Experimental Study on Partial Replacement of Fine Aggregate with Glass Waste

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Abstract— This paper enunciates that Glass is a unique inert material that could be recycled many times without changing its chemical properties. By using Glass in concrete is an interesting possibility for economy on wastage disposals. The inclusion glass concrete reduces the alkali silica reaction and improves the workability and durability properties of concrete. Glass cullet used in concrete making leads to green environment. The objective of this paper detects the effectiveness of the fly ash and glass aggregate based concrete. In this investigation the fine aggregate was replaced by the waste glass in the concrete as (10% 20% 30% 40% and 50%). Compressive strength of cubes at 28 days of duration were studied. Fineness modulus, specific gravity, moisture content, water absorption was also studied. Based on the test results, the ideal percentage of mix which shows maximum compressive strength, and tensile strength was identified.

Key words: Alkali Silica, Flyash, Durability, Compressive Strength

I. INTRODUCTION

Many construction industries is facing major issue in the emission of CO_2 and it may be due to various reasons like combustion, energy use, demolition and usage of materials etc., It can be minimized by using alternate resources like Crushed waste Glass pieces for fine aggregate and Flyash for cement in the concrete, which will be ecofriendly and it helps in utilizing waste products for construction process. Concrete is in general, cement-based concrete, which meets special performance requirement with regard to workability, strength and durability, that cannot always be obtained with techniques and materials adopted for producing conventional cement concrete. Fine aggregate is important construction material, which is widely used, in construction works. Nowadays the cost of concrete is increased since the cost of fine aggregate is increased. To fulfill the requirements and to reduce cost of concrete some alternative materials are needed to replace the fine aggregate. The challenge for the civil engineering is the utilization of solid wastes in construction materials is one of such innovative efforts. An important process in the concrete mixing is the formation of C-S-H gel which is primarily due to the addition of cement. The hydration of the Portland cement results from the production of portlandite crystal [$Ca(0H)_2$] and amorphous calcium silicate hydrate gel [$C_3S_2H_3$] (C-S-H) in large amounts. The hydrated cement paste contains approximately 70% C-S-H, 20% Ca $(0H)_2$; 7% sulpho-aluminates and 3% secondary phases. The $Ca(0H)_2$ which appears due to the chemical reactions affect the quality of concrete adversely by forming cavities, as it is partly soluble in water and also lacks enough strength. The Ground Granulated Blast-Furnace Slag when used along with cement has positive effect on the $Ca(0H)_2$ compound. At the end of the secondary reaction between GGBS and $Ca(0H)_2$, hydration product such as C-S-H gel is formed.

A. *Glass Concrete*

In this project the Flyash and Glass are chosen as alternative material for the cement and fine aggregate respectively. In this report the detailed experimental investigations on partial replacement of fine aggregate with glass wastes and cement with flyash was presented. A major concern regarding the use of glass in concrete is the chemical reaction that takes place between silica-rich glass particles and the alkali in the pore solution of concrete, i.e., alkali-silica reaction. This reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. Such preventive actions could be achieved by incorporating a suitable Pozzolonic material such as fly ash in the concrete mix at appropriate proportions. The limitations include the long-term inspecting of the effectiveness of alkali-silica reaction suppressants. The inclusion of fly ash in glass concrete reduces the environmental pollution and improves the workability and strength properties of concrete. The objective of this paper is to find out the optimum percentage of mix for the partial replacement of fine aggregate with glass and cement with flyash. Natural fine aggregate is substituted by weight by glass powder at rates varying from 10, 20, 30, 40, and 50 percentages. For each mix standard sizes of cubes and cylinder were casted and tested for compressive strength and split tensile strength at age of 28 days as per Indian Standards respectively.

II. OBJECTIVE OF THE STUDY

The objectives of the experimental investigation are as follows

- To study the properties of glass waste was replace by fine aggregate. To study the behaviour as well as properties of concrete in fresh and hardened state
- To study the effect of glass waste on the workability of concrete.
- To study the structural behaviour of concrete made with glass waste as fine aggregate
- To study the mechanical properties such as compressive strength, split tensile strength, flexural strength of concrete incorporating steel slag as partial replacement materials of fine aggregate by glass waste respectively.

III. REVIEW OF LITERATURE

A. *The Use of Sheet Glass Powder as Fine Aggregate Replacement in Concrete. M. Mageswari1 and Dr. B. Vidivelli*

From the tests conducted on SGP replaced in fine aggregate for concrete as presented in various sections, the following conclusions are made: The SGP is suitable for use in concrete making. The fineness modulus, specific gravity, moisture content, uncompact bulk density and compacted bulk density at 10% Sheet glass powder (SGP) were found to be 2.25,3.27,2.57%,1510kg/m3 and 1620kg/m3 for a given mix, the water requirement decreases as the SGP content increases. The compressive strength of cubes and cylinders of the concrete for all mix increases as the % of SGP increases but decreases as the age of curing increases due to alkali silica reaction. The Tensile strength of cubes and cylinders of the concrete for all mix increases than that of conventional concrete age of curing and decreases as the SGP content increases. The Flexural strength of the beam of concrete for all mix increases with age of curing and decreases as the SGP content increases.100% replacement of SGP in concrete showed better results than that of conventional concrete at 28 days and 45 days curing but later it started to decrease its strength because of its alkali silica reactions. The density of SGP concrete is more that of conventional concrete. SGP is available in significant quantities as a waste and can be utilized for making concrete. This will go a long way to reduce the quantity of waste in our environment. The optimum replacement level in fine aggregate with SGP is 10%.

B. Study on Partial Replacement of Fine Aggregate with Glass Wastes and Cement with Flyash. M. Christina Josephine

The compressive strength and the split tensile strength test of 28 days of curing were observed experimentally. It shows that partially replaced concrete with the combination of both flyash and glass cullet show higher strength when compared to the conventional concrete. The optimum replacement of cement by flyash was found to be 10% as it showed the compressive strength of cube as 30.67 N/mm2.The optimum replacement of cement by flyash was found to be 10% as it showed the Split tensile strength of cylinder as 3.78 N/mm2.The optimum replacement of Fine aggregate by Glass wastes was found to be 20% as it showed the compressive strength of cube as 30.64 N/mm2.

C. Studies on Glass Powder as Partial Replacement of Cement in Concrete Production. Dr. G. Vijayakumar, Ms H. Vishaliny, Dr. D. Govindarajulu

Conventional concrete shows at 28 days compressive strength as 31.1 N/mm2, split tensile strength of 2.27N/mm2 and flexural strength of 3.25N/mm2.Replacement of glass powder in cement by 20%, 30% and 40% increases the compressive strength by 19.6%, 25.3% and 33.7% respectively. Replacement of glass powder in cement by 40% increases the split tensile strength by 4.4% respectively. Replacement of glass powder in cement by 20%, 30% and 40% increases the flexural strength by 83.07%, 99.07% and 100% respectively. Glass powder concrete increases the compressive, tensile and flexural strength effectively, when compared with conventional concrete. Very finely ground glass has been shown to be excellent filler and may have sufficient pozzolonic properties to serve as partial cement replacement, the effect of ASR appear to be reduced with finer glass particles, with replacement level.

D. Study The Influence of Waste Glass Powder on the Properties of Concrete. K. Madhangopal and B. Nagakiran.

From our experimental investigations, the strength of traditional concrete cubes for 28 days was found to be 28.5 N/mm2 .As we further continued our investigation by adding waste glass powder to concrete by 10%, 20%, 30%, After 28 days the compressive strengths are 43.99 N/mm2 , 54.32 N/mm2 , and 47.56 N/mm2 respectively. When we compared the strengths of traditional concrete and concrete with partially replaced fine aggregate with glass powder exhibits more strength. We have also found that the concrete cubes exhibit more strength when 20% of glass powder is added. We have also conducted the split tensile strength and flexural strength of the concrete cylinders and beams and found out that the beams exhibit maximum strength at 20%.

E. Performance of using Waste Glass Powder in Concrete as Replacement of Cement. Gunalaan Vasudevan, Seri Ganis Kanapathy Pillay

As a conclusion, all the objectives of this study are achieved Concrete with using waste glass powder has a very high workability from control sample. This result achieved from the slump test that use of waste glass powder were will increase the workability of concrete. In term of strength, concrete with using waste glass powder averagely have higher strength at 14 days but once the concrete reached at 28 days the control mix give more higher value compare to mix that contained waste glass powder but still give high value of the grade 30.From this research, using waste glass powder is giving positive value even though the value compare to standard mix it just less about 1N/mm.2 Concrete become lighter when mix with waste glass powder. The average cube density of concrete with using more percentages of waste glass powder averagely gives lowest value compared to control sample. Therefore, concrete mix that using glass powder is giving lightweight concrete .I have chosen this topic because of most developing country facing shortage of post consumer’s disposal waste site and it’s become very serious problems. For this reason, regenerating and using waste product as resources and prevent environmental pollutions. From the analysis and discussion, we are clearly understood that the objectives of this study are achieved. The objectives of the research are: The main purpose of this research is to check the compressive strength of the concrete using the waste glass powder. b) To check the workability of the concrete using the waste glass powder. c) To check the density of the concrete using waste glass powder.

F. Reusing of Glass Powder and Industrial Waste Materials in Concrete. Raghavendra K, Virendra Kumara. K. N.

The compressive strength of concrete at 7, 14 and 28 days increases initially as the percentage of replacement of waste glass powder and waste foundry sand increases and becomes maximum at a proportion around A40.The split tensile strength of concrete at 7, 14 and 28 days increases initially as the percentage of replacement of waste glass powder and waste foundry sand increases and becomes maximum at a proportion around A40.The water absorption of concrete at 28 days decreases gradually as the percentage of waste glass powder and waste foundry sand increases and becomes least at a proportion around A50.Optimum replacement level for waste glass powder and waste foundry sand in place of ordinary Portland cement and natural fine aggregate respectively is found to be proportion of A40 from the consideration of strength and durability tests of concrete additional stiffening and use of large thickness Corrugated steel webs were recently proposed to replace the stiffened steel plates /box girders to improve the strength and the economy of the structure. Researchers have attempted to use corrugated plate in the webs of hot-rolled I-girder. This can overcome the disadvantages of conventional stiffened flat webs. Such as web instability due to bending stress and fatigue failure. Past researchers investigated on I-girders with trapezoidal corrugation of hot rolled section. The use of corrugated webs is a potential method to achieve adequate out-of-plane stiffness and shear buckling resistance without using stiffeners; therefore, it considerably reduces the cost of beam fabrication and the weights of superstructures. Because the corrugated web carries only shear forces and the flanges carry the moment due to the accordion effect. In order to benefit from these characteristics, prestressed concrete box girder bridges with corrugated webs are used extensively. Shear stresses can cause the failure of the web by shear buckling or yielding depending on the geometric characteristics of the corrugated webs. Therefore, most studies on corrugated webs are restricted to the shear buckling of corrugated webs. Recently, several researchers have attempted to use corrugated plates in the webs. This can overcome the disadvantages of conventional stiffened flat webs such as web instability due to bending stress and fatigue failure.

IV. Material Property

A. Materials Used

The following materials are used in the experimental investigations reported in this thesis.

- Cement
- Glass Waste Powder
- River Sand
- Coarse Aggregate
- Water

1) Cement

Ordinary Portland cement of 53 grade confirming IS 12269 was used in the experimental work and its properties as listed in Table 1. The brand of cement used is Bharathi cements purchased from a Salem city cement retail shop. The physical properties of the cement used in this work were tested prior to use as per laid down IS specifications.

S. No	Types of Test	Cement
1	Specific gravity	3.12
2	Consistency	31%
3	Initial Setting time	32 minutes
4	Final Setting time	260 minutes
5	Fineness	4.2%
6	Water content	NIL

Table 1: Physical Properties of Cement

2) Coarse Aggregate

Coarse aggregate is an important constituent in concrete. It gives body to the concrete, reduce shrinkage and effect economy. One of the most important factors that influence the workability of concrete is gradation of aggregates. Well graded aggregates are the aggregate samples that contains fractions of aggregates in required proportion such that it can be densified with minimum voids. Concrete cast with well graded aggregates containing minimum voids requires minimum cement paste to fill up the voids among the aggregates. Minimum cement paste will result in less quantity of binding material and water which will further increase economy, higher strength, reduce shrinkage and greater durability. In the present investigation, crushed hard blue granite coarse aggregate used was obtained from the local approved quarry. Sieve Analysis has been carried out over the samples of coarse aggregate and the grading of coarse aggregate used in this study are given in Table 3.6 to 3.8In the experimental work the coarse aggregates of nominal size 20mm and 12.5mm are blended in the ratio of 60% and 40% respectively and used so that the aggregates are well graded to give required workability, minimum paste content and maximum strength.

Sieve Size	Weight Retained(g)	% Wt. Retained(g)	% Cumulative Wt. Retained(g)	% Cumulative Wt. Passing (g)	Permissible Limits IS 383-1970
40 mm	-	-	-	100	100
20 mm	733	14.66	14.66	85.34	85-100
16 mm	3094	61.88	76.54	23.46	-
12.5 mm	1115	22.30	98.84	1.16	-
10 mm	56	1.12	99.96	0.04	0-30
4.75 mm	2	0.04	100	0	0-5

Table 2: Sieve Analysis of Typical Normal Coarse Aggregate Sample (20mm)

Sieve Size	Weight Retained (g)	Cumulative Wt. Retained (g)	% Cumulative Wt. Retained (g)	% Cumulative Wt. Passing (g)	Permissible Limits IS 383-1970
20 mm	-	-	-	-	-
16 mm	-	-	-	100	100
12.5 mm	741	741	14.82	85.18	85-100
10 mm	2433	3174	63.48	36.52	0-45
4.75 mm	1826	5000	100	-	0-10

Table 3: Sieve Analysis of Typical Normal Coarse Aggregate Sample (12.5mm)

Sieve Size	Weight Retained (g)	Cumulative Wt. Retained (g)	% Cumulative Wt. Retained (g)	% Cumulative Wt. Passing (g)	Permissible Limits IS 383-1970
40 mm	-	-	-	100	100
20 mm	342	342	6.8	93.2	85-100
16 mm	1478	1822	36.44	63.56	60-85

12.5 mm	872	2694	53.88	46.12	30-70
10 mm	1560	4254	85.08	14.92	0-30
4.75 mm	746	5000	100	0	0-10

Table 4: Sieve Analysis on 20mm and 12.5 mm Blended Coarse Aggregate (60:40)

3) *Fine Aggregate (River Sand)*

In the present investigation, normal river sand quarried from Cauvery river near Musiri town was used as a fine aggregate. The fine aggregate was screened to remove deleterious materials and tested as per procedure given in IS 2386 - 1963.

The results of sieve analysis on fine aggregates are given in Table 3.9. The fineness modulus of sand is 2.69 and confirms to Zone 2 grading.

Sieve Size	Wt. Retained (g)	% Wt. Retained	% Cumulative Wt. Retained (g)	% Cumulative Wt. Passing (g)	Permissible Limits IS 383-1970
10mm	-	-	-	100	100
4.75mm	73	4.65	4.65	95.35	90-100
2.36mm	100	6.369	11.019	88.981	75-100
1.18mm	463	29.49	40.509	59.491	55-90
600 mic	604	38.47	78.979	21.012	35-59
300 mic	278	17.71	96.689	3.311	8-30
150 mic	43	2.74	99.429	0.571	0-10
75 mic	9	0.57	100	-	-

Table 5: Sieve Analysis of Typical Fine Aggregate Sample

4) *Glass Powder*

The Glass is crushed in the form of powder and it was sieved of less than 2mm of sieve size, as shown in the given fig

Fig. 1: Glass powder

Fineness Modulus	3.18
Specific Gravity	3.01

Table 6: Physical properties of Glass powder

The physical properties of the Glass powder are presented in the table

5) *Water*

The water used for concrete making and curing was tap water available in the laboratory and free from all types of harmful chemicals, organic material, oil, chloride, silt and suspended materials confirming IS 456-2000. No test on the quality of water has been carried out as the water available in the laboratory is of drinking water quality

V. EXPERIMENTAL INVESTIGATIONS

A. *General*

Experimental investigations have been carried out to the test specimens to ascertain the, mechanical related properties such as compressive strength and split tensile test and durability related properties such as saturated water absorption and porosity of designed M_{20} grade trial mixes. Minimum three specimens were tested for each trial mix. All the tests were conducted as per specifications.

B. *Preparation of Test Specimen*

1) *Batching*

The measurement of materials for making concrete is known as batching. Here, we have adopted weigh-batching method, and it is the concrete method too. Use of weigh system batching, facilitates accuracy, flexibility and simplicity. Different types of weigh batchers are available the particular type to be used depends up on the nature of the job. When weigh batching is adopted, the measurement of water must be done accurately. Addition of water in terms of liter will not be accurate enough for the reasons of spillage of water etc.

2) *Preparation of mould*

The compressive strength of the concrete was determined by cubes of size 150mmx150mmx150mm. Split tensile strength of concrete is done by casting a cylinder of size 150mm and height 300mm. These sizes are standard sizes and are adopted everywhere. All the faces of the moulds are assembled by using nuts and bolts and are clamped to the base plate. It is also to be noted that, all the internal angle of the mould must be 90 degree. The faces must be thinly coated with mould oil to prevent leakage during filling. The inside of the mould must also be preventing the concrete from sticking to it.

3) *Mixing*

Thorough mixing of the material is essential for the production of uniform course. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. As the mixing cannot be thorough, it is desirable to add 10% more materials. The mixing was done by concrete mixer machine first pour little amount of water inside the drum. Rotate the drum, add coarse aggregate, cement and hypo sludge material as in the mix. Add remaining water inside. Rotate the drum continuously till the mix become homogeneous

4) *Pouring of concrete*

After mixing, the moulds are filled immediately by pouring the concrete inside. Concrete is filled in three layers, each layers is compacted well by using needle vibrator of standard size (25mm), so as to avoid entrapped air inside the concrete cubes and honey combing effects on the sides. During pouring of concrete is wasting of concrete for effective and economical usage.

5) *Compaction of concrete*

Compaction of concrete is process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete air is likely to get entrapped. Machine compaction was done using a needle vibrator of 25mm diameter. When machine compaction is adopted, the consistency of concrete is maintained at higher. Concrete is filled in layers of 15 to 20mm, and each layer is compacted using needle vibrator. During compaction the strokes should be distributed in a surface of concrete, and should not forcibly strike the bottom of the mould. After the top layer has been compacted, a strike off bar is used to strike out the excess concrete.

6) Demoulding

The cube specimens are demoulded after 24 hours from the process of moldings. If the concrete has not achieved sufficient strength to enable demoulding the specimens, then the process must be delayed for another 24 hours care should be taken not to damage the specimen during the process because, if any damage is caused, the strength of the concrete may get reduced. After demoulding, specimen is marked with a legible identification, on any of the faces by using paint and placed in a water tank for curing, till the age of test.

C. Tests for Concrete

The strength related tests were carried out on hardened specimen at the age of 28 days of curing to ascertain the strength related properties such as cube compressive strength, cylinder split tensile strength.

1) Cube Compressive Strength

For cube compression testing of concrete, 150mm cubes were employed. All the cubes were tested in saturated condition, after wiping out the surface moisture. For each trial mix combination, two cubes were tested at the age of 14 and 28 days of curing using 400tone capacity HEICO compression testing machine as per BIS: 516-1959.The test was carried out at a uniform stress after the specimen has been sending in the testing machine. Loading was continued till the dial gauge needle just reverses its direction of motion. The reversal in the direction of motion of the needle indicates that the specimen has failed. The dial gauge reading at that instant was noted, which is the ultimate load. The ultimate load divided by the cross sectional area of the specimen is equal to the ultimate cube compressive strength. The test setup for the compressive strength and typical failure pattern is shown in the photos.

Compression strength = load/area

Fig. 2: Test Setup for Compressive Strength

2) Split Tensile Strength

This is an indirect test to determine the split tensile strength of the specimen. Splitting tensile strength was carried out on 150mmx300mm cylinder specimens at the age of 28 days curing, using 400 tone compression testing machine as per BIS: 5816-1970.The load was applied gradually till the specimen split and readings were noted. The test setup for the split tensile strength test on the cylinder specimen and typical failure pattern is shown in photos. Similarly to the behavior of compressive strength, the incorporation of any type of plastic aggregate lowers the splitting tensile strength of concrete. The causes for the reductions observed in splitting tensile strength reported in various references were similar to those used to explain the decrease in compressive strength due to the incorporation of plastic aggregate. Some results on the tensile strength behavior of concrete and mortar containing various percentages of different types of plastic aggregates are presented. The splitting tensile strength has been calculated using the following formula.

$$Fsp=2p/\pi dl$$

Where,

Fsp= tensile strength of the specimen inMpa

p = maximum load in 'N' applies to the specimen

d =measured diameter in 'mm' of the specimen, and

l =measures length in 'mm' of the specimen

VI. TEST RESULTS & DISCUSSIONS

A. Slump Test

The slump cone test was used to find the workability of fresh concrete mixes. Slump value is high for the initial mixes but when the replacement percentage of steel slag increases, the slump decreases. The degree of workability exhibited by all the test mixes is given in Table below

Mix Name	Steel Slag (%)	Slump Value
M-1	10	76 mm
M-2	20	74 mm
M-3	30	70 mm
M-4	40	65 mm
M-5	50	63 mm

Table 7: Slump Values of the Test Mixes

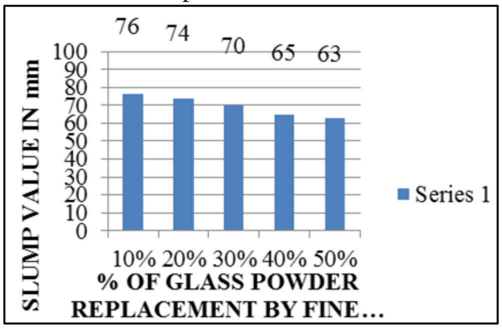

Fig. 3: Slump Value (Fresh Property)

1) Compressive strength

It is the most common of all test of concrete is the compressive strength test because of the intrinsic importance of the compressive strength of concrete in construction. Three test specimens shall be made from each sample for testing 28 days. Additional cubes may be required for various purposes such as to determine the strength of concrete at 7, 14 and 28days.

2) Compressive strength of partially replaced by steel slag

The test result of M20 grade of concrete compressive strength of glass waste powder as fine aggregate concrete are furnished in table.

Mix Name	Steel Slag (%)	Compressive strength (N/mm^2)
M-1	10	29.82
M-2	20	30.64
M-3	30	30.64
M-4	40	28.75
M-5	50	27.42

Table 8: Compressive strength of partially replaced by steel slag

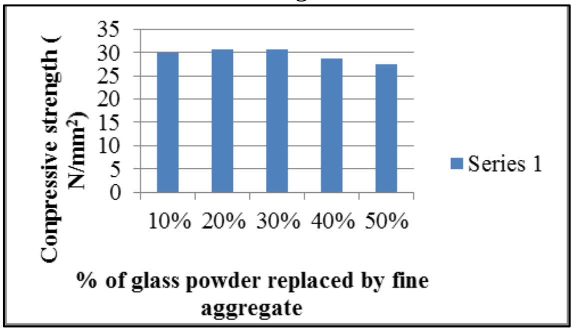

Fig. 4: Compressive Strength N/mm^2

VII. CONCLUSION

It shows that partially replaced concrete with the 30% glass cullet as fine aggregate shows higher strength when compared to the conventional concrete. The optimum replacement of cement by glass cullet was found to be 30% as it showed the compressive strength of cube as 30.67 N/mm2.It shows that the increase of replacement of glass powder as partial replacement of fine aggregate will reduced the plastic property like slump value.

REFERENCES

[1] Mageswari .M and Dr. Vidivelli .B "The Use of Sheet Glass Powder as Fine Aggregate Replacement in Concrete" The Open Civil Engineering Journal, Vol 4, 2010 , pages 65-71
[2] Rama Mohan Rao .P, Sudarsana Rao .H, Sekar .S. "Effect of Glass Fibres on Flyash Based Concrete"
[3] International journal of civil and structural engineering-Vol 1, No 3, 2010, pages 606-612.
[4] B. Topcu, M. Canbaz, "Properties of concrete containing waste glass," vol. 34, February 2004, pages 57-84.
[5] C. D. Johnston, "Waste glass as coarse aggregate for concrete," vol. 2, May 2003, pages 97-110.
[6] S.B. Park, "Development of recycling and treatment technologies for construction wastes," Vol.3, Oct 2000, pages 50-82.
[7] Job Thomas, "Utilization of quarry powder as a substitute for the river sand in concrete", vol.32, no.5, pages 401-407, January 2006.
[8] C. Meyer, and S. Baxter, "Use of recycled glass and fly ash for precast concrete," vol.1, pages. 98- 18, October 2002.
[9] Y. Shao, T. Lefort, S. Moras, and D. Rodriguez, "Studies on concrete containing ground waste glass," vol. 30, no. 1, pages. 91-100, June 2000.
[10] A.Shayan, "Value - Added Utilization of waste glass in Concrete," vol. 34, no.1, pages. 81-89, May 2004.
[11] W. Jin, C. Meyer, and S. Baxter, "Glass Concrete with glass aggregate," ACI journal, vol. 2, pages. 208-213, May 2000.
[12] C. Polley, S.M. Cramer, and R.V. Crug, "Potential for using waste glass in Portland Cement Concrete," J. Mater. Civil Eng., vol. 10, no. 4, pages. 210-219, May 2001.
[13] Turgut .P, Yahlizade .E. S. "Research into Concrete Blocks with Waste Glass" International journal of civil and environmental engineering 1:4, 2009, pages 203-209.