An Experimental Investigation on Metakaolin Modified Concrete Paver Blocks

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Abstract- *Concrete paver blocks play a crucial role in exterior landscaping, offering durability in challenging environments. This study explores enhancing their performance through Metakaolin-modified concrete. Metakaolin, known for its pozzolanic properties, refines concrete microstructures, enhancing durability. Evaluating compressive, flexural strengths, and water absorption, Metakaolin replaced cement at 5%, 10%, and 15% in various paver block designs. Results reveal that 10% replacement yields optimal compressive and flexural strengths with minimal water absorption across all designs. This underscores Metakaolin's efficacy in bolstering concrete paver*

I. INTRODUCTION

Concrete, a fundamental material in construction, is crafted from a blend of cement, sand, gravel, and water. This composite substance, integral to construction globally, derives its name from the Latin term "concretus," signifying cohesion and hardening. The efficacy of concrete hinges upon the quality and synergy of its constituent materials.

However, the manufacturing process of cement, a key component of concrete, poses environmental challenges due to high CO2 emissions. To mitigate this impact, alternative cementitious materials like Metakaolin (MK), bottom ash, rice husk ash, Ground Granulated Blast Furnace Slag (GGBS), and silica fume are increasingly employed. Metakaolin, a dehydroxylated form of kaolin clay, reacts with calcium hydroxide—a by-product of cement hydration—forming calcium silicate hydrate (C-S-H) gel. This reaction not only enhances the strength and durability of concrete but also reduces its porosity and permeability.

Concrete paver blocks, initially introduced in Holland as substitutes for traditional paving bricks, have evolved over the past five decades to meet diverse application needs. These precast concrete units, adaptable to various shapes and sizes, offer versatility, speed of construction, and resilience against light, medium, and heavy traffic conditions.

Materials play a crucial role in concrete production. Ordinary Portland Cement (OPC), categorized into different grades like OPC-53, OPC-43, and OPC-33, serves as the backbone of concrete. The chemical composition of OPC, comprising tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetra calcium aluminoferrite, influences its properties and performance.

Metakaolin, as a highly reactive Pozzolana, enriches concrete formulations. Manufactured through controlled heating of kaolin clay, Metakaolin's quality and consistency surpass those of industrial by-product Pozzolana. When substituted for cement at 5% to 10%, Metakaolin enhances concrete cohesiveness, reduces bleeding, and increases compressive strength. Higher replacement levels (up to 20%) further improve concrete density, reducing porosity and permeability. This enhances resistance to aggressive substances and enhances freeze-thaw resistance.

The pozzolanic reaction of Metakaolin involves its interaction with calcium hydroxide, yielding secondary C-S-H gel and calcium aluminate hydrates. These cementitious compounds contribute to the formation of a denser and smoother concrete matrix, mitigating voids and enhancing the overall strength and durability of the material.

In the context of concrete paver blocks, their evolution from traditional rectangular shapes to interlocking designs reflects advancements in functionality and aesthetics. These precast units, laid on compacted bedding over a base course, offer adaptability to various terrains and environments. They expedite construction processes and ensure safe passage under varying traffic conditions.

Metakaolin's integration into concrete paver blocks augments their performance. By substituting cement with Metakaolin, these blocks exhibit improved compressive and flexural strengths, along with reduced water absorption. This optimization underscores Metakaolin's efficacy in enhancing the durability and longevity of concrete paver blocks, making them suitable for diverse applications in exterior landscaping and pavement construction.

In conclusion, the utilization of Metakaolin and other alternative cementitious materials presents a sustainable approach to concrete production, mitigating environmental impacts while enhancing material performance. Concrete paver blocks, fortified with Metakaolin, exemplify this synergy, offering durable and resilient solutions for modern construction challenges.

II. OBJECTIVE OF PRESENT INVESTIGATION

- The main objective of this project is to investigate the potential use of Metakaolin as a partial replacement of cement in paver blocks of different shapes.
- The study involves experimental results to determine mechanical properties of MK modified paver blocks.

III. 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 ofconcretebyusingtheIScode10262:2009 and specification given in the IS code15658: 2006

3.3.2.Stipulations for proportioning

Grade of concrete - M40 (medium traffic as per IS 15658:2006 table 1)Cement– Ordinary Port l and cement (43grade)
Cement content – minimum 400kg/m^3 and maximum 450 kg/m^3Aggregate size - Angular aggregate of maximum size is 10 mmW/C ratio -0.35
Slump value-zero(IScode15658:2008)Condition of exposure–Mild
Admixture–super plasticisers

Mix Design process

Target strength:
Mean target strength ft=fck+0.825s (as per IS15658-2006table3)
Standard deviation s =5N/mm^2 from table IS456
So the target strength =40 + 0.825 × 5 = 44.125 N/mm^2
Water-Cement ratio:
As per IS456, table no 5 the maximum water to cement ratio to be considered is 0.35

Water content
For 10 mm maximum size of the aggregate with 0 to 25 mm slump the required water is 208 lit from IS10262-2009 Table1. 30% water is reduced for super plasticizer. so required water is:
208 ×0.7=145.6 kg
Cement content
W/C=0.35,cement =148/0.35 = 416kg,
Minimum cement content required asperIS456-2000, 360kg/m^3

Calculation of volume of coarse and fine aggregate proportion

Fine aggregate of zone III, W/C=0.5, the volume of 10 mm coarse aggregate is 0.48. But for the w/c ratio of 0.35 after correction the volume of CA is 0.51
Volume of fine aggregate=1 -0.51=0.49

Mix calculations

Sg of cement =3.15
Sg of fine aggregate = 2.71
Sg of coarse aggregate=2.64

For1m^3 volume of concrete

Cement volume=cement weight /(Density of cement)
= 416/(3.15× 1000)= 0.1364m^3
Volume of water =weight of water/ (density of water)
=145.6/(1× 1000)=0.145m^3
All in aggregate volume =Total volume –volume of cement–volume of water
= 1-(0.1364+0.145)=0.7186m^3
Coarse aggregate weight = All in aggregate volume × coarse aggregate volume × Density of coarse aggregate =0.7186 ×0.51 ×2.7 × 1000 = 989.51 kg
Weight of fine aggregate = All in aggregate volume × Fine Aggregate Volume × Fine aggregate density = 0.7186 × 0.49 × 2.64 × 1000 =929.58kg.
While replacing cement with MK first cementitious material is increased 10 percent, then the materials are calculated.

1. *Mix design:1:2.58:2.68*

IV. RESULTS AND OBSERVATIOBS

7-DAYS COMPRESSIVE STRENGTH RESULT MPA

Mix	Metakaolin (%)	Zigzag (80mm)	Dumbel (60 mm)	I-shape (60 mm)
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

28-DAYS COMPRESSIVE STRENGTH RESULT MPA

Mix	Metakaolin (%)	Zigzag (80mm)	Dumbel (60mm)	I-shape (60mm)
0	0	61.43	60.83	59.23
1	5	66.42	65.24	63.9
2	10	73.24	74.26	71.2
3	15	70.01	69.54	68.54

V. CONCLUSION

- 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% Metakaolin exhibited maximum strength gain. Compared with I-shape Zigzag and Dumbel shape gave more strength and their behavior were 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 and19.22 was with zigzag shape.
- Maximum percentage increase were obtained for Dumbel shape then I shape and lowest for 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.

CEMENT REPLACEMENT VS WATER ABSORPTION

The test Results of water absorption test are tabulated in the Table 4.6. It is observed from Table4.6, water absorption of paver blocks of all the shapes are increasing up to 5 percentage replacement and again decreasing at 10 percentage of cement replacement. But maximum decrease in water absorption occur at 10% replacement of cement. For 5% cement replacement water absorption for all the shapes of paver blocks are more than control mix. The maximum water absorption occur at 5% replacement which is less than 6% specified in IS 15658-2006 as maximum limit.

% Water Absorption = [(WW – DW) / DW] x 100

Where, WW = Wet Weight of paver block, DW = Dry Weight of paver block

Cement replacement Vs. Water absorption

Mix	Metakaolin(%)	Zigzag(80mm)	Dumbel(60mm)	I-shape(60mm)
M0	0	2.3	2.1	2.2
M1	5	2.45	2.4	2.5
M2	10	1.6	1.9	1.8
M3	15	2.2	2.2	2.1

1. It is observed that compressive strength of paver block for all the shape and thickness at 7and 28 days are increased as percentage of cement replacement with MK increases up to10%. . 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 about23%morethan 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-day and 28-day flexural strength is increases up to 10 % replacement after that it decreases as percentage of replacement increases. Even

though there is decrease inflexural 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 Metakaolinas partial replacement of cement increases mechanical properties like compressive strength, flexural strength of concrete.
4. Concrete with Metakaolin also exhibited better durability in terms of water absorption.
5. It was observed that 10 percent Metakaolin used as partial replacement of cement improve overall properties of concrete paver blocks.
6. About 20% increase in 28-days compressive strength were observed for all types of paver blocks.
7. About 11% increase in 28-days flexural strength were observed for all types of paver blocks.
8. The maximum strength gain was observed for Dumbel shape paver blocks.
9. Metakaolin 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.
10. Less permeability makes it suitable to be used in industrial floors, parking garages, bridge decks etc.

REFERENCES

[1] Sing Lam and Sun Poon (2008): "The effect of aggregate-to-cement ratio and types of aggregates on the properties of pre-cast concrete blocks**"**, Cement and ConcreteComposites,Volume 30, Issue 4**,**April 2008, Pages 283–289**.**

[2] Patil B.B and Kumar P.D "Strength and Durability Properties of High Performance Concrete incorporating High Reactive Metakaolin" Vol. 2, Issue 3, may- June 2012, pp-1099-1104

[3] Srinivas rao, Ravi ch (2012): "Properties of concrete paving blocks made with waste marble", Journal of Cleaner Production ,Volume 21, Issue 1, January 2012, Pages 62–70

[4] Srivastava,VKumar.R , Agarwal V.C. and Mehta, P.K. 2012. "Effect of silica fume and metakaolin combination on concrete" International Journal of Civil Structural Engg. 2(3): 893 – 900

[5] Srinivasa Rao P, Sravana, Z. and Seshadri Sekhar, "Durability Studies on Steel Fiber Reinforced Metakaolin Blended Concrete", AKGEJC International Journal of Technology,Vol. 3, 2013 No.1, pp.38-43.

[6] Indian standard recommended guidelines for concrete mix design: 10262-1982.

[7] Kumar A and Kumar S (2013): "Development of paving blocks from synergistic use of red mud and fly ash using geopolymerization", Construction and Building Materials 38 ,865–871

[8] Kumar N "A study of Metakaolin and Silica Fume used in various Cement Concrete Designs" International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463 Vol. 3 Issue 6, June-2014, pp: (176-181).

[9] Saikumar A.V.S, Rao krishna.B "A Study on Strength of Concrete With Partial Replacement of Cement With Quarry Dust And Metakaolin" International Journal of Innovative Research in Science, Engineering and Technology vol. 3, Issue 3, March 2014

[10] Aiswarya S, Arularj G, Dilip C (2014): "A Review on use of metakaolin in concrete", Engineering Science and Technology: An International Journal (ESTIJ),ISSN: 2250-3498, Vol.3, No.3, June 2014.

[11] Revathi S, Kumutha R and vijiay K (2015): "Properties of Paver Blocks with Groundnut Husk Ash as Fine Aggregates", International Research Journal of Engineering and Technology (IRJET) , Volume: 02 Issue: 02 May-2015

[12] Devi M (2015): "Implication of Metakaolin in Quarry Dust Concrete", International Journal of Structural and Civil Engineering Research Vol. 4, No. 2, May 2015

[13] NishikantKoli, Sangar Abishek (2016): Manufacturing of paving blocks by using waste glass", International Journal of Scientific and Research Publications, Volume 6, Issue 6, June 2016 61 ISSN 2250-3153.

[14] Shan C Sabu, Rijuldas V, AiswaryaS(2016): "Effect of metakaolin on various properties of concrete", International Journal of Advanced Technology in Engineering and Science, Vol. No.4, Issue No.01, January 2016

[15] BIS, IS 1893 (Part 1): (2002), Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions and Buildings, Bureau of Indian Standards, Fifthrevision

[16] ACI Committee, ACI 318-99, Building Code Requirements for Structural Concrete-Code of Practice, American ConcreteInstitute

[17] ACI Committee, ACI 440.2R-02, Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures- Code of Practice, American Concrete Institute