Mechanical Properties of High Performance Concrete using Steatite powder

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Abstract**—***Concrete is probably the most extensively used construction material in the world. The addition of mineral admixture in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials. Mineral admixtures such as fly ash, rice husk ash, silica fume etc are more commonly used in the development of HPC mixes. Addition of such materials has indicated the improvements in the strength and durability properties of concrete. In the present investigation, a feasibility study is made to utilize the Steatite powder and Metakaolin as an mineral admixtures in HPC and to investigate the mechanical and durability properties of concrete. The properties of cement, fine aggregate, coarse aggregate and water for M60 grade concrete is arrived. HPC mixes incorporating different percentages of Steatite powder by weight of cement along with 10% of Metakaolin. HPC with mineral admixture of Steatite powder at the replacement levels of 0%, 5%, 10%, 15% & 20% along with industrial by-products of Metakaolin at the replacement level of 10% were studied. The strength characteristics such as compressive strength, tensile strength and flexural strength were investigated to find the optimum replacement of mineral admixture and by-product admixture.*

Keywords—component; formatting; style; styling; insert (key words)

I. INTRODUCTION (*HEADING 1*)

Conventional concrete in India is often produced with four components namely, a) cement and b) Water, together they act as binder. c) The crushed or uncrushed stone and d) natural sand or stone dust. In addition to the above ingredients one or two additional chemicals are also added to the recipe of concrete in order to enhance some properties. Certain materials of mineral origin are also added to concrete to enhance their strength and durability properties of concrete materials such as flyash, silicafume, metakalion which are generally very fine, may be finer than cement, when added to concrete in right proportion can improve the strength and durability of concrete drastically and high strength and high performance concrete is obtained in this manner.

High Performance concrete means concrete which meets special combination of performance and uniformity requirements that cannot be achieved through normal mixing, placing and curing techniques.

HPC is a concrete that has been designed to be more durable and if necessary, stronger than conventional concrete. HPC mixtures are essentially composed of the same materials as conventional concrete mixtures. But the proportions are designed or engineered to provide the strength and durability needed for the structural and environmental requirements of the project.

The demand for Portland cement is increasing significantly in developing countries. Portland cement manufacture is one of the major reasons for CO_2 emissions into atmosphere. It is due to the use of fossil fuels, essential to generate electricity during cement manufacturing process.

The cement industry is one of the two primary product producers of carbon-di-oxide(CO_2), create up to 5% of worldwide man –made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. The CO_2 emission from the concrete is directly proportional to the cement content used in the concrete; 900 kg of CO_2 are emitted for the manufacture of every ton of cement. However, environmental concerns concerning rapid utilization of natural resources and CO_2 emission during cement manufacturing process have brought pressure to reduce cement consumption by the use of cement replacement materials (CRMs).

Pozzolanic additives are the materials or admixtures that can improve concrete properties such as concrete strength, durability and impermeability. Pozzolanic additives are used either as partial substitutes of Portland cement or as an addition. The use of pozzolanas for making concrete is considered efficient, as it allows the reduction of the cement utilization while improving the strength and durability properties of the concrete.

The use of supplementary cementitous materials (SCMs) is essential in developing low cost construction materials for use in developing countries.

Metakaolin differs from other supplementary cementitious materials (SCMs), like fly ash, silica fume in that it is not a by-product of an industrial process; it is manufactured for a specific purpose under carefully controlled conditions. Metakaolin when used as a partial substitute substance for cement, it reacts with $Ca(OH)_2$ one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength. Metakaolin is obtained by thermal creation of kaolin clay. This activation will cause a considerable loss of water in its constitution causing a rearrangement of its structure. To find an adequate thermal activation, the temperature range should be established between 650 to 750ºC. Metakaolin is used in oil well cementing to advance the compressive and flexural strength of the hardened cement. Metakaolin also reduces the hardened cement impermeability to liquids and gases. Hence by partially replacing Portland cement with Metakaolin not only reduces CO_2 emissions but also increases the repair life of buildings.

Chemical formula of Metakaolin is

$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$.

II. Material Details

A. Cement

The most important feature in concrete is Cement. The important criteria for the selection of cement are binding property and it produces microstructure in concrete. OPC of 53 Grade locally available is used in this investigation. The Cement is tested for different properties as per the IS: 4031–1988 and found to be confirming to various specifications of IS: 12269–1987.

Standard Consistency	Specific gravity	Initial setting time in min	Final setting time in min
32.5%	3.13	34	554

TABLE I. PHYSICAL PROPERTIES OF CEMENT

B. Coarse aggregates

The crushed aggregate were collected from the local quarry. The aggregates are locally available. The fractions from 20 mm to 4.75 mm are used as coarse aggregate. Specific gravity of aggregate is 2.75 and Fineness modulus of 6.73. Aggregates are the most mined material in the world.The coarse aggregate used in this experimentation were of 20mm and down size aggregate and tested as per IS: 2386-1963 (I, II and III) specifications. Physical and mechanical properties of coarse aggregates are given in Table II.

Properties	Results	Permissible limit as per IS: 2386-1963
Specific gravity	2.75	In between range 2.6-2.8
Moisture content	0.7%	-
Fineness modulus	6.73	-

TABLE II.PHYSICAL AND MECHANICAL PROPERTIES OF COARSE AGGREGATE

C. fine aggregates

Locally available river sand was used as fine aggregate. The sand used having fineness modulus 3.76 and confirmed to grading zone-II as per IS: 383-1970 specification. Physical properties of fine aggregate are given in Table III.

TABLE III.PHYSICAL PROPERTIES OF FINE AGGREGATE

Property	Results	Permissible limit as per IS: 383-1970
Specific gravity	2.68	Should be between the limit 2.6-2.7
Moisture Content	0.65%	-
Fineness modulus	3.76	-
Grading	Zone-II	-
Bulk density a. Loose b.Compacted	$14.67 kN/m^3$ $16.04 kN/m^3$	-

D. Water

As per IS: 456-200 Portable water was used for concreting .Water to be used for mixing and curing should be free from harmful materials. In this study, tap water was used for both mixing and curing purposes.

E. Natural Steatite

Natural steatite is also called soapstone or soaprock. It is a talc-schist ($Mg_3Si_4O_{10}(OH)_2$) which is a type of metamorphic rock. It is chiefly composed of the mineral talc and is thus rich in magnesium. Soapstone is moderately soft because of its high talc content, talc having a definitional value of 1 on the Mohs hardness scale. Softer grades may experience soapy when touched. There is no permanent hardness for soapstone because the amount of talc it contains varies broadly.

F. Metakaolin

Metakaolin is a chemical segment that forms upon thermal treatment of kaolinite. Kaolinite's chemical composition is Al_2O_3:$2SiO_2$. $2H_2O$ and as a result of thermal treatment in the range of 400-500°C, the water is driven away to form an amorphous aluminosilicate called metakaolin. Metakaolin is white in colour and acts as a pozzolanic material. The reactivity of the metakaolin may also be affected by grinding to a finer particle size. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with Ca(OH)2 one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength.

III. MIX DESIGN

A. Mix Proportion

The aim of mix proportioning is to attain required strength at optimum cost and to enhance the critical, noncritical properties. Mix proportion selection is often best handled by using ACI method combined with EFNARC Guide lines.Mix design is done as per ACI method for M60grade concrete of code ACI 211.4R-93.

Mix	Cement kg/m³	F.A kg/m³	C.A kg/m³	Water litre/ m³
1:1.2:2.62	496.640	606.85	1302.34	151. 475

TABLE V. MIX PROPORTIONS

B. Combinations of Mixes

Mix designation	Mix combinations
CC	C+S+CA
HPC-SM1	C+5%SP+10%MK
HPC-SM2	C+10%SP+10%MK
HPC-SM3	C+15%SP+10%MK
HPC-SM4	C+20%SP+10%MK

TABLE VI. MIX COMBINATIONS

IV. CASTING AND CURING OF SPECIMENS

Concrete testing specimens of required number were casted and cured for 28days, which is correspond to M60 grade of concrete with water binder ratios 0.32 and replacement of cement by Steatite powder for various percentages viz 5,10,15 and 20 along with 10% of Metakaolin. Concrete specimens of size 150 x 150 x 150 mm were casted to find residual compressive strength and size of 100m x 100mm x 100mm were casted to find percentage weight loss after 28 and 56 days of hydrochloric acid immersion.

The specimens were cast in well lubricated moulds. Concrete were placed on the mould and compacted thereafter and left at room temperature for 24hrs before being transferred into the curing tank. After 24 hours, they wereimmersed in water curing tanks until their testing ages.

V. EXPERIMENTAL PROCEDURE

A. Compressive Strength Test:

The cube compressive strength results at the 28 days for different replacement levels of Steatite powder along with 10%
Metakaolin of cement. Three specimens were casted for each mix and average value was taken. Specimens were tested on compressive testing machine as per IS 516:1959.

Compressive strength = P/A

Where,

P = Maximum load in N applied to the sample

A = Cross sectional area of the specimen in mm^2

B. Split Tensile Strength:

It is an indirect experiment to determine the tensile strength of cylindrical specimens. It was carried out in compression testing machine as per IS 5816:1999.Three specimens were casted for each mix designation and average value was taken.
Split tensile strength test for all mix variations were done for 7 & 28 days and test results obtained are tabulated in Table VIII.

F = 2P/LD

Where, P = Load in N

L = Length of the specimen in mm

D = diameter in mm

C. Flexural strength:

It is used to determine of modulus of rupture an unreinforced concrete beam to resist the failure. Flexural strength is depends on the type, size and volume of coarse aggregate used. Three specimens were casted for each mix and average value was taken. Split tensile test was carried out in compression testing machine as per IS 5816:1999.

Flexural strength F = PL/BD^2 in N/mm^2

Where,

P = Ultimate load applied to the specimen in N

L = Length of specimen between supports in mm

B = Breadth of the specimen in mm

D = Depth of the specimen in mm

D Acid Attack:

The concrete cube specimens of different concrete mixtures of size 100 mm were cast, and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube sample were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 90 days after 28 days of curing. Hydrochloric acid with pH of about 2 at 5% weight of water was added to water, in which the concrete cubes were stored. The pH was maintained throughout the period of 90 days. After 90 days of immersion, the concrete cubes were taken out of acid water. Then, the specimens were tested for compressive strength. The resistance of concrete to acid attack was found by the Percentage loss of weight of specimen and the Percentage loss of compressive strength on immersing concrete cubes in acid water.

E. Sulfate Attack Test:

The resistance of concrete to sulfate attack was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulfate water.

Sulphate attack test was carried out by using the concrete cubes of size 150mmX150mmX150mm. The concrete cubes of 150 mm size after 28 days of water curing and dried for 1 day were immersed in 5% $MgSO_4$ and 5% $MgSO_4$ added water for 90 days. The concentration of sulfate water was maintained throughout the period. After 90 days immersion period, the concrete cubes were removed from the sulfate waters and after wiping out the water from the surface of cubes tested for compressive strength following the procedure prescribed in IS: 516-1959. The sulphate attack is obtained from parameters such as loss in mass and loss in strength. This type of accelerated test of finding out the loss of compressive strength is used for determining for assessing sulfate resistance of concrete.

Weight loss (%) = ((W1 - W2)/W1) x 100

V. EXPERIMENTAL RESULTS

TABLE VII. Compressive Strength Test Results

Mix Designation	Compressive Strength in N/mm2	
	7 days	28 days
CC	40.29	61.62
HPC-SM1	42.95	65.03
HPC-SM2	43.55	68.43
HPC-SM3	**46.21**	**72.29**
HPC-SM4	44.22	69.48

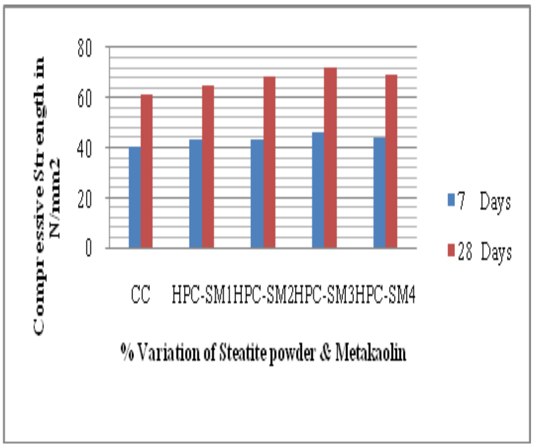

Fig. 1 Comparison of 7, 28 days compressive strength of conventional concrete and Steatite powder admixed concrete

TABLE VIII. Split Tensile Strength Test Results

Mix Designation	Split Tensile Strength in N/mm2	
	7 days	28 days
CC	4.16	5.72
HPC-SM1	4.68	6.43
HPC-SM2	4.90	7.32
HPC-SM3	**5.11**	**7.87**
HPC-SM4	4.73	7.23

Fig. 2 Comparison of 7, 28 days split tensile strength of conventional concrete and Steatite powder admixed concrete

Mix Designation	Flexural Strength in N/mm2
	28 days
CC	5.32
HPC-SM1	5.58
HPC-SM2	5.75
HPC-SM3	**5.90**
HPC-SM4	5.81

TABLE IX. Flexural Strength Test Results

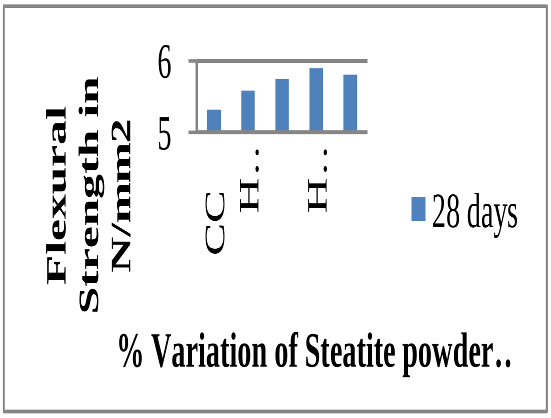

Fig. 3 28 days Flexural strength of conventional concrete and Steatite powder admixed concrete

Mix Designation	Weight before immersion in acid W1 (kg)	Weight after immersion in acid (kg) For 28 days	%loss in Mass for 28 days	%loss in Mass for 56 days
CC	8.416	8.315	1.200	1.307
HPC-SM1	8.652	8.589	0.728	0.797
HPC-SM2	8.407	8.352	0.654	0.713
HPC-SM3	**8.722**	**8.673**	**0.562**	**0.676**
HPC-SM4	8.561	8.486	0.876	0.934

TABLE X. Results of acid resistance test

Mix Designation	Weight before immersion in acid (kg)	Weight after immersion in acid (kg) For 28 days	%loss in Mass for 28 days	%loss in Mass for 56 days
CC	8.56	8.45	1.29	1.40
HPC-SM1	8.57	8.51	0.70	0.93
HPC-SM2	8.26	8.2	0.73	0.85
HPC-SM3	**8.48**	**8.44**	**0.47**	**0.71**
HPC-SM4	8.42	8.35	0.83	0.95

TABLE XI. Results of Sulphate resistance test

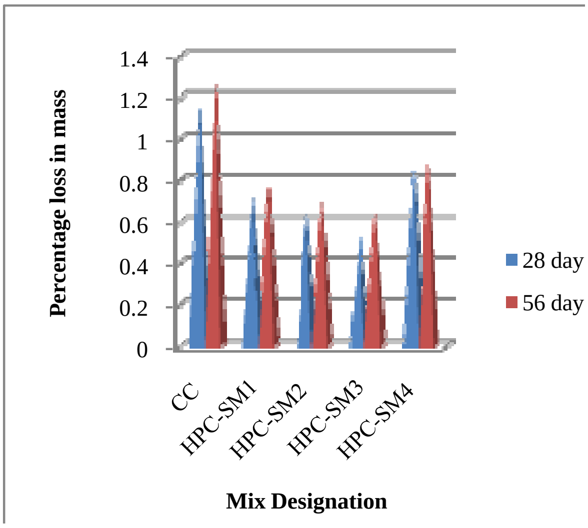

Fig. 4 Weight Loss Due To Sulphate Attack

VI. CONCLUSIONS

1. The compressive strength of concrete for 7&28 days of curing with varying % replacement of Steatite powder and Metakaolin has been increased and have achieved target strength.
2. The split tensile strength of concrete for 7&28 days of curing with varying % replacement of Steatite powder and Metakaolin has been increased and have achieved target strength.
3. The flexural strength of Metakaolin based concrete maintained good result.
4. Concrete mix variations with % replacement of Steatite powder and Metakaolin have showed lower values in case of acid resistance and density of concrete is increased as % replacement of Steatite powder and Metakaolin as increased.

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