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An Experimental Study on Split Tensile Strength of Concrete by Incorporating Plastic waste & Demolished Concrete Waste as Aggregate

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Abstract*—According to global scenario, consumption of concrete is high. Economy of a concrete structure relies on the price and availability of concrete and other building materials. On the other hand due to rapid urbanization and industrialization all over the world, huge quantities of plastic waste and demolished waste are being generated ensuing to harmful environment and difficulty in disposal which is cost ineffectual. In this situation, construction industry is in need of finding cost effective and efficient materials. So, in this research initiative, it is dealt with the possibility of using the plastic waste and demolished waste as the partial replacement of fine aggregate and coarse aggregate in concrete mix respectively. In this view it is aimed to compare the properties of conventional concrete mix with collaborative concrete mix of plastic waste by 10% in place of fines and demolished waste (0%, 10%, 20%, 30%, 40% and 50%) in place of coarse aggregate. The conventional mix has been designed for M_{25} grade concrete and is adopted with a water-cement ratio of 0.45. In this investigation seven mixes are prepared, the specimens used are cylinders of size 150mm×300mm. Initially conventional mix is prepared by using conventional materials (cement, natural sand, natural aggregate and water) and concrete mix with recycled aggregate are prepared to compare their respective properties. For every mix, 6 specimens (6 cylinders) were cast and tested for split tensile strength at 7 and 28 days after curing. With constant percentage replacement of plastic waste in place of sand and varying percentage replacement of coarse aggregate with demolished aggregate, it is found that the density of concrete can be varied from 2500 to 2100 kg/m^3. The workability of fresh concrete was decreased with increase in addition of recycled aggregate. From the results it is found, with this replacement, split tensile strength (f_t) reaches to the value of conventional mix with 10% plastic waste(fine aggregate) and 10% demolished waste (coarse aggregate). The properties of fresh concrete were good and also it reached the acceptable strength of conventional concrete

Index Terms*— Split Tensile Strength, Plastic Waste, Demolished Aggregate, Workabil

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I. INTRODUCTION

Present day infrastructure development across the world created a demand for construction materials which are cost ineffective and easily available. Concrete is the premier civil engineering construction material. Concrete contains materials like cement, aggregate, water and admixtures. At present, huge quantities of construction materials are required due to the enhancement in infrastructure and also huge quantities of plastic wastes and demolition wastes are generated every year. The disposal of this waste is a very serious problem because on one side it requires huge space for its disposal while on the other side it pollutes the environment. It is also necessary to conserve the natural resources. Utmost use of natural- resources is another major problem.

So, the sustainable concept was introduced in construction field to meet the future concern of our planet, because it is a huge consumer of natural resources as well as waste producer. Accumulation of demolished and plastic wastes emerged as global issue. Hence there is a need to recycle these wastes into something more useful and eco friendly. To achieve this major emphasis must be laid on the use of wastes from various industries. The use of aggregate from demolition wastes in pavement beds is the most usual way of reusing this material as established technique, it is not the best economic valorization of this resource and it is considered by many researchers to be a down-cycling process that depreciates the capacities of the material. But the production of structural concrete with recycled aggregates, however, offers great potential and recycles the materials viably and effectively. Research into innovative use of waste materials being

Undertaken world-wide and ideas that are expressed are worthy. In addition to the environmental benefits, demand of land and cost of treatment for disposing waste decreased enormously.

The largest proportions of demolition waste are concrete rubbles and plastic wastes are covers, polythene bags, PVC pipes etc. It has been shown that the crushed concrete rubble after separated from other demolition wastes are sieved, can be used as a substitute for natural coarse aggregate in concrete. Reuse of bulky wastes is considered as the best environmental alternative for solving the problem of disposal.

. EXPERIMENTAL INVESTIGATION

To start with, M25 grade concrete has been designed according to IS method of design using normal constituents of concrete. In the course of investigation, natural sand has been replaced by 10% (constant for all the mixes) of plastic waste and also coarse aggregate has been replaced by 0%, 10%, 20%, 30%, 40% and 50% of demolished aggregate. For the study of various properties different specimens have been cast and tested. Here a constant water-cement ratio of 0.45 has been adopted. The experimental part of the investigation has been planned in the following three stages.

Stage I: Selection of Materials and their testing
Stage II: Casting of specimens and curing
Stage III: Testing of specimens

STAGE I :

Main constituents of concrete viz., fine aggregate, coarse aggregate, cement, water, plastic waste and demolished aggregate have been procured from various places. Fine aggregate has been procured from local river, coarse aggregate (20mm) has been procured from crushing plant. Potable water is used for mixing and curing of concrete. Plastic waste (1-2.5mm size pieces) which is produced from households, factories, commercial places etc., has been procured from Industrial Estate and the demolished aggregate is obtained from demolished buildings, tested concrete specimens from laboratory are procured and made into pieces and they are sieved to 20mm size.

Cement:

Locally available Nagarjuna Ordinary Portland Cement (OPC) of 53 grade conforming to ISI standards has been procured and various tests have been carried out according to IS8112-1989. From them it is found that

a) Specific gravity of cement is 3.15
b) Initial and Final setting times of cement are 32 minutes and 580 minutes respectively
c) Fineness of cement is 4%

Fine aggregate:

Locally available river sand is procured and is found to be conformed to Zone-I of table 4 of IS: 383-1970. Various tests have been carried out as per norms laid in IS: 383-1970. Specific Gravity of fine aggregate is 2.60

a) Bulk Density Loose: 1400 kg/m^3 Compacted: 1557 kg/m^3
b) Fineness modulus of fine aggregate is 2.90

The sieve analysis results are presented in Table 1 and the set of sieves is shown.

Table 1 Sieve Analysis of Fine Aggregate:

Weight of aggregate taken: 1000gms

IS Sieve No.	Weight Retained in (Grams)	Cumulative Weight Retained in (Grams)	Cumulative Percentage Weight Retained (X)	Cumulative Percentage Weight Passing N=100-X
4.75	0	0	0	100
2.36	97	97	9.7	90.30
2.00	45.8	142.8	14.28	85.72
1.18	223.7	366.5	36.65	63.35
0.6	350	716.5	71.65	28.35
0.425	58.7	775.2	77.52	22.48
0.3	120.7	895.9	89.59	10.41
0.125	94.1	990	99.00	1.0
0.09	7.8	997.8	99.78	0.22
Pan	2.2	1000	100	0

Fineness modulus: 2.90

A VIEW OF SET OF SIEVES

Plastic Waste:

The waste plastics are collected from dumping yard and from various factories. The collected plastic is cleaned and grounded into pieces of varying size from 1-2.5 mm. Various tests have been conducted on plastic waste and following results are stipulated,

a) Specific gravity of plastic waste is 0.46
b) Density of plastic waste is 72 kg/m^3
c) Fineness Modulus of plastic waste is 4.7

A VIEW OF PLASTIC GRANULES

Coarse Aggregate:

Machine crushed aggregate conforming to IS: 383-1970 consisting of 20mm maximum size of aggregate has been obtained from the local quarry. The test result of coarse aggregate as below.

a) Specific Gravity of coarse aggregate is 2.64
b) Water absorption of coarse aggregate is 1.02%
c) Bulk Density

Loose: 1481 kg/m^3
Compacted: 1651kg/m^3

d) Fineness modulus of Coarse aggregate is 6.75

The sieve analysis results are presented in Table 2.

Table 2 Sieve Analysis of Coarse Aggregate:

Weight of aggregate taken = 5000gms

IS Sieve No.	Weight Retained in (Grams)	Cumulative Weight Retained in (Grams)	Cumulative Percentage Weight Retained (X)	Cumulative Percentage Weight Passing N = 100-X
25	0	0	0	100
20	1660	1660	33.2	66.8
12.5	2080	3740	74.8	26.2
10	1035	4775	95.5	4.5
6.3	145	4920	98.4	1.6
4.75	40	4960	99.2	0.8
Pan	40	5000	100	0

Fineness modulus: 6.75

Demolished Aggregate:

Demolished aggregate is procured from demolished structures and the concrete specimens from laboratory. After collecting, they are broken down into pieces and also various tests are conducted on it.

a) Specific Gravity of Demolished aggregate is 2.45
b) Water absorption of demolished aggregate is 0.7%

The demolished aggregate is shown and its sieve analysis results are presented in Table 3

Table 3 Sieve Analysis of Demolished Aggregate:

Weight of aggregate taken = 5000gms

S. No	IS Sieve No.	Weight Retained in (Grams)	Cumulative Weight Retained in (Grams)	Cumulative Percentage Weight Retained (X)	Cumulative Percentage Weight Passing N= 100-X
1.	26.5	180	180	3.6	96.4
2.	20	2760	2940	58.6	41.4
3.	12.5	1920	4860	97.2	2.8
4.	10	110	4970	99.4	0.6
5.	6.3	20	4990	99.8	0.2
6.	4.75	10	5000	100	0
7.	Pan	0	5000	100	0

Fineness modulus : 5.85

A VIEW OF THE DEMOLISHED AGGREGATE USED

Water:

Potable water which is available in the laboratory has been used in this experimental program for mixing and curing.

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MIX DESIGN:

Mix design can be defined as the process of selecting suitable constituents of concrete and determining their relative proportions with the objective of producing concrete of target mean strength and durability as economically as possible. The design of concrete mix is not a simple task on account of widely varying properties of the constituent materials, the conditions that prevail at work are considered.

Design of concrete mix requires complete knowledge of various properties of the constituent materials. The complications arises in case of conditional changes at the site. The design of concrete mix needs not only the knowledge of material properties of concrete in plastic condition but also needs erudite knowledge and experience of concreting. Even then, the proportion of the materials of the concrete found out at the laboratory requires modifications and readjustments to suit the field conditions.

In the present investigation M_{25} grade concrete is considered. The mix of concrete is designed as per the guidelines given in IS 10262, and the mix proportion is 1:1.36:2.66 with a water/cement ratio of 0.45. Subsequently mixes were prepared with replacement of fine aggregate by plastic waste at a constant percentage of 10% and replacing the coarse aggregate by demolished aggregate at percentages of 0, 10, 20, 30, 40 and 50. For every weight replacement cylinders are cast and tested to find various test results.

Mixing of Concrete:

Initially the constituents such as cement and sand are mixed to which plastic waste is added and thoroughly mixed. After some time coarse aggregate and demolished aggregate are added and thoroughly mixed. Water is measured exactly then it is added to the dry mix and it is thoroughly mixed until a mixture of uniform colour and consistency are achieved which is then ready for casting. Prior to casting of specimens, workability is measured in accordance with the code IS: 1199-1959 and determined by slump and compaction factor tests.

STAGE II:

Slump cone test:

Slump cone is a mould of 1.18 mm thick galvanized metal in the form of the lateral surface of the height 300 mm. The base and the top shall be open and parallel to each other and at right to the axis of the cone. The mould shall be provided with a foot piece on each side for holding the mould in place and with handles for lifting the mould from the sample. Tamping rod is a straight steel rod 16mm in diameter and approximately 600 mm in length. End of tamping rod shall be a hemisphere 16 mm in diameter.

Dampen the mould and place it on a flat, moist, non-absorbent rigid surface. Hold firmly in place by standing on the two foot pieces. Fill the cone 1/3 full and uniformly rod the layer 25 times to its full depth. Fill the cone with a second layer until 2/3 full by volume and rod 25 times uniformly, ensuring that the rod just penetrates into the first layer, overfill the cone with the third layer and rod uniformly 25 times with the rod just penetrating into the second layer. Strike off the excess concrete level with the top of the cone by a screening and rolling motion of the tamping rod. Remove any spilled concrete from around the bottom of the cone. Immediately remove the mould from the concrete by raising it carefully in a vertical direction without lateral or torsional motion. Measure the difference between the height of the mould and the height of the specimen at its highest point to the nearest. This distance will be the slump of the concrete. The apparatus of slump cone and slump is shown . When practicable, duplicate slump test should be made and the average of the two slumps are reported. The concrete temperature at time of testing should also be reported. The entire operation from the start of filling to the removal of the mould should be carried out without interruption and be completed within an elapsed time of 1.5 minutes.

VIEW OF SLUMP CONE TEST

Density of concrete:

The density of concrete varies depending on the density of the aggregate used to mix the concrete and the amount of air within it. Floors, bridges and other structural components use high-density concrete, while low-density concrete works lie in areas with harsh weather and in some roads. Density is defined as mass divided by volume. The unit weight is determined by the formula below.

$$D = (M_c - M_m)/V_m$$

Where,

D = Density of the concrete in N/m^3

M_c = Weight of the measure holding the concrete in N

M_m =Weight of the empty concrete measure in N

V_m = Volume of the measure in m^3

Fresh concrete in the Mould is shown below.

FRESH CONCRETE IN THE MOULD

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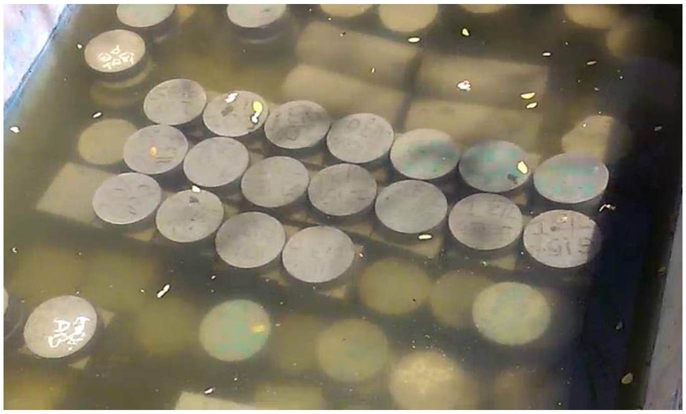
Casting of Specimens:

After the completion of workability tests, the concrete has been placed in the standard metallic moulds in three layers and has been compacted each time by tamping rod. Before placing the concrete inside faces of the mould are coated with the machine oil for easy removal afterwards. The concrete in the moulds have been vibrated for 30 seconds using the table vibrator and the surfaces of the specimens have been finished smoothly. The cast specimens are shown.

A VIEW OF CAST SPECIMENS IN MOULDS

Curing Procedure:

After casting of cubes, the moulds are kept for air curing for one day and the specimens are removed from the moulds after 24 hours. Marking has been done on the specimens to identify the percentage of plastic waste and percentage of demolished aggregate. Then they are placed in water tank for curing. All the specimens have been cured for desired time period. Specimens in curing tank are shown.



SPECIMENS IN CURING TANK

The identification of the specimens is as follows.

1. N-100% Natural aggregate concrete or Conventional concrete
2. A-10% Plastic Waste, 90% Natural Sand and 100% natural coarse aggregate concrete
3. B-10% Plastic Waste, 90% Natural Sand, 10%Demolished aggregate and 90% natural coarse aggregate concrete
4. C-10% Plastic Waste, 90% Natural Sand, 20%Demolished aggregate and 80% natural coarse aggregate concrete
5. D-10% Plastic Waste, 90% Natural Sand, 30%Demolished aggregate and 70% natural coarse aggregate concrete
6. E-10% Plastic Waste, 90% Natural Sand, 40%Demolished aggregate and 60% natural coarse aggregate concrete
7. F-10% Plastic Waste, 90% Natural Sand, 50% Demolished aggregate and 50% natural coarse aggregate concrete

Details of Test Conducted:

Cylindrical split tensile strength of concrete

For each percentage of plastic waste and demolished aggregate, 6 cylinder specimens have been cast. A total of 42 cylinders of size 150mm diameter and 300mm height have been cast.

STAGE III :

Testing of Cylinders for Split tensile strength:

Split tensile strength test was conducted in accordance with ASTMC96. Cylinders of 150x300mm size were used for this test, the test specimens were placed between two platens with two pieces of 3mm thick and approximately 25mm wide plywood strips on the top and bottom of the specimens. The split tensile strength was conducted in the same machine on which the compressive strength test was performed. The specimens were tested for 7 and 28 days. This test is conducted in a 2000KN capacity compression testing machine by placing the cylinder specimen, so that its axis is horizontal to the plates of the test machine. Narrow strips of packing materials i.e., plywood is placed between the plates and the cylinder to receive compressive stress. The load was applied uniformly at a constant rate until failure by splitting along the vertical axis takes place. Load at which the specimens failed is recorded and the split tensile stress is obtained using the formula based on IS: 5816-1970. The splitting of cylinder is shown.

The following relation is used to find out the Split tensile strength of cylinder

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

Where,
P= Compressive load on the cylinder
L= Length of the cylinder
D= Diameter of the cylinder

The results have been tabulated and graphical variations have been studied

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VIEW OF SPLIT TENSILE STRENGTH TEST OF CYLINDER

III. RESULTS AND DISCUSSION

This paper explains about the fresh properties of concrete such as workability, density and also hardened properties such as tensile strength. A comprehensive summary of the test results of the properties of all the concrete mixes are presented in tables and charts.

Properties of Fresh Concrete:

From the visual observations during mixing and compaction of all the concrete mixes it is seen that the concrete mixes were homogeneous as there was no segregation and bleeding , the mixes were compactable. The fresh state performance of the Plastic waste and Recycled aggregate concrete was comparable with conventional concrete. This observation suggests that addition of recycled aggregate decreases workability. The workability of fresh concrete is tested and presented in Table 4 and Fig 1 shows relationship between density of the concrete and % of Plastic waste and Recycled aggregate replacement. It may be observed there is good relationship between the variables.

From the table 5 and figure 1 it may be observed that the density gets reduced with the replacement of sand by plastic waste and coarse aggregate with demolished aggregate from 0 to 50%.

The density of 100% natural aggregate concrete is 2373 kg/m^3 and density of F (10% Plastic waste and 50% Demolished waste) concrete mix is 2130 kg/m^3.

Table 4 WORKABILITY OF CONCRETE

Mix Name	% of Plastic Waste	% of Demolished Waste	Slump in mm	Compaction Factor in %
N	0	0	80	85.00
A	10	0	100	89.00
B	10	10	90	82.50
C	10	20	75	89.20
D	10	30	50	83.40
E	10	40	30	82.10
F	10	50	20	84.30

Table 5 DENSITIES OF PLASTIC WASTE AND DEMOLISHED AGGREGATE CONCRETE

S . N o	Mix Name	% of Plastic Waste	% of Demolished Waste	Density in kg/m^3
1	N	0	0	2373
2	A	10	0	2135
3	B	10	10	2170
4	C	10	20	2174
5	D	10	30	2188
6	E	10	40	2165
7	F	10	50	2130

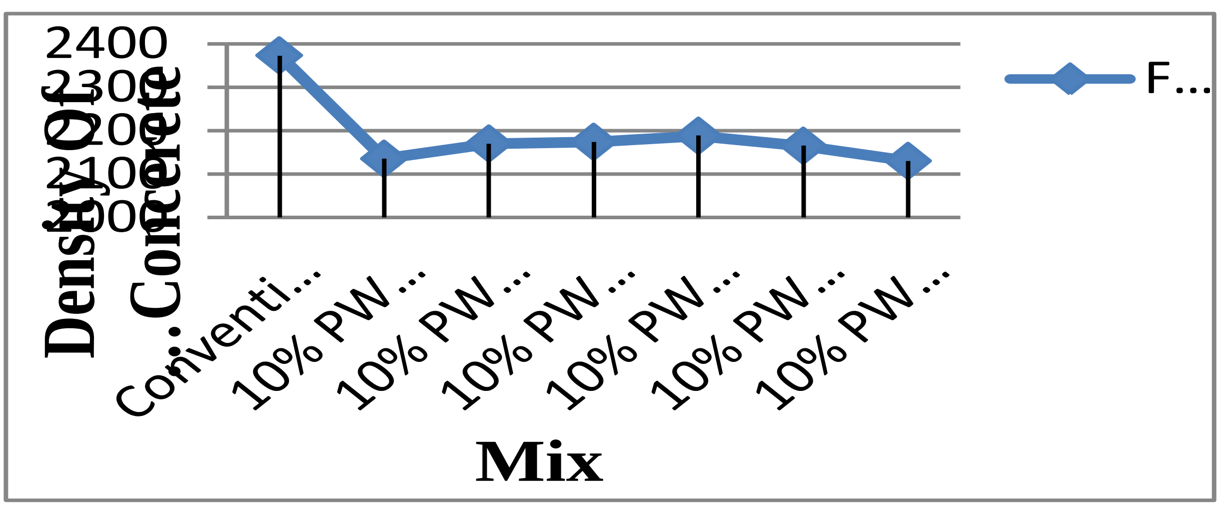

Fig 1 Density of concrete Vs Percentage replacement of Plastic waste and Demolished aggregate

Properties of Hardened Concrete:

Split Tensile strength:

The Cylinder Split tensile strength results with constant percentage replacement of fine aggregate by plastic waste and varying percentage replacement of coarse aggregate by demolished aggregate are presented in Table 6. The graphical variation of Split tensile strength versus percentage replacement of fine aggregate by plastic waste and varying percentage replacement of coarse aggregate by demolished aggregate are presented in Fig 2. From the Table 6 and figure2 it may be observed that there is a decrease in split tensile strength with 10% Plastic waste and 0% to 50% replacement of demolished waste in place of natural sand and coarse aggregate. With the introduction of plastic waste of 10% and with 100% natural coarse aggregate the strength decreased. Also it may be observed that the split tensile strength increased slightly with the replacement of 10% & 20% recycled coarse aggregate. With high percentage replacement of recycled coarse aggregate i.e.; 30%, 40% & 50% a decrement in strength is observed.

IV. CONCLUSIONS

i. Increase in workability of concrete is recorded with increase in percentage of recycled coarse aggregate.
ii. 10.24% declination in density of concrete has been attained on 50% replacement of coarse aggregate by recycled coarse aggregate.
iii. Concrete with 10% plastic waste & 10% recycled coarse aggregate has shown equivalent behavior as conventional concrete in terms of split tensile strength.
iv. Declination of split tensile strength is recorded with increase in percentage of recycled coarse aggregate with 10% plastic waste.

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