Introduction Because of the large amount of fibrous materials generated each year and the potential for significant benefit, a broad range of research has been conducted to convert the fibrous materials into useful products. The main intent of this article is to determine the technical feasibility of utilizing Geofibers for properties improvement of glass-concrete composites. The results are indicative of strong potentials for application of geofiber for the reinforcement of glass-concrete ("glasscrete") composites. Meanwhile, using waste glass in this geofiber composite would contribute to cleaning the environment. Utilization of waste glass and reducing the landfilling can demonstrate the cost effectiveness of this project. This approach could have significant impact to the use of large amount waste glass and improve the performance of glass cement composites. In general, waste glass produced can be sorted out as: building/automobile windows and doors; - glassware and bottles; television tubes and light bulbs; - others such as mirror and clock covers. Among them, the first two are the major sources. Several domestic glass manufacturers have attempted to recycle the glass waste. Waste recycling has become increasingly important for western society over the past few years. The European desire to increase recycling of glass, particularly that of glass bottles, has led to a large collect system in containers and a target of 75% of the collected glass (2.2 million tons) recycled by the year 2005 in France [1]. Nevertheless, there will still be 5% of collected glass (0.1 to 0.15 million tons) that is not recycled and must be disposed of, as glass can only be melted down after the removal of non-ferrous metals and other contaminants, which are mixed with the smallest glass fragments [2]. For the long period of disposal, it is predicted that the waste glass will corrode very slowly by contact with groundwater, and certain quantities of radionuclides will be released from the glass. Therefore, the waste glass corrosion and associated radionuclide release for the long-term are one of the most important phenomena to be evaluated for safety assessment of the disposal system [1]. Glass is a thermodynamically metastable, highly viscous liquid phase. When glass is placed in aqueous environments, various reactions, such as ion exchange, hydrolysis and transformation to more stable phases, occur simultaneously, and the effects of these reactions are generally referred to as “corrosion”. However, the glass corrosion allows the release of radionuclides from glass, and the glass corrosion and associated radionuclide release for the long-term must be evaluated sufficiently [3]. Geofiber reinforcement is used nowadays in many applications. Geofiber reinforced concrete is also well understood. The use of geofiber as reinforcement for cementitious composites, however, is a relatively new field for which some detailed research is needed. Concrete, the composite material consisting of aggregate held together by a hydraulic cementing agent, has been known to ancient civilizations. In spite of its worldwide popularity, the proliferation of concrete has been a mixed blessing [3]. If mixed or placed improperly or maintained inadequately, concrete structures can deteriorate prematurely and thereby contribute to the problems referred to generally as our “crumbling infrastructure”. Also the indiscriminate use of concrete without concern for esthetic appearance has led to the partially deserved reputation of concrete as being ugly. More significantly, the increased worldwide concern about environmental issues and the need to change our way of life for the sake of sustainable development has led to the identification of the concrete industry as a major user and abuser of natural resources and energy and as an important contributor to the release of greenhouse gases. These issues pose formidable challenges for the concrete industry for years to come. The construction community as well as the public at large will demand increased emphasis on environmentally friendly high-performance building materials at affordable cost. This implies not only excellent mechanical properties but durability as well. Fortunately, concrete materials science has emerged as a tool well suited to face these issues [4]. Background The use of composite materials has increased significantly during the recent years. A composite material usually consists of two materials with physically separable phases. In a polymeric composite the first phase is some kind of polymer material (called binder material or matrix) which surrounds the second phase (reinforcement). The reinforcement may be platelets, particles or fibers (long or short). Usually this second phase is added to improve stiffness, strength and toughness of the matrix material. Since the polymeric matrix has low density, composites based on these materials often show excellent specific properties. Long fibers that is oriented in the direction of loading offer the most efficient load transfer. This is because the ineffective fiber length (the distance at the ends of the fiber with less efficient load transfer) is short compared to the whole fiber length. A fiber is considered long when its length to diameter ratio is higher than 100. Popular fibers are glass-, carbon- and aramide fibers which are all synthetic. Another group of fibers that often qualifies as long fibers are the natural fibers. When we talk about natural fiber composites we mean a composite material that is reinforced with fibers from natural or renewable resources, in contrast to for example carbon fibers that have to be synthesized (with crude oil as origin). Natural geofibers may come from plants, animals or minerals. The use of natural geofibers and natural fiber composites are certainly not new to mankind. Bricks made from clay reinforced with straws have been used for thousands of years as building material. Textiles and ropes made from flax and hemp have been around for very long time and are still used today. Paper and cotton sheets impregnated with phenol- or melamine-formaldehyde resin were introduced in the early 1900 for electronic purposes. For the last decades concrete producers have made wide use of waste or by-product materials in concrete [1, 2]. Proper replacement of these materials in concrete would have two major significant: improving fresh and hardened properties of concrete and minimizing the environmental pollutions due to solid waste disposal. Glass is one of the materials produced in many forms such as containers, windows, light bulbs, etc. which all have a limited life. Glass is an inert material that could be recycled many times but in many countries waste glass are sent to landfill and stockpile. Since the glass is not a biodegradable material in landfill so there is a strong need to utilize waste glass. For solving the disposal of large amount of waste glass, reuse in concrete industry may be the most feasible application [2-6]. Waste glass can be used as partial replacement of coarse aggregate, fine aggregate, cementitious materials or ultra fine filler in concrete, depending on its chemical composition and particle size. Previous efforts have been made shown that replacement of glass as a part of coarse aggregate was not satisfactory because of chemical reaction between the alkali in the cement and the silica in the glass [7]. This strongly expansive alkali-silica reaction (ASR) creates a gel, which swells in the presence of moisture, causes cracking and unacceptable damage of the concrete. Recent studies have shown that if the waste glass finely ground, could be used in mortars and concrete as a very fine addition without introducing problems concerning ASR. In fact, a general conclusion of literatures shows that if the waste glass is finely ground under 75μm, ASR does not occur and mortar durability is guaranteed because of its pozzolanic properties. Also on a market price basis, it would be much more profitable to use the glass in powder form as cement replacement to make a value added composite cement. Glass is a non-metallic inorganic material made by sintering selected raw materials comprising silicate and other minor oxides as shown in Table 1. By cooling the molten glass on mold beds sheet glass of desirable sizes is formed. A conventional glass is rather brittle, easily broken by a small impact. This physical property has been used to crush the waste glass to form desirable particles for mixing purpose. In general, broken glass has a specific gravity of 2.5, a bulk unit weight of 1.3-1.4 tons per cubic meter, and a water absorption rate of 0.3-0.4 wt%. It has high volumetric stability under a temperature up to 700°C. Its thermal expansion coefficient and softening point are 8.8-9.2×10-6 cm/cm/°C and 718–738°C, respectively. Table 1 - Chemical composition of glass Oxide Weight, % SiO_2 Na_2O CaO Al_2O_3 K_2O SO_2 MgO Fe_2O_3 TiO_2 70.87-72.83 12.40-13.67 8.84-10.47 1.47-2.43 0.79-1.17 0.20-0.26 0.11-3.91 0.03-0.37 0.01-0.04 In developing concrete products with crushed waste glass aggregate, the economics is controlled by the price the product can fetch on the open market. Commodity products, by definition, are characterized by low values, which exert strong pressures on the production and manufacturing technology [5]. The value added by the glass is marginal to nonexistent in those cases. But by utilizing the special properties of glass, chemical, physical, or esthetic, novel products can be developed, for which the prices fetched in the open market are much less exposed to competitive pressures. What makes glass such a special ingredient for concrete becomes apparent by summarizing its special properties: • Because it has basically zero water absorption, it is one of the most durable materials known to man. With the current emphasis on durability of high-performance concrete, it is only natural to rely on extremely durable ingredients. • The excellent hardness of glass gives the concrete an abrasion resistance that can be reached only with few natural stone aggregates. • For a number of reasons, glass aggregate improves the flow properties of fresh concrete so that very high strengths can be obtained even without the use of superplasticizers [6]. • The esthetic potential of color-sorted post-consumer glass, not to mention specialty glass, has barely been explored at all and offers numerous novel applications for design professionals. • Very finely ground glass has pozzolanic properties and therefore can serve both as partial cement replacement and filler [7]. Experimental The term glass comprises several chemical varieties including binary alkali-silicate glass, boro-silicate glass, and ternary soda-lime silicate glass. Most of the packaging glass which is the subject of this paper is of the soda-lime silicate variety. It is manufactured in various colours, mostly green, amber and clear, but waste glass after being collected from the domestic waste stream is of a mixed colour. Research on the use of crushed glass as a partial replacement for aggregate dates back many decades [1]. Major tests carried out in this program followed the ACI standard procedures. Fig. 1 gives the general flow chart of the test programs. Fig. 1 - Test Flow Chart for "GeoFiber™-Galsscrete" composite Material specification Clean flat glass and waste carpet fibers were used in this study. The chemical composition of the glass was analyzed using an X-ray microprobe analyzer and listed in Table 2 together with that of silica fume and rice husk ash for comparison. In accordance to ASTM C618, the glass satisfies the basic chemical requirements for a pozzolanic material. However, it does not meet the optional requirement for the alkali content because of high percentage of Na2O. Table 2 - Chemical composition of glass, silica fume and rice husk ash (by weight percent) Glass Silica fume Rice husk ash SiO2 72.50 91.1 92.15 Al2O3 1.06 1.55 0.41 Fe2O3 0.36 2.00 0.21 CaO 8.00 2.24 0.41 MgO 4.18 0.60 0.45 Na2O 13.1 - 0.08 K2O 0.26 - 2.31 CL 0.05 - - SO3 0.18 0.45 - L.O.I. - 2.10 - To satisfy the physical requirements for fineness, the glass has to be ground to pass a 45μm sieve. This was accomplished by crushing and grinding of glass in the laboratory, and by sieving the ground glass to the desired particle size. To study particle size effect, two different ground glasses were used: · Type I: ground glass having particles passing a #80 sieve (180μm); · Type II: ground glass having particles passing a #200 sieve (75μm). According to ASTM C618, the 180μm and 75μm glass did not qualify as a pozzolan due to the coarse particle size. The purpose of this study was to examine if the coarse ground glass could still be a pozzolan. The particle size distribution for two types of ground glass, silica fume, rice husk ash and ordinary Portland cement were studied using laser particle size analysis and listed in Table 3. Results indicate that glass type I and II respectively have 42% and 70% fine particles smaller that 45μm would have pozzolanic behaviour according to ASTM C618. The particle shapes of all materials were analyzed using the scanning electronic microscope is shown in Fig. 2. Table 3 - Laser particle size analysis of material (by percentage) Particle size (μm) Cement Glass I Glass II Silica fume Rice husk ash 1 2 3 4 5 6 4.5 14.95 4.69 7.81 42.67 24.63 5.5 18.42 5.98 9.96 51.15 29.88 6.5 21.75 7.30 12.16 58.37 34.63 7.5 24.93 8.64 14.40 64.48 38.93 9 29.42 10.66 17.70 71.98 44.68 11 34.90 13.29 22.15 79.50 51.25 13 39.82 15.82 26.63 84.75 56.80 15.5 45.24 18.78 31.30 88.98 62.61 18.5 50.82 22.00 36.66 91.83 68.38 21.5 55.59 24.89 41.48 93.38 73.21 25 60.41 27.93 46.55 94.47

78.00 30 66.27 31.85 53.03 95.52 83.67 37.5 73.50 37.18 61.96 96.71 90.08 45 79.35 42.09 70.15 97.63 94.35 End tabl. 3 1 2 3 4 5 6 42.5 84.05 46.72 77.86 98.24 96.92 62.5 88.89 52.60 87.66 98.75 98.67 75 93.31 59.74 100.00 99.20 99.55 90 96.82 67.91 100.00 99.64 99.91 105 98.72 75.21 100.00 99.88 100.00 125 99.68 83.22 100.00 99.97 100.00 150 100.00 90.57 100.00 100.00 100.00 180 100.00 100.00 100.00 100.00 100.00 Av. particle size (μm) 27.17 76.90 7.38 15.83 Scatter Module 0.96 1.04 0.92 0.97 Fig. 2 - Particle size and shape of ground waste glass type I, type II, silica fume, rice husk ash and ordinary Portland cement The high-modulus Geofiber™ obtained from industrial sectors has desirable strength retention properties under long-term exposure to aggressive environment. Properties of this GeoFiber™ are shown in Table 4. Table 4 - GeoFiber™ properties Fiber properties GeoFiber™ Nominal denier, Tex 1880 Tenacity, cN/tex 85 Tenacity, gm/d 8 Breaking load, N 161 Elongation at break, % 22 Mix design Compressive strength test were conducted to study the strength development of composite cement paste containing the ground waste glass at early age. The cement replacement by the ground waste glass was 10%, 20%, 30% and 40% by total weight. The composite cement paste containing ground waste glass were compared to the cement having the same percent replacement by silica fume and rice husk ash as well as to the control specimen without any mineral additives. The five batches were defined as follows: Ordinary Portland cement paste: no mineral additives Waste glass type I: 10%, 20%, 30% and 40% by weight of the Portland cement replaced by waste glass type I Waste glass type II: 10%, 20%, 30% and 40% by weight of the Portland cement replaced by waste glass type II Silica fume: 10%, 20%, 30% and 40% by weight of the Portland cement replaced by waste silica fume Rice husk ash: 10%, 20%, 30% and 40% by weight of the Portland cement replaced by husk rice ash. The cement paste was mixed in a paste mixer and the water to cementitious ratio for achieving the suitable workability was selected according to Table 5. To evaluate the strength development of composite cements at the age of 3, 7, 14 and 28 days for each batches four 20x40 mm cylindrical specimens were cast. 24 hours after casting, the specimens were demolded and cured in water at 20°C. As shown in this table the glass needs lower water to cementitious ratio because of low waster absorption. Table 5 - Water to cementitious ratio for various mixtures Mixture Percentage of replacement 10% 20% 30% 40% Water to cementitious ratio Glass Type I 26 26 26 26 Glass Type II 26 26 26 26 Silica fume 28 30 32 34 Rice husk ash 29 31 33 35 Portland cement (Control) Water/Cement = 26% Results The compressive strength of the composite cements in comparison with control specimens are shown in Fig. 3. Result of all tests in Fig. 3 shows that increasing the amount of replacement form 10% to 40% decrease the compressive strength of composite cements. However, the highest compressive strength has seen in rice husk ash with 10% replacement but by increasing the amount of replacement its strength decreases sharply in comparison with other composite cements. This principle is also seen in silica fume specimens. Fig. 3 - Compressive strength test results It seems that there exists a competition in strength development between 10% replacement of waste glass with different particle size. The effect of glass particle size on the compressive strength shows that the smaller size of ground glass leads to a higher compressive strength. Also results indicate that compressive strength of glass type II which has particle size of smaller than 75µm, have reached the control specimen strength after 14 days. So, it is clear that the glass of type II between others exhibits a pozzolanic behaviour and it's the best choice for producing “Glasscrete”. Geofiber™ used in all the samples (Fig. 4). Fig. 4 - Geofiber™ in glasscrete composite Conclusion Local recycling pressures are providing an impetus to examine the use of unconventional materials in construction such as waste glass in Portland cement concrete. Storage or reuse conditions of waste are still currently defined on a regulatory or technical basis which does not take into account the impact of the waste deposit on the environment, due to lack of technical data in this domain. One of the objectives was to develop mixes of relatively low reactivity containing glass, Geofiber™, pozzolanic materials and various admixtures. It should be noted that with the large number of variables, the detection of unfavorable components prior to excessive long-term testing is essential. The work led to the development of reliable novel composite replacing traditional concrete mixtures. It can serve as a valuable composite in the development of new concrete products. The results of this study confirm the advantage "glasscrete" containing Geofiber™ over concrete that contains only regular components. The data presented in this article show that there is a great potential for the utilization of Geofiber™ in concrete. It is considered this utilization would provide much greater opportunities for value adding and cost recovery as it could be used as a replacement for expensive materials. A smaller particle size of glass results in a higher compressive strength in cement paste. Results show that the best percentage of waste glass replacement in cement paste is 10% by weight. The use of ground waste glass as a replacement in cement seems feasible. The purpose of present study is to protect environment by saving more landfills, to increase the cement plant capacity by using more beneficial additives. This laboratory study shows the first step toward producing concrete with mixture of waste glass and Geofiber™. Waste utilization is an attractive alternative to disposal cost and potential pollution problems are reduced or even eliminated along with the achievement of resource conservation. There are million tons of waste glass is land filled each year around the world.