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REVIEW ARTICLE

THE ADDITION OF PLASTIC WASTE IN SELF-COMPACTED CONCRETE: A CRITICAL REVIEW

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ABSTRACT

This paper intends to review past studies regarding the addition of waste plastic in self-compacted concrete. SCC is one of the ingenuities products in concrete technology. It is also a special type of highly flowable concrete that does not require vibration for placing and compaction. Mixture proportion could be done by adding a different material to SCC mixtures to improve the properties of SCC. Innovative materials are generally used for partial replacement of cement, sand and a combination of two or more items. The use of plastic waste materials in concrete is a common solution for waste disposal and also serves an economic purpose. Different research studies have been conducted on the use of plastic waste as creative material to produce good quality concrete. The result shows that using waste plastic as a fine aggregate improves the workability and reduces the density and the compressive strength of concrete containing between 10% and 20% of waste by 10% to 24 % respectively. In addition, when used as a coarse aggregate, the properties such as compressive as well as tensile strength are reduced, and the thermal conductivity of concrete is reduced, but the best usage of waste plastic was as a fiber because of its high compressive and flexural strength.

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INTRODUCTION

Self-compacted concrete (SCC) started in Japan in 1988 (Panda and Bal, 2013; Loukili, 2013). Super plasticizer is one of the major contents (Mardani-Aghabaglou, 2013; Rai, 2012). In addition, there is a need to use filler in SCC to enhance its strength, achieve high workability, increase durability (Grdic, 2010; Nik and Omran, 2013) and enable it to flow without coming apart, giving greater freedom in design with good finishing (Safi, 2013). In addition to this, eliminating the need for vibration leads to a reduction in the amount of labor and noise level. As a result of this, construction sites are getting safer and more environmentally friendly (Bhogayata, 2011; Domone, 2007). In faster construction projects, as a rule, "saving time equals saving money", so it is economical (Khayat and De Schutter, 2014; Reddy, 2013). There are many admixtures, such as fly ash (Pathak and Siddique, 2012; Mohamed, 2011), slag (Chen *et al.*, 2013; Raharjo and Subakti, 2013), sludge, waste rubber (Bignozzi and Sandrolini, 2006; Pacheco-Torgal *et al.*, 2012), waste glass (Vanjare and Mahure, 2012; Kou and Poon, 2009), wood ash, coal ash, phosphate (Siad, 2015), waste steel, husk ash, concrete rubble, olive oil waste (Batayneh *et al.*, 2007), and waste plastic (Uysal and Yilmaz, 2011; Morin, 2011; Byung-Wan *et al.*, 2006), that, if added to SCC, improve its fresh and hard properties (Fonseca *et al.*, 2011; Paine, 2009). On the other hand, adding waste material to SCC will reduce its environmental impact (Dehwah, 2012; Islam *et al.*, 2011). The volume of waste plastic is increasing and they require long periods to biodegrade (Pezzi, 2006; Bhogayata, 2012). Using them in SCC helps to save natural resources (Avila and Duarte, 2003; Albano, 2009) as well as prevent the bad effect of waste plastic in the environment like releasing harmful gases, such as CO_2, SO_2, NO_2 and H_2S (Patil *et al.*, 2014), soil and water damage (Bhogayata, 2012), acid rain phenomena, and harmful effects on the health of animal (Ghernouti, 2011; Wun, 2012). These are all reasons to mix waste plastic in SCC (Hannawi *et al.*, 2010; Kou and Poon, 2009).

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Adding waste plastic in concrete as a fiber

A number of studies have been carried out to investigate the fresh and hardened properties of self-compacted concrete by adding waste plastic as a fiber (Chaudhary *et al.*, 2014; Hensher, 2013). Studied adding non-recyclable thin polyethylene bags as a fiber material to concrete without significant change on its basic properties or with a slight compromise in strength and studied the compressive strength of concrete, its workability by percentage 0.5%, 0.75% and 1.0% of cement. Compressive strength was determined at 7, 28 and 56 days of curing (Foti, 2011; Asokan *et al.*, 2009). They had observed that workability of concrete was reduced and slump loss was increased with the increase of waste polyethylene; in addition, when using percentage 0.5%, the compressive strength of concrete was increased by 3.03%, 1.32% and 2.76% at 7, 28 and at 56 days, and by using 0.75% of waste polythene, the compressive strength of concrete increased by 4.03%, 4.55% and 17.11% at 7, 28 and 56 days and it decreased up to 0.75% (Kim, 2010). Manikandran *et al.* (2015) studied the effect of Low Density Polyethylene (LDPE) on bituminous pavements or concrete in terms of modifying the strength and ductility by using large quantities of non-degradable LDPE material (3-5%) under different temperatures (70°C, 80°C and 90°C) and duration of thermal curing (4, 8 and 16 hours) on compressive strength and corrosion resistance (Khan *et al.*, 2012). The result showed that compressive strength for all percentages of LDPE was higher than the control concrete, whereas the concrete with 5% LDPE was of maximum compressive strength. On the other hand, strength and durability criteria concrete with 3% LDPE was found to be an optimum percentage of addition when concrete was subjected to thermal curing at an optimum temperature of 80°C for the curing duration of 4 hours. Though we get similar results for 16 hours curing, considering the economy and practical difficulties, the above optimum values were suggested (Gencel, 2011).

Fresh and hardened properties of self-compacting concrete containing plastic bag waste fibers (WFSCC) were investigated (Ghernouti, 2015; Razaqpur, 2010). Koo *et al.*, (2014) studied the fresh and hardened properties of SCC containing plastic bag waste fibers (PBWF). They prepared fibers from recycling waste materials like plastic bags. They made fourteen mixtures of SCC with 0.40 of water/cement ratio, twelve SCC mixtures with plastic bag waste fiber (WFSCC) by varying length of fiber (2, 4 and 6 cm) with different levels of incorporation (1, 3, 5 and 7) kg/m^3 and two other mixtures, one with 1 kg/m^3 of polypropylene fibers (PFSCC) and another without fiber (SCC) (Koo *et al.*, 2014). Fresh properties of mixtures were prepared by using Slump flow, L-box, and sieve stability. Compressive strength, splitting tensile strength and flexural strength of the concrete were determined for the hardened properties. They concluded that the incorporation of PBWF in the concrete improves the slump flow spreading, facilitates the flow of the fresh concrete and has a positive effect on the split tensile strength value after 2-8 days.

The increase in fibers length and content decreased the stability; on the other hand, the presence of PBWF in SCC prevents the sudden break and increases the fracture toughness of the material (Prahallada, and Prakash 2011). Yahya *et al.* (2014) investigated the effects of polymeric materials on high-performance concrete (HPC) by using ordinary Portland cement, silica fume, super plasticiser and linear low-density polyethylene (LLDPE) with additives of 1.5%, 3% and 5% of cement (Khaloo *et al.*, 2014). They measured mechanical and fracture properties, including compressive and tensile strengths, the modulus of rupture, fracture energy, fracture toughness and dynamic elastic modulus.

The results indicate that the polymers increase the compressive and tensile strengths of the HPC, in particular for the 1.5% weight content but did not enhance other properties. The test results at 28 days indicate that the additions of 1.5% and 3% LLDPE into the HPC improved the compressive strength by up to 15.7%, while the addition of 5% LLDPE did not result in any enhancement of the concrete and the tensile strength could be increased by as much as 83% (Silva, 2005). The moduli of rupture, fracture toughness and dynamic Young's moduli obtained from the tests on the notched HPC beams were not enhanced for lower amounts of polymers and were slightly decreased for higher amounts. This could be due to the slight increase in the brittleness of the HPC with these polymers (Kandasamy and Murugesan, 2011).

Adding waste plastic in concrete as aggregate (fine and/or coarse)

A number of studies have been carried out to investigate the fresh and hardened properties of self-compacted concrete by adding waste plastic as fine and coarse aggregate**.** For example, Ghernouti *et al.* (2011) studied the possibility of recycling a plastic bag waste material (BBW) that is now produced in large quantities in the formulation of concrete as fine aggregate by substitution of a variable percentage of sand (10%, 20%, 30% and 40 %) (Frigione, 2010; Choi, 2009) and the influence of the PBW on the fresh and hardened properties of the concrete—workability, bulk density, ultrasonic pulse velocity testing, compressive and flexural strength of the different concretes.

The results showed that the use of PBW improves the workability and the density and reduces the compressive strength of concrete containing between 10% and 20% of waste by 10% to 24 %, respectively (De Castro and de Brito, 2013; Remadnia, 2009). Saikia *et al.* (2012) studied recycling of plastic waste to produce new materials like concrete or mortaras one of the best solutions to plastic waste disposal, which will lead to economic and ecological advantages through the recycling of plastic waste as aggregate in cement mortar and concrete productions (Silva *et al*., 2013). Saikia *et al.* concluded that adding plastic to concrete reduces the density, tensile splitting strength and flexural strength of concrete and also leads to improvement in the permeability behavior of concrete and its durability in the face of chemical attack (Saikia and de Brito, 2014; Choi, 2005). Rai *et al*. (Al-Tayeb, 2012) studied fresh and hardened properties when using waste plastic with concrete as partial replacement of sand by different percentages.

Plastic waste mixed concrete with and without superplasticizer was tested at room temperature. Forty-eight cube samples were molded for compressive strength tests at three, seven, and twenty-eight days. Eight beams were also cast to study the flexural strength characteristics of plastic waste mixed concrete. Rai *et al*. found that workability increased from 10% to 15% when super plasticizer is added to the plastic waste mixed concrete (Iucolano, 2013). On the other hand, the comprehensive strength and flexural strength are decreased by increasing plastic waste ratios. In conclusion, Rai *et al.* observed that the effect of plasticizer on flexural strength of concrete is irrelevant.

Ghernoutiy *et al*. (Ramadevi and Manju, 2012) explored the possibility of recycling plastic bag waste material (PBW) that is now produced in large quantities in the formulation of concrete as a fine aggregate by partial replacement of sand by 10%, 20%, 30% and 40%. They also studied the influence of the PBW on the fresh and hardened properties of the concrete—workability, bulk density, ultrasonic pulse velocity testing, compressive and flexural strength of the different concretes. Ghernoutiy *et al.* conclude that bulk density and the mechanical resistance decreased with the replacement of sand with plastic waste. In addition, concrete has good workability and the fluidity was improved by the presence of this waste (Bandodkar, 2011). Mali *et al*. (2014) studied disposal of plastic waste in concrete as partial replacement by 0%, 25%, 50%, 75% and 100% of fine aggregate. He also determined the workability test, weight and compressive strength. Mali *et al* found that water-cement ratio increases and weight of the cube decreases with increase in replacement of sand by plastic material. On the other hand, there is not much change in the strength of concrete that contains more than 25% replacement of sand by plastic material. Mali *et al*. also noted the impact on the disposal of a lot of plastics, which pose a huge threat to the environment, and the problems involved in the extraction of natural sand from river basins.

Ganesh *et al*. (2016) studied the use of industrial wastes from plastic bottles, pallets, carry bags, polypropylene (PP) and polyethylene Terephthalate (PET) as partial replacements of aggregates by 10%, 20% and 30% in concrete (Hannawi *et al*., 2010). Ganesh *et al*. conclude that when plastic is used in a concrete mix, it reduces the weight and strength. Raghatate (Liguori, 2014) studied the disposal of a large quantity of plastic bags that may cause pollution of land, water bodies and air by adding plastic in concrete to improve certain properties of concrete by different percentages of plastic. Raghatate summarized that the compressive strength of concrete decreases as the percentage of plastic increases and that the use of plastic could increase the tensile strength of concrete (Liguori, 2014). M. Muzafar, (Silva *et al*., 2014) studied the use of recycled plastics in concrete by partial replacement of coarse aggregate to investigate the properties of concrete, such as workability, compressive, tensile strengths and thermal characteristics of the concrete. The results indicate that the use of plastic solid waste in concrete lead to lightweight concrete; in addition, properties, such as compressive, tensile strength and the thermal conductivity of concrete, are reduced (Ismail and Al-Hashmi, 2008).

Conclusion

Accumulation of plastic waste poses a danger to the environment; adding plastic waste to concrete reduces this risk. Studies of the economics of adding plastic waste in all shapes—fibre, fine and coarse aggregate—to concrete conclude that when adding plastic waste as a fiber, the compressive strength increases and the workability decreases, whereas when using plastic waste as a fine aggregate, the compressive strength and workability improve. On the other hand, when adding plastic waste as a coarse aggregate, the compressive strength and flexure decrease; the workability also decreases, but there is a joint result that when adding plastic in any shape the weight of concrete decreases.

After all results, the use of plastic waste as a fiber by between 1.5% and 3%improved the compressive strength of concrete by up to 15.7%, while the addition of 5% did not show any enhancement on concrete.

REFERENCES

Albano, C. *et al*. 2009. Influence of content and particle size of waste pet bottles on concrete behavior at different w/c ratios. *Waste Management,* 29(10): p. 2707-2716.

Al-Tayeb, M.M. *et al*. 2012. Effect of partial replacements of sand and cement by waste rubber on the fracture characteristics of concrete. *Polymer-Plastics Technology and Engineering,* 51(6): p. 583-589.

Asokan, P., Osmani, M. and Price, A.D. 2009. Assessing the recycling potential of glass fibre reinforced plastic waste in concrete and cement composites. *Journal of Cleaner Production,* 17(9): p. 821-829.

Avila, A.F. and Duarte, M.V. 2003. A mechanical analysis on recycled PET/HDPE composites. *Polymer Degradation and Stability,* 80(2): p. 373-382.

Bandodkar, L. *et al*. 2011. Pulverised PET bottles as partial replacement for sand. *International Journal of Earth Sciences and Engineering,* 1009: p. 1009-1012.

Batayneh, M., Marie, I. and Asi, I. 2007. Use of selected waste materials in concrete mixes. Waste Management, 27(12): p. 1870-1876.

Bhogayata, A. and Arora, N.K. 2011. Green concrete from the postconsumer plastic wastes: Indian scenario. *ICTSET proceedings,* p. 437-40.

Bhogayata, A. *et al*. 2012. Feasibility of wastes metallised polythene used as concrete constituent. *Int. J. Eng. Adv. Technol,* 1(5): p. 204-207.

Bhogayata, A. *et al*. 2012. Performance of concrete by using Non-recyclable plastic wastes as concrete constituent. *International Journal of Engineering Research and Technology.* ESRSA Publications.

Bignozzi, M. and Sandrolini, F. 2006. Tyre rubber waste recycling in self-compacting concrete. *Cement and Concrete Research,* 36(4): p. 735-739.

Byung-Wan, J., Park, S.K. and Cheol-Hwan, K. 2006. Mechanical properties of polyester polymer concrete using recycled polyethylene terephthalate. *ACI Structural Journal,* 103(2): p. 219.

Chaudhary, M., Srivastava, V. and Agarwal, V. 2014. Effect of waste low density polyethylene on mechanical properties of concrete. *Journal of Academia and Industrial Research* (JAIR), 3(3): p. 123.

Chen, Y.Y., Tuan, B.L.A. and Hwang, C.L. 2013. Effect of paste amount on the properties of self-consolidating concrete containing fly ash and slag. *Construction and Building Materials,* 47: p. 340-346.

Choi, Y.W. *et al*. 2005. Effects of waste PET bottles aggregate on the properties of concrete. *Cement and Concrete Research,* 35(4): p. 776-781.

Choi, Y.W. *et al*. 2009. Characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles. *Construction and Building Materials,* 23(8): p. 2829-2835.

De Castro, S. and de Brito, J. 2013. Evaluation of the durability of concrete made with crushed glass aggregates. *Journal of Cleaner Production,* 41: p. 7-14.

Dehwah, H. 2012. Mechanical properties of self-compacting concrete incorporating quarry dust powder, silica fume or fly ash. *Construction and Building Materials,* 26(1): p. 547-551.

Domone, P. 2007. A review of the hardened mechanical properties of self-compacting concrete. *Cement and Concrete Composites*, 29(1): p. 1-12.

Ferreira, L., de Brito, J. and Saikia, N. 2012. Influence of curing conditions on the mechanical performance of concrete containing recycled plastic aggregate. Construction and Building Materials, 36: p. 196-204.

Fonseca, N., De Brito, J. and Evangelista, L. 2001. The influence of curing conditions on the mechanical performance of concrete made with recycled concrete waste. *Cement and Concrete Composites*, 33(6): p. 637-643.

Foti, D. 2011. Preliminary analysis of concrete reinforced with waste bottles PET fibers. *Construction and building materials,* 25(4): p. 1906-1915.

Frigione, M. 2010. Recycling of PET bottles as fine aggregate in concrete. Waste Management, 2010. 30(6): p. 1101-1106.

Gencel, O. *et al*. 2011. Mechanical properties of self-compacting concrete reinforced with polypropylene fibres. Materials Research Innovations, 15(3): p. 216-225.

Ghernouti, Y. *et al*. 2011. Use of recycled plastic bag waste in the concrete.The International Journal of scientific publications: *Material, Methods and technologies*.

Ghernouti, Y. *et al*. 2015. Fresh and hardened properties of self-compacting concrete containing plastic bag waste fibers (WFSCC). *Construction and Building Materials,* 82: p. 89-100.

Grdic, Z.J. *et al*. 2010. Properties of self-compacting concrete prepared with coarse recycled concrete aggregate. *Construction and Building Materials,* 24(7): p. 1129-1133.

Hannawi, K., Kamali-Bernard, S. and Prince, W. 2010. Physical and mechanical properties of mortars containing PET and PC waste aggregates. *Waste Management,* 30(11): p. 2312-2320.

Hannawi, K., Prince, W. and Kamali-Bernard, S. 2010. Effect of thermoplastic aggregates incorporation on physical, mechanical and transfer behaviour of cementitious materials. *Waste and Biomass Valorization,* 1(2):p.251-259.

Hensher, D.A. 2013. Fiber-reinforced-plastic (FRP) reinforcement for concrete structures: properties and applications. Vol. 42. 2013: Elsevier.

Islam, M., Rahman, M. and Ahmed, M. 2011. Polymer-modified concrete: World experience and potential for Bangladesh. *The Indian Concrete Journal,* 1: p. 55-63.

Ismail, Z.Z. and Al-Hashmi, E.A. 2008. Use of waste plastic in concrete mixture as aggregate replacement. Waste Management, 28(11): p. 2041-2047.

Iucolano, F. *et al*. 2013. Recycled plastic aggregate in mortars composition: Effect on physical and mechanical properties. *Materials & Design*, 2013. 52: p. 916-922.

Kandasamy, R. and Murugesan, R. 2011. Fibre reinforced concrete using domestic waste plastics as fibres. ARPN *Journal of Engineering and Applied Sciences,* 6(3): p. 75-82.

Prahallada, M.C, and Prakash K.B., Strength and workability characteristics of waste plastic fibre reinforced concrete produced from recycled aggregates. International Journal of Engineering Research, 2011. 1(4): p. 1791-1802.

Khaloo, A. *et al*. 2014. Mechanical performance of self-compacting concrete reinforced with steel fibers. Construction and Building Materials, 2014. 51: p. 179-186.

Khan, N.U., Khan, B. and Badshah, N. 2012. Performanceof polymeric concrete with synthetic fiber reinforcement against reflective cracking in rigid pavement overlay.

Khayat, K.H. and De Schutter, G. 2014. Mechanical properties of self-compacting concrete.

Kim, S.B. *et al*. 2010. Material and structural performance evaluation of recycled PET fiber reinforced concrete. Cement and Concrete Composites, 2010. 32(3): p. 232-240.

Koo, B.M. *et al*. 2014. Material and structural performance evaluations of hwangtoh admixtures and recycled PET fiber-added eco-friendly concrete for co2 emission reduction. *Materials,* 7(8): p. 5959-5981.

Kou, S. and Poon, C. 2009. Properties of self-compacting concrete prepared with recycled glass aggregate. *Cement and Concrete Composites,* 31(2): p. 107-113.

Kou, S. and Poon, C. 2009. Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates. *Cement and Concrete Composites*, 2009. 31(9): p. 622-627.

Liguori, B. *et al*. 2014. The effect of recycled plastic aggregate on chemico-physical and functional properties of composite mortars. *Materials & Design*, 57: p. 578-584.

Loukili, A. 2013. Self compacting concrete. John Wiley & Sons.

Mali, M.J. 2014. An investigation of the properties of concrete containing granulated plastic bottle waste as a partial replacement of fine aggregates, University Of Nairobi.

Manikandran, R., Nirmala, D. and Dhinakaran, G. 2015. Effect of LDPE raw material on strength, corrosion and sorptivity of concrete. *Journal of Engineering Science and Technology,* 10(4): p. 485-495.

Mardani-Aghabaglou, A. *et al*. 2013. Effect of different types of superplasticizer on fresh, rheological and strength properties of self-consolidating concrete. *Construction and Building Materials.* 47: p. 1020-1025.

Mohamed, H.A. 2011. Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions. *Ain Shams Engineering Journal*. 2(2): p. 79-86.

Morin, V. *et al*. 2011. Effect of polymer modification of the paste-aggregate interface on the mechanical properties of concretes. *Cement and Concrete Research*, 2011. 41(5): p. 459-466.

Nik, A.S. and Omran, O.L. 2013. Estimation of compressive strength of self-compacted concrete with fibers consisting nano-SiO 2 using ultrasonic pulse velocity. *Construction and Building Materials,* 44: p. 654-662.

Pacheco-Torgal, F., Ding, Y. and Jalali, S. 2012. Properties and durability of concrete containing polymeric wastes (tyre rubber and polyethylene terephthalate bottles): An overview. *Construction and Building Materials,* 30: p. 714-724.

Paine, K.A., Collery, D.J. and Dhir, R.K. 2009. Strength and deformation characteristics of concrete containing coarse recycled and manufactured aggregates. 11th International Conference on Non-conventional Materials and Technologies (NOCMAT 2009). University of Bath.

Panda, K. and Bal, P. 2013. Properties of self compacting concrete using recycled coarse aggregate. *Procedia Engineering,* 51: p. 159-164.

Pathak, N. and Siddique, R. 2012. Properties of self-compacting-concrete containing fly ash subjected to elevated temperatures. *Construction and Building Materials,* 30: p. 274-280.

Patil, P.S. *et al*., Innovative techniques of waste plastic used in concrete mixture. *International Journal of Research in Engineering and Technology*.

Pezzi, L. *et al*. 2006. Concrete products with waste's plastic material (bottle, glass, plate). In Materials science forum. Trans Tech Publ.

Raharjo, D. and Subakti, A. 2013. Mixed concrete optimization using fly ash, silica fume and iron slag on the SCC's compressive strength. *Procedia Engineering,* 54: p. 827-839.

Rai, B. *et al*. 2012. Study of waste plastic mix concrete with plasticizer. *ISRN Civil Engineering*. 2012.

Ramadevi, K. and Manju, R. 2012. Experimental investigation on the properties of concrete with plastic PET (bottle) fibres as fine aggregates. *International Journal of Emerging Technology and Advanced Engineering,* 2(6): p. 42-46.

Razaqpur, A.G., Shedid, M. and Isgor, B. 2010. Shear strength of fiber-reinforced polymer reinforced concrete beams subject to unsymmetric loading. *Journal of Composites for Construction*, 15(4): p. 500-512.

Reddy, M.M. *et al*. 2013. Biobased plastics and bionanocomposites: *Current status and future opportunities. Progress in Polymer Science,* 38(10): p. 1653-1689.

Remadnia, A. *et al*. 2009. Use of animal proteins as foaming agent in cementitious concrete composites manufactured with recycled PET aggregates. *Construction and Building Materials*, 23(10): p. 3118-3123.

Safi, B. *et al*. 2013. The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties. *Construction and Building Materials,* 43: p. 436-442.

Saikia, N. and de Brito, J. 2014. Mechanical properties and abrasion behaviour of concrete containing shredded PET bottle waste as a partial substitution of natural aggregate. *Construction and Building Materials,* 52: p. 236-244.

Saikia, N. and de Brito, J.2012. Use of plastic waste as aggregate in cement mortar and concrete preparation: A review. *Construction and Building Materials*, 34: p. 385-401.

Sharma, R. and Bansal, P.P. 2016. Use of different forms of waste plastic in concrete—a review. *Journal of Cleaner Production,* 112: p. 473-482.

Siad, H. *et al*. 2015. Assessment of the long-term performance of SCC incorporating different mineral admixtures in a magnesium sulphate environment. *Construction and Building Materials,* 80: p. 141-154.

Silva, D.A.D. *et al*. 2005. Degradation of recycled PET fibers in Portland cement-based materials. Cement and Concrete Research, 2005. 35(9): p. 1741-1746.

Silva, R., de Brito, J. and Dhir, R. 2014. Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production. Construction and Building Materials. 65: p. 201-217.

Silva, R., de Brito, J. and Saikia, N.2013. Influence of curing conditions on the durability-related performance of concrete made with selected plastic waste aggregates. *Cement and Concrete Composites,* 35(1): p. 23-31.

Uysal, M. and Yilmaz, K. 2011. Effect of mineral admixtures on properties of self-compacting concrete. Cement and Concrete Composites, 2011. 33(7): p. 771-776.

Vanjare, M.B. and Mahure, S.H. 2012. Experimental investigation on self compacting concrete using glass powder. *International Journal of Engineering Application and Research,* 2(3): p. 1488-1492.

Wun, J.L. 2012. Study on engineering and abrasion resistance properties of polymer modified concrete.

Yahya, M., Zhang, B. and Barker, M. 2014.The effect of polymers like SBR, PVDC and LLDPE on the fracture characteristics of High Performance Concrete (HPC).

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