

A Study on Sustainable and Eco-friendly Admixture for Concrete

Adhish Tripathi¹, Aditi Gupta², Jitendra Tiwari³, Akshay Guru⁴

Student, Department of Civil Engineering, Prestige Institute of Engineering, Management and Research, Indore,
Madhya Pradesh, India^{1,2,3,4}

ABSTRACT: Mankind has been flourishing at an extremely rapid rate but at the same time it has ignored the need to be environmentally responsible. The study of crushed glass as admixture was done owing to the fact that colored bottles containing alcoholic drinks and other bottles made of glass are not recycled in India. Instead of being recycled they are thrown away in dump yards thereby causing harm to the environment and hence it would be very fruitful to determine whether discarded glass has an immense potential to be used as admixture or not. Use of waste materials as construction materials has numerous benefits such as reduction in cost, saving energy, and most importantly protection of the environment. Crushed glass is a waste material, which can be a substitute/admixture for fine aggregate. So, the main objective of this project is to encourage the use of Crushed glass as a construction material and to prepare concrete by using Crushed glass as fine aggregate. In this project, experimental study has been done on strength characteristics of M25 concrete with replacement of 5%, 10%, and 15% of fine aggregate by Crushed glass as well as 15% Basalt, all in separate specimens. The proportion used in this study is 1:1:2 and water cement ratio is 0.4, and 0.5. Cubes were casted and the compressive strength of concrete was evaluated and results were compared for both the replacements as well. The strength of concrete increased as the percentage of crushed glass material increased up to a limit of 15%.

KEYWORDS: Sustainable admixture, Sustainable concrete, Crushed glass admixture, Recycling wastes, Recycled crushed glass, Basalt admixture.

I. INTRODUCTION

Our experimental research led us to the inference that all the bottles that are made of silicon based glass, are completely discarded in our country. This leaves no scope for recycling. Due to this inference, we crushed the aforementioned glass bottles into fine particles in a Los Angeles Abrasion Testing Machine and instead of sand, we mixed the fine glass particles by the volume of 5%, 10%, and 15% and found out that the experimental results exceeded the results shown by the presence of normal sand in cement. This ensured that the glass bottles were appropriately used and did not affect the efficacy of the concrete mix and instead increased its characteristic strength.

II. EXPERIMENTAL INVESTIGATIONS

- **Materials:** The constituent materials used in this project were obtained from local sources and these were Ordinary Portland Cement (O.P.C), sand and crushed glass both as fine aggregate, and crushed granite as coarse aggregate. Potable water was used for mixing and curing.

✚ **Cement:** Ordinary Portland cement grade 43 with trade name Reliance was used conforming to IS 1489- 1991(Part1) and physical property are given below.

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S.No.	Physical Property	Test Results
1.	Standard Consistency	34%
2.	Fineness of cement	6%
3.	Initial Setting Time	106 min
4.	Final Setting Time	5 hr 12 min
5.	Specific Gravity	3.055

✦ **Fine aggregate:** River sand was used as fine aggregate conforming to zone III as per IS 383-1970

S.No.	Physical Property	Test Results
1.	Specific Gravity	2.678
2.	Fineness Modulus	2.289
3.	Bulk Density	1.617gm/cm ³

✦ **Coarse Aggregate:** Crushed granite was used as coarse aggregate of size 20mm and 10mm both. The results obtained have been mentioned in table.

S.No.	Physical Property	Test Results
1.	Specific Gravity	2.88
2.	Fineness Modulus	6.9
3.	Bulk Density	1.845gm/cm ³
4.	Water Absorption	0.15%
5.	Impact Value	15.6%

✦ **Basalt:** The table refers to the continuous basalt fiber from a specific producer. Data from all the manufacturers are different; the difference is sometimes very large.

Property	Value
Tensile strength	4.84 GPa
Elastic modulus	89 GPa
Elongation at break	3.15%
Density	2.7 g/cm ³

✦ **Glass obtained from Colored container bottles:**

Properties	Container glass
Chemical composition, wt%	74 SiO ₂ , 13 Na ₂ O, 10.5 CaO, 1.3 Al ₂ O ₃ , 0.3 K ₂ O, 0.2 SO ₃ , 0.2 MgO, 0.04 Fe ₂ O ₃ , 0.01 TiO ₂
Viscosity $\log(\eta, \text{dPa}\cdot\text{s or Poise}) = A + B / (T \text{ in } ^\circ\text{C} - T_0)$	550 °C (1,022 °F)–1,450 °C (2,640 °F): A = -2.309, B = 3922, T ₀ = 291
Glass transition temperature, T _g	573 °C (1,063 °F)
Coefficient of thermal expansion, ppm/K, ~100 °C (212 °F)–300 °C (572 °F)	9
Density at 20 °C (68 °F), g/cm ³	2.52
Refractive index n _D at 20 °C (68 °F)	1.518
Dispersion at 20 °C (68 °F), 10 ⁴ ×(n _F –n _C)	86.7
Young's modulus at 20 °C (68 °F), GPa	72
Shear modulus at 20 °C (68 °F), GPa	29.8
Liquid's temperature	1,040 °C (1,900 °F)
Heat capacity at 20 °C (68 °F), J/(mol·K)	49
Surface tension, at ~1,300 °C (2,370 °F), mJ/m ²	315
Chemical durability, Hydrolytic class, after ISO 719	3

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What is Basalt?

Basalt is a dark-colored, fine-grained, **igneous rock** composed mainly of plagioclase and pyroxene minerals. The image of basalt is attached below.

Composition

Average chemical composition of basalt is determined by 3594 chemical analyses of basaltic rocks (numbers are mass percents, recalculated volatile-free to total 100%):

SiO ₂	—	49.97
TiO ₂	—	1.87
Al ₂ O ₃	—	15.99
Fe ₂ O ₃	—	3.85
FeO	—	7.24
MnO	—	0.20
MgO	—	6.84
CaO	—	9.62
Na ₂ O	—	2.96
K ₂ O	—	1.12
P ₂ O ₅	—	0.35



(a) This image shows finely crushed basalt rock which was later added to the concrete cube as concrete mix.

- **Mix Proportions:** To investigate the properties of concrete, first of all, control mix without the replacement of fine aggregate with other materials was made. After that different concrete mixes were prepared by replacing of fine aggregate by 5%, 10%, 15% crushed glass & 15% Basalt. Constant water cement ratio of 0.4 and 0.5 for crushed glass and basalt concrete mixes respectively was maintained for all M25 mix concrete simultaneously which had the proportion 1: 1: 2.
- **Mixing, compaction, Specimen preparation, and Curing:** With the help of electronic weigh balance, batching was done as per the mix proportions. After addition of water, mixing was done for 3-4 minutes in tilting mixer. Cubical moulds were cleaned and oiled and tamping was done after placing the concrete in moulds. Table vibrator removes the entrapped air in concrete. After 24 hours, de-moulding was done and concrete cubes were kept in curing tank for 7 days. Concrete cubes were then removed from curing tank to conduct tests on the hardened concrete cubes.

❖ Procedure for Concrete with Admixtures

- **Casting of Concrete Cubes** –The test moulds are kept ready before preparing the mix. Tighten the bolts of the moulds carefully because if the bolts of the moulds are not screwed tight the concrete slurry might come out of the mould when vibration takes place. Then moulds are cleaned and oiled on all the inner contact surfaces of the moulds. The concrete is filled into moulds in layers and then vibrated on a vibrating table. The top surface of concrete is struck off level with a trowel. The number and date of casting are put on the top surface of the cubes.
- **Test for Compressive strength of concrete cubes-** To calculate the compressive strength of concrete cubes, the universal testing machine (UTM) having capacity of 300 tons was used. In this test the strength is obtained in tons. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest N/mm².

Out of many test applied to the concrete, this is by far of the utmost importance which gives an idea about all the characteristics of concrete that relate to it. By this single test one judge that whether concreting has been done properly or not. For tests performed on concrete cubes, two types of specimens, either cubes of 15cm X 15cm X 15cm or 10cm X 10 cm X 10 cm depending upon the size of aggregate, are used. For most of the work, cubical moulds of size 15 cm X 15cm X 15 cm are commonly used. These specimens are tested by compression testing machine after 7 days curing, 14 days curing, 28 days curing. Load should be applied gradually at the rate of 140

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kg/cm² per minute till the specimens fail. Load at the failure divided by area of specimen gives the compressive strength of concrete.

III. PROCEDURE FOLLOWED FOR DIFFERENT CUBES

❖ Basalt

Test Procedure: -

- Take a clean cubical mould of size 150mm X 150mm X 150 mm and properly tighten all the screws into the mould.
- Prepare the mould assembly by properly applying oil on the inner sides of the mould so as to fill the pores and the gaps to avoid leakage and for the easy removal of the cube once it is molded and dried.
- Add the basalt in the concrete mix by the volume % of the concrete mix
- To make the concrete cube of M-25 grade of 30 kg concrete, containing 15% basalt by volume of the concrete, add the following materials in the given amounts-
 - Cement = 6.55 kg
 - Sand = 6.55 kg
 - Aggregates = 13.1 kg
 - Basalt = 3.8 kg
- Fine aggregates used to prepare the concrete mix should pass from the sieve of size 600 micron and retain on the 300-micron sieve.
- Coarse aggregates used in the mix should be passing the sieve of size 15mm.
- Basalt added in the mix shall pass as 300 mm sieve size.
- The ratio of amount of water to amount of cement in the mix is kept 0.5.
- All the mix ingredients shall be thoroughly mixed.
- The moulds will be filled with prepared mix in 3 equal layers, pour the 1st layer in the mould and tamper it with a rod for 25 times, repeat the same with the second and third layers.
- Put the mould at Mould Vibrator for some time to allow compacting and the removal of voids.
- Let the mould dry in air for 24 hours, and after 24 hours, the cube shall be removed from the mould and placed in a water tank for 7 days.
- Generally 3 moulds should be made to analyze the results by taking the average of outcomes from each cube.

❖ Crushed glasses

Test Procedure: -

- Take a clean cubical mould of size 150mm X 150mm X 150 mm and properly tighten all the screws into the mould.
- Prepare the mould assembly by properly applying oil on the inner sides of the mould so as to fill the pores and the gaps to avoid leakage and for the easy removal of the cube once it is molded and dried.
- Add the crushed glasses in the concrete mix by the volume % of the concrete mix
- To make the concrete cube of M-25 grade of 30 kg concrete, containing 15% glass fiber by volume of the concrete, add the following materials in the given amounts-
 - Cement = 6.55 kg
 - Sand = 6.55 kg
 - Aggregates = 13.1 kg
 - Crushed glasses = 3.8 kg
- Fine aggregates used to prepare the concrete mix should pass from the sieve of size 600 micron and retain on the 300-micron sieve.
- Coarse aggregates used in the mix should be passing the sieve of size 15mm.
- Crushed glasses are obtained by grinding the waste glass bottles in the Los Angeles Abrasion Testing Machine.
- The ratio of amount of water to amount of cement in the mix is kept 0.4.

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- All the mix ingredients shall be thoroughly mixed.
- The moulds will be filled with prepared mix in 3 equal layers, pour the 1st layer in the mould and tamper it with a rod for 25 times, repeat the same with the second and third layers.
- Put the mould at Mould Vibrator for some time to allow compacting and the removal of voids.
- Let the mould dry in air for 24 hours, and after 24 hours, the cube shall be removed from the mould and placed in a water tank for 7 days.
- Generally 3 moulds should be made to analyze the results by taking the average of outcomes from each cube.

The same procedure shall be followed for the cube specimens with 5% and 10% crushed glass in the concrete mix.



(b) This is the image of the above prepared concrete mixes in the cubical moulds

IV. OBSERVATIONS AND CALCULATIONS

$$\text{Compressive strength} = \frac{\text{Maximum load}}{\text{Area}} = P/A$$

A. COMPRESSION TESTING MACHINE RESULTS (7 DAYS)-

- **Crushed glass (15%) with concrete:** given below is the table containing load readings for cube containing concrete mix with 15% crushed glass.

Specimen	Weight of specimen	Analog CTM reading	Digital CTM reading
1	8.630 kg	510 kN	500 kN
2	8.450 kg	615 kN	608 kN
3	8.480 kg	690 kN	679 kN

- **Crushed glass (10%) with concrete:** given below is the table containing load readings for cube containing concrete mix with 10% crushed glass.

Specimen	Weight of specimen	Analog CTM reading	Digital CTM reading
1	8.510 kg	450 kN	430 kN
2	8.410 kg	415 kN	408 kN
3	8.500 kg	510 kN	527 kN

- **Crushed glass (5%) with concrete:** given below is the table containing load readings for cube containing concrete mix with 5% crushed glass.

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Specimen	Weight of specimen	Analog CTM reading	Digital CTM reading
1	8.530 kg	410 kN	400 kN
2	8.450 kg	395 kN	410 kN
3	8.450 kg	450 kN	470 kN

- **Basalt (15%) with concrete:** given below is the table containing load readings for cube containing concrete mix with 15% basalt.

Specimen	Weight of specimen	Analog CTM reading	Digital CTM reading
1	8.430 kg	510 kN	494 kN
2	8.510 kg	590 kN	573 kN
3	8.340	640 kN	620 kN

B. PRESSURE CALCULATION –

- **Concrete with 15% Crushed glass-** given below is the table containing pressure readings for cube containing concrete mix with 15% crushed glass.

Specimen No.	Load	Area	Pressure= Load/Area
1	$500 \times 10^3 \text{ kN}$	22500 mm^2	22.22 N/mm^2
2	$608 \times 10^3 \text{ kN}$	22500 mm^2	27.02 N/mm^2
3	$679 \times 10^3 \text{ kN}$	22500 mm^2	30.18 N/mm^2

- **Concrete with 10% Crushed glass -** given below is the table containing pressure readings for cube containing concrete mix with 10% crushed glass.

Specimen No.	Load	Area	Pressure= Load/Area
1	$430 \times 10^3 \text{ kN}$	22500 mm^2	19.11 N/mm^2
2	$408 \times 10^3 \text{ kN}$	22500 mm^2	18.13 N/mm^2
3	$527 \times 10^3 \text{ kN}$	22500 mm^2	23.42 N/mm^2

- **Concrete with 5% Crushed glass -** given below is the table containing pressure readings for cube containing concrete mix with 5% crushed glass.

Specimen No.	Load	Area	Pressure= Load/Area
1	$400 \times 10^3 \text{ kN}$	22500 mm^2	17.78 N/mm^2
2	$410 \times 10^3 \text{ kN}$	22500 mm^2	18.22 N/mm^2
3	$470 \times 10^3 \text{ kN}$	22500 mm^2	20.89 N/mm^2

- **Concrete with 15% Basalt -** given below is the table containing pressure readings for cube containing concrete mix with 15% basalt.

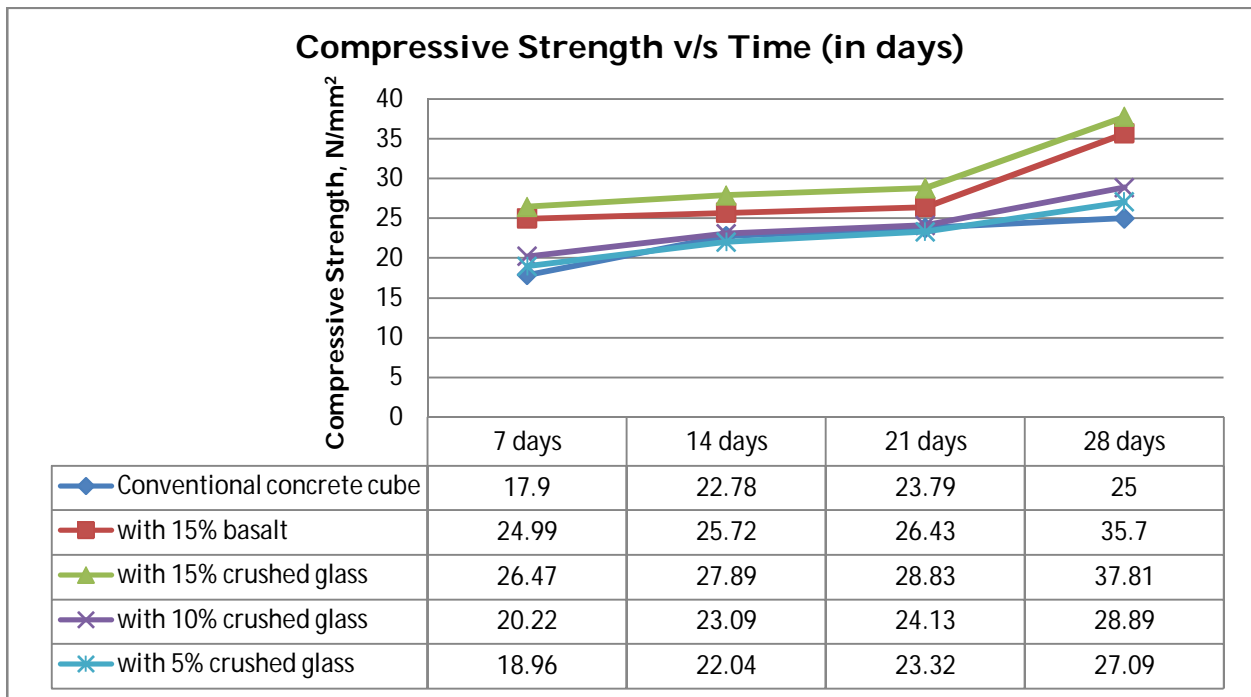
Specimen No.	Load	Area	Pressure= Load/Area
1	$494 \times 10^3 \text{ kN}$	22500 mm^2	21.95 N/mm^2
2	$573 \times 10^3 \text{ kN}$	22500 mm^2	25.47 N/mm^2
3	$620 \times 10^3 \text{ kN}$	22500 mm^2	27.55 N/mm^2

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This graph shows the relationship between the compressive strength of various cubes containing different concrete mixes with time.

V. RESULTS

The following conclusions can be drawn from the experimental investigation carried out -

- The compaction factor increased as the percentage of Crushed glass and Basalt increases and increased in comparison with the conventional concrete.

S.No.	Type of Cube	Calculation	Cost (in rs)
1	Conventional cube	$(6.55 \times 6) + (6.55 \times 1) + (13.1 \times 0.41) + (3.8 \times 1) = 55.021$	55.021 rs
2	Cube with 15% crushed glass	$(6.55 \times 6) + (10.35 \times 1) + (13.1 \times 0.41) = 55.021$	55.021 rs

- It was concluded that basalt is too expensive to be used as a replacement for fine aggregate and the current prices for sand ranges to be around 3/- Rs to 6/- Rs. It was also inferred that crushed glass can be conveniently used as an admixture not only to increase the characteristic strength of concrete but it can also be a sustainable and eco-friendly way of disposing a huge portion of waste. Along with the aforementioned **advantages of using crushed glass as an admixture, it also reduces cost and hence can act as a very useful** admixture for concrete.
- The specific gravity of crushed glass is high as compared to the fine aggregate and the water absorption is low for crushed glass than fine aggregate and hence the strength increased in comparison with the conventional concrete.
- Concrete having 15% of fine aggregate replaced with Crushed glass and 15% of fine aggregate replaced with basalt resulted that the compressive strength is increased when compared with the conventional concrete.
- The compressive strength of the concrete increased with increasing percentage of the crushed glass and basalt replacement.
- The cube compressive strength of concrete at the age of 7 days resulted in increase with 15% replacement of fine aggregate with crushed glass and basalt.
- The strength of concrete increased as the percentage of replacement of the conventional material increased up to a certain point.
- The compressive strength increased with the percentage replacement of crushed glass and basalt increases at the ages

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7 days, 14 days, and 28 days.

- The compressive strength with percentage replacement of cement and coarse aggregates increased is high and hence can be used for important work utilizing the waste material that is produced in large quantities.

VI. CONCLUSIONS

The properties of Crushed glass aggregate concrete are examined and the use of Crushed glass aggregate in construction is tested. In this project, replacement is done in two ways. One is replacement of 15% of fine aggregate by crushed glass and another is replacement of 15% of basalt with fine aggregate along with 15% by Crushed glass. The parameters that were tested are workability, density, permeability voids, water absorption, and compressive strength, tensile and flexural strength of concrete cubes. A comprehensive summary of properties of normal and crushed glass, basalt concretes are presented with the help of Table and Graphs.

- **Further scope of work-**
- The study can be carried out with varying percentage replacement of the material for specific low cost housing applications.
- The engineering properties like water absorption, reduction in weight of concrete and study on economic aspects can be carried out.
- The effect of temperature on the concrete developed can be studied.
- The study can be extended to assess the durability aspects of the concrete with varying replacement proportions.

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