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A COMPARATIVE STUDY ON HARDENED PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN BY EXPERIMENTAL AND ANSYS APPROACH

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Abstract: An increase in demand in concrete is significantly increasing day by day. For general construction, concrete grade of M15 to up to M30 shall be used. For special purposes such as heavy structures as like flyovers, high rise buildings, dams, etc. special concrete should be required which will give the same or higher strength as the conventional concrete. In this project, we decided to design M50 grade of concrete and replace the cement partially with metakaolin by 0%, 10%, 20%, 30%, and 40% by weight of the cement and will check the physical properties such as slump cone test, compressive strength. Concrete mix design is done for M50 grade as per IS code for concrete with and without replacement of cement with metakaolin. The cubes were made of 150mm X 150mm X 150mm size to determine the compressive strength of concrete. Chemical and physical properties of the materials to be used shall be check such as fineness, specific gravity, density, slump cone test and compressive strength test. After experimental work is done, the model will be created in ANSYS software, to determine the strength of the cube after no of load applications. Later, comparison study will be done for strength parameter by experimental and ANSYS model.

Keywords: Metakaolin, partial replacement, concrete mix design, compressive strength, ANSYS model.

1. INTRODUCTION

In concrete, the materials that are generally used are cement, coarse aggregate, fine aggregate and water to make a durable and strong concrete. Among these, cement is the largest used material and while production of cement, it emits large amount of CO2 gas in the atmosphere. In India, cement production is in tones and every tone of cement releases a tone of CO2 gas in the atmosphere. Statistics shows that, by the year 2022, the production of cement will reach 381 million tonnes. For the environmental issue, there is a necessity to reduce the effect of CO2 emission in the atmosphere by reducing the cement use. The alternative material that are waste industrial

by products will be used such as fly ash, metakaolin, GGBS, silica fume, etc. as the replacement to the cement. Metakaolin is looks to be suitable for the replacement as it has smaller particle size and smaller surface area as compare to pozzolana cement. It is used as a supplementary cementitious material (SCM) in replacement with cement.

2. MATERIAL USED

2.1 Cement

Ordinary Portland cement of grade 53 as per IS code IS:12269-1993 is used. It is important material in the concrete mix as it binds the material and provides high strength and durability to structures because of its optimum particle size distribution and superior crystalized structure.

Table 1
Properties Of Cement

Sr. No.	Properties	Obtained values	Standard values
1	Grade of cement	OPC 53	OPC 53
2	Specific gravity	3.15	3.15
3	Initial setting time	130 min	≯ 30 min
4	Final setting time	210 min	≮ 600 min
5	fineness	311 m^2/kg	225 m^2/kg
6	Compressive strength	56.2 Mpa (28 days)	53 Mpa (28 days)

2.2 Coarse Aggregate

The crushed stone aggregate of 20 mm is obtained from crushing plant are used in this project. The properties were determined as per IS 2386 (Part1)-1963.

Table 2
Properties Of Coarse Aggregate

Sr. No.	Properties	Value
1	Specific gravity	2.91
2	Density	1.54
3	Water absorption	1.33%

2.3 Fine Aggregate

The river sand is used as a fine aggregate and the sieve analysis is done using 4.75 mm sieve. The properties of the sample taken was determined by the IS 2386 (Part 1)-1963.

Table 3

Properties Of Fine Aggregate

Sr. No.	Properties	Value
1	Specific gravity	2.64
2	Density	1.61
3	Water absorption	0.71%

2.4 Metakaolin

It is a dehydroxylated form of the clay mineral kaolinite (china clay), is heated to between 600ºC and 800ºC. It is commonly used in the production of ceramics, but is also used as cement replacement in concrete. The metakaolin serve as a valuable supplementary cementitious material (SCM) to enhance the durability of concrete in local aggressive environment. By using proper amount of metakaolin as replacement can increase the strength.

Table 4

Physical Properties Of Metakaolin

Sr. No.	Properties	Obtained value	Standard value
1	Particle size *< 10 microns* *< 2 microns*	 95 ± 2 80 ± 1	
2	Specific gravity	2 ± 0.1	2.60
3	Bulk density	320 ± 20 gm/lt	0.3-0.4 g/cm3

Table 5

Chemical Composition

Sr. No.	Component	Value
1	SiO2	52.8
2	Al2O3	36.3
3	Fe2O3	4.21
4	MgO	0.81
5	CaO	<0.10
6	K2O	1.41
7	LOI	3053

2.5 Water

Water is one of the major constituents of concrete. It will help to bind the materials together in the mix and enhance the properties of the material and also take part in chemical reaction. The amount of water should be calculated before adding into the concrete mix with the help of IS code and according to the mix design and quality should be tested before using as it will affect the properties then such as strength of the concrete. The pH value should be lie between 6 to 8 that indicate the water is free from organic matter.

2.6 Superplasticizer

Superplasticizer should be used to increase the workability of concrete. Superplasticizer should be used to achieve water reduction in the concrete. The superplasticizer added to this mix is Napta SNS base. The amount of superplasticizer is used in this project is 1%.

3. MIX DESIGN

3.1 Mix Proportion

The concrete grade is used is M50 in this project. Calculation is done using code book.

The mix design is done with and without the replacement of metakaolin for $1m^3$ of quantity.

Table 6
Mix Proportion of Nominal Concrete (M1)

Sr. no.	Materials	Quantity (kg/m^3)
1	Cement	441
2	Coarse aggregate	1167
3	Fine aggregate	808
4	Water	150
5	Super plasticizer	4.41
6	w/c ratio	0.34

3.2 Replacement of cement with metakaolin

Metakaolin is partially replaced with cement at 10%, 20%, 30% and 40% by the weight of the cement for $1m^3$ of quantity.

Table 7

Replacement And Addition For Cement

Sr. no.	Mix	Mix proportion	Cement (Kg/m^3)	Metakaolin (Kg/m^3)
1	M1	100% OPC	441	0
2	M2	90% OPC +10% MK	397	44.1
3	M3	80% OPC + 20% MK	352.8	88.2
4	M4	70% OPC +30% MK	308.7	132.3
5	M5	60% OPC + 40% MK	264.6	176.4

4. TESTS ON FRESH CONCRETE

4.1 Slump Cone Test

Slump cone test is carried out on various mix proportions.

Table 8
Slump Test

Sr. no.	Mix proportion	Slump value (mm)
1	M1	140
2	M2	160
3	M3	160
4	M4	170
5	M5	175

5. TEST ON HARDENED CONCRETE

5.1 Compressive strength test

Compressive strength test was carried out on compression testing machine (CTM) and
cube specimen size was 150mm X 150mm X 150mm.

Table 9
Compressive Strength Test

Sr. no	Mix proportion	Compressive strength (Mpa)		
		7 days	28 days	56 days
1	M1	47.62	69.82	71.19
2	M2	43.90	56.44	61.75
3	M3	42.10	48.96	55.33
4	M4	36.08	43.18	51.31
5	M5	26.09	42.90	48.16

6. ANSYS SIMULATION

ANSYS is Analytical System Software grounded on Finite Element Method (FEM). The concrete model is made and simulated in ANSYS. FEM analysis is a way to simulate loading condition on a design and determine design's response to those conditions. ANSYS is the most advanced comprehensive and estimable finite element analysis and design software package available for the structural engineering projects. ANSYS software interpretation 15 will be used to do the analytical work through many runs to get the compression stresses in concrete and displacement in z-direction (the direction of applying the load). The stresses and displacements due to applied load were represented and calculated using ANSYS program.

The load step is taken as the value get through the experimental work at 7, 28 and 56 days applied as a pressure on the upper surface of the cube. The program gives the results for the pressure applied and a run was done until failure. The poisons ratio was taken as 0.18 within the limit of 0.15-0.25 as per given in Textbook of Concrete Technology (P. D. Kulkarni, et al).

Properties assigned to the ANSYS model:

For making and simulating the model in ANSYS, it is necessary to assigned all the material properties required, viz., density, poissons ratio, etc.

Model of cube in ANSYS:

The model was made in geometry tool. For making the model of cube draw the rectangle on X-Y plane and assign the dimension in meter. Then select the extrude command to assign the depth to the model. The size of the model of concrete cube is 0.15mX0.15mX0.15m.

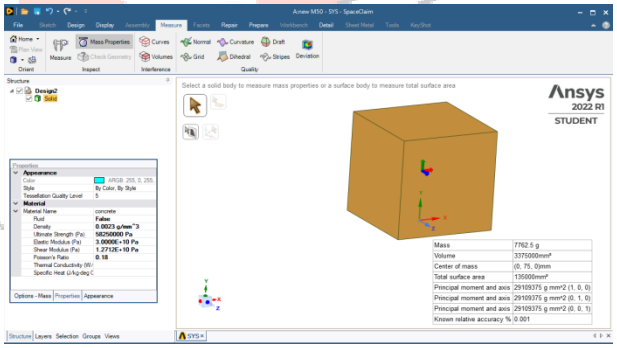

Fig.1 Model of cube in ANSYS

Stresses in ANSYS model:

To obtain the stresses first apply fixed support the model and then pressure on the top surface in Pa (N/m^2). Then apply displacement the model such as X- and Z- constraints as free and Y- constraints as zero. Then solve the model. After that, select normal stresses, Total deformation and evaluate all the results.

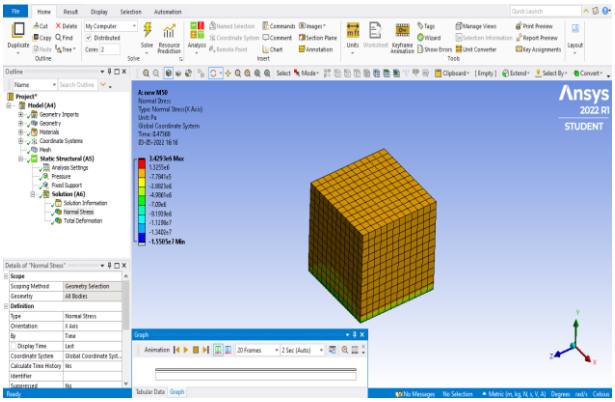

Fig. 2 Model of cube showing normal stresses

Table 10
Results From Ansys

Mix	Days	ANSYS
M1	7	34.91 MPa
	28	51.19 MPa
	56	54.84MPa

7. COMPARISION BETWEEN EXPERIMENTAL AND ANSYS RESULTS

Table 11
Comparative Results Between Experimental And Ansys Simulation

Mix	Days	Experimental results (MPa)	ANSYS results (MPa)
M1	7	47.62	34.91
	28	69.82	51.19
	56	71.19	54.84

8. CONCLUSION

1. Compressive strength of conventional concrete of M50 grade without replacing the cement with metakaolin is increased at 7, 28 and 56 days of curing as per the design limit.
2. Compressive strength at 10% replacement of cement with metakaolin of M50 grade of concrete at 7, 28 and 56 days of curing increased upto design limit.
3. While the replacement level of cement as 20%, 30% and 40% with metakaolin of M50 grade of concrete at 7, 28 and 56 days does not show significant compressive strength as per design strength and hence not acceptable.
4. The experimental results show that the usage of 10% of partial replacement of metakaolin with cement gives the maximum compressive strength.
5. Fresh properties like workability are increases as the percentage of metakaoline increases.
6. From the comparison of experimental values of compressive strength of M50 grade of concrete and ANSYS simulation it shows 26%, 26% and 23% decrease in strength at 7, 28, and 56 days of curing respectively.
7. Experimental results are within the design strength as compared to ANSYS results.

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