PRODUCTION OF CONCRETE BY UTILIZING WASTE AS A PARTIAL REPLACEMENT OF COARSE AGGREGATE

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A Thesis Submitted to the Department of Civil Engineering in Partial Fulfillment for the degree of Bachelor of Science in Civil Engineering



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147/I, GREEN ROAD, PANTHAPATH, DHAKA-1215, BANGLADESH

SECTION: 21 B

SEMESTER-YEAR (SPRING-2024)

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Dedicated
To
Our beloved parent's"

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ABSTRACT

The research examines the mechanical and durability characteristics of concrete incorporating waste plastic-based aggregate in lieu of natural coarse aggregate. The investigation encompasses various parameters including compressive strength, impermeability, and water resistance. The study underscores the growing significance of plastic waste within municipal solid waste streams, presenting a pressing environmental challenge due to its persistent presence and visual impact. Concurrently, the escalating pace of urbanization, particularly in developing nations, compounds the strain on natural resource reserves earmarked for the construction sector. Addressing these dual challenges necessitates effective waste management strategies, such as repurposing plastic waste into valuable construction materials. Consequently, the principal aim of this study is to evaluate the feasibility of integrating plastic waste as a substitute for coarse aggregates in concrete formulations.

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CHAPTER 1
INTRODUCTION

1.1 General

Traditional concrete has a history of more than two thousand years and its technical development is still proceeding. Partial replacement of coarse aggregate can be a great advantage of technical development. Plastic waste can be the possible replacement of coarse aggregate which will improve the concrete quality. Plastic waste can be effectively utilized as partial replacement of coarse aggregate for the possible solution of plastic waste pollution. The production of construction and demolition waste (CDW) in the Dhaka City is increases every year, which is becoming a problem for the environment. Therefore, the good use of this material will greatly reduce pollution. On the other hand, Dhaka is going through a construction expansion, widening and modernization of urban zones that bring an increase in waterproof areas, creating greater superficial runoff water to evacuate. If the city continues to grow under the traditional concept of evacuating its rainwater with the present system, sooner or later it will not be enough. previous concrete is a special type of highly porous concrete because when it is mixedwith plastic material at all it allows high volumes of water to pass through into the previous concrete by means of filtration (ACI, 2010). Therefore, it would address a solution to the production of construction and demolition waste and it would help to evacuate rainwater. Moreover, by being done with material, it would make it an environmentally friendly product. previous concrete is a concrete of consisting Portland cement, coarse aggregate, little or no fine aggregate, admixtures and water (ACI, 2010). The combination of these ingredients will produce a hardened material with connected pores, ranging in size from 02 to 15 mm, which allow water to pass through easily. The void content of previous concrete can range 18% to 35% with typical water to cement (w/c) ratio of 0.35 to 0.50 (NRMCA, 2004). Infiltration rate of previous concrete depends on aggregate size and density of mixture. Permeability of a pavement is in range of 200 to 800 cm/h are commonly observed. But permeability more than 2000 cm/h is indicating lower compressive strength of concrete (Bean et al., 2012). In Dhaka city the ground water table has downed to 61.18 m. Bangladesh AgriculturalDevelopment Corporation (BADC) informs that the ground water of Dhaka city has downed 35 m within last 11 years. According to WASA, water table of Dhaka city was 11.3 m below the ground in 70th century. In 80th century it is increased to 20 m water table has been decrease by an average depth of 3 m in each year from 1997 to 2007. According to Environmentalist of BADC the reason for the occurrence the 80% people of Dhaka city fulfill their daily demand from underground water and other one is ground of Dhaka city are getting paved or covered by roof due to rapid urbanization (Miah, 2008). Utilization of previous concrete in pavement and other area can minimize this problem. For safety purposes the previous concrete must have strength to carry the applied load on pavement or other areas. previous concrete can be designed to attained a compressive strength of 2.8 to 28 MPa but strength 2.8 to 10 MPa are most common (NRMCA, 2004). Addition of certain amount of fine aggregate to this concrete generally may reduce the void ratio and increase the compressive strength which may be certain in desirable situation. previous concrete is also a light weight concrete with density ranging from 1600 kg/m^3 to 1900 kg/m^3 (Obla, 2010). Güneyisi (2016) used coarse aggregate of crushed concrete and natural fine aggregate. In this research, concrete mixes ranging from 0-100% of RA. Concrete with 100% RAhad 14 MPa of

compressive strength and 1 MPa of flexural strength. In addition, they reported a permeability of 12.5 mm/s. Bhutta et al. (2012) developed previous concrete with the use of crushed concrete as coarse aggregate, obtaining a compressive strength of 10 MPa, a flexural strength of 1.8 MPa and a permeability of 35mm/s.Permeability, water absorption capacity and light weight properties are the main reason of using previous concrete. This Study summarizes the effects of plastic aggregate on the properties of previous concrete such as compressive strength, permeability. In addition to effects of water-cement ratio, aggregate cement ratio as well as plastic aggregate also studied in this research.

1.1.1 Field of Applications

Permeability, water absorption capacity and light weight properties are the main reason of using previous concrete in wide field. Pavements are dominant application for previous concrete in U.S as evident of Fig. 1.1 to Fig. 1.3. It has also been used asa structural material for many years in Europe. Application includes walls for high rise building, in fill panels for high rise buildings, sea groins, roads and parking lots. Table-1 shows various application of previous concrete.



Fig. 1.1.2: Application of previous concrete in pavements



Fig. 1.1.3: Application of previous concrete in road sides



Fig. 1.1.4: Application of previous concrete in tennis court

Low-volume pavements
Residential Roads, alleys and driveways
Sidewalks and pathways
Parking areas
Tennis courts
Sub base for conventional concrete pavements
Patios
Artificial reefs
Slop stabilization
Well linings
Tree grates in sidewalks
Foundation/floors for green houses, aquatic amusement centers and zoos
Hydraulic structures
Swimming pools decks
Pavement edge drains
Groins and seawalls

1.2 Research Objectives

1.2.1 The objectives of this study are as follows:

To produce alternative concrete.

To reduce environment pollution by recyling plastic waste.

To investigate the physical and mechanical properties of the concrete.

1.2.2 Scope of the Study

The present investigation addressed the strength of previous concrete by varying the percentage of plastic aggregate and water cement ratio. The study also includes the variation of permeability of previous concrete with the variation of plastic aggregate, water cement ratio. The water cement ratio was constant as 0.40, 0.45 and 0.50; Aggregate sizes was 19 mm downgraded; Cement aggregate ratio was 1:2:4 and percent of plastic were 0%, 2%, 5%. 7%, 10%, 12% and 15% used in this study. In this study compressive strength, void ratio and permeability are tested of the porous concrete.

1.3 Organization of the Thesis

1.3.1 This thesis covered by five chapters which are given below:

Chapter 1: Gives general, field of the application, objectives of the study andorganization of the thesis.
Chapter 2: Presents the general, background and properties of constituent materialsto the present study.
Chapter 3: Covers the general, materials, test of concrete making materials, mix design, preparation of specimens and testing of concrete.
Chapter 4: Results and discussions of this study are presented in a detailed manner in this chapter, categorized in the form of tables and graphical representation.
Chapter 5: In this chapter conclusion and recommendation are pre

CHAPTER 2
LITERATURE REVIEW

2.1 General

Discussion of the global plastic waste crisis, including statistics on production, consumption, and waste generation. Highlighting of environmental impacts such as pollution, habitat destruction, and wildlife endangerment.Life cycle assessments (LCAs) have been conducted to compare the environmental impacts of plastic waste concrete with conventional concrete. Plastic aggregates have the potential to replace natural resources and, in the process, address the issue of sustainability and environmental degradation, thus some countries outside Bangladesh have been using the product satisfactorily. However, the material is not used in large scale due to the lack of technical data, mix design specifications and quality control/quality assurance guidelines in the processing of plastic concrete aggregates and in the production of concrete comprising of plastic aggregates. In addition, there is a preconceived, albeit unjustified, perception that concrete made with plastic aggregates is inherently of inferior quality.

2.2 Background

In the present work, an attempt was made to collect the available literature on the performance of previous concrete by using partial replacement of plastic concrete aggregates. Here some of the main literature review was presented. The work ability test for on- concrete has been studied by brook in 1982. A visual check to ensure even costing of all particles is adequate. No fines concrete must be placed very rapidly because the thin layer cement paste can dry out; this would reducein strength. He also suggested no compaction should be applied to no fine concrete, but roding in corners of form works and around obstacles may be useful. Vibration other than very short duration can cause the cement paste to run of the aggregate. Malhotra (1976) suggested, because young no-fines concrete exhibits very little cohesion, form-work must remain in place until sufficient strength has been developed to hold the material together in this connection. Moist curing is important, especially in a dry climate or under windy conditions, because of small thickness of cement paste involved. Menninger (1988) carried out tests to find out the air void of no-fines concrete, he has suggested that no-fines concrete has at least a 15% air-void content on pavement around tests and in domestic car parks. Maguesvari and Narasimha (2013) studied the development of environmentally friendly material-porous concrete. They concluded that the increase in variation of cement content and percentage of addition of fine aggregate leads to increase in compressive strength, flexural strength and split tensile strength. And also, coefficient of permeability decreases with increase in variation of cement content. Rizvi et al. (2009) studied the incorporation of recycled concrete aggregate in previous concrete pavements. It was determined that the optimum replacement percentage for PA is 15% as it doesn't significantly affect the previous concrete. Koehler and Fowler (2007) studied the influence of recycled aggregate based previousconcrete with fly

ash. The result shows that the use of fully recycled aggregates gave desirable results in both strength and infiltration when compared to partially replaced plastic aggregate. Joshi and Dave (2016) discussed various combination of previous concrete with different aggregate size and w/c ratio. It was found that using 0.3 w/c ratio gives better strength and the density increases with increase in compressive strength. Literature review indicates that previous concrete can be used as a sustainable material. Therefore, the aim and objective of the present study is to carry out an experimental study on performance characteristics of previous concrete by usingpartial replacement of recycled concrete aggregate. Otani et al. (2005) studied the strength of previous concrete with four types of aggregates, namely natural, recycled concrete, blast-furnace and artificial lightweight. The results showed that the strength of previous concrete is affected by the density of aggregate. At a given porosity, the use of low modulus aggregate produced a significant reduction in the compressive strength. They also found that the type of cement had marginal effect on the strength of previous concrete having the same void content. According to NRMCA (2004), structural lightweight concrete has an in-place density (unit weight) on the order of 90 to 115 lb/ft^3 (1440 to 1840 kg/m^3) compared to normal weight concrete with a density in the range of 140 to 150 lb/ft^3 (2240 to 2400 kg/m^3). For structural applications the concrete strength should be greater than 2500 psi (17.0 MPa). The concrete mixture is made with a lightweight coarse aggregate. Void ratio is 14% to 31% and no fine aggregate ranging with w/c ratio of 0.35 to 0.50. This study discusses the development of previous concrete with plastic aggregate replacing stone aggregate. Compressive strength, void ratio and permeability of previous concrete using plastic aggregate have been investigated. Effects of water to cement ratio and plastic aggregated have been focused here. Correlation between void ratio and permeability was studied also. This paper also summarizes the percent replacement of plastic aggregate without affecting the properties of previous concrete.

2.3 Properties of Constituent Materials

The concrete mix consisted of Portland composite cement and coarse aggregate. The plastic aggregate was used as coarse aggregate replacing 0%, 2%, 5%, 7%, 10%, 12% & 15% of stone chips aggregate.

2.3.1 Cement

Cement is a fine gray powder that is mixed with water and aggregate to make concrete. Portland Cement is a type of cement, not a brand name. Many cement manufacturers make Portland Cement. It is a basic ingredient of concrete, made using a closely controlled chemical combination of calcium, silicon, aluminum, iron and small amounts of other ingredients to which gypsum is added in the final grinding process to regulate the setting time of the concrete. According to ASTM standard specification, the initial and final setting times were used 132 min and 310 minutes respectively (ASTM C150, 2004). They should be free from lumps, auditorium.

2.3.2 Water

Generally, portable water free from salts is used for casting and curing of

concrete. ater quality used in previous concrete should be the same as that used in conventional concrete: portable water, drinkable water, or tap water. Due to thesensitivity of previous concrete, water quality is very important.

2.3.3 Stone chips

BLACK STONE is commonly used in construction and landscaping projects. These stone chips serve as a versatile material for pathways, driveways, gardens, and other outdoor areas. They provide a natural and elegant look, enhancing the overall aesthetic appeal of any space. Whether it's for residential or commercial applications, the BLACK STONE is an excellent choice for adding a touch of sophistication to your project.

2.3.4 Plastic aggregate

A plastic is a large molecule made up of chains or rings of linked repeating subunits, which are called monomers. The word plastic designates an unspecified number of monomer units. When the number of monomers is very large, the compound is sometimes called a high plastic. plastics may be divided into two categories: 1.
Natural plastics 2. Synthetic plastics.
Examples of synthetic plastics include PVC (polyvinyl chloride), polystyrene, synthetic rubber, silicone, polyethylene, neoprene, and nylon. Synthetic plastics are used to make s, adhesives, paints, mechanical parts, and many common objects.s are a wide range of synthetic or semi-synthetic materials that use plastics asa main ingredient.

- ✓ Water Bottle and cap.
- ✓ Disposable coffee cups.
- ✓ Wine bottles with stoppers or screw lids.
- ✓ Chewing gum.
- ✓ Shopping bags.
- ✓ Toiletries containing micro-beads.
- ✓ Disposable pens

The success and dominance of s starting in the early 20th century has caused widespread environmental problems, due to their slow decomposition rate in natural ecosystems. Toward the end of the 20th century, the s industry promoted recycling in order to ease environmental concerns while continuing to produce virgin and to push the responsibility of pollution onto the consumer. Some pictures on plastic are shown in Figs. 2.1 to 2.3.



Fig. 2.3.5: Water bottle and cap of plastic



Fig. 2.3.6: Waste of plastic

CHAPTER 3

METHODOLOGY AND EXPERIMENTAL PROGRAM

3.1 General

This chapter presents materials and methodology used in the present study. Mixes were prepared using Portland composite cement with plastic aggregates. Water cement ratio was different (0.40, 0.45 and 0.50) in all mixes. There 9 phases of mixture. It has been used cement-aggregate ratio as 1:2:4. The ratio was based on weight basis. Experimental program accomplished into three phases. The first phase consisted of general tests to determine the physical properties. The second phase involved casting of different size cylinders in the laboratory and curing for 7 and 28 days. The third phase comprised of testing of three cylinders to know the crushing strength and permeability.

3.2 Materials

3.2.1 Cement

Portland composite cement was used as binding material for the preparation of previous concrete locally produced special Shah cement were use and stored them in air tight container. Fig. 3.1 shows the picture of cement used in this study.



Fig. 3.2.2: Cement



Fig. 3.2.3: Sand



Fig. 3.2.4: Plastic



Fig. 3.2.5: Stone Chips

3.3 Tests of Concrete Making Materials

Stone chips and waste plastic are used as a concrete making material. Stone chips have been tested for gradation, absorption capacity, specific gravity and unit weight whereas plastic aggregates have been tested for absorption capacity, specific gravity and unit weight. Test procedure of them have been described below.

3.3.1 Unit weight

The weight per unit volume is known as ″unit weight″. ASTM C 127 (2004) has been used to perform this test. The cylinder is filled 1/3rd full of aggregate and roded witha 5/8-inch tamping rod for 25 Nos stoke, uniform distributed over the surface. Thenthe cylinder is 2/3rd full and roded in same way as before. In this way the cylinder is completely full and leveled off the top of cylinder. The weight of the cylinder with full of aggregate is taken. Now the weight of the aggregate is weight with cylinder minus the weight of cylinder when empty.

Weight of aggregate =A

Volume of aggregate or Volume of cylinder =B

Hence the unit weight of aggregate =A/B

3.3.2 Absorption capacity

The surface moisture is expressed as a percentage of the difference between the weight of the moist aggregate and the weight of the saturated but surface dry aggregate dividing by the weight of the saturated but surface dry aggregate. ASTM C 127 (2004) has been used to perform this test. Therefore, surface moisture content = (wt. of moist aggregate – wt. of SSD)/ wt. of saturate but surface dry aggregate. Since absorption represents the water contented in the aggregate in a saturated and surface dry condition, the moisture content in the water in excess of that state the total water content of a moist aggregate is equal to the sum of absorption and moisture content. Therefore, the absorption of aggregate = (wt. of aggregate in SSD condition – wt. of aggregate in oven dried condition)/ wt. of aggregate in oven dried condition.

3.3.3 Specific gravity

The absorption specific gravity refers to the volume of the solid materials excluding all pores and can be defined as the ratio of the weight of solid, refers to vacuum, to the weight of an equal volume of gas-free distilled water at 4℃. The apparent specific gravity is the ratio of the weight of the aggregate dried in an oven (100 to 110) ℃ for 24 hours to the weight of the water occupying a volume equal to that of the solid including the impermeable pores. ASTM C 127 (2004) has been used to perform this test. Specific gravity of aggregate = (Oven dry weight of aggregate / weight of water displaced by aggregate).

3.3.4 Fineness modulus

The aggregate was used sizes of 19 mm downgraded for this study. 19 mm downgraded aggregates were retained on 10 mm sieve and 10 mm downgraded aggregate were retained on 4.75 mm sieve. 4.75 mm downgraded aggregate were retained on 2.36 mm sieve. 19 mm downgraded aggregate is well graded due to combination with lower sizes aggregate. So, for this experiment 19mm downgraded aggregate are used. This test is carried only for stone chips. American standard sieve sizes are 75mm, 37.5mm, 19mm, 10mm, 4.8mm, 2.4mm, 1.2mm, 0.6mm, 0.3mm and 0.2mm used. Retained aggregate are converted as percentage, this percentage are converted into cumulative summation, The summation is all of cumulative are divided by 100. This result is called FM (Fineness modulus). 19mm downgraded coarse aggregate are found out. ASTM C 136 (2004) has been used to perform this test.

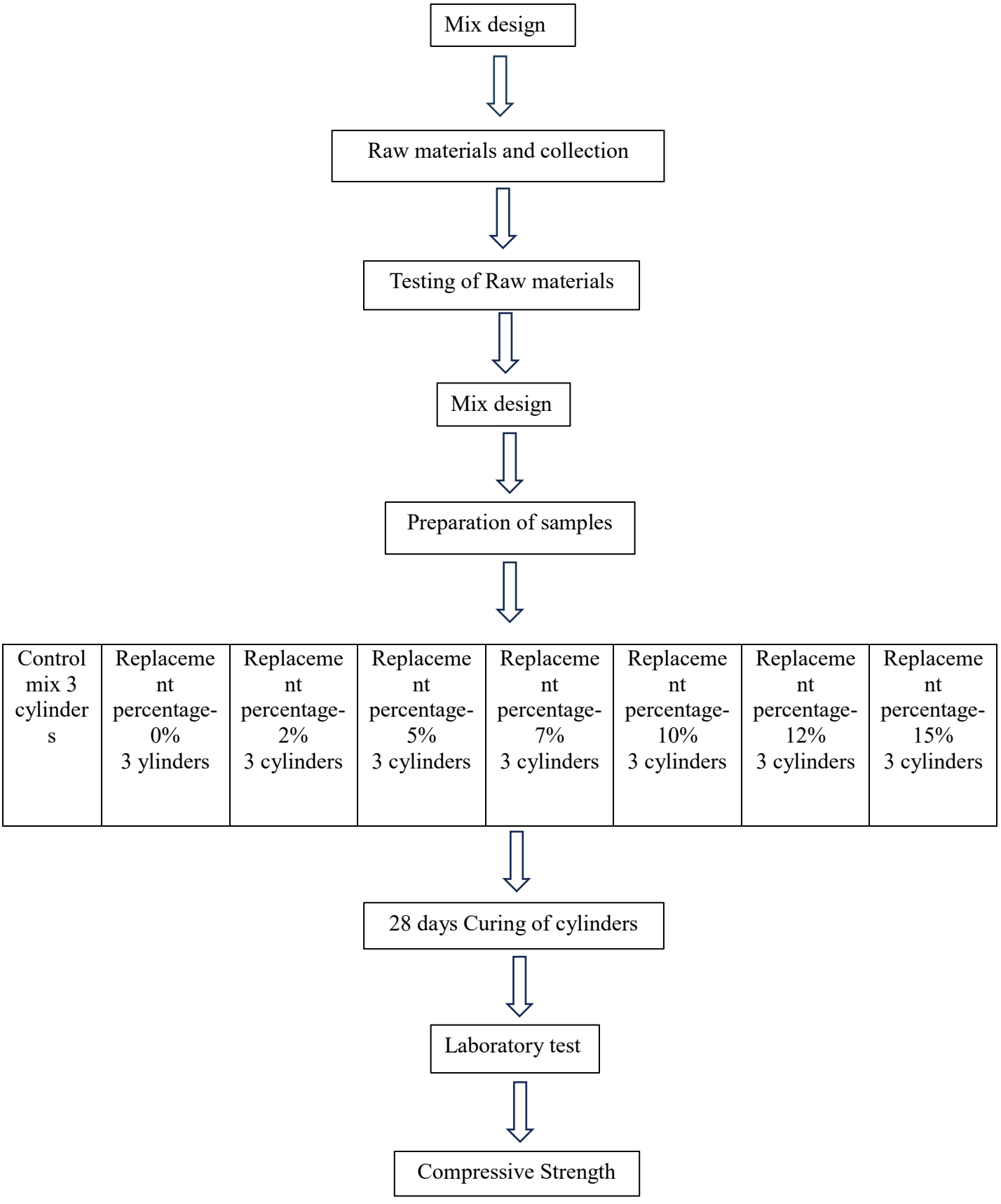


Fig 3.3.5: Methodology flow Chart

3.4 Mix Design

Mix design is not conducted. In this study used cement aggregate ratio 1:3. Cement aggregate ratio was based on weight basis. There were 9 phases that we have studiedin the study for 0%, 10% and 20%. Water cement ratio also was different that was 0.40, 0.45 and 0.50.

3.5 Preparation of Specimens

For mixing concrete machine mixing was selected. To improve the bond between the aggregate and cement paste, aggregate was first mixed with dry cement for one minute and half of the water was added and mixed for one minute. Next the remainingcement and water was added. Finally, the concrete was mixed three minutes and then mixed for additional two minutes before casting. Specimens were placed by rodding 25 times in three layers. The sample were demolded after 24 hour and then placed in water storage tanks at room temperature and cured. Before compression test the top surface of cylinder were grind smoothly instead of sulfur capping. A typical previous concrete mixture is shown in Fig. 3.5.



Fig. 3.2.6: A typical previous concrete mixture



Fig. 3.2.7: Cylinder

3.6 Testing of Concretes

3.6.1 Compressive strength

The compression strength of cylinder was tested according to ASTM C39 (2004). Cylinders of 100 mm × 200 mm were used for compression strength test. Fig 3.6 is shown specimen prepared for compressive strength. A failure surface of specimen after compression test is given in Fig 3.7 and Fig. 3.8. The sample is measured in diameter and applied load on it. The load applied for crush of cylinder to the area of cylinder is a compressive strength.



Fig. 3.6.2: Compressive Strength Load



Fig. 3.6.3: Specimen after application of compressive load

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 General

The present study deals with the compressive strength, void ratio and permeability of previous concrete using different proportion of plastic as coarse aggregate with w/c ratio of 0.40, 0.45 and 0.50. Total 63 concrete cylinders, where 45 (100mm × 200mm) and 9 (150mm × 300mm) concrete cylinders were cast for compressive strength test and 9 (100mm × 100 mm) were tested for permeability tests. The test results and analysis are discussed below.

4.2 Properties of Materials

4.2.1 Gradation of Stone chips

Stone chips are used in this study as coarse aggregates. Fig. 4.1 shows the gradation curve of 19 mm downgraded stone aggregates. Table 4.1 shows the properties of Stone chips.

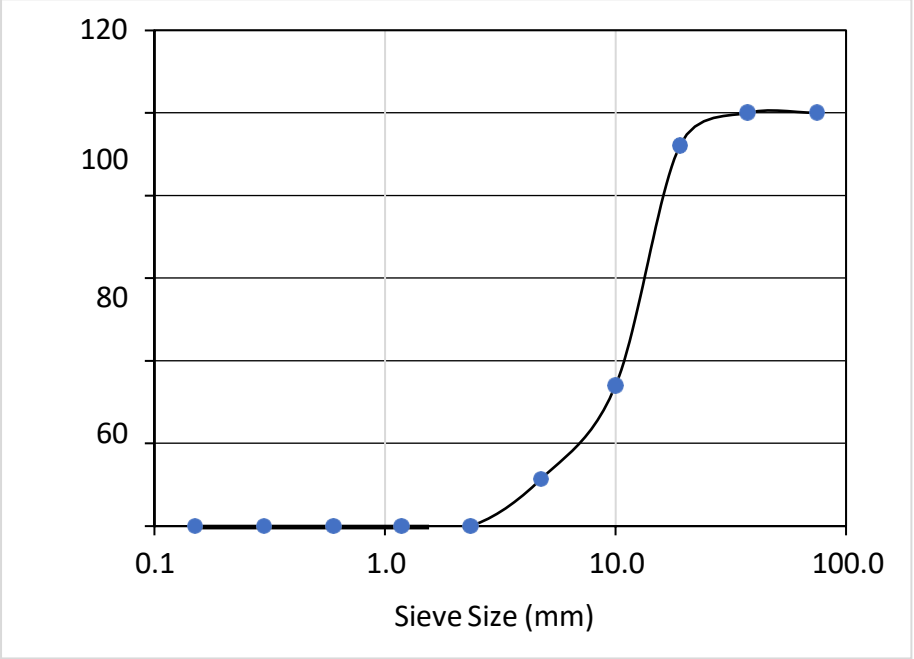


Fig. 4.1.2: Gradation of stone chips

4.2.2 Test for plastic

caps are mainly produced from high density polyethylene (HDPE) and polypropylene (PP). The size of plastic was used día 31 mm and Height 13 mm. Theproperties of plastic aggregate .

Properties	Value	
	Stone chips	plastic aggregate
Bulk specific gravity	1.78	1.06
Bulk unit weight (kg/m^3)	939	190
Apparent specific gravity	2.53	1.14
Absorption capacity (%)	11.50	6.50
Fineness Modulus	6.63	-

Table 4.2.3: Properties of stone chips and plastic aggregate

4.3 Properties of Concretes

4.3.1 Compressive strength

Figs. Below show the 28-days compressive strength of concretes. It has been found that the compressive strengths were decreasing with the percent replacement of plastic aggregate. Poor interlocking between cement pastes and plastic aggregate decreases the compressive strength of concretes.

4.3.2 Results and Discussions

Types of Block	Serial No	Sample ID	Crushing Strength MPa	Average Crushing Strength MPa
Pastic waste in cylinder 0%	1	CE-0%	27.5	27
	2	CE-0%	25.7	
	3	CE-0%	28.2	
Pastic waste in cylinder 2%	1	CE-2%	22.8	22
	2	CE-2%	20.9	
	3	CE-2%	21.4	
Pastic waste in cylinder 5%	1	CE-5%	17.3	18
	2	CE-5%	19.5	
	3	CE-5%	16.4	

Types of Block	Serial No	Sample ID	Crushing Strength MPa	Average Crushing Strength MPa
Pastic waste in cylinder 7%	1	CE-7%	15.3	15
	2	CE-7%	14.0	
	3	CE-7%	15.2	
Pastic waste in cylinder 10%	1	CE-10%	11.0	12
	2	CE-10%	12.8	
	3	CE-10%	13.2	
Pastic waste in cylinder 12%	1	CE-12%	11.0	10
	2	CE-12%	10.4	
	3	CE-12%	9.6	
Pastic waste in cylinder 15%	1	CE-12%	8.4	8
	2	CE-12%	7.9	
	3	CE-12%	7.2	

Table : 4.3.3: Compresive strength of different types of cylinder

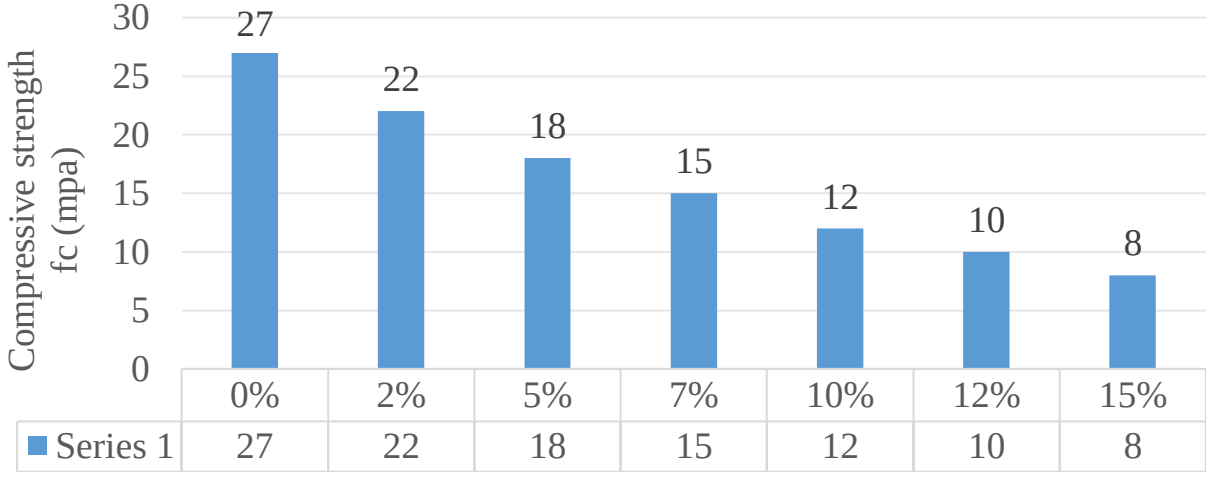


Fig: 4.3.4: 28 days Compressive strength of difference type of concrete

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The researchers have portrayed plastic waste in various forms as coarse aggregate for concrete production. They primarily concentrated on analyzing the compressive strength of concrete incorporating plastics, while giving minimal consideration to other concrete properties. These propositions stemmed from experimental findings derived from casting different concrete samples. Plastic was incorporated into the concrete by substituting coarse aggregates at proportions of 0%, 2%, 5%, 7%, 10%, 12%, 15%. Based on the outcomes of the current study, the following conclusions were drawn 28 days compressive strength of 0%, 2%, 5%, 7%, 10%, 12%, 15% concrete are 27 Mpa, 22 Mpa, 18 Mpa, 15 Mpa, 12 Mpa, 10 Mpa, 8 Mpa. Here 2% and 5% cylinder compressive strength 22 Mpa and 18 Mpa these value are in the reference range.

5.2 Recommendations

The following recommendation may be proposed for further study:

- Number of sample for each test should be increased.
- Before using this types of concretes cylinder commercially in building construction more extensive research is need to be done.
- For satisfying strength requirement, strength improving admixtures can be used fo1further research.

Various plastic aggregate size and type of plastic may be used for further research and to get more desired strength

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APPENDIX

Table A1: Gradation of coarse aggregate (19 mm downgraded aggregate)Fineness modulus of coarse aggregate (Stone chips) are shown below:

Sieve Size	SieveSize (mm)	Weight Retained (gm)	% Weight Retained	Cumulative % wt. retained	% Finer	F.M
3"	75.0	0	0	0.0	100	
1.5"	37.5	0	0	0.0	100	
0.75"	19.0	158	7.9	7.9	92.1	
0.375"	10.0	1163	58.2	66.1	34.0	
#4	4.8	452	22.6	88.7	11.4	
#8	2.4	227	11.4	100	0	6.63
#16	1.2	0	0	100	0	
#30	0.6	0	0	100	0	
#50	0.3	0	0	100	0	
#100	0.2	0	0	100	0	
Pan	Pan					
	Sum. of Total Weight =	2000	Sum. of Cum. Weight =	662.6		

TableA2: Compressive strength test result for different percentage PA with w/c ratio 0.40 at 28 days

From the result of compressive strength test of concrete strength decrease with the increasing of percentage plastic:

0% plastic								
Sample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kN)	Crushing Strength (Mpa)	Average Crushing Strength (Mpa)
1	99	98	99	98.7	7942.1	137	17.25	17.68
2	98	99	99	98.7	7642.1	136	17.80	
3	98.5	99	100	99.2	7719.7	139	18.00	
2 % plastic								
Sample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kN)	Crushing Strength (Mpa)	Average Crushing Strength (Mpa)
1	99	99.5	99	99.17	7724.14	120	15.53	15.44
2	98	99	98	98.33	7593.84	117	15.40	
3	98	99	99.5	97.5	7466.19	115	15.40	
5 % plastic								
Sample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kn)	Crushing Strength (Mpa)	Average Crushing Strength (Mpa)
1	99	99.5	99	99.17	7806.93	107	13.71	13.27
2	98	97	99	98	7542.96	102	13.52	
3	99.5	98.5	99	99	7697.69	97	12.60	
7 % plastic								
Sample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kn)	Crushing Strength (Mpa)	Average Crushing (Mpa)
1	98	99	98	98.33	7593.85	95	12.51	11.94
2	99	98	98.5	98.50	7620.12	91	11.94	
3	99.5	98.5	98	98.67	7646.46	87	11.38	
10 % plastic								
sSample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kn)	Crushing Strength (Mpa)	Average Crushing (Mpa)
1	99	99.5	99	99.17	7724.14	85	11.00	10.65
2	99.5	98.5	98.5	98.83	7671.27	83	10.82	
3	99.5	99.5	98	99	7697.68	78	10.13	
12 % plastic								

Sample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kn)	Crushing Strength (Mpa)	Average Crushing Strength (Mpa)
1	99.5	99	99	99.17	7724.15	65	8.42	7.92
2	99	98.5	99.5	99	7697.69	61	7.92	
3	99.5	98.5	98.5	98.83	7671.27	57	7.43	
15 % plastic								
Sample No	Diameter (mm)			Average Dia (mm)	Average Area (mm^2)	Crushing Load (kn)	Crushing Strength (Mpa)	Average Crushing Strength (Mpa)
1	99	99.5	99	99.17	7724.15	45	5.83	5.32
2	99.5	99.5	98.5	99.17	7724.15	40	5.18	
3	99.5	98.5	98	98.67	7646.46	38	4.97	