ lbs.

Air \_\_\_\_\_ %

### ACI Mix Design Adjustment Problem No. 3

The following Class A4 General Use mix design modified with 40% slag produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One yd<sup>3</sup>.

Based on SSD Condition

Cement	381 lbs.	Sand - F. M.	2.70
Sand	1285 lbs.	Sand - Sp. Gr.	2.62
No. 57	1799 lbs.	CA - Sp. Gr.	3.04
Water	286 lbs.	CA - Unit Weight	98 lb/ft <sup>3</sup>
Air	6.5 %		
Slag	254 lbs.	Slag - Sp. Gr. -	2.95

#### ANSWER

Cement \_\_\_\_\_ lbs.

Sand \_\_\_\_\_ lbs.

No. 57 \_\_\_\_\_ lbs.

Water \_\_\_\_\_ lbs.

Air \_\_\_\_\_ %

Slag \_\_\_\_\_ lbs.

**ACI Mix Design Adjustment Problem No. 4**

The following Class A3 General Use Mix Design produced a 2 inch slump. The contractor wants a 3 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One yd<sup>3</sup>

Based on SSD Condition

IP Cement	588 lbs.	Sand - F. M.	2.80
Sand	1107 lbs.	Sand - Sp. Gr.	2.64
No. 57	1934 lbs.	CA - Sp. Gr.	2.83
Water	288 lbs.	CA - Unit Weight	106.9 lb/ft <sup>3</sup>
Air	6.0 %	IP Cement - Sp. Gr.	3.05

## ANSWER

Cement \_\_\_\_\_ lbs.

Sand \_\_\_\_\_ lbs.

No. 57 \_\_\_\_\_ lbs.

Water \_\_\_\_\_ lbs.

Air \_\_\_\_\_ %

**ACI Mix Design Adjustment Problem No. 5**

The following Class A3 General Use Mix Design modified with 20% flyash produced a 3 inch slump. The contractor wants a 4 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One yd<sup>3</sup>

Based on SSD Condition

Cement	470 lbs.	Sand - F. M.	2.80
Sand	1120 lbs.	Sand - Sp. Gr.	2.83
No. 57	1863 lbs.	CA - Sp. Gr.	2.62
Water	288 lbs.	CA - Unit Weight	103 lb/ft <sup>3</sup>
Air	6.5 %	Flyash - Sp. Gr.	3.00
Flyash	118 lbs.		

**ANSWER**

Cement \_\_\_\_\_ lbs.

Sand \_\_\_\_\_ lbs.

No. 57 \_\_\_\_\_ lbs.

Water \_\_\_\_\_ lbs.

Air \_\_\_\_\_ %

Flyash \_\_\_\_\_ lbs.

**ACI Mix Design Adjustment Problem No. 6**

The following Class A4 General Use Mix Design produced a 2 inch slump. The contractor wants a 3 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One yd<sup>3</sup>

Based on SSD Condition

IS Cement	635 lbs.	Sand - F. M.	2.90
Sand	1094 lbs.	Sand - Sp. Gr.	2.62
No. 57	1871 lbs.	CA - Sp. Gr.	2.83
Water	286 lbs.	CA - Unit Weight	105 lb/ft <sup>3</sup>
Air	6.5 %	IS Cement - Sp. Gr.	3.02

**ANSWER**

Cement \_\_\_\_\_ lbs.

Sand \_\_\_\_\_ lbs.

No. 57 \_\_\_\_\_ lbs.

Water \_\_\_\_\_ lbs.

Air \_\_\_\_\_ %

---

# 4

## Moisture Content and Batch Weight Calculations

---

It is the duty of the producer to compute the moisture content and batch weight adjustments. Moisture contents are determined as follows:

A representative sample of each aggregate is taken from the storage bin, weigh hopper, or from the stockpile. The moisture content should be typical of the material being used. The sample should weigh a minimum of 500 grams. The sample is weighed, and the weight is recorded. The sample is dried either on a hot plate or in an oven. The weight of the dry sample is then determined. Subtract the dry weight from the wet weight and divide the difference by the dry weight. Multiply the answer by 100 to obtain the percent of total moisture in the sample. From this figure you must subtract the absorbed moisture to obtain the free moisture, which is used to adjust the batch weights. Absorbed moisture is that which is actually absorbed by the aggregate. The free moisture content is that moisture which is on the surface of the aggregate. The value to be used for absorbed moisture is found on the aggregate data sheets. (See Chapter 3) The moisture test for each size aggregate should be run separately. An example of the calculations needed to determine free moisture is found below:

$$\begin{aligned} \text{Weight of Wet Sample} &= 1040 \text{ grams} \\ \text{Weight of Dry Sample} &= 1000 \text{ grams} \\ \text{Total Moisture} &= \frac{1040 - 1000}{1000} \times 100 = 4.0\% \end{aligned}$$

Absorption as found on the Aggregate Data Sheet = 0.5%

$$\begin{aligned} \text{Total Moisture} - \text{Absorbed Moisture} &= \text{Free Moisture} \\ 4.0\% - 0.5\% &= 3.5\% \end{aligned}$$

In the event scales are not the tare type, and a pan weight has to be used, the following procedure is applied:

Weight of Wet Sample + Weight of Pan = 1050 grams

Weight of Dry Sample + Weight of Pan = 1010 grams

Weight of Pan = 10 grams

$$\text{Total Moisture} = \frac{(1050 - 10) - (1010 - 10)}{(1010 - 10)} \times 100 =$$

$$\frac{1040 - 1000}{1000} \times 100 = 4.0\%$$

Absorption as found on Aggregate Data Sheet = 0.4%

Total Moisture - Absorbed Moisture = Free Moisture

$$4.0\% - 0.4\% = 3.6\%$$

## BATCH WEIGHT ADJUSTMENTS

Since the free moisture on the aggregate will eventually become a part of the mixing water, it is necessary to deduct the water which is free moisture from the mix design. This can be shown best by example:

Free Moisture in Sand = 3.6%

Free Moisture in No. 57 = 1.0%

Design quantities for a one cubic yard batch:

Cement 588 lbs.

Sand 1206 lbs.

No. 57 1864 lbs.

Water 288 lbs.

Since there is obviously no water in cement, start with the sand:

Sand =  $1206 \times 3.6\% = 1206 \times 0.036 = 43$  lbs. of "free" water added to the mix by wet sand.

No. 57 =  $1864 \times 1\% = 1864 \times 0.01 = 19$  lbs. of "free" water added to the mix by wet No. 57

Next adjust the aggregate pull weights:

$$\text{Sand} = 1206 + 43 = 1249 \text{ lbs.}$$

$$\text{No. 57} = 1864 + 19 = 1883 \text{ lbs.}$$

The above are the quantities of fine and coarse aggregate to be used in the mix.

Next adjust the amount of water to be added to the mix.

$$\text{The total free water in the aggregates} = 43 + 19 = 62 \text{ lbs.}$$

This free water must be subtracted from the design water.

$$288 - 62 = 226 \text{ lbs.}$$

This is the amount of water to be added to the mix. To convert this to gallons, you must divide by 8.33 (weight of one gallon of water) as follows:

$$\frac{226 \text{ lbs.}}{8.33 \text{ lbs/gal.}} = 27.1 \text{ gallons}$$

$$8.33 \text{ lbs/gal.}$$

## Moisture Problem Example

A. Given the following information, determine the percent of free moisture in the Sand and No. 57.

### SAND

Weight of wet sample = 585 grams

Weight of dry sample = 540 grams

### NO. 57

Weight of wet sample = 1205 grams

Weight of dry sample = 1190 grams

### ABSORPTION

Sand = 0.5%

No. 57 = 0.9%

Free Moisture: Sand \_\_\_\_\_ No. 57 \_\_\_\_\_

CALCULATIONS:

$$\text{Sand: } \frac{585 - 540}{540} \times 100 = 8.3$$

$$\text{Free Moisture in Sand} = 8.3 - 0.5 = 7.8\%$$

$$\text{No. 57: } \frac{1205 - 1190}{1190} \times 100 = 1.3$$

$$\text{Free Moisture in No. 57} = 1.3 - 0.9 = 0.4\%$$

B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or “pull weights” for four cubic yards.

Mix Design - 1 yd<sup>3</sup> Based on SSD condition

Batch Quantities

Cement	635 lbs. / CY	Cement	<u>2540</u> lbs. (for 4 CY)
Sand	1070 lbs. / CY	Sand	<u>4612</u> lbs. (for 4 CY)
No. 57	1840 lbs. / CY	No. 57	<u>7388</u> lbs. (for 4 CY)
Water	286 lbs. / CY	Water:	<u>784</u> lbs. (for 4 CY)
	<u>94.1</u> gals. / CY		
Air	6 %	Air	<u>6</u> %

CALCULATIONS:

Sand 7.8 %

No. 57 0.4 %

Sand:  $1070 \text{ lbs.} \times 7.8\% = 1070 \times 0.078 = 83 \text{ lbs.}$  (added per CY)

$1070 + 83 = 1153 \text{ lbs.}$  (total per CY)

$1153 \times 4 = 4612 \text{ lbs.}$  (total for the 4 CY pull)

No. 57:  $1840 \text{ lbs.} \times 0.4\% = 1840 \times 0.004 = 7 \text{ lbs.}$  (added per CY)

$1840 + 7 = 1847 \text{ lbs.}$  (total per CY)

$1847 \times 4 = 7388 \text{ lbs.}$  (total for the 4 CY pull)

Water:  $83 + 7 = 90$

$286 - 90 = 196$

$196 \times 4 = 784 \text{ lbs.}$  or 784 lbs. = 94.1 gallons (8.33 lbs./gal.)

This is the water to be added to the mix

Cement:  $635 \times 4 = 2540 \text{ lbs.}$  (no change)

## Chapter 4

### Study Problems

#### Moisture Problem No. 1

A. Given the following information, determine the percent of free moisture in the sand and No. 57.

SAND

Weight of wet sample = 635 grams

Weight of dry sample = 598 grams

NO. 57

Weight of wet sample = 1240 grams

Weight of dry sample = 1220 grams

ABSORPTION

Sand = 0.6%

No. 57 = 0.2%

Free Moisture: Sand \_\_\_\_\_ No. 57 \_\_\_\_\_

CALCULATIONS:

B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or “pull weights” for one cubic yard.

Mix Design - One Cubic Yard  
Based on SSD Condition

		<u>Batch Quantities</u>
Cement	635 lbs.	Cement _____ lbs.
Sand	1067 lbs.	Sand _____ lbs.
No. 57	1835 lbs.	No. 57 _____ lbs.
Water	288 lbs.	Water _____ lbs. _____ gals.
Air	6.5 %	Air _____ %

CALCULATIONS:

**Moisture Problem No. 2**

A. Given the following information, determine the percent of free moisture in the sand and No. 57.

SAND

Weight of wet sample = 628 grams

Weight of dry sample = 582 grams

NO. 57

Weight of wet sample = 1245 grams

Weight of dry sample = 1215 grams

ABSORPTION

Sand = 0.9%

No. 57 = 0.4%

Free Moisture: Sand \_\_\_\_\_ No. 57 \_\_\_\_\_

CALCULATIONS:

B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or “pull weights” for one cubic yard.

Mix Design - One Cubic Yard  
Based on SSD Condition

Batch Quantities

Cement 635 lbs.

Cement \_\_\_\_\_ lbs.

Sand 1070 lbs.

Sand \_\_\_\_\_ lbs.

No. 57 1840 lbs.

No. 57 \_\_\_\_\_ lbs.

Water 286 lbs.

Water \_\_\_\_\_ lbs.  
\_\_\_\_\_ gals.

Air 6.0 %

Air \_\_\_\_\_ %

CALCULATIONS:

**Moisture Problem No. 3**

A. Given the following information, determine the percent of free moisture in the sand and No. 57.

SAND

Weight of wet sample = 621 grams

Weight of dry sample = 580 grams

NO. 57

Weight of wet sample = 1362 grams

Weight of dry sample = 1343 grams

ABSORPTION

Sand = 0.7%

No. 57 = 0.4%

Free Moisture: Sand \_\_\_\_\_ No. 57 \_\_\_\_\_ .

CALCULATIONS:

- B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or “pull weights” for four cubic yards.

Mix Design - One Cubic Yard

Based on SSD Condition

		Batch Quantities	
Cement	635 lbs.	Cement	_____lbs.
Sand	1070 lbs.	Sand	_____lbs.
No. 57	1840 lbs.	No. 57	_____lbs.
Water	286 lbs.	Water	_____lbs. _____gals.
Air	7.0 %	Air	_____%

CALCULATIONS:

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# 5

## Inspection of Plant and Equipment

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The District Materials Engineer or representative will be responsible for the initial inspection and approval of the plant and trucks.

### MIX DESIGN

Before any concrete is batched, it is the responsibility of the producer's technician to prepare and submit a mix design for approval. The approved design must be at the plant prior to the beginning of the batching operations. The approved mix design controls the amount of water and other materials used in the batching. A sample design (form TL-27) is shown on Page 5 - 3.

### AGGREGATES

Aggregates should be handled and stored to minimize segregation and to prevent contamination with deleterious substances. Stockpiles should be built in layers of uniform thickness. Stockpiles should not be built in high cone-shaped piles; this results in segregation. To minimize segregation, aggregates should be removed from stockpiles in horizontal layers.

Stockpiles are checked to determine that they are free from foreign matter, separated by space or bulkheads so that aggregates will not intermingle while loading, and kept in at least a saturated surface-dry (SSD) condition. In order to keep stockpiles in an SSD condition, they should be sprinkled, using an approved method, the night before batching. If aggregates are in less than SSD condition, there will be no surface moisture and only partial or no absorbed moisture, resulting in the loss of part of the mixing water to the aggregates. If stockpiles are built on the ground, the loader should remain at least twelve inches from the ground while removing the material. A check is made to see that the aggregates have been tested. When material comes from a local source, the delivery ticket is to have a certification stating that this material has come from a previously tested and approved stockpile, and the certification is to be signed by the producer or representative. In the case of rail shipments, each shipment should be accompanied by a seal or other evidence of inspection. If no evidence is found, or the material does not arrive at the plant in satisfactory condition, whether previously tested or not, the District Materials Engineer (DME) should be notified promptly. The DME will then decide whether or not the material must be resampled and tested before it is accepted for use.

## CEMENT

Cement storage structures should be checked to determine if they are weatherproof. Any moistening of the cement prior to its use, creating lumpy and partially hydrated material, shall be cause for rejection. Since there are many different types and brands of cement used, the producer's technician should make sure the type and brand used is the same as that shown on the mix design. Some silos have more than one compartment, and are capable of storing more than one type of cement. If more than one type is stored in one silo, the producer's technician should make sure that the correct type is being used.

Before any concrete is batched, the producer's technician should determine that there is a certification stating the cement meets the requirements of the VDOT Specifications.

## SCALES

Scales used for weighing aggregates and cement shall be approved and sealed in accordance with the requirements of Section 109.01 of the Specifications. Before weighing aggregates and cement, the technician should be sure the scales have been serviced within the past 6 months by a private scale service company certifying that all concrete hopper scales meet Handbook 44 Regulations. Scales should be checked and certified whenever the scales are moved, whenever there is reason to believe they are inaccurate, or at the request of the Engineer. Before the weigh hopper is loaded, the scales are to be on the zero mark. If scales are not on zero, weighing operations cannot begin. It is the duty of the Certified Concrete Plant Technician to see that the correct batch weights are used. The batch weights are to be shown on the TL-28A form which is the producers batch weight certification. Cement and aggregates are to be weighed within the following tolerances:

Cement	$\pm 1\%$
Water	$\pm 1\%$
Coarse & Fine Aggregate	$\pm 2\%$
Admixtures	$\pm 3\%$

For mobile production plants, cement may vary up to +4%.

Form TL-27MC (Revised 1/07)

**VIRGINIA DEPARTMENT OF TRANSPORTATION  
MATERIALS DIVISION**

**STATEMENT OF HYDRAULIC CEMENT CONCRETE MIX DESIGN**

Submit one copy to the District Administrator, Virginia Department of Transportation. Approval must be received by the contractor from the Materials Division before work is begun. This mix design is approved for all projects of the Department for the class of concrete shown: Calendar Year 2007 Mix Design No. 4-9907-07

Producer GENERAL READY MIX Plant Location RICHMOND, VA Phone 804-555-2000  
Type of Mix: Ready Mix X Job Mix \_\_\_\_\_ Date 02/15/2007

Mix Design - One Cubic Yard (Meter) Based on SSD Condition

Class of Concrete A-4 GENERAL (E) Slump/ 2 TO 4 In. \_\_\_\_\_ mm Air Content 6.50% %  
25% FLYASH Flow

Material	Type	Quantities	Code	Source Name	Plant/Quarry Location
Cement	<u>II</u>	<u>476</u> lbs. _____ kg.	<u>10</u>	<u>LEHIGH CEMENT CO.</u>	<u>UNION BRIDGE, MD</u>
Min. Admix. 1		<u>159</u> lbs. _____ kg.	<u>114</u>	<u>PROASH</u>	<u>ROXBORO, NC</u>
Min. Admix. 2		_____ lbs. _____ kg.			
Sand <sup>(1)</sup>		<u>1166</u> lbs. _____ kg.	<u>4017</u>	<u>TARMAC</u>	<u>KINGSLAND, VA</u>
No. <u>57</u> Stone <sup>(1)</sup>		<u>1748</u> lbs. _____ kg.	<u>4027</u>	<u>VULCAN MATERIALS</u>	<u>HYLAS, VA</u>
Gr./No. _____ Aggr. <sup>(1)</sup>		_____ lbs. _____ kg.			
Water <sup>(2)</sup> <u>267</u> lbs.		<u>32</u> gal. _____ L.		<u>DEEPWELL</u>	<u>RICHMOND, VA</u>
Admixture (AE) <sup>(3)</sup>		<u>2.5</u> oz. _____ ml.	<u>49</u>	<u>SIKA AEA 15</u>	<u>LYNDHURST, NJ</u>
Admixture (Retarder) <sup>(3)</sup>		<u>12.7</u> oz. _____ ml.	<u>6</u>	<u>SIKA PLASTIMENT</u>	<u>LYNDHURST, NJ</u>
Admixture (Other) <sup>(3)</sup>		_____ oz. _____ ml.			

NOTES:

(1) The quantities of fine and coarse aggregates necessary to conform to specifications in regard to consistency and workability shall be determined by the method described in "Recommended Practice for Selecting Proportions for Normal Weight Concrete" (ACI-211.1) and the actual quantities used shall not deviate more than plus or minus 5 percent from such quantities.

(2) To provide minimum slump permissible in Table II-17 while satisfying placement and finishing requirements. A separate design shall be submitted for each slump desired.

(3) The quantity of admixture will not be approved or disapproved since it varies considerably and must be initially established by trial and error by the producer or contractor with subsequent adjustment during batching to maintain the desired results within the range specified.

Mineral Admixture #1 - sp.gr.	<u>2.63</u>
Mineral Admixture #2 - sp.gr.	_____
Sand - Abs.	<u>0.6</u>
Sand - F.M.	<u>2.9</u>
Sand - sp.gr.	<u>2.62</u>

C.A. #1 - Abs.	<u>0.5</u>
C.A. #1 - sp.gr.	<u>2.69</u>
C.A. #1 Unit mass	<u>98.1</u> / _____
	Lbs./C.F. kg/C.M.

Aggr. #2 - Abs.	_____
Aggr. #2 - sp.gr.	_____
2nd F.A./C.A.-F.M./u.wt.	_____ / _____
	E M

Design W/C Ratio 0.42

Contractor GENERAL READY MIX  
(Name of Company)

By B. L. SMITH  
(Certified Technician Preparing Form)

Producer Technician's Expiration Date 12/31/2012  
(Do Not Use Social Security Number)

FOR DEPARTMENT USE ONLY

Remarks: \_\_\_\_\_

Copies: District Materials Engineer  
Project Inspector  
Plant Inspector  
Sub- Contractor and / or R.M. Producer

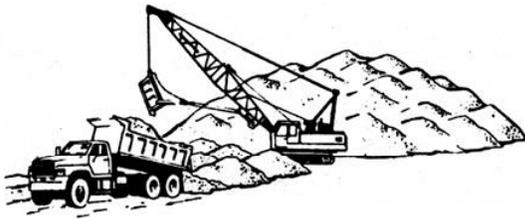
Checked by JOHN DOE

Approved by I. M. JONES  
District Materials Engineer

Approved tentatively subject to the production of material meeting the requirements of the Specifications and Special Provisions.

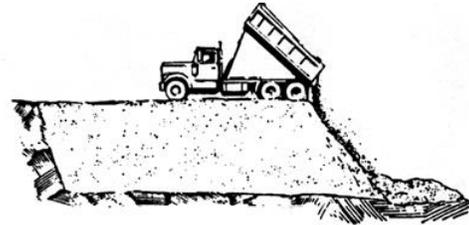
## CORRECT AND INCORRECT METHODS OF HANDLING AND STORING AGGREGATES

Incorrect methods of stockpiling aggregates cause segregation and breakage.



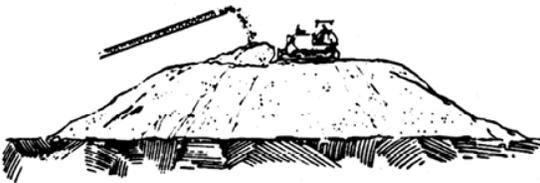
### PREFERABLE

Crane or other means of placing material in pile in units not larger than a truckload which remain where placed and do not run down slope.



### OBJECTIONABLE

Methods which permit the aggregate to roll down the slope as it is added to the pile or permit hauling equipment to operate over the same level repeatedly.



### LIMITED ACCEPTABILITY

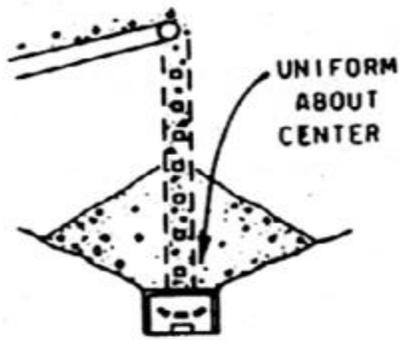
Pile built radially in horizontal layers by dozer or front end loader working from materials as dropped from conveyor belt. A rock ladder may be needed in setup.



### GENERALLY OBJECTIONABLE

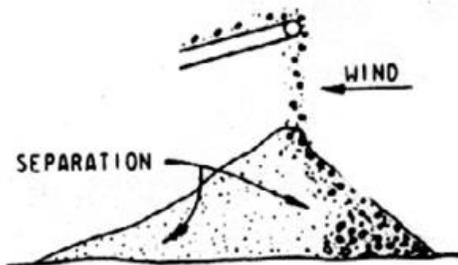
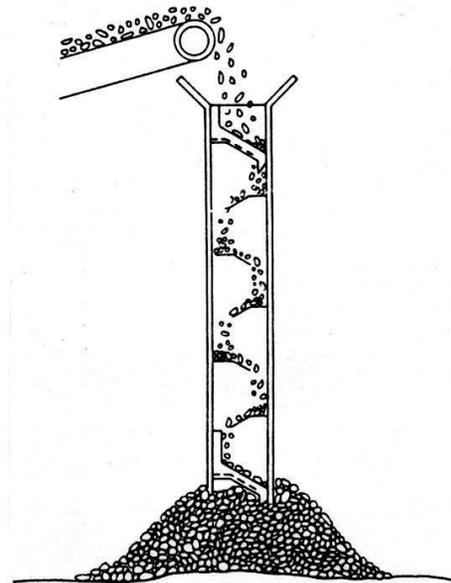
Dozer or front end loader stacking progressive layers on slope not flatter than 3:1 is objectionable unless materials strongly resist breakage.

FIGURE 13



**CORRECT**

Chimney surrounding material falling from end of conveyor belt to prevent wind from separating fine and coarse materials. Openings provided as required to discharge materials at various elevations on the pile.



**INCORRECT**

Free fall of material from high end of stacker permitting wind to separate fine from coarse material.

When stockpiling large sized aggregates from elevated conveyors, breakage is minimized by use of a rock ladder.

UNFINISHED OR FINE AGGREGATE STORAGE (DRY MATERIALS).

FINISHED AGGREGATE STORAGE

**Stockpiling of Coarse Aggregate When Permitted:** Stockpiled aggregate should be finish-screened at batch plant. When this is done no restrictions on stockpiling are required.

FIGURE 13

## WATER

Water must be previously approved and may be measured by either volume or weight. Means of dispensing water into the batch are by: meter, holding tank, or scales. Water is to be dispensed within an accuracy of  $\pm 1\%$ .

## ADMIXTURES

There are several types of admixtures used in highway concrete. Examples are: air entraining agents, set retarders, water reducers, and accelerators. The Department of Transportation publishes an approved list of admixtures periodically. Admixtures must be used and dispensed according to manufacturer recommendations by means of an approved, graduated, transparent, measuring device before they are introduced into the mixer. (Page 5 - 8). If more than one admixture is to be used, they shall be released in sequence rather than at the same instant as there may be a chemical reaction between the admixtures. Liquid admixtures should be agitated prior to their use. Admixtures must be dispensed within an accuracy of  $\pm 3\%$ . Admixtures must be stored and handled to prevent freezing, contamination, and deterioration.

## TRUCKS

Before a transit mix truck leaves the plant, the producer's technician should see that the required mixing revolutions are obtained. The correct speed can be obtained from the manufacturer's rating plate on the truck. Truck mixers are to be equipped with the following devices: revolution counter, manufacturer's rating plate which shows the mixing capacity (specifications require a maximum and minimum that can be mixed), and agitating speed of the mixer, and a properly calibrated water measuring device. (See Page 5 - 9). Periodically, the technician should make a visual inspection of the trucks to see that the blades are in good condition and there is no excessive buildup of hardened concrete in the drum. Before any truck is used for VDOT concrete, the technician should make sure the truck has a current VDOT strap tag.

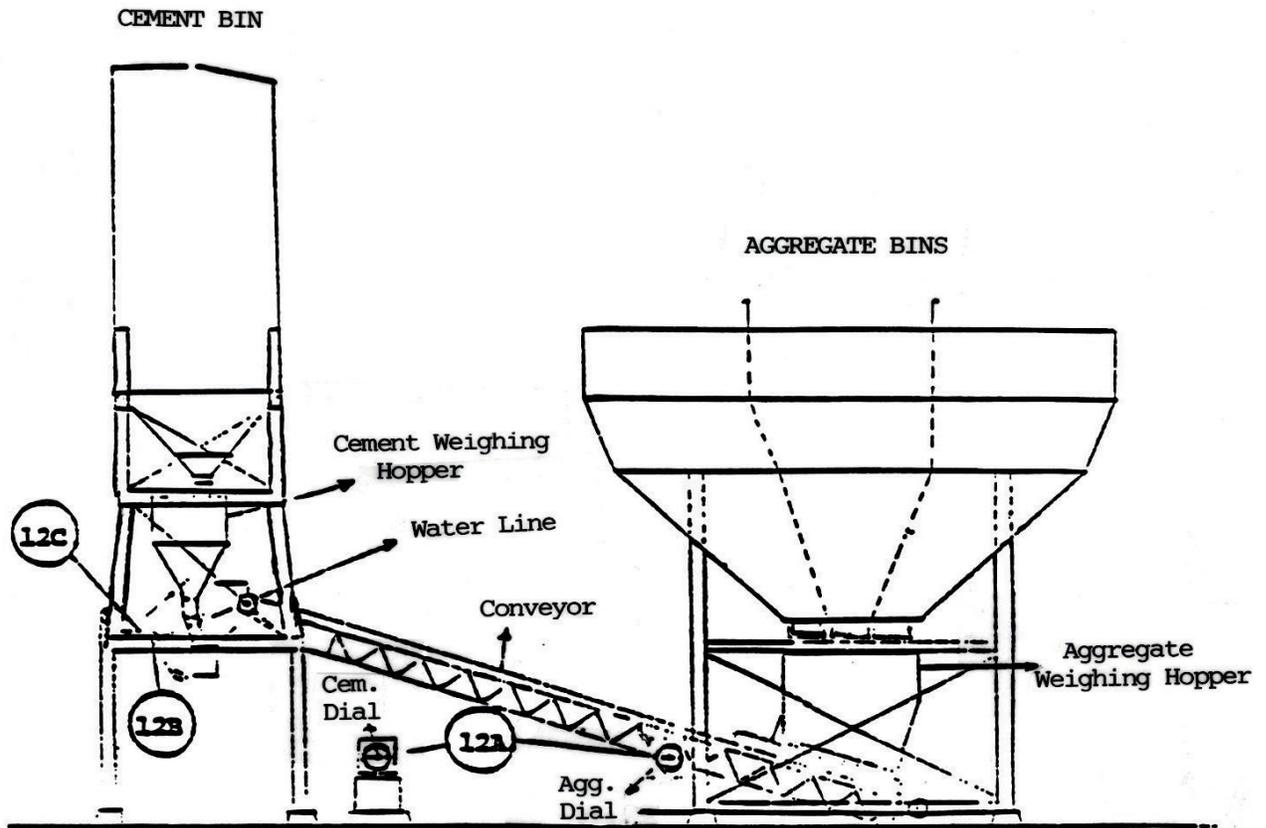
The volume of concrete mixed per batch shall not be less than 15 percent nor more than 110 percent of the mixer's rated capacity.

Consistency tests of individual samples at approximately the beginning, midpoint, and end of the load shall be conducted upon request by the Engineer. If consistency measurements vary by more than 2 inches for slump between high and low values, the mixer or agitator shall not be used until the inconsistency is corrected.

## CONCRETE BATCH REPORT - FORM TL-28A

Before the truck leaves the plant, the upper half of Form TL-28A, should be filled out by the producer. The technician should send the original to the project with the truck driver and retain the carbon copy for the plant's records. An example of Form TL-28A is shown on Page 7 - 9.

FIGURE 14 BATCH PLANT DIAGRAM



- 12A – SCALES
- 12B – WATER MEASURING DEVICE
- 12C – ADMIXTURE DISPENSER

FIGURE 15 ADMIXTURE DISPENSER

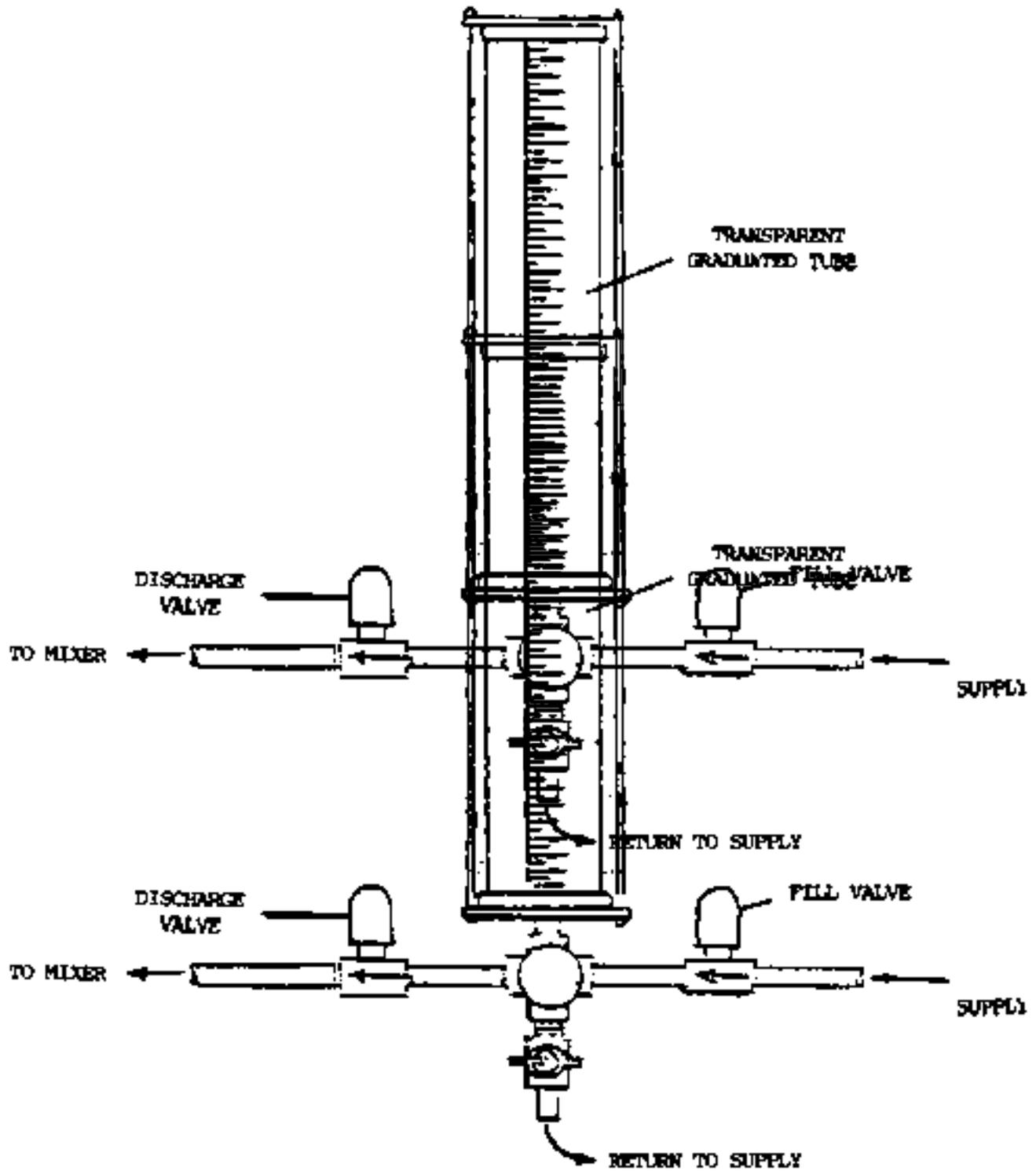
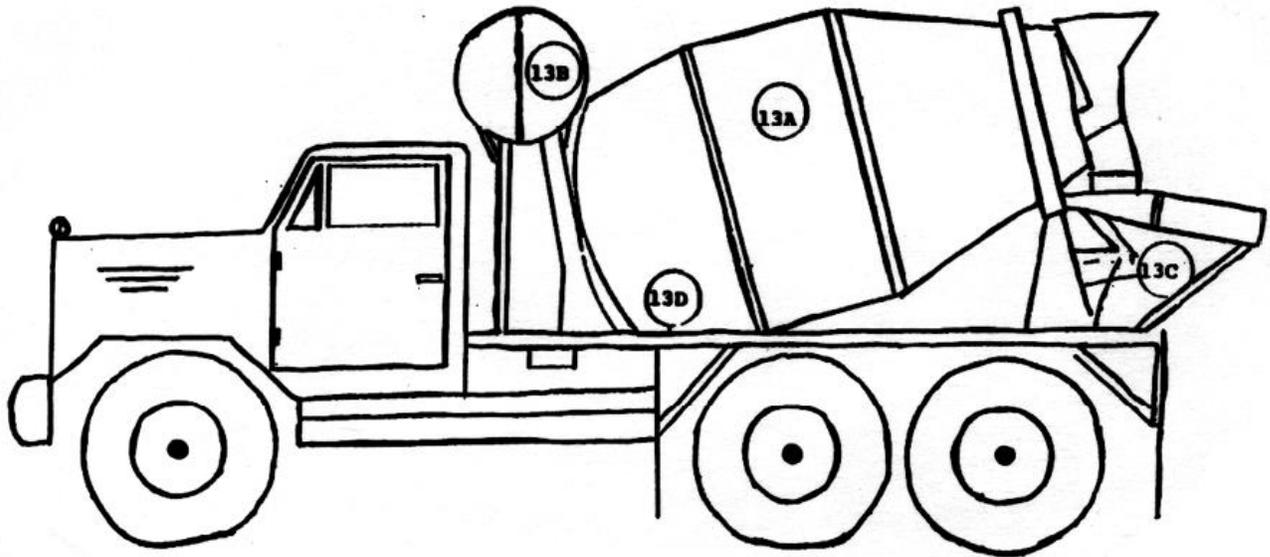
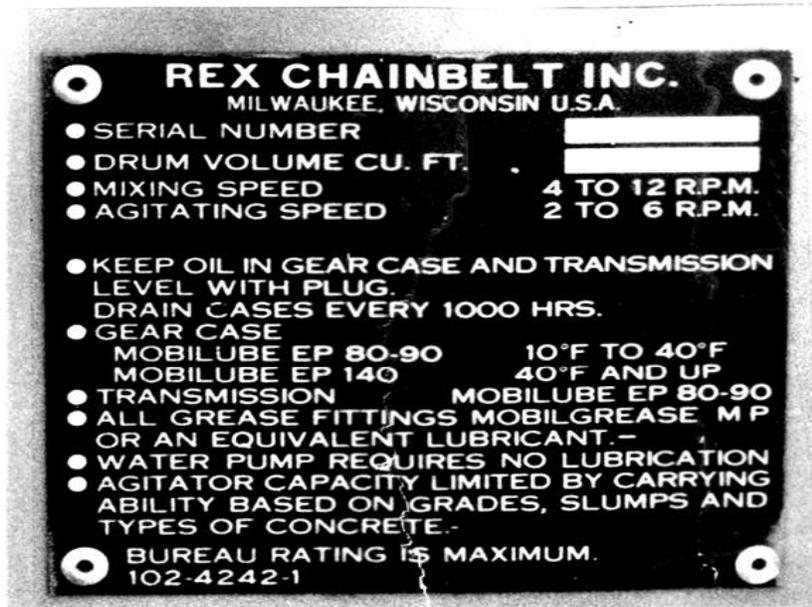


FIGURE 16 TRUCK MIXER



- 13A Drum and Blades
- 13B Water Tank
- 13C Manufacturer Plates
- 13D Revolution counter

FIGURE 17 MANUFACTURER PLATES



# Chapter 5

## Study Questions

1. Before any concrete is batched, the producer's technician should determine that there is an approved mix design at the plant. True or False
2. The required weighing accuracy for cement is \_\_\_\_\_.
3. Aggregates arriving at a plant by truck are acceptable for use if they are accompanied by a \_\_\_\_\_.
4. Hopper and cement scales for batching concrete materials must be \_\_\_\_\_.
5. Aggregates should be handled and stockpiled in such a manner as to minimize \_\_\_\_\_.
6. The required weighing accuracy for aggregate is \_\_\_\_\_.
7. The minimum and maximum limits of volume of concrete which can be mixed in a mixer are \_\_\_\_\_.
8. The loader should remain \_\_\_\_\_ from the ground while removing material if stockpiles are built on the ground.

---

# 6

## **Responsibilities of the Producers and VDOT Materials Technician**

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The goal of each of these technicians is to insure that concrete delivered to the project site complies with the specifications for the concrete being produced. He/she should also study all facets of the plant operation, so as to recognize and anticipate critical periods for quality control.

Each technician is to take the time to keep accurate and complete records. These records will be necessary in evaluating the performance of the concrete in the years to come. A record must be made of all tests, calibrations, and quantities used. Any changes in the plant operation should also be documented.

Perhaps the best way for production personnel to have a complete understanding of the responsibilities of quality control, would be to list the responsibilities of the Producer's Certified Concrete Technician and the Virginia Department of Transportation District Materials Technician. Listed below is an outline of the duties and responsibilities of each of the aforementioned technicians.

## DUTIES OF THE PRODUCER CERTIFIED CONCRETE TECHNICIAN

- I. Concrete Mix Design: Designs and submits the proposed mix design to the Department of Transportation for approval. It is his/her responsibility to see that all information contained in the proposed design is accurate and that the most current data has been used in the design calculations.
- II. Communication: Make sure good communication exists between the batching plant and the project site in the interest of quality control. Corrections to the batch may be performed much sooner if good communication exists.
- III. Plant Materials:
  - A. Cement: Assure that the cement is represented by a certification. Make periodic checks of the storage compartment to insure that the cement is maintained in a dry condition and that the cement is stored so as to avoid contamination with a different type of cement or other materials. Assurance must also be made that enough cement is on hand for completing one day of concreting operation.
  - B. Aggregate: Check to insure that all aggregates which are to be used have been previously tested. Check that the aggregates are stored in the proper manner so that intermingling is avoided and that segregation is minimized. Check that the aggregates are maintained in moist condition (at least at saturated surface-dry, (SSD) condition). Also to make sure there is enough for one day's output.
  - C. Admixtures: See that the admixtures proposed for use have been approved and that the admixtures are stored properly. Admixtures are to be stored in a place where they will not become frozen and to prevent contamination and deterioration. The technician should also see that the admixtures are dispensed into the mix in an approved manner.

## IV. Plant Equipment:

- A. Scales: Responsible for seeing that all weighing devices are properly inspected and have been serviced and certified within the past 6 months by a private scale service company. Check that the weighing devices are in good operating and clean condition.
- B. Bins and Weigh Hoppers: Responsible for proper maintenance and repair of all storage bins and weigh hoppers and that the storage bins are arranged in a manner so as to avoid intermingling of the material.
- C. Ready-Mix Trucks: See that a sufficient number of trucks are available for each concreting operation and that the trucks are maintained and are in compliance with the VDOT Specifications.

## V. Plant Operations

- A. Aggregate Moisture Checks: Responsible for performing two (2) moisture tests daily, or as required, for aggregate prior to each day's concreting operation.
- B. Batch Weight Adjustments: Responsible for adjusting the design weights to the corrected pull weights, based on the moisture content of the representative aggregate moisture test as noted above.
- C. Batching of Concrete: Based on the moisture test and the calculated adjusted batch weights, the Producer's Certified Concrete Technician will weigh the ingredients and they will then be properly discharged into the mixer or ready-mix truck.

## DUTIES OF THE VIRGINIA DEPARTMENT OF TRANSPORTATION MATERIALS TECHNICIAN

- I. Mix Designs:
  - A. Checks the items listed on the mix design as submitted by the Producer's Certified Concrete Technician.
  - B. Works closely with the field and the producer to insure that the designed concrete is giving the desired results.
  - C. Responsible for conducting the performance tests, such as yield tests.
- II. Sampling of Materials:
  - A. Cement, fly ash and slag - Obtains samples from the plant if there is a problem. These materials are accepted on certification.
  - B. Aggregates - Obtains samples from the plant if there is a problem. Plant should have shipping documentation verifying material is from an approved source.
  - C. Water - Samples and tests the water which will be used in the concrete mixture in the initial plant inspection and periodically thereafter.
- III. Plant Inspections: It is the responsibility of the Producer's Certified Concrete Technician to see that the plant is in compliance with specifications, equipment is functioning properly and that all materials are approved for use and are properly stored. VDOT's Materials Technician should review the items listed below and inform the Plant Technician of any deficiencies so corrective action can be taken.
  - A. Aggregates - Checks stockpiles to see that they are maintained properly and that shipping documentation verifies material is from an approved source.
  - B. Cement - Checks to see that the cement, fly ash, and slag are stored in weatherproof compartments and that the cement is properly represented by mill certifications.
  - C. Admixtures - Checks to see that admixtures are handled in a manner to prevent contamination, dispensed accurately and properly, and stored properly. Checks shipping documentation to verify that admixtures are from an approved source.
  - D. Water - Checks the water dispensing device for accuracy and also checks and approves the water heating system for cold weather concrete.
  - E. Weighing Devices - Checks all scales for accuracy and for compliance with specifications. A specific check is made to see that the certification on each weighing device is current.
  - F. Bins and Weigh Hoppers - Inspects all bins and weight hoppers for compliance with specifications.
  - G. Mixers - Inspects all mixing units for compliance with specifications. Items checked are revolution counters, timing devices, water gauges, and mixing blades.

- H. Testing Equipment - Assures that the following testing equipment is available at the concrete plant: moisture determination devices, air meter, and consistency testing device (slump cone).
  - I. Plant Personnel - Checks to see that qualified personnel are available for concrete mixing operations and that required records are maintained.
- IV. Project Site - Assists the Project Inspector by performing the following duties:
- A. Assists in the training of new VDOT personnel
  - B. Checks the adequacy of mixing trucks
  - C. Assists in performing various tests at the job site
  - D. Investigates the cause of test failures
  - E. Observes the placing of concrete to see that the mix design is giving the desired results
  - F. Assists and observes bridge deck placements

## Chapter 6

### Study Questions

1. \_\_\_\_\_ is responsible for designing the Concrete Mix.
2. \_\_\_\_\_ is responsible for assuring that concrete components are certified or approved.
3. \_\_\_\_\_ is responsible for conducting the performance tests, such as yield tests.
4. Making the moisture correction for aggregate is the responsibility of the \_\_\_\_\_.
5. Setting all the dials, gauges, scales, and meters at the batch plant is the responsibility of the \_\_\_\_\_.

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# 7

## Automated Data Processing of Concrete

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The purpose of the data system for which these instructions were prepared is to provide descriptive information about the materials used in highway work. Independent Assurance and concrete control tests shall be handled under the conventional method and using conventional forms.

Basically, the system is designed for coding test reports. For instance, in lieu of recording the Contractor's name and location, only a code is needed. The printout will show the Contractor's name and location. Code sheets have been included in this chapter for class purposes only. A complete list of codes may be obtained from the District Materials Section.

It is very important that all data entered on the Data Processing Forms be correct, in the proper blanks, and, most of all legible. Attached you will find a coding guide to be used for numeric and alphabetic characters. As a rule, numeric characters are recorded from the right to left, and alphabetic from the left to right. Please adhere to these standards.

### Form TL-28A Coding Form - Concrete Batch Report

The Hydraulic Cement Concrete Coding Form TL-28A contains three (3) records, A, B, and C. The plant record, A and B, is completed by the Producer's Technician, and the site record, C, is completed by the Project Inspector. The TL-28A is to accompany the first load of concrete delivered to the project. The load should not be tested or accepted until the TL-28A is received.

Under the job heading (Column 2), the Producer's Technician chooses a numerical (1-9) or alphabetical (A-Z) code for each day beginning with 1 or A, and then changes only if any item in A or B record changes (ex. yards<sup>3</sup> or pounds of free water changes). If all the loads are identical, then the Producer's Technician would fill in the A& B record only once. The Project Inspector would continue recording the project data in record C, until the Technician receives another TL-28A coding form from the Producer's Technician. The time batched would have to be shown on the producer's ticket.

On the next day, the Technician should restart with 1 or A. The codes that are needed for completing record C are attached. On record A the water is in pounds (kilograms), and on record B the water is in gallons (liters).

If the plant is a central-mix plant, mark an "X" in Section B, Column 71. If the plant is a ready-mix plant, leave Section B, Column 71 blank. The Producer's Technician signs the TL-28A coding form in the upper right corner.

Always record from the right to left. For miscellaneous concrete, the TL-28A will not be required unless cylinders are cast. If cylinders are cast, it will be required to obtain information that is not included on Forms TL-13 or TL-26A. Independent Assurance samples are not to be recorded on the TL-28A.

The remaining spaces on the form are self-explanatory.

The Project Inspector submits the TL-28A to the District Materials Section for review and data entry. The District Materials Office retains the original and the Project Inspector retains a copy.

## TL-13 Notice of Shipment of Concrete Cylinders

The TL-13 is to be filled out by the person molding the cylinders and it shall be submitted with each cluster of acceptance cylinders. Under the cylinder column, the cylinder number should be the same as shown on the TL-28A, (ex. if it is listed in the 1st column, the last 2 spaces on the TL-28A, list it the same way on the TL-13). Mark the sample number, project number, class of concrete and date cast on the cylinders. The District Materials Office will pick up the cylinders.

## Form TL-26A - Report of Structural Concrete

Form TL-26A is to be filled in by the District Materials Section to record the compressive strengths of the cylinders.

The District Materials Office retains the original and the Project Inspector retains a copy. The Project Inspector sends a copy to the Contractor if a sample fails.

CODING OF CHARACTERS  
FOR DATA PROCESSING INPUT DATA

Alphabet Characters  
Capital Letters Only

<b>A</b> Squared top not acceptable	<b>N</b> Parallel sides
<b>B</b> Overhang top and bottom to avoid confusion with numerals 8 or 13. Center division required to avoid similarity with the letter D.	<b>O</b> Loop added at top to avoid confusion with numeric zero
<b>C</b> Deep Curves to avoid similarity with parenthesis.	<b>P</b> Overhang at top added for consistency with letters B, D, R
<b>D</b> Overhang top and bottom to reduce confusion with the number zero.	<b>Q</b> No Special convention
<b>E</b> Straight leg	<b>R</b> Overhang at top added for consistency with letters B, D, P
<b>F</b> Straight leg	<b>S</b> Serif added at top only to distinguish from the numeral 5
<b>G</b> Emphasized serif reduces confusion with letter C or numerals six and zero.	<b>T</b> No Special convention
<b>H</b> Parallel sides	<b>U</b> Parallel side to distinguish from letter V.
<b>I</b> Serifs top and bottom are required	<b>V</b> No Special convention
<b>J</b> Top serif reduces confusion with letter U.	<b>W</b> Center division extends to top of letter. Rounded bottom should be avoided.
<b>K</b> Slanting legs are joined at the center	<b>X</b> No Special convention
<b>L</b> No special convention	<b>Y</b> Vertical leg bisects angle framed by top legs to avoid confusion with numeral 4.
<b>M</b> Legs spread at bottom center	<b>Z</b> Horizontal bar is standard

CODING OF CHARACTERS  
FOR DATA PROCESSING INPUT DATA

Numeric Characters

<b>0</b> Closed circle	<b>5</b> Vertical and top lines joined at right angle Loop closed at bottom to avoid confusion with
<b>1</b> Single vertical Bar	<b>6</b> zero or lower case b .
<b>2</b> No loop at bottom	<b>7</b> Crossed bar considered confusing with letter Z
<b>3</b> Curved lines, no straight top line	<b>8</b> Made with two circles adjoining vertically to avoid confusion with special character ampersand and dollar sign
<b>4</b> Open top to reduce confusion with 9.	<b>9</b> Straight Leg

## CODE LIST FOR CURING METHODS

<u>CODENO.</u>	<u>METHOD</u>
1	Liquid Membrane Seal
2	Polyethylene Sheeting
3	Burlap
4	Burlene
5	Wet Sand
6	Water Ponding
7	Steam
8	Heater Blanket

## CODE LIST FOR TYPE OF STRUCTURE

<u>CODENO.</u>	<u>TYPE STRUCTURE</u>
1	Box Culvert and/or Appurtenances
2	Bridge (except deck)
3	Bridge Deck
4	Parapet Wall
5	Approach Slab
6	Retaining Wall
7	Curb and Gutter
8	Slope Paving
9	Ditch Paving
10	Sidewalk
11	Precast Piling
12	Precast Beams
13	Precast Miscellaneous
14	Sidewalk or Driveway
15	Miscellaneous
16	Pier Stem
17	Paving
18	Tunnel

NOTES FOR MATERIALS DIVISION PERSONNEL  
 CODES NOT ON MASTER CODE LIST  
 CONCRETE CLASSIFICATIONS

<u>CONCLASS</u>	<u>CODE</u>	<u>NUMERIC EQUIVALENT</u>
A3	1	1
A4	2	2
A5	3	3
B2	4	4
C1	5	5
T3	6	6
SPECIAL PAVEMENT	7	7
A4 TUNNL	8	8
B2 TUNNL	9	9
E1 TUNNL	A	10
Y TUNNL	B	11
A3 FLYASH	C	12
A4 FLYASH	D	13
A5 FLYASH	E	14
B2 FLYASH	F	15
C1 FLYASH	G	16
T3 FLYASH	H	17
SPECFA	I	18
PAVEFA	J	19
A 4000	K	20
A 4000F (FLYASH)	L	21
*	M	22
*	N	23
A3SLAG	O	24
A4SLAG	P	25
A5SLAG	Q	26
B2SLAG	R	27
C1SLAG	S	28
T3SLAG	T	29
SPEC SG	U	30
PAVSG	V	31
A6	W	32
A 4000S (SLAG)	X	33
*	Y	34
	Z	35

CEMENT CLASSIFICATIONS

<u>CEMENT</u>	<u>NUMERIC EQUIVALENT</u>
I	1
II	2
III	3
IP	4
V	5
III MODIFIED	6

\* CODES RESERVED FOR FUTURE USE

FOR STUDY GUIDE PURPOSES ONLY. TO OBTAIN AN UP TO DATE LIST, PLEASE CONTACT YOUR DISTRICT MATERIALS OFFICE.

# CEMENT SOURCE

<u>TABLE</u>	<u>CODE</u>	<u>NAME</u>	<u>CITY</u>	<u>STATE</u>
CEMB	1	COPLAY	LIME KILN	MD
CEMB	2	BLUE CIRCLE ATLANTIC INC.	RAVENA	NY
CEMB	3	BLUE CIRCLE ATLANTIC INC.	VALENCIA	SP
CEMB	4	ATLANTIC	CHESAPEAKE	VA
CEMB	5	ATLANTIC	BALTIMORE	MD
CEMB	6	ROANOKE CEMENT CO.	CLOVERDALE	VA
CEMB	7	TARMAC-LONESTAR INC.	CHESAPEAKE	VA
CEMB	8	COPLAY	NAZARATH	PA
CEMB	9	IDEAL	CASTLE NAYNES	NC
CEMB	10	LEHIGH PORTLAND CEMENT CO.	UNIONBRIDGE	MD
CEMB	11	LEHIGH PORTLAND CEMENT CO.	ALLENTOWN	PA
CEMB	12	CAPITAL	MARTINSBURG	WV
CEMB	13	MARQUETTE	HAGERSTOWN	MD
CEMB	14	MEDUSA	YORK	PA
CEMB	15	DIXIE	KNOXVILLE	TN
CEMB	16	SANTEE	HOLLY HILL	SC
CEMB	17	UNIVERSAL ATLAS	BAHAMAS	GB
CEMB	18	LEHIGH PORTLAND CEMENT CO.	LEEDS	AL
CEMB	19	INDEPENDENT	HARLEYVILLE	SC
CEMB	20	GIFFORD HILL	EVANSVILLE	PA
CEMB	21	ALLENTOWN CEMENT CO.	KNOXVILLE	TN
CEMB	22	IDEAL	HAGERSTOWN	MD
CEMB	23	TARMAC	PERTIGALETE	VZ
CEMB	24	LEHIGH VENEZULAN	HAGERSTOWN	MD
CEMB	25	INDEPENDENT CEMENT CORP.	ASLAND	SP
CEMB	26	TARMAC	SAGUNTO	SP
CEMB	27	BLUE CIRCLE ATLANTIC INC.	PERTIGALETE	VZ
CEMB	28	TARMAC	MILAKI	GR
CEMB	29	TARMAC	ELEFSU	GR
CEMB	30	TARMAC	S.A.	GR
CEMB	31	TITAN	ALMERIA	SP
CEMB	32	HORNOS IBERICOS ALBA	VERACUZ	MX
CEMB	33	CEMENTOS APCOSCOSA	AMPAROPAULA	MX
CEMB	34	LEHIGH-TAMPICO CEMENT CO.	EVANSVILLE	PA
CEMB	36	ALLENTOWN CEMENT CO.	BEAUPORT	CA
CEMB	37	INDEPENDENT CEMENT	EVANSVILLE	PA
CEMB	38	COPLAY CEMENT CO.	BEAUPORT	CA
CEMB	39	LEHIGH PORTLAND CEMENT CO.	FREDERICK	MD
CEMB	40	HERCULES CEMENT CO.	NORFOLK	VA
CEMB	41	KOSMOS CEMENT CO.	STOCKERTOWN	MD
CEMB	42	INDEPENDENT CEMENT CORP.	LOUISVILLE	KY
CEMB	43	BLUE CIRCLE ATLANTIC INC.	BALTIMORE	MD
CEMB	44	BLUE CIRCLE ATLANTIC INC.	KAMARI	GR
CEMB	45	BLUE CIRCLE ATLANTIC BARRANQUILLA	ORIZABA	MX
CEMB	46	BLUE CIRCLE ATLANTIC BARQUISIMETO	COLUMBIA	SA
CEMB	47	BLUE CIRCLE ATLANTIC INC.	VENEZUELA	SA
CEMB	48	BLUE CIRCLE ATLANTIC CARTAGENA	ALCANCA	SP
CEMB	49	BLUE CIRCLE ATLANTIC PERTIGALETE	COLUMBIA	SA
CEMB	50	LEHIGH PORTLAND CEMENT CO.	VENEZUELA	SA
CEMB	51	COPLAY	MITCHELL	IN
CEMB	52	GIANT CEMENT CO.	SPEED	IN

THIS IS A CODE LIST FOR INPUT DATA ONLY. CHECK WITH YOUR DISTRICT MATERIALS ENGINEER FOR AN APPROVED LIST OF SOURCES.

### Concrete Plant Example Problem

It is the producer technician's responsibility to complete Lines A and B of the TL-28A coding form at the plant and send the form out to the state construction project site with the driver of the first load of concrete going to the project.

Using the information below and using Mix Design No. 4-7501-07 (see next page), fill in Lines A and B (upper portion) of the TL-28A coding form.

The contractor on project 0295-127-101,C501 orders 2 cubic yards of A-3 general concrete from B. M. Jones Ready Mix Plant in Richmond (Plant Code No. 4006) on January 12, 2007.

The cement is coming from Roanoke Cement Company in Cloverdale, VA. The producer code for Bedrock S&G is 4009 and for Smith Quarries is 4015. The code for MBAE Air Entraining Agent is 02.

The free moisture on the sand is 5% and on the Coarse Aggregate (No. 57) is 0.6%.

There were 70 mixing revolutions put on the mixer at the plant and 1 gallon of water per cubic yard was withheld.

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Form TL-27MC (Revised 1/07)

**VIRGINIA DEPARTMENT OF TRANSPORTATION  
MATERIALS DIVISION**

**STATEMENT OF HYDRAULIC CEMENT CONCRETE MIX DESIGN**

Submit one copy to the District Administrator, Virginia Department of Transportation. Approval must be received by the contractor from the Materials Division before work is begun. This mix design is approved for all projects of the Department for the class of concrete shown: Calendar Year 2007 Mix Design No. 4-7501-07

Producer B. M. JONES READY MIX Plant Location RICHMOND, VA Phone 804-555-1234  
Type of Mix: Ready Mix X Job Mix \_\_\_\_\_ Date 01/05/2007

Mix Design - One Cubic Yard (Meter) Based on SSD Condition

Class of Concrete A3 GENERAL (E) Slump/ 3.5 In. \_\_\_\_\_ mm Air Content 6 %  
(M) Flow

Material	Type	Quantities	Source		Plant/Quarry Location
			Code	Name	
Cement	<u>IP</u>	<u>588</u> lbs.	<u>6</u>	<u>ROANOKE CEMENT CO</u>	<u>CLOVERDALE, VA</u>
Min.Admix.1		_____ lbs.	_____	_____	_____
Min.Admix.2		_____ lbs.	_____	_____	_____
Sand <sup>(1)</sup>		<u>1228</u> lbs.	<u>4009</u>	<u>BEDROCK S &amp; G</u>	<u>RICHMOND, VA</u>
No. <u>57</u> Stone <sup>(1)</sup>		<u>1725</u> lbs.	<u>4015</u>	<u>SMITH QUARRIES</u>	<u>RICHMOND, VA</u>
Gr./No. _____ Aggr. <sup>(1)</sup>		_____ lbs.	_____	_____	_____
Water <sup>(2)</sup> <u>275</u> lbs.		<u>33</u> gal.	_____	<u>CITY WATER</u>	_____
Admixture (AE) <sup>(3)</sup>		<u>4.6</u> oz.	<u>2</u>	<u>MBAE 20 - MASTER BLDRS.</u>	<u>CLEVELAND, OHIO</u>
Admixture (Retarder) <sup>(3)</sup>		_____ oz.	_____	_____	_____
Admixture (Other) <sup>(3)</sup>		_____ oz.	_____	_____	_____

NOTES:

(1) The quantities of fine and coarse aggregates necessary to conform to specifications in regard to consistency and workability shall be determined by the method described in "Recommended Practice for Selecting Proportions for Normal Weight Concrete" (ACI-211.1) and the actual quantities used shall not deviate more than plus or minus 5 percent from such quantities.

(2) To provide minimum slump permissible in Table II-17 while satisfying placement and finishing requirements. A separate design shall be submitted for each slump desired.

(3) The quantity of admixture will not be approved or disapproved since it varies considerably and must be initially established by trial and error by the producer or contractor with subsequent adjustment during batching to maintain the desired results within the range specified.

Mineral Admixture #1 - sp.gr.	_____
Mineral Admixture #2 - sp.gr.	_____
Sand - Abs.	<u>0.5</u>
Sand - F.M.	<u>2.8</u>
Sand - sp.gr.	<u>2.64</u>
C.A. #1 - Abs.	<u>0.3</u>
C.A. #1 - sp.gr.	<u>2.59</u>
C.A. #1 Unit mass	<u>94.7</u> / _____
	Lbs./C.F. kg/C.M.
Aggr. #2 - Abs.	_____
Aggr. #2 - sp.gr.	_____
2nd F.A./C.A.-F.M./u.wt.	_____ / _____
	E M
Design W/C Ratio	<u>0.47</u>

Contractor B. M. JONES READY MIX, INC.  
(Name of Company)

By B. M. JONES  
(Certified Technician Preparing Form)

Producer Technician's Expiration Date

12/31/2012

(Do Not Use Social Security Number)

**FOR DEPARTMENT USE ONLY**

Remarks: \_\_\_\_\_

Copies: District Materials Engineer  
Project Inspector  
Plant Inspector  
Sub- Contractor and / or R.M. Producer

Checked by W. R. TAYLOR 1/5/07

Approved by H. R. JONES 1/5/07  
District Materials Engineer

Approved tentatively subject to the production of material meeting the requirements of the Specifications and Special Provisions.

### Calculations for Plant Example Problem

Cement Weight Calculation - Line A 38-41

588 lbs. (From TL-27) x 2 cubic yards = 1176 lbs. of cement for 2 cubic yards

Sand, SSD Weight Calculation - Line A 46-50

1228 lbs. (From TL-27) x 2 cubic yards = 2456 lbs. of sand for 2 cubic yards

Sand, Free Water Calculation - Line A 51-53

2456 lbs. of sand (Line A 46-50) x .05 (% Free Moisture in Sand expressed as a decimal) =  
122.8 (Rounded to nearest whole pound) = 123 lbs.

Coarse Aggregate (No.57), SSD Weight Calculation - Line A 60-64

1725 lbs. (From TL-27) x 2 cubic yards = 3450 lbs. of Coarse Aggregate for 2 cubic yards

Coarse Aggregate (No. 57), Free Water Calculation - Line A 65-67

3450 lbs. of C.A. (Line A 60-64) x .006 (% Free Moisture in C.A. expressed as a decimal) = 20.7 (Rounded to nearest whole pound) = 21 lbs.

Total Allowable Water - Line B 13-16

33 gals. (From TL-27) x 2 cubic yards = 66.0 gallons

Water Added at Plant - Line B 20-23

123 lbs. of free water in sand + 21 lbs. of free water in C.A. = 144 lbs.

144 lbs. of free water in sand and C.A. ÷ 8.33 weight of one gallon of water in lbs. = 17.3 gals.

1 gallon of water per cubic yard withheld at plant x 2 cubic yards = 2 gals. of water withheld

66.0 gallons (Line B 13-16) – 19.3 gallons of free and withheld water = 46.7 gallons of water added at plant

A. E. Admixture - Line B 31-34

4.6 oz. (TL-27) x 2 cubic yards = 9.2 oz. of Air Entrained Admixture for 2 cubic yards



## Chapter 7 Study Problems

### Concrete Plant Study Problem

Using the information below and the TL-27 Mix Design on the next page, fill in lines A & B (upper portion) of the TL-28A Coding Form.

The contractor on project U000-106-101,C501 is going to place 8 cubic yards of A-4 (Type IP), Retarded Concrete, in a bridge deck on August 18, 2007. This project is under Standard (English) Specifications.

The concrete will be supplied by Capitol Ready Mix and will be furnished by means of ten, 8 cubic yard loads.

The concrete will be batched from Mix Design No. 4-2905-07 (see attached) and this will be Job No. 1.

The plant code for Capitol Ready Mix is (4119). The code for Gray Cement is (10). The Producer Code for Hilltop S&G is (4001) and for Bluestone Quarry is (4007). The code for Air 20 Air Entraining Agent is (06) and for Slo-Go Retarder is (03).

The free moisture on the sand is 6.0% and on the 57 Aggregate is 0.2%.

There were 70 mixing revolutions put on the loads at the plant and 1 gallon of water per cubic yard held out of each load.

# VIRGINIA DEPARTMENT OF TRANSPORTATION MATERIALS DIVISION

## STATEMENT OF HYDRAULIC CEMENT CONCRETE MIX DESIGN

Submit one copy to the District Administrator, Virginia Department of Transportation. Approval must be received by the contractor from the Materials Division before work is begun. This mix design is approved for all projects of the Department for the class of concrete shown: Calendar Year 2007 Mix Design No. 4-2905-07

Producer Capital Ready Mix Plant Location Petersburg, VA Phone 804-555-2000  
 Type of Mix: Ready Mix X Job Mix \_\_\_\_\_ Date 8/9/2007

### Mix Design - One Cubic Yard (Meter) Based on SSD Condition

Class of Concrete A4 Retarded (E) Slump/ 3.0 In. \_\_\_\_\_ mm Air Content 6.5 %  
 \_\_\_\_\_ (M) Flow

Material	Type	IP	Quantities		Code	/	Source Name	Plant/Quarry Location
			lbs.	kg.				
Cement			<u>635</u>	_____	<u>10</u>	/	<u>Gray Cement</u>	<u>Roanoke, VA</u>
Min. Admix. 1			_____	_____	_____	/	_____	_____
Min. Admix. 2			_____	_____	_____	/	_____	_____
Sand <sup>(1)</sup>			<u>946</u>	_____	<u>4001</u>	/	<u>Hilltop S&amp;G</u>	<u>Petersburg, VA</u>
No. <u>57</u> Stone <sup>(1)</sup>			<u>1922</u>	_____	<u>4007</u>	/	<u>Bluestone Quarry</u>	<u>Dinwiddie, VA</u>
Gr./No. _____ Aggr. <sup>(1)</sup>			_____	_____	_____	/	_____	_____
Water <sup>(2)</sup>	<u>271</u>	lbs.	<u>32.5</u>	gal.	_____	/	<u>Deep Well</u>	<u>On-Site</u>
Admixture (AE) <sup>(3)</sup>	<u>5</u>	oz.	_____	ml.	<u>6</u>	/	<u>Air 20 Master Builders</u>	<u>Richmond, VA</u>
Admixture (Retarder) <sup>(3)</sup>	<u>25</u>	oz.	_____	ml.	<u>3</u>	/	<u>Slo-Go Master Builders</u>	<u>Richmond, VA</u>
Admixture (Other) <sup>(3)</sup>	_____	oz.	_____	ml.	_____	/	_____	_____

**NOTES:**

(1) The quantities of fine and coarse aggregates necessary to conform to specifications in regard to consistency and workability shall be determined by the method described in "Recommended Practice for Selecting Proportions for Normal Weight Concrete" (ACI-211.1) and the actual quantities used shall not deviate more than plus or minus 5 percent from such quantities.

(2) To provide minimum slump permissible in Table II-17 while satisfying placement and finishing requirements. A separate design shall be submitted for each slump desired.

(3) The quantity of admixture will not be approved or disapproved since it varies considerably and must be initially established by trial and error by the producer or contractor with subsequent adjustment during batching to maintain the desired results within the range specified.

Mineral Admixture #1 - sp.gr.	_____
Mineral Admixture #2 - sp.gr.	_____
Sand - Abs.	<u>0.3</u>
Sand - F.M.	<u>2.52</u>
Sand - sp.gr.	<u>2.64</u>

C.A. #1 - Abs.	<u>0.3</u>
C.A. #1 - sp.gr.	<u>2.63</u>
C.A. #1 Unit mass	<u>101.7</u> / _____
	<small>Lbs./C.F.                      kg/C.M.</small>

Aggr. #2 - Abs.	_____
Aggr. #2 - sp.gr.	_____
2nd F.A./C.A.-F.M./u.wt.	_____ / _____
	<small>E                                      M</small>

Design W/C Ratio 0.43

Contractor Capital Ready Mix  
(Name of Company)

By I. M. Certified  
(Certified Technician Preparing Form)

Producer Technician's Expiration Date \_\_\_\_\_

12/31/2012  
(Do Not Use Social Security Number)

**FOR DEPARTMENT USE ONLY**

Remarks: \_\_\_\_\_

Copies: District Materials Engineer  
 Project Inspector  
 Plant Inspector  
 Sub- Contractor and / or R.M. Producer

Checked by G. R. Jones 8/9/2007

Approved by M. J. Clark 8/9/2007  
District Materials Engineer

Approved tentatively subject to the production of material meeting the requirements of the Specifications and Special Provisions.



# APPENDICES

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# Concrete Plant Appendices

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Appendix B	Symbols, Abbreviations and Metric Conversion Factors
Appendix C	Concrete Specifications
Appendix D	Answers to Study Questions and Problems
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## Definitions and English Conversion Factors

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### Definitions

**Abrasion Resistance of an Aggregate** - The ability of an aggregate to resist polishing.

**Absolute Volume** - The volume of a material, in cubic feet, in a voidless state.

**Absorbed Moisture** - The moisture within the pores and capillaries of an aggregate.

**Accelerator** - A chemical, such as Calcium Chloride, used to “speed up” the setting time of concrete.

**Acid Water** - Water which contains concentrations of hydrochloric, sulfuric, or other common acids.

**Aggregate** - An inert filler material, such as, crushed stone, gravel and sand which is mixed with cement and water to make concrete.

**Air-dry** - A condition at which an aggregate particle is dry on the surface but contains some moisture within the pores of the aggregate.

**Air Entraining Agent** - A material, which when added to concrete, entrains microscopic air voids in the concrete.

**Air Entrained Concrete** - Concrete which has had an air entraining agent added to entrain minute air bubbles that are distributed uniformly throughout the cement paste.

**Alkaline Water** - Water which contains concentrations of sodium hydroxide, potassium, or other hydroxide.

**Bleeding of Concrete** - A condition whereby an excess amount of mixing water accumulates on the surface of plastic concrete. This condition is caused by settlement and consolidation of the plastic concrete.

---

**Cement** - The bonding agent used in a concrete mix.

**Coarse Aggregate** - Aggregate larger than about 1/4 inch in diameter, usually referred to as stone or gravel.

**Consistency** - A condition of plastic concrete which relates to its cohesion, wetness, or to flow. The consistency is usually measured by the slump test.

**Deleterious Substances in Aggregates** - Undesirable substances that may be found in aggregates. These harmful substances include organic impurities, silty clay, coal, lignite, and certain lightweight and soft particles.

**Dry-Rodded Unit Weight** - The weight per unit volume (pcf) of dry aggregate compacted in a container by rodding in three layers.

**Durability** - The ability of hardened concrete to resist the deterioration caused by weathering (freezing, thawing, heating, cooling, wetting, drying, etc.), chemicals, and abrasions.

**False Set** - A significant loss of plasticity shortly after the concrete is mixed.

**Fine Aggregate** - A natural silica or manufactured aggregate smaller than about 1/4" in diameter, normally referred to as sand.

**Fineness Modulus** - An index to the coarseness or fineness of an aggregate.

**Fineness of Cement** - The particle size to which a cement is ground. The fineness of cement affects the rate of hydration. As cement fineness increases, the rate of cement hydration increases and causes an acceleration in strength development.

**Free Moisture** - The moisture on the surface of an aggregate. The amount of free moisture is the difference between the total moisture and the absorbed moisture.

**Freeze-Thaw Resistance of an Aggregate** - A condition related to an aggregate's porosity, absorption, and pore structure.

**Gradation of an Aggregate** - The relative amounts of aggregate particles of consecutively larger and smaller sizes.

**Harsh Mix** - A coarse mix which is difficult to place and finish. This usually indicates that the mix does not contain enough fine aggregate to provide a dense, workable mixture. A harsh mix segregates easily because it is not cohesive (or buttery).

**Heat of Hydration** - The heat generated when cement and water react.

**Set Retarder** - A material composed of (1) calcium, sodium, potassium, or ammonium salt of lignosulfonic acid; (2) hydroxylated carboxylic acid or its salt; or (3) carbohydrates, except sucrose, that is used for the purpose of delaying the setting time of concrete. Retarders provide a lubricating effect and may function as a water reducing agent also.

**Setting Time** - The time that it takes a cement paste to begin hardening.

---

**Sieve Analysis** - A process in which an aggregate is separated into its various sizes by passing it through screens of various size openings for the purpose of determining the distribution of the quantities separated.

**Soundness of a Hardened Cement Paste** - The ability of a hardened cement paste to retain its volume after setting.

**Specific Gravity** - The ratio of the weight of a given volume of material to the weight of an equal volume of water (both being at the same temperature).

**Total Moisture** - The sum of the moisture on the surface and the moisture absorbed into the pores and capillaries of an aggregate.

**Water** - The ingredient in a concrete mix that causes a chemical reaction with cement, called hydration. The water assists in providing the necessary workability for the concrete.

**Water Cement Ratio** - The ratio of the amount of water to the amount of cement in a concrete mix; preferably stated as a decimal by weight.

**Water-Reducing Agent** - Material used for the purpose of reducing the quantity of mixing water in concrete. This additive, which provides a lubricating effect, will cause an increase in slump and workability when placed in a concrete mix of a given consistency.

**Well-Graded Aggregate** - An aggregate which contains a uniform percentage of material retained on each standard sieve. Gradation change is uniform from coarse to fine.

**Workability** - The property of freshly mixed concrete which is the ease or difficulty in the placing and finishing of concrete. "Good Workability" means that the concrete may be placed or finished with little difficulty and the mass contains a uniform gradation of aggregates.

## English Conversion Factors

One cubic foot of water equals 7.5 gallons.

One cubic foot of water equals 62.4 pounds

One gallon of water equals 8.33 pounds.

One cubic yard equals 27 cubic feet.

One bag of cement equals 94 pounds.

One bag of cement equals one cubic foot (loose volume).

One bag of cement equals 0.48 cubic feet (absolute volume).

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# B

## Symbols, Abbreviations and Metric Conversion Factors

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### Signs and Symbols

+	plus, or more than
-	minus, or less than
±	plus or minus
'	Feet
"	Inches
>	is greater than
≥	is greater than or equal to
<	is less than
≤	is less than or equal to
#	number, if before a figure; pounds if after a figure
/	per, as kg/sqft; of; after; to; upon; proportion
<b>123</b>	superior figures (exponents) indicate the power to which a given number is to be raised, as 12 <sup>2</sup> (squared), 10 <sup>3</sup> (cubed)
°	degree; °F – degree Fahrenheit; °C – degree Celsius
%	Percent
μ	micro (10 <sup>-6</sup> )

## Abbreviations

A	ampere
AASHTO	American Association of State Highway & Transportation Officials
ABS (%)	Percent of Absorbed Moisture
Abs. Vol.	Absolute Volume
ACI	American Concrete Institute
AE	Air-Entrained
AEA	Air-Entrained Admixture
aggr.	Aggregate
AMP	ampere
Are	100 m <sup>2</sup>
ASTM	American Society for Testing and Materials
bbls.	Barrels (Measurement of Cement)
C	centi (10 <sup>-2</sup> )
C. A.	Coarse Aggregate
cem.	cement
C. F.	Cement Factor
conc.	Concrete
Cu	cubic
cu. ft.	cubic foot
cu. ft. <sup>3</sup>	cubic feet
cu. in.	cubic inch
cu. in. <sup>3</sup>	cubic inches
c. y.	cubic yard
D	deci (10 <sup>-1</sup> )
Da	deka (10)
deg., °	degree
Dm	decimeter (metric) dm <sup>2</sup> ; dm <sup>3</sup>
Eq	equal
Ex	example
F	Fahrenheit
F. A.	Fine Aggregate
Ft.	Foot or Feet
F. M.	Fineness Modulus
g.	gram (metric)
H	hecto (10 <sup>-2</sup> )
Ha	hectare
In.	inch(es); in. <sup>2</sup> in. <sup>3</sup>
K	kilo (10 <sup>3</sup> )
K.	Kelvin (absolute scale of temperature)
kg.	kilogram (metric)
kg/m <sup>3</sup>	kilograms per cubic meter

kip	thousand (kilo) pounds (structural)
km	kilometer (metric); km <sup>2</sup> ; km <sup>3</sup>
kW	Kilowatt(s)
kWh	kilowatt- hour
L	Liter (metric)
lb.	pound
lb.- ft.	pound-foot
lb./ft. <sup>2</sup>	pounds per square foot
lb.-in.	pound-inch
lb/in <sup>2</sup>	pounds per square inch
lin. foot	linear foot
m	meter (metric); milli (10 <sup>-2</sup> )
m <sup>2</sup>	square meter
m <sup>3</sup>	cubic meter
m.	mass
M	Mega (10 <sup>6</sup> )
max	maximum
mg	milligram (metric)
ml	milliliter (metric)
mm	millimeter (metric)
Mg	Megagram (metric ton)
mPa	MegaPascal
Mat'ls	Materials
min.	minimum
mod.	modified
n	Nano (10 <sup>-9</sup> )
oz	ounce(s)
Pa	Pascal
PCA	Portland Cement Association
pcf	pounds per cubic foot
psi	pounds per square inch
sp. gr.	specific gravity (density)
SI	system international (metric system)
SSD	Saturated Surface Dry
sq.	square, as in sq. yd.
sq. ft., ft <sup>2</sup>	square foot or feet
sq. in., in <sup>2</sup>	square inch or inches
t	metric ton
VDOT	Virginia Department of Transportation
VTM	Virginia Test Methods
W/C	Water/Cement ratio
wt.	weight
yd.	yard
yd <sup>2</sup> sq. yd.	square yard(s)
yd <sup>3</sup> cu. yd.	cubic yard(s)

## Temperature Conversion Table

To convert from degrees Celsius to degrees Fahrenheit or vice versa, the following formulas may be used:

$$F = 9/5 (C + 32)$$

$$C = 5/9 (F - 32)$$

The following table may be used for quick conversion of temperatures in the most common working ranges. The numbers in the center of each column refer to temperatures in either degrees Celsius or Fahrenheit. In the center, find the known temperature, and the corresponding Celsius or Fahrenheit temperatures is then found at the sides.

°C		°F	°C	°F	
-45.6	-50	-58	77	170	338
-40	-40	-40	82	180	356
-34.4	-30	-22	88	190	374
-28.9	-20	-4	93	200	392
-23.3	-10	14	99	210	410
-17.8	0	32	100	212	413
-12.2	10	50	104	220	428
-6.6	20	68	110	230	446
-1.1	30	86	116	240	464
4.4	40	104	121	250	482
10	50	122	127	260	500
15.6	60	140	132	270	518
21.1	70	158	138	280	536
26.7	80	176	143	290	554
32.2	90	194	149	300	572
37.8	100	212	177	350	662
43	110	230	204	400	752
49	120	248	232	450	842
54	130	266	260	500	932
60	140	284	288	550	1022
66	150	302	316	600	1122
71	160	320			

Metric unit of temperature = Kelvin (K) = °C + 273.15

(The terms Celsius and Centigrade have the same meaning, but Celsius is the preferred term.)

## U. S. A. Standard Sieve Series

Sieve Designation		Nominal Sieve Opening, In.
Standard	Alternative	
50 mm	2 in.	2
37.5 mm	1 ½ in.	1.5
31.5 mm	1 ¼ in.	1.25
25.0mm	1 in.	1
19.0 mm	¾ in.	0.750
16.0 mm	5/8 in.	0.625
12.5 mm	½ in.	0.500
9.5 mm	3/8 in.	0.375
8.0 mm	5/16 in.	0.312
6.3 mm	¼ in.	0.250
4.75 mm	No. 4	0.187
4.00 mm	No. 5	0.157
3.35 mm	No. 6	0.132
2.36 mm	No. 8	0.0937
2.00 mm	No. 10	0.0787
1.70 mm	No. 12	0.0661
1.18 mm	No. 16	0.0469
850 µm	No. 20	0.0331
600 µm	No. 30	0.0234
425 µm	No. 40	0.0165
300 µm	No. 50	0.0117
250 µm	No. 60	0.0098
212 µm	No. 70	0.0083
180 µm	No. 80	0.0070
150 µm	No. 100	0.0059
106 µm	No. 140	0.0041
75 µm	No. 200	0.0029
53 µm	No. 270	0.0021
45 µm	No. 325	0.0017
38 µm	No. 400	0.0015

## Weights and Measures (English and Metric)

Metric Units	Metric Prefixes
Length = meter m	$10^9 = 1,000,000,000 = \text{giga} = \text{G}$
Mass = kilogram kg	$10^6 = 1,000,000 = \text{mega} = \text{M}$
Time = second s	$10^3 = 1,000 = \text{kilo} = \text{k}$
Electric Current = ampere A	$10^{-1} = 0.1 = \text{deci} = \text{d}$
Thermodynamic Temperature = Kelvin K	$10^{-2} = 0.01 = \text{centi} = \text{c}$
Amount of Substances = mole mol	$10^{-3} = 0.001 = \text{milli} = \text{m}$
Luminous Intensity = candela cd	$10^{-6} = 0.000,001 = \text{micro} = \mu$

## Conversion Tables

### Metric to Inch-pound

### Inch-pound to Metric

Linear Measure	
1 m = 39.3701 in.	1 in. = 0.0254 meters
1 m = 3.28084 in.	1 ft. = 0.3048 meters
1 km = 0.67137 mile	1 mile = 1.60934 kilometers

Surface Measure ( 1 hectare = 10,000 square meters)	
1 mm <sup>2</sup> = 0.00155 in <sup>2</sup>	1 in <sup>2</sup> = 645.16 mm <sup>2</sup>
1 cm <sup>2</sup> = 0.1550 in <sup>2</sup>	1 in <sup>2</sup> = 6.4516 cm <sup>2</sup>
1 dm <sup>2</sup> = 0.1076 ft <sup>2</sup>	1 ft <sup>2</sup> = 9.2903 dm <sup>2</sup>
1 m <sup>2</sup> = 10.7639 ft <sup>2</sup>	1 ft <sup>2</sup> = 0.092903 m <sup>2</sup>
1 m <sup>2</sup> = 1.19599 yd <sup>2</sup>	1 yd <sup>2</sup> = 0.83617 m <sup>2</sup>
1 hectare = 2.47105 acres	1 acre = 0.404686 hectares
1 hectare = 0.00386 mi <sup>2</sup>	1 mi <sup>2</sup> = 258.99 hectares

Volume Measure	
1 cm <sup>3</sup> = 0.061024 in <sup>3</sup>	1 in <sup>3</sup> = 16.3871 cm <sup>3</sup>
1 dm <sup>3</sup> = 0.035315 ft <sup>3</sup>	1 ft <sup>3</sup> = 28.3168 dm <sup>3</sup>
1 m <sup>3</sup> = 1.30795 yd <sup>3</sup>	1 yd <sup>3</sup> = 0.764555 m <sup>3</sup>

<b>Mass (Weight) Measure</b>	
1 g = 0.035274 oz.	1 oz. = 28.3495 g
1 g = 0.002205 lb.	1 lb. = 453.592 g
1 kg. = 2.20462 lb.	1 lb. = 0.453592 kg
1 metric ton = 1.1023 net ton (2000 lb. ton)	1 net ton = 0.9072 metric tons

<b>Liquid Measure</b>	
1 L = 33.81402 oz.	1 oz. = 0.02957 L
1 L = 1.05669 qt.	1 qt. = 0.946353 L
1 L = 0.264172 gal.	1 gal. = 3.78541 L
1 m <sup>3</sup> = 264.72 gal.	1 gal. = 0.003785 m <sup>3</sup>

<b>Force &amp; Stress Measure</b>	
1 N (Newton) = 0.224809 lb. (f)	1 lb. (f) = 4.44822 N
1 N/m = 0.06852 lb/ft	1 lb/ft = 14.5939 N/m
1 Pa (Pascal) = 0.000145 psi	1 psi = 6,894.76 Pa
1 kPa = 0.145 psi	1 psi = 6.89476 kPa
1 mPa = 145.038 psi	1 psi = 0.006895 mPa
1 Pa = 0.020885 psf	1 psf = 47.88026 Pa
1 kg/m <sup>3</sup> = 0.062428 lb/ft <sup>3</sup>	1 lb/ft <sup>3</sup> = 16.01846 kg/m <sup>3</sup>
1 kg/m <sup>3</sup> = 1.625555 lb/yd <sup>3</sup>	1 lb/yd <sup>3</sup> = 0.5932764 kg/m <sup>3</sup>

## Reinforcing Steel

ASTM Standard Reinforcing Bars				
Bar Size Designation	Nominal Mass (kg/m)	Nominal Dimensions – Round Sections		
		Diameter (mm)	Cross Sectional Area (mm <sup>2</sup> )	Perimeter (mm)
#10	0.560	9.53	70.97	29.92
#13	0.994	12.70	129.03	39.90
#16	1.552	15.88	200.00	49.86
#19	2.235	19.05	283.87	59.84
#22	3.042	22.23	387.10	69.83
#25	3.973	25.40	509.68	79.81
#29	5.060	28.65	645.16	90.02
#33	6.404	32.26	819.35	101.35
#36	7.907	35.81	1006.45	112.52
#43	11.384	43.00	1451.61	135.13





## Concrete Specifications

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**Note:** These specifications are for training purposes only. Do not use them in the field or on a project. Contact VDOT - Construction Division for an up to date Road and Bridge Specification Book. <http://www.virginiadot.org/business/const/spec-default.asp>

# Division II

## Materials

### SECTION 201--MINERAL FILLER

#### 201.01--Description.

These specifications cover inorganic material such as lime or fly ash, usually of very fine grading, added to soil or asphalt to produce a desired effect.

#### 201.02--Detail Requirements.

Mineral filler shall conform to the requirements of AASHTO M17. Tests will be performed in accordance with the requirements of AASHTO T37.

### SECTION 202--FINE AGGREGATE

#### 202.01--Description.

These specifications cover material for use as fine aggregate in hydraulic cement concrete, mortar, asphalt concrete, and asphalt surface treatments.

#### 202.02--Materials.

Fine aggregate is classified herein in accordance with its occurrence or method of manufacture as natural sand or stone sand. Natural sand shall consist of grains of hard, sound material, predominantly quartz, occurring in natural deposits or in loosely bound deposits, such as sandstone conglomerate. Stone sand shall consist of sound crushed particles of approved Grade A stone, essentially free from flat or elongated pieces, with sharp edges and corners removed.

Fine aggregates for use in hydraulic cement concrete that are obtained from more than one source shall not be used alternately or mixed without the consent of the Engineer.

#### 202.03--Detail Requirements.

- (a) **Grading:** Grading shall conform to the requirements of Table II-1. Tests will be performed in accordance with the requirements of AASHTO T27.
- (b) **Soundness:** Soundness shall conform to the requirements of Table II-2. Tests will be performed in accordance with the requirements of AASHTO T103 or T104.

**TABLE II-1  
Fine Aggregate**

Grading	Amounts Finer Than Each Laboratory Sieve (Square Openings) ( % by Mass)							
	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200
A	Min. 100	95-100	80-100	50-85	25-60	5-30	Max. 10	
B	Min. 100	94-100					Max. 10	
C	Min. 100	94-100				Max. 25		

**TABLE II-2  
Soundness**

Use	Soundness Loss	( Max. % )
	Magnesium Sulphate ( 5 Cycles )	Freeze and Thaw ( 100 Cycles )
Hydraulic Cement Concrete	18	8
Asphalt concrete surfaces and surface treatments	25	15
Asphalt concrete bases	30	15

- (c) Organic Impurities: When fine aggregate is to be used in hydraulic cement concrete, the percentage of organic impurities shall conform to the requirements of AASHTO T21; however, material producing a darker color than that specified in AASHTO T21 may be accepted in accordance with the requirements of AASHTO M6.
- (d) Void Content: Void content will be tested in accordance with the requirements of VTM-5.
- (e) Deleterious Material: The amount of deleterious material in sands shall be not more than the following:

Material	% by Mass	AASHTO Test Method
Clay lumps	0.25	T112
Shale, mica, coated grains, soft or flaky particles	1.0	T113
Organic material	0	T21
Total material passing No. 200 sieve by washing <sup>1</sup>		T11 and T27
For use in concrete subject to abrasion	3	
For other concrete	5	

<sup>1</sup>In the case of stone sand, if the material passing the No. 200 sieve is dust of fracture, essentially free from clay or shale, the percentages shown for use in concrete subject to abrasion and in other concrete may be increased to 5.0% and 7.0%, respectively.

### SECTION 203--COARSE AGGREGATE

#### 203.01--Description.

These specifications cover material for use as coarse aggregate in hydraulic cement concrete, asphalt concrete, asphalt surface treatments, and drainage.

**203.02--Materials.**

Coarse aggregate shall consist of crushed stone, crushed slag, or crushed or uncrushed gravel with clean, hard, tough, and durable pieces free from adherent coatings and deleterious amounts of friable, thin, elongated, or laminated pieces; soluble salts; or organic materials.

- (a) **Crushed hydraulic cement concrete** will be permitted for use as a coarse aggregate provided it conforms to the physical requirements specified herein and shows no adverse chemical reaction. Crushed hydraulic cement concrete will not be permitted in the following: (1) reinforced cement concrete (2) in combination with other materials in contact with geotextile fabric when such fabric is used as a drainage item and (3) in backfill or bedding for perforated pipe.
- (b) **Crushed gravel** shall consist of particles of which at least 80 percent by weight shall have at least one face fractured by artificial crushing. Tests will be performed in accordance with the requirements of VTM-15.
- (c) **Blast furnace slag** shall be relatively free from foreign minerals and glassy or spongy pieces. It shall have a dry rodded unit mass of at least 70 pounds per cubic foot for size No. 68 and smaller, and at least 65 pounds per cubic foot for larger sizes. Tests will be performed in accordance with the requirements of AASHTO T19. When used in asphalt surface treatments, blast furnace slag shall not contain more than 10 percent nonporous material and shall have an absorption of at least 3 percent. Tests will be performed in accordance with the requirements of AASHTO T85.

**203.03--Detail Requirements.**

- (a) **Grading:** Open graded aggregates shall conform to the requirements of Table II-3. Tests will be performed in accordance with the requirements of AASHTO T27.

**TABLE II-3**  
**Sizes of Open Graded Coarse Aggregates**

Amounts Finer Than Each Laboratory Sieve (Square Openings) (% by Mass)

<b>Va. Size No.</b>	<b>4 inch</b>	<b>3½ inch</b>	<b>3 inch</b>	<b>2½ inch</b>	<b>2 inch</b>	<b>1½ inch</b>	<b>1 inch</b>	<b>¾ inch</b>
1	Min. 100	90-100		25-60		Max. 15		Max 5
2			Min. 100	90-100	35-70	Max. 15		Max 5
3				Min. 100	90-100	35-70	0-15	
357				Min. 100	95-100		35-70	
5						Min. 100	90-100	20-55
56						Min. 100	90-100	40-85
57						Min. 100	95 -100	
67							Min. 100	90-100
68							Min. 100	90-100
7								Min. 100
78								Min. 100
8								
8P								
9								
10								

(Continued)

**TABLE II-3**  
**Sizes of Open Graded Coarse Aggregates**  
**(Continued)**

Va. Size No.	½ inch	3/8 inch	No. 4	No. 8	No. 16	No. 50	No. 100
1							
2							
3	Max. 5						
357	10-30		Max. 5				
5	Max. 10	Max. 5					
56	10-40	Max. 15	Max. 5				
57	25-60		Max. 10	Max. 5			
67		20-55	Max. 10	Max. 5			
68		30-65	5-25	Max. 10	Max. 5		
7	90-100	40-70	Max. 15	Max. 5			
78	90-100	40-75	5-25	Max. 10	Max. 5		
8	Min. 100	85-100	10-30	Max. 10	Max. 5		
8P	Min. 100	75-100	5-30	Max. 5			
9		Min. 100	85-100	10-40	Max. 10	Max. 5	
10		Min. 100	85-100				10-30

- (b) **Soundness:** Soundness shall conform to the requirements of Table II-4. Tests will be performed in accordance with the requirements of AASHTO T103 or T104.

**TABLE II-4**  
**Soundness**

<b>Max. Soundness Loss (%)</b>		
<b>Use</b>	<b>Magnesium Sulphate (5 Cycles)</b>	<b>Freeze and Thaw (100 Cycles)</b>
Hydraulic cement concrete	12	5
Asphalt surface courses	15	6
Asphalt and aggregate bases	20	7
Select material (Type I) and subbase	30	12

- (c) **Abrasion Loss:** Abrasion loss shall conform to the requirements of Table II-5. Tests will be performed in accordance with the requirements of AASHTO T96 on aggregate with a grading the most nearly identical with the grading to be used in the work.

**TABLE II-5**  
**Abrasion**

<b>Max. Los Angeles Abrasion Loss (%)</b>		
<b>Use</b>	<b>100 Rev.</b>	<b>500 Rev.</b>
Grade A stone	9	40
Grade B stone	12	45
Grade C stone	14	50
Slag	12	45
Gravel	12	45

- (d) **Deleterious Material:** The amount of deleterious material shall be not more than the following:

<b>Material</b>	<b>% by Mass</b>	<b>AASHTO Test Method</b>
Coal and lignite	0.25	T113
Clay lumps	0.25	T112
Material passing No. 200 sieve by washing <sup>1</sup>	1.00	T11

<sup>1</sup>When the material passing the No. 200 sieve by washing is dust of fracture, the percentage of deleterious material may be increased to 1.50%.

- (e) **Flat & Elongated:** Coarse Aggregate to be used as a riding surface during construction activities or as the riding surface after construction shall contain not more than 30 percent by mass of aggregate particles retained on and above the 3/8-inch sieve having a maximum to minimum dimensional ratio greater than 5 as determined by ASTM D4791.

## SECTION 206--LIGHTWEIGHT AGGREGATE

### 206.01--Description.

These specifications cover lightweight aggregate used in hydraulic cement concrete and asphalt surface treatment.

### 206.02--Detail Requirements.

Lightweight aggregate shall consist of clay, shale, or slate expanded through a sintering or rotary kiln.

- (a) **Lightweight aggregate used in hydraulic cement concrete** shall conform to the requirements of AASHTO M195.
- (b) **Lightweight aggregate used for asphalt surface treatment** shall conform to the requirements of AASHTO M195 except that Sections 3, 6, and 8 will not apply. Grading shall conform to the requirements of Table II-3 except that the maximum percentage by weight of material passing the No. 8 sieve shall be 16 percent and passing the No. 16 sieve shall be 9 percent.

## SECTION 214--HYDRAULIC CEMENT

### 214.01--Description.

These specifications cover cements that harden when mixed with water. The various types have special characteristics to be used as denoted in other parts of these specifications.

### 214.02--Detail Requirements.

- (a) **Blended hydraulic cement** shall conform to the requirements of AASHTO M240, Type I(P) or Type I(S).
- (b) **Portland cements** shall conform to the requirements of AASHTO M85 except as follows:
  - 1. The SO<sub>3</sub> content as specified in AASHTO M85 will be permitted, provided the supporting data specified in AASHTO M85 are submitted to the Department for review and acceptance prior to use of the material.
- (c) **Expansive hydraulic cement** shall conform to the requirements of ASTM C 845 Type K.

**SECTION 215--HYDRAULIC CEMENT CONCRETE ADMIXTURES****215.01--Description.**

These specifications cover materials that are chemical or organic elements that may be added to a concrete mixture, when permitted elsewhere in these specifications, to achieve some desired effect.

**215.02--Materials.**

- (a) **Air-entraining admixtures** shall conform to the requirements of AASHTO M154.
- (b) **Water-reducing and retarding admixtures** shall conform to the requirements of AASHTO M194, Type D, and shall be free from water-soluble chlorides.

Use of water-reducing and retarding admixtures that have not been tested for compatibility with the brand, type, source, and quantity of cement proposed for use will not be permitted until tests have been performed in accordance with the requirements of VTM 16 and the test results conform to the requirements of Table I therein.

- (c) **Water-reducing admixtures** shall conform to the requirements of AASHTO M194, Type A, and shall be free from water-soluble chlorides.
- (d) **Accelerating admixtures** shall conform to the requirements of AASHTO M194, Type C or E.
- (e) **High-range water-reducing and high-range water-reducing and retarding admixtures** shall conform to the requirements of AASHTO M194, Type F or G, and shall be free from water-soluble chlorides.
- (f) **Calcium chloride** shall conform to the requirements of AASHTO M144, Type 2.
- (g) **Pozzolans** shall conform to the requirements of Section 241 of the Specifications.
- (h) **Granulated iron blast-furnace slag** shall conform to the requirements of ASTM C989, Grade 100 or 120.
- (i) **Silica Fume** shall conform to the requirements of AASHTO M307.
- (j) **Corrosion Inhibitor** shall contain a minimum 30 percent solution of calcium nitrite or other approved material.
- (k) **Metakaolin** shall conform to the requirements of AASHTO M321.

**215.03--Detail Requirements.**

Approved admixture(s) shall be used in concrete in the proportions recommended by the manufacturer to obtain the optimum effect where seasonal, atmospheric, or job conditions dictate its use.

Only admixtures (a) through (e) that appear on the Department's approved list shall be used. Initial approval will be based on independent laboratory data submitted by the manufacturer. Following initial approval of concrete admixtures, the manufacturer shall annually certify to the Engineer in writing that the material currently being

furnished is identical in both composition and chemical concentrations with the material for which the laboratory tests were performed. If the Contractor proposes to use an admixture that differs in concentration from the acceptance sample, a certificate will be required from the manufacturer stating that the material is essentially the same in chemical composition as the approved mixture.

When placing concrete by pumping is authorized, the use of pump-aid admixtures approved by the Department will be allowed provided they are used in accordance with the manufacturer's recommendations.

## **SECTION 216--WATER FOR USE WITH CEMENT OR LIME**

### **216.01--Description.**

These specifications cover water for use in mixing with cement or lime.

### **216.02--Detail Requirements.**

Water shall be clean, clear, and free from oil, acid, salt, alkali, organic matter, or other deleterious substances.

Water that has been approved for drinking purposes may be accepted without testing for use in hydraulic cement concrete, cement, or lime stabilization. Water from other sources and pumping methods shall be approved by the Engineer before use.

The acidity or alkalinity of water will be determined colorimetrically or electrometrically. Water shall have a pH between 4.5 and 8.5. When subjected to the mortar test in accordance with the requirements of AASHTO T26, water shall produce a mortar having a compressive strength of at least 90 percent of a mortar of the same design using distilled water.

Wash water from hydraulic cement concrete mixer operations will be permitted to be reused in the concrete mixture provided it is metered and is 25 percent or less of the total water. The total water shall conform to the acceptance criteria of ASTM C1602, Tables 1 and 2. A uniform amount of wash water shall be used in consecutive batches, with subsequent admixture rates adjusted accordingly to produce a workable concrete conforming to the specifications.

## **SECTION 217--HYDRAULIC CEMENT CONCRETE**

### **217.01--Description.**

These specifications cover materials, design criteria, and mixing and testing procedures for hydraulic cement concrete.

### **217.02--Materials.**

Hydraulic cement concrete shall consist of hydraulic cement, fine aggregate, coarse aggregate, water, and admixture(s) mixed in the approved proportions for the various classes of concrete by one of the methods designated hereinafter.

The Contractor shall be responsible for the quality control and condition of materials during handling, blending, and mixing operations and for the initial determination and necessary adjustments in the proportioning of materials used to produce the concrete.

- (a) **Cementitious materials** shall be a blend of mineral admixtures and Portland cement or a blended cement. In overlay concretes, expansive hydraulic cement is permitted in lieu of portland cement. Portland cement (Types I, II, III), blended cements (Types IP, IS) or expansive cement (Type K) shall conform to Section 214 of the Specifications. Fly ash, ground granulated iron blast-furnace slag (GGBFS), silica fume or metakaolin shall conform to Section 215 of the Specifications. As a portion of the cementitious material, Table 1 lists the minimum percents of specific pozzolans required by the mass of the cementitious material depending on the alkali content of the cement. Any other mineral admixture or any other amount or combination of mineral admixtures may be used if approved by the Engineer. As a portion of the cementitious material, the fly ash content shall not exceed 30 percent for Class F, the ground granulated blast furnace slag content shall not exceed 50 percent, and the silica fume content shall not exceed 10 percent unless approved by the Engineer. Class C Flyash or other pozzolans may be used provided the contractor demonstrates that the percent usage of Class C Flyash or other pozzolans have a maximum expansion of 0.15% according to ASTM C227 at 56 days using borosilicate glass as aggregate. Blended cements require no further pozzolan additions to meet minimum pozzolan content to compensate for the alkali-silica reaction..

Up to 7 percent silica fume may be added to all combinations of cementitious materials to reduce early permeability without approval by the Engineer. Other silica fume additions must be approved by the Engineer.

**Table 1 - Minimum percent pozzolan required by mass of cementitious material as a portion of the total cementitious materials and are based upon the alkali content of the cement.**

	Total Alkalies of Cement less than or equal to 0.75%	Total Alkalies of Cement greater than 0.75% and less than or equal to 1.0%
Class F Fly Ash	20%	25%
GGBF Slag	40%	50%
Silica Fume	7%	10%
Metakaolin	7%	10%

- (b) **Formulated latex modifier** shall be a nontoxic, film-forming, polymeric emulsion of which 90 percent of the nonvolatiles are styrenebutadiene polymers. It shall be homogeneous and uniform in composition and free from chlorides. Latex modifier shall conform to the chemical and physical properties specified hereinafter when tested in accordance with the requirements of FHWA's Report No. RD-78-35. Initial approval of the modifier will be based on an analysis of the results of tests performed by an independent laboratory. After initial acceptance, material will be accepted upon certification subject to periodic testing. A copy of the initial test report shall be submitted to the Department and shall show the following chemical and physical properties:

**Property**

**Value**

Butadiene content (%)	30-40
Solids (%)	46-53
pH	8.5-12
Coagulum (%)	Max. 0.10
Surface tension	Max. 50 dynes/cm
Particle size:	
Mean Angstrom	1400-2500
Median Angstrom	1400-2500
Distribution	Unimodal
95% range Angstrom	Max. 2000
Freeze-thaw stability (% coagulum after 2 cycles)	Max. 0.10
Concrete slump	Greater than standard
Concrete air content	Max. 9%
Time for 50% slump loss	±25% standard
Concrete compressive strength (24 hr and 28 days)	Min. 75% standard
Compressive strength loss (28-42 days)	Max. 20%
Concrete flexural strength (24 hr and 28 days)	Greater than standard
Flexural strength loss (28-42 days)	Max. 25%
Bond strength/slant shear (% monolithic latex concrete cylinder)	Min. 45
Deicer scaling (50 cycles)	
Median grading	Max. 3
Worst rated	Below 5
Chloride permeability (95% absorbed)	
1/16 – ½ in. (% Cl.-)	Max. 0.320
½ - 1 in. (% Cl.-)	Max. 0.064

Values for viscosity and density spectrographs of the solid portion and volatile portion shall be provided in the report.

For latex-modified concrete, Type I, Type II, Type III or Type K cement shall be used without mineral admixtures.

- (c) **Fine aggregate** shall conform to the requirements of Section 202 for Grading A.
- (d) **Coarse aggregate** shall be stone, air-cooled blast-furnace slag, or gravel conforming to the requirements of Section 203 for the class of concrete being produced.
- (e) **Water** shall conform to the requirements of Section 216.
- (f) **Admixtures** shall conform to the requirements of Section 215.
- (g) **White portland cement concrete** shall conform to the requirements herein except as follows:
  - 1. **Cement** shall be white portland cement conforming to the requirements of Section 214 for Type I portland cement except that it shall not contain more than 0.55 percent by mass of  $\text{Fe}_2\text{O}_3$ .
  - 2. **Fine aggregate** shall consist of clean, hard, durable, uncoated particles of quartz composed of at least 95 percent silica; shall be free from lumps of clay, soft or flaky material, loam, organic material, or other deleterious material; and shall conform to the requirements of Section 202. It shall not contain more than 3 percent inorganic silt by actual dry mass when tested in accordance with the requirements of AASHTO T11. Stone sands that produce an acceptable white concrete may also be used.
  - 3. **Coarse aggregate** shall be crushed stone or crushed or uncrushed gravel conforming to the requirements of Section 203.
- (h) **Fly ash** shall conform to the requirements of Section 241.
- (i) **Granulated iron blast-furnace slag** shall conform to the requirements of Section 215.
- (j) **Concrete to which a high-range water reducer is to be added** shall conform to the requirements of Table II-17. Concrete shall be mixed 70 to 100 revolutions at mixing speed.
- (k) **Silica fume** shall conform to the requirements of Section 215.

#### 217.03--Handling and Storing Materials.

- (a) **Aggregate** shall be kept separated by size until batched. Aggregates shall be clean and shall be maintained in at least a saturated, surface-dry condition.

Fine aggregate that has been washed shall not be used within 24 hours after being placed in the stockpile or until surplus water has disappeared and the material has a consistent free moisture content. Stockpiles shall be located and constructed so that surplus water will drain from stockpiles and the batcher.

- (b) **Cement** that is reclaimed or that shows evidence of hydration, such as lumps or cakes, shall not be used.

Loose cement shall be transported to the mixer either in tight compartments for each batch or between the fine and coarse aggregate. Cement in original shipping packages may be transported on top of the aggregates, with each batch containing the number of bags required.

- (c) **Latex modifier** shall be kept in enclosures that will protect it from exposure to temperatures below 40 °F or above 85 °F. Containers of latex modifier shall be protected from direct sunlight.

- (d) **Admixtures** shall be stored and handled so that contamination and deterioration will be prevented. Liquid admixtures shall not be used unless thoroughly agitated. Admixtures that are frozen or partially frozen shall not be used.

- (e) **Aluminum forms, chutes, buckets, pump lines, and other conveying devices** shall not be used if the aluminum comes in contact with concrete.

#### 217.04--Measurement of Materials.

Measuring devices shall be subject to the approval of the Engineer.

- (a) **Stationary Production Plant:**

1. **Cement** shall be measured by weight. Cement in standard packages (94 lbs. Net per bag) need not be weighed, but bulk cement and fractional packages shall be weighed within an accuracy of 1 percent of weight.
2. **Mixing water** shall be measured by volume or weight. The water measuring device shall be readily adjustable and capable of delivering the required amount. Under all operating conditions, the device shall have an accuracy of within 1 percent of the quantity of water required for the batch.
3. **Aggregates** shall be measured by weight within an accuracy of 2 percent. Fine and coarse aggregate shall be weighed separately. Prior to mixing concrete, the moisture content of aggregates shall be determined and proper allowance made for the water content. The moisture content shall be determined prior to the start of mixing and thereafter as changes occur in the condition of aggregates. The Contractor shall perform moisture determinations and tests for slump and air content and provide necessary testing equipment.
4. **Admixtures** shall be dispensed and used according to manufacturer's recommendations. They shall be added within a limit of accuracy of 3 percent, by means of an approved, graduated, transparent, measuring device before they are introduced into the mixer. If more than one admixture is to be used, they shall be released in sequence rather than at the same instant. Once established, the sequence of dispensing admixtures shall not be

altered. However when the amount of admixture required to give the specified results deviates appreciably from the manufacturer's recommended dosage, use of the material shall be discontinued.

- (b) **Mobile Production Plant:** Aggregates, cement, and water shall be measured by weight or volume. If ingredients are measured by volume, the Contractor shall furnish, at his expense, approved scales and containers suitable for checking the calibration of the equipment's measuring system. The manufacturer's recommendations shall be followed in operating the equipment and calibrating the gages and gate openings. Mixing water shall be measured by a calibrated flow meter. The introduction of mixing water to the mixer shall be properly coordinated with the introduction of cement and aggregates. Ingredients shall be proportioned within the following tolerances, which are based on the volume/mass relationship established by calibration of the measuring devices:

Ingredients	Tolerance
Cement	0 to +4%
Fine aggregate	±2%
Coarse aggregate	±2%
Admixtures	±3%
Water	±1%

Tolerances will be applied to approved mixture design quantities.

Means shall be provided whereby samples of the various ingredients can be taken from the feed prior to blending and mixing to test the calibration of the equipment.

#### 217.05--Equipment.

Equipment and tools necessary for handling materials and performing all parts of the work shall be as approved by the Engineer.

- (a) **Batching Equipment:** Bins with separate compartments for fine aggregate and for each required size of coarse aggregate shall be provided in the batching plant. Bins for bulk cement shall be arranged so that cement is weighed on a scale separate from those used for other materials and in a hopper free and independent of hoppers used for weighing aggregates. The cement hopper shall be properly sealed and vented to preclude dusting during operation. Each compartment shall be designed to discharge aggregate efficiently and freely into the weighing hopper. A means of control shall be provided so that material may be added slowly and shut off with precision. A port or other opening shall be provided to remove any overrun of any of the several materials from the weighing hopper. Weighing hoppers shall be constructed to prevent accumulation of materials and to discharge fully.

Scales used for weighing aggregates and cement shall be approved and sealed in accordance with the requirements of Section 109 of the Specifications.

When beam scales are used, provision shall be made for indicating to the operator that the required load in the weighing hopper is being approached. The indicator shall indicate at least the last 200 pounds of load. Scales and indicating devices shall be in full view of the operator while the hopper is charged, and the operator shall have convenient access to all controls.

- (b) **Mixers and Agitators:** Mixers may be stationary or truck mixers. Agitators may be truck mixers or truck agitators. Each mixer and agitator shall have a metal plate(s) attached in a prominent place by the manufacturer on which the following are marked: the various uses for which the equipment is designed, capacity of the drum or container in terms of the volume of mixed concrete, and speed of rotation of the mixing drum or blades. Each stationary mixer shall be equipped with an approved timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. Each truck mixer shall be equipped with an approved counter by which the number of revolutions of the drum or blades may be readily verified.

The mixer shall be capable of combining ingredients of concrete into a thoroughly mixed and uniform mass and of discharging concrete with a satisfactory degree of uniformity.

The agitator shall be capable of maintaining mixed concrete in a thoroughly mixed and uniform mass and of discharging concrete within a satisfactory degree of uniformity.

Mechanical details of the mixer or agitator, such as the water measuring and discharge apparatus, condition of the blades, speed of rotation of the drum, general mechanical condition of the unit, and cleanliness of the drum, shall be checked before use of the unit is permitted. Upon request by the Engineer, consistency tests of individual samples at approximately the beginning, midpoint, and end of the load shall be conducted. If consistency measurements vary by more than 2 inches for slump between high and low values, the mixer or agitator shall not be used until the condition is corrected.

- (c) **Mobile Production Plants:** The Contractor may produce Class A3 general use hydraulic cement concrete for incidental construction items from a mobile production plant. Mobile production plants will be permitted to produce concrete used in bridges for overlays; box culverts; pavements; patching, except retaining walls. If the Contractor elects to use a mobile production plant as permitted, the equipment requirements specified hereinbefore will not apply and the concrete shall be mixed at the point of delivery by a combination materials transport and mixer unit conforming to the following:
1. The unit shall be capable of carrying ingredients needed for concrete production in separate compartments and of mixing ingredients at the point of delivery. The unit shall be equipped with calibrated proportioning devices to vary mixture proportions of dry ingredients and water. The unit shall be capable of changing the slump at any interval of continuous discharge of concrete.
  2. The mixing mechanism shall be a part of the transportation unit carrying dry ingredients. The mixer may be any type capable of combining ingredients of concrete into a thoroughly mixed and uniform mass and of discharging concrete with a satisfactory degree of uniformity within the specified time of mixing.
  3. Each unit shall have a metal plate(s) attached in a prominent place by the manufacturer on which the following are plainly marked: the gross volume of the transportation unit in terms of mixed concrete, discharge speed, and weight calibrated constant of the machine in terms of an indicator revolution counter.
  4. During discharge, the consistency, determined by the slump cone method (ASTM C 143) on representative samples taken from the discharge of the mixer at random intervals, shall not vary by more than 1 inch.

Classes and uses of concrete are specified in Table II-17. Page C - 27

### **217.07--Proportioning Concrete Mixtures.**

The Contractor is responsible for having a Certified Concrete Plant Technician available during batching operations, and a Certified Concrete Field Technician shall be present during placing operations.

**A Certified Concrete Plant Technician** is that person who is capable of performing adjustments in the proportioning of materials used to produce the specified concrete should adjustments become necessary.

**A Certified Concrete Field Technician** is that person who is responsible for quality control of concrete work at the project site. The Contractor shall have at least one Certified Concrete Field Technician on the project for single or multiple incidental concrete placements. The Contractor shall have at least one Certified Concrete Field Technician present at each site during the placement of pavements, bridge decks, bridge piers and abutments, box culverts and any placement of 50 or more cubic yards.

The Certified Concrete Field Technician shall provide control over methods used for discharging, conveying, spreading, consolidating, screeding, finishing, texturing, curing and protecting the concrete. Deficiencies in conformance to specification requirements and good concreting practices shall be corrected as soon as they begin to occur.

The concrete producer shall plan batching operations so that delays do not occur because of the absence of certified personnel.

Concrete shall be proportioned to secure the strength and durability required for the pavement or the part of the structure in which it is to be used.

Prior to mixing concrete, the Contractor shall submit, or shall have his supplier submit, for approval concrete mixture design(s) conforming to the specifications for the class of concrete specified.

The Contractor shall furnish and incorporate an approved water-reducing and retarding admixture in bridge deck concrete and in other concrete when conditions are such that the initial set may occur prior to completion of approved finishing operations. An approved water-reducing admixture shall be furnished and incorporated in concrete when necessary to provide the required slump without exceeding the maximum water/cement ratio and shall be used in bridge deck concrete when the requirement for a water-reducing and retarding admixture is waived by the Engineer. The Contractor shall demonstrate that use of the admixture will not cause segregation. The two admixtures shall not be used together in the same concrete batch unless tests indicate the admixtures are compatible in accordance with the requirements of Section 215.02 (b). Costs for admixture(s) shall be included in the contract unit price for the respective concrete item.

Concrete shall be air entrained. The air content shall conform to the requirements of Table II-17.

Except for latex hydraulic cement concrete, the quantities of fine and coarse aggregates necessary to conform to these specifications in regard to consistency and workability shall be determined by the method described in ACI 211.2 or ACI 211.1 except that proportions shall be computed on the absolute volume basis and the 10 percent adjustment allowed in Table 5.3.6 will not be permitted. The actual quantities used, as determined by the methods described herein, shall not deviate more than  $\pm 5$  percent from such quantities.

For latex hydraulic cement content, the dry mass ratio of cement/fine aggregate/coarse aggregate shall be 1:2.5:2. A maximum adjustment of 10 percent may be made in the masses of the aggregate, as approved by the Engineer, to compensate for grading changes and variable specific gravity.

Batch quantities shall be adjusted during the course of the work to compensate for changes in workability caused by differences in characteristics of aggregates and cements within the specification requirements. Such adjustments shall be made only by the Contractor and shall not change the yield.

If concrete cannot be obtained with the required workability or consistency or with the maximum design water content with the materials furnished, the Contractor shall make changes to secure the desired properties subject to the limiting requirements specified in Table II-17 and the approval of the Engineer. When the void content of the fine aggregate is more than 50.5 percent and the concrete does not have the desired properties, the Contractor shall use a fine aggregate having a void content of less than 50.5 percent. In lieu of changing the fine aggregate, the Contractor may take one or more of the following actions:

1. Use an approved water-reducing admixture.
2. Increase the cement content.
3. Change the source of coarse aggregate.
4. In hot weather, add ice or otherwise reduce the temperature to increase the workability.
5. Submit other recommendations to the Engineer for approval.

However, when any of the options is exercised, the Contractor shall make trial batches under the observation of the Engineer to verify that concrete of the required workability and consistency is obtained within the specified water content. At least one trial batch shall be made with the concrete temperature at approximately 90 °F to verify that the concrete mixture has sufficient workability and consistency without exceeding the specified water content. When the fineness modulus of the fine aggregate changes more than 0.2 from the original design and the concrete does not have the desired properties, the concrete mixture shall be redesigned. Costs incurred because of adjustments of concrete mixture design(s) and for trial batches shall be borne by the Contractor, and no additional compensation will be made.

#### **217.08--Acceptance.**

- (a) **Air and Consistency Tests:** Air and consistency tests will be performed by the Department prior to discharge into forms to ensure that specification requirements are consistently being complied with for each class of concrete. The sample secured for the tests shall be taken after at least 2 cubic feet of concrete has been discharged from the delivery vehicle. The two cubic feet discharged is not to be used as part of the test sample. Any deviation from sampling and testing procedures must be approved of the Engineer. The Contractor shall provide a receptacle conforming to the requirements of ASTM C31, Section 5.9, for the Department's use in obtaining its sample. If either determination yields a result that is outside the allowable range for air content or consistency, the following procedures will be used:
1. The Engineer will immediately perform a recheck determination. If the results confirm the original test results, the load will be rejected.
  2. The Contractor's representative will be immediately informed of the test results.
  3. The Contractor's representative shall notify the producer of the test results through a pre-established means of communication.

The Engineer may perform any additional tests deemed necessary and reject all remaining material that fails the tests.

Entrained air content will be determined in accordance with the requirements of ASTM C231 or C173. Acceptance or rejection will be based on the results obtained from these tests.

In general, a mixture that contains the minimum amount of water consistent with the required workability shall be used. Consistency will be determined in accordance with the requirements of ASTM C143. Adding cement to loads previously rejected for excessive water content or consistency will not be permitted.

- (b) **Strength Tests:** The 28-day strengths specified in Table II-17 are strengths used in the design calculations. The Engineer will verify design strengths by tests made during the progress of the work in accordance with the requirements of ASTM C39 and C31 with the exception that the fresh concrete sample used for testing is secured after at least two cubic feet has been discharged from the delivery vehicle. The two cubic feet discharged is not to be used as part of the test sample. Any deviation from sampling and testing procedures must be approved by the Engineer. If the test results do not conform to the strengths specified in Table II-17, immediate steps shall be taken to adjust the design mixture and an investigation will be initiated by the Engineer to determine the acceptability of the concrete. Use of ASTM C42 will be at the Engineer's discretion.

The Contractor shall provide a storage chamber at his expense for temporary storage of the Department's concrete cylinders before concrete is placed. The contractor shall be responsible for the chamber maintaining the concrete test cylinders in a continuously moist condition within a temperature range of 60 °F to 80 °F and shall be equipped with a continuously recording thermometer accurate to  $\pm 2$  °F for the duration of concrete field cylinder curing period. The chamber shall be located in an area where the test cylinders will not be subject to vibration and shall be of sufficient size or number to store, without crowding or wedging, the required number of test cylinders as determined by the Contractor based on his plan of operations. The chamber and location of the chamber must be approved by the Engineer.

When use of high-early-strength hydraulic cement concrete is required, it shall conform to the requirements of Table II-17 except that the 28-day strength shall be obtained in 7 days. Up to 800 pounds per cubic yard of Type I or Type II cement may be used to produce high-early-strength concrete in lieu of using Type III modified cement.

- (c) **Concrete Temperature** shall be measured in accordance with ASTM C1064.

#### **217.09--Mixing.**

The method of mixing shall be approved by the Engineer prior to the start of concrete work.

The volume of concrete mixed per batch shall be at least 15 but not more than 110 percent of the mixer's rated capacity.

Concrete that becomes non-plastic, unworkable, or outside the limits of the slump specified shall not be used. Retempered concrete shall not be used. Concrete delivery shall be regulated so that placement is at a continuous rate. Intervals between the delivery of batches shall not be so great as to allow concrete in place to begin initial set.

- (a) **Mixing at Job Site:** Concrete shall be mixed in a batch mixer designed to ensure a uniform distribution of materials throughout the mass. When bag cement is used, batches shall be proportioned on the basis of integral bags of cement.

Mixing shall be performed in accordance with the requirements of (b)3. herein.

Upon the cessation of mixing for more than 30 minutes, the mixer shall be thoroughly cleaned.

- (b) **Ready-Mixed Concrete:** Ready-mixed concrete shall be delivered to the designated point ready for use.

Each load of transit or shrink-mixed concrete shall be accompanied by Form TL-28 signed by the VDOT Certified Concrete Plant Technician or a designated company representative working under the direction of the VDOT Certified Concrete Plant Technician. The form shall be delivered to the Inspector at the site of the work. Loads that do not carry such information or that do not arrive in satisfactory condition shall not be used.

Each batch of concrete shall be delivered to the site of work and discharged within 90 minutes of the time the cement is introduced into the mixture unless otherwise approved by the Engineer.

Mixing and delivery shall be in accordance with the following:

1. **Transit mixing:** Concrete shall be mixed in a truck mixer. Mixing shall begin immediately after all ingredients are in the mixer and shall continue for at least 70 revolutions of the drum or blades at the rate of at least 14 but not more than 20 revolutions per minute.

Additional rotations of the drum or blades shall be at the rated agitating speed. The mixer shall be operated within the capacity and speed of rotation designed by the manufacturer.

2. **Shrink mixing:** Materials, including water, shall be partially mixed in a stationary mixer for at least 30 seconds. Mixing shall be completed in a truck mixer with at least 60 but not more than 100 revolutions of the drum or blades at the rated mixing speed. Additional rotations of the drum or blades shall be at the rated agitating speed. Mixers shall be operated within the capacity and speed of rotation designated by the manufacturer of the equipment.

3. **Central mixing:** Concrete shall be completely mixed in a stationary mixer and transported in the agitator equipment to the point of delivery. Use of non-agitator equipment will be approved only when the plant is in the immediate vicinity of the project.

Mixing time for mixers having a capacity of 1 cubic yard or less shall be at least 60 seconds. Mixing time for mixers having a capacity of more than 1 but less than 10 cubic yards shall be at least 75 seconds. Mixing times for mixers having a capacity of more than 10 cubic yards shall be as determined by the Engineer. Performance tests shall be conducted in accordance with the requirements of VTM-17 by an approved commercial laboratory at the Contractor's expense. Lesser times will be approved if the requirements of VTM-17 are conformed to. In any event, mixing time shall be not less than 40 seconds.

The requirements of VTM-17 shall not be construed as a nullification of the requirements of Table II-17. If subsequent evaluation check tests indicate that the reduced mixing time is not satisfactory, the Contractor shall reestablish the necessary mixing time.

Concrete mixed for less than the specified time will be rejected. Mixing time starts when solid materials are in the mixing compartment and ends when any part of the concrete begins to discharge. The mixer shall be operated at the drum speed specified on the name plate of the approved mixer.

Bodies of non-agitating equipment used to transport concrete shall be smooth, mortartight, non-aluminum metal containers capable of discharging concrete at a controlled rate without segregation. Upon discharge of concrete, the body of the equipment shall be free from concrete. Concrete shall be delivered to the work site in a thoroughly mixed and uniform

mass. Upon the request of the Engineer, consistency tests of individual samples at approximately the beginning, midpoint, and end of the load shall be conducted. If consistency measurements vary by more than 2 inches for slump between high and low values, mixer or agitator equipment shall be used in lieu of non-agitating equipment.

- (c) **Automatic Mobile Continuous Mixers:** Mobile continuous mixers shall be calibrated to proportion the mixture accurately and shall have been certified within 60 days prior to use on the project for the type of material specified. Certifications will be valid for 6 months or until the source of materials changes or the grading or moisture changes significantly so as to affect the consistency of the concrete. Evaluation and certification will be performed by the Department or an approved testing agency to determine that the true yield is within a tolerance of  $\pm 1.0$  percent. A recording meter, visible at all times and equipped with a ticket printout, shall indicate the calibrated measurement.
- (d) **Hand Mixing:** Hand mixing will be permitted only in case of emergency and with permission. Batches shall be not more than  $\frac{1}{2}$  cubic yard and shall be mixed in a watertight container in a manner approved by the Engineer. Ingredients shall be measured by placing them in any suitable, rigid container in the volumetric proportions of 1 part cement to 2 parts fine aggregate to 2  $\frac{1}{2}$  parts coarse aggregate. The container shall be filled and leveled with each ingredient to ensure the proportions specified as nearly as possible. Water shall be added to produce a slump of not more than 3 inches.

#### **217.10--Placement Limitations.**

The Contractor shall be responsible for the quality of concrete placed in any weather or atmospheric condition. At the time of placement, concrete shall have a temperature in accordance with the following:

- (a) Class A3 general use concrete used in the construction of incidental items specified in Division V of these specifications, except retaining walls, shall have a temperature of at least 40 °F but not more than 95 °F.
- (b) Class A3 paving concrete placed by the slipform method and containing an approved water reducer shall have a temperature of at least 40 °F but not more than 95 °F.
- (c) Concrete used in the construction of bridge decks shall have a temperature of at least 40 °F but not more than 85 °F.
- (d) Retaining walls and other concrete not specified in 1., 2., or 3. herein shall have a temperature of at least 40 °F but not more than 90 °F.

In cold weather, water and aggregates may be heated to not more than 150 °F to maintain concrete at the required temperature. The heating apparatus shall be such that materials will be heated uniformly and the possibility of the occurrence of overheated areas that might damage materials will be precluded. Steam shall not come in contact with aggregates. Cement shall not be heated. Heating equipment or methods that alter or prevent entrainment of the required amount of air in concrete shall not be used. Materials containing frost, lumps, crusts, or hardened material shall not be used.

In hot weather, aggregates or the mixing water shall be cooled as necessary to maintain the temperature of the concrete within the specified maximum.

**SECTION 220--CONCRETE CURING MATERIALS****220.01--Description.**

These specifications cover materials used to maintain the humidity and temperature of freshly placed concrete to ensure satisfactory hydration and proper hardening of the concrete.

**220.02--Detail Requirements.**

Concrete curing materials shall consist of waterproof paper, PE film, a combination of burlap and PE film, liquid membrane-forming compound, or water. Concrete curing materials shall be free from impurities that may be detrimental to the surface of concrete.

- (a) **Waterproof paper** shall conform to the requirements of AASHTO M171. One side shall be composed of white, light-reflecting paper.
- (b) **PE film** shall conform to the requirements of AASHTO M171 except that its nominal thickness shall be 3.0 mils. The thickness at any point shall be at least 2.5 mils.
- (c) **Burlap and PE film** may be used in combination. They shall be bonded securely so that they cannot be easily separated in a dry or saturated condition. White PE film shall conform to the reflectance requirements of AASHTO M171. Burlap shall conform to the requirements of AASHTO M182, Class 3.
- (d) **Liquid membrane-forming compounds** shall be used on concrete masonry except bridge substructure elements. Fugitive dye compounds shall be used on bridge substructure elements. The Contractor shall remove liquid membrane-forming compound from concrete surfaces to which a bonding compound, joint sealer, or waterproofing material is to be applied.

Liquid membrane-forming compounds will be tested in accordance with the requirements of VTM-2 and shall conform to the following:

1. Liquid membrane-forming compounds shall contain an easily dispersed opaque, white, finely ground pigment or a fugitive dye. They shall not react with the components of concrete and shall not contain oils, waxes, or other materials that would prevent bonding of traffic paints. The resulting film shall be continuous, uniform, and free from pinholes, bubbles, or blisters and shall not darken the hardened concrete. The dye shall have sufficient color to be distinctly visible for at least 30 minutes after application and to disappear within 7 days.
2. The membrane shall not peel. It shall disappear by gradual disintegration from exposure to the elements over a period of at least 30 days but not more than 1 year. Within 60 days after application, the membrane shall be capable of being readily removed by means of steel wire brushes or another abrasive that will not damage the concrete surface.
3. When applied by pressure spray to a troweled, vertical, damp concrete surface at the rate specified, material shall adhere to the surface in a continuous, tenacious film without running off or sagging appreciably.
4. Shipping containers shall identify the trade name of the material and a lot or batch number except for small, locally repackaged containers bearing the Department's seal.

5. The average moisture loss at 24 hours shall be not more than 0.20 kilograms per square meter of exposed surface. At 72 hours, it shall be not more than 0.30 kilograms per square meter.
  6. When applied to the test specimen, white pigmented material shall have a daylight reflectance of at least 60 percent of that of magnesium oxide.
- (e) **Water** used for curing concrete shall be clean, clear, and free from oil and other deleterious substances and shall have a pH of at least 4.5.

## SECTION 223--STEEL REINFORCEMENT

### 223.01--Description.

These specifications cover steel items designed to give added flexural strength to hydraulic cement concrete or to control and reduce cracking.

### 223.02--Detail Requirements.

(a) **Reinforcement:**

1. **Deformed bars** shall conform to the requirements of ASTM A615, Grade 40 or 60.
2. **Plain bars** shall conform to the requirements of ASTM A615, Grade 40 or 60, deformation waived. When used as a dowel, material may be a plain bar, Grade 40 or 60 (ASTM A615), or a plain dowel (ASTM A709 Grade 36).
3. **Welded wire fabric** shall conform to the requirements of ASTM A185. When used in continuously reinforced pavement, wire fabric shall be deformed and furnished in flat sheets and shall conform to the requirements of ASTM A497 (high yield of 70,000 pounds per square inch).
4. **Longitudinal bars** for continuous reinforced concrete pavement shall conform to the requirements of ASTM A615, Grade 60.
5. **Structural steel** shall conform to the requirements of Section 226.
6. **Bar mats** shall conform to the requirements of ASTM A184.
7. **Spiral wire** shall conform to the requirements of AASHTO M32 (ASTM A82).
8. **Wire mesh** for use in gabions shall be made of galvanized steel wire at least 0.105 inches (12 gage) in diameter. The tensile strength of the wire shall be at least 60,000 pounds per square inch. Wire mesh shall be galvanized in accordance with the requirements of ASTM A641, Class 3. When PVC coating is specified, it shall be at least 0.015 inches in thickness and shall be black.

Wire shall be welded to form rectangular openings or twisted to form hexagonal openings of uniform size. The linear dimension of the openings shall be not more than 4 ½ inches. The area of the opening shall be not more than 9 square inches. The unit shall be nonraveling. Nonraveling is defined as the ability to resist pulling apart at any of the twists or connections forming the mesh when a single wire strand in a section is cut.

- (b) **Prestressing Tendons:** Seven-wire stress-relieved strands, stress-relieved wire, and low-relaxation strands shall conform to the requirements of ASTM A416, Grade 270; ASTM A421; and ASTM A416, Supplement I; respectively, with the following modifications:
1. Strands or wires used in units of any one bed layout shall be manufactured by the same plant.
  2. A manufacturer's certification and load-elongation curve, in accordance with the requirements of ASTM A416 or A421, shall be obtained by the prestressed concrete fabricator for each lot of strand. The data shall be submitted to the Engineer for approval, in permanent record form.
- (c) **Reinforcing Steel To Be Epoxy Coated:** Steel shall conform to the requirements herein and shall be coated in accordance with the requirements of AASHTO M284.
1. Plants that epoxy coat reinforcing steel shall be CRSI certified for epoxy coating. CRSI inspection reports shall be on file at the plant and shall be available to the Engineer.
  2. Handling and storage of the coated bars shall conform to the requirements of AASHTO M284.
  3. Visible damage to the epoxy coating shall be patched or repaired with materials compatible to the existing coating in accordance with AASHTO M284.
- (d) **Reinforcing Steel To Be Galvanized:** Steel shall conform to the requirements herein and shall be galvanized in accordance with requirements of ASTM A767.

#### SECTION 241--FLY ASH

##### 241.01--Description.

These specifications cover fly ash (burnt coal residue) used as an additive in hydraulic cement concrete or as a soil stabilizer.

##### 241.02--Detail Requirements.

- (a) **Fly ash or natural pozzolans used in hydraulic cement concrete** shall conform to the requirements of ASTM C618, Class F, Class C, or Class N.
- (b) **Fly ash used in lime stabilization** shall conform to the requirements of ASTM C593. Bulk material may be used as approved by the Engineer.

Class of Concrete	Design Min. Laboratory Compressive Strength at 28 days (f c) (psi)	Aggregate Size No. <sup>6</sup>	Design Max. Laboratory Permeability at 28 days (Coulombs) <sup>5</sup>	Design Max. Laboratory Permeability at 28 days - Over tidal water (Coulombs) <sup>5</sup>	Nominal Max. Aggregate Size (in)	Min. Grade Aggregate	Min. Cementitious Content (lb/cu.yd)	Max. Water/ Cementitious Mat. (lb. Water/ lb. Cement)	Consistency (in of slump)	Air Content (percent) <sup>1</sup>
A5 Pre-stressed and other special designs <sup>2</sup>	5,000 or as specified on plans	57 or 68	1,500	1,500	1	A	635	0.40	0-4	4 1/2 ± 1 1/2
A4 General	4,000	56 or 57	2,500	2,000	1	A	635	0.45	2-4	6 1/2 ± 1 1/2
A4 Posts & rails	4,000	7, 8 or 78	2,500	2,000	0.5	A	635	0.45	2-5	7 ± 2
A3 General	3,000	56 or 57	3,500	2,000	1	A	588	0.49	1-5	6 ± 2
A3a Paving	3,000	56 or 57	3,500	3,500	1	A	564	0.49	0-3	6 ± 2
A3b Paving	3,000	357	3,500	3,500	2	A	N.A.	0.49	0-3	6 ± 2
B2 Massive or lightly reinforced	2,200	57	N.A.	N.A.	1	B	494	0.58	0-4	4 ± 2
C1 Massive Unreinforced	1,500	57	N.A.	N.A.	1	B	423	0.71	0-3	4 ± 2
T3 Tremie seal	3,000	56 or 57	N.A.	N.A.	1	A	635	0.49	3-6	4 ± 2
Latex Hydraulic cement concrete overlay <sup>3</sup>	3,500	7, 8 or 78	1,500	1,500	0.5	A	658	0.40	4-6	5 ± 2
Silica fume , Silica fume/ Class F fy ash or silica fume/slag concrete overlay <sup>4</sup>	5,000	7, 8 or 78	1,500	1,500	0.5	A	658	0.40	4-7	6 ± 2
Class F F y ash or slag overlay	4,000	7, 8 or 78	1,500	1,500	0.5	A	658	0.40	4-7	6 ± 2

**Footnotes**

<sup>1</sup>When a high-range water reducer is used, the target air content shall be increased 1% and the slump shall not exceed 7 inches.

<sup>2</sup>When Class A5 concrete is used as the finished bridge deck riding surface, or when it is to be covered with asphalt concrete with or without waterproofing, the air content shall be 5VJ.±1%%.

<sup>3</sup>The latex modifier content shall be 3.5 gallons per bag of cement. Slump shall be measured approximately 4 minutes after discharge from the mixer.

<sup>4</sup>Silica fume with a minimum of 7% by weight of cementitious material; silica fume with a range of 2.5-5% shall be combined with Class F Fly Ash in range of 15-20% minimum cement of 77.5% by weight of cementitious material; silica fume with a range of 2.5-5% shall be combined with Ground Granulated Blast Furnace Slag in the range of 30-35% and a minimum cement of 67.5% by weight of cementitious material.

<sup>5</sup>The permeability testing does not apply to small bridges identified on the bridge plans and to concrete structures and incidental concrete as described in Sections 219, 232, 302, 415, 502, 504, 506 and 519. Curing and testing of test cylinders for permeability will be in accordance with Vf M-112.

<sup>6</sup>The contractor may use different aggregate sizes or a combination of sizes to increase the coarse aggregate content of the concrete as approved by the Engineer. The maximum size of the coarse aggregate shall not exceed 2.5 inches.

*Note:* With the approval of the Engineer, the Contractor may substitute a higher class of concrete for that specified at the Contractor's expense.



# Division III

## Roadway Construction

### SECTION 316--HYDRAULIC CEMENT CONCRETE PAVEMENT

#### 316.01--Description.

This work shall consist of constructing pavement and approach slabs composed of hydraulic cement concrete, with or without reinforcement as specified, or a continuously reinforced pavement on a prepared subgrade or base course in accordance with the requirements of these specifications and in reasonably close conformity with the lines, grades, thicknesses, and typical cross sections shown on the plans or as established by the Engineer.

#### 316.02--Materials.

- (a) **Concrete** shall be central mixed and shall conform to the requirements of Table II-17 for Class A3 paving concrete except that the slump shall be not more than 2 inches for placement by the slipform method. Concrete for placement by the slipform method shall be sufficiently cohesive to prevent detrimental sloughing at the pavement edges as the forms advance. Transit mixture concrete may be furnished for use in constructing approach slabs, ramps, transitions, connections, crossovers, and other miscellaneous pavement. Aggregate used in concrete for pavement and approach slabs that are used as riding surfaces shall be non-polishing aggregate.
- (b) **Reinforcing steel dowels, tie bars, hook bolts, and welded wire fabric** shall conform to the requirements of Section 223.
- (c) **Wide flange beams** used in the anchor slab of continuously reinforced pavement shall conform to the requirements of ASTM A36.
- (d) **Joint sealer and filler** shall conform to the requirements of Section 212.
- (e) **Load transfer devices** shall be fabricated of steel and shall be of an approved type and design.
- (f) **Curing materials** shall conform to the requirements of Section 220.

#### 316.03--Equipment.

Equipment and tools necessary for handling materials and performing the work shall be subject to the approval of the Engineer.

The Contractor shall provide the equipment and tools specified herein, or their approved equivalent, and they shall be of such capacity that the rate of placing concrete and finishing pavement will be continuous. If any piece of equipment does not have sufficient capacity to keep pace with the other operations, the Contractor shall limit the size of the batch or otherwise limit the rate of production to preclude poor workmanship or frequent delays.

- (a) **Forms:** Straight side forms shall be made of metal at least 7/32 inch in thickness and shall be furnished in sections at least 10 feet in length. Forms shall have a depth at least equal to the prescribed edge thickness of the concrete, without horizontal joints, and a base width equal to at least the depth of the forms. Flexible or curved forms of proper radius shall be used for curves with a radius of 100 feet or less. Flexible or curved forms shall be of a design acceptable to the Engineer. Forms shall be provided with adequate devices for secure placement so that when set they will withstand the impact and vibration of consolidating and finishing without visible springing or settlement. Flange braces shall extend outward on the base at least 2/3 the height of the form. Forms that are bent, twisted, or broken or that have battered top surfaces shall be removed. Repaired forms shall not be used until inspected and approved. Built-in forms shall not be used except where the total area of pavement on the project is less than 2,000 square yards. The top face of the form shall not vary from a true plane more than 1/8 inch in 10 feet, and the vertical side shall not vary from a true plane more than ¼ inch in 10 feet. Forms shall contain provisions for locking the ends of abutting form sections together tightly and for secure setting.
- (b) **Subgrade Machine:** The machine shall be of an approved mechanical type, capable of preparing the subgrade to within ¼ inch of the grade shown on the plans or established by the Engineer.
- (c) **Subgrade Roller:** The roller shall be of an approved type and capable of obtaining the required density.
- (d) **Bulkheads:** Bulkheads for construction joints shall be of sufficient strength to prevent deformation of the joint and shall be constructed to permit dowels or other reinforcement to extend through the joint.
- (e) **Work Bridges:** Work bridges shall be provided by the Contractor.
- (f) **Mechanical Spreader:** The mechanical spreader shall be a self-powered, self-propelled unit capable of placing the concrete mechanically on the subgrade over the full width and depth of the pavement.
- The spreader shall be equipped with a hopper or other type of spreading equipment that will distribute the concrete over the subgrade without segregation. The concrete shall not be placed directly on the subgrade from the hauling equipment except in areas where hand labor must be performed.
- (g) **Vibrators:** Vibrators for full-width vibration of concrete pavements shall be internal vibrators with multiple spuds. They may be attached to the spreader or mounted on a separate carriage operating directly behind the spreader. The frequency of vibrators shall be at least 7,000 impulses per minute.
- When spud internal vibrators, either hand operated or attached to spreaders, are used adjacent to forms, they shall have a frequency of at least 3,500 impulses per minute.
- Vibration shall be controlled by the forward movement of the spreader so that vibration automatically ceases when the forward movement of the spreader is stopped.
- (h) **Spraying Equipment:** When liquid membrane-forming compound is used for curing concrete pavement, the Contractor shall provide mechanical spraying equipment mounted on movable bridges. The equipment shall be the full atomizing type equipped with a tank agitator and a gage to measure the quantity of material applied. The equipment shall be capable of continuously agitating the membrane during application.
- (i) **Concrete Saw:** When sawing joints is elected or specified, the Contractor shall provide sawing equipment adequate in number of units and power to complete the sawing to the required dimensions and at the required rate with a water-cooled, diamond-edged saw blade or an abrasive wheel.

- (j) **Slipform Paver:** The paver shall be designed to consolidate, screed, and float finish the freshly placed concrete in one complete pass of the machine and in a manner so that a minimum of hand finishing will be necessary to provide a dense and homogeneous pavement. The paver shall be equipped to vibrate the concrete thoroughly for the full width and depth of the strip of pavement being placed.

### 316.04--Procedures.

- (a) **Concrete Base Course:** The subgrade or subbase upon which the base course is to be placed shall be prepared in accordance with the requirements of the applicable provisions of these specifications for such course.

The construction of a hydraulic cement concrete base course shall conform to the requirements of these specifications except for floating and final finishing of the surface. The surface shall be finished so that there will be no deviation of more than ¼ inch between any two contact points when tested with a 10-foot straightedge placed parallel to the center line. A heavy broomed texture shall be applied.

- (b) **Preparing Grade:** The subgrade shall be prepared as specified in Section 305. The course upon which the concrete pavement will rest, including the area that will support the paving equipment, shall be graded and compacted to the required profile.

Before or after side forms have been securely set to grade, the subgrade or subbase course shall be brought to the proper cross section. The finished grade shall be maintained in a smooth and compacted condition until pavement is placed.

The subgrade or subbase course shall be uniformly moist when concrete is placed. However, the method of moistening shall not be such as to form mud or pools of water.

- (c) **Placing Reinforcing Steel for Continuously Reinforced Pavement:** At each location where five or more consecutive days will elapse between placement operations, a "leave out" joint shall be installed as detailed on the plans. Longitudinal bars shall be positioned in the finished pavement within  $\pm 1/2$  inch of the specified vertical position and  $\pm 1$  inch of the specified horizontal position with a cover of at least 2 inches.

Prebent deformed tie bars, Grade 40 or 60, may be used in the joint between the mainline and ramp pavement to facilitate the use of the slipform paver. Bars shall be prebent with equipment designed especially for fabricating 90-degree bends in 5/8 inch deformed bars without damage to the bars. Side forms of the slipform paver shall be designed in a manner so that the prebent tie bars can be inserted in an appropriate slot and will pass between the edge of the pavement and the inside face of the trailing forms as the paver advances.

When reinforced concrete pavement is placed in two layers, the entire width of the bottom layer shall be vibrated and struck off to such length and depth that the sheet of fabric or bar mat may be laid full length on the concrete in its final position without further manipulation. The reinforcement shall then be placed directly on the concrete, after which the top layer of concrete shall be placed, struck off, and screeded. Any portion of the bottom layer of concrete that has been placed more than 30 minutes without being covered with the top layer shall be removed and replaced with freshly mixed concrete at the Contractor's expense. When reinforced concrete is placed in one layer, the reinforcement may be positioned in advance of concrete placement or placed by approved mechanical or vibratory means in fresh concrete after spreading.

Reinforcing steel shall be straight, and its surface condition shall conform to the requirements of Section 406.03(b).

- (d) **Setting Forms:** The foundation under forms shall be compacted to grade so that forms, when set, will be firmly in contact for their entire length and at the specified grade. Any foundation grade that is found to be low shall be filled to grade with granular material in lifts of ½ inch or less for a distance of 18 inches on each side of the base of the form and thoroughly compacted. Imperfections or variations above grade shall be corrected by tamping or cutting as necessary.

Forms shall be set at least 500 feet in advance of concrete placement. Where local conditions make this requirement impracticable, it may be waived. After the forms have been set, the grade shall be thoroughly tamped at the inside and outside edges of the base of forms. Forms shall be staked into place with a sufficient number of pins of sufficient length for any section to hold the form at the correct line and grade. Form sections shall be tightly locked, free from play or movement. The top of the form, when tested with a 10 foot straightedge, shall not deviate more than 1/8 inch and the longitudinal axis of the vertical face shall not vary more than ¼ inch from the straightedge. No excessive settlement or springing of forms under the finishing machine will be allowed. Forms shall be cleaned and oiled prior to concrete placement.

The alignment and grade elevation of forms shall be checked and corrections made by the Contractor immediately before concrete placement. If any form has been disturbed or any grade has become unstable, the form shall be reset and rechecked.

- (e) **Placing Concrete:** Concrete shall be placed on the grade in a quantity that will provide a uniform and adequate supply for the finishing equipment. Spreading shall be accomplished with a mechanical spreader. Necessary hand spreading shall be performed using square-faced shovels. The use of rakes or hoes will not be permitted. Workers shall not be allowed to walk in the freshly mixed concrete with boots or shoes coated with soil or foreign substances.

Where concrete is placed adjoining a previously constructed lane and mechanical equipment will be operated from the existing lane, the concrete in that lane shall have attained a modulus of rupture strength of at least 450 pounds per square inch. Test specimens for this purpose shall conform to the requirements of ASTM C 31 and shall be tested in accordance with the requirements of ASTM C 293. Equipment that will damage the surface of the existing pavement will not be permitted.

Concrete shall be thoroughly consolidated against forms and joint assemblies by means of full-width vibration. Vibrators will not be permitted to come in contact with a joint assembly, reinforcement, or side forms. The vibrator shall not be operated for more than 15 seconds in any one location. When fabric or bar mat reinforcement is placed by mechanical equipment that uses vibration or a tamping action, other vibratory equipment may be eliminated except in areas adjacent to side forms.

Concrete shall be placed as close to expansion and contraction joints as is possible without disturbing the joints. Concrete shall be placed over and around dowels in a manner so that dowels are fully embedded without displacement.

Concrete for continuously reinforced pavement shall be placed through the openings in the steel in one lift and vibrated with an internal vibrator for the entire width and depth. Special attention shall be given to the consolidation of the concrete in the immediate vicinity of construction joints and other areas where the performance of vibrators mounted on the paving equipment is questionable.

Following concrete placement, concrete shall be struck off to conform to the cross section shown on the plans and to an elevation such that when the concrete is properly consolidated and finished, the surface of the pavement will be reasonably close to the elevation shown on the plans or as established by the Engineer.

If concrete operations are permitted to extend after sunset, adequate lighting shall be provided.

- (f) **Test Specimens:** The Contractor shall furnish the concrete necessary for casting test beams in accordance with the requirements of Section 316.04 (o). Beams shall be cured by a designated method as specified for the pavement in accordance with the requirements of ASTM C 31.
- (g) **Jointed Pavement:** Joints shall be installed in a manner and at such time to prevent random or uncontrolled cracking. If random or uncontrolled cracking occurs, sufficient concrete shall be removed and replaced on each side of the cracking to form a slab at least 10 feet long. Transverse construction joints shall be constructed at each end of the slab in accordance with the requirements of applicable provisions of 4. herein.
1. **Longitudinal joints:** Deformed tie bars of the specified length, size, spacing, and material shall be placed perpendicular to the longitudinal joints. They shall be placed by approved mechanical equipment and rigidly secured by chairs or other approved supports to prevent displacement or by the insertion of bars with an approved hand tool. When adjacent lanes of pavement are constructed separately, approved two-piece connectors shall be used.

Longitudinal joints shall be sawed, formed, or created using a strip insert. Longitudinal center joints shall be installed in a manner so that full contact is made at intersections with transverse joints.

- a. **Formed joints:** Formed joints shall consist of a groove extending downward from, and normal to, the surface of the pavement and shall be formed by an approved nonmetallic or removable device that consistently demonstrates its ability to produce in fresh concrete a joint having the dimensions and line indicated on the plans. The groove shall be sealed with a premolded or poured joint material as required.
- b. **Strip insert joints:** A longitudinal weakened plane joint may be furnished at traffic lane lines in multilane monolithic concrete pavement in lieu of forming or sawing such joints. Strip insert joints shall be formed by placing a continuous strip of plastic or other approved material. The insert strip shall be of sufficient width to form a weakened plane to the depth shown on the plans. The thickness of the insert material shall be at least 20 mils. Strip insert joints shall not be sawed.

The insert strip shall be inserted with a mechanical device that places the material in a continuous strip. Splices will be permitted provided they are effective in maintaining the continuity of the insert strip. The top edge of the insert strip shall be positioned flush with the finished surface. The insert strip shall not be deformed from a vertical position during installation or in subsequent finishing operations performed on the concrete. The alignment of the finished joint shall be uniformly parallel with the center line of the pavement and free from local irregularities in alignment that are more than ½ inch in 10 feet. The mechanical installation device shall vibrate the concrete during the insertion of the strip in a manner to cause the disturbed concrete to return evenly along the sides of the strip without segregating or developing voids.

If the Contractor is unable to furnish a satisfactory strip insert joint consistently, he shall, upon being notified by the Engineer, discontinue furnishing such joints and furnish other approved formed or sawed joints without additional compensation.

- c. **Sawed joints:** Longitudinal sawed joints shall be cut by approved concrete saws. Suitable guidelines or devices shall be used to ensure cutting the longitudinal joint on the true line as shown as soon as the concrete has hardened sufficiently to

permit sawing without chipping, spalling, or tearing. Concrete faces of the saw cut shall be protected from drying until the end of the specified curing period. Sawed joints shall be thoroughly cleaned and dried prior to being sealed.

2. **Transverse expansion joints:** Transverse expansion joints shall be formed in accordance with the requirements of 1.a. herein and shall be sealed using Type D material. Expansion joint filler shall be continuous from form to form, shaped to the subgrade. Preformed joint filler shall be furnished in lengths equal to the pavement width or the width of one lane. Damaged or repaired joint filler shall not be used.

Expansion joint filler shall be held in a position perpendicular to the subgrade. An approved installing bar, or other device, shall be used, if required, to secure preformed joint filler at the proper grade and alignment during placing and finishing of concrete. Finished joints shall not deviate more than  $\frac{1}{4}$  inch in the horizontal alignment from a straight line. If joint filler is assembled in sections, there shall be no offsets between adjacent units.

3. **Transverse contraction joints:** Transverse contraction joints shall consist of planes of weakness created by cutting grooves in the surface of the pavement and, when shown on the plans, shall include load transfer assemblies.

Edges of concrete adjacent to the joint may be rounded or beveled to a radius or length approved by the Engineer. Any joint having insufficient opening shall be resawed or ground to the proper size. Where a joint opening is larger than that specified, the Contractor may be required to build up the joint with epoxy mortar or to furnish a larger size seal as determined by the Engineer. The cost of any such additional work or material shall be borne by the Contractor.

4. **Transverse construction joints:**
  - a. **Jointed pavement:** Unless specified expansion joints occur at the same points, transverse construction joints shall be constructed at the end of each day's work or when there is an interruption of more than 30 minutes in the concreting operations. A transverse construction joint shall not be constructed within 10 feet of an expansion joint, contraction joint, or plane of weakness. If sufficient concrete has not been mixed at the time of interruption to form a slab at least 10 feet long, the excess concrete back to the last preceding joint shall be removed and disposed of as directed. An approved header board, cut to the required cross section, shall be used to form joints. Deformed dowel bars shall be used in transverse construction joints whose location does not coincide with the specified location of a transverse expansion or contraction joint.
  - b. **Continuously reinforced concrete pavement:** Transverse construction joints shall be formed by the use of an approved header board in accordance with the requirements of 4.a. herein. The header shall consist of two sections, one being placed above and one being placed below the reinforcing mat, and shall be furnished with openings to accommodate the longitudinal steel and additional reinforcement required.

At any location where a "leave out" is necessary for a detour, at least 100 feet shall be maintained between transverse construction joints.

5. **Load transfer devices:** Plain dowels shall be held in position parallel to the surface and center line of the slab by a metal device that is left in the pavement.

The entire free end of each dowel shall be painted with one coat of approved paint. When the paint has dried and immediately before dowels are placed in position, the free end shall be thoroughly coated with an approved lubricant. A metal or plastic dowel cap of approved design to cover 2 inches,  $\pm 1/4$  inch, of the dowel, with a closed end, and with a suitable stop to hold the end of the sleeve at least 1 inch from the end of the dowel bar shall be furnished for each dowel bar used in expansion joints. Caps or sleeves shall fit the dowel bar tightly, and the closed end shall be mortar-tight. Dowels, plastic coated in accordance with the requirements of Federal Specification L-C-530 C or epoxy coated in accordance with the requirements of ASTM A775, may be used in lieu of painted and lubricated dowel bars.

In lieu of using dowel assemblies at contraction joints, dowel bars may be placed in the full thickness of pavement by an approved device.

6. **Isolation joints at structures:** Isolation joints shall be formed by placing a strip of  $1/2$  inch preformed expansion joint filler around each structure that extends into or through the pavement before concrete is placed at that location.
- (h) **Final Striking Off, Consolidating, and Finishing:** The sequence of operations shall be as follows: (1) striking off, (2) consolidating, (3) floating, (4) removing laitance, (5) straightedging, and (6) finishing. If the application of moisture to the surface is permitted, it shall be applied as a fog spray by means of approved spray equipment.
1. **Finishing at joints:** Concrete adjacent to joints shall be mechanically vibrated to prevent voids and segregation from occurring against the joint material, also under and around load transfer devices, joint assembly units, and other features designed to extend into the pavement.
    - a. **Machine finishing:** Concrete shall be spread as soon as placed, struck off, and then screeded by an approved finishing machine. Vibration for the full width of the paving slabs shall be provided in accordance with the requirements of Section 316.03(g). The machine shall be operated over each area of pavement as many times and at such intervals as necessary to result in proper consolidation and develop a surface of uniform texture. Excessive manipulation of a given area shall be avoided.

During the first pass of the finishing machine, a uniform roll of concrete shall be maintained ahead of the front screed for its entire length.

If a uniform and satisfactory density of concrete is not obtained at joints, along forms, at structures, and throughout the pavement, the Contractor will be required to furnish equipment and use methods that will produce pavement conforming to the requirements specified herein.
    - b. **Hand finishing:** Hand finishing will be permitted only under the following conditions: (1) to finish concrete already deposited on the grade in the event of a breakdown of mechanical equipment; and (2) to finish narrow widths, approach slabs, or other areas of irregular dimensions where the operation of mechanical equipment is impractical.

Concrete shall be struck off as it is placed and screeded with an approved portable screed. If reinforcement is required, the bottom of concrete shall be screeded prior to placement of reinforcement.

Consolidation shall be attained by the use of an approved vibrator or other approved equipment.

Hand finishing shall be kept to the absolute minimum necessary to attain a surface that has a uniform texture, is true to the approximate grade and cross section, and has a closed surface.

2. **Floating:** After concrete has been struck off and consolidated, it shall be further smoothed and made true by means of a float using one of the following methods as specified or permitted:

- a. **Mechanical method:** A mechanical float shall be adjusted so that its full length will be in continuous contact with the surface of the pavement.

If necessary, long-handled floats having blades at least 5 feet in length and 6 inches in width may be used to smooth and fill in open-textured areas in the pavement. Long-handled floats shall not be used to float the entire surface of the pavement in lieu of, or supplementing, the prescribed method of floating.

- b. **Hand method:** This method will be permitted only in those instances specified in 1.b. herein. Following strike off by an approved screed, concrete shall be smoothed with a darby to level raised spots or fill depressions. Long-handled floats or hand floats of wood or metal, as the area dictates, may be used in lieu of darbies to smooth and level the concrete surface. Excessive bleed water shall be wasted over the side forms after each pass of the float.

3. **Straightedge testing and surface correction:** After floating has been completed and excess water removed, but while concrete is still fresh, the surface of the concrete shall be tested for trueness with a 10 foot straightedge. The Contractor shall furnish and use an accurate 10 foot straightedge swung from handles 3 feet longer than  $1/2$  the width of the slab. The straightedge shall be held in contact with the surface in successive positions parallel to the pavement center line, and the entire area shall be gone over from one side of the slab to the other as necessary. Advancement along the pavement shall be in successive stages of not more than  $1/2$  the length of the straightedge. Depressions shall be immediately filled with freshly mixed concrete, struck off, consolidated, refinished, and retested. High areas shall be cut down and refinished. Special attention shall be given to ensure that the surface across joints conforms to the requirements for smoothness. Straightedge testing and surface corrections shall continue until the entire surface is found to be free from observable departures from the straightedge and the slab conforms to the required grade and cross section.

4. **Final finish (texture):** Prior to grooving, multi-ply damp fabric shall be dragged over the pavement surface to provide a gritty texture on ridges between grooves. The roadway pavement riding surface shall be textured with (1) uniformly pronounced grooves approximately  $1/8$  inch in depth and  $1/8$  inch in width on approximately  $3/4$  inch centers and transverse to the pavement center line, or (2) a combination of uniformly pronounced grooves approximately  $1/8$  inch in depth and  $1/8$  inch in width on approximately  $3/4$  inch centers and longitudinal to the pavement center line, and additional grooves  $1/8$  inch in depth and  $1/8$  inch in width on approximately 3 inch centers and transverse to the pavement center line.

- (i) **Stenciling Station Numbers and Dates:** Before concrete takes its final set and after finishing operations are completed, the Contractor shall stencil station numbers and dates into the pavement in accordance with the standard drawings. The dies for numbering and dating will be

furnished by and remain the property of the Department. Dies or numerals lost or damaged by the Contractor shall be replaced at his expense.

(j) **Curing:**

1. **Membrane-forming compounds:** The entire surface of the pavement shall be sprayed uniformly with a white pigmented membrane-forming compound immediately following the texturing operation.

The compound shall be applied under constant pressure at the rate of 100 to 150 square feet per gallon by mechanical sprayers mounted on movable bridges. On textured surfaces, the rate shall be as close to 100 square feet per gallon as possible. Application shall be such that an even, continuous membrane is produced on the concrete surface. At the time of use, the compound shall be in a thoroughly mixed condition, with the pigment uniformly dispersed throughout the vehicle. During application, the compound shall be continuously and effectively agitated. Hand spraying of odd widths or shapes and concrete surfaces exposed by removing forms and sawing joints will be permitted.

The membrane shall harden 30 minutes after application. Personnel and equipment shall be kept off the freshly applied material to prevent damage to the seal. If the membrane becomes damaged within the initial 72 hours, damaged portions shall be repaired immediately with additional compound.

Upon removal of side forms, sides of exposed slabs shall be protected immediately to provide a curing treatment equal to that provided for the surface.

If the slipform method of paving is used, edges of pavement shall be cured in the same manner and at the same time as the surface.

2. **PE film:** When PE film is used for curing, it shall be white. However, from November 1 to April 1, clear or opaque PE film will be permitted.
3. **Protection in cold weather:** The Contractor shall prevent the temperature at the surface of the concrete from falling below 40°F during the first 72 hours immediately following concrete placement. Protective material shall be left in place for an additional 48 hours if freezing air temperatures are expected to continue. Such protection shall be furnished in addition to the curing material required elsewhere in these specifications. The Contractor shall be responsible for the quality of the concrete placed during cold weather. Concrete damaged by the action of frost or by freezing shall be removed and replaced at the Contractor's expense.
4. **Curing in hot, low-humidity, or windy weather:** Care shall be taken in hot, dry, or windy weather to protect the concrete from shrinkage cracking by applying the curing medium at the earliest possible time after finishing operations and after the sheen has disappeared from the surface of the pavement.

- (k) **Surface test:** As soon as concrete has hardened sufficiently, the pavement surface will be tested by the Engineer with a 10-foot straightedge. Areas showing high spots of more than 3/16 inch on mainline pavement and approach slabs but not exceeding 1/2 inch in 10 feet shall be marked and, after the concrete has attained the design compressive strength, cut down with an approved cutting tool to an elevation where the area or spot will not show surface deviations in excess of 3/16 inch. Areas showing high spots of more than 3/8 inch on ramps when tested with a 10-foot straightedge shall be marked and, after the concrete has attained the design compressive strength, corrected to within the 3/8 inch tolerance by removing and replacing or by cutting as specified

herein. If the slipform method of paving is used, a straightedge tolerance of  $\pm 1/4$  inch in 10 feet will be permitted for the area within 6 inches of the slipformed edge except for pavement adjacent to connections and ramps. Equipment for cutting shall be designed to cut the surface of the pavement in a longitudinal direction parallel to the center line and in a uniform planing action. However, the cutting operation shall not produce a polished pavement surface. The equipment shall be adjustable so as to vary the depth of the cut as required. Bush hammering, rubbing with carborundum stone, or hand grinding will not be permitted. Where the departure from correct cross section exceeds  $1/2$  inch on mainline pavement, the pavement shall be removed and replaced by and at the expense of the Contractor.

- (l) **Removing Forms:** Forms shall not be removed from freshly placed concrete until it has set for at least 12 hours. Forms shall be removed carefully to avoid damage to the pavement. After forms are removed, the sides of the slab shall be cured as specified by one of the methods described herein. Major honeycombed areas will be considered defective work and shall be removed and replaced. Any area of section removed shall be not less than 10 feet in length or less than the full width of the lane involved. When it is necessary to remove and replace a section of pavement, any remaining portion of the slab adjacent to the joints that is less than 10 feet in length shall also be removed and replaced.
- (m) **Sealing Joints:** Before pavement is opened to traffic, including the Contractor's equipment, and as soon after completion of the curing period as practicable, joints required to be sealed shall be filled with joint-sealing material. Just prior to sealing or resealing, each joint shall be thoroughly cleaned by brushing, routing, sawing, grinding, blast cleaning, or any combination thereof to eliminate oil, grease, existing joint material, membrane-forming compound, laitance, protrusions or hardened concrete, dirt, or other foreign material that cannot be removed by means of compressed air to a depth at which the sealer and backup material, if required, are to be installed. Dust and loose material shall be removed from the joint with oil-free and water-free compressed air delivered at a minimum of 120 cubic feet of air per minute and a nozzle pressure of at least 90 pounds per square inch. Existing joint material extending outside the joint shall be removed.

Joint material shall be installed in accordance with the manufacturer's recommendations. However, in the absence of specific recommendations or plan details, the following provisions shall apply.

1. Preformed seals shall be installed by machines that are designed especially for such installation and shall not damage the seal. Types A and D material shall be installed by machine. The seal shall be installed with its vertical axis parallel to the interfaces of the joint.
2. The method of installing preformed seals shall be such that the seal is not stretched more than 5 percent of the length of the joint.

The method of installation shall be checked for stretching, using transverse joint sealer. The check shall consist of installing sealer in five joints, the full width of the pavement, and removing the sealer immediately after installation and checking the length. If the measured length of any of the five sealers is less than 95 percent of the minimum theoretical length required to seal the joint, the installation method shall be modified so that stretching greater than 5 percent no longer occurs. Once sealing operations have started, 1 joint per every 100 shall be removed and checked for stretch in excess of 5 percent. If a stretched condition is detected, the joint sealers on either side shall be removed until the condition disappears. Affected joints shall be resealed in a satisfactory manner at the Contractor's expense.

3. For rounded or beveled joints, seal or sealant shall be installed at a depth of at least  $1/8$  inch but not more than  $1/4$  inch below the bottom edge of the rounding or bevel. For joints with vertical sides, seals or sealant shall be installed at a depth of  $1/4$  inch,  $\pm 1/16$  inch, below the level of the pavement surface.

4. Hot-poured sealer shall be applied to a completely dry joint. The ambient air temperature shall not be below 40 °F. The joint shall be filled with hot-poured sealer by means of a sealing device that will not cause air to be entrapped in the joint. Sufficient passes shall be made to achieve the filled joint requirement.
5. Material for hot-poured sealer shall be stirred during heating so that localized overheating does not occur.
6. Sealer shall not be placed directly on the filler but shall be prevented from bonding to the filler by a carefully placed strip of waxed or silicone paper, plastic tape, aluminum foil, or other suitable material placed over the filler before sealer is applied. Masking tape or other means shall be used to avoid spilling sealer onto adjacent concrete surfaces. Excess sealer on such surfaces shall be cleaned off before the material has set without damaging the material in the joint.
7. Silicone sealer shall not be applied when the air temperature is below 40 °F. Sealer shall fill the joint and shall be applied inside the joint from the bottom up by means of an application device that will not cause air to be entrapped. Immediately after application, sealer shall be tooled to form a recess below the pavement surface in accordance with the standard drawings. The use of soap, water, or oil as a tooling aid will not be permitted. Primer, if used with silicone sealer, shall be applied to the joint faces prior to installation of backup material. Backup material shall be approximately 25 percent larger than the joint width and shall be installed in the joint such that it is not displaced during the sealing application.

Sealing material shall be applied in a manner so that it will not be spilled on the exposed surfaces of the concrete. Excess material on the surface of the concrete pavement shall be removed immediately, and the pavement surface cleaned. The use of sand or similar material as a cover for the seal will not be permitted.

- (n) **Protecting Pavement:** The Contractor shall protect the pavement and its appurtenances against public traffic and traffic caused by his employees and agents. This shall include furnishing watchpersons and flaggers to direct traffic and erecting and maintaining warning signs, lights, pavement bridges, or crossovers.

In order that the concrete may be properly protected against the effects of rain before it has attained final set, the Contractor shall have covering material available at the work site, such as burlap, cotton mats, curing paper, or plastic sheeting.

If the slipform method of paving is used, the Contractor shall also have material available at all times for protecting the edges of unhardened concrete. Protective materials shall consist of standard metal forms or wood planks having a nominal thickness of at least 2 inches and a nominal width of at least the thickness of the pavement at its edges.

When rain appears imminent, concrete placement operations shall be halted and available personnel shall assist in covering the surface of unhardened concrete.

A layer of coarse burlap shall be applied to the surface of fresh concrete prior to the application of PE film or other protective coverings that tend to “wipe out” or reduce the texture upon contact.

The Engineer will carefully consider any damage to the pavement occurring prior to final acceptance and may allow the Contractor to repair such damage or require the damaged pavement to be replaced.

- (o) **Opening to Traffic:** Pavement shall not be opened to traffic until specimen beams conforming to the requirements of (f) herein have attained a modulus of rupture strength of 600 pounds per square inch when tested by the third point loading method in accordance with the requirements of ASTM C 78. The Contractor may use the Maturity Test Method in accordance with ASTM C1074 to confirm the development of satisfactory strength gain to open to traffic provided the maturity test results are based upon the same concrete mix design as used in the pavement as approved by the Engineer. In the absence of such tests, pavement shall not be opened to traffic until 14 days after concrete is placed. Prior to opening to traffic, pavement shall be cleaned, all joints sealed and trimmed and all permanent traffic lines and messages shall be installed.

### **316.05--Tolerances.**

The thickness of pavement will be determined by average caliper measurements of cores taken therefrom, as described in VTM-26, and tested in accordance with the requirements of AASHTO T148.

Areas found to be deficient in thickness by more than 1 inch will be evaluated by the Engineer, and if in his judgment the deficient areas warrant removal, they shall be removed and replaced with concrete of the thickness specified on the plans. The deficient area shall be the product of the full width of the slab or lane of pavement multiplied by the sum of the distances in each direction from the deficient core along the center line of the pavement to the first actual cores found not deficient in thickness by more than 1 inch.

The Contractor shall fill test holes with the same type of concrete as in the pavement.

### **316.06--Measurement and Payment.**

**Hydraulic cement concrete pavement** will be measured in square yards of concrete pavement, complete-in-place, and will be paid for at the contract unit price per square yard. This price shall include furnishing and placing materials, including dowels, reinforcement, and joint material, provided that for any pavement found deficient in average thickness, as described in VTM-26, by more than 0.20 inches but not more than 1 inch only the reduced price stated herein will be paid. The width of measurement will be the width of the pavement shown on the typical cross section of the plans, additional widening where called for, or as otherwise directed in writing by the Engineer. The length will be measured horizontally along the center line of each roadway or ramp.

**Concrete entrance pavement, concrete launching ramps, and anchor slabs** will be measured in square yards of surface area, complete-in-place, and will be paid for at the contract unit price per square yard.

**Bridge approach slabs**, when a pay item, will be measured in cubic yards of concrete and pounds of reinforcing steel, complete-in-place, and will be paid for at the contract unit price per cubic yard of concrete and per pound of reinforcing steel.

**Bridge approach expansion joints** will be measured in linear feet of transverse measure, complete-in-place, and will be paid for at the contract unit price per linear foot. This price shall include subslab excavating and furnishing and placing materials.

No additional payment over the contract unit price will be made for any pavement that has an average thickness in excess of that specified on the plans.

**Resealing joints**, when a pay item, will be paid for at the contract unit price per linear foot. This price shall include joint preparation, furnishing and placing sealer, and removing and disposing of debris.

**Price adjustments:** Where the average thickness of pavement is deficient by more than 0.20 inch but not more than 1 inch, payment will be made at an adjusted price as specified by the following:

<b>Deficiency in Thickness (in.)</b>	<b>% of Contract Unit Price Allowed</b>
0.00 – 0.20	100
0.21 – 0.30	80
0.31 – 0.40	72
0.41 – 0.50	68
0.51 – 0.75	57
0.76 – 1.00	50

When the thickness of pavement is deficient by more than 1 inch and the Engineer determines that the area of such deficiency should not be removed and replaced, there will be no payment for the area retained.

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
Hydraulic cement base course (Depth)	Square yard
Plain hydraulic cement concrete pavement (Depth)	Square yard
Reinforced hydraulic cement concrete pavement (Depth)	Square yard
Continuously reinforced hydraulic cement concrete pavement (Depth)	Square yard
Concrete, Class A4, bridge approach slab	Cubic yard
Reinforcing steel, bridge approach slab	Pound
Bridge approach expansion joint	Linear Foot
Concrete entrance pavement (Depth)	Square Yard
Concrete launching ramp (Standard)	Square Yard
Anchor slabs (Type)	Square Yard
Resealing (Type) joints (Material)	Linear Foot

# Division IV

## Bridges and Structures

### SECTION 401--STRUCTURE EXCAVATION

#### 401.01--Description.

This work shall consist of excavating and backfilling or disposing of material necessary for constructing substructures and superstructures of new bridges and altering existing bridges in accordance with the requirements of these specifications and in reasonably close conformity with the lines and grades shown on the plans or as established by the Engineer.

#### 401.02--Materials.

- (a) **Backfill** shall be approved by the Engineer and shall be free from large or frozen lumps, wood, or rocks more than 3 inches in their greatest dimension or other extraneous material. Porous backfill shall conform to the requirements of Section 204.
- (b) **Pipe underdrains** shall conform to the requirements of Section 232.

#### 401.03--Procedures.

Excavated material shall generally be used for backfilling and constructing embankments over and around the structure. Surplus or unsuitable material shall be disposed of in a place and manner such that it will not affect or re-enter streams or otherwise impair the hydraulic efficiency or appearance of the structure or any part of the roadway.

Where practicable, substructures shall be constructed in open excavation and, where necessary, the excavation shall be sheeted, shored, braced, or protected by other means. If footings can be placed in the dry without the use of sheeting or cofferdams, forms may be omitted with the approval of the Engineer and the entire excavation filled with concrete to the required elevation of the top of the footing. When forms are eliminated, measurement and payment for structure excavation and concrete will be on a plan quantity basis wherein no adjustments will be made.

Unless tremie placement of concrete is specified, foundations for footings shall be kept free from standing or surface water until concrete and backfill operations have been completed. However, if the foundation is rock or the footing is supported on piles, other than for shelf abutments, dewatering need be performed only during concrete and backfill operations.

- (a) **Preserving the Channel:** Excavation shall not be performed outside caissons, cribs, cofferdams, or sheet piles. The natural stream bed adjacent to the structure shall not be disturbed. Material deposited in the stream area because of the Contractor's operations shall be removed, and the stream area shall be freed from obstructions caused by the Contractor's operations.

Prior to beginning work, the Contractor shall submit a plan that shall include the specific location of temporary structures or other obstructions that will constrict the stream flow, a description of construction activities that will contribute to constricting the stream flow, the dimensions and number of temporary structures and constrictions that are to be placed in the stream at any one time, and a dimensional elevation view of the stream and proposed temporary structures and constrictions.

- (b) **Depths of Foundations:** Elevations denoting the bottom of footings shown on the plans shall be considered approximate only. Foundations shall not be considered satisfactory until approved by the Engineer.

When requested, the Contractor shall explore foundations by rod soundings or drillings to determine, to the satisfaction of the Engineer, the adequacy for the foundations to support the structure. If explorations indicate that satisfactory foundations can be obtained, variations from plan depths to foundations of open column abutments and solid or column piers shall be made only by adjusting stem lengths. Footing depths shown on the plans shall be considered minimum depths. Plan depths of concrete for footings may be increased not more than 24 inches at points of local irregularity over solid rock foundations.

Variations from plan depths to foundations of solid or deep curtain-wall abutments shall be made only by adjusting the depths of footings. Plan depths shall be considered minimum depths and shall not be exceeded by more than 3 feet.

If explorations reveal that foundations or subfoundations are inadequate for the structure, or are not within the limits of permissible variation from the bottom of footing elevations, the Engineer shall be consulted for instructions for further action or redesign.

- (c) **Preparing Foundations for Footings:** Hard foundation material shall be freed from loose material, cleaned, and cut to a firm surface, either level, stepped, or serrated as directed by the Engineer. Seams shall be cleaned out and filled with concrete as directed by the Engineer.

When concrete is to rest on an excavated surface other than rock, the bottom of the excavation shall not be disturbed. The final removal of foundation material to grade shall not be performed until just prior to concrete placement.

When the elevation of the bottom of a footing is above the level of the original ground, the footing shall not be placed until the approach embankment has been placed and compacted to the elevation of the top of the footing and excavation has been performed through the embankment to the elevation of the bottom of the footing. When a footing is to be placed over material subject to movement because of pressure from overlying or adjacent fill, the footing or piles for the footing shall not be placed until after the fill has been placed and compacted. Excavation for shelf abutment footings shall be limited to a perimeter extending not more than 18 inches outside the neat lines at the bottom of the footing.

When the material on which a foundation is to be placed using piles is declared unsatisfactory by the Engineer, the excavation shall be undercut for a depth of 6 to 12 inches as directed and backfilled with crusher run aggregate, select borrow, or other material approved by the Engineer.

- (d) **Holes for Drilled-In Caissons:** Foundation bearing areas shall be cut to an approximately level surface except that they may be stepped or serrated on hard rock. If material is encountered that is not sufficiently cohesive to maintain the proper diameter of the hole, casing shall be used.
- (e) **Cofferdams:** Cofferdams for foundation construction shall be as watertight as practicable and carried to a depth that will allow them to function properly without displacement. The interior dimensions of cofferdams shall be such as to give sufficient clearance for the construction of forms and inspection of their exteriors and permit pumping from outside the forms. Cofferdams that are tilted or moved laterally during sinking shall be realigned to provide the required clearance.

If conditions are encountered that render it impracticable to dewater the foundation, the Contractor may be required to construct a concrete foundation seal of the dimensions necessary to ensure that the balance of the concrete can be placed in the dry. When weighted cofferdams are employed and the weight is used to overcome the hydrostatic pressure acting against the bottom of the foundation seal, anchorage, such as dowels or keys, shall be provided to transfer the entire weight of the cofferdam into the foundation seal. Cofferdams that are to remain in place shall be ported at the low water level.

Cofferdams shall be constructed in a manner to prevent damage to fresh concrete from a sudden rising of the stream and prevent damage to the foundation by erosion. Timber or bracing left in cofferdams shall not extend into the substructure concrete.

Cofferdams, including sheeting and bracing, shall be removed after completion of the substructure in a manner that will not disturb or damage the finished concrete.

- (f) **Pumping:** Pumping from the interior of a foundation enclosure shall be performed in a manner to preclude the possibility of water moving through any fresh concrete. Pumping will not be permitted during concrete placement or for at least 24 hours thereafter unless it is performed from a suitable sump separated from the concrete work.
- (g) **Protecting Existing Structures or Utilities:** When foundations are located such that excavation may endanger or interfere with an existing structure or utility, the location of bracing and method of protection shall be subject to approval by the owner of the structure or utility.
- (h) **Inspection:** After each excavation has been completed, the Contractor shall notify the Engineer and request his inspection and approval. Concrete shall not be placed until the depth of the excavation and the character of the foundation material have been approved.
- (i) **Backfilling:** Excavated spaces that are not occupied by abutments, piers, or other permanent work shall be backfilled with soil to the surface of the surrounding ground. Backfill shall be uniformly compacted, and the top surface shall be neatly graded.

The fill around the perimeter of abutments, wing walls, and retaining walls shall be placed in horizontal layers not more than 6 inches in loose thickness and compacted at  $\pm 20$  percent of optimum moisture to a density of at least 95 percent as compared to the theoretical maximum density as defined in Division II. Tests for compliance with density requirements will be performed in accordance with the requirements of VTM-12. As the work progresses, backfill in front of units shall be placed and compacted in horizontal layers to the same elevation as the layers behind units until the final elevation in front is reached. Backfill shall be placed in a manner to prevent wedging action against the concrete. Slopes bounding excavation for abutments, wingwalls, or retaining walls shall be destroyed by stepping or serrating. Jetting of the fill behind abutments, wingwalls, or retaining walls will not be permitted.

Fills and backfills around piers not included in the roadway prism shall be constructed in uniformly compacted layers and placed alternately to maintain a uniform elevation on both sides of the structure. However, the density requirement will be waived.

Provision shall be made for drainage of backfill. Two-inch crusher run aggregate, conforming to the requirements of Section 205, shall be placed at the back of weep holes to extend 18 inches behind the entrance to the hole, 18 inches above the elevation of the bottom of the hole, and 18 inches laterally on each side of the center line of the hole.

Backfill shall not be placed against abutments or wingwalls until concrete has been in place 14 days, exclusive of days on which the average high-low air temperature is below 40 °F in the shade or until test cylinders have attained a compressive strength equal to 93 percent of the required 28-day design compressive strength.

Backfill shall be placed as soon as practicable following attainment of the required compressive strength but not later than 30 days after concrete placement. Excavation openings shall be maintained as dry as practicable at the time of backfilling. Backfill shall be placed in a manner to deter impoundment of water and facilitate existing drainage.

- (j) **Filled Spandrel Arches:** Fill for spandrel arches within 1 1/2 times the height of the arch shall be placed in a manner to load the ring uniformly and symmetrically. Fill material shall be homogeneous soil and shall be placed in horizontal layers not more than 6 inches in loose thickness, compacted in accordance with the requirements of Section 303.04(h), and brought up simultaneously from both haunches. Wedge-shaped sections of fill material against spandrels, wings, or abutments will not be permitted.
- (k) **Approach Embankment:** Approach embankment shall be constructed in accordance with the requirements of Section 303.04(h).

#### **401.04--Measurement and Payment.**

**Structure excavation** will be measured in cubic meters of material removed from the limits of vertical planes within 18 inches outside the neat lines of footings or of neat work that does not have footings directly beneath it, such as curtain walls or cantilevered wing walls. It will be measured from the surface of the original ground or approach roadway down to the bottom of the foundation shown on the plans or such foundation as the Engineer may approve, or down to 18 inches below the bottom of the neat work not directly over footings, or to the top of existing concrete where excavation is to permit placing new concrete over existing concrete.

When specified on the plans, structure excavation will include material removed outside the limits specified for the substructure, in the vicinity of the substructure on which a superstructure rests, and to a depth of 18 inches below the lowest beam or bottom of the slab of the superstructure, or to such depth as shown on the plans. The width of such excavation shall be limited to 18 inches outside the exterior beams or edges of the slab or as shown on the plans.

Excavation above the bottom of a proposed channel change or roadway template or an overpassed road will not be included as structure excavation.

Structure excavation will be paid for at the contract unit price per cubic yard. This price shall include clearing and grubbing, sheeting, shoring, bracing, placing and compacting backfill, dewatering, furnishing and placing aggregate for weep holes, disposing of unsuitable or surplus material, and clearing the channel of obstructions caused by construction operations.

**Excavation for drilled-in caissons** will be measured in linear feet of drilled hole from the existing ground to the bottom of the finished hole as measured along the center line of the hole and will be paid for at the contract unit price per linear foot. This price shall include drilling, under reaming, casing, and preparing the hole.

**Furnishing and placing backfill** will be included in the price for structure excavation and will not be measured for separate payment unless specific material is required by the Engineer and no suitable material is available within the construction limits. When specific material is required for backfill by the Engineer, measurement and payment will be in accordance with the requirements of Section 104.03.

**Porous backfill**, when a pay item, will be measured in cubic yards of material within the limits shown on the plans or as otherwise directed by the Engineer and will be paid for at the contract unit price per cubic yard.

**Pipe underdrains**, when a pay item, will be measured in linear feet and will be paid for at the contract unit price per linear foot.

**Unsuitable materials removed below the plan foundation** will be measured and paid for as structure excavation.

**Foundation seals** required by the Engineer and that are properly placed for structural adequacy as a part of the planned footing will be accepted as part of the permanent footing. Measurement and payment will be in accordance with the requirements of Section 404.08. Foundation seals that are not required by the Engineer will be included in the price for structure excavation.

**Clearing and grubbing within the area defined by lines connecting the extremities of the substructure units**, regardless of whether excavation is involved, shall be included in the price for structure excavation unless otherwise specified in the Contract.

**Cofferdams** will be measured in units of each per foundation and will be paid for at the contract unit price per each. This price shall include furnishing, erecting, maintaining, and removing.

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
Structure excavation	Cubic yard
Drilled holes	Linear Foot
Porous backfill	Cubic yard
Pipe underdrain (Size)	Linear Foot
Cofferdams	Each

## SECTION 404--HYDRAULIC CEMENT CONCRETE OPERATIONS

### 404.01--Description.

This work shall consist of furnishing and placing hydraulic cement concrete in accordance with these specifications and in reasonably close conformity with the dimensions, lines, and grades shown on the plans or as established by the Engineer.

#### 404.02--Materials.

- (a) **Concrete** shall conform to the requirements of Section 217. Aggregate used in concrete for bridge decks shall be nonpolishing.
- (b) **Curing materials** shall conform to the requirements of Section 220.
- (c) **Concrete admixtures** shall be used as specified in Section 217.
- (d) **Corrugated metal bridge deck forms** shall be galvanized steel conforming to the requirements of ASTM A653, Grade SS40, SS50, or SS80 and shall be coating designation G165. Supports, closures, and other fabricated parts shall conform to the requirements of ASTM A653, Grade SS33, SS40, or SS80 and shall be coating designation G165.
- (e) **Prestressed concrete deck panels** shall conform to the requirements of Section 405 except as specified herein.
- (f) **Anchor bolts** shall conform to the requirements of Section 226.
- (g) **Reinforcing steel** shall conform to the requirements of Section 223.
- (h) **Waterstops** shall conform to the requirements of Section 212.

#### 404.03--Procedures.

- (a) **Forms:** On concrete beam bridges, the Contractor shall have the option of using corrugated metal bridge deck forms, prestressed deck panels, or wood forms to form that portion of bridge decks between beams unless otherwise specified on the plans. On steel beam bridges, the Contractor shall have the option of using corrugated metal bridge deck forms or wood forms to form that portion of bridge decks between beams or girders unless otherwise specified on the plans. However, corrugated metal forms and prestressed deck panels shall not be used to form overhangs or portions of slabs where a longitudinal joint occurs between beams or girders.

Devices for supporting forms of any type shall not be welded to steel beams or girders unless specified on the plans.

Formwork shall be mortartight and of sufficient rigidity to prevent distortion attributable to the pressure of the concrete and other loads incidental to construction operations.

Forms for exposed surfaces shall have a form liner of an approved type and shall be mortartight. Forms for exposed surfaces below the bottom of slabs of bridges, including substructures, and on endwalls and wing walls of culverts down to an elevation of 1 foot below low water or 2 feet below the final ground line above water shall be faced with metal, plyboard, or other approved smooth-faced material constructed to provide a minimum of joints and prevent leakage. Concrete shall present a uniform and smooth surface without requiring touch-up or surface finishing upon removal of forms. Uneven joint protrusions of more than 1/8 inch shall be removed. Forms shall be filleted 3/4 inch at sharp corners and given a bevel or draft in the case of projections, such as girders and copings, to ensure easy removal.

Metal ties or anchorages within the form shall be constructed to permit their removal to a depth of at least 1 inch from the face without damage to the concrete. If ordinary wire ties are permitted, wires shall be cut back at least  $\frac{1}{4}$  inch from the face of the concrete with chisels or nippers upon removal of forms. Fittings for metal ties shall be of such design that cavities left upon their removal will be the smallest size possible. Cavities shall be filled with cement mortar, and the surface left sound, smooth, even, and uniform in color.

Forms shall be set and maintained true to line. When forms appear to be unsatisfactory, either before or during concrete placement, the Engineer may order the work stopped until defects have been corrected.

The shape, strength, rigidity, watertightness, and surface smoothness of reused forms shall be maintained at all times. Warped or bulged lumber shall be resized before being reused.

For narrow walls and columns where the bottom of the form is inaccessible, the lower form boards shall be left loose so that they may be removed for cleaning immediately before concrete placement.

Forms shall be treated with an approved oil or form-coating material or thoroughly wetted with water immediately before concrete placement. For rail or other units with exposed faces, forms shall be treated with an approved oil or form-coating material to prevent adherence of concrete. Material that will adhere to or discolor concrete shall not be used.

Forms shall be maintained at a temperature that will not adversely affect curing of concrete.

Formed voids in concrete shall be of accurate dimensions and locations so that the thickness of surrounding concrete shall not be reduced from plan dimensions.

Methods of positioning void forms and placing surrounding concrete shall be subject to the approval of the Engineer prior to their use.

Bridge deck slabs shall be constructed in a manner so that the thickness of the finished slab shall be not less than the thickness shown on the plans or more than the thickness plus  $\frac{1}{2}$  inch.

1. **Corrugated metal bridge deck forms:** If the Contractor elects to use corrugated metal bridge deck forms, he shall submit details of the forms, including fabrication and erection details, to the Engineer for approval in accordance with the requirements of Section 105.02. Forms shall be designed and erected in accordance with the following:

- a. **Design:** The thickness of forms shall be at least 0.037 inch (20 gage). The unit working stress in the sheet metal and supporting units shall be not more than 0.725 of the specified minimum yield strength of the material furnished. In no case shall it be more than 36,000 pounds per square inch. The maximum stress under a design load equal to the weight of the forms and plastic concrete plus a construction live load of 50 pounds per square inch shall be not more than the unit working stress for the material furnished. Deflection of forms under the weight of the form, plastic concrete, and reinforcement shall be not more than  $\frac{1}{180}$  of the span of the forms or  $\frac{1}{2}$  inch, whichever is less. In no case shall the loading be less than 120 pounds per square foot total.

When the actual dead load attributable to the use of metal bridge deck forms is more than the design allowance for construction tolerances and methods shown on the plans, the Contractor shall strengthen the beams or girders to the extent necessary to maintain the design live load rating of the bridge and shall submit supporting information and calculations to the Engineer for review.

- b. **Erection:** Forms shall be installed in accordance with reviewed fabrication and erection plans. Field cutting of forms, supports, and closures at expansion joints, diaphragms, and abutments in skewed areas or in any area where girders or beams are not parallel shall be performed with saws or shears. The outstanding leg of the support angle, channel, or other device shall be not more than 3 inches.

Form sheets shall not rest directly on the top of the stringer or floor beam flanges. Sheets shall be securely fastened to form supports and shall have a minimum bearing length of 1 inch at each end. Form supports shall be placed in direct contact with the stringer or floor beam flange by hangers or clips. Attachment of the forms to the form supports shall be made by permissible welds, screws, clips or other approved means. Fasteners along the ends and edges of form sheets shall be spaced at intervals not to exceed 18 inches.

Welding and welds shall conform to the requirements of Section 407.04 except that 1/8 inch fillet welds will be permitted.

Permanently exposed form metal whose galvanized coating has been damaged shall be repaired in accordance with the requirements of Section 233.

Corrugated metal forms shall be positioned such that the specified cover for the reinforcing steel and minimum design slab thickness are maintained above crests of the corrugation.

Transverse construction joints shall be located at the bottom of a flute, and ¼ inch weep holes shall be field drilled at not more than 12 inches on center along the line of the joint.

Closures at edges of forms parallel to beams or girders shall be made by crimping corrugations. Closures at skewed ends may be of the serrated or channel type.

The design span of the sheet shall be the clear span of the form plus 2 inches measured parallel to form flutes.

The permissible form camber shall be based on the actual dead load condition. Camber shall not be used to compensate for deflection in excess of the foregoing limits.

Physical design properties shall be computed in accordance with the requirements of AISI's specifications for the design of cold-formed steel structural units.

- c. **Inspection:** After concrete has been in place for at least 2 days, the Contractor shall sound at least 50 percent of the area of at least 25 percent of the individual form panels using a moderate blow administered with a carpenter's hammer. Individual form panels to be sounded will be selected randomly by the Engineer. Areas of questionable soundness shall be exposed by removing forms. The amount of sounding and form removal required will be adjusted as the work progresses according to conditions detected by the investigation. When procedures, materials, or equipment used during placement of concrete warrant additional inspection of the underside as determined by the Engineer, the Contractor shall remove at least one form panel at each location selected by the Engineer. If the initial inspection reveals inferior workmanship or unsatisfactory material as determined by the Engineer, additional panels shall be removed to ascertain the extent of the deficiency. The Contractor will not be required to

replace metal forms at locations where sections of forms are removed for inspection purposes. However, adjacent metal forms and supports shall be repaired to the extent necessary to render their attachment secure.

The Contractor shall provide facilities required for the safe and convenient conduct of the Engineer's inspection.

2. **Prestressed deck panel forms:** If the Contractor elects to use prestressed deck panel forms, he shall redesign the deck slab in accordance with the requirements of AASHTO's Standard Specifications for Highway Bridges and the interim specifications as modified by the Department and shall submit the redesign of the deck slab, reinforcing steel schedule, design calculations, and working drawings to the Engineer for acceptance in accordance with the requirements of Section 105.02. Working drawings shall show the permissible construction live load. The Contractor's submittal shall be made at least 60 days prior to the time necessary for ordering materials for the work.
  - a. **Design:** The following conditions shall apply to the redesign of the cast-in-place deck slab:
    1. The size, spacing, and area of transverse reinforcing steel in the top of deck slabs shall be not less than that shown on the plans. The transverse reinforcing steel shown on the plans in the bottom of the deck slab shall be eliminated.
    2. Longitudinal reinforcing steel shown on the plans in the bottom of the deck slab shall be replaced by reinforcing bars having the identical size and spacing as the main transverse reinforcing bars in the deck slab. These bars shall be placed  $\frac{1}{2}$  inch clear above the top of the deck panels. Longitudinal reinforcing steel shown on the plans in the top of the deck slab may be eliminated, except over intermediate supports of continuous spans, provided adequate tie bars having no more than 24 inch spacing are used for securing top transverse steel. The distance from the face of the concrete to the center of the top layer of main reinforcing steel shall be  $2\frac{3}{4}$  inches.
    3. Shear connectors on steel beams or girders and vertical reinforcement in prestressed concrete beams may be adjusted to facilitate placing prestressed deck panels.
    4. The design for deck panels shall provide for the same total slab thickness as shown on the plans.
    5. When epoxy-coated steel is specified on the plans, reinforcing steel in the cast-in-place section of the slab shall be epoxy coated.
    6. The depth of intermediate diaphragms for prestressed concrete beams shall be modified to provide clearance between the panel and diaphragm.

7. Lifting devices installed in panels for handling may be left in place provided they do not project closer than 2 inches to the finished deck surface.
8. Panels will not be allowed over the end supports for bridges skewed more than 15 degrees. End sections of slabs shall be cast the full depth shown on the plans.
9. Panels shall be roughened in the direction parallel to the strands.

The following conditions shall apply to the design of the deck panels:

1. The strand size shall be not more than 3/8 inch.
2. A cover of at least 1 ½ inches shall be provided on the bottom of deck panels for prestressing strands and reinforcing steel.
3. The cracking load a unit can sustain shall be at least  $1.2(D) + 1.5(L + I)$  without the concrete tensile stress exceeding  $7.5 f'c$  where  $D$  = dead load;  $L + I$  = live load + impact; and  $f'c$  = the 28-day design compressive strength of concrete in pounds per square inch.
4. At least 0.11 square inch per foot of reinforcing steel transverse to strands shall be provided in panels.
5. The length of the panel in the direction of strands shall be at least 5 feet 2 inches.
6. Strands shall project at least 3 inches from the concrete at both ends of the panel.
7. Mild reinforcing steel in the deck panel, including tie bars and reinforcing bars used for panel-lifting purposes, shall be epoxy coated. Bar supports shall conform to the requirements of Section 406.03(d).

Panel sides that are parallel to the strands may be cast to provide full-depth contact with the adjacent panel or cast with angular sides that, when installed with an adjacent panel, will form a V-shaped joint, which shall be mortartight at its base.

- b. **Erection:** Precast bridge deck panels shall be erected in accordance with the accepted working drawings and with the strands transverse to the longitudinal direction of the beams. Panels shall be tightly butted together and shall be mortartight, with panel joints staggered on each side of the supporting beam. Panel joints that are not in full contact or that are not mortartight shall be sealed by epoxy mortar or other approved method at the Contractor's expense.

Prior to placement of the deck surface concrete, foreign material detrimental to achieving a bond shall be removed by sandblasting, waterblasting, or other approved methods. The top surface of deck panels shall be thoroughly and

continuously water soaked for at least 1 hour prior to placement of deck surface concrete. Puddles of standing water shall be removed prior to placement of deck surface concrete. Panels shall be supported by one of the following methods to provide the same total slab thickness as shown on the plans:

1. nonshrink cement mortar bed  $3 \pm \frac{1}{4}$  inches in width with a thickness of at least  $\frac{1}{2}$  inch conforming to the requirements of Section 218 except that the compressive strength shall be 5,000 pounds per square inch. When shims are used to construct the mortar bed, they shall be removed prior to placement of the deck concrete.
2. galvanized steel support angles having an outstanding leg width of at least 1 inch and a thickness of at least  $\frac{1}{8}$  inch or 10 gage. The unit working stress shall be not more than 72  $\frac{1}{2}$  percent of the specified minimum yield strength of the material furnished but in no case more than 36,000 pounds per square inch. A strip of  $\frac{1}{8}$  inch asphalt felt the same width as the angle shall be placed between the support angle and the deck panel. When cast in place slab concrete is to be used to provide permanent support for panels, concrete shall be placed in continuous strips over the girders and consolidated to ensure concrete penetrates under the panels, prior to placing concrete on top of the panels. Slab overlay concrete shall penetrate under the panels to a width of  $3 \pm \frac{1}{4}$  inch and a thickness of at least  $1 \frac{1}{2}$  inch to provide the rigid support for the panels. If this method of support is used, bridge seat elevations shall be adjusted as necessary at the Contractor's expense.
3. Welding and welds shall conform to Section 407.04, except that  $\frac{1}{8}$  inch fillet welds will be permitted. Welding to beam or girder flanges will not be permitted.

Regardless of the method of support used, the Contractor shall ensure the stability of the deck panels until the slab overlay concrete has set.

- (b) **Falsework and Centering:** The Contractor shall have a Professional Engineer (holding a valid license to practice engineering in the Commonwealth of Virginia) inspect the completed falsework assembly supporting a bridge superstructure prior to placing loads. The Professional Engineer shall provide a certification, based upon visual inspection of the completed falsework assembly, that the falsework assembly conforms to the approved working drawings. However, such certification shall not require an exhaustive inspection or testing, nor shall it make the Professional Engineer liable for any deficiencies in workmanship or materials by the Contractor, or for such conditions that cannot be ascertained from a visual inspection.

Falsework shall be designed and constructed to provide the necessary rigidity and support the loads without appreciable settlement or deformation. The Contractor may be required to employ screw jacks or hardwood wedges to take up settlement in the formwork either before or during concrete placement. A design weight of 150 pounds per cubic foot shall be assumed for fresh concrete.

Falsework that cannot be founded on a satisfactory footing shall be supported on piles that are spaced, driven, and removed in a manner approved by the Engineer.

Falsework shall be set in a manner so that after its removal the finished structure will have the finished grade specified or indicated on the plans. Correction for dead-load deflection of cast-in-place concrete beams and slab spans shall be provided for by applying an upward parabolic camber having an ordinate at midspan of 1/8 inch per 10 feet of span length.

Falsework-supporting elements shall remain in place until concrete in the element has attained at least the minimum 28-day design compressive strength.

Arch centering shall be constructed according to centering plans approved by the Engineer. Provision shall be made by means of suitable wedges, sand boxes, or other devices for gradual lowering of centers and rendering the arch self-supporting. When directed by the Engineer, centering shall be placed on approved jacks to take up and correct settlement that may occur after concrete placement has begun.

- (c) **Placement and Consolidation:** Individual placements of more than 25 cubic yards of concrete shall be at the following rate:

	Quantity (yd <sup>3</sup> )	Min. Placement Rate
	26-80	25%/hr
	Over 80	20 yd <sup>3</sup> /hr

If corrugated metal bridge deck forms are used in lieu of removable forms, concrete placement shall proceed in the direction opposite that of form placement.

Concrete shall be placed as soon as practicable after forms are prepared and excavation is completed. Water shall be removed from excavations before concrete is placed. Flowing water within the excavation shall be diverted outside concrete areas to a sump.

Before concrete is placed, sawdust, chips, dirt, and other debris and temporary struts and braces shall be removed from the space to be occupied by concrete. Removable forms shall be thoroughly wetted, oiled, or treated with an approved form-coating material. The depth and character of foundations and the placing of reinforcing steel shall have been approved by the Engineer.

Concrete shall be placed in forms immediately after mixing. Concrete that does not reach its final position in forms within the time specified in Section 217 shall not be used. The method of placement shall be such as to avoid the possibility of segregating ingredients and displacing reinforcement or void forms.

The use of long chutes for conveying concrete from the mixing plant to forms will be permitted only with the written permission of the Engineer. If chutes are allowed and the quality of concrete as it reaches the forms or the methods of placing it therein are not satisfactory, the Contractor shall, upon direction from the Engineer, discontinue the use of chutes and re-equip his operation for placing concrete in a satisfactory manner.

Where steep slopes are required, chutes shall be equipped with baffle boards. When pipes are used, they shall be kept full of concrete and have their lower ends buried in fresh concrete where necessary to prevent an excessive flow rate. Chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by thorough flushing with water after each run. Water used for flushing shall be discharged clear of concrete in place and filtered prior to entry into state waters. Open troughs and chutes shall be metal or lined with metal and shall extend as nearly as possible to the point of deposit. When discharge must be intermittent, a hopper or other device for regulating discharge shall be provided.

Dropping concrete a distance of more than 5 feet or depositing a large quantity at any point and running or working it along forms will not be permitted. However, the 5 foot limitation will not apply to dropping concrete into forms for walls of box culverts, catch basins, drop inlets, or end walls unless there is evidence of segregation.

Concrete placement shall be regulated so that pressures caused by fresh concrete shall be not more than those used in the design of forms.

Embedded materials shown on the plans shall be installed during each stage of concrete operations and suitably supported and maintained in the correct position. Reinforcement shall be placed in accordance with the requirements of Section 406.03(d).

Care shall be taken to fill each part of a form by placing concrete as near its final position as possible, working coarse aggregates back from forms, and moving concrete under and around reinforcing bars without displacing them. After concrete has taken its initial set, care shall be taken to avoid jarring forms or placing strain on ends of projecting reinforcement.

Concrete shall be thoroughly consolidated during and immediately following placement. Consolidation shall be accomplished by mechanical vibration subject to the following provisions:

1. Vibration shall be internal to the concrete but not applied directly to reinforcement or formwork.
2. Vibrators shall be of a type and design approved by the Engineer.
3. The intensity of vibration shall visibly affect a mass of concrete over a radius of at least 18 inches.
4. The Contractor shall provide a sufficient number of vibrators to consolidate each batch immediately after it is placed in forms.
5. Vibrators shall be manipulated to work concrete thoroughly around reinforcement and embedded fixtures and into corners and angles of forms. Vibration shall be applied at the point of deposit and in the area of the freshly placed concrete. Vibrators shall not be pulled through concrete and shall be inserted and withdrawn slowly and maintained nearly vertical at all times. Vibration shall be of sufficient duration and intensity to consolidate concrete thoroughly but shall not be continued so as to cause segregation. Vibration shall not be continued at any one point to the extent that localized areas of grout are formed. Application of vibrators shall be at points uniformly spaced and not further apart than twice the radius over which the vibration is visibly effective.
6. Vibration shall not be applied directly or indirectly to sections or layers of concrete that have hardened to the degree that it ceases to be plastic under vibration. Vibration shall not be used to make concrete flow in forms, and vibrators shall not be used to transport concrete in forms.
7. Vibration shall be supplemented by such spading as is necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations inaccessible to vibrators.
8. These specifications shall apply to filler concrete for steel grid floors except that vibration shall be applied to the steel.

9. These specifications shall apply to precast piling, concrete cribbing, and other precast units except that the manufacturer's methods of vibration may be used if approved by the Engineer.

When vibrating is not practicable, concrete shall be consolidated and its faces well spaded by continuous working with a suitable tool in a manner acceptable to the Engineer.

Concrete shall be placed in continuous horizontal layers not more than 12 inches in thickness. However, slabs shall be placed in a single layer. When it is necessary in an emergency to place less than a complete horizontal layer in one operation, the layer shall terminate in a vertical bulkhead. In any given layer, separate batches shall follow each other so closely that each one shall be placed and consolidated before the preceding one has taken initial set. Each layer of concrete shall be left rough to secure efficient bonding with the layer above. A succeeding layer placed before the underlying layer has become set shall be consolidated in a manner to prohibit the tendency to produce a construction joint between layers.

Layers placed at the end of one day's work or prior to temporarily discontinuing operations shall be cleaned of laitance and other objectionable material as soon as the surface has become sufficiently firm to retain its form. The top surface of concrete adjacent to forms shall be smoothed with a trowel.

Horizontal layers located to produce a construction joint at a location wherein a feather edge might be produced in the succeeding layer shall be formed by inset formwork so that the succeeding layer will end in a body of concrete having a thickness of at least 6 inches.

The work on any section or layer shall not be stopped or temporarily discontinued within 18 inches below the top of any face unless the details of the work provide for a coping having a thickness of not more than 18 inches, in which case the construction joint may be made at the underside of the coping at the option of the Engineer.

Care shall be taken when placing concrete to avoid coating reinforcing steel, structural steel, forms, and other items that extend into areas to be involved in a subsequent placement. If coating of steel does occur, no attempt shall be made to remove the mortar until after the concrete steel bond of the earlier placement has developed sufficiently to withstand a cleaning operation. Any coating of mortar on deformed bars that cannot be removed by hand brushing with a wire bristle brush or a light chipping action will not have to be removed.

The method and manner of placing concrete shall be regulated so as to place construction joints across regions of low shearing stress and in locations that will be hidden from view to the greatest extent possible.

Placing and consolidating concrete shall be conducted to form a compact, dense, impervious mass of uniform texture that will show smooth faces on exposed surfaces. Any section of concrete found to be defective shall be removed or repaired as directed by the Engineer.

If concrete operations are permitted to extend after sunset, the work area shall be brightly lighted so that all operations are plainly visible.

1. **Culverts:** Sidewalls of box culverts shall be carefully bonded to the base slab in accordance with (h) herein. Each wing shall be constructed as a monolith if possible. Construction joints, where unavoidable, shall be horizontal.

2. **Girders, slabs, and columns:** Concrete shall be placed by beginning at the center of the span and working toward the ends. Concrete in girders shall be placed uniformly for the full length of the girder and brought up evenly in horizontal layers.

The concrete floor and girders for each span of concrete through girder spans and concrete in T-beams, slab spans, and deck girders shall be placed monolithically.

If the finished top surface of a concrete unit being placed is not level, care in the method of vibration, the use of low slump concrete, or other means shall be taken to prevent downgrade movement of newly placed concrete. Special attention shall be given to sloping slabs.

Concrete in columns shall be placed in one continuous operation. If cap forms are supported by falsework independent of columns or column forms or are otherwise designed so that no load is placed on columns, concrete may be placed in caps after concrete in columns has set for at least 12 hours. Otherwise, the requirements of Table IV-2 for columns carrying a load shall have been conformed to before concrete is placed in caps.

Concrete shall not be placed in the superstructure until column forms have been stripped sufficiently to determine the character of concrete in columns.

- (d) **Pneumatic Placement:** Pneumatic concrete placement will be permitted only when authorized by the Engineer and the method is approved by the Engineer. When permitted, placement shall be in accordance with the requirements of Section 412.
- (e) **Pumping:** Placing concrete by pumping will be permitted only when authorized by the Engineer and provided concrete is pumped through a conduit system that is not aluminum. Equipment shall be arranged such that no vibrations that might damage freshly placed concrete will occur. Equipment shall be thoroughly cleaned prior to use. The operation of the pump shall be such that a continuous stream of concrete without air pockets is delivered. If concrete remaining in the pipe line is to be used, it shall be ejected in such a manner that there will be no contamination of concrete or separation of ingredients.
- (f) **Depositing Concrete Under Water:** Concrete shall not be deposited in water except with the approval of the Engineer.

Concrete placed in water shall be Class T3. Concrete shall be carefully placed in a compact mass in its final position by means of a tremie or another approved method and shall not be disturbed after being deposited except as specifically provided herein. Still water shall be maintained at the point of placement.

A tremie shall consist of a tube having a diameter of at least 10 inches, constructed in sections having flanged couplings fitted with gaskets. The discharge end shall be closed at the start of work and entirely sealed at all times. The tremie tube shall be kept full to the bottom of the hopper. When a batch of concrete is dumped into the hopper, the flow of concrete shall be induced by slightly raising the discharge end, always keeping it in the placed concrete. Concrete seal shall be placed continuously from start to finish. Concrete shall be placed at a rate of at least 1 vertical foot per hour over the entire area of the seal course. The surface of concrete shall be maintained in a horizontal plane within a tolerance of 6 inches at all times during placement. The tremie shall be supported so that its discharge end is freely movable over the entire work area, or multiple tremies shall be used. Vibration shall be used only when deemed necessary by the Engineer. Supports for tremies shall permit rapid lowering of discharge ends when necessary to retard or stop the flow of concrete. The method of placing the seal shall be subject to the approval of the Engineer prior to concrete placement.

Removal of water from cofferdams or other structures may proceed when the concrete seal has attained final set. Laitance or other unsatisfactory material shall be removed from the exposed surface by scraping and chipping with pneumatic or hand tools to an extent that will expose the aggregate for good bond with the footing to be cast upon it but not to an extent that will damage the concrete.

- (g) **Construction Joints:** Construction joints that are not detailed on the plans shall be placed as directed or approved by the Engineer. Shear keys or inclined reinforcement shall be used where necessary to transmit shear or bond the two sections together. Joints shall be constructed so that featheredging does not occur.

For construction joints in deck slabs, a 2 by 1 ½ inch shear key shall be provided between mats of reinforcing steel.

Construction joints against which earth fill is placed shall be protected by a heavy coat of asphalt conforming to the requirements of Section 213, applied for a distance of 3 inches on each side of the joint and continuous throughout its length.

In construction joints exposed to view, a waterstop conforming to the requirements of Section 213 shall be inserted. The waterstop shall be placed at least 3 inches from the face of concrete and shall extend at least 2 inches into each section of concrete.

Longitudinal or transverse construction joints may be used to facilitate placing concrete in continuous slab spans. Longitudinal joints shall be spaced so that each concrete placement will be at least 10 feet in width. Transverse joints shall be placed at the center lines of piers provided they are located infrequently, permitting simultaneous longitudinal screeding of as many spans as possible. Concrete shall be placed in one continuous operation between construction joints. The volume of concrete in any one placement shall be not less than the volume of concrete in one end span.

- (h) **Bonding Construction Joints:** In joining fresh concrete to set concrete, the work already in place shall have its surface roughened thoroughly. Shavings, sawdust, and other loose and foreign material shall be removed. The surface shall be washed and scrubbed with wire brooms when necessary to remove substances that will interfere with bonding. Concrete of the preceding placement shall be thoroughly wetted prior to placement of the next unit of fresh concrete.

For construction joints in deck slabs, the vertical face shall be sandblasted to expose the coarse aggregate. When epoxy-coated reinforcing steel is used, the epoxy coating shall be protected during sandblasting operations. Damaged areas of coated bars shall be repaired in accordance with the requirements of Section 223. Prior to placement of adjoining concrete, the vertical face shall be coated with epoxy, Type EP-4. After the concrete in the second placement has set, a V groove shall be formed along the top of the joint by sandblasting to a depth of at least ¼ inch and shall be sealed with epoxy, Type EP-5, low viscosity, conforming to the requirements of Section 243.

To bond successive courses, suitable keys shall be formed at the top of the upper layer of each day's work and at other levels where work is interrupted. Keys shall be formed by inserting and subsequently removing beveled wood strips, which shall be saturated with water to induce swelling prior to insertion in fresh concrete. At the discretion of the Engineer, rough stone or steel dowels may be used in lieu of keys. Dowels shall extend an equal distance on each side of the construction joint. Prior to the inserting or driving of dowels into predrilled or preformed holes, holes shall be filled with hydraulic cement grout in the proportion of 1 part cement to 2 parts sand. The size and spacing of keys and dowels shall be determined by the Engineer.

- (i) **Concrete Exposed to Tidal Water:** Concrete structures other than box culverts subject to the action of tidal water shall not have construction joints located within a zone 5 feet above to 5 feet below the elevation of the mean tide.

Concrete within 5 feet of the mean tide shall be cured in forms for 48 hours and allowed to dry for 5 days after forms are stripped. After drying, one coat of primer and four coats of asphalt, conforming to the requirements of Section 213, shall be applied during a period of 48 hours. Each coat shall be allowed to set before the succeeding one is applied. In lieu of primer and asphalt, the coating may consist of one coat of epoxy, Type EP-3B, followed by one coat of epoxy, Type EP-3T, and shall have a total thickness of at least 20 mils.

For precast concrete, protective coatings shall be applied in the same manner, but the seal coat shall be allowed to dry 4 days, or as long as necessary to harden, before handling.

Requirements for protective coating shall also apply to inside surfaces of box culverts that are subject to the ebb and flood of tidal water.

Concrete exposed to the action of ice, drift, or other forces producing shock and abrasion shall be protected by encasing that portion of the exposed surface with a special sheathing or protective armor. Provision shall be made in the size of the original cofferdam for sufficient clearance to permit access to the concrete surface for the installation and effective anchorage of the sheathing.

- (j) **Removing Formwork and Constructing Superimposed Elements:** In the determination of the time for removing formwork and constructing superimposed elements, consideration shall be given to the location and character of the structure, the weather, other conditions influencing setting of concrete, and materials used in the mixture. Formwork shall include forms, braces, ties, guy wires, and other instruments of stabilization.

1. Formwork may be removed as follows:

- a. Side forms or elements not immediately subjected to loading (for example: footings and walls or columns with height and width ratios less than 10:1 [h/w <10:1]: 48 hours or 30% concrete strength ( $f'c$ ). For the purposes herein width will be considered the narrowest portion of the element measured horizontally across its surface.

The time period noted for form removal shall begin at the completion of the concrete placement and is exclusive of hours when any portion of the concrete element's surface is below 40°F.

- b. All other elements: 60% concrete strength ( $f'c$ ).

2. Forming for superimposed elements may be as follows:

- a. Elements not immediately subjected to loading (for example: footings and walls or columns with height to width ratios less than 10:1 [h/w <10:1]: 48 hours or 30% concrete strength ( $f'c$ ). For the purposes herein width will be considered the narrowest portion of the element measured horizontally across its surface.

The time period needed for forming for superimposed elements shall begin at the completion of the concrete placement and is exclusive of hours when any portion of the concrete element's surface is below 40°F.

- b. All other elements: 60% concrete strength ( $f'c$ ).

3. Placing concrete in forms for superimposed elements shall not be done until concrete has attained 60% concrete strength ( $f'c$ ) except for footings, where concrete may be placed when the footing has attained 40% concrete strength ( $f'c$ ).

The Contractor may submit calculations to show that lower strength requirements may be used, but may not proceed to use these requirements before receiving written permission to do so.

Concrete strength ( $f'c$ ) is the design minimum laboratory compressive strength at 28 days as specified in Table II-17 Requirements for Hydraulic Cement Concrete for the class of concrete designated. If the time for removing formwork and forming for or placing concrete in superimposed elements is determined by control cylinder strengths, the Contractor will be permitted to perform these operations when the control cylinder strengths reach the values previously noted. Control cylinders shall be cured under conditions that are not more favorable than the most unfavorable conditions for the portion of the concrete the cylinders represent. The Contractor shall furnish molds, labor, and materials; make sufficient test specimens; and transport specimens to the testing facility. Single-use wax paper, paper, plastic, or light-gage metal molds conforming to the requirements of ASTM C 470 may be used for making control cylinders. Control cylinders shall be molded under the observation of the Engineer. Tests for compressive strengths will be performed by or under the observation of the Engineer.

The concrete strengths and time periods noted herein for removing formwork or forming for or placing concrete in superimposed elements shall not apply to the use of equipment of other live loads on the structure. Stockpiling materials or using unauthorized equipment on the structure will not be permitted until conformance to the requirements of Section 404.03(m) has been obtained.

Methods of form removal that will overstress concrete shall not be used. Formwork and its supports shall not be removed without the approval of the Engineer. The Contractor shall ensure that proper curing as required by the Specifications is provided immediately after form removal.

For falsework requirements see Section 404.03(b).

- (k) **Curing Concrete:** The method of curing concrete shall be subject to the approval of the Engineer prior to mixing or placing concrete. When the atmospheric temperature is above 40 °F in the shade, concrete surfaces that are not protected by formwork and surfaces from which forms have been removed shall be cured using approved materials applied before the sheen disappears from fresh concrete or immediately upon removal of formwork. Concrete shall be cured for 7 days, regardless of the strength obtained with control cylinders. During this 7 day curing period, a curing agent or medium shall be used.

PE film used for curing shall be white except that opaque or transparent PE film may be used between November 1 and April 1.

When liquid membrane seal is used for curing grooved horizontal surfaces, the application rate shall be 100 to 150 square feet per gallon. The application rate for all other surfaces shall be 150 to 200 square feet per gallon. Application shall be such that an even, white continuous membrane is produced on the concrete surface.

If the atmospheric temperature falls below 40 °F in the shade, water curing shall be discontinued except when it is accomplished by flooding as specified herein. Curing shall be immediately resumed using insulated blankets or other approved methods that will retain or supply moisture and maintain the temperature at the outermost surfaces of the concrete mass above 50 °F for at least 72 hours and above 40 °F for at least 48 additional hours immediately following concrete placement.

In the event the Contractor begins masonry concrete operations when the atmospheric temperature is below 40 °F in the shade, the method of cure and protection shall retain or supply moisture and maintain the temperature at the outermost surfaces of the concrete mass above 50 °F for at least 72 hours immediately following the placement of the concrete and above 40 °F for not less than 48 additional hours.

When concrete is cured by flooding with water and the temperature is below 40 °F in the shade, a depth of at least 6 inches shall be maintained above the surface of the mass until concrete has attained the minimum required design strength as determined by a test cylinder cured in the same water.

1. **Bridge Deck Curing:** Bridge deck concrete shall be moist cured with polyethylene sheeting with or without the use of wet burlap. The concrete shall be maintained in a moist condition by fogging after screeding and until covered with the white polyethylene sheeting. The concrete surface shall stay wet under the white polyethylene sheeting until the end of the moist-curing period. The moist-curing period shall be for at least 7 days and until 70 percent concrete strength ( $f'c$ ) is achieved. The initial temperature of the outermost surfaces of the concrete mass shall be above 50°F for at least 72 hours and above 40°F until the completion of the moist-curing period. When the white polyethylene sheeting is removed, burlap (if used) shall be removed also. White pigmented curing compound shall be applied at the rate of 100 to 150 square feet per gallon while the surface of the concrete deck is damp and free of standing water. Bridge deck concrete overlay shall be cured in accordance with the requirements of Section 412 of the Specifications.

(i) **Protecting Concrete:** Protection of concrete shall begin immediately following concrete placement in the formwork and shall continue without interruption throughout the curing period.

1. **Weather:** The Contractor shall schedule the placement of structural concrete so that the date and hour decided upon reflect consideration of weather conditions.

Concrete shall be protected from rain.

Concrete shall not be placed against surfaces whose temperature is below 40 °F. Concrete shall be protected from freezing by approved coverings and, when necessary, heating the surrounding air in such a manner that the concrete will not dry.

Protection shall be provided to prevent rapid drying of concrete as a result of low humidity, high wind, higher concrete temperatures than atmospheric temperatures, or combinations thereof. The Contractor shall perform evaporation rate testing for bridge deck placements and concrete overlays. Immediately after screeding and until the application of wet burlap and/or plastic sheeting, no surface of the freshly mixed concrete shall be allowed to dry. Fogging, with pressure sprayers acceptable to the Engineer and sufficient to maintain a moist surface, shall be required. The protective measures taken shall be sufficient to maintain an evaporation rate at or below 0.10 lb./sq.ft./hr. for normal concrete bridge deck placements or 0.05 lb./sq.ft./hr. for concrete overlays over the exposed surface of the concrete. Other preventative

measures described in ACI 308 can also be used in addition to fogging. Evaporation retardant films may be applied in a fine mist immediately after screeding to ensure that the surface remains wet until covered. If such materials are used, there shall be no disturbance of the concrete surface after placement of the retardant film and such film shall not be intermixed with the surface mortar. If plastic shrinkage cracking occurs, the Engineer may direct the Contractor to make repairs by epoxy injections, concrete removal and replacement or other methods approved by the Engineer at no additional cost to the Department.

2. **Construction activities:** Care shall be taken to avoid damage to concrete from vibration created by blasting and pile driving operations, movement of equipment in the vicinity of the structure, or disturbance of formwork or protruding reinforcement.

Concrete shall be protected from the heat of an open fire. A watchperson shall be provided at the structure throughout any period in which open-flame heaters are operated in the vicinity of the concrete.

After concrete in finished surfaces has begun to set, it shall not be walked on or otherwise disturbed for at least 24 hours except as provided for in (j) herein.

3. **Silicone treatment:** When unpainted weathering steel is used in a structure and no other concrete waterproofing surface finish is specified, a 5 percent solids, solvent-based, clear, water-repellent silicone treatment shall be applied in two coats to the surface of the concrete substructure on exposed concrete surfaces below and including the bridge seats, within the limits of vertical planes parallel to and 2 feet outside the extreme edges of exterior beams or girders. The first coat shall be applied at the rate of 60 to 70 square feet of surface area per gallon of treatment solution and the second coat at the rate of 90 to 110 square feet per gallon. If the treatment is applied by spraying, the nozzle shall not be held further than 2 feet from the surface being treated. The treatment shall be applied after cleaning of exposed substructure concrete surfaces and before any structural steel is erected.

- (m) **Opening to Traffic:** Structures shall not be opened to traffic, including construction traffic, or used for storing materials before concrete has attained the 28 day design compressive strength, as specified in Table II-17. Cylinders used for control purposes shall be cured under conditions that are not more favorable than the most unfavorable conditions for the portions of concrete the cylinders represent. When traffic is to be permitted on a partially completed slab span, falsework shall remain in place in accordance with the strength requirements specified herein. Other structures supported on falsework from the ground shall not be opened to traffic until falsework is removed.

#### **404.04--Bridge Deck Construction.**

Prior to the beginning of deck placement, screeds shall be approved by the Engineer.

When the longitudinal screed is used, the overall length shall be such as to screed independently supported spans up to and including 80 feet. The length of the screed shall be not less than the full length of the span for spans less than 80 feet. When using the longitudinal screed on independently supported spans exceeding 80 feet in length with a screed length less than the full length of the span, the center half of the span shall be completed first. Bulkheads or other substantial supports for the screed shall be placed over abutments and piers and at the terminal point of placements within the span. The surface of a previously placed section shall not be used as a bearing area for the screed track until control cylinders have attained a strength of at least 50 percent of  $f'c$  as specified in Table II-15.

When a transverse screed is used, the screed shall be of sufficient size to finish the full width of the deck between curbs or parapets unless a longitudinal joint in the deck is specified, in which case the portion on either side of the joint shall be placed and finished separately. Wheels of the screed shall bear on temporary rails supported on and directly above the main structural units or on form supports. With continuous spans, form supports shall be fully supported by the principal structural units supporting the deck. Rails shall be sufficiently rigid and strong to permit the screed to finish the surface of the deck within specified requirements. If rails are placed within the roadway area, they shall be elevated a sufficient distance above the deck to permit simultaneous finishing by hand of any portion not finished by the screed. Rail supports extending above the roadway surface shall be fabricated and installed in a manner to permit their removal to at least 2 inches below the top surface of the deck slab. Where rail supports are placed in that portion of the deck under curbs or parapets, supports shall be placed so that they will be at least 2 inches from the face of the curb, parapet walls, or outside edge of the slab.

An approved positive means of permitting access to the surface of the bridge shall be provided for operations requiring access to the deck surface after passing of the screed. The means of access shall not make contact with the deck surface.

Concrete for the entire span or section to be placed shall remain workable until the entire operation of placing, screeding, patching, rescreeding, finishing, and testing is completed. Excess water or soupy material collected by a screeding operation shall be immediately removed from the deck.

If the concrete in the deck of a continuous beam or girder span group cannot be placed in one operation, the location of construction joints and sequence of placement shall be in accordance with the approved placement schedule. After the initial placement has been made in any one group of continuous spans, no further placement shall be made until previously placed concrete in the deck of that group has been in place for at least 3 days or until the cylinder strength is at least 0.4 f'c.

The deck surface shall be tested with a 10-foot straightedge and rescreeded as many times as is necessary to ensure a smooth riding surface. The straightedge shall be held in successive positions at the edges and quarter points and on the center line, parallel thereto and in contact with the surface. Advancement along the deck shall be in successive stages of not more than the length of the straightedge. The surface shall also be checked transversely at the ends, quarter points, and center of the span. Areas showing high spots or depressions of more than 1/8 inch in 10 feet in the longitudinal direction and 1/4 inch in 10 feet in the transverse direction shall be struck off or filled with freshly mixed concrete. Attention shall be given to ensure that the surface across joints conforms to the requirements for smoothness.

#### **404.05--Expansion and Fixed Joints.**

- (a) **Open Joints:** Open joints shall be constructed by inserting and subsequently removing wood strips, metal plates, or other approved material. Insertion and removal of the template shall be accomplished without chipping or breaking the corners of the concrete.

Edges of concrete adjacent to joints shall be finished to a radius of approximately 1/8 inch or as shown on the plans.

- (b) **Filled Joints:** Materials for filled joints shall conform to the requirements of Section 212 and shall be installed in accordance with the requirements of Section 316.04(m). When not specified or shown on the plans, filler shall be performed asphalt joint filler, and sealer shall be the hot-poured type.

Edges of concrete adjacent to joints shall be finished to a radius of approximately 1/4 inch or as shown on the plans.

When expanded rubber, PVC, or PE filler is used, it shall be attached to the first-placed side of the joint with an approved adhesive and the concrete on the other side shall then be placed against the filler. Care shall be taken not to displace or compress the filler.

Other types of premolded fillers shall be similarly placed but need not be attached by an adhesive.

Joints shall be free from cracked and spalled areas, and their faces shall be free from foreign matter, curing compounds, oil, grease, and dirt. Faces shall be sandblasted, and the joint blown out with oil-free and water-free compressed air just prior to application of primer or sealer.

- (c) **Steel Joints:** Plates, angles, or other structural shapes shall be fabricated to conform to the section of the concrete floor. Fabrication and painting shall conform to the requirements of Sections 407 and 411. Care shall be taken to ensure that the surface in the finished plane is true and free from warping. Positive methods shall be employed in placing joints to keep them in the correct position during concrete placement so that the opening at expansion joints shall be that designated on the plans at normal temperature. Care shall be taken to avoid impairing the clearance in any manner. Normal temperature shall be considered as 60 °F, and correction to this temperature shall be computed using a coefficient of expansion of 0.000065 per foot per degree Fahrenheit.

- (d) **Waterstops:** Metal waterstops shall be spliced, welded, or soldered to form continuous, watertight joints.

Nonmetal waterstops shall be furnished full length for each straight portion of the joint, without field splices. Manufacturer's shop splices shall be fully vulcanized.

Field splices for neoprene waterstops shall be vulcanized; mechanical, using stainless steel parts; or made with a splicing union of the same stock as the waterstop. Finished splices shall have a full-size tensile strength of 100 pounds per inch of width.

Field splices for PVC waterstops shall be made by heat sealing adjacent surfaces in accordance with the requirements of the manufacturer's recommendations. A thermostatically controlled electric source of heat shall be used to make splices. The heat shall be sufficient to melt but not char the material.

When being installed, waterstops shall be cut and spliced at changes in direction as may be necessary to avoid buckling or distorting the web or flange.

If waterstops are out of position or shape after concrete is placed, the surrounding concrete shall be removed, the waterstop reset, and the concrete replaced, all at the Contractor's expense.

#### **404.06--Bridge Seat Bearing Areas.**

Bridge seat bearing areas shall be finished plane and level and shall not deviate more than 1/16 inch from plane or more than 1/32 inch per foot from level or from the slope specified on the plans. These limits of tolerance do not necessarily represent fully acceptable construction but are the limits at which construction may become unacceptable. In general, workmanship on bearing areas shall be at a level of quality that will be well within the tolerance limits. Bearing area roughness for elastomeric pads shall conform to the requirements of Section 408.03(g).

Bearing areas shall be cleaned and tested for planeness and levelness prior to placement of bearing pads or preparation for bearing plates. Preparation of bearing areas for placing bearing plates and setting anchor bolts shall be in accordance with the requirements of Section 408.03(g) and (h).

#### **404.07--Finishing Concrete Surfaces.**

Following replacement or satisfactory repair of defective concrete, surface defects produced by form ties, honeycombing, spalls, or broken corners or edges shall be cleaned, wetted, filled with a mortar conforming to the requirements of Section 218, and troweled or struck off flush with the surrounding surface. If the surface cannot be repaired immediately following removal of forms or before the concrete surface has become dry, the surface shall be kept wet for 1 to 3 hours, as directed by the Engineer, prior to application of mortar. Repaired areas shall be cured in accordance with the requirements of Section 404.03(k).

The formed face of the following concrete items shall be given a Class 1 finish: (1) bridge items: wheel guards, the inside and outside faces of parapet walls and concrete posts and rails; and (2) other items: curbs, raised medians, steps, and retaining walls that lie within 30 feet of the edge of the pavement.

- (a) **Class 1, Ordinary Surface Finish:** Following removal of forms, fins and irregular projections shall be removed from exposed surfaces and surfaces to be waterproofed.

Immediately following removal of forms, surfaces that contain cavities having a diameter or depth greater than  $\frac{1}{4}$  inch shall be cleaned, wetted, filled with a mortar conforming to the requirements of Section 218, and rubbed with burlap. If the surface cannot be finished immediately following removal of forms or before the concrete surface has become dry, the surface shall be kept wet for 1 to 3 hours, as directed by the Engineer, prior to application of mortar. The finished surface shall be cured in accordance with the requirements of Section 404.03(k).

Construction and expansion joints in the completed work shall be left free from mortar and concrete. Joint filler shall be left exposed for its full length.

- (b) **Class 2, Rubbed Finish:** Rubbing of concrete shall be started immediately after forms are removed. Immediately before this work, concrete shall be kept wet for at least 3 hours. Sufficient time shall elapse before wetting to allow mortar used in the pointing of rod holes and defects to set thoroughly. Surfaces to be finished shall be rubbed with a medium-coarse carborundum stone with a small amount of mortar on its face. Mortar shall be composed of cement and fine aggregate mixed in the proportions used in the concrete being finished. Rubbing shall be continued until form marks, projections, and irregularities are removed; voids are filled; and a uniform surface is obtained. Paste shall be left in place.

The final finish shall be obtained by rubbing with a fine carborundum stone and water. Rubbing shall be continued until the entire surface has a smooth texture and uniform color.

After final rubbing is completed and the surface has dried, the surface shall be rubbed with burlap and left free from unsound patches, paste, powder, and objectionable marks.

- (c) **Class 3, Tooled Finish:** This finish shall be produced by the use of a brush hammer, pick, crandall, or other approved tool. Tooling shall not be done until concrete has set for at least 14 days and as much longer as may be necessary to prevent aggregate particles from being picked out of the surface. The finished surface shall show a grouping of broken aggregate particles in a matrix of mortar, with each aggregate particle in slight relief.
- (d) **Class 4, Sandblasted Finish:** The thoroughly cured concrete surface shall be sandblasted to produce an even, fine-grained surface in which mortar has been cut away, leaving the aggregate exposed.

- (e) **Class 5, Wire Brushed or Scrubbed Finish:** This finish shall be produced by scrubbing the surface of the plastic concrete with stiff wire or fiber brushes, using a solution of muriatic acid in the proportion of 1 part acid to 4 parts water. As soon as forms are removed and while concrete is comparatively plastic, the surface shall be scrubbed thoroughly and evenly until the cement film or surface is removed and aggregate particles are exposed, leaving an even, pebbled texture presenting an appearance grading from that of fine granite to coarse conglomerate, depending on the size and grading of aggregate used. As soon as scrubbing has progressed sufficiently to produce the texture desired, the entire surface shall be thoroughly washed with water to which sufficient ammonia has been added to remove all traces of acid.
- (f) **Class 6, Bridge Deck Finish:** Methods, procedures, and equipment shall conform to the requirements of Section 404.03 and shall not result in segregating ingredients of the concrete and shall ensure a smooth riding surface.

Hydraulic cement concrete bridge deck surfaces shall be textured with uniformly pronounced grooves sawed transversely to the center line. After final screeding of the deck, a multi-ply damp fabric shall be dragged over the deck surface to provide a gritty texture. The deck concrete shall not be grooved until it has reached an age of 14 days or 85 percent of the 28-day design compressive strength. Grooves shall be sawed approximately  $3/16 \pm 1/16$  inch in depth and  $1/8$  inch in width (nominal) on  $3/4$  inch (nominal) centers. Grooves shall terminate  $12 \pm 1$  inch from the parapet wall or curb line. Grooves shall not be sawed closer than 2 or further than 3 inches from the edge of any joint. When the width of the cutting head on the grooving machine is such that grooves cannot be practically sawed to within the required tolerance for a skewed transverse joint, grooving shall not be closer than 2 inches or more than 36 inches from the edge of the joint. On curved decks, each pass of the grooving machine shall begin on the side of the deck having the smaller radius, and the nominal spacing of grooves at the starting point shall be  $3/4$  inches on center.

Bridge decks should be grooved prior to opening to traffic. However, the Contractor will be permitted to delay grooving up to 6 months. The Contractor shall provide the Engineer with a plan for traffic control when working under traffic.

If a single pass of the grooving machine cannot be made across the width of the bridge, the mating ends of subsequent passes shall not overlap previous grooves or leave more than 25 millimeters of surface ungrooved.

After concrete has set and prior to placement of other slabs, the deck surface will be tested by the Engineer. Areas showing high spots or depressions of more than the specified tolerances will be marked as failing to conform to smoothness requirements. Levels may also be run over the surface to determine if there is any deviation from grade and cross section. Decks that do not conform to thickness and surface smoothness requirements will not be accepted until deficiencies have been corrected as directed by the Engineer. Sections that cannot be satisfactorily corrected shall be removed and replaced at the Contractor's expense.

Bridge decks that are to receive an asphalt concrete overlay of 1 inch or more in thickness shall be finished to a tolerance of  $1/4$  inch in 10 feet in both longitudinal and transverse directions except at expansion joints, where the finished tolerance shall be  $1/8$  inch in 10 feet.

- (g) **Class 7, Sidewalk Finish:** After concrete has been placed, it shall be consolidated and the surface struck off with a strike board and floated with wooden or cork floats. Light metal marking rollers may

be used if desired after the initial set. An edging tool shall be used on edges and at joints. The surface shall not vary more than ¼ inch under a 10 foot straightedge and shall have a granular texture that will not be slick when wet.

#### 404.08--Measurement and Payment.

**Concrete** will be measured in cubic yards within the neat lines of the structure as shown on the plans and will be paid for at the contract unit price per cubic yard, complete-in-place. Deductions will not be made for chamfers 1 inch or less in width or for grooves less than 1 inch in depth. The volume of reinforcing steel or any other material or internal voids within the concrete will be deducted.

The volume of bridge deck slab concrete allowed for payment will be computed using the actual thickness of the slab, not to exceed the plan thickness plus ½ inch, for the area between faces of sidewalks, curb lines, railings or parapets. The area beneath sidewalks, curbs, railings, or parapets will be based on plan thickness. If prestressed concrete deck panel forms are used, the volume they displace will be computed using plan dimensions and the volume of the cast-in-place portion will be measured as provided herein.

Unless designated as pay items, this price shall include waterstops, waterproofing, damp-proofing, anchor bolts, drain assemblies, silicone treatment, protective coating for concrete exposed to tidal waters, and trial batches.

If corrugated metal bridge deck forms are used in lieu of removable forms, the price for concrete shall include furnishing and placing metal forms, additional concrete required to fill corrugations, work necessary to facilitate inspection of the underside of the deck, repairing deficiencies, and strengthening beams or girders to maintain the design live-load rating of the bridge. If prestressed deck panel forms are used in lieu of removable forms, the price shall include casting, furnishing, and placing forms.

**Bridge-deck grooving** will be measured in square yards of deck surface area from the faces of parapets, sidewalks, or curb lines and will be paid for at the contract unit price per square yard. No deduction will be made for drainage items and joints.

Payment will be made under:

Pay Item	Pay Unit
Concrete (Class) item	Cubic yard
Bridge-deck grooving	Square yard

### SECTION 406--REINFORCING STEEL

#### 406.01--Description.

This work shall consist of furnishing; coating, if required; and placing reinforcing steel or wire mesh used in concrete operations, except prestressed strands and wires, in accordance with these specifications and in reasonably close conformity to the lines and details shown on the plans.

#### 406.02--Materials.

- (a) **Steel used for reinforcement** shall conform to the requirements of Section 223. Except for spiral bars, bars more than ¼ inch in diameter shall be deformed bars.
- (b) **Epoxy-coated bars** shall conform to the requirements of Section 223.

- (c) **Welded wire fabric** shall conform to the requirements of Section 223.
- (d) **Bar mat reinforcement** shall conform to the requirements of Section 223.

**406.03--Procedures.**

- (a) **Order Lists and Bending Diagrams:** Copies of order lists and bending diagrams shall be furnished the Engineer when required.
- (b) **Protecting Material:** Reinforcing steel shall be stored on platforms, skids, or other supports that will keep the steel above ground, well drained, and protected against deformation.

Upon delivery to the project site, epoxy coated reinforcing steel shall be covered with an opaque covering. In addition, epoxy coated reinforcing steel which has been partially embedded in concrete or placed in formwork and not covered with concrete shall have the exposed surfaces covered with an opaque covering after 30 days exposure to sunlight. The opaque coverings shall be placed in a manner to provide air circulation and prevent condensation on the reinforcing steel.

When placed in the work, steel reinforcement shall be free from dirt, paint, oil, or other foreign substances. Steel reinforcement with rust or mill scale will be permitted provided samples wire brushed by hand conform to the requirements for mass and height of deformation.

- (c) **Fabrication:** Bent bar reinforcement shall be cold bent to the shape shown on the plans. Fabrication shall be in accordance with the requirements of the Manual of Standard Practice for Detailing Reinforced Concrete Structures (ACI 315).

Spiral bars shall be fabricated to have the proper diameter when placed in position at the pitch shown on the plans. Each end of a spiral bar shall have 1 1/2 finishing turns at each end in a plane perpendicular to the axis of the spiral.

- (d) **Placing and Fastening:** Steel reinforcement shall be firmly held during the placing and setting of concrete. Bars, except those to be placed in vertical mats, shall be tied at every intersection where the spacing is more than 12 inches in any direction. Bars in vertical mats and in other mats where the spacing is 12 inches or less in each direction shall be tied at every intersection or at alternate intersections provided such alternate ties accurately maintain the position of steel reinforcement during the placing and setting of concrete.

Tie wires used with epoxy-coated steel shall be plastic coated or epoxy coated.

Following placement of epoxy-coated reinforcement and prior to concrete placement, the reinforcement will be inspected. All visible damage of the epoxy coating shall be repaired in accordance with Section 223 of the Specifications.

The minimum clear distance from the face of concrete to any reinforcing bar shall be maintained as specified herein. In superstructures, the cover shall be at least 2 ½ inches except as follows:

1. bottom of slab: 1 ¼ inches
2. stirrups and ties in T-beams: 1 ½ inches
3. rails, rail posts, curbs, and parapets: 1 inch

In substructures, the cover shall be at least 3 inches except as follows:

1. abutment neat work and pier caps: 2 ½ inches
2. spirals and ties: 2 inches

In corrosive or marine environments or under other severe exposure conditions, the minimum cover shall be increased 1 inch except where epoxy-coated reinforcement is used. Bars that must be positioned by maintaining clearances from more than one face shall be centered so that clearances indicated by the plan dimension of bars are equalized.

Bars shall be placed so that the concrete cover as indicated on the plans will be maintained within a tolerance of 0 to + ½ inch in the finally cast concrete.

Where anchor bolts interfere with reinforcing steel, the steel position shall be adjusted without cutting to permit placing anchors in their proper locations.

Reinforcement in bridge deck slabs and slab spans shall be supported by standard CRSI metal or precast concrete bar supports. Bar supports shall be spaced as recommended by CRSI but not more than 4 feet apart transversely or longitudinally. Precast concrete supports shall be less than 1 foot in length and staggered so as not to form a continuous line. The lower mat of steel reinforcement shall be supported by a bolster block or individual bar chair supports, and the upper mat shall be supported by high chair supports. Bar supports shall be firmly stabilized so as not to displace under construction activities. Reinforcing bar supports (STANDEES) may be used for the top mat of steel of simple slab spans provided they hold the reinforcing steel to the requirements specified herein and are firmly tied to the lower mat to prevent slippage. The use of standees will not be permitted for the top mat of steel on any continuous slab spans.

Precast concrete bar supports shall have a 28-day design compressive strength of at least 4,500 pounds per square inch and shall be from the Department's list of approved products for the use specified. Supports shall be furnished with epoxy-coated or plastic ties or shaped to prevent slippage from beneath the reinforcing bar. Metal bar supports shall be fabricated from one of the following: (1) stainless steel wire conforming to the requirements of ASTM A493, or (2) cold-drawn wire protected by plastic coating conforming to CRSI standards, epoxy coating, or other protective coating as approved by the Engineer.

In reinforced concrete sections other than bridge slabs, the specified clear distance from the face of concrete to any reinforcing bar and the specified spacing between bars shall be maintained by means of approved types of stays, ties, hangers, or other supports. The use of pieces of gravel, stone, brick, concrete, metal pipe, or wooden blocks will not be permitted as supports or spacers for reinforcing steel. The use of precast concrete block supports will be permitted provided blocks are furnished in correct thicknesses and are shaped or tied to prevent slippage from beneath reinforcing bars. The clear distance between bars shall be at least 1 1/2 times the specified maximum size of coarse aggregate but not less than 1 ½ inches. Before concrete is placed, reinforcing steel will be inspected and approved for proper position and the adequacy of the method for maintaining position.

- (e) **Splicing and Lapping:** Reinforcement shall be furnished in full lengths as indicated on the plans. Except where shown on the plans, splicing bars will not be permitted without the written approval of the Engineer. Splices shall be as far apart as possible.

Bars shall be lapped at least 30 bar diameters to make the splice. In lapped splices, bars shall be placed in contact and wired together. Mechanical butt splicing will be permitted at longitudinal joints in deck slabs and other locations shown on the plans provided the mechanical connection develops in tension or compression, as required, at least 125 percent of the specified yield strength of the bar. Reinforcing steel shall be welded only if specified on the plans. Welding shall be in accordance with the requirements of Section 407.

Laps for sheets of welded wire fabric or bar mat reinforcement shall be at least one mesh in width.

#### **406.04--Measurement and Payment.**

Reinforcing steel will be measured in pounds of steel placed in the structure as shown on the plans. The mass of welded wire fabric will be computed from the theoretical weight per square yard placed, including allowance for laps not to exceed 8 percent of the net area. Reinforcing steel or welded wire fabric will be paid for at the contract unit price per pound. These prices shall include furnishing, fabricating, and placing reinforcement in the structure. In structures of reinforced concrete where there are no structural steel contract items, expansion joints, plates, rockers, bolts, and similar minor metal parts will be paid for at the contract unit price for reinforcement.

Epoxy-coated reinforcing steel, when a pay item, will be measured in pounds of uncoated steel and will be paid for at the contract unit price per pound. The weight will be computed from the theoretical weight of the nominal sizes of steel specified and placed in the structure. Measurement will not be made for epoxy-coating material. This price shall include furnishing steel and epoxy-coating material; applying coating material; fabricating, shipping, and placing epoxy-coated reinforcement in the structure; and necessary repairing of epoxy coatings. When the Contractor elects to eliminate the epoxy coating of reinforcing steel and furnish a latex hydraulic cement concrete deck surface, payment will be made at the same contract unit price as if epoxy-coated reinforcing steel had been used.

No payment will be made for fastening devices that may be used by the Contractor for keeping reinforcing bars in their correct position. When the substitution of larger bars than those specified is allowed, payment will be made for only the amount of metal that would have been required if the specified size of bar had been used. When full-length bars are shown on the plans and the Contractor obtains approval to use short bars for his convenience, the mass paid for will be based on the full-length dimensions with no allowance made for splices.

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
Reinforcing steel	Pound
Welded wire fabric	Pound
Epoxy-coated reinforcing steel	Pound

### **SECTION 410--RAILINGS AND PARAPETS**

#### **410.01--Description.**

This work shall consist of furnishing and installing railings, bridge median barriers, and concrete parapets reasonably true to the line, grade, and dimensions shown on the plans or as established by the Engineer.

**410.02--Materials.**

- (a) **Concrete** shall conform to the requirements of Section 217. In the event the Contractor places concrete by the extrusion method, the slump may be less than 2 inches, the air content shall be no less than 4% and coarse aggregate shall be no less than No. 7.
- (b) **Steel reinforcement** shall conform to the requirements of Section 223.
- (c) **Steel for metal parapets** shall conform to the requirements of Section 226.
- (d) **Hydraulic cement mortar and grout** shall be non-shrinking and shall conform to the requirements of Section 218.
- (e) **Aluminum railings and materials** shall conform to the requirements of Section 229.
- (f) **Anchor bolts** shall conform to the requirements of Section 226.
- (g) **Grounding materials** shall conform to the requirements of Section 238.

**410.03--Procedures.**

- (a) **Post Alignment:** Posts shall be normal with respect to the profile grade and plumb in the transverse direction regardless of the cross slope.
- (b) **Metal Railings:** Fabrication and erection shall be performed in accordance with the requirements of Section 407. Working drawings shall be furnished in accordance with the requirements of Section 407. In welded railing, exposed joints shall be finished by grinding or filing to give a neat appearance.

When alternate metal railings are permitted, bridges under any one contract shall have the same type of railing.

Metal railings shall be carefully adjusted prior to being fixed in place to ensure proper matching at abutting joints and correct alignment and camber throughout their length. Holes for field connections shall be drilled wherever possible with railing in place at the proper grade and alignment.

Abutment ends of metal railings and metal parapets shall be grounded. Grounding conductor shall be bare or insulated (green) copper. Grounding electrode(s) shall be installed in accordance with the requirements of Section 700 and shall conform to the requirements of the NEC. All sections of metal railings, movable joints of metal railings, metal parapets, and the gaps in the metal railings created by the concrete pole supports or other design modifications shall be bonded internally to maintain continuity. Grounding conductors shall pass through bridge parapets and backwalls in one inch conduit or raceway to a point 4 to 8 inches below the finished grade and attached to a grounding electrode(s) with a minimum of 8 feet contact with soil. Each run of grounding conductor shall be provided with a 4-inch exposed loop at expansion joints and at termination points. Each metal rail section adjacent to the next metal railing shall be tested for continuity to ensure system grounding. The Contractor shall test the grounding electrode(s) after installation using the Fall of Potential (three point measurement) method. All testing shall be documented and submitted to the Engineer.

1. **Painting:** Steel or iron railing that is not galvanized shall be given one shop coat and three field coats of paint after erection. Painting shall be in accordance with the requirements of Section 411.
2. **Anchorage:** Metal railing anchorages in concrete shall be placed in accordance with the requirements of Sections 404 and 408.

3. **Aluminum railings:** Components of railing shall be designed for adequate structural strength. Castings shall have a thickness of at least  $\frac{1}{4}$  inch, and other units shall have a thickness of at least  $\frac{3}{16}$  inch.

Aluminum in contact with concrete shall be coated with an approved aluminum-impregnated caulking compound. Aluminum surfaces in contact with metals other than stainless or galvanized steel shall be insulated with approved materials.

- (c) **Concrete Railings, Bridge Median Barriers, and Parapets:** Concrete railings or parapets shall not be placed until centering or falsework for the span has been released, rendering the span self-supporting.

Railings, bridge median barriers, and parapets shall be constructed in accordance with the requirements of Section 404, for the class of concrete specified on the plans, and shall be given a Class I finish. Care shall be taken to secure smooth and tight-fitting forms that can be rigidly held to line and grade and removed without damage to concrete. Concrete parapets and median barriers shall be constructed within an allowable tolerance of  $\pm 1/2$  inch for overall depth and overall width,  $\pm 1/4$  inch for the width of the upper portion of the barrier, and  $\pm 1/4$  inch per 10 feet for horizontal alignment.

Forms for concrete railing shall be fabricated of single-width boards lined with approved material. Form joints in plane surfaces will not be permitted.

Moldings, panel work, and bevel strips shall be constructed with neatly mitered joints. Corners in finished work shall be true, sharp, clean cut, and free from cracks, spalls, or other defects.

Reinforcing steel shall be placed in accordance with the requirements of Section 406.

Expansion joints shall be constructed so as to permit freedom of movement. After all other work is completed, loose or thin shells of mortar likely to spall under movement shall be removed from expansion joints by means of a sharp chisel.

In the event the Contractor elects to construct railing, parapet or median barrier by the extrusion method, construction shall conform to the following:

1. In the event the bridge deck needs to be widened or additional reinforcing steel placed in the railing, parapet or median barrier to accommodate the extrusion machine, the Contractor shall submit all necessary details for approval. Cost for widening the bridge deck or placement of additional reinforcing steel shall be at the Contractor's expense.
2. The extrusion machine shall be equipped with internal vibrators to consolidate concrete along the face and adjacent joints in one complete pass of the machine. This shall be accomplished in such a manner that a minimum of hand finishing will be required to produce a dense homogenous finish, free from voids and honeycomb.
3. When the plans require horizontal drains in the railing, parapet or median barrier, the Contractor shall submit his proposed method of forming drains to the Engineer for approval.
4. Deflection and expansion joints shall be grooved in accordance with the plans immediately after the extrusion process and all required saw cutting shall be completed the same day the concrete is placed.

**410.04--Measurement and Payment.**

Railing will be measured in linear feet along the center line of the top rail between the extremities of each railing, without deductions for breaks or interruptions. When railing is not a pay item, the cost thereof shall be included in the price for other appropriate items. When a pay item, railing will be paid for at the contract unit price per linear foot. This price shall include furnishing rails, rail posts, post bearing pads, anchor assemblies, and sleeves; furnishing and installing grounding materials; painting; and galvanizing; reinforcing steel necessary; and concrete where applicable.

Parapets will be measured in linear feet along the face of the parapet, and bridge median barriers will be measured in linear feet along the barrier center line. Parapets and bridge median barriers will be paid for at the contract unit price per linear foot. This price shall include furnishing and installing materials designated above the bridge deck surface, including anchorage material, reinforcing steel, and junction boxes, conduits and or raceways used for rail grounding.

Payment will be made under:

Pay Item	Pay Unit
Railing (Type)	Linear Foot
Parapet (Type)	Linear Foot
Bridge median barrier (Type)	Linear Foot

**SECTION 412 - WIDENING, REPAIRING, AND RECONSTRUCTING EXISTING STRUCTURES****412.01- -Description**

This work shall consist of widening, repairing, or reconstructing existing structures in accordance with plan details and these specifications or as directed by the Engineer. The Department will specify whether latex hydraulic cement concrete or silica fume hydraulic cement concrete will be used on bridge deck in the widening, repairing, or reconstruction of existing structures. The specific overlay deck material and the depth of the overlay will be shown in the contract documents.

**412.02--Materials.**

- (a) **Epoxy and mineral fillers** shall conform to the requirements of Section 243. Epoxy for epoxy mortar shall be Type EP-5. Epoxy used for crack repair shall be Type EP-4 or EP-5, low viscosity.
- (b) **Hydraulic cement concrete and latex hydraulic cement concrete** shall conform to the requirements of Section 217 except No. 57 aggregate may be used for depths and steel clearances more than 2 inches. The inclusion of fly ash or slag will not be permitted in concrete mixes used in bridge deck overlays or deck patching operations.
- (c) **Reinforcing steel** shall conform to the requirements of Section 406.
- (d) **Accelerators** shall be noncorrosive and shall be approved by the Engineer.
- (e) **Materials for Shotcrete** shall be as follows:
  1. Portland and blended cements shall conform to the requirements of Section 214.

2. Fly ash, slag, and silica fume shall conform to the requirements of Section 215.
  3. Water shall conform to the requirements of Section 216.
  4. Air entraining admixtures shall conform to the requirements of Section 215.
  5. High-range and regular water reducers shall conform to the requirements of Section 215.
  6. Accelerators shall conform to the requirements of Section 215 but may be used only if approved by the Engineer. If used, they shall be added at the nozzle.
  7. Fine aggregates shall conform to the requirements of Section 202 for Grading A. Coarse aggregates shall conform to the requirements of Section 203 for size No. 8.
  8. Steel fibers shall have a minimum length of  $\frac{3}{4}$  inches and a diameter between 0.015 and 0.025 inches. They shall have bent or deformed ends or be continuously deformed throughout.
  9. Synthetic fibers shall have a minimum length of  $\frac{3}{4}$  inches and shall have demonstrated long-term resistance to deterioration in concrete.
- (f) **Welded wire fabric** shall conform to the requirements of Section 223 and shall be galvanized or epoxy coated.
- (g) **Expansion bolts** shall conform to the requirements of Section 226.02(d).

#### 412.03--Procedures.

Repairing concrete structures shall consist of removing and replacing deteriorated material, thoroughly cleaning exposed concrete surfaces and reinforcing steel, and replacing reinforcing steel. Cleaning shall be performed by sandblasting, waterblasting, or other approved methods to remove concrete, rust, oil, and other foreign materials detrimental to achieving a bond. The area and depth of repairs shall be as directed by the Engineer.

Dimensions of existing structures shown on the plans are approximate, and those that are pertinent to the construction of the new portion shall be check measured in the field by the Contractor. Where details of new portions of the structure shown on the plans are not adaptable to the shape of the existing structure, practical modifications may be made during construction with the approval of the Engineer provided neither the existing nor the new portions are impaired in structural strength.

Areas to be repaired shall be outlined with saw cuts to a depth of at least 1 inch or to a depth that will clear the top of the reinforcing steel.

Loose and unsound materials shall be removed by the use of hand tools or pneumatic hammers weighing a nominal 35 pounds or less. Hammer weight applies to the weight of the pneumatic hammer alone. Pneumatic hammers shall be worked at an angle of 45 to 60 degrees to the plane of the concrete surface being removed. The surface shall be sounded with a masonry hammer to determine the relative concrete strength.

When reinforcing bars are exposed, the exposed length shall be cleaned. Epoxy-coated steel shall not be cleaned by sandblasting. Damaged epoxy coating shall be repaired in accordance with the requirements of Section 243. Care shall be taken to prevent striking reinforcing bars with hammer points. Reinforcing steel that has lost 1/4 or more

of its original cross-sectional area shall be lapped with new bars of the same size and shape. New bars shall lap existing bars a length of 30 diameters on each side of the damaged portion if a sufficient length of the existing bar is exposed. Otherwise, new bars shall be welded with a 6 inch arc-welded lap on each side of the damaged portion with a double-flare V-groove weld in accordance with the requirements of Section 407 or mechanically connected in accordance with the requirements of Section 406.

Dust and debris shall be removed by blowing with compressed air or hosing with water. A fine spray of moisture shall be applied to the surface to outline, as it evaporates, loose fragments that are locked in place. Just prior to placement of repair material, the surface shall be cleaned.

Unsupported areas shall be supported with forms.

Excess material and debris resulting from repairs shall be removed and disposed of in an approved disposal area in accordance with the requirements of Section 106.04.

Wherever concrete is placed against existing concrete, dowels at least  $\frac{3}{4}$  inches in diameter shall be placed at no more than 2 ft. 6 inches center to center over the entire jointing surface and 6 to 12 inches from the edge. Dowels shall be placed perpendicular to the surface of existing concrete by drilling and grouting and shall project into both new concrete and existing concrete to a depth as great as the thickness of the concrete will allow but need not project more than 9 inches.

For footings and neat work of substructures where joining planes are vertical,  $\frac{3}{4}$  inch headed expansion bolts shall be used instead of dowels. Bolts shall project at least 9 inches into new concrete and shall extend sufficiently far into existing concrete to develop their rated pullout strength, but not less than 6 inches. When drilling holes for expansion bolts, care shall be taken so that existing reinforcing steel is not damaged.

Where necessary to prevent featheredges, existing concrete shall be removed to ensure a thickness for new concrete of at least 6 inches.

Concrete shall be constructed in accordance with the requirements of Section 404 except that surfaces shall be finished to match the existing adjacent surfaces. Superstructure concrete shall be Class 30, and substructure concrete shall be Class 25.

(a) **Bridge Superstructure Repairs:**

1. **Type A milling** shall consist of milling the surface of the bridge deck and concrete approaches to a depth of  $\frac{1}{2}$  inch.

Equipment shall be capable of removing material to the required depth while maintaining a reasonably uniform surface without damaging adjacent areas or the remaining material. Milling equipment shall be capable of removing at least  $\frac{1}{2}$  inch of existing material per pass. Power driven hand tools for removing unsound concrete around reinforcing steel and in confined areas will be required.

2. **Type A patching** shall consist of repairing the deck from the existing deck surface or milled surface to a depth that will not expose reinforcing steel.
3. **Type B patching** shall consist of repairing the deck from the existing deck surface or milled surface to a depth at least 1 inch below the top mat of reinforcing steel.
4. **Type C patching** shall consist of repairing the deck from the existing deck surface or milled surface to its full depth. Forms may be suspended from reinforcing steel by wire ties for areas of less than 3 square feet. In the case of larger area openings, forms shall be supported by blocking. Sound concrete shall be removed to obtain a somewhat vertically shaped surface at the edges of the patch.

5. **Epoxy-mortar patching** shall be performed in accordance with Type A patching and to a depth up to and including  $\frac{3}{4}$  inch. Proportions of sand and epoxy shall be approved by the Engineer. Surface areas to be patched shall be dry and primed with neat epoxy just prior to mortar placement. Mortar may be troweled in place to feather edges. The patched surface shall be sprinkled with sand before the epoxy sets or sandblasted just prior to placement of the seal to ensure bonding. When epoxy mortar is to be the finished riding surface, patches exceeding 8 feet in a longitudinal direction shall be tested in that direction in accordance with the requirements of Section 404.04.
6. **Crack repairs** shall be performed as follows: Structural cracks and dormant cracks shall be V-grooved to a depth of approximately  $\frac{1}{2}$  inch and blown clean. The groove shall be filled with neat epoxy. At the Contractor's option, latex concrete may be brushed into the groove in lieu of epoxy when latex concrete is monolithically placed for Type A, B, or C patching or joint repairs.
7. **Concrete superstructure surface repair** shall include repairing raised medians, median barriers, beams, diaphragms, parapets, posts, rails, curbs, and sidewalks. Superstructure surface repair shall be performed in accordance with Type B patching.

When the thickness of the surface repair is 2 inches or more, 2 inches by 2 inches W 1.4 by W 1.4 welded wire fabric shall be used. The fabric shall be tied to reinforcing steel where possible. If reinforcing steel is not exposed or if the steel has a spacing greater than 18 inches, expansion bolts  $\frac{3}{8}$  inch in diameter shall be placed and the fabric tied to the bolts. The expansion bolts shall be spaced not more than 18 inches apart and shall be embedded at least 2 inches into the concrete. The minimum thickness of Class A and Class B shotcrete over reinforcing steel, including expansion bolts and welded wire fabrics, shall be 2 inches, except in transition areas where shotcrete is feathered to existing concrete with less than 2 inches of cover or where patches are made on existing concrete with less than 2 inches of cover. Where shotcrete containing silica fume is used, the minimum cover over reinforcing steel shall be  $1\frac{1}{2}$  inches.

8. **Joint opening repairs shall be performed as follows:** Expansion joint removal shall consist of removing and disposing of concrete, repairing and replacing reinforcing steel, and cleaning exposed surfaces.

Expansion joint reconstruction shall consist of removing and disposing of concrete, repairing and replacing reinforcing steel, cleaning exposed surfaces, and recasting the joint to the limits detailed with hydraulic cement concrete.

When not included in other joint repairs, saw cutting of the joint shall consist of saw cutting concrete to the limits detailed.

9. **Joint reseal:** Existing joints shall be resealed in accordance with Section 316 of the Specifications, unless otherwise specified on the plans.

- (b) **Bridge Deck Overlay Repairs:** Overlays shall not be placed until deck repair concrete has attained 93 percent of the minimum design compressive strength. Vehicular traffic will not be permitted on the bridge until the overlay has attained a compressive strength of 3,500 pounds per square inch.

Unless otherwise specified, the Contractor may use latex hydraulic cement concrete or silica fume hydraulic cement concrete in the overlay.

Expansion joints and dams shall be maintained through the overlay. A bulkhead equal in thickness to the width of the joint shall be installed to the required grade and profile prior to concrete placement.

A construction dam or bulkhead shall be installed in the case of a major delay in placement operations. During minor delays of 1 hour or less, the end of the placement shall be protected from drying.

1. **Latex, Silica Fume, Ground Granulated Iron Blast Furnace Slag or Class F Fly Ash:** Within 24 hours immediately preceding the beginning of the overlay operations, the entire surface to be overlaid and the edge of previously placed overlay shall be thoroughly cleaned. This shall include the widened portion of bridge decks that are specified to be overlaid with latex, silica fume, ground granulated iron blast furnace slag or Class F Fly Ash concrete.

For at least 1 hour prior to placement of overlay concrete, the surface shall be continuously and thoroughly water soaked. Puddles of standing water shall be removed before overlay is placed.

Overlay shall be placed only when the ambient air temperature is 50 °F and rising. At temperatures above 85 °F, the Engineer may require placement to be made at night or during early morning hours if a satisfactory surface finish is not being achieved.

Mixers for latex hydraulic cement concrete shall be batch mixers or automatic mobile continuous mixers conforming to the requirements of Section 217. The mixing capacity shall be such that placing and finishing operations can proceed at a uniform rate, with final finishing completed before formation of the plastic surface film. Yield test shall be performed by the Contractor prior to deck placement for each mixing unit, when each unit is moved from the job site for recharging, when the source of stockpiled materials is changed and when there is reason to believe that the calibration may be erroneous. Mixers for silica fume, ground granulated iron blast furnace slag or Class F Fly Ash concrete shall be truck mixers conforming to the requirements of Section 217. The amount mixed shall be such that the placing and finishing operations can proceed at a uniform rate. The latex concrete shall be uniform in composition and consistency when discharged from the mixer.

The overlay shall have a thickness of at least 1 ¼ inches of latex, silica fume, ground granulated iron blast furnace slag or Class F Fly Ash hydraulic cement concrete. At the Contractor's option, latex, silica fume, ground granulated iron blast furnace slag or Class F Fly Ash concrete may be used in lieu of hydraulic cement concrete as required for Types A, B or C patching, or joint and crack repairs, and such material shall be placed monolithically with the overlay.

Prior to placement of overlay, a portion of the latex, silica fume, ground granulated iron blast furnace slag or Class F Fly Ash concrete shall be brushed onto the prepared surface. Care shall be taken to ensure that both vertical and horizontal surfaces receive a thorough even coating, and that the rate of progress is limited so that the brushed material does not become dry before it is covered with additional material and brought to final grade. Excess coarse aggregate remaining after brushing shall be removed.

If the rate of evaporation of surface moisture from the latex modified, silica fume, ground granulated iron blast furnace slag or Class F Fly Ash concrete exceeds 0.05 pounds per square foot per hour during placement, measures shall be taken to reduce the rate of evaporation. One effective method is to increase the relative humidity near the surface by fogging.

The surface shall be protected from drying or cracking by prompt application of wet burlap. Care shall be taken to ensure that the burlap is well drained, and that it is placed as soon as the surface will support it without deformation. The burlap and surface of the concrete shall be maintained in a continuously moist condition during the initial curing period. For the latex concrete, the initial moist curing period shall be 48 hours, unless otherwise specified, followed by an additional 48 hours of air curing before opening to traffic. For the silica fume, ground granulated iron blast furnace slag or Class F Fly Ash concrete, the initial moist curing period shall be 72 hours, unless otherwise specified, followed by the immediate application of a liquid membrane-forming curing compound conforming to Section 220. The curing compound shall be completely dry before opening the overlay to traffic.

2. **Polymer:** Polymer overlays shall be placed in accordance with the applicable special provisions.
- (c) **Removing Asphalt Concrete Overlay:** Removal of the asphalt wearing surface from bridge decks and approach slabs shall be performed in a manner such that underlying sound concrete can be prepared to receive necessary treatment. The asphalt material shall be disposed of in an approved manner. Sound concrete damaged as a result of the Contractor's operations shall be repaired in accordance with (a) herein at the Contractor's expense. Fuel oils or other materials that will prevent subsequent treatments from bonding to remaining concrete shall not be used.
- (d) **Bridge Substructure Repairs:** Concrete substructure surface repair shall include repairing piers, wing blocks, and abutments. Substructure surface repair shall be performed in accordance with Type B patching. Removal of concrete shall be to a depth as specified on the plans or as directed by the Engineer. Welded wire fabric shall be installed in accordance with the requirements of (a)7. herein.
- (e) **Blocking and Jacking Beams:** The Contractor shall submit to the Engineer for approval his method of jacking and blocking beams to repair beam seats. Unless approved by the Engineer in writing, structures supported on jacks will not be subjected to traffic loadings.
- (f) **Shotcrete** - When specified for repairs or approved in lieu of hydraulic cement concrete, shotcrete repairs shall be performed in accordance with the requirements of Section 412.03 (a) 7 and (d) herein.
1. **Classes of Shotcrete and Mixture Proportions:** Two classes of shotcrete are established. The minimum amount of cementitious material shall be 658 pounds per cubic yard for Class A, and 635 pounds per cubic yard for Class B. The classes are as follows:
  - a. **Class A** - Class A shotcrete shall be reinforced by either steel or synthetic fibers as specified on the plans and shall have a minimum compressive strength at 28 days of 5,000 pounds per square inch. When steel fibers are used, the minimum fiber content shall be 60 pounds per cubic yard. When synthetic fibers are used, the minimum fiber content shall be 6 ¾ pounds per cubic yard. Shotcrete shall also contain silica fume at a minimum of 7 percent by mass of the cementitious material. Use of fly ash (maximum 20 percent by mass of the cementitious material) or slag (maximum 50 percent by mass of the cementitious material) will be permitted. Minimum thickness of Class A shotcrete cover over reinforcing steel shall be 2 inches except in transition areas where shotcrete is feathered to existing concrete with less than 2 inches of cover or where patches are made on existing concrete with less than 2 inches of cover over reinforcing steel.

- b. **Class B** - Class B shotcrete shall have a minimum 28-day compressive strength of 4,000 pounds per square inch. The cementitious material shall be either all portland cement; portland cement and fly ash (maximum 20 percent by mass of the cementitious material); portland cement and slag (maximum 50 percent by mass of the cementitious material); or portland cement and silica fume (minimum 7 percent by mass of the cementitious material). The minimum thickness of Class B shotcrete cover over reinforcing steel shall be 2 inches except in transition areas where shotcrete is feathered to existing concrete with less than 2 inches of cover or where patches are made on existing concrete with less than 2 inches of cover over reinforcing steel. Where shotcrete containing silica fume is used, the minimum cover over reinforcing steel shall be 1 ½ inches.

The Contractor shall submit for the Engineer's approval shotcrete mixture proportions and performance test data for each class of shotcrete based on the materials to be used in the project. If appropriate recent test data does not exist, the Contractor shall prepare trial mixtures and submit the test results as obtained from tests specified in Section B.

**Wet Process:** Shotcrete subject to freezing and thawing shall contain an air content of 7.0% ± 1.5% as delivered to the job site. The materials for wet process shotcrete shall be mixed in accordance with the requirements of Section 217 and applied within 90 minutes after batching.

**Dry Process:** Solid ingredients for dry-mix shotcrete shall be predampened as needed and mixed in a batch type or continuous mixer. Most of the mixing water shall be added at the nozzle. Dry-mix shotcrete material shall be applied within 45 minutes after batching or predampening.

## 2. **Equipment and Personnel:**

- a. **Equipment:** Shotcrete delivery equipment shall be approved by the Engineer before the commencement of the work. It shall be capable of discharging the shotcrete mixture in a continuously smooth stream of uniformly mixed ingredients. Air added at the nozzle shall be free from oil or other contaminants, and the air pressure shall be capable of maintaining sufficient nozzle velocity to all parts of the work.
- b. **Personnel:** Nozzlemen with at least 100 hours of recent similar shotcrete application experience and supervisors with at least 3 years of recent similar shotcreting experience who can provide references showing satisfactory performance on at least three similar jobs may be approved as being qualified without gunning prequalifying panels.

When proposed nozzlemen do not have the required experience or when the Engineer deems the work to be done is of a sufficiently critical nature to require prequalifying tests for nozzlemen, approval will be based on test panels as described herein prior to the commencement of the work. The Engineer will observe the gunning of such test panels and judge the qualifications of the nozzleman on the basis of the texture, uniformity of work, and adequacy of the encasement of shotcrete around the reinforcement.

## 3. **Surface Preparation**

- a. The perimeter of all areas where concrete is removed shall be tapered at approximately a 45-degree angle, except that the outer edges of all areas removed by chipping shall be sawcut perpendicular to the surface to a minimum depth of ½ inch to prevent featheredging unless otherwise approved by the Engineer.

- b. Earth surfaces shall be trimmed to line and grade and shall have adequate support to prevent displacement during shotcrete placement. Shotcrete shall not be placed on an earth surface that is frozen, spongy, or subject to free running water at the time of the application of shotcrete. Active seeps, drips, and flowing water shall be controlled by installation of suitable drain systems such that water pressure does not build behind shotcrete linings. The Contractor shall prevent excessive loss of mixing water from the shotcrete. This shall be accomplished by one of the following procedures:
    - 1. Wet the soil prior to the time of gunning to the extent that it is damp but with no visible free water on the surface. Puddling, ponding, or free standing water shall be eliminated from areas to be shotcreted.
    - 2. As an alternative or when specified, install a moisture barrier system to inhibit the movement of moisture from the newly placed shotcrete into the earth. Wrinkling and folding of moisture barrier will not be permitted.
  - c. Rock surfaces shall be free of loose material, debris, chips, mud, dirt, and other foreign matter. Surfaces shall be damp at the time of gunning, but puddling, ponding, or free standing water shall not be permitted.
  - d. Wood forms which are to be removed after use shall have a form release agent applied to prevent the absorption of moisture and inhibit the bond between shotcrete and the form.
4. **Application:**
- a. When applied, shotcrete shall have a temperature of at least 50 °F but not more than 85 °F. The ambient and surface temperature shall be 50 °F and rising. At ambient air temperatures above 85 °F the Engineer may require placement to be made at night or during early morning hours.
  - b. Shotcrete to be applied to uneven and previously repaired surfaces shall first be applied to any deep hole, deeply excavated sections, corners, or areas where rebound cannot escape or be blown free. The thickness of the shotcrete layer shall be such that no sloughing, sagging, tearing, or debonding will occur. Existing concrete shall be sandblasted within 24 hours of application and the surface shall be damp just prior to application.
  - c. Where a layer of shotcrete is to be covered by a succeeding layer, it shall be first allowed to develop its initial set. Then all loose, uneven, or excess material, glaze, and rebound shall be removed by brooming, scraping, or other means. Any surface deposits that take a final set shall be removed by sandblasting, and the surface cleaned with an air-water blast from the nozzle. Curing compounds shall not be applied to surfaces that will be covered by an additional layer of shotcrete.
  - d. Shooting wires, ground wires, or other devices acceptable to the Engineer shall be used to control the line, grade, and thickness of the shotcrete.
  - e. During the shotcrete application, the nozzle shall be held perpendicular to, and when possible, 3 to 5 feet away from the receiving surface and rotated steadily in series of small oval or circular patterns. Whenever possible, sections shall be gunned in one layer to the full design thickness. However, for multiple layers of reinforcement, gunning of one layer of shotcrete may be required for each layer of reinforcement.

- f. When encasing reinforcement, the nozzle shall be held closer than normal and at a slight upward angle. The mixture may be wetter than normal, but not so wet that sloughing behind the reinforcement will occur.
- g. Vertical surfaces shall be gunned starting at the bottom. Rebound or previously expended material shall not be incorporated in the applied layer, and all such material shall be removed from the surface and work area prior to final set and before placement of shotcrete on adjacent surfaces. Shotcrete shall not be placed if drying or stiffening of the mixture is occurring.

5. **Finishing:**

Prior to the initial set, the shotcrete surface shall be scraped or cut with a trowel or metal template to obtain an even and aesthetically acceptable appearance. The final finishing shall be with a wet sponge unless otherwise specified. Trowel or float smoothing will not be allowed.

6. **Curing:**

After gunning, the surfaces of shotcrete shall be protected from drying or cracking. When necessary, fogging shall be used prior to the application of moist curing or a curing compound. Shotcrete shall be moist cured for a period of at least 7 days or cured using a curing compound conforming to the requirements of Section 220 of the Specifications. The rate of application shall be not less than 1 liter of curing compound per 100 square feet of surface. The color of the curing compound shall be approximately that of the existing concrete.

7. **Quality Assurance and Testing:**

- a. Preconstruction testing may be waived by the Engineer if it can be shown that the crew to be used is qualified and that the mixture has been successfully used in similar work.

Test panels 24 inches x 24 inches x 4 inches deep containing steel reinforcement representative of that to be used on the project shall be prepared. Each crew shall gun two test panels with the mix design to be used on the project and for each gunning orientation to be encountered on the job. Panels will be cured in the field in the same manner as the structure for 1 day and transported to the laboratory, where curing shall be continued until time of testing. For shotcrete jobs of less than 200 square feet, the Contractor shall cut one of the test panels with a trowel or a metal template before the initial set, in the presence of the Engineer, to check visually for possible voids under the reinforcement. For larger jobs where specific evidence of good encasement of reinforcing bars is needed, the Contractor shall cut cores from the test panels after the concrete has hardened for at least 3 days. Cores shall be cut through the steel.

The second panels for all jobs shall be used to determine the compressive strength of the applied shotcrete. Cores shall be 2 inches to 4 inches in diameter and shall be taken between the reinforcement and tested by the Department at the specified age in accordance with the requirements of ASTM C42.

- b. In-place shotcrete shall be of uniform quality and free from segregation, honeycombing, sand pockets, sand lenses, sagging, dry patches, overspray, rebound, or incomplete encasement of reinforcement. It shall also be free from delamination, cracking, or single voids with dimensions in excess of ¼ inches.

The Department reserves the right to test any section and reject shotcrete that does not conform to the specification requirements in terms of test values, soundings, and visual examination. Cost of any additional testing of disputed shotcrete that results in rejection shall be borne by the Contractor.

The Contractor shall remove and replace or correct defective shotcrete to the satisfaction of the Engineer.

- c. For compressive strength tests, one test panel shall be prepared for each day's production or for each 200 square feet of shotcreting by each crew using the same ingredients and gunning orientation as the shotcrete applied to the job. These panels shall be cured and delivered to the designated testing laboratory as earlier specified in this section.

Test values on such panels shall equal or exceed the required 28 day strength requirements. Should failures occur, acceptance of the material will be determined by tests on cores from the applied work. A minimum of three cores shall be taken from the area in question. The average compressive strength of the cores taken from the work shall equal or exceed the specified strength for the class of shotcrete applied, and no single core shall have a strength less than 85 percent of the specified value. If deemed necessary by the Engineer, the adequacy of bond between the existing concrete and the shotcrete shall be determined by pull-off tests in accordance with the requirements of ACI 503. A minimum bond strength of 250 psi will be accepted as satisfactory. Bond failure at less than 250 psi due to failure of existing concrete will not be cause for rejection. The cost of up to three pull-off tests will be the responsibility of the Contractor, additional pull-off tests will be the responsibility of the Department.

#### **412.04--Measurement and Payment.**

Volumes outlined by the completed excavation, formwork, and surfaces of the existing concrete will be measured prior to concrete placement so that quantities can be accurately computed.

**Hydraulic cement concrete** for the class specified will be measured and paid for in accordance with the requirements of Section 404.

**Type A milling** will be measured and paid for in square yard for the depth specified.

**Types A, B, and C patching and concrete substructure or superstructure surface repair** will be measured in square yards of surface area and will be paid for at the contract unit price per square yard. This price shall include furnishing and placing concrete to fill the prepared areas.

**Epoxy-mortar patching** will be measured in gallons of epoxy-mixed system used as a binder for mortar in place and for priming prior to application of epoxy mortar and will be paid for at the contract unit price per gallon.

**Expansion joint removal, expansion joint reconstruction, and back wall reconstruction** will be measured in linear feet and will be paid for at the contract unit price per linear foot. This price shall include furnishing and placing concrete to fill the prepared areas for expansion joint reconstruction and backwall reconstruction.

**Saw cutting**, when a pay item, will be measured in linear feet of concrete sawed and will be paid for at the contract unit price per linear foot.

**Jacking and blocking of beams** as required to complete beam seat repair, when a pay item, will be paid for on an each basis per beam end.

**Latex hydraulic cement concrete** will be measured and paid for at the contract unit price per square yard on a plan quantity basis. The price bid will be full compensation for producing, delivering, and placing the latex hydraulic cement concrete mix to the job site. This price shall also include handling, finishing, and curing the latex hydraulic cement concrete, and for all material, labor, tools, equipment, and incidentals necessary to complete the work. Latex hydraulic cement concrete shall be placed within the range of depth specified and verified by the Engineer prior to and during placement operations. The Engineer may direct additional depth of latex hydraulic cement concrete to address cross slope and other surface irregularities and ride-ability issues. Additional latex hydraulic cement concrete beyond the depth range of the pay item that is requested to address such issues at the direction of the Engineer will be compensated for in accordance with Sections 104.02 and 109.05 of the Specifications. Only those volumes of additional latex hydraulic cement concrete that are approved by the Engineer prior to or during the placement of the overlay will be considered for payment. Payment will be made for the actual cost only for furnishing the mixture to the jobsite.

**Silica fume hydraulic cement concrete** will be measured and paid for at the contract unit price per square yard on a plan quantity basis. The price bid will be full compensation for furnishing silica fume hydraulic cement concrete, placing, handling, finishing and curing the silica fume hydraulic cement concrete and for all material, labor, tools, equipment and incidentals necessary to complete the work. Silica fume hydraulic cement concrete shall be placed within the range of depth specified and verified by the Engineer prior to and during placement operations. The Engineer may direct additional depth of silica fume hydraulic cement concrete to address cross slope and other surface irregularities and ride-ability issues. Additional silica fume hydraulic cement concrete beyond the depth range of the pay item that is requested to address such issues at the direction of the Engineer will be compensated for in accordance with Sections 104.02 and 109.05 of the Specifications. Only those volumes of additional silica fume hydraulic cement concrete that are approved by the Engineer prior to or during the placement of the overlay will be considered for payment. Payment will be made for the actual cost only for furnishing the mixture to the jobsite.

**Placing latex and silica fume hydraulic cement concrete** will be measured and paid for at the contract unit price per square yard and paid for on a plan quantity basis, which will be full compensation for placing, finishing and curing the latex or silica fume hydraulic cement concrete.

**Crack repair** will be measured in linear feet and will be paid for at the contract unit price per linear foot.

**Removal of asphalt concrete overlay** will be measured in square yards of surface area and will be paid for at the contract unit price per square yard.

**Shotcrete**, when specified as a pay item, will be measured in square yard of surface to which it is applied and will be paid for at the contract unit price per square foot or per cubic foot for the type specified.

These prices shall include cutting, drilling, hammering, and all other work involved in the complete removal and disposal of concrete and other materials necessary to provide for joining the new and old portions of the structure according to the plans or as directed by the Engineer. The contract unit price shall also include dowels or other approved anchoring devices, disposing of surplus material, cleaning and repairing reinforcing steel, and welded wire fabric, if necessary. If Class A shotcrete is used, the price shall also include steel or synthetic fibers.

Payment will be made under:

Pay Item	Pay Unit
Type A milling (depth)	Square yard
Type A patching	Square yard
Type B patching	Square yard

Type C patching	Square yard
Epoxy-mortar patching	Gallon
Concrete substructure surface repair	Square yard
Concrete superstructure surface repair	Square yard
Expansion joint removal	Linear Foot
Expansion joint reconstruction	Linear Foot
Back wall reconstruction	Linear Foot
Saw cutting	Linear Foot
Jacking and blocking	Each
Crack repair	Linear Foot
Removal of asphalt concrete overlay	Square yard
Pneumatically applied mortar	Square yard
Shotcrete (Class __)	Square foot or cubic foot
Latex hydraulic cement concrete (1 ¼ inches – 1 ¾ inches)	Square Yard
Silica fume hydraulic cement concrete (1 ¼ inches – 1 ¾ inches)	Square Yard

## Division V

# Incidental Construction

### SECTION 502--INCIDENTAL CONCRETE ITEMS

#### 502.01--Description.

This work shall consist of constructing curbs, gutters, combination curbs and gutters, paved ditches, paved flumes, bridge drainage aprons and chutes, concrete median barriers, median strips, sign islands, and directional island curbs in accordance with these specifications and in reasonably close conformity to the lines and grades shown on the plans or as established by the Engineer.

#### 502.02--Materials.

- (a) **Hydraulic cement concrete** shall conform to the requirements of Section 217. With the approval of the Engineer, the design of the mixture may be modified to accommodate the placement equipment to be used.
- (b) **Asphalt concrete** shall conform to the requirements of Section 211.

- (c) **Preformed joint filler** shall conform to the requirements of Section 212. Material shall be approximately ½ inch in thickness and shall have a width and depth equal to those of the incidental structure.
- (d) **Curing materials** shall conform to the requirements of Section 220.
- (e) **Reinforcing steel** shall conform to the requirements of Section 223, Grade 40 or 60.
- (f) **Rubble stone** shall conform to the requirements of Section 205.
- (g) **Grout** shall conform to the requirements of Section 218.
- (h) **Foundation course** shall be aggregate No. 68 conforming to the requirements of Section 203.
- (i) **Dry filler** shall consist of aggregate conforming to the requirements of Section 202 or 203, as applicable.
- (j) **Seed** shall conform to the requirements of Section 244.
- (k) **Topsoil** shall conform to the requirements of Section 244.

#### 502.03--Procedures.

The foundation shall be constructed to the required elevation. Unsuitable material shall be removed and replaced as directed by the Engineer. The subgrade shall be thoroughly compacted and shaped to provide a uniform, smooth surface. The foundation for hydraulic cement concrete items shall conform to the specified density of the course and shall be moist when concrete is placed.

Immediately following finishing operations, hydraulic cement concrete shall be cured and protected in accordance with the requirements of Section 316.04.

##### (a) Fixed Form Requirements

Fixed forms shall be straight, free from warp, and of such construction that there will be no interference with the inspection of grade and alignment. Forms shall extend the entire depth of the item and shall be braced and secured so that no deflection from alignment or grade will occur during concrete placement. Radial forms shall be sufficiently flexible or otherwise designed to provide a smooth, uniform, curved surface of the required radius. Face forms shall be removed as soon as concrete has attained sufficient set for the curb to stand without slumping. The exposed surface shall then be smoothed by the use of a suitable finishing tool.

Transverse joints for crack control for fixed forms shall be provided at the following locations:

1. at approximately 20 foot intervals;
2. at the gutter where the curb and gutter tie to the gutter apron of drop inlets;
3. when time elapsing between consecutive concrete placements exceeds 45 minutes.
4. No section shall be less than 6 feet in length.

Crack control joints may be formed by using one of the following methods:

- a. removable 1/8 inch thick templates
- b. scoring or sawing for a depth of not less than 3/4 inches when using curb machine
- c. approved "leave-in" type insert or may be formed or created using other approved methods which will successfully induce and control the location and shape of the transverse cracks.

The joint at the gutter where the curb and gutter ties to the apron gutter of the drop inlet shall be formed by scoring or sawing.

Expansion joints shall be formed at intervals of approximately 100 feet, all radii points at concrete entrances and curb returns and at locations no less than 6 feet and no more than 10 feet from drop inlets.

Hydraulic cement concrete shall be sufficiently consolidated to produce a uniform, closed surface. Edges shall be rounded to a 1/4 inch radius.

Exposed surfaces immediately adjacent to the roadway, except concrete median barrier, shall be given a light broom finish. Concrete median barrier shall be given a Class 1 finish in accordance with the requirements of Section 404.07(a). Paved ditches and paved flumes shall be given a coarse or roughened texture. Other exposed surfaces shall be given a rough wood float finish. Mortar used in the removal of surface irregularities shall be prepared in accordance with the requirements of Section 218.

**(b) Slipform Requirements**

The Contractor will be permitted to slipform incidental concrete items provided the following conditions contained herein are met. Approval by the Department to allow the contractor the option of slipforming concrete items is permissive only and in no way relieves the Contractor from his responsibility to meet the contract requirements and conditions.

Slipform equipment shall produce a product equal to or better than that produced by fixed form construction. Equipment for slipforming operations shall be designed or engineered to form the type of construction design for which its use is intended. Where equipment has been modified to such an extent that its use is questionable, the Contractor may be required at his expense to demonstrate to the Engineer's satisfaction that the equipment can consistently produce the desired type of construction. The slipform equipment shall be self-propelled and shall be equipped to consolidate, form, extrude, and finish the freshly placed concrete in such a manner that a minimum of hand finishing is required to produce a dense, consolidated, homogenous product. Slipform equipment shall be controlled to line and grade by automatic sensing, guidance and control devices such that the machine automatically senses and follows taut guidelines or other stable reference, performing any necessary corrective action to ensure the correct grade and alignment is achieved. The Contractor shall ensure the slipform operation is planned to result in the full cross section and grade of the desired design at the beginning and end of the placement. Slipform equipment shall operate with a continuous forward movement. The Contractor shall plan and stage the work to eliminate the need for the slipform machine to be stopped during placement operations. If for any reason it is absolutely necessary to stop the forward progress of the machine; operation of the vibrating

and tamping elements shall be stopped immediately. Equipment used for slipforming shall conform to the general requirements of Section 108.07. If the results of the slipform operation are not satisfactory to the Engineer in accordance with the requirements stated herein, the continued use of the equipment will not be permitted.

Concrete for use in slipform operations may be manufactured with a slump as low as zero ("0"). The top of the slump range shall conform to the class of concrete specified on the plans or special provisions in accordance with Section 217. The concrete shall have properties that consistently maintain workability and the cross section, line, and grade of the proposed product. Concrete shall be finished to a light broom finish. If water is held back to maintain the desired slump, it may be added in increments provided the maximum water per cubic yard has not been exceeded and a minimum of 30 revolutions at mixing speed is used for complete mixing.

Where reinforcing steel is incorporated into the proposed design, it shall be uncoated steel conforming to Section 223. Reinforcing steel shall be tied at 100 percent of the bar intersections and shall be sufficiently strengthened with braces, additional reinforcement or chairs to make the reinforcement cage rigid so as to prevent any movement during concrete placement. If the reinforcing steel exhibits any movement during concrete placement using slipforming methods, the work shall be suspended until the reinforcing steel has been sufficiently tied and stabilized to the satisfaction of the Engineer. The reinforcing steel shall be continuous from fixed object to fixed object. All reinforcing steel shall have the appropriate amount of concrete cover for the particular design with a tolerance of  $-0 + \frac{1}{2}$  inch; however, in no case shall the amount of cover be less than  $1 \frac{1}{2}$  inches. Reinforcing steel inserted in the freshly placed concrete shall be inserted with the use of vibration to achieve adequate bond of the reinforcing steel. Where bonding is suspect, the Engineer may require pull out tests be performed by the Contractor at his expense. If such tests confirm the presence of adequate bond, the Department will reimburse the Contractor the cost of such testing.

The maximum height of any extrusion shall be limited such that the alignment and cross sectional shape of the design is maintained within the construction tolerances. If the Contractor elects to use or is required to use multiple placements to achieve a particular design, the Contractor shall submit a plan outlining the details of each placement for approval by the Engineer prior to beginning placement operations. Where multiple placements are permitted for installation of a particular design, the separate placements shall be staged so that any horizontal joints incorporated in the phased construction shall be arranged in such a manner as to prevent water infiltration in the final design and water flowing through any longitudinal joint.

Where weep holes are part of the proposed median barrier design, the Contractor shall use 6 inch diameter underdrain pipe in lieu of weep holes. Underdrain pipe conforming to Section 232 shall be installed at the grade at the bottom of the footing and shall terminate in catch basins or drop inlets.

Where naturally occurring vertical contraction cracking occurs and where there exists a grade separation on each side of the barrier, the Contractor shall install a waterproofing membrane conforming to Section 213, spanning  $1 \frac{1}{2}$  feet on each side of the contraction crack at the back surface of the higher grade side of the barrier to prevent water from passing through the barrier.

Expansion joint material 1 ½ inches thick shall be installed adjacent to each fixed object. Expansion material shall be placed against each fixed object prior to placement of the slipformed concrete. Contraction joints will not be required with slipformed operations provided the reinforcing steel is continuous from fixed object to fixed object.

(c) **Individual Item Requirements**

1. **Hydraulic Cement Concrete Curbs, Gutters, Combination Curbs and Gutters, Paved Ditches, and Paved Flumes:** Where standard mountable curb or combination curb and gutter with mountable curb is specified, adjacent curbs of standard entrance gutter and standard connection for streets shall be modified to provide a mountable shape corresponding to the standard mountable shape.

Where integral curb is specified, the curb shall be placed simultaneously with or immediately after placement of the slab. The time period between slab and curb placement shall be not more than 45 minutes except as hereinafter specified. The surface of the slab on which the curb is to be placed shall be roughened, and the concrete shall be placed so as to secure a bond between the slab and curb.

When authorized by the Engineer, the Contractor may construct the integral curb by providing steel dowels 5/8 inches in diameter, 7 inches in length, to be embedded in the slab at 1 foot intervals. Dowels shall be placed so as to extend at least 2 inches into the curb. While the slab is still plastic, it shall be roughened to a depth of approximately ½ inch below the screeded surface for the full width of the curb.

Local irregularities in the face and top of curbs shall be not more than 3/8 inch in 10 feet. Vertical alignment shall be sufficiently uniform and regular to ensure complete drainage.

Any curb, gutter or combination curb and gutter, except those on structures, may be placed by the slipform method provided the finished product is true to line, cross section and grade and the concrete is dense and has the required surface texture. The concrete shall be of such consistency that it will remain the desired shape or cross section of the design without support.

Where concrete curb and or curb and gutter is placed over existing pavement, it shall be anchored to the existing pavement either by placing steel dowels and reinforcing steel or by using an approved adhesive. Steel dowels shall be firmly mortared with 1:1 Portland cement and sand mortar in holes drilled in the pavement. If an adhesive is used, the surface of the pavement shall be thoroughly cleaned before the adhesive is applied. Adhesive shall be EP-4 epoxy resin, a two component system conforming to Section 243 of the Specifications. The pavement shall be cleaned either by blast cleaning or by wire brushing so that the prepared surface is free of dust, loose material, oil, or any other material that may prove deleterious to bonding.

The grade for the top of the extruded curb shall be indicated by an offset guideline set by the Contractor from survey information supplied to the Department. The forming tube portion of the extrusion machine shall be readily adjustable vertically to accommodate, when necessary, a variable height of curb conforming to the predetermined curb grade line. A grade line gage or pointer shall be attached to the machine to monitor the elevation of the curb being placed against the established

grade line so as to make corrective adjustment as necessary. In lieu of a grade line gage or pointer the extrusion machine may be operated on rails or forms set to produce the predetermined finished grade line for the curbing.

Concrete shall be continuously fed to the slipforming machine at a uniform rate. The machine shall be operated under sufficient uniform restraint of forward motion so as to produce a well compacted homogenous mass of concrete free from surface pits larger than 1/2 inch in diameter and requiring no further finishing other than light brushing with a broom. Finishing with a brush application of grout will not be permitted.

Expansion joints shall be constructed as specified for fixed formed curbing or shall be constructed by sawing through the curb section to its full depth. The width of the cut shall be such to allow the insertion of the joint filler with a snug fit. If sawing is performed before the concrete has hardened, the adjacent portions of the curb shall be supported firmly with close fitting shields. The operations of sawing and inserting the joint filler shall be completed before curing the concrete.

If sawing is performed after the concrete has hardened, the joint filler shall be mortared in place with heavy trowel pressure. After sawing is performed, all exposed portions of the curb in the vicinity of the joint shall be covered with another application of curing compound. At the conclusion of the curing period, the filler in each sawn joint shall be checked for tightness of fit. Any loose filler shall be mortared in place again and cured.

Within 3 to 7 days, the Contractor shall backfill curb, gutter and combination curb and gutter to the required elevation with approved material. Backfill material shall be compacted with curbs and gutters remaining plumb.

2. **Asphalt Concrete Curbs and Paved Ditches:** The curb shall be placed on a clean dry surface. Immediately prior to placement of the asphalt mixture, a tack coat of asphalt shall be applied to the surface at a rate between 0.05 and 0.15 gallons per square yard of surface. Asphalt shall be prevented from spreading outside the area to be occupied by the curb.

Asphalt concrete curb shall be placed by a self-propelled automatic curb machine or a paver having curbing attachments to form a satisfactorily compacted curb of a uniform texture, shape, and density. The Engineer may permit construction of curbs by other means when short sections or sections with short radii are required. The resulting curbs shall conform in all respects to curbs produced by a curb machine.

Sealing or painting shall be performed only on curbs that are clean, dry, and cooled to ambient temperature.

Asphalt concrete paved ditches shall be placed and compacted so as to provide a smooth, uniform, and dense texture.

3. **Grouted Rubble Gutter:** Aggregate for the foundation course shall be spread on the subgrade to a depth of at least 4 inches.

Gutter stones shall be bedded in the foundation course perpendicular to the finished surface, flat side up, in straight rows, with the longest dimension perpendicular to the centerline of the gutter. Joints shall be broken in a satisfactory manner, and the width of interstices in the dry gutter shall be not more than 1 inch.

Stones shall be rammed until the surface is firm and conforms to the finished grade and cross section. Joints shall then be filled with dry filler to within 4 inches of the top of stones, and the surface shall be rammed to ensure proper compaction of filler. After irregularities have been corrected, cement grout shall be poured and broomed into joints and over stones. Additional grout shall be applied and brooming shall be continued until grout remains flush with the top of stones.

4. **Concrete Median Barriers:** Concrete median barriers shall be constructed in accordance with the requirements specified herein and in Sections 512, 404, and 410.

Concrete median barriers shall be constructed within an allowable tolerance of  $\pm 1/2$  inch for overall depth and overall width,  $\pm 1/4$  inch for the width of the upper portion of the barrier, and  $\pm 1/4$  inch per 10 feet for horizontal alignment.

After the specified curing time has elapsed, concrete median barriers for roadways shall be backfilled to the required elevation with approved material. Material shall be thoroughly tamped in layers not more than 6 inches in depth before compaction. Delineators shall be installed on median barriers in accordance with the requirements of Section 702.03.

#### **502.04--Measurement and Payment.**

**Standard concrete curbs, radial curbs, standard combination curb and gutter, radial combination curb and gutter, and asphalt concrete curbs** will be measured in linear feet along the face of the curb, complete-in-place, and will be paid for at the contract unit price per linear foot. The price shall include modifying curbs for standard entrance gutters, standard street connection pavement, and standard median strips. Where the curb or curb and gutter is adjacent to drop inlets, the contract unit price for the drop inlets shall include that part of the curb or curb and gutter within the limits of the structure.

Where there is no excavation within the limits of the curb, gutter, combination curb and gutter, or median barrier other than that necessary for its construction, the contract unit price shall include excavating, backfilling, compacting, and disposing of surplus and unsuitable material. Where excavation is necessary for the roadway, the part within the limits of the curb, gutter, combination curb and gutter, or median barrier section will be paid for as regular excavation in accordance with the requirements of Section 303.06.

**Standard, radial, entrance, and grouted rubble gutters; paved ditches; paved flumes; street connection pavement; and bridge drainage aprons and chutes** will be measured in square yards of surface area, complete-in-place, and will be paid for at the contract unit price per square yard. The price for grouted rubble gutter shall include rubble stone, grout, foundation course, and filler. When pipe drain ditch liner is substituted for standard paved ditch at the Contractor's option, payment will be made at the contract unit price for the standard paved ditch specified. When pipe drain ditch liner is specified on the plans, payment will be made at the contract unit price per linear foot, complete-in-place.

The cost of excavation below the finished grade or below the slope surface of cut or fill sections that is necessary for installing and backfilling paved ditches and flumes shall be included in the contract unit price for the paved ditch or flume. Undercut excavation below the neat lines of paved ditches in cut sections, including replacement backfill for

undercut excavation and excavation above the upper lateral limits of paved ditches and paved flumes that are outside the normal plan earthwork limits, will be measured and paid for in accordance with the requirements of Section 303.06.

**Ditch Flume Connector** will be measured in units of each, complete in place, and will be paid for at the contract unit price per each. This price shall include excavation when required, dowels, welded wire fabric, reinforcing steel, anchor lugs, curtain walls and concrete.

**Cattle guards** will be measured in units of each, complete-in-place, and will be paid for at the contract unit price per each.

**Energy dissipators** will be measured in units of each, complete-in-place, and will be paid for at the contract unit price per each.

**Median barriers** will be measured in linear feet along the centerline of barriers complete in place and will be paid for at the contract unit price per linear foot. Unless otherwise specified, this price shall include furnishing and placing delineators, aggregate, excavation, backfill, weep hole covering, concrete cap, dowels and joint sealer.

**Curb-cut ramps** will not be measured for separate payment but will be measured in the units specified for their components.

**Median strips** will be measured in linear feet as specified and will be paid for at the contract unit price per square yard or linear foot.

**Sign islands** will be measured in units of each or square yards, complete-in-place, exclusive of posts and signs, and will be paid for at the contract unit price per each or per square yard.

**Directional island curbs** will be measured in linear feet along the face of the curb and will be paid for at the contract unit price per linear foot.

**Embankment material between curb lines** will be measured and paid for in accordance with the requirements of Section 303.06 except as specified below.

When there is no excavation or construction other than that necessary for constructing median strips, sign islands, or directional island curbs, the contract unit price shall include excavating, removing existing pavement, disposing of surplus and unsuitable material, backfilling, and compacting. When excavation or demolition of pavement is necessary for the adjoining roadway, that portion within the limits of the median strip, sign island, or directional island curb will be paid for as regular excavation or demolition of pavement in accordance with the requirements of Sections 303.06 and 508.03, respectively.

These prices shall include applying topsoil and seed.

Payment will be made under:

Pay Item	Pay Unit
Curb (Type and standard)	Linear Foot
Combination curb and gutter (Type and standard)	Linear Foot
Gutter (Type and standard)	Square yard
Paved ditch (Standard)	Square yard
Pipe drain ditch liner (Standard)	Linear Foot
Paved flume (Standard)	Square yard

Energy dissipator (Standard)	Each
Entrance gutter (Standard)	Square yard
Street connection pavement (Standard)	Square yard
Median barrier (Standard)	Linear Foot
Bridge drainage apron and chute (Standard)	Square yard
Median strip (Standard width)	Square Yard or Linear Foot
Sign island (Standard)	Each or Linear Foot
Directional island curb (Standard)	Linear Foot
Cattle guard (Standard)	Each
Ditch flume connector (Standard)	Each

#### SECTION 509--PATCHING HYDRAULIC CEMENT CONCRETE PAVEMENT

##### 509.01--Description.

This work shall consist of removing designated areas of defective hydraulic cement concrete pavement and unstable subbase material, replacing subbase material where required, and replacing pavement with high-early-strength hydraulic cement concrete in accordance with these specifications and in reasonably close conformity to the original lines and grades or those established by the Engineer.

##### 509.02--Materials.

- (a) **Hydraulic cement concrete** shall conform to the requirements of Section 217 for Class A3 paving concrete except that the compressive strength shall be at least 3,000 psi within 24 hours. The accelerated strength gain shall be achieved by the use of  $800 \pm 50$  pounds per cubic yard of Type III cement conforming to the requirements of AASHTO M-85 and approved air-entraining, accelerating, and water-reducing admixtures conforming to the requirements of Section 215. If calcium chloride is permitted as an accelerating admixture, it shall be limited to 2 percent by mass. The air content shall be  $6 \pm 2$  percent. The water/cement ratio shall be not more than 0.42 by weight.

The Contractor shall prepare a sufficient number of trial batches in the presence of the Engineer to verify the strength and workability of the mixture design when required. The continued adequacy of the mixture design and minimum compressive strength will be verified monthly by the Engineer.

- (b) **Asphalt concrete** shall conform to the requirements of Section 211 except that material may be accepted by certification and visually inspected at the job site.
- (c) **Subbase material** shall conform to the requirements of Section 208.
- (d) **Preformed asphalt joint filler and joint sealer** shall conform to the requirements of Section 212.

- (e) **Curing material** shall conform to the requirements of Section 220.
- (f) **Reinforcing steel** shall conform to the requirements of Section 223.

#### 509.03--Procedures.

Where the existing joint dowel assembly is to be removed, existing concrete shall be saw cut and removed at least 1 foot on each side of transverse joints. Undisturbed portions of pavement adjacent to the area to be patched shall be left with straight, vertical sides. In areas from which concrete has been removed, the subbase shall be dressed, brought to grade, and mechanically compacted. Dowels and assemblies shall be removed and disposed of off the project.

Saw cuts shall not extend into adjacent concrete pavement except when repairs are to be extended at that location. Saw cuts shall be straight, neat, vertical, and parallel or perpendicular to the center line as required.

Unsuitable subbase shall be removed, disposed of, and replaced in accordance with the requirements of Section 307 or 308, whichever is applicable. Where soil cement subbase is present and sound, excavation below the top of the soil cement line and under adjacent slabs will not be required.

Preformed asphalt joint filler shall be installed in accordance with the requirements of Section 316.04(g)2.

Joint material and reinforcing steel shall be placed in accordance with the following:

1. **Patches less than 10 feet in length:** Preformed asphalt joint filler shall be placed flush against the run-off side of the adjacent pavement.
2. **Patches greater than 10 feet in length:** Preformed asphalt joint filler shall be placed flush against sides of the adjacent pavement.
3. **Patches 20 feet in length or greater:** Patches shall conform to the requirements of the applicable reinforced concrete pavement standards.
4. **Load transfer devices used in initial construction:** Load transfer devices shall be left intact, straightened, and used for tying in the replaced slab or shall be replaced with an approved load transfer device.
5. **Joints:** Rounded or beveled transverse joints shall be provided adjacent to the undisturbed pavement to allow installation of sealant at a depth of at least  $\frac{1}{4}$  inch but not more than  $\frac{1}{2}$  inch.

The excavated area shall be thoroughly cleaned and moistened before concrete is placed.

Full-depth forms shall be of sufficient strength to support plastic concrete without deformation.

Existing pavement shall not be removed if removal will result in concrete being placed when the air temperature is below 55 °F. The concrete temperature at the time of placement shall be at least 70 °F but not more than 95 °F.

Concrete shall be placed on the subgrade and consolidated so that it fills the area of the patch. Concrete shall be finished in accordance with the requirements of Section 316.04(h) except that the final surface shall have a texture similar to that of the adjoining pavement.

As soon as concrete is finished and prior to its initial set, the patch and existing pavement for a distance of 8 feet shall be tested by means of a 10-foot straightedge placed parallel to the center line of the road surface. Irregularities in the patch in excess of  $\frac{1}{4}$  inch shall be corrected.

Immediately after it has been textured, concrete shall be covered with wet burlap and PE film. An insulating blanket shall be placed over the PE film whenever the air temperature is below 65 °F during the curing period. Curing shall continue until immediately before opening to traffic but will not be required beyond 24 hours.

Transverse joints at pavement repair locations shall be cleaned and resealed in accordance with the requirements of Section 316.04(m).

Asphalt concrete shoulders that are damaged during repair operations shall be reconstructed within 24 hours after completion of a patch in accordance with the requirements of Section 315 with full-depth SM-2A asphalt concrete to match the finished grade. If traffic is to be permitted on the patch prior to reconstruction of the shoulder, the shoulder shall be temporarily repaired to prevent any hazardous condition.

Traffic shall be maintained in accordance with the requirements of Section 512 or as directed by the Engineer.

**509.04--Measurement and Payment.**

Patching hydraulic cement concrete pavement will be measured in square yards of pavement surface area, complete-in-place, and will be paid for at the contract unit price per square yard. This price shall include saw cutting pavement full depth; removing and disposing of existing concrete; preparing subgrade; furnishing and installing preformed asphalt joint filler; placing, finishing, and curing special design concrete; trial batches; cleaning and resealing joints; repairing shoulders; sealing joints; and reinforcing steel.

Payment will be made under:

Pay Item	Pay Unit
Patching hydraulic cement concrete pavement	Square yard



## Answers to Concrete Plant Study Questions and Problems

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### CHAPTER 1 – for Concrete Plant

1. **Hydration** is the chemical reaction between water and cement.
2. **Workability** is the property of freshly mixed concrete which is the ease or difficulty in the placing and finishing of concrete.
3. A chemical, such as calcium chloride used to “speed up” the setting time of concrete is **accelerator**.
4. **False set** is a significant loss of plasticity shortly after the concrete is mixed.
5. The time it takes a cement paste to begin hardening is known as **setting time**.
6. A condition at which an aggregate will neither absorb moisture from concrete nor contribute moisture to the mix is **saturated surface dry**.
7. **Set retarder** is a material used for the purpose of delaying the setting time of concrete.
8. **Consistency** is a condition of plastic concrete which relates to its cohesion, wetness, or to flow.
9. **Cement** is the bonding agent used in a concrete mix.
10. The ability of hardened concrete to resist the deterioration caused by weathering, chemicals, and abrasion is known as **durability**.
11. The pH value of water used with cement shall be between **4.5** and **8.5** as found in Section **216.02**.
12. Gypsum is added to cement to control **time of set**.
13. List two desirable qualities of hardened concrete: **durability and water-tightness (others listed on page 1-1)**.
14. The primary effect of air entrainment in concrete is to improve **freeze thaw resistance**.
15. List two desirable properties of an aggregate: **low absorption and abrasive resistance (others listed on pages 1-6 to 1-8)**.

16. Admixtures shall be dispensed **according to manufacturer recommendations and within an accuracy of +/-3%.**
17. List two principal raw components in the manufacture of cement: **Lime and Silica.**
18. The type of cement which has the highest fineness reading and the highest tricalcium silicate (C3S) composition, both factors in accelerated strength is **Type III.**
19. The void content of identically graded fine aggregates will vary with **particle shape.**
20. **3.15** is the specific gravity of Portland Cement.
21. **Water-cement ratio** has the greatest effect on the strength, durability and water tightness of concrete.
22. If the amount of admixture is constant and the concrete temperature is increased, the entrained air content will **decrease.**
23. A pH value of 6.0 indicates **acidity** and a pH value of 7.5 indicates **alkalinity.**
24. The strength requirements for High Early Strength Portland Cement Concrete shall be obtained in **7 days** as stated in Section **217.08(b).**
25. In no case shall a vibrator be operated longer than **15** seconds in any one location as stated in Section **316.04(e).**
26. The specification requirements for the approval to use admixtures in Hydraulic Cement Concrete are found in Section **215.03.**
27. Each batch of concrete shall be delivered to the site of work and discharged within **90 minutes** of the time the cement is introduced into the mixture unless approved otherwise by the Engineer as found in Section **217.09(b).**
28. According to Section **217.10,** in cold weather, **water and aggregates** may be heated; however, **cement** is not to be heated.
29. Is Wash water from hydraulic cement concrete mixer operations is permitted to be reused in the concrete mix? **Yes, according to Section 216.02.**

## CHAPTER 2 – Concrete PLANT

### Sieve Analysis - No. 1

Check the following sieve analysis of a sample of natural sand for use in concrete subject to abrasion and determine if it meets Virginia Department of Transportation requirements for Grading "A" Sand. Circle the sieve not passing, if any.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0	0.0	100.0	100
No. 4	16.6	2.9	97.1	95-100
No. 8	64.5	11.3	88.7	80-100
No. 16	214.1	37.4	62.6	50-85
No. 30	389.2	67.9	32.1	25-60
No. 50	483.0	84.3	15.7	5-30
No. 100	543.4	94.8	5.2	0-10
No. 200	565.0	98.6	1.4	0-3
<b>Total Wt.</b>	<b><u>573.0</u></b>			

Yes XX No \_\_\_\_\_

What is the Fineness Modulus? 2.99

$$\frac{0.0+2.9+11.3+37.4+67.9+84.3+94.8}{100} = \frac{298.6}{100} = \underline{2.99}$$

## Sieve Analysis - No. 2

Check the following sieve analysis of a sample of natural sand for use in concrete subject to abrasion and determine if it meets Virginia Department of Transportation requirements for Grading "A" Sand. Circle the sieve not passing, if any.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0	0.0	100.0	100
No. 4	6.9	1.4	98.6	<del>95-100</del>
No. 8	28.3	5.6	94.4	80-100
No. 16	34.9	6.9	93.1	50-85
No. 30	219.2	43.6	56.4	25-60
No. 50	398.8	79.3	20.7	5-30
No. 100	482.9	96.0	4.0	0-10
No. 200	498.1	99.0	1.0	0-3
<b>Total Wt.</b>	<b><u>503.0</u></b>			

Yes \_\_\_\_\_ No XX

What is the Fineness Modulus? 2.33

$$\frac{0.0+1.4+5.6+6.9+43.6+79.3+96.0}{100} = \frac{232.8}{100} = \underline{2.33}$$

### Sieve Analysis - No. 3

Check the following sieve analysis of a sample of natural sand for use in concrete not subject to abrasion and determine if it meets Virginia Department of Transportation requirements for Grading "A" Sand. Circle the sieve not passing, if any.

Sieve Size	Cumulative Grams Retained	Cumulative %Retained	%Passing	VDOT Specs. (%Passing)
3/8 inch	0.0	0.0	100.0	100
No. 4	6.7	1.4	98.6	95-100
No. 8	54.0	11.3	88.7	80-100
No. 16	168.6	35.1	64.9	50-85
No. 30	340.5	70.9	29.1	25-60
No. 50	407.7	84.9	15.1	5-30
No. 100	459.1	95.6	4.4	0-10
No. 200	468.1	97.5	2.5	0-5
<b>Total Wt.</b>	<b><u>480.0</u></b>			

Yes XX No \_\_\_\_\_

What is the Fineness Modulus? 2.99

$$\frac{0.0+1.4+11.3+35.1+70.9+84.9+95.6}{100} = \frac{299.2}{100} = \underline{2.99}$$

# CHAPTER 3 – Concrete PLANT

## ACI MIX DESIGN PROBLEM NO. 1

CLASS A4 MIX DESIGN MODIFIED

WITH Flyash

FINE AGGREGATE

COARSE AGGREGATE

F.M. 2.70

DRY RODDED UNIT WT. 103 lb/ft<sup>3</sup>

SP. GR. 2.64

SP. GR. 2.63

NOMINAL MAX. SIZE C.A. 1 inch

TABLE A1.5.3.6 FACTOR 0.68

OTHER DATA NEEDED FOR SPECIAL DESIGNS Flyash 20% Replacement  
Sp. Gr. 2.35

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 0.68 X 27 ft<sup>3</sup> X UNIT WT. 103 = 1891 lbs.

### ABSOLUTE VOLUMES

PORTLAND CEMENT .20 x 635 = 127  $\frac{635 - 127 = 508 \text{ lbs.}}{3.15 \times 62.4}$  = 2.58 ft<sup>3</sup>

WATER  $\frac{.45 \times 635 = 286 \text{ lbs.}}{1.00 \times 62.4}$  = 4.58 ft<sup>3</sup>

AIR  $\frac{6.5}{100} \% \times 27 =$  1.76 ft<sup>3</sup>

C. AGGR.  $\frac{1891 \text{ lbs.}}{\text{SP.GR. } 2.63} \times 62.4 =$  11.52 ft<sup>3</sup>

ADDITIONAL MATERIALS  $\frac{.20 \times 635 = 127}{2.35 \times 62.4} =$  0.87 ft<sup>3</sup>

27.00 ft<sup>3</sup> TOTAL = 21.31 ft<sup>3</sup>  
- 21.31 ft<sup>3</sup>

F.A. 5.69 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 937 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 508 kg

WATER 286 lbs. or 34.3 gals.

AIR 6.5 %

C. AGGR. 1891 lbs. - [ ] + [ ]

F. AGGR. 937 lbs. - [ ] + [ ]

ADDL. MATLS. Flyash = 127 lbs.

### ACI MIX DESIGN PROBLEM NO. 2

CLASS **A4 General** MIX DESIGN

MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE \_\_\_\_\_ COARSE AGGREGATE \_\_\_\_\_  
 F.M. 3.0 DRY RODDED UNIT WT. 105lb/ft<sup>3</sup>  
 SP. GR. 2.64 SP. GR. 2.83 NOMINAL  
 MAX. SIZE C.A. 1 inch TABLE A1.5.3.6 FACTOR 0.65 OTHER \_\_\_\_\_  
 DATA NEEDED FOR SPECIAL DESIGNS Sp.Gr. of IP 3.02

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.65 X 27 ft<sup>3</sup> X UNIT WT. 105 = 1843 lbs.

**ABSOLUTE  
VOLUMES**

IP <del>PORTLAND</del> CEMENT	<u>635</u> lbs.	=	<u>3.37</u> ft <sup>3</sup>
	<small>3.15 x 62.4</small>		
WATER	<u>.45 x 635 = 286</u> lbs.	=	<u>4.58</u> ft <sup>3</sup>
	<small>1.00 x 62.4</small>		
AIR	<u>6.5</u> % x 27	=	<u>1.76</u> ft <sup>3</sup>
	<small>100</small>		
C. AGGR.	<u>1843</u> lbs.	=	<u>10.44</u> ft <sup>3</sup>
	<small>SP.GR. <u>2.83</u> X 62.4</small>		
ADDITIONAL MATERIALS	_____	=	_____ ft <sup>3</sup>
	_____	=	_____ ft <sup>3</sup>
	TOTAL	=	<u>20.15</u> ft <sup>3</sup>

27.00 ft<sup>3</sup>  
 - 20.15 ft<sup>3</sup>

F.A. 6.85 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1128 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 635 lbs.  
 WATER 286 lbs. or 34.3 gals.  
 AIR 6.5 %  
 C. AGGR. 1843 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]  
 F. AGGR. 1128 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]  
 ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

### ACI MIX DESIGN PROBLEM NO. 3

CLASS A4 Post & Rail MIX DESIGN

FINE AGGREGATE F.M. <u>2.7</u> SP. GR. <u>2.62</u> NOMINAL MAX. SIZE C.A. <u>½ inch</u>	MODIFIED WITH	<u>Slag</u> COARSE AGGREGATE DRY RODDED UNIT WT. <u>101 lb/ft<sup>3</sup></u> SP. GR. <u>2.62</u> TABLE A1.5.3.6 FACTOR <u>0.56</u>
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OTHER DATA NEEDED FOR SPECIAL DESIGNS Slag 40% Replacement (Sp. Gr. 2.94)  
w/c 0.43

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.56 X 27 ft<sup>3</sup> X UNIT WT. 101 = 1527 lbs.

#### ABSOLUTE VOLUMES

PORTLAND CEMENT .40 x 635 = 254  $\frac{635 - 254}{3.15 \times 62.4} = 381$  lbs. = 1.94 ft<sup>3</sup>

WATER  $\frac{.43 \times 635}{1.00 \times 62.4} = 273$  lbs. = 4.38 ft<sup>3</sup>

AIR  $\frac{7.0}{100} \times 27 = 1.89$  ft<sup>3</sup>

C. AGGR.  $\frac{1527}{\text{SP.GR. } 2.62} \times 62.4 = 9.34$  ft<sup>3</sup>

ADDITIONAL MATERIALS 40% Slag  $\frac{635 \times .40}{2.94 \times 62.4} = 1.38$  ft<sup>3</sup>

TOTAL = 18.93 ft<sup>3</sup>

27.00 ft<sup>3</sup>  
 - 18.93 ft<sup>3</sup>

F.A. 8.07 ft<sup>3</sup> X 2.62 SP.GR. X 62.4 = 1319 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 381 lbs.

WATER 273 lbs. or 32.8 gals.

AIR 7.0 %

C. AGGR. 1527 lbs. - [ ] + [ ]

F. AGGR. 1319 lbs. - [ ] + [ ]

ADDL. MATLS. Slag = 254 lbs.

\_\_\_\_\_ =

**ACI MIX DESIGN PROBLEM NO. 4 - MODIFIED WITH FLY ASH**

CLASS A4 General MIX DESIGN

MODIFIED WITH Fly Ash

FINE AGGREGATE	COARSE AGGREGATE
F.M. <u>3.0</u>	DRY RODDED UNIT WT. <u>105 lb/ft<sup>3</sup></u>
SP. GR. <u>2.64</u>	SP. GR. <u>3.04</u>
NOMINAL MAX. SIZE C.A. <u>1 inch</u>	TABLE A1.5.3.6 FACTOR <u>0.65</u>

OTHER DATA NEEDED FOR SPECIAL DESIGNS Fly Ash 20% Replacement  
Sp. Gr. 2.35

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.65 X 27 ft<sup>3</sup> X UNIT WT. 105 = 1843 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT  $.20 \times 635 = 127$   $\frac{635 - 127}{3.15 \times 62.4} = 508$  lbs. = 2.58 ft<sup>3</sup>

WATER  $.45 \times 635 = 286$  lbs. = 4.58 ft<sup>3</sup>  
 $\frac{286}{1.00 \times 62.4}$

AIR  $\frac{6.5}{100} \times 27 = 1.76$  ft<sup>3</sup>

C. AGGR.  $\frac{1843 \text{ lbs.}}{3.04 \text{ SP.GR.}} \times 62.4 = 9.72$  ft<sup>3</sup>

ADDITIONAL MATERIALS  $\frac{635 \times .20 = 127}{2.35 \times 62.4} = 0.87$  ft<sup>3</sup>  
 = \_\_\_\_\_ ft<sup>3</sup>

TOTAL = 19.51 ft<sup>3</sup>

27.00 ft<sup>3</sup>  
 - 19.51 ft<sup>3</sup>

F.A. 7.49 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1234 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 508 lbs.

WATER 286 lbs. or 34.3 gals.

AIR 6.5 %

C. AGGR. 1843 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

F. AGGR. 1234 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]

ADDL. MATLS. Fly Ash = 127 lbs.

\_\_\_\_\_ =

**ACI MIX DESIGN PROBLEM NO. 5**

CLASS A4 General MIX DESIGN

MODIFIED WITH \_\_\_\_\_

FINE AGGREGATE \_\_\_\_\_ COARSE AGGREGATE \_\_\_\_\_  
 F.M. 2.8 DRY RODDED UNIT WT. 100 lb/ft<sup>3</sup>  
 SP. GR. 2.64 SP. GR. 3.04  
 NOMINAL MAX. SIZE C.A. 1 inch TABLE A1.5.3.6 FACTOR 0.67  
 OTHER DATA NEEDED FOR SPECIAL DESIGNS IS Sp. Gr. 3.05

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.67 X 27 ft<sup>3</sup> X UNIT WT. 100 = 1809 lbs.

**ABSOLUTE VOLUMES**

IS PORTLAND CEMENT  $\frac{635 \text{ lbs.}}{3.05 \times 62.4} = 3.34 \text{ ft}^3$   
 WATER  $\frac{.45 \times 635 = 286 \text{ lbs.}}{1.00 \times 62.4} = 4.58 \text{ ft}^3$   
 AIR  $\frac{6.5 \% \times 27}{100} = 1.76 \text{ ft}^3$   
 C. AGGR.  $\frac{1809 \text{ lbs.}}{\text{SP.GR. } 3.04 \times 62.4} = 9.54 \text{ ft}^3$

ADDITIONAL MATERIALS \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>  
 \_\_\_\_\_ = \_\_\_\_\_ ft<sup>3</sup>

27.00 ft<sup>3</sup>  
 - 19.22 ft<sup>3</sup>  
 TOTAL = 7.78 ft<sup>3</sup>

F.A. 7.78 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1282 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 635 lbs. WATER  
286 lbs. or 34.3 gals. AIR  
6.5 %  
 C. AGGR. 1809 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]  
 F. AGGR. 1282 lbs. - [ \_\_\_\_\_ ] + [ \_\_\_\_\_ ]  
 ADDL. MATLS. \_\_\_\_\_ =  
 \_\_\_\_\_ =

### ACI MIX DESIGN PROBLEM NO. 6

CLASS A3 General MIX DESIGN

MODIFIED WITH Slag

FINE AGGREGATE	COARSE AGGREGATE
F.M. <u>3.0</u>	DRY RODDED UNIT WT. <u>99 lb/ft<sup>3</sup></u>
SP. GR. <u>2.64</u>	SP. GR. <u>2.62</u>
NOMINAL MAX. SIZE C.A. <u>1 inch</u>	TABLE A1.5.3.6 FACTOR <u>0.65</u>
OTHER DATA NEEDED FOR SPECIAL DESIGNS <u>40% Slag Replacement (Sp. Gr. 2.94)</u>	

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.65 X 27 ft<sup>3</sup> X UNIT WT. 99 = 1737 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT	.40 x 588 = 235	$\frac{588 - 235}{3.15 \times 62.4} = 353$	lbs.	=	<u>1.80</u>	ft <sup>3</sup>
WATER	.49 x 588 = 288	$\frac{288}{1.00 \times 62.4} = 4.62$	lbs.	=	<u>4.62</u>	ft <sup>3</sup>
AIR	6.0	$\frac{6.0}{100} \times 27 = 1.62$	%	=	<u>1.62</u>	ft <sup>3</sup>
C. AGGR.	1737	$\frac{1737}{2.62 \times 62.4} = 10.62$	lbs.	=	<u>10.62</u>	ft <sup>3</sup>
ADDITIONAL MATERIALS	.40 x 588 = 235	$\frac{235}{2.94 \times 62.4} = 1.28$	lbs.	=	<u>1.28</u>	ft <sup>3</sup>
				=	<u>19.94</u>	ft <sup>3</sup>
		TOTAL		=	<u>19.94</u>	ft <sup>3</sup>
	27.00					ft <sup>3</sup>
	- 19.94					ft <sup>3</sup>

F.A. 7.06 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1163 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT	<u>353</u>	lbs.	
WATER	<u>288</u> lbs. or <u>34.6</u>	gals.	
AIR	<u>6.0</u>	%	
C. AGGR.	<u>1737</u>	lbs.	- [ <u>        </u> ] + [ <u>        </u> ]
F. AGGR.	<u>1163</u>	lbs.	- [ <u>        </u> ] + [ <u>        </u> ]
ADDL. MATLS.	<u>Slag</u>	= <u>235</u>	lbs.
	<u>        </u>	=	

**ACI MIX DESIGN PROBLEM NO. 7**

CLASS A3 Paving MIX DESIGN

MODIFIED WITH Slag

FINE AGGREGATE \_\_\_\_\_ COARSE AGGREGATE \_\_\_\_\_  
 F.M. 2.7 DRY RODDED UNIT WT. 104 lb/ft<sup>3</sup>  
 SP. GR. 2.64 SP. GR. 2.60  
 NOMINAL MAX. SIZE C.A. 1 inch TABLE A1.5.3.6 FACTOR 0.68  
 OTHER DATA NEEDED FOR SPECIAL DESIGNS 50% Slag Replacement (Sp. Gr. 2.94)

QUANTITY OF COARSE AGGREGATE  
 TABLE A1.5.3.6 0.68 X 27 ft<sup>3</sup> X UNIT WT. 104 = 1909 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT  $.50 \times 564 = 282$  lbs. =  $\frac{282}{3.15 \times 62.4} = 1.43$  ft<sup>3</sup>  
 WATER  $.49 \times 564 = 276$  lbs. =  $\frac{276}{1.00 \times 62.4} = 4.42$  ft<sup>3</sup>  
 AIR  $\frac{6.0}{100} \% \times 27 = 1.62$  ft<sup>3</sup>  
 C. AGGR.  $\frac{1909 \text{ lbs.}}{\text{SP.GR. } 2.60} \times 62.4 = 11.77$  ft<sup>3</sup>  
 ADDITIONAL MATERIALS 50% Slag  $\frac{564 \times .50 = 282}{2.94 \times 62.4} = 1.54$  ft<sup>3</sup>  
 TOTAL = 20.78 ft<sup>3</sup>  
 27.00 ft<sup>3</sup>  
 - 20.78 ft<sup>3</sup>

F.A. 6.22 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1025 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 282 lbs.  
 WATER 276 lbs. or 33.1 gals.  
 AIR 6.0 %  
 C. AGGR. 1909 lbs. - [ ] + [ ]  
 F. AGGR. 1025 lbs. - [ ] + [ ]  
 ADDL. MATLS. Slag = 282 lbs.  
 \_\_\_\_\_ =

### ACI MIX DESIGN PROBLEM NO. 8 - MODIFIED WITH FLY ASH

CLASS A3 General MIX DESIGN

MODIFIED WITH Fly Ash  
COARSE AGGREGATE

FINE AGGREGATE

F.M. 2.8

DRY RODDED UNIT WT. 105 lb/ft<sup>3</sup>

SP. GR. 2.64

SP. GR. 2.63

NOMINAL MAX. SIZE C.A. 1 inch

TABLE A1.5.3.6 FACTOR 0.67

OTHER DATA NEEDED FOR SPECIAL DESIGNS 20% Fly Ash Replacement  
Sp. Gr. 2.22

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 0.67 X 27 ft<sup>3</sup> X UNIT WT. 105 = 1899 lbs.

#### ABSOLUTE VOLUMES

PORTLAND CEMENT  $\frac{588 \times .80}{3.15 \times 62.4} = 2.39$  ft<sup>3</sup>

WATER  $\frac{.49 \times 588}{1.00 \times 62.4} = 4.62$  ft<sup>3</sup>

AIR  $\frac{6.0}{100} \times 27 = 1.62$  ft<sup>3</sup>

C. AGGR.  $\frac{1899}{2.63 \times 62.4} = 11.57$  ft<sup>3</sup>

ADDITIONAL MATERIALS  $\frac{588 \times .20}{2.22 \times 62.4} = 0.85$  ft<sup>3</sup>

TOTAL = 21.05 ft<sup>3</sup>

27.00 ft<sup>3</sup>

- 21.05 ft<sup>3</sup>

F.A. 5.95 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 980 lbs.

SUGGESTED QUANTITIES ± 5% TOLERANCE

CEMENT 470 lbs.

WATER 288 kg or 34.6 gals.

AIR 6.0 %

C. AGGR. 1899 lbs. - [ ] + [ ]

F. AGGR. 980 lbs. - [ ] + [ ]

ADDL. MATLS. Fly Ash = 118 lbs.

\_\_\_\_\_ =

**ACI MIX DESIGN PROBLEM NO. 9 - MODIFIED WITH FLY ASH**

CLASS A4 General MIX DESIGN

MODIFIED WITH Fly Ash  
COARSE AGGREGATE

FINE AGGREGATE

F.M. 3.0

DRY RODDED UNIT WT. 98 lb/ft<sup>3</sup>

SP. GR. 2.64

SP. GR. 2.62

NOMINAL MAX. SIZE C.A. 1 inch

TABLE A1.5.3.6 FACTOR 0.65

OTHER DATA NEEDED FOR SPECIAL DESIGNS 25% Fly Ash Replacement  
Sp. Gr. 2.30

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 0.65 X 27 ft<sup>3</sup> X UNIT WT. 98 = 1720 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT .25 x 635 = 159  $\frac{635 - 159}{3.15 \times 62.4} = 476$  lbs. = 2.42 ft<sup>3</sup>

WATER .45 x 635 = 286 lbs. = 4.58 ft<sup>3</sup>  
 $\frac{286}{1.00 \times 62.4}$

AIR 6.5 % x 27 = 1.76 ft<sup>3</sup>  
 $\frac{6.5}{100}$

C. AGGR.  $\frac{1720}{2.62 \times 62.4} = 10.52$  ft<sup>3</sup>  
SP.GR. 2.62 X 62.4

ADDITIONAL MATERIALS  $\frac{635 \times .25 = 159}{2.30 \times 62.4} = 1.11$  ft<sup>3</sup>

TOTAL = 20.39 ft<sup>3</sup>

27.00 ft<sup>3</sup>

- 20.39 ft<sup>3</sup>

F.A. 6.61 ft<sup>3</sup> X 2.64 SP.GR. X 62.4 = 1089 lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT 476 lbs.

WATER 286 lbs. or 34.3 gals.

AIR 6.5 %

C. AGGR. 1720 lbs. - [ ] + [ ]

F. AGGR. 1089 lbs. - [ ] + [ ]

ADDL. MATLS. Fly Ash = 159 lbs.

=

**ACI MIX DESIGN PROBLEM NO. 10 - MODIFIED WITH SLAG**

CLASS A4 Post & Rail MIX DESIGN

MODIFIED WITH Slag  
COARSE AGGREGATE

FINE AGGREGATE

F.M. 2.80

DRY RODDED UNIT WT. 102 lb/ft<sup>3</sup>

SP. GR. 2.83

SP. GR. 2.81

NOMINAL MAX. SIZE C.A. ½ inch

TABLE A1.5.3.6 FACTOR 0.55

OTHER DATA NEEDED FOR SPECIAL DESIGNS Slag 50% Replacement (Sp. Gr. 2.85 )

QUANTITY OF COARSE AGGREGATE

TABLE A1.5.3.6 0.55 X 27 ft<sup>3</sup> X UNIT WT. 102 = 1515 lbs.

**ABSOLUTE VOLUMES**

PORTLAND CEMENT 635 x .50 = 318  $\frac{635 - 318}{3.15 \times 62.4} = \frac{317}{197.76}$  lbs. = 1.61 ft<sup>3</sup>

WATER  $\frac{.45 \times 635}{1.00 \times 62.4} = \frac{286}{62.4}$  lbs. = 4.58 ft<sup>3</sup>

AIR  $\frac{7.0}{100} \% \times 27 = 1.89$  ft<sup>3</sup>

C. AGGR.  $\frac{1515}{SP.GR. 2.81} \times 62.4 = 8.64$  ft<sup>3</sup>

ADDITIONAL MATERIALS 50% Slag  $\frac{635 \times .50}{2.85 \times 62.4} = \frac{318}{178.74}$  = 1.79 ft<sup>3</sup>

TOTAL = 18.51 ft<sup>3</sup>

27.00 ft<sup>3</sup>

- 18.51 ft<sup>3</sup>

F.A. 8.49 ft<sup>3</sup> X 2.83 P.GR. X 62.4 = 1499 lbs.

SUGGESTED QUANTITIES

± 5% TOLERANCE

CEMENT 317 lbs.

WATER 286 lbs. or 34.3 gals.

AIR 7.0 %

C. AGGR. 1515 lbs. - [ ] + [ ]

F. AGGR. 1499 lbs. - [ ] + [ ]

ADDL. MATLS. Slag 50% = 318 lbs.

=

### ACI MIX DESIGN ADJUSTMENT PROBLEM NO. 1

The following Class A4 General Use mix design produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One Cu. Yard  
Based on SSD Condition

IP Cement	635 lbs.	Sand - F. M.	2.80
Sand	1150 lbs.	Sand - Sp. Gr.	2.64
No. 57	1954 lbs.	CA - Sp. Gr.	3.04
Water	286 lbs.	CA - Unit Weight	108 lb/ft <sup>3</sup>
Air	6.5 %	IP Cement - Sp. Gr.	3.05

#### ANSWERS

Cement 635 lbs.

Sand 1208 lbs.

No. 57 1888 lbs.

Water 286 lbs.

Air 6.5% lbs.

#### CALCULATIONS:

$$\text{SAND: } 1150 \times 0.05 = 57.5$$

$$1150 + 58 = 1208$$

$$\text{NO 57: } \frac{58}{2.64 \times 62.4} = \frac{58}{164.736} = 0.35$$

$$0.35 \times 3.04 \times 62.4 = 66.0$$

$$1954 - 66 = 1888$$

## ACI MIX DESIGN ADJUSTMENT PROBLEM NO. 2

The following Class A3 General Use mix design produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One Cu. Yard  
Based on SSD Condition

IS Cement	588 lbs.	Sand - F. M.	2.70
Sand	983 lbs.	Sand - Sp. Gr.	2.66
No. 57	1909 lbs.	CA - Sp. Gr.	2.61
Water	288 lbs.	CA - Unit Weight	104 lb/ft <sup>3</sup>
Air	6.0 %	IS Cement - Sp. Gr.	3.02

### ANSWERS

Cement 588 lbs.

Sand 1032 lbs.

No. 57 1860 lbs.

Water 288 lbs.

Air 6.0 %

### CALCULATIONS:

SAND:  $983 \times 0.05 = 49.15$

$983 + 49 = 1032$

NO 57:  $\frac{49}{2.66 \times 62.4} = \frac{49}{165.984} = 0.30$

$0.30 \times 2.61 \times 62.4 = 49$

$1909 - 49 = 1860$

### ACI MIX DESIGN ADJUSTMENT PROBLEM NO. 3

The following Class A4 General Use mix design modified with 40% slag produced a harsh mix. The contractor wants to reduce the harshness. What are the maximum allowable adjustments under VDOT specifications that could be made to reduce the harshness?

Mix Design - One Cu. Yard  
Based on SSD Condition

Cement	381 lbs.	Sand - F. M.	2.70
Sand	1285 lbs.	Sand - Sp. Gr.	2.62
No. 57	1799 lbs.	CA - Sp. Gr.	3.04
Water	286 lbs.	CA - Unit Weight	98 lb/ft <sup>3</sup>
Air	6.5 %		
Slag	254 lbs.	Slag - Sp. Gr.	2.95

#### ANSWERS

Cement 381 lbs.

Sand 1349 lbs.

No. 57 1725 lbs.

Water 286 lbs.

Air 6.5 %

Slag 254 lbs.

#### CALCULATIONS:

$$\text{SAND: } 1285 \times 0.05 = 64.25$$

$$1285 + 64 = 1349$$

$$\text{NO 57: } \frac{64}{2.62 \times 62.4} = \frac{64}{163.488} = 0.39$$

$$0.39 \times 3.04 \times 62.4 = 74$$

$$1799 - 74 = 1725$$

### ACI MIX DESIGN ADJUSTMENT PROBLEM NO. 4

The following Class A3 General Use Mix Design produced a 2 inch slump. The contractor wants a 3 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One Cu. Yard  
Based on SSD Condition

IP Cement	588 lbs.	Sand - F. M.	2.80
Sand	1107 lbs.	Sand - Sp. Gr.	2.64
No. 57	1934 lbs.	CA - Sp. Gr.	2.83
Water	288 lbs.	CA - Unit Weight	106.9 lb/ft <sup>3</sup>
Air	6.0 %	IP Cement - Sp. Gr.	3.05

#### ANSWERS

Cement 588 lbs.

Sand 1052 lbs.

No. 57 1992 lbs.

Water 288 lbs.

Air 6.0 %

#### CALCULATIONS:

$$\text{SAND: } 1107 \times 0.05 = 55.35$$

$$1107 - 55 = 1052$$

$$\text{NO 57: } \frac{55}{2.64 \times 62.4} = \frac{55}{164.736} = 0.33$$

$$0.33 \times 2.83 \times 62.4 = 58$$

$$1934 + 58 = 1992$$

### ACI MIX DESIGN ADJUSTMENT PROBLEM NO. 5

The following Class A3 general use mix design modified with 20% flyash produced a 3 inch slump. The contractor wants a 4 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One Cu. Yard  
Based on SSD Condition

Cement	470 lbs.	Sand - F. M.	2.80
Sand	1120 lbs.	Sand - Sp. Gr.	2.83
No. 57	1863 lbs.	CA - Sp. Gr.	2.62
Water	288 lbs.	CA - Unit Weight	103 lb/ft <sup>3</sup>
Air	6.0 %		
Flyash	118 lbs.	Flyash - Sp. Gr.	3.00

#### ANSWERS

Cement 470 lbs.

Sand 1064 lbs.

No. 57 1915 lbs.

Water 288 lbs.

Air 6.0 %

Flyash 118 lbs.

#### CALCULATIONS:

$$\text{SAND: } 1120 \times 0.05 = 56$$

$$1120 - 56 = 1064$$

$$\text{NO 57: } \frac{56}{2.83 \times 62.4} = \frac{56}{176.592} = 0.32$$

$$0.32 \times 2.62 \times 62.4 = 52$$

$$1863 + 52 = 1915$$

### ACI MIX DESIGN ADJUSTMENT PROBLEM NO. 6

The following Class A4 general use mix design produced a 2 inch slump. The contractor wants a 3 inch slump. What are the maximum allowable adjustments under VDOT specifications that could be made to increase the slump as much as possible?

Mix Design - One Cu. Yard  
Based on SSD Condition

IS Cement	635 lbs.	Sand - F. M.	2.90
Sand	1094 lbs.	Sand - Sp. Gr.	2.62
No. 57	1871 lbs.	CA - Sp. Gr.	2.83
Water	286 lbs.	CA - Unit Weight	105 lb/ft <sup>3</sup>
Air	6.5 %	IS Cement - Sp. Gr.	3.02

#### ANSWERS

Cement 635 lbs.

Sand 1039 lbs.

No. 57 1931 lbs.

Water 286 lbs.

Air 6.5 %

#### CALCULATIONS:

$$\text{SAND: } 1094 \times 0.05 = 54.7$$

$$1094 - 55 = 1039$$

$$\text{NO 57: } \frac{55}{2.62 \times 62.4} = \frac{55}{163.488} = 0.34$$

$$0.34 \times 2.83 \times 62.4 = 60$$

$$1871 + 60 = 1931$$

## CHAPTER 4 – Concrete PLANT

### MOISTURE PROBLEM NO. 1

- A. Given the following information, determine the percent of free moisture in the sand and No. 57.

#### SAND

Weight of wet sample = 635 grams  
Weight of dry sample = 598 grams

#### NO. 57

Weight of wet sample = 1240 grams  
Weight of dry sample = 1220 grams

#### ABSORPTION

Sand = 0.6%  
No. 57 = 0.2%

Free Moisture: Sand 5.6% No. 57 1.4%

#### CALCULATIONS:

Sand:	$\begin{array}{r} 635 \\ -598 \\ \hline 37 \end{array}$	$\frac{37}{598} \times 100 = 6.2$	$\begin{array}{r} 6.2 \\ -0.6 \\ \hline 5.6\% \end{array}$
No. 57	$\begin{array}{r} 1240 \\ -1220 \\ \hline 20 \end{array}$	$\frac{20}{1220} \times 100 = 1.6$	$\begin{array}{r} 1.6 \\ -0.2 \\ \hline 1.4\% \end{array}$

- B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or "pull weights" for one cubic yard.

Mix Design - One Cubic Yard  
Based on SSD Condition

Batch Quantities

Cement	635 lbs.	Cement	<u>635</u> lbs.
Sand	1067 lbs.	Sand	<u>1127</u> lbs.
No. 57	1835 lbs.	No. 57	<u>1861</u> lbs.
Water	288 lbs.	Water	<u>202</u> lbs.
			<u>24.2</u> gals.
Air	6.5 %	Air	<u>6.5</u> %

CALCULATIONS:

Sand:  $1067 \times 0.056 = 60$

$$1067 + 60 = 1127$$

No. 57:  $1835 \times 0.014 = 26$

$$1835 + 26 = 1861$$

Water:  $60 + 26 = 86$

$$288 - 86 = 202$$

$$\frac{202}{8.33} = 24.2 \text{ gals.}$$

## MOISTURE PROBLEM NO. 2

- A. Given the following information, determine the percent of free moisture in the sand and No. 57.

### SAND

Weight of wet sample = 628 grams

Weight of dry sample = 582 grams

### NO. 57

Weight of wet sample = 1245 grams

Weight of dry sample = 1215 grams

### ABSORPTION

Sand = 0.9%

No. 57 = 0.4%

Free Moisture: Sand 7.0% No. 57 2.1%

### CALCULATIONS:

$$\begin{array}{r} \text{Sand: } 628 \\ \underline{-582} \\ 46 \end{array} \quad \begin{array}{r} \underline{46} \\ 582 \end{array} \times 100 = 7.9 \quad \begin{array}{r} 7.9 \\ \underline{-0.9} \\ 7.0 \end{array}$$

$$\begin{array}{r} \text{No. 57: } 1245 \\ \underline{-1215} \\ 30 \end{array} \quad \begin{array}{r} \underline{30} \\ 1215 \end{array} \times 100 = 2.5 \quad \begin{array}{r} 2.5 \\ \underline{-0.4} \\ 2.1 \end{array}$$

- B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or "pull weights" for one cubic yard.

Mix Design - One Cubic Yard  
Based on SSD Condition

Batch Quantities

Cement	635 lbs.	Cement	<u>635</u> lbs.
Sand	1070 lbs.	Sand	<u>1145</u> lbs.
No. 57	1840 lbs.	No. 57	<u>1879</u> lbs.
Water	286 lbs.	Water	<u>172</u> lbs.
			<u>20.6</u> gals.
Air	6.0 %	Air	<u>6.0</u> %

CALCULATIONS:

Sand:	$1070 \times 0.070 = 75$
	$1070 + 75 = 1145$
No. 57:	$1840 \times 0.021 = 39$
	$1840 + 39 = 1879$
Water:	$75 + 39 = 114$
	$286 - 114 = 172$
	$\frac{172}{8.33} = 20.6 \text{ gals.}$

**MOISTURE PROBLEM NO. 3**

- A. Given the following information, determine the percent of free moisture in the sand and No. 57.

SAND

Weight of wet sample = 621 grams  
 Weight of dry sample = 580 grams

NO.57

Weight of wet sample = 1362 grams  
 Weight of dry sample = 1343 grams

ABSORPTION

Sand = 0.7%  
 No. 57 = 0.4%

Free Moisture: Sand 6.4% No. 57 1.0%

## CALCULATIONS:

Sand:	$\begin{array}{r} 621 \\ -580 \\ \hline 41 \end{array}$	$\frac{41}{580} \times 100 = 7.1$	$\begin{array}{r} 7.1 \\ -0.7 \\ \hline 6.4 \end{array}$
No. 57	$\begin{array}{r} 1362 \\ -1343 \\ \hline 19 \end{array}$	$\frac{19}{1343} \times 100 = 1.4$	$\begin{array}{r} 1.4 \\ -0.4 \\ \hline 1.0 \end{array}$

- B. Based on the preceding moisture determination, correct the following mix design weights to batch weights or "pull weights" for four cubic yards.

Mix Design - One Cubic Yard  
Based on SSD Condition

Batch Quantities

Cement	635 lbs.	Cement	<u>2540</u> lbs.
Sand	1070 lbs.	Sand	<u>4552</u> lbs.
No. 57	1840 lbs.	No. 57	<u>7432</u> lbs.
Water	286 lbs.	Water	<u>800</u> lbs.
			<u>96.0</u> gals.
Air	7.0 %	Air	<u>7.0</u> %

CALCULATIONS:

Sand:	$1070 \times 0.064 = 68$
	$(1070 + 68) \times 4 = 4552$
No. 57:	$1840 \times 0.010 = 18$ (1840
	$+ 18) \times 4 = 7432$
Water:	$68 + 18 = 86$
	$(286 - 86) \times 4 = 800$
	$\frac{800}{8.33} = 96.0$ gals.
Cement:	$635 \times 4 = 2540$

## CHAPTER 5 – Concrete PLANT

1. Before any concrete is batched, the producer's technician should determine that there is an approved **mixdesign** at the plant.
2. The required weighing accuracy for cement is **1 percent**.
3. Aggregates arriving at a plant by truck are acceptable for use if they are accompanied by a **statement of certification**.
4. Hopper and cement scales for batching concrete materials must be **serviced by a Private Scale Company**.
5. Aggregates should be handled and stockpiled in such a manner as to minimize **segregation**.
6. The required weighing accuracy for aggregate is **2 percent**.
7. The minimum and maximum limits of volume of concrete which can be mixed in a mixer are **15percent-110percent**.
8. The loader should remain **12inches** from the ground while removing material if stockpiles are built on the ground.

## CHAPTER 6 – Concrete PLANT

1. **Producer's Technician** is responsible for designing the Concrete Mix.
2. **Producer's Technician** is responsible for assuring that concrete components are certified or approved.
3. **District Concrete Technician** is responsible for conducting the performance tests, such as yield tests.
4. Making the moisture correction for aggregate is the responsibility of the **Producer's Technician**.
5. Setting all the dials, gauges, scales, and meters at the batch plant is the responsibility of the **Producer's Technician**.

## Chapter 7

## Calculations for Concrete Plant Study Problem

1. Cement Weight Calculation (Line A 38-41)  
**635 lbs. (from TL-27) x 8 cubic yards = 5,080 lbs. of cement for 8 cubic yards**
2. Sand, SSD Weight Calculation (Line A 46-50)  
**946 lbs. (from TL-27) x 8 cubic yards. = 7,568 lbs. of sand for 8 cubic yards**
3. Sand, Free Water Calculation (Line A 51-53)  
**7,568 lbs. of sand for 8 cubic yards x .06 (% Free Moisture of Sand Expressed as a decimal) = 454.1 lbs. of free water = 454 lbs. (rounded to nearest whole lb.)**
4. Coarse Aggregate (No. 57), SSD Weight Calculation (Line A 60-64)  
**1,922 lbs. (From TL-27) x 8 cubic yards = 15,376 lbs. of Coarse Aggregate for 8 cubic yards**
5. Coarse Aggregate (No. 57), Free Water Calculation (Line A 65-67)  
**15,376 lbs. of C.A. (No. 57) for 8 yd<sup>3</sup> X .002 (% Free Moist. of C.A. expressed as a decimal) = 30.8 lbs. of free water = 31 lbs. (Rounded to nearest whole lb.)**
6. Total Allowable Water (Line B 13-16)  
**32.5 gals. (From TL-27) x 8 cubic yards = 260.0 gals. for 8 cubic yards**

NOTE: All water on Line A is in pounds, but all water on Line B is in gallons.

7. Water Added at Plant (Line B 20-23)

**454 lbs. of free water in sand (Line A 51-53)**  
**+ 31 lbs. of free water in coarse aggregate (No. 57) (Line A 65-67)**  
**485 lbs. of free water in sand and coarse aggregate**

The pounds of free water in the sand and coarse aggregate from Line A must be converted to gallons. One gallon of water weighs 8.33 lbs.

485

8.33 = 58.2 gals. of free water in sand and coarse aggregate (rounded to nearest tenth)

1 gallon of water per cubic yard is being withheld at the concrete plant on each 8 yd<sup>3</sup> load.

1 gal. per cubic yard x 8 cubic yards = 8.0 gals. of water withheld on each 8 yd<sup>3</sup> load

The 58.2 gals. of free water in the sand and coarse aggregate goes into the mix with this material and becomes part of the mixing water and therefore must be subtracted from the total allowable water. Also, the 8 gals. of water withheld at the plant must be subtracted from the total allowable water.

58.2 gals. of free water in the sand and coarse aggregate  
 + 8.0 gals. of water withheld per load at the concrete plant  
 66.2 gals. of water to be subtracted from the total allowable water

260.0 gals. of total allowable water (Line B 13-16)  
 - 66.2 gals. of free water in sand and C.A. plus 8 gals. per load withheld at plant  
 193.8 gals. of water added at plant (Line B 20-23)

8. A. E. Admixture (Line B 31-34)

**5.0 oz. (From TL-27) x 8.0 cubic yards = 40.0 oz. for 8 cubic yards**

9. Retarding Admixture (Line B 38-41)

**25.0 oz. (From TL-27) x 8 cubic yards = 200.0 oz. for 8 cubic yards**



VDOT Concrete Plant  
Summary Review

Answer Sheet:

1.     A      B      C      D
2.     A      B      C      D
3.     A      B      C      D
4.     A      B      C      D
5.     A      B      C      D
6.     A      B      C      D
7.     A      B      C      D
8.     A      B      C      D
9.     A      B      C      D
10.    A      B      C      D
11.    A      B      C      D
12.    A      B      C      D
13.    A      B      C      D
14.    A      B      C      D
15.    A      B      C      D

VDOT Concrete Plant  
Summary Review

1. Water used for concrete mixes that contain the following substances should not be used:
  - a. inorganic salts
  - b. sanitary sewage
  - c. industrial waste
  - d. all of the above
  
2. Specification 215 defines the requirements for the use of \_\_\_\_\_:
  - a. Fine aggregates
  - b. Coarse aggregates
  - c. HCC admixtures
  - d. Hydraulic Cement
  
3. A TL-28 shows code "6" in blocks 34-36 (Line C). What does this indicate?
  - a. A3 concrete
  - b. Retaining Wall
  - c. Class III modified
  - d. Water ponding
  
4. The TL-28A is:
  - a. completed by the Inspector
  - b. completed by the Producer's Technician
  - c. completed by both the Inspector and the Producer's Technician
  - d. only required for new mix designs
  
5. If the total alkalis of the cement is less or equal to 0.75%, the minimum percentage of the total cement contact that may be replaced by GGBF slag is:
  - a. 50%
  - b. 40%
  - c. 20%
  - d. 25%
  
6. What is the minimum cementitious content for a 4-CY batch of A4 General:
  - a. 635 lbs
  - b. 588 lbs
  - c. 2,352 lbs
  - d. 2,540 lbs

VDOT Concrete Plant  
Summary Review

7. For the mix shown in question 6, what is the absolute volume of the cementitious material, if only Portland cement is used?
  - a. 12.9 CF
  - b. 12.0 CF
  - c. 3.2 CF
  - d. 3.0 CF
  
8. For a A4 Post & Rail mix, the maximum aggregate size is \_\_\_\_\_. Assume that the Fine Aggregate Fineness Modulus is 2.80, what is the volume of coarse aggregate per unit of volume?
  - a. 0.5", 0.67
  - b. 0.5", 0.55
  - c. 1", 0.67
  - d. 1", 0.55
  
9. For the mix shown in question 8, if the dry rodded unit weight is 105 lbs/ft<sup>3</sup>, what is the design weight of the coarse aggregate for 1 CY?
  - a. 58 lbs
  - b. 70 lbs
  - c. 1559 lbs
  - d. 1899 lbs
  
10. The volume of concrete mixed per batch shall not be less than \_\_\_\_ percent nor more than \_\_\_\_ percent of the mixer's rated capacity.
  - a. 5, 110
  - b. 15, 120
  - c. 15, 110
  - d. 20, 110
  
11. A sieve analysis shows that 35% of a sample passed the No. 50 sieve, does the sample meet the specifications for the following Fine Aggregate Grading:
  - a. Grading A
  - b. Grading B
  - c. Grading C
  - d. All of the above
  
12. Before any concrete is batched, the producer's technician should determine that there is a \_\_\_\_\_ stating the cement meets the requirements of the \_\_\_\_\_ Specifications.
  - a. Certification, VDOT
  - b. Test Report, ASTM
  - c. Certification, ACI
  - d. Test Report, AASHTO

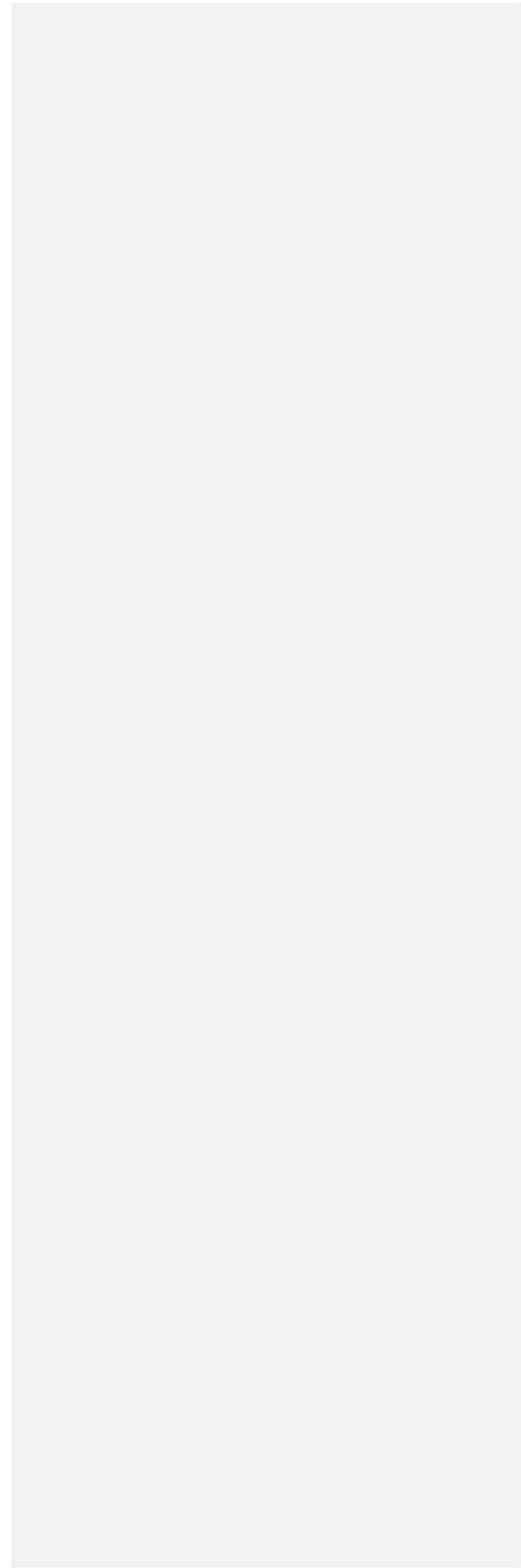
VDOT Concrete Plant  
Summary Review

13. Step 1 in a sieve analysis is to obtain a \_\_\_\_\_, by either a sample splitter or the \_\_\_\_\_ method
- 5 lbs sample, quartering
  - 10 lbs sample, quartering
  - 5 lbs, VDOT
  - Representative sample, quartering
14. Using the sample coarse aggregate data sheets provided, what is the Specific Gravity and Absorption shown for the Coarse aggregate from Lone Star Industries?
- 2.62, 0.9%
  - 2.64, 0.3%
  - 2.63, 0.8%
  - 2.64, 0.6%

VDOT Concrete Plant  
Summary Review

Answer Sheet:

1.     A     B     C     D
2.     A     B     C     D
3.     A     B     C     D
4.     A     B     C     D
5.     A     B     C     D
6.     A     B     C     D
7.     A     B     C     D
8.     A     B     C     D
9.     A     B     C     D
10.    A     B     C     D
11.    A     B     C     D
12.    A     B     C     D
13.    A     B     C     D
14.    A     B     C     D
15.    A     B     C     D



VDOT Concrete Plant  
Summary Review

1. Water used for concrete mixes that contain the following substances should not be used:

- a. inorganic salts
- b. sanitary sewage
- c. industrial waste
- d. **all of the above**

**Commented [DKS1]:** Page 1-6

2. Specification 215 defines the requirements for the use of \_\_\_\_\_:

- a. Fine aggregates
- b. Coarse aggregates
- c. **HCC admixtures**
- d. Hydraulic Cement

**Commented [DKS2]:** Page C-11

3. A TL-28 shows code "6" in blocks 34-36 (Line C). What does this indicate?

- a. A3 concrete
- b. **Retaining Wall**
- c. Class III modified
- d. Water ponding

**Commented [DKS3]:** Page 5-4

4. The TL-28A is:

- a. completed by the Inspector
- b. completed by the Producer's Technician
- c. **completed by both the Inspector and the Producer's Technician**
- d. only required for new mix designs

**Commented [DKS4]:** Page 7-1

5. If the total alkalis of the cement is less or equal to 0.75%, the minimum percentage of the total cement contact that may be replaced by GGBF slag is:

- a. 50%
- b. **40%**
- c. 20%
- d. 25%

**Commented [DKS5]:** Page C-13

6. What is the minimum cementitious content for a 4-CY batch of A4 General:

- a. 635 lbs
- b. 588 lbs
- c. 2,352 lbs
- d. **2,540 lbs**

**Commented [DKS6]:** Page 3-4, Table II-17 (4 CY)

VDOT Concrete Plant  
Summary Review

7. For the mix shown in question 6, what is the absolute volume of the cementitious material, if only Portland cement is used?

- a. 12.9 CF
- b. 12.0 CF
- c. 3.2 CF
- d. 3.0 CF

Commented [DKS7]:  $2540 / (3.15 \times 62.4)$

8. For a A4 Post & Rail mix, the maximum aggregate size is \_\_\_\_\_. Assume that the Fine Aggregate Fineness Modulus is 2.80, what is the volume of coarse aggregate per unit of volume?

- a. 0.5", 0.67
- b. 0.5", 0.55
- c. 1", 0.67
- d. 1", 0.55

Commented [DKS8]: Table II-17 & A1.5.3.6

9. For the mix shown in question 8, if the dry rodded unit weight is 105 lbs/ft<sup>3</sup>, what is the design weight of the coarse aggregate for 1 CY?

- a. 58 lbs
- b. 70 lbs
- c. 1559 lbs
- d. 1899 lbs

Commented [DKS9]:  $.55 \times 27 \times 105$

10. The volume of concrete mixed per batch shall not be less than \_\_\_\_ percent nor more than \_\_\_\_ percent of the mixer's rated capacity.

- a. 5, 110
- b. 15, 120
- c. 15, 110
- d. 20, 110

Commented [DKS10]: Page 5-6

11. A sieve analysis shows that 35% of a sample passed the No. 50 sieve, does the sample meet the specifications for the following Fine Aggregate Grading:

- a. Grading A
- b. Grading B
- c. Grading C
- d. All of the above

Commented [DKS11]: Table II-1

12. Before any concrete is batched, the producer's technician should determine that there is a \_\_\_\_\_ stating the cement meets the requirements of the \_\_\_\_\_ Specifications.

- a. Certification, VDOT
- b. Test Report, ASTM
- c. Certification, ACI
- d. Test Report, AASHTO

Commented [DKS12]: Page 5-2

VDOT Concrete Plant  
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13. Step 1 in a sieve analysis is to obtain a \_\_\_\_\_, by either a sample splitter or the \_\_\_\_\_ method.

- a. 5 lbs sample, quartering
- b. 10 lbs sample, quartering
- c. 5 lbs, VDOT
- d. Representative sample, quartering

Commented [DKS13]: Page 2-4

14. Using the sample coarse aggregate data sheets provided, what is the Specific Gravity and Absorption shown for the Coarse aggregate from Lone Star Industries?

- a. 2.62, 0.9%
- b. 2.64, 0.3%
- c. 2.63, 0.8%
- d. 2.64, 0.6%

Commented [DKS14]: Page 3-36

15. Before starting a mix design, the following information is acquired from the specifications:

- a. Minimum cement content
- b. Water : Cement ratio
- c. Air Content
- d. All of the above

Commented [DKS15]: Page 3-2