SUGGESTIONS ON SPECIFYING CONCRETE PAVEMENTS:

PARTNERING WITH YOUR CONCRETE SUPPLIER

This document is intended to help clear up confusion or miscommunications that occasionally occur during the bidding process between the design documents and contractors or material suppliers. We will look at some general topics and offer insights based on observations made when projects come to us for bidding.

Prescriptive or Performance Specifications

Types of Cement

Water-Cement Ratio

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CEMEX

PRESCRIPTIVE OR PERFORMANCE SPECIFICATIONS

Performance-based specifications tell the contractor what the pavement must be capable of doing, such as reaching a certain compressive or flexural strength, once constructed without given much detail on the specific mix. These specifications are versatile and readily adapted to any location, and most projects, as they allow the contractor and producer to provide the appropriate mix, based on experience, for the desired result. Performance-based specifications can sometimes lack necessary mix information to help a pavement perform under unique conditions, such as extreme temperature swings.

Prescriptive specifications give more direction on how to achieve the desired result by providing specific information on the make-up of a concrete mix, such as air-entrainment, water/cement ratio, supplementary cementitious materials, or other components. Prescriptive specifications, by providing more detailed direction on a concrete mix, can help the pavement resist harsh exposure conditions, like those mentioned above, that may be unique to your project. The potential downside to prescriptive specifications is that they lack a certain amount of flexibility when dealing with changes in material availability or other unforeseen circumstances.

SUGGESTION: While either approach can be effective, many paving applications are well suited to the use of performance-based specifications. Let us help you make the most of available materials for your paving application.

COMPRESSIVE OR FLEXURAL STRENGTH

Concrete paving is most commonly specified using the compressive strength of the mix, such as "minimum 4000 psi compressive strength at 28 days". We also occasionally see the flexural strength used on details, such as "650 psi flexural strength at 28 days". The flexural strength of a standard concrete mix, such as 4000 psi compressive, will vary depending on the aggregate material used and falls into a range of values mathematically correlated to that compressive strength value. As an example, a typical range of flexural strength values for a 4000 psi compressive strength is approximately 505 psi – 632 psi. Your local producer will be able to provide information on the correlation between compressive and flexural strength for individual mixes.

SUGGESTION: Specify concrete using compressive strength or flexural strength. Avoid referencing both strength designations simultaneously as it can be contradictory and lead to confusion on the required concrete mix during the bidding process. Let us help you identify the right concrete mix for your paving application.

CEMENT TYPES

Worldwide, the most commonly used cement type is Portland Cement, which gets its name from stone quarried on the Isle of Portland in Dorset, England. Portland Cement is made from limestone and clay minerals which are heated in a kiln to form clinker. The clinker is ground into a fine powder and combined with a small amount of gypsum. It is this powder that reacts with water, in a process known as hydration, and acts as the binder for Portland Cement Concrete (PCC).

ASTM C150 Standard Specification for Portland Cement covers eight types of Portland Cement, designated as Types I-V. Designations IA, IIA, are Types I-III with air-entraining agents added. The table below offers descriptions of cement types I-V:

Cement	Description
Type I	General purpose when special properties are not required.
Type II	General purpose with moderate sulfate resistance and moderate heat of hydration.
Type III	Used for high early strength
Type IV	Used when low heat of hydration is needed.
Type V	Used when high sulfate resistance is needed.

Cements may meet requirements of more than one type, such as Type I/II or Type II/V. Type III, IV, and V cements may be rare or may be seeing diminishing use in some places.

SUGGESTION: Allow your paving mix designs to make use of commonly available cement types, including blended cements (cements with limestone, slag, or pozzolans added) in the market where your project is located. Let us help you identify available materials for your application.

SUPPLEMENTARY CEMENTITIOUS MATERIALS

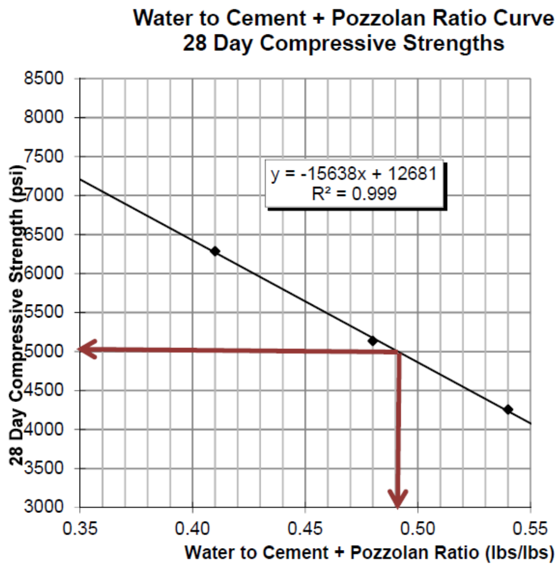
Supplementary Cementitious Materials (SCM's) are frequently added to a concrete mix, in conjunction with the cement, to help enhance properties of hardened concrete including, but not limited to, Durability/Permeability, Alkali-Silica Reactivity (ASR), and Sulfate Resistance. Two of the most frequently discussed SCM's are Fly Ash and Slag, although others, such as Silica Fume, also exist.

Fly ash is a byproduct of coal burning furnaces related to power generation. C-ash and F-ash, the two primary types of fly ash, differ in that they are produced by different coal types and the fact that C-ash has some cementitious properties of its own while F-ash does not. Slag, or Blast Furnace Slag, is a byproduct of the process which reduces iron ore to pig iron. The liquid slag is cooled to form granules which are crushed into a powder, which is use as an SCM.

SUGGESTION: Allow contingencies in your paving mix considerations. Availability of SCM's can vary based on geographic location, in the case of slag, and even on the time of year, in the case of the two types of fly ash. Let us help you adapt your mix to available materials.

WATER-CEMENT RATIO

The water-cement (w/cm) ratio is the relationship between the amount of water, by weight, and the amount of cement, or cement plus supplementary cementitious materials, by weight, in a concrete mix. As shown in the figure below, there is a direct correlation between the w/cm ratio and the 28-day compressive strength.



Concrete mixes with higher w/cm ratios often have excess water content beyond what is needed for hydration. When the excess water evaporates or bleeds out of the concrete, tiny voids are left in the matrix which can contribute to material segregation, separating sand and rock from cement, and offer the potential for increased amounts of shrinkage and cracking. Lower strength gain is seen in mixes with higher water-cement ratios. Concrete mixes with lower water-cement ratios tend to gain higher strengths without some of the issues attributed to a lot of excess water from hydration, as mentioned above. However, the lower water content may not allow the concrete to flow well, making it more difficult to place and finish.

SUGGESTION: When specifying a compressive strength, it is often not necessary to include the w/cm ratio. If a specified water-cement ratio is desired, using a maximum value (such w/cm max = 0.49) rather than an exact or minimum value gives a specification that is achievable and will reduce the risk of the concrete failing to gain the required strength.

SLUMP

Slump is often used to describe the workability, how easy it is to handle during placement, of a concrete mix. ASTM C143 describes the "Standard Test Method for Slump of Hydraulic-Cement Concrete", or slump test. The test is done by placing a cone with a bottom diameter of 8", a top diameter of 4", and a height of 12" on a smooth flat surface and filling it with fresh concrete. The cone is carefully lifted off allowing the concrete to settle, or slump. The difference in height from the top of the cone to the top of the settled concrete is its slump. Slump is specified in inches with a tolerance of 1 inch, such as 3.0" +/- 1.0". Higher slumps identify concrete mixes that are typically more liquid, or fluid, and lower slumps generally indicate a dryer mix and slumps can vary by application and placement method. Slump tests are typically done multiple times during a concrete pour and is a good way to track consistency during batching and delivery.

SUGGESTION: For paving, follow the guidance of ACI 330R-08 Guide for the Design and Construction of Concrete Parking Lots or ACI 330.2R-17 Guide for the Design and Construction of Concrete Site Paving for Industrial and Trucking Facilities. ACI 330R-08 recommends the slump for slipform paving to be 1.5" or less and the slump for hand placed paving to be 4" or less. ACI 330.2R-17 provides the following table:

Method of Construction	Slump, without exceeding the specified w/cm ratio
Slipform Paving	1" – 2"
Truss Screed	3" – 5"
Laser-guided Screed	3" – 6"
Hand Placement	3" – 6"

ENTRAINED AIR

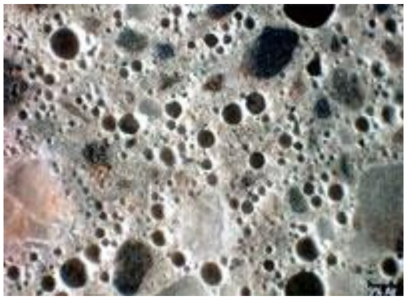


Figure 1: Air-entrained Concrete. Portland Cement Association cement.org/Cement & Concrete Applications/working-with-concrete/air-entrained-concrete

Air entrainment is the process of creating tiny air bubbles in concrete. This is typically done during batching operations using air entraining admixtures. These bubbles are regular in shape, as shown in the picture to the left, and provide space to accommodate the expansion of moisture in the concrete when it freezes. This function increases durability in a concrete pavement exposed to freezing-and-thawing cycles. Average recommended air contents vary with the severity of exposure conditions, identified as mild, moderate, or severe.

Entrapped air is different from entrained air. Air is entrapped in concrete when excess water from hydration evaporates and leaves voids. These voids are typically more irregularly shaped than those created by air entrainment and, as such, can be deleterious to hardened concrete. Concrete mixes are designed to minimize entrapped air, but it does still occur. Typical volumes of entrapped air vary with maximum nominal aggregate size. As the maximum aggregate size increases, the volume of entrapped air decreases. The dosage rate for entrained air is the difference between the recommended average air content and the typical air content (entrapped) for a non-air-entrained mix.

SUGGESTION: Follow air content recommendations in ACI 330R-08 Guide for the Design and Construction of Concrete Parking Lots, Table 4.1-Recommendd Air Contents, also shown below.

Table 4.1—Recommended air contents

Nominal maximum size aggregate, in. (mm)	Typical air contents of non-air-entrained concrete, %	Recommended average air content for air-entrained concretes, %		
		Mild exposure	Moderate exposure	Severe exposure
3/8 (10)	3.0	4.5	6.0	7.5
1/2 (13)	2.5	4.0	5.5	7.0
3/4 (19)	2.0	3.5	5.0	6.0
1 (25)	1.5	3.0	4.5	6.0
1-1/2 (38)	1.0	2.5	4.5	5.5

Note: Tolerances: ±1.5%. There is conflicting opinion on whether air contents lower than those given in the table should be permitted for high-strength (over 5500 psi [38 MPa]) concrete. This committee believes that where supporting experience or experimental data exist for particular combinations of material, construction practices, and exposure, the air contents can be reduced by approximately 1%.

ADMIXTURES

Admixtures are chemicals introduced to concrete before or during mixing to enhance certain properties of fresh or hardened concrete, or to help overcome challenging circumstances during construction. ASTM C-494 identifies seven admixture types used singularly and in combination. The most commonly used admixtures are water reducers, retarders, accelerators, and entrained air, which was discussed above.

Water reducing admixtures, as the name implies, lower the required water content of a concrete mix. Benefits of such a water reduction include maintaining a lower water-cement ratio leading to increased strength and increasing the effective slump of fresh concrete without an increase in water, making the mix easier to work with during placing and finishing operations.

Retarding and accelerating admixtures are used to help overcome constraints to construction brought on by temperature extremes or other factors. Retarders delay the initial setting of a concrete mix giving more time to employ effective finishing and curing techniques during hotter weather. Retarders can also be used on large jobs to improve uniformity in setting of concrete across the entire project. Accelerators are used to reduce set times in colder weather, allowing for quicker strength gain which, in turn, helps concrete resist damage due to freezing. Accelerators can also be used when construction schedules call for early form removal to move on to the next pour.

SUGGESTION: Admixtures make an effective tool for overcoming challenging conditions surrounding your concrete pavement. Let us help you determine if an admixture is necessary and appropriate for your project.

AGGREGATES

Aggregates typically make up a large percentage (60% - 75%) of a concrete mix and sizes are typically designated as coarse and fine. Aggregate sizes ranging from material retained on a No. 4 sieve (3/16 in.) up to a maximum of 1 ½ inch are considered coarse and material passing a No. 4 sieve is considered fine aggregate. In a standard concrete mix, the aggregate components may be defined as sand for fine aggregates and #57 stone, for example, as the coarse aggregate. #57 stone is defined by a range of particle sizes from 1 in. down to material retained on a No. 4 sieve. Concrete mixes, such as the one shown in Figure 1, made up of coarse and fine aggregate, and without an intermediate aggregate size, are sometimes referred to as gap-graded mixes.

Figure 2: Conventional Concrete

A well-graded concrete mix includes the addition of an intermediate sized aggregate, such as #89 stone which has a typical maximum size of 3/8 inch. to increase the performance of a pavement and make more efficient use of all the concrete constituents. Adding an intermediate aggregate helps increase the performance of a pavement and make more efficient use of mix constituents by replacing some of the space occupied by water and cement paste with stone. Roller Compacted Concrete, shown in Figure 2, is an example of a well graded concrete mix.

Figure 3: Roller Compacted Concrete (RCC)

SUGGESTION: Set up concrete mixes to make use of the most commonly available aggregate sizes, such as #57 or #89 stone referenced above, in your market. Also be aware that some plants may not have available space for a third stone size. Let us help you determine a mix that efficiently makes use of available materials and assets.