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FLEXURAL BEHAVIOR OF HIGH STRENGTH CONCRETE USING MINERAL ADMIXTURES

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Abstract:

This paper reports the use of alternative substitute material for cement in order to reduce the environmental hazards like greenhouse effect global warming etc., to minimize the CO2 emission into the atmosphere and also to use the byproduct materials such as fly ash (FA) and ground granulated blast furnace slag (GGBS) has been used as substitute material in the concrete industry. This paper is to study the flexural strength Characteristics of GGBS and metakaolin (MK) usedin high strength concrete along with replacement of fine aggregate with bottom ash. The results clearly indicate that replacement of Cement with GGBFS (20%) with bottom ash (60%) and MK (20%) with bottom ash (45%) gives the optimum strength with permissible deflection when compared with the conventional concrete.

Key words: fly ash, ground granulated blast furnace slag, metakaolin.

Introduction:

The Usage of Concrete is one of the major ingredients in the construction world. Cement industries are the principal producer of the greenhouse gases into the atmosphere. In this aspect utilization of by product and waste materials such as fly ash, ground granulated blast furnace slag, metakaolin, silica fume as a supplementary cementitious material along with cement to lift the mechanical properties of concrete. This can be used as an optimum approach to construction practices, also the productive usage of these waste materials also been considered as a safe method of disposal with the reduction in the initial cost. By this approach there is a considerable reduction in the carbon footprint into the atmosphere there by reduces the usage of OPCCs which are constantly observe to be less durable in some of the very severe environmental and climatic conditions Therefore it is necessary to developan alternative concrete materials to carry the extensive research done by the research investigators for the potential of supplementary materials as a prospective construction material. The advancement of alternative concretes is of great importance to India, where theconstruction industry is in a boom and large quantities of industrial wastes are beinggenerated by the allied industries.

Literature Review:

The flexural strength of GGBS along with steel fiber was increased about 40% of ultimate load when compared with the control beam. The failure of the beam is purely due to flexure. Partial replacement of cement with GGBS reduces the environmental pollution (1). The characteristic strength of concrete has increased upto 40% replacement of GGBS (2). The good strength in flexural behavior clearly shows that 50% replacement of GGBS leads to lesser the crack formation and ultimate load carrying capacity was found to be high (3). The M40 grade of Flexural beam of GGBS along with glass fiber gives high flexural strength when compared with conventional concrete and also it shows high load carrying capacity as the first crack load also increases when compared with conventional concrete of same grade (4). The characteristic strength of concrete has increased for M40 grade of concrete with 40% slag sand and 40% GGBS replacement of mineral admixture. All the beams are designed as under reinforced section. The beams fail by flexure only. The flexural crack has been propagated from tension zone to compression zone with crushing of concrete at the surface. It was observed that no horizontal cracks at the level of reinforcement. The flexural result shows that cracking moment has increased up to 23.38% for 0.72% reinforcement and 34.90% for 1.03% reinforcement. The crack width was observed as 0.2081 mm and 0.176 mm. these widths are within the permissible limits (5). The flexural behavior of high performance rectangular beams with 10% metakaolin and 10% silicafume and fine aggregate by 20% bottom ash gives 60

% increase in load carrying capacity of beams when compared with control beam (6).An experimental investigation has been carried out on 7-RC beam to investigate the behavior of reinforced concrete beams with 10% of Nano-Metakaolin in flexural to study effect of utilizing Nano-Metakaolin, effect of flexural reinforcement(7).Mineral based composites are being used. The results focused are ultimate load, maximum deflection and crack pattern of control, flexure deficient, shear deficient and preloadedretrofitted beams. From the result, concluded that the load carrying capacity is enhanced in retrofitted beams. In retrofitted shear deficient beams brittle type of shear failure mode is shifted to ductile flexure failure with the development of flexure cracks. It is also inferred that the ultimate load taken by the preloaded FRP wrapped beams are more as compared to control beam (8).

Materials Used:

The Ordinary Portland cement (OPC) of grade 43 was used for this present work. The physical properties in cement were tested as per Indian standards. The Fine aggregate used for this study was river sand with size passing through 4.75 mm sieve and retained on 600 µm sieve which confirming to zone – III has been used as per Indian standards.. The fineness modulus of fine aggregate was found to be 3.35. The specific gravity of fine aggregate was found to be 2.65. The coarse aggregate of 20 mm size with specific gravity of 2.78 has been used for this study work.

Reinforcement:

The longitudinal reinforcements were used as deformed hot rolled, high yield strength bars of 16 mm diameter. The stirrups were made from mild steel bars with 8 mm diameter. The yield strength of steel reinforcements used in this experimental program was determined by performing the standard tensile test on the three

specimens of each bar. The average yield stresses of steel bars obtained were 390 N/mm^2, 375 N/mm^2 and 240 N/mm^2 for 16 mm, 8 mm and diameter respectively.

Concrete:

The maximum aggregate of size 20mm were used in the present study. The concrete mix proportion designed by IS method to achieve the strength of 60 N/mm^2. The mix ratio was fixed as 1:0.73:2.25 by mass. The designed water cement ratio was 0.32. Three cube specimens were cast and tested at the time of beam test to determine the compressive strength of concrete. The average compressive strength of the concrete was 50.01 N/mm^2

Metakaolin:

Metakaolin is white, amorphous, highly reactive aluminum silicate pozzolan forming stabile hydrates after mixing with lime stone in water and providing mortar with hydraulic properties. Heating up of clay with kaolinite $Al_2O_3.2SiO_2.2H_2O$ as the basic mineral component to the temperature of 500°C - 600°C causes loss of structural water with the result of deformation of crystalline structure of kaolinite and formation of an unhydrated reactive form metakaolinite.

Fig. 1: Physical Appearance of Metakaolin

Bottom Ash:

Bottom ash is a byproduct of coal and lignite combustion. The largest producers of bottom ash are power plants, which burn a very high volume of coal and lignite annually to generate electricity. Bottom ash obtained after burning of Lignite with calorific value of 2600 kcal/kg. Fineness modulus of bottom ash is found to be 2.967.

Fig. 2: Physical Appearance of Bottom Ash

Experimental Investigation:

The experimental investigation are carried out in reinforced concrete beams in order to determine the flexural behavior of high strength concrete, the cross sectional dimensions of the flexural beam are shown in figure 3. Todetermine the flexural behaviorof high strength concrete beams.The test werecarried out on 100 mm x 150 mm x 1200 mm beam prototypes at the age of 28 days using 1000kN capacity flexural strength testing machine which is shown in figure 4. The test setup includes two point loading using a hydraulic jack loading system by which the loads are transferred equally to the two points using a spreader beam and two rollers. Electrical resistance type strain gauges were fitted at the mid span of longitudinal tension zone before casting. Dial gauges are placed in the bottom of the beam at the mid-point to find the deflection. Demacs are placed on the surface of the beam to find the surface strain which isplacedatadistanceof100mmfromoneanother.Thesetrainsatthesepoints are found using mechanicaland electrical straingauges. The crack patterns are noted on both sides ofthebeamsatParticularintervals.Thegaugelength between the loading points is 333.33 mm and 100 mm are left on both sides of the beam at the supports. The corresponding deflection was noted by using dial gauges of 0.01 mm under the load point and also at the midspan of the beam. The dial gauge readings were noted until the failure of the beam. The strain in steel was also noted using electrical strain gauge. The flexural behavior of the beam was observed carefully and the first crack load was noted. All the specimens were capped for uniform loading prior testing. The control of load over the test was 10kN/min. Automatic data acquisition system was used to record the load, strain and axial displacement which in turn connected to the computer. Test setup is shown in Figure 4.

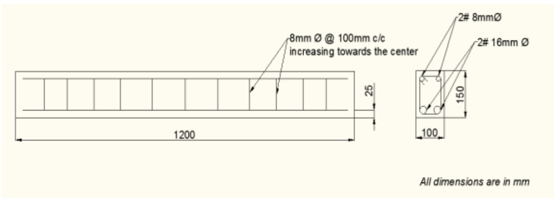

Fig.3: Reinforcement details of M50 grade Beam

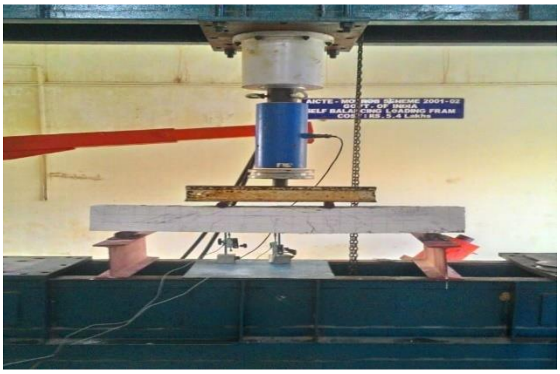

Fig.4: Test setup for flexural behavior of RC beam

To understand the behavior of simply supported beam subjected to two point loading as shown in Figure 2, the maximum load carrying capacity, ultimate moment and the maximum permissible deflection was calculated using IS 456 – 2000. The initial crack load for beams of M50 grade concrete are given in Table 1. It has been observed that that optimum mix of first case MKreplaced by cement and BA replaced by fineaggregate and second case GGBFSreplaced by cement and BA replaced by fine aggregate compared with the control mix of the admixtures of the concrete. From this, it is evident that the inclusion of first case MK and BA and second case of GGBFS and BA in concrete improved the flexural strength of the beams as the delays the first crack load of control beam respectively. The initial crack load was observed for beams of first case with MK and BA and second case of beamGGBFS and BA, Theoptimum value in a ternary combination shows the initial crack load. Replacement of mineral admixture gives high strength so it resist load maximum up to 20kN,25kN and 35kN and after that loads, it start a first crack and continues till it attain a peak load.Graph results of peak load and first crack load are shown in figure 5.

Table 1: Results for high strength concrete beam

Beam Type	First Crack load (kN)	Peak load (kN)	Mode of Failure
Control Beam	20	53.6	Yielding of bars
GGBFS (20%) + BA (60%)	25	60.5	Crushing of concrete
MK (20%) + BA (45%)	35	68.5	Crushing of concrete

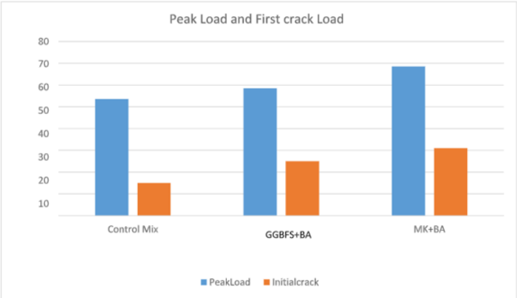

Fig.5: Results of first crack load and ultimate load

The ultimate load or Peak load for beams of control mix was about 53.6 KN, for metakaolin was68.5kNand ground granulated blast furnace slag was about 58.5kN respectively.The test results clearly indicates that the beams cast first combinations of MK and BA, second beams combinations of GGBFS and BA showed similar load carrying capacities when compared to control beam.

Load –Deflection:

At every load increment, it was noted that Metakaolin, bottom ash and combination of cement andMet kaolin and bottom ash has equal deflection values. The first beams shows the replacement of MK and BA the second beams GGBFS and BA. Optimum mix is more deflected when compared to the ad mixers beam. Maximum deflections for different mixes were given in Table 3 and Table 6.8and the results are plotted in graph as shown in figure 6. The ultimate moment capacities for the beam are considerably improved with the addition of Metakaolin, bottom ash and ground granulated blast furnace slag.

Table 3. Results for high strength concrete beam

	Ultimate load(kn)	Deflection of control beam	Ultimate load(kn) MK and BA	Deflection of MK and BA in mm	Ultimate load(kn GGBS and BA)	Deflection of control GGBS and BA in mm
1	10		10	-	10	-
2	20		20	-	20	-
3	30	0.5	30	0.5	30	-
4	40	0.75	40	1	40	0.5
5	50	3	50	4	50	3
6	55	5	60	6	60	5
7					70	14

Crack pattern and failure mode:

Cracks patternof the control beam compare toGGBS and bottom ash of beam.It was observed that First flexural cracks were formed in the constant moment zone and these cracks are extended vertically upwards and developed gradually wide as the load is increased. As the load increases, the extreme fiber stresses in bending increase until the tensile strength of concrete is reached. This cases flexural cracking initially in the constant momentregion. The first case of beamthe cracks are less compared to control beam. The cracks appear in regular interval.In the second case MK and BA flexure failures are less compared to control beam.First cases of beam in the cracks appearance are less compare to second case. The finally failure of the beam is described by large strains in the steel reinforcement & considerable deflection near collapse followed by extensivecracking.

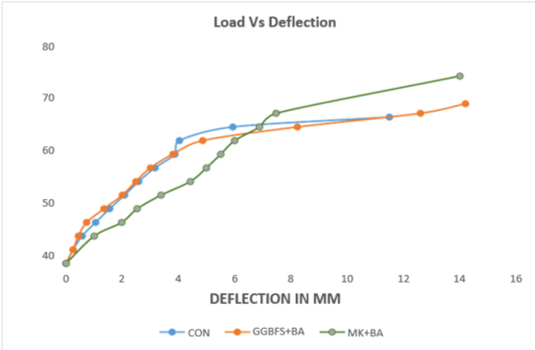

Fig. 7: Load deflection curves

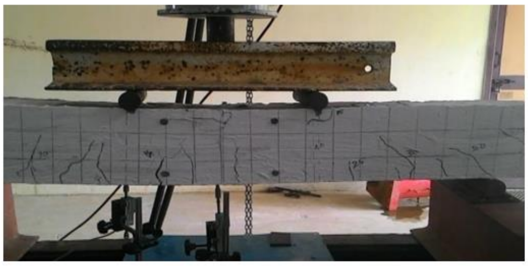

Fig. 8(a): Crack pattern for control mix

Fig. 8(b): Crack pattern for GGBS and BA

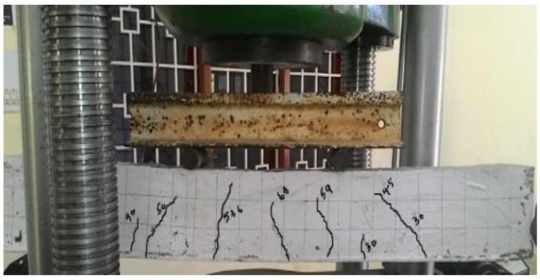

Fig. 8(c): Crack pattern for MK and BA

Fig. 8: Crack Patterns of various RC high strength concrete beams

Conclusion:

From the beam results which has been done in this present work, the following conclusion can be drawn

1. The behavior of mineral admixture based high strength concrete beam produced by replacing cement by Metakaolin and ground granulated blast furnace slag and natural sand by bottom ash has been studied.

2. The results reveals that the use of Metakaolin, GGBFS and Bottom ash, as alternate pozzolanic material for partial cement replacement and sand replacement in producing high strength concrete and can compensate for its usage inenvironmental and climatic conditions and also in economic issues caused in the production of cementindustry.

3. The maximum load and first crack load for the beams with optimum mix is higher than the control beam for the M50 grade due to the immediate grain filler effect, and alsothe it acceleratesthe cementhydration reaction.

4. From the above result control specimen compare with the metakaolin and bottom ash, ground granulate blast furnace slag reaches the higher value of the concrete.

5. The maximum load carrying capacity of high strength concrete control beam was about 53.6 kN, for metakaolin based high strength concrete beam was 68.5 kNand ground granulated blast furnace slag base high strength concrete beam was about 58.5kN respectively. It was also concluded that for metakaolin based high strength concrete beam attains 28% more load and GGBS based high strength concrete beam was about 10% more load when compared with the control high strength concrete beam.

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