INVESTIGATION OF EFFECTS OF METAKAOLIN ON CONCRETE PROPERTIES

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Abstract

Many mineral admixtures are available in the construction market, Metakaolin is one of them, whose potential is not fully tested, and not many studies have been carried out on use of it for development of high strength concrete. Metakaolin is a supplementary cementitious material derived from heat treatment of natural deposits of kaolin. Metakaolin shows high pozzolana reactivity due to their amorphous structure and high surface area. For this project, cement was partially replaced by metakaolin in M_{50} concrete mix in increasing amounts of 0%,10%,20% and 30%. The mix design was made making the use of IS 10262:2019 and IS 456:2000.

Results obtained were observed and discussed upon to come up to a conclusion regarding the effects of metakaolin on properties of M_{50} grade concrete.

Key Words: *Concrete, Metakaolin, Strength, carbon dioxide*.

1.INTRODUCTION

Concrete is a very versatile man-made material in the construction industry. Various researches are done for development of high strength concrete due to increasing demands of construction industry. Due to these increasing demands, enhancement of strength of concrete is done with replacement of cement in concrete mix with certain cementitious materials like silica fume, fly ash, and GGBS.It is seen that partial replacement of cement in concrete mix with pozzolanic materials can be beneficial for strength improvements. This is due to fact that calcium hydroxide which gets produced during cement hydration reacts with pozzolans and produces gel which causes pore blocking effect and pore structure gets changed and strength gets improved. Strength improvement includes enhancement of strengths such as compressive, tensile and flexural strength. For such strength enhancement, partial replacement of cement with metakaolin is a new approach.

Metakaolin is an ultra-fine pozzolanic material which is used to produce high strength concrete. The temperature of 600°C-800°C is maintained for production of metakaolin. Hydrous aluminium silicate which is also known as kaolinite has composition as $2H_2O.Al_2O3.2SiO_2$ and it is a main constituent of metakaolin. The study of metakaolin as cement replacement material came into existence in recent years still there are many unknowns with metakaolin. Metakaolin is an artificial material hence its engineering values can be well controlled.

As of today the cement manufacturing produces 5% of the total carbon dioxide emissions produced by manmade activities, and a major part of this is due to the high clinkering temperature for cement production which is about 1500°C whereas during production of metakaolin clinkering occurs at 600-700°C hence reducing carbon dioxide emissions. Other SCMs are generally waste products from other industries and the demand for the products of these industries governs the waste output and hence can lead to unsteady supply if the production of these industries fluctuate due to fluctuating demand of their primary product ,metakaolin being an engineered product can be produced as and when required, ensuring steady supply.

2. MATERIALS AND METHODOLOGY

2.1 Materials

Cement: 53 grade ordinary portland cement was used.
Fine aggregate: Crushed sand confirming to zone II with specific gravity 2.61 was used.
Coarse aggregate: Maximum size of coarse aggregate used was 20mm having specific gravity 2.82.
Metakaolin: In this experiment, white metakaolin having specific gravity 2.3 was used.
Admixture: Sikaplast 5201 NS from Sika India Pvt. Ltd. was used.

Fig. 2.1.1. Metakaolin

Fig. 2.1.2. Batched materials

2.2 Methodology

2.2.1. Mix design

Mix design was carried out for M_{50} grade of concrete having slump in the range of 125mm to 150mm by IS 10262:2019 and IS 456:2000 ,resulting in a mix proportion of 1:1.69:2.28 with water binder ratio of 0.33 , and in this mix design cement was replaced by metakaolin in proprtions of 10% ,20% and 30%.

2.2.2. Workability test

Slump values are a measure of workability of prepared concrete mix.For this test a standard slump cone is used having the following internal dimensions, 200mm base diameter, 100mm top diameter and 300 mm length. This cone is filled upto the brim with the prepared concrete mix in layers along with continuous tamping. Once filled, the cone is lifted and the slump is measured.

2.2.3. Compressive strength test

Concrete cubes of dimensions 150mm x 150mm x 150mm are cast by pouring concrete in standard moulds of said dimensions and are tested in compression testing machine of load capacity 3000 kN after curing the cubes by submerging them in curing tank filled with water for 7 and 28 days. This procedure is repeated for all the different mixes made by replacing cement by metakaolin in proportions of 10% ,20% and 30%. The apparatus is shown in **Fig.2.2.3**.

Fig. 2.2.3. Compression testing machine

2.2.4. Flexural strength test

Concrete prisms of dimensions 100mm x 100mm x 500mm are cast by pouring concrete in standard moulds of said dimensions and are tested in flexural testing machine after curing the prisms by submerging them in curing tank filled with water for 7 and 28 days. This procedure is repeated for all the different mixes made by replacing cement by metakaolin in proportions of 10% ,20% and 30%. The apparatus is shown in **Fig.2.2.5**.

2.2.5. Split tensile strength test

Concrete prisms of dimensions 100mm x 100mm x 500mm are cast by pouring concrete in standard moulds of said dimensions and are tested in flexural testing machine after curing the prisms by submerging them in curing tank filled with water for 7 and 28 days. This procedure is repeated for all the different mixes made by replacing cement by metakaolin in proportions of 10% ,20% and 30%. The apparatus is shown in **Fig.2.2.5**.

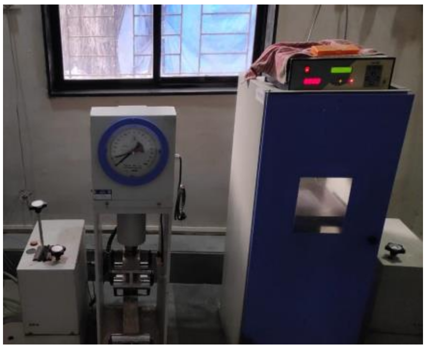

Fig. 2.2.5. Flexural and split tensile strength test apparatus

3. TEST RESULTS AND DISCUSSION

3.1 Workability

Workability of the concrete mixes varies in the following manner. 147mm for control mix that is 0% replacement, 136mm for 10% replacement, 129mm for 20% replacement and 110mm for 30% replacement.

3.2. Compressive strength

Results of compressive strength tests conducted on hardened concrete samples with 0-30% metakaolin cured for 7 and 28 days are shown in **Table 3.2** below. The results show increasing results up to 20% replacement of cement with metakaolin.

Mix	% metakaolin	7-day compressive strength in Mpa	28-day compressive strength in Mpa
M0	0	33.39	53.13
M1	10	37.12	56.3
M2	20	39.67	60.56
M3	30	34.4	55.13

Table 3.2. Compressive strength test results

3.3. Flexural strength

Results of Flexural strength tests conducted on hardened concrete samples with 0-30% metakaolin cured for 7 and 28 days are shown in **Table 3.3** below. Flexural strength increases up to 20% replacement with metakaolin.

Mix	% metakaolin	7-day flexural strength in Mpa	28-day flexural strength in Mpa
M0	0	1.42	6.75
M1	10	1.53	7.5
M2	20	1.6	7.97
M3	30	1.49	6.96

Table 3.3. Flexural strength test results

3.4. Split tensile strength

Results of split tensile strength tests conducted on hardened concrete samples with 0-30% metakaolin cured for 7 and 28 days are shown in **Table 3.4** below. Results show optimum replacement of 20%.

Mix	% metakaolin	7-day split tensile strength in Mpa	7-day split tensile strength in Mpa
M0	0	1.73	3.34
M1	10	1.81	3.59
M2	20	1.92	3.69
M3	30	1.79	3.4

Table 3.4. Split tensile strength test results

4. CONCLUSION

Due to the pore filling action of metakaolin we can see an increase in compressive strength, flexural strength and split tensile strength up to 20% replacement of cement by metakaolin and hence 20% replacement can be considered as the ideal dosage for M50 grade concrete.Since cement content decreases in the mix its lubricating effect also goes on decreasing due to which the workability of the concrete mix also goes on decreasing from 0% replacement to 30% replacement.

Based on observations following conclusions can be drawn

1. 20% of metakaolin increased the compressive strength of concrete by 16%.
2. 20% of metakaolin increased the flexure strength of concrete by 11.25%
3. 20% of metakaolin increased the split tensile strength of concrete by 9.89%.
4. We can safely say that metakaolin can be safely used as a greener alternative at dosage of 10%-20% replacement of cement to increase the strength of concrete.

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