

Effect of Influence of Metakaolin and Shredded Plastic Waste on Strength and Durability Properties of M20 Grade Concrete



M. Sivaraj, R.Sundararajan, V. Karthik

Abstract: The production of cement liberates the equal amount of CO₂ into the environment. This will result in various social and environmental problems. There is a need in determining the new cement materials from waste or industrial waste. Second, the extraction of natural aggregates from natural resources poses other environmental problems. So in this article, the experimental programme is conducted to determine the strength and durability performance of cement partially replaced with Metakaolin (MK) (0%, 2.5%, 5%, 7.5% and 10%) and coarse aggregate substituted by shredded plastic waste (SPW) at 0.5% by weight. The main objective of this article was limited to analyzing the strength parameters along with the durability parameters.

Keywords: Metakaolin, Shredded Plastic Waste, Mechanical Strength and Durability Parameters.

I. INTRODUCTION

Cement is a broadly used construction material due to its ease of mixing and placing. During the production of cement, large amount of CO₂ are released, a rather harmful greenhouse gas [Choate, W.T. (2003)]. 7% of global greenhouse gas emissions are incorporated by the cement production industry. To reduce the effect of greenhouse gases on the environment, several substitute materials are used for cement. Among all the other cementitious materials, MK is white in color and has strong pozzolanic activity derived from kaolinite rocks [Siddique, R. (2008)].

The use of natural aggregates leads to exploitation of natural resources in the large manner and creates various social and environmental problems [Malik et al (2013)]. The demand for the new building is consistently increasing at steady state as the population increases. So the need for the eco-friendly aggregates has become a challenge. By considering these aspects, the future of the construction sector looks bleak.

In India, the amount of solid waste is increasing rapidly due to population growth. Among solid wastes, plastics account for 8% by weight of total solid waste [Asoka, P et al (2007)].

In order to solve the problem of disposal of large quantities of plastic and to solve the growing demand for aggregates in concrete, application of plastic waste material in concrete can be considered a viable application.

Based on the detailed investigation on the literatures, it was concluded that the cement can be replaced by MK which has the higher pozzolanic properties than other substitute materials. Disposal waste plastics directly on the environment creates various problems and takes hundreds of years to decompose naturally. As per the previous literatures, it is possible to use the waste plastics as a coarse aggregate in the concrete. In this study, it was proposed that, the cement was partially substituted by MK up to 10% at an intervals of 2.5% and shredded plastic wastes are replaces the coarse aggregate by 0.5% and detailed investigations has been carried out on various properties of concrete.

II. MATERIALS USED

The list of materials used in this study is as follows.

- Cement (OPC 53 grade)
- Metakaolin
- Fine aggregate (River sand)
- Shredded plastic waste
- Coarse aggregate (Gravel)
- Super Plasticizers.

A. Cement

For this study, an OPC grade of 53 was used, thus confirming IS: 12269 – 2004 and the basic properties of cement were illustrated in Table 1.

Table 1: Properties of Cement

Properties	Results
Standard consistency	30%
Specific gravity	3.12
Fineness of cement	6.07
Setting Time (min) Initial	37
Final	585

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Fig.1: Cement



Fig.2: Metakaolin



Fig.3: Shredded Plastic Waste

B. Metakaolin

Metakaolin is manufactured under carefully controlled conditions to adjust the particle size, remove inert impurities and to refine its color, so as to obtain high purity and pozzolanic responsiveness. It is very useful to increase the resistance, to decrease the attack by the sulphates.

Table 2: Properties of Metakaolin

Property	Value
Colour	Off White
Physical Form	Powder
Specific Gravity	2.50
Surface Area	15m ² /kg

C. Fine Aggregate (Natural River Sand)

The fine aggregate used in this experimental study was purchased from KARUR and corresponded to zone II of IS 383-1970 (Part-4). The properties of sand are given in Table 3. Table 3: Properties of Fine Aggregate

Property	Results
Specific Gravity	2.53
Bulking of Sand	1.17%
Fineness Modulus	3.29
Bulk density (g/cc) Loose State	1.43
Dense State	1.63

D. Shredded Plastic Wastes

The plastic wastes were crushed and removed foreign matters then heated at a particular temperature and crushed down to the size of aggregates. The physical characteristics of shredded plastic waste are shown in Table 4.

Table 4: Properties of Shredded Plastic Waste

Property	Specific gravity	Crushing Value	Density
Value	0.95	2.5%	0.90 g/cc

E. Coarse Aggregate (Gravel)

For the experimental investigation, crushed coarse aggregates locally available at 20 mm were obtained. Before being used for experimental investigations, the tests were performed in accordance with IS 383-1970 (Part 4). The different properties of the coarse aggregate are given in Tables 5.

Table 5: Properties of Coarse Aggregate

Property	Results
Specific Gravity	2.79
Bulk density (g/cc) Loose State	1.51
Dense State	1.69
Crushing Strength	15.96%
Water Absorption	1.17%
Fineness modulus	6.54

F. Super Plasticizer

To provide the desired additional properties (i.e., improve process ability), a superplasticizer (CONPLAST SP-430) was used. The dosage of the plasticizer was mixed with 2.5% by weight of cement.

G. Water

Throughout the investigation, drinking water complying with IS 456: 2000 was used for mixing and curing, which contained no harmful external agents.

III. MIX DESIGN

The mix design was created in accordance with the guidelines of IS 10262: 2009. The trial mixes are designated as NMC and MP_x, where NMC stands for Nominal Mix

Concrete with 0% MK and 0% SPW and MP stands for Mix proportion with different percentages of MK and 0.5% of SPW.

Table 6: Mix Proportions

Mix ID	M	P	Quantity of Materials (kg/m ³)					SP (lit/m ³)	w/c ratio
			Cement	Meta kaolin	FA	CA	SPW		
NMC	0	0	352	0	800	1155	0	8.8	0.45
MP ₁		2.5	0.5	343.2	8.8	800	1149.22	5.78	8.8
MP ₂	5	0.5	334.4	17.6	800	1149.22	5.78	8.8	
MP ₃		7.5	0.5	325.6	26.4	800	1149.22	5.78	8.8

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MP ₄	10	0.5	316.8	35.2	800	1149.22	5.78	8.8
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[M – Metakaolin Percentage; P – Shredded Plastic Waste Percentage; SPW – Shredded Plastic Waste; SP – Super Plasticizer]

IV. DETAILS OF MECHANICAL STRENGTH PROPERTIES

Mechanical strength properties of concrete specimens are determined on the curing periods of 7, 14 and 28 days. After curing period, the specimens were kept dry and then they were tested in UTM of 2000kN capacity.

On the basis of the results of the mechanical properties, each resistance parameter is increased according to the increasing percentage of replacement of the MK content in the concrete mix. But replacing the cement with MK at 10%, strength values are reduced and the MP₃ concrete mix was considered the optimal mix. The strength properties of the MP₃ mix were 17.71%, 8.83%, and 9.54% higher than those of the NMC mix after 28 days of curing.

Table 7: Summary of Mechanical Strength Properties

Mix ID	Strength Properties at varying curing period (MPa)								
	Compressive			Split Tensile			Flexural		
	7	14	28	7	14	28	7	14	28
NMC	18.46	19.73	28	1.4	1.9	3.1	2.8	3.78	6.29
MP ₃	20.91	22.6	32.96	1.5	2.0	3.4	3.1	4.14	6.89
% Increase	13.27	14.54	17.71	7.53	8.85	8.83	9.47	9.52	9.54

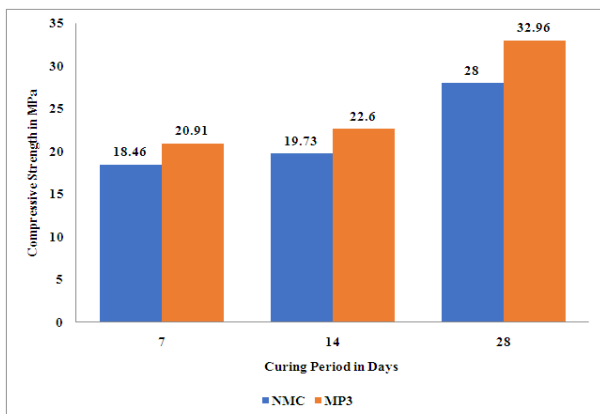


Fig. 4: Comparison of NMC and MP3 (Compressive Strength)

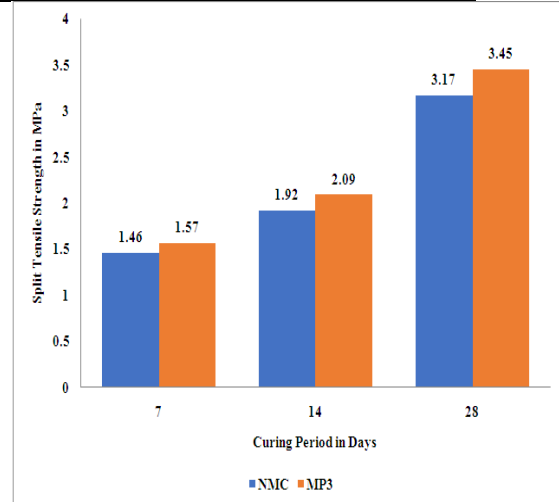


Fig. 5: Comparison of NMC and MP3 (Split Tensile Strength)

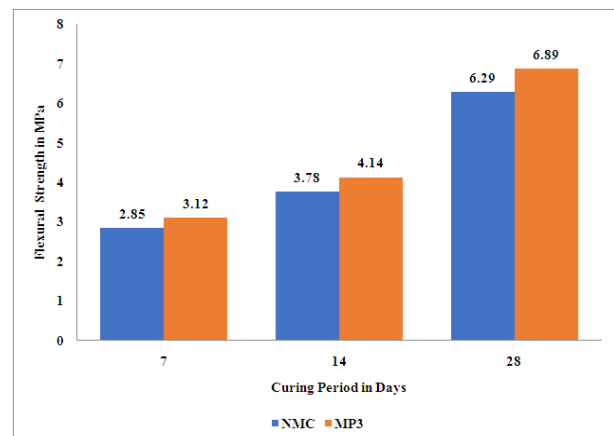


Fig. 6: Comparison of NMC and MP3 (Flexural Strength)

V. DETAILS OF DURABILITY PROPERTIES

A. Saturated Water Absorption Test (SWA)

The test was carried out in accordance with ASTM C 642-81 with the concrete specimens at 28 days of curing was illustrated in Table 8.



Fig.7: Saturated Water Absorption Test

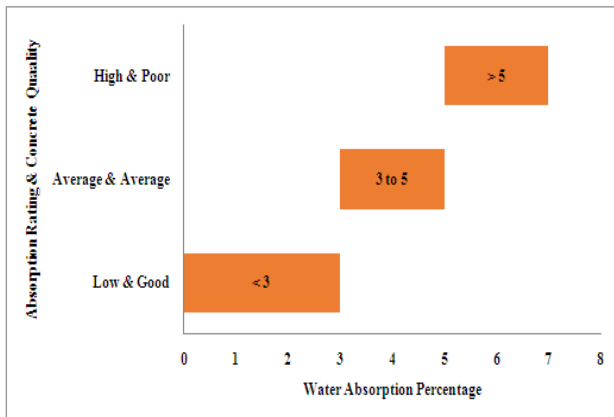


Fig. 8: Assessment Criteria for Water Absorption

Table 8: SWA Test Results

Mix ID	Weight of Specimen (kg)		Saturated Water Absorption (%)
	Initial (W ₁)	Final (W ₂)	
NMC	8.51	8.61	1.96
MP ₁	8.36	8.52	1.78
MP ₂	8.31	8.45	1.66
MP ₃	8.25	8.38	1.55
MP ₄	8.19	8.31	1.48

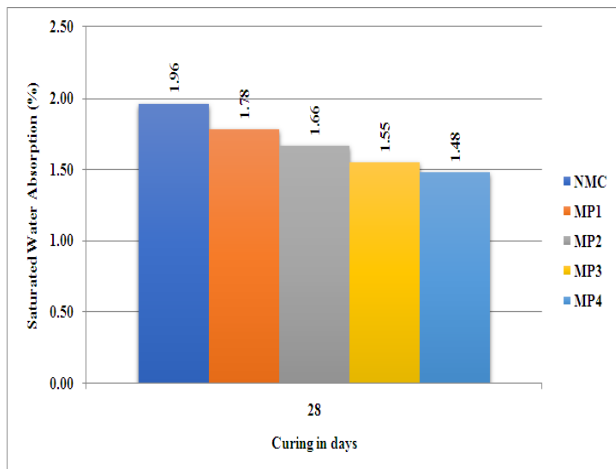


Fig. 9: Saturated Water Absorption Test Results

B. Rapid Chloride Ion Permeability Test

The permeation of the chloride ions was measured on concrete cubes at 7 and 28 days as per the guidelines

mentioned in ASTM C1202 (AASHTO T277). RCPT test specimens are mentioned in Table 9.

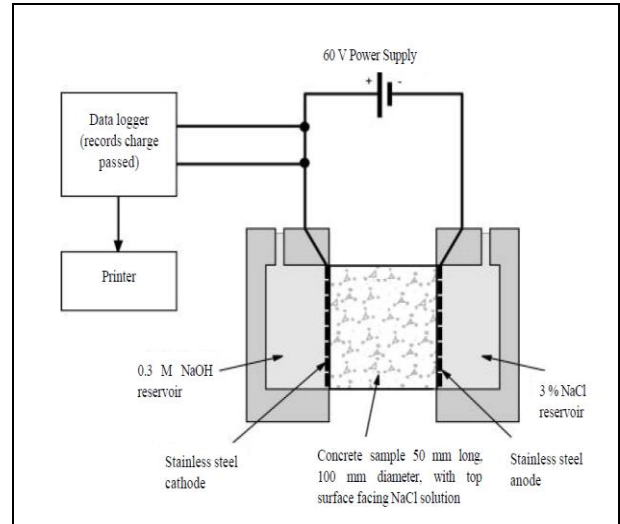


Fig. 10: Rapid Chloride Ion Permeability Test

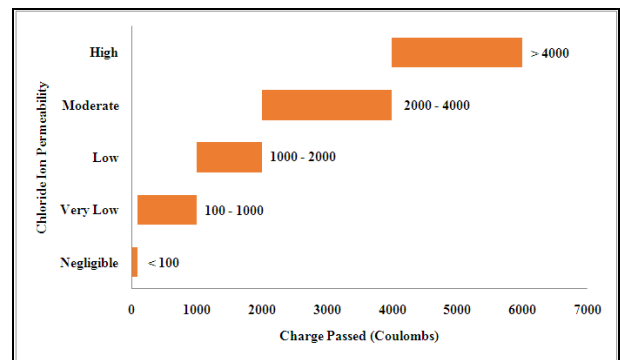


Fig. 11: RCPT Ratings as per ASTM C1202

TABLE 9: RCPT Results

Mix ID	Charge Passed (Coulombs)		Chloride Permeability as per ASTM 1202	
	7days Curing	28days Curing	7days Curing	28days Curing
NMC	5667	2649	High	Moderate
MP ₁	5572	2560	High	Moderate
MP ₂	5549	2513	High	Moderate
MP ₃	5139	2407	High	Moderate
MP ₄	4681	2302	High	Moderate

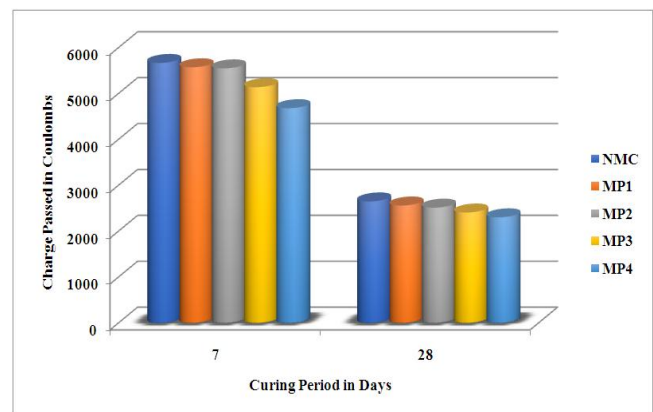


Fig. 12: RCPT Results

C. Acid Attack Test

The effect of sulfuric acid attack on concrete samples was determined by weight loss methods. Results obtained from the acid attack test was shown in Table 10.



Fig. 13: Removal of Concrete specimens from H₂SO₄ solution

Table 10: Acid Attack Test Results

Mix ID	Weight Loss due to Acid Attack (%)	
	28 Days	56 Days
NMC	3.18	3.40
MP ₁	3.22	3.51
MP ₂	3.53	3.69
MP ₃	3.69	3.86
MP ₄	4.15	4.41

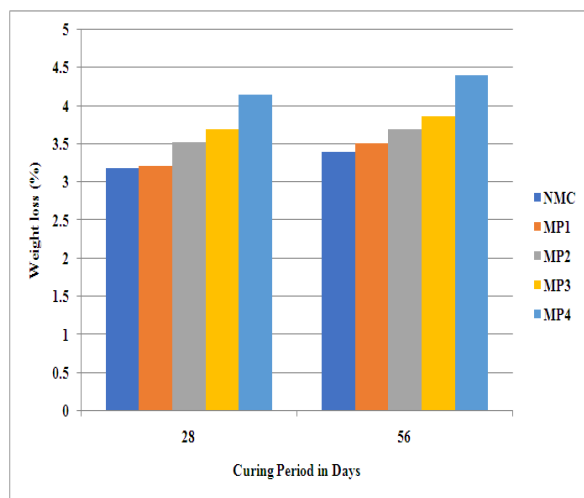


Fig. 14: Acid Attack Test Results

VI. CONCLUSIONS

The following conclusions are drawn from the investigations done on concrete specimens made with different percentage of MK content and 0.5% of SPW.

- The strength properties of the MP₃ mix were 17.71%, 8.83%, and 9.54% higher than those of the NMC mix after 28 days of curing.
- The concrete specimens behave better in all the aggressive environmental conditions.
- In SWA test, the results shown that, the MP₃ mix absorbs 1.55% of water content by its initial weight. The concrete mix NMC has more water absorption capacity of 1.96%.

- MP₄ mix absorbs water about 1.48% than its original weight; this happens due to the replacement of metakaolin content will seals off the pores on the surface of the concrete specimens.
- In RCPT test, the test results show that, the chloride ion permeation was high at specimens with 7days of curing and moderate permeation was observed at specimens with 28days of curing.
- The age of concrete will reduce the amount of chloride ion permeation in concrete specimens.
- Addition of metakaolin content in concrete mixes makes the concrete denser, so the increase in replacement percentage of metakaolin will gradually reducing the chloride ion permeability.
- In acid attack test, the loss of weight was obtained between of 28 days and 56 days cured specimens.
- Acid Attack test results shows that the specimens have higher reduction in weight loss when the specimens are immersed in Acid solutions for 56 days. MP₃ mix has 3.86% weight loss when it is immersed in acid for 56 days and 3.69% weight loss when it is immersed in acid for 28 days.

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