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Experimental study on the flexural strength of Ternary blended concrete beam with RHA and GGBS

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Abstract
Ternary blended concrete is a mixture of three different cementitious materials. To create a sustainable environment cement is replaced with Secondary Cementitious Materials. This paper deals with the usage of SCMs such as RHA and GGBS in the replacement of cement. The strength characteristics of ternary blended concrete beam with Ground Granualted Blast Furnace Slag (GGBS) and Rice Husk Ash (RHA) by replacing the ordinary Portland cement by 0%,10%,20%,30%. Flexural strength of concrete beam is done after 28 days of curing using loading frame.
OPC-RHA-GGBS ternary cement concrete could be used as lightweight concrete in civil engineering and building works. The observations were critically analyzed and the different attributes of the various mixes were correlated with the RHA content in the mix.

Keywords: RHA, GGBS, SCM

Introduction

Concrete is the most used construction material in Civil Engineering. It is needless to say that cement is the most important ingredients of concrete. However, cement is also a criticized material by the public, for its intensive CO2 emission from production process. The production of cement accounts for about 5-8% of the non-natural CO2 worldwide.

Researchers of cement studied a viable method for replacing cement by using Supplementary Cementitious Materials (SCMs). SCMs are commonly industry byproducts or raw materials, such as slag, limestone, fly ash, silica fume, natural pozzolan. Nowadays, whether binary blended or even ternary blended, SCMs can replace part of cement without sacrificing equivalent engineering properties is being investigated. The addition of SCMs in concrete has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials. Use of these byproducts facilitates sustainable development. High Performance Concrete (HPC) is the latest development in concrete. It has become more popular these days and is being used in many prestigious projects.

Concrete with SCM often displays slower hydration, accompanied by slower setting and lower early-age strength, especially under cold weather conditions. Most of the SCMs are industrial by-products. These materials are generally not used as cements by themselves, but when blended with OPC, they make a significant cementing contribution to the properties of hardened concrete through hydraulic and/or pozzolanic activity. SCMs are increasingly used in concrete because of the advantage that it reduces economic and environmental concerns by utilizing industrial wastes, reducing carbon dioxide emissions, and lowering energy requirements for OPC clinker production and also it helps to improve the concrete properties, such as workability, impermeability, ultimate strength, and durability, including enhanced resistance to alkali-silica reactions, corrosion of steel, salt scaling, delayed ettringite formation and sulphate attack.

To create a sustainable environment cement is replaced with two different materials. This forms a ternary mixture. Ternary concrete mixtures include three different cementitious materials. This report includes combinations of portland cement, slag cement, and a third cementitious material.

The ternary mixtures can be designed for: high strength, low permeability, corrosion resistance, sulphate resistance, ASR resistance and elimination of thermal cracking.

The optimum mixture proportions for ternary blends, as with other concrete, will be dependent on the final use of the concrete, construction requirements and seasonal considerations. As with other concrete, cold weather will affect the early strength gain and mixture proportions may need to be adjusted to assure job-site performance.

Ternary concretes is used mainly in

- General construction (residential, commercial, industrial)
- Paving
- High performance concrete
- Precast concrete
- Masonry and masonry units
- Mass concrete
- Shotcrete

Objective

The main objective of this paper is to study the flexural strength of ternary blended concrete beam with Ground Granualted Blast Furnace Slag (GGBS) and Rice Husk Ash (RHA) replacing the ordinary Portland cement by 0%, 10%, 20%, 30% of pozzolon blend containing 30% RHA and 70%GGBS using loading frame machine**.**

GGBS-Ground Granulated Blast Furnace Slag

It is obtained by quenching molten iron slag from a blast furnace in water or steam, and hence produces a glassy granular product that is then dried and ground into a fine powder.

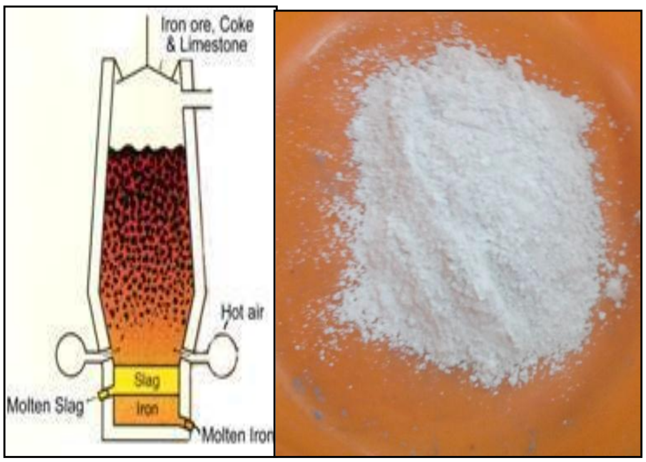

Fig 1: Process of quenching of iron slag and GGBS.

RHA-Rice Husk Ash

Rice milling produces a byproduct known as husk and about 22% of it is rice husk. It contains about 75% organic volatile matter and 25% of weight of husk is converted into ash during firing process. RHA contains around 85%-90% amorphous silica. RHA (25 microns) fills the interstices in between the cement in aggregate. Thus it can reduce the amount of cement in the concrete mix.

Table 1: Typical composition of GGBS (From XRF analysis)

MgO	5.575	%
Al2O3	17.044	%
SiO2	31.778	%
CaO	41.773	%
Fe2O3	0.709	%

Table 2: Typical composition of RHA (From XRF analysis)

MgO	0.216	%
Al2O3	0.166	%
SiO2	94.018	%
CaO	1.3	%
Fe2O3	0.411	%
MnO	0.159	%
P2O5	1.649	%

Density - 3.0 g/cm3

Specific Surface -5,000 cm2/g Activity - 87.0 %

It is mainly used as a mineral additive for concrete production and substitutes for cement. 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.

Slag cement can be used as the main additive. Quenching of iron and GGBS is shown in figure 1.

Fig 2: RHA –Rice Husk Ash (RHA contains 85%-90% amorphous silica).

Procedures

Methodology

1. First Step

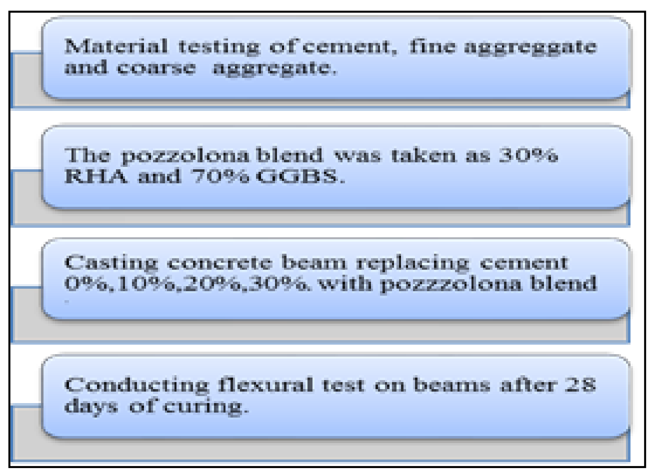

Fig 3: Methodology flow chart

Fine aggregate -Fine aggregate used is M-sand that is manufactured sand.

- Coarse aggregate-As per IS 2386(Part 1)1963. 20mm size of aggregate was taken.
- Admixture used Glenium Sky 8233 -Master Glenium SKY 8233 is an admixture of a new generation based on modified polycarboxylicether. Master Glenium SKY 8233 is free of chloride & low alkali. It is compatible with all types of cements.

Mix Proportion
Mix design was done according code IS 10262 for mix design for pozzolona.
Mix proportion of cement: pozzolona: fine: coarse For 30% replacement of cement 1 : 0.42 : 1.63 : 2.96
For 20% replacement of cement 1: 0.25: 1.43: 2.59.
For 10% replacement of cement 1: 0.11: 1.27: 2.306.

Specimens Cast
Before casting, workability tests were conducted by
RHA was collected from Shree Shree Goursundar
Rice and Oil mills, Bargarh, Orissa. GGBS was collected from Erode.
Material such as cement, sand and aggregates were collected from nearby industrial sources.

2. Second Step
Basic characteristics of cement such as consistency, intial setting time, final setting time, specific gravity were obtained by conducting test. Specific gravity tests were conducted for RHA and GGBS. Workability tests were conducted on fresh concrete. The proportion taken for replacing cement is 30RHA and 70 GGBS.

3. Third Step
The mix calculations were done for each replacement. Then the cubes and cylinders were cast. The cube specimen having size 150×150×150 were tested for 7th, 14th, 28^{th} day tests and cylinder been tested for 28th day for modulus of elasticity and split tensile test.

Constituent materials
a) OPC 43 grade - OPC 43 cement shall conform to IS: 8112-1989 and the designed strength of 28 days shall be minimum 43 MPa.
b) GGBS -An industrial waste produced from quenching. The use of GGBS in addition to Portland cement in concrete in Europe is covered in the concrete standard EN 206:2013.
c) RHA -Rice husk ash (RHA), a waste material made available from the rice industry.

Adding an admixture Glenium SKY 8233.The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. Then the beams were cast.

From workability test
- 10% replacement of cement -adding 0.6% of admixture.
- 20% replacement of cement- adding 0.75% of admixture.
- 30% replacement of cement –adding 0.9% of admixture

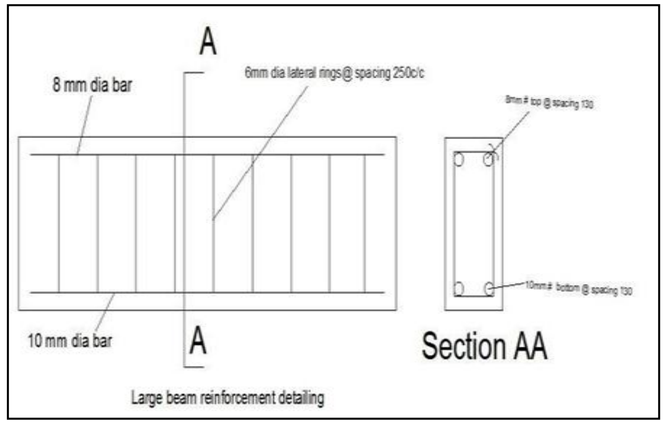

Fig 4: Large Beam detailing

Fig 5: Beam cast

Results of Experimental Investigations
The beams were tested after 28 days of curing. The flexural strength of large beams (1000×300×150) were tested in loading frame. Loading frame consists of a loading cell, LVDT, loading frame and a control panel.
For 30% replacement of cement the beam are named as P30. Similarlly for 20% replacement as P20 and for 10% replacement as P10.

Fig 6: Loading frame

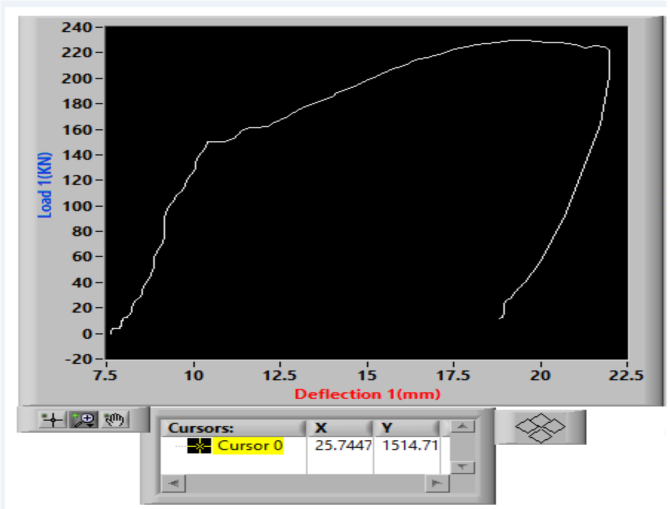

Fig 7: Deflection curve of P10

Table 3: Loading frame test results for P10

Time(Sec(s))	Deflection 1(mm)	Load 1(kN)	Deflection 2(mm)
74	17.27	220.4	-0.95
75	17.9	224.4	-0.56
76	18.75	228.3	0.01
77	19.56	230	0.4
78	20.57	228.3	1.64
79	21.55	225.1	2.51

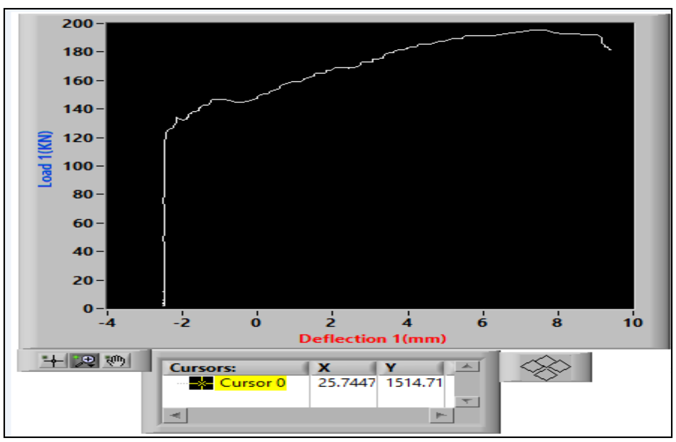

Fig 8: Deflection curve of P20

Table 4: Loading frame results for P20

Time(Sec(s))	Deflection 1(mm)	Load 1(kN)	Deflection 2(mm)
103	6.43	192.3	10.75
104	6.79	193.6	10.98
105	7.31	195.2	11.08
106	7.63	195.6	11.27
107	7.89	193.7	11.33

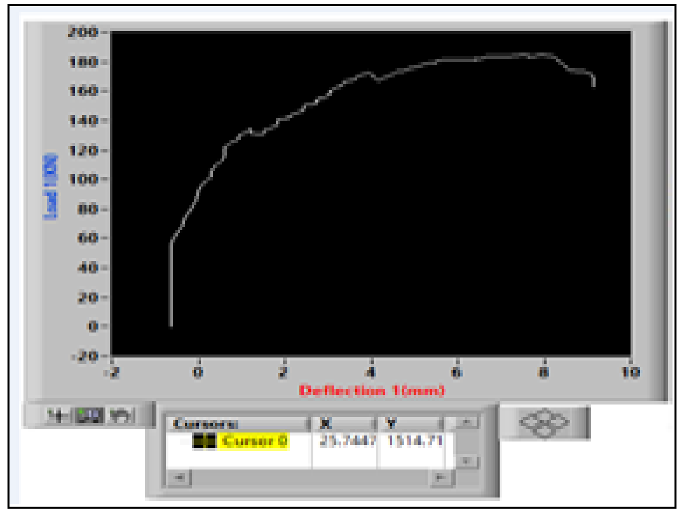

Fig 9: Deflection curve of P30

Table 5: Loading frame results of P30

Time(Sec(s))	Deflection 1(mm)	Load 1(kN)	Deflection 2(mm)
102	7.52	184.9	2.17
103	7.78	183.7	2.76
104	8.13	184.2	3.02
105	8.59	174.1	4.04
106	9.1	171.4	5.22

The optimum load carried is the 10% replacement of cement P10 shows maximum load carring capacity compared to other beams.

Table 6

Replacement of cement	Specimen Name	Ultimate Load(kN)	Flexural Strength(N/mm2)
0%	Conventional	191.6	14.60
10%	P10	230	17.03
20%	P20	195.6	14.44
30%	P30	184.9	13.60

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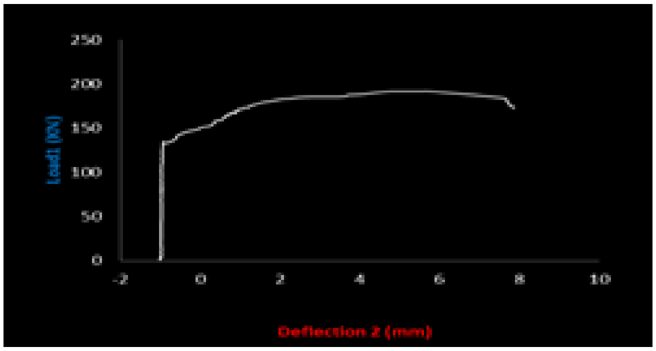

Fig 10: Deflection curve of conventional beam

Table 7: Loading frame values of conventional.

Time(Sec(s))	Deflection 1(mm)	Load 1(kN)	Deflection 2(mm)
224	-4.39	191.6	4.94
225	-4.38	191.6	5.21
226	-4.38	191.6	5.5
227	-4.37	191.6	5.78
228	-4.37	189.3	6.42

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