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An Experimental Study On The Strength Of Concrete Using GGBS and Pond Ash

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ABSTRACT

Concrete is the most widely used construction material in India with annual consumption exceeding 100 million cubic metres. Production of one ton of Portland cement emits one ton of Carbon-di-oxide and other greenhouse gases leading to atmospheric pollution. Hence the need arises to replace cement with some other cementitious materials which are eco-friendly.

Moreover the present method of disposal of ash generated in thermal power plants is not environmentally safe.The bottom ash and fly ash are mixed with water and the slurry thus formed is pumped into dykes. This method of disposal leads to ground water contamination, smaking adjacent lands infertile and causing air pollution. Hence there is urgent need to find a suitable and constructive way of disposal of the pond ash stored in these dykes.

The purpose of this study is to find the extent of GGBS as a replacement material for cement and pond ash as a replacement material for fine aggregate in concrete without compromising the strength and durability of conventional concrete. The physical and chemical properties of GGBS and pond ash have been studied and it has been found that both the industrial wastes can replace the cement upto 50% and 30% respectively in concrete from literatures.

Concrete mix design for M35 grade has been carried out with conventional ingredients. Sixteen concrete mixes were cast by partially replacing cement by GGBS and river sand by pond ash in stages of 10%. Sufficient number of concrete cubes, cylindrical and prism specimens were cast to find the optimum values for GGBS and pond ash content.

The specimens were tested for mechanical properties such as compressive strength, split tensile strength and flexural strength on 7, 14, 21 and 28 days. After determining the properties of the concrete mixes, the optimum percentage replacement levels for GGBS and pond ash has been found and reinforced concrete beams were cast to study the flexural behaviour of the optimized concrete mix.

I. INTRODUCTION

Concrete is considered to be very durable material that requires little or no maintenance. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure viz., buildings, industrial structures, bridges and highways etc., leading to utilization of large quantity of cement and fine aggregate. Portland cement, already being a very expensive material constitutes a substantial part of the total construction cost of any project and the situation has further been aggravated by the energy crisis, which has further increased the cost of production of Portland cement. Therefore, it is of current important for a country to explore and develop alternate cementing materials cheaper than the Portland cement.

Cement is the most important constituent of the concrete and occupies about 20% of the volume of concrete. The demand for concrete is an ever increasing scale, leading to higher cement production. But the production of cement releases equal amount of CO_2 in to the atmosphere leading to global warming.

One of the major emitter of CO_2 into the atmosphere is cement industry. Already carbon credits are being traded between countries and industries. Global efforts are also there to reduce the emission of gases responsible for global warming due to green house effect. Cement consumption worldwide has triggered mushrooming of cement industries and corresponding emissions of CO_2. As cement consumption cannot be reduced, efforts were on to find an alternate cementitious material. For instance, research steps have been taken to use mineral admixtures such as Ground Granulated Blast Furnace Slag (GGBS), Fly ash and Silica fume in concrete as a partial replacement for cement because they improve durability, reduce porosity and improve the interface with the aggregate.

An important process in the concrete mixing is the formation of C-S-H gel which is primarily due to the addition of cement. The hydration of the Portland cement results from the production of portlandite crystal [$Ca(0H)_2$] and amorphous calcium silicate hydrate gel [$C_3S_2H_3$] (C-S-H) in large amounts. The hydrated cement paste contains approximately 70% C-S-H, 20% Ca $(0H)_2$; 7% sulpho-aluminates and 3% secondary phases.

The $Ca(0H)_2$ which appears due to the chemical reactions affect the quality of concrete adversely by forming cavities, as it is partly soluble in water and also lacks enough strength. The Ground Granulated Blast-Furnace Slag when used along with cement has positive effect on the $Ca(0H)_2$ compound. At the end of the secondary reaction between GGBS and $Ca(0H)_2$, hydration product such as C-S-H gel is formed.

II. REVIEW OF LITERATURE

EXPERIMENTAL INVESTIGATION ON STRENGTH OF HIGH PERFORMANCE CONCRETE WITH GGBS AND CRUSHER SAND

Mahesh Patel, Prof. P. S. Rao, T. N. Patel (2013), In this study,. It is found that by the partial replacement of cement with GGBS and sand with Crusher sand helped in improving the strength of the concrete substantially compared to normal mix concrete.

A STUDY ON CONCRETE PROPERTIES BY PARTIAL REPLACEMENT OF SAND BY POND ASH

Tushar G. More, Pankaj B. Autade (2015), This study shows the basic properties of Pond ash. It also compares these properties with natural sand. It is necessary to find the exact suitable percentages of pond ash so that it is decided to use in varying percentage as 0%, 5% 10%, 15%, 20%, 25%, 30%. And to check the properties of fresh concrete and hardened concrete such as slump and compressive strength, tensile strength, flexural strength respectively.

ASSESSMENT OF NATURAL SAND AND POND ASH IN INDIAN CONTEXT

Gaurav Kantilal Patel, Prof. JayeshkumarPitrodas (2013), This research paper reports the basic properties of Pond ash.. Pond ash are needed from the view of point of experimental preservation and effective utilization of resources. However, information about pond ash using in concrete as fine aggregate with partial replace with pond ash is still insufficient so it will be an advisable to get more details about the characteristics of concrete using pond ash.

STRENGTH AND DURABILITY STUDIES ON GGBS CONCRETE

Santosh Kumar Karri, G.V.Rama Rao, P.MarkandeyaRaju (2015), This investigation is aimed to study on high performance concrete with GGBS and robo sand nd concluded that the percentage increase of compressive strength of concrete is 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.environmental sustainability is at stake both in terms of damage caused by the extraction of raw material and CO2 emission during cement manufacture. This brought pressures on researchers for the reduction of cement consumption by partial replacement of cement by supplementary materials. This needs to examine the admixtures performance when blended with concrete so as to ensure a reduced life cycle cost. The present paper focuses on investigating characteristics of M20 and M40 grade concrete with partial replacement of cement with ground granulated blast furnace slag (GGBS) by replacing cement via 30%, 40%, 50%. The cubes, cylinders and prisms are tested for compressive strength, split tensile strength, flexural strength. Durability studies with sulphuric acid and hydrochloric acid were also conducted.

III. MATERIALS USED IN CONCRETE

GENERAL

Pond ash contributes to two major environmental problems namely generation of respirable particulate matter (a major air pollutant) and pollution of soil and water due to leaching of heavy metals. The major obstacle in use of pond ash in a concrete is that the chemical properties of pond ash are different from place to place and it depends upon the origin of the coal and also the porosity is high.

MATERIALS USED

The following materials are used in the experimental investigations reported in this thesis.

- Cement
- Pond Ash
- Ground Granulated Blast Furnace Slag
- River Sand
- Coarse Aggregate
- Super Plasticizer
- Water

CEMENT

Ordinary Portland Cement of 53 grade confirming IS 12269 was used in the experimental work and its properties as listed in Table 3.1 .The brand of cement used is Bharathi cements purchased from a Salem city cement retail shop.

The physical properties of the cement used in this work were tested prior to use as per laid down IS specifications.

POND ASH

Pond Ash, a waste product from thermal power plants, is one such material that can be used as a replacement material for fine aggregate in concrete replacing river sand partially or fully. Encouraging the usage of such a waste material as constituent in concrete will address the issues related to its disposal, environmental and ecological problems. It is one of the social responsibility of researchers, contributing to the 3Rs - Reduce Reuse and Recycle there by promoting sustainable construction. It is commonly thought that as inert filler, fine aggregate has very little effect on the finished concrete properties. However fine aggregate (natural sand or alternative material) and its characteristics plays a substantial role in influencing the workability, strength, and durability of the concrete. Thus, detailed characterization of pond ash and its influence on the strength and durability is essential to boost the confidence of engineers in using such concretes.

In the present investigation work, the pond ash used is obtained from **Mettur Thermal Power Station (MTPS), Mettur Dam, Salem**. The wet pond ash has been made available at free of cost to this experimental work by MTPS authorities. The river sand has been quite costly due to its depleting sources of availability. When compared to the cost of river sand, the cost of wet pond ash will be very low even if MTPS charges some price for the same.

IV. Chemical Composition of Pond Ash

Sieve Analysis of the Pond Ash Sample

GROUND GRANULATED BLAST FURNACE SLAG

The blast furnace slag is a by-product of the steel industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500^{o}C to 1600^{o}C. The molten slag has a composition of about 30% to 40% SiO_2 and about 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residues (Higgins, 2007) is then water-quenched rapidly, resulting in the formation of glassy granulates. This glassy granulate is dried and ground to the required size (Hooton, 2000), known as ground granulated blast furnace slag (GGBS).

The production of GGBS requires little additional energy as compared with the energy needed for the production of Portland cement. The replacement of Portland cement with GGBS will lead to significant reduction in carbon dioxide gas emission. GGBS is therefore an environmentally friendly construction material. It can be used to replace as much as 70% of the Portland cement used in concrete. GGBS concrete has better water impermeability and soundness characteristics as well as improved resistance to corrosion and sulphate attack. As a result, the service life of structures can be enhanced with reduction in the maintenance cost. In view of the potential advantages of using GGBS, the Standing Committee on Concrete Technology endorsed in 2008, the proposal by the Public Works Central Laboratory to conduct a research study to investigate the strength development and durability of GGBS concrete.

Production of GGBS

The GGBS used in this study was brought from Nandhi cements, Bangalore. The physical properties of GGBS used were found as per standard procedure and the findings are tabulated in Table 3.5

COARSE AGGREGATE

Coarse aggregate is an important constituent in concrete. It gives body to the concrete, reduce shrinkage and effect economy. One of the most important factors that influence the workability of concrete is gradation of aggregates. Well graded aggregates are the aggregate samples that contains fractions of aggregates in required proportion such that it can be densified with minimum voids. Concrete cast with well graded aggregates containing minimum voids requires minimum cement paste to fill up the voids among the aggregates. Minimum cement paste will result in less quantity of binding material and water which will further increase economy, higher strength, reduce shrinkage and greater durability.

In the present investigation, crushed hard blue granite coarse aggregate used was obtained from the local approved quarry. Sieve Analysis has been carried out over the samples of coarse aggregate and the grading of coarse aggregate used in this study are given in Table 3.6 to 3.8

In the experimental work the coarse aggregates of nominal size 20mm and 12.5mm are blended in the ratio of 60% and 40% respectively and used so that the aggregates are well graded to give required workability, minimum paste content and maximum strength.

FINE AGGREGATE (RIVER SAND)

In the present investigation, normal river sand quarried from Cauvery river near Musiri town was used as a fine aggregate. The fine aggregate was screened to remove deleterious materials and tested as per procedure given in IS 2386 - 1963. The results of sieve analysis on fine aggregates are given in Table 3.9. The fineness modulus of sand is 2.69 and confirms to Zone II grading.

WATER

The water used for concrete making and curing was tap water available in the laboratory and free from all types of harmful chemicals, organic material, oil, chloride, silt and suspended materials confirming IS 456-2000. No test on the quality of water has been carried out as the water available in the laboratory is of drinking water quality.

SUPER PLASTICIZER

A sulphonated naphthalene formaldehyde based super plasticizer commercially available under the brand name conplast SP430 has been used to get the required workability in fresh concrete in this experimental investigation.

Due to addition of pond ash in concrete, the workability of the concrete reduces. In order to maintain the required degree of workability, conplast SP 430 has been used. The dosage of conplast SP430 has been kept in the range of 0.5 to 1.0% of the weight of cement used in the mix. Totally 5 trail mixes were casted keeping the w/c ratio constant. The mix proportions of M_{35} concrete are 1:1.41:2.98.The mix which attains the strength of M_{35} grade concrete in 28 days is chosen as the conventional mix for the study.

V. EXPERIMENTAL WORK

EXPERIMENTAL INVESTIGATION

Experimental investigation on the concrete mixes incorporating GGBS and pond ash has been carried out. The following tests were conducted on Pond ash – GGBS based concrete to ascertain the strength and durability properties, so that the same can be compared with that of control concrete.

1. Workability

i. Slump Test

2. Mechanical Properties

i. Compressive strength test

ii. Split tensile test

iii. Flexural strength test

3.Flexural Properties

i. Flexural Strength

ii. Flexural Behaviour

VI. RESULTS AND DISCUSSION

SLUMP TEST

The slump cone test was used to find the workability of fresh concrete mixes. Slump value is high for the initial mixes but when the replacement percentage of sand by pond ash increases, the slump decreases. The degree of workability exhibited by all the test mixes is given in Table 6.1 below.

Table 6.1: Slump Values of the Test Mixes

The workability test conducted clearly indicate that the presence of GGBS in concrete doesnot affect the workability adversely when compared with that of control concrete. On the contrary, the addition of pond ash drastically reduces the workability of concrete. Even in such conditions, increased percentage of GGBS in concrete enhance the workability as shown in Fig.6.1.

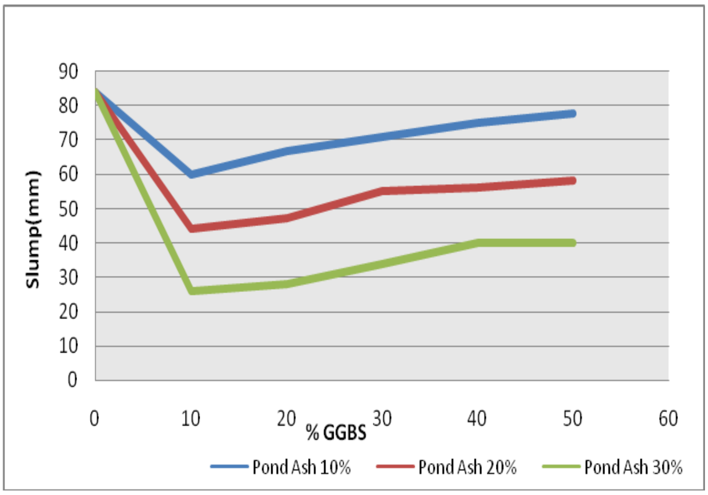
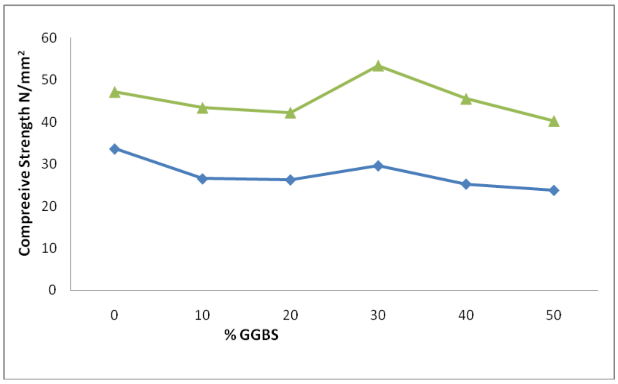


Fig.6.1: Slump Values of the Test Mixes

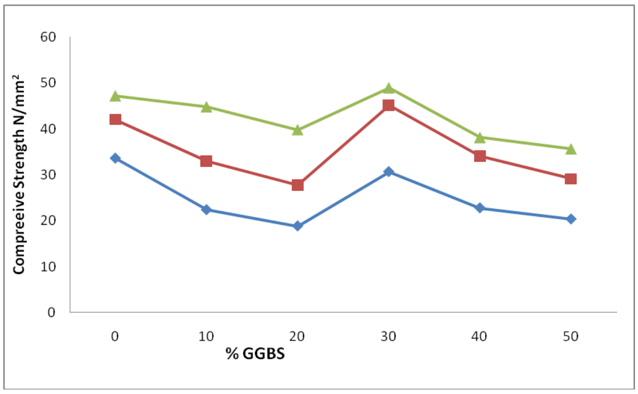
COMPRESSIVE STRNGTH OF CONCRETE

The compressive strength of the hardened concrete specimens were found by casting 150 mm cubes as per standard procedure. After 24 hours, concrete from the moulds were removed and put into water for immersion curing. These specimens were tested in compression testing machine on 7, 28, 56 and 90 days strength.

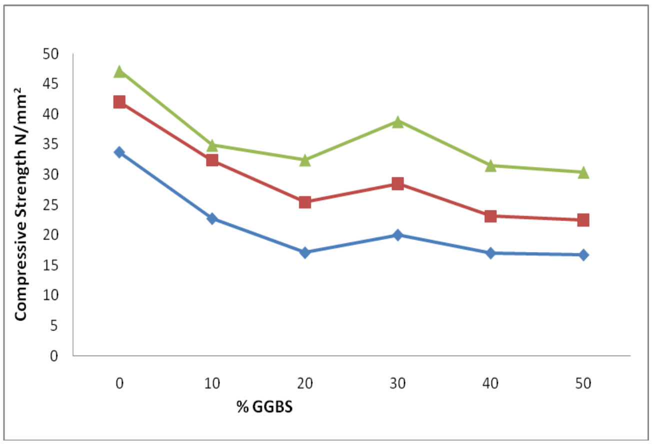
The mix M-8 containing 30% GGBS and 20% pond ash attained target compressive strength with maximum percentage of replacement. The compressive strength test conducted clearly indicate that replacement of GGBS beyond 30% reduces the strength than the control concrete. Also, when the pond ash content goes beyond 20%, there is reduction in the compressive strength of the concrete mixes. The results of the compressive strength of all the test mixes are shown in Table.6.2.



Compressive Strength of Concrete with 10% Pond Ash



Compressive Strength of Concrete with 20% Pond Ash

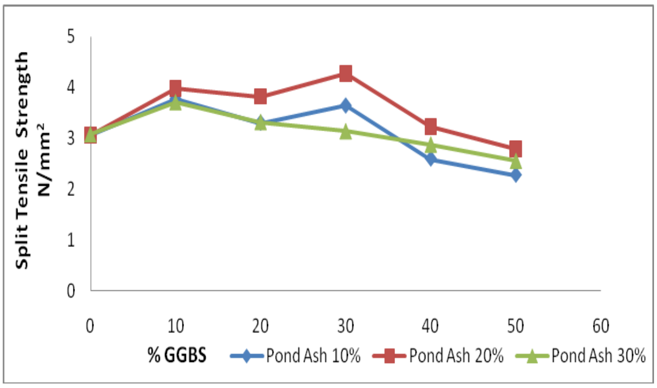


Compressive Strength of Concrete with 30% Pond Ash

SPLIT TENSILE STRENGTH

Cylindrical test specimens of size 150 mm diameter and 300 mm height were cast and after 28 days of water curing, tension in the concrete was measured indirectly by conducting split tensile strength as per standard procedure.

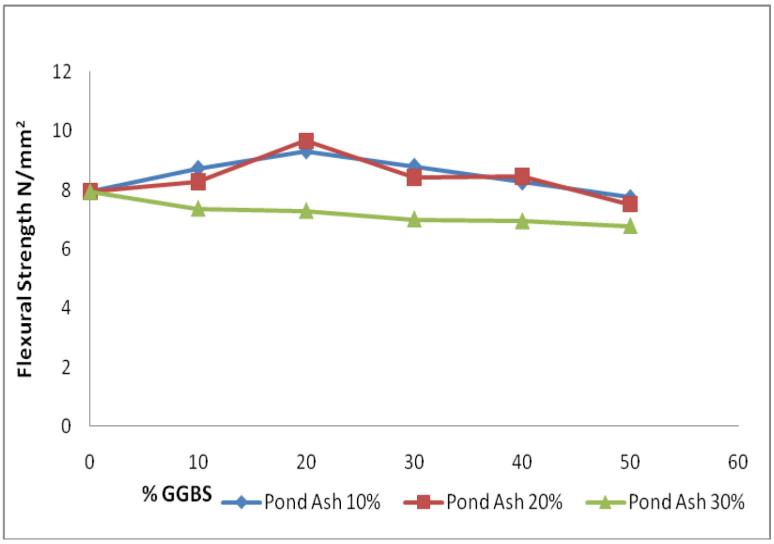
The maximum split tensile strength is exhibited by Mix No-8 in which cement is replaced 30% by GGBS and fine aggregate is replaced 20% by pond ash. When GGBS content goes beyond 40%, the split tensile strength get reduced irrespective of pond ash content. The above also indicates that the presence of pond ash has very insignificant influence on the split tensile strength. The results of the split tensile strength of all the test mixes are shown in Table.6.3.



Split Tensile Strength of Concrete

FLEXURAL STRENGTH

Beam Specimens of size 100 x 100 mm x 500 mm were cast and after 28 days of water curing, the flexural strength was determined. Beam specimens were tested under two point loading and the specimen is loaded until the ultimate load is reached. The testing is done as per standard procedure and the failure pattern obtained for the beam specimens are shown in .



Flexural Strength of Concrete

BEHAVIOUR OF RC BEAMS

Reinforced Concrete Beams (2000x125x250 mm) were cast with optimum percentage of GGBS and pond ash and tested at 28th day from the date of casting. The specimens are white washed before testing to facilitate marking of crack patterns. Deflectometer is used to measure the deflections at mid-span, L/3 distance and at the overhanging end. The beam specimens are subjected to two point loading. Flexural cracks were marked on the beam at every load interval.

Flexural Behaviour of RC Beams

Parameters from the flexural behaviour Of RC beam:

First Crack Load = 74.97 kN

Failure Load = 92.82 kN

Theoritical Bending Stress at first crack (f_{ct}) = 4.14 N/mm^2

Actual Bending Stress at first crack (f_{ca}) = 16.31 N/mm^2

Ultimate Bending Stress = 21.75 N/mm^2

Theoritical Moment of Resistance = 8.09 kN.m

Actual Moment of Resistance = 21.24 kN.m

The load deflection curve for the optimised RC beam is shown in Figure, It is clear that the curve is linear up to the formation of first crack in the beam which reduces the moment carrying capacity of the beam. The beam attains the ultimate load after which the permananent failure occurs in the beam.

Load vs Deflection Curve of RC Beam

VII. SUMMARY OF RESULTS

1. Concrete Mix-5 containing 50% GGBS & 10% pond ash yielded maximum slump value. When GGBS is replaced upto 50% for cement, the workability of concrete increases and while increasing pond ash content from 10% up to 30%, slump value decreases due to low plasticizing property of pond ash. Due to increase of pond ash content, the slump values of concrete decreases above 20%
2. Concrete Mix-8 containing 30% GGBS & 20% pond ash shows maximum value of compressive strength. It is clear that when GGBS content goes beyond 40% and pond ash content beyond 20%, the compressive strength get reduced compared to that of control mix.
3. The maximum split tensile strength is exhibited by Mix No-8 in which cement is replaced 30% by GGBS and fine aggregate is replaced 20% by pond ash. When GGBS content goes beyond 40%, the split tensile strength get reduced irrespective of pond ash content. The above also indicates that the presence of pond ash has very insignificant influence on the split tensile strength.
4. The maximum flexural strength is exhibited by Mix No-7 in which cement is replaced 20% by GGBS and fine aggregate is replaced 20% by pond ash. When the GGBS content reaches 50%, the flexural strength get reduced compared to that of control mix. Likewise when pond ash content reaches 30% the flexural strength reduction of mixes takes place irrespective of GGBS content.
5. The optimum percentage of replacement level of GGBS for cement is 30% and pond ash for fine aggregate is 20% without compromising the workability and mechanical properties of concrete.
6. The Ultimate load carrying capacity of the GGBS-PA RC beam is 100 kN. It is noticed that the first crack always appears close to the mid span of the beam. The load carrying capacity of the beam will increase with increase of curing period due to low heat of hydration of GGBS.

CONCLUSION

The following conclusions are drawn from the limited experimental study

1. Concrete mix with high proportions of pond ash as fine aggregate show very harsh mixing characteristics, demanding more water for the mix to satisfy workability criteria. Use of superplasticizer is essential to maintain the desired degree of workability
2. Addition of pond ash drastically reduces the workability of concrete mixes due to coarse nature of pond ash and high carbon content, whereas the addition of increased percentage of GGBS improves the workability of pond ash mixed concrete due to fineness of GGBS particles.
3. There is a reduction of compressive strength of concrete mixes at 28 days of curing for all the mixes due to low heat of hydration of GGBS and pond ash. At 90 days, the compressive strength of the mixes with GGBS upto 30% and pond ash upto 10% showed compressive strength more than control concrete. All other mixes failed to recover initial loss in early gain in strength.
4. The split tensile strength of concrete is not affected by pond ash. But when GGBS content goes beyond 30% the same is adversely affected.
5. The flexural strength of the concrete has been affected when GGBS content is more than 50% and pond ash content more than 30%.
6. Reinforced Concrete beams with optimized mix containing 30% GGBS and 20% pond ash exhibited good flexural behaviour. The load deflection curve is linear upto the first crack load after which the beam attains ultimate load and then the final failure occurs. The behaviour of RC beams with optimized mix can be improved by increasing the curing period

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