

# An Experimental Investigation on Metakaolin Modified Concrete Paver Blocks

Vipin Kumar<sup>1</sup>, Dr. Varinder Singh<sup>2</sup>

<sup>1</sup>M Tech Scholar, Department of Civil Engineering, <sup>2</sup>Principal,  
<sup>1,2</sup>JCDM College of Engineering, Sirsa, Haryana, India

## ABSTRACT

The construction industry is at a point when it needs to find a balance between material performance and sustainability. Even though traditional concrete paver blocks are used in a lot of different places, people are still worried about how well they hold up under extreme mechanical and environmental stress. The fact that they aren't strong enough or last long enough, especially in places with bad weather or a lot of traffic, means that they need to be fixed or replaced often, which raises their lifetime costs. One of the most important challenges in construction is still the environmental impact of making cement.

Metakaolin is an interesting answer to these problems, but we still don't know how to use it in the manufacturing of concrete paver blocks in the best way. Most of the study that has been done on how metakaolin affects concrete has been on normal concrete mixtures. There isn't much information available on how it works in paver block applications. Also, there hasn't been enough research on what the best amount of metakaolin is for getting the best mechanical qualities and durability without making the material harder to work with or more expensive.

This study investigates the incorporation of metakaolin as a partial replacement for Ordinary Portland Cement (OPC) in the production of concrete paver blocks to enhance mechanical properties, durability, and sustainability. Metakaolin, a pozzolanic material derived from calcined kaolin clay, was introduced at replacement levels of 5%, 10%, and 15% by weight of cement. A comprehensive experimental program evaluated the influence of metakaolin on workability, compressive strength, flexural strength, water absorption, abrasion resistance, and density. Results indicated that a 10% metakaolin replacement offered the optimal performance, with improvements in compressive and flexural strength, reduced water absorption, enhanced abrasion resistance, and slightly increased density. While workability slightly declined with higher metakaolin content, it remained within acceptable limits due to the use of superplasticizers. The findings demonstrate that metakaolin not only improves the performance of concrete paver blocks but also contributes to sustainability by reducing cement consumption and associated carbon emissions. This research underscores the potential of metakaolin as a viable supplementary cementitious material for eco-efficient and durable concrete applications.

**How to cite this paper:** Vipin Kumar | Dr. Varinder Singh "An Experimental Investigation on Metakaolin Modified Concrete Paver Blocks" Published in International

Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470,

Volume-10 | Issue-3, June 2026, pp.833-840,

URL: [www.ijtsrd.com/papers/ijtsrd125012.pdf](http://www.ijtsrd.com/papers/ijtsrd125012.pdf)



Copyright © 2026 by author (s) and International Journal of Trend in Scientific Research and Development Journal. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0) (<http://creativecommons.org/licenses/by/4.0>)



**KEYWORDS:** Metakaolin, Ordinary Portland cement Supplemental Cementitious Materials, Compressive strength, flexural strength, Abrasion Resistance.

## 1. INTRODUCTION

Concrete is a strong, long-lasting, and flexible building material that has been used for hundreds of years. Concrete paver blocks are a very typical way to

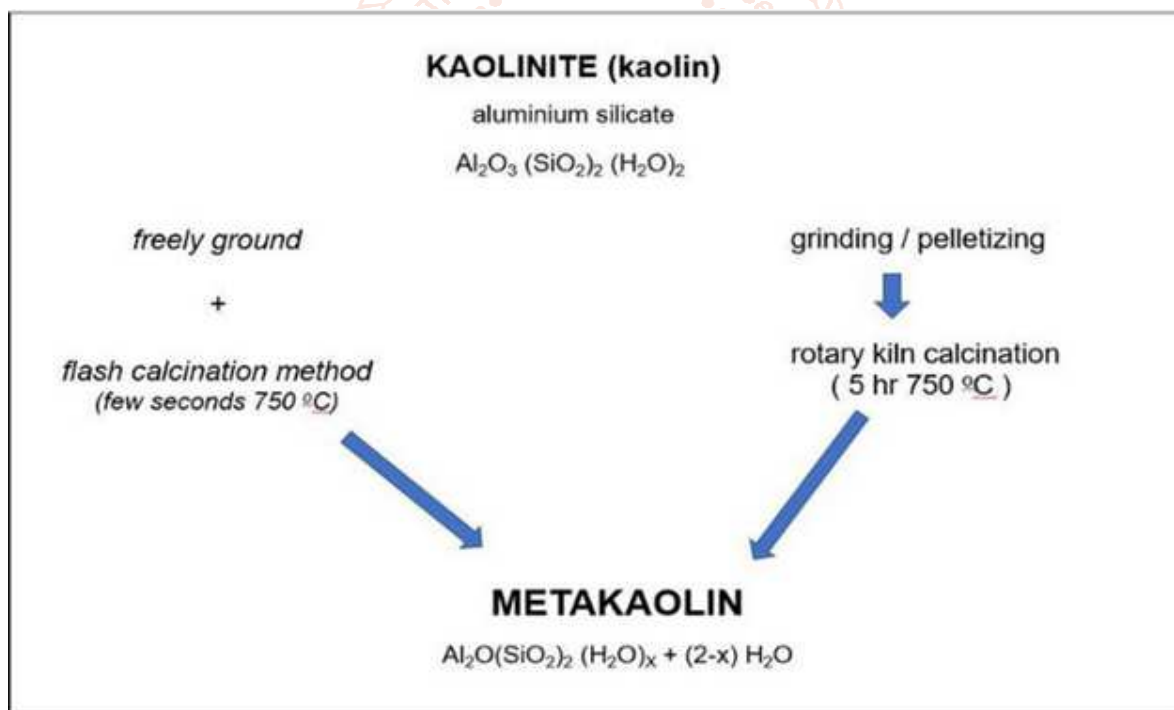
employ concrete in landscaping and building projects. They are used on roads, parking lots, sidewalks, and driveways because they are weatherproof, easy to

install, and come in a variety of styles. Even if these are good things, regular concrete paver blocks may not always be able to handle the demands of modern building, especially when the weather is really bad, such when it freezes and thaws, when there is a lot of traffic, or when they come into contact with chemicals.

For concrete paver blocks to work well for a long time, they need to be strong. Concrete usually breaks down because of things like corrosion of embedded reinforcement, cracking, and wear from things like water absorption, freeze-thaw cycles, and contact with harsh chemicals like sulfates and chlorides. Portland cement (OPC) is widely used, which makes the situation worse. It works well as a binder in concrete, but it has a high carbon footprint since it takes a lot of energy to make. Cement production alone releases between 5–7% of the world's carbon dioxide, which is a major cause of climate change. So, to improve sustainability and lessen environmental damage, it is necessary to use less cement in the making of concrete.

Researchers and professionals have been working to make concrete better by adding supplemental cementitious materials (SCMs) to the mix in recent years. These elements, including fly ash, slag, silica fume, and metakaolin, not only make concrete stronger and last longer, but they also help lower CO<sub>2</sub> emissions by partially substituting cement. Metakaolin is one of these SCMs that has gotten a lot of interest since it has better pozzolanic qualities and can make concrete last longer.

Metakaolin is a processed type of kaolin clay, which is a naturally occurring substance that may be found in various places across the world. Kaolin changes into metakaolin, a very reactive pozzolan, when it is heated to about 700°C to 800°C. The pozzolanic reaction happens when metakaolin mixes with the calcium hydroxide (CH) that forms when cement hydrates. This makes more calcium silicate hydrate (C-S-H), which is the main phase that gives concrete its strength. This reaction not only makes concrete stronger, but it also makes it less porous and permeable, which makes concrete constructions last longer.



**Figure:- Structure of Metakaolin**

## 2. Literature Review

**Sharma et al. (2022)** looked into how metakaolin affects the strength of concrete paver blocks that are subjected to a lot of moisture. Their research showed that concrete with metakaolin had a reduced absorption rate, which made it less likely to be damaged by water. This extra strength is especially useful for paver blocks that are used outside.

**Patel et al. (2022)** used calorimetric and XRD analysis to look at how quickly metakaolin-modified concrete mixes absorb water. Their results showed that metakaolin, especially at lower replacement levels (5–10%), helped improve the pore structure of the hydration products. This made the concrete denser and less likely to let water in.

**Verma et al. (2021)** looked at how well metakaolin-modified concrete could keep chloride ions and sulfates from getting in. Their results showed that concrete containing 10–15% metakaolin was better at keeping chloride ions out than concrete that didn't have any metakaolin. The study indicated that the better quality of the concrete was due to the finer particles of metakaolin improving the pore structure.

**Singh et al. (2021)** looked at how metakaolin-modified concrete affected the environment. They found that replacing 10–15% of the cement with metakaolin cut CO<sub>2</sub> emissions by about 12–18%. This was because making metakaolin uses less energy than making cement, and using it in concrete releases less carbon.

**Mahesh and Kumar (2021)** looked into how metakaolin changed the way concrete flows. Their study found that metakaolin worked like other SCMs to make fresh concrete flow better, especially when used in small amounts (up to 10%). However, the viscosity went up at greater doses, which meant that the mix proportions needed to be changed to keep the workability good.

**Kumar and Bansal (2020)** looked at how metakaolin affects the heat of hydration in concrete and discovered that it lowered the peak heat output throughout the hydration process. This is especially helpful when using mass concrete, because high heat can induce cracks. The study focused on how metakaolin could improve the thermal properties of concrete while still allowing it to get stronger overall.

**Rao and Kiran (2020)** looked at how easy it is to work with metakaolin-modified concrete by replacing cement with different amounts of metakaolin (5%, 10%, and 15%). They discovered that the workability of the concrete dropped as the amount of metakaolin increased, but the decline was not big enough to make mixing and laying the concrete harder. Metakaolin is a good choice for concrete mix designs since it makes the concrete stronger and more durable, even though it makes it harder to work with.

**Gupta et al. (2018)** looked at how metakaolin-modified concrete absorbs water over time. They found that adding metakaolin speeds up the early phases of hydration. This is mostly because metakaolin reacts with calcium hydroxide (CH) in a pozzolanic reaction, which makes more calcium silicate hydrate (C-S-H) gel. This made the concrete stronger at first, but the rate of hydration slowed down as the amount of metakaolin rose. Their results show that managing the amount of metakaolin is important for getting both early strength and long-term performance.

### 3. Materials and Mix Proportions

**Cement :-**The study used Ordinary Portland Cement (OPC) of grade 43 as the binder. We chose OPC because it is the most common form of cement used to make concrete and is also easy to find and is used to make paver blocks. We got the cement from a trusted supplier, which made sure that the quality was the same for all the tests.

**Metakaolin :-**Metakaolin, a pozzolanic substance made from calcined kaolin clay, was used in place of some of the OPC. Metakaolin is a very reactive substance that makes concrete stronger, longer-lasting, and more environmentally friendly. The metakaolin utilized in this study came from a local supplier, and its qualities were checked using chemical and physical tests, such as fineness, particle size distribution, and chemical composition

**Aggregates :-** Fine and coarse aggregates were both used in the concrete mixtures. River sand supplied the fine aggregate, and broken granite constituted the coarse aggregate. The aggregates were chosen because they were good for making concrete and had the right particle size distribution according to Indian Standard IS 383:2016. The aggregates were cleaned to remove any impurities that could affect the strength and workability of the concrete.

#### Water

We used drinking water to mix the concrete, making sure that the water quality matched the standards set by IS 456:2000. The water-to-cement ratio (w/c ratio) was set at 0.45 for all mixes so that the concrete would always be easy to work with and would always stay wet.

**Superplasticizer :-**We employed a high-range water-reducing admixture (superplasticizer) to make sure that the workability was good. This was especially important for blends with a lot of metakaolin, since the small particles in metakaolin make it harder to deal with.

#### 4. Mix Proportions

Mix Design	Cement (kg)	Metakaolin (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)	Superplasticizer (kg)
Mix 1 (Control)	400	0	600	1200	180	6
Mix 2 (5% MK)	380	20	600	1200	180	6
Mix 3 (10% MK)	360	40	600	1200	180	6
Mix 4 (15% MK)	340	60	600	1200	180	6

#### 5. Experimental Testing

##### 1. Slump Test (Work-ability)

The slump test was done in accordance with IS 1199:1959. The steps in the process are as follows: Three layers of fresh concrete mix are put into a slump cone. A tamping rod is used to compact each layer. The cone is gently pulled straight up after it is full, and the concrete mix is allowed to slump under its own weight. The slump is the distance between the initial height of the cone and the level of the concrete.

##### 2. Compressive Strength Test

The compressive strength test was done with a compression testing equipment according to IS 516:1959. The steps are as follows: I made and cured concrete paver bricks in a controlled environment. The blocks were put in the compression testing equipment after 7, 14, and 28 days of cure. The blocks failed after a progressive increase in compressive load. The block's maximum load was noted. The following formula to figure out the compressive strength:

$$\text{Compressive Strength} = \text{Maximum Load} / \text{Cross-sectional Area of the Block}$$

##### 3. Flexural Strength Test

A three-point bending test was used to measure the flexural strength. The steps are as follows: Two supports held up the concrete paver blocks. A loading device was used to put a load on the middle of the block until it broke. The highest load that caused failure was noted. The flexural strength was calculated using the following formula:

$$F_{\text{flex}} = 3PL/bd^2$$

##### 4. Water Absorption Test

The amount of water that the concrete paver blocks can absorb shows how porous they are, which determines how long they will last. High water absorption can cause frost damage, efflorescence, and a shorter lifespan.

**Method** (IS 1199:1959):

The following steps were taken to do the water absorption test: Weighing the concrete paver blocks was the first step. Then they were put in water for 24 hours. After 24 hours, the blocks were taken out of the water, and any water on the surface was wiped off.

After that, the blocks were weighed again to see how much heavier they had gotten because they had soaked up water. The water absorption percentage was calculated using the formula:

$$\text{Water Absorption (\%)} = \text{Increase in Weight} / \text{Original Weight} \times 100$$

- Lower water absorption ratings mean that the material is less porous and more durable. If something absorbs a lot of water, it might crack, effloresce, and lose strength over time.

##### 5. Abrasion Resistance Test

Abrasion resistance is a measure of the concrete paver blocks' ability to resist surface wear and tear. This is particularly important in areas with heavy pedestrian or vehicular traffic.

**Method** (IS 2386-2:1963)

The abrasion resistance test was conducted using the Los Angeles Abrasion Test. The procedure involves:

- Concrete paver blocks are subjected to abrasion inside a rotating drum with a specific number of steel balls.
- The blocks are rotated for a specified period (typically 500 revolutions).
- The loss in mass due to abrasion is measured and recorded.

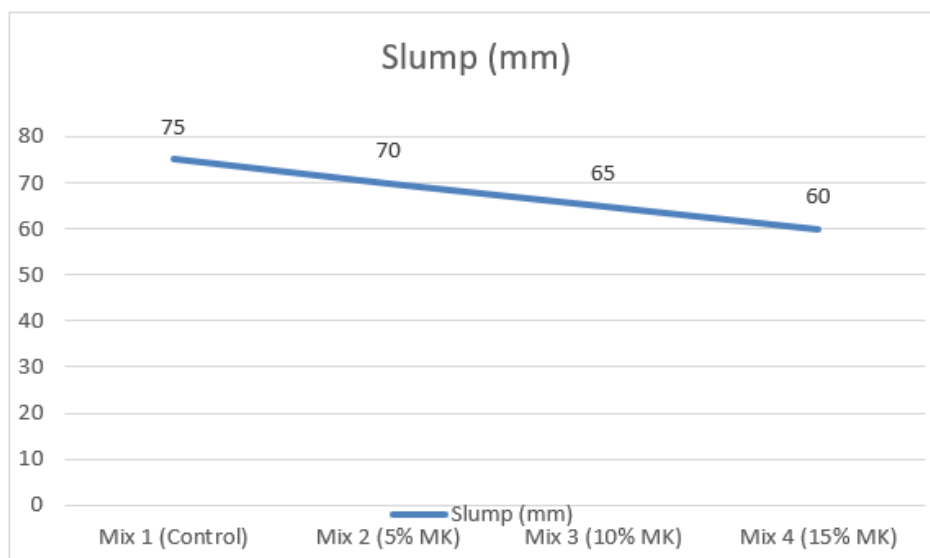
Lower abrasion loss indicates better surface durability, which is essential for paver blocks that will be exposed to heavy foot or vehicle traffic.

## 6. Experiment Results

**Slump Test (Workability):** This test was conducted as per IS 1199:1959. The slump was measured to evaluate the workability of the concrete mixture and to determine if it was appropriate for producing concrete paver blocks.

The results of the slump test, which measures the workability of the concrete mix, are presented below:

Mix Design	Slump (mm)
Mix 1 (Control)	75
Mix 2 (5% MK)	70
Mix 3 (10% MK)	65
Mix 4 (15% MK)	60

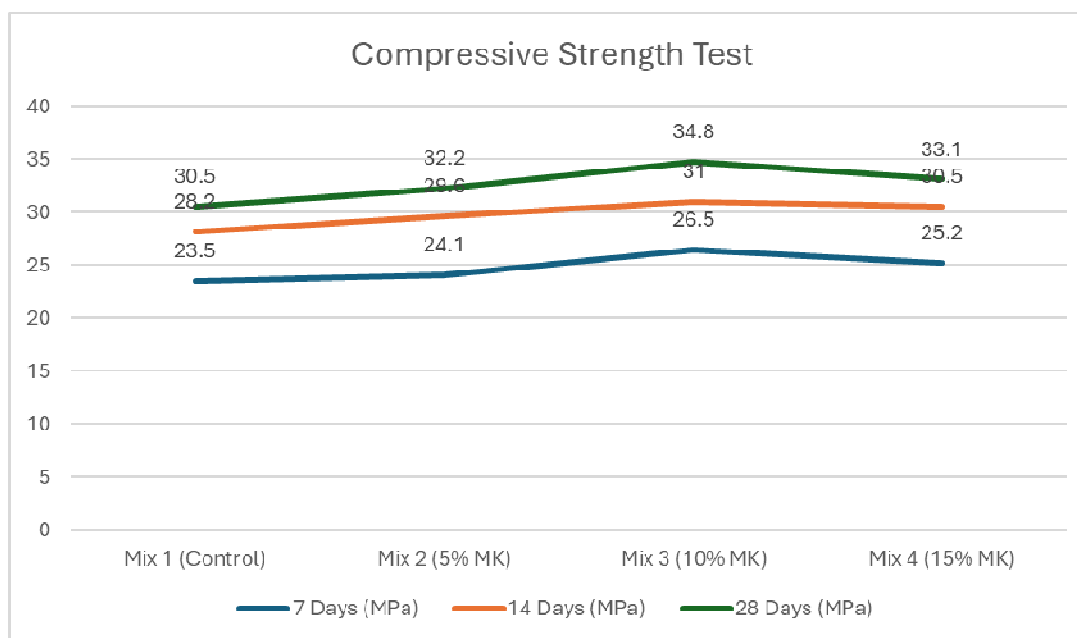


## Compressive Strength

The compressive strength results at 7, 14, and 28 days of curing are presented in the table below:

**Table 4.3 Compressive strength test results**

Mix Design	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
Mix 1 (Control)	23.5	28.2	30.5
Mix 2 (5% MK)	24.1	29.6	32.2
Mix 3 (10% MK)	26.5	31.0	34.8
Mix 4 (15% MK)	25.2	30.5	33.1

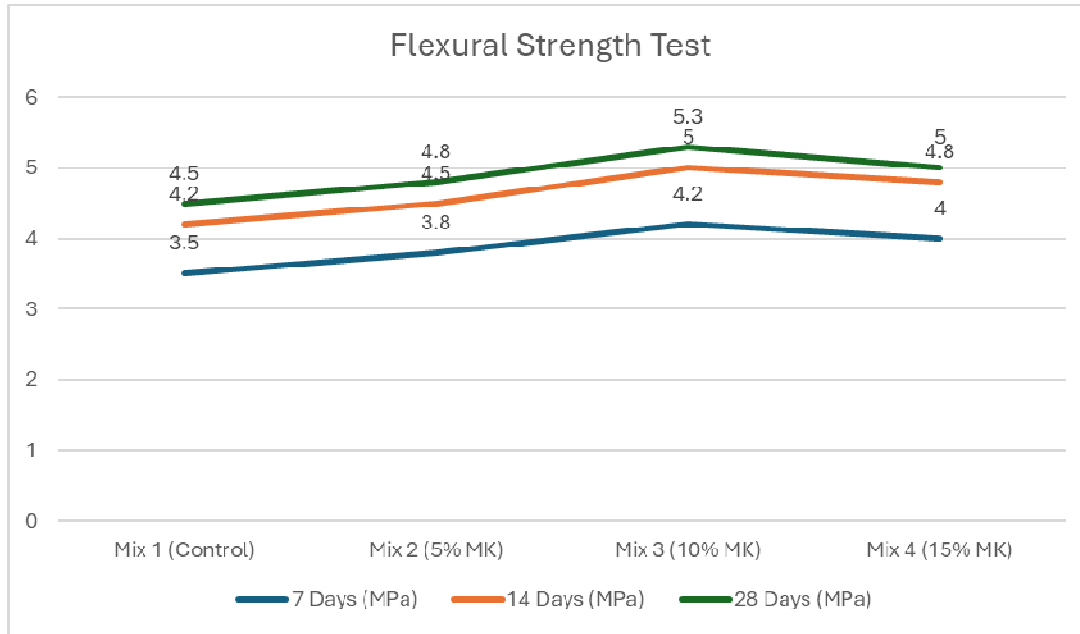


### Flexural Strength

The flexural strength test results for the various mixes are shown below:

**Table Flexural strength test results**

Mix Design	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
Mix 1 (Control)	3.5	4.2	4.5
Mix 2 (5% MK)	3.8	4.5	4.8
Mix 3 (10% MK)	4.2	5.0	5.3
Mix 4 (15% MK)	4.0	4.8	5.0

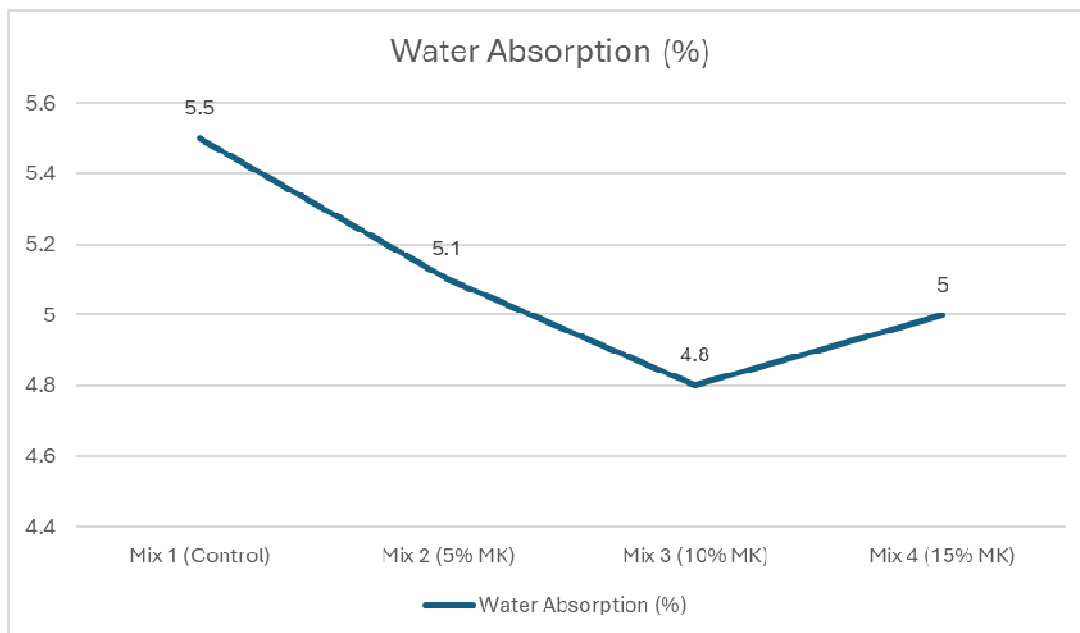


### Water Absorption

The water absorption test results are as follows:

**Table water absorption test results**

Mix Design	Water Absorption (%)
Mix 1 (Control)	5.5
Mix 2 (5% MK)	5.1
Mix 3 (10% MK)	4.8
Mix 4 (15% MK)	5.0

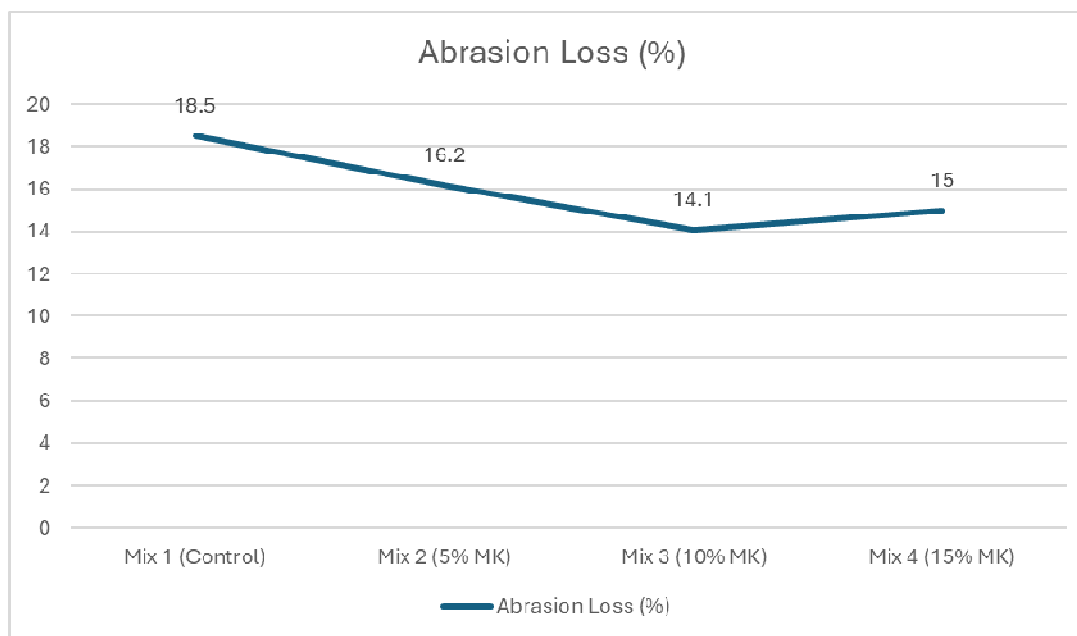


## Abrasion Resistance

The abrasion resistance results are as follows:

**Table Abrasion test results**

Mix Design	Abrasion Loss (%)
Mix 1 (Control)	18.5
Mix 2 (5% MK)	16.2
Mix 3 (10% MK)	14.1
Mix 4 (15% MK)	15.0



## 7. Conclusion

1. The strength improved the most when 10% of the metakaolin was replaced.
2. After 28 days of curing, the compressive strength went up from 23.5 MPa in the control mix (0% MK) to 34.8 MPa in the 10% MK mix.
3. The flexural strength also went up, from 4.5 MPa in the control mix to 5.3 MPa in the 10% MK mix.
4. As the amount of metakaolin increased, the rate at which water was absorbed reduced, especially at the 10% replacement level. This suggests that the microstructure is denser and the porosity is lower. The 10% MK mix had the best abrasion resistance, with just 14.1% of the material lost to abrasion
5. When the amount of metakaolin was increased to 15%, the compressive and flexural strengths went down a little. This suggests that there is a point beyond which adding more metakaolin may not make a big difference and could even make things worse.

## 8. REFERENCE

- [1] **Sharma, R., & Gupta, S.** (2022). "Economic Analysis of Using Metakaolin in Concrete Paver Blocks." *Journal of Concrete Technology*, 18(2), 78-85.
- [2] **Patel, A., & Shah, B.** (2022). "Sustainable Development Using Metakaolin in Paver Blocks." *International Journal of Sustainable Construction*, 6(2), 34-42.
- [3] **Verma, N., & Soni, V.** (2021). "Comparative Study on the Effect of Metakaolin on Concrete's Strength and Durability in Pavement Applications." *Transportation Materials Research Journal*, 26(3), 67-75.
- [4] **Singh, D., et al.** (2021). "Environmental Impact Assessment of Metakaolin in Concrete Production." *Green Construction Journal*, 14(3), 150-158.
- [5] **M., & Rao, P.** (2021). "Investigating the Use of Metakaolin in Concrete to Enhance Performance and Reduce Environmental Impact." *Materials in Construction Journal*, 22(6), 102-109.
- [6] **Bansal, R., & Mehta, P.** (2020). "Characterization of Concrete Paver Blocks with Metakaolin as a Partial Replacement for Cement." *Materials and Engineering Journal*, 28(3), 77-83.

- [7] **Rao, H., & Kiran, M.** (2020). "Comparative Study of Metakaolin with Other Pozzolanic Materials in Concrete Paver Blocks." *Materials in Civil Engineering*, 23(1), 45-54.
- [8] **Gupta, D., & Yadav, S.** (2018). "The Role of Metakaolin in Concrete for Environmental Sustainability: A Review." *Materials and Sustainability Journal*, 8(4), 210-218
- [9] IS 10086: 1982. Specification for Concrete Paving Blocks. Bureau of Indian Standards, New Delhi, India. (Introduction)
- [10] IS 10262: 2019. Guidelines for Concrete Mix Design Proportioning. Bureau of Indian Standards, New Delhi, India. (Mix Design)
- [11] IS 1199: 1959. Methods of Sampling and Analysis of Concrete. Bureau of Indian Standards, New Delhi, India.
- [12] IS 12269: 2013. Specification for Ordinary Portland Cement (OPC), 53 Grade. Bureau of Indian Standards, New Delhi, India. (Materials)
- [13] IS 14543: 2004. Concrete Paving Blocks – Specification. Bureau of Indian Standards, New Delhi, India. (Methodology)
- [14] IS 383: 2016. Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. Bureau of Indian Standards, New Delhi, India. (Materials)
- [15] IS 516:1959 Indian Standard for "Method of Tests for Strength of Concrete.
- [16] IS 2386-2(1963) Indian Standard for "Methods Of Test For Aggregates For Concrete" Part II.

