Utilization of Crushed Pet Bottles as Partial Replacement of Aggregate in Concrete

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Abstract - **The consumption of plastic has grown substantially all over the world in recent years and this has created huge quantities of plastic-based waste. Plastic waste is now a serious environmental threat to the modern way of living. This research work demonstrates the possibilities of using crushed pet bottles as partial replacements of aggregate in concrete. This research work presents an investigation of compressive strength, of concrete by adding crushed pet bottles as partial replacement of aggregate in various percentages. The compressive strength development of concrete containing all types of PET-aggregate behaves like in conventional concrete, though the incorporation of any type of PET-aggregate significantly lowers the compressive strength of the resulting concrete. The PET-aggregate incorporation improves the toughness behavior of the resulting concrete. This behavior is dependent on PET-aggregate's shape and is maximized for concrete containing coarse, flaky PET-aggregate. The splitting tensile and flexural strength characteristics are proportional to the loss in compressive strength of concrete containing plastic aggregates. Ordinary Portland cement in Concrete and an attempt has been made to investigate the strength parameters of concrete (Compressive Strength). For control concrete, IS method of mix design is adopted and considering this a basis, mix design for replacement method has been made. Five different replacement levels namely 5%, 10%, 13%, 15%and 20% are chosen for the study concern to replacement method. Large range of curing periods starting from 7days and 28days are considered in the present study. Cubes (150×150×150mm) with varying ratios of PET will be casted. Total no of cubes casted would be 42. The various tests would be performed to evaluate the action of these materials will be normal consistency, setting time, compressive strength, and water absorption. The study would be conducted in the framework of a research project aiming at improving the utilization potential of pet bottles.**

INTRODUCTION

The completion of any project brings with it a sense of satisfaction, but it is never complete without thanking those people who made it possible and whose constant support has crowned our efforts with success.
One cannot even imagine the power of the force that guides us all and neither can we succeed without acknowledging it .Our deepest gratitude to Almighty God for holding our hands and guiding us throughout our lives.
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GENERAL

Concrete is one of the most widely used construction products in the world. It is mixture of cement, fine aggregate, course aggregate and water. Concrete construction does not require highly skilled labour. The durability of concrete depends upon proportioning, mixing and compacting of the ingredients. Many researchers have tried for the utilization of plastic waste and few have suggested its utilization in concrete in many forms. The utilization of waste in the construction industry has two glaring dividends, one, environmental impact is addressed by disposal of the waste and second, the economic impact and this waste has the edge of being available large quantity. Concrete being the widely used construction material in the world estimated up to 11 billion metric tons every year. Typical concrete ingredients are cement, sand and coarse aggregate which are used universally for producing concrete.

Waste PET Bottles

The consumption of plastic has grown substantially all over the world in recent years and this has created huge quantities of plastic-based waste. Plastic waste is now a serious environmental threat to the modern way of living. Recycling plastic waste to produce new materials like aggregate in concrete could be one of the best solutions for disposing of it, given its economic and ecological advantages. Naturally, the use of waste materials as aggregate in concrete production will reduce the pressure on the exploitation of natural resources. Plastic aggregate (PA) is produced by mechanically separating and processing plastic waste. A life cycle analysis of mixed household plastics shows that mechanical recycling provides a higher net positive environmental impact than the recovery of energy or land-filling. Different types of plastic waste have been used as aggregate, filler or fiber in cement mortar and concrete after mechanical treatment. They include: polyethylene terephthalate (PET) bottles, polyvinyl chloride, PVC pipes, high density polyethylene, HDPE, thermosetting plastics, mixed plastic waste, expanded polystyrene foam, polyurethane foam, polycarbonate, and glass reinforced plastic. PA is significantly lighter than natural aggregate (NA) and therefore its incorporation lowers the densities of the resulting concrete. This property can be used to develop lightweight concrete. The use of shredded waste PA in concrete can reduce the dead weight of concrete, thus lowering the earthquake risk of a building, and it could be helpful in the design of an earthquake-resistant building.

Properties of PET (Polythene terephthalate)

PET is commonly used for carbonated beverage, water bottles and many food products .PET provides very good alcohol and essential oil barrier properties, generally good chemical resistance and a high degree of impact resistance and tensile strength. The orienting process serves to improve gas and moisture barrier properties and impact strength. This material does not provide resistance to very high temperature applications –max. Temperature 200°F (93°C).

ENVIRONMENTAL PROBLEMS

The environmental problems associated with the disposal of industrial wastes are summarized below:

Problems associated with open dumps

- Direct influence by rain, such as leaching.
- Inaccessibility to the area and the surroundings.
- Chemical degradation.
- Breeding of Insects etc. causing health problems.
- When wet dumps get dried up, entrainment of dust in the air.

Problems associated with Covered Dumps

Buried wastes are subject to:

- Influence by rain through seepage.
- Pollution of nearby water sources.
- Long term alteration in solid stability, strength etc in the region.

Problems associated with River/Ocean Dumping

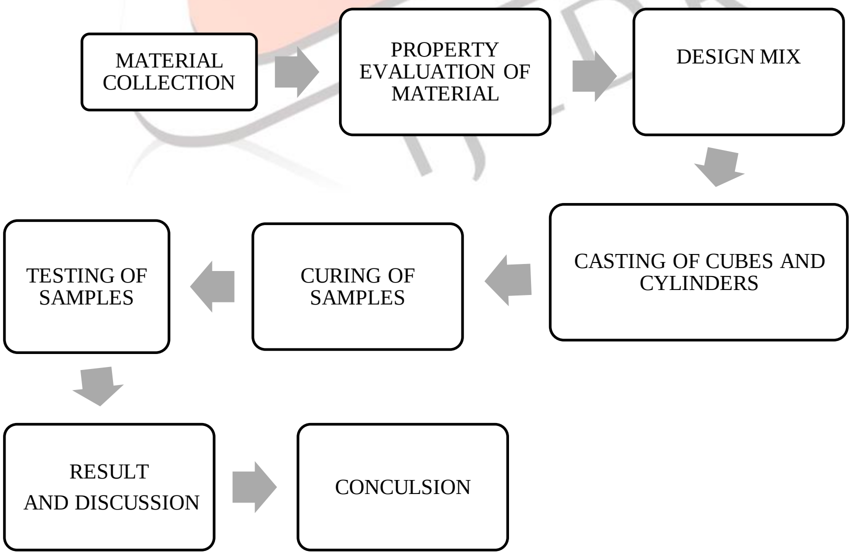
This has adverse effect on:

- Marine life
- Downstream users of river water

SCOPE

- To provide a most economical concrete.
- Using the wastes in useful manner.
- To reduce the cost of the construction.

LAYOUT OF WORK DONE



MATERIALS AND METHODS

CEMENT

Cement is a material, generally in powder from, that can be made into a paste usually by addition of water and, when poured, will set into a solid mass Cement is binder material with adhesive and cohesive properties. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. A typical chemical composition of an ordinary Portland cement is given in Table 1.1. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days.

Fig1: Cement.

Table 1.1: Typical composition of OPC

Name of Compound	Formula	Abbreviated Formula	% Content
Tricalcium Silicate	$3CaO.SiO_2$	C_3S	40-55
Diacalcium Silicate	$2CaO.SiO_2$	C_2S	15-30
Tricalcium aluminate	$3CaOAl2O_3$	C_3A	8-11
Tetra calcium aluminoferrite	$4CaOAl_2O3Fe2O_3$	C_4AF	13-17

AGGREGATES

Generally, aggregates occupy 70% to 80% of the volume of concrete and have an important influence on its properties. Aggregates should also be free of impurities like silt, clay, dirt, or organic matter.

Fine Aggregates

These are those aggregates which passes through IS sieve 4.75 mm

Fig.1.2: Fine Aggregates

Coarse Aggregates

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The coarse aggregates may be of following types:-

- Crushed graves or stone obtained by crushing of gravel or hard stone.
- Uncrushed gravel or stone resulting from the natural disintegration of rocks.
- Partially crushed gravel obtained as product of blending of above two types.

Fig.1.3: Coarse Aggregates

WATER

Drinking water is good for making concrete. Water is used to prepare a plastic mixture of the various ingredients and to impart workability to concrete. Water is also needed for the hydration of the cementing materials to set and harden during the period of curing.

TEST METHODS

The methods used for testing cement, coarse aggregates, fine aggregate, rice husk ash, waste paper sludge ash and concrete are given below:

Tests on Cement

Normal Consistency

This test determines the quantity of water required to produce a cement paste of standard consistency for the use in other test. The Vicat's apparatus (IS: 5513-1976) is used for this purpose. The consistency of standard cement paste is defined as that consistency which will permit the Vicat's plunger 50mm long and having the bottom of the Vicat's mould.

Results

Express the amount of water as % by weight of dry cement.

Initial and Final Setting Time

Vicat's apparatus will be used to estimate initial and final setting time of cement at normal consistency.

Fig1.4: Vicat's Apparatus

Fineness Test of Cement

This test will be performed according to IS: 4031-15.

Results

Fineness of cement (%) = W2/W1 x100.

Specific Gravity

This test was performed according to IS 2386-Part (iii) 1963.To determine the specific gravity and water absorption of fine aggregates.

Calculation

Sp. Gr. = D/A-(B-C)

Water Absorption = 100(A-D)/D

Where,

A= Weight of saturated surface dry sample

B= Weight of Pycnometer containing a sample filled with water

C=Weight of Pycnometer filled with Distilled water only

D=Weight of Oven dried sample

Results

The individual and mean results shall be reported.

Fig.1.5: Specific Gravity Apparatus

Tests on Fresh Concrete

Slump Test

The workability of all concrete mixture was determined through slump test. The slump tests were performed according to IS 1199-1959.

Fig.3.5.3.1: Slump Cone

Maximum size of aggregates

Degree of Workability	**Slump (mm)**
Very Low	-
Low	25-75
Medium	50-100
High	100-150

Table 1.6: Workability, Slump of Concrete with 20mm or 40 mm

Compaction Factor Test

This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. It is more precise and sensitive than the slump test.

Calculation

The compacting factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall normally be stated to the nearest second decimal place.

Fig.1.7: Compaction Factor Apparatus

Degree of Workability	**Compacting Factor**
Very Low	0.78
Low	0.85
Medium	0.92
High	0.95

Table 3.5.3.2: Compacting Factor of Concrete

Hardened Concrete Tests

Compressive Strength

This test is performed on cube specimens to determine compressive strength at various ages.

Fig.1.8: Compression test on CTM

EXPERIMENTAL WORK AND METHODOLOGY

GENERAL

The properties of material used for making concrete mix is determined in laboratory as per relevant codes of practice. Different materials used in tests were OPC, coarse aggregates, fine aggregates, rice husk ash and waste paper sludge ash.

ORDINARY PORTLAND CEMENT

Ordinary Portland Cement (OPC) of 53 Grade was used throughout the course of the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 12269:1987 are listed in Table 1.9.

Table 2: Properties of OPC 53 Grade

Sr. No.	Characteristics	Values Obtained Experimentally	Values Specified By IS 12269:1987
1.	Specific Gravity	3.00	3.00-3.15
2.	Standard Consistency	31%	30-35
3.	Initial Setting Time	115 minutes	30min(minimum)
4.	Final Setting Time	283 minutes	600min(maximum)
5.	Compressive Strength(N/mm2) 7 days 28 days	 38.49 N/mm2 52.31 N/mm2	 37 N/mm2 53 N/mm2

AGGREGATES

Aggregates constitute the bulk of a concrete mixture and give dimensional stability to concrete. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important.

Fine Aggregates

The sand used for the work was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The results are given below in Table 2.1 (A) and 2.2(B). The fine aggregated belonged to grading zone III.

Table 2.1(A): Sieve Analysis of Fine Aggregate

Weight of sample taken =1000 gm					
Sr. No	**IS-Sieve (mm)**	**Mass Retained (gm)**	**%Mass Retained**	**Cumulative %age mass Retained**	**Cumulative %mass passing through**
1	4.75	8	0.8	0.8	99.2
2	2.00	7	0.7	1.5	99.3
3	1.00	10	1.0	2.5	99
4	600µ	82	0.82	3.32	99.18
5	425µ	130	13	16.32	87.00
6	300 µ	77	0.77	17.09	99.23
7	212µ	359	35.9	52.99	64.1
8	150µ	217	21.7	74.69	78.3
9	75µ	175	17.5	92.19	82.5
	TOTAL			**∑261.4**	

FM of fine aggregate = 261.4/100=2.614

Table 2.2. (B): Physical Properties of fine aggregates

Characteristics	Value
Specific gravity	2.57
Bulk density	5%
Fineness modulus	2.83

Coarse Aggregates

Locally available coarse aggregate having the maximum size of 20 mm was used in this work. The aggregates were tested as per IS: 383-1970. The results are shown in Table 2.3(A) and Table2.4 (B).

Table 2.3(A): Sieve Analysis of Coarse Aggregate (20 mm)

Weight of sample taken =2000 gm					
Sr. No	**IS-Sieve (mm)**	**Mass Retained (gm)**	**Cumulative mass Retained**	**Cumulative %age mass Retained**	**Cumulative % mass passing through**
1	40	0	0	0	100
2	20	145	145	7.25	92.75
3	10	1829	1974	98.7	1.3
5	4.74	24	1998	99.9	0.1
6	2.36	0	1998	99.9	0.1
7	1.18	0	1998	99.9	0.1
8	600µ	0	1998	99.9	0.1
9	300µ	0	1998	99.9	0.1
10	150 µ	0	1998	99.9	0.1
11	Below150µ	2	2000	100	0
	Total			**Σ805.35**	

FM of Coarse aggregate = 805.35/100=8.0535

Table 2.4(B): Properties of Coarse Aggregates

Characteristics	**Value**
Type	Crushed
Color	Grey
Shape	Angular
Nominal Size	20 mm
Specific Gravity	2.71
Total Water Absorption	0.89
Fineness Modulus	8.05

PET Bottles

In this work, Crushed Pet bottles firstly wash with portable water then dried in the sun.

Table 2.5: Physical properties of Crushed Pet bottles

Appearance	Crushed
Particle Size	10mm
Specific gravity	1.10
Color	Colorful

MIX DESIGN

The concrete mix design was done by using IS 10262 for M-20 grade of concrete.

Design stipulations for proportioning

- Grade designation M35
- Type of cement grade OPC 53 grade confirming to IS12269:1987
- Maximum nominal size of aggregates 20 mm
- Minimum cement content kg/m3 340 kg/m3
- Maximum water cement ratio 0.48
- Workability 75 mm (slump)
- Exposure condition Mild
- Degree of supervision Good
- Type of aggregate Crushed angular aggregate
- Maximum cement content 400 kg/m3
- Chemical admixture Not

Test Data for Materials

- Cement used OPC 53 grade confirming to IS 12269:1987
- Specific gravity of cement 3.00
- Specific gravity of
    - Coarse aggregate 2.71
    - Fine aggregate 2.57

- Sieve analysis
    - Coarse aggregate
    - Fine aggregate

Coarse aggregate : Conforming to Table 2 of IS: 383
Fine aggregate : Conforming to Zone III of IS: 383

Target Strength for Mix Proportioning

f'ck = fck + 1.65 s

Where

f'ck = Target average compressive strength at 28 days,
fck = Characteristic compressive strength at 28 days,
s= Standard deviation

From Table 1 standard deviation, s = 5.3 N/mm^2

Therefore target strength = 35 + 1.65 x 5.3 = 41.95 N/mm^2

Table 3: The mixture proportions used in laboratory for Experimentation are shown in table

Mix	%	W/c ratio	Water (Kg/m^3)	Cement (Kg/m^3)	Fine aggregates (Kg/m^3)	Coarse aggregates (Kg/m^3)	Pet bottles Plastic (Kg/m^3)
Control	-	0.48	192	400	673.044	1064.39	-
Plastic	5	0.48	192	400	673.044	1011.18	53.21
	10	0.48	192	400	673.044	957.99	106.4
	13	0.48	192	400	673.044	926.02	138.37
	15	0.48	192	400	673.044	904.74	159.65
	20	0.48	192	400	673.044	851.52	212.87
	25	0.48	192	400	673.044	798.29	266.097

CASTING

Before casting, the entire moulds were cleaned and oiled properly. These were tightened properly before casting. The coarse aggregates, fine aggregates, cement and other ingredients (RHA & WPSA) were weighed first with accuracy. The concrete mix was done by hand mixing on a non-absorbing platform. Firstly the dry mix is done. Then made a space in the center of dry mix and 70 to 80% water was added, mix uniformly and rest was sprinkled on the mix. For each mix 12 samples were casted, 6 cubes (150 x 150 x 150mm) for compressive strength at 7and 28days and 6 cylinders for splitting tensile strength at 7and 28 days. Casting was done with varying percentage 5%, 10%, 15%& 20% respectively as a partial replacement of cement with rice husk ash and waste paper sludge ash. Total 156 specimens were made 78 cubes and 78 cylinders.



(A)Oiling of Cubes &Cylinder **(B) Dry mixing** **(C) Filling of Moulds**

COMPACTION

The compaction was done by hand using tamping bar. The concrete was filled in the moulds in four layers and each layer was approximately one quarter of the height of mould. Each layer was tamped with 25 strokes of the round end of the tamping bar. The strokes should be distributed over the entire area of the mould. Finally the surface of concrete was leveled and finished and smoothened by metal trowel.

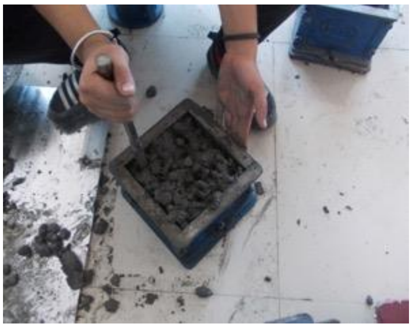


Fig.3.1: Compaction

CURING OF CONCRETE

Curing is the process of preventing the loss of moisture from the concrete whilst maintaining a satisfactory temperature regime. It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete and enhance its durability by extending the hydration of the cement, particularly in its surface zone.

Fig.3.2: Curing Tank

Also curing prevents the exposure of concrete to a hot atmosphere and to drying winds which may lead to quick drying out of moisture in the concrete and thereby subjected it to contraction stresses at a stage when the concrete would not be strong enough to resists them. Concrete is usually cured by water although scaling compounds are also used. It makes the concrete stronger, more durable, more impermeable and more resistant to abrasion and to frost curing is done by spraying water or by spending wet heissian cloth over the surface. Usually, curing starts as soon as the concrete is sufficiently hard. Normally 14 or more days of curing for ordinary concrete is the requirement. However, the rate of hardening of concrete is very much reduced with the reduction of ambient temperature. The period of curing shall not be less than 10 days. In this work curing was done by immersing the specimens in the curing tank, after they are removed from the casting moulds. The specimens are cured for 7 and 28 days and taken out from water at the time of testing.

RESULTS AND DISCUSSION

GENERAL

This chapter presents a summary of the results obtained from laboratory tests that have been done on the specimen. Tests were done on materials (cement, fine aggregates, coarse aggregates, PET), fresh and hardened concrete.

FRESH CONCRETE

Slump Test

The slump value of all the mixture are represented in Table 5.1.1

Table 4: Slump Tests Results

Mix	Percentag	Slump valu
Contro	0%	90mm
	5%	65mm
	10%	55mm
	13%	47mm
	15%	35mm
	20%	25mm
	25%	23mm

The slump value and percentage of replacement was shown in Fig 5.1.1. The slump decreased when a higher amount of pet bottles plastic, was added in concrete.

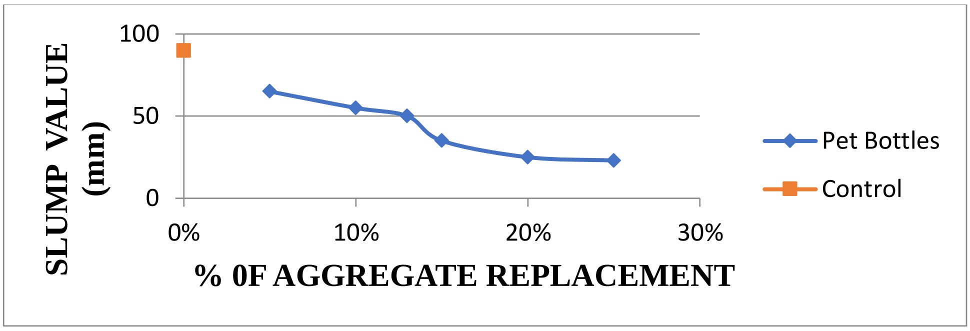


Fig.4: Slump Value

Compaction Factor Test

The Compaction factor values of all the mixture are represented in Table 5.1.2

Table 5: Compaction Factor Results

Mix	Percentage	Compaction factor
Control	0%	0.95
Pet plastic	5%	0.90
	10%	0.85
	13%	0.80
	15%	0.78
	20%	0.75
	25%	0.71

The compaction factor value of control concrete is 0.95. As we go on increasing the % replacement of cement with the pet bottles from 5 to 20% the compaction factor value decreases from 0.90 to 0.75.

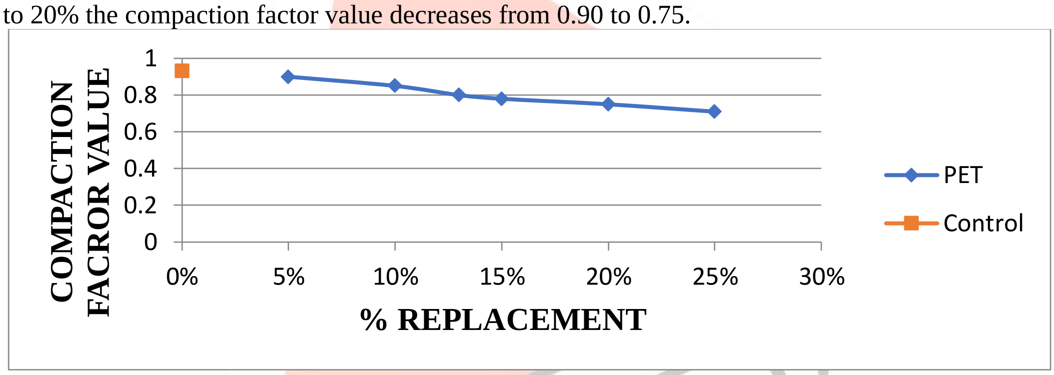


Fig.5.1: Compaction Value

5.2 Hardened Concrete

5.2.1: Effect of Age on Compressive Strength

The 28 days strength obtained for M35 Grade Control concrete is 42.21 N/mm2.The strength results reported in table are presented in the form of graphical variations, where the compressive strength is plotted against the % of cement replacement.

Table 5.2: Compressive Strength of Control concrete in N/mm2

Grade of concrete	7Days	28Days
M35	27.44	42.21

The strength achieved at different ages namely, 7 and 28 for Control concrete are also represented graphically in figure5.3.1.

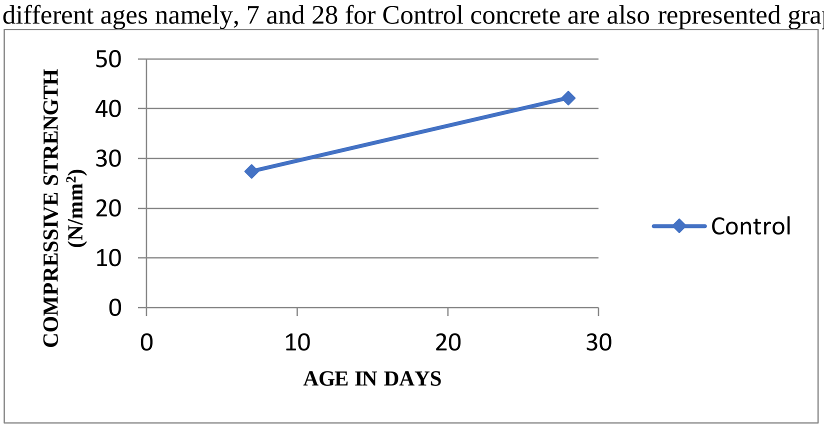


Fig.5.2: Compressive Strength of Control Concrete

From the figure, it is clear that as the age advances, the strength of Control concrete increases. The rate of increase of strength is higher at curing period up to 28 days. However the strength gain continues at a slower rate after 28 days.

Effect on Compressive Strength of Concrete Containing various percentages of PET.

Table 5.3: Compressive Strength of PET Concrete

Mix	**Percentage of Cement Replacement**	**Cube Compressive Strength (N/mm2)**	
		7 days	**28 Days**
CONTROL	0%	27.44	42.21
PET	5%	31.10	30.78
	10%	29.99	30.77
	13%	25.99	29.78
	15%	23.88	28.77
	20%	26.72	34.11
	25%	24.50	28.43

As per experimental program and results shown in table no. 5.3 and graph no. 5.3.3(A) and 5.3.3(B) we can replace aggregates by PET up to 10%. Because the compressive strength up to 10% replacement of aggregate is comparatively equal to control mix design. If aggregate is replaced by PET more than 10% the loss in compressive strength is comparatively greater than the replacement up to 10%.

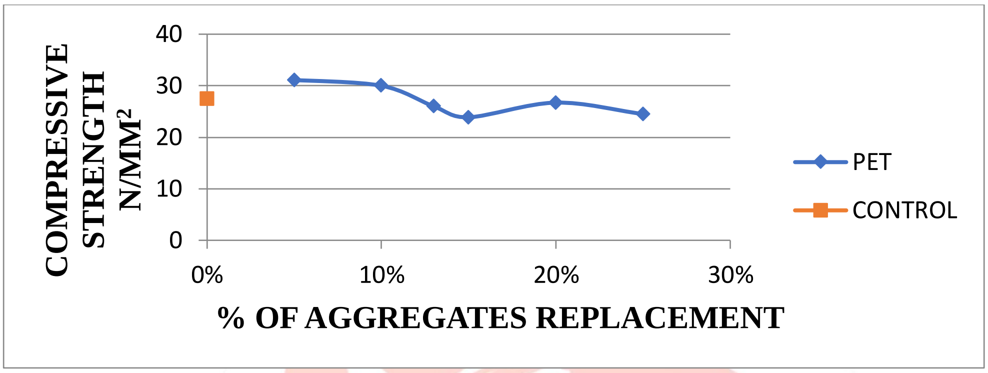


Fig.5.2.2 (A): Compressive Strength of PET Concrete at 7 Days

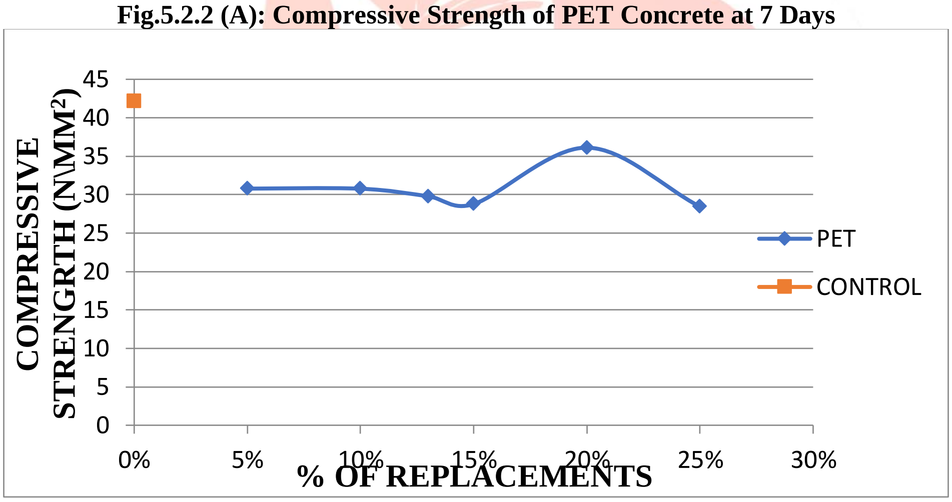


Fig.5.2.2 (B): Compressive Strength of Concrete at 28 Days

CONCLUSIONS

GERENAL

The objective of this experimentation has been to evaluate the possibility of successful replacement of aggregate with PET in concrete.

The conclusion drawn during the experimentations are as follows:

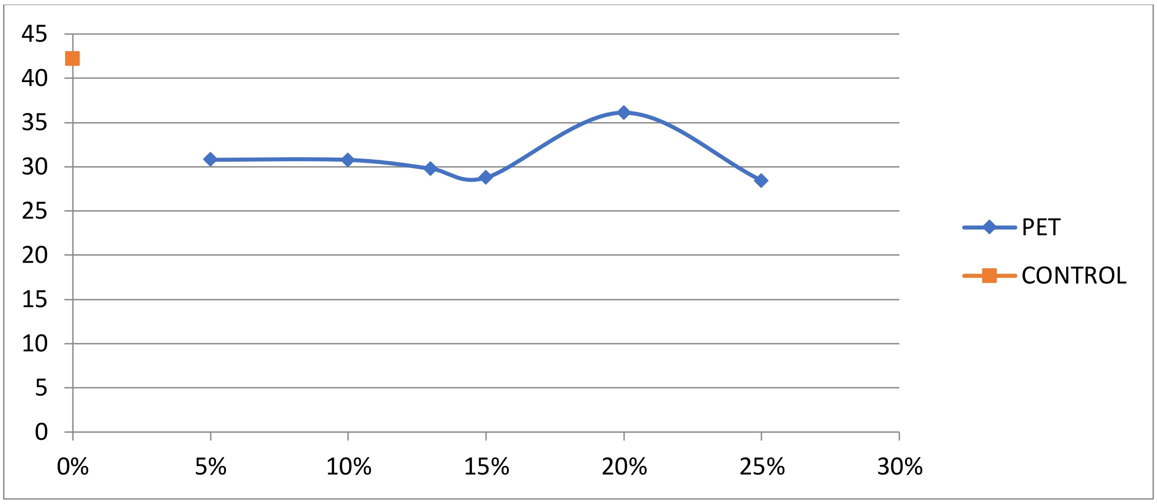


Fig 6.1: Compressive Strength of Control Concrete and PET Mix at 28 Days

1. The compressive strength decreased up to 10% with 5% replacement of PET. Further decreases the strength gradually and up to 20% replacement it cannot be used as a supplementary material in M20 grade of Concrete
2. .The above results shows that it is not possible to design M20 grade of concrete incorporating with PET content.
3. The study showed that the early strength of PET concrete was found to be less and the strength increased with age then again it starts decreasing.
4. The workability of PET concrete has been found to decrease with the increase in replacements.

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