International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Experimental Study on behaviour of Paver Block Using Partial Replacement of Metakaolin

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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. Metakaolin, 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 react rapidly with the excess calcium hydroxide resulting from OPC hydration by a pozzolanic reaction, to produce calcium silicate hydrate and calcium alum inosilicate hydrates.

Hence the objective of the present work was to evaluate the performance of concrete modified with Metakaolin 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 Metakaolin.

Metakaolin was used as partial replacement of cement in the study and three percentages 5%.10% and 15% were adopted for determination of compressive strength, flexural strength and water absorption of zigzag, dumbel and I shape paver blocks. The mix with 10% replacement was found to give maximum compressive, flexural strength and minimum water absorption for all types of paver blocks.

KEY WORDS – Metakaolin, flexural strength, water absorption, pozzolanic, compressive strength, calcium hydroxid

INTODUCTION:

Concrete is a material that is created artificially by appropriately combining cement, sand, gravel, and water. Concrete is a composite material that is widely employed in the global building industry, as is well known. Its artificially proficient by blending the cementitious components, aggregates, and water in a particular ratio. "Concretus" is a Latin word which means "to grow together to harden," is where the English word "concrete" first appeared. The characteristics of the constituent materials utilised, as well as their combined action, determine the concrete's strength attributes.

The production of cement produces significant amounts of CO2 gas, which harms the environment and alters the climate. In order to reduce the amount of cement required, Cement is used in the production of concrete as a partial backup, together with other cementitious materials such Metakaolin (MK), bottom ash, RHS, GGBS, and silica fume, among others. MK is a dehydroxylated range of mineral kaolin clay. The term "china clay" (also known as "kaolin") refers to stones with a high concentration of kaolinite, which has historically been used to make porcelain ceramics. C-S-H gel is created when metakaolin combines with Ca(OH)2, one of the byproducts of cement's hydration reaction. The strength and durability of the concrete are increased as a result of this gel formation. The strength and durability of the concrete are increased, the porosity is decreased, and the permeability is also decreased by using MK in place of cement.

PAVER BLOCKS

The first time concrete paver blocks were used in place of paver blocks was in Holland. These blocks were almost the same size as bricks and had a rectangular shape. Depending on the applications, paving block shapes have changed during the past fifty years. They were initially intended to be non-interlocking or partially interlocking shape types, which were later changed to completely interlocking shape types. These precast concrete paver blocks are used to build pavements and are put on a thin, compacted bedding over a contoured base course.

Concrete Block Pavement (CBP) is what the pavement is known as when paver blocks are used, while Interlocking Concrete Block Pavement (ICBP) is what the pavement is known as when interlocking paver blocks are used (ICBP).

Due to their pre-cast nature, these paving stones can be used in any place and are not dependent on the geological or environmental conditions. To meet the need, they can be made in all forms and sizes.

Additionally, they provide quick construction and have safety handled light, medium, and severe traffic conditions.

Fig. Paver Blocks

MATERIALS

Cement

Its generally used cement is called Ordinary Portland Cement (OPC). It serves as a fundamental component of concrete. The grades of regular Portland cement are OPC-53, OPC-43, and OPC-33. In India, the most widely used all-purpose cement is OPC 43 grade.

The fundamental qualities in the cement concrete mix are derived from their proportional percentage in cement. Preposition of Ordinary Portland cement given in Table 1.1

Table OPC COMPOSITION

Chemicals	Mass (%)
CaO	60-67
SiO2	17-25
Al2O3	3-8
Fe2O3	0.5-6
MgO	0.1-4

Metakaolin

For usage in concrete, metakaolin is a highly reactive Pozzolana. Its obtained when china clay is heated a temperature b/w 600 and 800ºC; its not a by-product but a manufactured-for-use by-product. As a result of manufacturing quality controls, it has substantially lower variability than industrial Pozzolana byproducts. With the initial goal of preventing damage from the alkali-silica reaction, Metakaolin was successfully included into the concrete during the 1960s when a number of big dams were being built in Brazil.

Its frequently added cohesive and a smaller amount likely to blend when its replaced cement at 5 to 10% by wt. Processes like pumping and finishing become easier as a result. At this degree of replacement, the compressive strength of hardened concrete likewise increases.

Replacement levels that are a little bit higher (up to 20%) result in a cement matrix with low porosity and permeability. Due to this, the hardened concrete is more resistant to assault from sulphates, chloride ions, and other aggressive chemicals like mineral and organic acids. When Metakaolin concrete is finished and properly cured, its resistance to freeze-thaw is increased and the likelihood of damage brought on by impact or abrasion is decreased.

Table Chemical Composition of Metakaolin

Chemical Composition	**Mass (%)**
SiO2	61.88
Al2O3	27.96
Fe2O3	1.41
CaO	0.78
MgO	0.56

Fig 1.2 Metakaolin

Pozzolanic reaction of Metakaolin

Like pozzolana, metakaolin has an effect. Along with calcium aluminate hydrate and calcium aluminosilicate hydrate gels, it reacts with CH hydrates to create secondary CSH gel. They have a cementitious composition. They deposit on the primary CSH gel and create a structure resembling compact, smooth plates. Metakaolin is also used to fill the spaces between the hydrate plates, which raises the density of the hydrated mass.

Cement + Water = Primary CSH gel [Cementitious] + Ca (OH)2 [NonCementitious]

Ca(OH)2+Metakaolin = Calcium Aluminate hydrate(C4AH13) [Cementitious]

+ Calcium Aluminosilicate hydrate (C2ASH8) [Cementitious].

+ secondary CSH gel [Cementitious].

LITERATURE REVIEW:

Satyendra Dubey et al. (2015) intended to investigate how Metakaolin affected the concrete's compressive strengthening. In concrete of grade M25, substitute 0, 5, 10, or 15% MK for the cement. The findings showed that 10% MK is the best replacement and that other MK percentages, including 5 and 15%, are also acceptable, significantly improved the strengthening properties of concrete when compared to normal concrete.

Nikhil K and Ajay A.H (2015) MK conducted research on the evaluation of Plain Cement Concrete Strength with Partial Cement Substitution. For M20 and M25, replacement of cement with MK and fly ash was seen at 0%, 5%, 10%, and 15% for 7 days and 28 days. And these outcomes were compared to traditional concrete. Finally, they came to the conclusion that, while strength was diminished above 15% replacement cement with MK and fly ash, strength was increased up to this point. Therefore, for the best results, it is always preferable to utilise 10%.

Yogesh R. Suryawanshi et al. (2015) Utilizing Metakaolin, researchers looked at the compressive strength of concrete. They looked into how MK and Super plasticizer affected the strength characteristics of M35 grade concrete in their research study. By partially replacing the cement in the manufacturing of concrete with MK, their research programme aims to determine the compressive strength of the material. For a constant water-cement ratio of 0.43, the replacement levels of cement by MK were chosen to be 0%, 4%, 8%, 12%, 16%, and 20%. Compressive strength is reported at 3, 7, and 28 for all mixtures. A recent experimental investigation demonstrates that using MK as a 12% cement alternative results in greater strength. MK more than doubles the concrete's compressive strength.

Naresh Kumar (2014) investigated the application of MK and SF in different cement concrete blocks. Effects of MK and Silica Fume are utilised in his research through the compressive and flexural strengths of concrete. With a W/C ratio of 0.42, MK and SF are utilised as cement substitutes at 5%, 10%, and 15% by mass, respectively. Strengths in compression and flexion were reported after 7 and 28 days of cure. In the end, he came to the conclusion that adding MK replacement boosts compressive strength throughout the curing process. The best replacement, though, is 10%, and the improved strength is between 1.66 and 2.05% higher than plain concrete. At all phases of curing, replacing the MK also increases the flexural strength; however, the ideal dose is 10%, and the improved strength is concerning 1.5% additional than normal concrete.

Sai Kumar A.V.S, Krishna Rao.B (2014) evaluate the strength of concrete where quarry dust and MK were used to substitute some of the cement. This study looked at the continual replacement of fine aggregate (FA) with 25% Robo sand by adjusting the MK percentage to 2.5, 5, 7.5, and 10%. The findings demonstrated that, with a percentage replacement of MK cement in the cement mix, all properties have met their goal levels of man strength and flexural strength at 28 days. And after 28 days, with a 10% replacement of MK for cement, split tensile strength also increases.

Nazeer M et al. (2014) In general, adding pozzolana to concrete can enhance certain qualities including workability, strength as it ages, and resistance to sulphate and chloride attacks. In their research, Class-F MK was used to replace 50% of the cement in concrete mixes for M30 grade, as well as 0%, 5%, 10%, 15%, and 20% of Metakaolin. This research study led them to the conclusion that adding MK and SF to concrete reduces Workability. Compressive strength, split tensile strength, and elastic modulus are examples of mechanical properties exhibit a declining tendency as MK increases. According to the MK content in the mix, the decreased workability of high-volume MK concrete.

Nova John (2013) investigated the strength characteristics of concrete using MK Admixture. In this investigation, the strength characteristics of M30 concrete were examined at 0%, 5%, 10%, 15%, and 20%. They came to the conclusion that MK provides early age strength more quickly and that mixtures with 15% are superior to all other mixes. The use of additional cementitious materials, such as MK concrete, can make up for the economic and environmental problems brought on by the cement industry.

Patil B.B and Kumar P.D (2012) The concrete business is currently following a trend with its rich performance. The strength, workability, and durability of M60 grade High Performance Concrete at various MK percentages were the subjects of this investigation. The 7.5% substitution was found to be superior and to have strong environmental resistance.

Sanjay N. Patil et al. (2012) with the study's objective was to review the literature on the impact of metakaolin on concrete. The authors of the research came to the following conclusion: The benefits are not seen until at least 10% MK is used. The ideal proportion is reached by substituting 7% to 15% of cement with MK. After 28 days, the compressive strength of concrete containing MK can rise by 20%. Super-plasticizer dosage appears to be necessary to assure a longer time of workability as the proportion of MK increases.

Kim et al. (2007) used Korean MK to explore the durability and strength perspectives of high strength concrete. In their study, they substituted Metakaolin for cement in amounts of 5%, 10%, 15%, and 20%. Finally, their findings indicate that, at replacement levels of 5 to 15%, Metakaolin has no appreciable impact on either split tensile strength or flexural strength. However, at ages fewer than 28 days, there can be minor declines in strength in the 20% replacement share. The strength of all mixes at all stages is significantly increased at a 10% replacement of Metakaolin. Finally, they came to the conclusion that 10% MK may be used in Korean concrete production.

Koli Nishikant et al. (2016) conducted research on the viability of using waste glass in partial FA replacement systems. The characteristics of concrete were examined, along with the use of waste glass as a partial substitute for FA levels of 15%, 30%, and 45%. The used glass garbage was delivered by waste collectors. The obtained results unambiguously show that adding glass to completed concrete products enhances their compressive strength properties. The study found that recycled glass may successfully replace fine aggregate (up to 45%) without substantially impacting strength. The study found that as waste glass content increased, the density of concrete reduced, making it lighter in weight and reducing the proportion of water absorption. From 15% to 30% of glass is replaced, which results in an increase in compressive strength. From 30% to 45% of glass is replaced with garbage, which results in a drop in strength. The interior cavities of waste glass may be the cause of strength losses reported.

Vishal and Mishra A.K (2016) conducted investigation on waste steel aggregate-based paver bricks. Various amounts of waste steel bearing balls are mixed into the concrete of paver bricks. Under the paver bricks, elastic rubber pads are also employed. It is done to test the impact and compression strengths of paver bricks made with various amounts of discarded steel aggregate and elastic rubber pads. According to test results, a combination of using elastic Rubber Pads and adding various amounts of discarded steel aggregate to paver bricks results in up to 50% higher strengthening than normally used blocks.

Dixit N and Jayeshkumar R (2014) To assess the strength of ICPB, used foundry sand is used in place of cement in their study. After 7, 14, and 28 days of curing, the replacement is tested for its compressive and flexural strength at 10%, 20%, 30%, 40%, and 50%. 28 days have passed since the water absorption test was conducted. Their analysis came to the conclusion that a compressive strength of 23.48 N/mm2 could be attained with 50% cement replacement. Additionally, as replacement percentages are increased, water absorptions and compressive strength are both reduced. Water absorption is reported to be 2% with a compressive strength of 23.48 N/mm2 at maximum replacement 50%.

Navya G and Venkateswara Rao J (2014) In this investigation, polyester fibres were added to the top 20 mm of paving block thickness to measure compressive strength, water absorption, and flexural strength. In the volume of concrete, polyester fibres were added in percentages of 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%. At the conclusion of 7 and 28 days, the compressive, flexural strength, and water absorption tests were evaluated. According to the test results, 0.4% of polyester fibre added to paving blocks results in maximum compressive and flexural strengthening and least water absorption at 7^{th} and 28^{th} days. Results indicating fibres addition increases compressive and flexural strengths by up to 50% .

Khandve P.V and Rathi A.S (2016) Following studies shows the effort to substitute the coarse aggregate used to make typical concrete pavement blocks with waste from the kota stone industry. Its examine water absorption, compressive strengthening, and splitting tensile strengthening while taking into account different percentages of kota stone waste aggregates. The findings indicated that for the best outcomes, a maximum 50% replacement of conventional aggregate with kota stone waste aggregate is feasible. Utilizing waste materials lowers manufacturing costs, addresses the issue of how to dispose of construction waste, and contributes to environmental protection.

Rangan B.V. Et Al (2006), used two different kinds of fly ash in tests on geopolymers. Geopolymers are fire resistant, they discovered. After 14 days, they discovered that the compressive strength ranged from 5 to 51 MPa. The mixing procedure and the chemical make-up of the fly ash were the factors impacting the compressive strength. A higher CaO content reducing the porosity of microstructure and improving the compressive strengthening. moreover, the ratio of fly ash to water had an impact on strengthening.

Lloyd, N. And Rangan, V (2009), brief description of fly ash-based geopolymer concrete was offered. An example has been given to discuss and illustrate a straightforward technique for designing geopolymer concrete mixtures. Excellent qualities make geopolymer concrete ideally suited for producing precast concrete components required for disaster recovery and construction refurbishment. Additionally discussed are the geopolymer concrete's economic advantages and contributions to sustainable development.

D.B. Raijiwala And H.S. Patil (2011), investigated the effect of temperature (30o C and 60oC for 1, 7 and 28 days) on compressive strength test on fly ash mortar, concluded that higher mixing temperature and higher curing temperature resulted in higher compressive strength at early stages and compressive strength increases further with longer curing. When the samples were mixed at 25o C and cured at 30oC, the compressive strength was low at an early stage, but gradually increased and finally, had as high strength as those of higher temperature cured mortars.

Radhakrishna et.al (2015) has determined geopolymer masonry as sustainable Building material by complete elimination of cement by using fly ash, blast furnace slag as binders and River sand replaced with msand and other recycled aggregates. Industrial byproducts class F fly ash and slag were used as binders. They were cured in open air by conserving water.

Venugopal K et.al (2015) has studied geo-polymer masonry with complete elimination of cement is achieved without compromising the strength and durability. This study use of marginal materials fly ash, blast furnace slag as binders. River sand can be replaced with M-sand as fine aggregates.

Tejas.Ostwal1.et.al.(2014). In this study geo-polymer blocks prepared by without the use of cement. The materials used are Fly ash (Class F), Ground granulated blast furnace slag (GGBS), Quarry dust and sand. The mass reduction of GPC block due to hydrochloric acid resistance at the end of 84 days is found to be 0.72%.

EXPERIMENTAL INVESTIGAITON

Through the mix design process, the mixing materials and their corresponding proportions are chosen. The concrete mix design can be discovered in several methods. The techniques used in India are amenable with BIS. Cement, water, F.A., and C.A.—should be combined to produce concrete with the desired strength, durability, and workability, as well as to potentially satisfy other requirements as outlined in IS: 456-2000. The IS: 10262-2009 code provides instructions for the recommended concrete mix designs.

The characteristics of the substance utilised and the process for developing concrete mixes with Metakaolin at various percentages are covered in this chapter. The evaluation of mechanical properties with respect to compressive strengthening, flexural strengthening, and water absorption was the primary goal of this research work. This chapter has covered the supplies utilised for the research as well as the experiments done on concrete samples.

Material Used

Cement It having binding property that hardens and sets in construction and can bond other materials. The most common varieties of cement are used in masonry mortar and concrete structure, Mixture of cement and aggregate that forms a strong building material.

S. No	Properties	Test Results	Standard values acc. to IS: 8112-1989
1	Fineness	3%	< 10 %
2	Normal Consistency	29%	26%-33%
3	Sp. Gravity	3.14	3.14-3.15
4	Initial setting time	92 min.	>30 min.
5	Final setting time	186 min.	< 600 min.

Natural F.A.

As F.A., river coarse sand that is locally accessible is employed. The table below displays the fine aggregate's physical characteristics and sieve analysis. According to IS: 383-1970, fine aggregate (sand) complies with Grading Zone-III.

Wt. of Sample Taken=1000gms.

Table Sieve analysis of F.A.

S.No	IS Sieve Size (mm)	Retained Wt. (gms)	% Wt. Retained	Cumulative % Retained	% finer
1	4.75	16	1.6	1.6	98.4
2	2.36	28	2.8	4.4	95.6
3	1.18	97	9.7	14.1	85.6
4	0.6	282	28.2	42.3	57.7
5	0.3	221	22.1	64.4	35.6
6	0.15	331	33.1	99.5	0.5
7	Pan	20	0.2	99.7	0.3

Table Physical properties of F.A.

S.No	Property	Observed Value
1	W.A. (%)	0.515
2	Fineness Modulus	3.757
3	Sp. gravity	2.64

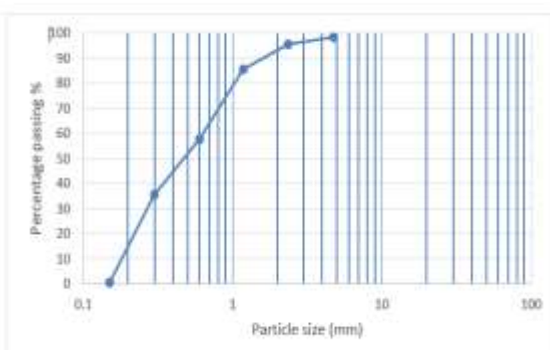

Fig Particle size distribution of F.A.

Course Aggrigate

As C.A., readily accessible aggregates are used. The table below displays sieve analysis and physical characteristics of C.A..

Wt. of Sample Taken=5000gms.

Table Physical properties of C.A,

S.No	Property	Observed Value

1	W.A. (%)	0.8
2	Fineness Modulus	5.2
3	Sp. gravity	2.71

Table Sieve analysis of C.A.

S.No	**Sieve Size (mm)**	**Retained Wt. (gms)**	**% Retained Wt.**	**Cumulative % Retained**	**% Finer**
1	10	560	11.2	11.2	88.8
2	4.75	4370	87.4	98.6	1.4
3	2.36	70	1.4	100	0
4	1.18	0	0	100	0
5	0.6	0	0	100	0
6	0.3	0	0	100	0
7	0.15	0	0	100	0
8	Pan	0	0	100	0

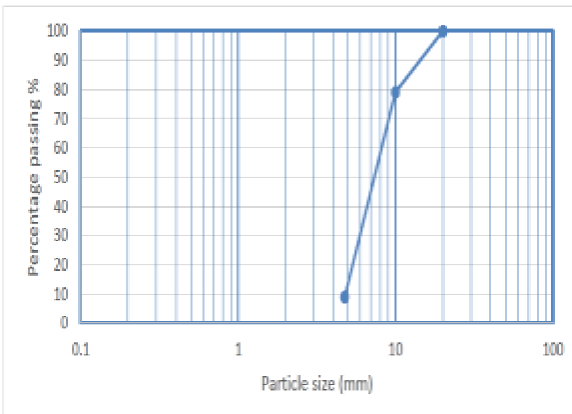

Fig 3.7 Particle size distribution of C.A.

Water

Its very useful in the formation of concrete mixture because it participates in heat of hydration process with cement. In presence of water the gel is form which helps in increase the strengthening of concrete. Almost any naturally available water which is used for drinkable purpose and having no taste or odour should be used for mixing. Water available from lakes, ponds, and streams are containing marine life which is usually suitable for concrete mixture. Water which is used for mixing, preparing concrete and curing should be fresh or free from harmful substance of alkalis, salt, acids, organic matter, oils, sugar and any other matters which can be harmful to the life of other building materials like stones, bricks, concrete structure. Portable water is usually used for satisfactory addition.

PH value of constructional water should not be less than 6 to 8 for concrete construction if its value less than its permissible limit than it's harmful for other building materials and there are various concentration given below.

a) Limits of acidity: If water is highly acidic then its effect the concrete so to reduce the effect of acid take 100ml solution of water and used phenolphthalein as indicator and it shall not required more than 5ml of 0.02 normal NaOH and complete detail of this test is given in IS 3025.

b) Limit of alkalinity: If water is more alkaline so it's also effect the working of concrete so to neutralize it take 100ml solution of water and using mixed indicator. it doesn't required more than 25ml of 0.02 normal H_2SO_4 and complete detail of this test is given in IS 3025.

c) % of solid: Max. permitted limit of any solids when its tested should be classified under IS 3025

Table Maximum limits of solids in water

Types of solids	Limits
Organic solids	200 mg/litres
Inorganic solids	3000 mg/litres
Sulphates	400 mg/litres
Chlorides	2000 mg/litres for concrete not contain embed steel, and 500 mg/litres for R.C.C. works
2000 mg/litres	

The naturally available ground water should be tested along with soil investigation as well as physical and chemical properties. if water is not found up to the requirements of IS 456 – 2000, the tender documents should obviously specify that the contractors have to arranged excellent quality of water which is suitable for construction and different source indicating the properties.

a) Water is to be found suitable for mixing and curing. However, it is use for mixing and curing purpose should not be producing any unpleasant stains or unsightly particle deposition on the surface.

b) Sea or marine water can't be useful for concrete mixing and curing.

c) Water available from any source should be tested before starting any construction work and subsequently tested in every 3 months till the ending of construction work. In case of ground water, testing is generally done for various points of drawdown. Water available from any source should be tested in summer season before monsoon and again in summer season.

SUMMARY:

The current study project's objective is to ascertain the mechanical characteristics of concrete for M40 grade concrete paver blocks that contains MK as an additive.

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