STUDY OF CONCRETE PROPERTIES INCORPORATING WASTE GLASS

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ABSTRACT
A few of the world's waste glass is recycled into new glass. This study is an attempt to recycle the waste glass by replacing natural sand with crushed waste glass in concrete. The objectives of this investigation are to study the strength of concrete made with 100% replacement of natural sand by glass sand (glasscrete) and also to compare the result with concrete made with natural sand. The results show that glasscrete gain less strength than normal concrete and require less w/c ratio. On the other hand, glasscrete have greater elastic modulus than normal concrete.

Keywords: waste glass; glasscrete; concrete; strength and elastic modulus

INTRODUCTION
Concrete is the most widely used artificial substance on earth owing to its remarkable versatility as a construction material (Crow, 2008). The annual concrete production exceeding 2 billion metric tons per year across the world. One shortcoming of concrete as a construction material is the harmful effects on the environment posed by the production of its components (Roskos et al., 2014).
The generation of waste is vastly increased due to rapid growth of population and industry. So, worldwide recycling of waste materials has become a serious issue. The closed loop recycling technique is considered as the most appropriate practice to recycle waste materials. However, sometimes, because of high cost enforced from sorting and cleaning processes of waste material, the closed loop cannot be applied in recycling process. For example, the closed loop recycling process is not viable to recycle contaminated mixed-color waste recycled glass in glass industry because it required high cost for sorting and cleaning and inconsistence in the properties of the contaminated mixed-color waste recycled glass (Taha and Nounu, 2010).
Numerous research works were performed to examine the opportunity of reusing waste recycled glass in concrete and construction industry as alternative solution to reduce the generated bulk of mixed-color waste recycled glass, and establish solid ground for clear understanding and further investigation (Dhir et al., 2004; Jin et al., 2000; Shayan and Xu, 2003). Most of the past research on the use of glass aggregates in concrete engrossed on the mitigation of the deleterious alkali-silica reaction (ASR). ASR develops when aggregates with highly amorphous silicates (e.g., glass) are in contact with the alkaline pore solution of concrete. This contact causes dissolution of the silicates and formation of ASR gel, which swells and might crack the concrete (Wright et al., 2014).
This investigation was performed to study the strength of concrete made with 100% replacement of natural sand by glass sand (glasscrete) and also to compare the result with concrete made with natural sand. This study will present the results of a research effort focused on developing a green concrete for structural application made with Portland Composite Cement (PCC) as a binder material and crushed waste glass as fine aggregate.

METHODOLOGY
One of the most important tasks of this study was collection of waste glass and preparation of glass aggregate. The main ingredient of study waste glass was collected from locally available glass stores, domestic wastes and wastes of construction work [Fig. 1]. The glass was crushed to sand size using a standard Los Angeles (LA) abrasion machine to obtain a fineness modulus similar to the natural sand used in this study [Fig.2]. Although the FM is a rough estimation of consistency across mixtures, its

simplicity evaluation provides a basis for quality control of workability (Mindess et al., 2003).The coarse glass aggregate was collected by separating from the crushed aggregate using a No. 4 ASTM standard sieve. Crushed glass passed through on N0. 4 sieve was used as fine aggregate.

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Fig. 1: Collected Waste Glass

Fig. 2: Fine Glass Aggregate

The natural sand used in this thesis was locally available river sand, locally known as Sylhet sand, adhering to ASTM C33 (ASTM, 2011), with a saturated surface dry (SSD)specific gravity of 2.4,water absorption 4.1% and fineness modulus(FM) of 2.9. The dry rodded unit weight of the natural sand was determined 1600 kg/m^3. The glass sand adhered to the ASTM C33 (ASTM, 2011) gradation and had a specific gravity of 2.6 and water absorption 0.00%. The FM was maintained at 2.9 ± 0.1. The glass sand also had dry rodded unit weight of 1795 kg/m^3. The natural coarse aggregate used in this research was crushed stone chips adhered to the ASTM C33 (ASTM, 2011) gradation as a #57 coarse aggregate with a dry rodded unit weight of 1495 kg/m^3 ,SSD specific gravity of 2.73, and water absorption 0.70%.

Table 1: Proportion of concrete mixtures (kg/m^3)

Mix Design	Cement	Coarse Aggregate	Fine Aggregate		Water	Design Strength(psi)
			Natural Sand	Glass Sand		
N1	465.12	930	803.06	-	200	5000
G1	465.12	900	-	793.19	200	5000
N2	363.64	930	777.36	-	200	4000
G2	363.64	900	-	870.71	200	4000
N3	333.33	930	800.45	-	200	3500
G3	333.33	900	-	895.72	200	3500
N4	307.69	930	819.99	-	200	3000
G4	307.69	900	-	916.89	200	3000
N5	285.71	930	836.73	-	200	2500
G5	285.71	900	-	935.03	200	2500

Proportioning of concrete was performed according to the ACI 211.1 standard volumetric proportioning method. Concrete was mixed according to ASTM C192 (ASTM, 2007) using a standard concrete mixture. 100mm×200mm concrete cylinders were cast and compacted according to ASTM C31 (ASTM, 2000) in two layers with 25-rod blows per layer. Concrete cylinders were cast for various desired strength [Table 1] and compressive strength was tested at 1, 3, 7 and 28 days after casting. Elastic modulus was determined at 28 days after casting. In Table 1 the mixture identifier starts with N refers natural sand and G refers glass sand.

RESULTS AND DISCUSSION

The compressive strength development over time between the glasscrete and the conventional natural sand mixtures that were designed for a 28-day compressive strength of 5,000 psi (G1 and N1) and 4000 psi (G2 and N2) are shown in Fig. 3 and Fig. 4 respectively. It is observed that glasscrete always gain less compressive strength than concrete made with natural sand.

Both N1 and G1 exceed their design strength 5000 psi at 28 day but conventional concrete gains more strength than glasscrete .The strength difference between them is 6.42% of their designed strength. The same observes for N2 and G2 mixtures whose desired strength was 4000 psi at 28 days and strength difference is 11.4%.

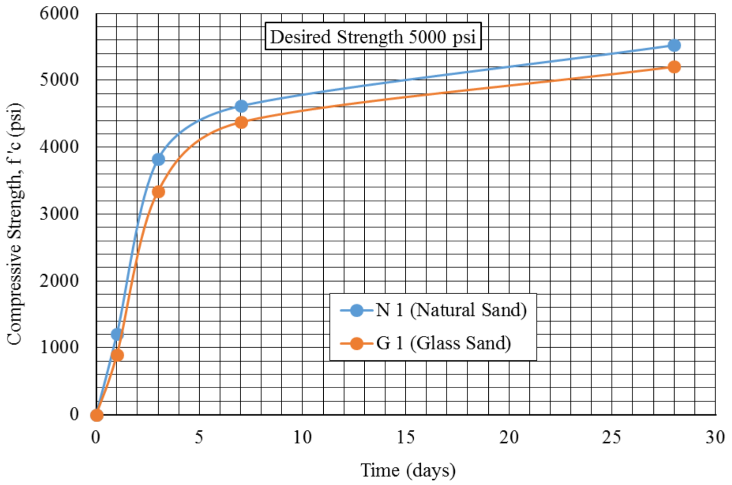

Fig. 3: Compressive Strength Gain Curve for N1 and G1 Mixtures

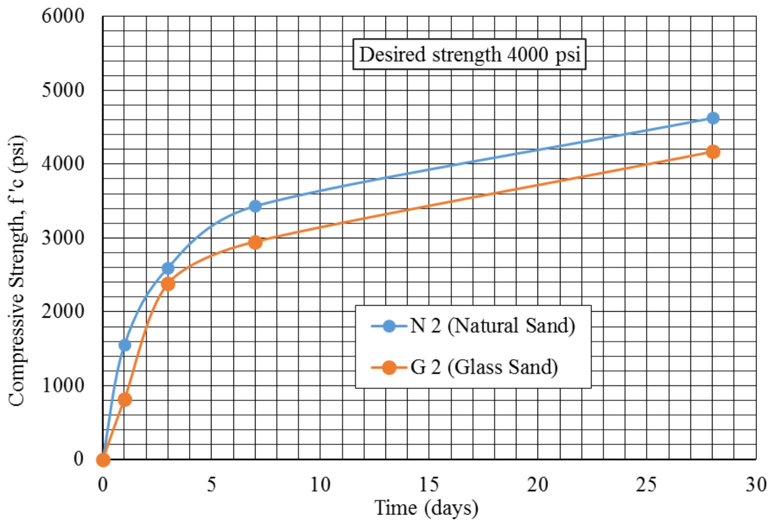

Fig. 4: Compressive Strength Gain Curve for N2 and G2 Mixtures

As concrete matures, the weaker bonding of glass aggregate to hydrated cement paste may become the weak link, which controls the compressive failure of glasscrete mixtures. Natural sand may allow for a better bond with cement paste given its greater surface roughness and moisture absorption capacity.
Correlations were determined between the w/cm and the compressive strength at seven [Fig. 5] and 28 [Fig. 6] days, for glasscrete and natural sand concrete mixtures. Exponential regression curves were fitted with the experimental results and the correlation coefficients are offered. These figures may serve as design tools for proportioning concrete mixtures containing recycled glass fine aggregates to achieve a target compressive strength. For example, Fig.6 shows that to design a glasscrete mixture with 28-day strength of 4,000 psi, w/cm= 0.51 is required, whereas this strength is achieved in a conventional mixture with w/cm =0.55.
Elastic modulus of both glasscrete and conventional concrete was determined at 28 days after casting. A comparison of elastic modulus is presented in Fig. 7. It is observed that for 100% sand replacement (glasscrete) always attain higher elastic modulus than conventional concrete for all mixtures. So glasscrete is stiffer than conventional concrete.

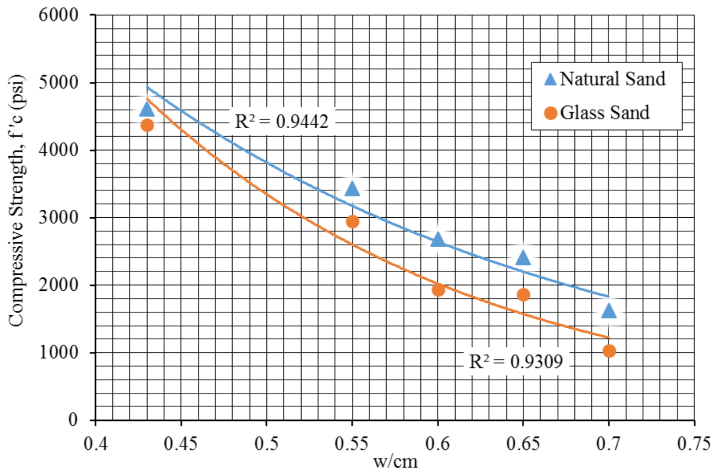

Fig. 5: Relation between w/cm and compressive strength at 7 days

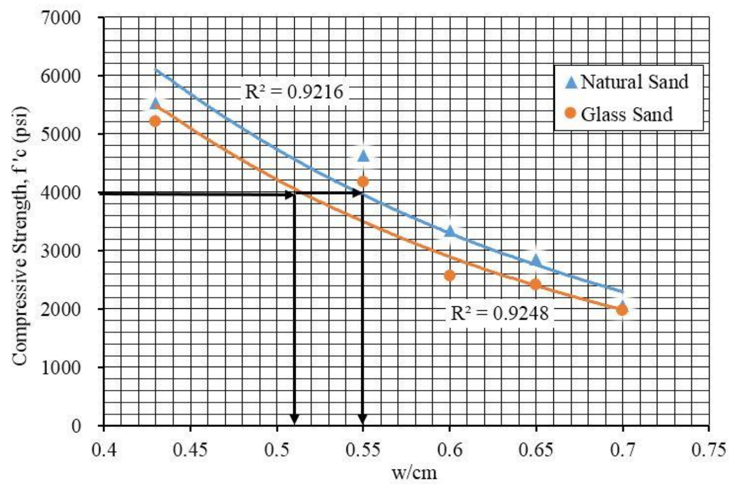

Fig. 6: Relation between w/cm and compressive strength at 28 days

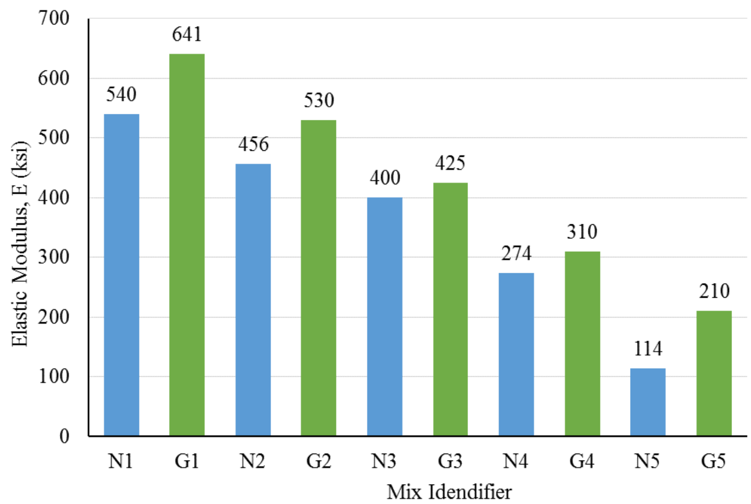

Fig. 7: Elastic modulus Comparison of natural sand concrete and glasscrete

CONCLUSION

This paper studied the performance of conventional concretes and concretes containing 100% glass sand as replacement of natural concrete (glasscrete). This study found that glasscrete always attain less compressive strength than conventional concrete for a similar w/cm ratio. Similarly for a definite desired strength glasscrete required less w/cm ratio than conventional concrete. This may happen for a lower fracture toughness of glass particles and weaker bond between glass aggregates and cement paste.

The empirical correlations that were developed in this study might be useful in practicing glasscrete mixtures. On the other hand, for a similar w/cm ratio glasscrete always attain larger elastic modulus compared to conventional concrete. Hence, glasscrete exhibits more stiffness than conventional concrete.

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