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Use of Plastic Aggregates in Concrete

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***ABSTRACT:** There is no doubt concrete is most useful thing in construction industry but it has a negative impact also, just like a coin has two faces. Raw materials used in manufacturing of concrete affects the environment in one or the another negative way. Like manufacturing of cement produce carbon dioxide whereas the production of aggregates adds dust to the environment. Production of coarse aggregates also impact the geology of the area from they were extracted. A step taken in this direction is the use of waste products along with or in replacement of cement. Many of these materials are already in use, like silica fume, fly ash etc. In this study, plastic coarse aggregates were used in place of natural coarse aggregates. Plastic aggregates were produced by little processing of waste plastic. Plastic is the biggest threat to the environment, and it is affecting the environment rapidly. Some recent studies show that it can be used construction industry due to some of its properties like inert behavior, resistance to degradation etc. Also use of waste plastic can help in reducing plastic waste*

Various experiments were performed to test the mechanical properties of the concrete with plastic coarse aggregates. Concrete was prepared using plastic coarse aggregates in varying proportions of 0, 2.5, 5, 7.5 and 10%.

I. INTRODUCTION

Concrete is the mostly used man made material used in construction industry and is the second after water as the most utilized thing on the Earth. In simple words it is defined as a mixture of four ingredients as **coarse aggregates** that form the largest proportion of the mix, **fine aggregates** such as sand that act as filler material in the voids, **binding material** such as lime or Portland cement that binds these material together and **water** that reacts with binding material. The mixing of these four materials gives us a paste that is called as matrix. At this stage it is called as fresh concrete or green concrete and get hardened like a stone, as the water reacts with binding material. This reaction is called as hydration of concrete. In fresh state concrete can be casted into any desired shape by placing it in forms. This property of concrete help in using the concrete in most efficient manner.

Plastic needs no introduction as it is the widely used material now a days on our Earth. Due to its properties like strength, durability and easy processing it can be used for many purposes. Studies shows that plastic is nearly inert that is it get very less affected by the chemicals and have higher durability. Disposal of plastic waste is a huge problem as due to absence of organic compounds, it is non-decomposable material and proves to be a threat to our environment as it has many health hazards.

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As decomposition of plastic is a serious problem as it takes very long time and adversely affection the environment in many ways. So we can use it in construction, where we need life of structure to be improved and use of waste plastic after small processing can help us to reduce the waste in the environment which is new motto of civil engineering.

II. SCOPE

We get most of the aggregates by quarrying the stones and then crushing. As quarrying of stones cause change in geological aspects of the area, crushing causes the entry of dust particles in the environment. So causing bad impact to the environment in dual manner. To minimize this researchers focused on the usage of waste materials that were also adversely affecting the environment. Some of these are already in use such as Iron slag, Crusher Dust, etc. and many others are under research. So usage of these waste materials helping in dual role by minimizing the usage of raw material of concrete and by using the waste materials that are affecting the environment. The other advantage of using these waste materials is that they are helping in improving the properties of concrete.

The waste materials we have taken for our study is Plastic. Plastic has very bad impact on our environment but due to some of its properties it can be used in concrete.

III. LITERATURE REVIEW

Elango A and Ashok Kumar A in 2018 performed study concrete with plastic fine aggregates. They used OPC 53 grade, River sand and crushed aggregates. They used plastic in place of fine aggregates in proportion of 10%, 20% and 30%. They test mechanical and durability properties on their concrete samples. They found the decrease in strength of concrete. But found that the concrete shows good results against acid attacks and increase in elasticity. So they concluded that the plastic aggregate concrete can be used in place where we need less compressive strength but more durability.

LhakpaWangmoThinghTamanget. al. in 2017 performed experiment on Plastics in Concrete as Coarse Aggregate. They performed the testing of mechanical properties of concrete containing Plastic aggregates They use plastic aggregates in proportion of 10%, 15%, and 20%. They found marginal reduction in strength and suggested the optimum result as 15% replacement.

B Jaivignesh and A Sofi in 2017 performed Study Properties of Concrete with Plastic Waste as Aggregate. They used the plastic place of fine aggregates as well as coarse aggregates in proportion of 10%, 15 % and 20%. They also added steel fibre to the concrete. Their research concludes to the reduction in strength but suggested its use in favor of reduction of waste material and eco friendly materials.

MB Hossain et. al. in 2016 performed work on Use of waste plastic in concrete as a constituent material. They replace coarse aggregates in proportion of 5%, 10% and 20 5. They found that the concrete was lighter in weight. But the compressive strength was lesser than that of conventional concrete. They also found that the concrete with 10% plastic aggregates shows strength nearly similar to the conventional concrete. So, the optimum result was 10% plastic aggregates.

RaghatateAtul M. in 2012 performed study on use of plastic bags in form of fiber in concrete and test it properties. He adds fiber in proportion of 0.2%, 0.4%, 0.6%, 0.8% and 1% by weight of concrete. He found that there was reduction of compressive strength with increase in plastic content, but there was increase in tensile strength with optimum strength at 0.8% addition.

Praveen Mathew et. al. in 2013 study the use of Recycled Plastics as Coarse Aggregate for Structural Concrete. They performed test on concrete with various proportions of plastic aggregates in replacement of coarse aggregates and found the optimum result at 22% replacement of coarse aggregates with plastic aggregates. They further performed the test for other properties on concrete with 22% plastic aggregates and found that concrete with plastic aggregates was weaker in fire resistance.

S. Vanitha et al. in 2015 performed studies on use of waste plastic in Concrete Blocks. Paver Blocks and Solid Blocks of size 200 mm X 150 mm X 60 mm and 200 mm X 100mm X 65 mm were casted for M20 grade of concrete and tested for 7, 14 and 28 days strength. Plastic was added to a proportion of 2%, 4%, 6%, 8% and 10% in equal replacement of aggregates. They found the optimum result for paver block at 4% replacement of aggregates with plastic aggregates. And 2% of plastic in case of solid blocks.

Baboo Rai et. al. in 2012 study of Waste Plastic in Concrete with Plasticizer. They prepared M30 grade of concrete with varying proportion plastic pallets and then test the concrete with and without plasticizers. They add plastic pallets in proportion of 5%, 10% and 15% by weight of concrete. They found that there was reduction in density that can help in achieving low density or light weight concrete. they also found that there was reduction in slump and hence affects the workability but addition of plasticizers resolves the problem. They found reduction in compressive and flexural strengths but it was very low and can be allowed.

Daniel Yaw Osei in 2014 performed experiments on plastics aggregate in concrete. He replace the coarse aggregates in concrete of ratio 1:2:4 by 25%, 50%, 75% and 100% with plastic. He found that there was reduction in strength of concrete as well as density of concrete. They suggested that replacement of aggregates more than 36% is not suitable for structural concrete. They also suggested plastic as a medium for production of light weight concrete.

T.Subramani and V.K.Pugal in 2015 performed an experiments on plastic waste as coarse aggregatesin concrete. They prepared the concrete with 5%, 10% and 15% replacement of aggregates in concrete with plastic. They found the optimum results at 10% replacement of aggregates with plastic. Further increase in plastic content decreases the strength of concrete.

NabajyotiSaikia and Jorge de Brito in 2012 study use of plastic in cement mortar and concrete. They found that workability decreases on use of angular plastic aggregates but increases with use of smooth aggregates. Irrespective of type of plastic, there was reduction of compressive strength, but the reduction of flexural and tensile strength was low as compared to compressive strength.

Amalu.R.Get. al. in 2016 performed the study the use of waste plastic as fine aggregate in concrete. They use plastic as substitute of fine aggregates in proportion of 10%, 15%, 20% and 25%. They found reduction in strength of concrete but support the use of plastic in non structural concrete for the reason it shows higher workability and reduce environmental waste.

Manhal A Jibrael and Farah Peter in 2016 studies the Strength and Behaviour of Concrete Contains Waste Plastic. They replace fine aggregates in concrete with plastic bottles and plastic bags in varying proportions from 0% to 5%. They concluded the results to use the plastic in concrete for non structural purposes as it reduces the strength in both cases.

IV. RESEARCH GAP

The following conclusions were drawn from past experimental work.

- There is reduction in compressive strength of concrete with more than 10% of plastic.
- There is an enhancement in the tensile strengths for respective replacement of aggregate with plastic
- The flexural strength of concrete increases with addition of plastic between 10% to 15% replacement by weight of plastic.
- It is observed that the split tensile strength of concrete increased up to 10% replacement of aggregates by plastic
- The workability decreases with increase in percentage of plastic.

V. OBJECTIVE OF THE STUDY

The properties of concrete that can be modified using Plastic are its

a) Compressive Strength
b) Split Tensile Strength
c) Flexural Strength

There are some other important properties of concrete will also be under consideration such as workability, compaction, bleeding and segregation of concrete.

VI. METHODOLOGY

The methodology adopted for this study is given below:

1. Literature study was done on the available data on use of plastic in concrete.
2. Plastic was collected from the waste material.
3. Plastic was cleaned for the removal of any foreign material, dust etc.
4. It was then sundried for few hours and then melted in container.
5. The melted plastic was the drawn into sheets by pouring it on flat surface, and then allowed to cool down and get hard.
6. Cooled and hard plastic sheets were then broken into smaller particles by hammering the sheets.
7. Test related to properties of cement and aggregates were performed.

8. Proportion of plastic coarse aggregates (PCA) in different mixes was selected on the basis of available literature.
9. Mix design for different proportions of concrete was decided and tests were performed to obtain the mechanical properties of different mixes.
10. Based on the literature survey and optimum quantities of plastic, the following combinations were adopted.

Table 1: Percentage replacement of NCA by PCA

S. No.	Concrete Name	Natural Coarse Aggregates (NCA) %	Plastic Coarse Aggregates (PCA) %
1	M1	100	0
2	M2	97.5	2.5
3	M3	95	5
4	M4	92.5	7.5
5	M5	90	10

6.1 Design Of Concrete Mix

Concrete mix is the way by which we choose the different constituents used in the concrete and deteremining their amount and by taking care about the economy and various properties of the concrete like workability, slump value , strength criteria etc. For designing the concrete mix we followed IS:10262-2009. A design mix for M25 grade od concrete was prepared and trial mixes were prepared to check the mix design and to adjust amount of admixture and Water cement ratio. The following parameters were used for mix design

- Grade of concrete = M25
- Type of Cement = OPC-43 Grade
- Brand of Cemenat =ACC
- Admixture Used = RHEOPLAST SP-450
- Fine Aggregates =Zone III
- Specific Gravity of Cement = 3.16
- Specific gravity of FA = 2.61
- Specific Gravity of C.A
  10mm = 2.66
  20mm =2.65
- Moisture content of FA =4%

The design mix adopted for M25 grade mix is given in table

Table 2 Mix Proportion for M25 grade Concrete

Unit of Batch	Cement (Kg)	Fine Aggregates (Kg)	Coarse Aggregates(Kg)		Water (Kg)	Admixture
			10mm	20mm		
Cubic meter content	320	608	512	768	124.8	3.2
Ratio	1	1.9	1.6	2.4	0.39	0.01

The design mix was strictly followed to get the desired results. The cement content was increased when hand mixing was done.

6.2 Specimens

All the specimens were casted according to the mix proportions. For these mix proportions required quantities were measured and then mixed. Mixing of concrete was done with hand, so the cement content was increased by 10% of weight.

6.2.1 Specimens for Compressive Strength

To check the compressive strength of concrete mix, specimens of cubical shape size 150mmX150mmX150mm were prepared. The required quantities of materials required were weighed according to the mix proportion. Aggregates and cement was firstly thoroughly mixed. Admixture was added to the water. Water was then added to the dry mix. Total 9 similar cubes were casted, each three cubes for 7 days, 14 days and 28 days testing. After 24 hours of casting, the cubes were demoulded then placed into curing tank.

6.2.2 Specimens for Split Tensile Strength

To check the Split Tensile Strength of concrete mix, cylinderical specimens of size 150mm diameter and 300mm height were prepared. The required quantities of materials required were weighed according to the mix proportion. Aggregates and cement was firstly thoroughly mixed. Admixture was added to the water.. Total 9 similar cylinders were casted, each three cylinders for 7 days, 14 days and 28 days testing. After 24 hours of cating, the cylinders were demoulded and were then placed into curing tank.

6.2.3 Specimens for Flexure Strength

To check the Flexure strength of concrete mix, beam specimens of size 100mmX100mmX500mm were prepared. The required quantities of materials required were weighed according to the mix proportion. Aggregates and cement was firstly thoroughly mixed. Admixture was added to the water. Water was then added to the dry mix. Total 9 similar beams were casted, each three beams for 7 days, 14 days and 28 days testing. After 24 hours of cating, the beams were demoulded and were then placed into curing tank.

6.3 Testing of Concrete

After casting, specimens were tested after 7, 14 and 28 days of curing. In this article, the procedure adopted for testing of specimensfor various properties like compressive sterngth, split tensile strength and flexure strength have been discussed.

6.3.1 Compressive Strength

To evaluate the compressive strength of concrete, cube specimens were used. The test were performed according to IS 516-1959. Specimens were then placed in curing tank for specified period. Specimens were then taken out of tank after 7, 14 and 28 days of curing and surface dried. They should be dried under shade not under direct sunlight or in oven. Specimens were then placed in Compression Testing Machine (CTM). The rate of loading was then set at 140Kg/m^3/minute or 5.2 KN per second. The load was applied and the peak load at which the apecimen fails was noted.

Compressive strength = P/A

Where, P = load in KN and A = Area of cross section

Setup for Compressive strength

6.3.2 Split Tensile Strength

The tensile strength is obatained by placing the cylinder in the CTM, so that the compressive force acts horizontally. The failure occurs along the vertical axis due to the tension developed in transverse direction. It was also tested for 7 days, 14 days and 28 days. The rate of loading was 2.1 KN per second.

The Split Tensile Strength can be calculated as

$$\sigma_c = \frac{2P}{\pi DL}$$

where, P = load in KN

D= diameter of cylinder

L= Length of cylinder

σ_t=split tensile strength of specimen in N/mm^2

Plate Setup for Split Tensile Strength

6.3.3 Flexure Strength Test

The flexure strength test is obtained for the beams. The beams were placed in CTM, but the arrangement for that is different. Additional setups were installed in the CTM. it includes 4 point load setup, two at bottom side and two at upper side. The rate of loading was 0.1 KN/second.

The flexure strength of the beam can be determined by using formulae,

$\sigma_c = \frac{3PL}{4bd^2}$} if crack occurs at the middle third span of the beam, or

$\sigma_c = \frac{3Pa}{4bd^2}$} if the crack occurs at the outer third span of the beam

Where, P = load in KN,

L= length of beam

b= width of beam,

d= depth of beam, and

a = distance between crack and the nearest support

Setup for Flexure Strength Test

VII. RESULTS AND DISCUSSION

7.1 Slump Test

Slump test was performed on freshly prepared concrete mixes to check the workability of concrete. Workability of concrete is defined as the ease to do work with it, without segregation. Workability of concrete is an important property of fresh concrete. Concrete should have good workability.

Table :Slump test values for different mixes

S No.	Mix	Slump Value
1	M1	87
2	M2	89
3	M3	92
4	M4	90
5	M5	86

The result of slump test shows that there was firstly increase in slump upto 5% addition of plastic and then it start decreasing.

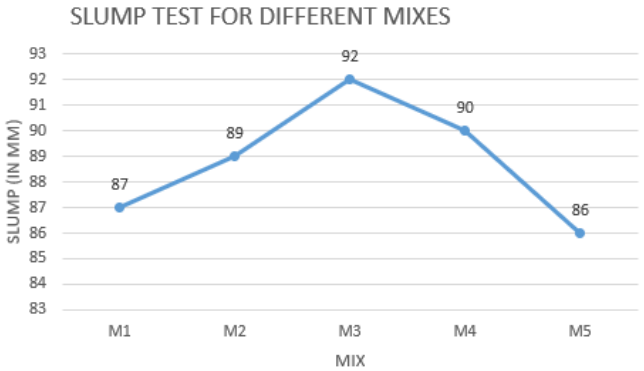


Fig.: Variation of Slump for different mix proportions

VIII. COMPRESSIVE STRENGTH TEST

This test is performed on hardened concrete, to check the strength of concrete. The concrete specimens were put under the load per unit area of cross section in uniaxial compression under a fixed rate of loading.

The compressive strength of concrete is expressed in N/mm^2. We performed this test on standard cubes of size 150mmX150mmX150mm. Concrete mix with different proportions was prepared and filled into cube mould. It was then left for 24 hours for initial setting. For every mix proportion 9 specimens were prepared, 3 specimens for each 7 days, 14 days and 28 days testing. After completion of curing period the specimens were tested using Compression testing machine (CTM). Surface dried specimens were placed in CTM. A fixed rate of loading of 140Kg/m^2/minute or 5.2 KN was applied. The maximum value of load (P) under which the specimen fails was noted down.

Compressive strength =P/A

Here, P = load on the cube

A= cross-sectional area of cube

Table Compressive strength of concrete

Mix Name	7 days strength (N/mm^2)	14 days strength (N/mm^2)	28 days strength (N/mm^2)
M1	21.23	27.61	30.57
M2	22.57	27.93	30.63
M3	20.42	27.1	29.86
M4	19.68	26.4	29.07
M5	18.84	25.98	28.74

Case I : Compressive strength after 7 days

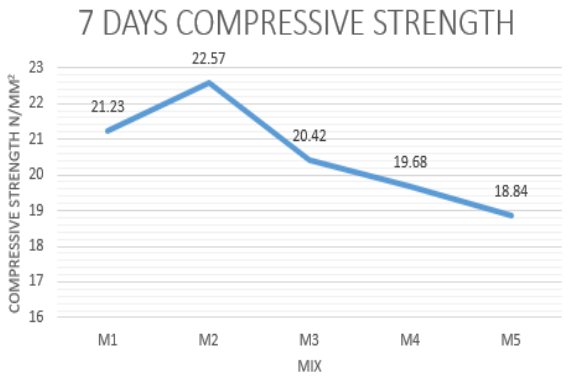


Fig. Variation of compressive strength of concrete after 7 days

Case II Compressive strength after 14 days

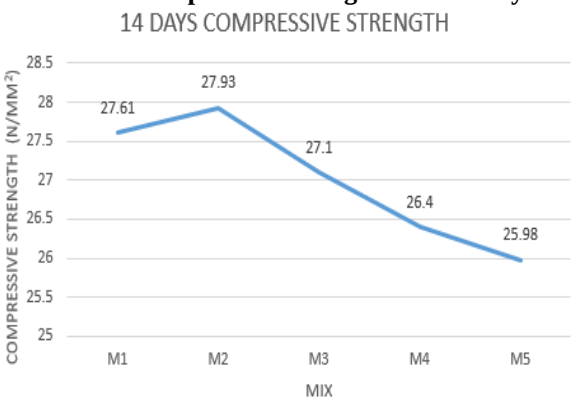


Fig. Variation of compressive strength of concrete after 14 days

Case III Compressive strength after 28 days

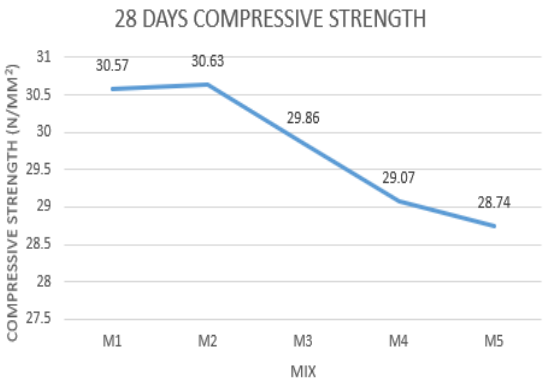
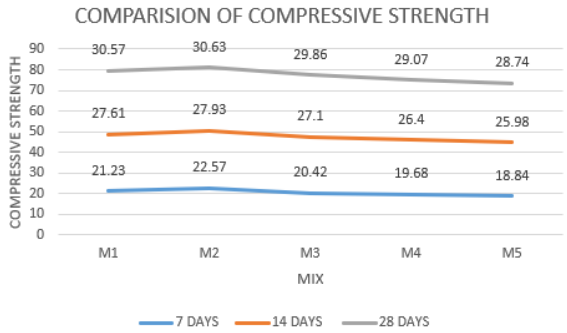


Fig. Variation of compressive strength of concrete after 28 days



FigComparison of Compressive strength of concrete at 7 days, 14 days and 28 days

7.3 Split Tensile Strength

This test is performedto evaluate the tensile strength of concrete. The tensile strength is obatained by placing the cylinder in the CTM, so that the compressive force acts horizontally. The failure occurs along the vertical axis due to the tension developed in transverse direction. It was also tested for 7 days, 14 days and 28 days. The rate of loading was 2.1 KN per second.

The Split Tensile Strength can be calculated as

$$\sigma_t = 2P/\pi DL$$

where, P = load in KN

D= diameter of cylinder

L= Length of cylinder

The test result of Split tensile strength test are in table 7.3

Table 7.3 Split Tensile strength of concrete

Mix Name	7 days Strength (N/mm^2)	14 days Strength (N/mm^2)	28 days Strength (N/mm^2)
M1	2.01	2.72	2.98
M2	2.47	2.86	3.12
M3	2.51	2.91	3.19
M4	2.33	2.79	3.04
M5	2.1	2.68	2.97

Case I Split Tensile strength after 7 days

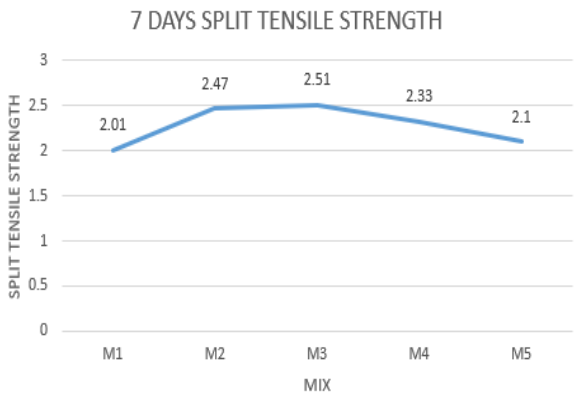


Fig. Variation of Split Tensile strength of concrete after 7 days

Case II Split Tensile strength after 14 days

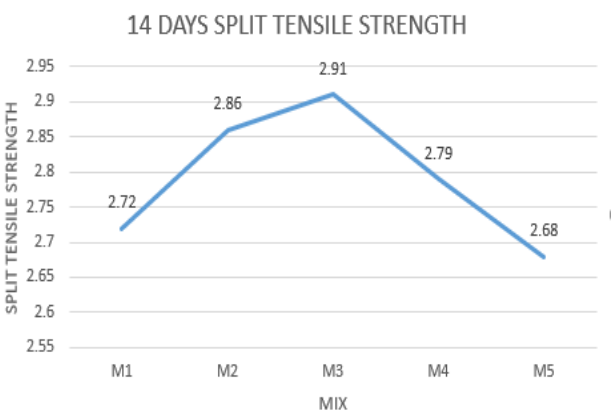


Fig. Variation of Split Tensile strength of concrete after 14 days

Case III Split Tensile strength after 28 days

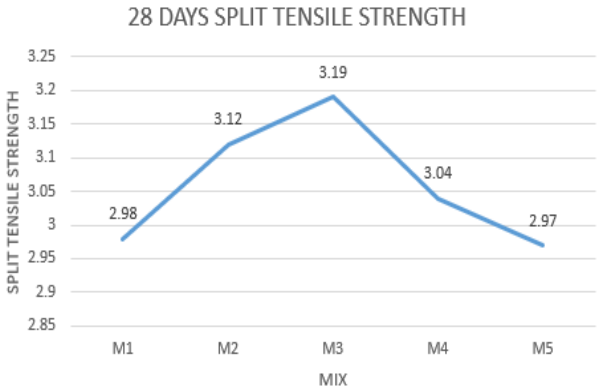
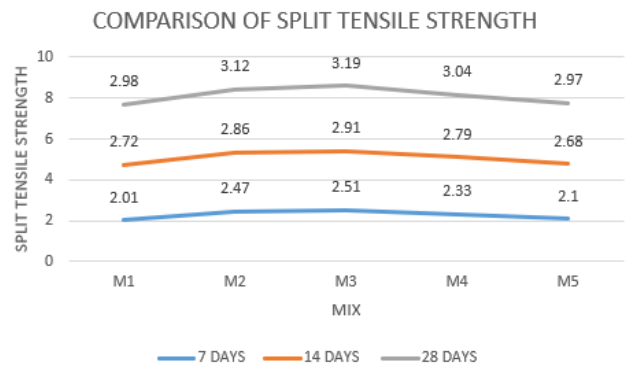


Fig. Variation of Split Tensile strength of concrete after 28 days



FigComparison of Split Tensile strength of concrete at 7 days, 14 days and 28 days

7.4 Flexure Strength

The flexure strength test is obtained for the beams. The beams were placed in CTM, but the arrangement for that is different. Additional setups were installed in the CTM. it includes 4 point load setup, two at bottom side and two at upper side. The rate of loading was 0.1KN/second.

The flexure strength of the beam can be determined by using formulae,

$\sigma_c = 3PL/4bd^2$ } if crack occurs at the middle third span of the beam, or

$\sigma_c = 3Pa/4bd^2$ } if the crack occurs at the outer third span of the beam

Where, P = load in KN, L= length of the specimen

b= width of specimen, d= depth of specimen, and

a = distance between crack and the nearest support

Table Flexure strength of concrete

Mix Name	7 days Strength (N/mm^2)	14 days Strength (N/mm^2)	28 days Strength (N/mm^2)
M1	4.09	5.47	6.01
M2	5.12	5.61	6.19
M3	4.02	5.37	5.98
M4	3.95	5.28	5.91
M5	3.89	5.21	5.84

Case I Flexure strength after 7 days

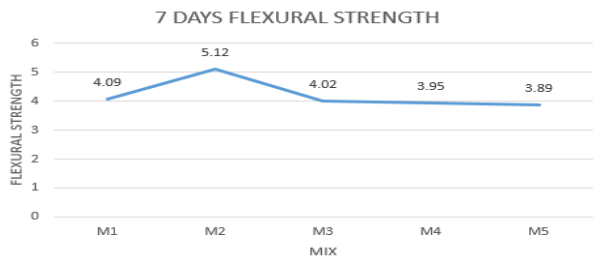


Fig. Variation of Flexure strength of concrete after 7 days

Case II Flexure strength after 14 days

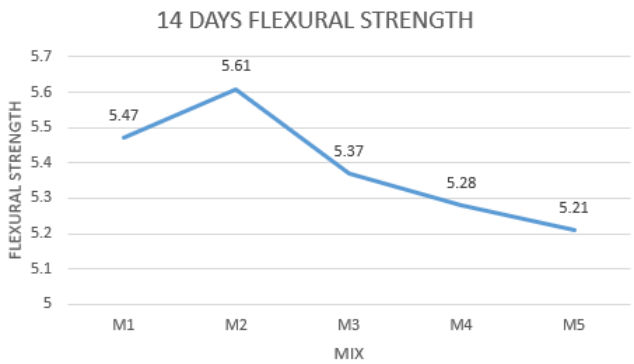


Fig. Variation of Flexure strength of concrete after 14 days

Case III Flexure strength after 28 days

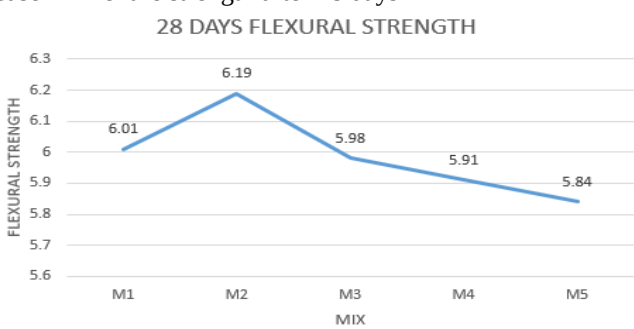


Fig. Variation of Flexure strength of concrete after 28 days

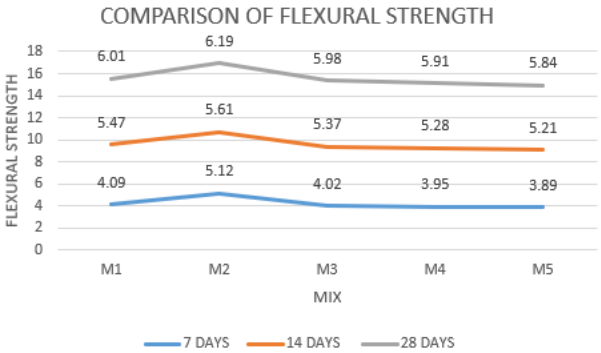


Fig Comparison of Compressive strength of concrete at 7 days, 14 days and 28 days

IX. CONCLUSIONS

Plastic was added to concrete in replacement of coarse aggregates by proportion of 0, 2.5, 5, 7.5 and 10%. On the basis of the results from the present study, following conclusions were drawn

i. The material used in the experiments is good and workable.
ii. The admixture used in the experiments gave the great impact on the strength of concrete.
iii. The specific gravity of plastic was lesser than that of aggregates.
iv. While testing the flexural strength of the beam, it is seen that beam failed in between the loading span between its two supports and hence formula that we used is $3PL/4bd^{2.}$
v. It was observed while experimentthat the compressive strength of concrete initially increases at 2.5% PCA but further addition of PCA shows reduction in strength.
vi. The optimum compressive strength is obtained at 2.5% PCA.
vii. The tensile strength of cylinder shows better result as compared to other strengths.
viii. Flexural Strength shows similar result to that of compressive strength.

8.2 Future Scope of the Study

We have performed the experimental investigation to check the strength and performance of design mix concrete i.e. M25 grade as various replacement of NCA with PCA.

Various tests performed in the laboratory are compressive strength, split tensile strength, and flexural strength by curing the specimen at 7 days, 14 days and 28 days. In future, it can be tested for durability conditions and effect of various chemical reactions on it. It can also be tested for higher grades of concrete. The strength of concrete containing PCA for a longer age of curing can also be tested.

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