Utilization of Plastic Waste in Concrete as Fine Aggregate

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Abstract -*Most of the buildings in the whole world is made of concrete which makes it one of the most extensively used construction material in the world. These materials are often used in residential buildings, commercial buildings, building foundations, roads etc. Solid waste management, especially solid waste plastic is one of the major environmental concerns in the world today. The plastic waste which we have used in our experiment is collected from local plastic waste management centre, it includes all type plastics like LDPE, HDPE, PET, PVC, PS, ETC. Our experiment investigates the utilization of plastic wastes as partial replacement for fine aggregates in concrete for the production of lightweight concrete. The aim of the experiment is to evaluate the effect of addition of shredded waste plastics on the compressive strength, density of concrete and weight of concrete. Ordinary Portland cement was mixed with the fine aggregate and coarse aggregate to produce the concrete composites. Standard concrete mix design of M-25 and 0.50 w/c ratio was used for the experiment. Four weight fractions 0%, 4% and 8% of shredded plastic waste were used to replace the fine aggregate in the batching. The concrete mixture was tested for slump; cast into moulds of 150 mm by 150 mm by 150 mm sizes; cured for 7, 14, and 28 days respectively. The compressive strength and weight of the concrete specimens were determined*.

Key Words – Shredded plastic waste, River sand, concrete test, Sieve Analysis, Property Analysis, Mix Design

1. Introduction

The swift urbanization and industrialization all over the world has resulted in large deposition of different type of plastic wastes material. In 1950, the world produced only 2 million tonnes of plastic annually. Since then, annual production has increased from that to 381 million tonnes in 2015. This is roughly equivalent to the mass of two-thirds of the world population. In last 70 years, 8.3 billion tonnes of plastic have been produced globally. In India, 25,940 tonnes of plastic wastes is being produced every day. Plastic waste materials consist of extra, out-dated, damaged, old plastic furniture, different household plastic materials, tools, anti-static packaging materials and devices made of plastic. These plastic wastes are almost non-degradable in the natural environment even after a long period of exposure.

"A plastic bottle takes between 450-1000 years to decompose" **–** *Harsh Vardhan, environmental minister, India.*

Addition of plastic waste in concrete can be a proper utilization of this valuable property. Thus, utilization of plastic waste material in making concrete/mortar can be good solution to this environmental hazard. It is been estimated by Ministry of Petroleum and Natural gas that the annual per capita consumption in India would be 20 kg by 2022. Only 60% of total plastic produced in India is being recycled. The Central Pollution Control Board (CPCB) has estimated that 80.28% of total plastic waste produced is collected by respective authorities of different cities in India, out of which only 28.4% was treated. Other remaining quantities were disposed in landfills, open dumps or in ocean. Dumping the plastic waste in ocean has greatly affected the oceanic life, dumping it on the land pollutes the land minerals and air quality too.

2. Literature Review

Ankur C. Bhogayata et al. He have represented the test results of fresh and hardened reinforced concrete properties with metalized plastic waste (MPW) by dispose of food packaging industries. In this study, the prospects of MPW fibre reinforcing member in concrete for evaluating the slump and strength properties. Films of MPW were shredded into 5mm, 10mm and 20mm long fibres, mixed in concrete in various quantities from 0% to 2% by volume of concrete mix. The test results shows that addition of MPW fibres in concrete improves the ductility & crack resistance capacity of concrete. It also improves the deformation capacity at higher loads subjected to axial compression. Finally the incorporation of MPW fibres up to 1% will be acceptable alteration of the concrete property.

Ramesh et al. He have examined the usage of LDPE plastic waste by partially replacing coarse in concrete to determine its harden properties. Different specimen were prepared of various quantities of LDPE 0%,20%,30%& 40% of recycled plastic aggregate obtained by heating treatment of waste plastic in plastic recycling machine. A concrete mix design of 1:1.5:3 proportion & W/C ratio of 0.5 was used. By replacing plastic waste up to 30%, 80% strength is achieved and after clear reduction in compressive strength with further increase in percentage of plastic aggregate. The research shows that the application of recycled plastic aggregate in light weight aggregate & future research scope on plastic aggregate and its durability aspects for columns and beams.

Raghatate Atul M He have studied the experimental results of concrete specimens casted with plastic bag pieces to determine its compressive and splitting tensile strength. Concrete mix of OPC, natural river sand as fine aggregate and coarse aggregate containing varying percentage of waste plastic bags of 0.2%, 0.4%, 0.8% &1% was prepared. He examined that the compressive strength of concrete is decreasing by increasing the percentage of plastic bag pieces. A 20% decrease in compressive strength with 1% inclusion of plastic bag pieces and increase in tensile strength of concrete by adding 0.8% of plastic bag pieces in concrete mix, afterward it starts decreasing when adding more than 0.8% of waste plastic bag pieces. From this study, it was concluded that utility of plastic bag pieces can be used for increase in split tensile strength in concrete and by varying the shape & size of plastic bags used in concrete mix its performance is analysed in further research.

Charudatta P Thosar et al. She have carried out an experimental study on replacement of fine aggregate by using plastic waste recycled from Polyethylene Teryphalate (PET) or Polypropylene (PP) waste. Partial replacement of fine aggregate by plastic waste material up to 20%, 40% & 60% in M20 grade of concrete mix and tested after 28 days for compressive strength, tensile strength, flexural strength and modified density of concrete. From the experiment results revealed that the partial replacement of plastic waste material can be done to a limit of 20% to 40% for the satisfactory properties of concrete which is acceptable.

Pramod S Patil et al. He have experimentally investigated the application of plastic recycled aggregate as replacement of coarse aggregate in concrete. Various plastic percentages of 0%, 10%, 20%, 30%, 40% and 50% are used as replacement of coarse aggregate in concrete mixes. Various tests were conducted and observed decrease in density of concrete with increase percentage of replacement of recycled plastic aggregates. From the result conclude that feasibility of replacing 20% of recycled plastic aggregate will satisfy the permissible limits of strength of concrete.

Youcef Ghernouti et al. He have studied the plastic fine aggregate obtained from crushing of waste plastic bags as partial replacement of fine aggregate. Plastic bags were heated and cooled then further crushed to plastic sand. Fine aggregate in concrete was replaced with 10%, 20%, 30%& 40% of plastic bag waste sand. Fresh and harden properties of concrete mix were determined and increasing percentage of plastic bag waste sand in concrete mix reduction in strength is observed. From this results show that 10 to 20% replacement of fine aggregate with plastic fine aggregate probable strength property is observed. They suggest future research scope on plastic aggregate with use of admixture to address the strength improvement property of concrete.

Zainab Z. Ismail et al. She have examined the prospect of reusing plastic sand, as partially replacing fine aggregate in concrete and determine its compressive strength, flexural strength, toughness and dry/fresh density of concrete specimen. The collected waste plastic consists of 80% polyethylene and 20% polystyrene which was shredded and converted into pulverized particles. The results indicate that increasing the plastic waste ratio there is slight decrease in compressive and flexural strength. However load deflection of plastic waste concrete shows the arrest of propagation of micro cracks and high toughness in concrete mix. The study has shown good workability in low slump value but water cement ratio content kept constant in all concrete samples.

3. Materials

3.1 Shredded plastic waste

Figure 1 Sieved shredded plastic waste

Plastic is the most broadly used material in the current modern era. It is very cheap, very durable, easy to manufacture, very versatile, very light weight, electrically and thermally insulated and gives very good resistant to shock, corrosion, chemicals and water, these kind of properties and characteristics of the plastic makes it very useful for many different purpose. In our experimental study we have used shredded plastic waste, which was shredded by Surat Municipal Corporation's Plastic waste management centre in Bhatar area of Surat. This plastic waste was produced locally and collected by local garbage collecting service. This plastic waste contains all types of plastics which are being used in daily life. Brief description of all type of plastic which is present in the sample is described below in tabular form.

Table 1 Types of plastic and its sources

Plastic waste	Origin
Low Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High Density Polyethylene (HDPE)	Carry bags, bottle caps, house hold articles etc.
Polyethylene Terephthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent and biscuit, wafer packs, microwave trays for readymade meals etc.
Polystyrene (PS)	Yogurt pots, clear egg packs, bottle caps, foamed polystyrene: food trays, egg boxes, disposable cups, protective packaging etc.
Polyvinyl Chloride (PCV)	Mineral water bottles, credit cards, toys, pipes and gutters, electrical fittings, furniture, folders and pens, medical disposables etc.

3.2 Cement

OPC 53 grade was used conforming to IS 269-2015

3.3 Fine aggregate

Sand conforming to Zone-II (White Sand) was used as the fine aggregate, as per I.S 383-1970. The sand was air dried and free from any foreign material, earlier than mixing. The sand which was locally available and passing through 4.75mm IS sieve is used. The specific gravity of fine aggregate was 2.60. Locally available river sand conforming to Grading zone-II of IS: 383 – 1970.Clean and dry river sand available locally will be used. Sand passing through IS 4.75mm Sieve will be used for casting all the specimens. Fine aggregate is defined as material that will pass from No.4 sieve and will, for the most part, be retained on a No. 200 sieve, for increased workability and for economy as reflected by use of less cement, the fine aggregate should have a rounded shape. The purpose of the fine aggregate is to fill the voids in the coarse aggregate and to act as a workability agent.

3.4 Coarse Aggregate

Aggregates generally occupy 70 to 80 percent of the volume of concrete and can therefore be expected to have an important influence on its properties. We have used coarse aggregate maximum size of 20 mm. They are granular materials, derived for the most part from natural rock (crushed stone or natural gravels) and sands, although synthetic materials such as slag and expanded clay or shale are used to some extent, mostly in lightweight concretes. In addition to their use as economical filler, aggregates generally provide concrete with better dimensional stability and wear resistance. Aggregate classifications are made principally for the purpose of easier identification of particular aggregate lots, or to become familiar with the different types of aggregates. There are numerous ways of classifying aggregates.

3.5 Water

Water to be used in the concrete work should have following properties: It should be free from injurious amount of oil, acids, alkalis or other organic or inorganic impurities. It should be free from iron, vegetable matter or other any type of substances, which are likely to have adverse effect on concrete or reinforcement. It should be quite satisfactory for drinking purpose which is used in mixing of concrete.

3.6 Plastic waste

Firstly plastic waste was collected by local garbage collecting service form different areas of Surat, then it was transported to the plastic waste management centre of S.M.C and shredded in aglo machine. We collected shredded plastic waste from plastic management centre in Bhatar area of Surat. We collected total 10 kg of shredded plastic waste. Then the shredded plastic waste was passed through IS 4.75 mm sieve and retained on a IS 0.150mm sieve are used.

Figure 2 Plastic Waste management centre

4. Mix Design

Step 1 Design stipulation for proportioning

Table 2 Design stipulation for proportioning

Grade of concrete (N/mm^2)	M25
Type of cement	Ultratech OPC 53
Max. Nominal size of aggregate	20 mm
Min. cement content	44.5 kg
Max. W/C ratio	0.55
Workability	40 to 150 mm
Exposure condition	Severe
Method of concrete placing	By hand
Degree of supervision	Good
Type of aggregate	Crushed angular aggregate

Step: 2 Test Data for Materials

Cement used - Ordinary Portland Cement (53 grade)

Specific gravity of cement = 3.13
Specific gravity of fine aggregate = 2.65
Specific gravity of 20 mm aggregate. = 2.91

Water Absorption:-

Table 3 Water absorption

Coarse Aggregate 20mm	1.78 %
Fine Aggregate	1.83%

Step: 3 Target Mean Strength of Concrete

$f_{target} = f_{ck} + 1.65 * s$

where,

f_{target} = Target average compressive strength at 28 days
f_{ck} = compressive strength at 28 days
s = Standard deviation

$f_{target} = f_{ck} + 1.65 * s$
$= 25 + (1.65 * 4.0) = 31.6\ N/mm^2$

Step: 4 Selection of W/C ratio

We took W/C ratio of .50 for 4 % and 8 % replacement of fine aggregate by shredded plastic waste.

Step: 5 Selection of cement content (For 1 cube)

For M25 (1:1:2),
Density of cement = 1440 kg/m^3
Volume of cube = 15cm X 15cm X 15cm
Wet volume = 15cm X 15cm X 15cm
= 3375 cm^3
$= 3.375 * 10^{-3}\ m^3$
Dry volume is 54% more than wet volume.
Therefor,
Dry volume = $1.54 * 3.375 * 10^{-3}\ m^3$
$= 5.19 * 10^{-3}\ m^3$
Volume of Cement = $1 * 5.19 * 10^{-3}/(1+1+2)$
$= 1.3 * 10^{-3}\ m^3$
Weight cement = $1440 * 1.3 * 10^{-3}$
= 1.87 Kg

Step: 6 Selection of water content (For 1 cube)

W/C = 0.50
Therefor,
W = 0.50 * 1.87
= 0.93 kg
~ 1 kg or 1 litre

Step: 7 Selection of Fine aggregate and coarse aggregate (For 1 cube)

Density of Fine aggregate = 1600 kg/m^3
Volume of Fine aggregate = $1 * 5.19 * 10^{-3}/(1+1+2)$
$= 1.3 * 10^{-3}\ m^3$
Weight Fine aggregate = $1600 * 1.3 * 10^{-3}$
= 2.06 Kg
Density of coarse aggregate = 1520 kg/m^3
Volume of coarse aggregate = $2 * 5.19 * 10^{-3}/(1+1+2)$
$= 2.6 * 10^{-3}\ m^3$
Weight coarse aggregate = $1520 * 2.6 * 10^{-3}$
= 3.92 Kg

Step: 8 Mix design of M25 for 1 m^3 (C:FA:CA)

Table 4 Mix Design

Volume of concrete	1 m^3
Mass of cement	554.4 kg
Mass of water	277.2 kg
Mass of coarse aggregate 20 mm	1170.4 kg
Mass of Fine aggregate	739.2 kg

Step: 9 Mix design of M25 with 4 % and 8 % shredded plastic waste

Table 5 Mix design with plastic waste

Plastic	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)	Water (kg)
0 %	554.4	739.2	1170.4	277.2
4% (29.6kg)	554.4	709.6	1170.4	277.2
8%(59.1kg)	554.4	680.1	1170.4	277.2

5. Preparation of Specimen

Concrete Mix Design:

M-25 grade of concrete was designed by I.S 10262-1982 method. The fine aggregate were replaced by shredded plastic waste as 0%, 4% and 8% for now, we will add more plastic waste in future. The test results were analysed and compared with theoretical values, obtained from various codes.

Batching and Mixing:

Weigh Batching was practiced with the help of electronic weigh balance. Batching was done as per the mix proportions. Mixing was done in the mixer. It was mixed for 2-3 minutes, after addition of water.

Placing and Compaction:

Cubes are cleaned and oiled to prevent the formation of bond between concrete and moulds. Place the fresh concrete in cubes in 3 layers, tamping each layer 25 times. The entrapped air in concrete is removed by manually vibrating the cubes.

De moulding:

After placing fresh concrete in moulds, it was allowed to set for 24 hours

Figure 3 Preparation of specimen

5.1 Measurements of Ingredients

All cement, sand, coarse aggregate and coconut shell measured with digital balance. Water is measured measuring cylinder of capacity 1 lit and measuring jar of capacity 100 ml and 200 ml.
Mixing of concrete

The ingredients were thoroughly mixed in concrete mixer. The cement, sand and coarse aggregate were measured accurately and mixed in dry state for normal concrete. Whereas for the concrete containing the shredded plastic waste, first measured quantity of cement and other required ingredients as per mix design and then added in concrete mixer. Care is taken to avoid segregation of concrete.

Figure 4 Concrete mixing machine

5.2 Placing of Concrete

The fresh concrete is placed in the moulds by trowel. It is ensured that the representative volume is filled evenly in all the specimens to avoid accumulation of aggregate, segregation etc. Placing of concrete in the mould was done in three layers, each layer was tempted 35 time. While placing concrete in moulds compaction is done to remove entrapped air or voids in concrete.

Figure 5(a)

Figure 5(b)

Figure 5 Placing of concrete and tempting of concrete

Concrete is worked trowel to give uniform surface. Care is taken not to add any extra cement, water or cement mortar for achieving good surface finish. The additional concrete is chopped off from the top surface of the mould for avoiding over sizes etc. Identification marks are given on specimens by embossing over the surface after initial drying.

5.3 De-moulding of Specimens

The plain cement concrete specimens were de-moulted after 24 hours of casting and kept in water tank for curing. Similarly shredded plastic waste concrete specimens were de-moulded after 24 hours of casting and kept in water tank for curing at 7 days, 14 days and 28 days.

5.4 Curing of Specimens

The specimens were de-moulded after 24 hours of casting and immediately stored in the curing tank.

6. Result Analysis

6.1 Slump test for fresh concrete

Table 6 Result of slump test

W/C Ratio	0.50	0.50	0.50
% Plastic	0 %	4 %	8 %
Slump	150 mm	150mm	60 mm

6.2 Compressive strength test of concrete

- Grade M – 25
- W/C – 0.50

6.2.1 Conventional concrete

Table 7 Result of 7 day test

% Plastic	Load (KN)	Weight of specimen (kg)	Compressive strength (N/mm^2)
0 %	536.40	8.40	23.84
0 %	515.50	8.44	22.90
0 %	522.00	8.42	23.20

Table 8 Result of 14 day test

% Plastic	Load (KN)	Weight of specimen (kg)	Compressive strength (N/mm^2)
0 %	596.92	8.40	26.53
0 %	610.20	8.42	27.12
0 %	580.72	8.41	25.80

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Table 9 Result of 28 day test

% Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
0 %	708.07	8.46	31.47
0 %	730.80	8.36	32.48
0 %	684.00	8.42	30.40

6.2.2 Concrete containing 4% plastic

Table 10 Result of 7 day test

% Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
4 %	559.00	8.20	24.84
4 %	573.30	8.14	25.48
4 %	559.40	8.15	24.86

Table 11 Result of 14 day test

% Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
4 %	587.25	8.20	27.10
4 %	626.85	8.17	27.86
4 %	621.00	8.22	27.60

Table 12 Result of 28 day test

% Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
4 %	632.40	8.22	28.10
4 %	706.60	8.12	31.40
4 %	689.70	8.18	30.65

6.2.3 Concrete containing 8% plastic

Table 13 Result of 7 day test

% Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
8 %	504.00	7.82	22.40
8 %	496.40	7.82	22.06
8 %	525.40	7.90	23.35

Table 14 Result of 14 day test

%Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
8%	518.40	7.82	23.04
8%	519.75	7.80	23.10
8%	524.70	7.84	23.32

Table 15 Result of 28 day test

% Plastic	Load (KN)	Weight of specimen(kg)	Compressive strength (N/mm²)
8 %	601.20	7.80	26.72
8 %	583.20	7.79	25.92
8 %	540.90	7.84	24.04

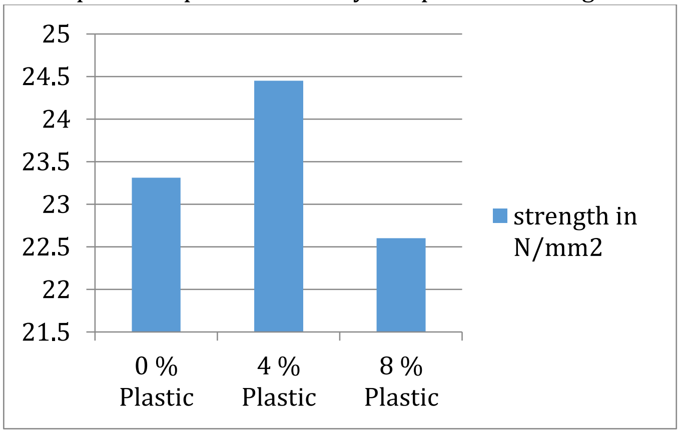
7. Comparison of compressive strength

7.1 Comparison of 7 day compressive strength

Table 16 Comparison of 7 day compressive strength

% Plastic	**Compressive strength**
0 %	23.31
4 %	24.45
8 %	22.60

Graph 1 Comparison of 7 day compressive strength

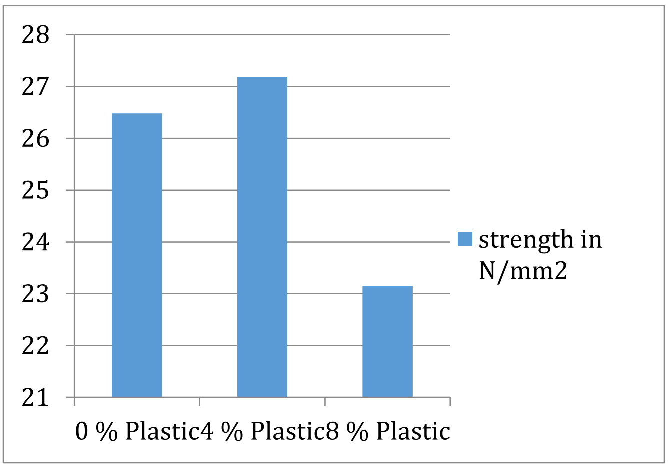


7.2 Comparison of 14 day compressive strength

Table 17 Comparison of 14 day compressive strength

% Plastic	Compressive strength (N/mm²)
0 %	26.48
4 %	27.18
8 %	23.15

Graph 2 Comparison of 14 day compressive strength

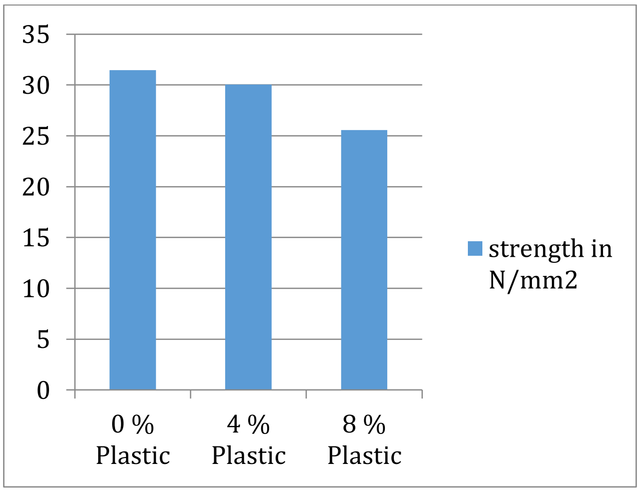


7.3 Comparison of 28 day compressive strength

Table 18 Comparison of 28 day compressive strength

% Plastic	Compressive strength (N/mm^2)
0 %	31.46
4 %	30.05
8 %	25.56

Graph 3 Comparison of 28 day compressive strength

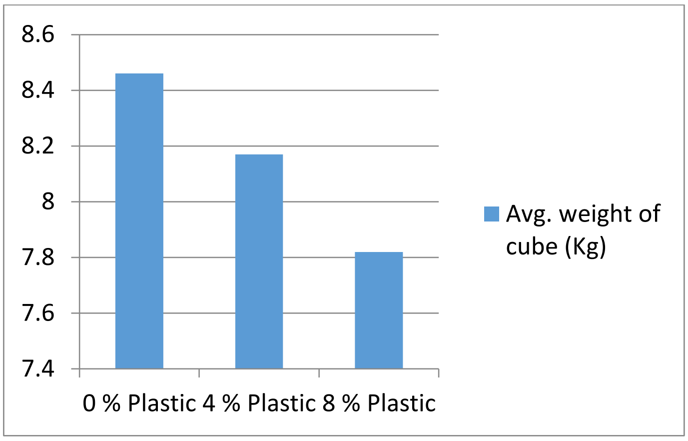


8. Difference of weight of specimen

- Average weight of normal concrete – 8.46 kg
- Average weight of concrete containing plastic waste – 7.99 kg

The weight of the concrete is decreasing with increase in the plastic content.

Graph 4 Difference in average weight of cube



9. Conclusion

From the results of slump test, the slump of concrete containing 0 % plastic and 4 % plastic waste is very identical which is 150mm but when we added 8 % plastic waste slump reduced to 60mm,which is acceptable. This shows that the workability of the concrete decreases with increase in plastic waste.

This concludes that we may have to use proper admixtures to maintain the workability of the concrete.

The average weight of the concrete containing 0 % plastic waste is 8.46 Kg and that of concrete containing plastic waste is 7.99 kg.

This concludes that the weight of the concrete is decreasing with increase in plastic waste content. Adding plastic waste makes concrete light weight.

The average compressive strength of concrete containing 0 %, 4 % and 8% plastic waste for 7 day is 23.31, 24.45 and 22.60 respectively, for 14 day it is 26.48, 27.18 and 23.15 and for 28 day it is 31.46, 30.05 and 25.56.

This concludes that difference in compressive strength of concrete containing 0 % and 4 % plastic waste is not very significant but for the concrete containing 8 % plastic the difference is quite significant but still acceptable.

So far, from all the experiments we concluded that we can add 4 % and 8 % plastic waste without compromising the compressive strength of the concrete but if we add proper admixture in the concrete we may get better results.

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