

Utilization of Plastic Waste (PET Bottles) and Fly Ash in Concrete: A Review

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Paper ID - 110263

Abstract

Origins of all basic ingredients of concrete are nature and reducing with an increase in the consumption of concrete. It requires finding alternate material that can be utilized in the production of concrete; the revolutionary in the construction industry called green concrete, which is produced by adopting the wastes. In this study, a review is done on previously reported work for the utilization of fly ash and plastic waste in concrete. Many research works have been studied and it is concluded that the major focus was to evaluate the effect of fly ash and plastic waste on the fresh concrete property such as workability and hardened concrete properties such as compressive strength, flexural strength, split tensile strength; whereas much of durability properties are yet to be studied. Also, the behaviour of the green concrete post-fire exposure has not been dealt so far.

Keywords: Green concrete, Fly ash, Plastic waste, PET bottles

1. Introduction

Solid wastes generated from municipal waste and industries are becoming important to manage and treat. These wastes are generated in huge amount and relatively inert to hazardous in nature. In rural and city areas, the biggest problem is dumping and disposal of wastes. The shortage of area for land filling, environmental effect and the developing demand are forcing to researchers for reuse of the waste as alternative to disposal.

Basic ingredients of concrete which are naturally available in limited quantity, are reducing with increase in consumption of concrete due to popular growth of construction industry. Therefore it is require finding alternate material which can be utilized in the production of concrete. The revolutionary in construction industry called green concrete, which is produced by adopting the waste.

There is a growing interest in using waste materials as ingredient in concrete and considerable research has been undertaken on the use of many different materials as aggregate substitutes and cementitious material. Among the materials studied are granulated coal ash, blast furnace slag, fibre glass waste materials, waste plastics, rubber waste and sintered sludge pellets. As a consequence, the main issue of wastes may be solved through its utilization in concrete and this could become a very cost effective and environment effective approach for disposal of wastes.

2. Review of Literature

There is a growing interest in using waste materials as ingredient in concrete and considerable research has been

undertaken on the use of many different materials as aggregate substitutes and cementitious material. Numerous studies have been done on the use of plastic waste and fly ash in concrete and are as discussed as follow:

Dan Ravina et al. (1986) examined the effect of replacement of cement by class F and class C fly ash in various percentages from 35% to 50%. Workability, water requirement, bleeding and setting time are examined. Workability of all concrete mixtures containing fly ash was found to be better than that of the control mixtures (without fly ash). The water requirement for obtaining the designated slump (5 cm) of all concrete mixtures containing fly ash was reduced by 5-10%. Depending on type and fly ash, the bleeding of water was either higher or same as of control mix. Setting time was delayed for both fly ash types and at all levels of fly ash substitution compared with the control mixture.

Naik et al. (1996) used post-consumer high density polyethylene (HDPE) waste plastic in concrete as soft filler by shredding the plastic into small particles. These plastic particles added into concrete in varying percentage of 0%, 0.5%, 1% and 2% of total weight of concrete. In order to enhance the bonding with concrete, plastic samples were treated by three chemical methods viz. water, bleach and bleach plus NaOH and compressive strength was measured for each test mixture. The results showed that for bleach plus NaOH treatment, the compressive strength value was highest and also beyond 0.5% plastic addition, compressive strength of concrete decreased drastically. Therefore it was concluded that to generate best result regarding compressive

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strength, plastic concentration in concrete must be controlled.

N. Bouzouba and M. Lachemi (2001) investigated properties of fresh concrete and mechanical properties of hardened concretes such as compressive strength and drying shrinkage for nine SCC mixtures and one control concrete. The content of the cementitious materials was maintained constant. While the water to cementitious material ratios (w/c) ranged from 0.35 to 0.45. Cement was replaced by class F fly ash in 40%, 50%, and 60% in the self-compacting concrete. They concluded that an economical SCC could successfully be developed by incorporating high volumes of Class F fly ash.

Prinya Chindaprasirt et al. (2005) presented an experimental investigation on the effect of fly ash fineness on compressive strength, porosity and pore size distribution of hardened cement pastes. Class F fly ash with two fineness were used viz. (1) original fly ash (Median particle size of 19.1 μm) and (2) classified fly ash (Median particle size of 6.4 μm). Fly ash partially replaced Portland cement at 0%, 20%, and 40% by weight and water to cementitious material ratio (w/c) adopted as 0.35. They concluded that the blended cement paste with classified fly ash produced paste with higher compressive strength than that with original fly ash. The incorporation of classified fly ash decreased the porosity and average pore size of the paste as compared to that with ordinary fly ash. The total porosity and capillary pores decreased while the gel pore increased as a result of the addition of finer fly ash at all replacement levels.

Yun-Wang Choi et al. (2005) made Waste PET Bottles Lightweight Aggregate (WPLA) from the waste PET bottles & GBFS and experimental tests were conducted for 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 varies from 1940 to 2260 kg/m^3 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 owing to the reaction with calcium hydroxide.

Halit Yazici et al. (2008) replaced cement with Class C fly ash varying from 30% to 60%. Durability properties of various self-compacting concrete (SCC) mixtures such as, freezing and thawing and chloride penetration resistance have been investigated besides mechanical properties. Similar tests were carried out with the incorporation of 10% silica fume to the same mixtures. Test results indicate that SCC could be obtained with a high volume FA. Additions of 10% of silica fume to the concrete positively affected both the fresh and hardened properties of SCC. Although there is a little cement content, these mixtures have good mechanical properties, freeze thaw and chloride penetration resistance.

Marzouk et al. (2007) used polyethylene terephthalate (PET) bottles as replacement of fine aggregate by different volume percentage of plastic 2%, 5%, 10%, 15%, 20%,

30%, 50%, 70% and 100%. He examined various properties of concrete like bulk density, compressive strength, flexural strength and modulus of elasticity. Results showed that with rise in percentage of plastic waste, the bulk density, compressive strength, flexural strength and modulus of elasticity decreased. All these mechanical properties remained similar to reference mortar up to 30% replacement. Thus he reached to conclusion that plastic bottles shredded into small particles could effectively use to replace fine aggregates to some extent.

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J.M. Khatib et al. (2008) studied influence of including fly ash to replace the Portland cement in 0% to 80% on the properties of self-compacting concrete (SCC) at water to cementitious material ratio of 0.36 for all mixes. The results indicated that high volume of fly ash can be used in SCC to produce high strength and low shrinkage. Shrinkage was reduced systematically with increase in fly ash content and at 80% of fly ash content the shrinkage reduced by two third compared with the control at 56 days.

Ismail and Hashmi (2008) used waste plastic containers mainly consist of approximately 80% polyethylene and 20% polystyrene in different volume proportion of 0%, 10%, 15% and 20% as partial replacement of sand in concrete. Various properties like workability, density, compressive test and flexural test and toughness indices were examined. Results showed that by increasing the plastic waste content, the slump, density, compressive strength and flexural strength reduced. The outcome also showed that the arrest of the propagation of micro cracks by introducing plastic waste of fabric form shapes to concrete mixture.

M. L. Berndt et al. (2009) studied suitability of using more sustainable concrete for wind turbine foundations and other applications involving large quantities of concrete by partial replacement of cement with fly ash and blast furnace slag and by using recycled concrete aggregate. Five basic concrete mixes were considered viz. (1) conventional mix with no material substitutions, (2) 50% replacement of cement with fly ash, (3) 50% replacement of cement with blast furnace slag, (4) 70% replacement of cement with blast furnace slag and (5) 25% replacement of cement with fly ash and 25% replacement with blast furnace slag. The result showed that concrete mix containing 50% blast furnace slag gave the best performance whereas 50% fly ash content had relatively poor performance.

Albano et al. (2009) studied the mechanical behavior of concrete containing recycled polyethylene terephthalate (PET) with maintaining w/c ratio as 0.50 and 0.60. Fine aggregate was swapped with 10% and 20% volume of two different PET particle sizes (0.26 cm, 1.14 cm) and mix of both sizes with equal quantity. It was observed that

properties like compressive strength, splitting tensile strength, modulus of elasticity and ultrasonic pulse velocity of concrete gave better result with 10% PET replacement. The lower particle size and w/c ratio showed significant improvement over high particle size and w/c ratio.

Vidivelli and Mageswari (2010) carried out investigation on concrete with partial replacement of cement by fly ash at various percentages like 10%, 20%, 30% and 40%. The basic ingredients used were Ordinary Portland cement of 53 grade, Natural River sand as fine aggregate, 20 mm size coarse aggregate. The mix was designed for 1:1.66:3.61 with water to cementitious material ratio (w/c) varied from 0.39 to 0.48 and workability was maintained to 40-60 mm. Various tests like compressive, flexural and split tensile strength were carried out at the ages of 28, 45, 60, 90 and 180 days. They observed that at 10% and 20% replacement compressive, flexural and tensile strength increased at all the ages of curing whereas at 30% and 40% replacement compressive, flexural and tensile strength decreased for all curing ages in comparison to conventional concrete.

Frigione et al. (2010) investigated the influence of the 5% substitution of fine aggregate by waste PET bottle by weight. It was discovered that the waste PET concretes gave same workability characteristic as conventional concrete. It was also noticeable that the addition of waste PET particle reducing the compressive strength and splitting tensile strength of concrete than the conventional concretes.

Md Moinul et al. (2010) studied the effect of fly ash on strength development of mortar and optimum use of fly ash in mortar. Replacement of cement by fly ash up to 50% in mortar exhibit satisfactory results for both compressive and tensile strength test. The optimum fly ash content may be about 40% of cement.

Rafat Siddique et al. (2011) examined properties of self-compacting concrete (SCC) made with Class F fly ash. The mixes were prepared with 5% of class F fly ash ranging from 15% to 35%. He concluded that carbonation depth increased with the increase in age for all the SCC mix. Maximum carbonation depth for that concrete mix was observed in which 20% cement replacement was done by fly ash. The pH value was greater than 11 for all five SCC mixes. Very low chloride permeability resistance was observed in SCC mixes made with fly ash.

Kandasamy and Murugesan (2011) carried out the experimental investigation on the properties of concrete containing domestic waste plastic bags at dosage of 0.5% by weight of cement. The properties examined were compressive strength and split tensile strength for M20 concrete mix. Six cubes (size of specimen 150×150×150 mm) and three cylinders (size of specimen 150 mm diameter and 300mm height) were prepared for compression test and three cylinders (size of specimen 150 mm diameter and 300 mm height) were prepared for split tensile test and tested at the age of 7 and 28 days. The addition of 0.5% of waste polythene bags to concrete increases the cube compressive strength, cylinder compressive strength and split tensile strength of concrete in 28 days. Hence they concluded that the mixing of polythene waste to concrete increases the various mechanical properties of concrete mixes.

Ghernouti et al. (2011) used recycled waste plastic bag material as replacement of fine aggregate in various

percentages like 10%, 20%, 30% and 40%. The recycle plastic bags were given the heat treatment followed by cooling and crushing to get the ultimate product. The bulk density, workability (slump test), compressive strength, flexural strength and ultra-sonic pulse velocity experiment were performed for determining the fresh and hardened properties of concrete. On testing, it was examined that workability increases but the bulk density, compressive strength, flexural strength and ultra-sonic pulse velocity reduced. Up to 20% replacement mechanical properties remained close to the reference concrete. Hence, it was concluded that the waste plastic bag aggregates can be used successfully as partial replacement of conventional aggregates in the production of concrete.

Baboo Rai et al. (2012) carried out comparative study of concrete mix to find the effect of replacing fine aggregates by plastic pallets, without superplasticizer and with superplasticizer. Properties of waste plastic mix concrete such as fresh density, dry density, workability and compressive and flexural strength have been studied. They reported reduced slump values of waste plastic concrete mixes. However, the workability increased by about 10 to 15% when superplasticizer was added to the waste plastic mix concrete. The compressive strength decreased with increasing waste plastic ratios at all curing ages; whereas increased by about 5% after addition of superplasticizer to the mix. Flexural strength of waste plastic mix concrete decreased with the increase in percentage of plastic waste. It was observed that the effect of plasticizer on flexural strength of concrete is irrelevant.

Jayeshkumar et al. (2012) used fly ash in concrete as a partial replacement to cement at various percentages like 10%, 20%, 30%, and 40%. The concrete mix was designed for M-25 grade and M-40 grade. Ordinary Portland cement, natural river sand, coarse aggregate of size 20mm were used with water cementitious material ratio w/c ratio of 0.40 for M-25 and 0.30 for M-40 concrete. Tests like compressive and tensile strength were conducted and results were compared with conventional concrete. The conclusion of the experiment was that with increase in fly ash content, the compressive strength and split tensile strength decreases.

Chandrashekar et al. (2012) carried out investigation on steel fiber reinforced concrete. Steel fibers of different dimensions were used. Two mixes were casted viz. (1) 0.25% flat fibers and 0.25% wire fibers and (2) 0.50% flat fibers and 0.5% wire fibers). Various tests like compressive strength for 7, 28, 56 and 90 days, split tensile strength for 28 days, flexural strength for 28 and 90 days and modulus of elasticity for 28 days was carried out. The compressive strength was observed to be increased by 8% for 1st mix and 18% for 2nd mix. Increase in tensile strength was observed to be 28% to 42% and improvement in elastic modulus was found to be 36% to 50%.

Bhogayata et al. (2012) used non recycled polyethylene plastic bags, shredded into fiber form of 20 micron thick in M25 concrete mix. The bags were shredded in form of fibers through two ways (1) manually and (2) by using shredders and introduced into concrete in different proportions like 0%, 0.3%, 0.6%, 0.9% and 1.2% of the volume of concrete. Cubes of 150 mm×150mm×150 mm size were prepared for the compressive strength tests at the 7 and 28 days of curing. The shredded fibers had good workability and get

well mixed and evenly sprayed in the mix compared to hand cut fibers because hand cut fibers were having lower aspect ratio or bigger size. Addition of fibers also affected the compressive strength by reducing the compressive strength value with increase in percentage of fiber. The hand cut macro fibers showed higher strength loss, compared to shredded fibers. For this reason, it was concluded that the plastic bags would be used preferably in shredded form to avoid difficulty in workability and achieve higher strength properties.

Raghatate et al. (2012) studied the use of plastic bags pieces as fiber form in concrete mix to enhance the properties of concrete. The properties of concrete containing varying percentages 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1% of plastic bags, were tested for compressive strength and split tensile strength. On addition of plastic with varying percentage was found to decrease the compressive strength of concrete. It was found that addition of 1% of plastic in concrete causes about 20% reduction in strength after 28 days curing. It was also seen that up to 0.8% addition of plastic enhance splitting tensile strength, thereafter decreased. Hence, the use of plastic in concrete is one of the best plastic disposal method and which can be possible to enhance the properties of concrete.

Baboo et al. (2012) studied fresh and hardened properties of waste plastic mix concrete of M30 grade. Sand was partially replaced by waste plastic flakes in varying percentages like 0%, 5%, 10% and 15% by volume. Superplasticizer Conplast SP 320 was used. Samples were prepared by using plasticizer and without using superplasticizer. It was observed that fresh density decreased below the reference mix at 5%, 10% and 15% of waste plastic flakes, whereas dry density of all mixtures was reduced at all curing ages. Workability was low without superplasticizer. When superplasticizer was added workability becomes medium till 10% of plastic content. Compressive strength decreased when superplasticizer was not used. Compressive strength increased when superplasticizer was used till 10% of plastic flakes. As the percentage of waste plastic flake increased flexural strength decreased.

Prahallada and Prakash (2013) studied the properties of plastic fiber reinforced concrete with replacement of cement by fly ash in varying percentages like 0%, 5%, 10%, 15%, 20% and 25%. The addition of plastic fibers was 0.5% by volume of concrete mix. The concrete mix was designed for M30 grade. Basic ingredients used in concrete were Ordinary Portland cement of 53 grade, natural river sand as fine aggregate, coarse aggregate of 10 mm size, portable water free from impurities and salts. Water to cementitious material ratio (w/c) adopted was 0.46. Fly ash used was obtained from Harihara Polyfibres Plant (Kumarpatnam). All the samples were tested at 28 days of curing. It was observed that impact strength, workability, tensile strength, flexural strength, compressive strength increased upto 10% addition of fly ash into it after 10% addition of fly ash all the strengths was decreased.

Bhogayata et al. (2013) investigated the strength properties of concrete containing plastic waste in different proportion from 0%, 0.5%, 1% and 1.5% of the volume of concrete along with fly ash was also added from 0% to 30%. The polythene waste bags were shredded to the macro pellet

form. All specimens of standard size were prepared, cured and test for compressive, split tensile and surface tensile strength tests. Compressive strength, split tensile strength and surface tensile strength were reduced by 56%, 43% and 56% respectively at 1.5% fly ash content. It was also seen that the additions of fibers from 0.5% to 1% in the concrete, produced similar compressive strength, split tensile strength and surface tensile strength as conventional concrete. For this reason it was concluded that the addition of plastic fibers to the concrete could be a secure option for the disposal problem of plastic wastes.

Kumar et al. (2014) carried out experimental study on utilizing shredded polythene bags into fiber form as partial replacement of cement in different percentage like 0%, 0.5%, 0.75% and 1% by weight of cement together with 0.4% super plasticizer in the production of eco-friendly concrete. The workability and compressive strength test (size of specimen 100mm×100mm×100mm cubes) were carried out for 7, 28 and 56 days curing. It was determined that the workability of concrete was decreased with the increase in dose of waste polythene. Till 0.75% addition of polythene, compressive strength of concrete increased. Beyond which further addition of polythene resulted into lowering of compressive strength; but compressive strength at 1% waste polythene was greater than the referral concrete. Hence, it was concluded that concrete mixture can be prepared with polythene waste as fibrous form to fortify the strength of concrete mixture.

Patil et al. (2014) investigated the use of recycled plastic aggregate as replacement of coarse aggregate to the production of concrete. M20 grade of concrete with six different volume percentages of plastic (0%, 10%, 20%, 30%, 40% and 50%) used as replacement of coarse aggregate in concrete mixes were cast. Various tests such as density of concrete, compressive test and flexural test were conducted. It was observed that the density of concrete and compressive strength reduced with increase in the percentage of recycle plastic aggregate for 7 and 28 days. Also it was seen that growth in flexural strength up to 10% addition of plastic waste, thereafter flexural strength was reducing. It was recommended that the feasibility of changing 10% coarse aggregate with plastic will fulfil the permissible limits of strength.

Ali Sadrmomtazi et al. (2015) studied the combined effects of waste (PET) particles and pozzolanic materials on the rheological, mechanical and durability properties of self-compacting concrete (SCC). The replacement ratios of fine aggregates with the same weight of waste PET aggregates are 5, 10 and 15 weight percent (wt.%). Moreover, the replacement ratio of cement with the same weight of silica fume and fly ash is 10 and 30 wt.% respectively. The workability of SCC containing waste PET particles was determined using slump flow, V-funnel and L-box tests. Mechanical (compressive, tensile and flexural strengths and modulus of elasticity), rheological (L-Box, slump flow and V-funnel) and durability (water absorption and electrical resistance) properties are assessed. The results show that waste PET particles can be reused as aggregates in SCCs. Use of waste PET in SCC decreases compressive, tensile and flexural strengths. However, pozzolanic materials (fly ash and silica fume) compensate the loss of strength caused

by adding PET. The use of waste PET has several advantages. Waste PET has no effect on electrical resistance and decreases the brittleness of concrete.

Chethan Chandru and Dr. Chandrashekhar (2015) made an attempt to study the properties of fibre reinforced concrete produced from plastic fibers and fly ash. Fly ash were varied by 5%, 10%, 15%, 20%, 25% and 30% by weight of cement and plastic waste at a constant dosage of 0.5% and 1.0% by volume of concrete. They concluded that compressive strength was gained at 15% for the combination of 0.5% plastic fiber and 15% fly ash at 7, 28 and 56 days. Split tensile strength of fly ash concrete, concrete with the combination of fly ash + 0.5% plastic fibers and 1.0% plastic fibers was increased at 15% replacement for 28 days curing period. Flexural strength was increased at 15% for fly ash + cement, 0.5% plastic fibers + fly ash and 1.0% plastic fibres + fly ash combinations for 28 days curing.

Usman et al. (2015) investigated the performance of concrete made with polythene bags as coarse aggregate. Coarse aggregate was replaced with shredded plastic waste in various percentages like 0%, 2%, 5% and 7%. The concrete mix of M25 grade was made to produce concrete specimens. The compressive strength test for 7 and 28 days, split tensile strength test and workability test were carried out. The result of investigation showed that the increase in the percentage of the waste polythene reduces the compressive strength of the mix as well as its weight. The workability of the concrete decreased as the amount of the polythene waste. The overall experiment performance revealed that the polythene waste up to 5% as replacement of coarse aggregate in concrete can be utilized for the construction purposes effectively because the strength characteristics of concrete containing waste polythene was nearly equal to conventional concrete.

S. Premalatha et al. (2016) carried out an experimental investigation on Polyethylene Terephthalate (PET) bottles filled manually with industrial by – products such as brick kiln dust, bagasse ash and fly ash in separate bottles. The filled bottles were sealed tightly and tested for compressive strength. Results showed that compressive strength of the PET bottles filled with brick kiln dust is greater than standard bricks and cost was 41% less than the standard bricks.

Sabarathan and Suresh^[36] (2016) investigated the fresh and hardened properties of concrete with waste plastic fiber and stone dust as coarse and fine aggregate replacement respectively. The different percentage 0%, 5%, 10%, 15%, 20%, 25% of waste plastic fiber and stone dust were utilized to evaluate the workability, compressive strength, and split tensile strength of concrete. It was examined that the workability of concrete decreased as the percentage of waste plastic fiber increase. It was also examined that the compressive strength and split tensile strength of concrete increase by the addition of waste plastic fiber and stone dust but all these properties decrease after 10% replacement. Hence, it was concluded that the 10% is nominal for replacing both waste plastic fiber and stone dust in concrete mix.

Zerdi et al. (2016) studied the characteristic of concrete with the addition of waste high density polyethylene (HDPE) granules as partial replacement of coarse aggregate.

The varying percentage of waste HDPE granules 0%, 10%, 20%, 30% were used to determine the compressive strength of concrete. The result of investigation signified that the compressive strength of concrete decreases with the addition of waste HDPE but the optimum compressive strength was obtained at 10% HDPE replacement. It was also concluded that the use of waste HDPE in the concrete lowers the unit weight of concrete which is sufficient enough to produce light weight concrete.

Al Hadithi and Hilal (2016) carried out the experimental investigation on the properties of self-compacting concrete by adding waste plastic fiber of HDPE bottles. The various percentage of waste plastic fiber contents of 0%, 0.25%, 0.5%, 0.75%, 1%, 1.25%, 1.5%, 1.75% and 2% were added to measure the workability, density, compressive strength, flexural strength of concrete mix. The result showed that the workability and density of concrete decreased with the increase in waste plastic fiber content. It was reported that the compressive strength and flexural strength increase with the increase in fiber content while lowest strength was achieved at 2% waste HDPE replacement. Hence it was concluded that the plastic fibers have adverse effect on the fresh properties of self-compacting concrete and improvement by hardened properties.

Islam and Gupta (2016) studied the strength, plastic shrinkage, and permeability of concrete incorporating polypropylene fiber. The plastic fibers were added to the mix with different proportion from 0%, 0.10%, 0.15%, 0.2%, 0.25% and 0.3% by the volume of concrete. It was examined that with the addition of polypropylene fiber the compressive strength decreased. The 0.10% fiber content was achieved optimum for which reduction of compressive strength about 2% compared to reference concrete. It was reported that the plastic shrinkage cracks were reduced by 50% to 99% compared to reference concrete by addition of 0.1% to 0.3% plastic fibers. The results also showed that the water and gas permeability was increased with the addition of polypropylene fibers. It was concluded that the fiber reinforced concrete would work better for plastic shrinkage susceptible structural elements (flat elements such as slab) and requires careful judgment while applying to a water retaining structures.

Gopal Paliwal and Savita Maru (2017) partially replaced cement with 0%, 5%, 10%, 15% and 20% fly ash (by weight) and plastic waste was added in shredded form at 0.6% by weight of concrete in the concrete mix of M25 grade at 0.45 water to cementitious material ratio. Workability was examined during casting the specimens and hardened properties such as compressive and flexural strength, density, dynamic modulus of elasticity, abrasion resistance, water permeability and impact resistance were examined at 7 & 28. They concluded that addition of 0.6% (by weight of the concrete) plastic waste with 10% (by weight of cement) replacement of cement by fly ash result an improvement in properties of the concrete than conventional mix.

M Prathap Reddy et al. (2018) studied compressive strength and split tensile strength of concrete by partially replacing cement by fly ash in 5%, 10% and 15% and coarse aggregate by Pet bottle caps (PBC) at 2%. Test results

showed that, inclusion of fly ash and pet bottle caps generally improves the concrete properties and maximum strengths attained at 10 % FA and 2% PBC replacement.

Alexandru Timu et al. (2018) examined the mechanical strengths of fly ash cement concrete with chopped plastic bottles as substitution of fine aggregate. The mechanical and deformation characteristics of fly ash concrete with 10% chopped PET as substitution of fine aggregate were experimentally determined. The mechanical strengths such as compressive strength, flexural strength and splitting strength had shown that this type of concrete has a structural concrete characteristics with good values of strengths and the density over 2,000 kg/m³.

B. Jeevitha et al. (2019) performed experimental study on M-25 grade concrete mix, designed by replacing 20% of cement by fly ash and 22% by volume of coarse aggregate by shredded plastic. To this standard, mix percentage of metakaolin was varied from 0%, 5%, 10% and 15% at Water–cement ratio of 0.45 and experimental work was carried out to fix the optimum percentage of metakaolin. Initial age compressive strength shows a gradual increase in strength with increase in percentage of metakaolin whereas 28-day curing of cubes, showed higher compressive strength for 10% replacement of metakaolin beyond which strength decreased. Tensile strength of cylinder increased with increase in the percentage of metakaolin. Flexural strength of beams initially increased for 5% metakaolin compared to 0% metakaolin, but there was a sudden fall in strength for beams with 10% metakaolin, and later strength increased for 15% metakaolin.

Sheelan M. Hama and Nahla N. Hilal (2019) examined fresh properties of concrete containing plastic aggregate obtained from High-density polyethylene, waste compact disks and plate cover of water drink bottle. Due to the difference in the specific gravity of natural aggregate and plastic aggregate, the volumetric design method adopted. They concluded that shape and content of plastic, concrete had affected the workability. The increasing of angular shape plastic aggregate content led to decrease in the slump of concrete. In general, all types of plastic aggregate (either fine or coarse) decreased the density of concrete due to low specific gravity of plastic aggregate.

Ibrahim Almeshal et al. (2020) investigated the effects of utilising poly-ethylene terephthalate (PET) as a partial substitute for sand at 0%, 10%, 20%, 30%, 40% and 50%. The experimental results showed a reduction in unit weight, the sand replacement harmed the concrete mechanical properties at varying rates and proved that plastic waste can be disposed of by specific ratios. The workability of concrete containing recycled plastic was reduced due to non-uniform and irregular shapes of particles. Also with increase in plastic proportion, the compressive strength, splitting tensile and flexural strengths decreased. Ultrasonic pulse velocity, which reflected the quality of the concrete, decreased with an increase in the proportion of PET. Emissions of malodorous toxic white smoke occurred in the concrete sample with 30% or higher replacement ratio. Thus they concluded that although the PET concrete can be used for external work, it is not recommended for internal work

due to its poor fire-resistant behaviour, except in the case of concrete coating with insulating materials.

3. Gap Area

From the literature review, it is evident that limited numbers of study are available on the utilization of plastic waste from PET bottles with fly ash in concrete and their effects on durability properties of concrete.

The major focus was to evaluate the effect on compressive strength, split tensile strength and flexural strength but the other properties of concrete like abrasion resistance, water permeability of concrete, static and dynamic modulus of elasticity were never examined.

In many applications such as explosion, transportation structures, high impact resistance is required. The impact resistance behaviour of concrete containing PET bottles and fly ash is also yet to be evaluated. Also behaviour of the green concrete post fire exposure has never been dealt.

4. Concluding remarks

Utilizing plastic waste as concrete ingredient may lead to poor workable concrete. At the same time using fly ash in the concrete, enhances the workability of the concrete. In same fashion some other properties which are weakens by using plastic waste may get improved by adding fly ash in the concrete.

Ibrahim Almeshal et al. reported degradation in workability, unit weight, compressive strength, splitting tensile strength, flexural strength, Ultrasonic pulse velocity with addition of plastic waste. Also due to fire susceptible nature of plastic, the post fire exposure behaviour was examined and at 30%, 40% and 50% replacement ratios, emission of malodorous toxic white smoke occurred as a result of plastic combustion. Gopal Paliwal et al. concluded enhancement in workability, compressive and flexural strength, and density, dynamic modulus of elasticity, abrasion resistance, water permeability and impact resistance when 0.6% (by weight of the concrete) polythene bags was added along with 10% (by weight of cement) fly ash as partial replacement of cement.

It is evident from this study that polythene bags in shredded form when mixed along with fly ash into the concrete, the resulting concrete gives better properties. At the same time there are not much research work varies out on utilizing PET bottles in the concrete. Also as plastics are highly susceptible to fire, therefore utilizing them as ingredient in concrete may lead to make the concrete fire non-resistant therefore it become important to check with the behaviour of the concrete containing plastic waste to various tests post fire treatment. Till now the major focus of the researchers was to evaluate the few properties such as compressive strength, workability, flexural strength etc. but limited number of work has been carried out on finding the durability properties of the concrete containing PET bottles and fly ash.

From this study following suggestions will be recommended for future work:

- Plastic fibres along with steel fibres can be utilized to increase the strength of concrete.

- Many properties of concrete mix such as fatigue properties, chloride attack, carbonation test, freezing-thawing effect can also be determined.
- The behaviour of the green concrete can be determined in acidic media.

Disclosures

Free Access to this article is sponsored by SARL ALPHA CRISTO INDUSTRIAL.

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