Recycled Glass in Portland Cement Concrete

Material: Recycled Glass

Issue: *When glass cullet is indiscriminately combined with Portland Cement, chemical reactions can occur which may reduce the strength of the concrete. These include sugar contamination and an alkali-silica reaction. To minimize the adverse effects of these reactions, ingredients and methods used in standard PCC production should be modified.*

Best Practice: An adverse result of using glass cullet in Portland Cement Concrete (PCC) is the alkali-silica reaction (ASR). PCC producers have known ASR for many years because it can also occur when using vitreous (glassy) rock or slag with high amorphous silica content. The silica from the cullet or aggregate can combine with the alkalis in Portland Cement to form a siliceous gel. This gel will then absorb water and expand, causing structural weaknesses in the concrete. In addition, when mixed in PCC, sugar can cause an unpredictable increase in setting time and a decrease in the ultimate strength.

A number of methods have been proposed to minimize sugar residue contamination and ASR, or to reduce their adverse affects. Modifications to the standard production of PCC include the following:

- Cleaning of glass aggregate
- Use of low alkali cement
- Use of low alkali pozzolan or set retarder
- Use of an air entrainment system
- Reduction of moisture content
- Increasing surface area to volume ratio of glass aggregate

Visual inspection of otherwise clean glass cullet may not reveal the presence of sugar residue from previous food contents. Therefore, all cullet should be washed prior to its use as aggregate in PCC. If possible, a high temperature wash should be used to expedite the removal of sugar from the cullet. The glass can then be air-dried to minimize the addition of any uncalculated moisture to the PCC mixture.

Reducing the reactants present in the PCC mixture can minimize the alkali-silica reaction. Because the cement is the source of the alkalis (Na_2O + K_2O), low alkali Portland Cement should be used. The American Society for Testing Materials defines low alkali cement as consisting of less than 0.60% by weight of alkalis. The amount of alkalis can also be reduced by replacing up to 25% of the Portland Cement with a low alkali siliceous pozzolan, such as ASTM Class F fly ash.

Alternately, a set retarder can be used in place of the pozzolan to slow the curing time of the PCC. This allows more time for the ASR gel to form and expand before the concrete hardens, resulting in less internal stress. It should be noted that using the set retarder in conjunction with a pozzolan will not increase the overall resistance to ASR. However, a set retarder can be used in conjunction with an air

entrainment system, which incorporates evenly dispersed microscopic pockets of air in the PCC. When ASR occurs, these air pockets allow additional space for the gel to expand, thereby lessening the potential for structural weakness.

The impact of ASR can also be alleviated by minimizing the amount of moisture in the PCC mixture, which will decrease the expansion of any gel produced. However, using less water will also cause an increase in viscosity, thereby decreasing the "slump." The resulting mixture may be difficult to pour. If a lower viscosity is needed, a High Range Water Reducing (HRWR) admixture can be added.

Research shows that increasing the surface area to volume ratio of the glass will reduce the effects of the reaction. This can be accomplished by using glass with smaller particles. Finer particles tend to accelerate the reaction, which may allow the gel to expand before the concrete hardens. Research has suggested that up to 20% of the total aggregate should be replaced by glass 16 mesh and finer particles.

Air drying the poured PCC for several weeks to months, as opposed to any accelerated drying methods, will also minimize the ASR. Air-drying appears to lock the alkali in a solid state, and future rewetting the concrete only brings a portion of the alkali back into solution.

In addition, some research suggests that a higher proportion of green glass in the cullet source may also suppress the ASR. This may be due to the higher concentration of chromium oxide in green glass, although adding this chemical directly to the PCC mix does not appear to affect the reaction.

Implementation: Glass has been used in aesthetic applications in PCC for many years. However, research is not yet conclusive enough to recommend the use of glass in structural concrete. Therefore, these strategies should only be used with Portland Cement in areas where unpredictable final strength will not endanger the public.

Benefits: The methods outlined in this best practice will help minimize adverse effects encountered when using recycled glass as aggregate in non-structural Portland Cement Concrete.

Application Sites: Glass suppliers, concrete fabrication facilities, and construction sites.

Contact: For more information about this Best Practice, contact CWC, (206) 443-7746, e-mail info@cwc.org.

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