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PULCHOWK CAMPUS

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Experimental Study on the Properties of Concrete with Partial Replacement of Sand by Plastic Pet Bottle Fiber

by

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ABSTRACT

The suitability of plastic pet bottle fiber as fine aggregate in concrete and its advantages are discussed here. The effect of the plastic fiber as a partial replacement of sand in concrete production was studied here. Several things which were invented for our convenient life are responsible for polluting environment due to improper waste management technique. Polyethylene Terephthalate (PET) is routinely used for carbonated beverage and water bottles. This is an environmental issue as waste plastic bottles are difficult to biodegrade. In the Modern world, the construction industry is searching for cost-effective materials for enhancing the strength of concrete structures. This work is carried out with use of waste PET bottles as the partial replacement of fine aggregate in Ordinary Portland cement. As 100% replacement of natural fine aggregate with plastic fine aggregate is not feasible, partial replacement at various percentage were examined.

The properties of the materials were determined before the experimental works were carried out. The normal consistency, soundness, initial and final setting time, compressive strength and specific gravity of cement used for the experiment were found as 31%, 3mm ,65minutes, 280minutes, 59.38N/mm^2 and 3.15 respectively. Water absorption and specific gravity of fine aggregate were found 1.40% and 2.63 respectively and for coarse aggregate were 1.19% and 2.69 respectively. Sieve Analysis was performed to determine the particle size distribution of sand and coarse aggregates from the fineness modulus, the average size of particle of sand and coarse aggregates used for the experimental works were found.

M20 grade of concrete was prepared at 0.50 water cement ratio. Concrete cube of 150x150x150mm and beam of size 75x75x300mm were prepared for the tests. Cube specimens, beam specimens were casted, cured and tested for 7 day and 28 days strength. Concrete with 1%, 2%, 2.5%, 3% and 5% PET bottle fibers for fine aggregate were produced and compared against control mix with no replacement of sand. Tests such as Compressive strength test and flexural strength test were done and the results were compared with control specimens. The observed results revealed an increase in compression and Flexural strength up to 2%-2.5% of sand replacement. hence with the increasing demand for fine aggregate, PET bottle fiber replacements can be adopted. This study was carried out to investigate the properties of concrete with plastic pet bottle fiber as partial replacement of fine aggregates.

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List of Acronym and Abbreviation

PUF:	Polyurethane Formaldehyde
PET:	Polyethylene Terephthalate
LDPE:	Low Density Polyethylene
HDPE:	High Density Polyethylene
UPVC:	Unplasticised Polyvinyl Chloride
PPVC:	Plasticised Polyvinyl Chloride
PP:	Polypropylene
PS:	Polystyrene
PA:	Polyamides
CD:	Compact Disc
PVC:	Polyvinyl Chloride
PE:	Polyethylene
MM:	Millimeter
Kg:	Kilogram
Kg/mm^2:	Kilogram per Square millimeter
KN:	Kilo Newton
^0C:	Degree Centigrade
%:	Percentage
IS:	Indian Standard
UNEP:	United Nation Environment Programme

CHAPTER ONE

INTRODUCTION

1.1 Background

Concrete is widely used materials in the world. Based on global uses it is placed at second position after water. Concrete is a composite material consists of fine aggregate and coarse aggregate bonded together with cement paste that hardens with time. It requires workability, strength and durability that cannot be obtained with techniques and materials adopted for producing conventional cement concrete. Fine aggregate is important construction materials, which is widely used in construction works. Nowadays the cost of concrete is increasing since the cost of fine aggregates increasing. To reduce the requirements and cost of concrete some alternatives materials are needed to replace the fine aggregates.

River sand is one of the constituents used in the production of the conventional concrete has become highly expensive and scarcity. In the backdrop of such a bleak atmosphere, there is large demand for alternative materials from the industrial and household waste. The waste plastic pet bottle can be used as an alternative material for replacement of the sand. The rapid urbanization and industrialization all over the world has resulted in large deposition of waste polymer materials.

The world's annual consumption of plastic materials has increased from around 5 million tons in the 1950s to nearly 300 million tons in 2015 (Plastic : the fact 2015). Plastic waste materials consist of surplus, obsolete, broken, old plastic furniture, different household plastic materials, equipment, anti-static packaging materials and devices made of plastic. These polymer wastes are almost non-degradable in the natural environment even after a long period of exposure.

Inclusion of polymer waste in concrete can be a proper utilization of this valuable property. Thus, utilization of waste polymer material in making concrete/mortar can be a good solution to this environmental hazard. Very few information is available regarding recycling of polyurethane formaldehyde (PUF) -based polymer wastes and its use as construction materials. Kathmandu alone uses around 4,700,000 to 4,800,000 plastic bags daily. In Nepal, 16 percent of urban waste is comprised of plastic, which is 2.7 tons of daily plastic garbage production (The Kathmandu post 5th June 2018). When you look at the global level the data is staggering. Researchers claim humans have produced 9.1 billion tons of plastic so far, and much of it ends up in nature causing harm to both living beings and the environment. The safe use of plastic waste is very important because plastics are normally stable and not biodegradable. The aim of this research is to investigate the effect of two types of waste plastic on strength of concrete.

1.2 Main Objective

To evaluate the possibility of using plastic pet bottle fiber as partial replacement of sand in concrete.

Specific objectives of this work include:

1) To study the effect of replacing sand with plastic pet bottle fiber on workability, compressive strength and flexural strength of concrete.
2) To study the effect of replacing sand with plastic pet bottle fiber on weight of concrete.
3) To find the optimum percentage of replacement of sand using plastic pet fiber.

1.3 Limitation of the Study

While carrying out this research, various limitations were considered. Due to this, the accuracy of the results obtained is limited. Some of them are as follows:

1) Only M20 grade of concrete was considered for the study and mixing was performed manually with hand.
2) The water cement ratio was chosen as 0.50 for the entire experimental works.
3) Plastic pet bottles are manually grinding of 3 mm size approximately.
4) Compressive strength test and Flexural strength test were carried out only for the samples cured for 7 days and 28 days.
5) Among various tests, compressive strength test and flexural strength test were performed to check the effect of Plastic PET bottles fiber on the properties of concrete.
6) Only 2 samples each for compressive and flexural test are casted for 7 and 28 days of experiments.

1.4 Organization of the Thesis

The whole thesis is composed of five main chapters. Chapter one gives the background information of the research work including the research objectives and hypothesis. Chapter two reviews the available literature relating to the topic and the description of the various materials, their properties and the experimental tests. Chapter three describes the whole research methodology starting from the material collection to the experimental program adapted to this research. Various material test are listed here along with their procedures. Also the obtained data from various test are shown in this chapter. Chapter four covers the analysis of the data mentioned in chapter three and the discussion and comparison of the results obtained with the previous research. Chapter five contains conclusion and recommendation based on the results obtained, establishing the objectives of the research. The remaining includes reference and appendices at the end to shape this thesis as a complete works.

CHAPTER TWO

LITERATURE REVIEW

This chapter provides an overview of previous studies related to the subject of this research work. This is done in order to scope out the key data collection requirements for the primary research to be conducted, and it formed part of the emergent research design process.

2.1 Introduction

Plastics are polymers, a very large molecule made up of smaller units called monomers which are joined together in a chain by a process called polymerization. The polymers generally contain carbon and hydrogen with, sometimes, other elements such as oxygen, nitrogen, chlorine or fluorine (UNEP, 2009). Plastics have become an integral part of our lives. The amount of plastics consumed annually has been growing steadily. Its low density, strength, user-friendly designs, fabrication capabilities, long life, lightweight, and low cost are the factors behind such phenomenal growth. Plastics have been used in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, water desalination, land/soil conservation, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses. With such large and varying applications, plastics contribute to an ever increasing volume in the solid waste stream. The world's annual consumption of plastic materials has increased from around 5 million tons in the 1950s to nearly100 million tons in 2001.Quantities of waste plastic have been rising rapidly during the recent decades due to the high increase in industrialization and the considerable improvement in the standards of living, but unfortunately, the majority of these waste quantities are not being recycled but rather abandoned causing certain serious problems such as the waste of natural resources and environmental pollution.

2.2 Types and Uses of Plastic:

Plastic are classified according to the basis of the polymer, from which they are made. The types of plastics that are most commonly reprocessed are polyethylene (PE), Polypropylene (PP), Polyethylene Terephthalate (PET), Polystyrene (PS), and Polyvinyl chloride (PVC).

Table 1: Details the types and uses of plastic and recycled plastic. (UNEP, 2009)

Type of plastic	Description	Some uses for virgin plastic	Some uses for recycled plastic
Polyethylene terephthalate(PET)	Clear tough plastic, may be used as a fiber	Soft drink and mineral water bottles	clear film for packaging, carpet fibers, fleecy jackets
Low density polyethylene (LDPE)	Soft, flexible plastic, milky white, unless a pigment is added	Lids of ice-cream containers, garbage bags, and garbage bins	Film for builders, industry, packaging and plant nurseries
High density Polyethylene (HDPE)	Very common plastic, usually white or colored	Crinkly shopping bags, freezer bags, and milk	Compost bins, Detergent bottles, crates , and mobile rubbish bins
Unplasticised Polyvinyl chloride (UPVC)	Hard rigid plastic, may be clear	Clear cordial and juice bottles, plumbing pipes and fittings	Detergent bottles, tiles, and plumbing pipe fittings
Plasticized Polyvinyl chloride (PPVC)	Flexible, clear, elastic Plastic	Garden hose, shoe soles, blood bags and tubing	Hose inner core, and industrial flooring
Polypropylene (PP)	Hard, but flexible plastic	Ice-cream containers, potato crisp bags, stools and chairs	Compost bins, kerb side recycling crates, and worm factories
Polystyrene (PS)	Rigid, brittle plastic. May be clear, glassy	cheap, transparent kitchen ware, light fittings, bottles, toys, and food containers	Clothes pegs, coat hangers , and video/CD boxes
Polyester (EPS)	Foamed, lightweight, energy absorbing ,and thermal insulation	Hot drink cups, and takeaway food containers	spools, rulers, and video/CD boxes
Polyamides (PA)	Nylons fibers,	toothbrush bristles, and fishing	

2.3 Previous studies related to using recycled plastic as aggregate:

Plastic aggregates used in many studies prepared from plastic waste obtained from different sources. As example plastic bottles were grinded in the laboratory by using a grinding machine and then sieved to get the suitable size fraction.

Akcaozoglu et al. (2009) reported that waste Poly-ethylene Terephthalate (PET) bottle granules can be used as lightweight aggregates of sizes between 0 to 4mm, in mortar. Tests were conducted on mortars prepared with only PET aggregates with PET and sand aggregates together and blast-furnace slag as the replacement of cement on mass basis up to 50% to reduce the amount of cement used and provide savings. The water–binder ratio and PET–binder ratios of 0.45 and 0.50 were used. It was reported that mortars containing only PET aggregate, mortar containing PET and sand aggregate, and mortars modified with slag as cement replacement can be considered as structural lightweight concretes, as far unit weight and strength properties are concerned. Authors further concluded that shredded waste PET granules can be used as aggregate in the production of structural lightweight concrete since shredded waste PET granules reduces the unit weight of concrete, being light. This is helpful in reduction of dead load of the structure as a whole, thus resulting in economy and reduced dead weight in seismic design. The eco-friendly advantages include reduction in the use of natural resources, disposal of wastes, prevention of environmental pollution, and energy saving.

Ramadev K.et. al. (2012) in his research paper “Experimental Investigation on the Properties of Concrete with Plastic PET (Bottle) Fibers as Fine Aggregates” investigates that Waste plastic bottles are major cause of solid waste disposal. Polyethylene Terephthalate (PET) is commonly used for carbonated beverage and water bottles. This is an environmental issue as waste plastic bottles are difficult to biodegrade and involves processes either to recycle or reuse. Concrete with 1%, 2%, 4% and 6% PET bottle fibers for fine aggregate were produced and compared against control mix with no replacement. Cube specimens, cylinder specimens and prism specimens of 18 numbers each were cast, cured and tested for 7 day and 28 days strength. This paper concluded that the concrete with PET fiber reduced the weight of concrete and thus if mortar with plastic fibers can be made into light weight concrete based on unit weight

(1) It was observed that the compressive strength increased up to 2% replacement of the fine aggregate with PET bottle fibers and it gradually decreased for 4% and 6% replacements. Hence replacement of fine aggregate with 2% replacement will be reasonable.
(2) It was observed that the split tensile strength increased up to 2% replacement of the fine aggregate with PET bottle fibers and it gradually decreased for 4% and 6% replacements. Hence, the replacement of the fine aggregate with 2% replacement will be reasonable with high split tensile strength compared to the other specimens casted and tested.
(3) It was observed that the flexural strength increased up to 2% replacement of the fine aggregate with PET bottle fibers and it gradually decreased for 4% and remains the same for 6% replacements.
(4) Hence, the replacement of the fine aggregate with 2% of PET bottle fibers will be reasonable than other replacement percentages like 4% and 6% as the compression and split tensile strength reduces gradually.

Frigione (2010) from Department of Engineering (Italy) had tried to reuse the plastic by recycling of pet bottle as partial replacement for fine aggregate in concrete. Sand in concrete was replaced by PET aggregates manufactured from the waste un-washed pet bottles to the extent of 5% by weight of fine aggregate. Specimens with different cement content and water/cement ratio were manufactured and various tests like compressive strength at 28 days and 365 days, workability test etc. were conducted. It was reported that the increase in strength at 365 days with respect to the value measured at 28 days is similar for the two concrete and in line with standard concrete. Compressive strength was slightly decreased when PET bottle aggregates were added in substitution of sand. From the stress-strain curve determined from compression test for the reference concrete and PET concrete, it was observed that these two types of concretes display very similar compressive strength trends. It was also concluded that for both type of fresh concretes, same workability was observed. Also, the difference in 28-days and one year compressive strength for ordinary concrete and PET concrete was very low for water: cement ratio of 0.45, but increased at higher water: cement ratios up to 0.55. Thus, it was felt that waste PET can be used in concrete without any special treatment and in eco-friendly manner.

Hopewell et al. (2009) found that adverse impact of plastics on surrounding can be reduced by recycling. Recycling reduces the quantity of wastes which are thrown in open areas, and also reduces the use of oil and emission of carbon dioxide. These recycled plastics are used for packaging, agricultural films, etc. It was also reported that substantial increase in the rate of recovery and recycling of plastic waste is possible.

Maqbool Younus et al (2019) studied Experimental investigation on the properties of concrete with plastic pet (bottle) fiber as partial replacement of fine aggregates with the varying percentage (1%, 2%, 2.5%, 3% and 5%) of the Plastic PET bottles. In this research we can found that the compressive strength of the concrete increase with increase in plastic fiber up to 2% added of the Plastic fiber, there after the Compressive strength reduces with increase of the addition of the plastic fiber. Whereas the Flexural strength of the Concrete increases with increases as percentage increase up to 2.5%. Thereafter it reduces with increase of the addition of the plastic fiber.

2.4 Laboratory test

2.4.1 Slump test

The slump of the concrete is measured by measuring the distance from the top of the slumped concrete to the level of the top of the slump cone. Place the mould on a smooth horizontal non- porous base plate. Fill the mould with the prepared concrete mix in 4 approximately equal layers. Tamp each layer with 25 strokes of the rounded end of the tamping rod in a uniform manner over the cross section of the mould.

The apparatus required for the slump test includes –Standard moulds (frustum of the cone), standard flat base plate preferably steel, standard tamping rod, standard graduated steel rule from 0 to 300mm at 5mm intervals and a scoop approximately 100mm wide.

2.4.2 Compressive strength test

Out of many test applied to the concrete, compressive test is an important test which gives an idea about all characteristics of concrete. By this single test one can determine whether the concreting has been done properly or not. Compressive strength of the concrete depends on many factors such as water cement ratio, cement strength, quality of the concrete materials and quality control during production of the concrete. The compressive strength test of the cube generally size of the 15 mm determined by the help of the compression testing machine, the compression plate of which shall have ball seating in the form of portion of a sphere center of which coincides with the center of the plate.

Apparatus required for the compression test includes- platform balance, Iron moulds, 150mm cubes steel trowel, vibrator, spade, mixing trough etc.

Procedure:

1) The inside of the mould surfaces is first clean and oiled in order to prevent development of bond between concrete and the mould. The moulds are then assembled and bolts and nuts tightened to prevent leakage of cement paste.
2) Using the specified mixes the weights of the materials is determined.
3) The materials are mixed in the concrete mixer to the uniform consistency.
4) The specimens are casted in the iron moulds150mm cubes. A poker vibrator is used to ensure sufficient compaction without causing segregation of the concrete.
5) The top of the concrete is leveled off using the vibrator and smoothen off using a steel trowel.
6) The specimens are then left in the mould undisturbed for the 24 hours before taking them out of the moulds.

Curing of the concrete cubes

Curing may be defined as the procedures used for the hydration of cement, and consists of a control of temperature and of the moisture movement from and into the concrete. The objectives of the curing is to keep concrete as nearly saturated as possible until the originally water filled space in the fresh cement pate is filled to the desired extent by the products of hydration of cement. The temperature during curing also controls the rate of progress of the reactions of the hydration and consequently affects the development of the strength of the concrete. The cubes are placed in a curing pond / tank at the temperature of 25 ± 2^0C for the specified period of time. Before placing cubes into a curing pond / tank they are marked with a water proof marker. Details to be marked on the cubes are mainly; type of mix, date of casting, duration for curing and crushing day.

2.4.3 Flexural Strength Test

Flexure testing is used to determine the flexure or bending properties of a material. It is one measure of the tensile strength of concrete. It is measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. Sometimes referred to as a transverse beam test, it involves placing a sample between two knife-edge points and initiating a load at the midpoint of the sample. Maximum stress and strain are calculated on the incremental load applied.

Casting of Beams

Plain concrete beams are cast in moulds. The beam is of square size. The overall length of the specimen is 5d. The ratio of d to the maximum particle size of aggregate is not less than three. Compaction is done manually with 35 strokes or with vibration machine. After compaction the top layer, it is then smoothened level using a plasterer's float and the mould wiped clean to remove adhering concrete on its outer surfaces. The specimens are then stored for 24 hours in an undisturbed place and then cure for 7 days and 28 days.

Loading of beams

1) Beam specimens are removing from the curing tank and placed in the testing machine. The specimens are centered with the longitudinal axis of the beam at right angles to the rollers.
2) A load is applied at a constant rate through one roller at the midpoint of the span until the specimen failed. The load is not applied until all load and supporting rollers are resting evenly against the test specimens. The load is applied without shock and increases continuously, at the selected constant rate $\pm$10 % until no greater load is sustained.

Expression of results

The flexural strength as per IS516: 1959 is given by the equation

$$F = \frac{PL}{BD}$$

Where,

F= Flexural strength of the concrete

P= Load in Newton

L= Span of support in mm

B= Width of beam in mm

D= depth of beam in mm

2.4.4 Density Test

Density is defined as the weight to volume of a substance. The density of the cube blocks is determined by dividing the weight of the block prior to crushing with the net volume.

$$Density = \frac{Mass}{Volume}$$

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Research Design

The whole research was based on laboratory experiment so the approach of the research adopted here was Experimental Research. The quantitative paradigm methods were used for the interpretation of results obtained through the experiments.

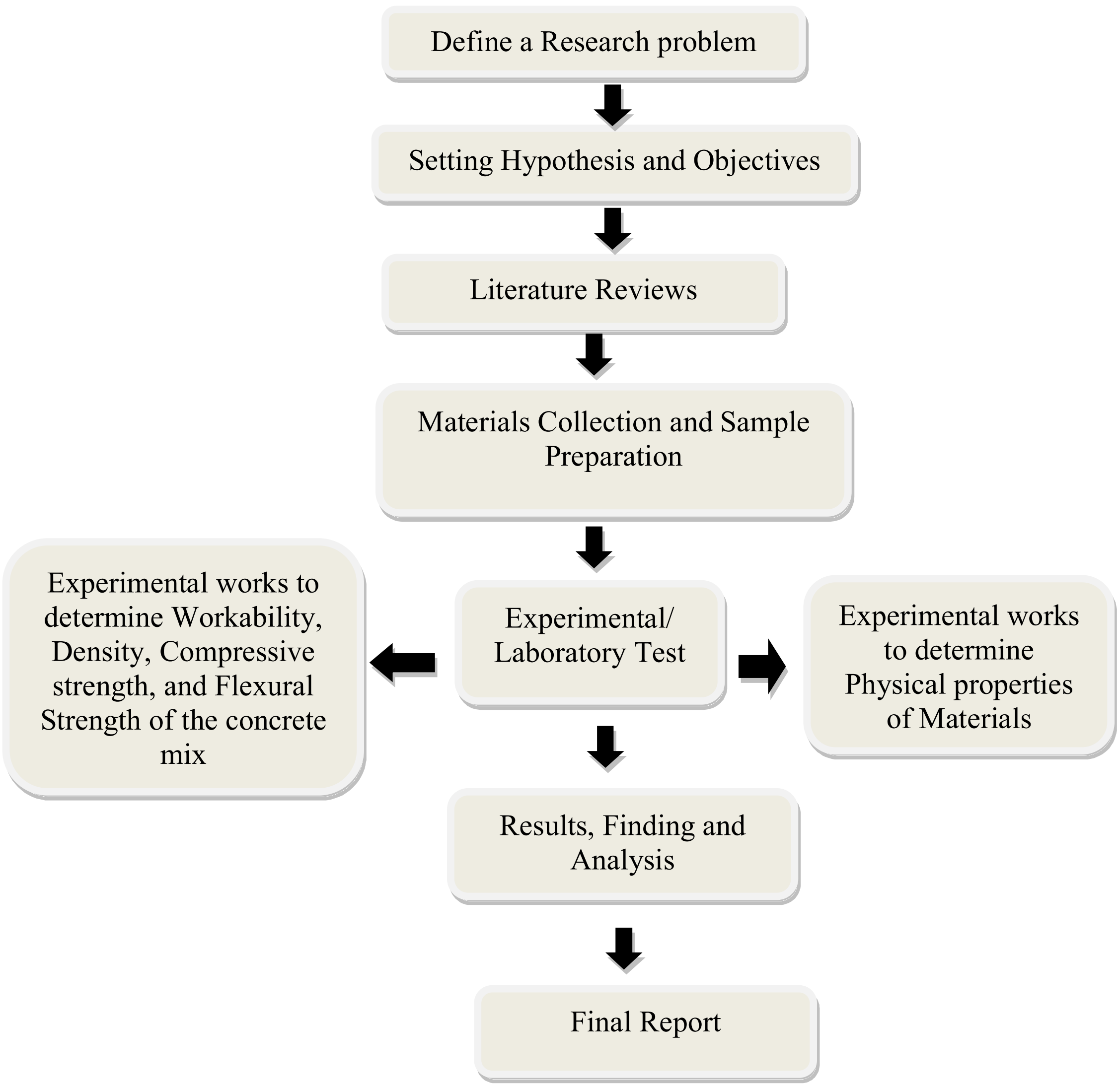

Figure 1: Flow Chart of Methodology

3.2 Details of Specimens

The experiment consists of casting and testing of 24 (150mm×150mm×150mm) cubes for determining compressive strength (f_{cu}), and 24 Beam (75mm×75mm×300mm) for determining flexural strength or modulus of rupture (f_r) of concrete.

The specimens classify into six groups, each group contains 4 cubes, and 4 Beams. The first group is planned to study the compressive and flexural strength as control sample with 0% replacement of sand. Second group is used to study the same parameters as group one, but with 1% plastic pet bottle fiber as partial replacement, in concrete mix. Groups three, four, five and six in contrast, are used to study the same parameters, but with 2%, 2.5%, 3% and 5% plastic pet bottle fiber as partial replacement of sand respectively.

Table 2:.Various specimen type prepared

S.N.	Specimen Type	No. of specimen Prepared with % replacement of Sand						Total no of specimen prepared from each type
		0%	1%	2%	2.5%	3%	5%	
1	Cube (150x150x150)	4	4	4	4	4	4	24
2	Beam (75x75x300)	4	4	4	4	4	4	24
	Total no. of specimen prepared							48

3.3 Material Used

The materials used are listed in Table 3.

Table 3: Materials used.

Basic materials	**Specifications**
Cement	Ordinary Portland cement 53 Grade from Maruti Cement was used.
Sand	The fine aggregate was sand from River Sand Belkhu having a specific gravity 2.63.
Gravel	Maximum size of 20 mm, specific gravity of 2.69 was used as coarse aggregate.
Waste Plastic Pet Bottles	Recycled waste plastic PET Bottles with a percentage 1%, 2%, 2.5%, 3% and 5% replacement of sand was used.
Water	Fresh water was used for mixing process and curing.

The different equipments/ machine used for the experimental works are as follows:

a) Sieve sets as per Indian Standard
b) Sieve shaking machine
c) Volumetric Flask
d) Thermometer
e) Pycnometer
f) Vicat's Apparatus
g) Concrete Mixer
h) Buckets
i) 150x150x150mm cube moulds
j) 75x75x300mm beam moulds
k) Curing Tanks
l) Electronic Balance
m) Universal Testing Machine
n) Others

3.4 General Properties of Materials

3.4.1 Properties of Cement

OPC cement was used for the experimental works. The following properties were tested and determined as mentioned below.

a) Normal Consistency Test

Vicat's apparatus with 10mm diameter plunger was used to determine the normal consistency of cement paste which on penetration about 33-35mm of the cement paste from top gives the percentage of water required to make a standard paste of cement for the tests such as soundness test. The results of normal consistency test observed on lab are presented in Table A1 of Appendix A. And normal consistency of cement paste was found to be 31%.

b) Soundness Test

Soundness of cement was determined with the help of Le-Chatelier's apparatus. The cement paste was prepared with cement and the percentage of water taken as determined in the normal consistency. The apparatus was then filled with cement paste, covered with glass plate from both sides before whole apparatus was placed in water at 24^0C to 25^0C for 24 hours. After that, distance between two indicators with pointed ends was measured. The apparatus was again kept in water, boiled for 30 minutes. The apparatus was cooled before the distance between the indicators represents the expansion of cement on setting, and expansion beyond 10mm results in unsoundness of cement according to IS2386-5:1963. The results of this test are presented in table A2 of Appendix A .From where, the soundness of cement was found to be 3mm.

c) Initial and Final Setting time

Initial setting time gives the time at which the cement starts to set initially after mortar or concrete is laid. And final setting time after which the structure is almost nearly to use. Vicat's apparatus was used to determine the initial and final setting times and were found to be 65 minutes and 280 minutes respectively as shown in table A3 of Appendix A . The observed values were within the requirements of IS 8112:1989 i.e. for initial setting time, it should not be less than 30 minutes and for final setting time, it should not be more than 600 minutes.

d) Compressive Strength Test

Three cubes of size 70x70x70mm were prepared with 1:3 cement sand mortar, which on curing for 28 days, obtained the average compressive strength as 59.38 N/mm2. The laboratory observations are shown in table A4 of Appendix A.

The specific gravity of cement was taken as 3.15. The physical properties of cement as determined are summarized in table 4.

Table 4: Physical Properties of Cement

Particulars	Observed values	Requirements as per IS:8112:1989
Soundness	3 mm	Not more than 10 mm
Initial Setting Time	65 minutes	Not less than 30 minutes
Final Setting Time	280 minutes	Not more than 600 minutes
Compressive strength of 1:3 cement sand mortar cubes at 28 days	59.38 N/mm^2	
Normal Consistency	31%	
Specific Gravity	3.15	

3.4.2 Properties of Fine Aggregates

The sand used to prepare samples was well washed and dried one. Various mechanical and physical properties of sand were determined as described below.

1) Particle size distribution (Grading)

According to IS 2386-1:1963, the sieve of various opening size 4.75mm, 2.36mm, 1.18mm, 0.85mm, 0.60mm, 0.30mm, 0.15mm, and 0.075mm were used in sieve analysis of fine aggregates. Sample weighing about 2 kg was sieved for the period of 15 minutes in a shaking machine and the weight retained on each sieve was determined. From the percentage finer obtained as shown in table A5 of Appendix A. the maximum nominal size of sand was found to be 2.36mm. The grading curve of fine aggregate is shown in Figure 2.

2) Fineness Modulus

From Table A5 of Appendix A, the fineness modulus was found to be 2.58, which means the average size of the particle of given fine aggregate sample was between 0.3mm to 0.6mm. and from the result of sieve analysis, the fine aggregate falls into category of grading zone III according to the clause 4.3 of 383:1970.

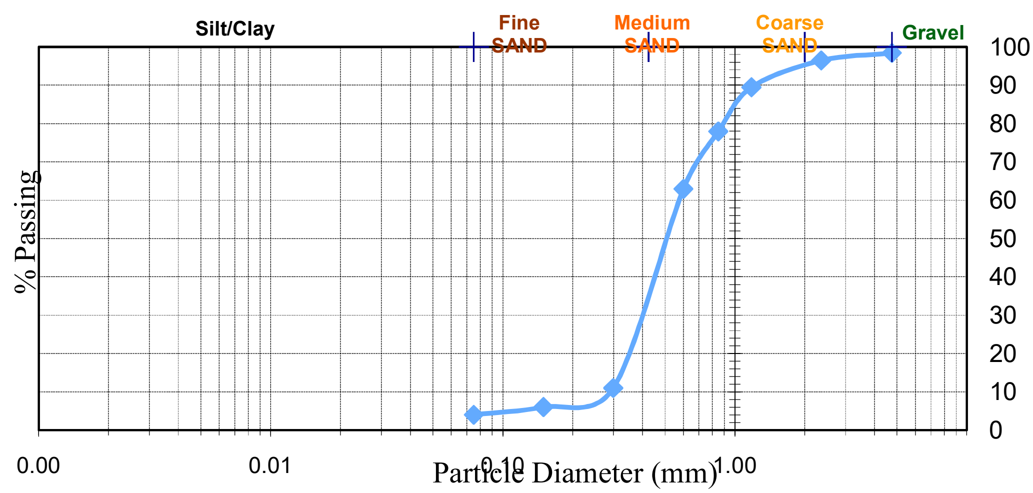

Figure 2: Gradation curve for Fine Aggregate.

3) Specific Gravity and Water Absorption

The Specific gravity and water absorption of sand were determined with the help of pycnometer as per IS 2386-3:1963. The specific gravity and water absorption were found to be 2.63 and 1.40% respectively. The results obtained are presented in Table A6 and A7 of Appendix A respectively.

3.4.3 Properties of Coarse Aggregates

The coarse aggregate of nominal size 20mm were considered for the experimental works. Various mechanical and physical of Aggregates were determined as described below:

1) Particle size Distribution (grading)

According to IS 2386-1:1963 the sieve of various opening sizes 40mm, 37.5mm, 28mm, 25mm, 20mm, 16mm,14mm, 12.5mm, 10mm, 6.30mm, were used in the sieve analysis of coarse aggregates . Sample weighing about 5 kg was sieved for the period of 15 minutes in a shaking machine and the weight retained on each sieve was determined. From the percentage finer obtained as shown in Table A8 of Appendix A. The maximum nominal size of aggregates was found to be 20mm.

2) Fineness Modulus

From the Table A8 of Appendix A, the fineness modulus of coarse aggregate was found to be 4.46, which means the average size of the particles of given coarse aggregate sample was between 10mm to 20mm. the grading curve of coarse aggregates is shown in Figure 3.

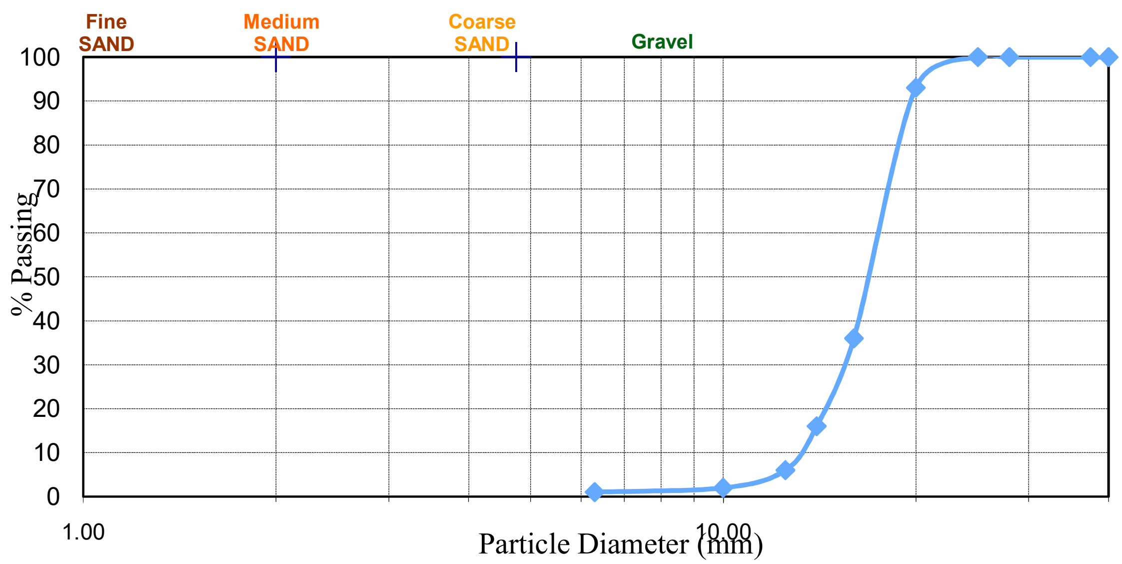

Figure 3: Gradation curve for Coarse Aggregates.

3) Specific Gravity and Water Absorption

The specific gravity and water absorption of coarse aggregate were determined with the help of graduated bottle as per IS2386-3:1963. The specific gravity and water absorption were found to be 2.69 and 1.15% respectively. The results are presented in Table A9 and A10 of Appendix A respectively.

3.4.4 Properties of PET Bottles Fiber

The plastic aggregates were produced mainly from waste PET bottles the plastic bottles were crushed and cut into small pieces using a crushing machine or by manually. The plastic aggregates were washed properly to make them clean and to ensure that no other dust particles were present there. Polyethylene terephthalate (PET) is thermoplastic polyester with tensile and flexural modulus of elasticity of about 2.9 and 2.4MPa respectively tensile strength up to 60MPa and excellent chemical resistance. It is a semi-crystalline polymer, with a melting point of about 260°C and a glass transition temperature ranging from 70 to 80°C, in relation to the amount of crystalline region enclosed in the amorphous phase.

3.4.5 Properties of Water

Clean water free from any deleterious materials was used for the experimental works.

3.5 Concrete mix Design

Mix design involves a process for the selection of proportion of concrete constituents like cement, water and aggregates to produce an economical concrete mix satisfying the required workability conditions. In order to optimize the amount of quantities used to prepare the concrete, mix design is performed. Maximum water-cement ratio, minimum cement content, minimum strength minimum workability maximum size of aggregates, air content within specified limit and type of exposure are considered as limiting values for the design.

Considering the M20 grade of concrete with water cement ratio as 0.50, the concrete mix was designed according to IS 10262:2009.concret without the mix of Plastic PET bottles fibers was used as the control concrete. The different proportions of cement, sand, aggregate, plastic fiber and water were determined as shown in table 5 as per the procedure defined in Appendix B and value obtained in Table B5 of Appendix B.

Table 5: Design values of mixes according to Indian Standard Guidelines.

Particulars	Design Values for the different percentage of Plastic PET bottle fibers					
	0%	1%	2%	2.5%	3%	5%
Concrete grade	M20	M20	M20	M20	M20	M20
Characteristic Strength (MPa)	20	20	20	20	20	20
Target Compressive Strength(MPa)	25.94	25.94	25.94	25.94	25.94	25.94
Mix Proportions:						
Water	0.50	0.50	0.50	0.50	0.50	0.50
Cement	1.00	1.00	1.00	1.00	1.00	1.00
Plastic PET Fibers	0	0.014	0.029	0.036	0.044	0.735
Sand	1.47	1.46	1.44	1.43	1.425	1.40
Coarse Aggregates	2.92	2.92	2.92	2.92	2.92	2.92

3.5.1 Batch/ Mixing Proportions

The proportions required to prepare the sample of cube size 150mmx150mmx150mm according to the mix design calculated is shown in Table 6. Similarly for the beam of size 75mmx75mmx300mm. the proportion of materials required is shown in Table 7. Table 6 and Table 7 showed the proportion of materials required for each of cubes and beams for the different percentage of sand replaced by Plastic Pet bottles Fibers respectively.

Table 6: Batching for a cube of size 150mmx150mmx150mm

Sand Replacement	Materials				
	Water(ltr)	Cement(Kg)	Plastic pet Fiber(Kg)	Sand (Kg)	Gravel(Kg)
0%	0.66	1.31	-	1.94	3.84
1%	0.66	1.31	0.019	1.92	3.84
2%	0.66	1.31	0.0388	1.90	3.84
2.5%	0.66	1.31	0.0485	1.89	3.84
3%	0.66	1.31	0.0582	1.88	3.84
5%	0.66	1.31	0.097	1.84	3.84

Table 7: Batching for beam of size 75mmX75mmx300mm

Sand Replacement	Materials				
	Water (ltr)	Cement (Kg)	Plastic pet Fiber (Kg)	Sand (Kg)	Gravel (Kg)
0%	0.33	0.655	-	0.97	1.92
1%	0.35	0.655	0.01	0.96	1.92
2%	0.35	0.655	0.02	0.95	1.92
2.5%	0.35	0.655	0.024	0.946	1.92
3%	0.35	0.655	0.0291	0.94	1.92
5%	0.35	0.655	0.048	0.922	1.92

3.6 Workability Tests

Slump test was performed to determine the degree of workability as per IS7320:1974 and IS1199:1959. For this a mould of standard frustum of cone was used. The fresh concrete prepared according to the batching designed was filled inside a mould wetted with water in three layers which was placed on the base plate firmly. Each layer was compacted with 25 strokes of the temping rod. After that the top of the mould was leveled horizontally and the cone was immediately lifted vertically. The distance between the underside of the tamping rod held horizontal on the top of the mould and highest point of the slumped concrete sample was measured. The observed slump values for the different percentage replacement of sand by plastic pet bottles fiber are shown in Table C1 of Appendix C.

3.7 Experimental Program

The following properties were tested with the samples prepared.

a) Bulk Density/ Unit Weight

b) Water Absorption

c) Compressive Strength

d) Flexural Strength

Total 24 cubes of size 150x150x150mm, 4 sample each for 0%, 1%, 2%, 2.5%, 3% and 5% of the sand replacement by plastic pet bottle fiber were prepared to determine the bulk density, water absorption and compressive strength. Similarly, total 24 plain concrete beam of size 75x75x300mm were prepared, 4 sample each for 0%, 1%, 2%, 2.5%, 3% and 5% of the sand replacement by plastic pet bottle fiber were prepared to determine the Flexural strength for 7 days and 28 days respectively. The procedure followed to determine the above properties according to the IS 516:1959 are discussed below:

3.7.1 Bulk Density/ Unit Weight

The bulk density or unit weight of cubes was determined by dividing the weight of the cube obtained after 28 days of curing with the net volume. For each sand replacement, 2 samples were prepared and the average bulk density was calculated from each 3 samples of same compositions. The obtained values of bulk density/ unit weight for different proportion of mixes are shown in Table C2 of Appendix C.

3.7.2 Water Absorption

The average water absorption was determined after 28 days of curing of cubes samples. the obtained values of water absorption for different proportion of mixes are shown in Table C3 of Appendix C.

3.7.3 Compressive strength

The compressive strength of cubes was determined by the help of compressive testing machine after 7 days and 28 days of curing. The machine used for the testing was universal testing machine of central Material Testing Laboratory of Pulchowk campus. The load applied for the compressive strength was $140KN/mm^2$/ minutes. The obtained values of Compressive strength for different proportion of mixes are shown in Table C4 and Table C5 of Appendix C.

3.7.4 Flexural Strength

The flexural strength of concrete beam was determined with the help of flexural testing machine after 7 days and 28 days of curing. The testing was carried out in Central material testing laboratory of Pulchowk campus. The three point loading method was performed to determine the failure load of beam. The load was applied at the rate not more than 300N/min. The obtained values of Flexural strength for different proportion of mixes are shown in Table C6 and C7 of Appendix C.

CHAPTER FOUR

RESULTS AND DISCUSSION

The results obtained from the experimental program are presented and discussed in this chapter. The obtained results are analyzed and compared with some relevant outcomes of the previous research works.

The various properties of cement mainly normal consistency, compressive strength, initial and final setting time, soundness and specific gravity were determined and mentioned in chapter three. Similarly, the properties of aggregates and plastic pets fiber mainly particles size distribution, fineness modulus, specific gravity and water absorption were determined and analyzed in chapter three. The mix designs for various composition of plastic pet bottle fiber mainly 0%, 1%, 2%, 2.5%, 3% and 5% as partial replacement of sand were determined in chapter three. With the determination of mix proportions from the mix design, the total forty-eight samples were prepared, Twenty four each samples for compressive strength test and flexural strength test. For different proportion of plastic pet bottle fiber two samples were prepared and tested. In this chapter, the results shown are the average of two measured results.

4.1 Workability of the Mixes

The degree of workability for all the concrete mixes containing different proportions of Pet bottle fiber was determined as shown in table 8.

Table 8: Slump value of concrete containing different percentage of Plastic pet bottle fiber.

Sand Replacement	Slump values	Percentage change in slump as compared to control sample
0%	35mm	0%
1%	45mm	28.57%
2%	50mm	42.85%
2.5%	60mm	71.43%
3%	65mm	85.71%
5%	75mm	114.29%

It was observed that for 0% or no replacement of sand by plastic pet bottle fiber, the slump value was 35mm.Similarly for 1%, 2%, 2.5%, 3% and 5% replacement of sand by plastic pet bottle fiber, the slump values were 45mm, 50mm, 60mm, 65mm, and 75mm respectively. From the above test performed, it was observed that the workability increases when the fiber percentage increases. This is because plastic pet absorbs very less water and more water is available to the mix. All the values of slump lies within as specified by Indian standard code 1199:1959. The 0% or no replacement of sand by plastic pet bottle fiber was considered as control sample. For the 1% replacement of Plastic pet bottle fiber, the slump was found to be increased by 28.57% to that of control sample. Similarly, for 2%, 2.5%, 3% and 5% replacement of sand by plastic pet bottle fiber the slump values were found to be increased by 42.85%, 71%, 85.71% and 114.29% respectively.

Considering the results obtained here of workability, the concrete containing increment values of plastic pet bottle fiber can be used for various civil engineering works as recommended by Indian Standard code 1199:1959.

The degree of workability of control sample was very low and that of mix containing 5% of plastic pet bottle fiber as replacement of sand had medium workability. The variation of the slump of concrete with the plastic pet bottle fiber content is shown in Figure 4.

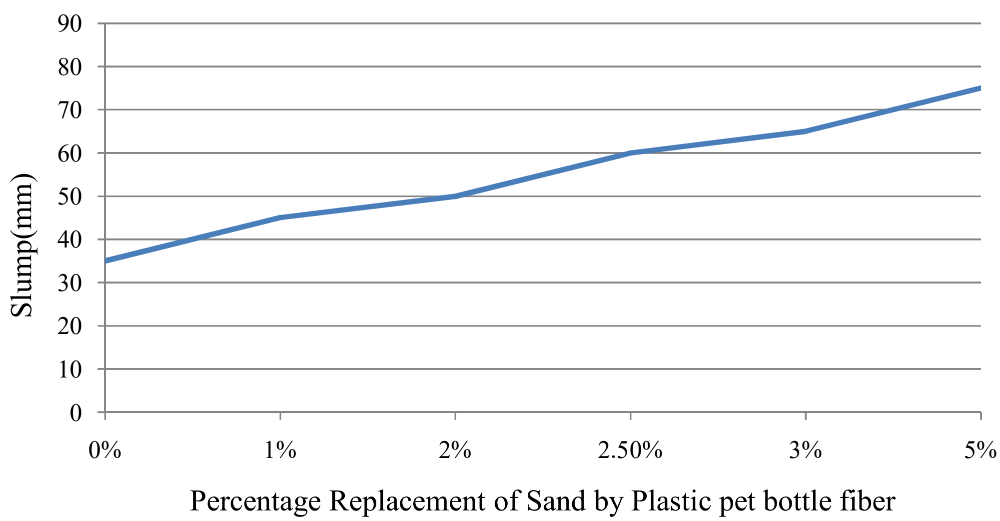

Figure 4: variation of slump of concrete containing different percentage of Plastic pet bottle fiber.

From Figure 4 it can be seen that the increase in slump increases as increase percentage of Plastic pet bottle fiber. it can be observed that the degree of workability is increased with the percentage of plastic pet bottle fiber increased in the concrete mix. This increase in slump value means the concrete becomes more workable with increase in percent of plastic pet bottle fiber as sand replacement.

4.2 Bulk Density/ Unit weight of the Mixes

The average bulk density or unit weight for all the concrete mixes containing different proportion of plastic pet bottle fiber was determined after 28 days of curing as shown in Table 9.

Table 9: Average Bulk Density/Unit Weight Results

Sand Replacement (%)	S.N.	Bulk Density (Kg/m^3)	Unit weight (KN/m^3)	Average Bulk Density (Kg/m^3)	Average Unit weight (KN/m^3)	Standard Deviation of Bulk Density (KN/m^3)	Percent change in bulk density / unit weight as compared to control sample
0	1	2490	24.90	2475	24.75	0.21	0
	2	2460	24.60				
1	1	2475	24.75	2462	24.62	0.17	-0.53%
	2	2450	24.50				
2	1	2440	24.40	2450	24.50	0.17	-0.93%
	2	2460	24.60				
2.5	1	2420	24.20	2434	24.34	0.19	-1.65%
	2	2447	24.47				
3	1	2430	24.30	2415	24.15	0..21	-2.42%
	2	2400	24.00				
5	1	2350	23.50	2375	23.75	0.35	-4.04%
	2	2400	24.00				

Considering the IS code, the average density of normal concrete is 2400 Kg/m^3 and that of light weight concrete is 1750 Kg/m^3. The result obtained showed that the bulk density decreases with the increase in percent of plastic pet bottle fiber in concrete in concrete mix, which is graphically represented in figure 6. It was observed that for 0% or no replacement of sand by plastic pet bottle fiber, the average bulk density was 2475 kg/m^3. Similarly for 1% , 2% 2.5%, 3% and 5% replacement of sand by plastic pet bottle fiber the average bulk density were 2462 kg/m^3, 2450 kg/m^3 , 2434 kg/m^3 , 2415 kg/m^3 and 2375 kg/m^3 respectively.

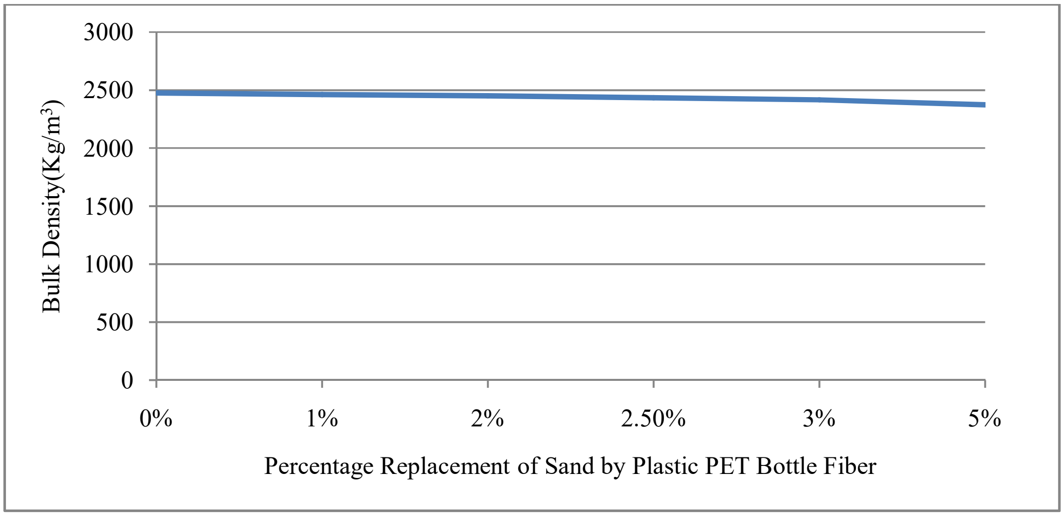

Figure 5: Variation of Bulk Density of Concrete containing different percentage of Plastic Pet Bottle Fiber.

From Figure 5 It can be seen that the decrease in average bulk density or unit weight with the increasing percentage of Plastic Pet Bottle Fiber. The 0% or no replacement of sand by Plastic Pet Bottle Fiber was considered as control sample for 1%,2%,2.5%,3% and 5% replacement of sand by Plastic Pet Bottle Fiber the bulk density were found to be decreased by 0.53%, 0.93%, 1.65%, 2.42% and 4.04% respectively. This decrease in bulk density is mainly due to the low specific gravity of Plastic than sand. From the results obtained of Bulk Density on replacement of sand by Plastic Pet Bottle Fiber at different amounts concluded that the concrete such produced with increasing value of plastic pet bottle fiber results a concrete lighter weight in comparison to control sample. Light weight concrete generally not preferred for the loading bearing structures. Lightweight concrete are mainly suitable to build moderate bearing capacity structures with the use of less reinforcement.

4.3 Water Absorption of the mixes

The average water absorption for all the concrete mixes containing different proportion of plastic pet bottle fiber was determined after 28 days of curing as shown in Table 10.

Table 10: Average water Absorption

Sand Replacement (%)	S.N.	Water Absorption (%)	Average Water Absorption (%)	Standard Deviation Water Absorption (%)	Percent change in Water Absorption as compared to control sample
0	1	0.50	0.49	0.14	0
	2	0.48			
1	1	0.48	0.47	0.14	-4.08%
	2	0.46			
2	1	0.42	0.44	0.28	-10.2%
	2	0.46			
2.5	1	0.40	0.42	0.28	-14.28%
	2	0.44			
3	1	0.38	0.40	0.28	-18.36%
	2	0.42			
5	1	0.40	0.38	0.28	-22.44%
	2	0.36			

It was observed that for 0% or no replacement of sand by Plastic Pet Bottle Fiber the average water absorption was 0.49 %. Similarly for 1%, 2%, 2.5%, 3% and 5% replacement of sand by Plastic Pet Bottle Fiber the Water absorption were found to be 0.47%, 0.44%, 0.42%, 0.40% and 0.38% respectively. The 0% or no replacement of sand by plastic pet bottle fiber was considered as control sample. For 1%, 2%, 2.5%, 3% and 5% replacement of sand by Plastic Pet Bottle Fiber the water absorption were found to be decreased by 4.08%, 10.20%, 14.28%, 18.36% and 22.45% respectively. This decrease in Water absorption is mainly due to the lower porosity and plastic pet bottles fiber in the concrete mix .Due to the hand mix and compaction of sample, the values of water absorption are highly affected here. The results such obtained is graphically represented in Figure 6 showing the water absorption decrease with the increasing percent of plastic pet bottle fiber in the concrete mix.

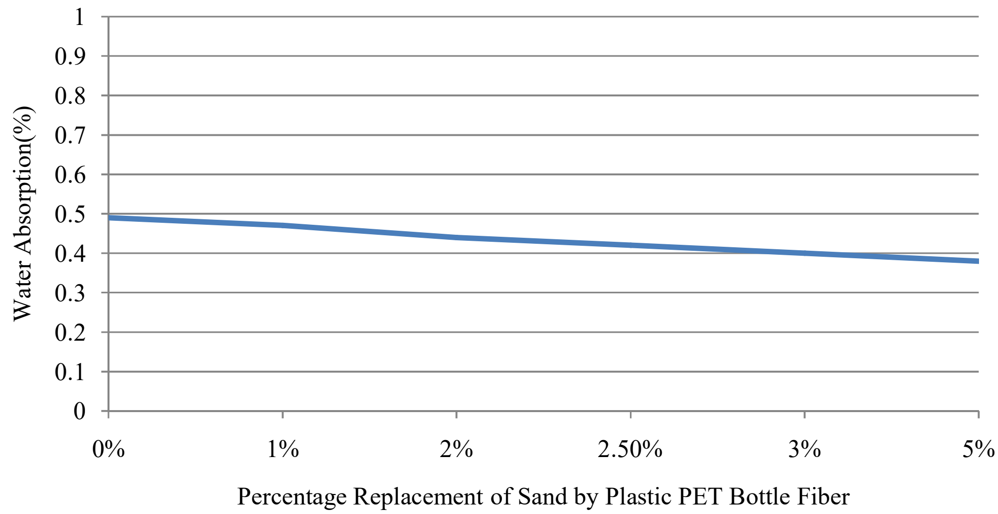

Figure 6: Variation of water Absorption of concrete containing different percentage of plastic pet bottle fiber.

4.4 Compressive strength test

Figure 7: Compressive strength testing of concrete containing different percentage of plastic pet bottle fiber.

It is the most common of all tests on hardened concrete; in addition, compressive strength is the most important parameter in structural design. Three standard cubes of 150x150x150 mm are formed for each mix. The compressive strength test is carried out according to the BS EN 12390-3 (2002) at ages of 7 and 28 days.

Table 11 and 12 indicates the test results of compressive strength of hardened concrete of 7 days and 28 days Equation 1 is used to calculate the compressive stress in MPa.

$F_{cu} = P/A$ (1)

Where,

F_{cu} = Compressive strength of the Concrete

P= Failure Load

A= Area of Contact

Table 11: Variation of seven-day compressive strength

S. N	Percentage addition of Plastic PET Bottle Fiber	Failure load (KN)	Average Failure Load (KN)	The Average compressive strength of seven days (Mpa)	Percentage change in compressive strength
1	0%	320	330	14.67	0.00
2		340			
3	1%	380	370	16.44	12.06%
4		360			
5	2%	395	390	17.33	18.13%
6		385			
7	2.5%	370	365	16.22	10.56%
8		360			
9	3%	330	320	14.22	-3.07
10		310			
11	5%	270	280	12.44	-15.20
12		290			

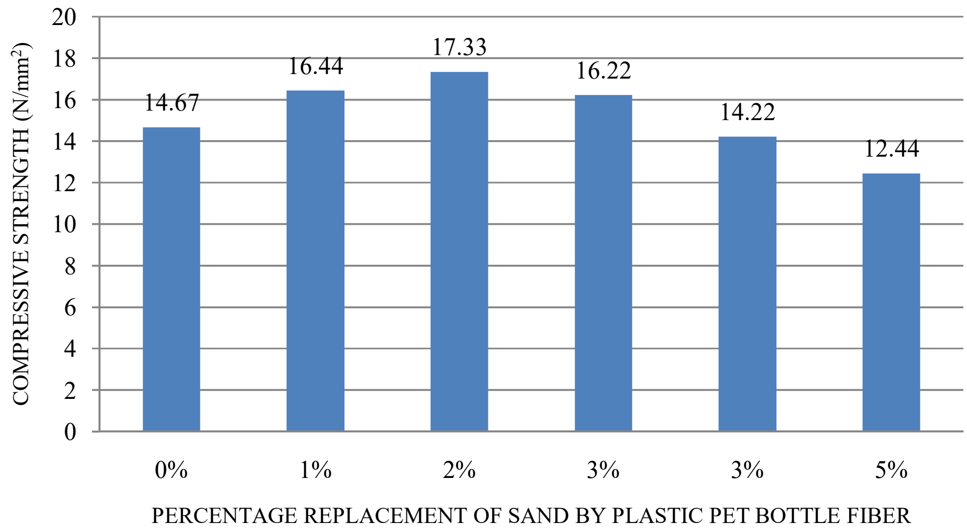

Fig. 8: 7 day compressive strength versus percentage replacement of sand by plastic pet bottle fiber.

It was noticed that the compressive strength increases with increase in the percentage of plastic pet bottle fiber in 7 day tests up to 2% replacement of the fine aggregate with Pet bottle fiber and then decrease for 2.5%, 3% and 5% replacements. The compressive strength of 2% plastic pet bottle fiber mix concrete has found to be 18.13% increase in strength when compared to that of Control concrete sample. This may be because when plastic pet fiber is added to the mixture in order to partial replacement of sand, the silica content reduces and equivalent carbon content replaces it. In silicon electrons forming the bond are far from the nucleus and energy is less release in forming the bond. The silicon bond is weaker than carbon bond because the silicon atom is bigger than the carbon atom. But if plastic pet fiber is added beyond 2% the compressive strength decreases because all free carbon is bonded and increase in fiber content decreases bond strength between fiber. Hence replacement of fine aggregate with 2% replacement will be optimum strength occurs.

Table 12: Variation of 28 day Compressive Strength Test.

S. N	Percentage addition of fiber	Failure load (KN)	Average Failure load (KN)	Compressive strength of 28 days (Mpa)	Percentage change in Compressive strength as compared to control sample (%)
1	0%	560	570	25.33	0.00
		580			
2	1%	630	635	28.22	11.41%
		640			
3	2%	660	655	29.11	14.92%
		650			
4	2.5%	620	625	27.78	9.67%
		630			
5	3%	520	530	23.56	-6.98%
		540			
6	5%	480	485	21.55	-14.92%
		490			

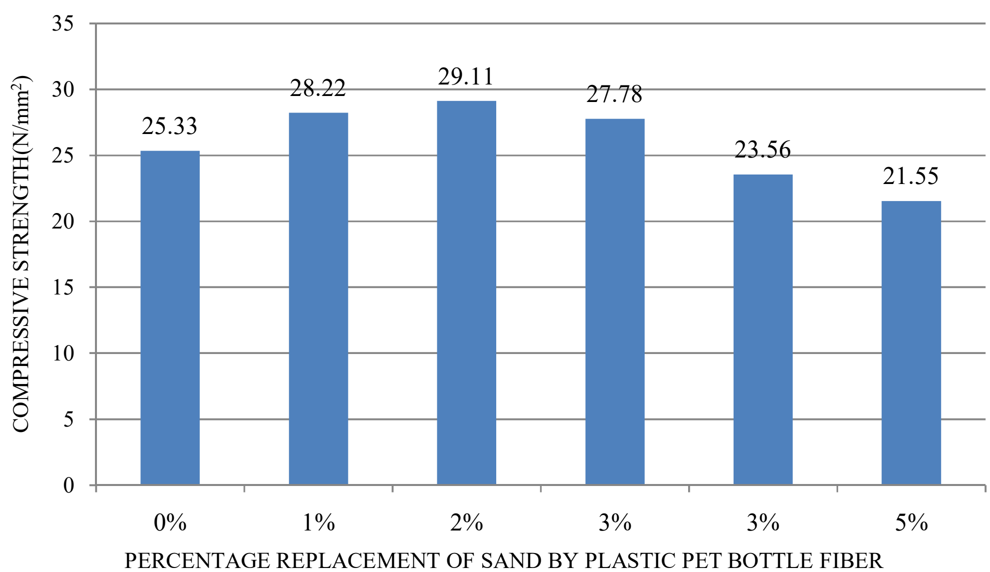

Figure 9: 28 day compressive strength v/s percentage replacement of sand by Plastic Pet Bottle Fiber.

From Figure 9 the compressive strength of concrete increases with increase in the percentage of plastic pet bottle fiber in 28 days up to 2% replacement of sand with plastic pet bottle fiber and then decrease for 2.5%, 3% and 5%. The compressive strength of 2% plastic pet bottle fiber mix concrete has found to be 14.92% increase in strength when compared to that of Control concrete sample.

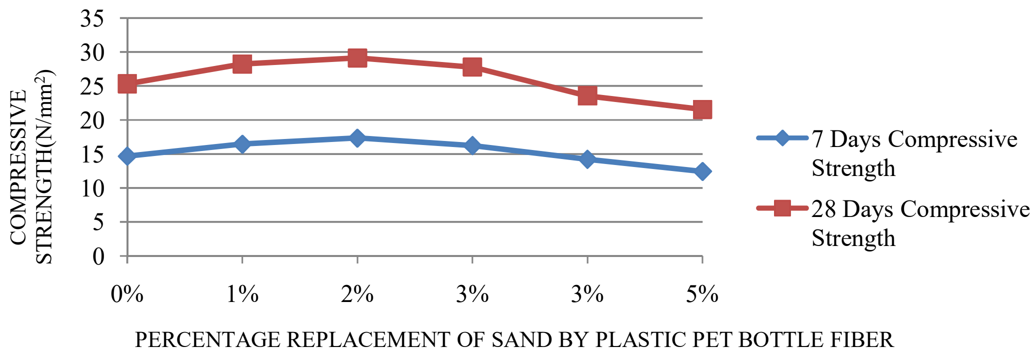

Figure 10: Comparison between 7 day and 28 day compressive strength v/s percentage replacement of sand by Plastic Pet Bottle Fiber

4.5 Flexural Strength (modulus of rupture) Test

Figure 11: Flexural strength testing of concrete containing different percentage of plastic pet bottle fiber.

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for material, identified as a material's ability to resist deformation under load. The flexural test is applied with a circular or rectangular section until fracture using a three-point flexural test. The flexural strength represents the highest load occurs within the material at its moment of rupture. It is measured in terms of stress.

The method for the flexural test is usually involves on a universal testing machine. The value of modulus of rupture depends upon the dimensions of beam and application of loading. In symmetrical two-point loading, the critical crack may appear at any section. Beam of 300×75×75mm specimens is used in this test to computing modulus of rupture of concrete.

Table 13: Variation of seven-day Flexural strength

S.N	% PET Added	Breaking Load (N)	Average Breaking Load (N)	Flexural Strength (N/mm^2)	Percentage Change in Flexural strength as compared to control sample
1	0%	2000	2025	1.44	0
		2050			
2	1%	2150	2175	1.55	7.63%
		2200			
3	2%	2300	2310	1.64	13.89%
		2320			
4	2.5%	2450	2435	1.73	20.13%
		2420			
5	3%	2400	2390	1.70	18.05%
		2380			
6	5%	2300	2325	1.65	14.58%
		2350			

Table 13 indicates the test results of flexural strength (modulus of rupture); Modulus of rupture is calculated using equation 3:

$$F = PL/BD^2 \qquad (3)$$

Where F= Flexural Strength (N/mm^2)

P= Breaking Load (N)

L= Length of the support span (mm)

B =Breadth (mm)

D = Depth/ Thickness (mm)

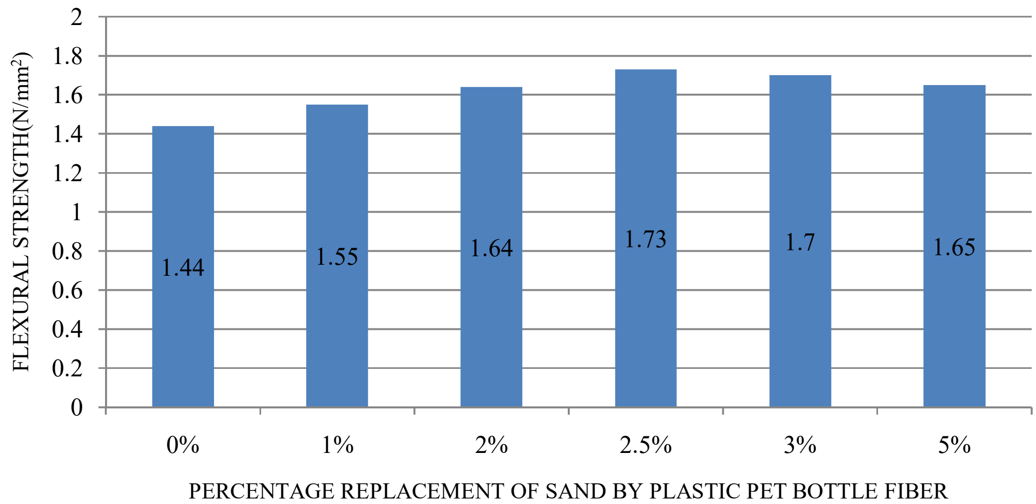

Figure 12: Variation of Flexural strength of concrete at 7 days

Table 14: Variation of flexural strength test at 28 days

S.N	% PET Added	Breaking Load (N)	Average Breaking Load (N)	Flexural Strength (N/mm^2)	Percentage change in Flexural strength as compared to control sample
1	0%	4500 4650	4575	3.25	0
2	1%	5000 5200	5100	3.62	11.38%
3	2%	5500 5450	5475	3.89	19.69%
4	2.5%	5600 5800	5700	4.05	24.61%
5	3%	5500 5600	5550	3.95	21.54%
6	5%	5300 5400	5350	3.80	16.92%

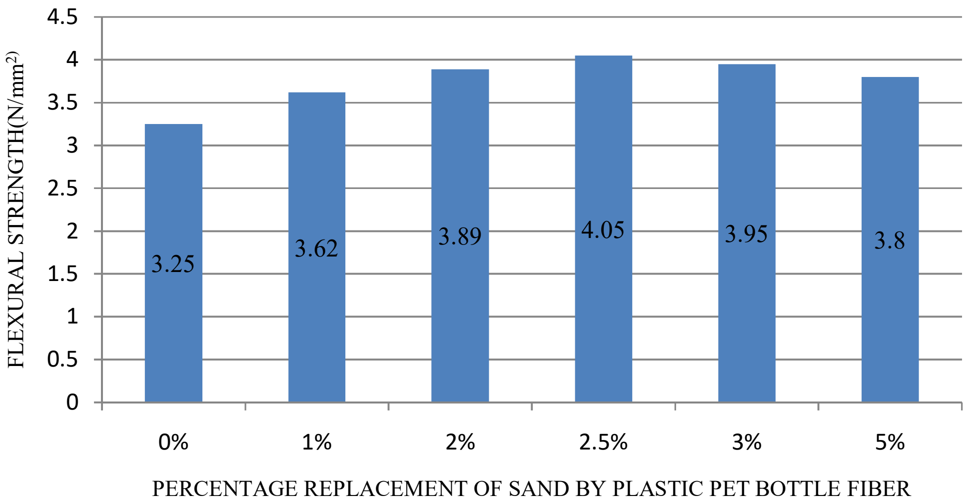

Figure 13: Variation of Flexural strength of concrete at 28 days

From Figure 13 the Flexural strength of concrete increases with increase in the percentage of plastic pet bottle fiber in 28 days up to 2.5% replacement of sand with plastic pet bottle fiber and then decrease for 2.5%, 3% and 5%. The Flexural strength of 2.5% plastic pet bottle fiber mix concrete has found to be 24.61% increase in strength when compared to that of Control concrete sample.

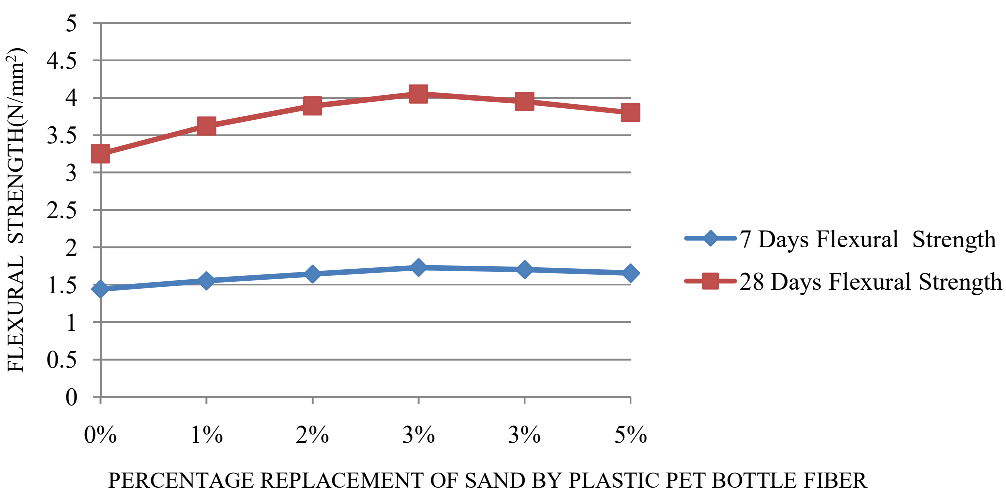

Figure 14: Comparison between 7 and 28 day Flexural strength of concrete v/s percentage replacement of sand by Plastic Pet Bottle Fiber

4.6 Discussion: Comparative

4.6.1 Comparative Analysis

Not many researches were found conducted by mixing plastic pet bottle fiber in concrete to determine the various physical and mechanical properties of concrete. The compressive strength obtained at 28 days of curing in this research was compared with that of Maqbool Younus et al (2019) shown in figure 15. The curve obtained in this research has similar trends of increasing and decreasing strength to that of previous results. The compressive strength obtained is higher than that of the previous results because of the concrete mix, properties of the material used, size of the coarse aggregate etc.

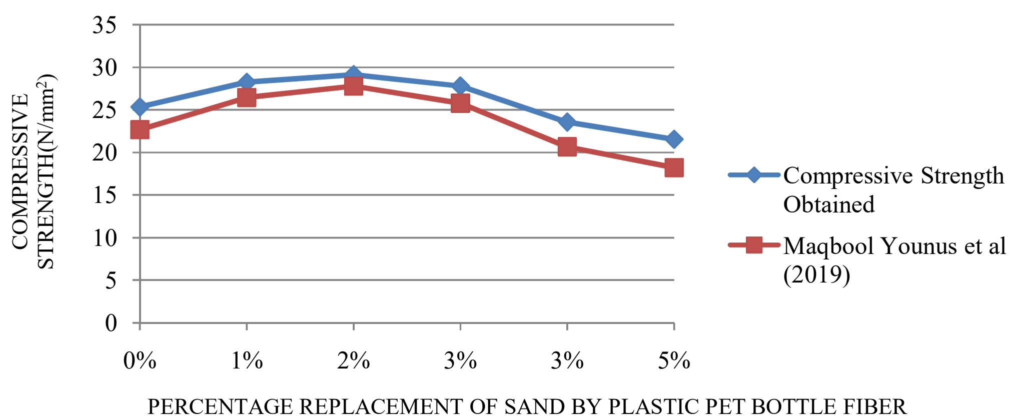

Figure 15: Comparison between compressive Strength at 28 days

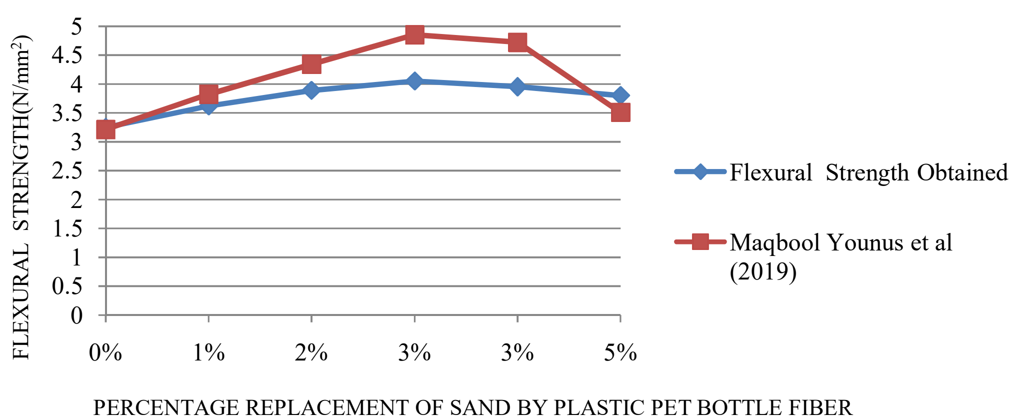

Figure 16: Comparison between Flexural Strength at 28 days

The flexural strength obtained at 28 days of curing in this research was compared with that of Maqbool Younus et al. (2019) shown in figure 16. The curve obtained in this research has different trends of increasing and decreasing of flexural strength to that of previous results because of the difference in ratio of the concrete mix, water cement ratio, temperature, relative humidity, the properties of the materials used in the study. Also the dimension of the beam sample used for the previous experiment is 100mmx100mmx500mm whereas we studied the dimension of 75mmx75mmx300mm. This may also affect the flexural strength of the concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

1) The mix proportions of concrete containing cement, sand and coarse aggregates considering M20 grade was determined as 1:1.47:2.92.
2) The degree of workability of concrete varied between 35mm to 75mm. this showed that the increase in workability with the increase in percent replacement of sand by plastic pet bottle fiber.
3) The concrete with Plastic PET bottle fiber increases the flow properties of concrete and reduces the weight of concrete and thus Concrete with plastic pet bottle fiber can be made into lightweight concrete based on unit weight.
4) The maximum compressive strength was at 2% of plastic fiber content was 14.92 % and maximum flexural strength was at 2.5% of plastic fiber content was 24.61% at 28 day more over control concrete. The increase in strength was observed with the inclusion of plastic fibers in concrete. The optimum strength was observed between 2 to 2.5% of fiber content for all types of strength thereafter reduction in strength were observed.
5) Other kinds of admixtures can be used to increase the strength of concrete at further addition of plastic pet bottles fiber.

5.2 RECOMMENDATION

The significant improvements in strengths were observed with the inclusion of plastic pet fibers in concrete. The optimum strength was observed between 2 to 2.5% of fiber content for all types of strengths, thereafter reductions in strength were observed. Hench for the optimum strength 2-2.5% of the plastic pet bottle fibers can be recommended to use in concrete production as a replacement of sand. And also from this experimental investigation, the PET bottles would appear to be low-cost materials which would help to resolve solid waste problems and preventing environmental pollution. And for the further research more percentage of the plastic pet bottle fiber can be added with the use of super plasticizers admixtures if required to meet the target strength of the concrete and improve the bonding of the fibers. And also the plastic pet bottle can be grinding and replacing of coarse aggregate partially can also be studied for the further application in concrete as well in future.

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APPENDIX A: OBSERVATION OF PROPERTIES OF MATERIALS

Table A1: Normal consistency test observation

Weight of cement	% of water added	Penetration Value
350 gm	30	30
350gm	31	35
350gm	32	40

Table A2: Soundness test observation and calculation

Weight of cement Taken	100gm
Volume of water added (as per normal consistency test)	31 ml
Distance between indicators before boiling	15mm
Distance between indicators before boiling	18mm
Difference	**3mm**

Table A3: Initial and Final setting time observation and calculations

Observation	**Time**
Starting time	0 (considered)
Initial setting time	65 minutes
Final setting time	280 minutes

Table A4: Compressive strength of 1:3 cement sand mortar cubes at 28 days

Weight of cement taken =185 gm			
Volume of water added= 85 ml			
Sample No.	Load at Failure (KN)	Compressive strength (N/mm^2)	Average Compressive strength (N/mm^2)
1	290	59.18	59.38
2	295	60.21	
3	288	58.76	

Table A5: Sieve analysis of Fine Aggregates

Sample Weight = 2 Kg				
Sieve size (mm)	Mass Retained (gm)	Percent Mass Retained (%)	Cumulative percent Retained (%)	Cumulative Percent Passing (Percent Finer) (%)
4.75	30.00	1.50	1.50	98.50
2.36	40.00	2.00	3.50	96.50
1.18	140.00	7.00	10.50	89.50
0.85	230.00	11.50	22.00	78.00
0.60	300.00	15.00	37.00	63.00
0.30	1040.00	52.00	89.00	11.00
0.15	100.00	5.00	94.00	6.00
0.075	40.00	2.00	-	-
On Pan	80.00	4.00	-	-
Total	**2000.00**	**100.00**	**257.50**	
Therefore Fineness Modulus= 257.5/100= 2.575				
Nominal Maximum Fine Aggregate size =2.36				

Table A6: Specific Gravity Observation and calculation of Fine Aggregates

Weight of empty pycnometer (W_1)	500gm
Weight of pycnometer+ dried sand(W_2)	766 gm
Weight of pycnometer+ fully saturated sand (W_3)	1215 gm
Weight of pycnometer+ water (W_4)	1050 gm
Specific Gravity	**2.63**

Table A7: Water Absorption Observation and Calculation of Fine Aggregates

Weight of empty Dry pan (W_1)	830gm
Weight of Pan+ dried sand(W_2)	1545 gm
Weight of pan+ surface dried saturated sand (W_3)	1555 gm
Water Absorption	**1.40%**

Table A8: Sieve analysis of Coarse Aggregates

Sample Weight = 5 Kg				
Sieve size (mm)	Mass Retained (gm)	Percent Mass Retained (%)	Cumulative percent Retained (%)	Cumulative Percent Passing (Percent Finer) (%)
40.00	0.00	0.00	0.00	100.00
37.50	0.00	0.00	0.00	100.00
28.00	0.00	0.00	0.00	100.00
25.00	0.00	0.00	0.00	100.00
20.00	350.00	7.00	7.00	93.00
16.00	2850.0	57.00	64.00	36.00
14.00	1000.00	20.00	84.00	16.00
12.50	500.00	10.00	94.00	6.00
10.00	200.00	4.00	98.00	2.00
6.30	50.00	1.00	99.00	1.00
On Pan	50.00	1.00	-	-
Total	**5000.00**	**100.00**	**446**	
Therefore Fineness Modulus= 446/100= 4.46				
Nominal Maximum Coarse Aggregate size =20mm				

Table A9: Specific Gravity Observation and calculation of Coarse Aggregates

Weight of empty dry Bottle (W_1)	550gm
Weight of Bottle+ dried Gravels (W_2)	1155 gm
Weight of Bottle+ fully saturated Gravels (W_3)	2090 gm
Weight of Bottle+ water (W_4)	1710 gm
Specific Gravity	**2.69**

Table A10: Water Absorption Observation and Calculation of Coarse Aggregates

Weight of empty Dry pan (W_1)	840gm
Weight of Pan+ dried gravels (W_2)	1710 gm
Weight of pan+ surface dried saturated gravels (W_3)	1720 gm
Water Absorption	**1.15%**

APPENDIX B: DESIGN PROCEDURE OF CONCRETE MIXES

Design Procedure of Concrete mixes according to IS10262-2009 are as follows:

1) At first , the target mean strength is calculated from the characteristic strength specified with the relation:

$F'_{ck} = F_{ck} + 1.65s$

Where,

F'_{ck} = target mean compressive strength at 28 days in N/mm^2

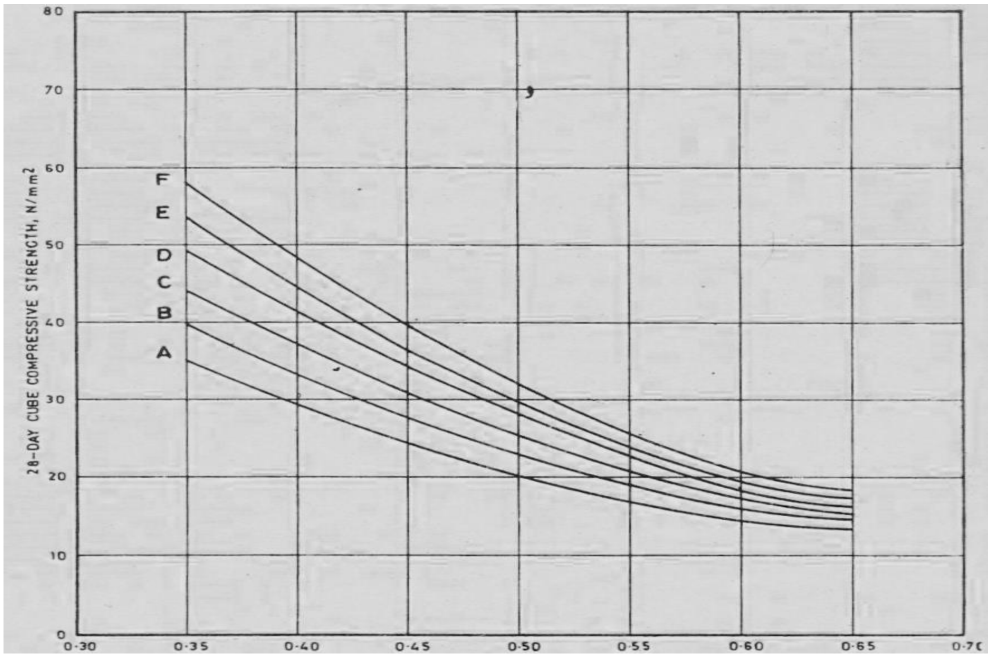
F_{ck} = Characteristic compressive strength at 28 days in N/mm^2

S = standard deviation N/mm^2 (Table B1)

Grade of Concrete	Standard Deviation for different degree of control (N/mm^2)		
	Very good	Good	Fair
M10	2.0	2.3	3.3
M15	2.5	3.5	4.5
M20	3.6	4.6	5.6
M25	4.3	5.3	6.3
M30	5.0	6.0	7.0
M35	5.3	6.3	7.3
M40	5.6	6.6	7.6
M45	6.0	7.0	8.0
M50	6.4	7.4	8.4
M55	6.7	7.7	8.7
M60	6.8	7.8	8.8

Table B1: Suggest Standard Deviation

2) The water cement ratio for the desired mean target is detemined by using a graph as shown in figure B1.The water cement ratio so chosen is checked aginst the limiting water cement ratio for the requirement of durability using the table B2 and the lower value is adopted.



Water cement Ratio
7 days strength of cement, tested according to IS4031-1968
A= 21.6-25.0 N/mm^2 C=29.8-35.0 N/mm^2 E=41.5-48.0 N/mm^2
B= 25.0-29.8 N/mm^2 D= 35.0-41.5 N/mm^2 F= 48.0-53.4 N/mm^2

Figure B1: Relation between water- cement ratio and 28 days cube compressive strength N/mm^2

Exposure	Plain Concrete			Reinforced Concrete		
	Minimum Cement content Kg/m^3	Maximum free water–cement ratio	Minimum grade of concrete	Minimum Cement content Kg/m^3	Maximum free water–cement ratio	Minimum grade of concrete
Mild	220	0.60		300	0.55	M20
Moderate	240	0.60	M15	300	0.50	M25
Severe	250	0.50	M20	320	0.45	M30
Very Severe	260	0.45	M20	340	0.45	M35
Extreme	280	0.40	M25	360	0.40	M40

Note: The minimum cement content is based on 20mm aggregate. For 40mm aggregate, it should be reduced by 30 kg/m^3 and similarly for 10mm aggregate, it should be increased by 40 kg/m^3.

3) The approximate entrapped air content for nominal maximum size of aggregates of 10mm, 20mm and 40mm is taken as 3.0, 2.0 and 1.0 percent of volume of concrete.

4) The water cement and percentage of sand in total aggregate by absolute volume from the Table 3 for medium and high strength concrete respectively, for the following conditions:

1) Crushed (angular) coarse aggregate
2) Fine aggregate consisting of natural sand conforming to zone –ii of the Table B4, IS 383-1970, in saturated dry condition.
3) Water-cement ratio of 0.60 and 0.35 for medium and high strength concrete respectively.
4) Workability corresponds to compacting factor of 0.80.

Table B3: Approximate sand and water contents per cubic meter of concrete

For the concrete upto M35

Maximum size of aggregate (mm)	w/c per cubic meter of concrete (kg)	Sand as percent of total aggregate by absolute volume
10	208	40
20	186	35
40	165	30

For concrete above M35

Maximum size of aggregate (mm)	w/c per cubic meter of concrete (kg)	Sand as percent of total aggregate by absolute volume
10	200	26
20	190	23

5) For other conditions of workability, water- cement ratio, grading of fine aggregate and for rounded aggregates, adjustments in water content and percentage of sand in total aggregate are made as per Table B4.
6) The cement content is calculated from the water-cement ratio and the final water content arrived after adjustment, is checked against the minimum cement content required for durability (Table B2) and greater of the two values is adopted.

Table B4: Adjustment of values in water cement and sand percentage for other conditions

Maximum size of aggregate (mm)	Adjustment required in	
	Water Content	Percentage sand in total aggregate
For sand confirming to grading zone I, Zone II ,Zone III or Zone IV of table 4, IS 383-1970	0	1.5% for zone I and Zone II and 3.0% for Zone IV
Incresese or decrease in the value of compacting factor by 0.1. Each 0.05 increase or decrease in water cement ratio. For rounded aggregate	$\pm$ 3 percent 0 -15 kg/m^3	0 $\pm$1% -7%

7) With quantities of water and cement per unit volume of concrete and percentage of sand in total aggregate already determined, the coarse aggregate and fine aggregates content perunit volume of concrete are calculated from the following equations:

$$V = \left[\mathrm{Ww} + \frac{\mathrm{Wc}}{c} + \frac{\mathrm{Ws}}{p.s}\right]/1000$$

$$V = \left[\mathrm{Ww} + \frac{\mathrm{Wc}}{c} + \frac{\mathrm{Wca}}{(1-p).ca}\right]/1000$$

Where,

V= absolute volume of fresh concrete (excluding the air content i.e. 1cum volume of entrapped air)

C= specific gravity of cement

S= specific gravity of sand

Ca= specific gravity of coarse aggregate

Ww = mass of water in kg per cum of concrete

Wc =mass of cement in kg per cum of concrete

Ws =mass of sand in kg per cum of concrete

Wca =mass of coarse aggregate in kg per cum of concrete

p = ratio of fine aggregate to total aggregate by absolute volume.

8) If any liquid admixture is to be added then the water content should also be adjusted to the volume of the water in the admixture. Gauge water equal to the volume of water in the admixture, is deducted from the total water content.

Table B5: Design of concrete Mixes according to Indian Standards for different percentage of sand replacement by Plastic pet bottles fiber

M20 grade of concretes

Particulars	Design values for different percentage of Plastic pet bottle fiber						Remarks
	0%	1%	2%	2.5%	3%	5%	
Characteristic strength, F_{ck}(MPa)	20	20	20	20	20	20	-Cement used = maruti OPC Cement S=3.6 Sp. Gravity of cement=3.15 For moderate exposure w/c =0.50 Maximum nominal size of aggregate=20mm (crushed) Minimum cement content = 260kg/m^3 Wokability =30-60mm Degree of supervision = Good sp. gravity of sand =2.63 sp.gravity of coarse agg. =2.69 sand passing through 600μm sieve=63.00% (grading zone III) free moisture for sand= nil free moisture for coarse agg.= nil
Target Strength for mix proportion $F'_{ck} = F_{ck} + 1.65s$(MPa)	25.94	25.94	25.94	25.94	25.94	25.94	
Water cement Ratio considering D curve	0.50	0.50	0.50	0.50	0.50	0.50	
Selected water cement ratio	0.50	0.50	0.50	0.50	0.50	0.50	
Water content(kg/m^3)	195	1.95	195	195	195	195	
Cement Content (kg/m^3)	390	390	390	390	390	390	
Plastic pet bottles fiber (kg/m^3)	-	5.74	11.48	14.35	17.22	28.70	
Sand content(kg/m^3)	574	568.26	562.52	559.65	556.78	545.30	
Coarse Aggregate content (kg/m^3)	1138	1138	1138	1138	1138	1138	
Mix Propertions:							
Water	0.50	0.50	0.50	0.50	0.50	0.50	
cement	1	1	1	1	1	1	
Plastic pet bottles fiber	-	0.014	0.029	0.036	0.044	0.073	
Sand	1.47	1.46	1.44	1.43	1.425	1.40	
Coarse Aggregate	2.92	2.92	2.92	2.92	2.92	2.92	

APPENDIX C: OBSERVATION OF PROPERTIES OF CONCRETE MIXES

Table C1: Slump value of Fresh Concrete

Sand Replacement	**Slump value**
0%	35
1%	45
2%	50
2.5%	60
3%	65
5%	75

Table C2: Bulk Density/ Unit Weight of 28 days cured concrete at different percentage of Sand Replacement

Sand Replacement (%)	S.N.	Length (mm)	Breadth (mm)	Depth (mm)	Volume (cm^3)	Weight after 28 days of curing (gm)	Bulk Density (Kg/m^3)	Unit weight (KN/m^3)
0	1	150	150	150	3375	8404	2490	24.90
	2	150	150	150	3375	8303	2460	24.60
1	1	150	150	150	3375	8353	2475	24.75
	2	150	150	150	3375	8269	2450	24.50
2	1	150	150	150	3375	8235	2440	24.40
	2	150	150	150	3375	8303	2460	24.60
2.5	1	150	150	150	3375	8168	2420	24.20
	2	150	150	150	3375	8259	2447	24.47
3	1	150	150	150	3375	8201	2430	24.30
	2	150	150	150	3375	8100	2400	24.00
5	1	150	150	150	3375	7931	2350	23.50
	2	150	150	150	3375	8100	2400	24.00

Table C3: Water Absorption of 28 days cured concrete at different percentage of Sand Replacement.

Sand Replacement (%)	S.N.	Weight before curing (gm)	Weight of cube after 28 days of curing (gm)	Difference in Weight (gm)	Water Absorption (%)
0	1	8362	8404	42	0.50
	2	8263	8303	40	0.48
1	1	8313	8353	40	0.48
	2	8231	8269	38	0.46
2	1	8200	8235	35	0.42
	2	8265	8303	38	0.46
2.5	1	8135	8168	33	0.40
	2	8223	8259	36	0.44
3	1	8170	8201	31	0.38
	2	8066	8100	34	0.42
5	1	7899	7931	32	0.40
	2	8071	8100	29	0.36

Table C4: Compressive strength of the 7 days cured concrete at different percentage of sand Replacement

Sand Replacement (%)	S.N	Length (mm)	Breadth (mm)	Depth (mm)	Area (cm^2)	Failure load (KN)	Compressive Strength (N/mm^2)
0%	1	150	150	150	225	320	14.22
	2	150	150	150	225	340	15.11
1%	1	150	150	150	225	380	16.89
	2	150	150	150	225	360	16.00
2%	1	150	150	150	225	395	17.56
	2	150	150	150	225	385	17.11
2.5%	1	150	150	150	225	370	16.44
	2	150	150	150	225	360	16.00
3%	1	150	150	150	225	330	14.66
	2	150	150	150	225	310	13.78
5%	1	150	150	150	225	270	12.00
	2	150	150	150	225	290	12.89

Table C5: Compressive strength of the 28 days cured concrete at different percentage of sand Replacement

Sand Replacement (%)	S.N	Length (mm)	Breadth (mm)	Depth (mm)	Area (cm^2)	Weight after 28 day of curing (gm)	Failure load (KN)	Compressive Strength (N/mm^2)
0%	1	150	150	150	225	8404	560	24.88
	2	150	150	150	225	8303	580	25.77
1%	1	150	150	150	225	8353	630	28.00
	2	150	150	150	225	8269	640	28.44
2%	1	150	150	150	225	8235	660	29.33
	2	150	150	150	225	8303	650	28.89
2.5%	1	150	150	150	225	8168	620	27.56
	2	150	150	150	225	8259	630	28.00
3%	1	150	150	150	225	8201	520	23.11
	2	150	150	150	225	8100	540	24.00
5%	1	150	150	150	225	7931	480	21.33
	2	150	150	150	225	8100	490	21.77

Table C6: Flexural strength of the 7 days cured concrete at different percentage of sand Replacement

Sand Replacement	S. N	Length (mm)	Length Between Support (mm)	Breadth (mm)	Depth (mm)	Load At Failure (N)	Flexural Strength (N/mm^2)
0%	1	300	200	75	75	2500	1.77
1%	2	300	200	75	75	2600	1.84
2%	3	300	200	75	75	3000	2.13
2.5%	4	300	200	75	75	3200	2.27
3%	5	300	200	75	75	2900	2.06
5%	6	300	200	75	75	2700	1.92

Table C7: Flexural strength of the 28 days cured concrete at different percentage of sand Replacement

Sand Replacement	S.N	Length (mm)	Length Between Support (mm)	Breadth (mm)	Depth (mm)	Load At Failure (N)	Flexural Strength (N/mm^2)
0%	1	300	200	75	75	5000	3.55
1%	2	300	200	75	75	5200	3.69
2%	3	300	200	75	75	5600	3.98
2.5%	4	300	200	75	75	5800	4.12
3%	5	300	200	75	75	5500	3.91
5%	6	300	200	75	75	5100	3.63

APPENDIX D: PHOTOGRAPHS

OPC Cement

Coarse Aggregates

Waste Plastic Pet Bottles Fiber

Fine Aggregates (Sand)

Concrete Mixing Process

Waste plastic pet bottle collection

Cone Slump Test

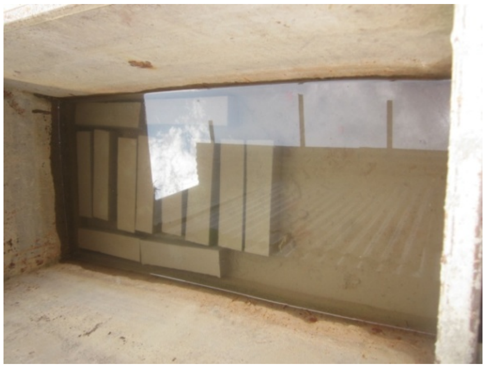
Beam Sample Preparation

Beam Sample Preparation

Cube Sample Preparation

Concrete Mixer

Compression testing Machine



Curing of Sample

Samples after Curing

Weighing of samples

Central Material Testing Laboratory

Compressive Strength Testing

Flexural Strength Testing

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