Influence of Different Waste Materials on the Compressive Strength of Medium Strength Concrete

A. Abdul Rahim[1*], A. Rahaman[2]
[1]School of Civil and Chemical Engineering, VIT University, Vellore, Tamil Nadu, India
[2]School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India
***Corresponding author: E-Mail: abdulrahim.a@vit.ac.in, errahim@gmail.com**

ABSTRACT

Present study concentrated on the inclusion of glass powder and glass granules along with quarry dust under different curing condition. The glass powder was 20% replaced with binder content, glass granules was replaced 50% with fine aggregate content of the concrete mixes. In some mixes quarry dust also replaced 50% with fine aggregate content of concrete. The effect of glass powder, granules and quarry dust on improvement of compressive strength of concrete was assessed. The results indicated that 20% glass powder replaced concrete observed fast strength gain at early age and lesser deterioration in compressive strength in silane curing condition. The concrete mix containing 50% fine aggregate replacement by quarry dust yielded higher compressive strength among all other mixes.

KEY WORDS: concrete, compressive strength, glass powder, glass granules, quarry dust.

1. INTRODUCTION

Worldwide various types of wastes are generated as a result of manufacturing and servicing industries irrespective of the nature of their products, discarding of these wastes is a big challenge to every industry and has unlimited impact on environment. Disposal of generated industrial wastes are very detrimental to environment as well as human beings and also it construct health related issues due to their non-biodegradable in nature. Normally glass is less friendly to environment because it is non-biodegradable in nature although does not harm to the environment in any way and it does not give off pollutants. However it can harm humans as well as animals, if not dealt carefully. Hence, new technologies and alternative ways have been required to address the problem for safe disposal and utilization in another way.

The construction community keeps on showing interest on recycled materials to use in concrete to improve the certain properties as well as increase the sustainability in construction materials. The utilization industrial wastes and by-products are solution to reduce the end point of disposal to landfills, reducing the ecological problems, saving in energy, and protecting the environment form possible pollution effects.

Now-a-days, strength enhancement and microstructural modifications can be possible in concrete and this can be attained with incorporating different types of pozzolanic materials. The pozzolanic materials are highly reactive in nature and abundantly available as by-products. Hence, these of industrial wastes such as fly ash, silica fume and blast furnace slag, rice husk, metakaolin, plastics, broken / powdered glass and burnt ceramic are being commonly consumed by numerous types of concretes (Gupta, 2016). These waste products when ground to reduce in to the size equivalent to cement particles, its shows pozzolanic properties. Hence these by-products are used in concrete as pozzolanic material to enhance the performance of concrete in its fresh and hardened state properties and it helps in reducing the cost of cement and concrete manufacturing (Walczak, 2015; Tchakoute, 2016). Glass is one the most versatile substances on Earth, in daily life it is used as a packing material for cater wide range of products. The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass and borosilicate glass (Wang, 2015; Lopez, 2016). The collection of post-consumer glass from various sources as a raw material for making new glass products is very limited because of the high cost of collection and processing. Hence a huge amount of glass left as waste material which increase burden to land fill and leads so many complications (Wright, 2014).

Waste glass is acknowledged an ideal material for recycling. The recycled waste glass is used for verity of purposes (Vieira, 2016). Utilisation of recycled glass products may help to cut down the consumption natural resources and alter the micro structure behaviour, physical, mechanical and durability properties of mortar and concrete, which are difficult to achieve by the use of ordinary binder material. When waste glass is crushed into sand-like particle sizes, similar to that of natural sand, it exhibits properties of an aggregate material (Kushartomo, 2015). While the waste glass is to be grinding as fine powder, it behave as pozzolanic material to contribute the strength of concrete and also results in saving of cement and aggregate which directly contributes towards saving of natural resources (Matos, 2012).

Very limited studies have been performed to investigate the effectiveness in concrete. An application of unconventional waste glass products in concrete still needs improvement. In this regard the present project was made an attempt by replacing cement with waste glass powder in concrete having particle size equal to that of binder which possess pozzolanic property also with another attempt of replacing fine aggregate with glass granules and quarry dust in concrete having grain size equivalent to fine aggregate exposing of concrete to normal curing and saline curing conditions. The waste glass powder and its aggregates have been used as construction material to minimize environmental problems. An interest is being promoted to discover novel type of concrete with glass waste create. As result of recycling waste glass, glass powder and aggregates were obtained. In civil engineering practice, the fine powder of waste products is used as pozzolana (supplementary cementitious materials) to enhance the mechanical and physical properties in the concrete. In this study, the main research objective is to investigate the effect of waste glass products (fine powder and glass granules) in concrete to improve the compressive strength of various mix combinations.

2. EXPERIMENTAL

This section provide the comprehensive experimental program involving procedure of casting and testing of cubic specimens to investigate the effects of glass power as pozzolanic material and glass granules as fine aggregate incorporated in different types of concrete mixes along with quarry dust and fly ash. Before starting the key operations of the experimental investigation, the constituent materials of concrete were tested for required physical properties ass per Indian relevant standard and then proportioned.

Materials information: In this research program, locally manufactured and commercially available ordinary Portland cement (OPC) of 43 grade was used for preparing the concrete mixes complying with IS 8112:1989.

Fig.1. Photographs of Fly ash, Quarry dust, glass powder and glass granules

Natural river sand was used to confirming IS-383-1970 of grading zone-II. Same source of sand was maintained for entire experimental work. The fineness modulus and specific gravity sans were 2.9 and 2.7 respectively. Locally available hard granite rock aggregate 20 mm nominal size was used as coarse aggregate. The aggregates were in angular shape passed from 20 mm sieve and retained of 10 mm sieve had used. The fineness modulus and specific gravity of aggregates were 7.12 and 2.7 respectively. Both sand and coarse aggregates were used in saturated and surface dry (SSD) conditions for preparing the mixes. A fuel coal ash (fly ash) was obtained from Ennure thermal power plant. The specific gravity of the fly ash was 2.25 and it was replaced with cement. A commercially available glass powder and glass granules were procured from dealer in two different sizes 50- 90 microns down and 1.18 mm to 600 micron shown in Fig. 1. These materials were replaced with cement and sand during experiments. The fineness modulus of glass powder and granules were found out 2.67 respectively. The Table 1 shows the chemical composition of cement, fly ash and glass powered used in the experiment.

Table.1. Chemical composition of cement, fly ash and glass powder

Content	Cement (% by mass)	Fly ash (% by mass)	Glass powder (% by mass)
SiO_2	21.17	68.10	72.42
Al_2O_3	4.7	20.80	1.44
Fe_2O_3	3.07	0.90	0.07
CaO	61.9	2.50	11.5
MgO	2.16	0.98	0.32
Na_2O	-	0.09	13.64
K_2O	0.35	0.02	-
SO_3	3.19	0.24	0.21

Details about Mix proportions and Test specimens: In this research program, the conceptual concrete mix was designed to achieve the compressive strength of M-30 grade as per IS 10262- 2009. A total 60 numbers of cubic specimens were prepared using five different combinations of concrete mixes consuming ordinary Portland cement, fly ash, glass powder, glass granules and quarry dust. The details of mix combination are given in Table 2.

Mix 1: This is a reference (control) mix which was prepared without altering the binder content and fine aggregate content to compare other mixes. The ingredients were measured by weight batching to cast standard cubes.

Mix 2: In this case the cement content has been replaced with 20% of glass powder having particle size equivalent to that of cement and rest of the ingredients were kept unaltered.

Table.2. Processing condition for preparing different mixes

Mix Id	Description of mix proportions
Mix 1	Control mix (100% cement)
Mix 2	80 % Cement + 20% glass powder
Mix 3	100% cement+ 50% natural fine aggregate + 50% glass granules
Mix 4	100% cement+50% Natural fine aggregate + 50% quarry dust
Mix 5	100% cement + 50% Glass granules + 50% quarry dust

Mix 3: This mix case reveals that the cement quantity was kept as conceptual mix (mix 1) but the fine aggregate was replaced by 50% of glass granules having size equivalent to natural sand used for casting control concrete cubes.

Mix 4: In this case fine aggregate was replaced by 50% of the granite quarry dust and rest of the ingredients was kept same as control concrete.

Mix 5: In this case, the cubes were cast using 50% of the glass granules and 50% of the granite quarry dust to substitute natural sand.

Sample Preparation: The whole casting work was conducted under the controlled laboratory conditions. All samples of different concrete mixture were prepared under constant water- binder (w/b) ratio of 0.45. The concrete ingredients were mixed using 30 liters capacity tilting drum mixer and the specimens were cast in standard 100 mm cubic molds. The day after casting, the samples were demolded, marked and submerged into normal fresh water and saline condition for 28 days. Once the specimens reach the target curing days, the compressive strength test was conducted for all test samples to study the compressive behaviour for all the cement and FA replacement cases by comparing it with standard one. A detail of mix proportions (various cases) and casting details of specimens are shown in Table 3.

In the experimental work all five cases of cubes were kept in two different curing regimes. The specimens were soaked in fresh water and saline solution to achieve the normal and saline curing conditions. The silane curing condition was simulated to get the result of concrete structures exposed in coastal areas. The alkaline condition was created using rock salt chiefly available in sea water having concentration of 35gms/liter. All the cube specimens are tested for compressive strength. The compressive strength of concrete cubes were measured according to IS 516-1963 and shown in Fig. 2.

Table.3. Concrete mixes and details specimens

Mix details	Normal fresh water curing		Alkaline curing	
	7 days	28 days	7 days	28 days
Mix 1	3	3	3	3
Mix 2	3	3	3	3
Mix 3	3	3	3	3
Mix 4	3	3	3	3
Mix 5	3	3	3	3

Fig.2. Compressive strength testing setup

3. RESULTS AND DISCUSSION

Table 4 and Fig.3 – Fig. 7 present the compressive strength of different mix configurations at 7 days and 28 days. The control concrete mix was observed higher compressive strength as 27.70 and 38.43MPa at 7days and 28 days for normal curing condition. Though the results showed that the normal curing condition have yielded the better compressive strength to all types of concrete other than silane curing condition. This perhaps indicated that the silane curing condition badly affect the strength development process of control concrete as well as all other types of concretes (Zhu, 2013).

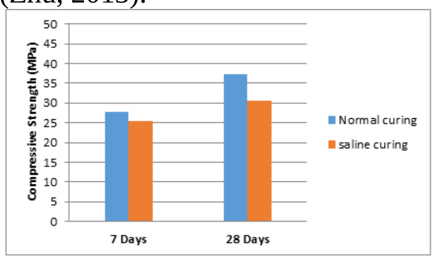

Fig.3. Compressive strength for Mix 1

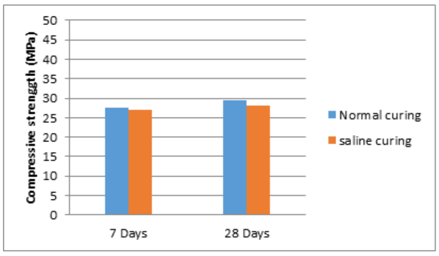

Fig.4. Compressive strength for Mix 2

The compressive strength of concrete was measured 27.5 and 29.53 MPa at 7 days and 28 days of curing period with 20% replacement of cement by glass powder, as shown in Fig.4.

This glass powder incorporated mixes have shown very fast initial strength gain at early ages. At later ages it was somewhat surpassed (Wright, 2014). This mix combination has attained reduced compressive strength about 21.10% for normal water curing condition similarly 8.28% lost for silane curing condition. Though, this mix was observed lesser deterioration in compressive strength in silane curing condition. This is because of non-reactive nature of waste glass particles.

The mix 3 was replaced 50% of fine aggregate (natural sand) by glass granules. This concrete gained a lesser amount of compressive strength than all other mixes. The strength drop was observed about 23.3% for natural water curing condition and 20.13% for silane curing condition at 28 days curing age (Fig. 5).

Table.4. Compressive strength results for different types of mixes

Mixes	Compressive strength			
	7 days		28 days	
	Normal water curing	Saline curing	Normal water curing	Saline curing
Mix 1	27.70	25.50	37.43	30.54
Mix 2	27.50	27.00	29.53	28.01
Mix 3	22.34	19.55	31.28	24.39
Mix 4	34.05	31.50	46.46	37.67
Mix 5	10.24	11.32	15.35	12.30

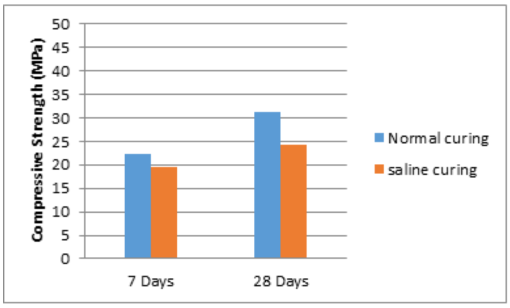

Fig.5. Compressive strength for Mix 3

This concrete mix has shown lower strength attainment at both ages and both curing conditions. This could be weaker bonding between surface of glass granules and concrete matrix, which be responsible for negative effect on the compressive strength of concrete.

The concrete mix containing 50% fine aggregate replacement by quarry dust yielded higher compressive strength among all other mixes. The previous research data also confirm the improvement in compressive strength of concrete while using the quarry dust in concrete mixes (Devi and Kannan 2011). This concrete has shown in compressive strength improvement about 22.92% and 24.13% for normal water cutting condition, 23.53% and 23.34% for saline curing conditions for both ages curing respectively, as shown in Fig. 6. This was expected that the mix was optimally packed each other by fine aggregate and quarry dust particles. Generally the quarry dust particle having large surface area for holding binding materials and improves the transition zone interactions between paste and aggregates.

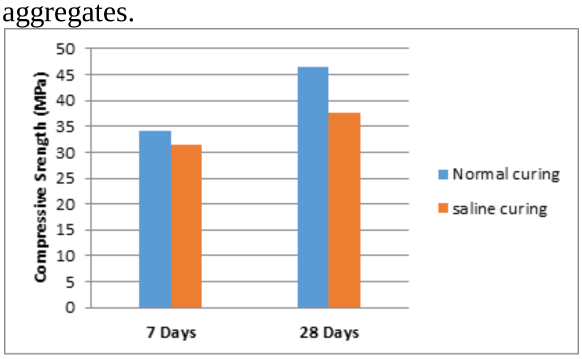

Fig.6. Compressive strength for Mix 4

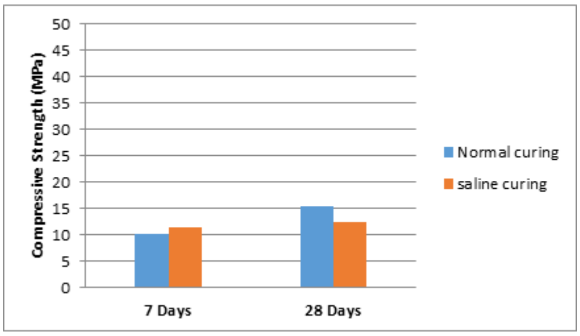

Fig.7. Compressive strength for Mix 5

Total replacement of natural sand by 50% of the glass granules and 50% of the granite quarry dust as a substitute to concrete was yielded lower compressive strength than other concrete mixes. The compressive strength was measured 10.24 and 11.32 MPa at 7 days and 15.35 and 12.30 MPa at 28 days for both curing conditions (Fig.7). This strength developed was very marginal and attained only 40 to 45% of control concrete strength. The strength loss of concrete mix may be due to the smooth surface and cubic shape of the glass granules and rough surface and flakey nature of quarry dust fine aggregate not having intimate bonding to hydrated cement paste may produce weaker link.

4. CONCLUSION

This research study was carried out to evaluate the compressive strength development of utilizing recycling waste glass products like glass powder, glass granules and quarry dust in concrete as a partial substitute along cement and fine aggregates. Based on the experimental results following conclusions have been drawn.

- The research findings indicate that the normal curing condition exhibited promising improvements in compressive strength than saline curing condition. The saline curing was badly affected the strength development of concrete both curing conditions.
- The concrete mix proportioned 20% glass powder has shown fast gaining of initial strength at early age. At later age it was suppressed due to non-reactiveness of glass powder. Also the lesser deterioration in compressive strength (i.e. 8.28%) was observed in saline cured concrete than normal cured concrete (i.e. 21.10%).
- The designed concrete mix incorporating 50% replaced by quarry dust concrete has produced higher compressive strength compared to all other mixes.
- The concrete mix 50% of fine aggregate replaced by glass granules has obtained lesser amount of compressive strength than all other mixes.
- The propositioned mix of 50% natural sand and 50% of glass granules concrete, has shown poorer compressive strength than other concrete mixes.

REFERENCES

Devi M, Kannan K, Analysis of strength and corrosion resistance behaviour of inhibitors in concrete containing quarry dust as fine aggregate, ARPN Journal of Engineering and Applied sciences, 6, 2011, 124-134.

Gupta T, Chaudhary S, and Sharma RK, Mechanical and durability properties of waste rubber fiber concrete with and without silica fume, Journal of Cleaner Production, 112, 2016, 702-711.

Kushartomo W, Bali I, Sulaiman B, Mechanical behavior of reactive powder concrete with glass powder substitute, Procedia Engineering, 125, 2015, 617 – 622.

Lopez RM, Garcia JE, Alkali activated composite binders of waste silica soda lime glass and blast furnace slag: Strength as a function of the composition, Construction and Building Materials, 119, 2016, 119–129.

Matos AM, Sousa-Coutinho J, Durability of mortar using waste glass powder as cement replacement, Construction and Building Materials, 36, 2012, 205-215.

Tchakoute HK, Ruscher CH, Kong S, Kamseu E, Leonelli C, Geopolymer binders from metakaolin using sodium waterglass from waste glass and rice husk ash as alternative activators: A comparative study, Construction and Building Materials, 114, 2016, 276–289.

Vieira CS, Pereira PM, Lopes M, Recycled Construction and Demolition Wastes as filling material for geosynthetic reinforced structures Interface properties, Journal of Cleaner Production, 124, 2016, 299-311.

Walczak P, Małolepszy J, Reben M, Szymański P, Rzepa K, Utilization of waste glass in autoclaved aerated concrete, Procedia Engineering, 122, 2015, 302 – 309.

Wang WC, Chen BT, Wang HY, Chou HC, A study of the engineering properties of alkali-activated waste glass material (AAWGM), Construction and Building Materials, 112, 2016, 962–969.

Wright J, Cartwright C, Fura D, Rajabipour F, Fresh and Hardened Properties of Concrete Incorporating Recycled Glass as 100% Sand Replacement, Journal of Materials in Civil Engineering, 26, 2014, 04014073-1-11.

Zhu YG, Kou SC, Poon CS, Dai JG, Li QY, Influence of silane-based water repellent on the durability properties of recycled aggregate concrete, Cement and Concrete Composites, 35, 2013, 32–38.