Reducing Cement Usage of Florida Structural Concrete by Optimizing Aggregate Gradation and Minimizing Paste Content

HungWen Chung, Thanachart Subgranon and Mang Tia

ABSTRACT

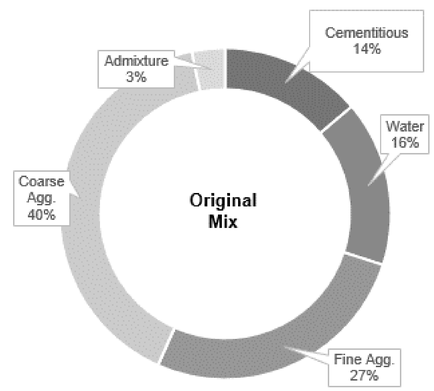
The concrete industry in Florida is presently facing two major challenges, namely (1) the rising cost of cement and (2) the shortage of fly ash. The ascending price of cement has increased by 17.8% from 2012 to 2015. According to the forecast of fly ash utilization from American Road and Transportation Builders Association in 2015, the demand for fly ash will increase by at least 53% for the next 20 years. One of the possible solutions to these challenges is through a more effective design of concrete mixes for which the cementitious materials contents have been minimized.

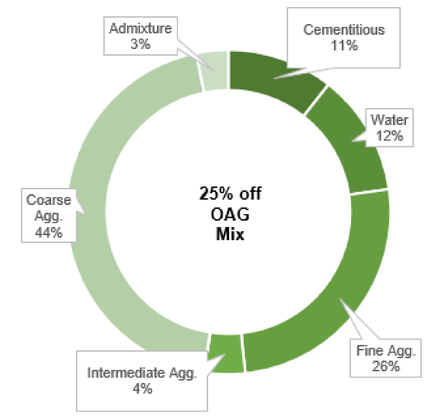
Preliminary investigations have indicated that most FDOT concrete mixes have an excess of paste. The main reason for this is due to the mistaken assumption that concrete can always be made stronger and with quicker strength gain by increasing the content of cementitious material. In reality, 10 to 20% of the cement content in most FDOT concrete mixes can be removed without any adverse effects on the plastic or hardened concrete properties. This reduction in cement content can be maximized by using an intermediate-sized coarse aggregate along with the original aggregate (for example, using standard #57 graded coarse aggregate with #89 graded coarse aggregate). By adjusting the gradation of the coarse aggregate blend, an optimum packing of aggregate (optimized aggregate gradation, OAG) can be obtained such that the aggregate volume content is maximized. The use of OAG along with the reduction of paste (cement) content can improve the properties of the concrete mix, including (1) improved workability of fresh concrete, (2) reduced shrinkage, (3) increased resistance to intrusion of deleterious chlorides and sulfates, and (4) reduced heat of hydration. Also, the reduction in the use of cementitious materials would significantly reduce the cost of concrete, and reduce the environmental impact by conserving natural resources, lowering energy consumption, and lowering carbon dioxide emission. Based on preliminary testing results, the cost of proper OAG mix reduces 3.87% total costs than SC mix. Moreover, the emission of carbon dioxide of OAG mixes also decrease around 5.0%. In the end, OAG concrete could be cost-saving, environmental-friendly and sustainable green concrete in a long term. According the results, reducing cement usage of concrete by OAG method is an approach to improve Florida structural concrete

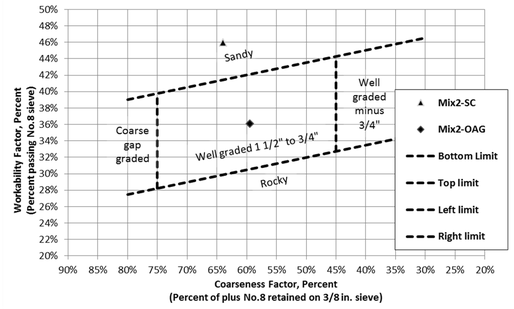
OBJECTIVE

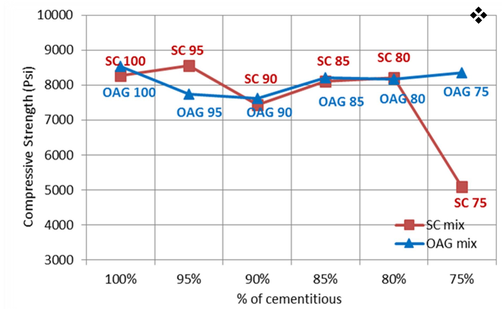
- To conduct a laboratory testing program to investigate an effective method to achieve OAG in Florida concrete.
- To conduct a laboratory testing program to evaluate the effects of OAG and minimizing paste content) on properties of fresh and hardened concrete.
- To evaluate the cost-effectiveness and Carbon Dioxides emission of using of OAG mixes in the production of concrete in the concrete and cement plants.

WHAT IS NEXT?









BENEFITS of MINIMIZING CEMENT CONCTENT

1. Saving Cost
2. Better Workability
3. Same Strength
4. Quality Control
5. Wasted Materials
6. Environmentally Friendly

Optimized Aggregates Gradation

Shilstone (1990) develop a chart to adjust gradation, which including two main factors, workability factor (WF) and coarseness factor (CF). The X-axis, CF, presents the amount of coarse aggregates divided by the sum of the coarse and intermediate aggregates. The Y-axis, WF, means that the percent of the aggregates passed #8 and adjusted the sum of cementitious material in a mixture.

LABORATORY RESULTS

- **The plastic properties of fresh concrete,**
  1. Workability, OAG concrete has higher workability than conventional concrete (Saving admixture and cost).
  2. Air Content, the air content of OAG concrete is more stable than standard concrete (SC) (Quality Control).
- **The properties of harden concrete,**
  1. Strength, there is no different between OAG concrete and SC (Comparable strength).
  2. Permeability, OAG concrete has lessor early-age permeability (Durability)
  3. Anti-Crack potential, according the restrained ring test, OAG concrete has less potential of cracking.
  4. Shrinkage, because of less cement content, the drying shrinkage of OAG is less than SC.

FUTURE INVESTIGATION

Because raw materials of producing cement is lacking, the new Type IL cement have been developed. Type IL cement (8-14% replacement by limestone powder) have been approved by FDOT to use in the construction recently. But Type IL cement concrete is not widely using in construction. Based on our laboratory results of the results, the OAG approach could decrease 25% cementitious content (Type I/II cement) and improve the properties of harden concrete. So, the future research will focus on the Type IL cement concrete incorporated with OAG method.

REFERENCE & CONTACT

Tia, M., and H.Chung. [2018] "Reducing Portland Cement Content and Improving Concrete Durability ". Florida Department of Transportation, Research Project

HungWen Chung, Ph.D. Student
Email: chweying@ufl.edu
Office: 265H Weil Hall, Civil Engineering Department