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A review on Use of waste plastic in concrete mixture as aggregate replacement

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Abstract*— One of the major environmental problems today is the dumping of the waste plastics. The plastic waste is rising day by day. On another side, the construction industry is facing difficulty due to the insufficient and unavailability of the construction resources. The improper disposal of plastic has been a major worry to the environment as it is not easily degradable. Plastic waste is increasing continuously, especially in the form of throw away packaging such as drinking water bottles, polythene bags, plastic cans, polyvinyl chloride useful etc. Plastic disposal, however, is difficult and has a lower recyclability rate than other types of materials such as glass and paper. The consumption of various forms of plastics is a challenging environment protection issue. All forms of used plastic become waste which need large areas of land for storing and placing because a number of tons of waste plastics cannot be fully recycled at once. The low biodegradability of plastic and the presence in large quantities of waste plastic negatively impact the environment. Previously, various studies were performed to identify safe and environmentally friendly methods for disposing of plastics. Now a day's various forms of plastics have been embedded in concrete to reduce the direct contact of waste plastic with the environment so that harm to the environment by plastic can be minimized. If waste plastic will find its place in construction industry then burden of plastic harms on environment can be reduce to great extent.

Keywords— polyester concrete (PC), polyethylene terepthalate (PET), Compressive Strength, Split Tensile Strength, Plastic Bag, structural behavior, flexural strength, construction applications

I. INTRODUCTION

The quick urbanization and industrialization all over the world has resulted in large deposition of waste polymer materials. Generation of plastic waste is one of the fastest growing area. Continuous research efforts have established concrete as a versatile material. Concrete required for extensive construction activity can be made available since all the ingredients of concrete are of geological origin. The most extensively used construction material is concrete, usually made by mixing Portland cement with sand, crushed rock and water. The world consumption of concrete is estimated at ten billion tonnes every year or one tonne for every human being. Concrete is characterized by a number of defects such as low tensile strength, low ductility, heavy weight and low energy absorption. These disadvantages have triggered the civil engineers to make use of the conventional reinforcement in order to increase the tensile strength and ductility. The concept of using fibers as reinforcement is not a new one. Addition of fibers to concrete would act as crack inhibitors and substantially increase the low resistant to cracking, lower impact strength, heavy weight, etc, but some remedial measures can be taken to minimize these limiting properties of concrete. Research concerning the use of waste products to augment the properties of concrete has been going on for many years and in the recent decades, efforts have been made to use industry waste products such as foundry sand, polyethylene terephthalate, high density polyethylene (HDPE), un plasticized polyvinyl chloride (UPVC) plasticized polyvinyl chloride (PPVC), low density polyethylene (LDPE), polypropylene (PP), polystyrene (PS) expanded polystyrene (UPS). The quantity of plastics consumed annually all over the world has been rising phenomenally. Its exceptionally user-friendly characteristics/features, unique flexibility, coupled with immense cost-effectiveness and longevity are the main reasons for such astronomical growth. moreover its wide use in packaging, automotive and industrial applications, plastics are also widely used in medical delivery systems, artificial implants and other healthcare applications, water desalination and bacteria removal, preservation and distribution of food, housing appliances, communication and the electronics industry, etc. the uses of plastics and recycled plastics.

II. LITERATURE SURVEY

K.S. Rebeiz [1996] His study has shown that very high-quality mechanical and durability properties can be obtained with Plastic concrete using unsaturated polyester resins based on recycled PET and fly ash waste fillers. The use of steel bars can be very efficient in increasing the strength of PC materials. Compared to steel-reinforced Portland cement concrete, the material is a lot stronger and more ductile. PC would also need less reinforcement cover for the tensile reinforcing steel than Portland cement concrete because of its inherent high flexural strength, low permeability, and very good chemical resistance. The material may be used cost efficiently in pavements, bridges, and precast works.

Yung Wang Choi et al. [2004] His paper investigates the surface microstructure of waste polyethylene terephthalate (PET) bottles lightweight aggregate (WPLA) to study the effect of granulated blast-furnace slag (GBFS) on WPLA. The WPLA was prepared from the waste PET bottles and GBFS, and experimental tests were conducted on compressive strength, splitting tensile strength, modulus of elasticity, slump, and density of waste PET bottles lightweight aggregate concrete (WPLAC).The 28-day compressive strength of WPLAC with the replacement ratio of 75% reduces about 33% compared to the control concrete in the water cement ratio of 45%. The density of WPLAC ranges from 1940 to 2260 kg/m3 by the influence of WPLA. The structural efficiency of WPLAC decreases as the replacement ratio increases. The workability of concrete with 75% WPLA improves about 123% compared to that of the normal concrete in the water–cement ratio of 53%. The adhered GBFS is able to strengthen the surface of WPLA and to narrow the transition zone unsettled to the reaction with calcium hydroxide.

Prakash Parasivamurthy et al. [2007] Experimental investigations comprised of testing physical requirements of coarse aggregates, fine aggregates, cement and the modifier. M20 concrete was prepared as per IS SP: 23-1982. The said percentage of modifier was blended with the cement concrete mix and the optimum modifier content was found. Cubes were cast and tested for 1, 3, 7, 14 and 28 day strength. These tests discovered that by adding modifier, the strength of concrete increased. At 5% optimum modifier content, the strength of the modified concrete was found to be 1.2 times superior than the plain cement concrete. By using Plastic waste as modifier, we can decrease the quantity of cement and sand by their weight, hence decreasing the overall cost of construction .The Modified cement concrete can be used in the construction of small drainage works and rigid pavement.

Z. Z. Ismail et al. [2007] investigates waste plastic use in concrete mixture as aggregate replacement, this study involved 86 experiments and 254 tests to determine the efficiency of reusing waste plastic in the production of concrete. Thirty kilograms of waste plastic of fabriform shapes was used as a partial replacement for sand by 0%, 10%, 15%, and 20% with 800 kg of concrete mixtures. All of the concrete mixtures were tested at room temperature. These tests include performing slump, fresh density, dry density, compressive strength, flexural strength, and toughness tests. Seventy cubes were molded for compressive strength and dry density tests, and 54 prisms were cast for flexural strength and toughness indices tests. Curing ages of 3, 7, 14, and 28 days for the concrete mixtures were applied.

Mariaenrica Frigione et al. [2010] conducted an experimental study for recycling of PET bottles as fine aggregate in concrete and investigated substitute in concrete the 5% by weight of fine aggregate (natural sand) with an equal weight of PET aggregates manufactured from the waste un-washed PET bottles (WPET), is presented. The WPET particles possessed a granulometry similar to that of the substituted sand. Specimens with dissimilar cement content and w/c ratio were manufactured. Rheological description on fresh concrete and mechanical tests at the ages of 28 and 365 days were performed on the WPET concretes as well as on reference concretes containing only natural fine aggregate in order to examine the influence of the replacement of WPET to the fine aggregate in concrete. It was found that the WPET concretes exhibit similar workability characteristics, compressive strength and splitting tensile strength to some extent lower that the reference concrete and a moderately higher ductility.

H. M. Rasel et al. [2011] investigated the properties of bitumen mixed with PVC (2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5% and 20% by the weight of bitumen) at optimum bitumen content and to test the design criteria of bituminous mixes using this bitumen-PVC binder. The research concentrated on the test of strength properties of coarse aggregates and Marshall Design properties of bituminous mixes according to the test procedure specified by AASHTO. Some of the measured properties of bituminous mix with bitumen-PVC binder used in this study were within the acceptable recommended limits. On the basis of experimental results of this study, it is concluded that the dense graded bituminous mixes with bitumen containing PVC up to 10% can be used for bituminous pavement construction in warmer region from the stand point of stability, stiffness and voids characteristics

K.Ramadevi et al. [2012] Investigated the concrete with PET fibers compact the weight of concrete and thus if mortar with plastic fibers can be made into light weight concrete based on unit weight. It was experimented 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 replacing of fine aggregate with 2% replacement will be reasonable. It was observed that the split tensile strength increased up to 2% replacing 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 logical with high split tensile strength compared to the other specimens casted and tested. It was examined that the flexural strength rises up to 2% replacement of the fine aggregate with PET bottle fibers and it steadily decreased for 4% and remains the same for 6% replacements. Hence, the replacement of the fine aggregate with 2% of PET bottle fibers will be logical than other replacement percentages like 4% and 6% as the compression and split tensile strength reduces slowly.

Nabajyoti Saikia et al. [2012] The early compressive strength increase (0 to 7 days) relation to the strength determined after 91 days of curing for most of the concretes containing PET-aggregates is more than that observed for conventional concrete;The integration of PET-aggregate in concrete increases the toughness behavior. For a given amount of PET addition, this order is: PC > PF > PP, which shows that adding large-flake PET-aggregate can have more effect on the upgrading of the toughness behavior of resulting concrete than the two other fractions and the splitting tensile and flexural strength of concrete having any type of PET aggregate are proportional to its loss of compressive strength. This preliminary examination has thus shown that the accepted and assumed relationships between engineering properties and compressive strength, as used in European design codes, can be applied to concrete containing PET-aggregate

B.Harini et al. [2015] conducted an experimental study by partially replacing fine aggregate with plastic in concrete. The properties of M30 grade concrete are studied with different plastic percentage proportions. The various plastic proportions are 5%, 6%, 8%, 10%, 15% and 20% by volume. There is decrease in compressive strength when the ratio of plastic to aggregate was increased .We have taken the mix for which compressive strength was least and to that mix we have partially replaced cement with silica fume of 5%, 10%, 15% by weight. The strength properties were again studied, It was noticed that when cement was partially replaced by 10%, 15% of silica fume was higher than reference mix.

Salahaldein Alsadey [2016] Compressive strength of concrete is affected by addition of plastic bottle fiber and it goes on increasing the percentage of plastic increases with addition of 1.5% of plastic in concrete causes about 16% increase in strength after 28 days curing. Thus it is conclude that the use plastic bottle fiber can be possible to increase the strength of concrete.

M Mahesh et al [2016] Waste plastic can be efficiently re-used without affecting the mechanical properties considerably (5-10%). With raise in the percentage of plastic there has been a sudden decrease in early strength but the strength gained to the value as that of the conventional M25 concrete when 28 day tests were performed. It is observed that for more percentage addition of plastics i.e 6% in the present case, the 7 day strength has been redused by when compared with conventional concrete. For less percentage addition (2-4%) of plastic, there is no reasonable variation in 7 day, 14 day, and 28 day compression strength and split tensile strength. Since Specific gravity of waste plastic is less than that of fine aggregate, thus self weight of concrete reduces, hence it reduces the weight of the structure/structural component as a entire.

Mastan Vali N. et al [2017] The solid with PET waste considerably reduces the cement weight and this helps in the preparation of concrete technology with reduced amount of unit weight. The compressive quality expanded up to 10% supplanting of the fine total with PET container filaments and it step by step diminished for 15 % and 20% substitutions. Thus supplanting of fine total with 10% substitution will be reasonable. The flexural quality expanded up to 10% supplanting of the fine total with PET container waste and it slowly diminished for 15% and continues as before for 20%

Substitutions. It was watched that the spilt rigidity extended up to 10% supplanting of the fine total with PET container waste and it step by step diminished for 15% and continues as before for 20% substitutions. Thus, the supplanting of the fine total with 5% of PET jug waste will be sensible than other substitution rates like 10%,15% and 20% as the pressure and flexural quality lessens step by step.

III. PLASTIC AS AGGREGATE

Plastics can be separated into two types. The first type is thermoplastic, which can be melted for recycling in the plastic industry. These plastics are polyethylene, polypropylene, polyamide, polyoxymethylene, polytetrafluorethylene, and polyethyleneterephthalate. The second type is thermosetting plastic. This plastic cannot be melted by heating because the molecular chains are bonded resolutely with meshed Crosslink. These plastic types are known as phenolic, melamine, unsaturated polyester, epoxy resin, silicone, and polyurethane. At present, these plastic wastes are disposed by either burning or buying. However, these processes are costly. If the thermosetting plastic waste can be reused, the pollution that is caused by the burning process as well as the cost of these waste management processes can be reduced. To attain this purpose, a detailed study of these thermosetting plastics for application into construction materials has been conducted, mainly for the concrete wall in buildings. In Thailand, lightweight concrete is extensively used for the construction of interior and exterior walls of buildings for the case where the walls are not designed for lateral loads. This is due to the special characteristics of lightweight concrete (panyakapo, 2007).

The quantity of plastics consumed annually all over the world has been growing phenomenally. Its exceptionally user-friendly characteristics/features, unique flexibility, coupled with immense cost-effectiveness and longevity are the main reasons for such astronomical growth. Besides its wide use in packaging, automotive and industrial applications, plastics are also broadly used in medical delivery systems, artificial implants and other healthcare applications, water desalination and bacteria removal, preservation and distribution of food, housing appliances, communication and the electronics industry, etc. were the uses of plastics and recycled plastics. These all forms of plastics can be mixed in concrete as plastic fibers or as aggregate replacement by shredding in pieces of required aggregate size accordingly. The types of recycled plastics are shown in tabular form in Table (I)

TABLE I

TYPE OF RECYCLED PLASTICS (NABAJYOTI AND BRITO 2012)

S. No	Name of Plastic	Description	Range of product	Use of plastic made from Recycled Waste Plastic
1	Polyethylene terephthalate	Clear tough plastic	Soft drink & mineral water bottles	Soft drink bottles; detergent bottles; clear packaging film; fleecy jackets; carpet Fibers
2	High density polyethylene(HDPE)	Usually white coloured very common plastic	Milk, cream, shampoo and cleaner bottles; Milk crates; Freezer bag	Compost bins;
3	Unplasticized polyvinyl chloride (UPVC) Plasticized polyvinyl chloride (PPVC)	Hard rigid plastic may be clear. Flexible Elastic & Plastic.	Juice bottles; plumbing fittings Garden hoses, Shoe soles.	Tiles; Detergent bottles; plumbing pipes & Fittings.
4	Low density polyethylene (LDPE)	Soft, flexible Plastic.	Garbage bags, black plastic sheet; ice cream Container lids.	Film & bags for building and Packaging.
5	Polypropylene(PP)	Hard but flexible plastic	Ice-cream containers, drinking straws Potato crisp bags.	Compost bins; Kerbside recycling crates.
6	Polystyrene (PS) Expanded polystyrene (UPS)	Rigid, brittle Plastic. May be clear or Glassy.	Yoghurt containers; plastic Cutlery. Hot drink cups; meat trays; Packaging.	Clothes pegs, coat hangers, video & CD boxes.

IV. LAB TESTS PERFORMED

To check strength and various stresses taking ability of plastic modified concrete samples of modified concrete are tested under some lab tests. The tests and results which were followed by many researchers were

- **Compressive strength test-** The 3 days, 7 days and 28 days compressive strength result were examined. The compressive strength of concrete goes on decreasing with increase in percentage of plastic pieces but the rate of reducing compressive strength is very low.
- **Splitting tensile strength test-** Result of Split tensile strength after 7 days, 14 days, and 28 days were Decrease in splitting tensile strength after addition of plastic pieces in concrete was observed .The concept of mixing of plastic wastes in concrete could be a very environment friendly method of disposal of solid waste in the country, this study has shown a Potential towards this concept.

IV. CONCLUSIONS

This paper provides the overview on polymer or plastic modified cement concrete. Research performed on plastic and concrete feasibility gives a general result that the compressive strength, indirect tensile strength and modules of rupture are found to be decreased with increasing the percentages of waste plastic bottle and waste plastic bag. It can be also stated that the effect of waste plastic bottles on the decreasing strengths is less than the waste of plastic bags. To add, the usage of waste plastic in concrete leads to a change in the modes of failure from brittle (rapid) failure to more ductile failure.

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