EFFECT OF WASTE GLASS ON THE PROPERTIES OF CONVENTIONAL CONCRETE

S. Y. Morshed*

Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh
**Corresponding Author: yadmorshed@gmail.com*

ABSTRACT

World is producing a huge amount of waste glass, that is an environmental concern. These waste glass provide an available resource for potential use in concrete by partially replacing coarse and fine natural aggregates. The objective of this study was to test the fundamental properties of concrete that utilized 15%, 30%, 40% and 50% waste glass as a partial replacement for coarse and fine natural aggregates in conventional concrete. This study also compared the results with conventional concrete. The outcome of this research demonstrate that waste glass has negative impact on the compressive strength of concrete. On the other hand, waste glass improve resistance against chloride ion penetration and lesser the water sorptivity compared to the conventional concrete.

Keywords: waste glass; concrete; strength; chloride ion penetration and water sorptivity.

INTRODUCTION

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 (Taha and Nounu, 2009). Numerous efforts have been made within the concrete industry to use waste glass (WG) as a partial replacement for natural aggregates or ordinary portland cement (OPC), with work using crushed WG as a concrete aggregate first being published in 1974 (Johnston, 1974). 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).

Due to the strong reaction between the alkali in the cement and the reactive silica in the glass, the use of glass in concrete has been previously found to not be satisfactory due to excessive expansion and strength loss (Almesfer and Ingham, 2014). This effect of alkali-silica reaction (ASR) can be mitigated by using 20% fly ash of weight of ordinary Portland cement (Wright et al., 2014).

This paper investigated the effect of partially replacement of coarse and fine aggregate by glass aggregate in conventional concrete, where Portland Composite Cement was the key binding material. The objective of this study was to test the fundamental properties of concrete that utilized 15%, 30%, 40% and 50% waste glass as a partial replacement for coarse and fine natural aggregates in conventional concrete. This study also compared the results with conventional concrete.

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 [Fig. 3] was collected by separating from the crushed aggregate using a No. 4 ASTM standard sieve. Crushed glass retained on N0. 4 sieve was used as coarse aggregate and passing material was used as fine aggregate.

. Fig. 1: Collected Waste Glass

Fig. 2: Fine Glass Aggregate

Fig.3: Coarse Glass Aggregate

The natural sand used in this thesis was locally available river sand, locally known as Sylhet sand, adhering to ASTM C33 (ASTM, 2011a), 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, 2011a) 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, 2011a) 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%. As mentioned earlier, coarse glass aggregate was separated from the crushed waste glass by using ASTM standard No. 4 sieve and then they were prepared to adhere the ASTM C33 (ASTM, 2011a) gradation as a #57 coarse aggregate with a dry rodded unit weight of 1522 kg/m^3 ,SSD specific gravity of 2.6, and water absorption 0%.

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

Mix Identifier	**Cement**	**Coarse Aggregate**		**Fine Aggregate**		**Water**
		Glass	**Stone chips**	**Natural Sand**	**Glass Sand**	
R0	364	-	930	777	-	200
R15	364	140	790	661	117	200
R30	364	279	651	544	233	200
R40	364	372	558	466	311	200
R50	364	465	465	389	389	200

In this study, total five batches of concrete were cast and all the mixture were designed for 4000 psi compressive strength at 28 days after casting. The proportion of different ingredients of concrete is given in Table 1. In the table R represent replacement and the lateral digits represents the percent of natural coarse and fine aggregate was replaced by glass aggregates. Proportioning of concrete was performed according to ACI 211.1 and 100×200 mm concrete cylinder was cast and compacted according to ASTM C31 (ASTM, 2000) in two layers with 25-rod blows per layer.

The uniaxial compressive strength of concrete was determined at 1, 3, 7 and 28 days after casting. Test for static elastic modulus was performed at 28 days and Rapid Chloride penetration test (RCPT) and water sorptivity test were at 90 days after casting.

RCPT and Water Sorptivity Test

The ability of concrete to resist penetration from aggressive elements (i.e., chloride ions) is key to the durability of reinforcing steel in concrete.

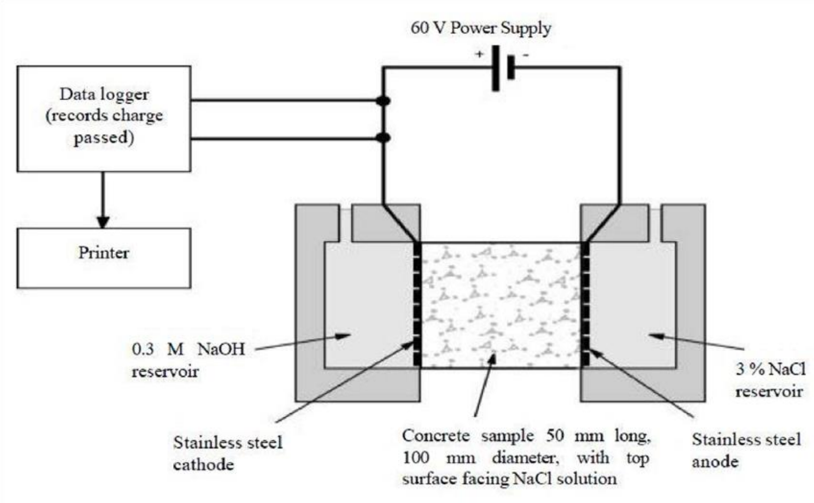

Fig. 4: Schematic diagram of RCPT test

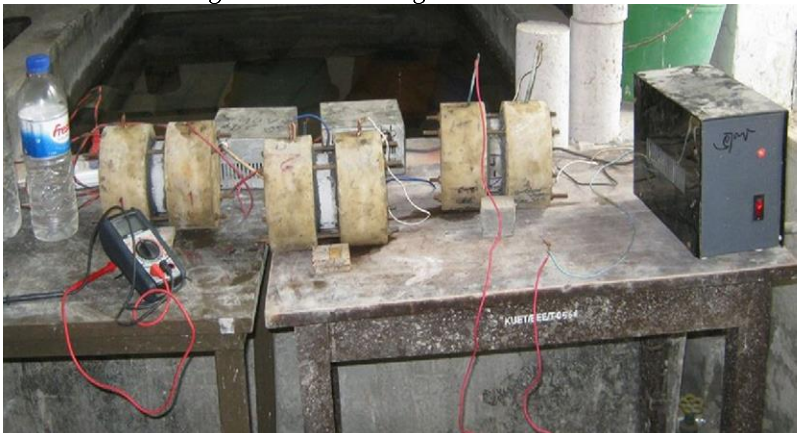

Fig.5: Experimental Setup of RCPT test

To evaluate the resistance of concrete against chloride penetration (RCPT), this test was performed on one specimen per mixture at the age of 90 days. Concrete cylinders 100×200mm in size were prepared and cut into 50mm thick disks from the center of the specimen. The test was performed according ASTM C1202 (ASTM, 2010). A schematics diagram of RCTP test and experimental setup of this test are shown in Fig.4 and Fig.5 respectively.

Water sorptivity test of concrete was performed according to ASTM C1585 (ASTM, 2011b). For this test 50 mm thick disk from a 100×200mm concrete cylinder and they were kept at 60^{o} C for three days. Then they were kept in atmospheric condition for 15 days.

Fig. 6: Experimental setup of water sorptivity test

RESULTS AND DISCUSSION

The compressive strength gain curve for all five mixtures are presented in Fig. 7 and comparison of compressive strength is made [Fig. 8] at 1, 3, 7 and 28 days after casting. All of the mixtures were designed for 4000 psi. None of the mixtures attained the designed strength 4000 psi except R 0, where no waste glass was used. The maximum strength gained 3755 psi for 30% replacement of natural aggregates by glass aggregates, which is 93.88% of the design strength. Minimum strength was found 74.98% of designed strength for 50% replacement of natural aggregates

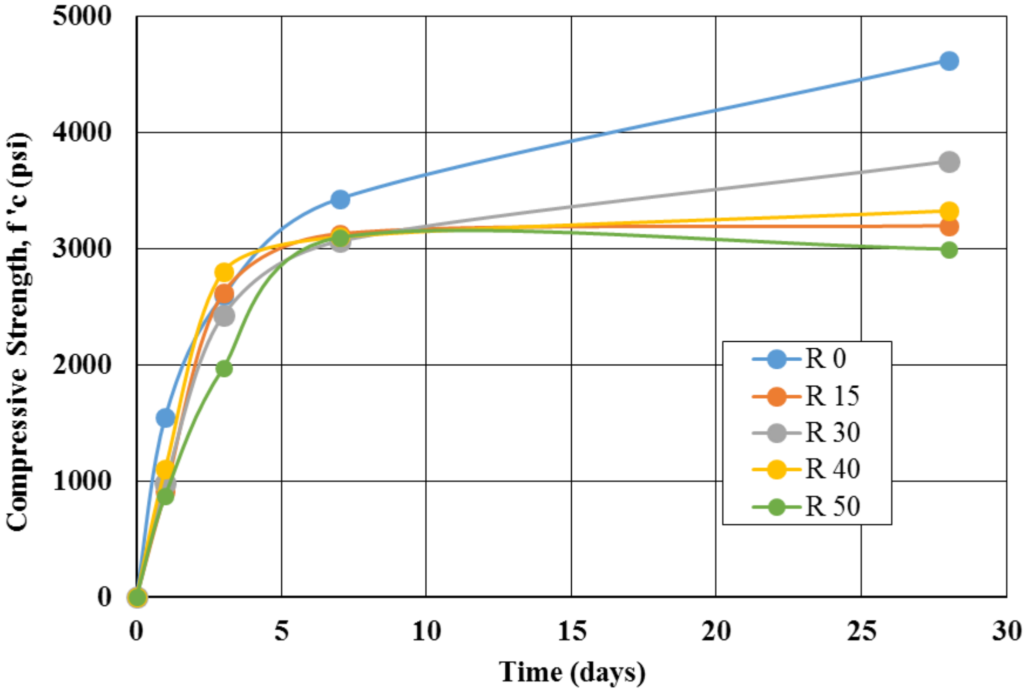

Fig. 7: Compressive Strength Gain Curves

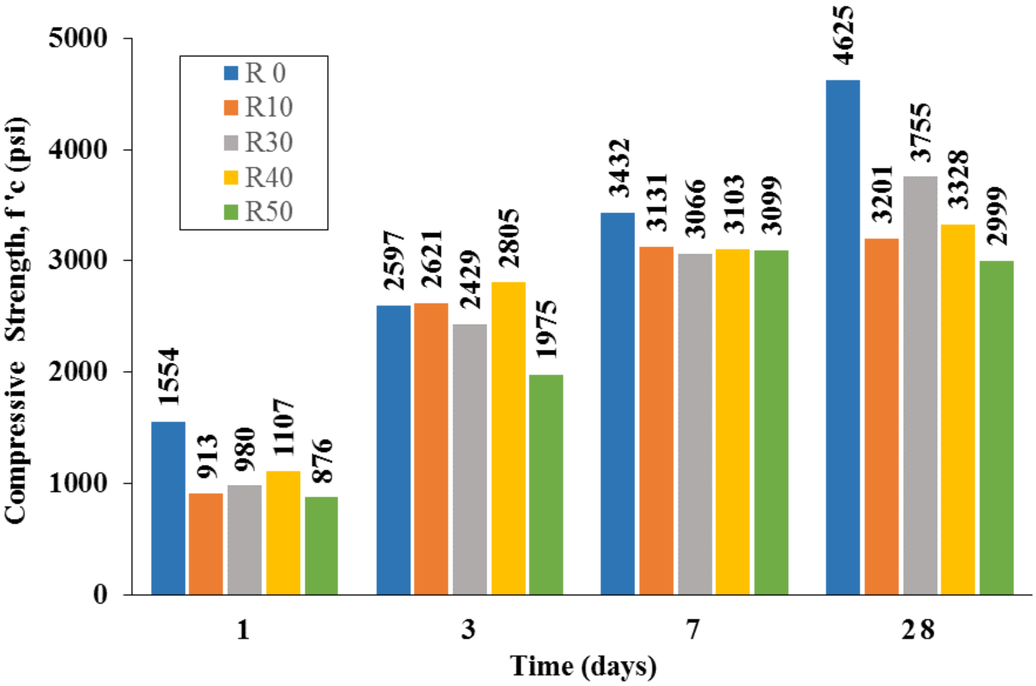

Fig. 8: Comparison of Compressive Strength

Elastic modulus of concrete was determined at 28 days after casting. Maximum elastic modules was found 552 ksi for R50 mixture [Fig. 9], where 50% replacement of natural aggregate was made. On the other hand, conventional concrete (R0) attained 456 ksi which is less than that for R50.

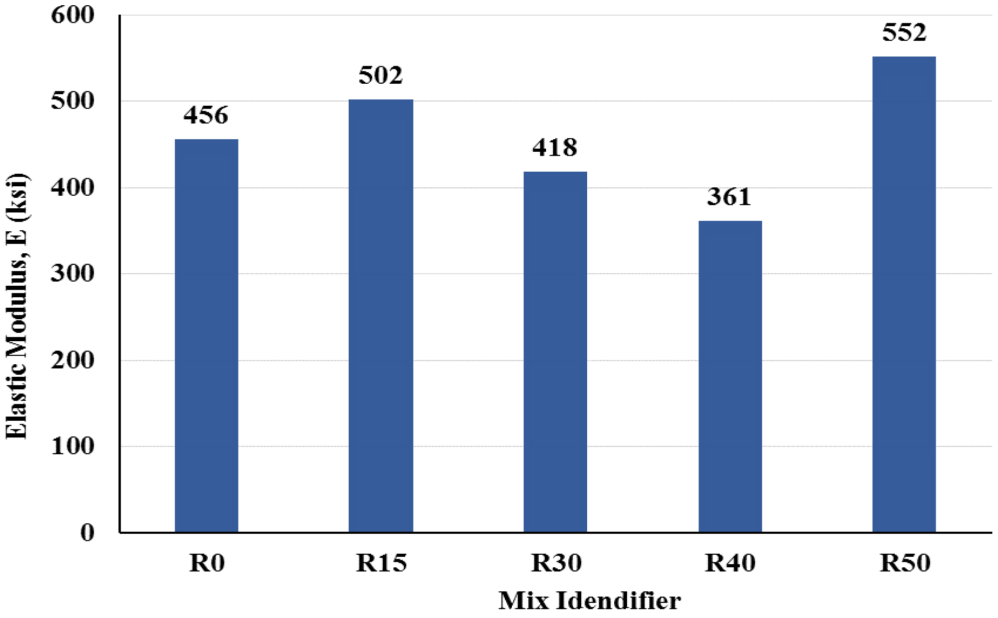

Fig. 9: Comparison of Static Elastic Modulus

The result showed with the percentile increased of glass aggregate in concrete, the charge passed through concrete decreased [Fig.10]. The strength may reduce for a lower fracture toughness of glass particles and weaker bond between glass aggregates and cement paste. On the other hand with the increase in glass aggregates, increased resistance in charge passing. Waste glass also improved the water sorptivity of concrete than conventional concrete.

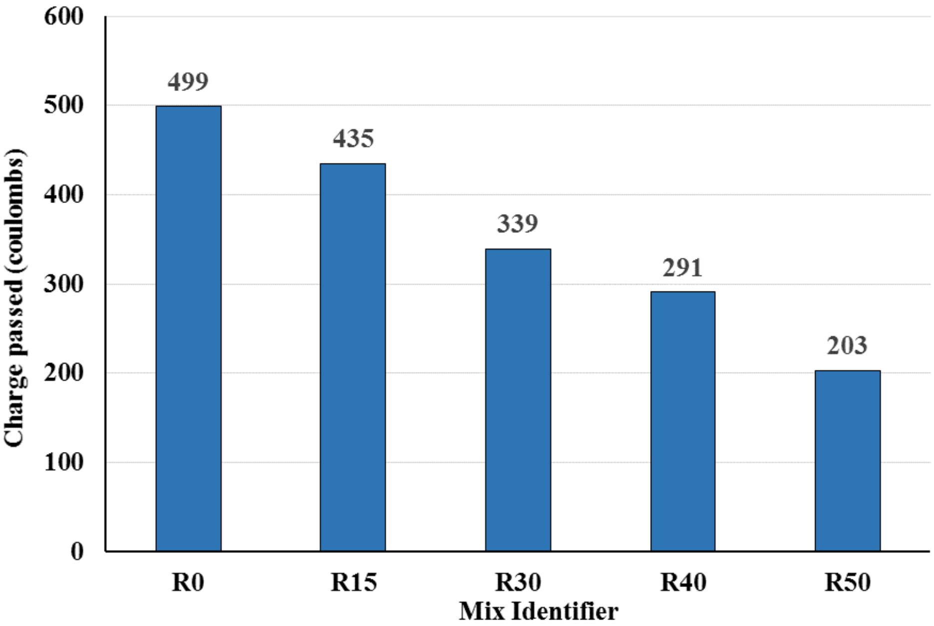

Fig. 10: Comparison of RCPT results

Table 2: Results of sorptivity test

Mix Identifier	R0	R15	R30	R40	R50
Initial sorptivity (10^{-4} mm/s$^{0.5}$)	140	165	140	136	142
Final sorptivity (10^{-4} mm/s$^{0.5}$)	14	14	17	15	11

The results of sorptivity test are presented in Table 2. The results showed that percentile increasing glass aggregates in conventional, bot initial and final sorptivity (rate of water absorption) decrease. So introducing waste glass aggregate in conventional concrete reduce water absorption thus increase durability.

CONCLUSION

This paper studied the effect of partially replacement of both natural fine and coarse aggregates by glass aggregate. Glass aggregate notably reduced the compressive strength of concrete. 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. On the other hand, considering durability performance glass aggregates have positive effect on conventional concrete. With percentile increasing glass aggregate in conventional concrete, RCPT and water sorptivity decreased.

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