Utilizing Plastic Waste in Concrete as a Partial Replacement of Coarse Aggregate

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Dedicated

to

"Our beloved parent's"

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ABSTRACT

The study presents the mechanical and durability properties of concrete made up of waste plastic -based aggregate as replacement of natural coarse aggregate, respectively. For this purpose, compressive strength, captivity, water permeability. The fresh and hardened properties of waste plastic mix concrete have been studied. Plastic wastes have represented a significant portion of municipal solid wastes and pose a serious pollution problem due to both their extended life cycle and visibility. On the other hand, rapid urbanization especially in developing countries results the depletion of natural resources for construction industry. The both problems can be mitigated by proper management such as recycling these plastic wastes into useful products, such as construction building materials. Therefore, the main objective of this paper is to assess the potential of using plastic waste as a replacement of coarse aggregates in concrete mixes.

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CHAPTER 1

INTRODUCTION

1.1 Historical Background

Concrete is the mostly 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.

The changed lifestyle and endlessly increasing population has resulted in a significant rise in the quantity of post-consumer plastic waste. The world's annual consumption of plastic materials has increased from around 5 million tons in the 1950's to nearly 100 million tons in recent times, resulting in a significant increase in the amount of plastic waste generation. Out of this waste, a significant part is recycled but the majority of post-consumer plastic wastes, like shampoo sachets, carry-bags, nitro packs, milk and water pouches etc. though recyclable, remains comparatively untouched as they are difficult to separate from household garbage.

In most of the cases, such post-consumer waste either litters all around or is disposed of by land filling. The disposal of post-consumer plastic waste in this manner poses significant environmental hazards as it results in reduction in soil fertility, reduction in water percolation, emission of toxic gases, health hazard to animals and birds consuming the wastes, poor drainage due to landfill, pollution of ground water due to leaching of chemicals from these waste products etc.

Thanks to advancements in the research community, a recent study by BBC NEWS states that reusing plastic by renewing it is better for the environment than dumping it. In many developing countries, the majority of the population belongs to the middle and lower classes. Therefore, by replacing higher-valued coarse aggregate in quantities with cost-effective alternatives, the cost of construction can be reduced.

1.2 Research Objectives and Overview

The population increase has also led to a rapid rise in urbanization, resulting in heavy usage of natural resources such as Fine Aggregates (Sand), Coarse Aggregates, etc. This process has resulted in several problems, such as increased waste productivity and a shortage of natural construction materials. As these resources are non-renewable, it is essential to come up with alternative solutions to meet the demand while preserving natural resources and protecting the environment.

The properties of concrete that can be modified using waste plastic.

1. Introducing plastic wastes in concrete as partial replacement of coarse aggregate.
2. Compare and analyze compressive strength of concrete cylinders.

Fig 1.2.1 : Plastic waste materials recycling machine

Fig 1.2.2 : Plastic waste

While plastic has many valuable uses, we have become addicted to single-use plastic products — with severe environmental, social, economic and health consequences.

Around the world, one million plastic bottles are purchased every minute, while up to five trillion plastic bags are used worldwide every year. In total, half of all plastic produced is designed for single-use purposes – used just once and then thrown away.

Plastics including microplastics are now ubiquitous in our natural environment. They are becoming part of the Earth's fossil record and a marker of the Anthropocene, our current geological era. They have even given their name to a new marine microbial habitat called the "plastisphere".

1.3 Organization of the thesis

Chapter 1: Introduction and Objective: In this study, the opportunities to use waste plastic in concrete mixes have been investigated and Introducing plastic wastes in concrete as partial replacement of coarse aggregate and Compare and analyze compressive strength of concrete cylinders.

Chapter 2: Literature Review: The study present the partial replacement of coarse aggregate in concrete by using plastic coarse aggregate obtained from the crushing of waste plastic.

Chapter 3: Methodology: The main research of that project is to waste plastic use as a coarse aggregate weight volume for the production of concrete . It is essential to know the replacement of Plastic Aggregate (PA) in concrete is acceptable or not for a concrete mixture.

Chapter 4: Results and Discussion: This test is performed 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/mm2.

Chapter 5: Conclusions: It was observed a small amount of workability improved due to partial replacement of recycled aggregate and Concrete made as 10% partial replacement by recycled coarse aggregate weight volume is effective.

1.4 Specific Aim

- Introducing plastic wastes in concrete as partial replacement of coarse aggregate.
- Create a useful technique for using used plastics.
- Use less of coarse aggregate like brick chips.
- To reduce soil and water deterioration and the risk of pollution, reduce and reuse the formation of waste plastics on land and in water.
- To create materials that are affordable to the average person.
- Less plastic in trash streams means less non-renewable resource use.

CHAPTER 2

Literature Review

2.1 Introduction

Some of the significant research works that have been reported in the literature review in the context of the different waste materials cited in the afore-mentioned section is discussed in brief in the subsequent paragraphs. Besides, the plastic has a low density compared to the aggregate. As a result, the use of plastic waste as a partial replacement for the aggregate significantly boosts the efficiency of thermal and sound lightweight concrete insulation.

At 10% and 7% partial replacement, can waste had about 9% and 12.5% higher compressive and tensile strengths than the control specimen. As a result, it is proposed that using wastes that may enhance concrete properties will lower the need for normal coarse and fine aggregates, enabling natural resource conservation.

2.2 Literature Review Overview

Amalu.R.Get. al. in 2016 performed the study the use of waste plastic as fine aggregate in concrete. They use plastic as substitute of fine aggregates in proportion of 10%, 15%, 20% and 25%. They found reduction in strength of concrete but support the use of plastic in non structural concrete for the reason it shows higher workability and reduce environmental waste.[1]

B Jaivignesh and A Sofi in 2017 performed Study Properties of Concrete with Plastic Waste as Aggregate. They used the plastic place 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 materials.[2]

Daniel Yaw Osei in 2014 performed experiments on plastics aggregate in concrete. He replace the coarse aggregates in concrete of ratio 1:2:4 by 25%, 50%, 75% and 100% with plastic. He found that there was reduction in strength of concrete as well as density of concrete. They suggested that replacement of aggregates more than 36% is not suitable for structural concrete. They also suggested plastic as a medium for production of light weight concrete.[3]

Manhal A Jibrael and Farah Peter in 2016 studies the Strength and Behaviour of Concrete Contains Waste Plastic. They replace fine aggregates in concrete with plastic bottles and plastic bags in varying proportions from 0% to 5%. They concluded the results to use the plastic in concrete for non structural purposes as it reduces the strength in both cases.[4]

NabajyotiSaikia and Jorge de Brito in 2012 study use of plastic in cement mortar and concrete. They found that workability decreases on use of angular plastic aggregates but increases with use of smooth aggregates. Irrespective of type of plastic, there was reduction of compressive strength, but the reduction of flexural and tensile strength was low as compared to compressive strength.[5]

Praveen Mathew et. al. in 2013 study the use of Recycled Plastics as Coarse Aggregate for Structural Concrete. They performed test on concrete with various proportions of plastic aggregates in replacement of coarse aggregates and found the optimum result at 22% replacement of coarse aggregates with plastic aggregates. They further performed the test for other properties on concrete with 22% plastic aggregates and found that concrete with plastic aggregates was weaker in fire resistance.[6]

RaghatateAtul M. in 2012 performed study on use of plastic bags in form of fiber in concrete and test it properties. He adds fiber in proportion of 0.2%, 0.4%, 0.6%, 0.8% and 1% by weight of concrete. He found that there was reduction of compressive strength with increase in plastic content, but there was increase in tensile strength with optimum strength at 0.8% addition.[7]

T.Subramani and V.K.Pugal in 2015 performed an experiments on plastic waste as coarse aggregates in concrete. They prepared the concrete with 5%, 10% and 15% replacement of aggregates in concrete with plastic. They found the optimum results at 10% replacement of aggregates with plastic. Further increase in plastic content decreases the strength of concrete.[8]

2.3 Summary

In this study we know how many time research of waste plastic in concrete mixture. And Use of Waste Plastic in Concrete Mixture as Coarse Aggregate. It helps to save and sustain natural resources that are not replenished, it decreases the pollution of the environment, and it also helps to save and recycle energy production processes.

We study & research on waste plastic as coarse aggregate in concrete. We replace coarse aggregate in concrete with waste plastic in varying proportion from 0%, 5%, 10% and 15%. After 28 days curing of concrete cylinder and Compare between the strength and Compressive strength of concrete cylinder.

CHAPTER 3

Methodology

3.1 Introduction

Research of that project is to waste plastic as a coarse aggregate in concrete mixture. It is essential to know the replacement of Plastic Aggregate (PA) in concrete is acceptable there are for the making of concrete used coarse aggregate, selection sand, brick chips and Portland cement used for making a concrete and plastic aggregate used in crushed concrete from the tested cylinders. Test carried out on these aggregate specific gravity and Bulk density, and sieve analysis. After testing, a mix design is produced in accordance with the properties obtained from test results after testing; a mix design is produced in accordance with the properties obtained from test results. Concrete is then produced with replacement of 0%, 5%, 10% and 15% of plastic aggregate replacement of **coarse aggregate weight ratio**. Tests conducted on these concretes include the slump of fresh concrete. For the hardened concrete, compressive strength, were determined. 28 days the results at each testing age are reported as an average. The engineering properties of the PA were also compared to those of the reference concrete.

In the research materials:

Cement: Cement used for the test was ordinary Portland cement.

Fine Aggregate: Selection Sand was used as fine aggregate.

Coarse aggregate: Crushed brick chips obtained from local quarries were used as a coarse aggregate. The maximum size of coarse aggregate used was 20 mm.

Water: Portable water free from impurities and salt used for casting and curing the concrete blocks as per calculations.

Plastic Aggregate: Plastics collected from the disposal area were sorted to get the superior one. Use as per requirement size.

Waste Plastic

Cement

Sand **Brick chips**

Fig 3.1.1: Materials

Below are some materials tests for our research,

I. Sieve Analysis of Fine aggregate and Coarse aggregate
II. Specific gravity of Fine aggregate and Coarse aggregate
III. Unit weight

Concrete Mix Design

Table 3.1.1: Specific Gravity & Unit Weight

Materials	Specific Gravity	Unit Weight (kg/m^3)
Cement	3.1	1.294
Coarse Aggregate	2.8	2.966
Fine Aggregate	2.3	4.267.67

Material Required for preparing 1 cubic meter of concrete

Table 3.1.2: Volume of Materials

Materials	Mass(kg)	Volume(m^3)	Volume(cft)
Cement	350	0.27	9.55
Coarse Aggregate	1065.83	0.76	26.89
Fine Aggregate	791.76	0.61	21.51
Water	175	0.18	6.18

Compaction Factor	With Water	Without Water
	1.82	1.64

Unit Weight of concrete= 2382.59Kg

Table 3.1.3: Percentage% of replacement

Case	% Replacement	Number of Cylinders
1	0%	3
2	5%	3
3	10%	3
4	15%	3
Total		12

Table 3.1.4: Testing volume of materials

Sample	%Replacement	Number of Cylinders	Cement (kg)	C.A. (kg)	F.A. (kg)	P.R. (kg)	Water
1	0%	3	3.08	6.83	6.71	0.00	1.55
2	5%	3	3.08	6.49	6.71	0.34	1.55
3	10%	3	3.08	6.14	6.71	0.68	1.55
4	15%	3	3.08	5.80	6.71	1.02	1.55

3.2 Methodology Overview

The methodology adopted for this study is given below:

- ✓ Literature study was done on the available data on use of plastic in concrete.
- ✓ Plastic was collected from a plastic factory which in Dhaka city, Bangladesh.
- ✓ Plastic was cleaned and small in size.
- ✓ Proportion of plastic coarse aggregates (PCA) in different mixes was selected on the basis of available literature.
- ✓ Sieve Analysis , Specific Gravity and Unit weight test for mix design.
- ✓ Mix design for different proportions of concrete was decided and tests were performed to obtain the mechanical properties of different mixes.
- ✓ Based on the literature survey and optimum quantities of plastic, the following combinations were adopted.

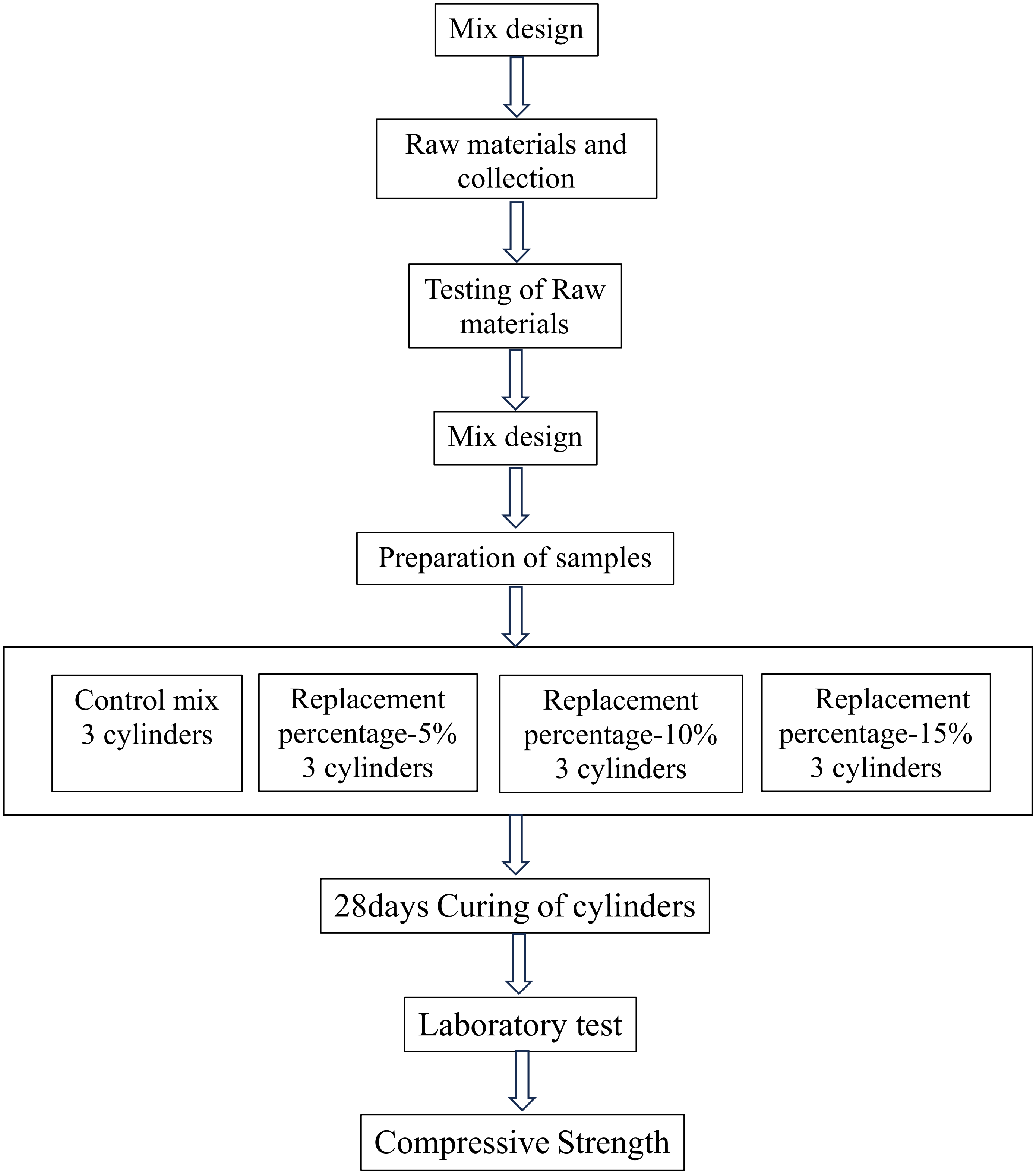

Fig 3.2.1: Methodology flow chart

Concrete mix is the way by which we choose the different constituents used in the concrete and determining their amount and by taking care about the economy and various properties of the concrete like workability, slump value , strength criteria etc. Mathematical solutions of mixing are used to prepare concrete and to check mix design and to adjust mix volume and water cement ratio. The following parameters were used for mix design

Table 3.2.1: Input Data

INPUT		
	Specific Gravity	Unit Weight (kg/m^3)
Cement	3.1	1294
Coarse Aggregate	2.8	1400
Fine Aggregate	2.3	1300
Weight of cement to be used for 1 cubic meter concrete=		350
Water to cement ratio	=	0.5
Sand to aggregate ratio	=	0.44
Void ratio =		0.02

Table 3.2.2: Output Data

OUTPUT			
Material Required for preparing 1 cubic meter of concrete			
	Mass(kg)	Volume(m^3)	Volume(cft)
Cement	350	0.27	9.55
Coarse Aggregate	1085.21	0.78	27.37
Fine Aggregate	700.40	0.54	19.03
Water	175	0.18	6.18
	With Water	Without Water	
Compaction Factor	1.76	1.58	
Unit Weight of concrete=	2310.61 kg		

All the specimens were casted according to the mix proportions. For these mix proportions required quantities were measured and then mixed. Mixing of concrete was done with hand. Specimens for Compressive Strength To check the compressive strength of concrete mix, specimens of cylinder shape size Height-204mm & diameter 100mm were prepared. The required quantities of materials required were weighed according to the mix proportion. Aggregates and cement was firstly thoroughly mixed. Admixture was added to the water. Water was then added to the dry mix. Total 12 similar cylinders were casted, cylinders for 28 days testing.

Fig: 3.2.2: Casting Cylinders

After 24 hours of casting, the castings were removed from the cylinders and placed in the curing tank.

Fig: 3.2.3: Casting Cylinders Curing time

Testing of Concrete: After casting, specimens were tested after 28 days of curing. In this article, the procedure adopted for testing of specimens for various properties like compressive strength, have been discussed.

Compressive Strength To evaluate the compressive strength of concrete, cube specimens were used. Specimens were then taken out of tank after 28 days of curing and surface dried.

Specimens were then placed in Compression Testing Machine. The load was applied and the peak load at which the specimen fails was noted.

Fig: 3.2.4: Dry Casting cylinders

Compressive strength = P/A
Where, P = load in KN and A = Area of cross section

Fig: 3.2.5: Compressive strength test

3.3 **Summary**

Before anything else, plastic waste needs to be gathered and separated from other trash. Next, we the used plastic into tiny pieces. We have the ability to thoroughly mix and create a mixture. Concrete is then produced with replacement of 0%, 5%, 10% and 15% of plastic aggregate replacement of coarse aggregate weight volume & 28 days curing time. Tests conducted on these concretes include the slump of fresh concrete. For the hardened concrete, compressive strength, were determined.

CHAPTER 4

Results and Discussion

4.1 Introduction

This 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. Workability of concrete is an important property of fresh concrete. Concrete materials used in this study included type Portland cement, selection sand, ¾ inch crushed brick chips and water.

COMPRESSIVE STRENGTH TEST

The concrete cylinder is the most common sample type for tests of concrete compressive strength. There are other ways to determine concrete strength, and some methods may be more cost-effective and arguably better, but concrete cylinder testing remains the standard for acceptance.

Well-made concrete cylinders are easy and inexpensive to produce. Typically, one technician posted at the point of discharge or point of placement is sufficient to sample and test concrete batches for the slump, air content, unit weight, and cylinders. Technicians must follow standard practices and be certified in most regions, but training is neither extensive nor complex.

A compressive axial load is applied to molded cylinders or cores until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load achieved during the test by the cross-sectional area of the specimen. The results of this test method are used as a basis for quality control of concrete.

This test is performed 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/mm2. We performed this test on standard cylinder of size 150mmX150mmX150mm. Concrete mix with different proportions was prepared and filled into cylinder mound. It was then left for 24 hours for initial setting. For every mix proportion 12 specimens were prepared, for 28 days testing. After completion of curing period the specimens were tested using Compression testing machine (CTM). Surface dried specimens were placed in CTM. The maximum value of load (P) under which the specimen fails was noted down.

Compressive strength =P/A
Here, P = load on the cylinder
A= cross-sectional area of cylinder

4.2 Data Analysis

Table 4.2.1: Sieve analysis of Fine aggregate

Sieve No.	Sieve Size (mm)	Weight(gm)	Weight retained %	Cumulative weight %	Cumulative passing %
4	4.75	0	0	0	100.00
8	2.36	75	9.59	9.59	61.38
16	1.18	227	29.03	38.62	61.38
30	0.6	215	27.49	66.11	33.89
50	0.3	215	27.49	93.61	6.39
100	0.175	50	6.39	100.00	0
Total		782	100		


Fig 4.2.1: Test of Sieve analysis

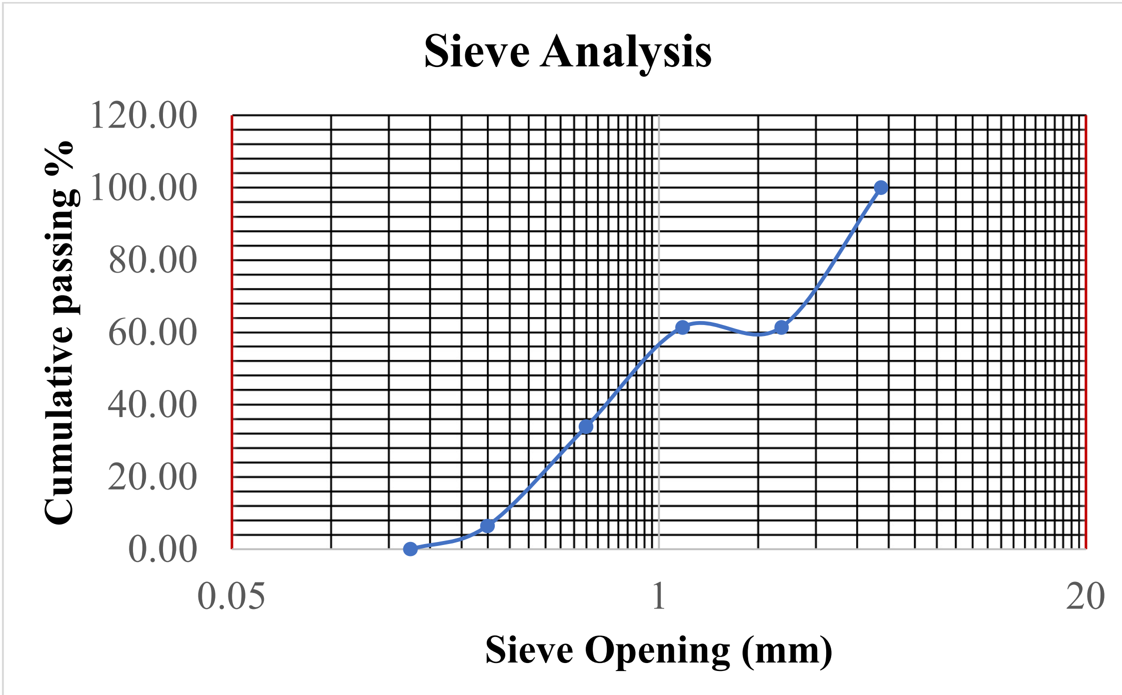

Fig 4.2.2: Graph of Sieve analysis

- **Specific gravity**

Coarse aggregate

Test Data	
	Weight(gm)
B	1490
C	730
A	1230

$$\text{Specific Gravity} = \frac{\mathbf{C}}{\mathbf{B - A}}$$

$$= \frac{730}{260}$$

$$= 2.807692$$

Fine aggregate

Test Data	
	Weight(gm)
B	652
A	288
C	833
S	300

$$\text{Specific Gravity} = \frac{\mathbf{C}}{\mathbf{B - A}}$$

$$= \frac{833}{364}$$

$$= 2.288462$$

Fig 4.2.3: Specific gravity test

- **Unit Weight**

Table 4.2.2: Unit weight of Fine aggregate

Fine aggregate				
Method	Weight with bucket(kg/m^3)	Weight of bucket(kg/m^3)	Weight without bucket(kg/m^3)	Unit weight (kg/m^3)
Shoveling Procedure	7.891	4.000	3.891	
Rodding Procedure	8.351	4.000	4.351	4.268
Jiggling Procedure	8.561	4.000	4.561	

Table 4.2.3: Unit weight of Coarse aggregate

Coarse aggregate				
Method	Weight with bucket(kg/m^3)	Weight of bucket(kg/m^3)	Weight without bucket(kg/m^3)	Unit weight (kg/m^3)
Shoveling Procedure	6.684	4.000	2.684	2.966
Rodding Procedure	7.014	4.000	3.014	
Jiggling Procedure	7.200	4.000	3.200	

Table 4.2.4: Unit weight of Plastic Waste

Waste Plastics				
Method	Weight with bucket(kg/m^3)	Weight of bucket(kg/m^3)	Weight without bucket(kg/m^3)	Unit weight (kg/m^3)
Shoveling Procedure	5.065	4.000	1.065	1.186
Rodding Procedure	5.207	4.000	1.207	
Jiggling Procedure	5.285	4.000	1.285	

Table 4.2.5: Unit weight of Water

Unit weight of Water	**Weight with bucket(kg/m^3)**	**Weight of bucket(kg/m^3)**	**Weight without bucket(kg/m^3)**	**Unit weight (kg/m^3)**
	8.151	**4.000**	**1.397**	**2.754**

Fig 4.2.4: Unit weight test

Unit Weight Measures are used to determine the unit weight and void content of aggregates for quality control and mix design specifications. Measures can also be used to determine cement content, yield, and relative yield for concrete volume verification and mixture air content.

Table 4.2.6: Load capacity lab test data

Cylinder load capacity lab test data																
	Dia(mm)				Height(mm)				Weight(gm)				Load Capacity (kN)			
Cylinder No / %	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg	1	2	3	Avg
0%	101.55	101.50	102.15	101.73	250	253	250	251.00	3463	3505	3584	3517.33	135	140	132	135.67
5%	102.21	103.01	101.02	102.08	248	250	255	251.00	3455	3468	3417	3446.67	123	117	120	120.00
10%	102.34	102.50	102.24	102.36	257	250	245	250.67	3386	3309	3335	3343.33	124	125	127	125.33
15%	103.02	102.15	103.15	102.77	252	247	250	249.67	3325	3315	3329	3323.00	123	119	116	119.33

In this table limited experimental results have been reported in the literature on the fatigue and ultimate static loading of cylinder.

Compressive strength = P/A
Here, P = load on the cylinder
A= cross-sectional area of cylinder

Table 4.2.7: Compressive strength of concrete

% of Mixture	28 days strength (N/mm2)
0%	16.69
5%	14.66
10%	15.23
15%	14.39

Compressive Strength of Concrete Cylinder: The compressive strength of the specimen is calculated by dividing the maximum load achieved during the test by the cross-sectional area of the specimen. The results of this test method are used as a basis for quality control of concrete. Show in graph Fig 4.1.2.

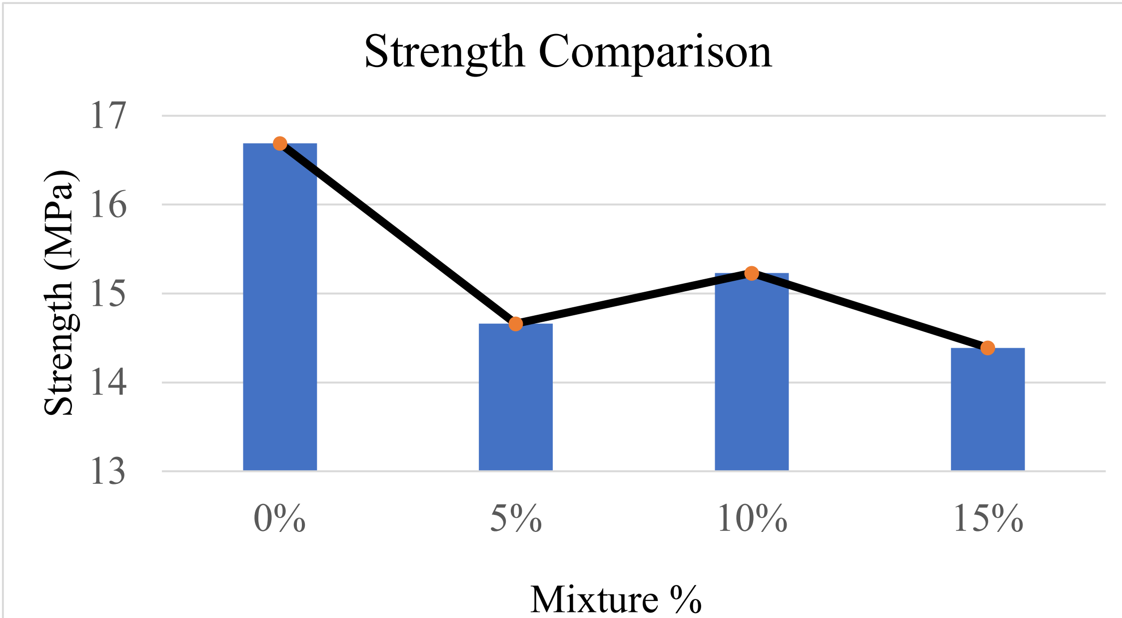

Fig 4.2.5: Strength Comparison of Concrete Cylinder

For a Simple Solid Concrete Cylinder, like a Round. This test method describes the procedure for determining the weight in kg concrete cylinder. Shown in Fig 4.1.2

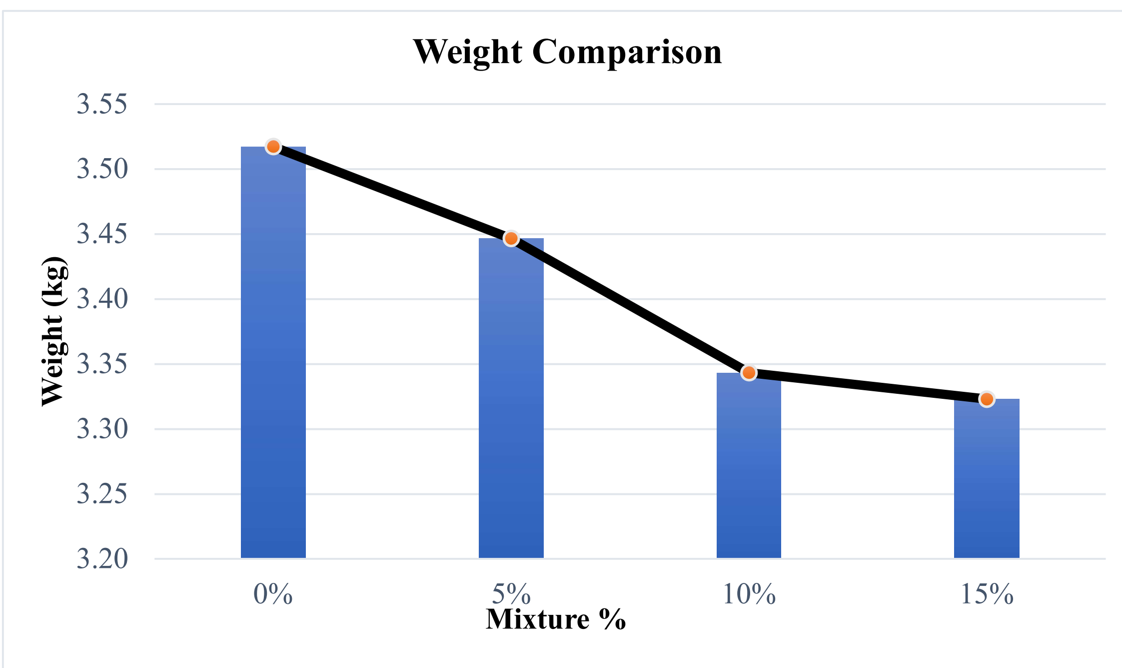

Fig 4.2.6: Weight Comparison of Concrete cylinder

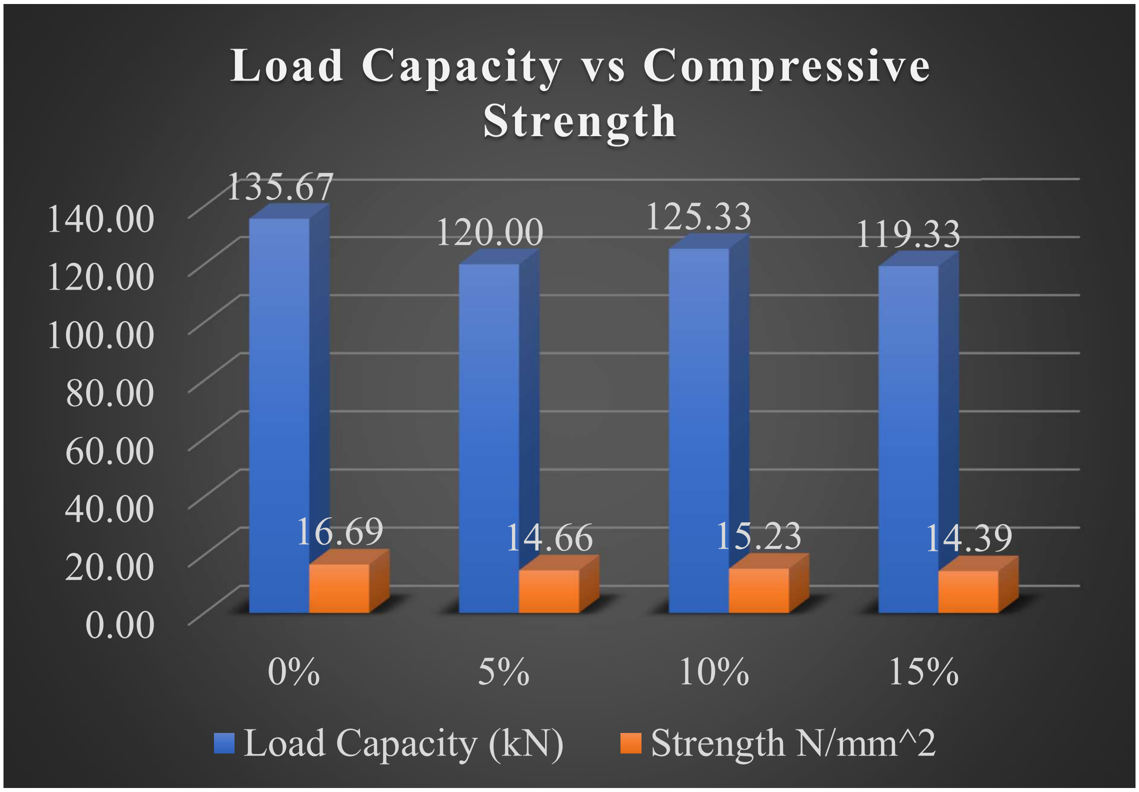

Fig 4.2.7: Compare of Load Capacity & Compressive Strength

Partially replacing the coarse aggregates with recycled plastics gives us lighter concrete. But it also reduces the compressive strength. 10 % replacement (by weight) gives better compressive strength than 5% and 15% replacement (by weight). It may be because of arrangement of aggregate particles, compaction and reduction in voids.

3.23% weight loss was found for every 5% replacement in the concrete cylinder.

The compressive strength test is the most crucial of the several tests conducted on the concrete since it provides information about the properties of the concrete. Compressive strength can be defined as the capacity of concrete to withstand loads before failure.

CHAPTER 5

Conclusions

5.1 Conclusions

During the last decade, a lot of research works have studied the performance of cement composite with waste plastic aggregate. The main purpose of this paper, which was the development of a review of scientific research works in that field, was achieved. Forty papers were analyzed in-depth and remarkable results were found and discussed. Hereunder, conclusions and recommendations for future research works are presented.

The researchers have represented forms of plastic waste as coarse aggregate which can be use in production of concrete. The main focus of researchers was on the compressive strength of concrete containing plastics and very less attention was given to other properties of concrete. This proposals were based on results obtained from experimentation of various casted concrete samples. Plastic was added to concrete in replacement of coarse aggregates weight volume by proportion of 0%, 5%, 10% and 15%. On the basis of the results from the present study, following conclusions were drawn

- Partially replacing the coarse aggregates with recycled plastics gives us lighter concrete. But it also reduces the compressive strength. 10 % replacement (by weight) gives better compressive strength than 5% and 15% replacement (by weight). It may be because of arrangement of aggregate particles, compaction and reduction in voids.
- 3.23% weight loss was found for every 5% replacement in the concrete cylinder.

5.2 Limitations

- As the UTM was not calibrated, we are not that confident about the results.
- We couldn't collect more plastics waste because they suspected us as law enforcing agency.
- We could not manufacture enough concrete cylinders to test and get more strength data due to shortage of molds in our lab.

5.3 Scope for Future Study

- Comparatively better result was found with 10 % replacement (by weight). The reason behind this could be particle interlocking, compaction and reduction in voids, which could be further taken into study.

- Study on direct tensile strength or split tensile strength may be taken into consideration.

- Better strength results could be found reducing water-cement ratio and utilizing water reducing admixture.

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