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STUDY OF POLYETHYLENE TEREPHTALATE PET BOTTES AS FIBRE IN CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH SILICA

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ABSTRACT

Concrete is the most widely used man made material in construction industry and now we are making jungles of concrete in replacement of the natural habitat. There is no doubt it 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. So now the researchers in the field of Civil Engineering are moving their interest towards the use of materials that can cause least harm to the environment. 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. Along with it many other materials are being added to concrete to improve its properties. Some of the materials are fibrous in nature and form a micro level reinforcement to improve the properties of concrete that mainly includes its strengths.

In this study, plastic is used as fiber in concrete. Plastic from the polyethylene terephthalate PET plastic bottles was firstly shredded into small pieces in form of fiber. It was then mixed with concrete containing silica fume in partial replacement of cement by 15%. Fiber was added in proportion of 0,2.5, 5, 7.5 and 10% by weight of cement without any replacement. Results shows improvement in strengths upto 5% and optimum quantity was concluded at 5% addition of plastic fiber.

Keywords: *Silica Fume, Compressive Strength,M25 Concrete, Flexural Strength, Split Tensile Strength, Concretecuring, Durability.*

I. INTRODUCTION

Concrete is the most widely 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. Based on its compressive strength, the concrete can be graded as M10, M15, M20 and so on, where M is denomination for mix and 10, 15, 20 are the characteristic compressive strength of concrete after 28 days.

The binding material used in the concrete is of greater importance as it is the only thing in concrete that binds all other materials together. Portland cement is the most widely used binding material in concrete. But it has some limitations such as its limited availability and its adverse effect on environment during its manufacturing. Also the emerging trends in engineering divert the interest of researchers towards the usage of waste material in concrete.

Many of the waste materials are already in use such as fly ash, rice husk ash, silica fume and blast furnace slag. These materials are termed as supplementary cementitious materials as they are used as a partial replacement of concrete. But researches are still ongoing on other waste materials for their use in concrete such as rubber tires, waste glass, egg shell etc.

Fiber concrete is not a very new concept. The idea of using animal hairs and straw as a reinforcing material in brittle matrix was first developed in ancient Egypt .About 3400 years ago straws were used in mud walls as a reinforcing material ,they were also used in sun dried bricks. Asbestos fibers were found in 1900's and were widely used to enhance the various properties of the concrete. These days various types of fibers are developed in construction industry such as glass fiber carbon fiber and steel fiber. Different types of manmade fibers (nylon, polypropylene) and natural fibers(hairfibers , coconut coir, bamboo) are also used , they also have wide verities in their properties and costs. Recently developed modified polymer fibers are very helpful in enhancing the mechanical properties of the concrete.

Plastic

Plastic needs no introduction as it is the most widely used material now a days on our planet 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. 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.

Table 1.Different types of plastic and their properties.

Plastic type	Name	Properties	Density Range	Common Uses
	Polyethylene Terephthalate	Tough, rigid, shatter-resistant softens when heated	1.38-1.39 g/mL	Soda, water, juice, and cooking oil bottles
	High Density Polyethylene	Semi-rigid, tough, and flexible	0.95-0.97 g/mL	Milk and water jugs, bleach bottles
	Polyvinyl Chloride	Strong, semi-rigid, glossy	1.16-1.35 g/mL	Detergent bottles, shampoo bottles, shrink wrap, pipes
	Low Density Polyethylene	Flexible, not crinkly, moisture proof	0.92-0.94g/mL	Garbage bags, sandwich bags, 6-pack rings
	Polypropylene	Non-glossy, semi-rigid	0.90-0.91 g/mL	Yogurt cups, margarine tubs, screw-on lids/ caps
	Polystyrene	Often brittle, sometimes glossy, often has strong chemical reactions	1.05-1.07 g/mL	Styrofoam, egg cartons, packing pellets, take-out containers

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Silica Fume

Silica fume, also referred to as Microsilica or condensed silica fume, is a byproduct material that is used as a pozzolan. This byproduct is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Silica fume rises as an oxidized vapor from the 2000°C furnaces. When it cools it condenses and is collected in huge cloth bags. The condensed silica fume is then processed to remove impurities and to control particle size. Condensed silica fume is essentially silicon dioxide (usually more than 90%) in non-crystalline form. Since it is an airborne material, it has a spherical shape. It is extremely fine with particles less than 1 µm in diameter and with an average diameter of about 0.1 µm, about 100 times smaller than average cement particles. Its physical properties and chemical composition are as in below tables

Table 1.1 : Physical Properties of Silica fume

Physical property	description
Color	White, pale grey, dark grey
Specific Gravity	2.4-2.55
Particle size	less than 1 µm
Bulk density Kg/m^3	230-300
Surface Area m^2/Kg	20000

Table 1.2 chemical composition of Silica Fume

Chemical	% composition
SiO2	90-96
Al2O3	0.5-0.8
Fe2O3	0.2-0.8
MgO	0.5-0.8
Na2O	0.150.2-0.7
Others	0.8-1.2

So these two materials will be added to the concrete as partial replacement of cement and the experiments will be done to check the variation in properties of concrete.

II. SCOPE

Concrete is the most widely used man made material in construction industry. Due to the limited availability of its raw materials and their bad effects on the environment, researchers are now moving their focus on other raw materials. The first preference of today's engineering is to minimize the adverse effects of whatever they build on environment. To achieve these objectives researchers focused their study on using waste materials that are causing adverse effect to the environment but may be useful to construction industry.

Scope of the Study

Fiber concrete is not a new concept, but researchers are focusing their interest towards use of fibers derived from waste material by their little or no processing. Many of the fibers are already in use such as steel fiber, glass fiber etc. also mineral derived from the industrial waste are also not new such as fly ash. 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.

III. REVIEW OF LITERATURE

Elango A and Ashok Kumar A in 2018 performed study on partial replacement of plastic waste as fine aggregate in concrete. They used OPC 53 grade, River sand and crushed aggregates. They used plastic in partial **replacement** of fine aggregates in proportion of 10%, 20% and 30%. They performed experimental study on mechanical and durability properties on their concrete samples. They found the gradual decrease in compressive 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 Use of Plastics in Concrete as Coarse Aggregate. They performed the testing of mechanical properties of concrete containing Plastic aggregates in the partial replacement of coarse aggregates in concrete. They use plastic in replacement of coarse aggregates in proportion of 10%, 15%, and 20%. They performed test for compressive strength, split tensile strength and flexural strength. They found marginal reduction in strength and suggested the optimum result as 15% replacement.

B Jaivignesh and A Sofi in 2017 performed Study on Mechanical Properties of Concrete Using Plastic Waste as an Aggregate. They used the plastic in partial replacement 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 material.

IV. OBJECTIVE OF THE STUDY

The materials we are using for our research are waste materials but their chemical composition shows that they can be used to enhance the properties of the concrete. So it is up to us that how effectively we make use of these materials so that these materials can be used in service of mankind.

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.

Summary So the objective of the study is to find the optimum quantity of the plastic aggregates that can be used in concrete.

V. METHODOLOGY

Research 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 bottles were collected and cleaned.
3. They were then shredded into small pieces to form fiber.
4. Silica fume was collected from the glass factory as it is a byproduct of glass factory.
5. Test related to properties of cement and aggregates were performed.
6. Silica fume was added to concrete in a fixed proportion of 15% by weight of cement in its replacement.
7. Proportion of plastic fiber in different mixes was selected on the basis of available literature.
8. Mix design for different proportions of concrete was decided and tests were performed to obtain the mechanical properties of different mixes.
9. Based on the literature survey the following combinations were adopted.

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Materials used:

Plastic fiber: Used plastic bottles were collected and cleaned. They were available free of cost. They were cleaned and dried under natural conditions. They were then shredded into thin and long fibers using cutters. The lengths of the fiber was maintained between 2.5-3.5 cm.

Table 1.3 Laboratory results for Physical Properties of plastic

Physical property	Value
Specific Gravity	1.37
Color	Varying color
Particle size	Fiber form 2.5-3.5 cm long

Figure.1. Plastic fiber

Cement

Ordinary Portland cement(OPC) of 43 Grade (ACC) was used. The various test confirming to IS:8112-1986 were performed.

Table 1.4: Physical Properties of OPC

S.No.	Property	Value Obtained
1	Specific gravity	3.16
2	Standard consistency, (%)	33.9
3	Initial setting time,Final setting time, minutes	36,490 minutes respectively
4	Finesness(%)	3.75
5	Conmpressive Strength (N/mm2) 7 days 28 days	 31.1 43.9

Fine aggregates

Locally available river sand was used asfine aggregates. It was available at nominal cost. Various test confirming to IS:383-1970 were performed. The physical properties and sieve analysis results are given in table 6.4 and table 6.5 respectively.

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Figure.2. River sand

Table 1.5physical properties of Fine aggregates

S. No.	Property	Value Obtained
1	Type	Natural River Sand
2	Specific Gravity	2.61
3	Fineness modulus	2.55
4	Grading Zone	III

Coarse Aggregates

Locally available crushed stone aggregates were used. Tests were performed as per IS:383-1970 for various properties of aggregates. 10mm and 20mm size of coarse aggregates were used. The various properties of Coarse Aggregates are given in table.

Figure.3. Coarse Aggregates

Water

Generally, water that is suitable for dringking can be used in concrete. Also water from lakes and streams that contains marine life can also be used. The water adopted from above said souces need not to be tested. But when water contains sewage, industrial waste ar any chemical, it should be tested for permissible values of different chemicals. For our experimental work, normal tap water was available. So no test were performed on water.

Admixture

The admixture used is **RHEOPLAST SP-450.** It is a high range water reducing dispersing agent. It is brown on color. It is based on synthetic Sulphonated napthalene formaldehyde condensates. It can be used for almost all types of cements. It confirms to IS: 9103-1979.

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%

Table 1.6 The design mix proportion adopted for M25 grade mix is given below.

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	1.90	1.60	2.40	.39	0.01

Casting of Specimens

All the specimens were casted according to the mix proportions mentioned in table 6.6. 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.

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Figure.4. Casting of Specimens

Specimens for Compressive Strength

To check the compressive strength of concrete mix, cube specimens of size 150mmX150mmX150mm were prepared. The required quantities of materials required were weighed according to the mix proportion. Cement, silica fume were firstly mixed thorughly and then coarse aggregates were added and mixed again. Plastic fiber was then added to concrete. Admixture was added to the water. Water was then added to the dry mix and mixed thorughly. Firstly 50% of water was added to dry mix and mixed thorughly to distribute water. Then 40% water was added and again mixed. Remaining 10 % water was sprinkled at the last. The moulds for the cubes were closed earlier and oiled properly. The oiled molds were filled with concrete mixture and were put on vibrating table for proper compaction. The moulds were filled completely.

Figure.5.Compressive Strength test

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. Cement, silica fume were firstly mixed thorughly and then coarse aggregates were added and mixed again. Plastic fiber was then added to concrete. Admixture was added to the water. Water was then added to the dry mix and mixed thorughly. Firstly 50% of water was added to dry mix and mixed thorughly to distribute water. Then 40% water was added and again mixed. Remaining 10 % water was sprinkled at the last. The moulds for the cylinders were closed earlier and oiled properly. The oiled molds were filled with concrete mixture and were put on vibrating table for proper compaction.

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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 the specimen

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

a = distance between crack and the nearest support

Figure.6. Setup for Flexure Strength Test

VI. RESULTS AND DISCUSSION

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.

The concrete prepared for testing its mechanical properties was tested for its workability by Slump Test. The following apparatus was used for slump test:

Mould: The frustum of a cone with following dimensions was used.

Height = 300mm

Bottom diameter = 200mm

Top diameter = 100mm

Rod: A 600mm long rod having diameter of 16mm was used.

Base plate: A smooth base plate having clips to hold the cone mould was used.

Table 1.7 Concrete slump value.

S No.	Mix	Slump Value
1	M1	87
2	M2	89
3	M3	92
4	M4	90
5	M5	86
6	M6	84

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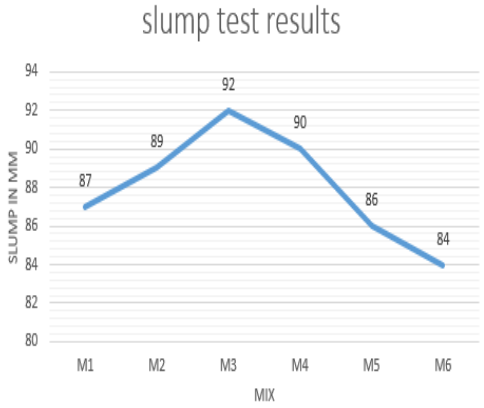
The result of slump test shows that there was firstly increase in slump upto 5% addition of plastic and then it start decreasing



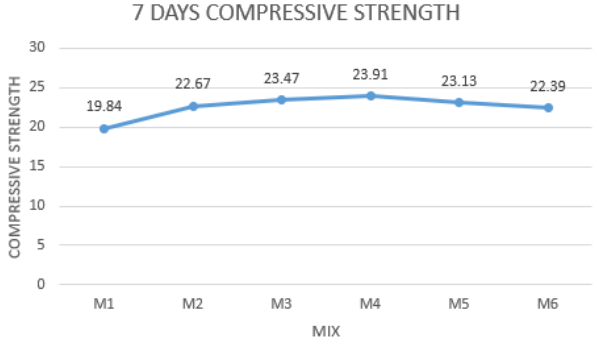
Compressive Strength Test

It is a test conducted 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. The specimens were demolded and put into curing tank for curing period of 7 days, 14 days and 28 days. 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.

Table1.8 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	19.84	26.43	30.57
M2	22.67	29.56	33.97
M3	23.47	30.41	35.14
M4	23.91	31.38	36.48
M5	23.13	31.16	35.08

Compressive strength after 7 days



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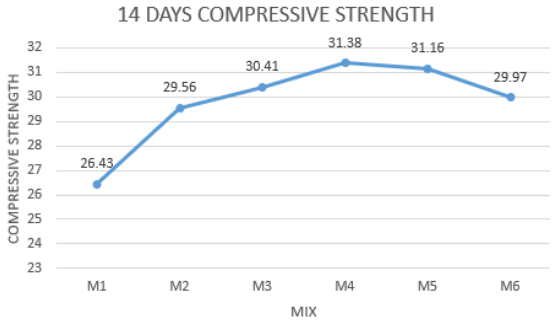
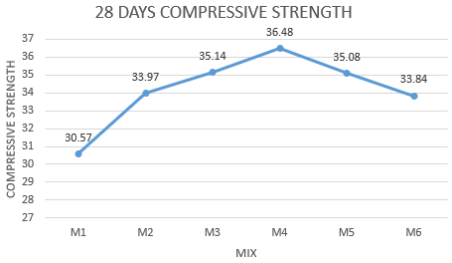
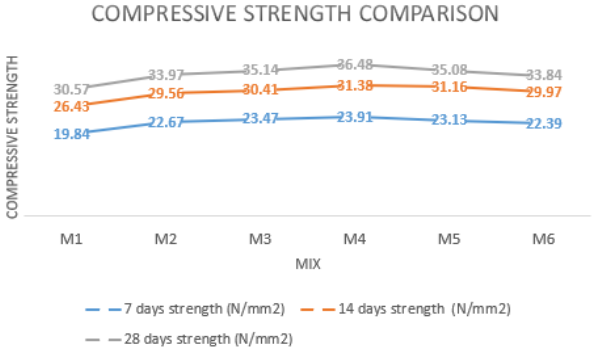
Compressive strength after 14 days



Compressive strength after 28 days



Variation of compressive strength of concrete after 28 days



VII. CONCLUSIONS

The present study concluded the effect of addition of plastic fiber as coarse aggregate, on mechanical properties of concrete mixes. In this study plastic fiber was added to concrete in 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 is observed while experiment that the compressive strength of concrete increases at 5% addition of plastic fiber.
vi. Addition of silica fume shows improved results
vii. The optimum compressive strength is obtained at 5% plastic fiber.
viii. The tensile strength of cylinder shows similar result to that of compressive strength.
ix. Flexural Strength shows similar result to that of compressive strength.

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.

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 Plastic fiber for a longer age of curing can also be tested.

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