Durability Characteristics of Modified Concrete Under Acidic Environment

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Abstract- *The making of ordinary Portland cement involves enormous size of energy consumption, leading to a mammoth discharge of carbon dioxide to the air, which is being a great task to the sustainable advance. Efforts are required to grow an environmental sociable construction material to reduce release of greenhouse gases to the atmosphere. One of the efforts to reduce the carbon footprint, waste by products used as alternative binders to the cement. Concrete is the second most consumed material in the world after water and the waste produced from glass industry is in tones, that can be partially utilized in the regular concrete in place of cement and thus it will reduce carbon dioxide emission at large scale. The experimental study has been done by partially replacing the ordinary Portland cement by metakaolin in different percentages. The main goal is to investigate the possibility to improve the strength over a range of metakaolin percentages. In this project report the results of the tests carried out on Sulphate attack on concrete cubes in water curing along with H2SO4 solution. Fresh concrete tests like compaction factor test and hardened concrete tests like compressive Strength at the age of 7 days and 28 days was obtained and also durability aspect of metakaolin concrete for sulphate attack was tested*

Keywords- Metakaolin, workability, compressive strength, split tensile strength test, water absorption test, Durability studies

I. INTRODUCTION

In the last decades, environmental sustainability has become one of the most important issues. Cement is the most important ingredient of the concrete which produces carbon dioxide which is May harmful. So it is a main concern to reduce the usage of cement. The increase in price of the cement not only will increase the budget of a construction however additionally poses a significant threat to the country's development. it's known that some industrial waste product like nano silica are having some building material and silicious properties. So the use of the commercial and agricultural wastages in concrete part as cement replacement, scale back the price of constructing concrete, additionally causes improvement within the properties of concrete

Cement is the most important ingredient of the concrete which produces carbon dioxide which is May harmful. So it is a main concern to reduce the usage of cement. The increase in price of the cement not only will increase the budget of a construction however additionally poses a significant threat to the country's development. It's known that some waste product like nano silica and metakaolin are having some building material and siliceous properties. The impact of carbon dioxide emission due to production of Portland cement can be reduced by partial replacement of cement with supplementary cementitious materials. Nano silica and metakaolin like waste materials comprise pozzolanic properties but their disposal is causing acute environmental setbacks. Rapid industrial expansion produces severe difficulties all around the world, including as the depletion of natural resources and the creation of vast amounts of waste materials throughout the manufacturing, construction, and demolition stages; one option to mitigate this problem is to utilize wastes.

The impact of carbon dioxide emission due to production of Portland cement can be reduced by partial replacement of cement with supplementary cementitious materials. Metakaolin is industrial waste materials comprise pozzolanic properties but their disposal is causing acute environmental setbacks. The utilization of industrial and agricultural waste product in concrete has been a major step on waste reduction. Metakaolin can be effectively used in concrete as partial replacement of cement because of their high content of silica and pozzolanic properties which plays an important role in achieving high strength and durability in concrete.

Metakaolin is a fine, natural white clay which contains the highest content of siliceous, so called as High Reactivity Metakaolin (HRM). During the cement hydration process, water reacts with Portland cement and forms calcium-silicate hydrate (CSH). The by-product of this reaction is the formation of calcium hydroxide (lime). This lime has weak link in concrete, and hence reduces the effect of the C-S-H. When Metakaolin is added in the hydration process, it reacts with the free lime to form additional C-S-H material, thereby making the concrete stronger and more durable.

Metakaolin is the anhydrous calcined type of the mud mineral kaolinite. Minerals that are wealthy in kaolinite are known as china mud or kaolin, generally utilized in the assembling of porcelain. The molecule size of metakaolin is little than concrete particles, however not as fine as silica fume. Metakaolin can be created from an assortment of essential and optional sources containing kaolinite.

The present project involves a comprehensive laboratory experimentation study for the application of new waste materials in the preparation of concrete. The main objective of investigation is to study the strength behaviour i.e. compressive strength and impact resistance of concrete with different percentages replacement of cement with metakaolin and to study out on Sulphate attack on concrete cubes in water curing along with H_2SO_4 solution. Fresh concrete tests like compaction factor test and hardened concrete tests like compressive Strength at the age of 7 days and 28 days was obtained and also durability aspect of metakaolin concrete for sulphate attack was tested.

The objective of the present study was to investigate experimentally the properties of Concrete with the following test results

1. Workability
2. Compressive strength
3. Flexure strength
4. Tensile strength
5. Acid resistance test

II. REVIEW OF LITERATURE

Considering above background, an experimental investigation was carried out to consider the both types and amount of contents of different types of cement and sand replacement materials on the properties of concrete. A lot of work has been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. Literature review of metakaolin and concrete exposure to severe acidic environment is presented in the following sections.

Deb, P. S., Nath, P., & Sarker, P. K. (2014): Ground granulated blast furnace slag (GGBS) with mixture of flyash content showing huge improve in the consequences of workability and high strength contrasted with Ordinary Portland Cement (OPC). By changing dissimilar (0%,10% and 20%)contents of Ground granulated blast furnace slag (GGBS) with various proportions of flayash content showing a few blemishes, One of them is with increment in GGBS content workability is diminishing simultaneously strength is expanding. By keeping up silicates to alkaline proportions of 1.5 to 2.5 and following ACI 318 and AS 3600 codes for curing we can accomplish above outcomes when contrasted with OPC.

Junaid, M. T., Kayali, O., Khennane, A., and Black, J. (2015): In this paper he decided the mix proportions geopolymer concrete (GPC) by utilizing Calcium Class F Flay Ash and Alkaline solutions of sodium silicates and sodium hydroxide. For the distinctive mix plans he discovered ideal substance of alkaline fluid to fly ash (AL/FA) proportion, water to geopolymer concrete (W/GPS) proportion and Alkaline to water (AL/W) proportion.

Patankar, S. V., Ghugal, Y. M., and Jamkar, S. S. (2015): Geopolymer concrete is made by utilizing different evaluations of fly ash and consistent sodium hydroxide with 13M focus. In view of experimentation he accomplished the ideal proportions like water to geopolymer (W/GPC) connection of 0.35, Alkaline to fly ash proportion of 0.35, sodium silicate to sodium hydroxide proportion of 1. Later he discovered workability, compressive strength for the plan mix of geopolymer concrete, the outcome came palatable for the above mix plan.

S. M. AlamgirKabir (2015) investigation concerns the use of the optimum mix proportion of two locally available pozzolanic waste materials, namely, ground granulated blast furnace slag (GGBS) and palm oil fuel ash (POFA), together with metakaolin (MK) as binders. In addition, another local waste material, manufactured sand (M-sand), was used as a replacement for conventional sand in the development of green geopolymer mortar. Twenty-four mortar mixtures were designed with varying binder contents and alkaline activators. The oven dry curing was also kept consistent for all the mix proportions at a temperature of 65°C for 24 hours. The highest 28-day compressive strength of about 48 MPa was obtained for the mortar containing 20% of MK, 35% of GGBS, and 45% of POFA. The increment of MK beyond 20% leads to reduction of the compressive strength. The GGBS replacement beyond 35% also reduced the compressive strength. The entire specimen achieved average 80% of the 28-day strength at the age of 3 days. The density decreased with the increase of POFA percentage. The finding of this research by using the combination of MK, GGBS, and POFA as binders to wholly replace conventional ordinary Portland cement would lead to alternate eco-friendly geopolymer matrix.

MoslihAmerSalih (2014) focused on producing high strength mortar from the alkali activation of palm oil fuel ash (POFA) blended with GGBS. Compression test was applied to evaluate the mechanical properties, TGA/DTG, and DSC tests were conducted to study the chemical composition of the geopolymeric binding phase. POFA activated with sodium silicate and sodium hydroxide at room ambient temperature. Results showed that 50% of POFA blended with 50% of GGBS was applicable to produce high strength geopolymer mortar with 70 MPa compressive strength at the age of 28 days and 85 MPa at the age of 90 days.

Sunny AJagtap, Mohan N Shirsath, Sambhaji L Karpe (2017) studied the Effect of Metakaolin on the Properties of Concrete. Environmental issues are playing essential role in the sustainable development of concrete industry. Cement replacement by glass powder in the range 5% to 25% with an interval of 5% is to be studied. It was tested for compressive strength, Split tensile strength and flexural strength at the age of 7, 28 days and compared with the results of conventional concrete. The overall test results shows that Metakaolin could be used in concrete as a partial replacement of cement.

Saxena, S. K., Kumar, M., & Singh, N. B. (2018): In this paper he compared results of geopolymer cement with ordinary portland cement in terms of compressive strength, durability test by using sulphuric acid. The geopolymer cement was made by using fly ash, Alkaline Solution (14M NaOH) and Silicate solution (Sodium silicate solution) and also he used alccofine powder which has have similar properties of silica fume. Finally he concluded that compared to OPC this designed mix (geopolymer mix) giving better reliable results than OPC in terms of durability, Compressive strength.

Hadi, M. N., Zhang, H., & Parkinson, S. (2019): In this paper he compared the result of OPC paste vs proposed geopolymer concrete mix. In suggested mix he used ground granulated blast furnace slag (GGBFS) and Class F fly ash (FA) as silicate fount and Instead of using W/C ratio he used , sodium silicate solution to sodium hydroxide solution SS/SH, Aw/Bi ratio & alkaline solution to binder (Al/Bi) ratio in his proposed mix. Finally he concluded that at given alkaline solution to binder (Al/Bi) ratio of 0.5, sodium silicate solution to sodium hydroxide solution (SS/SH) ratio of 2, Aw/Bi of 0.15 & 40% GGBS proposed geopolymer paste given better results in respect of compressive strength, Slump test & setting time.

It has been noted that the sunshine fastness of banana fibre is inferior to cotton. this could be attributed to the impurities gift within the banana fibre within the variety of polymer and therefore the different insoluble matter. The revealed analysis works on flexural plasticity of nylon fiber ferroconcrete beam are studied by several researches few mentioned the influence of nylon fiber issue on flexural plasticity of beam and terminated that plasticity indexes increase with increasing of fiber issue.

D. Patil, Patil&Veshmawala Observed the Performance of Copper Slag as Sand Replacement in Concrete.M30 concrete was used and several tests like compressive, flexural, split tensile strength were taken for different portions of copper slag and sand from 0 to 100%. The outcome showed that workability increases with growth in percentage of copper slag. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate with copper slag, and up to 80% replacement of copper slag, concrete gain more force than normal concrete strength. The flexural strength of concrete found to be increased by 14% with 30% substitution of copper slag.

A.N.Dancygier and Z.Savir studied the influence of nylon fiber on flexural performance of high strength concrete beam with low longitudinal reinforcement magnitude relation, that tried that nylon fiber enhance crispiness of beam compared to it of beam with minimum longitudinal reinforcement magnitude relation. Compared to nylon fiber concrete, the hybrid fiber with completely different kind and size will improve effectively strength and toughness of concrete, kind hybrid result throughout completely different fiber, play various useful influence from completely different level. However, few researches on flexural performance of hybrid fiber strengthened RC beam were studied.

Sasikumar&Tamilvanan Performed an Experimental Investigation on Properties of Silica Fumes as a Partial Replacement of Cement. The main parameters investigated in this study is M30 grade concrete with partial replacement of cement by silica fume0%, 25%, 30%, 40% and 50%. The normal consistency increases about 40% when the silica fume percentage increases from 0% to 25%. The optimum 7 and 28-day compressive strength has been obtained in the 25 % silica fume replacement level. As well the split tensile strength is high when using 25% silica fume replacement for cement.

Ghutke&Bhandari Examine the Influence of silica fume in concrete. Results indicated that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with % of silica fume. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varying from 10% to 15% replacement level.

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. Metakaolin
5. Sulphuric acid solution

1. Cement

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. Fine Aggregate

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. Coarse Aggregate

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. Metakaolin

Metakaolin is a white, amorphous, highly reactive aluminium silicate pozzoloan forming stabile hydrates after mixing with lime stone in water and providing mortar with hydraulic properties. It is a mineral admixture obtained from clay. Metakaolin is a highly pozzolanic material, it is in powder form and fineness of MK up to 700 to 800m²/kg. It is derived from the calcination of a high-purity kaolin clay. The product is then ground to between 1-2 gm. (about 10 times finer than cement). Indeed Metakaolin is not a by-product, one of the prominent use of MK is mixing with concrete because its physical and chemical properties are similar to the cement.

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262-2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M30.

V. RESULTS AND DISCUSSIONS

This session provides an outline of the experimental results and endeavors to draw some conclusions. The take a look at result covers the workability, mechanical properties and sturdiness properties of concrete with and while not admixtures. The results of the experimental investigation on metakaolin concrete wherever nano silica and metakaolin has been used as partial replacement of cement in concrete mixes. On commutation cement with completely different percentages of metakaolin the workability, compressive strength, split tensile strength and flexural strength is studied then to the optimum share of metakaolin , keeping metakaolin constant acid resistance tests are conducted in H_2SO_4 solution.

5.1 REPLACEMENT DETAILS

The replacement details of nano silica and metakaolin has been given in the below table. The replacement of cement percentages by 0, 10, 20, 30 and 40% with metakaolin varying the cement replacement percentages by metakaolin.

5.2 VARIATION OF SLUMP VALUES FOR PERCENTAGE REPLACEMENT OF METAKAOLIN

Slump test is used to determine the workability of concrete. The apparatus used for doing slump test are slump cone and tamping rod. Slump test is used to determine the workability of concrete. The apparatus used for doing slump test are slump cone and tamping rod. This is the most commonly used test of measuring the consistency of concrete. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing neither workability, not it is always a representative of the place ability of the concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. It is performed with the help of a vessel, shaped in form of a frustum of a cone opened at both ends. Diameter of top end is 10cm while that of the bottom end is

20cm, height of the vessel is 30cm, a 16mm diameter and 60cm long steel rod is used for tamping purposes.

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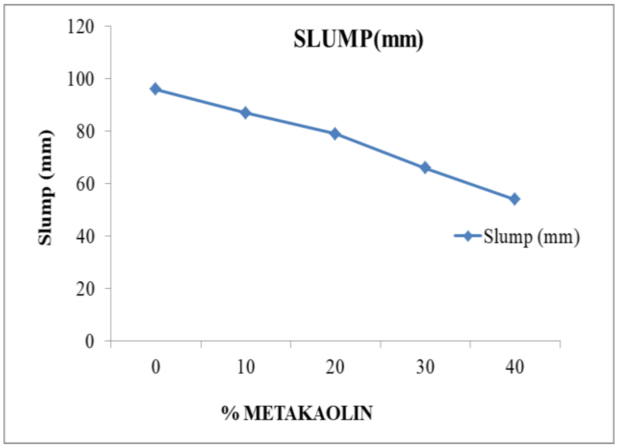
The slump of the freshly mixed concrete was measured by using a slump cone in accordance to ASTM C143. It can be observed from Figure 5.1 that all mixtures have a slump of less than 45mm and are observed that slump values increasing with increase in slag content.

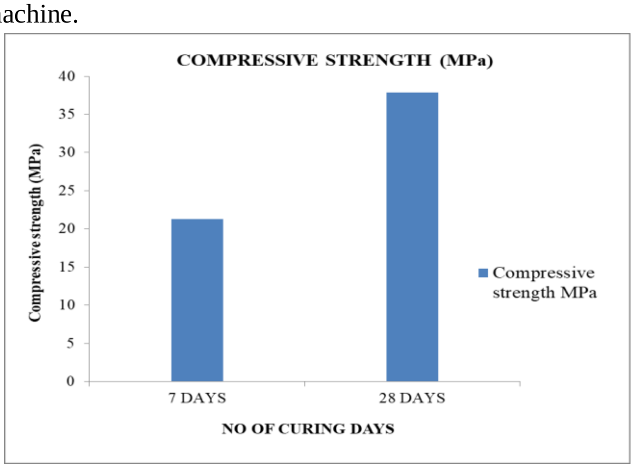


Graph 5.1 Slump vs. % metakaolin replacements

5.3 COMPRESSIVE STRENGTH

The main function of the concrete in structure is mainly to resist the compressive forces. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal.

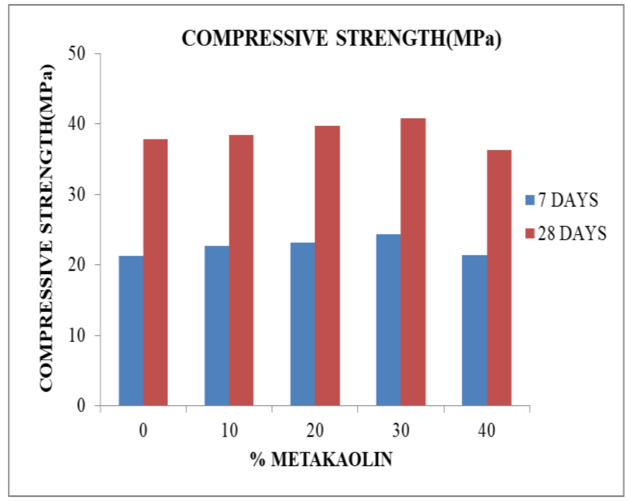
Cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimens tested for 7, 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur. The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine.



Graph 5.2 Variation in Compressive Strength for M30 grade normal concrete for different curing periods

5.4 VARIATION OF COMPRESSIVE STRENGTH FOR ADDITION OF METAKAOLIN TO OPTIMUM PERCENTAGE OF NANO SILICA

Compressive strength of concrete keeping 10% nano silica as constant and with different percentages of metakaolin for curing period of 7-days and 28-days respectively and fig shows the summarized Compressive strength Results for different curing periods– M30 grade.



Graph 5.3 Variation in Compressive Strength for % Replacement of Metakaolin at 7 Days and 28 Days

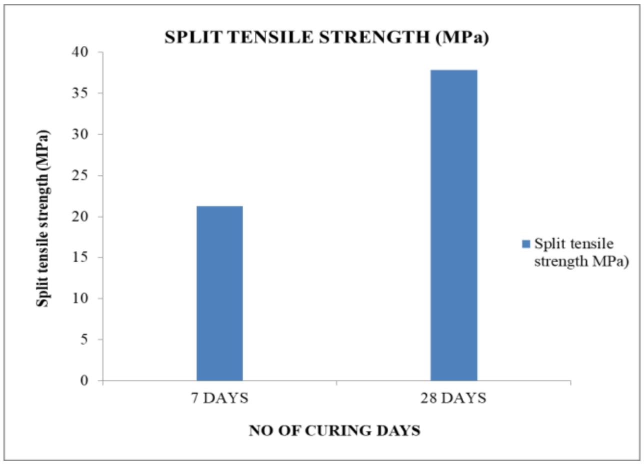
5.5 SPLIT TENSILE STRENGTH TEST

The size of specimens 150 mm dia and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per as per IS 516 (1959) and IS 5816 (1999).

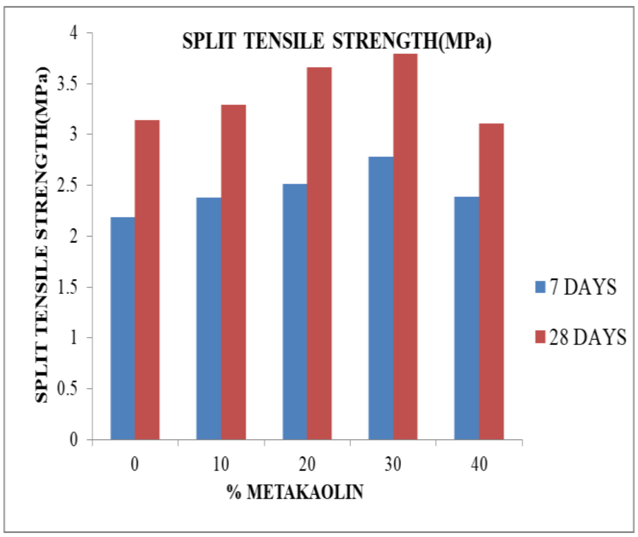
The Split Tensile strength of the concrete mix for with partial replacement of cement by metakaolin showed higher Strength against splitting after 7 and 28 days for M30 grade.

Compressive stress = $2P/\pi LD \{D^2 / (D-r)-1\}$
Tensile stress $=2P / \Pi ld$

Where, P = Compressive load on cylinder
L = Length of cylinder =300 mm
D = Diameter of cylinder = 150mm
r& (D-r) are distance of the element from the two loads respectively.



Graph 5.4 Variation in Split tensile Strength for M30 grade normal concrete for different curing periods



Graph 5.5 Variation in Split tensile Strength for % Replacement of Metakaolin at 7 and 28 Days

5.6 FLEXURAL STRENGTH TEST

In the flexural strength test theoretical maximum tensile stress reached at the bottom fibers of the test beam is known as the modulus of rupture. When concrete is subjected to bending stress, compressive as well as tensile stresses are developed at top and bottom fibers respectively. If the largest nominal size of aggregate does not exceed 20mm, the dimension of specimen may be 150mm×150mm×700mm.

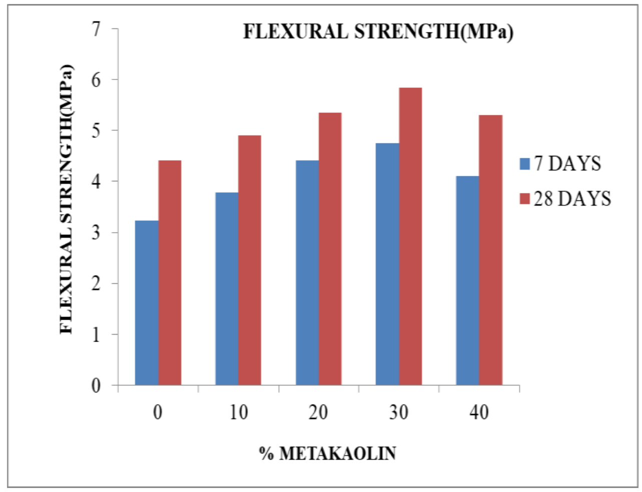
$$f = \frac{M}{Z} = \frac{(PL/6)}{(bd^2/6)}$$

$$f_b = \frac{PL}{Bd^2}$$

When ‘a’ greater than 20 cm for a 15cm specimen,

$$f_b = \frac{3Pa}{bd^2}$$

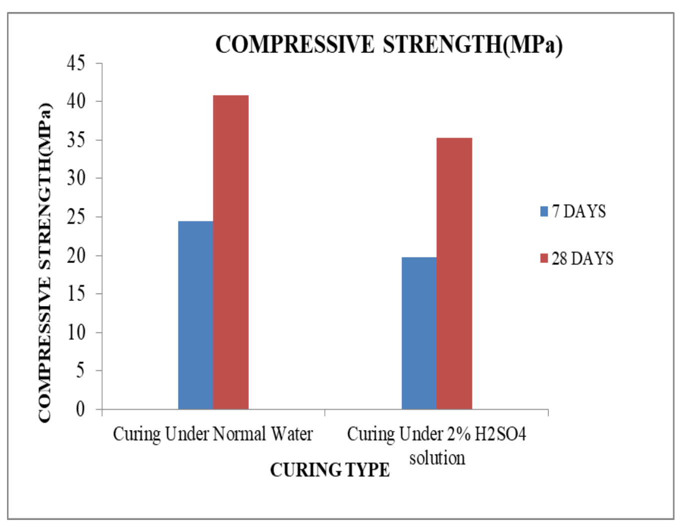
The Flexural strength of the concrete mix for with partial replacement of cement by Silica fume and Cenosphere respectively showed higher Strength against splitting after 7 , and 28 days for M30 grade.



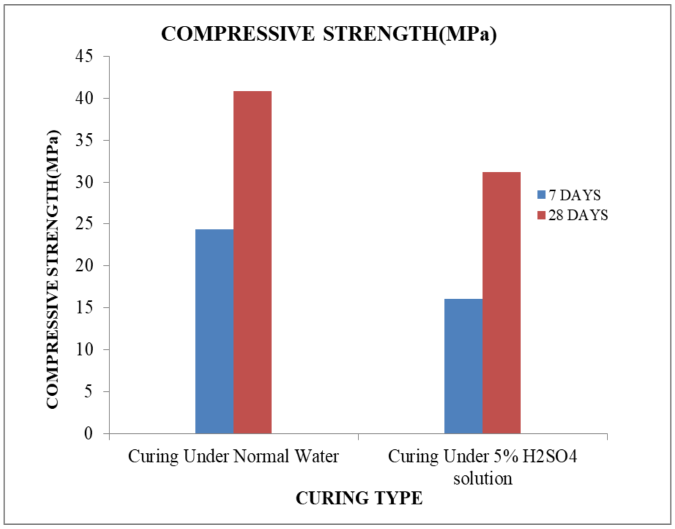
Graph 5.6 Effect of Metakaolin on Flexural strength of concrete at 7 and 28 days curing

5.7 DURABILITY STUDIES

The durability properties of the concrete mainly depend on its curing age among the other factors. When concrete is exposed to aggressive environment, its durability may get affected. Earlier, people were more concerned about the strength of concrete without thinking about its durability. But at present the durability of concrete and concrete structures has become a major concern. In this experimental study, the effect of sulphuric Acid on concrete made using metakaolin was investigated. The optimum replacement level of Ordinary Portland Cement (OPC) with metakaolin in respect of compressive strength was found i.e. 30%. After obtaining the optimum replacement level, cubes were casted for both the Normal Concrete and metakaolin Mixed Concrete for further studies.



Graph 5.7 Compressive strength of metakaolin concrete after immersion in 2% dilute H_2SO_4 solution



Graph 5.8 Compressive strength of metakaolin concrete after immersion in 5% dilute H_2SO_4 solution

VI. CONCLUSIONS

The Conclusions and Recommendations that could be drawn from the results of this project and experiments are summarized and the use of metakaolin as a cement replacing material in concrete production was studied and concrete resistance to acid attack i.e in sulphuric acid solution was studied and after the research work is done, the following conclusions were made:

- It has been observed that by the incorporation of Metakaolin as partial replacement to cement in fresh and plain concrete decreases workability when compared to the workability of normal concrete.
- It has been observed that workability decreases linearly at rate of 10 % for every 10% metakaolin addition.
- Compressive strength of concrete increases linearly with increase of % Metakaolin up to 30 % and decreases thenceforth. Hence 30 % is the optimum Metakaolin limit for M30 concrete.
- The compressive strengths of M30 concrete for optimum values of metakaolin (30%) is 40.80 MPa for 28 days. It is evident from the present investigation that the use metakaolin in place of cement to concrete improves compressive strength.
- The split tensile strength of M30 concrete for optimum values of metakaolin (30%) is 3.79 MPa for 28 days and for flexural strength it is about 5.84 MPa for 28 days. It is observed from the present results that the use metakaolin in place of cement to concrete improves split tensile strength flexural strength also.
- It is noted that there is 7.8 % increase in the compressive strength and 20.7 % increase in the tensile strength and 32.42 % increase in the flexural strength were observed when compared to normal concrete.
- In the case of metakaolin concrete cube specimens immersed in H_2SO_4 diluted solution, the loss in compressive strength has increased gradually with increase in percentage of solution. For 5% solution there is more degradation when compared to 2% H_2SO_4 diluted solution and normal concrete.
- The severity of degradation of concrete exposed to diluted H_2SO_4 solution depends on the quantity of cement paste that is available to react chemically.
- The decrease in the 28 day cube compressive strength H_2SO_4 concrete after immersion in diluted H_2SO_4 solutions could be accredited to the reaction of H2SO4 with calcium hydroxide to form dehydrate gypsum.
- It has been observed that the mass loss (%) and decrease in compressive strength of concrete cube specimens is found to be more in the case of hydrochloric a sulphuric acid.
- The use of Metakaolin is economical when compared to cement in concrete. Likewise saves a great deal of waste disposal problems and reduces the cement price rise and intensities of CO_2 release by the cement production. Also these materials make the concrete more sustainable, light weight and low energy emitting which is noble.

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