UTILIZATION OF PLASTIC WASTE IN CONCRETE AS A PARTIAL REPLACEMENT OF FINE AGGREGATE

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ABSTRACT
The onset of industrialization and the sustained urban growth of large population causes the build-up of large amount plastic wastes. Because of the non-biodegradable property of plastics, decomposition is not possible. So, they remain in the environment for a long time, pollute soil and water that creates ecological problems. If these harmful non-biodegradable materials can be substituted as a construction material by using in concrete, that will be a significant source of plastic wastes management. This paper deals with the investigation of using grinded plastic wastes as a partial replacement of fine aggregate in concrete and to find the optimum percentage of plastic that can be used in concrete without reduction of concrete strength or with a slight amount of strength reduction which are considered as negligible. Plastic wastes consist of discarded old computers, TVs, refrigerators, radios, old electrical and electronic equipment were collected at first and then grinded through using a pulverizing machine. Through ACI method, a mix design was made for concrete of grade M-28. The proportion of mixing of the grinded plastic wastes are 2 %, 4 %, 6 %, 8 % & 10 %. The specimens have been cured for 7 & 28 days. Compressive strength and Tensile strength test of concrete were conducted. As the melting temperature of the plastic is low thus it is susceptible to temperature. So, it is important to focus on the impact of heat in concrete strength when using grinded plastic. Post-heat compressive strength test was also conducted. After obtaining the data, they were analyzed by comparing with a controlled specimen. Result had showed that there was slight reduction in strength with the mix proportion of 2%, 4% and 6% of grinded plastic wastes.

Keywords: Non-biodegradable materials; plastic waste; compressive strength; tensile strength; temperature

INTRODUCTION
Plastic waste is a pertinent part of the complete amount of waste worldwide. Due to rapid industrialization and civilization the quantity of plastic waste generated each year, especially computers, televisions and all other kinds of electronic wastes has assumed alarming proportions. According to a projection of the International Association of Electronics Recyclers (IAER) in 2006 that 3 billion electronic and electrical appliances would become WEEE (Waste Electrical and Electronic Equipment) by 2010.Now it is 2015 and so obviously the projected amount have already acceded. Each year more than 22.88 million tons of electronic waste generated in Bangladesh (ESD, 2010). A report shows that, About 50% assembler companies are sold out the generated waste, 30% are dumped, 20% are stored for long time.30% repairers stored the old TV sets for repairer and farther uses, 15% dumps it, 5% didn't give any importance to inform. Among the customers 40% sold rejected sets to the repairers, 10% through away and 20% reuses it after repairing. Also, Some eight million metric tons of plastic waste makes its way into the world's oceans each year and the amount of the debris is likely to increase greatly over the next decade unless nations take strong measures to dispose of their trash responsibly, new research suggests. The report, which appeared in the journal Science on Thursday, is the most ambitious effort yet to estimate how much plastic debris ends up in the sea. The amount of plastic that entered the oceans in the year measured, 2010, might be as little as 4.8 million metric tons or as much as 12.7 million. So it is a great concern to dump it. But Traditional landfill is not

environmentally friendly way to get rid of. In the disposal process is also very difficult to accomplish the EPA regulations. How to reuse the non-biodegradable Electronic Waste and Plastic Waste become an important research topic. And so we have made an effort to use this non-biodegradable components in concrete industry as partial replacement of fine aggregate. This study alleviates the crisis in decomposition of non-biodegradable thermoplastic. It will also provide a significant substitutional way to control the huge amount of wastes plastic and a substitute construction materials at a very low cost.
The main purpose of this project is to study the strength of concrete due to replacement of fine aggregate by plastic wastes in concrete. The variation of compressive strength, tensile strength of concrete using plastic, the optimum replacement level of sand by plastic for maximum strength, minimization of the cost of construction and making environmentally friendly concrete by using plastic as a replacement of sand, which otherwise been dumped and make environmental hazard, all are the main objectives of this project.

METHODOLOGY

Experimental Investigation

The aim of the experimental programme is to compare the properties of concrete made with and without plastic, used as fine aggregate.

Experimental Programme

For preparing the testing specimen, an ACI mix design has been conducted for concrete with strength of M28. Fine aggregate has been replaced by plastic as proportion of weight by 0%, 2%,4%,6%,8% and 10%. The specimen have been tested for 7 days & 28 days curing period.

Mix Design

An ACI Mix Design has been conducted for M28 strength of concrete. Specification of Materials according to ACI Mix Design- Fine Aggregate (796 kg/m3), Coarse Aggregate (992 kg/m3) & Cement (422.22 kg/m3).

Material Properties

Cement:	Ordinary Portland Cement(OPC)		
SL No.	Characteristics	Value Obtained	Value ASTM
1.	Fineness (cm2/gm.)	253	>=280
2.	Normal Consistency		
3.	Soundness		
4.	Setting Time: Initial Setting: Final Setting:	 56 min 108 min	 >=45 min <=6 hr. 15 min

Properties of Aggregate		
Properties	Fine Aggregate	Coarse Aggregate
Fineness Modulus	2.6	4.54
Specific Gravity	2.4	2.8
Unit Weight	1580 kg/m3	1600 kg/m3
Absorption Capacity	.36 %	.25 %
Moisture Content	5.26 %	2.04 %

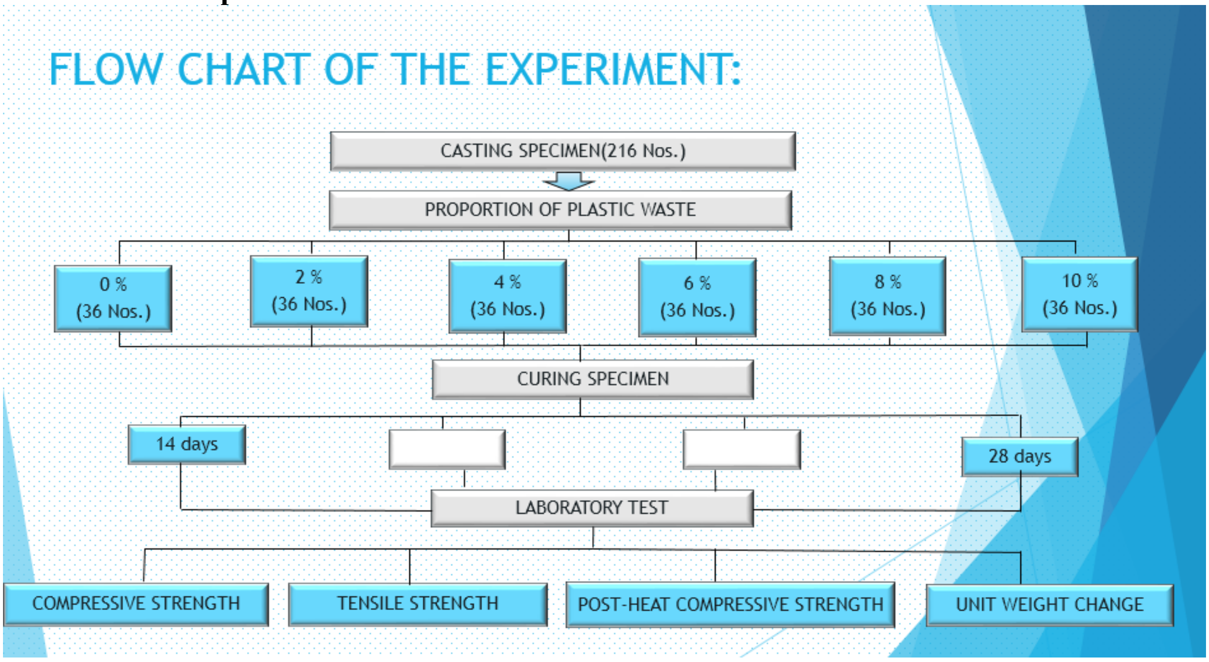
Plastic Wastes

At first, various types of plastic are collected from different sources like old TV, electronic board, old computer monitor etc. Then all of them are grinded through grinded machine into small pieces. As there residues some big particle of plastic after grinding process, they are sieved through No.4 sieve. Then they have been collected for further use in concrete as a partial replacement of fine aggregate.

Properties of Plastic Wastes

PROPERTIES NAME	VALUE
Specific Gravity	1.01
Absorption (%)	<0.2
Color	White
Fineness Modulus	6.58
Shape	Angular
Melting Temperature	80-85° C

Flow Chart of Experiment



Design Strength Test:

For the testing specimen, mix design of 28 MPa concrete have been conducted. For the design strength test, 3 cylindrical specimens of 6 inch dia and 12 inch length, have been casted with different water cement ratio. They have been cured for 28 days in fresh water. After 28 days curing period, they have been taken for the compressive strength test. Three different water ratio i.e .40, .45 and .50 have been used for casting the test specimens. After conducting the test, it has been found that .40 water cement ratio have given the required strength for the design test specimen. So we have used .40 w/c ratio for casting the concrete cube specimen.

Compressive Strength with regard to Different Water Cement Ratio

Water Cement Ratio	Specimen No	Applied Load(KN)	Average Applied Load(KN)	Average Compressive Strength(MPa)
0.4	1	50		
	2	52	51.67	28.41
	3	53		
0.45	1	49		
	2	48	49.00	26.80
	3	50		
0.5	1	48		
	2	48	47.33	25.79
	3	46		

Fig. 1 : Cylinder Compressive Strength Test

Fig. 2 : Specimen Under Applied Compression Force

Fig. 3 : Specimen Under Applied Tensile Force

Fig. 4 :Crushed Concrete Cube

RESULTS AND DISCUSSIONS

GRAPHICAL REPRESENTATION OF COMPRESSIVE STRENGTH(MPa):

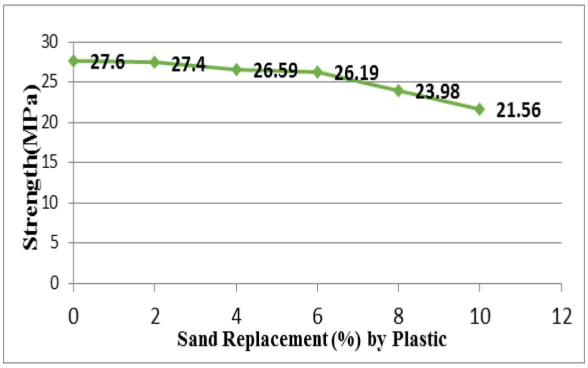


Fig. 5: Compressive Strength of Concrete(7 Days)

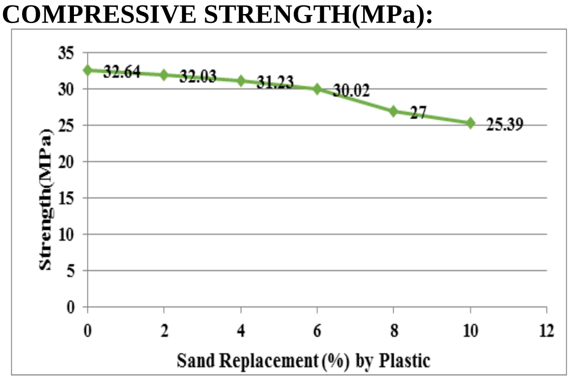


Fig. 6: Compressive Strength of Concrete (28 Days)

GRAPHICAL REPRESENTATION OF POST HEAT COMPRESSIVE STRENGTH(MPa):

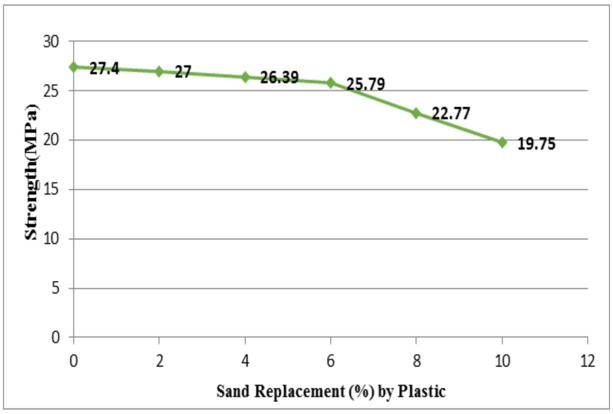


Fig. 7: Post Heat Compressive Strength of Concrete (7 Days)

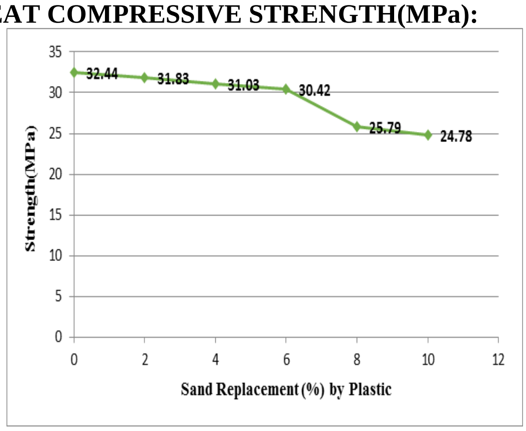


Fig. 8: Post Heat Compressive Strength of Concrete (28 Days)

GRAPHICAL REPRESENTATION TENSILE STRENGTH(MPa):

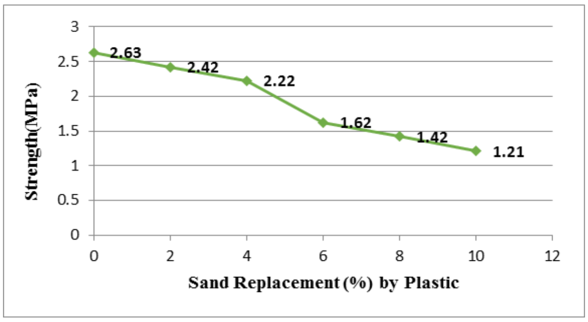


Fig. 9: Tensile Strength of Concrete(7 Days)

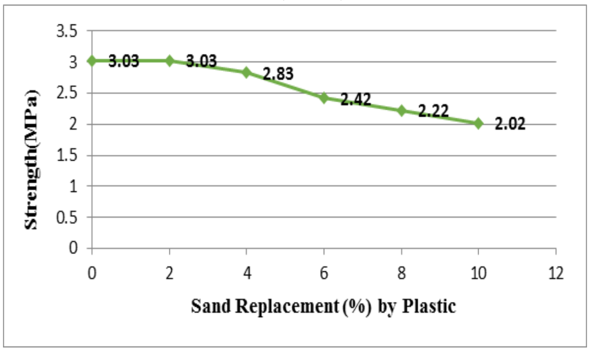


Fig. 10: Tensile Strength of Concrete (28 Days)

GRAPHICAL REPRESENTATION OF VARIATION BETWEEN COMPRESSIVE STRENGTH AND POST HEAT COMPRESSIVE STRENGTH:

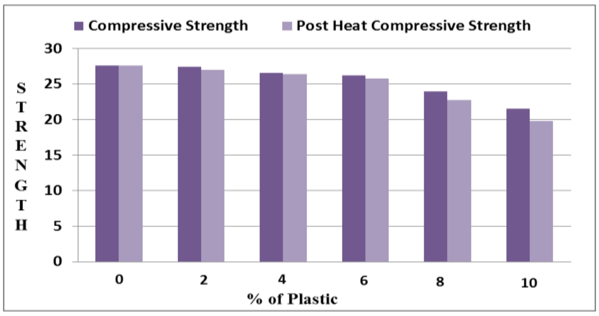


Fig. 11: Compressive Strength vs Post Heat Compressive Strength(7 Days)

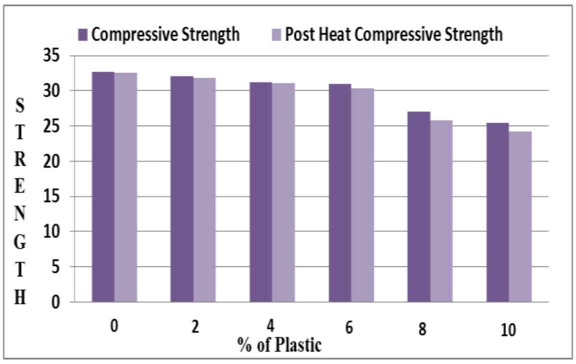


Fig. 12: Compressive Strength vs Post Heat Compressive Strength(28 Days)

DISCUSSION:

In this test all laboratory test are done carefully. In spite of these experimental result may vary from actual result due to following reason:

In the compressive, tensile and post heat compressive strength test mixing is done manually whereas mechanical mixing give actual strength.

The specimen are cured in open air water tank, which may contain impurities. As a result the strength may affected.

Although the specimen must be dried up before the test, in the rainy season it is very difficult to dry, so actual result may vary.

In post heat compression test the thermal exposure of mechanical oven could not be controlled properly due to mechanical error, so the actual result may vary.

CONCLUSIONS

Following conclusions can be made based upon the studies we have conducted:

1. Compressive strength of concrete has been found decreasing gradually with increasing of adding plastic. From our investigation, it has been found that 28 days compressive strength for 2 % is 32.03 MPa, 4% is 31.23 MPa, 6% is 30.02 MPa, 8% is 27 MPa and 10% is 25.39 MPa. There is also a sharp decrease in compressive strength with percentage of 8 % and 10 % of plastic. That clearly represents that plastic can be used as a substitute material by 2%, 4 % and 6 % of sand by weight because it provides sufficient compressive strength. But for further increase in percentage of plastic the compressive strength goes down rapidly.

2. With the increase in percentage of plastics that is used as a partial replacement of sand the post-heat compressive strength also decreases. From the results, the 28 days Post-heat compressive strength for 0% is 32.44 MPa, 2% is 31.83 MPa, 4% is 31.03 MPa, 6% is 30.42 MPa,8% is 25.79 MPa & 10% is 24.78 MPa. It clearly shows that if we increase the percentage of plastics beyond 6% the post-heat compressive strength reduces rapidly.

Introduction of plastics in concrete tends to make concrete ductile, hence increasing the ability of concrete to significantly deform before failure. This characteristic makes the concrete useful in situations where it will be subjected to harsh weather such as expansion and contraction, or freeze and thaw.

3. For 1 m3 concrete, It has been found that replacing sand by 2 % of plastic wastes, sand is substituted by 15.92 Kg of plastic .Replacing sand by 4 % of plastic wastes, sand is substituted by 31.84 Kg of plastic. Replacing sand by 6 % of plastic wastes, sand is substituted by 47.76 Kg of plastic .So, when it would be used in large scale in construction site, there would be a significant way to control this huge amount of plastic wastes that have to be dumped.

SCOPE FOR FURTHER RESEARCH:

The use of recycled plastics in concrete is relatively a new development in the world of concrete technology and lot of research must go in before this material is actively used in concrete construction. The use of plastics in concrete lowered the strength of resultant concrete, therefore, the research must be oriented towards ternary systems that helps in overcoming this drawback of use of plastics in concrete. Emphasis has been given to grind the waste into fine powder and mix into such proportion so as to achieve maximum packing density which may result to increase in compressive strength.

NEED FOR FURTHER WORK:

It is necessary to work out a project proposal to carry out further studies on various aspects such as collection, processing and effective utilization of this waste material. To start with, such a study could be initiated with the following components:

1. Estimation of the types, quantity and useful components present in the waste plastic materials in the city and surrounding areas.
2. Methodology for collection and sorting out the useful components of the plastic waste.
3. Methodology for processing the plastic bags as required for use in the preparation of modified bitumen, including cleaning, shredding and further processing of the plastic waste materials.
4. Identification of two or three construction companies / entrepreneurs who could incorporate appropriate mixing units in their hot mix plant to add and mix the required proportion of the processed plastic additive.
5. Carrying out further laboratory investigations, construction of some test tracks and field studies on the performance of concrete using the modified concrete.
6. Preparation of specifications and standards for the construction industry. It is hoped that on completion of the above project, the plastic waste materials will be put to effective use in construction industry, resulting in improved environmentally friendly concrete structures and also relief from the waste plastic materials being littered all around urban areas.

REFERENCES

Ghernouti Y; Rabehi B; Safi B and Chaid R. 2012. Use of recycled plastic bag waste in the concrete, Volume 8, ISSN 1314-7269.

Kumar M and Goyal, S. 2008. Laboratory investigation of the properties of concrete containing recycled plastic waste.

Tomas, UG. 2014.Effect of Thermoplastic as Fine Aggregate to Concrete Mixture,IJAST, 62:31-42.

Zoorob SE and Suparma BL. 2000. Laboratory design and investigation of continiously graded asphaltic concrete containing recycled plastic aggregate replacement, Cement and Concrete Composite 22-233-242.

Pantsios A. 2015. 8 Million Metric Tons of Plastic Dumped Into World‟s Oceans Each Year, http://ecowatch.com/2015/02/16/8-million-tons-plasticdumped-into-oceans/ [Accessed 16 February 2015].

Schwartzfeb J. 2015. Study Finds Rising Levels of Plastics in Oceans, http://www.nytimes.com/2015/02/13/science/earth/plastic-ocean-waste-levelsgoing-up-study-says.html?_r=0 [Accessed 13 February 2015].

Wikipedia, Compressive Strength, https://en.wikipedia.org/wiki/Compressive_strength .