Study on Effect of Waste Polyethylene Terephthalate Bottle Fibers on Silica Fume Concrete – A Review

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Abstract— The waste disposal is the vital challenge in every country. PET (polyethylene terephthalate) bottles have increasingly become an indispensable part of a common man's life. With the phenomenal increase in plastic consumption the problems with plastic waste disposal have also aggravated. The post-consumer PET mineral water bottles are recycled or disposes into land fill. Improper handling of these waste bottles leads to the harm to the environment. And Silica fume is a by-product of the manufacture of silicon metal and ferro-silicon alloys. Therefore in this study waste PET mineral bottles were used in fiber form to form reinforced plain concrete with silica fume.

Index Terms— Compressive strength, Concrete, Flexural strength, PET fibers, Plastic Fibers, Silica fume, Waste bottles.

1 Introduction

THE problem of recycling waste materials of various types, is, and will be, certainly, one of the major problems that will most trouble the society in the future and that we must have to resolve in all possible ways. It is needed to be done that the researchers will find solutions to the reuse of the waste. Waste plastic bottles are major reason of solid waste disposal. The lack of space for landfilling and due to an ever increasing cost, the consciousness is towards the reuse of waste as alternative to disposal.

The construction industry is in need of finding cost effective materials for increasing the strength of concrete structures. Research is constantly more interested in the use of such products in the concrete.

2 Polyethylene Terephthalate (PET)

Among different waste fragment, plastic waste justifies special attention because of non-biodegradable property which is creating a lot of problems in the environment. In India 62 million tons of solid waste is generated annually, out of which 5.6 million tonnes is plastic waste. Plastics are largely utilized and therefore contribute to an ever increasing of the solid waste volume. Among the plastic waste, polyethylene contributes the largest fraction, followed by polyethylene terephthalate, generally known as PET. Polyethylene Terephthalate (PET) is extensively used for containers of carbonated beverage and water bottles. The waste plastic bottles are difficult to biodegrade and include processes either to recycle or reuse. It is a transparent polymer that has good mechanical properties. It also has good dimensional stability under variable load. The common characteristics of PET are semi crystalline thermoplastic polyester, durable, low gas permeability, chemically and thermally stable, wear and tear resistant, easily processed and handled, on bio-degradable. Based on its different properties it is also used in sportswear, utility ware textiles etc. Food processing industries favours PET due to hygienic, strong and light weight. Excellent physical properties are possessing by PET.

Fig.1 Polyethylene Terepthalate Fibers

3 Silica Fume

Silica fume is a secondary product of the manufacture of silicon metal and ferro-silicon alloys. Silica fume is a very fine powder consisting mainly of spherical particles or microspheres of mean diameter about 0.15 microns. The principle physical effect of silica fume in concrete is of filler, which because of its fineness can fit into space between cement grains that sand fills the voids between particles of coarse aggregates or the cement grains fill the space between the sand grains. Silica fume is a highly reactive pozzolana that converts all or most of the liberated calcium hydroxide to C-S-H. Silica fume is known to improve both the mechanical characteristics and

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durability of concrete. The use of silica fume in concrete has both engineering potential and economic advantage.

Fig.2 silica fume

3.1 Properties

The physical and chemical properties of silica fume and OPC are presented in table 1.

TABLE 1
PHYSICAL AND CHEMICAL PROPERTIES OF SILICA FUME

Properties	OPC	Silica fume
Physical		
Specific gravity	3.1	2.2
Mean grain size (μm)	22.5	0.1
Specific area cm^2/gm	3250	200000
Colour	Dark Grey	Light to Dark Grey
Chemical compositions (%)		
Silicon dioxide (SiO_2)	22.03	96.0
Aluminium oxide (Al_2O_3)	4.03	0.1
Iron oxide (Fe_2O_3)	3.67	0.6
Calcium oxide (CaO)	65.19	0.1
Magnesium oxide (MgO)	0.88	0.2
Sulphite (SO3)	2.86	-
Sodium oxide (Na2O)	0.12	0.1
Potassium oxide (K2O)	0.20	0.4
Loss on ignition	0.98	1.7

4 USE OF PET FIBERS IN CONCRETE

Concrete is characterized by a number of defects such as low ductility, heavy weight, low tensile strength,and low energy absorption. These disadvantages have caused the civil engineers to make use of the normal reinforcement in order to gain the tensile strength and ductility. The concept of using fibers as reinforcement is not a new. Addition of fibers to concrete would act as crack retarders and considerably increase the tensile strength, impact strength, cracking resistance, fatigue, wear and tear, resistance and ductility of concrete (M. Sulyman et. al. 2016, Bon-Min Koo et. al. 1996- 1944). In addition to the advantage of recycling of the solid waste, the addition of plastics such as PET wastes in concretes is essential as a light weight aggregate.One of the goals of production of earthquake resistant structures is to decrease of unit weight of concrete (A. A. Abdel-Azim 1996). PET fiber reinforced concrete has experimentally been demostrated to perform better (R. N. Nibudey et. al. 2013, Ms. K. Ramadevi et. al. 2012, R. N. Nibudey et. al. 2014, Margareth da Silva Magalhães et. al. 2015). The PET fibers show most success in practical applications and experiments as they have qualities that are unique compared to the ordinary fibers such as,they are chemically inert, do not corrode, allow easy jetting of concrete, lighter than steel fibers of the same number, allow a better control of the plastic shrinkage cracking (Dora Foti 2011)

Hence reusing of PET wastes in the construction industry is an effective approach in preventing environmental pollution and designing economical buildings.

5 MECHANICAL BEHAVIOUR OF MODIFIED CONCRETE

A comprehensive review of study of researchers on the different mechanical properties of modified concrete is discussed below in this section.

5.1 Compressive Strength

R.N. Nibudey et. al.2013 reported that fibers made from waste PET bottles were suitable for concrete reinforcement. The experimental compressive strength of PET fiber reinforced concrete (PFRC) was found to increase by 7.35% compared to normal concrete for M_{20} grade of aspect ratio 50 for 1% fiber volume fraction afterwards the strength decreased at higher percentage volumes of fraction, for 3% fiber volume fraction for the same grade and aspect ratio they noted a 27% fall in compressive strength. The rise in compressive strength for M30 grade concrete is very little and the fall in strength on gaining the fiber volume fraction was very low. For higher aspect ratio increase in compressive strength of PFRC was higher. In the analysis of tests done by Ms. K. Ramadevi et. al. 2012 for a mix design of M25 grade concrete a considerable gain in compressive strength is observed till 2% replacement of fine aggregate by PET bottle fibers and then the compressive strength gradually decreases (R. Kandasamy et. al.2011). For conventional concrete of grade M25 the replacement of fine aggregates by 2% increases the compressive strength by 12% (Sahil Verma et. al. 2015) Hence 2% replacement of fine aggregate is found to be reasonable.

Strength of silica fume concrete is influenced by several factors viz. type of cement, proportion and quality of silica fume and curing temperature. The contribution of silica fume to development of concrete strength at normal curing temperature takes place from 3 to 28 days. In the strength development of concrete, contribution of silica fume after 28 days is minimum (ACI, 234R- 96, 1996). Sengupta and Bhanja (2003) reported that addition of silica fume in the range of 5-25% increases compressive strength near about 6-30% for water cement ratio in the range of 0.26-0.42. Sakr (2006) described that at 15% silica fume content gravel concrete, concrete ilmenite and barite concrete showed increased compressive strength by 23.33%, 23.07% and 23.52% respectively at 7 d, 21.34%, 20% and 22.58% respectively at 28 d, 16.5%, 18.7% and 22% respectively at 56 d and 18%, 7.14% and 22.80% respectively at 90 dKadri and Dual (1998) reported that at 10% replacement level, compressive strength increased in the range about 10-17% at different water cement ratio (0.25-0.45). Khayat et al. (1997) described that, compressive strength increased in the range of about 10-17% at different water cement ratio (w/c) at 7.5% replacement level. Babu Ganesh and Suryaprakash (1995) described that concrete with silica fume up to 40% replacement showed strength higher than that of the conventional concrete. The development in strength at the different percentages of replacement at any water cement ratio were also differs over a wide range. Khan and Ayers (1995) described 67% increase in compressive strength at 10% replacement level and 0.38 w/c. Cong et al. (1992) reported that concrete with silica fume as a partial replacement of cement shows an increased compressive strength in large part because of the improved strength of its cement paste constituent. Slaniska and Lamacska (1991) outlined that at different replacement level of cement by silica fume (3.75-10.25%) increase in compressive strength in the range of about 12%-57% is observed. Detwiler and Mehta (1989) reported that silica fume concrete showed better compressive strength in the range of 11.56%-18.89% than the conventional concrete at different water cement ratio. Yogendran et al. (1987) reported that at 0.34 w/c, the compressive strength of concrete at 7, 28 and 56 d with 5 and 10% replacement level are slightly higher than the control mix. Ramakrishnan and Srinivasan (1982) reported that high strength fibre reinforced concretes can be produced by addition of silica fume. Compressive strength as high as 58 MPa have been obtained with locally available lime stone aggregate. Gafoori and Diaware (2007) reported that at 28 d concrete with 5, 10, 15 and 20% silica fume (as partial replacement of fine aggregate) showed gain in compressive strength of concrete by 25, 64, 42 and 25% respectively when compared with referral.

5.2 Flexural Strength

The flexural strength of concrete with substitution of the fine aggregate with PET bottle fibers increases slowly with increase in the replacement percentage (R.Kandasamy and R.Murugesan 2011). Ms. K. Ramadevi et. al. 2012 described from her study that the flexural strength of the modified M25 grade concrete increased at 2% replacement of fine aggregates with PET bottle fiber, slowly decreased for 4% and remains the same for 6% replacement.

Flexural strength of concrete incorporating silica fume is similar to that observed in concretes without silica fume. Wolsiefer (1984) reported that for the 98 MPa concrete containing 593 Kg/m3 of cement and 20% silica fume, the ratio of flexural to compressive strength varies between 0.13 to 0.15. Yogendran et al. (1987) reported that at 0.34 w/c, the flexural strength of concrete was at 7, 28 and 56 d with 5 and 10% replacement level which are slightly higher than the control mix. However at 15% replacement level, loss in strength is observed due to improper compaction since, the voids could not be removed even using vibrating table. Ramakrishnan and Srinivasan (1982) reported that flexural strength of silica fume concrete was higher by 10-15% as compared that of ordinary fibre concrete. Sakr (2006) reported that at 15% replacement level, flexural strength of silica fume concrete found to be increase in the range of 52-65% as compared to concrete without silica fume.

5.3 Split Tensile Strength

The experiments carried by J. M. Irwan et. al. 2013 shows that PET fiber can increase the splitting tensile strength of concrete cylinder. As compared to normal concrete Strength of concrete containing PET fibers increased by 0.5% -1.5%, at all ages. The increment of splitting tensile strength of concrete containing PET fibers at 0.5%, 1.0% and 1.5% was by 9.1%, 15.5% and 23.6% respectively at 28 days. Results of bending tests carried by Dora Foti et. al. 2010 showed that the tensile strength increased with the inclusion of PET fiber reinforcement at 8.19KN as compared to conventional concrete specimen at 7.88KN tensile strength. The split tensile strength is increasing till the 2% replacement of fine aggregates with PET bottle fibers and then decreases slowly with increase in replacement (R.Kandasamy and R.Murugesan 2011). The role of adding PET fiber in concrete is bringing across the crack and enhancing the bonding of its element in concrete, we can conclude that the PET fiber added will improve the bending strength as well as the splitting tensile strength.

Splitting tensile strength of concrete and incorporating silica fume is similar to that observed in concretes without silica fume. As the compressive strength increases the tensile strength also increases, but at a gradually decreasing rate (Goldman, 1987). Several study showed that splitting tensile strength at various ages ranged between 5.8-15% of the compressive strength. Paillere et al. (1989) reported that at 15% silica fume content and tensile strength of concrete found to be in the range of 4.79-5.34% of its compressive strength. Sakr (2006) reported that at 15% replacement level, tensile strength of silica fume concrete increased in the range of 27-34% as compared to concrete without silica fume.

6 Conclusion

Case studies based on researches and experimental works and scientific reports have shown that waste PET may be applied for the modification of concrete. The addition of PET bottle fibers as reinforcement in concrete has shown, on the basis of different tests on its mechanical properties, that there is a significant improvement in the modified concrete. The use of PET fibers as reinforcement of cement composites is an encouraging technique for developing sustainable materials to be applied in the construction industry. Hence concrete with waste PET bottle fiber can be used not only as a successful plastic waste management practice but also as a blueprint to produce more economic and sustainable building materials in the future.

The partial replacement of 10% silica fume with cement can giving most extreme conceivable compressive strength. Silica fume has no large impact on flexural strength of concrete

REFERENCES

[1] Sampada Chavan, Pooja Rao, "Utilization of Waste PET Bottle Fibers in Concrete as an Innovation in Building Materials", *International Journal of Engineering Research,* Volume No.5, Issue Special 1 pp : 304-307

[2] Dora Foti (2011) ," Preliminary analysis of concrete reinforced with waste bottles PET fibers", *Construction and Building Materials* 25 (2011) 1906–1915

[3] P. Ganesh Prabhu, C. Arun Kumar, R. Pandiyaraj, P. Rajesh & L. Sasi Kumar (2014) "Study On Utilization Of Waste Pet Bottle Fiber In Concrete", *International Journal of Research in Engineering & Technology* Vol. 2, Issue 5, May 2014, 233- 240.

[4] Dora Foti (2013) "Use Of Recycled Waste Pet Bottles Fibers For The Reinforcement Of Concrete", *Composite Structures* 96, 396–404.

[5] Ms. K.ramadevi , Ms. R. Manju (2012) "Experimental Investigation On The Properties Of Concrete With Plastic Pet (Bottle) Fibers As Fine Aggregates" *International Journal of Emerging Technology and Advanced Engineering*, Volume 2, Issue 6, June 2012,42-46

[6] P.Vinayagam (2012) "Experimental Investigation On High Performance Concrete Using Silica Fume And Superplasticizer" International Journal of Computer and Communication Engineering, Vol. 1, No. 2, July 2012, 168-171.

[7] Vaishali G. Ghorpade (2010) "An Experimental Investigation On Glass Fiber Reinforced High Performance Concrete With Silica fume As Admixture"35th Conference on OUR WORLD IN CONCRETE & STRUCTURES: 25 – 27 August 2010, Singapore.

[8] N. K. Amudhavalli , Jeena Mathew (2012) "Effect Of Silica Fume On Strength And Durability Parameters Of Concrete" International Journal of Engineering Sciences & Emerging Technologies, August 2012,Volume 3, Issue 1, pp: 28-35