THE APPLICATION OF WASTE GLASS AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

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ABSTRACT

Construction and demolition activity has led to increased piling up of waste in the landfills of Malaysia, a developing country. Glass waste is among the generated waste as well. Other than that, the demand of cement, an important construction material has been increasing every year which led to increase in production of cement. Cement production is a significant source of global carbon dioxide (CO_2) emissions. This paper looks at the possibility of glass waste usage as cement replacement in concrete mixture. The mechanical strength of the glass waste concrete was analyzed. The percentages used as a partial replacement, were 5%, 10%, 15%, 20% and 25%. The results of this study have proven that glass waste construction possesses a pozzolanic strength of 82.3% making it suitable pozzolanic material. The compressive strength, tensile strength, flexural strength and elastic modulus strength had shown 10% of glass waste replacement to be the optimum percentage that gives higher strength than the normal concrete strength.

ABSTRAK

Pembinaan dan aktiviti perobohan telah membawa peningkatan penimbunan sisa di tapak pelupusan di Malaysia yang merupakan sebuah negara membangun. Sisa kaca adalah antara bahan buangan yang dihasilkan daripada aktiviti tersebut. Selain daripada itu, permintaan simen, bahan binaan yang penting untuk pembangunan telah meningkat setiap tahun yang membawa kepada peningkatan dalam pengeluaran simen. Pengeluaran simen adalah sumber besar karbon dioksida global (CO_2). Artikel ini mengkaji dalam penggunaan sisa kaca sebagai pengganti simen dalam campuran konkrit. Kekuatan mekanikal konkrit sisa kaca telah dianalisis. Peratusan digunakan sebagai pengganti separa ini, adalah 5%, 10%, 15%, 20% dan 25%. Keputusan kajian ini telah membuktikan bahawa pembinaan sisa kaca mempunyai kekuatan pozzolanic sebanyak 82.3% justeru boleh menjadikannya bahan pozzolanic sesuai. Kekuatan mampatan, kekuatan tegangan, kekuatan lenturan dan kekuatan modulus elastik telah menunjukkan 10% daripada penggantian sisa kaca sebagai peratusan optimum yang memberikan kekuatan yang lebih tinggi daripada kekuatan konkrit biasa.

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MSW	-	Malaysia's Municipal Solid Waste
BS	-	British Standard
ASTM	-	American Society for Testing and Materials
CO_2	-	Carbon Dioxide
CCBs	-	Coal Combustion By-Products
OPC	-	Ordinary Portland Cement
SEM	-	Scanning Electron Microscope
ASR	-	Alkali-Silica Reaction
SCM	-	Supplementary Cementitious Material
SDA	-	Saw-Dust Ash
XRF	-	X-ray fluorescence
XRD	-	X-ray diffraction

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysian construction industry approached a critical limit, especially in terms of composition and amount of waste materials generated by it. Problems in the removal of such waste are mounting. For quite a few years, large construction building and infrastructure development projects have led to increased production of construction waste material. The construction waste has impacted the environment due to the sheer quantity of waste production (Begum RA et al., 2007). Most of the waste materials disposed into landfill compromise construction and workers' productivity as well as causing wider environmental implication. Moreover, Malaysia has little reliable

statistic for construction and demolition that shows the rate of waste generation, type of waste, method of handling wastage, and the quantity of material wastage minimized at source, reused or recycled on-site or off-site in a specific type of construction such as residential construction (Haliza, 2010). A study conducted on 30 construction sites identified six types of waste materials which included concrete (12.32%), metals (9.62%), bricks (6.54%), plastics (0.43%), wood (69.10%) and waste that included glass (2%). Wasted wood generation was more than others among the construction waste (Faridah et. al., 2004).

An article from The Star (April, 2015) reported that on Aug 9 last year, Lafarge's cement production capacity was about 12.95 million tonnes, followed by YTL Cement at 5.95 million tonnes, CIMA at 3.4 million tonnes, Tasek Corp at 2.3 million tonnes and both Hume Cement and Holcim Malaysia at 2 million tonnes each. Carbon dioxide is emmitted during the production of clinker (a component of cement) in which calcium carbonate (CaCO3) is heated under high temperature (1450o to 1600o) in a rotary kiln to induce a series of complex chemical reactions. CO2 is emmitted as a by-product during calcination, which occurs in the upper, cooler end of the kiln, or a precalciner, at temperatures of 600-900°C, and results in the conversion of carbonates to oxides (Michael J. et al, 2012).

There are many examples of successful recycling of waste glass as cullet, as raw material for the production of abrasives, in sand-blasting, as an aggregate substitute in concrete, in road beds, pavement and parking lots, as raw materials to produce glass pellets or beads used in reflective paint for highways, to produce fiberglass, and as fractionators for lighting matches and firing ammunition (Chen et al., 2002).

Substitutions of waste glass in concrete production have been investigated by many researchers. Waste glass was used either as an aggregate replacement in concrete mixture or as a cement replacement. The possibility of reusing waste glass from crushed containers and building demolition as aggregates for preparing mortars and concrete was studied. It involved varying the particles size of the finely ground waste glass. No reaction was observed with particles size up to 100μm. A strong improvement of the mortar mechanical performance was also noted (Corinaldesi et al, 2004).

Yet another research was conducted to analyze the possibilities of recycling waste glass as fine aggregate for concrete. They concluded that the compressive, tensile and flexural strengths of concrete decreased when the content of waste glass was increased. The concrete containing waste glass of 30% mixing ratio gave the highest strength properties (Park et al, 2004). The results obtained in another study proved that 28 days achieved 80% of the pozzolanic strength from an optimum percentage of glass (20%) resulting in maximum value of compressive and flexural strength (Zainab and Enas, 2008).

Another studies investigated on the possibilities of using finely ground waste glass as partial cement replacement in concrete three sets of tests the lime-glass tests to assess the pozzolanic activity of ground glass, the compressive strength tests of concrete having 30% cement replaced by ground glass to monitor the strength development, and the mortar bar tests to study the potential expansion. The results showed that ground glass having a particle size finer than 38μm did exhibit a pozzolanic behavior. The mortar bar tests demonstrated that the finely ground glass

helped reduce the expansion by up to 50%. Shao did crystalinity test of the glass using X-ray diffraction technique and the result shows that soda lime glass is a typical amorphous material (Shao et al. 1999).

1.2 Problem Statement

Numerous waste materials are generated from manufacturing processes, service industries and municipal solid wastes. The increasing awareness about the environment has tremendously contributed to the concerns related with disposal of the generated wastes. Solid waste management is one of the major environmental concerns in the world. With the scarcity of space for landfilling and due to its ever increasing cost, waste utilization has become an attractive alternative to disposal. Research is being carried out on the utilization of waste products in concrete. Such waste products include discarded tires, plastic, glass, steel, burnt foundry sand, and coal combustion by-products (CCBs). Each of these waste products has provided a specific effect on the properties of fresh and hardened concrete. The use of waste products in concrete not only makes it economical, but also helps in reducing disposal problems. Reuse of bulky wastes is considered the best environmental alternative for solving the problem of disposal. This study overcomes the problem of the glass waste that is generated from construction and demolition activity. In order to reduce the product of glass waste, it has been suggested to reuse glass waste materials to substitute a percentage of the cement used in the ordinary portland cement (OPC). Waste glass will be used as partial replacement for cement in concrete. The purpose is to analyze the possibilities of using recycled waste glasses in production of concrete.

1.3 Objectives of Study

1. To investigate the applicability of recycled glass in concrete mixture.
2. To investigate the Scanning Electron Microscope (SEM) of concrete with waste glass replacement.
3. To examine the mechanical properties of the concrete with recycled glass as replacement of cement in concrete.

1.4 Significant of Study

1. Development of concrete with recycled glass as cement to protect the environment.
2. To study the physical and mechanical properties of concrete in which contained waste glass.

REFERENCES

1. Agamuthu P, Fauziah SH, Kahlil K. Evolution of solid waste management in Malaysia: impacts and implications of the solid waste bill. J Mater Cycles Waste Manage (Oxford) 2009;11:96–103.

2. Agarwal, S. K. (2006). Pozzolanic activity of various siliceous materials. Cement and Concrete Research, 36(9), 1735-1739.

3. A.J. Francis, The Cement Industry 1796–1914: A History, David and Charles, England, 1977.

4. A. Khmiri, M. Chaabouni, B. Samet, Chemical behaviour of ground waste glass when used as partial cement replacement in mortars, Construction and Building Materials 44 (2013) 74–80

5. A. Komar, 1979. Building Materials and Component. Mir Publishers.

6. Ali, E. E., & Al-Tersawy, S. H. (2012). Recycled glass as a partial replacement for fine aggregate in self compacting concrete. Construction and Building Materials, 35, 785-791.

7. Bates, R. L., and J. A. Jackson. "Glossary of Geology, 2nd." American Geological Institute 751 (1980).

8. Batayneh, Malek, Iqbal Marie, and Ibrahim Asi. "Use of selected waste materials in concrete mixes."Waste management 27.12 (2007): 1870-1876.

9. Begum, R. A., Siwar, C., Pereira, J. J., & Jaafar, A. H. (2007). Implementation of waste management and minimisation in the construction industry of Malaysia. Resources, Conservation and Recycling, 51(1), 190-202.

10. Čechák, T., Kopecká, I., Trojek, T., Štanzel, T., & Bártová, H. (2015). Application of X-ray fluorescence in an investigation of photographic heritage. Radiation Physics and Chemistry.

11. Cecil C. Handisyde, 1969. Building Materials Science and Practice. London, The Architect Press.

12. Chua K.H., Endang Jati Mat Sahid, Dr. Y. P. Leong, Principal Lecturer, Institution of Energy Policy and Research, UNITEN, Sustainable Municipal Solid Waste Management and GHG Abatementin Malaysia, 2013

13. Corinaldesi, V., Gnappi, G., Moriconi, G., & Montenero, A. (2005). Reuse of ground waste glass as aggregate for mortars. Waste Management, 25(2), 197-201.

14. de Castro, S., & de Brito, J. (2013). Evaluation of the durability of concrete made with crushed glass aggregates. Journal of Cleaner Production, 41, 7-14.

15. Dr. K.H. Chua, Endang Jati Mat Sahid, Dr. Y. P. Leong, Principal Lecturer, Institution of Energy Policy and Research, UNITEN, Sustainable Municipal Solid Waste Management and GHG Abatementin Malaysia, 2013

16. Donatello, S., Tyrer, M., & Cheeseman, C. R. (2010). Comparison of test methods to assess pozzolanic activity. Cement and Concrete Composites, 32(2), 121-127.

17. Du, H., & Tan, K. H. (2014). Waste Glass Powder as Cement Replacement in Concrete. Journal of Advanced Concrete Technology, 12(11), 468-477.

18. Federico, L. M., and S. E. Chidiac. "Waste glass as a supplementary cementitious material in concrete–critical review of treatment methods." Cement and concrete composites 31.8 (2009): 606-610.

19. Federico, Lisa. "WASTE GLASS-A SUPPLEMENTARY CEMENTITIOUS MATERIAL." (2013).

20. G. Chen, H. Lee, K.L. Young, P.L. Yue, A. Wong, T. Tao, K.K. Choi, Glass recycling in cement production – an innovative approach Waste Management, 22 (7) (2002), pp. 747–753

21. Haimei Zhang, 2011. Building Material in Civil Engineering. Woodhead Publishing in Materials Noor ZZ, Yusuf RO, Abba AH, Abu Hassan MA, Mohd Din MF. An overview for energy recovery from municipal solid wastes (MSW) in Malaysia scenario. Renew Sustain Energy Rev 2013;20:378–84.

22. Haliza, M. J. O. (2010). Effect of recycled aggregate from concrete waste on concrete compressive strength (Doctoral dissertation, University Malaysia Pahang).

23. lker Bekir Topc¸u*, Mehmet Canbaz (2003), Properties of concrete containing waste glass,Civil Engineering Department, Osmangazi University, Eskis¸ehir 26480, Turkey.

24. Ismail, Zainab Z., and Enas A. Al-Hashmi. "Recycling of waste glass as a partial replacement for fine aggregate in concrete." Waste management 29.2 (2009): 655-659

25. Jani, Yahya, and William Hogland. "Waste glass in the production of cement and concrete–A review."Journal of Environmental Chemical Engineering 2.3 (2014): 1767-1775.

26. J. Hormesa, A. Diekampc, W. Klysubund, G.-L. Bovenkampb, N. Börstee (2015). The characterization of historic mortars: A comparison between powder diffraction and synchrotron radiation based X-ray absorption and X-ray fluorescence spectroscopy.

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

28. Lam, Chi Sing, Chi Sun Poon, and Dixon Chan. "Enhancing the performance of pre-cast concrete blocks by incorporating waste glass–ASR consideration." Cement and Concrete Composites29.8 (2007): 616-625.

29. Limbachiya, M. C. (2009). Bulk engineering and durability properties of washed glass sand concrete. Construction and Building Materials, 23(2), 1078-1083.

30. Ling, T. C., & Poon, C. S. (2012). Feasible use of recycled CRT funnel glass as heavyweight fine aggregate in barite concrete. Journal of Cleaner Production, 33, 42-49.

31. Ling, T. C., Poon, C. S., & Wong, H. W. (2013). Management and recycling of waste glass in concrete products: Current situations in Hong Kong. Resources, Conservation and Recycling, 70, 25-31.

32. Ling, T. C., & Poon, C. S. (2012). A comparative study on the feasible use of recycled beverage and CRT funnel glass as fine aggregate in cement mortar. Journal of cleaner production, 29, 46-52.

33. Liu, S., Xie, G., & Wang, S. (2014). Effect of glass powder on microstructure of cement pastes. Advances in Cement Research, 27(5), 259-267.

34. Maraghechi, H., Maraghechi, M., Rajabipour, F., & Pantano, C. G. (2014). Pozzolanic reactivity of recycled glass powder at elevated temperatures: Reaction stoichiometry, reaction products and effect of alkali activation. Cement and Concrete Composites, 53, 105-114.

35. Mirzahosseini, M., & Riding, K. A. (2014). Effect of curing temperature and glass type on the pozzolanic reactivity of glass powder. Cement and Concrete Research, 58, 103-111.

36. Mostafa, N. Y., El-Hemaly, S. A. S., Al-Wakeel, E. I., El-Korashy, S. A., & Brown, P. W. (2001). Characterization and evaluation of the pozzolanic activity of Egyptian industrial by-products: I: Silica fume and dealuminated kaolin. Cement and Concrete Research, 31(3), 467-474.

37. Mukesh C. Limbachiya, Concrete and Masonry Research Group, Faculty of Engineering, Kingston University, Bulk engineering and durability properties of washed glass sand concrete, 2008.
38. Nagapan, S., Abdul Rahman, I., & Asmi, A. (2012). Construction waste management: Malaysian perspective.
39. Noor, Z. Z., Yusuf, R. O., Abba, A. H., Hassan, M. A. A., & Din, M. F. M. (2013). An overview for energy recovery from municipal solid wastes (MSW) in Malaysia scenario. Renewable and Sustainable Energy Reviews, 20, 378-384.
40. Obla, K. H. (2008). Specifying fly ash for use in concrete. Concrete InFocus, 7(1), 60-66.
41. Oliveira, R., de Brito, J., & Veiga, R. (2015). Reduction of the cement content in rendering mortars with fine glass aggregates. Journal of Cleaner Production, 95, 75-88.
42. Omoniyi, T.E., Akinyemi B.A., Fowowe A.O. "Effects of Waste Glass Powder as Pozzolanic Material in Saw Dust Cement Brick" Scholars Journal of Engineering and Technology (SJET), (2014): 2(4A):517-522.
43. Park, Seung Bum, Bong Chun Lee, and Jeong Hwan Kim. "Studies on mechanical properties of concrete containing waste glass aggregate." Cement and concrete research 34.12 (2004): 2181-2189.
44. Poole, A. B. "Introduction to alkali-aggregate reaction in concrete." Swamy RN In The alkali–silica reaction in concrete London, UK: Blackie (1992).
45. Rao, A., Jha, K. N., & Misra, S. (2007). Use of aggregates from recycled construction and demolition waste in concrete. Resources, conservation and Recycling, 50(1), 71-81.
46. Sadoon Abdallah, Mizi Fan (2011). International Journal of Engineering and Technical Research (IJETR). Characteristics of concrete with waste glass as fine aggregate replacement.
47. Shao, Y., Lefort, T., Moras, S., & Rodriguez, D. (2000). Studies on concrete containing ground waste glass. Cement and Concrete Research, 30(1), 91-100.

48. Shayan, A., & Xu, A. (2004). Value-added utilisation of waste glass in concrete. Cement and concrete research, 34(1), 81-89.

49. Shi, C., & Zheng, K. (2007). A review on the use of waste glasses in the production of cement and concrete. Resources, Conservation and Recycling, 52(2), 234-247.

50. Shi, C., Wu, Y., Riefler, C., & Wang, H. (2005). Characteristics and pozzolanic reactivity of glass powders. Cement and Concrete Research, 35(5), 987-993.

51. Smith, Michael A. "The economic and environmental benefits of increased use of pfa and granulated slag."Resources Policy 1.3 (1975): 154-170.

52. Soroushian, P. (2012). Strength and durability of recycled aggregate concrete containing milled glass as partial replacement for cement. Construction and Building Materials, 29, 368-377.

53. Swamy, B. J. R., Sanyal, B., Gandhi, Y., Kadam, R. M., Rajan, V. N., Rao, P. R., & Veeraiah, N. (2013). Thermoluminescence study of MnO doped borophosphate glass samples for radiation dosimetry. Journal of Non-Crystalline Solids, 368, 40-44.

54. Taha, B., & Nounu, G. (2009). Utilizing waste recycled glass as sand/cement replacement in concrete. Journal of Materials in Civil Engineering.

55. Tam, Vivian WY, and C. M. Tam. "A review on the viable technology for construction waste recycling."Resources, Conservation and Recycling 47.3 (2006): 209-221.

56. Thomas, M. D. A. (2007). Optimizing the use of fly ash in concrete (Vol. 5420). Skokie, IL: Portland Cement Association.

57. Topcu, I. B., & Canbaz, M. (2004). Properties of concrete containing waste glass. Cement and Concrete Research, 34(2), 267-274.

58. Vaitkevičius, V., Šerelis, E., & Hilbig, H. (2014). The effect of glass powder on the microstructure of ultra high performance concrete. Construction and Building Materials, 68, 102-109.

59. Wang, H. Y. (2009). A study of the effects of LCD glass sand on the properties of concrete. Waste Management, 29(1), 335-341.

60. Wang, H. Y., & Huang, W. L. (2010). Durability of self-consolidating concrete using waste LCD glass. Construction and Building Materials, 24(6), 1008-1013.