EXPERIMENTAL ANALYSIS OF EFFECT OF MINERAL ADMIXTURES ON LIGHT WEIGHT HIGH STRENGTH CONCRETE

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Abstract - *Many high raised buildings are evolved in recent years which increase the usage of High Strength concrete (HSC). In general, the density of HSC is high which increases the dead load of superstructure. The compressive strength of HSC lies in the range 60 - 100MPa.and the density of HSC is in the range of 2500- 2700kg/m3. The one or more parameters of concrete are supreme then the concrete is said to be HSC. In order to reduce the density of concrete it is suggested to use High Strength Light Wight Concrete (HSLWC). The HSLWC is the concrete with both high Strength and light weight concrete. The primary objective of the study is to obtain the effect of replacement of coarse aggregate with lightweight aggregate and cement with mineral admixtures on compressive strength.*

When lightweight concrete first came into being, usage of lightweight aggregates was the only way to achieve lesser density. The bond between lightweight aggregates and the matrix is stronger than in conventional concrete. This is because the cement paste can penetrate inside the aggregates due to their porous nature. Nearly all lightweight aggregates are fire-resistant

Key Words: **Cement, METAKAOLIN (MK), Aggregates (Fine and Course), Lightweight Aggregate Concrete, Cellular Lightweight Concrete, Silica fume.**

1.INTRODUCTION

The high performance of concrete can be achieved by replacing partially of cement with mineral admixtures like Metakaolin (Mk), Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (FA), Silica fume (SF) etc. By using these mineral admixtures leads to lowering the global warming. These are finely divided siliceous materials which are added to concrete in the range 20 to 60 percent by mass of the total cementitious material. These are the waste by- products from various industries. These are of two types: 1. Chemically active mineral admixtures like MK, SF, 2. Micro Filler mineral admixtures like GGBS, and FA.

It is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The addition of GGBS makes concrete more durable, due to its lower setting time the heat of hydration is lowered. GGBS contains silicates and alumino-silicates of calcium and is a by-product of iron manufactured in a blast furnace.

2. LITERATURE REVIEW

A brief review of literature on influence of mineral admixtures on the fresh and hardened concrete, strength and durability aspects are reported and discussed. The literature review of behaviour of structural member beam is also presented. The selection of available documents that are published on the topic, which contains information, ideas, data and evidence written from a particular standard point to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed.

Metakaolin was mixed with each fine aggregate at cement replacement ratios of 0%, 5%, 10%, 15%, and 20% by weight. The effects of metakaolin on the workability, density, porosity, compressive strength, and modulus of elasticity of lightweight concrete are addressed in detail.

3. EXPERIMENTAL PROGRAM

This chapter presents the details of experimental investigations carried out on the test specimens to study the strength characteristics of concrete using metakaolin, Silica fume as partial cement replacement materials in different combinations.

TEST PROGRAM

The accompanying test program was intended to test the cubes compressive strength for 7, 14, 28-days age of different mixes and flexural strength, peak load, first crack, maximum deflection and failure pattern were observed for the beam with different mix design of M70 grade, M70 with air entraining agent and M70 with light weight coarse aggregate were observed.

- Obtained the design mix ratio for M70 Grade concrete.
- Different set of mixes are obtained with partial replacement of cement with metakaolin, silica fume adding air entraining agent as batch 1 and coarse aggregates with pumice stone as batch 2.
- Casting of cubes with different set of mixes with batch 1 and batch 2 then testing compressive strength for the cubes for 7, 14, 28 days.

- Based on the highest compressive strength obtained from batch 1, batch 2, 2 singly reinforced beam specimens are casted as per the requirement of the test and other beam specimen of M70 grade concrete.
- Testing the beams after 28 days for peak load, first crack load, Maximum deflection with two-point loading, load deflection at midpoint of beam and crack pattern are observed.

MATERIALS USED

Cement

Testing the beams after 28 days for peak load, first crack load, Maximum deflection with two-point loading, load deflection at midpoint of beam and crack pattern are observed.0000Cement is the most important ingredient and acts as a binding material (having adhesive and cohesive properties). Cement is obtained by pulversing clinker formed by calcining raw materials primarily comprising of liming (CaO), Silica (SiO2), Alumina (Al2O3 and Ferric Oxide (Fe2O3) along with some minor oxide.0000OPC of 43 grade conforming to IS: 8122-1989 was used for the present experimental investigation.

Fine Aggregate

Aggregate is an important ingredient of concrete since it occupies about 70-75% vo- lume concrete, relatively cheap as its quality affects the durability and structural be- havior of concrete members. Natural river sand with fraction passing through 4.75 mm sieve and retained on 600μm sieve confirming to gradation zone –III was used as fine aggregate. The fineness modulus of sand used was 2.81 with a specific gravity of 2.65.

Fine aggregate

Coarse Aggregate

As explained aggregate used for concrete production is classified as fine aggregate and coarse aggregate depending on its particle size. Aggregate of size more than 4.75mm, is called as coarse aggregate and is one of the most important ingredient of concrete. It gives strength to the concrete and constituents about 70 to 75 percent volume of concrete. Crushed stone in general used as coarse aggregate which is black in colour, angular and local name known as black metal. Crushed granite of size ranging 20mm – 10mm was used and specific gravity was found to be 2.74.

Water

Although water is an important constituent of concrete, but it does not receive due attention in preparation and quality control of concrete. Strength and other properties of concrete are developed as a result of reaction cement and water (hydration) and thus water plays a critical role. Potable tap water available in the laboratory was used for mixing of concrete and curing. The PH estimation of the water was 7.0

Metakaolin

It is a dehydroxylated form of the clay mineral kaolinite and obtained from calcination of kaolinite clay in the range of 740 – 840oC. The particle size of metakaolin is smaller than cement particles. Replacing Portland cement with 0–30%(byweight)MK produces a concrete mix, which exhibits favourable engineering properties, including: the filler effect and the pozzolanic reaction.0000The filler effect is immediate, while the effect of pozzolanic reaction occurs between 3 to 14 days.0000Metakaolin was obtained from ASTRRA chemicals.

Silica fume

Proper introduction of silica fume in concrete improves both the mechanical and durability characteristics of the concrete. It emphasized the effect of silica fume on workability level and its maintenance of fresh concrete; strength development, strength optimization and elastic modulus of hardened concrete; Silica fume was obtained from Akbar Ali chemicals, Salem and its physical and chemical properties.

Pumice stone

Pumice is a very light weight, porous and abrasive material and it has been used for centuries in the construction and beauty industry. Pumice is widely used to make lightweight concrete and insulative low-density cinder blocks.

Pumice stone was acquired from Future Farms, having a specific gravity of 0.64.

Pumice stone

4. CONCRETE MIX DESIGN

MIX DESIGN FOR M70 GRADE OF CONCRETE:

S.NO	MATERIALS	CONTENTS
1.	Grade designation	70 mpa
2.	Type of cement	Ordinary Portland cement. (opc) 43 grade
3.	Minimum cement. Content	320 kg/m3
4.	Maximum size of aggregates	20mm
5.	Maximum water content.	0.45
6.	Workability (slump)	100 mm
7.	Degree of supervisions	Good
8.	Exposure conditions	Severe
9.	Maximum cement contents	450 kg/m3

Mix design stipulations

S.NO	MATERIALS	CONTENTS
1.	Cement used	opc 43 grade
2.	Specific gravity of coarse aggregate(20 mm)	2.78
3.	Specific gravity of cement.	3.04
4.	specific gravity of fine aggregate	2.59
5.	Water absorption of fine aggregate	1.54
6.	Water absorption of coarse aggregate	0.62
7.	Chemical admixtures	Superplasticizer
8.	Free surface moisture of fine aggregate	Nil
9.	Free surface moisture of coarse aggregate	Nil

TARGET AVG STRENGTH FOR M70 MIX PROPORTION:

F ck = fck + ts

Where Fck = Target avg compressive strength at 28 days

fck = Characteristic of the compressive strength at 28 days

t = 1.65

s = Standard deviation (S=6)

Fck = 20 + 1.65x6

= 79.9 N/mm2.

5. MIX PROPORTIONING

The concrete used is of grade M70 and was designed as per the guidelines of IS 10262-2009. The designed mix proportion by weight is 1:1.80:2.61 and the water/cement ratio is 0.34. The two different batches of mixes with various proportions of the binder materials like Mk and Silica fume were replaced to cement. In mix A replacement with 20% of cement with 15% metakaolin and 5% Silica fume with air entraing agent 0.4%.In mix B replacement with 20% of cement with 15% metakaolin and 8% Silica fume with air entraing agent 0.5%.In mix C replacement with 20% of cement with 12% metakaolin and 8% Silica fume with air entraing agent 0.4%.In mix D replacement with 20% of cement with 12% metakaolin and 8% Silica fume with air entrain agent 0.5%. The AEA is used as weight reducing agent in the set of mixes of Batch 1.

Compressive strength for concrete with 100% cement content is = 82.31N/mm2.

Material composition of Batch 1 mixes

	Cement (%)	Metakaol in (%)	Silica fume (%)	AEA added with respect to cement (%)
A	80	15	5	0.4
B	80	15	5	0.5
C	80	12	8	0.4
D	80	12	8	0.5

Whereas in Batch 2 the Pumice stone is used as LWA in concrete which were tabulated in table 6b

Material composition of Batch 2 mixes

	Cement (%)	Metakaol in (%)	Silica fume (%)	AEA added with respect to cement (%)
E	80	15	5	25
F	80	15	5	20
G	80	12	8	25
H	80	12	8	20

CASTING AND CURING

To examine the consequence of addition of Metakaolin and Silica fume combination (as partial replacement of cement), 150mm x 150mm x 150mm cubes were cast for reference and additional mixes comprising different mix combinations of Metakaolin and Silica fume. Chemical admixture is added in all the mixes as it gives better results and good workability. Based on the test results of compressive strength, 100mm × 150mm × 1200mm size beam specimens were cast for optimum mix proportion obtained for M70 grade of concrete from batch 1 and batch 2. Concrete were placed in the well lubricated mould and compacted and the specimens were left at room temperature for 24hrs and after that specimens were placed in curing tank till their testing ages.

TESTING OF SPECIMEN

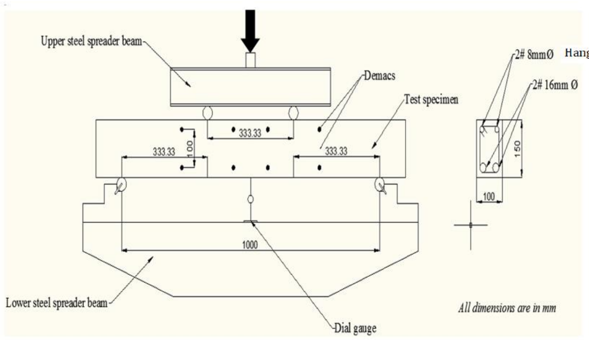
Compressive strength test

The compressive strength test is the most common test conducted because most of the desirable characteristic properties of concrete and the structural design purpose are qualitatively related to compressive strength. The test setup is shown below in Figure 6(a) Test setup for compressive strength.

The test was conducted in compression testing machine of 3000kN capacity for different ages of concrete viz.7, 14 and 28 days as per the specifications given in IS 516: 1959 under normal room temperature.

FLEXURAL BEHAVIOUR TEST

For finding flexural behaviour, tests were carried on 100 mm x 150 mm x 1200 mm beam prototypes at the age of 28 days using 1000kN capacity flexural strength testing machine. The test setup includes two point loading using a single point loading system by which the loads are transferred equally to the two points using a spreader beam and two rollers. 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 are placed at a distance of 100mm from one another. The strains at these points are found using a mechanical strain gauge. The crack patterns are noted on both sides of the beams at particular intervals. The gauge length between the loading points are 333.33 mm and 100 mm are left on both sides of the beam at the supports. All the specimens were capped for uniform loading prior testing. The control of load over the test was 10 kN/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 5.



Test setup for flexural behavior

6. RESULTS AND DISCUSSIONS

CHEMICAL COMPOSITION OF MATERIALS

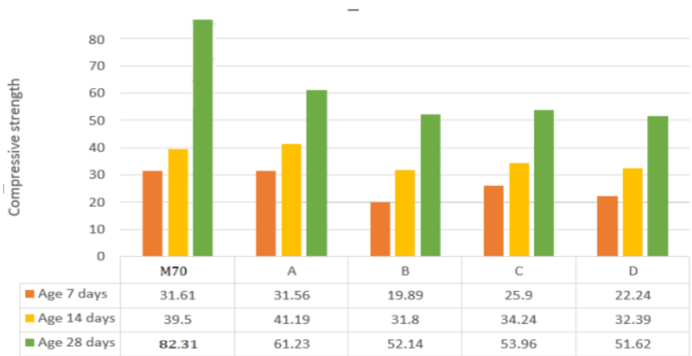
The chemical composition was obtained by X-Ray Fluorescencetest using XRF- analyzer of model Tiger88 to determine major and trace elements insolids. Table7a it shows the main elements (expressed as oxides) present in cement, SF and MK. Cao and Silica (SiO2) constituted 75percentage sand were the major component sin slag, followed by Al2O3 and MgO with 12 and10% respectively. All the other components constituted only 3%. In the case of MK, composition dominated by SiO2 and Al2O3 with 94.5% and remaining components was found to be only5.5%. CaO and MgO were found to be very less in MK.0000Table:7.a Composition of materials opc, metakaolin, silica fume

Description	OPC	Metakaolin	Silica fume
Color	Grey	Off white	Grey
Specific gravity	3.1	2.7	2.2
CaO (%)	62.8	0.8	0.2-0.8
SiO2 (%)	20.3	53.7	89.5
Al2O3 (%)	5.4	40.8	1.2
Fe2O3 (%)	3.9	1.6	2
MgO (%)	2.7	0.3	0.2-0.8
Na2O (%)	0.14	0.18	0.5-1.2

COMPRESSIVE STRENGTH RESULTS

EFFECTS OF AEA

The variation of compressive strength due to addition of air entraining agent for different ages of concrete was depicted in Figure 7(a) to understand the effect of age of concrete. Increase in age of concrete increases compressive strength. At the age of 28days, M70 concrete yielded 82.31MPa. For mixes with 15% MK and 5% SF as replacement for cement with 0.4% AEA gave 61.23MPa and for concrete with 12% MK and 8% SF with same 0.4% AEA was found to be 52.14 MPa. Similar trend was observed for other mixes with increase in AEA of 0.5%. Hence it was understood that increase in AEA beyond 0.4% made further reduction compressive strength of concrete. Around 26% of compressive strength got reduced due to addition of 0.4% AEA, which was not acceptable if we are going to light weight sections. The rate of reduction of compressive strength increases further for AEA = 0.5% decreased content of MK from 15 to 12%. The reduction went upto 28% for other cases and hence concrete with 15% MK and 5% silica fume and AEA with 0.4% was found to be optimum values. In the above case cement was replaced about 20% and hence total cost per unit quantity will be reduced.



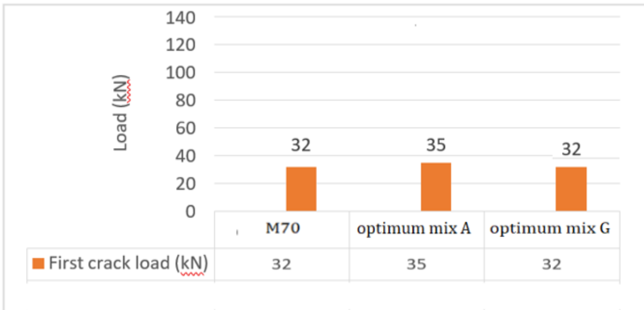
Effect of Air Entraining Agent on compressive strength

EFFECT OF PUMICE STONE AS LIGHT WEIGHT AGGREGATE

The variation of compressive strength due to replacement of coarse aggregate with Pumice stone as light weight aggregate for different ages of concrete was depicted in Figure 2 to understand the effect of age of concrete. Use of Pumice stone as light weight aggregate gave lesser compressive strength at all the ages of concrete irrespective the combination of mix compared to control concrete. Concrete with 25% Pumice stone gave slightly higher compressive strength than that of concrete with 20% pumice stone. The rate of reduction compared to control concrete was about 38% and 45% for LWA with 25% and 20% respectively in concrete with 15% MK and 5% silica fume. The rate of reduction comes down to 37% and 38% for LWA with 25% and 20% respectively in concrete with 12% MK and 8% silica fume. Similar trend was observed in earlier age of concrete also.

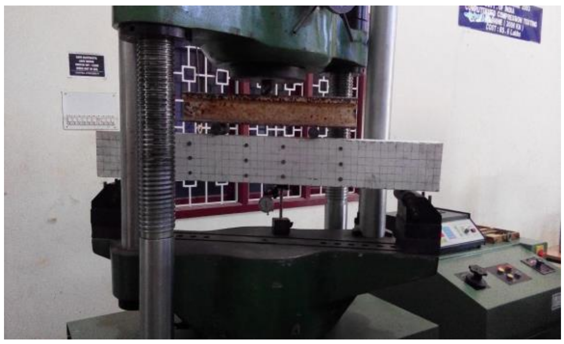
FIRST CRACK LOAD

The first crack load for beams cast with AEA and Pumice stone are given in Table 7(a). It can be seen that optimum mix i.e. A and G and M70 mix beam exhibits similar first crack load.

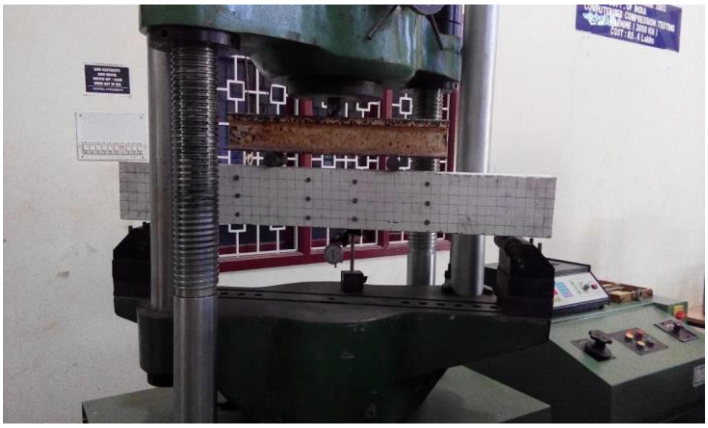


First crack load for different mixes

The first crack load of M70 design beam and beam cast with PS were almost equal. Whereas the first crack load of beam with AEA is increased with 9% when compared with M70 mix. From the result load for first crack load is almost similar for M70 and Mix G where as Mix A has slightly higher.



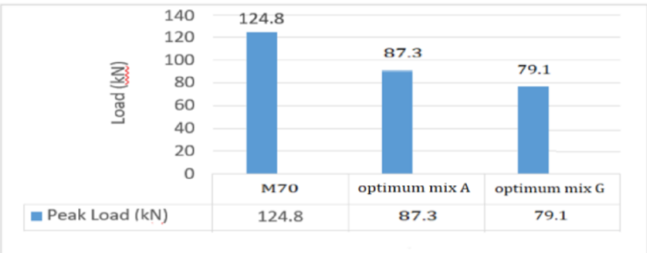
Flexural test



Beam testing for flexural behaviou

PEAK LOAD

The ultimate load or Peak load for beam of M70 is 124.8kN and the beam with mix A and Mix G were gradually decreased. It can be seen that ultimate load of 124.8kN, 87.3kN and 79.1kN respectively. It was observed that the beams cast with MK, SF, AEA and Pumice Stone showed decrease in load carrying capacities compared to M70 design beam.



LOAD – DEFLECTION BEHAVIOUR

Figure 7(h) gives the load deflection curve for M70 and optimal mix beams for mix A and G.

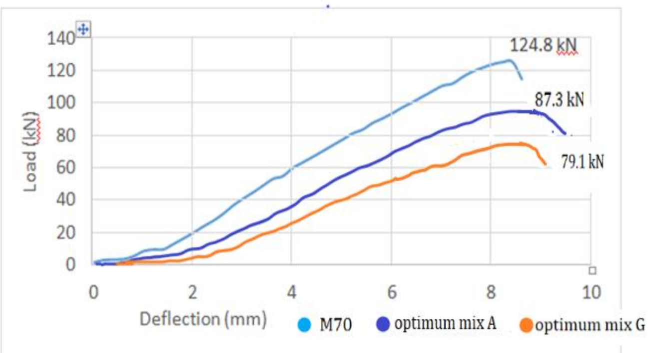


Figure 7(h): Load – deflection curve for beam of M70 design mix and optimal mixes.

The ultimate moment capacity for the beam specimens is considerably decreased with the addition of MK and SF. From the graph we can see increase in the the deflection from M70 is less when compared with the Mix A and Mix G due to addition of admixtures and light weight aggregate the defelection is maximum in mixA and mix G at 87.3kN and 79.1kN respectively.

DISCUSSION:

As the load increases, the extreme fiber stresses in bending increase until the tensile strength of concrete is reached. This causes flexural cracking initially in the constant moment region. Flexural cracking causes a marked reduction in stiffness as shown by a sudden change of gradient in the response.

Cracks are started in the shear spans of the beam also with increased loads. The final failure of the beam is described by large strains in the steel reinforcement & considerable deflection near collapse followed by extensive cracking;

7. CONCLUSIONS

Higher reduction of compressive strength of 26% was observed in high Strength light weight concrete with air entraining agent with 0.4%. This reduction of only 13% was acceptable in the field ensuring the reduction in weight of the concrete. In this mix cement was replaced with Metakaolin and Silica fume to an extent of 20%, which will reduce the overall cost of concrete per unit quantity.

Higher reduction was observed in compressive strength when light weight aggregate (Pumice stone) used as partial substitute to coarse aggregate irrespective of its percentage. Maximum reduction of 37% was observed. Use of 25% of Pumice stone as LWA with 15% Metakaolin and 8% Silica fume yielded 37% reduction in compressive strength compared to M70 concrete. Hence when CA to be replaced with LWA, 25% may be permitted.

From the results, the beams with M70 mix and optimal mixes using 0.4 % AEA by weight of cement and 25% LA replacing CA have shown decrease in ultimate load but similar in first crack loads.

Mix using 0.4 % AEA by weight of cement have shown an 4.7 % increase in the deflection and mix having 25% LA which replaces CA had 2.3 % increase in the deflection values when compared with the M70 specimen.

From the results observed, it is found that 25%of Pumice stone as a replacer for coarse aggregate and usage of 0.4% Air Entraining Agent were to be Optiv- mum values to produce High Strength Light Weight Concrete.

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