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EXPERIMENTAL STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF HIGH STRENGTH CONCRETE CONTAINING NANO SILICA AND METAKAOLIN

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Abstract: ***An experimental investigation on the use of Metakaolin(MK) and Nano-Silica(NS) on various properties of concrete are presented. Metakaolin and Nano-Silica are used as partial replacement of cement for the preparation of concrete. In the present work initially cement is partially replaced by Metakaolin 5% , 10% and 15% and nano silica replace by 1%,2%,3% and 4% by weight of cement. Further investigation is carried out by combined replacement of Metakaolin at 5% and 10% with Nano–Silica at 1%, 2% and 3% by weight of cement. For structural applications the various properties, such as compressive strength, split tensile strength and flexural strength of M60 grade concrete containing MK and NS are evaluated and the results are compared with the controlled concrete and also check the durability properties of concrete.***

Key Words: ***HIGH STRENGTH CONCRETE, NANO SILICA, METAKAOLIN***

I. INTRODUCTION

Concrete is the most widely used construction material with the ever increasing industrialization and urbanization huge amount of natural resources are required to make concrete. It is the mixture of the cement, sand, water and aggregate. The hardening of concrete is caused by chemical action between the water and cement and continues for long time period. It is the quality that makes the concrete different from other binding materials High strength of concrete has the characteristics strength is about 50 to 100 N/mm2.high strength of concrete also having higher resistance capacity against chloride and abrasion of concrete. With development of new and efficient admixtures for concrete for example like metakaoline and high quality additives like high range of water reducer are used for the production of high strength of concrete. The introduction into general use of high performance materials, such as High Strength Concrete, is of great importance as the move towards sustainable design certainly requires that materials be utilized to their full potential, in order for this to happen a proper understanding of the behaviour of these materials is required. Metakaolin is the most recent supplementary cementitoius materials to be commercially introduced to the concrete construction industry. Unlike other supplementary cementitious materials, metakaoline is not an industrial by product; it is produced by calcining High purity kaolin clay at temperatures of 700 to 800 C. It has been shown that the inclusion of metakaolin could improve the properties and durability performance of concrete. Metakaoline is the very reactive calcined clay and it has focused on many of investigations. High reactivity metakaoline is recently developed material for achieving the high strength of concrete.it simply converts the material to MK phase, which is an amorphous aluminosilicate. Metakaoline has been refined carefully such that to remove its impurities, its particle size controlled and lightened color like the other industrial product like Silica fume, blast furnace slag and Fly ash.. The particle size of metakaolin is generally smaller than the size of cement particles and it is less than 2 µm. Metakaoline is an efficient pozzolona and react with the calcium hydroxide which comes from the cement hydration by pozzolanic reaction which produce the calcium aluminosilicate hydrates and calcium silicate hydrates. This two products reacts with Ca (OH) 2 which is by-products of hydration reaction of cement produced C-S-H gel which has been increase the strength of concrete.in this chapter we summarised the detailed study on turnery material and various test conducted for that. The aim of study is to identifying the strength parameters of high strength concrete by using metakaoiline and nano silica. The particle size of metakaoline is finer size so we can replace that materials by cement. The is replace by weight of cement about 5% and 10% and nano silica is replaced by 1%,2% and 3% by weight of cement. i find the replacement for this materials for to achieving the high strength and to compare the result.

II. EXPERIMENTAL INVESTIGATION

2.1Materials

2.1.1.cement:

The most widely recognized cement at present utilized as a part of development is OPC 53 grade. This sort of cement is regularly utilized as a part of development and is promptly accessible from an assortment of sources. The Blaine fineness is utilized to measure the surface zone of cement. The surface territory gives an immediate sign of the cement fineness. The commonplace fineness of cement reaches from 350 to 500 m2/kg for OPC 53 grade cement. Determination of the kind of cement will rely on upon the general necessities for the concrete, for example, strength, toughness and so on.C3A content higher than 10% may bring about issues of poor workability maintenance. The regular substance of cement is 350-450 Kg/m3.More than 500 Kg/m3 cement can be dangerous and increase the shrinkage cracks. Less than 350 Kg/m3 may only be suitable with the

inclusion of other fine filler, such as fly ash, pozzolona, etc. Cement has higher content of lime CaO about 62% and silica about 22%. Cement is obtained by burning of calcareous materials at very high temperature about 1400 ºc alkali oxides Na2O, K2O, MgO are harmful for cement.

2.1.2 Fine aggregate:

All type of sands are suitable for concrete. Either crushed or rounded sands can be used. Siliceous or calcareous sands can be used. Sand is generally considered to have a lower size limit of about 0.07 mm. material between 0.06 and 0.002 is classified as silt.

A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation. There are different types of sand is natural sand , crushed gravel sand , crushed stone sand etc.it is depending upon the particle size distribution according to IS: 383-1970 has divided the fine aggregate in to four grading zone.

2.1.3. coarse aggregate:

All types of aggregates are suitable for concrete. The normal maximum size is generally 16 – 20 mm. Consistency of grading is of vital importance. Regarding the Characteristics of different types of aggregate, crushed aggregates tend to improve the strength because of the interlocking of the angular particles, whilst rounded aggregates improve the flow because of lower internal friction. Gap graded aggregates are frequently better than those continuously graded, which might experience greater internal friction and give reduced flow.

2.1.4. Metakaolin:

High-reactivity metakaolin (HRM) is a highly processed reactive aluminosilicate pozzolan, a finely-divided material that reacts with slaked lime at ordinary temperature and in the presence of moisture to form a strong slow-hardening cement. It is formed by calcining purified kaolinite, generally between 650–700 °C in an externally fired rotary kiln. It is also reported that HRM is responsible for acceleration in the hydration of ordinary Portland cement (OPC), and its major impact is seen within 24 hours. It also reduces the deterioration of concrete by Alkali Silica Reaction (ASR), particularly useful when using recycled crushed glass or glass fines as aggregate.

2.1.5. Nano silica :

Nano-silica particles are divided into P-type and S-type according to their structure. The Ptype particles are characterized by numerous nanopores having a pore rate less. The S-type particles have a comparatively smaller surface area. The P-type nano-silica particles exhibit a higher ultraviolet reflectivity when compared to the S-type. Nano silica nanoparticles appear in the form of a powder.

2.2 Mix Proportions

M60 grade of Concrete is used to present the investigation. mix design was done based on IS: 10262-1982. Quantity of 1 M3 of concrete containing 450.56 kg cement, 1120.9 kg coarse aggregate, 702.3 kg fine aggregate and 157.6 litters of water.

2.3 Experimental Procedure

The specimen of standard cube of 150x150x150 mm, standard cylinder of 300x150 mm and standard beam of 700x150x150 mm were used to determine the compressive strength , split tensile strength and flexural strength specimens are tested for 7,14 and 28 days with each proportion of combination of metakaolin and nano silica with replacement of cement. w/c ratio is constant for all mix is 0.35 . the constituents are weighted and materials were mixed by mixture. The concrete was filled in different layers by compaction. The specimen were Demoulded after 24 hours , cured in water for 7, 14 and 28 days and then it is tested for its compressive strength, split tensile strength and flexural strength. For durability check cubes To be tested at in different corrosive environment such as sulfuric acid and sodium sulphate solution.

III. TEST RESULT AND DISCUSSIONS

Result of fresh concrete with partial replacement of metakaolin and nano silica is to be investigated and result is compare with normal concrete. workability of concrete is carried out by slump test. from slump test result i can say that the slump value is very less for high strength concrete and for its combinations.

slump test

Slump test result for M60 grade concrete with metakaolin and nano silica is shown as below:

SR NO	CONCRETE MIX	SLUMP VALUE(mm)
1	NORMAL	10
2	1%NS , 5%MK	09
3	2%NS , 5%,MK	09
4	3%NS , 5%MK	08
5	1%NS ,10%MK	08
6	2%NS , 10%MK	08
7	3%NS , 10%MK	07

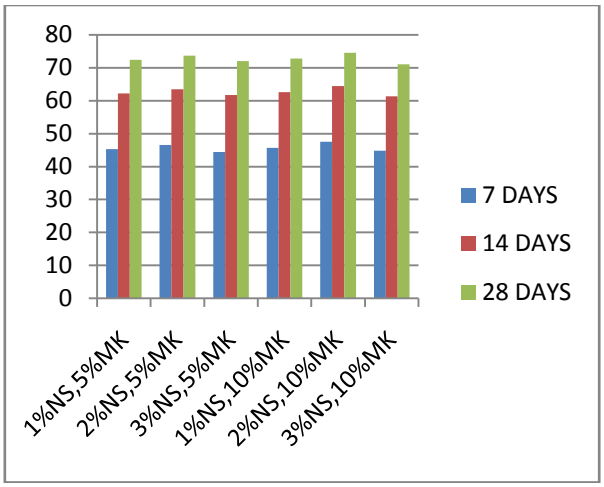
Hardened concrete test

Compressive strength test:

The compressive strength of cube specimen is checked after 7, 14 & 28 days in compressive testing machine. The specimens containing MK and NS with varying percentage are tested during this project.The results of compressive strength are as shown In Table. I also tested the result 28 Days.

Table 1. Compressive strength test result

SR NO	MK%	NS%	COMP. STRENGTH Mpa		
			7 days	14 days	28 days
0	0%	0%	43.1	59.1	69.3
1	5%	1%	45.3	62.2	72.4
2	5%	2%	46.6	63.5	73.7
3	5%	3%	44.4	61.7	72
4	10%	1%	45.7	62.6	72.8
5	10%	2%	47.5	64.4	74.6
6	10%	3%	44.8	61.3	71.1

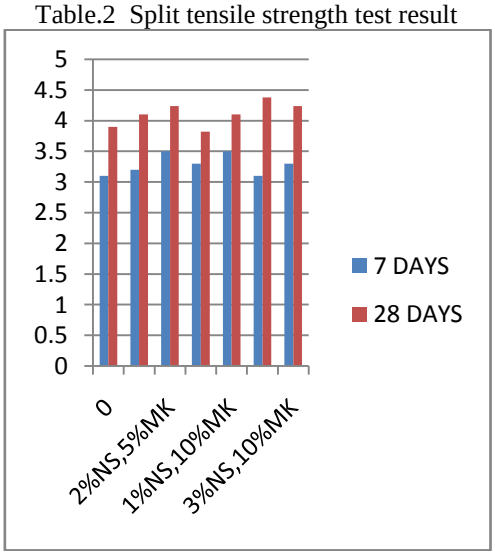


Split Tensile Strength:

The variation of Split tensile strength of M60 grade concrete prepared using 5% and 10% Metakaolin with increase in Nano- Silica. The split tensile strength of Metakaolin concrete initially increases up to 2% of Nano- Silica and with further increase in the Nano Silica content the split tensile strength decreases. Similar trend is observed with the concrete containing 5% and 10% Metakaolin.The increase in split tensile strength of 5% and 10% Metakaolin further strength is decreases.

SR NO	MK%	NS%	7 days	28 days
0	0	0	3.1	3.9
1	5%	1%	3.2	4.1
2	5%	2%	3.5	4.24
3	5%	3%	3.3	3.82
4	10%	1%	3.5	4.10
5	10%	2%	3.6	4.38
6	10%	3%	3.3	4.24

Table.2 Split tensile strength test result



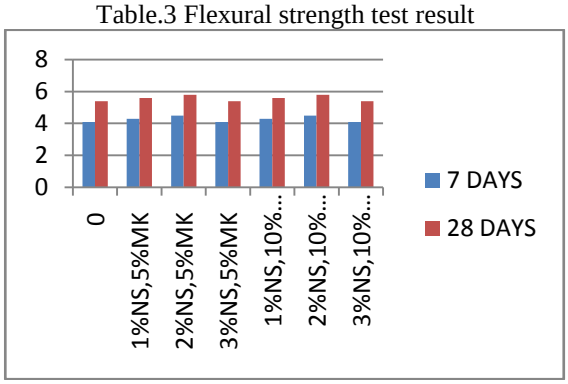
Split tensile strength test result

Flexural strength test:

Concrete has very smaller flexural strength. the a fig shows the flexural strength of concrete is increased up 2% of Ns and 10% MK and it will reduced for further replacement.Flexural strength test is performed on the beam Standard size of beam is 700x150x150 mm.

SR NO	MK%	NS%	7 days	28 days
0	0	0	4.1	5.39
1	5%	1%	4.3	5.6
2	5%	2%	4.5	5.8
3	5%	3%	4.1	5.39
4	10%	1%	4.3	5.6
5	10%	2%	4.5	5.8
6	10%	3%	4.1	5.39

Table.3 Flexural strength test result



Flexural strength test result

IV. DURABILITY TEST ON CONCRETE

4.1 Acid resistance test :

The acid resistance tests were carried out on 150 mm size cube specimens at the age of 28 days curing based on ASTM C 267-01. After 28 days, all the specimens are kept in atmosphere for 2 days for constant weight. The specimens were weighed and immersed in 5% Sulphuric acid (H2SO4) solution for 28 days. The solution was kept at room temperature and stirred regularly, at least twice a day to maintain uniformity. The solution was replaced at regular intervals to maintain concentration of solution throughout the test period. The evaluations were conducted after 28 days. After 28 days of immersion, the specimens are taken out and the surfaces were cleaned with a soft nylon wire brush under the running tap water to remove weak products and loose material from the surface. After drying, the change in weight and the compressive strengths of the specimens were found out and the compressive strength were calculated.

4.2 Sulphate resistance test :

The tests were conducted based on ASTM C 452-02 test method. Concrete cubes of size 150mm were cast and cured for 28 days. After 28 days of curing the specimens were dried. Initial dry weight of the cubes was found. Then, the cubes were immersed in 5% Na2SO4 Solution for 28 days. After 28 days of immersion the specimens were taken out and visually observed for the deterioration of the concrete due to sulfate attack. The surfaces of the cubes were cleaned. the loss of compressive strength were calculated.

V. RESULTS AND DISCUSSIONS

5.1 Acid resistance test results :

The loss of compressive strength for , were 3.8%, 1.7%,1.76%, 1.25% , 2.33%,1.20% and 2.53%.The results indicated that the combination of concrete subjected to excellent acid attack in 5% sulphuric acid solution and also strength loss were very less 1.20% compared to CC. The results of acid resistance test and percentage strength loss are shown in Table4

5.2 Sulfate resistance test :

The percentage loss in strength were 2.59%, 2.48%, 2.30%, 1.25%, 2.33%,1.20% and 2.53%. The results indicated that the combination of concrete subjected to excellent acid attack in 5% sulphuric acid solution and also strength loss were very less 1.20% compared to CC. The results of acid resistance test and percentage strength loss are shown in Table5.

Mix	Before immersion strength	After immersion strength	% loss strength
0	69.3	66.6	3.8
1%NS 5%MK	72.4	71.1	1.7
2%NS 5%MK	73.7	72.4	1.76
3%NS 5%MK	72	71.1	1.25
1%NS 10%MK	72.8	71.1	2.33
2%NS 10%MK	74.6	73.7	1.20
3%NS 10%MK	71.1	69.3	2.53

Table 4 Acid resistance test results :

Mix	Before immersion strength	After immersion strength	% loss strength
0	69.3	67.5	2.59
1%NS 5%MK	72.4	70.6	2.48
2%NS 5%MK	73.7	72	2.30
3%NS 5%MK	72	71.1	1.25
1%NS 10%MK	72.8	71.1	2.33
2%NS 10%MK	74.6	73.7	1.20
3%NS 10%MK	71.1	69.3	2.53

Table 5 Sulfate resistance test result

VI. CONCLUSION

- Concluded that for a given Metakaolin content, the compressive strength of concrete increases as the percentage of Metakaolin is increased up to 10% and then decreases with increase in Metakaolin content.
- By the addition of nano silica and metakaolin the workability of the mix was improved.
- Further investigation is carried out by conducting tests on standard concrete
- specimens to obtain compressive strength for combined replacement of cement with
- Metakaolin and Nano- Silica using different combinations the test results, it can be concluded that for a variation compressive strength of split tensile strength and flexural strength test results of M60 grade concrete is increase.
- Further be concluded that, the various strength properties of concrete can be improved by the addition of a specified percentage (2%) of Nano-Silica and (10 %) of Metakaolin content.
- The Combination of nano silica and Metakaolin concrete shows better resistance against the acid attack. By Comparing the compressive strength at 28 days acid exposure the rate of strength loss were minimum.
- Sulfate Resistance Test , the strength loss percentage were reduced by the addition of Industrial Byproducts.

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