International Journal of Modern Agriculture, Volume 10, No.2, 2021
ISSN: 2305-7246

CONCRETE WITH GLASS POWDER AND PLASTIC AS PARTIAL REPLACEMENT

Ritesh Jain[1]

[1]Associate Professor, Department of Civil Engineering, Punjab Agricultural University

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 summarizes 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. Using both glass powder and plastic waste together in concrete as a partial replacement show best as glass powder used in the mixture counters the adverse effects of plastic.

Key words: Glass Powder- GP, Polyethylene terephthalate- PET, Compressive strength, Split Tensile strength, Flexural strength

Introduction

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.

Partial Replacement by Glass

Sadiqul et al. (2016) [1] used waste GP as replacement of cement for concrete in proportions of 0%, 10%, 15%, 20% and 25%. Water cement to ratio was kept 0.485. At 180 days compressive strength of concrete with 20% waste glass addition was found to be 10% higher than reference. At 360 days the same value rose to 14%. They reported 20% glass replacement as optimum from a 3 aspects which are compressive strength, environmental and financial considerations.

Ali and Sherif et al (2011) [2] used recycled glass as replacement of fine aggregate for concrete in proportions of 0%, 10%, 20%, 30%, 40% and 50% for 3 different cement contents (300,400,450 kg/m³) Water to cement ratio was 0.4. As the percent 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) [3] used GP with specific gravity 2.66 for replacement of fine aggregate in high strength concrete and is taken in 0%, 10%, 20% and 30% 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) [4] 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% replacement while the same figure for glass and coarse aggregate was found to be 10%. 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.

Bassam (2018) [5] studied the partial replacement of cement in concrete by marble, timber and GP. Cement replaced by GP, marble and timber in 10%, 20% and 30% proportion. It was evident from the results as the percentage of GP replacement increased, the compressive strength decreased. However anomaly shown in 10% case (56 days test) the compressive strength was actually more than 0% sample. A decrease in the compressive strength of concrete and workability was observed when the replacement level was increased from 10% to 30% for each waste material.

Meena et al. (2018) [6] conducted an experimental study on performance of concrete by using GP as a replacement of cement in proportions 0%, 10%, 15%, 20% and 40%.Water to binder ratio 0.40 was maintained throughout the study. Compressive Strength at 28 days was higher than 7 days and peaked at 15% replacement. Split tensile strength and flexural strength were also highest at 15% replacement level.

Evaldas et al. (2016) [7] utilized GP with surface area 3350 cm2/g in ultra-high performance concrete mixture and compared it to silica fume admixture as a replacement of quartz powder. 4 mixtures were prepared with varying quantities of silica fume, quartz powder and GP and in later stage micro steel fibres were added to make the concrete particle size distribution in accordance with industrial equipment and technology. It was concluded that GP instead of silica fume can be used and also an increase in compressive strength was observed in the samples having GP.

Faeez et al. (2018) [8] used white sheet GP with specific gravity 2.42-3.01 as a sand replacement in concrete with the replacement of 10%, 25% and 50% and the compressive strength was measured at 3, 7 and 28 days. Maximum compressive strength was obtained with 50% replacement at 28 days. Maximum flexural strength and split tensile strength were obtained for 10% replacement. GP also improved the micro structure of concrete, thus densifying the concrete and allowed degradation of the pore system generating increased durability.

Luiz et al. (2013) [9] studied the utilization of recycled GP with density 2525 kg/m3 and metakaolin with density 2580 kg/m3 as a replacement of cement in concrete to mitigate alkali-silica reaction. The replacement of cement by GP and metakaolin took place by 20%, 40% and 60%. It was concluded that GP and metakaolin brought the changes in concrete which mitigated alkali silica reaction to a large extent.

Bajad et.al.(2013) [10] studied the resistance of concrete containing waste GP and cement was replaced at different percentages (0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%). Cement, sand and aggregates were mixed in the ratio 1:2.35:4.47 and water to cement ratio of 0.5 was maintained. Study found that compressive strength increased with increasing curing time and maximum compressive strength of 27.3MPa (30% higher than control mix) was obtained with 20% replacement. With increase in glass content, the unit weight decreased. Flexural strength was observed and results were quite similar to compressive strength's, i.e. max flexural strength at 20% (22% higher than control mix). Both compressive and flexural strengths were tested for another batch of mixes, which were subjected to sulphate attack and higher resistance was obtained at 20% replacement.

Yaseen et al. (2019) [11] examined the impact of 10%, 15%, 20%, and 25% replacement of cement by GP. Water to binder ratio of 0.32 for the concrete mix was maintained and cement, sand and gravel were taken in ratio 1:1.5:3. Compressive strength was found at 28 days and 90 days, 15% replacement gave higher compressive strength at 90-day age while 20% replacement gave higher strength at 28-day age. The change in compressive strength recorded on 28-day age was 25.92%, 44.34%, 55.72%, and -14.65% for 10%, 15%, 20%, and 25% replacement respectively.

Arafa (2018) [12] studied the use of waste GP and fly ash in concrete. GP and fly ash was incorporated in terms of percentage of cement (10%, 20% and 30%). Another mix was also prepared in which 20% of cement was replaced by 10% waste GP and 10% fly ash. It was observed during the study that as the percentage of replacement by GP was increased, the compressive strength decreased. However in case of 10% replacement, compressive strength gained after 28-day age and 60-day age was comparable to reference. In case of other mixture, 10% glass and 10% fly ash, it was observed that glass was cancelling out the adverse effect of fly ash.

Salehuddin (2012) [13] prepared concrete mix in ratio 1:1:2 and glass was used to replace sand in proportion 10% and 20%. Water to cement ratio of 0.55 was maintained. The tests conducted for finding compressive strength gave results similar to that of Mohammed H. Arafa (2018), i.e. as the glass replacement increased, the compressive strength decreased. However the average workability for glass incorporated samples was higher.

Oluwarotimi et al. (2018) [14] prepared concrete mix in ratio 1:2:4 and glass was used to replace sand in proportion 25%, 50%, 75% and 100%. Water to cement ratio of 0.5 was maintained. It was clearly found in study that as the percent replacement by glass increased, the compressive strength decreased. However 25% glass replacement showed anomalous features during the whole testing period, it's compressive strength was observed to be increasing with curing age. Split tensile strength was found to be decreasing with increasing glass percentage and this can be linked to decrease to decrease in adhesive strength with increasing glass content.

Shaik and Bharath (2016) [15] 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% and 30% 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.

Shilpa and Kumar (2014) [16] studied the change in mechanical properties with incorporation of GP in concrete as replacement of cement. Glass replacement was made in increment of 5% in the range 5% to 40%. The sample with 20% 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.

Wildodo et al (2015) [17] did their research on utilization of GP as partial replacement of quartz powder in concrete. Replacement was made in proportion 10%, 20% and 30%. 20% 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% replacement of quartz powder by GP is possible and it also improves mechanical behaviour of concrete.

Partial Replacement by plastic

Nibudey et al. (2013) [28] 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% to 3% fibre content. Maximum increase in compressive strength was for 1% fibre and M20 grade concrete.

Charudatta and Husain (2017) [29] made use of granular plastic pieces made from recycled PET or PP. 20% to 60% replacement of fine aggregates was done with recycled granules in M20 concrete. Increase in compressive strength and flexural strength was observed for 20% and 40% replacement while only minor decrease was there in split tensile strength.

Mahdi et al. (2010) [30] 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 Benzoil 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 specimes was at par or more than corresponding grade of concrete.

Partial Replacement by Glass and Plastic

Wasan and Nazar (2018) [31] 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.

Balaji et al (2019) [32] studied partial replacement of sand by HDPE plastic granules and sand. Three series of mixtures were prepared. In first series, sand partially replaced by HDPE in proportion 0%, 5%, 10%, 15% & 20%. In second, sand partially replaced by GP in proportion 0%, 5%, 10%, 15% & 20%. In third, sand replaced by both glass and plastic (S80G15P5, S75G15P10, S70G15P15 & S65G15P20). It was observed across all three series that as the age increases, compressive strength, split tensile strength and flexural strength also increases. In case of first series, as the plastic percentage increased, the strengths decreased. In case of second series, S85G15 was found to have higher compressive strength and S90G10 was found to have higher split tensile strength and S80G20 was found to have higher flexural strength. In case of third series, the adverse effect of plastic was counterbalanced by GP and S75G15P10 was found to have higher compressive, split tensile and flexural strength. It was concluded that it is possible to replace 35% of sand by 20% HDPE and 15% glass as the strength tests conducted on S65G15P20 gave encouraging results.

Asmahan et al (2018) [33] prepared 4 series of mixtures, in first series only glass waste was added and in the upcoming series one new waste was introduced along with previous one as partial replacement of cement in proportion 15%, 20% and 25%. Wastes used were glass waste, fly ash, silica fume and styrene acrylic acid ester copolymer (SB). Compressive strength tests were conducted at 7, 14 and 28-day age. For series A,B and C the compressive strength was comparable or in some cases higher than reference. However for series D (which had glass waste, fly ash, silica fume and SB), the compressive strength of reference mix was higher, this decrease in compressive strength can be attributed to addition of SB.

Arghya et al (2016) [34] conducted a study to find the effects of addition of GP and plastic waste in concrete in proportion 0%, 5%, 10% and 20%. Strengths (compressive strength, split tensile strength and flexural strength) were determined for these replacement percentages at 28-day age. In case of plastic, a decrease in strengths was observed with increase in replacement percentage; for 20% replacement the compressive strength decreased by 69.12%, flexural strength reduced by 28.88% and split tensile strength reduced by 72.73% as compared to control mixture. In case of glass, increase in strengths was observed with increase in replacement percentage; for 20% replacement the compressive strength increased by 37.50%, flexural strength increased by 11.11% and split tensile strength increased by 6.66% as compared to control mixture.

Malek et al (2006) [35] 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 (2010) [36] 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% replacement of cement by glass had higher compressive strength than 0%, 40%, 60% and 80% for all plastic levels (i.e. 0%, 20%, 40%, 60% and 80%). Therefore it is correct to say that 20% cement replacement is possible and optimum. Plastic up to 20% can be used for construction purposes despite having lower strength nearly 20MPa.

Rasha (2020) [37] used glass and plastic as a replacement material of natural aggregate and cement. Four series of mixes prepared. In first, replacing glass by glass wastes. In second replacing natural aggregate by glass. In third, replacing natural aggregate by plastic. In fourth, cement replaced by plastic bin another by plastic wastes. It was observed that as the day age increased, the strength also increased. Replacement was made in proportion 0%, 5%, 10%, 15% and 20%. As the percentage replacement of sand by glass increased, the strength also increased. For cement replacement 15% glass replacement was found to have higher strength at both 7-day age and 28-day age. In case of plastic replacement of sand and natural aggregate, a decrease in strength was observed with increasing plastic content.

Harshad and Dalal (2017) [38] prepared a powder of PVC and glass waste and used it as partial replacement of fine aggregate in concrete. Replacement was made in proportion 0%, 10%, 15%, 20%, 25% and 30%. As the percent replacement increased, the density decreased. 28-day strength was found to be higher than 7-day strength. Strength was comparable till a particular percent replacement only but after that value the decrease in strength was more gradual and that value was 15%.

Compressive Strength

In order to study the effect on compressive strength when glass and plastics are added into the concrete as cement replacement and coarse aggregate replacement. The cube containing different proportion of glass and plastics were prepared and kept for curing for 28 days. Then the compressive strength of the mix is measured. Increase in compressive strength is very high when glass is added and is marginal when plastics are added to concrete.

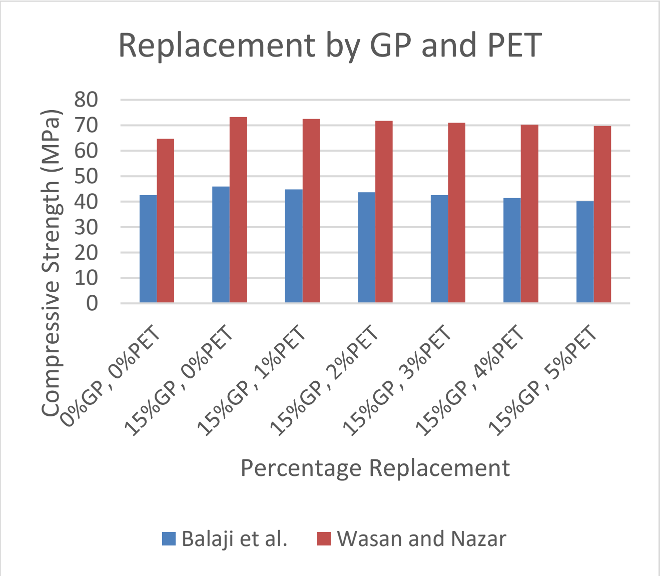

Fig. 1 Variation in compressive strength with varying PET percentage

Compressive strength is the most important property of concrete. So, it should not be decreased when replacement by glass and plastic is taking place. From fig. 4.1 it is quite clear that as the percent replacement by plastic increases, the compressive strength decreases. So hereby we can say that 5% PET along with 15% GP replacement is optimum for low strength concrete from compressive strength point of view.

Conclusion

Partial replacement of cement and fine aggregate by GP is possible in the range of 10-20%. 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 beyond 5%. Using both glass powder and plastic waste together in concrete as a partial replacement show best as glass powder used in the mixture counters the adverse effects of plastic.

References

1. G.M. Sadiqul Islam, M.H. Rahman, Nayem Kazi "Waste Glass Powder as Partial Replacement of Cement for Sustainable Concrete Practice", International Journal of Sustainable Built Environment (2017) 6, 37-44.

2. Esraa Emam Ali and Sherif H. Al-Tersawy "Recycled Glass as a Partial Replacement for Fine Aggregate in Self Compacting Concrete", Construction and Building Materials 35 (2012) 785-791.

3. Jostin P. Bose, S Suganya, Banu Priya "Use of Glass Powder as Fine aggregate in High Strength Concrete", International Journal of Science and Engineering Research vol 2 issue 2014.

4. Ekwulo E.O. and Eme D.B. "Comparative study on Compressive strength of Coarse and Fine Glass Aggregate Concrete", American Journal of Engineering Research Volume 7, Issue 2, pp-271-277.

5. Bassam A. Tayeh "Effects of Marble, Timber, and Glass Powder as Partial Replacements for Cement", Journal of Civil Engineering and Construction 7:2 (2018).

6. Er Manoj Kumar Meena et al. "Performance Of Concrete By Using Glass Powder", International Research Journal of Engineering and Technology (IRJET) Volume: 05 Issue: 09 | Sep 2018.

7. Evaldas Šerelis et al. "Mechanical Properties and Micro-structural Investigation of Ultra-High Performance Glass Powder Concrete", Journal of Sustainable Architecture and Civil Engineering.

8. Faeez Rizwan Yahya et al. "Sheet Glass Powder (SGP) as a Sand Replacement in Concrete Mixture", Concrete Technology: Research and Applications Series 2.

9. Luiz A. Pereira de Oliveira et al. "Glass waste powder addition used as mitigator of concrete alkali-silica reaction", Chemistry and Materials Research, Vol.5 2013 Special Issue for International Congress on Materials & Structural Stability, Rabat, Morocco, 27-30 November 2013.

10. M.N. Bajad, C.D. Modhera and A.k. Desai "Resistance of Concrete Containing Waste Glass Powder", Indian Concrete Journal 87(7):54-60.

11. Mohammed Mahir Yaseen et al. (2019) "Effectiveness of Glass Wastes as Powder on Some Hardened Properties of Concrete", Al-Nahrain Journal for Engineering Sciences NJES 22(1)14-17, 2019.

12. Mohammed H. Arafa "Incorporation of waste glass and bottom ash in concrete construction", Journal of Engineering Research and Technology, Volume 5, Issue 3, September 2018.

13. Nur Shahira Diana Binti Salehuddin "Compressive Strength of Concrete Using Glass Powder as a Filler Replacement", Thesis Universiti Malaysia Pahang.

14. Oluwarotimi M. Olofinnade et al. "Strength and microstructure of eco-concrete produced using waste glass as partial and complete replacement for sand", Cogent Engineering (2018), 5: 1483860.

15. Shaik Imam Hussain & V Sai Bharath "Utilizing The Unused Glass Substance In Stand-In Of Cement", International Journal of Innovative Technology and Research Volume no 4, Issue no 6, October-November 2016, 4623-4625.

16. Shilpa Raju & Dr PR Kumar "Effect of Using Glass Powder in Concrete", International Journal of Innovative Research in Science, Engineering and Technology Volume 3, Special Issue 5, July 2014.

17. Wildodo Kushartomo, Ika Bali & Budi Sulaiman "Mechanical behaviour of reactive powder concrete with glass powder substitute", Procedia Engineering 125 (2015) 617 – 622.

18. Balte Sanjaykumar and Daule S. N. (2017). "Use of plastic fibre in the concrete", SSRG International Journal of Civil Engineering, 4:4-7.

19. Asha S. and Resmi P. R. (2015). "Experimental research on concrete with straight and crimped waste plastic fibres", International Journal of Engineering Sciences & Emerging Technologies, 8:55-71.

20. Tharini V. and Nishanthi S. (2018). "Experimental Study on Comparative Analysis of Waste Plastic as Fine Aggregate in Fibre Reinforced Concrete", International Journal of Current Engineering and Scientific Research, 5:24-30.

21. Khatib J., Jahami A., Elkordi A. and Baalbaki O. (2019). "Structural performance of reinforced concrete beams containing plastic waste caps", Magazine of Civil Engineering, 91:73-79.

22. Ananthi A., Eniyan A. Jay Tamil and Venkatesh S. (2017). "Utilization of Waste Plastics as a Fibre in Concrete", International Journal of Concrete Technology, 3:1-5.

23. Irwan J. M., Asyraf R. M., Othman N., Koh H. B., Annas M. M. K. and Faisal S. K. (2013). "The Mechanical Properties of PET Fibre Reinforced Concrete from Recycled Bottle Wastes", Advanced Materials Research, 795:347-451.

24. Raghatate Atul M. (2012). "Use of Plastic in a Concrete to Improve its Properties", International Journal of Advanced Engineering Research and Studies, 1:109-111.

25. Ochi T., Okubo S, and Fukui K. (2007). "Development of recycled PET fibre and its application as concrete-reinforcing fibre", Cement & Concrete Composites, 29:448-455.

26. Venu Malagavelli and Rao P. N. (2010). "Effect of non-bio degradable waste in concrete slabs", International Journal of Civil and Structural Engineering, 1:449-457.

27. Choi Yun-Wang, Moon Dae-Joong, Chung Jee-Seung and Cho Sun-Kyu (2005). "Effects of waste PET bottles aggregate on the properties of concrete", Cement and Concrete Research, 35:776-781.

28. Nibudey R. N., Nagarnaik P. B., Parbat D. K., Pande A. M. (2013). "A model for compressive strength of PET fibre reinforced concrete", American Journal of Engineering Research, 2:367-372.

29. Charudatta P. Thosar, Dr. M. Husain (2017). "Reuse of Plastic Waste as Replacement of Sand in Concrete", International Journal of Innovative Research in Science, Engineering and Technology, 6:789-794.

30. Mahdi F., Abbas H., Khan A.A. (2010). "Strength characteristics of polymer mortar and concrete using different compositions of resins derived from post-consumer PET bottles", Construction and Building Materials, 24:25-36.

31. Wasan Khalil & Nazar Al Obeidy "Some properties of sustainable concrete containing two environmental wastes", MATEC Web of Conferences 162, 02029 (2018). https://doi.org/10.1051/matecconf/201816202029 BCEE3-2017

32. Balaji KVGD, T. Santosh Kumar & Kondra Nikhil Gupta "Adoption of Recycled HDPE Plastic Granules and waste Crushed Glass as a Partial Substitute of fine Sand in Concrete", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958, Volume-8 Issue-5, June 2019.

33. Asmahan Issa Jubeh & Doha M. Al Saffar & Bassam A. Tayeh "Effect of recycled glass powder on properties of cementitious materials contains styrene butadiene rubber", Arabian Journal of Geosciences (2019) 12:39 https://doi.org/10.1007/s12517-018-4212-0.

34. Arghya Dam, Sayan Roy Choudhary & Alinda Dev "A Review of the Use of Solid Waste Materials in Concrete Mix", Journal of Basic and Applied Engineering Research p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 11; July-September, 2016, pp. 948-954.

35. Malek Batayneh, Iqbal Marie & Ibrahim Asi "Use of selected waste materials in concrete mixes", Waste Management 27 (2007) 1870–1876.

36. Ankur Kataria "Studies on Mechanical Properties of Concrete containing Waste Glass Powder and Post Consumer Waste Plastic", Department of Civil Engineering Thapar University, Patiala.

37. Rasha Salah Al-Kizwini "Reuse Plastic and Glass Wastes as a Partial Replacement of Concrete Components", Journal of Engineering Science and Technology Vol. 15, No. 2 (2020) 1109 – 1123.

38. Harshad G Patel & Sejal P Dalal "An experimental investigation on Physical and Mechanical properties of Concrete with the replacement of fine aggregate by Poly Vinyl Chloride and Glass waste", Procedia Engineering 173 (2017) 1666 – 1671