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USE OF CERAMIC AND PLASTIC WASTE IN CONCRETE: A REVIEW

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ABSTRACT
One of the most serious problems of the world today is related to removal of waste and to find solution of reusing it. Numerous waste materials are generated from manufacturing processes, service industries, construction and demolition works and municipal solid wastes. The increasing awareness about the environment has tremendously contributed to the concerns related with disposal of these generated wastes. Solid waste management is one of the major environmental concerns in the world and with the scarcity of space for landfilling and due to its ever increasing cost; waste utilization has become an attractive alternative to disposal. There are numerous researches that are being carried out to utilize these wastes in the construction industry where most of them are related to using these wastes in concrete. This will lead to utilization of wastes as well as reduction of usage of naturally occurring construction materials which in turn are depleting the natural resources due to the increasing demand of construction materials, meanwhile making concrete economical and also will reduce the disposal problems associated with these waste materials.
This study deals with reviewing the usage of plastic and ceramic wastes in concrete and its effect on bulk density, air content, workability, compressive strength, splitting tensile strength, modulus of elasticity, impact resistance, permeability, and abrasion resistance of concrete.

1. INTRODUCTION

Ceramic materials contribute the highest percentage of wastes within the construction and demolition wastes i.e. about 54%. The global production of ceramic tiles during 2011-12 in the world is about 11,166 million square meters. China is the largest ceramic tiles producer (5,200 million square meters) which is 46.6% of world production as well as consumer (4,250 million square meters) which is 38.9% of world consumption. Compared to China, India ranks third; accounting for 691 million square meters tiles production which is 6.2% of world production and also ranks third in terms of consumption accounting for 681 million square meters which is 6.2% of world consumption. This huge amount of productions has caused them to be among the most commonly-consumed materials in the world. Usually, the wastage related to tile, ceramic and sanitary ware are created in different forms some of which are produced in companies during and after production process due to errors in either construction, human activities, and also inappropriate raw materials. Some others are produced in transportation and distribution procedures and finally, the most bulk of them are created as a result of destroying constructions. It is predicted that about 30% of daily production of ceramic materials in India change into wastage and this amount reaches to millions ton per year. This waste is not recycled in any form at present. Therefore, they are useless in practiced and cause environmental and disposal problems. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. The properties of these materials make them a good and suitable choice to be used in concrete. The use of waste ceramic tiles in concrete effects the properties of fresh and hardened concrete, and makes it economical and also solves some of the disposal problems(***Daniya and Ahmad, 2015***).

Plastics have become an inseparable and integral part of our lives. The amount of plastics consumed annually has been growing steadily. Its low density, strength, userfriendly designs, fabrication capabilities, long life, light weight, and low cost are the factors behind such phenomenal growth. Plastics have been used in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, water desalination, land/soil conservation, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses. With such large and varying applications, plastics contribute to an ever increasing volume in the solid waste stream. Among different waste fractions, plastic waste deserves special attention on account of its non-biodegradable property which is creating a lot of problems in the environment. In India approximately 40 million tons of solid waste is produced annually and is increasing at a rate of 1.5 to 2% every year. Plastic production also involves the use of potentially harmful chemicals, which are added as stabilizers or colorants. Many of these have not undergone an environmental risk assessment and their impact on human health and the environment is currently uncertain. Such an example is phthalates, which are used in the manufacture of PVC. PVC has in the past been used in toys for young children and there has been concern that phthalates may be released when these toys are sucked (come into contact with saliva). Risk assessments of the effects of phthalates on the environment are currently being carried out. The disposal of plastics products also contributes significantly to their environmental impact. Because most plastics are non-degradable, they take a long time to break down, possibly up tohundreds of years although no-one knows for certain as plastics have not existed for long enough when they are landfilled. With more and more plastics products, particularly plastics packaging, being disposed of soon after their purchase, the landfill space required by plastics waste is a growing concern.

2. Utilization of Ceramic Wastes in Concrete

Utilization of ceramic wastes can be done in a number of ways, this section refers to the utilization of ceramic wastes as partial replacement of aggregates. In 2005, ***Brito et al.*** studied the suitability of ceramic waste as a possible substitute for conventional coarse aggregates in the production of nonstructural concrete artefacts and found that the ceramic waste aggregates have a potential to be used as a replacement of natural coarse aggregates but in elements where the primary requirement is tensile strength and resistance to abrasion and not compressive strength. Similarly, ***Senthamarai and Manharan***also checked the suitability of ceramic waste as replacement of crushed stone aggregate and found that the workability of ceramic waste coarse aggregate made concrete is good and that the strength characteristics are comparable to that of the conventional concrete.

Correia et al. (2005)studied the durability of concrete made by partial replacement of ceramic wastes and found that the mechanical properties in terms of compressive and tensile strength were suitable however due to high water absorption eventual aggressive environmental agents, such as deleterious salts may penetrate easily into the concrete, which is not restrictive in non-reinforced concrete. Likewise, in 2006 ***Abdullah et al.***also examined the strength of concrete with ceramic waste as coarse aggregate and found that the ceramic waste aggregate satisfies the aggregate requirement of concrete; the surface texture of ceramic waste aggregate was smoother, the specific gravity of ceramic waste was 2.38 while that of natural aggregates was 2.63, the waster absorption of ceramic waste was 1.45% and that of natural aggregate was 1.25%. The compressive strength of ceramic waste aggregate concrete was 85% to 100% that of conventional concrete thus it is comparable to conventional concrete. ***Binici (2006)***also carried out experiments to determine the abrasion resistance, chloride penetration depths and compressive strengths of concrete made with crushed ceramic waste and basaltic pumice fine aggregates and found out that the workability of this concrete was good and the compressive strength has increased while the abrasion value decreased and the chloride penetration depths also increased.

In ***2010 Juan et al***. investigated the re-use of ceramic wastes in construction industry and demonstrate that the introduction of recycled ceramic aggregates has no negative effects on cement hydration, and can thus be considered an inert material and that waste from the ceramic sanitary ware industry can be used to partially substitute natural coarse aggregates, and indeed confers the recycled concrete with positive characteristics as regards mechanical behavior. The recycled concrete obtained can be used for structural purposes, since its characteristic compressive strength exceeds 25 N/mm^2, the minimum strength requires for structural concrete. Similarly, ***Sadek et al.*** investigated in ***2013*** the effect of partial/full replacement of conventional aggregates with recycled aggregates in manufacturing of solid cement bricks and reported the compressive strength, flexural strength, and water absorption. It was found that it is feasible to recycle quarry waste, marble waste and crushed ceramic as aggregate in the production of solid cement bricks from the technical, economical and environmental point of view as they will conserve natural resources, protect the environment from waste disposal, and produce a low cost product and higher quality product than the conventional one. In ***2015 Daniyal and Ahmad*** also investigated the effect ofaddition of crushed waste ceramic tiles as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution and analyzed that the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5was about 30%. The compressive and flexural strength of optimal concrete was found 5.43% and 32.2% higher than reference concrete respectively. Their findings reveal that using waste ceramic tile leads to enhancing the properties of concrete..

In the second part here ceramic wastes are considered as a replacement of cement in concrete. In 2010, ***Torgal and Jalali***examined the feasibility of using ceramic wastes in concrete and their results show that concrete with 20% cement replacement although has a minor strength loss but possess increased durability performance, while when concrete mixes with ceramic aggregates show better results than the control concrete mixtures concerning compressive strength, capillary water absorption, oxygen permeability and chlorine diffusion thus leading to more durable concrete structures, however in 2013 ***Raval et al.*** also performed the almost the same investigation and their results show that the use of ceramic masonry rubble as active addition endows cement with positive characteristics as major mechanical strength and the economic advantages. Reuse of this kind of waste has advantages economic and environmental, reduction in the number of natural spaces employed as refuse dumps. Indirectly, all the above contributes to a better quality of life for citizens and to introduce the concept of sustainability in the construction sector.

Lastly the other uses of ceramic wastes in the construction industry are being taken up. ***Rajamannan et al.*** in ***2013***investigated the effect of addition of ceramic waste to clay materials and concluded from chemical, mineralogical and morphological analyses, that water absorption and compressive strength tests show that ceramic waste can be added to the clay material with no detrimental effect on the properties of the sintered fire-clay products. The test results indicated that the ceramic waste could be used as filler in ceramic bricks, thus enhancing the possibility of its reuse in a safe and sustainable way.

In ***2014, Zimbili et al.*** investigated the usage of ceramic waste in construction and found that the temperatures at which the ceramic tiles are manufactured is sufficient to activate the pozzolanic properties of clay, thus it can be blended with in cement, after optimization (11-14% substitution) the cement blend performs better with no morphological difference between the cement blended with ceramic wastes and that blended with other pozzolanic materials.

While, ***Da Silva et al.*** in ***2014***performed a study to evaluate the physical and mechanical properties of solid bricks made with soil-cement mixtures uniaxially pressed with the addition of construction waste, having hydrated lime and Portland cement as binding agents to be used in formulations. Raw materials were characterized by particle size analysis, Atterberg limits. Solid bricks were made with soil-cement mixtures and Ceramic Wastes, which were cured for 7, 28 and 56 days and submitted to compressive strength, water absorption and modified durability tests. The best results obtained were for percentages of 12% cement and 4% incorporated Ceramic Wastes.

3. Utilization of Plastic Wastes in Concrete

Plastic wastes in construction industry are utilized according to its type, this section deals with usage of Polyethylene Terephthalate (PET) in concrete. ***Choi et al.***in ***2005*** studied the effects of polyethylene terephthalate (PET) bottles lightweight aggregate on the compressive strength of concrete. Mixture proportions of concrete were planned so that the water–cement ratios were 45%, 49%, and 53%, and the replacement ratios of plastic waste were 0%, 25%, 50%, and 75% by volume of fine aggregate. It was observed that the compressive strength of concrete mixtures decreased with the increase in PET aggregates and for a particular PET aggregate content, compressive strength increased with the reduction in water–cement ratio while ***Marzouk et al.*** in ***2005*** examined the use of recycled polyethylene terephthalate (RPET) and recycled high-density polyethylene (RHDPE) to partially and completely substitute for sand in Portland cement concrete composites. Various volume percentages of sand (2, 5,10,15,20, 30, 50 and 100%) were substituted by the same volume of granulated plastic waste. The results showed that substituting sand at a level exceeding 50% by volume with granulated; RPET affects neither the compressive strength nor the flexural strength of composites. When substitution with granulated RHDPE exceeds 30%, the compressive strength decreases whereas tensile strength remains constant. They also stated that recycled plastic bottles of PET and HDPE shredded into small particles may be used successfully as sand substituted aggregates in cementitious concrete composites and these composites would offer an attractive low-cost material with consistent properties and they would help in resolving some of the solid waste problems created by plastics production and in saving energy as well.

In 2009, ***Hannawi et al.*** investigated the use of non-biodegradable plastic fine aggregates made of polycarbonate and polyethylene terephthalate wastes as partial replacement of natural fine aggregates. Various volume fractions of sand i.e. 3%, 10%, 20%, 50% were replaced with the same volume of plastic and the physical and mechanical properties of this concrete were examined where the results showed a decrease in compressive strength and specific weight and a significant improvement in its post peak flexural behavior and the flexural toughness factors. The study shows the feasibility of the reuse of polycarbonate and polyethylene terephthalate waste aggregate materials as partial volume substitutes for natural aggregates in cementitious materials. While in 2010, ***MariaenricaFrigione***investigated the use of waste from polyethylene terephthalate (PET) aggregates to substitute 5% by weight of fine aggregates. Rheological characterization on fresh concrete and mechanical tests at the age of 28 and 365 days were performed and the results show that concrete with plastic waste possess slightly low workability characteristics, compressive strength and splitting tensile strength from the reference concrete while a moderately high ductility.

Nibudey et al. in2013 examined the conventional concrete which was reinforced by the plastic fibers obtained from waste plastic bottles. Cube and cylinder compressive strength of conventional concrete and plastic fibers reinforced concrete were determined. The M20 and M30 grades of concrete and two fiber geometry at volume fractions 0.0 % to 3.0 % were used and the results show that the workability and the dry density gets reduced while the compressive strength was nearly same to that of the reference concrete. It was also observed that the normal concrete cubes and cylinders broke suddenly whereas the failure of plastic waste cubes was ductile whereas in ***2016,Azhdarpoura et al.*** investigated the effects of adding plastic waste particles on the engineering properties of concrete. A mix concrete design was adopted in which pre-defined weight-based amounts of the concrete fine aggregates were replaced by equivalent waste fragments. At all the mixtures, the amount of the coarse aggregate (gravel) and the water–cement ratio remained constant. The results of laboratory tests showed that the physical properties e.g. density and ultrasound velocity, gradually decreased as the presence of plastic fragment ratios increased and compressive, tensile, and flexural strength of samples increased when 5–10% of the concrete fine aggregates were replaced by the same percentage of polyethylene terephthalate (PET) fragments. The results also indicated that substitutions greater than 10% cause dramatic decline in all strength-related parameters of the concretes. It is therefore argued that replacement of fine particles with PET fragments may positively affect the strength-related values of the concrete samples provided that as long as the substation rate is under 10% and ***Guendouz et al.*** investigated the utilization of two type of waste plastic, Polyethylene Terephthalate (PET) and Low Density Polyethylene (LDPE) used for bags manufacture, as a fiber and fine aggregates (powder) in sand concrete. Various volume fractions of sand (10%, 20%,30% and 40%) were substituted by the same volume of plastic aggregates, and various amount of plastic fibers (0.5%, 1%, 1.5%,2%) were introduced by volume in sand concrete mixes and the results showed that the use of plastic waste as partial replacement of sand contributes to reduce the bulk density, decrease the air content, causing an increase in compressive and flexural strength for 10% and 20% of replacement. In addition, the reinforcement of the cementing matrix with plastic fibers induced a clear improvement of the tensile strength.

In this part PVC wastes is considered as a building material, in ***2008,Kou et al.*** investigated the properties of fresh and hardened concrete which was prepared with the use of recycled plastic waste from scrapped PVC pipes to replace river sand as fine aggregates. 0%, 5%, 15%, 30% and 45% by volume replacements were done and the results show that the concrete was lighter (lower density), was more ductile (greater Poisson's ratio and reduced modulus of elasticity), lower drying shrinkage and higher resistance to chloride ion penetration whereas the workability, compressive strength and splitting tensile strength of the concrete got reduced. While in 2015 ***Senhadji et al.*** investigated the use of non-biodegradable plastic aggregates made of polyvinylchloride (PVC) waste, obtained from scrapped PVC pipes as partial replacement of conventional aggregates in concrete. For this purpose, a number of laboratory prepared concrete mixes were tested, in which natural sand and coarse aggregates were partially replaced by PVC plastic waste aggregates in the proportions of 30, 50, and 70% by volume. Fresh concrete mixtures were tested for workability and density, and hardened concrete specimens were used to investigate compressive strength, ultrasonic wave velocity, and resistance to chloride ion penetration. The results of the laboratory study showed that concrete made with 50 and 70% of recycled PVC aggregates fell into the category of structural lightweight concrete in terms of unit weight and strength properties. Their study gave quite encouraging results and opened up a new way of recycling PVC waste as a lightweight aggregate in concrete.

In this part other types of plastic wastes are considered, in ***2007***, ***Ismail and Hashmi*** determined the efficiency of concrete by reusing waste plastic. 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. The tests include performing slump, fresh density, dry density, compressive strength, flexural strength, and toughness indices and the results insured that reusing waste plastic as a sand-substitution aggregate in concrete gives a good approach to reduce the cost of materials and solve some of the solid waste problems posed by plastics. While ***Mustafa Al Bakri et al.*** in 2008 studied the properties and characterization of polymer HDPE as the replacement of coarse aggregate in concrete. Heating process were done at five different temperature; 160°C, 170°C,180°C, 190°C and 200°C . Five compositions of coarse aggregate with different crushed stone: high density polyethylene waste ratios were used that are 0:100, 15:85, 30:70, 45:55, and 60:40 by volumetric method. The comparisons of conventional concrete with polymer waste as coarse aggregate were investigated. The effects of polymer wastes on the workability and strength of the concrete with fresh and hardened concrete tests were analyzed. The compressive strength was measured after 28 days and it was found that the polymer concrete is suitable for nonstructural usage. As for cost analysis, the results showed that the polymer concrete is more cost effective than conventional concrete.

In 2014,***Kumar et al.*** investigated the compressive strength of concrete made by using plastic bags as fibrous material and the effect of polyethylene plastic bags on the workability and compressive strength of M25 concrete. The proportions of waste plastic added in concrete are 0.5%, 0.75% and 1.0% by weight of cement and compressive strength is determined at 7, 28 and 56 days of curing. It was observed that the workability was reduced with increase in the quantity of polythene and the compressive strength increased on inclusion of waste polythene in concrete at all edges up to 0.75% and thereafter it started decreasing, on the contrary ***Kaliyavardhan and Bhaskar*** also in ***2014*** examined the use of electronic plastic chips (E-plastic) as partial replacement of coarse aggregates in concrete. 5, 10, 15 and 20 % weight of coarse aggregates have been replaced by E-plastic waste. It was observed that the slump showed a significant decrease upon increasing the E-plastic quantity. The concrete specimens were tested on 7, 14 and 28 days. E-plastic concrete has low unit weight and considerable ductility. The Compressive, splitting tensile and flexural strength were found to be decreased by 42.35%, 36.33% and 40.98%, respectively, for 20% replacement of E-plastic compared to control concrete. However, incorporation of E-plastic waste as an aggregate replacement in concrete, gave scope to develop new construction materials valuable for both the construction and the electronic waste recycling industries.

While in 2014***Chaudhary et al.*** investigated the use of waste plastic bags (Low Density Polyethylene (LDPE)) in concrete. Waste plastic (LDPE) mix in concrete with or without superplasticizer. Cubes and cylinders are casted with 0%, 0.4%, 0.6%, 0.8% and 1% (by weight) with plastic waste. Samples were tested for the compressive strength and split tensile strength of concrete with plastic waste as aggregate and observed a good strength gain. All specimens were tested after curing age of 7 and 28 days.

Klovaset al.in2015analyzed the use of plastic shavings for the reinforcement of concrete. The technological properties of cement slurry as well as mechanical, physical and porosity properties of cured sandcrete were examined and the results reveal that the usage of plastic shavings decreased slurry slump and density. The flexural strength of cured sandcrete increased and the residual strength after crack opening is bigger with the usage of plastic shavings as a secondary raw material compared with reference specimen.

4. Conclusion

After analyzing the above papers it can be concluded that use of ceramic waste as partial replacement of cement, fine aggregates and coarse aggregates, respectively is feasible and can be added upto an optimum percentage of 10% for cement and 30% for both fine and coarse aggregates as it shows positive results for compressive and tensile strength test of concrete while addition of plastic wastes is feasible only upto 10% replacement as partial replacement of both fine and coarse aggregates as it reduces the binding property of cement, on further addition of plastic wastes, the compressive and tensile strength both gets reduced and thus this concrete is only suitable for nonstructural concrete.

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