Feasibility of using Iron Oxide Powder as Partial Replacement to Cement in Concrete Paving Blocks with Polypropylene Fibre

Aathira K R
PG Student
Department of Civil Engineering
Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Dr. Mathews M Paul
Professor
Department of Civil Engineering
Mar Athanasius College of Engineering, Kothamangalam, Kerala, India

Abstract

Advancements in technology enhance not only human comforts but also damage the environment. Production of Portland cement is responsible for the evolution of high amount of CO2. Nowadays the use of concrete paving blocks has been increased rapidly. In recent years, almost every mineral producing country is facing the problem of better utilization of mine waste because of its accumulation and lack of suitable storage space. In order to reduce the use of Portland cement, iron oxide powder a mine waste is used as a partial replacement to cement in the production of concrete paving blocks. Fibres used in concrete arrests cracks, increases resistance to impact/abrasion and greatly improves quality of construction. The present study aims to determine the optimum amount of cement replacement required to achieve a desired compressive strength of 40MPa for the concrete paving blocks with polypropylene fibre. The replacement level of iron oxide powder with cement is from 5% to 25%. The variation of polypropylene fibre is from 0.1% to 0.4%. The work also includes the evaluation of various properties like compressive strength, flexural strength and abrasion resistance of the concrete paving blocks.

Keywords: Abrasion Resistance, Concrete Paving Blocks, Iron Oxide Powder, Polypropylene Fibres, Portland cement

I. INTRODUCTION

Paving blocks has been introduced in India in construction, a decade ago, for specific requirement like footpaths, parking areas etc. Superior engineering properties, low maintenance, ease of placement and removal, reuse of original blocks, aesthetic appeal, and immediate availability are the primary reasons for choosing concrete paving block. The raw materials required for the manufacturing of paving blocks are Ordinary Portland Cement (OPC) and aggregates which are available locally in every part of the country. Production of one tonne of OPC requires about two tonnes of raw materials and releases approximately one tonne of Carbon dioxide. One method to produce more environment friendly concrete is to reduce the use of OPC in concrete, for that we need to replace the cement. In several mining industry the iron oxide powder remains as a waste material except its usage as a pigment in paving blocks. In this project an attempt is made to replace the cement with iron oxide powder obtained as a waste from mining industry to make concrete paving blocks of 40MPa strength which is suitable for medium traffic. The iron oxide powder is taken from KMML, Kollam. The powder contains chloride as impurity, so it is neutralized with quicklime before use.

$$3CaO + 2FeCl_3 \rightarrow Fe_2O_3 + 3CaCl_2$$

Fibre reinforced concrete increases the structural integrity. Polypropylene fiber is used as a secondary reinforcement in this paving block.

II. MATERIALS

The ingredients used in this concrete paving blocks are Portland cement, iron oxide powder, quicklime, polypropylene fibre, fine aggregate, coarse aggregate and water.

A. Portland cement

Portland cement of 53 grade (Deccan) is used in this study conforming to IS specifications. The results of various tests conducted on cement are shown in Table – 1.

Table – 1
Physical Properties of Cement

SI.NO.	*Properties*	*Values*
1	*Specific gravity*	*3.12*
2	*Standard consistency*	*32%*
3	*Initial setting time*	*75 minutes*

4	*Final setting time*	*280 minutes*
5	*Fineness*	*8 %*
6	*Compressive strength of mortar cubes*	*53.2N/mm^2*

B. Iron oxide powder

Iron oxide powder is the materials left over, in the mining industry. It is an inorganic compound with formula Fe_2O_3. The material contains chloride as impurity, so it is neutralized by adding quicklime.

C. Quicklime

Quicklime (CaO) is a calcium containing inorganic material. It is white in colour.

D. Polypropylene fibre

The polypropylene fibre has the following properties as shown in Table - 2 given by the manufacturer.

Table – 2
Specifications of Polypropylene Fibre

Property	*Specifications*
Length	*20mm*
Equivalent Diameter (µm)	*30 - 60*
Melting point	*165ºC*
Absorption	*Nil*
Acid resistance	*High*
Salt resistance	*High*
Alkali resistance	*Full*
Electrical conductivity	*Low*
Thermal conductivity	*Low*

E. Aggregates

Fine aggregate of size less than 4.75mm and coarse aggregate of 10 mm maximum size is used in this study conforming to IS specifications. Various tests were conducted on aggregates according to IS specifications and it is shown in Table – 3 and Table – 4.

Table – 3
Physical Properties of Fine Aggregate

SI.NO.	*Properties*	*Values*
1	*Specific gravity*	*2.53*
2	*Bulk density*	*1.57 kg/l*
3	*Water absorption*	*4 %*
4	*Fineness modulus*	*3.86*

Table – 4
Physical Properties of Coarse Aggregate

SI.NO.	*Properties*	*Values*
1	*Specific gravity*	*2.71*
2	*Bulk density*	*1.72 kg/l*
3	*Water absorption*	*0.45%*
4	*Crushing value*	*28.92%*
5	*Fineness modulus*	*3.1*

III. MIX DESIGN

The paving block used in this study is of grade M40 and mix design is done according to IS specifications. The material quantity as per mix design is shown in Table – 5.

Table – 5
Quantity of Materials as Per Mix Design (For 1m^3)

Contents	*Quantity*
Cement	*400 kg/m^3*
Fine aggregate	*499 kg/m^3*
Coarse aggregate	*1347 kg/m^3*
Water	*174 kg/m^3*
Mix proportion	*1:1.25:3.37*
Water cement ratio	*0.37*
Iron oxide powder	*5% - 25% weight of cement*
Polypropylene fibre	*0.1% - 0.4% weight of concrete*

Table – 6
Mix Specification

Mix ID	*Description*
NC	*Normal concrete*
CI_1	*Concrete with 5% iron oxide powder*
CI_2	*Concrete with 10% iron oxide powder*
CI_3	*Concrete with 15% iron oxide powder*
CI_4	*Concrete with 20% iron oxide powder*
CI_5	*Concrete with 25% iron oxide powder*
CI_1P_1	*Concrete with 5% iron oxide powder and 0.1%polypropylene fibre*
CI_1P_2	*Concrete with 5% iron oxide powder and 0.2%polypropylene fibre*
CI_1P_3	*Concrete with 5% iron oxide powder and 0.3%polypropylene fibre*
CI_1P_4	*Concrete with 5% iron oxide powder and 0.4%polypropylene fibre*

IV. RESULTS

A. Adoptable Amount of Iron Oxide Powder

For finding the adoptable amount of iron oxide powder, compressive strength test of three concrete cubes of size 150mm were done for each mix. The adoptable percentage of iron oxide powder is 5% by weight of cement. In all other percentages the compressive strength is lower than the target strength for M40 concrete.

Table – 7
Compressive Strength to Obtain Adoptable Amount of Iron Oxide Powder

Mix ID	*Average Compressive Strength (N/mm^2)*	
	7^{th} day	*28^{th} day*
NC	*32.5*	*51.6*
CI_1	*31.9*	*49.8*
CI_2	*28.8*	*45*
CI_3	*22*	*38.9*
CI_4	*18.9*	*35*
CI_5	*17.9*	*32.1*

B. Optimum Amount of Polypropylene Fibre

For finding the optimum amount of polypropylene fibre addition, compressive strength test of three concrete cubes of size 150mm were done for each mix. Cubes were tested in compression testing machine after 7 and 28 days of curing.

Table – 8
Compressive Strength to Obtain Optimum Amount of Polypropylene Fibre

Mix ID	*Average Compressive Strength (N/mm^2)*	
	7^{th} day	*28^{th} day*
CI_1P_1	*30.9*	*48.6*
CI_1P_2	*32.8*	*52.1*
CI_1P_3	*31.1*	*49.2*
CI_1P_4	*29.2*	*46.5*

C. Hardened Properties

The iron oxide powder (adoptable amount) contained concrete paving blocks, with and without optimum amount of polypropylene fibre was prepared. Specimens are cured by submerging it in clean, fresh water and kept there until taken out just prior to test.

1) Compressive strength

The variations of compressive strength of different concrete paving blocks mix at 7^{th}, 14^{th} and 28^{th} day were shown in the Fig. 1.

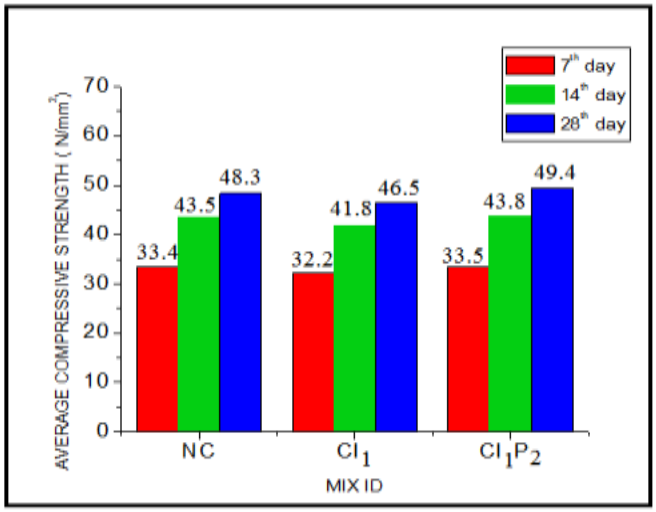

Fig. 1: Variation of Compressive Strength of Different Concrete Paving Blocks Mixes

2) Flexural strength

The variations of flexural strength of different concrete paving blocks mix at 28th day were shown in the Fig. 2.

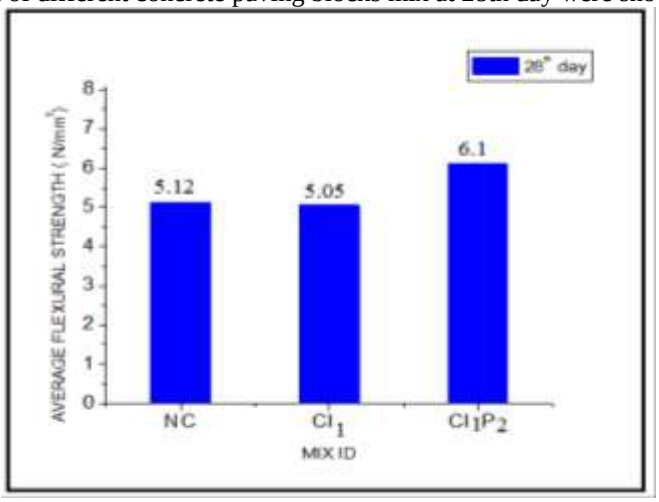

Fig. 2: Variation of Flexural Strength of Different Concrete Paving Blocks Mixes

3) Abrasion Resistance

The variations of abrasion value of different concrete paving blocks mix at 28th day were shown in the Fig. 3.

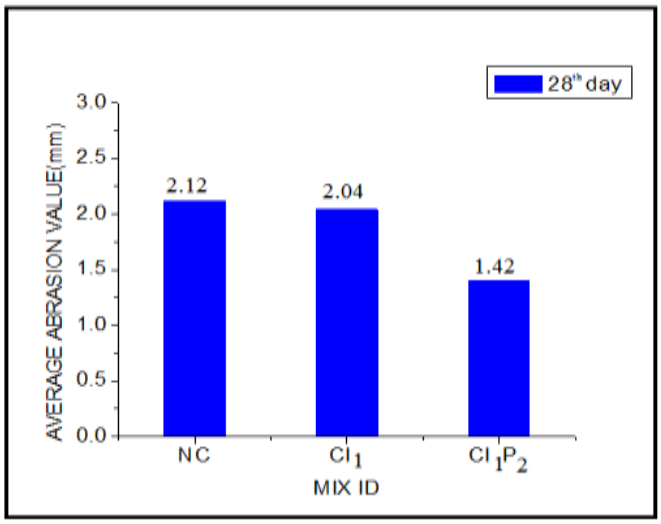

Fig. 3: Variation of Abrasion Value of Different Concrete Paving Blocks Mixes

V. CONCLUSIONS

Based on the results of this study it is clear that when iron oxide content increases compressive strength decreases and the adoptable amount is 5% by weight of cement. The optimum amount of polypropylene fibre is 0.2%. By analysing the results of compressive strength, flexural strength and abrasion resistance of paving blocks it is observed that the addition of polypropylene fibre causes increase in these properties. Paving blocks containing iron oxide powder gives slightly higher abrasion resistance than normal concrete blocks. Abrasion resistance and flexural strength of paving blocks with polypropylene fibre is higher than normal concrete blocks by 33% and 20% respectively.

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