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An Experimental Investigation on Meta Kaolin Modified Concrete Paver Blocks

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ABSTRACT

Concrete paver blocks are special pre-cast pieces of concrete blocks of non-interlocking or interlocking types, commonly used in exterior landscaping pavement applications. Properly designed and constructed paver blocks give excellent performance at locations where conventional pavement systems have lower service life due to a number of environmental, geological constraints. But with the use of high performance concrete they can be designed to sustain light, medium, heavy and very heavy traffic conditions under any constraints. Modern concrete can be modified with addition of mineral admixtures which refine the microstructures of the concrete and enhance its physical properties and durability. Meta kaolin, produced by controlled thermal treatment of kaolin, can be used as a concrete constituent, since it has pozzolanic properties. It is a highly efficient Pozzolana and reacts rapidly with the excess calcium hydroxide resulting from OPC hydration by a pozzolanic reaction, to produce calcium silicate hydrate and calcium alumino silicate hydrates. Hence the objective of the present work was to evaluate the performance of concrete modified with Meta kaolin for paver blocks for use in pavements and other application areas. As compressive, flexural strengths and water absorption are the most significant properties for concrete paver blocks the same have been studied for various concrete mixes with varying percentages of Meta kaolin.

INTRODUCTION

Concrete is a product attained artificially by hardening the mixture of cement, sand, gravel and water in suitable quantities. As we know concrete is a composite material which is mostly used in construction industry all over the world. It is artificially attained by mixing the cementitious materials, aggregates and water in predetermined quantities. The word "concrete" is originated from the Latin word "concrete" which has the meaning to grow together to harden. The strength properties for the concrete depend upon the properties for constituent of material used and their combined action

In the manufacturing process of cement CO2 gas emission is high, which results in damaging the natural environment and climatic conditions. To reduce the utilization of cement, partial standby of cement with some additional cementitious materials like Meta kaolin (MK), bottom ash, rice husk ash, GGBS and silica fume etc., are used in concrete production. Meta kaolin is a de hydroxylated form of the Kaolin clay mineral. Stones having the high percentage of kaolinite are called as the china clay (kaolin) was traditionally used as the manufacturing of the porcelain ceramic material. Meta kaolin reacts with Ca (OH)2 which is one of the by-product of hydration reaction of cement and its forms the C-S-H gel. This gel formation results in increasing strength and durability of the concrete. By replacing cement with MK increases the strength and durability and reduces the porosity in the concrete and reduces the permeability also.

MATERIALS

Cement

Ordinary Portland Cement (OPC) is the most common cement used in general concrete construction. It is used as a basic ingredient of concrete. Ordinary Portland cement is classified as OPC-53, OPC-43, OPC-33 grades. The 43 grade OPC is the most popular general-purpose cement in India.

Meta kaolin

Meta kaolin is a highly reactive Pozzolana for use in concrete. It is not a by-product but a product that is manufactured for use by-product and is formed when china clay, the mineral kaolin, is heated to a temperature between 600 and 800ºC. Its quality is controlled during manufacture, resulting in a much less variable material than industrial Pozzolana that are by-products. First used in the 1960s for the construction of a number of large dams in Brazil, Meta kaolin was successfully in corporated into the concrete with the original intention of suppressing any damage due to alkali-silica reaction**.**

Pozzolanic reaction of Meta kaolin
Meta kaolin acts like pozzolana. It reacts with CH hydrates and form secondary CSH gel along with calcium aluminate hydrates and calcium alumino silicate hydrate gels. They are of cementitious nature. The get deposited on primary CSH gel and form compact and smooth plates like structure. Meta kaolin also act like filler and fill the voids between the hydrate plates hence increasing density of hydrated mass

LITERATURE REVIEW

Satyendra Dubey et al. (2015) aimed to study effect of Meta kaolin on compressive strength of concrete. For M25grade of concrete by replacing cement with 0, 5, 10, 15% MK. The results to showed that 10% MK is the optimum % replacement and the other % of MK such as 5 and 15% also showed that considerable increase in strength characteristics of the concrete when compared with conventional concrete.

Nikhil K and Ajay A.H (2015) studied the valuation of Strength of Plain Cement Concrete with Partial substitute of Cement by MK. In this study they observed replacement of cement with MK and fly ash at 0%, 5%, 10% and 15% for 7days and 28 days for M20and M25. And these results compared with the conventional concrete.

Yogesh R. Suryawanshi et al. (2015) studied the Compressive Strength for the Concrete by using the Metakaolin. In their research study they investigated the effects of MK & Super plasticizeron the strength properties of M35grade concrete. Their research program is designed to find the compressive strength of concrete by partially substituting the cement with MK in concrete production.

Naresh Kumar (2014) aimed to investigate on A Study of MK and SF used in various Cement Concrete blocks. In his research work effect of MK and Silica Fume is used through compressive and flexural strength of concrete.

Sai Kumar A.V.S, Krishna Rao.B (2014) aimed to study on strength of concrete with partial replacement of cement with quarry dustand MK. This paper dealt at constant replacement of fine aggregate (FA) with 25% Robo sand by varying MK percentage as 2.5,5,7.5,10%.

Sanjay N. Patil et al. (2012) aimed to study the Literature Review on Metakaolin effect on Concrete with title as Metakaolin- Pozzolanic Material for the Cement in High Strength Concrete. In the paper they concluded that optimal percentage is attained by replacing 7% to15% of cement with MK and the benefits are not realized until at least 10% MK is used. Compressive strength of concrete with MK after 28 days can increases up to 20%.

Experimental Programme
The process to select the mixing materials and their appropriate quantities is done through mix design. There are ways to find the concrete mix design. The methods which are using in India are in accordance with the BIS.

The main objective of the concrete mix design is to find the appropriate proportion in which the concrete ingredients like cement, water, fine aggregate and coarse aggregate should be mixed to provide the specified strength, durability and workability and possibly meet other requirements according to IS: 456-2000. IS: 10262-2009 code which gives the guidelines for the nominal concrete mix designs.

Material and Their Properties
Cement
The physical properties of the cement used in present research work i.e. Ordinary Portland Cement of 43-Grade of Ultratech brand confirming to IS 8112: 2013.

Natural Fine Aggregate
Locally available river coarse sand is used as a fine aggregate. The sieve analysis and physical properties of fine aggregate have been shown in the table below. Fine aggregate (sand) conforms to Grading Zone-III as per **IS: 383-1970**.

Coarse aggregate
Locally available aggregates is used as a coarse aggregate .The sieve analysis and physical properties of coarse aggregate

Water
The water should be free from organic and deleterious impurities. The potable water is generally considered satisfactory for

the concrete as per clause 5.4of IS: 456-2000.Tap water available in the laboratory was used for production of concrete and curing of the concrete specimens.

Concrete Mix Design

Mix

Design

Mix design is done for the present study. Generally, for the manufacture of precast concrete paver blocks needs dry, low slump mixes. Mix design was done for control mix of M40 grade of concrete by using the IS code 10262: 2009 and specification given in the IS code 15658: 2006.

Manufacturing of paver block

Cement, sand, coarse aggregate, water and super plasticisers were mixed thoroughly in the concrete mixer. Then it was filled in the rubber paver mould of different shapes and different thickness. All the filled paver moulds were vibrated using table vibrator. After casting all the specimens were completed with a steel trowel and it was kept for 24 hours. After 24 hours they were remoulded from the paver moulds and kept in the water tank for water curing. The same procedure was done for 5%,10% and15% replacement of cement with metakaolin. To know the effect of standby of cement with metakaolin, compressive strength, flexural strength, were done on the paver block.

TESTING OF PAVER BLOCK

Compressive strength

As per IS 15658: 2006, compressive strength of paver block was determined at 7 and 28 day using universal testing machine (UTM). Minimum 3 samples were tested for 7 and 28 day strength. The average strength of 3 samples at 28 days were taken as compressive strength of paver block. The apparent compressive strength of paver block was multiplied with correction factor as it is mentioned in IS 15658: 2006 of table 5 Annex D to get corrected compressive strength of paver block.

FESEM and EDX

To investigate the effect of Metakaolin on the microstructure of concrete various techniques such as spectroscopy, X-ray powder diffraction (XRD), Field Emission Scanning Electron Microscope (FESEM) are used.

SEM micrographs are obtained using FESEM apparatus. During the examination, the accelerating voltage is kept at a range of 20 kV. Mineral components of the isolates are further characterized by Energy Dispersive X-ray Spectroscopy (EDX) analysis.

RESULTS AND DISCUSSIONS

The results obtained from experiments conducted on concrete paving blocks have been discussed in this chapter. A comparison of results has been made to evaluate the effect of the partial replacement of the cement by Meta kaolin in concrete mixes to determine the mechanical properties at the age of 7 days and 28 days. One reference mix M0 of M40 grade was prepared without addition of Meta kaolin and three more mixes M1, M2 and M3 were prepared with Meta kaolin of varying amounts 5%,10% and 15% used as partial replacement of cement respectively. Three different shapes of paver blocks, Zigzag, I shaped, and Dumbel shaped were adopted for the study. Eight specimens of each type of paver blocks were cast and cured for 7days and 28 days.

Compressive Strength

As per IS 15658: 2006, compressive strength of paver block was determined at 7 and 28 day using Universal testing machine (UTM). Minimum 3 samples were tested for each 7days and 28 day strength. The apparent compressive strength of paver block was multiplied with correction factor as it is mentioned in IS 15658: 2006 to get corrected compressive strength of paver block.

Table 7-days Compressive Strength Result MPa

Mix	Metakaolin (%)	Zigzag (80mm)	Dumbel (60mm)	I-shape (60mm)
M0	0	53.14	52.46	51.98
M1	5	55.9	56	54.5
M2	10	61.85	62.46	60.89
M3	15	57.95	58.13	56.79

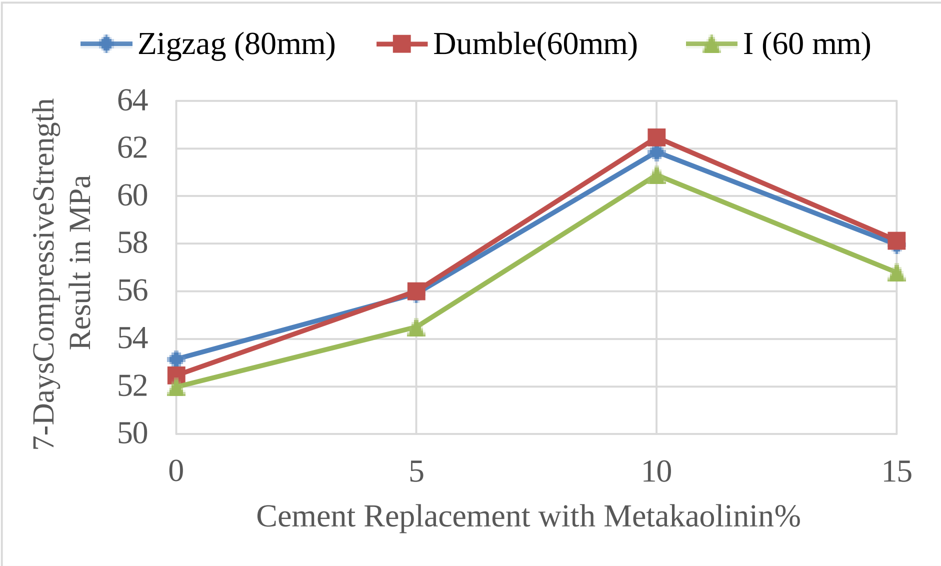

Fig: 7-daysCompressive strength result Mpa

Table 28-days Compressive Strength Result MPa

Mix	Metakaolin (%)	Zigzag (80mm)	Dumbel (60mm)	I-shape (60mm)
M0	0	61.43	60.83	59.23
M1	5	66.42	65.24	63.9
M2	10	73.24	74.26	71.2
M3	15	70.01	69.54	68.54

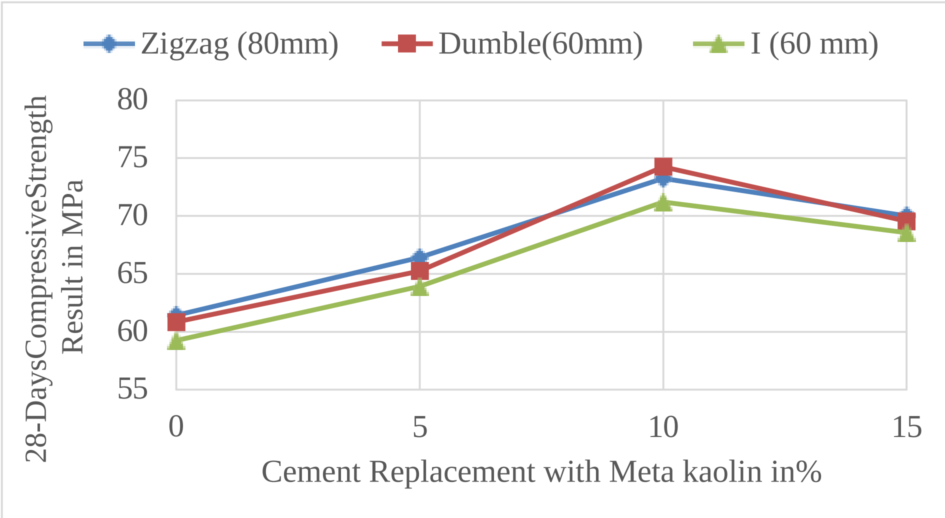

Fig: Days Compressive Strength Result MPa

- It was observed that 7-days and 28-days' compressive strength of all shapes of paver blocks had increased due to incorporation of Metakaolin compared to control mix M0. Mix with 10% Meta kaolin exhibited maximum strength gain. Compared with I-shape Zigzag and Dumbel shape gave more strength and their behavior was almost same.
- Compared with control mix maximum percentage increase in 7 days compressive strength for M10 mix was 17.14 % found with I shape, 19.06% with Dumbel shape and 16.39% with zigzag shape. Similarly maximum percentage increase in 28 days compressive strength was observed as 20.21% with I shape, 22.1 with Dumbel shape and 19.22was with zigzag shape.
- For Dumbel shape 7.25% increase in strength were found with 5% MK, 22.1% increase with 10% MK and 14.32 % increase with 15 % MK as partial replacement. The same trend was shown for other shapes.

CONCLUSIONS

The aim of the present research work is to determine the mechanical properties of concrete with MK as the admixture for M40 grade of concrete Paver blocks. On the basis of experimental investigation of the present research study, the following conclusions have been drawn.

1. It is observed that compressive strength of paver block for all the shape and thickness at 7 and 28 days are increased as percentage of cement replacement with MK increases up to 10%. . 7 days compressive strength of paver block for all the shapes are more than required target strength up to 15% cement replacement. The maximum compressive strength for all the shapes are more at 10% of replacement. The maximum compressive strength of Dumbel (60mm) thickness at 10% replacement is 74.26 MPa which is about 23% more than that of control concrete.
2. Flexural strength is increasing as cement replacement increases up to 10% after that for 15% cement replacement it is more than control concrete and also more than 5% replacement. 7-dayand 28-day flexural strength is increases up to 10 % replacement after that it decreases as percentage of replacement increases. Even though there is decrease in flexural strength at 28 days after 10% replacement of cement the flexural strength at 15% replacement also more than 4.5MPa for all the shapes which is required strength for rigid concrete pavement.
3. Use of Meta kaolin as partial replacement of cement increases mechanical properties like compressive strength, flexural strength of concrete.
4. Concrete with Meta kaolin also exhibited better durability in terms of water absorption.
5. It was observed that10 percent Meta kaolin used as partial replacement of cement improve overall properties of concrete paver blocks.
6. About20%increasein 28-days compressive strength were observed for all types of paver blocks.
7. About20%increasein 28-days compressive strength were observed for all types of paver blocks.
8. About11%increasein28-daysflexuralstrengthwereobservedforalltypesofpaver blocks.
9. The maximum strength gain was observed for Dumbel shape paver blocks.

10. Meta kaolin imparts distinct glassy white color to paver blocks which increase the reflectivity and makes it suitable for specific applications like in swimming pools, roofs etc. to enhance architectural beauty also.
11. Less permeability makes it suitable to be used in industrial floors, parking garages, bridge decks etc.
12. The microscopic observations by FESEM revealed that Meta kaolin in concrete forms dense structure mainly due to the increase of the amount of hydration products such as CSH,CAH and CASH and their later accumulation within the available pores giving high strength and less permeability.
13. The XRD and EDX analysis confirms the above observations**.**

SCOPE FOR FUTURE STUDY

1. The current study involves the experimental investigation on the mechanical properties of high strength concrete paver blocks prepared with concrete containing commercially available meta kaolin as mineral additive.
2. A concrete mix of M40 grade , suitable for making concrete paver blocks for medium traffic was designed following IS 15658:2006 . Three different shapes Zig Zag , Dumbbell and I-shape paver blocks were considered for the study.
3. The effect of replacing cement partially by 5% ,10% and 15% of meta kaolin were studied in terms of 7-days and 28-days of compressive strength, flexural strength, water absorption and abrasion resistance.
4. The results were compared with mix without meta kaolin referred as control mix.. The results indicated that addition of meta kaolin improve all characteristics of the paver blocks of all types.
5. The mix with 10% replacement was found to give maximum compressive, flexural strength , abrasion resistance and minimum water absorption characteristics .
6. The further increased percentage of meta kaolin were found to adversely affecting these characteristics due to dilution of Cement.
7. Comparing with control mix 20% increase in compressive strength, 12% increase in flexural strength, 16 % increase in abrasion resistance and 30 % decrease in water absorption were observed for the mix with 10% metakaolin.
8. The microscopic study of hydrated structure of metakaolin modified concrete mix were conducted through XRD ,FESEM and EDX techniques.
9. The XRD and EDX analysis indicated higher percentage of strength giving silicates hydrates phase and the FESEM images showed more refined , compact, smooth and layered micro structure for metakaolin modified concrete mix.
10. The microscopic study of hydrate structures of different mix justify the results obtained from mechanical tests.

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