Research article

Use of waste glass in cement mortar

Bhandari. P.S[1], Tajne. K.M[2]
1- Assistant Professor, Priyadarshini College of Engineering, Nagpur
2- Assistant Professor, Priyadarshini College of Engineering, Nagpur
pranita.bhandari11@gmail.com

ABSTRACT

The need to add value to wastes and the opening towards the use of sand replacement materials, both in mortars and concretes, with the purpose of promoting increased sustainability of building materials, were the grounds for this work that aims the formulation of mortars with crushed glass aggregate. In this paper, a parametric experimental study for producing mortar blocks using fine and coarse waste glass is presented. Mechanical properties of mortar blocks having various levels of fine glass (FG) and coarse glass (CG) replacements with fine aggregate (FA) are investigated. The test results show that the replacement of Fine aggregate by Fine Glass at level of 20% by weight has a significant effect on the compressive strength of the mortar blocks as compared with the control sample because of pozzolanic nature of FG. Results indicate pozzolanic reactivity of this waste and open possibilities for the use of this material in mortars

Keyword: Mortar block, Pozzolanic, Waste glass, Fine Glass, Coarse Glass.

1. Introduction

In recent years there has been an increasing worldwide demand for the construction of buildings, roads and airfields which has led to a local depletion of aggregates. In some urban areas, the enormous quantities of aggregate that have already been used means that local materials are no longer available and the deficit has to be made up by importing materials from other locations. Most cities have areas of land covered by spoil heaps which are unsightly and prevent large areas of land being used for anything else.

If the large amount of waste materials generated were used instead of natural materials in the construction industry there would be three benefits: conserving natural resources, disposing of waste materials (which are often unsightly) and freeing up valuable land for other uses[J Blewett et al., 2000]. Glass is a common product that can be found in different forms: bottles, jars, windows and windshields, bulbs, cathode ray tubes, etc. These products have a limited lifetime and must be used in order to avoid environmental problems related to their stockpiling or land filling. Several recycling channels already exist for glass recovery. This project deals with the recycling of glass bottles, which can usually be reused after being crushed and melted. This operation is easily feasible when the glass is recovered as separate colors to produce glass products of the same color. However, most of the time, the collected glass is mixed and so unusable for the production of bottles of a given color. Consequently, this glass can either be reused for other but limited purposes, or be sent to a landfill.

Due to the limited landfill space available and stringent environmental regulations, many waste glasses are attempting to develop efficient, economic and environmental sound alternatives for utilizing this waste glass. Therefore, the civil engineers have been challenged to convert this waste glass, in general, to useful building and construction materials.

Utilization of waste glass for construction shall not only solve waste problems, but also provide a new resource for construction purposes. The use of waste glass as a substitute for fine aggregates in mortar mix is one option that can alleviate waste glass disposal problem and has been studied widely in recent years. Despite of the recent studies, there are still many unknowns with the use of waste glass. Study is needed to determine the contribution of waste glass to the performance of hardened mortar. There are great concerns on the strength and durability of the mortar being produce with replacement material when used as construction materials in the construction industries. If it is proven that the mortar is durable and strong, this will lead to the use of waste glass to replace part of the fine aggregate in mortar. Finally, this study also aims to determine the most suitable mix proportion that can produce mortar of desirable strength without compromising engineering performance and quality.

2. Materials

2. 1. Aggregate

In this study two type of sand is used (1) Standard sand - Standard sand conforming from IS 650:1991 used for control mortar block.(2) Natural Sand - Fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies. The Wainganga sand was used as natural river sand.

2.2. Water

Water used for making masonry mortars shall be clean and free from injurious quantities of deleterious materials. Potable water is considered satisfactory for use in masonry mortar. For further requirements regarding limits of deleterious materials permitted reference may be made to IS 456-1978.

2.3. Cement

Ordinary Portland cement 53 grade (ultratech cement) complying with IS 269, 1976 was used. The cement was kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. The grade 53 is known for its rich quality and is highly durable. Hence it is used for constructing bigger structures like building foundations, bridges, tall buildings, and structures designed to withstand heavy pressure. With a good distribution network this cement is available most abundantly in Gujarat. The chemical and physical properties of this material were shown in Table 1.1.

Table 1: Properties of cement

Sr. No.	Chemical Ingredients	Range %	Common Proportion
1	Lime	60-70	63
2	Silica	17-25	22
3	Alumina	3-8	6
4	Iron Oxide	0.5-6	3
5	Magnesium Oxide	0.4-4	2.5
6	Sulphur Trioxide	1-3	1.75
7	Alkalies such as soda & potash	0.2-1	0.25
8	Loss on ignition	1-2	1.5

2.4. Waste glass

Figure 1: Colored fine glass aggregate

Figure 2: white fine glass aggregate

The broken windows glass is used as waste which is supplied from windows glass market.

The Fine Glass Aggregates and Coarse Glass aggregates are produced by using pulverizer and separated by sieving in two different particle sizes as follows:

Fine glass aggregate of size: - 600μm – 1.18mm

Corse glass aggregate of size: - 1.18mm – 4.75mm

In this study two different colour waste glasses are used in two different sizes as follows:

1. White fine glass aggregate (WFG): - 600μm – 1.18mm
2. Colour fine glass aggregate (CFG): - 600μm – 1.18mm
3. White corse glass aggregate (WFG): - 1.18mm – 4.75mm
4. Colour corse glass aggregate (CFG): - 1.18mm – 4.75mm

Waste Glass in mortar product offer several advantages:

1. It is one of the most durable materials known because it has basically zero water absorption.
2. The excellent hardness of glass may give the mortar improved abrasion resistance that can be reached only with few natural stone aggregates.
3. Glass aggregates may enhance the flow properties of fresh mortar so that very high strengths can be obtained even without the use of admixture (plasticisers, superplasticisers etc.).
4. The aesthetic potential of colour-sorted, post-consumer glass has barely been explored at all and offers numerous novel applications for architectural purposes.
5. Very finely ground glass has pozzolanic properties and therefore, can serve both as partial cement replacement and filler.

3. Methods

In this research, different mixes of mortar such as 1:2, 1:3 and 1:4 were used which is according to the IS 2250:1981 of Masonry mortar.

A total of fourteen series of mixtures of one proportion were prepared in the laboratory trials according to the requirements of IS 2250:1981. The fourteen mixtures in series includes a control mixture using only natural sand and standard sand with zero percent GA. The details of one mixed is given in Table 2.3. The cement and water proportions in the mixes were taken as constant to determine the effect of various FG and CG combinations. The replacements of FA with FG and CG were at levels from 10 to 30% by weight. For instance, the 20% replacement of FG means that the 20% of corresponding fine aggregate weight was replaced by FG in the FG-20 samples (see Table 1.4). In the mixing process of samples, waste glass, Fine aggregates and cement contents were placed in a mortar mixer and mixed for 1 min as dry. Then, water was poured into mortar mixer for another 3 min. Afterward, the fresh mixes were fed into the steel moulds with internal dimensions of 70.6x70.6x70.6 mm. The temperature of the water and that of the test room at the time when the mixing operation is being performed was 27 ± 2° C. The materials for each batch of moulds mixed separately using the quantities of dry materials, conforming to the proportions and the quantity of water was determined in accordance with the procedure of IS 2250:1981. The steel moulds were filled over with material to about half height and the layer compacted by tamping it with the tamping rod in a uniform manner over the mortar surface in such a way to produce full compaction of the mortar with neither segregation nor excessive laitance. The moulds were then be completely filled and the upper layer of the mortar compacted in a similar manner, after which the mould were kept on the vibrating table for 5 mins. Then the surface of the mortar struck off plane and levelled the top of the mould, using a trowel. The specimen shall then be marked for later identifications, removed from the moulds and stored in clean water until the time of tests. The temperature of the storage water was 27 ± 2°C. The specimen were tested according to the IS 2250:1981 at an interval 1, 3, 7 and 28 days.

Table 2: The details of one mortar mix proportion

Mix proportion of mortar 1:2								
S No.	Grade	No. Of Cubes	Material	% of Glass	Mix Proportion (gm)			
					Cement	Sand	Glass	Water(ml)
1	MM 1:2	12	Cement+ Standard Sand	0%	3200	6400	0	1152
2	MM 1:2	12	Cement+ Local Sand	0%	3200	6400	0	1152
3	MM 1:2	12	Cement+ Local Sand+ WFG	10%	3200	5760	640	1152
4	MM 1:2	12	Cement+ Local Sand+ WFG	20%	3200	5120	1280	1152
5	MM 1:2	12	Cement+ Local Sand+ WFG	30%	3200	4480	1920	1152
6	MM 1:2	12	Cement+ Local Sand+ WCG	10%	3200	5760	640	1152
7	MM 1:2	12	Cement+ Local Sand+ WCG	20%	3200	5120	1280	1152
8	MM 1:2	12	Cement+ Local Sand+ WCG	30%	3200	4480	1920	1152
3	MM 1:2	12	Cement+ Local Sand+ CFG	10%	3200	5760	640	1152
4	MM 1:2	12	Cement+ Local Sand+ CFG	20%	3200	5120	1280	1152
5	MM 1:2	12	Cement+ Local Sand+ CFG	30%	3200	4480	1920	1152
6	MM 1:2	12	Cement+ Local Sand+ CCG	10%	3200	5760	640	1152
7	MM 1:2	12	Cement+ Local Sand+ CCG	20%	3200	5120	1280	1152
8	MM 1:2	12	Cement+ Local Sand+ CCG	30%	3200	4480	1920	1152

Figure 3: Specimen before testing

Figure 4: Specimen after testing

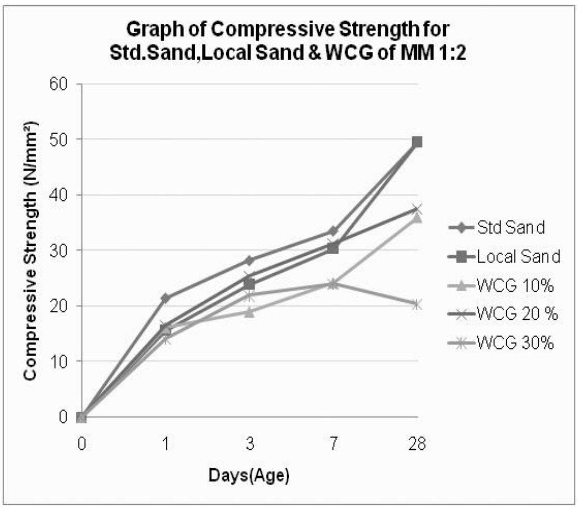
4. Results and discussion

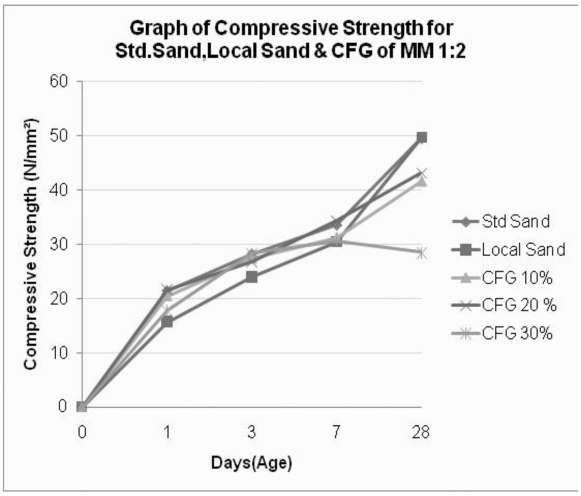
Strength of mortar is commonly considered its most valuable property. Compressive strength of mortar containing various percentage of waste glass cullet was studied in this section. Control specimens are mortar with 100% fine aggregate which is compared with the strength performance mortar containing 10%, 20% and 30% waste glass cullet that replaced fine aggregate (sand) of same percentage. Cubes with the size of 70.6 x 70.6 x 70.6 mm were tested at the ages of 1, 3, 7, and 28 days.

During the mixing process, it became apparent that waste glass cullet was displacing part of fine aggregate in a unit volume of mortar thereby, increases the density of mortar.

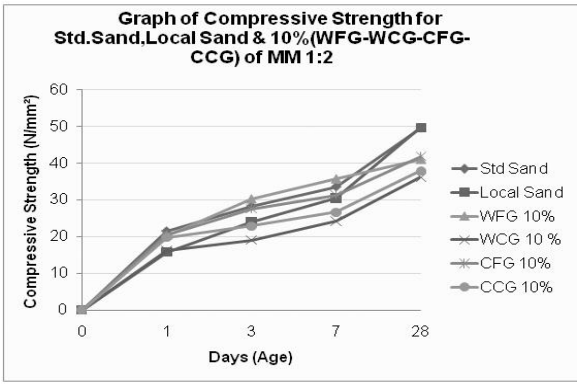
Table 3: Compressive test result of one mix

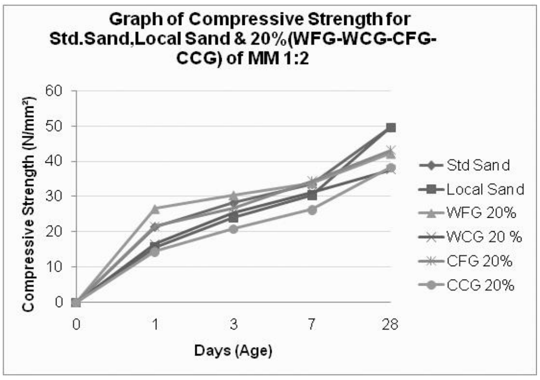
Compressive Strength Results of Mortar Mix 1:2					
S No.	No. Of Cubes	Material	% of Glass	Curing Days	Avg Strength (N/mm²)
1	12	Cement+ Std.Sand (Control Block)	0%	1	21.45
				3	28.22
				7	33.55
				28	49.55
2	12	Cement+ Local Sand (Control Block)	0%	1	15.69
				3	23.93
				7	30.46
				28	49.61
3	12	Cement+ Local Sand+ WFG	10%	1	20.35
				3	30.25
				7	35.69
				28	41.05
4	12	Cement+ Local Sand+ WFG	20%	1	26.56
				3	30.46
				7	33.78
				28	42.22
5	12	Cement+ Local Sand+ WFG	30%	1	20.48
				3	23.85
				7	31.86
				28	29.50
6	12	Cement+ Local Sand+ WCG	10%	1	16.02
				3	19.02
				7	24.25
				28	36.12
7	12	Cement+ Local Sand+ WCG	20%	1	16.55
				3	25.42
				7	31.27
				28	37.55
8	12	Cement+ Local Sand+ WCG	30%	1	14.19
				3	21.96
				7	24.06
				28	20.39
9	12	Cement+ Local Sand+ CFG	10%	1	20.52
				3	27.46
				7	31.30
				28	41.69
10	12	Cement+ Local Sand+ CFG	20%	1	21.62
				3	26.80
				7	34.41
				28	43.17
11	12	Cement+ Local Sand+ CFG	30%	1	17.77
				3	28.29
				7	30.50
				28	28.43
12	12	Cement+ Local Sand+ CCG	10%	1	19.78
				3	22.91
				7	26.67
				28	37.88
13	12	Cement+ Local Sand+ CCG	20%	1	14.40
				3	20.80
				7	26.27
				28	38.25
14	12	Cement+ Local Sand+ CCG	30%	1	18.33
				3	21.03
				7	24.35
				28	21.20



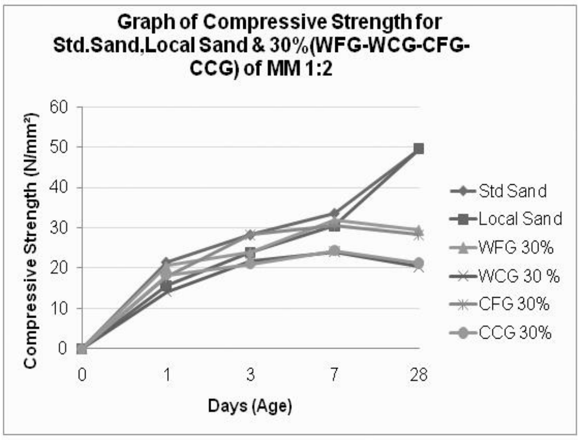


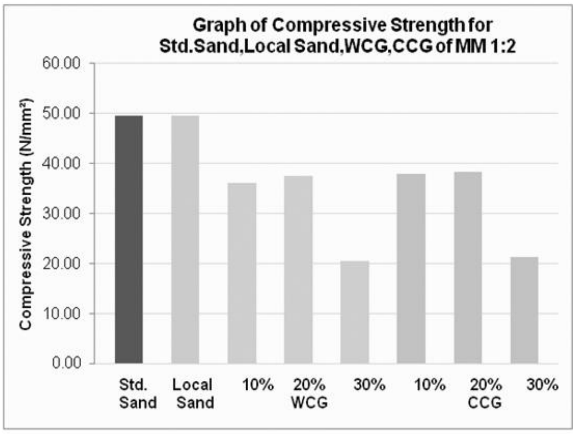
The compressive strength of mortar specimen with and without WG, after being cured for 28 days, was shown in graph. Compressive strength was observed to decrease, as the proportion of WG in mortar produced increased. The decrease in the compressive strength of the mortar blocks in the FG replacement levels of 10%, 20% and 30% were 15%, 12% and 40% as compared with the control sample, respectively. Similarly the decrease in the compressive strength of the mortar blocks in the CG replacement levels of 10%, 20% and 30% are 20%, 15% and 45% as compared with the control sample, respectively.





In mortar with cement as binder there is a decrease in compressive strength with glass residue addition. The high brittleness of WG leading to cracks was determined to lead to incomplete adhesion between the WG and cement paste interphase. Due to the poor geometry of WG, a homogenous distribution of aggregates could not be achieved. Accordingly, an increase in the amount of WG used in mortar decreased compressive strength. Graph shows the compressive strength that incorporation of glass residue reduced mechanical strength in cement mortar. Commonly, Pozzolana reacts with available CH producing CSH similar to that produced in cement hydration reactions. But in this case, CH is not much available, possibly forcing glass residue to act as an aggregate. Therefore, a lower percentage of pozzolana will probably increase mechanical strength.





5. Conclusion

The feasibility of mortar blocks with the Fine Glass and Coarse Glass was shown technically in the present study. Based on the experimental investigation, the following conclusions are drawn:

1. Compressive strength of OPC mortar for 1, 3, 7and 28 days for standard sand was observed to be greater than that of local sand (Wainganga sand) for control mix.
2. The use of waste glass aggregate usually reduces the water demand.
3. With the addition of waste glass aggregate, density of mortar increases.
4. With the addition of waste glass aggregate, compressive strength of mortar decreases.
5. Crushed waste glass aggregate have irregular shapes than local sand.
6. The reduction of mortar strength can be attributed to the high-water cement ratio and absence of rough surface of waste glass aggregate, which is essential for bonding and structuring of fresh mortar.
7. Mortar containing colour glass aggregate as fine aggregate achieve more strengths to that of white glass aggregate.
8. Water absorbed is less by cubes containing waste glass aggregate as compared to control mix cubes

6. References

1. Zainab Z. Ismail, Enas A. AL-Hashmi,(2009), Recycling of waste glass as a partial replacement for fine aggregate in concrete Waste management, 29(2), pp 655-659.

2. Mohamad J. Terro, (2006), Properties of concrete made with recycled crushed glass at elevated temperatures, Building and environment, 41(5), pp 633-639.

3. Seung Bum Park, Bong Chun Lee, Jeong Hwan Kim, (2004), Studies on mechanical properties of concrete containing waste glass aggregate, Cement and concrete research, 34(12), pp 2181-2189.

4. Jasem M. Alhumoud, Nayef Z. Al-Mutairi and Mohamad J. Terro, (2008), Recycling crushed glass in concrete mixes, Int. J. environment and waste management, 2(1/2), p 111.

5. Seung-Bum Park and Bong-Chun Lee, (2006), Studies on expansion properties in mortar containing waste glass and fibers, Department of civil engineering, Chungnam National university, Daejeon, South Korea, pp 305-764.

6. P. Turgut, E. S. Yahlizade, (2009), Research into concrete blocks with waste glass, International journal of environmental science and engineering.

7. Lker Bekir Topcu, Mehmet Canbaz, (2003), Properties of concrete containing waste glass, Civil engineering department, Osmangazi University, Eskisehir 26480, Turkey.

8. G. D. Perkins, Development of concrete containing waste glass, Civil engineering research unit, Division of civil & mechanical engineering, Faculty of advanced technology, University of Glamorgan, Pontypridd, CF37 1DL.

9. C. Meyer, N. Egosi, and C. Andela, (2001), Concrete with waste glass as aggregate, in Recycling and re-use of glass cullet, Dhir, Dyer and Limbachiya, editors, Proceedings of the international symposium concrete technology unit of ASCE and University of Dundee.

10. Assoc. Prof. Zsuzsanna Józsa - Rita Nemes, Recycled glass aggregate for lightweight concrete.

11. S. Laldji, G.Fares and A. Tagnit-Hamou, Glass frit in concrete as an alternative cementitious material, Faculty of engineering, University de Sherbooke, Canada.

12. Liang, Hong; Zhu, Huiying; Byars, Ewan A., use of waste glass as aggregate in concrete, UK Chinese Association of Resources and Environment.

13. Ahmad SHAYAN, Value-added utilisation of waste glass in concrete, Chief research scientist ARRB transport research Vermont South VIC Aust.

14. By J Blewett and PK Woodward, Some geotechnical properties of waste glass, Department of civil and offshore engineering, Heriot-Watt University, Edinburgh.