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by L. K. Couch—

Four-Part Series

Help for Pervious PCC Producers

Part 2: Chemical Admixtures for Pervious PCC

INTRODUCTION

Tennessee Technological University (TTU) researchers have recently been exploring ways to improve conventional (compacted) pervious Portland cement concrete (PCC). The Tennessee Concrete Association (TCA) has provided materials and guidance for the research described in the articles. We hope you find the information presented helpful in producing improved pervious PCC mixtures. In the second article, chemical admixture choices for pervious PCC are explored. Parts 3 and 4 in the series will examine:

3. Fine Aggregate for Pervious PCC
4. Putting It All Together for a High Performance Pervious Concrete Mixture Design

Tennessee concrete producers are already familiar with some of the benefits of chemical admixtures. Former TTU Graduate Student Jason Phillips [1], whose primary research was SCM substitution rates for pervious PCC, also took a preliminary look at chemical admixture effects on pervious PCC effective voids, compressive strength, and paste drain down.

MATERIALS

Type I Portland cement [2] was obtained from a local ready mix producer's bulk storage. An ASTM C 33 [3] No. 8 limestone was obtained from a local quarry. The average results of a washed sieve analysis [4] conducted in triplicate on the local limestone are shown in Table 1. Chemical admixtures were provided by the local representative of an international chemical producer.

RESEARCH PLAN

The research team developed a pervious PCC mixture (see Table 2) to act as the control or standard for comparison for the project. Throughout the research, the volumes of paste, aggregates, and water were held constant for all variable mixtures. Chemical admixtures at a dosage chosen from the manufacturer's recommended dosage range were added to or subtracted from the control mixture design. Variable mixture designs are shown in Tables 3 and 4.The control mixture was replicated three times. All other mixtures were only produced one time. The research team assumed that in the future, more promising variable mixtures could be further investigated. In order to compare chemical admixture costs, the following cost per gallon assumptions were made: viscosity modifier $6, accelerator $8, mid-range water reducer $10, retarder $4, and hydration stabilizer $4.

BACKGROUND

ASTM C 125 defines chemical admixtures as any material used in concrete or mortars other than water, aggregates, hydraulic cement and fiber reinforcement [5]. PCC producers are already familiar with ASTM C 494 [6] retarders, water reducers, and accelerators used in conventional PCC. Some of the less familiar chemical admixtures used in pervious PCC are briefly described in the following paragraphs. For more detailed information, contact a TCA member admixture representative. The TCA office can provide phone numbers, e-mail addresses, and websites.

Viscosity-Modifying Admixtures (VMA)

Viscosity modifying admixtures (VMAs) are designed to increase resistance to segregation and to improve the workability of a PCC mixture. VMAs are primarily used in self-consolidating concrete. However, research at Tennessee Technological University indicates that VMAs can be beneficial in preventing drain down of pervious PCC paste.

Hydration Stabilizers

Hydration stabilizers are made up of a two part chemical system. First, a stabilizer that behaves much like a retarder slowing down or even halting the hydration of cementing materials [7]. Next, an activator is sometimes added to re-establish normal hydration [7]. The stabilizer can suspend the hydration for up to 72 hours [7]. Observations made by TCA executive director Alan Sparkman indicate that hydration stabilizers can make unloading ready mix trucks easier and extend placement time available for pervious PCC.

PROCEDURE

All pervious PCC batches were 0.65-cubic feet in size. Each batch was mixed in a one-cubic-foot capacity electric mixer. Ten 4x8-inch cylinders were cast from each batch. Eight of the

TABLE 1. COARSE AGGREGATE USED FOR THE PROJECT

Sieve Size	Sieve Size (mm)	Project Coarse Aggregate (% finer by mass)	ASTM C33 No. 8 Coarse Aggregate Requirements for % finer by mass
1/2 inch	12.5	100	100
3/8 inch	9.5	97	85–100
No. 4	4.75	10	10–30
No. 8	2.36	2	0–10
No. 16	1.18	1	0–5

TABLE 2. CONTROL PERVIOUS PCC MIXTURE DESIGN

Component	Amount
Type I PC, lbs./CY	600
ASTM No. 8 Limestone Coarse Aggregate, SSD, lbs./CY	2600
Water, lbs./CY	180
Mid-Range Water Reducer, oz./cwt. (oz./CY)	5 (30)
Viscosity Modifier, oz./cwt (oz./CY)	2 (12)

TABLE 3. VARIABLE PERVIOUS PCC MIXTURE DESIGNS WITH ADMIXTURE SUBTRACTIONS

Component	Minus Mid-Range Water Reducer	Minus Viscosity Modifier
Type I PC, lbs./CY	600	600
ASTM No. 8 Limestone Coarse Aggregate, SSD, lbs./CY	2600	2600
Water, lbs./CY	180	180
Mid-Range Water Reducer, oz./cwt. (oz./CY)	5 (30)	5 (30)
Viscosity Modifier, oz./cwt (oz./CY)	2 (12)	0

TABLE 4. VARIABLE PERVIOUS PCC MIXTURE DESIGNS WITH ADMIXTURE ADDITIONS

Component	Plus Retarder	Plus Accelerator	Plus Hydration Stabilizere
Type I PC, lbs./CY	600	600	600
ASTM No. 8 Limestone Coarse Aggregate, SSD, lbs./CY	2600	2600	2600
Water, lbs./CY	180	180	180
Mid-Range Water Reducer, oz./cwt. (oz./CY)	5 (30)	5 (30)	5 (30)
Viscosity Modifier, oz./cwt (oz./CY)	2 (12)	2 (12)	2 (12)
Retarder, oz./cwt. (oz./CY)	4 (24)	0	0
Accelerator, oz./cwt. (oz./CY)	0	10 (60)	0
Hydration stabilizer, oz./cwt. (oz./CY)	0	0	4 (24)

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cylinders were used for compressive strength determination and two were used to determine effective void content and to asses drain down of the paste. All cylinders were cast in two layers in reusable metal molds. Each layer received 4 blows from an AASHTO T 245 Marshall Hammer [8]. The Marshall Hammer is one of the compaction devices being considered by the ASTM Pervious PCC Standard Test Method Subcommittees. Following casting, each cylinder was covered with plastic and allowed to cure for approximately 24 hours. The next day, the cylinders were de-molded and placed in a lime-water immersion tank. On the seventh day, the two effective voids cylinders were removed from the curing tank and dried at 230˚F for seven days. Effective void contents were then determined as per ASTM D 7063 [9]. Paste drain down was determined by visual inspection. Compressive strengths were determined for each batch at 7, 28, 56, and 91 days using a pair of cylinders. On the day of a scheduled break the pair of cylinders was removed from the curing tank and capped with sulfur mortar as per ASTM C 617 [10] and subsequently tested in accordance with ASTM C 39 [11].

RESULTS

Average results are shown in this article, for more detailed information see Phillips [1]. Table 5 shows average effective void contents. No paste drain down was observed in any of the chemical admixture variable mixtures. Control compressive strength results are shown in Figure 1. Similarly, chemical admixture variable mixture compressive strength results are shown in Figure 2. Each result is the average of two compressive strength cylinders at the prescribed age.

FLY ASH MIXTURES

ANALYSIS OF RESULTS

Effective Void Content

The variation in effective void content was small for the project. The small standard deviation suggests that there is no difference for results between 31.2 and 33.5 percent [1]. All results fell within this range.

Compressive Strength

Table 6 shows the average compressive strength of each chemical admixture variable mixture as a percentage of the average compressive strength of the control mixture at the same age. Since each variable mixture was only produced once, insufficient data was available for t-test comparisons to determine if differences observed were significant. Therefore, a ten percent difference from the average control mixture at that age was considered significant for this project. Table 6 is color coded for easier analysis: red shading indicates a twenty percent or more decrease in compressive strength; orange indicates a ten percent decrease; yellow indicates that the variable mixture strength is less than ten percent different from the average control compressive strength; Blue indicates a ten percent increase; and green indicates a twenty percent or more increase in compressive strength compared to the average control.

The compressive strength results shown here are from samples continuously cured in lime-water. Since adequate moisture and temperature for curing are not guaranteed in the field, it would take much longer for pervious PCC samples in the field to reach a 56 or 91 day laboratory curing level, if they ever reached that level. Seven and 28 day levels of laboratory curing are much more achievable in the field. Except in rare circumstances, pervious PCC producers should concentrate on the 7 and 28-day compressive strength results.

Three of the chemical admixtures, retarder, accelerator and viscosity modifier, had no significant effect on compressive strength. Having no significant difference is not necessarily a bad result, as chemical admixtures may perform functions other than increasing compressive strength (more in the following paragraphs). Leaving out the mid-range water reducer had the most significant detrimental effect on compressive strength. Average compressive strength results were 11 to 14 percent below the average control compressive strength at all four ages. The addition of a hydration stabilizer had the most significant beneficial effect on compressive strength. Seven and twenty-eight day average compressive strengths, the most important compressive strengths, were significantly higher.

Chemical Admixture Cost

Table 7 shows the chemical admixture costs based on the earlier stated cost-per-gallon assumptions (viscosity modifier $6, accelerator $8, mid-range water reducer $10, retarder $4, and hydration stabilizer $4). Table 7 is color coded for easier analysis: red shading indicates a twenty percent or more increase in cost; orange indicates a ten percent increase; yellow indicates

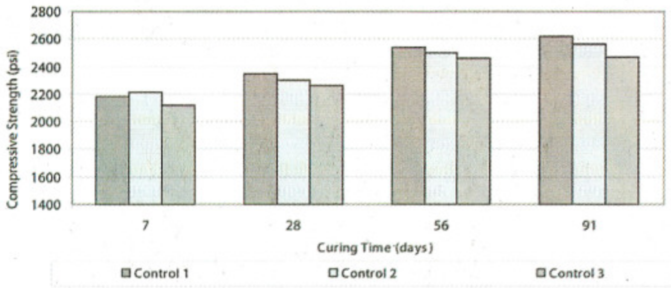

Figure 1. Control Mixture Compressive Strength Development

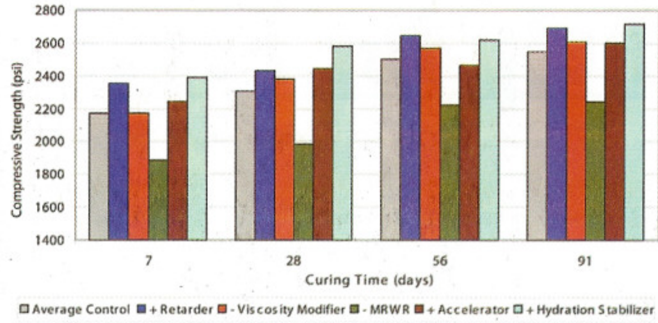

Figure 2. Compressive Strength Development of Class F Fly Ash Mixtures

TABLE 5. AVERAGE EFFECTIVE VOID CONTENT FOR PERVIOUS PCC MIXTURES

Mixture	Average Effective Void Content (%)
Average Control	33.3
Control + Retarder	31.2
Control + Hydration Stabilizer	32.1
Control + Accelerator	33.4
Control – Mid-Range Water Reducer	33.5
Control – Viscosity Modifier	33.5

TABLE 6. PERCENT OF AVERAGE CONTROL COMPRESSIVE STRENGTH AT SPECIFIED AGE

Tertiary Mixture	7 Days	28 Days	56 Days	91 Days
Control + Retarder	108	105	106	106
Control + Hydration Stabilizer	110	112	105	107
Control + Accelerator	103	106	99	102
Control – Mid-Range Water Reducer	87	86	89	88
Control – Viscosity Modifier	100	103	103	102

TABLE 7. CHEMICAL ADMIXTURE COST PER CUBIC YARD ($)

Mixture	
Control	2.91
Control + Retarder	3.65
Control + Hydration Stabilizer	3.65
Control + Accelerator	6.69
Control – Mid-Range Water Reducer	0.57
Control – Viscosity Modifier	2.34

20% or more less than control	10% or more less than control	Less than 10% different from control	10% or more greater than control	20% or more greater than control

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that the variable mixture cost is less than ten percent different from the control cost; blue indicates a ten percent decrease; and green indicates a twenty percent or more decrease in cost compared to the control cost. Hydration stabilizer was the clear winner in compressive strength increase per dollar. Mid-range water reducer was second. Mid-range water reducer actually had a greater impact on compressive strength but cost more per gallon.

Other Chemical Admixture Functions

This article provided a preliminary examination of chemical admixture choices for pervious PCC. The evaluation was based on measureable quantities such as effective void content and compressive strength. Albert Einstein said "Not everything that can be counted counts and not everything that counts can be counted." The following paragraphs describe some chemical admixture applications that would be hard (if not impossible) to accurately quantify.

Retarders and hydration stabilizers alter set times and provide more time for placement of pervious PCC in the field. Pervious concrete typically sets within a couple of hours due to a low w/cm ratio and high contents of cementing materials. Therefore, in order to delay setting time retarders or hydration-stabilizing admixtures are commonly used [12]. Accelerators may increase the reaction rate and reduce set time. Therefore, accelerators have been used in cold weather placements of pervious PCC [13]. However, in warm weather accelerators may reduce transport and placement time. Observations from TCA executive director Alan Sparkman indicate that hydration stabilizers can make pervious PCC mixtures easier to unload from ready mix trucks. ACI 522 [13] indicates that retarding admixtures also assist in the placement of the pervious PCC by acting like a lubricant between interlocking aggregates [13].

The effect of chemical admixtures on compressive strength and effective voids of pervious PCC is certainly important. However, these two criteria are not a sufficient basis for selecting chemical admixtures for pervious PCC. Chemical admixture selection for a particular pervious PCC mixture requires much more information. Factors such as weather conditions, placement conditions must be considered.

CHEMICAL ADMIXTURES FOR PERVIOUS PCC - HELP SUMMARY

The research presented herein is exploratory in nature, additional batches of the more promising mixtures should be produced to confirm the results obtained. Based on the results from this study, the following advice can be offered to pervious PCC producers.

1. Always make a trial batch of the pervious PCC mixture to check for PC/ SCM / admixture compatibility, compressive strength, effective voids, workability and paste drain down.
2. Always use a water reducing admixture to improve compressive strength and make unloading easier.
3. If it is not cold at the time of placement, use a hydration stabilizer. The hydration stabilizer improves compressive strength, makes unloading easier, and can extend placement time. Use a retarder if a hydration stabilizer is not available.
4. Viscosity modifiers increase the mixture cohesion and provide additional resistance against paste drain down and segregation.
5. If it is not cold at the placement, do not use an accelerator. If an accelerator is used exercise extreme caution. Pervious PCC already sets rapidly due to the high cementing materials content and low w/cm ratio.
6. The author recommends using a water reducer, hydration stabilizer and viscosity modifier in a typical pervious PCC mixture for Tennessee. Start with a dosage near the manufacturer's recommended minimum or get advice from a TCA member admixture representative.
7. Exercise caution with the water reducer dosage—especially if using a high range water reducer. In the opinion of the author, mid range water reducers are powerful enough and more forgiving than high range water reducers.

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