STUDIES ON STRENGTH CHARACTERISTICS OF CONCRETE WITH METAKOALIN AS AN AD MIXTURE

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Abstract- Metakaolin is a revolutionary artificial pozzolana admixture obtained from thermally activated ordinary clay and kaolinitic clay which greatly enhances the properties of ordinary concrete and become the central to the research in the making of special concrete. The use of Metakaolin and various chemical admixtures have become staple in gradients in the production of concrete with designed strength in excess of 7500psi(>50Mpa)or where service environments, exposure or life cycle cost considerations dictate the use of High performance concrete (HPC).
The compressive strength of concrete increased when cement is replaced by Metakaolin for both M20 and M40 grade of concrete. At 20% replacement of cement by Metakaolin the concrete attained maximum compressive strength for both M20 and M40 grade of concrete. The split tensile strength of concrete is increased when cement is replaced with Metakaolin. The split tensile strength is maximum at 20% of replacement. The flexural strength of concrete is also increased when the cement is replaced by Metakaolin. At 20% replacement, the flexural strength is maximum.
The compressive strength values of acid effected concrete decreases on comparison with of normal concrete, but the effect of acid on concrete decreases with the increase of percentage of metakaolin. At 20% replacement of metakaolin the resistance power of concrete is more. The compressive strength values of metakaolin concrete effected to HCl were greater than the metakaolin concrete effected to H2SO4. The effect of HCl on strength of the concrete is lower than the effect of H2SO4 on strength of the concrete. Workability of concrete decreases with the increase in metakaolin replacement level.

Keywords- Concrete, Metakaolin, Admixture, Compressive Strength.

I. INTRODUCTION

The quest for the development of high strength and high performance concretes has increased considerably in recent times because of the compelling demands from the construction industry. In the last three decades, supplementary cementitious materials such as fly ash, silica fume and ground granulated blast furnace slag have been judiciously utilized as cement replacement materials as these can significantly enhance the strength and durability characteristics of concrete in comparison with ordinary Portland cement (OPC) alone, provided there is adequate curing. Addition of Metakaolin is one of the latest development in this field.

Amongst the various methods used to improve the durability of concrete, and to achieve high performance concrete the use of Metakaolin is a relatively new approach. The partial replacement of ordinary Portland cement with pozzolanic materials can be advantageous in that it can increase the durability of paste, mortar or concrete if the proper curing regime is adopted. This is due to the fact that the Calcium Hydroxide produced by the cement hydration reacts with the pozzolana and produces additional gel which has a pore blocking effect and therefore alters the pore structure and the strength. In addition there is a reduction in Calcium Hydroxide (CH) which leads to improved resistance to sulphate attack and alkali-silica reaction Recently Metakaolin which is an ultra fine pozzolan produced from calcined clay has been added to the list of pozzolanic materials.

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, but not as fine as silica fume. Metakaolin is a high quality pozzolanic material, which is blended with Portland cement in order to improve the strength and durability of concrete and mortars. The Meta prefix in the term is used to denote change. It is a borrowing from Greek meaning after, along with, beyond. It is used, and is recognizable, in the formation of compound words metabolic, metamorphosis. The scientific use of the prefix is used for a combining form denoting the least hydrated of a series. In the case of Metakaolin, the change that is taking place is dehydroxylization, brought on by the application of heat over a defined period of time.

The overall objective of the present study is to study the effect of adding Metakaolin in concrete on its performance; however the task is divided in to specific objectives to achieve step by step through experimental procedures.
The main objectives of the present project work are listed below:

1. To prepare the concrete specimens such as cubes for compressive strength, cylinders for split tensile test, prisms for flexural strength and also cubes for durability studies in laboratory with 0%, 10%, 20% and 30% replacement of metakaolin with OPC for M20 and M40 grade concrete.
2. To evaluate the mechanical characteristics of concrete such as compressive strength, split tensile test, flexural strength.
3. To evaluate the durability studies of M20 and M40 grade metakaolin replaced concrete subjected to 1% and 5% concentrations of Hydrochloric acid (HCl) and Sulphuric acid (H2So4).
4. To evaluate and compare the results.

II. MATERIALS

A brief description about the materials used in this work is given below:

CEMENT:
Cement is a well-known building material and has occupied an indispensable place in construction works. There is a variety of cements available in the market and each type is used under certain conditions due to its special properties. The cement commonly used is Portland cement, and the fine and coarse aggregates used are those that are usually obtainable, from nearby sand, gravel or rock deposits. In order to obtain a strong, durable and economical concrete mix, it is necessary to understand the characteristics and behavior of the ingredients. In this work Ordinary Portland cement (OPC) confirming to IS-12269 (53 Grade) having specific gravity of 3.14.

AGGREGATES:
Aggregates are generally cheaper than cement and impart greater volume stability and durability to concrete. The aggregate is used primarily for the purpose of providing bulk to the concrete. To increase the density of the resulting mix, the aggregate is frequently used in two or more sizes. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. Aggregate was originally viewed as an inert, inexpensive material dispersed throughout the cement paste so as to produce a large volume of concrete. In fact, aggregate is not truly inert because it's physical, thermal and, sometimes, chemical properties influence the performance of concrete, for example, by improving its volume stability and durability over that of the cement paste. From the economic viewpoint, it is advantageous to use a mix with as much aggregate and as little cement as possible, but the cost benefit has to be balanced against the desired properties of concrete in its fresh and hardened state.
In this work sand conforming to Grading zone II of IS: 383 1970 having specific gravity of 2.6 and fineness modulus 2.47 was used as fine aggregate.
Crushed angular metal of 12 mm size having specific gravity of 2.78 and fineness modulus of 6.92 was used as coarse aggregate.

WATER:
Generally, cement requires about 3/10 of its weight of water for hydration. Hence the minimum water-cement ratio required is 0.35. But the concrete containing water in this proportion will be very harsh and difficult to place. Additional water is required to lubricate the mix, which makes the concrete workable. This additional water must be kept to the minimum, since too much water reduces the strength of concrete.
In this work Potable clean water was used.

METAKAOLIN:
In the present investigation Metakaolin marketed by specialty Minerals, Baroda, Gujarat, is used. The results furnished by the manufacturer are presented in table its specific gravity as found is 2.65 and bulk density is 710 kg/m3. The metakaolin appears like a fine powder with light grey colour shown in the Figure1 below

Fig 1. Metakaolin

III. METHODOLOGY

Preparation of concrete specimens such as cubes for compressive strength, cylinders for split tensile test, prisms for flexural strength and also cubes for durability studies in laboratory with 0%, 10%, 20% and 30% replacement of metakaolin with OPC for M20 and M40 grade concrete. Curing the specimens for 28 days and 90 days. Evaluation of the mechanical characteristics of concrete such as compressive strength, split tensile test, flexural strength.
Mix Proportions for One cubic meter of Concrete :

Cement	FA	CA	Water
kg/m3	kg/m3	kg/m3	lit
442.85	610.54	1167.54	186

Designed ratio is 1 :1.38 : 2.64 : 0.42
Among the trail mix conducted, the above mix gave required workability and required strength.

It is decided to Calculate the mix proportion with partial replacement of OPC with 0%, 10%, 20% and 30% of metakaolin.

Mix Proportions for M20 grade concrete:
Conventional Concrete – 1:1.9: 3.62: 0.55
10% replacement- 0.9:1.9: 3.62: 0.55
20% replacement – 0.8:1.9: 3.62: 0.55
30% replacement – 0.7:1.9: 3.62: 0.55
Mix Proportions for M40 grade concrete:
Conventional Concrete – 1:1.38: 2.64: 0.42
10% replacement- 0.9:1.38: 2.64: 0.42
20% replacement – 0.8:1.38: 2.64: 0.42
30% replacement – 0.7:1.38: 2.64: 0.42

Casting And Curing Of Test Specimens

The specimens of standard cubes (l50mmX150mmX150mm) 9No.s, Standard prisms (100mmx 100mm x 500mm) 3No.s and Standard cylinders of (150mm diameter 300mm height) 3Nos are cast for each cycle.

In all 240 specimens the cement was replaced by Metakaolin by (0%, 10%, 20%) with M20 case and M40 mix case were cast for 28days and 90 days curing.

Mixing

Measured quantities of coarse aggregate and fine aggregate were spread out over an impervious concrete floor. The dry ordinary Portland cement and Metakaolin were spread out on the aggregate and mixed thoroughly in dry state until uniform colour is obtained. Water measured exactly by weight mixed the super plasticizer, is added to the dry mix and is mixed thoroughly to obtain homogeneous concrete.

Placing and Compacting

The cube mould of the standard size, the prism mould of standard size, the cylinder mould of standard size confirming to IS 10086-L982 are cleaned. All care is to be taken for any irregular dimensions. The joint between the sections of the mould, the inner side and the bottom of the mould are to be greased properly.

The mould are arrange on the vibrating platform for casting. The mix is placed in three layers; each layer is compacted using table vibrator to obtain dense concrete

Curing

After 24 hours of casting the test specimens cubes, cylinders and prisms are de-moulded and immediately immersed in clean and fresh water tank and allow it for curing for 28 days and for 90days.

To evaluate the durability studies of M20 and M40 grade metakaolin replacement concrete with 1% and 5% concentrations of Hydrochloric acid (HCl) and Sulphuric acid (H_2SO_4).

IV. RESULTS & DISCUSSION

EFFECT OF VARIATION OF METAKAOLIN ON COMPRESSIVE STRENGTH

The test was carried out to obtain compressive strength of M20 and M40 grade concrete. The compressive strength of concrete is tested for 28 days, 90 days for 0%, 10%, 20% and 30% replacement of metakaolin and the values are presented in Table no.1 and 2 and also graphs were plotted bellow.

Table.1: Compressive Strength of concrete for M20

S.No:	% of Metakaolin	Compressive Strength(N/mm^2)	
		28 days	90 days
1	0	33.3	46.26
2	10	35.57	50.26
3	20	37.49	53.33
4	30	34.37	48.85

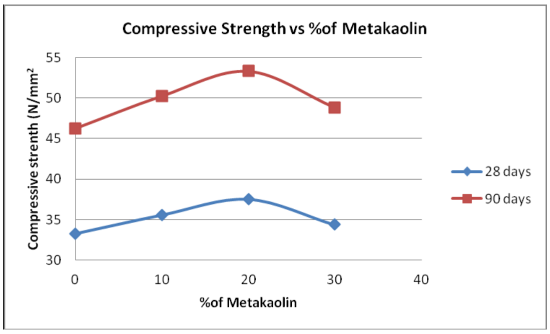

Figure 2. Graph between Compressive Strength of concrete for M20 vs % of metakaolin

Table.2: Compressive Strength of concrete for M40

S.No:	% of Metakaolin	Compressive Strength(N/mm^2)	
		28 days	90 days
1	0	49.99	54.22
2	10	51.66	56.99
3	20	54.59	58.11
4	30	50.36	54.44

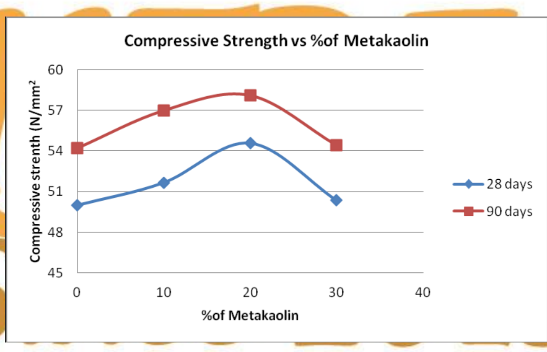

Figure 3. Graph between Compressive Strength of concrete for M40 vs % of metakaolin

From both tables and graphs it is observed that at about 20% replacement of cement with Metakaolin, concrete attains its maximum compressive strength for both M20 and M40 grade concretes, when the replacement exceeds 20%, the compressive is found to be decreasing slightly. And 10% replacement of metakaolin is greater than the 30% replacement of metakaolin.

EFFECT OF VARIATION OF METAKAOLIN ON SPLIT TENSILE STRENGTH

The test was carried out to obtain split tensile strength of M20 and M40 grade concrete. The split tensile strength of concrete is tested for 28 days, 90 days for 0%, 10%, 20% and 30% replacement of metakaolin and the values are presented in table no and also graphs were plotted bellow.

Table 3. Split Tensile Strength of Concrete for M20

S.No:	% of Metakaolin	Split Tensile Strength(N/mm^2)	
		28 days	90 days
1	0	2.69	3.5
2	10	2.9	3.69
3	20	3.1	3.9
4	30	2.82	3.71

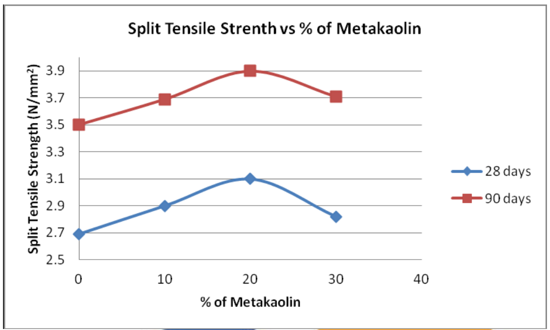

Figure 4. Graph between Split Tensile Strength of concrete for M20 vs % of metakaolin

Table 4 Split Tensile Strength of Concrete for M40

S.No:	% of Metakaolin	Split Tensile Strength(N/mm^2)	
		28 days	90 days
1	0	3.11	3.67
2	10	3.36	3.82
3	20	3.62	4.1
4	30	3.22	3.7

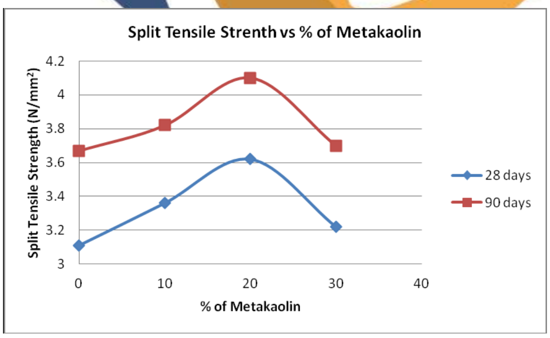

Figure 5. Graph between Split Tensile Strength of concrete for M40 vs % of metakaolin

From both tables and graphs it is observed that at about 20% replacement of cement with Metakaolin, concrete attains its maximum split tensile strength for both M20 and M40 grade concretes, when the replacement exceeds 20%, the compressive is found to be decreasing slightly. And 10% replacement of metakaolin is greater than the 30% replacement of metakaolin.

EFFECT OF VARIATION OF METAKAOLIN ON FLEXURAL STRENGTH

The test was carried out to obtain flexural strength of M20 and M40 grade concrete. The flexural strength of concrete is tested for 28 days, 90 days for 0%, 10%, 20% and 30% replacement of metakaolin and the values are presented in and also graphs were plotted bellow.

Table 5. Flexural Strength of Concrete for M20

S.No:	% of Metakaolin	Flexural Strength(N/mm^2)	
		28 days	90 days
1	0	5.21	6.51
2	10	5.64	7.12
3	20	5.91	7.95
4	30	5.32	6.62

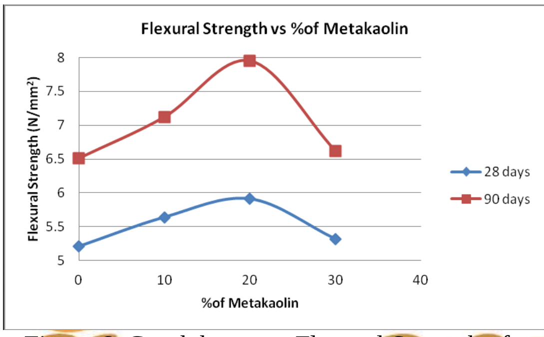

Figure 6 Graph between Flexural Strength of concrete for M20 vs % of metakaolin

Table 6 Flexural Strength of Concrete for M40

S.No:	% of Metakaolin	Flexural Strength(N/mm^2)	
		28 days	90 days
1	0	6.1	7.02
2	10	6.5	7.56
3	20	7.12	8.21
4	30	6.34	6.9

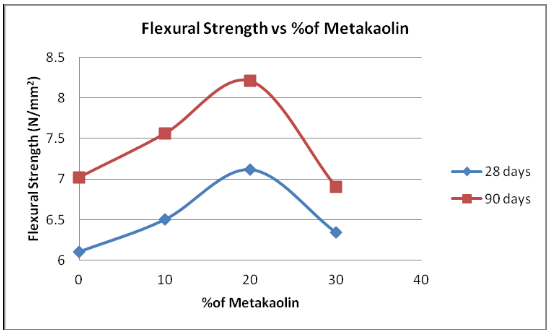

Figure 7 Graph between Flexural Strength of concrete for M40 vs % of metakaolin

From both tables and graphs it is observed that at about 20% replacement of cement with Metakaolin, concrete attains its maximum flexural strength for both M20 and M40 grade concretes, when the replacement exceeds 20%, the compressive is found to be decreasing slightly. And 10% replacement of metakaolin is greater than the 30% replacement of metakaolin.

EFFECT OF H2So4 AND HCl ACIDS ON CONCRETE (DURABILITY STUDIES)

Effect of H2SO4: From above tables and graphs it is observed that the compressive strength values of 5% (28 days) and 1% (90 days) concentration H2SO4 containing M20 and M40 grade concrete decreases, but resistance power of concrete increases with replacement of metakaolin against to H2SO4, up to 20% replacement resistance power increases beyond that resistance power decreases, but at 20% replacement of metakaolin the resistance power of concrete is more.
Effect of HCl: The compressive strength values of 5% (28 days) and 1% (90 days) concentration Hcl containing M20 and M40 grade concrete decreases, but resistance power of concrete increases with replacement of metakaolin against to Hcl, up to 20% replacement resistance power increases beyond that resistance power decreases, but at 20% replacement of metakaolin the resistance power of concrete is more.

V. CONCLUSIONS

Based on the analysis of experimental results and discussion there upon the following conclusions can be drawn.
1. The compressive strength of concrete increased when cement is replaced by Metakaolin for both M20 and M40 grade of concrete. At 20% replacement of cement by Metakaolin the concrete attained maximum compressive strength for both M20 and M40 grade of concrete.
2. The split tensile strength of concrete is increased when cement is replaced with Metakaolin .The split tensile strength is maximum at 20% of replacement.
3. The flexural strength of concrete is also increased when the cement is replaced by Metakaolin. At 20% replacement, the flexural strength is maximum.
4. The compressive strength values of acid effected concrete decreases on comparison with of normal concrete, but the effect of acid on concrete decreases with the increase of percentage of metakaolin. At 20% replacement of metakaolin the resistance power of concrete is more.
5. The compressive strength values of metakaolin concrete effected to HCl were greater than the metakaolin concrete effected to H2SO4. The effect of HCl on strength of the concrete is lower than the effect of H2SO4 on strength of the concrete
6. Workability of concrete decreases with the increase in metakaolin replacement level.

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