QC/QA OF LIGHTWEIGHT CONCRETE –
A READY MIXED CONCRETE PERSPECTIVE

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ABSTRACT

In the mid Atlantic area, structural lightweight concrete (LWC) is often used in floors and bridge decks. Because lightweight aggregate (LWA) has higher absorption than normalweight aggregate, moisture movement in and out of the LWA is an important QC/QA consideration. The concepts of absorbed water and "free" water can be used to explain the challenges that may occur during concrete placement, especially when placing with a concrete pump. Snow and freezing weather during the winter months pose another challenge that can negatively impact concrete production and quality. This paper discusses how Vulcan Materials addresses the QA/QC issues and produces consistent and pumpable LWC throughout the year. By understanding how free and absorbed water affect LWC, and the proper adjustments and quality control, the production and placement of LWC can be as routine as normalweight concrete (NWC.)

KEYWORDS: Lightweight Concrete, Production, Moisture Conditioning, Absorbed Water, Free Water, Pumping Concrete.

INTRODUCTION

In the mid Atlantic area, structural lightweight concrete (LWC) is often used in floors and bridge decks. The ready mixed concrete subsidiaries of Vulcan Materials in this market area are major producers of LWC. For example, in 2007, the total volume of LWC produced was >65,000 cubic yards (CY). A majority of this volume goes into composite steel floors. Assuming an average thickness of 6", the floor area produced was over 4 million square feet. Because lightweight aggregate (LWA) has high absorption value (5-25%)[1], moisture movement in and out of the LWA is an important QC/QA consideration. The concepts of absorbed water and "free" water can be used to explain the challenges that may occur during concrete placement, especially when placing with a concrete pump. Snow and freezing weather during the winter months pose another challenge. Ice formation on the LWA stockpile negatively impacts concrete production and quality. This paper discusses how Vulcan Materials addresses the QA/QC issues and produces consistent and pumpable LWC throughout the year.

TRANSPORTATION STRUCTURES WITH LIGHTWEIGHT CONCRETE

1. The I-95 James River Bridge Restoration, Richmond, VA[2]– This $49 million, six travel lane project was completed in August 2002. A lightweight concrete bridge deck was precast on new steel girders offsite to provide full-span segments. As each existing bridge deck segment was saw cut and lifted out (including the existing steel girders), a new precast deck segment was installed. Work was performed at night with minimal impact on traffic.

2. The Bascule Span on the new Woodrow Wilson Bridge Project, Washington, DC[3] – Lightweight concrete was used to reduce dead load and equipment requirements for these movable spans. The twelve travel lane $2.4 billion bridge was completed in 2008. The LWC was cast in place with a concrete pump.

3. The Whitehurst Freeway Rehabilitation Project, Washington, DC[4] – Completed around 1996, the reduced dead load of the new lightweight concrete bridge deck enabled the addition of one extra travel lane with minimal modification to the existing substructures. Using LWC allowed the bridge rating to be upgraded from AASHTO H20 to HS20.

4. The Chesapeake Bay Bridge Preservation Project, Annapolis, MD[5] – A $52 million project, the 4.3 mile long west bound deck is being replaced with precast post tensioned lightweight concrete panels.

5. The Battlefield Parkway Project, Leesburg, VA[6] – This $35 million four lane LWC bridge deck will be completed in late 2009. The LWC is being cast in place with concrete pump.

INTERNAL STRUCTURE OF LWA

An understanding of the behavior of fresh LWC begins with an appreciation of the internal structure of LWA. The manufacturing of LWA using the rotary kiln method with temperatures in excess of 2000 F (1100 C) forms a cellular structure that is composed of isolated and roughly spherical pores. The pores are surrounded by a strong durable ceramic matrix that has characteristics similar to those of vitrified clay brick[7]. The pore sizes range from 5 to 300 microns. Pores close to the surface of aggregate particles are readily permeable and fill with water within the first few hours of exposure to moisture. Interior pores may require months of submersion to approach saturation. A small fraction of interior pores will remain unfilled even after years of immersion[8].

FREE WATER AND ABSORBED WATER[1]

The cellular structure of LWA allows the absorption of water. Unlike normal weight aggregate (NWA), the absorbed water content of LWA does not remain constant in a pump line. One lightweight manufacturer's data[9] show an increase in absorbed water under high concrete pump pressure. Therefore, the total water requirement of LWC will be different than normal weight concrete (NWC).

ACI 304.2 divides the total water in LWC into two categories: free water and absorbed water. It explains, "The free water will establish the slump and have a direct bearing on the water-cementitious material relationship. The absorbed water, however, will be contained within the lightweight particles and will not change their displaced volume in the mixture . . . (it) will not affect quality of the mix."

More recent research[10] has shown that the absorbed water can affect the quality of the mix, but in a positive manner – it provides "internal curing" for concretes with a high cementitious content. High cementitious concretes are vulnerable to self-dessication and early-age cracking, that can be mitigated by the gradual release of the internal moisture from presoaked LWA.

PUMPING LWC

As can be expected, conversion of free water into absorbed water begins at mixing and continues unabated through the pump line, and may still be occuring after placement. More free water conversion will take place if the LWA is either intentionally or otherwise unsaturated. The reduction of free water, while lowering the water to cementitious ratio (w/cm), also lowers the slump, especially when the LWC is pumped. To successfully place this LWC, the following adjustments are made:

1. Extra water is added in the batch plant and at the project site to compensate for the loss of free water. However, the amount of extra water added never exceeds the quantity that may cause segregation of the LWC when it is discharged into a concrete pump hopper. A

segregated mix will clog the pump line and stop the pump. The slump at incipient segregation is a function of mix proportions. For example, one mix has a maximum slump limit of 7” to 8” slump measured at the truck before pumping. Experience shows that the pumping pressure can reduce the slump by as much as 3”, resulting in a slump of about 4” at the pump discharge on the deck, which is still adequate for placement.

2. Concrete sampling location is changed to the pump discharge on the deck. A sample obtained from the truck discharge will reflect the presence of excess free water. Because pump pressure converts free water to absorbed water, the properties of LWC may be substantially altered in the pump line. The conversion is more pronounced when the LWA has not been pre-conditioned with water. A sample obtained from the pump discharge on the deck will more accurately reflect the properties of the concrete in place. The following field experiences of pumped LWC illustrate the effects of the conversion of free water to absorbed water:

   - A high rise office tower was suffering from decreasing cylinder strengths as the floor level increased. When the traditional truck discharge sample was compared to a pump discharge sample for the same load, the latter sample had a significantly higher compressive strength. As the floor level continued to rise, samples taken at the pump discharge had approximately constant strength. In contrast, the truck discharge samples continued to trend downward in strength.

   - Cylinder strengths from a five level shopping mall were well below the specified strength (f'_c), enough to trigger an in-place strength testing program. In place strengths, regardless of floor level, appeared to be about the same, and were well above the specified f'_c.

3. Reduction of pump line pressure through the use of superplasticizer (high range water reducer) or in conjunction with smaller maximum size LWA. This strategy is critical when pumping a LWA with a high absorption value because the amount of extra water required may be excessive and cause mix segregation.

SLUMP CONTROL

Theoretically, if the LWA is completely saturated with absorbed water, then no free water can be converted into absorbed water during mixing, transporting and placing. If such conversion of free water does occur, it manifests itself in the loss of slump in the fresh concrete. With a low absorption LWA, regular lawn sprinklers can satisfy most of the absorbed water requirement, thus minimizing loss of slump. A higher absorption LWA may require saturation through thermal or vacuum methods, or immersion in a tank – all of which are more expensive and require special handling in the concrete batch plant. An economical solution is to follow the adjustments made for placing the LWC with a concrete pump. The magnitude of slump loss can be quickly established by sampling at both the truck and the deck when the first couple of loads arrive on site. Using the rule of thumb that 1 gal/cy of water would increase slump by about 1”, the right amount of water could be added to compensate for slump loss.

UNIT WEIGHT CONTROL

Placement of LWC with a unit weight outside the range specified by the design engineer can be costly to remedy. Unit weight control is crucial when placing a deck on the bascule leaves of a moveable bridge deck or when a composite floor has a certain Underwriters Laboratories (UL) fire rating. One UL rating may require a dry unit weight of 115±3 pcf, another 110±3 pcf. Therefore, prior to filling the LWA bin in the batch plant, the loose unit weight of the LWA should be checked. If the value falls outside of the range intended by the LWA manufacturer for the given moisture condition, the batch weight needs to be adjusted in order to yield the correct fresh concrete unit weight. A heavier LWA density may be the result of raw feed that did not “bloat” sufficiently during the manufacturing process, stockpile management practices that allow LW fines to accumulate in areas of the stockpile (segregation), or contamination with normalweight aggregates. It must be recognized that not all LWAs are the same. A particular LWA source may have a lower or higher aggregate particle strength than another. Those that are not as sturdy and may have a greater tendency to degrade each time a loader bucket cuts into the stockpile. The increase in fines from this degradation will tend to increase the unit weight.

The test for density or unit weight of LWC is governed by ASTM C 567. The publication of the 2005 edition of the standard replaces the concept of “dry” unit weight measured with 28-day “air-dried” cylinder with the calculated equilibrium unit weight. The equation for calculating the equilibrium unit weight is included in ASTM C 567 and no cylinder samples are required. For a given mix using one source of LWA, the fresh concrete unit weight is approximately 6 pcf heavier than the calculated equilibrium unit weight. For example, if the maximum specified equilibrium unit weight is a 118 pcf, then the allowable maximum fresh concrete unit weight is 124 pcf.

USING LWA DURING FREEZING WEATHER

During freezing weather, presoaking of LWA causes ice formation and agglomerates the LWA into big frozen lumps. The frozen lumps impede free flow of LWA in the aggregate hoppers in a concrete batch plant. It is virtually impossible to batch LWC under such conditions. The batching problem is solved by using surface dry or unsaturated LWA.

CONCLUSION

By understanding how free and absorbed water affect LWC, and the proper adjustments and quality control, the production and placement of LWC can be as routine as NWC.

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