A Study on the Partial Replacement of Fine Aggregate by Using Pet Bottles

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Abstract -Due to rapid growth of population in countries like India the disposing of solid waste is a major problem in our daily life. Solid waste management is one of the major environmental problem. Among the waste material, plastic is the material that is the major worries to most of the environmental effects. There are different types of plastic which are classified on the basis of the physical property. As the plastic waste is non degradable material, it is to be recycled or reused. The objective of study is to study the behavior of the concrete which is made of the recycled plastic materials along with the study of the some of the physical properties that are related. Usually M30 grade of the concrete is the most commonly used in the constructional works, hence in this study M30 cement concrete is considered in which the recycled plastic waste is used as the partial replacement of fine aggregate in the concrete. Concrete cubes were casted taking 2% , 4% , 6% and 8% of plastic as partial replacement of fine aggregate and tested for 28 days of compressive strength of concrete.

***Key Words*:**Environmental concerns, Non Degradable, Partial Replacement, Recycled or Reused, Compression Strength

1. INTRODUCTION

Because of a country's development is based on various factors and one of the major factor is infrastructure. Infrastructure mention to the fundamental facilities and systems serving a country, city, or area. It typically characterizes technical structures such as roads, bridges, tunnels, water-supply, sewers, electrical grids, telecommunications and so on. Hence, it is the physical components providing commodities and services essential to enable, sustain and enhance societal living. And for a physical component like a structure or a building to be constructed, one of the necessary component is concrete. Over the past few years, it is estimated roughly that 25 billion tonnes of concrete manufactured each year globally. The current concrete construction industries consumed vast amounts of natural aggregates and approximately 2 billion tonnes of Portland Cement. The excessive raw materials consumption potentially release of greenhouse gases leading to global warming. Therefore, the need to incorporate the recycled materials as the substitution to construction materials are essential to reduce landfill space as well as a shortage of natural resources. Waste materials increase with increasing population and most of these materials are non-degradable. The excessive disposal of non-degradable materials can lead to environmental pollution. To overcome this serious issue, the recycle of non-degradable materials is very substantial. Normally 60–80% of the aggregates used in concrete and it shows a significant function in concrete performance such as strength, workability, durability and stability. The unwanted materials as an alternative replacement to aggregate can potentially reduce environmental issues on lack of natural resources as well as abundant waste disposal.

1.1 Objective

The main objective of the project is to determine the change in compressive strength of concrete proportioned with partial replacement of PET Pellets in fine aggregate with the conventional concrete by adding mineral admixture.

2. EXPERIMENTALMETHOD

2.1 Materials used

2.1.1 Cement

A cement is a binder used as an construction material which sets, hardens, and adheres to other materials to bind them together. Cement is rarely used on its own, but rather to bind sand and gravel together. Cement combined with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Ordinary Portland Cement (OPC) of grade-43 is used in this project. The cement bag was bought from Chettinad Cement. Chettinad OPC is the high-quality and cost-effective cement best suited for house construction in India is mainly composed of clinker that meets all applicable chemical and physical requirements. Tricalcium silicate ($3CaO.SiO_2$), Dicalcium silicate ($2CaO.SiO_2$), Tricalcium aluminate ($3CaO.Al_2O_3$), and Tetra-calcium aluminoferrite ($4CaO.Al_2O_3Fe_2O_3$)are the four main components used to manufacture Portland cement. In an noble gas notation differing from the normal atomic symbols, these compounds are designated as C_3S, C_2S, C_3A, and C_4AF, where C stands for calcium oxide (lime), S stands for silica, A stands for alumina, and F stands for iron oxide. Small amounts of uncombined lime and magnesia are also present, along with alkalies and minor amounts of other elements.

2.1.2 Fine Aggregate

Manufactured sand (M-Sand) is used as an substitute of river sand for concrete construction. Manufactured sand is generated from hard granite stone by crushing. The crushed sand are in cubical shape with grounded edges, washed and graded as a construction material. The size of M-Sand is less than 4.75mm. In the fast growing construction industry, the demand for sand has been increased tremendously, causing deficiency for suitable river sand in most part of the world. Due to the depletion of good quality river sand for construction, the use of manufactured sand has been increased. Another reason for use of M-Sand is its availability and less transportation cost. Since M-sand can be produced from hard granite rocks, it can be easily available at the nearby place, reducing the cost of transportation from far-off river sand bed. The other advantage of using Manufactured Sand is it can be dust free, the sizes of m-sand can be controlled easily so that it meets the required grading for the given construction. The chemical composition of fine aggregates are SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Cl, Na_2O, K_2O, TiO_2, BaO, P_2O_5, loss on ignition.

2.1.3 Coarse Aggregate

Aggregates are coarse particulate rock-like material, which is consisting of a collection of particles ranging in size from < 0.1 mm to > 50 mm. Aggregate includes gravel, crushed rock, sand, recycled concrete, slag, and synthetic aggregate.Crushed stones passing through 20mm and retaining on 12.5mm sieve and stones passing through 12.5mm and retaining on 4mm sieve is used for the experimental work. Coarse aggregates have several uses in construction. The most apparent is as part of the mix in concrete. They are also used in the preparation of the moisture break under the slab and vapour barrier. The function of coarse aggregate is to act as a main load bearing component of the concrete.

2.1.4 PET pellets

Polyethylene terephthalate (PET) is a general-purpose thermoplastic polymer which belongs to the polyester family of polymers. It is also known by “polyester”, which often causes confusion, because polyester resins are thermosetting materials. Polyester resins are known for their outstanding combination of properties such as mechanical, thermal, chemical resistance as well as dimensional stability. Polyethylene terephthalate is highly flexible, colourless and semi-crystalline resin in its natural state. Depending upon how it is processed, it can be semi-rigid to rigid. It shows good dimensional stability and resistance to impact, moisture, alcohols and solvents. Polyethylene terephthalate is a transparent polymer, with a good mechanical properties and good dimensional stability under variable load. Moreover, Polyethylene terephthalate has good gas barrier properties and good chemical resistance. Polyethylene terephthalate is a clear, strong, and lightweight plastic that is commonly used for packaging foods and beverages, especially convenience-sized soft drinks, juices and water. Polyethylene terephthalate is a polyester polymer made by reacting ethylene glycol and terephthalic acid. Pellets of the Polyethylene terephthalate polymer are heated to a molten mass, which can easily be moulded into almost any shape. Polyethylene terephthalate is one of the most recycled thermoplastic, and has the number "1" as its recycling symbol.

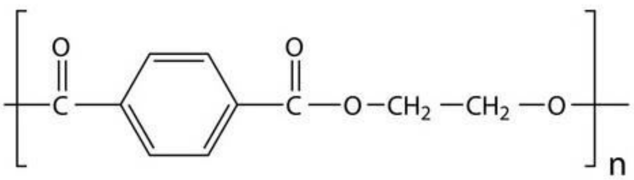

Fig-1: Molecular Structure of Polyethylene Terephthalate

2.1.5 PET Chemical Formula $(C_{10}H_8O_4)_n$

The basic building blocks of Polyethylene terephthalate are ethylene glycol and terephthalic acid, which are combined to form pellets of PET. These resin pellets are then heated to a molten liquid that can be easily extruded or moulded into items of practically any shape.More specifically, when the two raw materials of Polyethylene terephthalate are combined under high temperatures and low vacuum pressure, long chains of the polymer are formed. As the mixture becomes thicker, the chains grow longer. Once the suitable chain length is achieved, the reaction is stopped. The resulting spaghetti-like strands of Polyethylene terephthalate are then extruded, quickly cooled, and cut into small pellets. Resin pellets are reheated to a molten liquid stage, the polymer chains can be stretched in one direction (for fibres) or in two directions (for bottles and films). If the polymer is cooled quickly while it is stretched, the chains are frozen with their direction intact. Once the polymer is set in stretched form, the material is extremely tough.If PET is held in the stretched form at elevated temperatures, it slowly crystallizes and starts to become opaque, more rigid and less flexible. This crystalline form PET is often used for take-home and prepared-food containers and trays that can be reheated in the oven or microwave. PET bottles due to its lightweight properties have replaced the glass bottles and because of it is easy handling and storage. Plastic bottles made of PET, which originates a major fraction of domestic wastes. They are considered as non-biodegradable surplus materials which are injurious to public health. So making use of PET bottles waste in concrete production can be a useful method to get rid of plastics solid waste damage on the environment.

2.1.6 Water

Potable drinking water with pH value ranging between 6 to 7 available within the college campus has been used for making concrete.

2.1.7 Silica fume

Silica fume is a by-product of manufacturing silicon metal or ferrosilicon alloys. Silica fume are very reactive pozzolan, Because of its chemical and physical properties. So it is most beneficial to use silica fume in concrete. Concrete containing silica fume can have very high strength and also durable. Portland cement property can e improved by adding Silica fume, in particular its compressive strength, bond strength, and abrasion resistance. When silica fume is added to concrete, at first it remains inert. Whenportland cement and water in the mix start reacting with each other, primary chemical reactions produce two chemical compounds: Calcium Silicate Hydrate (CSH), and Calcium Hydroxide (CH). The transport properties through the silica fume concrete medium are magnificently curtailed, i.e. liquid compounds and even electrical currents experience a diminished capability to migrate, resulting in shallow permeability and high electrical resistivity. Silica fume’s benefits are already obvious in the fresh concrete state before it begins to harden. Due to high surface area of silica fume particles affecting the mobility of water within concrete, segregation and bleeding of concrete are virtually eliminated.

3. METHODOLOGY

3.1 Tests and methods of preparation of specimen

3.1.1 Testing of specimens

The compressive strength on concrete specimens incorporating PET pellets as fine aggregate was performed as per IS: 516-1959 on standard compression testing machine of 2000KN capacity. Total 15 numbers of cubical specimen of size 150mm x 150mm x 150mm were casted and tested for compressive strength at the age of 28 days.The step-by-step procedure to lay the concrete cubes are as follows:

3.1.2 Preparation of cube specimens

9 concrete cube moulds of volume $150mm^3$ each is collected to lay the cubes which is for 28 days test. So that average of 3 cubes at each particular day can be calculated.

3.1.3 Mixing

Hand mixing is the activity of mixing the ingredients of the concrete manually without a mixer machine. Mixing concrete without a mixer is only suitable for small works where the concrete requirement is less and quality control is less important. In the hand mixing of concrete, uniformity of mixing is hard to achieve and requires special care and efforts.

Fig-2: Mixing

3.1.4 Mixing procedure

Initially collect the calculated quantities of coarse aggregate, fine aggregate, cement, silica fume and water.Pour all the materials and add water as last component in the mix.Mix all the materials until the concrete appears to be homogeneous and it is of desired consistency.

3.1.5 Sampling

Clean the moulds and apply oil on its surface to reduce the frictional resistance between the mould and the concrete.Fill the concrete in the mould by 3 layers with not less than 30 strokes per layer using a tampering rod. The top surface should be levelled and smoothened with a trowel.Then, the concrete has to be placed on the vibrating table for compaction of concrete in the mould.

Fig -3: Sampling

3.1.6 Curing

The test specimens are stored in moist air for about 24 hours and after this period the specimens are marked and detached from the moulds and kept submerged in clean fresh water until it is taken out for the tests.

Fig -4: Curing

3.1.7 Testing procedure

Remove the specimen from the water after the specified curing time and wipe out excess water from the surface.Clean the bearing surface of the specimen as well as the testing machine.

Place the specimen in the machine in such a manner that the load could be applied to the opposite sides of the cubes.Align the specimen centrally on the base plate of the machine.Apply the load gradually and continuously without shock at the rate of 5 KN/sec till the specimen fails.

Fig -5: Compression Testing Machine

4. RESULTS AND DISCUSSION

4.1 Preliminary investigation

The optimal values of the material composition as the standard guidelines are tabulated in Table 1.

TABLE -1: Materials used

W/C ratio	Cement	Fine aggregate	Coarse aggregate
0.44	423	676	1119

Ratio between the density of a substance to the density of a given reference material is known as specific gravity. The specific gravity of the materials are determined in the preliminary investigation in order to prepare the mix design for the preparation of the cubic specimens and to determine the compressive strength for 28 days. The specific gravity results of the materials to be used for the preparation of the sample are shown in Table 2.

TABLE -2: Specific gravity results

Materials	Specific gravity
Cement	3.14
Coarse aggregate	2.67
M-sand	2.63
Plastic aggregate	0.8
Silica fume	2.21

The mix composition was done for various percentages of waste bottle plastic pellets i.e., 0%, 2%, 4%, 6% and 8% replacement for fine aggregate. The mix proportions for various batches are given in the Table 3.

TABLE -3: Mix Compositions

Pet pellets replacement as %	Materials used					
	Cement (kg/m^3)	Silica fume (kg/m^3)	Water	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	Plastic Aggregate (kg/m^3)
Conventional concrete	397.62	25.38	186	1119	676	0
2%	397.62	25.38	186	1119	662	4.11
4%	397.62	25.38	186	1119	649	8.22
6%	397.62	25.38	186	1119	635	12.33
8%	397.62	25.38	186	1119	622	16.44

4.2 Compressive strength test

The compressive strength of the cube specimen is calculated using the following formula:

Compressive Strength, $f_c = P/A$ N/mm^2

Where P = load at failure in N

A = Area subjected to compression in mm^2

The cubes tested on the 28^{th} day of the curing process are reported as the mean values obtained after testing is observed in the Table 4.

TABLE -4: Compression Strength Result

Proportions	Specimen 1	Specimen 2	Specimen 3	Average Result
0%	31.84	31.23	31.07	31.26
2%	32.75	32.68	33.03	32.82
4%	31.21	30.98	30.84	31.01
6%	30.43	30.94	30.52	30.63
8%	28.91	29.89	29.01	29.27

The below graph illustrates that there are some variations in the compressive strength of specimens with different replacement percentage of fine aggregates by plastic PET pellets.

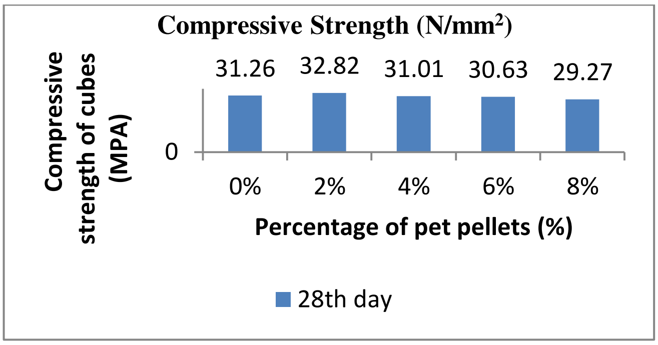

Chart1 :Compressive Strength of PET pellets

An appreciable increase in the compressive strength of concrete is observed for 2% replacement of fine aggregate with PET bottle pellets and then the compressive strength is gradually decreased. So, the replacement of fine aggregate with 2% of PET pellets is found to be reasonable.

5. CONCLUSION

The main purpose of this project is to utilize recycled materials for the production of concrete. As disposal of plastic waste is not possible easily, they create an adverse impact on the environment. Reuse of plastic waste in concrete industry is considered as the most feasible application. It decreases the pollution of the environment.The solid with PET pellets significantly reduces the cement weight and this helps in the preparation of concrete technology with reduces amount of unit weight.It was observed that the compressive strength increased upto 2% replacement of fine aggregate with PET bottle pellets and it gradually decreases for 4%, 6% and 8% replacements. Hence, replacement of fine aggregate with 2% of PET bottle pellets will be reasonable.

5.1 Benefits of using pet aggregate

PET aggregate generates good quality of concrete mixtures with lower volumetric weight but mechanical behaviour similar to that of natural concrete with adequate granulometry. The water cement (W/C) ratio is lower for light concretes when compare to natural concrete. It is economical when comparing to fine aggregate.

5.2 Future scope

Admixtures can be used to improve bonding of PET pellets.Plastic waste alongside steel filaments can be utilized to enhance the quality of the cement.

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