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RESEARCH ARTICLE

EXPERIMENTAL STUDY OF DEVELOPMENT OF HIGH STRENGTH CONCRETE USING METAKAOLIN

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ABSTRACT

Metakaolin is identified as a new pozzolanic admixture which is cost effective, cheaper and can also be considered as best alternative to micro silica. To achieve the economy ,Metakaolin which is derived from purified kaolin clay is added with ordinary Portland cement as partial replacement. The main objective of the present experimental investigation is to study the strength and behaviour concrete beams ,cubes and cylinders made by adding metakaolin , superplasticizer and other conventional materials. For achieving the above objective a total of 75 cubes of size 150mm x 150mm x 150mm , 15 beams of size 100mm x 100mm x 500mm and 15 cylinders of size 150mm x 300mm were casted and tested in the laboratory. The experimental work consists of compressive strength of cubes, tensile strength of cylinders and flexural behaviour of beams. The replacement is from 0 to 25%. W/C ratio is constant for all the specimens. W/C ratio is 0.35. Grade of concrete used is M50. Super plasticizer Conplast SP337 is added. Flexural tests were conducted on all the beam specimens with two points loading. The test results obtained are presented and discussed in this work.

Index Terms-*It is clear from the test results upto 15% replacement of cement with Metakaolin improved the ultimate load carrying capacity when compared with control specimen and other replacement specimens.*

INTRODUCTION

Concrete is one of the widely used common materials .There is rapid development in the area of cement, concrete technology and also in the admixtures like pozzolanic admixture, which can improve the performance characteristics of concrete. After the evolution of High strength concrete, it was found that the conventional concrete has the following drawbacks.

(a) Permeable to moisture and air resulting in corrosion of steel reinforcement.

(b) Less resistance to abrasion and chemical attack.

(c) Unable to achieve the required or intended life span of a structures due to environmental effects.

In order to overcome the above problems, considerable R&D efforts have been undertaken worldwide recently to develop high strength concrete. The term high performance concrete (HPC) is applied to concrete of high strength, which represents a better performance. High strength concrete is usually higher in initial cost. However, it proves to be more economical in life cycle cost of the project. It can be also said that high strength concrete has to be considered for all important structures where reliability of performance is very much essential.

It is possible to produce high strength concrete using chemical admixture in addition to the normal ingredients, which are generally used for conventional concrete. However such high strength concrete requires high paste volume, which often leads to excessive shrinkage and large evolution of heat of hydration besides increased cost. A partial replacement/ addition of cement by the admixtures such as Fly ash, Micro silica /silica fume, Metakaolin improve the properties of fresh and hardened concrete and enhance the durability characteristics. High strength concrete is one which satisfies the performance criteria which can be defined in terms of strength, durability, permeability, shrinkage etc. Due to virtue of this high strength concrete, it can be used in many important applications like in the construction of nuclear power plants, high rise buildings , bridges etc. In the protection of high strength concrete, use of admixture like pozzolanic admixture is attempt which makes the concrete less permeable and durable.

OBJECTIVE

The main endeavour of this project is to study the compressive strength , ultimate load carrying capacity and flexural behaviour on the concrete. The overall objective of this study was to develop a sound knowledge base so that they relate to this research, and to increase the understanding of the factors that influence the behaviour of the reinforced concrete beam with different replacement level of metakaolin. The aim of the present research were done by making cubes of size 150mm x 150mm x 150mm, beams of size 500mm x 100mm x100mm and cylinders of height 300mm and diameter 150mm by partially replacing cement with metakaolin. The two point loading pattern is used to achieve pure bending for the beams.

SCOPE

The purpose of this project is to study the mechanical property of concrete replaced with metakaolin.

SOURCE AND PROPERTIES OF MATERIALS

Materials that are used for making concrete for this study was tested before casting the specimens the properties obtained from the test was used in mix design. The preliminary tests were conducted for the following materials.

1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Water
5. Metakaolin
6. Superplasticizer

Cement

43 grade ordinary Portland cement produced by Ramcocement company has been used throughout the investigation. Cement is the most widely used cementitious ingredient in present day concrete. The function of the cement is first, to bind the fine aggregate and coarse aggregate to gathers, and second to fill the fine aggregate and coarse particle to form a compact mass. Although cement constitutes only about 10% of the concrete volume of the mix it is the active portion of the binding medium and only scientifically controlled ingredients of concrete.

AGGREGATES

Coarse aggregate

In this investigation, crushed hard blue granite of 20mm size confirming to IS:383-1970 have been used successfully as coarse aggregate. The specific gravity of coarse aggregate is 2.8 and the fineness modulus of 7.65. In order to produce optimum compressive strength with high cement contents and low w/c rates the maximum size of coarse should be kept to a minimum at 20 mm or 10mm. The strength increases are caused by the reduction on the average bond stress due to increased surface area of the individual aggregate. Another reason is the lesser concentration of stress around the particle caused by differences in the modulus of the paste and the aggregate. The ideal aggregate should be clean, cubical, angular, cent percent crushed with a minimum of flat and elongated particles.

Fine Aggregate

The natural river sand was used as fine aggregate. It is having fineness modulus of 7.65 and it corresponds to grading zone II of IS 383-1970 grading requirement. The specific gravity of fine aggregate is 2.6. The optimum gradation of fine aggregate is determined more by its effect on water requirement than on physical packing.

Water

As a general rule, water fit for drinking is also good for making concrete. Portable clean drinking available in the college supply system was used for mixing of concrete and curing of the test specimen. Water is needed for hydration of cement and moulding of concrete to the desired shape. The relationship between compressive strength and water cement ratio (w/c) ratio is well established. Smaller the (w/c) ratio higher is the compressive strength.

Usually water for concrete is specified to be a portable quality in pH ranges 6-8. The dissolved organic solids and sulphates, chlorides and suspended matters should be limited to 0.02, 0.03, 0.1 and 0.2 % respectively.

CHARACTERISTIC OF POZZOLANIC ADMIXTURE:

CALCINED CLAY – METAKAOLIN (HIMACEM)

Metakaolin is a chemical phase that forms upon thermal treatment of kaolinite. Kaolinite is a mineralogical term that is applicable to kaolin clays.Kaolin is fine , white clay mineral that has been traditionally used in the manufacture of porcelain. Metakaolin has the highest content of siliceous and aluminous minerals, because at least 90% of the product consists of silica and alumina,It is a white mineral admixture, having very good pozzolanic properties. It reacts with free lime produced during the hydration of cement to form additional cementitious products.

HIGH –REACTIVITY METAKAOLIN (HRM) as a value added concrete Admixture

High Reactivity Metakaolin is now established as a value-added concrete admixture and is being increasingly used in the developed countries in place of traditional pozzolanic materials.

HRM can be used as a highly effective pozzolanic admixture to,

a. Provide high compressive strengths.
b. Reduce permeability of concrete and reducing the penetration of chloride ions to reinforcing steel.

AREAS OF APPLICATION

Even though, HRM can be used in a wide variety of mix designs where improved compressive strengths impermeability is required, it is now being widely used in the following areas of application.

a. In Precast elements for high rise buildings.
b. In High strength concrete.
c. Marine and Chemical resistant structures.
d. Industrial Floors and other structures that require high compressive strength.
e. Bridge deck applications.

Benefits of HRM

The following are the benefits of using HRM in concrete.

a. Reduces permeability, since the additional cementitious products formed increase the density of the cement paste.
b. Increases chemical resistance by fixating the free lime.

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c. Reduces efflorescence, because of the fixation of lime and the resultant reduction in permeability. Controls Alkali-Silica Reactivity.
d. Reduces drying shrinkage by allowing the use of less cement while developing improved properties.

Super plasticizer: (CONPLAST SP 337)

Plasticizers are additives that increase the plasticity or fluidity of the material to which they are added.

Superplasticizers or High Range Water Reducers or Dispersants, are chemical admixtures that can be added to concrete mixtures to improve workability. However, note that most commercially available superplasticizers come dissolved in water, so the extra water added has to be accounted for in mix proportioning. Adding an excessive amount of superplasticizer will result in excessive segregation of concrete and is not advisible. Some studies also show that too much superplasticizer will result in a retarding effect sulfonated melamine formaldehyde , although new generation products based on polycarboxylic ethers are now available. Traditional ignosulfonate based plastizers , naphthalene and melamine sulfonate based superplastizers disperse the flocculated cement particles through a mechanism of electrostatic repulsion (see colloid) .In normal plastizers , the active substances are adsorbed on to the cement particles, giving them a negative charge , which leads to repulsion between particles. Lignin, naphthalene and melamine sulfonate superplastizers are organic polymers. The long molecules wrap themselves around the cement particles, giving them a highly negative charge so that they repel each other.

Polycarboxylate Ethers (PCE) or just polycarboxylate (PC) , the new generation of superplasticizers are not only chemically different from the older sulfonated melamine and naphthalene based products but their action mechanism is also different,giving cement dispersion by steric stabilisation, instead of electrostatic repulsion.Plasticizers can be obtained by local concrete manufacturer. Household washing up liquid may also be used as a simple plasticizer.

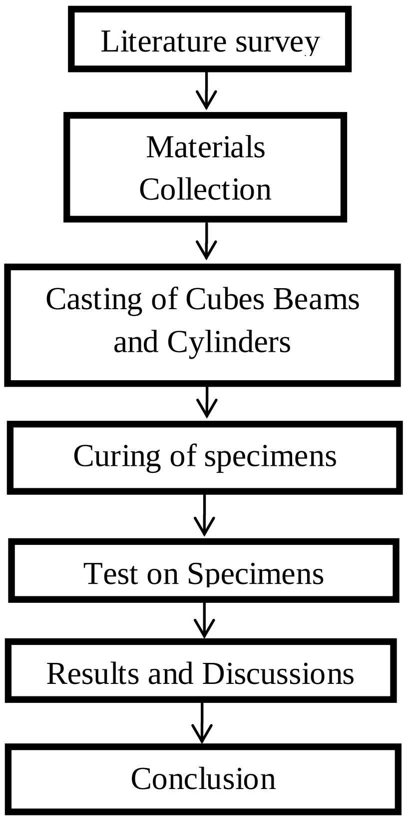
PRINCIPLE EFFECT

a. High range water reducing at equal consistency.

ADVANTAGES :

a. Significantly improve the workability of concrete without increasing water demand permits easier construction with quicker placing and compaction.
b. Major increases in strength at early ages without increased cement content.
c. Typical application includes concrete roads and airport runways.
d. Chloride free.

METHODOLOGY INVOLVED



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EXPERIMENTAL PROGRAMME

MATERIALS AND PROPERTIES

CEMENT: OPC 43 Grade : (Ramco Cement)

Specific Gravity of Cement (G)= 3.13

FINENESS TEST FOR CEMENT

The fineness of cement has an important bearing in the rate of hydration and hence on the rate of gain of strength. The percentage of residue left on the IS sieve is 0%.Since the obtained value is less than 10% and it was satisfying the IS specifications for Portland cement.

SETTING TIME OF CEMENT

To find setting time of cement, vicat apparatus method was followed and obtained results are as under:

Normal consistency	= 33%
Initial setting time	= 105 minutes
Final setting time	= 185 minutes

FINE AGGREGATE : (RIVER SAND)

The fine aggregate (sand) used is clean dry river sand. The sand is sieved to remove all pebbles.

SIEVE ANALYSIS FOR FINE AGGREGATE

About 1 kg of dry sample of fine aggregate was taken and sieved on IS sieve numbers viz 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ,150µ, 75µ..Then the material retained in each sieve was collected seperatelly and weighted. The result were tabulated and the percentage of fine aggregate of varying size that passed through each sieve was calculated and recorded.

$$\frac{\text{Total cumulative percentage retained}}{100} = 2.25$$

In order to ascertain the grading zone of sand, the obtained sieve analysis results were compared with various standards – grading zones as per IS 383 – 1970. Finally it was found that sand is conforming to grading zone – II.

SPECIFIC GRAVITY OF FINE AGGREGATE

Specific gravity of Fine Aggregate ,

Gs = 2.6

COARSE AGGREGATE

SIEVE ANALYSIS FOR COARSE AGGREGATE

About 1kg of dry sample of coarse aggregate was taken and sieved on IS sieve size 80mm, 40mm, 20mm, 12.5mm, 11.2mm, 10mm, 4.75mm and 2.36mm. Then the material retained in sieve was collected separately and weighted. The results were tabulated and the percentage of coarse aggregate of varying size that passed through each sieve size was calculated and recorded.

Cumulative percentage

weight retained = 765.6

Fineness modulus =7.65

SPECIFIC GRAVITY OF COASE AGGREGATE

Specific gravity of coarse aggregate ,

Gs =2.8

METAKAOLIN:(HIMACEM)

Specifications

+300 mesh w/w% (Max)	: 10%
Average Particle size	: 1.2 microns
Moisture w/w % (Max)	: 0.5 – 1.0
Metakaolin content % (Min)	: 98.0
Reactivity with Lime (%)	: Good

Typical Analysis

a) PHYSICAL

Appearance	: Off-White
PH (10 % Solids)	: 4.5 – 5.5
Bulk density (Kg/Lit)	: 0.4 – 0.5
Specific surface area m^2/g	: 10 – 12
Specific Gravity	: 2.6

b) CHEMICAL COMPOSITION (Mass%)

SiO_2		: 52.0
Al_2O_3		: 46.0
Fe_2O_3		: 0.60
TiO_2	(Max)	: 0.65
CaO	(Max)	: 0.09
MgO	(Max)	: 0.03
Na_2O	(Max)	: 0.10
K_2O	(Max)	: 0.03
Loss on Ignition		: 0.50

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SUPERPLASTICIZER: (CONPLAST SP 337)

a. Specific gravity: 1.18±0.01 Kg /l at 20º C
b. Typical dosage :0.5 - 1.5lit/100 Kg cement

MIX DESIGN

The mix proportion for M50 concrete was designed by using Indian Standard Method.

a) Design stipulations:

Characteristic compressive strength required in the field at 28 days= 50Mpa

Maximum size of aggregate = 12mm
Degree of workability = 0.9
Slump of 12mm aggregate = 50mm
Degree of quality control = good
Type of exposure = moderate

b) Test data for materials:

Specific gravity of cement = 3.13
Specific gravity of Fine aggregate = 2.6
Specific gravity of Coarse aggregate= 2.8
Specific gravity of Metakaolin = 2.6

DESIGN

1) Mean strength fm= fmin + ks

fmin=50

k = 1.65

Standard deviation as per IS 10262-2009

For M50 grade concrete standard deviation

's' = 5 N/mm^2

fm = 50+(1.65x5)

= 58.25Mpa

2) Water cement ratio (Assume)= 0.35

3) Calculation of water content:

Approximate water content for 20mm max. Size of aggregate = 186 kg /m^3

(As per IS : 10262). As plasticizer is proposed we can reduce water content by 20%.

So water content = 186 x 0.8

=148.8 kg /m^3

4) Calculation of cement content:

Cement content = Water content per cumec of concrete

Water cement ratio = 148.8/0.35

= 425.14 kg /m^3

Say 426 kg /m^3

Minimum cement content for moderate exposure condition is 300 kg /m^3

Hence ok.

5) Calculation of coarse aggregate and fine aggregate:

i. Volume of concrete = 1m^3

ii. Volume of cement = mass of cement

sp.gravity of cement x 1000

= 426/(3.13 x 1000)

= 0.136 m^3

iii. Volume of water = mass of water

sp.gravity of water x 1000

= 148.8/(1 x 1000)

= 0.148 m^3

Total weight other than aggregate (coarse and fine)= 0.136+0.148= 0.284 m^3

iv. Volume of coarse and fine aggregate

= 1-0.284= 0.716 m^3

v. Volume of fine aggregate:

Assuming 33% by total volume of aggregates

= 0.33x0.716 = 0.236 m^3

vi. Volume of coarse aggregate:

= 0.716-0.236 =0.480 m^3

Weight of fine aggregate = 614 kg /m^3

Weight of coarse aggregate =1344 kg /m^3

Mix proportion:

0.35 : 1 : 1.44 : 3.15

Material required for 1 m^3 of concrete are ,

Cement = 426 Kg
Fine aggregate = 614Kg
Coarse aggregate = 1344Kg
Water = 148.8Kg

TEST FOR MECHANICAL PURPOSE

The experimental program involves casting and testing of concrete specimens with and without Metakaolin. The different specimens include 3 set of 150 x 150 mm cubes for 7, 14, 28 days cube Compressive Strength, 3 set of 100 x 100 x 500 mm size beams for 28 days, 3 set of 150mm diameter and 300mm long cylinder for 28 days Split Tensile Strength. The cement was replaced with various percentages of metakaolin (10, 15, 20 & 25%). Before casting machine oil was applied on the inner surfaces of the cast iron mould.

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COMPRESSIVE STRENGTH TEST

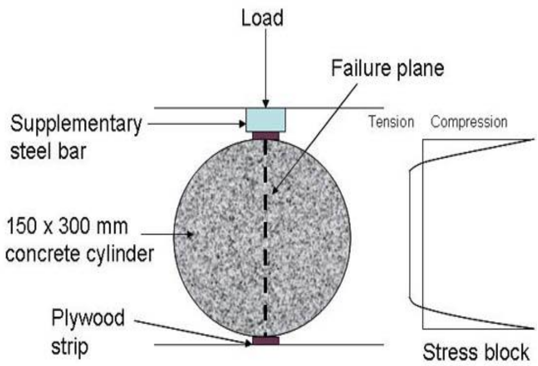
The testing machine may be of reliable type, of sufficient capacity for the test and capable of applying the load at the specified rate. The permissible error shall be not greater than +2 or -2 % of the maximum load.. The bearing surface of the platens, when new, shall not depart from a plane by more than 0.01mm at any point, and they shall be maintained with a permissible variation limit of 0.02 mm. The movable portion of the spherically seated compression platen shall be held on the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any directions.

Bearing surfaces of the testing machine shall be wiped clean and any loose sand or other materials removed from the surfaces of the specimen which are to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast , that is, not to the top and bottom. The maximum load applied to the specimen shall be then recorded and the appearance of the concrete and any usual features in the type of failure shall be noted.

SPLIT TENSILE TEST

Since there is no direct method for finding the tensile strength of concrete indirect method is adopted. In this same compression testing machine as used for finding the compressive strength is used. Unlike compression test , concrete cylinders of standard sixe 150 x 300mm as specified by Indian Standard are used for testing.

Bearing surface of testing machine shall be wiped clean and any loose sand or other material removed from the surface of the specimen which are to be in contact with the compression platens. The maximum load applied to the specimen shall be recorded and the appearance of any unusual cracks shall be noted.



LOADING IN CYLINDERS

Calculation

The measured tensile strength of the specimen shall be calculated by dividing the maximum load (P) applied to the specimen during the test by the circumferential area.

$$P_t = \frac{2P}{\pi DL}$$

FLEXURAL STRENGTH TEST

The testing machine may be of any reliable type of sufficient capacity for the tests and capable of applying the load at the specified rate.

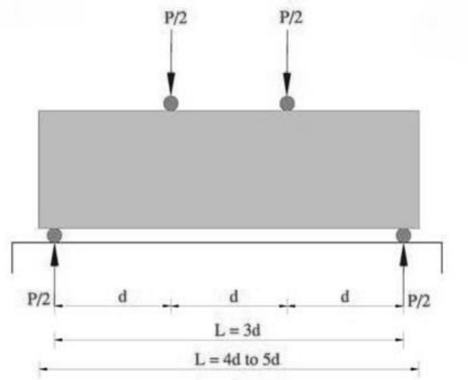
The permissible errors shall be not greater than +0.5 0r – 0.5 percent of the applied load where a high degree of accuracy is required and not greater than +1.5 or 1.5 percent of the applied load for commercial type of use.. The load shall be divided equally between the two loading rollers and shall be mounted in such a manner that the load is applied axially and without subjected to any torsional stresses or restraints. One suitable arrangement which complies with these requirements is indicated in the diagram.

Procedure

Test specimens stored in water at a temperature of 24 degree to 30 degree hours before testing shall be tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of each specimen shall be noted before testing. No preparation of the surface is required.

Placing the specimen in testing machine

The bearing surfaces of the supporting and loading rollers shall be wiped clean ,and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. load shall be applied without shock and increasing continuously at a rate such that the extreme fibre stress increases at approximately 7 Kg /sq cm/min , that is , at a rate of loading of 400Kg/min for the 15cm specimens and at a rate of 180Kg/min for the 10cm specimensThe appearance of the fractured faces of concrete and any unusual features in the type of failure shall be noted.



LOADING IN BEAMS

Calculation

The Flexural strength of the specimen shall be expressed as a modulus of rupture fb, which ,if 'a' equals the distance between the line of fracture and the nearer support , measured on the centre line of the tensile side of the specimen , in cm shall be calculated to the nearest 0.5 Kg /sq. cm as follows :

$$Fb = PL / bd^2$$

Where ,

b = measured width in cm of the specimen,

d = measured depth in cm of the specimen at the point of failure,

L = length in cm of the span on which the specimen was supported, and

P = maximum load in Kg applied to the specimen.

PREPARATION OF TEST SPECIMEN

The different materials needed are collected and kept ready. The total quantity of material required are measured out and the required Water for mixing assuming a water cement ratio 0.35 is also measured and kept ready. The cement, sand and standard coarse aggregates are proportioned in the ratio 1 : 1.44 : 3.15 by weight.The entire mixing operation is performed on a water tight non absorbent platform. The concrete thus prepared is tested using slump test.

Size of specimen and moulds

The cube specimens are of 15 x 15 x 15 cm size, cylinder specimens are 15 cm dia and 30 cm long and beam of size 10 x 10 x 50 cm. The mould and the base plate shall be coated with a thin film of mould of oil before use, to prevent adhesion of the concrete. A tampering bar of 16mm dia steel 0.6mm long with a bullet pointed out is used for tamping.

Mixing

The materials are mixed with using mixer machine. When the mixing drum is charged by power loader all mixing water shall introduced into the drum before the solid materials, then with cement and the finally remaining coarse aggregate on top. Mixing shall not be less than 2 minutes for thorough mixing.

Placing

The material obtained from the mixer machine is fed into the tightened and perfectly oiled mould, before the initial setting time the mixture should be placed.

Compacting

The specimens are made as soon as practicable after mixing to produce a fully compacted concrete. The concrete is filled in the moulds in layers approximately 5 cm deep. For cubical specimens concrete is subjected to not less than 35 stokes per layer and for cylindrical specimens not less than 30 stokes per layer. The filled up surface is finished smooth and level using a trowel.

Curing

The test specimens are stored in moisture for 24 hours and after this period this specimens are marked and removal from the moulds and kept submerged in clear fresh water until testing.

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Precautions

The water curing should be tested 7,14 and 28 days and the temperature of water must be mentioned at 27± 2ºC.

TEST FOR WORKABILITY

SLUMP TEST

Slump test is the most commonly method of measuring consistency of concrete that can be employed either in laboratory or at site of work. However, it is used conveniently as control test and gives an indication of the uniformity of concrete from batch to batch. Repeated batches of the same mix brought to the same slump, will have the same water content and water cement ratio provided the weights of aggregate, cement and admixtures and aggregate grading is within acceptable limits. Additional information on workability and quality of concrete can be obtained by observing the manner in which concrete slumps.

In case of rich mixes, the value is often satisfactory, their slump being sensitive to variations in workability.

RESULTS AND DISCUSSIONS

Compressive strength for cubes:

From the test result the compressive strength has been increased while replacing 15% of cement by metakaolin. The compressive strength for different percentage of replacements are given in *table 1*.

Table 1. compressive strength of concrete for different percentage replacements.

Sl.No:	Mix	7days N/mm^2	14days N/mm^2	28days N/mm^2
1	Normal mix	51.46	53.8	61.65
2	10%replacement	54.38	55.68	63.59
3	15%replacement	57.90	61.66	68.95
4	20%replacement	55.75	58.38	65.81
5	25%replacement	53.11	55.83	61.18

SPLIT TENSILE STRENGTH FOR CYLINDERS FOR 28 DAYS

The split tensile test for cylindrical specimens which was tested after 28 days of curing shows that the strength has been increased at 15% replacement of cement by HRM. The split tensile strength values are given in table 2.

Table 2. Split tensile strength of concrete after 28 days of curing.

Sl.No	Mix	Average load in KN 28 days	Split Tensile Strength (N/mm^2)
1	Normal mix	225	3.18
2	10% Replacement	240	3.4
3	15% Replacement	275	3.89
4	20% Replacement	260	3.68
5	25% Replacement	245	3.47

FLEXURAL STRENGTH FOR BEAMS FOR 28 DAYS

The flexural test for beam specimens which was tested after 28 days of curing shows that the strength has been increased at 15% replacement of cement by HRM. The flexural strength values are given in table 3.

Table 3. flexural strength of concrete after 28 days of curing

Sl.No	Mix	Average load in KN 28 days	Flexural Strength (N/mm^2)
1	Normal mix	11.6	5.8
2	10% Replacement	12.3	6.15
3	15% Replacement	15.3	7.65
4	20% Replacement	14.7	7.35
5	25% Replacement	13.6	6.8

CONCLUSION

The mix design for concrete mix M_{50} is done as per IS (Indian Standard) method by various test data's of materials such as specific gravity of cement, fine aggregate and coarse aggregate and the exposure condition of concrete. The mix proportion for 1 m^3 of concrete is 1:1.44:3.15:0.35.

- The compressive strength of Metakaolin blended concrete cubes increases up to 15% replacement. 15% replacement shows higher values at 28days by 11.84% when compared with normal concrete.
- The ultimate load bearing capacity of the beam shows enhanced results upto 15% replacement. 15% replacement shows higher value by 31.89% when compared with the normal specimen.

REFERENCES

1. Aiswarya S, Dilip C- "A REVIEW ON USE OF METAKAOLIN IN CONCRETE"-Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498,Vol.3, No.3, June 2013.
2. Jiping Bai, AlbinasGailius - "Consistency of fly ash and Metakaolin concrete"- Journal of Civil Engineering and Management ,vol-15, issue-2,2009.
3. ErhanGuneyisi, Mehmet Gesoglu - "Strength, permeability and shrinkage cracking of silica fume and metakaolin concretes" - Construction andBuilding Materials 34, (2012) 120–130.
4. Murali G, Sruthee P - "Experimental study of concrete with metakaolin as partial replacement of cement" - International journal emerging trends in engineering and development, Issue 2 vol. 4(May 2012),ISSN 2249-6149,pp.344-348
5. MadhavBhalachandraKumthekar , Gayatri Sachin Vyas, NageshTatobaSuryawanshi&Maruti Baba More – "Techno – Economical Benefit of Metakaolin Over Microsilica In Developing High Performance Concrete" - Civil Engineering & Construction Review – July 2007 ,issue no :7 , volume 20, pg : 42-50.
6. Shannag .M and Haddad .R –"Properties of Metakaolin High Strength Cementitious Grouts" – Journal of ASTM International (JAI) Volume 2, Issue 7 (July/August 2005) Published Online :8 June 2005
7. Poon.C.S ,Kou.S.C, Lam.L –"Compressive Strength ,Chloride diffusivity and Pore Structure Of High
8. Shetty M.S., "Concrete Technology", Chand and company, 2005.
9. Indian standard- Concrete Mix Proportioning guidelines. IS 10262-2009.