REPORT OF: CONCRETE MIX LAB BATCHING AND TESTING

PROJECT: Fox River Sediment Glass Aggregate Concrete Mix Batching & Testing

OMNNI PROJECT NO. T0868A03

CLIENT: Mr. Tom Bauduin
Minergy
1512 S. Commercial Street
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INTRODUCTION

This report presents the results of concrete mix batching and testing using glass aggregate produced by Minergy. Crushed glass aggregate from the Minergy Pilot Plant produced from Fox River sediments was used in the batching and testing. This glass aggregate was incorporated into an air entrained concrete mix with ¾" maximum nominal aggregate size that is typical of a concrete mix that is commonly used for commercial applications. The purpose of this testing and evaluation was to compare the physical properties of the concrete mixture containing the glass aggregate component to a similar mix composed exclusively of locally available, naturally occurring aggregates. Strength, water demand and workability of the mixture containing the glass aggregate were compared to the traditional concrete mix that used the naturally occurring aggregates exclusively. Our work was requested and authorized by Mr. Tom Bauduin of Minergy.

The scope of our work consisted of the following tasks:

- Mobilize technicians to a local concrete plant site to obtain aggregates to be used in concrete mix laboratory batching.

- Verify that aggregate gradations meet ASTM: C33 size 67 and fine aggregate gradation specifications. Determine aggregate specific gravity and absorption.

- Perform laboratory batching of a concrete mixture using an aggregate blend consisting of naturally occurring aggregates, cement, fly ash, water reducer, air entraining admixture and water. Perform laboratory batching of a second mix substituting a portion of the fine aggregate with a Fox River sediment glass aggregate component that had been crushed to meet ASTM: C33 gradation specifications. Perform slump, air content, concrete temperature and unit weight tests on each mixture. Cast both compressive and flexural strength test specimens and test at 7 and 28 days. Record mixture batch weights and determine yield and water/cement ratios for each mixture.

- Compare the physical properties of the mix using the glass aggregate to the mix that did not include the glass aggregate. Also compare the mixture workability and water/cement ratios.

- Prepare a report summarizing our findings.

MATERIALS

A 5 ½ bag, air entrained concrete mix using locally available aggregates was developed for the work. This mix type was chosen because it is very similar to concrete mixes commonly used locally for building and pavement construction. The mix components as listed on this design were used to perform our work. The following materials were used in designing and testing the concrete mixes:

1.	Cementitious Materials	Portland Cement – Holcim - Type I – Theodore, AL Fly ash – WPS, Weston– Class C –Schofield, WI
2.	Admixtures	Air Entrainment – Daravair M– WR Grace Water Reducer – WRDA-82 – WR Grace
3.	Fine Aggregate	CAM Materials, Newby Pit, Portage County, WI
4.	Coarse Aggregate	MCC, Inc., Mackville Quarry, Outagamie County WI
5.	Water	OMNNI Laboratory

Naturally occurring aggregates were obtained from a local concrete mix supplier's plant stockpiles. Cement, fly ash and admixtures were on hand at the OMNNI laboratory. The crushed stone coarse aggregate was produced from Ordivician age dolomitic limestone from the Sinnipee Group at the MCC, Inc. Mackville Quarry in Outagamie County, Wisconsin. The natural sand is composed predominantly of quartz sand and is mined from a glacial outwash deposit at the CAM Materials, Newby Pit in Portage County, Wisconsin. Fox River sediment glass aggregate was produced at the Winneconne pilot plant and was crushed to meet ASTM: C33 fine aggregate gradations specifications by Minergy personnel and delivered to our laboratory.

The naturally occurring course aggregate used in the laboratory batching was obtained from a Wisconsin DOT qualified aggregate source. Aggregate sources are qualified through the WisDOT Central Laboratory in Madison and the aggregate qualification typically involves the DOT testing them for Sodium Sulfate Soundness (AASHTO T104), LAR Wear (AASHTO T96) and Freeze-Thaw (AASHTO T103). The Wisconsin DOT performs testing for soundness, wear and freeze-thaw tests are performed on coarse aggregates only.

Aggregate test reports can be found in Appendix B.

TEST METHODS

The trial mixes were proportioned in accordance with ACI 211, "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete" using the absolute volume method. Both concrete mixtures were designed with 517 pounds per cubic yard total cementitious material, which consisted of 75% Type I Portland cement and 25% Class C fly ash. Fine and coarse aggregate weights were determined so that the fine aggregate would be 40% of the total aggregate blend by weight.

Admixtures used consisted of air entrainment and water reducer supplied by WR Grace. Each mixture was designed to target a 3-inch slump, 6.0% total air content, and a yield of 27.2 cubic feet per cubic yard.

Early trial batching indicated that, because of the angular nature of the glass aggregate, replacing all the natural fine aggregate with glass aggregate produced a mix that had high water demand and was not workable. To produce a workable mix and limit water demand, 50% by volume of the natural fine aggregate was replaced with the glass aggregate. The natural aggregate trial batching produced a mix that was very workable with anticipated water demand. Mix proportions for each cubic yard of concrete for each mix were as follows:

	Natural Aggregates Batch	Glass Aggregates Batch
1. Cementitious Material		
a. Holcim Type I Cement (lbs)	387	387
b. WPS-Weston , Class C Fly Ash	130	130
2. Admixtures (oz/yd)		
a. WR Grace, Daravair M	3.4	3.4
b. WR Grace, WRDA-82	15.5	15.5
3. Natural Fine Aggregate (lbs)*	1316	624
4. Glass Fine Aggregate (lbs)*	0	676
5. Coarse Aggregate-(3/4"-#4) (lbs)*	1965	1965
6. Net Water (lbs)	211	235
(gals)	25.3	28.2

*Weights shown are on a "bulk oven dry" basis.

Trial batching was performed at the OMNNI Laboratory for each concrete mix. The concrete trial batch that exclusively used the natural aggregates had a slump result of 2 ¾", an air content of 6.2% and a yield of 27.1 cf/cy. The concrete trial batch that replaced 50% of the natural fine aggregate with glass aggregate had a slump result of 2 ½", an air content of 6.7% and a yield of 27.0 cf/cy. Six 6"x12" concrete test cylinders and three 6"x6"x22" concrete beams were cast on each trial batch. Three of the test cylinders were tested for compressive strength at 7-days and three were tested at 28-days. One of the beams was tested in flexure at 7 days and two were tested at 28 days on both trial batches. A summary of trial batch water to cement ratios and average 28-day compressive and flexural strengths for the concrete trial batches is as follows:

	W/C Ratio	Average 28 Day Compressive Strength (psi)	Average 28 Day Flexural Strength (psi)
A. Natural Aggregate Batch	0.42	6010	890
B. Glass Aggregate Batch	0.45	4220	760

Compressive and flexural strength test reports can be found in Appendix A.

DISCUSSION AND CONCLUSIONS

Concrete strength is generally dependent on the water/cementitious materials ratio, age of the concrete, curing conditions, air content and the ability of the cement paste to bond with the aggregates. Lower water/cementitious materials ratios will typically result in greater concrete strength. Also, greater age and good curing conditions will affect the extent to which cement hydration has progressed and will result in higher strengths. All other properties being equal, higher air content will result in lower concrete strength. However, higher air content may also reduce the amount of water needed to achieve the desired consistency, reducing the water/cement ratio and offsetting some of the reduction in concrete strength. Good bonding of the cement paste with the aggregates will also result in higher concrete strength. A good indication of the ability of the cement paste to bond with the aggregates is the amount of fractured coarse aggregate particles on the face of a fractured concrete strength specimen. A high percentage of fractured coarse aggregate indicates that the cement/sand matrix strength is at least as strong as the coarse aggregates and that there is a good bond between the coarse aggregates and cement/sand matrix.

The replacement of half of the natural fine aggregate with the glass aggregate resulted in a significant decrease in compressive and flexural strength, a slight decrease in workability and an increase in water demand and, ultimately, the water/cement ratio. In our opinion, the increase in water/cement ratio and decrease in workability can be generally attributed to the angular nature of the glass aggregate. Because of the high degree of glass aggregate angularity, additional water was required in the mixture to maintain slump within the desired range. It is also our opinion that the decrease in strength can be primarily attributed to the inability of the cement paste to adhere to the glass aggregate particles and, to a lesser extent, an increase in water/cement ratio. This opinion is based on the following observations.

1. After performing strength testing of the mix containing the glass aggregate, we observed that the glass aggregate particles had pulled cleanly away from the cement paste on the fractured surfaces of the test specimens.
2. Many exposed glass aggregate particles could be cleanly removed from the concrete specimen with a fingernail. Very little concrete paste residue was observed on the exposed glass aggregate surfaces on the fractured surfaces of the test specimens.
3. Only approximately half of the coarse aggregate particles in the fractured face of the compressive test specimens were sheared.

The higher air content in the mix containing the glass aggregate probably also contributed to the lower strength results. However, it is our opinion that this would account for only a small portion of the decrease in strength. Based on information provided in the Portland Cement Association's 14th edition of "Design and Control of Concrete Mixtures", we have estimated that the 0.5% increase in air content would cause a decrease in compressive strength of approximately 80 psi. The addition of the glass aggregate did not appear to negatively affect the performance of the air entraining or water reducing admixtures.

Based on the results of our testing, it is our opinion that, the Fox River sediment glass aggregate included in this concrete mix could be used as an aggregate component in concrete mixes that would not need to be finished or be exposed to high loading, high traffic, or severe weathering conditions. However, because of significant differences in compressive and flexural strength and the indications of a poor bond between the glass aggregate and cement paste, it is also our opinion that higher compressive strength results could be obtained only by decreasing the glass aggregate replacement percentage of the fine aggregate. Additional testing would be required to determine a percentage of replacement that could provide more comparable results with a normal concrete mix. It should also be noted that our testing only considered the properties of workability, compressive strength and flexural strength. Depending on the application of the concrete mix, additional properties such as permeability, abrasion resistance, volume stability and durability may need to be investigated.

If you have any questions regarding this report, please contact us.

Sincerely,

Paul R. Eggen
Program Manager – Materials Testing