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Flexural strength investigation on ternary blended concrete beams

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Abstract

Ground granulated blast furnace slag (GGBS) is a pozzolanic material (termed by a few as a supplementary or complimentary cementitious material) which can be used as a cementitious ingredient in either cement or concrete composites. Slag is composed of calcium oxide (CaO), silica (SiO_2) and alumina (Al_2O_3). It is a by-product from steel mills.Along with GGBS, an agro-industrial waste product of sugar mills Bagasse Ash, which is a by-product obtained from burning of Bagasse for electricity generation. It has been recently been accepted as a pozzolanic material and can be used as a supplementary cementitious material in concrete. Although it is a pozzolanic material, much of this ash is still disposed in landfills everyday leading to environmental problems. A concrete mix of grade M_{30} was investigated by keeping water-binder ratio as 0.36. In this thesis work, mechanical properties of the ternary concrete are reviewed by replacing OPC of 43 grade by 0%, 10%, 20%, 30% of maximum pozzolanic action giving proportion of the blend containing GGBS and Bagasse ash(40% Bagasse ash and 60% GGBS). This paper presents an experimental study on flexural strength of concrete after 28 days of curing.

Keywords: GGBS, bagasse ash, agro-industrial waste pozzolanic properties

1. Introduction

Supplementary cementitious materials are often incorporated in the concrete mix to reduce cement contents, improve workability, increase strength and enhance durability. Concrete is by far the most widely used construction material because of its low cost, availability of raw materials, strength, durability and, most importantly, versatility. SCMs can be divided into two categories based on their type of reaction: hydraulic or pozzolanic. Hydraulic materials react directly with water to form cementitious compounds, while pozzolanic materials chemically react with calcium hydroxide (CH), a soluble reaction product, in the presence of moisture to form compounds possessing cementing properties. SCMs can be used either as an addition to the cement or as a replacement for a portion of the cement. Most often an SCM will be used to replace a portion of the cement content for economical or property-enhancement reasons.

Several types of blended cements with various combinations of fly ash–silica fume, fly ash–slag, or slag– silica fume, GGBS – Bagasse Ash were rapidly developed and nowadays are commonly used in several countries. These very fine-grained materials are added to the concrete mix to improve the properties of concrete (mineral admixtures), or as a replacement for Portland cement (blended cements). Products which incorporate limestone, fly ash, blast furnace slag, Bagasse Ash and other useful materials with pozzolanic properties into the mix, are being tested and used. This development is due to cement production being one of the largest producers (at about 5 to 10%) of global greenhouse gas emissions, as well as lowering costs, improving concrete properties, and recycling wastes.

Pozzolanic materials are siliceous or siliceous and aluminous materials, which in themselves possess little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature, to form compounds, possessing cementitious properties. Pozzolanic materials can be divided into two groups: natural pozzolans and artificial pozzolans.

Natural Pozzolans are Clay and shales, Opalinc cherts, Diatomaceous earth and Volcanic tuffs and pumicites.Artificial Pozzolans are Fly ash, Blast furnace slag, Silica fume, Rice husk ash, Bagasse Ash and Surkhi. Ground (GGBFS or GGBS) is a by-product of steel production is used to partially replace Portland cement (by up to 80% by mass). It has latent hydraulic properties. Metakaolin produces concrete with strength and durability similar to concrete made with silica fume. While silica fume is usually dark gray or black in color, high-reactivity metakaolin is usually bright white in color, making it the preferred choice for architectural concrete where appearance is important.

In the present investigation, cements containing ground granulated blast-furnace slag (GGBS) and Ordinary Portland Cement (OPC) were defined as blended cements or slag blended cements. The cement containing Bagasse Ash, slag, and OPC were defined as ternary cements. Binary cements are defined as cements consisting of only slag and OPC.

Supplementary cementitious materials are made from waste materials from industry. So waste management can be effectively done ie, accumulation of waste materials can be reduced. Blended cements are produced by intimately and uniformly inter-grinding or blending ordinary Portland cement (OPC) with one or more supplementary cementitious materials (SCMs). Most

SCMs, such as ground granulated blast-furnace slag (GGBS) or Bagasse Ash, 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 or pozzolanic activity.
However, experience also shows that concrete performance (such as workability, entrained air stability, and strength development) varies with the source and proportion of SCMs used. SCM concrete often displays slow hydration, accompanied by slow setting and low early-age strength. This effect is more pronounced as the proportion of SCMs in the blended cement is increased and when the concrete is cured at a low temperature. Therefore, more research is needed to have a better understanding of the effects of blended cement materials on concrete performance under different material, construction, and service conditions

2. Material Descriptions

2.1 Cement

The Ordinary Portland Cement [OPC] (43 grade according to IS8112:1989) used in the present work is of Dalmia brand. The term cement is commonly used to refer the powdered materials which develop strong adhesive qualities when combined with water.

2.2 Aggregate

Coarse aggregate of 20mm size is used whereas M-sand is used as fine aggregate.

2.3 Bagasse ash

Bagasse ash used in this project was sieved through 300 micron sieve and the ash passing through 300 micron sieve was rolled on abrasion testing machine with steel charges. Bagasse ash was sieved through 300 micron sieve to remove the unburned particles. The rolled Bagasse ash was then sieved through 90 micron sieve to make the fineness of Bagasse ash as same as cement. The Bagasse ash for the project was collected from Ponni sugar industry, Erode, Tamilnadu.

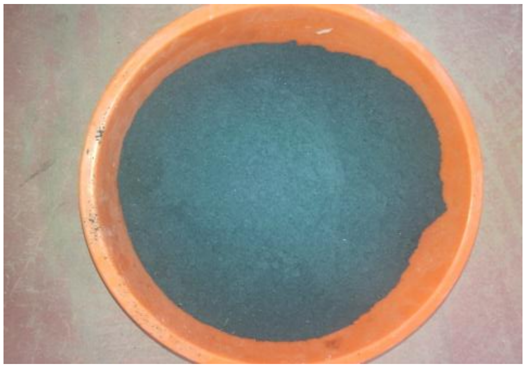

Fig 1: Bagasse ash

2.4 Ground Granulated Blast furnace Slag (GGBS)

Ground granulated blast furnace slag is obtained by quenching molten iron slag from a blast furnace in water or steam to produce a glassy granular product that is then dried and ground in to fine product. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and other pozzolanic materials.

Fig 2: GGBS

2.5 Superplasticizer

The use of superplastisizers permit the reduction of water to the extend upto 30 percent without reducing workability. These polymers are used as dispersants to avoid particle segregation and to improve the flow characteristics of suspensions. Their addition to concrete or mortar allows the reduction of water to cement ratio, not affecting the workability of mixtures and enables the production of self-consolidating concrete and high performance concrete. In this work we use the super plasticizer Master Glenium sky 8233, it is a high performance super plasticizer based on polycarboxylic ether for concrete.it is used in high performance concrete where highest durability and performance is required.it is free of chloride and low alkali.

Fig 3: Master Glenium sky 8233

2.6 Concrete mix proportion

Concrete mix proportion of M30 grade is shown in Table-1.

Table 1: Mix proportion

Water	Cement + pozzolana	Fine aggregate	Coarse aggregate
186	511.50	581.19	1054.40
0.3636	1	1.136	2.061

3. Detailing of Beam Specimen

The beams were designed as under-reinforced sections as per IS 456:2000 stipulations. Beams have the dimensions of overall length 1m. The cross sectional area of the beam is 150mm x 300mm. The clear cover provided was 30mm. Two 10mmΦ HYSD bars of Fe415 grade were provided at bottom as tension reinforcement and two 8mmΦ HYSD bars of Fe415 grade at top as stirrup holders. Two legged 6mmΦ stirrups at a spacing of 123mm c/c were provided as shear reinforcement. The details of the reinforcement provided are shown in Fig. 4.

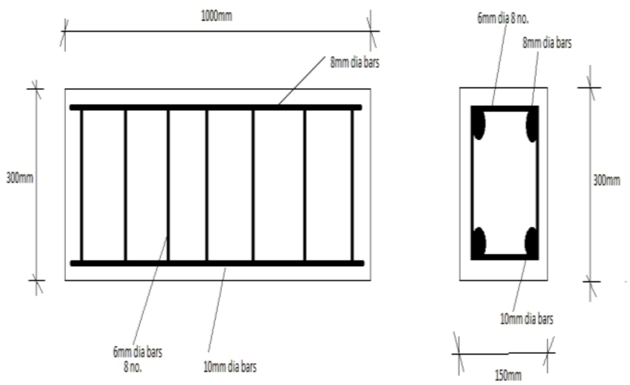

Fig 4: Beam Detailing (150mm x 300mm x 1000mm)

4. Preparation of Concrete Specimen

1. Measured quantity of cement, M-sand, GGBS, Bagasse ash, coarse aggregate and water with respect to the mix proportion were taken.
2. Cement, natural sand and pozzolonic material are mixed thoroughly in a mixing tray, until a uniform colour is obtained.
3. Coarse aggregate were added in to this uniform mixture and continue the mixing. A required amount of water is added to this to obtain the required concrete mix.
4. The concrete mix is filled in to the mould in three different layers. Proper reinforcements were provided.
5. Each layer is tamped 25 times to expel the entrapped air.
6. Remoulded the specimen after a period of 24 hours.
7. Cured the specimen for 28 days.
8. Control mix was prepared.
9. Different mixes with 10%, 20% and 30% of replacement of cement by pozzolanic material (40% Bagasse ash and 60% GGBS) were cast.
10. Beam specimens of each mix were cast.

Fig 5: Beam Specimens

5. Flexural Strength Test on Loading Frame

Reinforced concrete beams with replacement of cement (10%, 20%, 30%) were cast and tested. The span of the beam was 1000 mm and of size 150 mm x 300 mm. All the specimens were tested at 28th day from the date of casting. Reinforcement details of the specimens tested are given in Fig.4. Different designation is given to the specimens (T10, T20, T30) represents different percentage (10%, 20%, 30% respectively) replacement of cement. The testing was carried out in a loading frame of 100T capacity. All the specimens were white washed. LVDTs were used for measuring deflections. LVDTs were connected to a data logger from which the readings were captured by a computer at every load interval until failure of the beam occurred. The beams were subjected to three-point loads under a load control mode. Fig 6 shows the arrangement of LVDT in the experimental setup.

Fig 6: Testing of beam specimens

Flexural strength of concrete beam was studied by three point loading test conducted in loading frame and result obtained. Result shows that 30 % replacement of cement have high flexural strength. Here we can see that ultimate load of T10 and T20 are 181.4kN and 182.9kN respectively whereas ultimate load of T30 is 199.9kN.

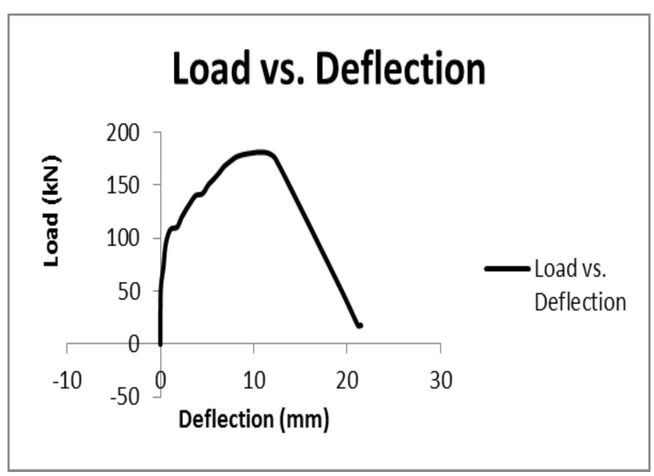

Fig 7: Load Vs. deflection graph of T10 beam

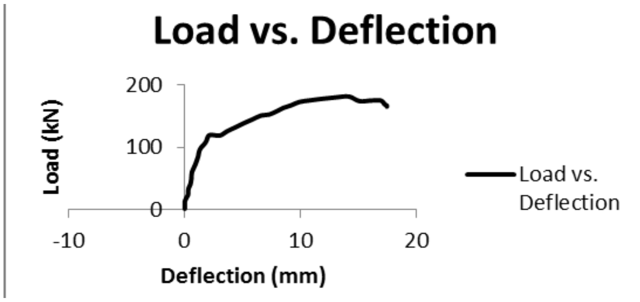

Fig 8: Load Vs. deflection graph of T20 beam

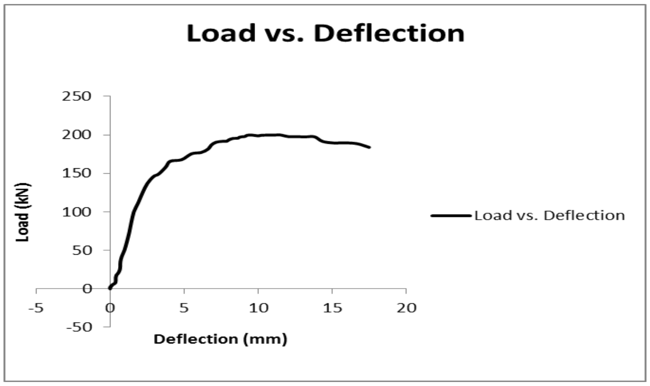

Fig 9: Load Vs. deflection graph of T30 beam

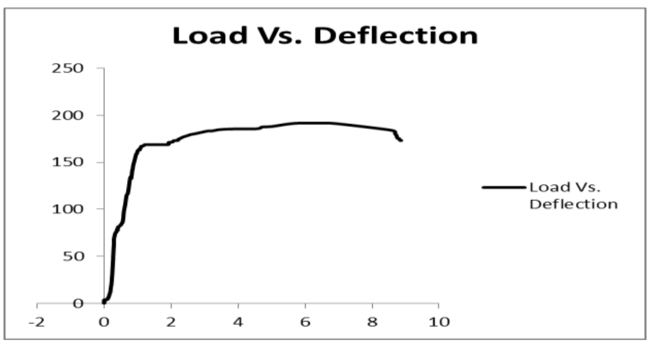

Fig 10: Load Vs. deflection graph of conventional beam

Table 2: Comparison of modulus of rupture of beams

Specimen	Glenium sky dosage (% mass of binder)	Ultimate load (kN)	Modulus of rupture (N/mm^2)
T30	**0.6%**	**199.9**	**13.32**
T20	0.7%	182.9	12.19
T10	0.5%	181.4	12.09
CONV	0.3%	191.6	12.77

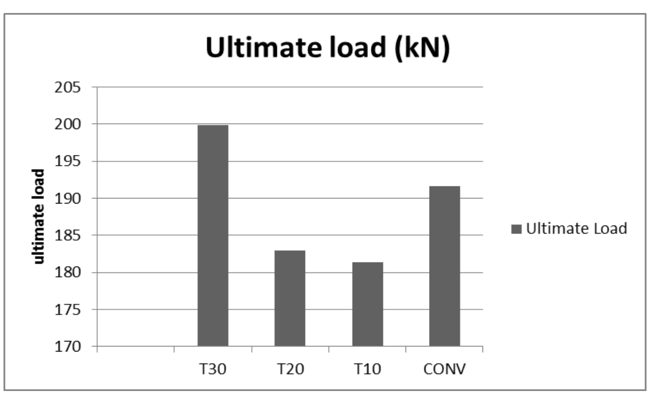

Fig 11: Chart showing ultimate load on beams

6. Conclusions

The following conclusions were drawn from this experimental study:

- 30% replacement (T30) shows high flexural strength than control mix.
- 20% as well as 10% replaced samples show 95.15% and 89.63% respectively of the flexural strength of 30% replacement.

Hence we can concluded that 30% cement replaced beam specimen by higher pozzolanic activity blend (60% GGBS and 40% Bagasse ash) shows higher flexural property compared to conventional concrete beams.

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