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RESEARCH ARTICLE

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EFFECTS ON CEMENT BLENDS OF CONCRETE CONTAINING METAKAOLIN, RICE HUSK ASH AND NATURAL STEATITE POWDER

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ABSTRACT

The aim of this study is to investigate the influence of partial replacement of cement with Metakaolin(5%), Rice husk ash(2.5%,5%) and Natural steatite powder(5%,10%) and finding the flexural strength, compressive strength and split tensile strength for 28 and 56 days . The test result reveals that the mix M5(5% metakaolin), R5(5% Rice husk ash) and M5R5NSP5(5% metakaolin, 5%Rice husk ash, 5% natural steatite powder) give the best improvement in the strength of concrete specimens.

The beam M5 gives flexural strength of 8 N/mm2 for 28 days which is 33% more than control M20 specimen and 8.2 N/mm2 for 56 days which is 28.5% more than control. The increase in flexural strength for the beam R2.5 is about 20% for 28 days and 15% for 56 days. The increase in flexural strength for the beam M5R5NSP5 is about 10% for 28 days and 10.5% for 56 days. The cube M5 gives compressive strength of about 34% more than the control for 28 days and 12% more than control for 56 days. The cube R2.5 gives compressive strength 26% more than control for 28 days and 7% more than control for 56 days and the cube M5R5NSP5 gives compressive strength of 28% more than control for 28 days and 9% more than control for 56 days. The cylinder M5 gives split tensile strength of about 39% more than the control for 28 days and 19% more than control for 56 days. The cylinder R2.5 gives strength 30% more than control for 28 days and 19.8% more than control for 56 days and the cylinder M5R5NSP5 gives split tensile strength of 33% more than control for 28 days and 22% more than control for 56 days.

Keywords—Concrete; Rice husk ash; Natural Steatite powder; Metakaolin;

INTRODUCTION

The use of industrial and biogenic wastes in concrete as supplementary cementing materials is the present vital issue to obtain a sustainable environmental solution, save energy and natural resources. Some of the commonly used supplementary pozzolanic and cementing materials are rice husk ash (RHA), silica fume, ground granulated blast furnace slag, fly ash and ash from timber etc. These wastes can be found as natural materials, by-products or industrial wastes; these materials are also obtained with requiring low cost, energy and time. Unfortunately, having technical benefits, most of those wastes are dumped into environment without any commercial return.

However, ordinary Portland cement (OPC) is a most important ingredient for concrete construction of any type of structures. Nowadays, 5 billion tons of concrete is produced annually and cement production is expected to rise to nearly 2 billion tons by year 2010. The production of 1 ton of cement contributes to about 1 ton of CO_2 into the atmosphere; approximately 7% world's carbon dioxide (CO_2) emission is accountable for production of OPC. The present crucial issue - the global warming - is caused for the production of greenhouse gases (CO_2).

Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration. Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability.

Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together. Less calcium hydroxide and more cementing compounds means stronger concrete. Metakaolin, because it is very fine and highly reactive, gives fresh concrete a creamy, nonsticky texture that makes finishing easier. Efflorescence, which appears as a whitish haze on concrete, is caused when calcium hydroxide reacts with carbon dioxide in the atmosphere.

Steatite is a type of metamorphic rock, largely composed of talc ore, rich in magnesium. It is composed of hydrated magnesium silicate: $Mg_3Si_4O_{10}(OH)_2$. Steatite is the softest known mineral and listed as 1 on the Mohs hardness scale. It is already used in paint industry, particularly in marine paints and protective coatings. This is used in ceramics due to its high resistivity, very low dielectric loss factor, and good mechanical strength. Addition of steatite powder increases the viscosity and mechanical properties of feed stock.

Indian steatite, mined in Rajasthan and Andhra Pradesh, is comparable with the best quality available in other countries. The steatite mined in India, with more than 92% brightness, less than 1% Fe_2O_3, and less than 1.5% $CaCO_3$, is preferred for exports. Indian steatite is considered to be the second best in the world next to Italian steatite. The UFSP used in this experiment develops M-S-H gel; hence the comparative study of C-S-H and M-S-H is vital. On account of the basic structural difference between the two gel types, M-S-H and C-S-H are essentially immiscible.

About 500 million tons of paddy is produced in the world annually. Rice husk is the outer covering of this paddy. The ash obtained by burning this rice husk is known as RHA. As a waste material, rice husk is produced in agricultural and industrial processes. After incineration, only about 20% weight of rice husk are transformed to RHA. Still now, there is no effective application of RHA and is usually dumped into water supplementary cementing materials has become an streams or as landfills causing environmental pollution of air, water and soils.

The use of this by-product is an environmental friendly method of disposal of large quantities of material. It is well known that concrete has gained popularity in the construction industry due to its satisfactory performance in strength requirements, its easiness in construction and better durability in normal environment.

Pozzolanic activity

It is a measure for the degree of reaction over time or the reaction rate between a pozzolans and Ca^{2+} or $Ca(OH)_2$ in the presence of water. The rate of pozzolanic reactions is dependent on the intrinsic characteristics of the pozzolans such as the specific surface area, the chemical composition and the active phase content. Physical surface area is not considered as being part of the pozzolanic activity, because no irreversible molecular bonds are formed in the process.

Particle properties

Prolonged grinding results in an increased pozzolanic activity by creating a larger specific surface area available for reaction. Moreover, grinding also creates crystallographic defects at and below the particle surface. The dissolution rate of the strained or partially disconnected silicate moieties is strongly enhanced. Even materials which are commonly not regarded to behave as a pozzolans such as quartz, can become reactive once ground below a certain critical particle diameter.

Reaction conditions

The rate of pozzolanic reaction can also be controlled by external factors such as the mix proportions, the amount of water or space available for the formation and the growth of hydration products and temperature of reaction. Therefore typical blended cement mix design properties such as the replacement ratio of pozzolans for Portland cement, the water to binder ratio and the curing conditions strongly affect the reactivity of the added pozzolans.

Review of literature

Malhotra.V.M et al., 1996 studied about the important contribution of RHA in the pozzolanic activity that can be formed due to amorphous phase substance. Calcium hydroxide Ca(OH) and calcium silicate hydrates C-S-H are the major hydration and reaction products for RHA paste. The incorporation of RHA in concrete reduces its porosity and the amount of Ca(OH)2 in the interfacial zone; the width of interfacial zone between aggregate and the cement paste is also reduced as compared to OPC paste.Sabir.B.B et al., 2001 carried out a study on the utilization of Metakaolin as pozzolanic ssmaterial for mortar and concrete and mentioned about the wide range application of Metakaolin in construction industry .They reported that the usage of Metakaolin as a pozzolana will help in the development of early strength and some improvement in long term strength. They mentioned that Metakaolin alters the pore structure in cement paste mortar and concrete and greatly improves its resistance to transportation of water and diffusion of harmful ions which lead to the degradation of the matrix.Jian-Tong Ding et al., 2002 experimentally found out the effects of Metakaolin and Silica Metakaolin on concrete. Eight mix proportions were used to produce high-performance concrete, where Metakaolin replaced either cement or sand of 10% or 20% by weight of the control cement content. The strength development of Metakaolin concrete was evaluated using the efficiency factor (k value). With regard to strength development the poor Greek Metakaolin and commercially obtained Metakaolin yielded the same results. The replacement with cement gave better results than that of sand. When Metakaolin replaced cement, its positive effect on concrete strength generally started after 2 days where as in case of sand it started only after 90 days. Both Metakaolin exhibited very high k-values (close to 3.0 at 28 days) and are characterized as highly reactive pozzolanic materials that can lead to concrete production with excellent performance.Feng et al., 2004 experimentally studied the effects on Cement replacement by rice husk ash accelerates the early hydration of C3S. The increase in the early hydration rate of C3S is attributed to the high specific surface area of the rice husk ash. Pacheco Torgal.F et al., 2011 determined the effect of Metakaolin and Fly ash on strength and durability of concrete. The durability was found by three methods namely water absorption, oxygen permeability and concrete resistivity. They reported that partial replacement of Portland cement by 30% fly ash leads to serious decrease in early age compressive strength than the reference mix made with 100% Portland cement. The use of hybrid of them at 15% Fly ash and 15% Metakaolin based mixtures resulted in minor strength loss at early stages but showed outstanding improvement in durability. Sudalaimani.K et al., 2014 effects on the setting time and pozzolanic activity of cement when ultra fine natural steatite powder is used as replacement for cement. Initial setting time, final setting time, and mortar cube strength were studied, due to the replacement of ultra fine natural steatite powder with cement at 5%, 10%, 15%, 20%, and 25% by mass of cement. Scanning electron microscopy and X-ray diffraction were applied to investigate the microstructural behavior and chemical element distribution inside cement-binder matrix. Results indicate that the length of dormant period is shortened. Dojkov.I et al., 2013 experimentally studied the reaction between Metakaolin-Ca(OH)2-water and Fly ash-Ca(OH)2-water. It was clear that during the initial period of curing (up to 7 days), Metakaolin combined lime with a very high rate. This indicated that the overall rate of the reaction taking place in early age of Portland cement -Metakaolin concretes and cement mortars was limited by the hydration of the cement phases. The reaction between Fly ash-Ca(OH)2-water was taking place at a moderate rate in the initial age as compared with Metakaolin-Ca(OH)2-water. The experimental results justified the possible combined use of Metakaolin-Fly ash-Portland cement in concrete industry.

Experimental Program

Materials Used

CEMENT

Cement must develop the appropriate strength. It must represent the appropriate rheological behaviour. Generally same type of cements has quite different rheological and strength characteristics, particularly used in combination with admixtures and supplementary cementing materials. The ingredients in the cement play a specific role in different properties of cement.

The ordinary Portland cement is for the most important type of cement.The OPC was classified into their grades namely 33 grades, 43 grades, 53 grades depending upon the strength of cement at 28days when tested as per IS 4031:1988.

The properties of cement were tested and the values are given below.

33 Grade – 33N/mm2 @ 28 days.

43 Grade – 43N/mm2 @ 28 days.

53 Grade – 53N/mm2 @28 days

FINE AGGREGATE

The aggregate whose size is 4.75mm and less is considered as fine aggregate. Locally available sand is used as fine aggregate. The particles of aggregate fit together in the mix, as influenced by gradation, shape and surface texture has an important effect on the workability and finishing characteristic of fresh concrete and on the properties of hardened concrete. A sample of the well graded aggregate containing minimum voids, which means it is provide increase the strength, lower the shrinkage and increase the durability. The grade of aggregate determined from sieve analysis test.

Particle size distribution

The percentage of various sizes of particles in a given dry soil sample is found by a particle size analysis or mechanical analysis. By mechanical analysis is meant the separation of a soil into its different size fractions.

Sieve analysis

In the BS and ASTM standards, the sieve sizes are given in the terms of the number of openings per inch. The number of openings per square inch is equal to the square of number of sieve. In the Indian Standard (IS: 460-1962), the sieves are designated by the sizes of the aperture in mm.

The complete sieve analysis can be divided into two parts – the coarse analysis and the fine analysis. An over dried sample of soil is separated into two fractions by sieving it through 4.75 mm IS sieve. The portion retained is termed as gravel fraction and it kept for coarse analysis, while the portion passing through is subjected to fine analysis. The following sets of sieves are used for coarse sieve analysis :IS :100, 63, 20, 10 and 4.75 mm.The sieves used for fine sieve analysis are :2mm, 1mm, 600, 425, 300, 212, 150, and 75 micron IS sieves.

Sieving is performed by arranging the various sieves one over the other in the order of their mesh opening –the largest aperture sieve being kept at the top and the smallest aperture sieve at the bottom .A receiver is kept at the bottom and the cover is kept at the top of the whole assembly. The soil sample is put on the top sieve and the whole assembly is putted on the sieve shake machine .The amount of shaking depends on the shape and number of particles. At least 10 minutes of shaking is desirable for soils of smaller particles. The portion of soil sample retained on each sieve is weighted.

The percentage of soil retained on the each sieve is calculated on the basis of total mass of soil sample taken and from the results. The percentage passing through each sieve is calculated. The Properties of fine aggregate are given in the table I

TABLE I. **PROPORTIES OF FINE AGGREGATE**

S.No	Parameter	Result
1	Specific gravity	2.61
2	Fineness modulus	2.58

COARSE AGGREGATE

As coarse aggregate in concrete occupy 35 to 70% of the volume of the concrete. Smaller sized aggregates produce higher concrete strength.

TABLE II. **PROPERTIES OF COARSE AGGREGATE**

S.No	Parameters	Result
1	Specific gravity	2.75
2	Fineness Modulus	3.77
3	Water absorption in (%)	0.15

Usually an aggregate with specific gravity more than 2.55 and absorption less than 1.5% can be regarded as being of good quality. The coarse aggregate are produced by the disintegration of rock and by crushing rock. Coarse aggregate are usually those particles which are retained on an IS 4.75mm sieve. Stones which are hard and durable such as granite, basalt, and quartzite provide good coarse aggregate. The property of coarse aggregate is given in table II.

WATER

Water is to be used in the concrete work should have following properties. It should be free from injurious amount of oil, acids, alkalis or other organic impurities. It should be free from iron, vegetables matter or any other type of substance which are likely to have adverse affect on concrete or reinforcement It should be quite satisfactory for drinking purpose which is used in mixing of concrete.

NATURAL STEATITE

Natural steatite is also called soapstone or soaprock. It is a talc-schist (Mg3Si4O10(OH)2) which is a type of metamorphic rock. It is largely composed of the mineral talc and is thus rich in magnesium. Soapstone is relatively soft because of its high talc content, talc having a definitional value of 1 on the Mohs hardness scale. Softer grades may feel soapy when touched, hence the name. There is no fixed hardness for soapstone because the amount of talc it contains varies widely.

RICE HUSK ASH

Rice husk ash is an agricultural waste material can be a highly reactive pozzolanic material produced by controlled burning of rice husk. Reactivity of rice husk ash is attributed to its high content of non crystalline silica and to its very large surface area governed by the cellular structure of the particles. The reactivity of the pozzolanic material can also be increased by increasing the fineness of the materials. When burning temperature exceeds 600o C partially changing silica to cristoballite, quartz and trydimite. For crystalline material grinding is especially important.

Pozzolanic activity of RHA is influenced by:

a) silica content
b) silica crystallization phase
c) size
d) surface area of ash particles

In addition, ash must contain only a small amount of carbon. Even for higher burning temperature with some crystalline silica, reactive RHA could be obtained by fine grinding. In order to ensure the quality of ash, a suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk. The presence of unburnt carbon can adversely affect the reactivity. Besides, duration and type of incineration are the important parameter influencing the reactivity of RHA as pozzolans.

METAKAOLIN

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles. The quality and reactivity of metakaolin is strongly dependent of the characteristics of the raw material used. Metakaolin can be produced from a variety of primary and secondary sources containing kaolinite

Need for metakaolin

i. Boost compressive strength
ii. Make finishing easier
iii. Reduce efflorescence
iv. Mitigate alkali-silica reaction
v. Maintain color, especially in white concrete.

TABLE III. ***CHEMICAL COMPOSITION OF BINDERS***

Composition	Cement (%)	Metakaolin (%)	Rice Husk Ash (%)	Natural steatite (%)
Cao	60-65	0.37	0.87	0.2
Sio_2	20-25	52.37	86.75	62.67
Al_2O_3	4-8	42.87	1.23	0.24
Fe_2O_3	2-4	1.12	2.09	0.3
MgO	1-3	0.25	1.02	33.26
Na_2O	0.1-0.5	0.12	1.16	-
SO_3	1-2	0.55	0.54	-

Experimental work

OBJECTIVE

The main objective of this work is to study the suitability of rice husk ash, metakaolin, natural steatite powder as a pozzolanic materials for cement replacement in concrete. However it is expected that the use of pozzolanic materials will improve the strength properties of concrete.

In this study initially the preliminary tests for cement, fine aggregate, coarse aggregate is conducted and the properties of the material are determined. A concrete mix design for M20 grade was developed using IS10262-1982.The cement is replaced with metakaolin(5%), Rice Husk Ash(2.5%, 5%) and Natural Steatite powder(5%, 10%).Casting and curing of samples.Testing the samples for flexural strength, compressive strength and split tensile strength at the age of 28 and 56 days.

TABLE IV. *COMPOSITION OF MATERIALS ADDED IN CEMENT:*

S.No	Cement (Kg)	Metakaolin (Kg)	Rice husk ash (Kg)	Natural Steatite (Kg)
1	455.05	23.95	-	-
2	467.03	-	11.97	-
3	455.05	-	23.95	-
4	455.05	-	-	23.95
5	431.1	-	-	47.9
6	443.08	23.95	11.97	-
7	431.1	23.95	23.95	-
8	431.1	23.95	-	23.95
9	407.15	23.95	-	47.9
10	419.13	23.95	11.97	23.95
11	395.18	23.95	11.97	47.9
12	407.15	23.95	23.95	23.95
13	383.2	23.95	23.95	47.9

CASTING OF CONCRETE CUBES, CYLINDERS AND BEAMS

The test moulds are kept ready before preparing the mix. Tighten the bolds of the moulds carefully. Then the moulds are cleaned and oiled on all contact surfaces of the moulds and place the moulds on the vibrating table. The concrete is filled into the moulds in layers and then vibrated. The top surface of concrete is struck off level with a trowel. The number and date of casting are put on the top surface of the cubes, cylinders and moulds.The cubes of size 100mm x 100mm and cylinder of size 150mm x 300mm and the beams of 100mm x 500mm are casted.

TESTING ON CEMENT

Fineness test

The fineness of cement has an important bearing on the rate of hydration, rate of gain strength and also on the rate of evolution of heat. Finer cement offer greater surface area for hydration and hence faster the development of strength.

Fineness of cement is tested in two ways:

a. By sieving

b. By determination of specific surface by air permeability apparatus

Sieve test:

Weight of cement taken W1 = 100g

Weight of cement retained on IS Sieve No. 9 W2 = 4g

% of retained = (W2 / W1) X100

= (4 /100) X100

= 4%

Specific gravity test

Empty weight of specific gravity bottle = 60(g)

Kerosene, v1 = 0ml

Cement v = 60(g)

Kerosene + Cement v2= 19

S.G =v/(v2− v1)

Specific Gravity of cement =3.15

Initial setting and Final setting time of cement

Weight of cement = 400 g

Normal consistency of cement = 31%

Needle used = 1 mm square

Amount of water= 0.85 x P/100

= 0.85 x31/10 = 26.35%

Adding of water = (26.35 x 400)/100 = 105.4 ml

Final setting time = 500 (mts)

TABLE V. **INITIAL SETTING TIME TEST**

S.No	Time	Penetrating index reading	Remarks
1	0	0	
2	5	0	
3	10	0	
4	15	0	Initial setting time =30 mts
5	20	2	
6	25	4	
7	28	4	
8	31	5	

TESTING ON AGGREGATE

Fineness modulus of fine aggregate

Fineness modulus is index for fineness or coarseness of material. It is an empirical factor obtained by adding the cumulative percentage of aggregate retained on each of the standard sieves.

TABLE VI. **FINENESS MODILUS OF FINE AGGREGATE**

S.No	IS Sieve No	Weight retained gm	% Weight retained	Cumulative % Weight retained	% passing
1	4.75 mm	60	1.2	1.2	98.8
2	2.36 mm	535	10.7	11.9	88.1

3	1.18 mm	1100	22	33.9	66.1
4	600 µ	1230	24.6	58.5	41.5
5	300 µ	1430	28.6	87.1	12.9
6	150 µ	235	4.7	91.8	8.2
7	75 µ	265	5.3	97.1	2.9
8	Pan	145	2.9	100	0

Fineness modulus of fine aggregate = cumulative % weight retained /100 = 258 /100 = 2.58

Fineness modulus of coarse aggregate

TABLE VII. **FINENESS MODULUS OF COARSE AGGREGATE**

S.No	Sieve size mm	Weight retained (gm)	% wt Retained	Cumulative % wt Retained	% passing
1	37.5	0	0	0	100
2	25	30	0.6	0.6	99.4
3	22.4	548	10.96	11.56	88.4
4	16	3080	61.6	73.16	26.7
6	6.7	372	7.44	99.6	26
7	6.3	16	0.32	100	0

Fineness modulus of coarse aggregate = 377.8/100 =3.77

Testing of concrete specimens

Compressive Strength

It is the capacity of the material to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation. Compressive strength is a key value for design of structures.

Test for compressive strength of concrete cubes

In this test, cubes of 10cm x 10cm x 10cm are used. These specimens are tested by compression testing machine after 28 and 56 days curing. Load should be applied gradually at the rate of 140 Kg/cm2 per minute till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength. The test set up for the compressive strength is shown in the figure 1

Compressive strength = Maximum load/ Area

Fig 1 compressive strength test set-up

Flexural Strength

Flexural strength is the measure of tensile strength of concrete. It is the measure of the concrete beam to resist failure in bending. The flexural strength is also expressed as modulus of rupture in Mpa, bend strength or fracture strength

Test for flexural strength of concrete beams

The value of modulus of rupture depends on the dimensions of the beam and manner of loading. Flexural strength depends on the type, size and volume of coarse aggregate used and is determined by standard test method of four point loading (ASTM C 78) or centre point loading (ASTM C 293).In this study the four point loading method is used. The test set up for the flexural strength is shown in the figure 2

Fig 2 flexural strength test set-up

Formula: $Fb = PL/bd^2$

Split Tensile Strength

Tensile strength of concrete is to determine the load at which the concrete members may crack. The cracking is a form of tensile failure.

Test for split tensile strength of concrete cylinders

The load at which splitting of specimens take place shall then be recorded. The split tensile strength of the specimen calculated from the following formula.

The flexural strength test set up is shown in the figure 3

Fig 3 split tensile strength set-up

Flexural strength is often measured on flexural testing machine. Two points loading is applied on the centre of the beam .The specimen is then placed in the machine in such a manner that the load is applied to the uppermost surface as cast in the mould. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surface of the specimen and the rollers. The load is applied without sock and increasing continuously. The load is increased until the specimen fails, and the maximum load is applied to the specimen during the test is recorded. Fig 4 shows the flexural strength test setup of the concrete beam.

The flexural strength $F_b = Pl/(bd^2)$

Fig 4 Flexural strength test set-up

Split tensile strength test

Cylindrical test specimens have a length equal to twice the diameter. There are 15cm in diameter and 30 cm long were casted. For each mixes 3 specimens were casted and the average of the mixes is taken for the calculation. Draw diametrical lines on two ends of the specimen so that they are in the same axis plane. The diameter of specimen to the nearest 0.2 mm by averaging the diameters of the specimen lying in the plane of remarked lines measured near the ends and the middle of the specimen. The length of specimen also shall be taken be nearest 0.2 mm by averaging the two lengths measured in the plane containing pre marked lines.

Place the specimen on the testing machine and align it so that the lines marked on the end of the specimen are vertical and centred over the plate. The assembly is positioned to ensure that lines marked on the end of specimen are vertical and the projection of the plane passing through these two lines interest the centre of the platen. Apply the load without shock and increase it continuously at the rate to produce a split tensile strength of approximately 1.4 to 7.5 N/mm2/min, until no greater load can be sustained. Record the maximum load applied to specimen. Fig 5 shows the split tensile strength test setup of the cylinder.

The split tensile strength $T = 2P/(\pi ld)$

Fig 5 Split tensile strength test set-up

Results and Discussion

The result of flexural strength, compressive strength and split tensile strength for various mixes are discussed.

TABLE VIII. STRENGTH PROPERTIES OF CONCRETE MIXES

Mix	Flexural strength N/mm^2		Compressive strength N/mm^2		Split tensile strength N/mm^2	
	28days	56days	28days	56days	28days	56days
C	6	6.4	26.7	35.9	3.4	4.03
M5	8	8.2	35.96	40.48	4.75	4.83
R2.5	4	4.8	33.7	38.76	4.43	4.7
R5	7.2	7.4	22.96	36.24	3.83	4.23

NSP5	6.2	6.4	28.25	29.73	4.03	4.6
NSP10	4.8	5	21.5	25.63	3.85	4.03
M5R2.5	4	4.8	27.9	21.86	3.86	4.07
M5R5	6.4	6.6	31.64	28.89	3.66	4.21
M5NSP5	3.2	3.4	26	21.47	3.6	4.11
M5NSP10	6.4	6.4	27.6	28.05	4.05	4.23
M5R2.5NSP5	4	4.2	24.98	30.38	3.57	3.98
M5R2.5NSP10	5	5	28.25	25.52	3.18	3.78
M5R5NSP5	6.6	6.8	34.3	39.3	4.53	4.92
M5R5NSP10	6	5.6	26.33	28.47	4.22	4.68

Flexural strength

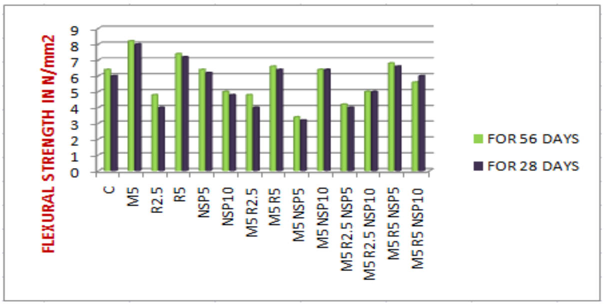

Fig 6 flexural strength for beams

On comparing all the specimens M5, R2.5, M5R5NSP5 give best results in flexural strength. The specimen M5(5% metakaolin) gives flexural strength of about 33% more than the control for 28 days and 28.5% more than control for 56 days. The specimen R2.5(2.5% rice husk ash) gives flexural strength 20% more than control for 28 days and 15% more than control for 56 days and the specimen M5R5NSP5(5% metakaolin, 5% rice husk ash, 5% natural steatite) gives flexural strength 10% more than control for 28 days and 10.5% more than control for 56 days.

COMPRESSIVE STRENGTH

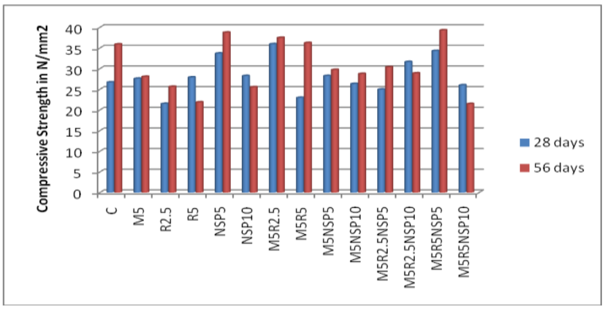

Fig 7 compressive strength for cubes

From fig 7 the result of compressive strength of specimen M5, R2.5, M5R5NSP5 give best results for 28 and 56 days. The specimen M5(5% metakaolin) gives compressive strength of about 34% more than the control for 28 days and 12% more than control for 56 days. The specimen R2.5(2.5% rice husk ash) gives compressive strength 26% more than control for 28 days and 7% more than control for 56 days and the specimen M5R5NSP5(5% metakaolin, 5% rice husk ash, 5% natural steatite) gives compressive strength 28% more than control for 28 days and 9% more than control for 56 days.

SPLIT TENSILE STRENGTH

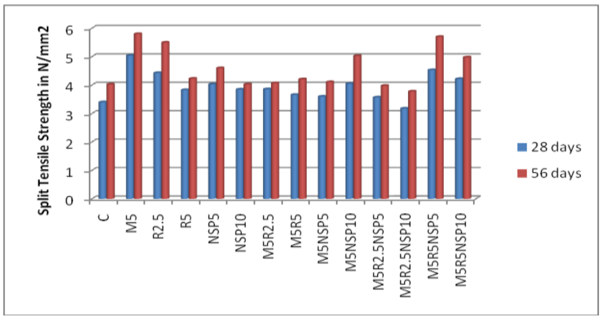

Fig 8 split tensile strength for cylinders

From the figure 8 the specimen M5(5% metakaolin) gives split tensile strength of about 39% more than the control for 28 days and 19% more than control for 56 days. The specimen R2.5(2.5% rice husk ash) gives strength 30% more than control for 28 days and 19.8% more than control for 56 days and the specimen M5R5NSP5(5% metakaolin, 5% rice husk ash, 5% natural steatite) gives strength about 33% more than control for 28 days and 22% more than control for 56 days.

Conclusion

The influence of metakaolin, rice husk ash and natural steatite powder used as partial replacement of cement on the behavior of concrete. On the basis of result it can be concluded that

The beam M5(5% metakaolin) gives high flexural strength compare to control M20 specimen. The increase in flexural strength is about 33% for 28 days and 28.5% for 56 days. The increase in flexural strength for the beam R5(5% Rice husk ash) is about 20% for 28 days and 15% for 56 days. The increase in flexural strength for the beam M5R5NSP5(5% metakaolin, 5% rice husk ash, 5% natural steatite powder) is about 10% for 28 days and 10.5% for 56 days.

In compressive strength test, the cube M5 gives compressive strength of about 34% more than the control for 28 days and 12% more than control for 56 days. The cube R2.5 gives compressive strength 26% more than control for 28 days and 7% more than control for 56 days and the cube M5R5NSP5 gives compressive strength of 28% more than control for 28 days and 9% more than control for 56 days.

In split tensile strength test, the cylinder M5 gives split tensile strength of about 39% more than the control for 28 days and 19% more than control for 56 days. The cylinder R2.5 gives strength 30% more than control for 28 days and 19.8% more than control for 56 days and the cylinder M5R5NSP5 gives split tensile strength of 33% more than control for 28 days and 22% more than control for 56 days

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