USE OF RECYCLE GLASS AS A COARSE AGGREGATE IN CONCRETE

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ABSTRACT

Concrete is a composite material composed of sand and gravel, chemically bound together by hydrated Portland cement. It is the most widely used construction material in the developed world. As a result, the concrete industry is also one of the biggest consumers of natural resources specifically sand, gravel, rock and water. Numerous environmental problems and natural disasters are occurred because of the high extraction of natural resources. Due to that, researchers were focused on recycled materials for future development, while protecting the environment. Low cost, availability and simple process to recycle, glass concrete applications could be significantly applied in the construction industry. Therefore, primary aim of this research is to explore the applicability and adaptability of glass as a recycled material for concrete and concrete applications in Sri Lankan construction industry. This research problem will be approached through experimental studies. The empirical study will be conducted by testing the glass concrete applications in a laboratory. The results will be analysed to evaluate the concrete properties, which are made from glass coarse aggregates and glass concrete aesthetic applications. A total number of 10 cubes will be casted and tested for compressive strength, flexural strength, slump test, absorption test. It is expected that concrete which made of glass concrete aggregate 16% less strength in compression, flexure than conventional concrete. This paper intend to recommends that recycle glass can be used as an alternate coarse aggregate in concrete and will have wide applications in aesthetic workings.

Keywords: *Concrete, Recycled Materials, Glass, Glass Concrete, Glass Concrete Aesthetic Applications.*

1. INTRODUCTION

Concrete is a composite material composed of sand and gravel, chemically bound together by hydrated Portland cement (McGregor, 1997). According to McGregor (1997), concrete is the most used man made construction material, during the last century due to fire resistant, withstand for both dead and live loads, maximum safety, flexibility in design, exceptional aesthetic possibilities. According to Jayanandana and Jayasinghe (1998), aggregates include in-between 60 to 75 percentages of the total volume of concrete. Using high proportion of aggregate in concrete lead to value addition for concrete, because it is inexpensive, economical and govern the engineering properties (Jayanandana and Jayasinghe, 1998).

Most of the aggregates are obtained from the environment and numerous environmental problems and natural disasters are occurred due to high extraction of metal and sand. Therefore, the researchers focused on the future development, while protecting the environment. Limbachiya *et al.* (2000) declared that recycled materials can be used as aggregate in new concrete, which offer a viable route to convert the waste to a valuable resource. Govind (1989) stated that use of recycled materials as concrete ingredients has become popular because of the increased environmental legislation such as administrative, legislative support and fiscal assistance through direct and indirect tax incentives.

Glass can be recycled many times without changing its chemical properties NAHB Research Centre (2001). Further, NAHB Research Centre (2001) emphasised that due to the low cost, availability and simple process to recycle, glass concrete applications are significantly applied in the construction industry. Glass concrete applications are generally defined as concrete products which are prepared by the use of recycled glasses by replacing natural aggregates that extract from the environment.

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Sri Lanka hasn't still implemented a project to find the applicability of recycled glass as an alternative material for concrete and concrete applications. Thus, this research anticipates filling this research gap by exploring the applicability of glass concrete applications in Sri Lankan context.

2. CONCRETE

According to building researchers and scientists McGregor (1997); Bhattacharjee (2010); Cement Concrete and Aggregates Australia (2004); the most used construction material in the industry is concrete. Gambhir (2004) highlighted that for being the most used construction material, the properties and qualities of the concrete heavily affected. Common ingredients made the way to the popularity of the concrete and it is possible to gain the properties of concrete to meet the demands of any particular situation. Further, Gambhir (2004) expressed that, the advances in concrete technology have paved the way to make the best use of locally available materials by judicious mix proportioning and proper workmanship, so as to produce concrete satisfying performance requirements.

The use of concrete in buildings is not new, but it has increased enormously since the discovery and development of Portland cement. Handisyde (1995) mentioned that concrete's different uses might make quite different demands upon its qualities. In one case strength may be all important; in other appearance may be the essential requirement. The excessive demand for the concrete is the major clue to express that the concrete is the main essential building material for construction industry. Further, Cement and Concrete Institute Australia (2008) found in a survey that worldwide each year, the making of concrete consumes 1.6 Billion tons of Portland cement, 10 Billion tons of sand and rock and 1 Billion tons of water, making the concrete industry the largest user of natural resources in the world.

For studying about the concrete, definition for concrete is important to distinguish the world most used construction material with the other materials. Portland cement concrete is a composite material made by combining cement, supplementary cementing materials, aggregates, water, and chemical admixtures in suitable proportions and allowing the resulting mixture to set and harden over time (Nawy, 2008). Watson's (2005) perspective towards the concrete is, it's strength and qualities depend not only on the quality and quantity of the materials, but on the procedures used in combining these materials and the skills involved in the placing and curing of concrete. Further, Watson (2005) expressed that the required quality and performance of the concrete should be defined by the authorised engineer for the construction. For that purpose, in most of the countries have been published standard documents which state the most suitable concrete types for each construction. In that sense the knowledge on properties and categories of concrete is essential for the professionals who engaged in construction activities. Designers began to change the properties and ingredients of the concrete in order to fulfil the different types of construction requirements. This could result in plenty of concrete types in the modern world. Because of that, concrete categorisation also became more sophisticated. Santhakumar (2007) explained about three types of concrete Ordinary concrete, Standard concrete and High-strength concrete. The properties of the concrete in the plastic stage are important in the construction stage while the hardened stage properties are important for the remainder of the duration of the construction. Orchard (1962) mentioned that main properties of hardened concrete are strength, permeability, shrinkage and elasticity. Mehta (1986) expressed that strength of the concrete can be defined by the ability to resist stress without failure and failure is sometimes identified with the appearance of cracks.

2.1. CONCRETE AGGREGATES

American Concrete Institute (2007) defined aggregate as granular material such as sand, gravel, crushed stone, blast-furnace slag and light weight aggregates that usually occupies approximately 60-75% of the volume of concrete. Aggregates are the important constituents in concrete therefore they give body to the concrete, reduce shrinkage and effect economy. According to Neville (1995), aggregate content is a factor which has direct and far reaching effects on both quality and cost of concrete. Arum and Olotuah (2006) explained that aggregate properties significantly affect the workability of plastic concrete and also to the durability, strength, thermal properties and density of hardened concrete. Orchard (1962) stated that, concrete aggregates can be classified according to their petro logical characteristics and further it can be mainly divided into three categories as heavy weight, normal weight and light weight aggregates and normal and light weight aggregates. Moreover, it can be subdivided into natural and artificial aggregates. As the major ingredient for concrete mix, aggregate properties are being given a special consideration and importance for the construction applications. The significant effect of aggregate properties, both physical and mechanical towards the strength, quality and optimum packing configuration in concrete has also been scientifically proven and discussed by Rajeswari (2004 cited Mohammad, 2009). It is evident that, most characteristics of aggregates greatly influence the properties of both fresh and hardened concrete. Neville and Brooks (2004) had been showed how the properties of aggregates evaluate primarily. Many properties of the aggregate depend on the properties of the parent rock. Gambhir (2004) explained about two types of properties of aggregates which are namely "mechanical properties" and "physical properties". Bond, strength, toughness, hardness defined under the mechanical properties of concrete while specific gravity, bulk density, porosity and absorption, moisture content, bulking, thermal properties categorised under physical properties. In the past, almost all the materials which have used in the construction industry were entirely natural. Therefore, during this century, numerous environmental problems and natural disasters are occurred due to high extraction of metal and sand. Thus, the researchers have been focused on the alternative aggregates for concrete to the future development, while protecting the environment.

2.2. ALTERNATIVE AGGREGATES FOR CONCRETE

It is widely acknowledged that the use of secondary and alternative aggregates in construction products contribute sustainable construction. According to Oikonomou (2005), by replacing part of the natural aggregates, the need of both quarrying and waste disposal systems are reduced with the associated benefits of reduced environmental and social impacts. Mehta (2001) explained it further by saying that environmental impact of the concrete industry can be reduced through resource productivity by conserving materials and energy for making of concrete and by improving the durability of concrete products.

According to Cement and Concrete Institute Australia (2008), there is a critical shortage of natural aggregates for production of new concrete, further Cement and Concrete Institute Australia (2008) expressed that, the enormous amounts of demolished concrete produced from deteriorated and obsolete structures create severe ecological and environmental problems. Therefore, recycled aggregate usability for the concrete construction will be solving environment problems as well as the material shortage problems. Cement and Concrete Institute Australia (2008) had classified aggregates into manufactured, recycled and reused by-product aggregates for the easiness to the separation of alternative aggregate from other construction materials.

Table 1: Alternative Aggregate Types

Manufactured aggregates	Foamed Blast Furnace Slag (BFS), fly ash, manufactured sand, polystyrene, explanded clays, shale and slates.
Recycled aggregates	Recycled concrete aggregate, recycled concrete and masonry, reclaimed aggregate, reclaimed asphalt pavement, reclaimed asphalt aggregate, glass cullet, scrap tyres.
Reused by product aggregates	Air cooled (BFS), granulated BFS, electric arc furnace slag, steel furnace slag, fly ash, furnace bottom ash, incinerator bottom ash, coal washery reject, organic materials.

2.3. ADAPTABILITY AND APPLICABILITY FOR REPLACEMENT OF AGGREGATES

Winston and Yeung (2000) experiments shows that, most of the recycled aggregates can be used for construction activities without serious problems. However, the market force will dictate which kinds of materials can be recycled practically into products with commercial value. Akbari *et al.* (2011) perspective view is different to previous explanation where Akbari *et al.* (2011) argued that, Recycled Aggregate Concrete (RAC) obtained lower in workability compared to concrete using natural aggregate and for hardened concrete performance, it was recognised that RAC is lower in strength compared to natural aggregate. The potential for alkali silica reactivity in new concrete can be happened due to the inappropriate recycling.

There are five factors which can be lead to overcome with the problems of RAC to adopt and to be applicable to the concrete production. Those are development of appropriate specifications, opportunities in the pre-cast industry, and changes in legislation to use the RAC in constructions, quality assurance, improve and motivate research and development activities of RAC (Hyungu, 2011).

However, Carpenter (1994) stated that there is a price to pay for being eco-friendly and that potential uses of secondary aggregates are hindered by consumer tastes and strict construction specifications. At present, the cost of primary aggregates is not much expensive when comparing to recycled aggregates; therefore, material suppliers, contractors and the construction community not likely to accept the use of recycled aggregates in construction because of RAC's variability in composition and properties and lower performance. As an emerging developing country in South Asia, recent past Sri Lanka has undergone various attempts to find alternative aggregates for construction to the material shortage problem with solutions.

2.4. Current Alternative Aggregates Use in Sri Lankan Construction Industry

Annual sand demand for the construction industry in Sri Lanka is nearly 8 Million cubic meters and all are obtained from major rivers (Jayawardena and Dissanayake, 2006). The excessive excavation of river sand is becoming a serious environmental problem in Sri Lanka such as erosion and failure of riverbanks, lowering of river beds, damaging to the bridge foundations, saline water intrusion into the land and coastal erosion are the major adverse effects due to intensive river sand mining. At present private sector with the collaboration of government, alternative sources have been introduced to the Sri Lankan construction industry such as dune sand, offshore sand, manufactured sand (crushed rock sand) and quarry dust.

Except for the replacement of the fine aggregates, still there is a need of alternative coarse aggregates to replace natural coarse aggregates in Sri Lanka. Due to the low cost to produce natural metal and coarse aggregates, the process of finding the alternative coarse aggregates is slowed down. Replacement of natural coarse aggregate with recycled material is a need, to resolve environmental problem in Sri Lanka. Recycled glass can be introduced as one alternative for coarse aggregate for concrete.

2.5. Recycling Process of Glass Aggregate

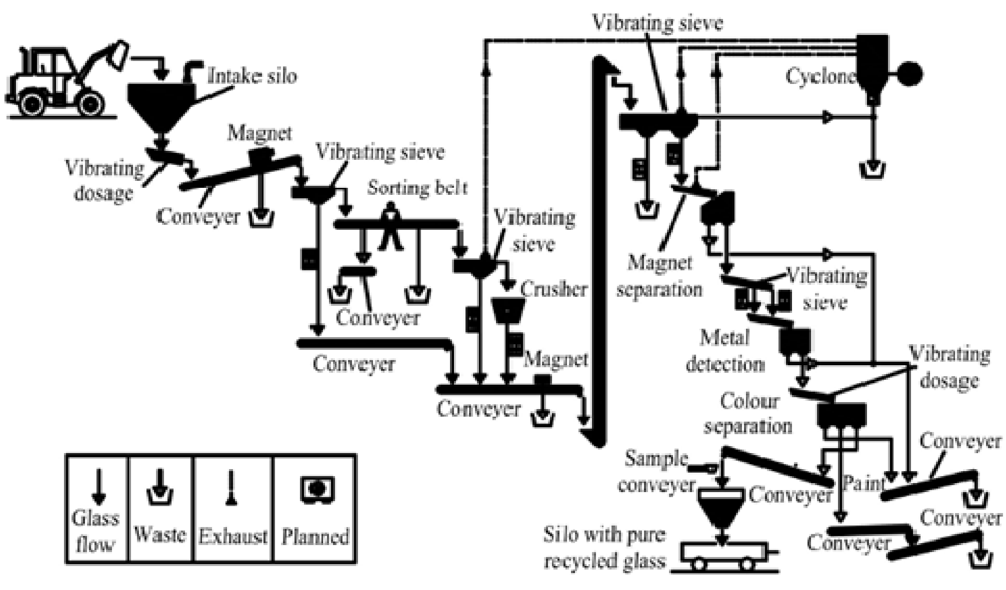

Figure 1: Recycling Process of Glass (Source: Meyer *et al.,* 2001, p.52)

2.6. STRUCTURAL STRENGTH OF GLASS AGGREGATE

Terro (2006); Shi and Keren (2007), and Sekar *et al.* (2011) experimented about the effect of replacement of coarse aggregates with recycled glass on the fresh and hardened properties of Portland cement concrete at ambient and elevated temperatures. Terro (2006) experiments indicated that the compressive strength of concrete made with recycled glasses decrease up to 20% of its original value. Shi and Keren (2007) expressed that concretes made with 10% glass coarse aggregates replacement to natural coarse aggregate replacement, had better properties in the fresh and hardened concrete states at ambient and high temperatures than those with larger replacement. Based on the studies conducted on strength characteristics of concrete made with utilising waste materials by Sekar *et al.* (2011), found that the compressive strength of concrete cubes made with glass concrete were found to be 16% and 26.34 % lesser respectively than that of conventional concrete. It was also found that the flexural strength and splitting tensile strength results were similar to that of compression strength test results.

2.7. GLASS CONCRETE ARCHITECTURAL APPLICATIONS

Glass concrete products can be categorised as "commodity products" and "value-added products" (Meyer *et al.*, 2001). "Commodity products" use as coarse and fine aggregate replacements in concrete and land filling. For "value added products", the aesthetic potential of the glass is utilised. Special aesthetic effects can be achieved with colour-sorted glass. Value added products are lead to substitute the expensive decorating applications such as granite and marble.

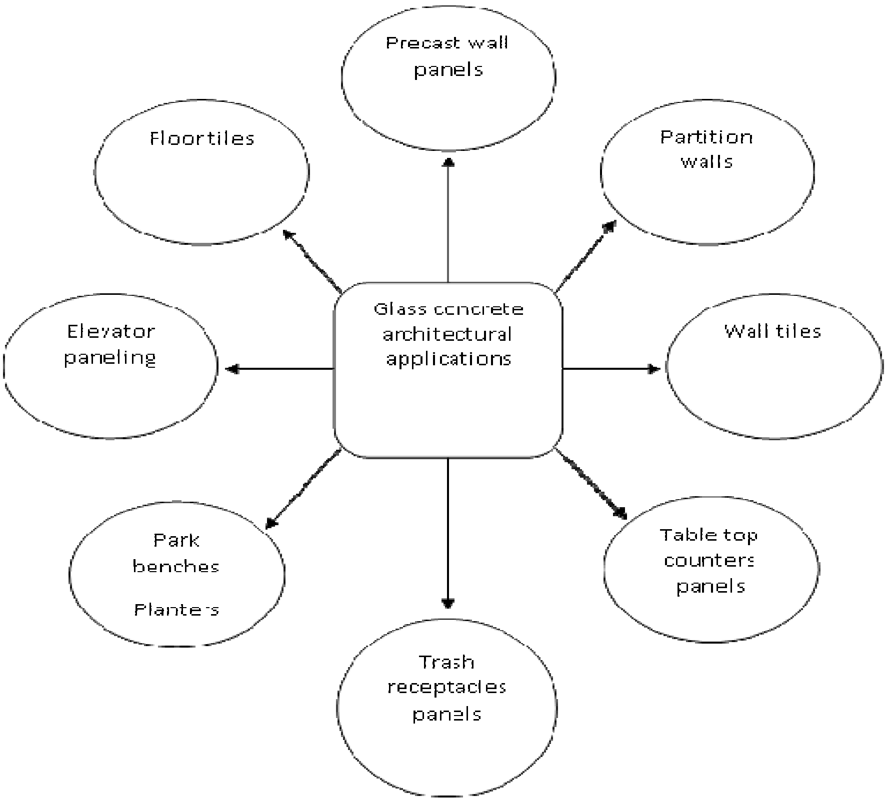

Figure 2: Glass Concrete Architectural Applications

3. RESEARCH METHODOLOGY

The research programme was divided into two parts. The first part was studying the impact of the presence of waste recycled glass as coarse aggregate replacement on plastic and hardened properties of concrete. In the second part studied the substitution of the aesthetic glass concrete to the expensive architectural items such as granite and marble.

3.1. MATERIALS

The materials used in this study include cement, sand, metal, glass, steel reinforcement. Each time a new aggregate sample was obtained, a new sieve analysis and slump test was performed. The following sections describe the materials used in the study.

CEMENT

Ordinary Portland cement had a strength class 42.5N according to the British standard BS EN 197 Part 1:2000. The alkali content (Na2Oeq) was 0.58%.

COARSE AGGREGATE

Used different types of glass of varying sizes 12.7-25.4mm brown, white, green colours were used instead of the 5-10mm normal aggregate in traditional concrete control mixer. The specific gravity of glass is 2.50.

FINE AGGREGATE

River sand was used for all the experimental works.

3.2. EXPERIMENTAL PROGRAMME

First the Architectural use of the glass for concrete had been experimented. Secondly expect to carry out the experiment for the structural use of glass for the concrete instead of coarse aggregates. For the architectural aspect used two different experimental segments. One segment includes 100% pure glasses as coarse aggregates and other segment includes 60% glass and 40% metal. In this experiment other variables make as constants. Such as Aggregate / Cement ratio, Aggregate moisture state, Cement type and strength, Water / Cement ratio, Admixtures and additions, Mixing method, Compaction method, Curing method, Cast shape, Test method, Mix proportions. The proportions of the concrete mix are 1:2:4 for the two types of experiments.

3.3. LABORATORY WORK

CASTING

Two moulds were prepared 0.91x1.2x0.04 m using timber sheets. After the moulds were coated with a layer of oil (to help in the removal of the specimens) and steel reinforcement placed, concrete was placed within the moulds in. After adding concrete, the concrete was consolidated using a ramp. After the moulds were put in place, they were moved to an environmentally controlled place for get hardening.

CURING

Pre-cast concrete slabs with mould were cured using water up to 14 days by applying sand on the top of the concrete surface to remaining more water on the concrete surface. After curing, the specimens were allowed to dry in a controlled temperature and humidity environment.

3.4. EXPERIMENTAL RESULTS

Architectural glass concrete slabs strength checked by applying 50 kg weight for 24 hours and no deformation occurred. Concrete cubes, 150 mm in size, supposed to test in order to determine compression and flexural strength, absorption. Preparation and testing expected to do in accordance with British Standard procedures. Concrete cubes expecting to make using 100% natural aggregate as well as with 10%, 20%, 40% and 60% aggregate replacement by glass cullet are subjected to test. These levels of replacement were used for concrete made with Portland cement. The proportioning used for all concrete mixes was the same. All batching, including glass cullet replacement, was by volume. The free water content, cement content and aggregate content were 180, 350 and 1820 kg/m^3 respectively. Allowance for aggregate absorption permitted the same free water to cement ratio.

Figure 3: Glass Concrete Architectural Applications (Table Top)

Figure 4: Glass Concrete Table Top After Applying Loads (35kg)

4. CONCLUSIONS

For many years, the recycling and waste management industry has struggled with the problem of identifying or developing reliable markets for broken glass. To date, only low value applications are available, which do not utilise the physical and other inherent properties of the glass. Recent research has made it possible to use such glass as aggregate in concrete, either in commodity products, with the only objective being to utilise as much glass as possible, or in value-added products that make full use of the physical and aesthetic properties of colour-sorted crushed glass. Not only as a waste management solution for glass but also as coarse aggregate conservation in the environment applicability of glass in concrete had been discussed. Data presented in this paper show that there is great potential for the utilisation of waste glass in concrete in several forms, including coarse aggregate and architectural forms with concrete. It is considered that the latter form would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for expensive materials such as granite, marble and terrazzo.

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