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Reusing waste materials in concrete

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■ **ABSTRACT :** Studies on glass powder (GP) and plastic incorporation in concrete and characteristics exhibited by mixtures prepared using different percentages have been carried out in the past and this review summarises the studies carried out in the past decade and presents the current understanding in the area. It is aimed to make this review a source for future studies in this aspect. This study was performed in 3 different approaches, in first approach possible partial replacement by glass waste was studied, in second, partial replacement by plastic waste was studied and in third, replacement by both glass and plastic waste together was studied. Selective targeting of mechanical characteristics such as compressive strength, flexural strength, split tensile strength, modulus of elasticity was done in the article as they are the most important aspects which need to be considered.

■ **KEY WORDS :** Glass powder, Polyethylene terephthalate, Compressive strength, Waste utilization

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Glass and plastic are indispensable to human use and the production, usage and waste generation of both, glass and plastic are on a daily rise due to heavy consumerism culture of modern societies. The increasing stockpiles of glass and plastic waste are of grave concern and according to IEA 2007 report, the total global waste estimate was 130 Mt for the year 2005 and the growing waste needs more space and more land and only a few percentage of this waste reaches Landfill or what we can do is follow the 3R principle *i.e.* reuse, reduce and recycle. According to Our World in Data based at Oxford, cumulative plastic waste generated in the year 2015 was 7.82 billion tonnes and most plastics are non-biodegradable. In this paper, we shall focus towards one way of reusing which is using the glass and plastic waste as ingredients in concrete for partial replacement of cement, fine aggregate and coarse aggregate. Glass shows pozzolanic properties when is grinned to micro size particles and good pozzolan functions as a mitigator of Alkali-Silica-Reaction (ASR). Concrete is the second most used product after water all over the world. Using waste in concrete can serve as two pronged weapon for protecting environment and saving natural resources for future use.

Patrial replacement by glass :

Islam Sadiqul *et al.* (2017) used waste glass powder as replacement of cement for concrete in proportions of 0 per cent, 10 per cent, 15 per cent, 20 per cent and 25 per cent. Water cement to ratio was kept 0.485. At 180 days compressive strength of concrete with 20 per cent waste glass addition was found to be 10 per cent higher than reference. At 360 days the same value rose to 14 per cent. They reported 20 per cent glass replacement as optimum from a 3 aspects which are compressive strength, environmental and financial considerations.

Ali and Tersawy Sherif (2012) used recycled glass as replacement of fine aggregate for concrete in proportions of 0 per cent, 10 per cent, 20 per cent, 30 per cent, 40 per cent and 50 per cent for 3 different cement contents (300,400,450 kg/m³) Water to cement ratio was 0.4. As the per cent replacement of fine aggregate by glass increased, strengths (compressive strength, flexural strength, split tensile strength) and modulus of elasticity decreased for 300, 400, 450 kg/m³ cement contents at 28 days.

Bose *et al*. (2014) used GP with specific gravity 2.66 for replacement of fine aggregate in high strength concrete and is taken in 0 per cent, 10 per cent, 20 per cent and 30 per cent by weight of fine aggregate. Compressive strength, split tensile strength and flexural strength of concrete with glass was found to be higher than reference but the concrete with GP was found to be less workable and durable as compared to conventional concrete. It was concluded that fine aggregate can be replaced by GP.

Ekwulo and Eme (2018) conducted a comparative study on compressive strength of coarse and fine glass aggregate concrete. Mix proportion of 1:2:4 and water cement ratio of 0.6 was maintained throughout the experiment. The maximum compressive strength for glass and fine aggregate was attained at 20 per cent replacement while the same figure for glass and coarse aggregate was found to be 10 per cent. It was also found that the strength increment level does not show that much growth as the concrete ages for both coarse and fine glass-aggregate concrete.

Shaik and Bharath carried out their research with aim to analyse the effects on strength and micro-structure due to partial replacement of cement by fly ash, silica fume and GP. Each material was used in proportion 15 per cent and 30 per cent of cement. The study concluded that glass finer than 100 micrometers exhibits pozzolanic behaviour and also the concrete containing glass was found to have greater compressive strength as compared to concrete containing fly ash. Also the compressive strength of GP concrete increased with increasing curing age.

Raju and Kumar studied the change in mechanical properties with incorporation of GP in concrete as replacement of cement. Glass replacement was made in increment of 5 per cent in the range 5 per cent to 40 per cent. The sample with 20 per cent replacement was found to have highest compressive strength and flexural strength at 90-days age. An increase in strength with increase in curing time was also observed.

Widodo *et al.* (2015) did their research on utilization of GP as partial replacement of quartz powder in concrete. Replacement was made in proportion 10 per cent, 20 per cent and 30 per cent. 20 per cent replacement sample was found to have higher compressive, split tensile and flexural strength than both other mixtures and is thus accurate to conclude that 20 per cent replacement of quartz powder by GP is possible and it also improves mechanical behaviour of concrete.

Partial replacement by plastic:

Balte and Daule (2017) studied effect of 0.5 per cent to 2 per cent with increment of 0.5 per cent replacement of fine aggregates with PET fibre on properties of concrete. The mix was prepared for compressive strength of 26 MPa at 28 days. The water cement ratio was 0.40 for the test. They reported optimal strength at 1.5 per cent replacement. There was increase of 4 per cent, 8 per cent and 59 per cent in compressive strength, split tensile strength and flexural strength respectively. However, the slump and compaction factors were reduced at higher percentage of fibre.

Asha and Resmi (2015) experimented to optimize benefits of straight and crimped fibres made from waste PET bottles. Checked strength of concrete by replacing cement in dry mix by 0.5 per cent, 1 per cent and 1.5 per cent plastic fibres. Straight and crimped fibres were used in different specimens. Both types of fibres gave optimal results at 1 per cent fibre. For straight fibres compressive and tensile strength increased by 16 per cent and 37 per cent, respectively on the other hand, for crimped fibres there was increase of 18 per cent and 42 per cent in compressive and split tensile strength.

Tharini and Nishanthi (2018) mixed pulverised plastic in M20 grade concrete. They experimented by replacing fine aggregate with 5 per cent to 15 per cent concrete with 2.5 per cent increment with HDPE and LDPE along with replacement of cement with 2 per cent polypropylene fibres. For 10 per cent fine aggregate replacement maximum increase in compressive strength, split tensile strength and flexural strength was observed in both HDPE and LDPE.

Siddique *et al.* (2008) examined possibility of partial replacement of coarse aggregates by waste plastic.

Waste plastic bottle caps were used by replacing them with coarse aggregates by volume. 10 per cent, 15 per cent and 20 per cent by volume of coarse aggregates where exchanged with bottle caps. First crack was observed at a load which increased with increase of bottle cap percentage and attained maximum value at 20 per cent replacement. There was an increase of 16 per cent in compressive strength for 20 per cent replacement as compared to control specimen.

Venu and Rao (2010) examined load carrying capacity of concrete specimen having plastic fibre. They used high density polypropylene (HDPP) and polyethylene terephthalate (PET) with 1 per cent and 2 per cent fibres by concrete volume. There was increase in strength for both type of fibres for 1 per cent fibre by volume of concrete. Ultimate load carrying capacity increased by 4.62 per cent for HDPP fibres and by 9.11 per cent for PET fibres. Similarly load carrying capacity under flexure also increased for 1 per cent PET fibres by maximum extent.

Nibudey *et al.* (2013) tested the use of fibres made from waste PET bottles without any processing. The fibres were of 25 mm length while two breadth of 1 mm and 2 mm were used. They performed the experiment for M20 and M30 grade concrete with 0 per cent to 3 per cent fibre content. Maximum increase in compressive strength was for 1 per cent fibre and M20 grade concrete.

Charudatta and Husain (2017) made use of granular plastic pieces made from recycled PET or PP. 20 per cent to 60 per cent replacement of fine aggregates was done with recycled granules in M20 concrete. Increase in compressive strength and flexural strength was observed for 20 per cent and 40 per cent replacement while only minor decrease was there in split tensile strength.

Mahdi *et al.*(2010) experimented by depolymerizing waste PET plastic to produce unsaturated polymer resin (UPER). This UPER was used as binding agent to make polymer mortar (PM) and polymer concrete (PC). They used two different PET to glycol ratio and two different initiator combinations *viz.,* Methyl ethyl ketone peroxide (MEKP) + cobalt naphthenate (CoNp) and Benzoyl peroxide (BPO) + N, N-diethyl aniline (NNDA). They found better results for 2:1 PET to glycol ratio and MEKP and CoNp initiator. Tensile strength of all specimens was at par or more than corresponding grade of concrete.

Partial replacement by glass and plastic:

Wasan and Nazar (2018) did an experimental study on use of plastic and GP as partial replacement of coarse aggregate and cement respectively. 6 mixes were prepared namely reference, G15P0 (glass 15% of cement, plastic 0% of coarse aggregate), G15P25, G15P50, G15P75 and G15P100. Cement, sand and coarse aggregate were taken in ratio 1:1.4:1.8 by weight and water to cement ratio was 0.27. Compressive, splitting tensile and flexural strength tests were conducted and G15P0 was found to have higher strength than others and also as the plastic percentage increased, strengths decreased. A decrease in density was observed with use of glass or with increasing plastic waste.

Malek *et al.* (2020) examined the change in mechanical properties due to replacement of fine aggregate by glass waste and plastic in concrete. Water to cement ratio of 0.56 was used. Glass replacement resulted in an increase in compressive, flexural and split tensile strength, however the increase in compressive strength with increasing glass content was much higher. It was also observed that glass incorporation in concrete had little effect on workability. But with the addition of plastic, a decrease in compressive, flexural and split tensile strength was observed.

Kataria studied the effects of addition of glass waste as partial replacement of cement and plastic as partial replacement of coarse aggregate in concrete. Compressive strength test was conducted at 7-day and 28-day age. 10 series of mixtures were prepared in each series one of the replacement was kept constant and other varying in regular intervals. In case of series which had glass was constant, the increasing plastic resulted in decrease of strength. In case of series which had plastic constant, 20 per cent replacement of cement by glass had higher compressive strength than 0 per cent, 40 per cent, 60 per cent and 80 per cent for all plastic levels (*i.e.* 0%, 20%, 40%, 60% and 80%). Therefore, it is correct to say that 20 per cent cement replacement is possible and optimum. Plastic upto 20 per cent can be used for construction purposes despite having lower strength nearly 20MPa.

Harshad and Dalal (2017) prepared a powder of PVC and glass waste and used it as partial replacement of fine aggregate in concrete. Replacement was made in proportion per cent, 10 per cent, 15 per cent, 20 per cent, 25 per cent and 30 per cent. As the per cent replacement increased, the density decreased. 28-day strength was found to be higher than 7-day strength. Strength was comparable till a particular per cent replacement only but after that value the decrease in strength was more gradual and that value was 15 per cent.

Conclusion:

Based on this study, it can be concluded that Partial replacement of cement and fine aggregate by GP is possible until a particular percentage is reached, which in most of the studies was found to be in the range of 10-20 per cent. Gain in strength with increasing curing age was also observed.

However, when partial replacement was made using plastic waste, strength decreased as the proportion of plastic increased and optimum replacement percentage was found to be 5 per cent.

Using both glass powder and plastic waste together in concrete as a partial replacement show strength similar to reference mixture as glass powder used in the mixture counters the adverse effects of plastic and it is still possible to use plastic for low strength concrete.

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