# CHAPTER 4
# Performance of Structural Concrete with Recycled Plastic Waste as A Partial Replacement for Fine Aggregate

**Prof. M. Vadivel**
*Nehru Institute of Technology, India*

**Prof. S. Sukumar**
*Nehru Institute of Technology, India*

**Ar. S. Sundar**
*Nehru School of Architecture, India*

**Ar. S. Stella Mary**
*Nehru School of Architecture, India*

## ABSTRACT

*Lots of wastes are dumped in environment by us every day many are non-biodegradable . At the same time one of the exploiting the environment largely goes to civil engineers. It is our duty to preserve the environment at least in the present condition for the future generation. Through this project the possibility of utilizing the waste plastic effectively is analyzed. Its various properties are found out to utilize these wastes in structural concrete. In addition to this possibility of using polypropylene plastic in structural concrete to enhance strength is also analyzed. This study insures that reusing waste plastic in sand concrete gives a positive approach to reduce the cost of materials and solve some environmental problems.*

***Keywords:*** *non-biodegradable , future generation, reusing waste plastic etc*

## INTRODUCTION

The amount of plastic waste is increasing and occupies a large part of solid waste. This type of waste is a serious problem for environment because of its non-biodegradable nature. Recycling of this type of waste to produce new materials like concrete or mortar appears as one of the best solution, due to its economic and ecological advantages. Plastic wastes are considered to be a serious environmental issue globally as the consumption is rapidly increasing for their favourable properties. The total plastic waste generation figure for the year was estimated at 1.6 million tonnes At least 40% of the plastic waste generated everyday 25,940 tonnes as per this CPCB (Central Pollution Control Board )

Poly propylene for large disposal rate in the Municipal Solid Waste (MSW) and comes third after Polyethylene Terephthalate (PET) and Low-density polyethylene (LDPE) and the high-density


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

polyethylene (HDPE). The use of plastic waste as partial replacement of sand contributes to reduce the bulk density, decrease the air content, causing a increase in compressive and flexural strength and especially for 10% and 20% of replacement. In addition, the reinforcement of the cementing matrix with plastic fibre induced a clear improvement of the tensile strength.

## INTRODUCTION OF POLYPROPYLENE

Polypropylene was first introduced into market in 1950s the product is non- crystallisable which result in low melting point.For the Polypropylene (PP) plastic, only plastic fibre were extensively used, since they are easy to produce, has high tensile strength good durability performance. The PP was used as fresh or recycled fibres and was used in the applications of reinforced concrete, the addition was usually in small dosages, up to 3% by volume showed great results, increasing this percentage may decrease the effect of the fibres on the various properties.

Polypropylene is the excellent chemical resistance , the lowest density , highest melting point (In the family of olefin fibre ), and moderate cost makes it an important fibre in industrial application

## MATERIALS USED

The basic materials for mixing concretes are required such as

- Cement
- Sand
- Aggregate
- Polypropylene (plastic)

The cement used for the present investigation was ordinary Portland cement

Sand is of Zone –II as per IS:383-1970 , 20mm graded aggregate as per IS:383-1970 .

The physical properties of aggregate were considered according IS:2386(1963)

## APPLICATION OF POLYPROPYLENE

As polypropylene is resistant to fatigue ,most plastic living hinges such as those on flip –top bottles are made from this material.It is the important to ensure that chai molecules are oriented across the hinge to maximise strength. Polypropylene is widely used in various application due to its good chemical resistance. Some common uses of polypropylene include: rigid packaging: polypropylene is blow moulded to produce crates, bottles , and pots Polypropylene thin walled container are commonly used for food packaging. Polypropylene fibre reinforced concrete is used in roads and pavements , driveways , overlay , and toppings , ground supported slabs , machine foundation ,off shore structures , tanks and pools etc.

## ADVANTAGES OF POLYPROPYLENE

- It is relatively inexpensive material.
- It possesses high flexural strength because of its semi crystalline nature.


ISBN: 978-93-5980-742-3, www.aetsjournal.com ― Handbook of research in Basic and Applied Science

- It has a low coefficient of friction.
- It is very resistant to moisture .
- It has good chemical resistance over a wide range of bases and acids.

## DISADVANTAGES OF POLYPROPYLENE

- It has high thermal expansion coefficient which limits its high temperature applications.
- It is susceptible to ultra violet degradation.
- It is known to be difficult to paint as it has poor bonding properties
- It has high flammability.
- It is susceptible to oxidation.

## POLYPROPYLENE & TYPES

Introduction

The amount of plastic waste is increasing and occupies a large part of solid waste. This type of waste is a serious problem for environment because of its non-biodegradable nature. Recycling of this type of waste to produce new materials like concrete or mortar appears as one of the best solution, due to its economic and ecological advantages.

## TYPES OF POLYPROPYLENE

Depending upon the position in a concrete , polypropylene may be classified as ;

- Polypropylene Homo polymer
- Polypropylene copolymer
  - Polypropylene random copolymer
  - Polypropylene block polymer
- Polypropylene impact copolymer
- Expanded polypropylene
- Polypropylene terpolymer
- Polypropylene high melt strength

## POLYPROPYLENE HOMO POLYMER

It is the most widely utilized general purpose grade.


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

It contains only propylene monomer in a semi crystalline solid form

Main application include packaging , textiles , healthcare , pipes , automotive and electrical applications.

## POLYPROPYLENE COPOLYMER

Polypropylene copolymer family is further divided into random copolymer and block copolymer produced by polymerizing of propene and ethane.

## POLYPROPYLENE RANDOM COPOLYMER

It is polymerizing together ethane and propene.It features ethane units, usually up to 6% by mass, incorporated randomly in the propylene chains These polymers are flexible and optically clear making them suitable of applications requiring transparency and for products requiring an excellent appearance .

## POLYPROPYLENE BLOCK COPOLYMER

While in polypropylene block copolymer , ethane content is larger ( between 5 and 15%).It has co manner units arranged in regular pattern. These polymers are suitable for application requiring high strength , such as industrial usages.

## POLYPROPYLENE IMPACT COPOLYMER

Propylene homo polymer containing a co-mixed propylene random copolymer phase which has an ethylene content of 45% - 65% is referred to pp impact copolymer. It is useful for good impact resistance . Impact copolymers are mainly used in packaging , house ware, film , and pipe applications.

## EXPANDED POLYPROPYLENE

It is closed cell bead foam with ultra low density. It is used to produce three dimensional polymer foam products . It has higher strength to weight ratio, excellent impact resistance , thermal insulation and chemical and water resistance It is used various application ranging from automobiles to packaging , from construction products.

## POLYPROPYLENE TERPOLYMER

It is composed by propylene segments joined by monomers ethylene and butane which appear randomly throughout the polymer chain . Polypropylene terpolymer has better transparency than pp homo. The incorporation of co-monomers reduces crystalline uniformity in the polymer making it suitable for sealing film applications.


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

## POLYPROPYLENE HIGH MELT STRENGTH

It is a long chain branched material , which combine both high melt strength and extensibility in the melt phase .PP HMS grade have a wide mechanical property range , high heat stability , good chemical resistance PP HMS is used to produce soft , low density foams for food packaging applications as well as used in construction industries .

## LITERATURE REVIEW ON , PLASTIC AND POLYPROPYLENE

## GENERAL

The paper deals with the effects of addition of various proportions of polypropylene fibers on the properties of High strength concrete. An increase in shear strength and flexural strength was found. The main aim of the investigation program was to first prepare the strength of concrete of grade M20 with locally available ingredient and then to study effects of different proportion of Polypropylene fiber and find optimum range of Polypropylene fiber content is 0.5%,1.0%,1.5% in the mix.The concrete specimens were tested at different age level for mechanical properties of concrete, namely, cube compressive strength, flexural strength and other test were conducted for cement, chemical admixture, coarse aggregate & fine aggregate. The study hence gave a significant reduction in settlement and drying shrinkage without having any significant change in compressive strength for the concrete mixes reinforced with fiber. Further, an improved abrasion resistance for the concrete mixes reinforced with fiber was also observed.

## LITERATURE REVIEW ON PLASTIC

The study present the partial replacement of fine aggregate in concrete by using plastic fine aggregate obtained from the crushing of waste plastic bags. Plastic bags waste was heated followed by cooling of liquid waste which was then cooled and crushed to obtained plastic sand having finesse modulus of 4.7. Fine aggregate in the mix proportion of concrete was replaced with plastic bag waste sand at 10%, 20%, 30% and 40% whereas other concrete materials remain same for all four mixes. In fresh properties of concrete it was observed from the results of slump test that with increase of waste content workability of concrete increases which is favourable for concrete because plastic cannot absorb water therefore excessive water is available. Bulk density decreases with increase of plastic bags waste. In harden state, flexural and compressive strength were tested at 28 days and reductions in both strengths with increasing percentage of plastic bag waste sand in concrete mix. Plastic waste increases the volume of voids in concrete which on other hand reduce the compactness of concrete simultaneously speed of sound in concrete is also decreased. Strength reduction in concrete mix was prime concern; however they recommend 10 to 20% replacement of fine aggregate with plastic aggregate. Use of admixtures to address the strength reduction property of concrete with addition of plastic aggregate is not emphasized.

## LITERATURE REVIEW ON POLYPROPYLENE FIBRE

For the Polypropylene (PP) plastic, only plastic fibre were extensively used, since they are easy to produce, has high tensile strength good durability performance. The PP was used as fresh or recycled fibres and was used in the applications of reinforced concrete, the addition was usually in small dosages, up to 3% by volume showed great results, increasing this percentage may decrease the effect of the fibres on the various


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

properties. The study hence gave a significant reduction in settlement and drying shrinkage without having any significant change in compressive strength for the concrete mixes reinforced with fiber.

## PROPERTIES OF POLYPROPYLENE FIBERS

The raw material of polypropylene is derived from monomer C3H6 which is purely hydrocarbon. Its mode of polymerization, its high molecular weight and the way it is processed into fibers combine to give polypropylene fibers very useful properties explained below:

- There is a satirically regular atomic arrangement in the polymer molecule and high crystalline due to regular structure , it is known as isotactic polypropylene

- Chemical inertness makes the fibers resistant to most chemicals .on contact with more aggressive chemicals , the concrete will always deteriorate first.

- The hydrophobic surface not being wet by cement paste helps to prevent chopped fiber from balling effect during mixing like other fibers.

- The water demand is nil for polypropylene fibers.

- The orientation leaves the film weak in the lateral direction which facilitates fibrillations the cement matrix can therefore penetrate in the mesh structure between the individual fibrils and create a mechanical bond between matrix and fiber

## MATERIALS USED AND MIX PROPORTION

The properties of the material ,which are used for investigation , are presented in this section . All the experiments that are adopted to determine characterize of the materials are carried out as per I.S code book specification . This section also includes mix design for concrete as per I.S code book specification.

## MATERIAL USED

The material that are used ,OPC – 43 special grade of cement Fine aggregate ( M – sand) Coarse aggregate (20mm) Polypropylene plastic (partial replacement by sand)

## TYPES OF CEMENT

1) Ordinary Portland cement 33grade -IS269:1969

2) Ordinary Portland cement 43 grade -IS8112:1989

3) Ordinary Portland cement 53 grade -IS12269:1987

4) Rapid hardening cement

5) Extra rapid hardening cement

6) Sulphate resisting cement


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

7) Portland slag cement

8) Quick setting cement

9) Super sulphated cement

10) Low heat cement

11) Portland pozzolana cement

12) Air entraining cement

13) Colour cement

14) Masonry cement

## MANUFACTURING PROCESS OF CEMENT

1) Wet process

2) Dry process

## WET PROCESS

During the wet process, the raw mix is fed into the kiln in the form of slurry that may contain water up to 30 to 40%. In the wet process, the kiln is a very long tube in comparison to dry process, and the slurry that is easy to blend and homogenize due to the water, is directly being fed into the kiln. Wet process could be selected as manufacturing technology is when raw materials have natural high moisture content. The amount of moisture in mineral sometimes can be even more than 12%, as in case of chalk and in marlstone.

The use of wet process is also essential when relatively poor grade limestone needs to be enriched through the beneficiation process. In this process, water is required as a process media. Until 1950, most of the cement processing kilns were wet kilns due to the ease of blending and homogenizing the components of the raw mix. In the wet process, the fuel consumption is in the range of 1300 to 1600 Kcal/Kg of clinker. Power consumption in manufacture process is about 110-115 kWh/ton of cement (Cement Industry, India, 2004).

## DRY PROCESS

To reduce the moisture content of minerals below 1%, which is required for dry process, the raw materials are dried in a combined drying and grinding plant. This drying of materials is reached by using exhaust gases coming from the kiln. The raw ground mix is homogenized in large silos. Development of appropriate blending and homogenizing systems, in general, is crucial for making the dry process practicable. The blended and homogenized raw mix is then fed into dry kiln with air suspension preheater where partial calcination of the raw mix starts to take place. Dry process is mostly limited to the use of air suspension preheater. This provides maximum benefits since the heat consumption is an important issue. Development of the dry process, using air suspension preheaters, is being integrated with pre- calcinators. Pre-calcinators ensure complete calcination of the raw mix before its entry to the kiln. The advantage of this process is that the fuel consumption is lowest in the existing technologies. In the dry process, the fuel use in this process


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

is in the range of 750-950 Kcal/Kg of clinker and the power consumption is in the range of 120-125 kWh/ton of cement (Cement Industry, India, 2004).

## CURING ON CONCRETE CUBES

The concrete cubes must be cured before they are tested. Unless required for test at 24 hours , the cube should be placed immediately after de-moulding in the curing tank. The curing temperature of the water in the curing tank should be maintained at 27- 30oc

## EXPERIMENTAL INVESTIGATION

Two series of concrete mix were produced to establish mix proportions for concrete mixes containing polypropylene plastic . Test on concrete, On hardened concrete.

## TEST ON HARDENED CONCRETE

The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested at 28 days (fck)- as per Indian Standards (ACI standards use cylinder of diameter 150 mm and height 300 mm). The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall Characteristic strength of concrete is the strength of concrete specimens casted and tested as per given code of practice and cured for a period of 28 days; 95% of tested cubes should not have a value less than this value.

## CONCLUSION

The concrete cube is made with 20%, 30%, 50% and 60% partial replacement of fine aggregate of waste plastic and addition of polypropylene with concrete cube

- 20% of Polypropylene plastic is adding partial replacement of fine aggregate in this compressive strength 20.08N/mm2 it is higher than required strength

- 20 % of polypropylene concrete is only give high compressive strength that is 20.08N/mm2 this type of concrete is used for structural building

- Remaining percentage (30%, 50%, 60%) of polypropylene concrete gives low compressive strength this type of concrete is used for only pavement , side walk etc.

- Pavement rehabilitation consist of structural enhancement that extends the service life of an existing pavement and r improve its load carrying capacity rehabilitation technique include restoration treatment and structural overlays .

## REFERENCES

[1]. N. Saikia et al.Mechanical properties and abrasion behaviour of concrete containing shredded PET bottle waste as a partial substitution of natural aggregateConstr. Build. Mater. (2014)


ISBN: 978-93-5980-742-3, www.aetsjournal.com — Handbook of research in Basic and Applied Science

[2]. C. Albano et al. Influence of content and particle size of waste pet bottles on concrete behaviour at different w/c ratios Waste Manage. (Oxford) (2009)
[3]. M. Frigione Recycling of PET bottles as fine aggregate in concrete Waste Manage. (Oxford) (2010)
[4]. L. Ferreira et al. Influence of curing conditions on the mechanical performance of concrete containing recycled plastic aggregate Constr. Build. Mater. (2012)
[5]. B. Safi et al. The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties Constr. Build. Mater. (2013)
[6]. Y.W. Choi et al. Effects of waste PET bottles aggregate on the properties of concrete Cem. Concr. Res. (2005)
[7]. M. Batayneh et al. Use of selected waste materials in concrete mixes Waste Manage. (Oxford) (2007)
[8]. M. Amianti et al. Recycling of EPS: a new methodology for production of concrete impregnated with polystyrene (CIP) Cem. Concr. Compos. (2008)
[9]. R. Siddique et al. Properties of concrete containing scrap-tire rubber – an overview Waste Manage. (Oxford) (2004)
[10]. M. Gesoglu et al. Mechanical and fracture characteristics of self-compacting concretes containing different percentage of plastic waste powder Constr. Build. Mater. (2017)


ISBN: 978-93-5980-742-3, www.aetsjournal.com ― Handbook of research in Basic and Applied Science