

# **Influence of GGBS and Eco Sand in Green Concrete**

M.Prabu<sup>1</sup>, S.Logeswaran<sup>2</sup>, Dr. Sunilaa George<sup>2</sup>

P.G. Student, Department of Civil Engineering, EASA College of Engineering & Technology, Coimbatore, Tamilnadu, India<sup>1</sup>

Asst. Professor, Department of Civil Engineering, EASA College of Engineering & Technology, Coimbatore, Tamilnadu, India<sup>3</sup>

Professor & Head, Department of Civil Engineering, EASA College of Engineering & Technology, Coimbatore, Tamilnadu, India<sup>3</sup>

**ABSTRACT:** The construction materials are making the idea of sustainable construction more believable every day. As more and more “green” buildings are constructed, builders and designers are beginning to develop more effective techniques for producing savings in both energy and materials usage. Green building movement is a relatively young phenomenon in the construction world. New methods nowadays, as the world population growth increase significantly, the used for more houses, buildings, and other infrastructures become major agenda for developing countries. India is one of the developing country adopting sustainable development agenda as national strategy. In this paper, GGBS & ECO SAND has been chemically and physically characterized and used as partial replacement in the ratio of 0%, 10%, 20%, 30% and 40% by weight of cement and sand in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken as well as hardened concrete tests like Compressive strength, Split Tensile strength, Flexural strength and Modulus of elasticity at the age of 7, 14 and 28 days has been done for M20 grade of concrete. Test results are compared between conventional concrete and Ultimate Concrete for GGBS & Eco sand with different percentages used as partial replacement.

**KEYWORDS:** GGBS, Eco Sand, Conventional Concrete, Compressive Strength, Split tensile strength, flexural strength and modulus of elasticity.

## **I. INTRODUCTION**

The construction industry is the base for all activities of development. Concrete and steel are the two most commonly used structural materials for construction. They sometimes complement one another, so that the structures of similar type and function can be built in either of these materials.

Concrete is one of the man made materials, which finds wider application in the construction industry. Concrete structures are maintenance free when compared to steel structures. The ingredients of concrete are cement, sand, coarse aggregate and water.

In the recent years, we are using large amount of concrete, which leads to an environmental impact due to the emission of CO<sub>2</sub> and the large-scale depletion of natural resources. Hence to avoid the impact on the concrete and to make them as an environmentally friendly material, a substitute or replacement product for making concrete needs to be found. This paper focuses on green concrete, which have an equivalent performance as that of concrete.

### **Green Concrete**

Engineers and architects have choices of the material and products they use to design projects when it comes to a building frame the choice is typically between concrete, steel and wood; for paving applications the choice is generally between concrete and asphalt. Material choice depends on several factors including cost, life cycle and performance for

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a specific application. Due to growing interest in sustainable development, engineers and architects are motivated more than ever before to choose materials that are more sustainable. However this is not as straight forward as selecting an energy star rated appliance or a vehicle providing high gas mileage. On what “measurement” basis can engineers and architects compare materials and choose one that is more sustainable or specify a material in such a way as to minimize environmental impact.

## II. LITERATURE REVIEW

### Ground Granulated Blastfurnace Slag

Many researchers have been carried out studies on GGBS in the past years to assess the properties and its behaviour. Some of the works carried out are discussed below.

**K.Ganesh Babu (2000)** presented an effort to quantify the 28days cementitious efficiency of ground granulated blast furnace slag in concrete at the various replacement levels. The replacement levels in the concrete studied varied from 10% to 80% and the strength efficiencies at the 28days were calculated. Strength efficiency factor varied from 1.29 to 0.70 for percentage replacement levels varying from 10% to 80%. Overall the prediction of the strength of concretes varying from 20 to 100Mpa with GGBS levels varying from 10% to 80% by this method was found to result in a regression coefficient of 0.94 which was also the same for normal concretes.

**Pazhani.K (2010)** presented that the slump value for 100% replacement of fine aggregate with copper slag increases by 60-85 mm. The replacement of 30% of cement by GGBS decreases the water absorption by 4.58%, chloride ion permeability by 29.9% and pH value by 0.39%. The replacement of 100% of fine aggregate by copper slag decreases water absorption by 33.59%, chloride ion permeability by 77.32% and pH value by 3.04%.

**Venu Malagavelli (2010)** investigated the characteristics of M30 concrete with partial replacement of cement with GGBS and sand with the ROBO sand (crusher dust). Compressive strength and split tensile strengths of cubes and cylinders were increased as the % of ROBO sand increased. The % of increase in compressive strength were 19.64 and 8.03% at the age of 7 and 28 days and % of increase in split tensile strength was 1.83% at the age of 28 days by replacing 30% sand with ROBO sand with 1.5% admixture. % of increase in compressive strength of concrete was 11.06 and 17.6% at the age of 7 and 28 days by replacing 50% of cement with GGBS and 25% of sand with ROBO sand.

**M.C.Nataraja (2013)** investigates, shows that the compressive strength of cement mortar increases as the replacement level of GGBS increases. This increase is not substantial. However for 100% replacement the strength decreases marginally compared to 100% natural sand. From this it is clear that GGBS sand can be used as an alternative to natural sand from the point of view of strength. Use of GGBS upto 75% can be recommended.

**Mahesh Patel (2013)** investigated the characteristics of M35 concrete with partial replacement of cement with GGBS and sand with crusher sand. Compressive & Tensile strength tests were carried out on cubes and cylinders. Based on the results the compressive strength and split tensile strength were increased as the % of crusher sand increased & 50% of cement can be replaced with GGBS. The % increase of compressive strength of concrete is 10.04 and 16.54% at the age of 7 and 28 days by replacing 40% of cement with GGBS and 20% of sand with crusher sand.

**Oormila.T.R & T.V. Preethi (2014)** carried out a study on soil characteristics was treated with various percentages of GGBS (15%, 20% & 25%) and UCC test was performed. From the UCS value it was found that soil treated with 20% of GGBS gives the optimum strength when compared with the virgin soil with an increment of 73.79% for 21 days of curing.

### GREEN CONCRETE

Many researchers have been carried out studies on Green Concrete in the past years to assess the properties and its behaviour. Some of the works carried out are discussed below.

**Karthik obla on (2009)** investigates done by CO<sub>2</sub> emissions from 1 tonne of concrete produced vary between 0.05 to 0.13 tons. 95% of all CO<sub>2</sub> emissions from a cubic yard of concrete is from cement manufacturing. It is important to reduce CO<sub>2</sub> emissions through the greater use of SCM. Focusing solely on CO<sub>2</sub> emissions from cement and concrete

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production increases the perception that concrete is not sustainable which is inaccurate since operationally concrete has substantial sustainability benefits. An incorrect perception can lead to a less sustainable material choice. removal of prescriptive specification restrictions and focusing on performance and the use of incentives is an effective way to encourage sustainable concrete with low CO<sub>2</sub> emission.

**Aakah Jain & Chirag Garg (2014)** investigates done by, clearly indicates an increasing trend and incentives for the greater use of manufactured and recycled aggregates in construction. These are, however limitations to the use such materials. It focuses on known benefits and limitations of a range of manufactured and recycled aggregates. Use of concrete product like green concrete in future will not only reduce the emission of CO<sub>2</sub> in environment and environmental impact, but it is also economical to produce.

## ECO SAND

Many researchers have been carried out investigated on Eco sand in the past years to assess the properties and its behaviour. Some of the works carried out are discussed below.

**S.L. Beckwith, J.M. Justice, L.H. Kennison, B.J. Mohr (2014)** investigates the performance of two metakaolins as Supplementary Cementitious Materials (SCMs) was evaluated at 8% by weight cement replacement. The metakaolins varied by their surface area (11.1 vs. 25.4 ECO25%/g). Performance of metakaolin mixtures was compared to control mixtures at water-to-cement ratios of 0.40, 0.50, and 0.60 where no SCM had been used and to mixtures where silica fume had been used as partial replacement for cement. In both mixtures containing metakaolins, compressive, splitting tensile and flexural strengths increased, as well as elastic modulus, as compared to control mixtures. Setting time was reduced in the pastes with both metakaolins. Additionally, considering durability, both metakaolins reduced rapid chloride ion permeability and expansion due to alkali-silica reaction when compared to control and silica fume mixtures. In general, the finer of the two metakaolins proved more effective in improving concrete properties, although both performed superior to silica fume.

**Vishnumanohar (2014)** investigates by carried out Eco sand (finely graded silica) is a locally available, low cost, and inert industrial solid waste whose disposal is a matter of concern likes construction waste. On an overall, the Eco sand can be comparable to the natural river sand. The Eco sand satisfies the zone III gradation for not only to partially replace the sand, but for making good concrete. From the obtained results we observed that the maximum strength is achieved by 15% of fine aggregate replacement with eco sand in concrete. While increasing the percentage of eco sand the compressive strength value is getting decreased. From the SEM analysis, at a 15% replacement the mix remains homogeneous as the micro pores are filled and the transition zone is densified. Higher the percentage of fine aggregate replacement higher was the strength activity index. The strength activity index nearly varies linearly with percentage replacement of fine aggregate with eco sand. The maximum strength activity index was 1.49 at 15% replacement level. From the experimental investigation it was found that 15% replacement level is the optimum level.

## III. EXPERIMENTAL STUDY

### Materials Used

- **Cement:** Ordinary Portland cement, 53 Grade conforming to IS 12269 – 1987.
- **Fine aggregate:** Locally available river sand, conforming to Grading zone II of IS 383 – 1970.
- **Coarse aggregate:** Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS 383 – 1970.
- **Ground Granulated Blast furnace Slag:** GGBS from Mangalore, Kerala. Two major uses of GGBS are in the production of quality-improved slag cement, namely Portland Blast Furnace cement (PBFC) and High-Slag Blast-Furnace cement (HSBFC), with GGBS content ranging typically from 30 to 70% and in the production of ready-mixed or site-batched durable concrete. Use of GGBS significantly reduces the risk of damages caused by Alkali - Silica Reaction (ASR), provides higher resistance to chloride ingress - reducing the risk of reinforcement corrosion - and provides higher resistance to attacks by sulphate and other chemicals. Chemical properties of GGBS are given in Table 1.

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**Table 1 Chemical Properties of GGBS**

Characteristics	Requirement As Per Bs : 6699	Test Result
Fineness (m <sup>2</sup> /Kg)	275 (Min)	396
Specific Gravity	-	2.88
Particle Size cumulative (%)	45 micron (Min)	97.10
Insoluble Residue (%)	1.5 (Max)	0.42
Magnesia Content (%)	14.0 (Max)	8.21
Sulphide Sulphur (%)	2.00 (Max)	0.46
Sulphite Content (%)	2.50 (Max)	0.30
Loss of Ignition (%)	3.00 (Max)	0.33
Manganese Content (%)	2.00 (Max)	0.07
Chloride Content (%)	0.10 (Max)	0.010
Glass Content (%)	67 (Min)	91
Moisture Content (%)	1.00 (Max)	0.10
<b>Chemical Moduli</b>		
CaO + MgO + SiO <sub>2</sub>	66.66 (Min)	75.81
CaO + MgO /SiO <sub>2</sub>	>1.0	1.29
CaO /SiO <sub>2</sub>	<1.40	1.04

- **Eco sand:** Eco sand obtained from ACC cement factory, Madukkarai, Coimbatore. Chemical composition of Eco sand are given in Table 2.

**Table 2 - Chemical Composition of Eco Sand**

Sl.NO	Chemicals	Amount (%)
1.	Silica (SiO <sub>2</sub> )	68.1
2.	Alumina (Al <sub>2</sub> O <sub>3</sub> )	10.7
3.	Potassium (K <sub>2</sub> O)	4.3
4.	Calcium (CaO)	2.2
5.	Iron (Fe <sub>2</sub> O <sub>3</sub> )	1.7
6.	Sodium (Na <sub>2</sub> O)	0.6
7.	Magnesium (MgO)	0.5
8.	Loss on Ignition (H <sub>2</sub> O)	11.5

- **Water:** Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials.
- **Mix Proportion:** The mix design has been adopted as per IS 10262-2009. The concrete used in this study was proportioned to attain Characteristic strength of 20 MPa.

GGBS & ECO SAND has been chemically and physically characterized, and partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by weight of cement and sand in concrete.

#### IV. RESULTS AND DISCUSSION

Based upon the comparative study conducted the ratio E1, E2, E3, E4 & E5 and G1, G2, G3, G4 & G5 were adopted for further testing processes as they are volume increase is substantial, mouldable, consistent, stable after curing. There were ten samples of E1, E2, E3, E4 & E5 and G1, G2, G3, G4 & G5 each for testing and the results would be taken as the three specimens of each mix. From the comparison of all the activity E3 & G4 was found to be

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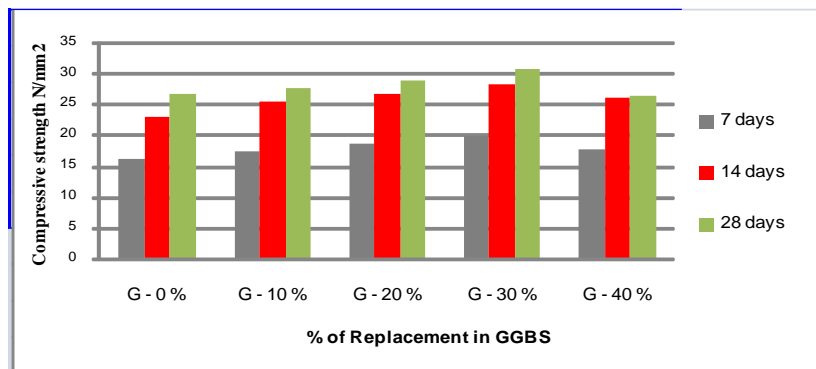
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the richest mix design. The compressive strength result was tested for various proportions replaced with GGBS in concrete at 7, 14, 28 days and the tested results are tabulated as per BIS 516 – 1959 in Table 3.

**Table 3 - Compressive Strength Results for GGBS (N/mm<sup>2</sup>)**

Specimen	7 Days	14 Days	28 Days
G1 - 0%	16.25	22.91	26.78
G2 - 10%	17.28	25.35	27.61
G3 - 20%	18.58	26.69	28.89
<b>G4 - 30%</b>	<b>19.90</b>	<b>28.17</b>	<b>30.57</b>
G5 - 40%	17.70	26.09	26.38



**Figure 1 – shows Compressive strength results for different percentages of GGBS**

The Compressive Strength result was tested for various proportions replaced with Eco sand in concrete at 7, 14, 28 days and the tested results are tabulated as per BIS 516 – 1959 in Table 4.

**Table 4 - Compressive Strength Results for Eco sand**

Specimen	7 Days (N/mm <sup>2</sup> )	14 Days (N/mm <sup>2</sup> )	28 Days
E1 - 0%	16.25	22.91	26.78
E2 - 10%	16.71	23.33	28.51
<b>E3 - 20%</b>	<b>19.16</b>	<b>24.24</b>	<b>31.16</b>
E4 - 30%	16.60	23.18	28.59
E5 - 40%	15.02	21.62	24.54

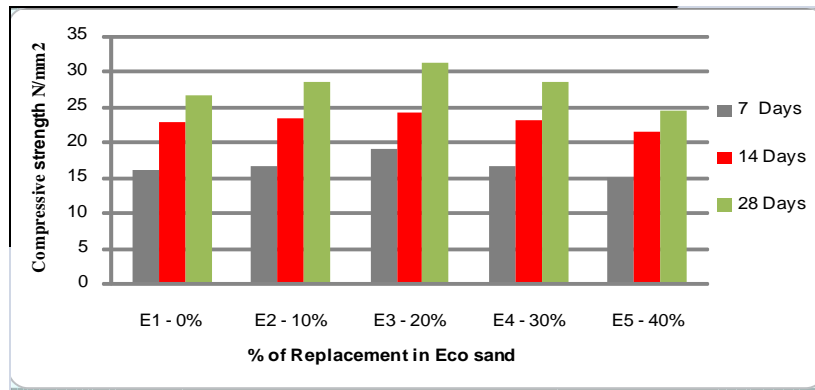


Figure 2 – shows Compressive strength for different percentages of ECO sand

The Compressive Strength is achieved at 30% replacement for cement with GGBS and 20% replacement for fine aggregate with Eco sand for conventional concrete and Ultimate concrete at 7, 14 and 28 days. The compressive strength results are tabulated in Table 5.

Table 5 - Compressive Strength Results for Conventional and Ultimate Concrete (30% GGBS & 20% Eco Sand)

Specimen	7 Days (N/mm <sup>2</sup> )	14 Days (N/mm <sup>2</sup> )	28 Days (N/mm <sup>2</sup> )
Conventional concrete	16.25	22.91	26.78
Ultimate concrete	20.17	25.36	30.06

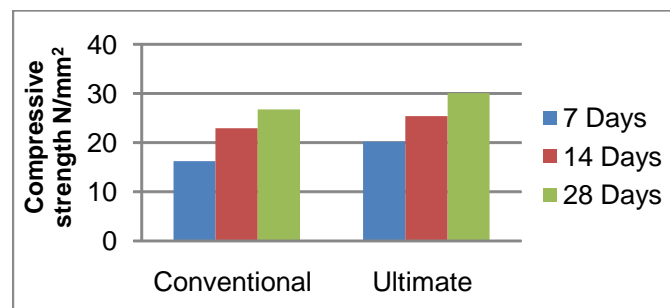


Figure 3 – shows Compressive strength results for Conventional concrete and Ultimate concrete

The Split Tensile Strength is achieved at 30% replacement for cement with GGBS and 20% replacement for fine aggregate with Eco sand for conventional concrete and Ultimate concrete at 7, 14 and 28 days. The Split Tensile Strength results are tabulated in Table 6.

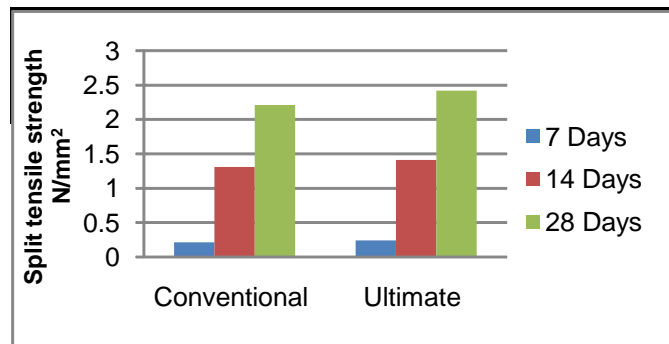
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**Table 6 - Split tensile strength results for Conventional & Ultimate concrete (M 20 Grade)**

Description	Days	Sample (KN)	Tensile Strength (N/mm <sup>2</sup> )
Conventional concrete	7	15	0.212
	14	92.6	1.310
	28	156.2	2.210
Ultimate Concrete	7	17	0.240
	14	99.66	1.410
	28	171	2.419



**Figure 4 – shows Split tensile strength results for Conventional concrete and Ultimate concrete**

The Modulus of Elasticity is achieved at 30% replacement for cement with GGBS and 20% replacement for fine aggregate with Eco sand for conventional concrete and Ultimate concrete at 7, 14 and 28 days. The Modulus of Elasticity results are tabulated in Table 7.

**Table 7: Modulus of Elasticity results for Conventional Concrete and Ultimate Concrete (M 20 Grade)**

Specimen	7 Days (KN/mm <sup>2</sup> )	14 Days (KN/mm <sup>2</sup> )	28 Days (KN/mm <sup>2</sup> )
Conventional Concrete	11.035	15.450	22.74
Ultimate Concrete	14.370	20.670	25.617

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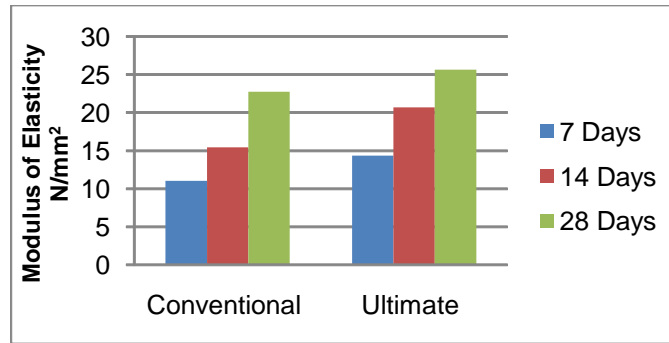


Figure 5 – shows Modulus of Elasticity results for Conventional concrete and Ultimate concrete

The Flexural strength is achieved at 30% replacement for cement with GGBS and 20% replacement for fine aggregate with Eco sand for conventional concrete and Ultimate concrete at 7, 14 and 28 days. The Flexural Strength results are tabulated in Table 8.

Table 8 - Flexural Strength results for Conventional Concrete & Ultimate Concrete (M20 Grade)

Specimen	7 Days (N/mm <sup>2</sup> )	14 Days (N/mm <sup>2</sup> )	28 Days (N/mm <sup>2</sup> )
Conventional Concrete	1.867	2.468	2.900
Ultimate Concrete (N/mm <sup>2</sup> )	2.330	3.111	3.868

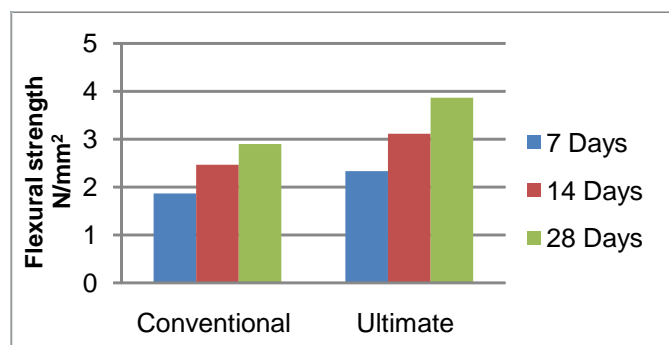


Figure 6 – shows Flexural strength results for Conventional concrete and Ultimate concrete

## V. CONCLUSION

- Green concrete eliminates the need for cements and hence reduction in global CO<sub>2</sub> emission.
- The degree of workability of concrete improved with addition of GGBS in concrete up to 30% replacement level for M20 grade concrete.
- GGBS replacement with cement with 30% gives optimum result but after that the strength got slowly



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decreases. Compression strength of cement by the replaced GGBS concrete specimens was higher than the plain cement concrete specimens. The strength differential between the GGBS concrete specimens and plain cement concrete specimens became more distinct after 28 days. Bleeding in GGBS concrete is significantly reduced and other properties like surface finish are improved. Results of this investigation suggest that GGBS could be very conveniently used in structural concrete.

- Use of GGBS reduces the amount of cement content as well as heat of hydration in a mortar mix. Thus, the construction work with GGBS concrete becomes environmentally safe and also economical. GGBS can be used as substitute for cement which will reduce the cost of cement in concrete and also reduce the consumption of cement. Therefore it is safe to replace the cement with 30% GGBS considering strength.
- Eco sand replacement with fine aggregate with 20% gives optimum result but after that, the strength got slowly decreases. The degree of workability of concrete improved with addition of Eco sand in concrete up to 20% replacement level for M20 grade concrete. Eco sand can be used as substitute for sand (fine aggregate) which will reduce the cost of sand in concrete and also reduce the consumption of sand. Therefore it is safe to replace the sand with 20% eco sand considering strength.
- It is observed that the compressive strength and the flexural strength of concrete can be improved by replacement with GGBS & Eco sand for cement and fine aggregate.
- From the above experimental results, it is proved that, GGBS and Eco sand can be used as replacement for the cement and Eco sand and compressive and flexural strength are increased as the Percentage of GGBS and Eco sand is increased up to optimum level. The optimum percentage of replacement of GGBS by cement is 30% and eco sand by fine aggregate is 20%.
- 28 days compressive strength, split tensile strength, modulus of elasticity, strength of ultimate concrete is more than the conventional concrete. From the result it is observed that the concrete with GGBS and eco sand is showing improvement of all types of strength characteristics. Hence it is concluded that concrete with GGBS and Eco sand can be used for all normal construction activities to that of the conventional one.

Since by using the GGBS and Eco sand at the optimum level in concrete works, it is seen that all the strength characters are increasing than in the conventional concrete. Particularly, this meets the sustainability conditions and saves the natural resources.

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