Comparative Analysis of Green Concrete with Conventional Concrete

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Abstract— In today's modern world there has been enormous development in the field of "Concrete Technology". With this development, there has also been enormous use of concrete in our day today life. Concrete mainly comprises of cement, sand and aggregate as its main constituents, which when mixed with water in correct proportion gives a by product called as "Concrete". The excess use of concrete has led to the environmental impact in terms of resources utilization as well as in terms of pollution. To overcome these impacts the concept of "Green Concrete" came into existence. Green concrete is a recent form to the existing types of concrete which resembles the conventional concrete but its manufacturing or handling of this concrete requires minimum amount of heat energy and causes the lowest harm to the surrounding environment. Since it deals into uses of the recycled aggregates and materials, it also reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net CO2 emissions are reduced. The reuse of materials also contributes intensively to economy. Green concrete can be considered elemental to sustainable development since it is eco-friendly in nature. One of the methods for manufacturing of green concrete involves reduction of amount of cement in the mix, which added to the reduction the total cement consumption. The use of waste materials also solves the problem of disposing the excessive amount of industrial wastes. Green Concrete is a concrete in which one or more of its constituents are replaced by a resource saving material, which ultimately has reduced environmental impacts in terms of both, resource utilization and pollution impacts together. This paper discusses the importance of Green Concrete in the present day context and highlights its merits over conventional concrete which otherwise posing a serious threat to the environment through global warming.

Keywords: Green Concrete, Conventional Concrete, GGBS – Ground Granulated Blast Furnace Slag, Quarry Dust, Demolised & Broken Brick Compressive Strength, Flexural Strength, Tensile Strength, Workability

I. INTRODUCTION

Green concrete is a concept of using environment-friendly materials in concrete, to finally make the system more sustainable. Green concrete is cheap to produce since waste products or recycled materials are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption while production is quite lower, and durability is much greater. This concrete is often confused with its colour. Waste can be recycled to produce new products or can be used as admixtures to relieve the burden on precious natural resources and also causing minimal negative impacts on the environment. Inorganic residual or tailing products like stone quarry dust, crushed concrete debris, marble waste can be used as green aggregates in concrete. Further, by replacing cement with ground granulated blast furnace slag, fly ash, micro silica in larger amounts, to produce new green cement and binding materials can ultimately lead to the use of alternative raw materials and fuels producing cement with low energy consumption. Considerable research has been carried out on the use of various industrial by-products and micro-fillers in concrete and their impact on concrete characteristics**.** When we replace one or more constituents of conventional concrete, by environmental friendly materials or recycled materials, the concrete formed is termed as "Green Concrete". As we know the manufacturing process of cement and aggregate causes huge environmental impact, and day by day this increasing demand of concrete materials is ultimately causing impact to our environment. Thus replacing cement and aggregate (conventional constituents of concrete) can in turn help in minimizing the environmental impact caused during manufacturing process of aggregate and cement.

Green concrete name easily gives a illusion of something related to the colour of the substance or the product. But this logic is nowhere in picture as the product has no resemblance to the green colour. Normally in the production of cement there is emission of carbon-di-oxide. The cement industry is also in question to lower its co2 emission as to rising global concerns. The connection between the cement industry and concrete industry is very evident as the latter cannot be produced with the former. So, Green concrete can also be an answer to those concerns. As this world is developing so fast it is next to impossible to replace concrete industry, it is evident from the fact that it is one among the largest industries providing economy, capital and employment. The only way-out is to find an alternative which can bring a balance between the development and the environmental concerns. That is why green concrete is catching eyeballs of various analysts worldwide, "Denmark" being the first among them. Checking the possible ways to get green concrete in work will certainly boost the development process without hampering the current growth rate. The by-products will also get value as they will be ultimately used in the green concrete making process. As green concrete presents various ways for its production that there are many entities of zero or low value which can be used. Dismantled concrete, Fly ash, Use of wasted wooden chunks from fitting can be utilized as aggregate mixture. Green concrete is also comparably cheap to manufacture, as, for example, waste products are used as a partial substitute for cement portion, costing for the disposal of waste are avoided, energy consumption of materials in manufacturing period is lower, while durability is greater. Green concrete is a new form to the existing (regular) types of concrete which resembles the conventional concrete but its manufacturing or usage of this concrete requires minimum amount of heat energy and causes the minimal destruction or damage to the surrounding environment.

II. OBJECTIVES OF THE STUDY

It was important to note that the quantity of by-product or waste replacement played a vital role to the properties of concrete. From all the previous studies, following points have been concluded:
There is significant potential in waste materials to produce green concrete.

- To use GGBS as a replacement of cement in concrete.
- To use stone quarry dust as a replacement of fine aggregate in concrete.
- To use broken and demolished bricks as a replacement of coarse aggregate in concrete.
- To conduct experimental analysis for the strength of different grades of concrete.
- To compare the economic feasibility of conventional concrete and green concrete made with recyclable materials.
- To check the suitability of such materials in higher grade of concrete.
- To conduct durability tests on high-performance concrete.

III. METHODOLOGY

There were various studies been conducted on the use of such recyclable materials in concrete which gives adequate strength and its durability? The studies also suggests about the difficulties arise for the use of such by-products in the proportion of concrete. Here, a short description on materials used, mix design procedure adopted for control concrete and the procedure and various steps carried out for the manufacturing of concrete mix been discussed. Also the various tests conducted on fresh and hardened concreted have been discussed below.

A. *Materials Used:*

1) *Cement:*

Ordinary Portland Cement (OPC) of 53 grade is taken for this project, as per IS: 8112-1989. Test results of cement as per Indian Standard codes are shown in Table below.

MIX	CEMENT (IN %)	GGBS (IN %)
M1	100%	0
M2	75%	25%
M3	60%	40&

Table 3.1: Different sample of cement tested

Tests conducted	M1	M2	M3
Specific Gravity	3.16	3.25	3.2
Standard Consistency (%)	29%	28%	28%
Initial Setting Time (min)	40	45	50
Final Setting Time (min)	360	385	410
Compressive Strength (MPa)	54.28	55.36	56.39

Table 3.2: Test Results on Cement

2) *Sand*

The sand taken for this project was tested for water absorption, specific gravity, bulk density and particle size grading as per IS: 2386 (I & III). Sand in each test was taken after sampling it as per IS: 2430-1969. The results are given in Table 3.2. Particle size analysis of sand is shown in Fig below.

Sample No.	Bulk Density of Oven Dried Sand (gm/cc)	Average Bulk Density (gm/cc)	Bulk Density of Quarry Dust (gm/cc)	Average Bulk Density of quarry dust (gm/cc)
1	1.509	1.512	1.507	1.515
2	1.5044		1.516	
3	1.523		1.521	

Table 3.3: Bulk Density of Sand & Quarry Dust

S.No	Properties	Test Conducted as per IS 2386	Result for sand	Result of Quarry Dust
1	Water Absorption	Using Pycnometer	1.21%	1.55%
2	Specific Gravity		2.63	2.38
3	Apparent Specific Gravity		2.64	2.4
4	Bulk Density	Using Cylindrical Measure of Capacity 3 L, Inside Dia – 15 cm & Inside Height – 17 cm	1.512	1.836
5	Fineness Modulus	Sieve Analysis	2.14	1.82

Table 3.4- Physical Properties of Sand & Quarry Dust

B. *Coarse Aggregates:*

The available coarse aggregate is of two types on basis of source as natural and Recycled Coarse Aggregates. These two aggregates are tested to know various physical properties such as size, toughness, hardness etc. These aggregates were tested as per Indian Specifications to ensure the quality of the aggregate. The test performed are water absorption (as per IS: 2386 part III-1963), specific gravity (as per IS: 2386 part III-1963), bulk density (as per IS: 2386 part III-1963), impact test (as per IS: 2386 part IV-1963), crushing value (as per IS: 2386 part IV-1963) and Fineness Modulus (as per IS: 2386 part III-1963). The results of the above test are tabulated in Tables 3.6 below.

S. No	Properties	Natural Aggregates	Aggregates with Broken Bricks	Standards
1	Water Absorption (%)	0.27	3.05	<2% (MoRTH 2013)
2	Specific Gravity	2.75	2.66	2.6-2.8 (IS:2386 Part III)
3	Bulk Density (Loose) (kg/m^3)	1498	1487	(IS:2386 Part III)

4	Bulk Density (Compacted) (kg/m^3)	1711	1708	
5	Fineness Modulus	7.04	7.06	(IS:2386 Part III)
6	Impact Value (%)	17.3	36.78	<30% (IS:2386 Part IV)
7	Crushing Value (N/mm^2)	22.06	21.11	<30N/mm^2 (IS:2386 Part IV)

Table 3.6: Physical Properties of Coarse Aggregates

1) Water

Water used in concrete mix is potable water conforming to the specification of IS 456:2000. Water used for mixing is free from injurious amount of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete.

C. Concrete Mix Design

FOR M 30 GRADE CONCRETE

Cement	Water	FA	CA
400	180	712	1165
1	0.45	1.78	2.91

Table 3.7: Mix Proportions for M30 Grade Concrete

FOR M 25 GRADE CONCRETE

Cement	Water	FA	CA
375	180	730	1168
1	0.48	1.94	3.11

Table 3.8: Mix Proportions for M25 Grade Concrete

FOR M 20 GRADE CONCRETE

Cement	Water	FA	CA
350	180	747	1172
1	0.51	2.13	3.34

D. Preparation of Sample

The measurement of materials for making concrete is known as Batching. There are two types of batching: weigh batching and volume batching. For this study weigh batching is used. This method facilitates accuracy, flexibility and simplicity. For our work, we considered following batching of mixes:

Particulars	Cement	Fine Agg.	Coarse Agg.	GGBS	Quarry Dust	Broken Bricks
M1	100%	100 %	100 %	0%	0%	0%
M2	75%	75%	85%	25%	25%	15%
M3	60%	60%	75%	40%	40%	25%

IV. RESULTS

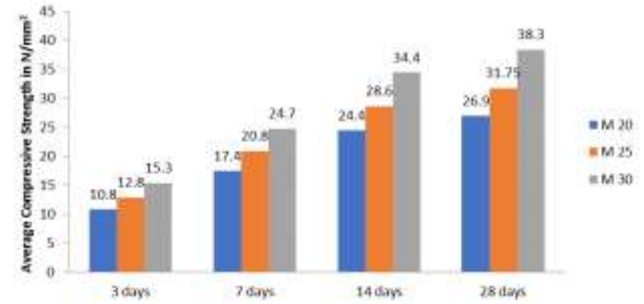
A. Workability Test

Workability is measured by the slump test in which the concrete mix is prepared and filled in to a cone of specific dimensions. The slump value is usually the standing height of concrete filled in slump cone

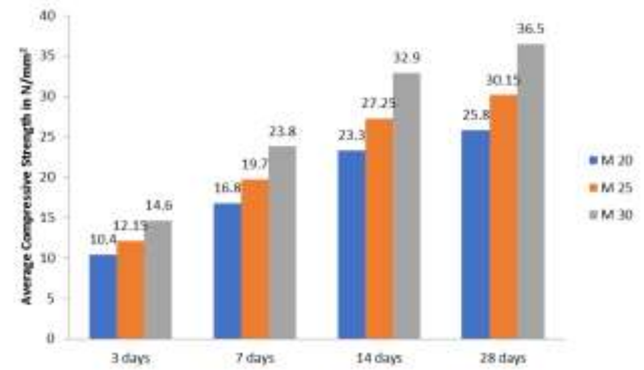
Grade of Concrete	Average Value of Slump in mm. for different types of mixes		
	M1	M2	M3
M 20	90	95	100
M 25	100	110	110
M 30	110	115	115

Compressive Strength Test Results - Compressive Strength of the cubes were tested by using CTM (Compressive Testing Machine) in which compressive load is applied on the specimen till the specimen fails in compression that load at which the specimen fails is termed as compressive strength. For this study, cubes of 150 mm nominal concrete cubes were casted.

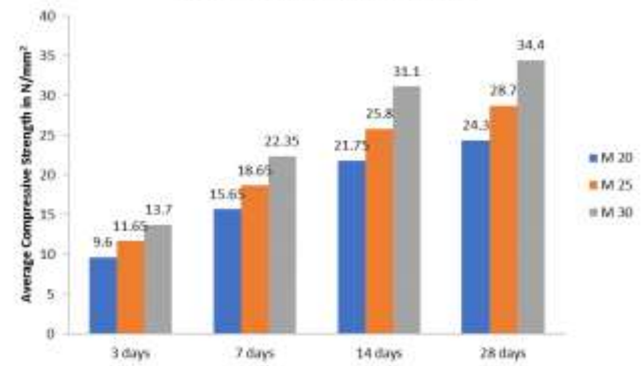
Graph 4.1: Compressive Strengths of Concrete having Mix Proportion M1

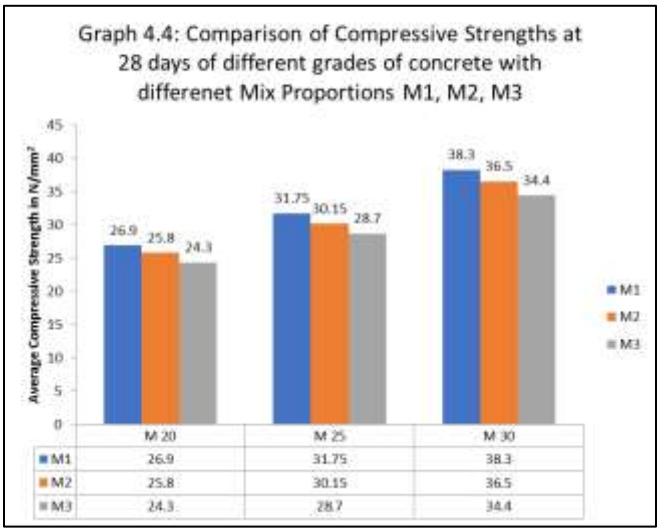


Graph 4.2: Compressive Strengths of Concrete having Mix Proportion M2



Graph 4.3: Compressive Strengths of Concrete having Mix Proportion M3

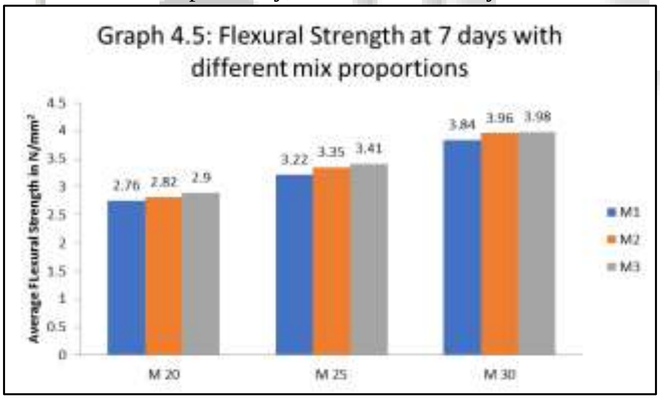




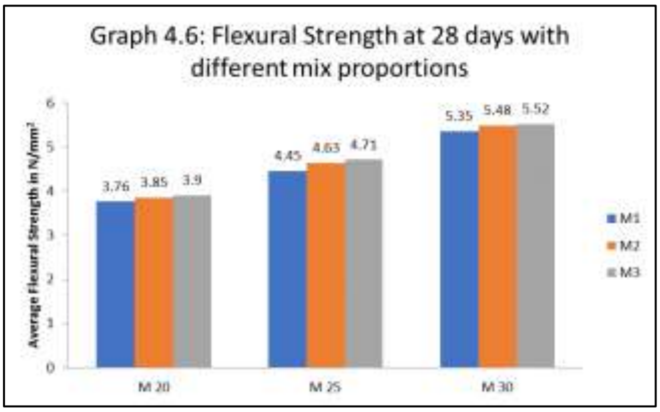
Graph 4.4: Comparison of Compressive Strengths at 28 days of different grades of concrete with differenet Mix Proportions M1, M2, M3

1) Flexural Strength Test Results

Beams of size 10cm*10cm*50cm are casted for determining flexural strength. Test on beams are performed at the age of 7 days & 28 days of the specimen. Placement of specimen in machine is done as per IS: 516-1959 in the clause no 8.3.1 page no 17. Load is applied at increasing rate of 108KN/min. Load is applied until specimen fails and load at which specimen fails is recorded. As specified in the IS code flexural strength is calculated and tabulated below. The average flexural strength of different concrete mixes is determined at the age of 7 & 28 days varies from 3 N/mm^2- 6 N/mm^2 respectively and is tabulated below. The reduction in flexural strength of green mix as compared to conventional mix is 3 -10% respectively, so it is satisfactory.



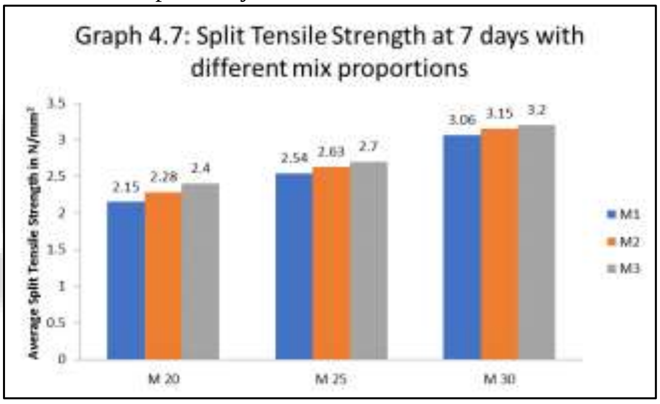
Graph 4.5: Flexural Strength at 7 days with different mix proportions



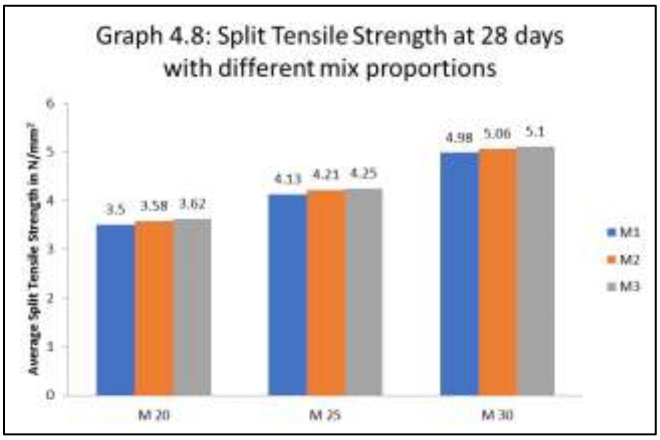
Graph 4.6: Flexural Strength at 28 days with different mix proportions

2) Split Tensile Strength Test Results

Cylinders of size 15 cm diameter and 30 cm height are casted for determining Split Tensile Strength. Test on cylinders are performed at the age of 7days & 28 days of the specimen. Placement of specimen in machine is done as per IS: 516-1959. Load is applied until specimen fails and load at which specimen fails is recorded. As specified in the IS code Split Tensile Strength is calculated and tabulated below. The average tensile strength of different concrete mixes is determined at the age of 7 & 28 days varies from 3 N/mm^2-4.5 N/mm^2 respectively and is tabulated below.



Graph 4.7: Split Tensile Strength at 7 days with different mix proportions



Graph 4.8: Split Tensile Strength at 28 days with different mix proportions

B. Cost Analysis Results –

COST COMPARISON OF M20 GRADE CONCRETE FOR 1 m^3 CONCRETE							
S. No.	Materials	M1		M2		M3	
		QTY (KG)	AMT (Rs.)	QTY (KG)	AMT (Rs.)	QTY (KG)	AMT (Rs.)
1	CEMENT	350	2415	262.5	1811	210	1449
2	GGBS			87.5	1094	140	1750
3	Fine Aggregates	747	995	560	745	448	596
4	Quarry Dust			187	198	299	317

5	Coarse Aggregates (NA)	1172	950	997	810	879	712
6	Broken Bricks	-	-	175	40	293	67
TOTAL			4360		4698		4891
% Cost Reduction			-		7.75%		12.17%

V. CONCLUSIONS

Based on the study, the following conclusions are drawn:

- Compressive strength of concrete in 28 days was found to be 2% to 5 % less than that of characteristic strength of concrete in 28 days for the given grade for the partial replacement of cement, sand & aggregates in the mix.
- Flexural strength and Split tensile strength for 28 days for the concrete whose constituents are partially replaced by GGBS, Quarry Dust & Broken Bricks found up to 1% to 3% higher than the conventional concrete which is satisfactory. Hence use of these mix proportions does not affect the functional requirements of the structure as per the findings of the test results.
- Physical properties of the broken bricks in combination with the natural aggregates show the suitability of these aggregates for construction and maintenance purposes. Various tests conducted on broken bricks as recycled aggregates and results compared with natural aggregates are satisfactory as per IS 2386.
- As a result of Cost Analysis, the cost of per m^3 of concrete partially replaced by GGBS, Quarry Dust & Broken Bricks found 7% to 25% more than conventional concrete for different grades.
- Due to use of such materials in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.
- The above test results are obtained without using any admixtures. And the design mix is based on the design mix ratio.

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