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EXPERIMENTAL STUDY ON THE FLEXURAL BEHAVIOR OF E-WASTE PLASTICS IN CONCRETE

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ABSTRACT

In this experimental work, the behaviour of shredded waste plastic (Bakelite) in concrete as partial replacement for aggregates is investigated. The percentage of replacement carried out in this work were 2%, 4%, 6%, 8%, 10% by weight of total aggregates. Moduli of rupture of shredded waste plastic plain concrete beams were found to be nominally less than that of control concrete. The flexural behaviour, deflection characteristics, stress vs. strain characteristics and crack patterns of reinforced shredded waste plastic concrete beams were found out. The use of shredded waste plastic increases the stiffness of the concrete which in turn reduces the ductility of the concrete. Specimen with 8% replacement of aggregates with waste plastic was found to be optimum which possesses high flexural strength, stiffness and ductility than other replacement specimens.

KEYWORDS: Shredded waste plastic, Bakelite, Stiffness and Ductility.

INTRODUCTION

A. General

Solid waste management is the thrust area. Of the various waste materials, plastic waste and municipal solid waste are of great concern. Finding proper use of the disposed plastics waste is the need of the hour. On the other side, plastics, a versatile packing material and a friend to common man, become a problem to the environment after its use. Moreover municipal solid waste, if contains PVC waste, when burnt, can give rise to toxic gases like dioxins. Disposal of plastic wastes in an eco-friendly way is the thrust area of today's research. This work mainly based on the use of the waste plastics in the construction field. This process helps to dispose the waste by eco-friendly method. This process can promote value addition to the waste plastic too.

Fig 1. Shredded Plastic

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Table 1. physical properties of plastic waste

S.No.	Test Particulars	Value
1.	Specific gravity	1.42
2.	Compressive strength	250 Mpa
3.	Tensile strength	50 Mpa
4.	Flexural strength	95 Mpa

B. Bakelite

Bakelite or polyoxybenzylmethylenglycolanhydride is an early plastic. It is a thermosetting phenol formaldehyde resin, formed from an elimination reaction of phenol with formaldehyde, usually with wood flour filler. It was developed in 1907 by Belgian chemist Leo Baekeland. Bakelite was used for its electrically nonconductive and heat resistant properties in radio and telephone casings and electrical insulators. In 1993 Bakelite was designated a National Historic Chemical Landmark by the American Chemical Society in recognition of its significance as the world's first synthetic plastic.

C. Toxic Effects of Bakelite

Generally toxic effects of Bakelite are due to the presence of phenol and also methyl and ethyl alcohols. The influence of Bakelite on water quality can be seen in an increase in oxidisability and in the appearance of phenol in the water. Hence disposal of Bakelite should be avoided to prevent water pollution.

SCOPE FOR RESEARCH

The objective of this experimental work is to study the structural behaviour of M20 grade concrete beam cast with replacement of aggregates by waste plastic.

The following parameters are studied.

- Compressive strength test
- Split tensile strength test
- Deflection behaviour
- Initial crack load and its location
- Location of crack and type of failure

Scope of Present Investigation

- Use of waste plastic as partial replacement of fine and coarse aggregates.
- Use of waste plastic in concrete to increase flexural stiffness.
- Use of waste plastic in concrete to increase corrosion resistance of concrete.

EXPERIMENTAL INVESTIGATION

The study aims to investigate the strength related properties of concrete of M20 grade made using waste plastic. Hence waste plastic were collected from various plastic collection industries and grinded tob maximum size of 10mm. The properties of waste plastic materials were found through laboratory tests. The proportions of ingredients of the control concrete of grade M20 had to be determined by mix design as per IS code.

Materials Used

- Cement (PPC 53 Grade)
- Fine Aggregate of specific gravity 2.6
- Coarse Aggregate of specific gravity 2.68
- Portable tap water of pH value 8.2
- Bakelite

Table 2. Details of M20 grade cube specimens

S.No.	Identification of Beam Specimen	% of Waste Plastic Replaced	No. of Cubes		
			7 days	14 days	28 days
1.	Control	0	3	3	3
2.	Sp1	2	3	3	3
3.	Sp2	4	3	3	3
4.	Sp3	6	3	3	3
5.	Sp4	8	3	3	3
6.	Sp5	10	3	3	3

Mix Proportion

Two concrete mixes were designed as per IS:10262-2009 for M20 grade of concrete. Those mixes were checked and the mix 2 has been used in this experimental work.

Table 3. Details of Mix proportion

Concrete	Cement	Fine aggregate	Coarse aggregate	Water
Kg/m^3 of concrete	360	585	1225	180
Per bag of cement	1	1.625	3.402	0.5

C. Description of Specimen

This experimental program includes six specimens. Control concrete specimen was named as C and concrete specimens with various proportions of waste plastic were named as Sp1, Sp2, Sp3, Sp4 and Sp5. Table shows various percentage of waste plastic which replace the aggregates in concrete.

Table 4.Description of specimen

S.No.	Identification of Specimen	% of Waste Plastic Replacing Aggregates
1.	C	0
2.	Sp1	2
3.	Sp2	4
4.	Sp3	6
5.	Sp4	8
6.	Sp5	10

D. Compressive Strength

All the concrete cube specimens were tested in a 2000KN capacity compression testing machine. The crushing strength of concrete cube is determined by applying compressive load at the rate 140 kgf/cm2/min or 140 KN/min till the specimen fail.

E. Split Tensile Strength

Split tensile test on concrete cylinders has been carried out in a 2000KN capacity compression testing machine. The split tensile strength of concrete cylinders are determined by applying compressive load at the rate 140 kgf/cm2/min or 140 KN/min till the specimen fail. Lateral surfaces of the specimen were between plates of compression testing machine and subjected to compression loading.

F. Test Specimen Setup

Fig 2. Compression Test on Concrete Cube

Fig 3. Split tensile Test on Concrete Cylinders

The specimens are beams of size 100mm X 150mm x 1700mm, reinforced with 2 numbers of 12mm diameter HYSD bars in tension and 2 numbers of 8mm diameter HYSD bars in compression zone as hanger rods. It was also provided with shear reinforcements in the form of 6mm diameter HYSD bar two legged stirrups at 90mm c/c. The specimens were cast in steel mould with machine mixed concrete and well vibrated with vibrating Table. All the specimens were cured for 28 days in open curing tank under ambient conditions.
All beams were tested in reaction type loading frame. The span of the beams kept as 2000 mm with simply supported end condition and was tested under two point loading applied at one third spans through a stiff beam. Deflections of the beam were measured by three LVDTs placed at the mid span.
Four strain gauge buttons were bonded in the specimens, two strain gauge buttons located above the neutral axis and other two located below the neutral axis. The demountable mechanical strain gauge was used to determine the maximum compressive and tensile strains. Plane load was applied through the hydraulic jack on the stiffener beam, which in turn converted load on to the test specimens. For each load increment of 2 KN, the deflection, strain and crack were observed and tabulated. In addition to this, the load cell and LVDTs were connected to a data logger.

G. Tests for Beams
The experimental setup is shown in Fig. All beams were tested in reaction type loading frame of capacity 500 KN. The span of the beams kept as 1500 mm with simply supported end condition and was tested under two point loading applied at one third span points through a stiff beam. Deflections of the beams were measured by three LVDTs at 1/3rd, 1/4th spans and center.

Fig 4. Testing of Beam Specimen

RESULTS AND DISCUSSIONS

A. Compressive Strength Test

The compressive strength of Sp1 specimen is found to be nominally more than control specimen indicating that the addition of waste plastic contributed strength to concrete cubes. The compressive strength of Sp2, Sp3 and Sp5 specimens are less than control specimen indicating that adding more plastic reduce strength due to lack of bond between ingredients of concrete. The compressive strength of Sp4 specimen is found to be more than control specimen indicating that when 8% of aggregates replaced by waste plastic, it have enough bond between ingredients of concrete.

Table 5. Compressive strength of concrete cube

S.No.	Description of Specimen	7th day Compressive Strength (N/mm^2)	14th day Compressive Strength (N/mm^2)	28th day Compressive Strength (N/mm^2)
1.	Control	18.22	21.33	31.55
2.	Sp1	19.11	24.59	33.03
3.	Sp2	15.44	18.66	26.07
4.	Sp3	13.77	18.37	26.51
5.	Sp4	23.85	27.11	37.03
6.	Sp5	10.37	14.07	18.37

B. Split Tensile Strength Test

The split tensile strength of Sp1, Sp2, Sp3, Sp4 and Sp5 specimens are found to be nominally less than control specimen indicating that the addition of waste plastic reduces split tensile strength of cylinders. Here, strength of Sp2 and Sp5 specimens are found to be nominally less than control concrete.

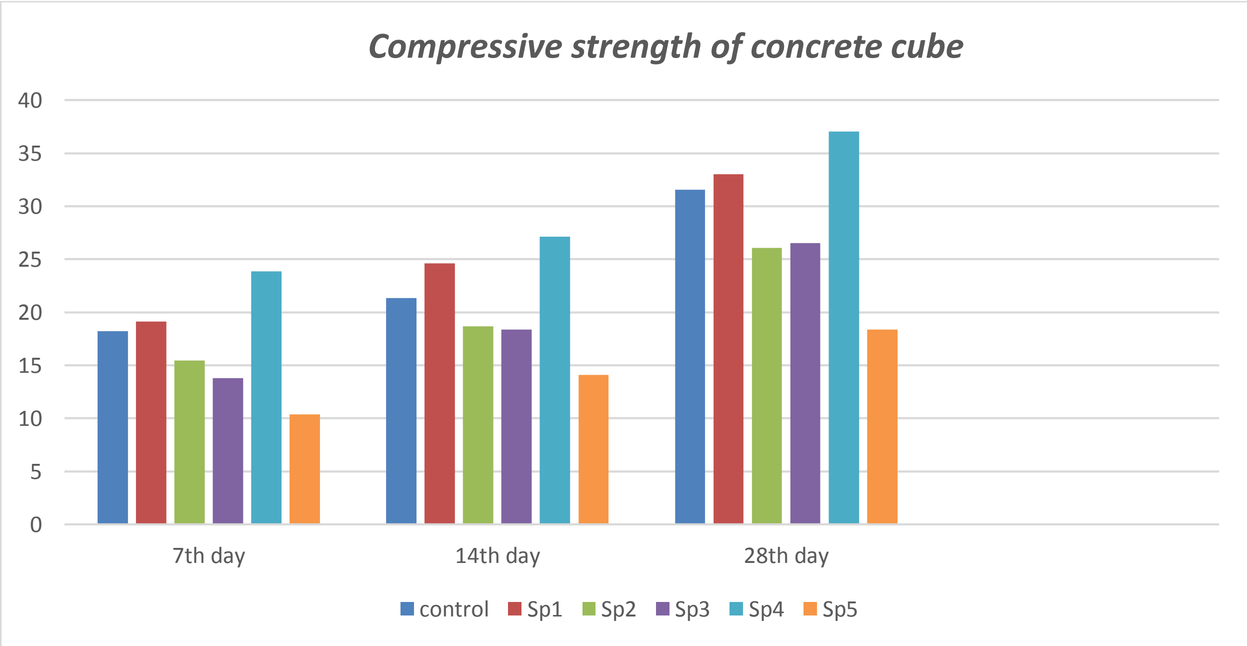

Table 6. Split tensile strength of concrete cylinders

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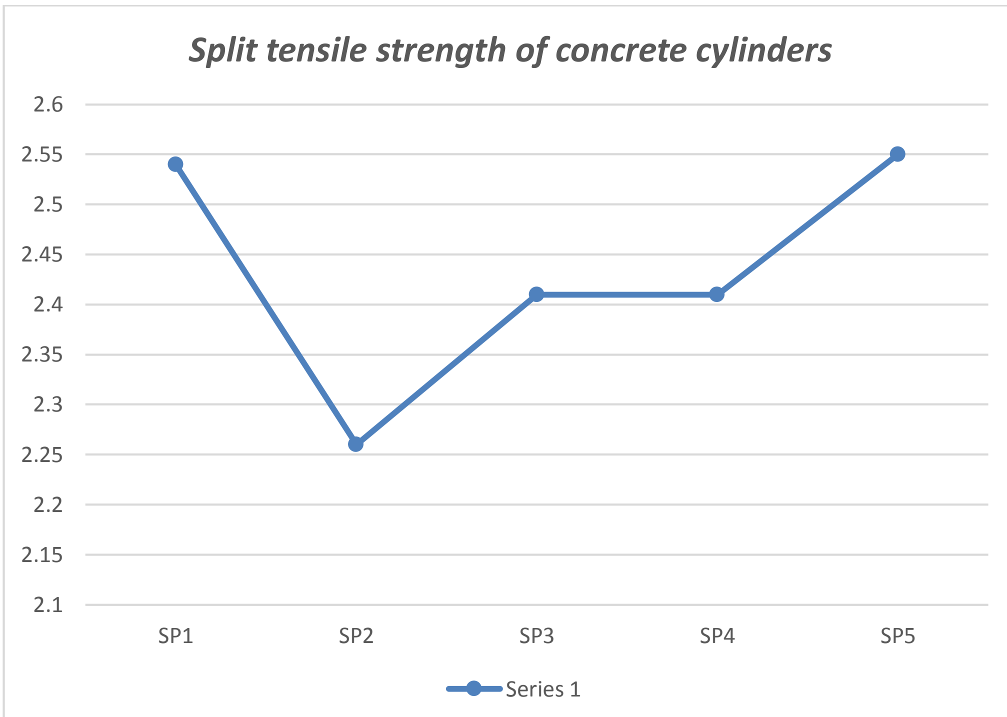
S.No.	Description of Specimen	28th day Compressive Strength (N/mm^2)
1.	Control	2.69
2.	Sp1	2.54
3.	Sp2	2.26
4.	Sp3	2.41
5.	Sp4	2.41
6.	Sp5	2.55



C. Deflection Characteristics

The results of the experimental investigation on six beam specimens are presented in this chapter. The behaviour of the specimens in terms of crack development, failure mode and ultimate loads were observed during the test. The salient test values of all beam specimens are given in Table.

It is clearly seen from Table that C and Sp4 specimens have the highest load carrying capacity among the group. The beam specimen Sp1 and Sp5 performed in a poor manner with low load carrying capacity. The remaining beams can be grouped under the same class as their load carrying capacity or ultimate load is nearly same. Hence for better flexural performance, addition of 8% of waste plastic as replacement for aggregates can be suggested.

Table 7. Test results on beam specimens

Specimen	Ultimate Failure Load (Pu) (kN)	Ultimate Failure Moment (kNm)	Ultimate Deflection (mm)			First Cracking Load (kN)	Mode of Failure
			L/2	L/3	L/4		
C	60.784	15.196	23.7775	20.6225	17.7915	10	Flexure
Sp1	41.396	10.349	24.27	19.1875	16.9215	8	Flexure
Sp2	52.793	13.19825	21.715	17.2625	15.8485	16	Flexure
Sp3	57.247	14.31175	20.5975	16.485	15.5585	14	Flexure
Sp4	60.391	15.09775	18.5675	14.1752	14.945	14	Flexure
Sp5	44.278	11.0695	18.3	16.0341	13.2425	10	Flexure

D. Cracking Behaviour

1. **Behaviour of Flexural Failure of Beams:**

In the under reinforced section beam, the member approaches failure due to gradual reduction of compression zone, exhibiting and cracks, which develop at the soffit and progress towards the compression face. When the area of concrete in compression zone is insufficient to resist the resultant compressive force, ultimate flexural failure of the member takes place through the crushing of concrete. Large deflection and wide cracks are the characteristics futures of the under reinforced section at failure. This type of behaviour is generally desirable since there is considerable warning before the impending failure. Generally over reinforced member failed sudden crushing of concrete, the failure being characterised by small deflection and narrow cracks. Cracks due to bending moment are widest at the bottom and narrower at the top compression side.

Fig 5. Flexural failure of the tested beam

2. **Behaviour Of Shear Failure Of Beams:**

The nominal shear is less than designed shear strength of concrete beam, the minimum shear reinforcement shall be provided. The nominal shear exceeds designed shear strength of concrete beam, the shear reinforcement shall be provided. The effect of shear stress is greatest in web of the beam and maximum at the neutral axis and decrease to zero at the extreme edges. Shear forces tend to cause diagonal cracks radiating from the top and at 45˚ to the plane of the beam. These are steeper where bending moment prevail and are more inclined where the shear forces are largest.

In this experimental work the specimens are behaving like same manner in the shear failure mode. Cracks due to shear are widest in the region of the neutral axis and become thinner towards the upper and the lower of the beam.

Fig 6. Shear failure of the tested beam

3. Mode of Failure:

The following points were observed

- All Reinforced cocnrete beams failed in flexure zone.
- After the first crack load, the reinforcement started yielding and more number of cracks have formed in the flexure zone and extended towards the point loads with increment in loads.
- At the ultimate load, the failure of all reinforced concrete beam occurred with crushing of concrete in compression zone.
- In the Specimens Sp1 and Sp5 more number of cracks formed in flexure zone. It indicates that those does not provide high strength in the flexure zone.
- In the Specimens Sp4 has less number of cracks formed in flexure zone. It indicates that 8% replacement of aggregates with waste plastic provide mariginally high strength.

4. Crack Pattern:

The crack patterns of the specimens are shown in Figure. All the beams were tested under two point loading. During testing time the initial crack load, first crack location and the ultimate failure load were taken. All the beams failed under flexure failure. The initial crack started from the middle bottom of the beam and run through middle of the beam. The major cracks have formed in the flexural region and extended towards the point loads.

Fig 7. Crack pattern at middle of the beams

CONCLUSION

The following conclusions may be arrived from the limited experimental works carried out.

The physical and mechanical properties of shredded waste plastic have been found to be favourable for use in concrete.

A. Compressive Strength Test

- The compressive strength of concrete with waste plastic found to increase nominally up to 8% replacement. Beyond which the compressive strength falls below that of control concrete.
- The optimum percentage of waste plastic can be taken as 8%, as it exhibited high early gain in strength and maximum strength on 28 days.
- Use of waste plastic higher than 8% in concrete is detrimental to strength of concrete.

B. Flexural test

- The flexural strength of 8% replacement specimen is nearly same as that of control specimen.
- The load corresponding to first crack is higher than control beam for all replacement specimen beams.
- The addition of waste plastic enhanced the range of linear behaviour of all replacement specimens when compared with that of control specimen up to first crack.

C. Concluding Remark

From the above findings, it is concluded that the shredded waste plastic up to 8% may be used for replacement of aggregates in concrete without any reduction in compressive strength, flexural strength.
It is also concluded that the use of industrial wastes such as plastic in concrete provides some advantages, like reduction in the use of natural resources, disposal of wastes, prevention of environmental pollution and energy saving.

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