International Journal of Research Radicals in Multidisciplinary Fields (IJRRMF), ISSN: 2960-043X
Volume 2, Issue 1, January-June, 2023, Available online at: www.researchradicals.com

# Improving the Reflectivity of Concrete Barriers by Substituting Recycled Glass Aggregate

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## ABSTRACT

**On the roadways of the United States, the need to improve the visibility of highway concrete barriers is necessitated by the rise in the number of accidents that occur at night and in wet weather conditions. The degree to which these delineators reflect light determines how easily they may be seen. The use of white cement as opposed to grey cement and the attachment of raised pavement markings to the side of the barriers are two of the recommended strategies for increasing the reflectivity of these concrete barriers. There are also a few more approaches that have the potential to improve the reflectivity of these concrete barriers. One of the suggested approaches that was subjected to more laboratory research was to include recycled glass into the concrete mixture. The purpose of the laboratory study was to determine the appropriate mixing proportions that reduce the risk of an alkali-silica reaction (ASR) occurring in recycled glass aggregate concretes without having any detrimental impacts on the compressive strength of the concrete. In addition, the retro reflectivity of various concrete mixes was measured and analyzed, and the results are reported in this study.**

**Keywords: Concrete Barriers, Glass Aggregate, Substituting Recycled**

## INTRODUCTION

### Environmental and Economic Benefits

The incorporation of recycled glass debris into concrete has garnered a significant amount of attention on a worldwide scale in recent years. The presence of post-consumer glass, which accounts for a significant portion of solid waste, as well as the challenge of finding adequate markets that would accept glass that had been collected for recycling both added to the challenges faced by the environment. In addition, the existence of this rubbish led to complications caused by the accumulation of junk over the course of time. In the year 1994, the United States of America disposed of about 9.2 million metric tonnes of glass that had previously been used in the production of consumer goods. Only in New York City are more than 100,000 tonnes of waste glass collected each year, with the bulk of this waste glass originating from container glass. This amount of glass is collected annually. The Material Recycling Facilities Company (MRFC) is willing to pay up to $45 per tonne for the disposal of certain waste products. Because of these considerations, study on the effects of using waste glass is necessary in order to assess its potential to replace waste glass as a fine aggregate in concrete.

This evaluation will help determine whether or not waste glass can replace waste glass. In particular, this study is necessary in order to investigate the possibilities presented by the material. The alkali-silica reaction, often known as the ASR, is a chemical reaction that occurs between the silica-rich glass particles that make up glass aggregate and the alkali that is present in cement. This reaction produces gel, and its activity will lead to swelling in the presence of moisture. This swelling will create expansions, which will ultimately lead to the degradation of the concrete. The greatest cause for worry, on the other hand, when it comes to the incorporation of glass into concrete is the chemical interaction that takes place between the silica-rich glass particles that make up the glass aggregate. The major purpose of this study is to investigate the characteristics of concrete that has been enhanced by the addition of finely crushed glass and to establish the appropriate percentage of finely crushed glass that should be added to concrete in order to achieve the desired features.

The recycling of broken glass is fast becoming one of the most important environmental challenges on a worldwide scale as a result of the rising amount of solid waste that is transported to landfills and the non-biodegradable nature of discarded glass. This is due to the fact that broken glass cannot be broken down by natural processes and that it is dumped. People from all over the world have shown a great deal of interest in the incorporation of recycled glass waste into concrete, and a significant amount of research has been carried out to demonstrate that recycled glass trash has the potential to be utilised as a building material by partially replacing concrete mixtures. Nevertheless, the results of the research might be categorised as follows, depending on how you look at it: One of the research fields that focuses on the use of glass cullet in pavement materials is asphalt paving, which has made use of glass cullet as a road construction aggregate (Reindl 2003). The American Association of State Highways and Transportation Officials (AASHTO) has established a new standard that is titled "Glass cullet use for soil aggregate base course" in recognition of the use of recycled materials in pavement.

According to the standard, after the glass cullet has been adequately treated, it should be reasonable to predict that it will give sufficient stability and load support when used as a substrate for roads or highways. This should be achievable since it should be possible to anticipate that it will have been appropriately treated. The term "Glassphalt" refers to crushed glass cullet that has been used as an aggregate in road construction or bituminous concrete pavement. This material is known by its common name. Since 1971, several experiments with glassphalt pavement have been carried out in various settings to simulate real-world conditions. It was found that it has a higher potential to hold heat than conventional asphalt does. This might be an advantage in situations where roadwork has to be done during cold weather or when extensive transit routes are required. In addition to this, the glass particles have the capability of increasing the reflectivity of the road surface, which, as a result, would make driving on the road safer at night. When compared to plain concrete, the crushed waste glass pavement has a stronger resistance to abrasion, a lower rate of shrinkage when it is subjected to dry circumstances, and a lower rate of water absorption. Additionally, the crushed waste glass pavement has a lower rate of water absorption.

The second area of study focuses on the use of recycled glass particles (sand) in the construction industry as an alternative aggregate for concrete. This industry is known as the building construction industry. The use of 30–70% waste glass as a fine aggregate in concrete, up to 100 microns, has been investigated, and the findings indicated no harmful impact at the macroscopic level, but rather an enhancement in the mortar's mechanical performance. This was the case regardless of the size of the aggregate. Shehata et al. (2005) came to the conclusion that the addition of waste glass to glascrete mixes as a partial volume replacement of fine aggregate resulted in enhanced modulus of rupture values across the board in comparison to the reference mix. It was found that using waste glass as a fine aggregate may offer strong interfacial bonding between cement paste and glass aggregates, and that the glass aggregates themselves operate as crack arrestors, preventing fractures from propagating through them. This was a discovery that was made possible by the utilisation of waste glass as a fine aggregate. This goal is attainable by the use of discarded glass as a fine aggregate.

In addition, the use of recycled glass sand particles, often referred to as RGS and frequently abbreviated as RGS, might potentially reduce the amount of water and air that are able to travel through the concrete. The third area of study focuses on exploring the potential for repurposed glass to serve in the role of pozzolanic material. In the presence of adequate amounts, a waste product with a high silica ($SiO_2$) concentration may be included into cement as a pozzolanic component. This is provided, however, that the waste product be utilised. In the presence of water and finely ground glass composed of the appropriate amorphous silica ($SiO_2$), a reaction can take place that results in the formation of hydrated compounds in a manner that is comparable to that of pozzolanic materials such as pulverized-fuel ash (PFA), ground-granulated blast furnace slag (GGBS), and silica fume (SF). This reaction can take place in the presence of water. The pozzolanicity of glass powder (GP) was researched for the first time in 1973 (Reindl 2003), but the area has seen substantial improvement in the last 10 years. Research that was published indicated that glass powder may react in a pozzolanic fashion in cementitious systems and contribute to the development of strength in concrete. This was proved by the research.

In addition, it was found that the pozzolanic reactivity increases as the material's fineness diminishes. This was a really interesting finding. (Shao et al. 2000) discovered that utilising concrete with a smaller glass particle size led to a stronger compressive strength and a lower expansion in their concrete composites at both early and late ages. These findings were based on the fact that the concrete had been aged for longer periods of time. This was in contrast to concrete that had fly ash already mixed into it. However, it is important to note that the maximum rate of heat evolution reduces in proportion to the quantity of Portland cement that is included in the mixture. This is something that should be kept in mind. This is owing to the fact that the pozzolanic reaction did not take place until a later stage and that it only created modest quantities of heat during the early stage of hydration, as stated by Dyer and Dhir (2001). This is because the pozzolanic reaction did not take place until a later stage. Shayan and Xu (2004) discovered that a decreased cement content, as opposed to the nature of GP itself, was the source of a drop in the compressive strength of GP mixes. This was determined to be the cause of a decrease in the compressive strength of GP mixes. Their observations provided the foundation for this discovery. In addition to this, he said that the compressive strength after ninety days was equivalent to that of the SF specimens when GP was used to replace thirty percent of the sand. This was reported to be the case when the test was conducted.

The fourth area of study focuses on the use of coloured glass aggregate as the topic of discussion. In a piece of study that was carried out in 2000 by Jin et al., the possibility of using coloured glass aggregate as a partial replacement for both fine and coarse aggregate was studied. It was said that the expansion of the concrete that resulted from the ASR reaction was bigger in the concrete that was manufactured with waste glass of a non-color compared to the expansion of the concrete that was made with waste glass of a colour. In addition, the use of coloured glass as aggregate has the potential to influence the slump as well as the mechanical qualities of concrete. When coloured glass is used as aggregate, there is less adhesion and binding strength between the coloured glass and the cement paste than there is when using clear glass as aggregate. This is due to the fact that coloured glass contains surfaces that are generally smooth, in contrast to the surfaces that are somewhat rough seen on natural aggregate. It was discovered that, for reasons of structure, a combination of coarse and fine glass aggregate could not account for more than fifty percent by weight of the typical aggregate. This was the conclusion reached after doing research into the matter. Terro (2006) discovered that the compressive strength of concrete made with colour waste glass dropped by up to twenty percent when subjected to an increase in temperature of up to 700 degrees Celsius from its original value. This was discovered as a result of an increase in temperature.

The fifth area that is being looked at and developed is the relationship that exists between glass and cement. It is generally accepted that aggregate particles are unaffected by the cement paste, and their selection is done on the basis of the attributes that they possess. On the other hand, some reactive aggregates and cement paste might provoke chemical reactions when they come into contact with one another. The alkali-silica reaction is one illustration of this phenomenon. In the beginning, it was believed that the only function that aggregate served in concrete was a mechanical one. The particles that would make up the aggregate were chosen on the basis of the physical attributes they had. It is a widely held assumption that glass cannot survive in an environment that contains concrete because of the presence of alkaline conditions. Despite the fact that silica makes up the bulk of each of these substances, sand and glass behave quite differently when exposed to certain conditions. According to Meyer 2003, the type of silica found in sand, which has a regular crystalline structure, is resistant to chemical effects and is generally stable. On the other hand, the amorphous form of silica that may be found in glass is not stable. This disparity in conduct could have something to do with the fact that the silica in sand has a crystalline structure that is organised in a regular pattern.

**Object**

- The Study Improving the Reflectivity of Concrete Barriers
- The Study Substituting Recycled Glass Aggregate

**Management Options of Waste Glass**

According to "Waste Statistics for 2010" and "Waste Reduction and Recovery Factsheet No.6," in the year 2010, there was a daily output of 373 tonnes of waste glass, which was equivalent to 4.1% of municipal solid rubbish. This figure was derived from the data presented in "Waste Statistics for 2010." The commercial and industrial sectors are each responsible for creating 17% of the waste glass, while the residential sector is responsible for producing 83% of the waste glass. The proportion of glass that was recycled in 2010 was 3.3%, and the volume of glass that was recycled in 2010 was 4500 tonnes per year. The remaining 96.7% of the glass was disposed of directly in landfills after being supplied to those locations. The information about the amount of glass that was recycled and thrown away during the course of the past four years is shown in When it comes to the handling of waste glass, there is a vast array of options available to choose from. After minimising waste and finding fresh use for unused objects, recycling is the next logical step to take. Glass that has been used before is referred to as post-consumer rubbish, and it is one of the key components that makes up the stream of solid waste in Hong Kong. In 2010, 96.7% of waste glass in Hong Kong, which equals to 131,864 tonnes, was thrown directly in landfills, as stated by the Environmental Protection Department (EPD). Even though it is projected that the three strategic landfills would be full in 2015 (EPD, 2005), it is of the highest significance to find a sustainable manner of reusing and recycling the glass. This is because of the impact that glass has on the environment.

**Glass**

Glass is a unique and inert material that may be recycled an unlimited number of times without having any effect on the chemical properties that it has. The unpleasant truth is that over time, a significant amount of glass will become unsuitable for recycling. This situation will ultimately arise. There are a lot of factors that have an influence on how efficient this process (that is, recycling) is. To begin, the efficacy of processes for collecting and sorting various colours of glass; for instance, if different hues of glass (such as clear, green, and amber) are mixed together, the resultant glass cannot be used in the creation of new glass containers because it does not meet the required standards. After the costs connected with exporting the goods, the number of contaminates that could be present in the stockpile is the second component that has an effect, and it is followed by the total cost of the export. mostly as a result of the lack of availability of recycling facilities in several of the nation's cities. As a result, the fundamental purpose of environmental authorities is to reduce, to the maximum degree that it is practically possible, the dumping of post-consumer glass in landfills and to increase the quantity of recycled glass that is utilised in the production of items made of glass. As a consequence of this, it has been hypothesised that the integration of glass into the production of concrete would greatly cut down on the disposal of waste glass or its usage in lesser valued works such as fill or road foundation materials. This is as a result of the fact that the incorporation of glass into the production of concrete would significantly cut down on the amount of waste glass. This is due to the fact that it has been hypothesised that the use of waste glass in these works of lesser value would result in greater savings in terms of money. On the other hand, the chemical reaction that takes place between the alkali in cement and the silica-rich glass particles that make up glass aggregate is the key reason for concern when it comes to the utilisation of glass in concrete. This reaction is the source of the principal cause for concern. The alkali-silica reaction is the name given to this particular chain of reactions.

**Glascrete**

When making glascrete, a special sort of concrete, portion of the sand, gravel, or both that would normally be used in the manufacturing process is replaced with crushed glass instead, depending on the particle size. This may be done alone or in any combination that suits your needs. Due to a chemical reaction that takes place between the alkali in the cement and the silica in the glass, using crushed waste glass as an aggregate can cause some problems. This reaction takes place between the two substances. This reaction, which is also known as the Alkali-Silica Reaction, produces a gel, and the activity of the gel promotes swelling when it is present in an environment containing moisture. This, in turn, induces expansions, which finally leads to the breakdown of the concrete. This reaction is possible to take place in regular concrete provided that the regular aggregate contains a significant quantity of silica. There are a number of different techniques that may be taken to reduce the danger of ASR, and a few of these ways have shown some viable solutions to the issue of alkali-silica reaction. With this strategy, the ASR problem is discussed, and the detrimental effects it has over the course of time are outlined. The solutions that were discussed are laid up in the following format:

1. Crushing the waste glass until it is at least 300 micrometres lower in size than the size minimum in the United States.
2. Replacing a part of the cement with mineral admixtures, such as meta kaolin, which has the capability of adsorbing alkalis ions and, as a consequence, lowering the reaction.
3. Applying a sealant to the concrete to avoid moisture damage to the material, since the reaction can only take place in the presence of water.
4. Modifying the glass chemistry, various studies have demonstrated that green chrome, which contains chrome oxide, does not generate any interaction between alkalis and silica (Meyer, 2000). This was shown when green chrome was added to glasses. This is due to the presence of chrome oxide in green chrome, which is the source of the problem.
5. Using a low-alkali cement, which is likely to be less effective, unless alkalies from the environment can be kept away from the cement; alternatively,

**Environmental and Economic Benefits**

Over the course of the last few years, there has been a discernible rise in the amount of focus placed on the incorporation of broken glass into concrete as a component of the material.

It is one of the most useful options that may lead to a partial solution of the related disposal problem, and at the same time, it will open up new chances to create new applications; hence, it is considered as one of the most value solutions since it will open up new opportunities to develop new applications. The use of recycled glass shards into concrete provides several significant benefits, including the following:

1. Cutting down on the costs associated with trash disposal, which are anticipated to rise as a consequence of the increase in the tax that is placed on landfills.
2. Keeping costs and the energy required for recycling, where a recycling cost of one tonne of waste glass reaches to $45 and this is viewed as excessively lavish spending, for example, New York City has collected waste glass up to 100.000 tonne annually (Chesner, 1992). Keeping the environment in mind while recycling, where a recycling cost of one tonne of waste paper gets to $25 and this is regarded as environmentally friendly. Keeping expenses and the necessary energy for composting, where the cost of composting one tonne of waste food may reach $45; this is seen as an extremely high cost.
3. Decreased costs associated with the production of concrete as a consequence of the utilisation of waste as a replacement for conventional concrete resources, which are more costly.
4. Protecting the natural environment by halting the annual loss of a sizeable quantity of essential raw materials and so reducing the amount of trash produced.
5. Extending the lifespan of our waste disposal facilities and making a contribution to the conservation of the natural environment in the surrounding area

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According to the standard, after the glass cullet has been adequately treated, it should be reasonable to predict that it will give sufficient stability and load support when used as a substrate for roads or highways. This should be achievable since it should be possible to anticipate that it will have been appropriately treated. The term "Glass halt" refers to crushed glass cullet that has been used as an aggregate in road construction or bituminous concrete pavement. This material is known by its common name. Since 1971, several experiments with glass halt pavement have been carried out in various settings to simulate real-world conditions. It was found that it has a higher potential to hold heat than conventional asphalt does. This might be an advantage in situations where roadwork has to be done during cold weather or when extensive transit routes are required. In addition to this, the glass particles have the capability of increasing the reflectivity of the road surface, which, as a result, would make driving on the road safer at night. When compared to plain concrete, the crushed waste glass pavement has a stronger resistance to abrasion, a lower rate of shrinkage when it is subjected to dry circumstances, and a lower rate of water absorption. Additionally, the crushed waste glass pavement has a lower rate of water absorption.

## CONCLUSION

The barrier's visibility may be improved by modifying the smooth surface such that it yields surfaces that face the light that is incident on the barrier. Incorporating reflecting elements into the concrete mixture to improve its retro reflectivity is still another approach that may be pursued. Examples of such materials include reflective aggregate and luminous admixtures. When crushed glass is integrated into the concrete mixture used for highway barriers, it has the ability to function as a reflecting medium; nevertheless, it is imperative that any possible issues, such as the alkalisilica reaction (ASR), be resolved.

Before this approach could even be considered as a possibility, more research into this possibility was necessary to establish whether or not ASR could be circumvented. Because of the favourable benefits it would have on the environment, we decided to conduct an experiment utilising recycled glass (RG) instead of glass beads that were specifically made. An outlet for the reuse of RG might be created if it were used instead of glass beads that were made specifically for the purpose. The use of RG was included into the design of a variety of concrete mixtures. The qualities of these mixes after they had been hardened and while they were fresh were examined. ASR research was also conducted on these mixes in accordance with the recommendations provided by ASTM C1293. Due to the fact that this is two-year research that has only been in progress for the last three months, only the preliminary data are being shared.

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