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Experimental Investigation on the Performance of Plastic Aggregate Concrete

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Abstract: ***This study is intended to explore the suitability of recycled high density polyethylene (HDPE) as coarse aggregate in concrete. Effect of replacement of coarse aggregate with various percentages (0% to 40%) of plastic aggregate on behaviour of concrete was experimentally investigated and the optimum percentage replacement of coarse aggregate was found out. The results showed that the addition of HDPE aggregate to the concrete mixture led to increase in the compressive strength of the concrete till a replacement of 30% of natural coarse aggregate. Also with the addition of plastic aggregate, the workability and tensile force of the resultant concrete increased. The bonding property of both the concrete mix was also studied with the help of pullout apparatus. The present investigation also focussed on the effect of H_2SO_4, HCl and Na_2SO_4 on concrete containing normal aggregate and plastic aggregate respectively. The rate of attack on mix containing plastic aggregate was comparatively less than that of control mix. The obtained results supported the use of HDPE aggregate for partial replacement of natural aggregate.***

Keywords: ***Bonding Property, Hydrochloric acid attack, Optimum replacement, Recycled HDPE, Sodium sulphate attack, Sulphuric acid attack***

I. INTRODUCTION

Indian construction industry today is amongst the five largest in the world. The demand for new construction is ever increasing with the rise in population. Hence the non-renewable aggregate supply has emerged as a problem in India. With the shortage as seen today, the future seems to be in dark for the construction sector. Seeking aggregates for concrete, new materials have been used in the construction field. Focusing on the environment and safeguarding natural resources, new waste materials have been used in the construction industry. In India, due to growing population the quantity of solid waste is increasing rapidly. Among the solid waste materials, plastics represent 8% by weight of the total solid wastes.

For solving the disposal of large amount of plastic materials and to meet the increasing need for aggregates, reuse of plastic in concrete is considered as the most feasible application. Plastic aggregates will not be crushed as easily as natural aggregate since plastic are polymers made up of long string molecules consisting of carbon atoms bonded with other atoms such as hydrogen, nitrogen, oxygen, fluorine. They develop a crystalline structure which is strong, hard and more resistant to chemical penetration and degradation. Hence it will be a boon to the construction industry if plastic is utilized to prepare aggregates rather than recycling it repeatedly.

Plastic materials are light in weight, unbreakable, odourless and can be easily moulded. They have excellent finishing; possess good shock absorption capacity, high strength as well as toughness. These have low thermal expansion of co-efficient. Therefore they possess good thermal and electrical insulating property. Plastics have water resistant property and possess good adhesiveness. They are strong, durable, good and cheap to produce. It is possible to recycle plastic; therefore no decomposition required which is much more expensive and hazardous than recycling. Plastic can be used in building, construction, electronics, packing and transportation industries. But in contrast to all the above, plastic is a soft, non-renewable resource which cannot be used for some crucial applications. Recycling of plastic is a cost effective process. The improper disposal of plastic can cause hazard to wildlife as they are not readily biodegradable. Plastic materials like plastic bags are mostly end up as harmful waste in landfill which may pollute the environment and threatening our health. The biodegradation of plastic takes 500 to 1,000 years but manufacturing takes only seconds. It is thus essential to find an alternative method to recycle plastic.

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II. MATERIALS USED

The materials used for the study were cement, coarse aggregate, fine aggregate, plastic aggregate, water and chemicals. Plastic aggregates were prepared from recycled HDPE materials. HDPE sheets of 20mm thick were made and the plastic aggregates were cut out.



Fig 1 Plastic Aggregate

Chemicals like sulphuric acid, hydrochloric acid and sodium sulphate anhydrous were used to carry out chemical curing. The chemicals were manufactured by NICE Chemicals Pvt. Ltd. The materials were tested as per IS specifications. The material properties are enlisted in Table 1

Table 1. Material Properties

Cement	Brand: Shankar Cement; 43 grade Portland Pozzolana Cement
	Standard Consistency: 32%
	Initial Setting Time: 190 min
	Final Setting Time: 365 min
	Specific Gravity: 2.965
	Mortar Cube Strength: 43 N/mm^2
Fine Aggregate	Fineness Modulus: 4.129
	Zone: 1
	Specific Gravity: 2.697
	Water Absorption: 0.2%
Coarse Aggregate	Fineness Modulus: 5.09
	Nominal Size: 20 mm
	Specific Gravity: 2.745
	Water absorption: 0.05%
Plastic Aggregate	Fineness Modulus: 5.63
	Nominal Size: 20mm
	Specific Gravity: 0.94

III. CONTROL MIX

An M20 mix was designed as per IS 10262 – 2009 (e.g. [5]).The adopted mix proportion is as given in Table 2.

Table 2 Mix Proportion – Control Mix

Material	Cement	Fine Aggregate	Coarse Aggregate	Water
Weight (kg/m^3)	383.16	733.584	1119.96	191.58
Ratio	1	1.914	2.922	0.5

IV. EXPERIMENTAL INVESTIGATION

Cubes, cylinders and beams were casted for varying percentage replacement of natural aggregate with plastic aggregate. The mix

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are designated as follows:

Table 3 Mix Designation

% Replacement of aggregate with plastic	5	10	15	20	25	30	35	40
Mix Designation	5P	10P	15P	20P	25P	30P	35P	40P

For the durability test, cubes were cured in 2% sulphuric acid solution, 2% hydrochloric acid solution and 2% sodium sulphate solution for 90 days respectively.



Casting of Specimens



Water Curing



2% H_2SO_4 Curing 2% HCl Curing 2% Na_2SO_4 Curing

Fig 2 Casting and Curing of Specimens

Bonding stress was evaluated using pullout apparatus. The cylindrical attachment used for the purpose had an inner diameter of 4 cm, outer diameter of 6 cm and a height of 10 cm.



Cylindrical Attachment Cube Casted for Pullut Test

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Fig 3 Casting of Specimen for Pullout Test

Durability and pullout test were conducted for control mix and optimum percentage replacement of natural aggregate with plastic aggregate.

Table 4 Total Number of Specimens Casted

Specimen	Dimension	Total Number
Cube	150 mm x 150 mm x 150 mm	117
Cylinder	150 mm diameter; 300 mm height	162
Beam	100 mm x 100 mm x 500 mm	162

V. TEST RESULTS

A. *Workability By Slump Test*

With the introduction of plastic in concrete the slump value increases; i.e. the workability of concrete increases.

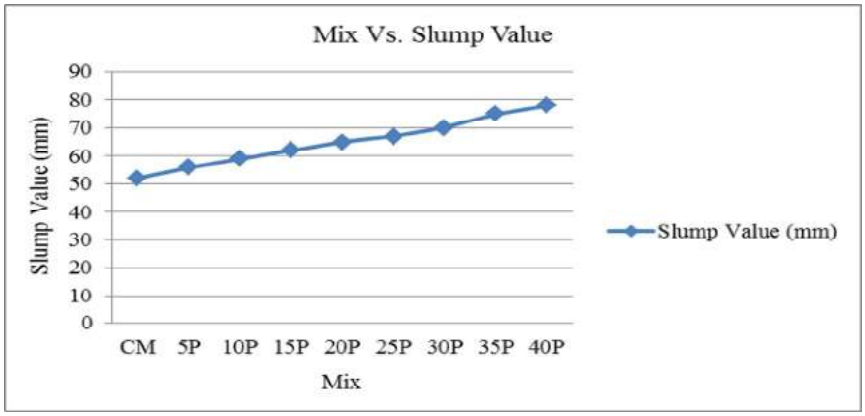


Fig 4 Variation in Slump Value for Various Mix

B. *Compressive Strength Of Cubes*

An increase in strength was observed till 30% replacement of natural aggregate with plastic aggregate and on further replacement strength was found to be decreasing.

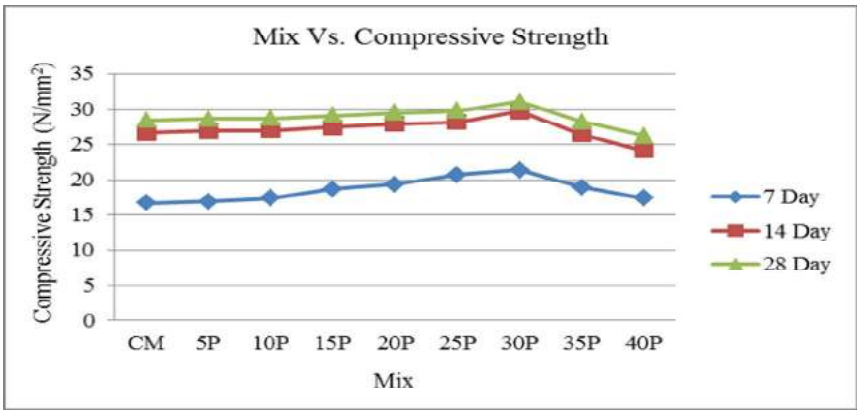


Fig 5 Variation in Compressive Strength of Cube for Various Mix

C. *Compressive Strength Of Cylinders*

It is seen 7 day, 14 day and 28 day compressive strength of cylinder increased gradually with the replacement of natural aggregate with plastic aggregate in concrete.

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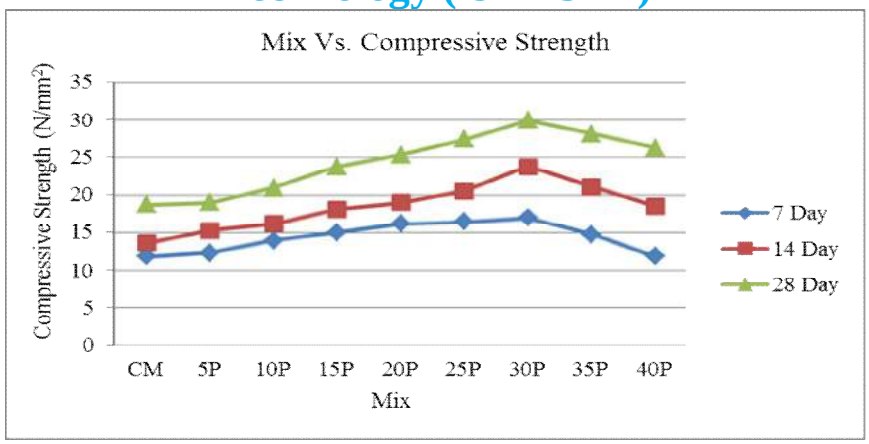


Fig 6 Variation in Compressive Strength of Cylinder for Various Mix

D. Splitting Tensile Strength Of Cylinder

An increasing trend in splitting tensile strength of concrete was observed till 30% replacement of natural aggregate with plastic aggregate.

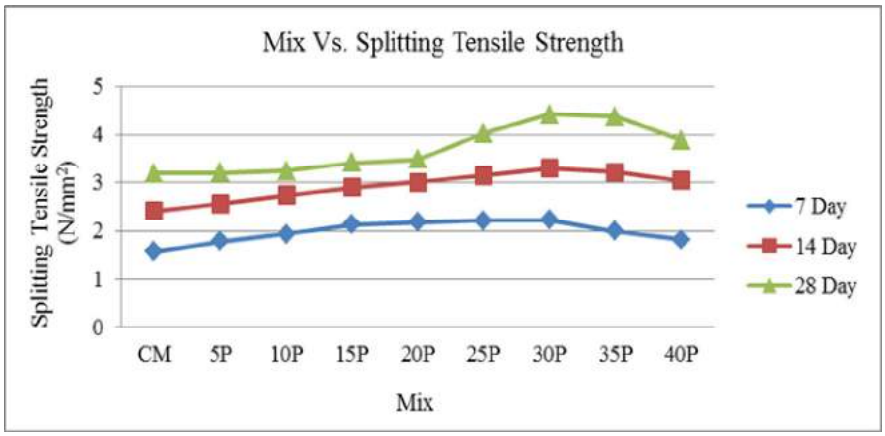


Fig 7 Variation in Splitting Tensile Strength of Cylinder for Various Mix

E. Flexural Strength Of P.C.C Beam

Flexural strength increased with the increase in plastic content in concrete.

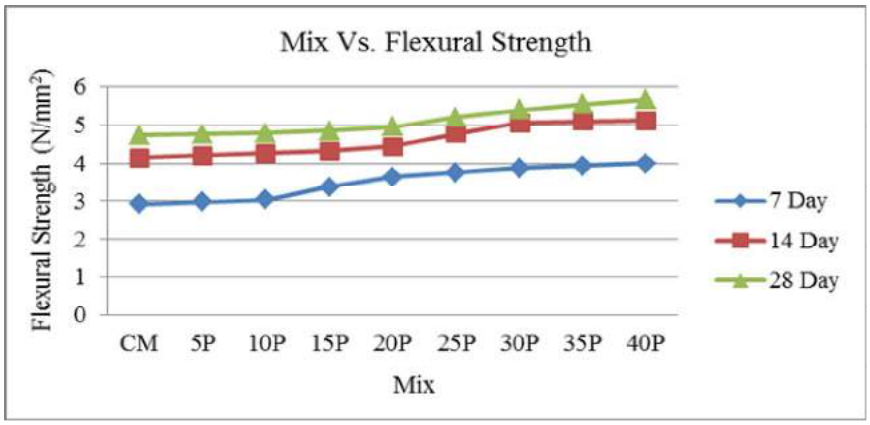


Fig 8 Variation in Flexural Strength of PCC Beam for Various Mix

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F. Breaking Load Of R.C.C Beam

Flexural strength increased with the increase in replacement of natural aggregate with plastic aggregate in concrete.

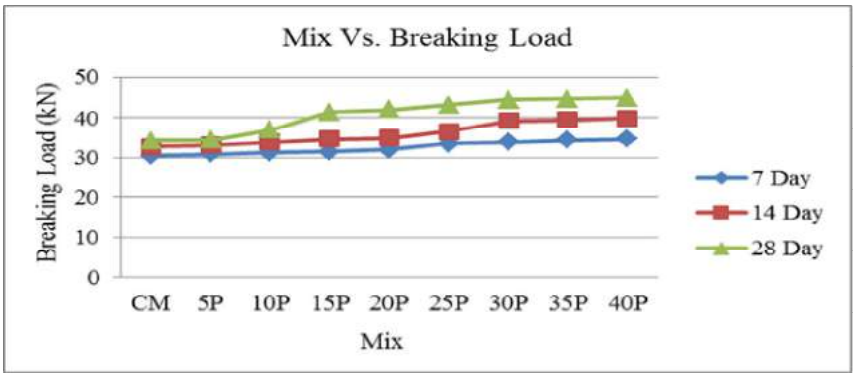


Fig 9 Variation in Breaking Load of RCC Beam for Various Mix

G. Cube Weight

Plastic being a light weight material tends to decrease the weight of the resultant concrete.

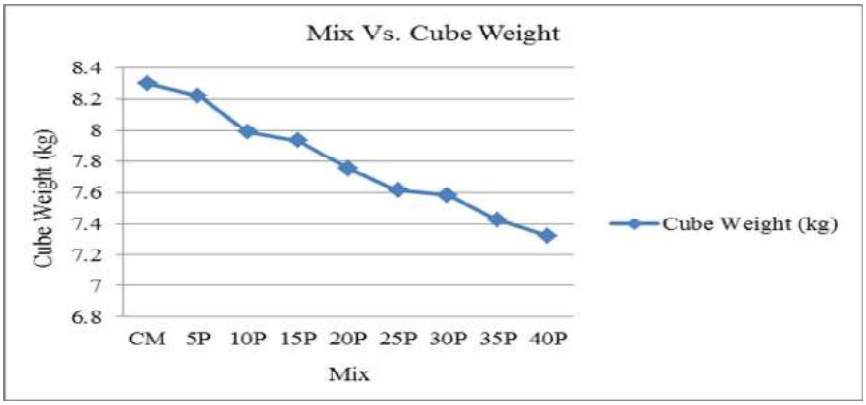
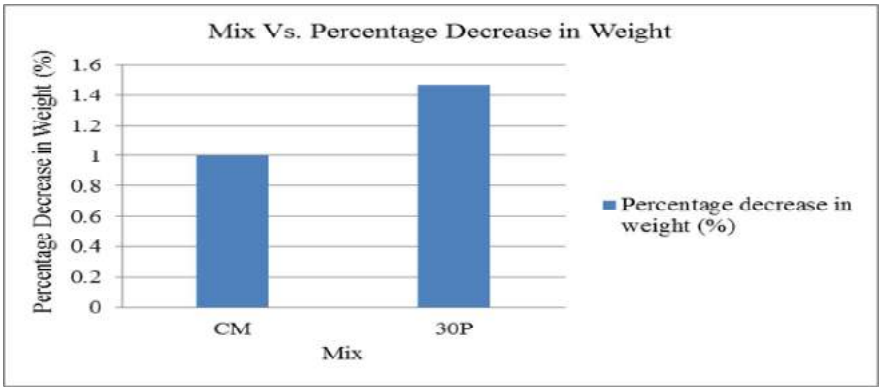


Fig 10 Variation in Weight of Cube for Various Mix

H. Sulphuric Acid Attack

When compared, significant differences in weight losses (Fig 11) were not observed for both the mixes after 90 days sulphuric acid curing. Mix using plastic aggregate showed more decrease in compressive strength after H_2SO_4 curing when compared with control mix using natural aggregate (Fig 12).



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Fig 11 Percentage Decrease in Weight of Cubes after H_2SO_4 Curing

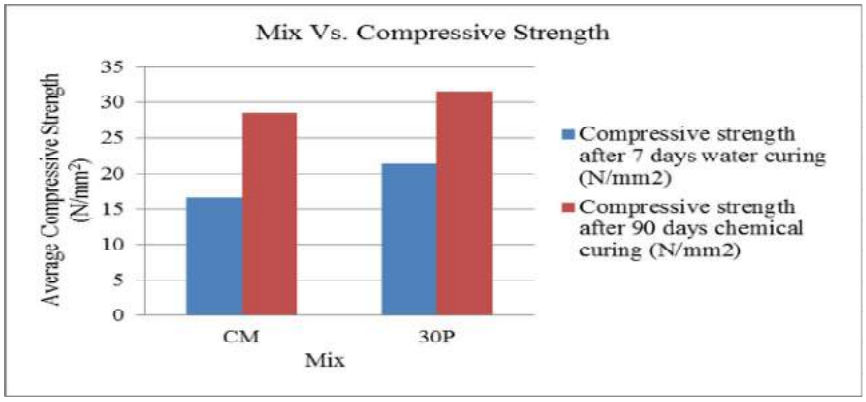


Fig 12 Variation in Compressive Strength of Cubes after H_2SO_4 Curing

I. Hydrochloric Acid Attack

Percentage decrease in weight loss (Fig 13) of specimen after 90 days hydrochloric acid curing was 1.46% and 0.5% for CM and 30P respectively. Variation in compressive strength (Fig 14) shows that concrete is highly resistance to chloride attack on replacement of natural aggregate with plastic aggregate.

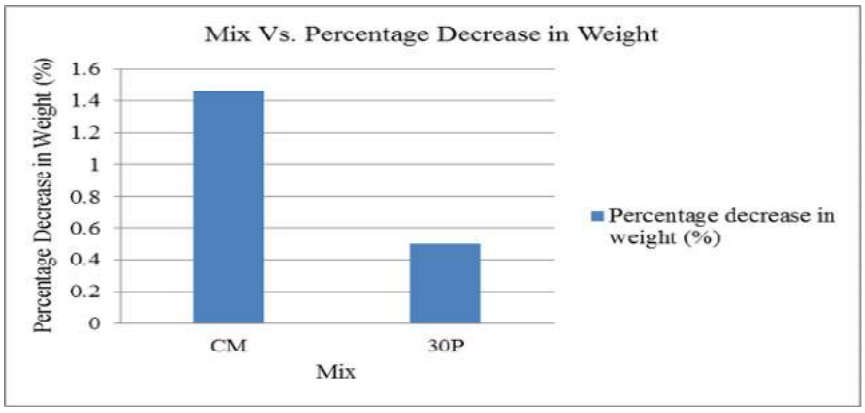


Fig 13 Percentage Decrease in Weight of Cubes after HCl Curing

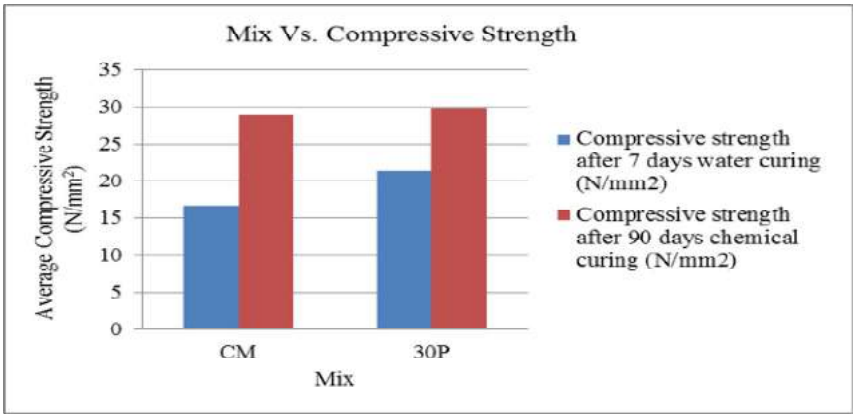


Fig 14 Variation in Compressive Strength of Cubes after HCl Curing

J. Sodium Sulphate Attack

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When compared, significant differences in weight losses were not observed for both the mixes after 90 days sulphuric acid curing. Plastic being chemically resistant increases the compressive strength of the resultant concrete when compared to conventional concrete.

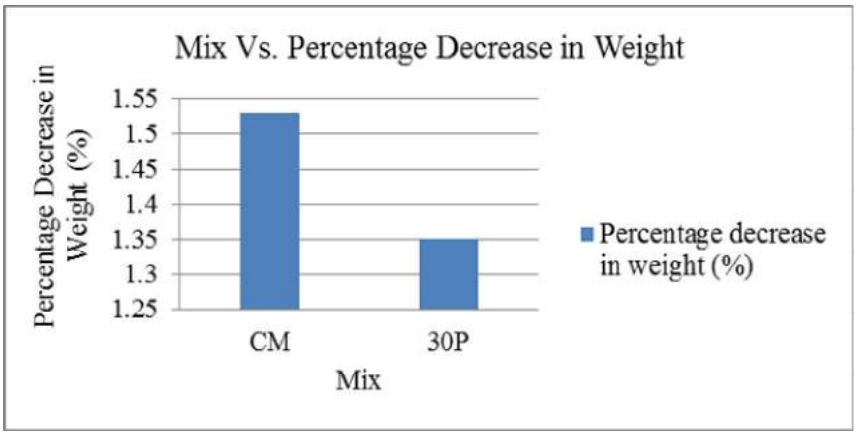


Fig 15 Percentage Decrease in Weight of Cubes after Na_2SO_4 Curing

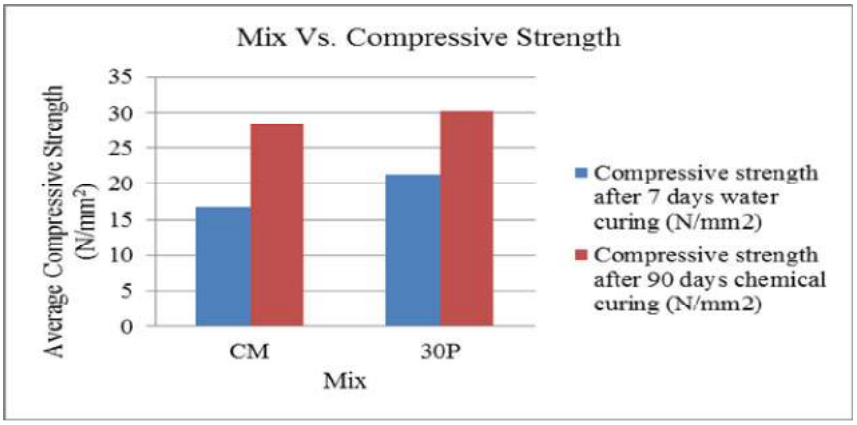


Fig 16 Variation in Compressive Strength of Cube after Na_2SO_4 Curing

K. Bonding Stress

The bonding stress of CM was found to be 0.4 N/mm^2 and that of 30P was 0.44 N/mm^2.

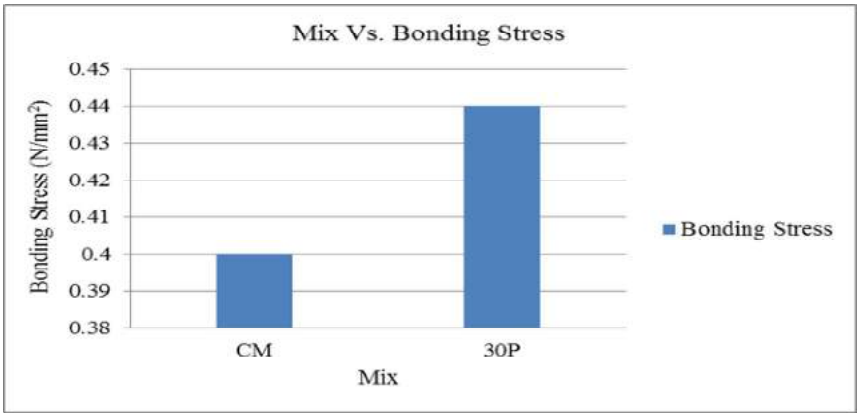


Fig 17 Variation in Bonding Stress

VI. CONCLUSIONS

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A study was conducted to investigate the possibility of making plastic aggregate and using the aggregate made from plastic as a substitute for natural coarse aggregate in concrete. The study can be concluded as follows:

Plastic aggregate is a lightweight material with specific gravity 0.94.

The workability of concrete increased by 50% for a mix containing 40% plastic aggregate.

Compressive strength and splitting tensile strength of concrete increased till 30% replacement of natural aggregate with plastic aggregate and on further replacement they tend to decrease but not below the target mean strength.

Compressive strength increased by 9.4% and splitting tensile strength by 39% for a mix with 30 % replacement of natural aggregate by plastic aggregate when compared to control mix.

Flexural strength of PCC beam and breaking load of RCC beam increased till 40% replacement. There was an improvement of 20% and 31% strength respectively.

The optimum percentage replacement of natural coarse aggregate using plastic aggregate was obtained as 30%

After 90 days sulphuric acid curing (2% solution), the percentage decrease in weight of the mix containing plastic aggregate was found to be 1.4% and that of control mix was 1%.

Compressive strength (after sulphuric acid curing) increased by 11% for a mix with 30% replacement of natural aggregate by plastic aggregate when compared to control mix.

After 90 days hydrochloric acid curing, the percentage decrease in weight of the control mix was 1.46% whereas that of the mix containing plastic aggregate was 0.5%

After hydrochloric acid curing, there was an improvement in compressive strength by 3% for the mix with 30% plastic aggregate when compared to control mix.

After 90 days sodium sulphate curing (2% solution), the percentage decrease in the weight of the mix containing plastic aggregate was 1.35% and that of control mix was 1.53%.

Compressive strength increased by 7% for the mix with 30% replacement of natural aggregate by plastic aggregate when compared to control mix; after sodium sulphate curing.

Results indicated that bonding stress was almost the same for both the mixes. The mix control mix had a bonding stress of 0.4 N/mm^2 whereas the mix containing plastic aggregate had a bonding stress of 0.44 N/mm^2.

It was found that plastic tends to reduce the unit weight of concrete. The weight was reduced by 12% for a mix with 40% replacement of plastic aggregate when compared to that of control mix.

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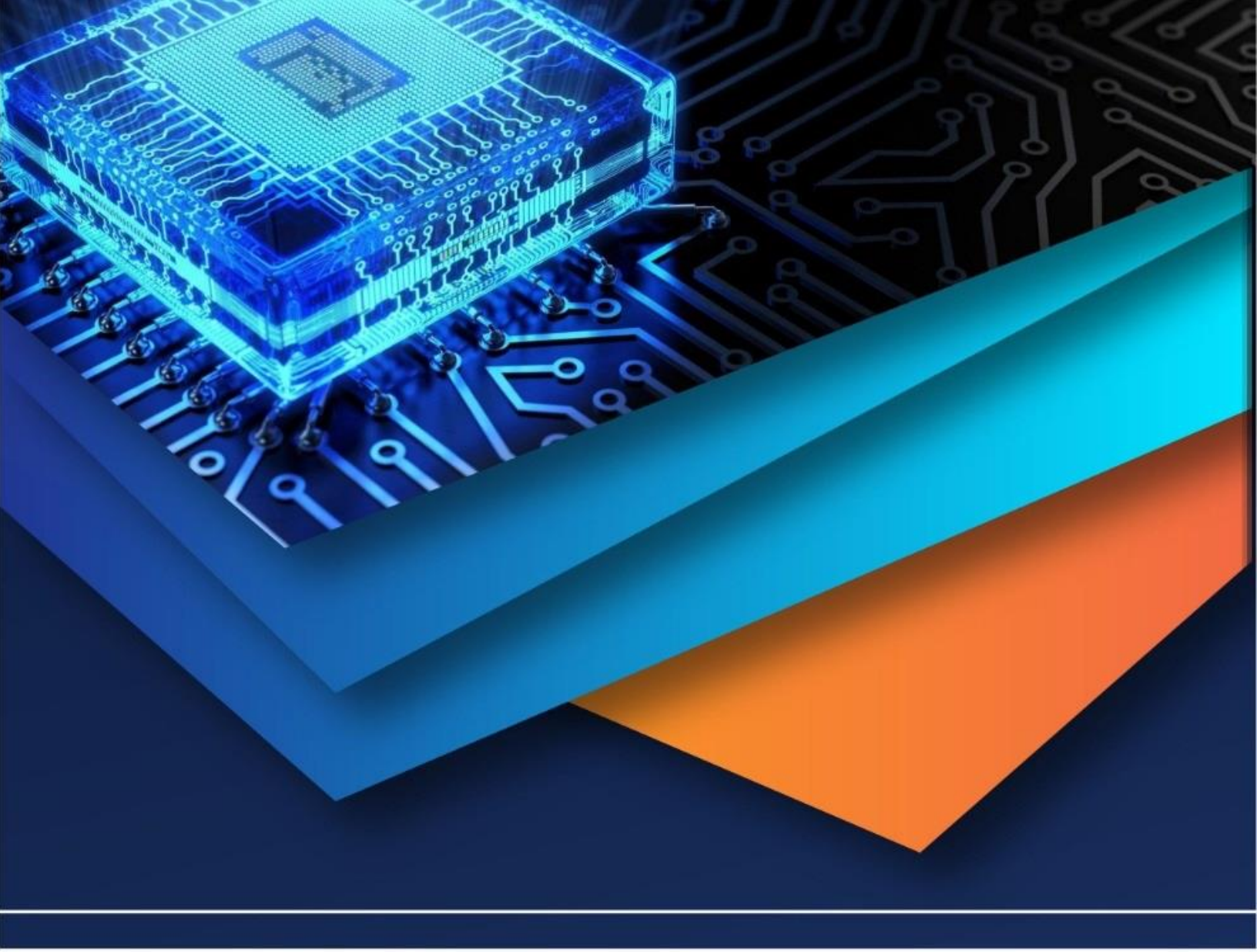


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