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WASTE GLASS A SUPPLEMENTARY CEMENTITIOUS MATERIAL IN CEMENT PRODUCTION

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Abstract- Glass is a material that is made from natural resources such as sand (Silica). All around the world annually million tons of waste glass is being generated. Waste glass is disposed as landfills, that does not decompose in the environment as it is non-biodegradable. When waste glass is grounded to micro size particles then it is expected to undergo pozzolanic reactions with cement hydrates, forming secondary Calcium Silicate Hydrate (C–S–H). In this research paper about waste glass and its properties were discussed. And its usage as supplementary cementitious material and environmental impact were also discussed.

Keywords: Waste glass; Supplementary cementitious material; Environment, pozzolanic.

1. INTRODUCTION

Glass waste is representing huge environmental problems all over the world. These materials occupy huge parts of the landfills spaces, due to the nonbiodegradable nature of glass, and causing serious environmental pollutions. The only solution to overcome over the environmental impact of these glass wastes is to reuse them. Recycling of these wastes will help to conserve the earth's natural resources and minimizes the landfills spaces and saves energy and money. The need of large quantities, low quality requirements and the broad sites of construction make the construction industry one of the most attractive ways to solve the environmental impact of the waste glass.

1.1 Waste Glass

Glass is a transparent material made by melting a mixture of fabrics such as silicon dioxide, soda ash, and CaCO3 at high temperature up to 1600ºC accompanied by cooling during which solidification occurs without crystallization.

Glass is widely used in our lives in various forms such as sheet glass, bottles, glassware, and vacuum tubing. The quantity of waste glass has gradually increased over the recent years due to an ever-growing role and demand of glass wares. And most of the waste glasses have been dumped into landfill sites. The Land filling of waste glasses is undesirable because they are not biodegradable and which makes them environmentally less friendly. So we can use the waste glass as a SCM in cement production.

1.2 Pozzolanic Properties of Waste Glass

Pozzolanic properties of waste glass refer to its ability to react with calcium hydroxide $Ca(OH)_2$ in the presence of water to form cementitious compounds. This reaction is known as the pozzolanic reaction, contributes to the strength and durability of cementitious materials.

1.3 Amorphous Silica Content

Waste glass typically contains a significant amount of amorphous silica, which is a key factor in its pozzolanic activity. Amorphous silica has a high surface area, allowing it to react readily with calcium hydroxide and form additional cementitious compounds.

1.4 Reactivity and Fineness

The reactivity of waste glass depends on many factors such as its chemical composition, particle size distribution and surface area. To increase its pozzolanic reactivity, waste glass is often ground to a fine powder. Increased fineness improves the contact between waste glass particles and calcium hydroxide that facilitate the pozzolanic reaction.

1.5 Pozzolanic Reaction Products

When waste glass reacts with calcium hydroxide in the presence of water, it forms the additional cementitious compounds, such as calcium silicate hydrate (C-S-H) gel. The C-S-H gel contributes to the strength and binding properties of the cementitious matrix.

Fig.1.1 Different Colours of Glass

Table-1.1 Physical Properties of Waste Glass and Sand

Physical Properties	Waste Glass	Sand
Specific Gravity	2.19	2.57
Density	1672	1688
Absorption (%)	0.39	2.71
Pozzolanic Index (%)	80	-

2. OBSERVATION

The absorption rate of waste glass is lower than that of sand by 14%, i.e. this means that concrete made up with glass as an aggregate has a lower absorption rate for water.

2.1 Partial Cement Replacement

It can be used as a partial replacement for cement in concrete production. Typically, a portion of the cement is substituted with finely ground waste glass powder. This reduces the overall cement content while maintaining or improving the mechanical properties and durability of the concrete.

2.2 Glass Powder Addition in Concrete Mixes

Waste glass powder can be directly added to concrete mixes as an additional pozzolanic material. It acts as a supplementary cementitious material alongside other pozzolanic materials like fly ash or silica fume. This combination enhances the reactivity and overall performance of the concrete.

2.3 Glass Aggregate in Concrete

In addition to using waste glass as a pozzolanic material, it can also be used as a fine or coarse aggregate in concrete production. By incorporating waste glass aggregates, both the pozzolanic and aggregate properties of the glass are utilised in concrete development. This approach increases the sustainability of concrete while maintaining structural integrity.

2.4 Glass Fibre Reinforcement

Waste glass fibres can be used as reinforcement in cementitious composites. The glass fibres provide tensile strength and improve the overall performance of the concrete. This application is particularly useful in construction elements requiring enhanced durability and crack resistance.

2.5 Glass as Pozzolanic additive in Mortars

Waste glass can be used as a pozzolanic additive in mortar mixes. Mortars containing waste glass exhibit improved workability, increased strength and reduced permeability. This makes them suitable for various applications such as plastering, masonry and tile adhesives.

Fig. 2.1 Glass in Concrete Structure

3. EFFECT OF WASTE GLASS ADDITION

3.1 Increased Strength and Durability

The incorporation of waste glass as a pozzolanic material in concrete leads to the formation of additional cementitious compounds. These compounds, such as calcium silicate hydrate (C-S-H) gel, contribute to the development of strength and durability of the concrete. The pozzolanic reaction between waste glass and calcium hydroxide results in denser and more compact concrete that improve its compressive and flexural strength.

3.2 Reduced Permeability

Concrete containing waste glass exhibits reduced permeability to water and other potentially harmful substances. The pozzolanic reaction of waste glass results in the formation of a refined pore structure within the concrete matrix. This refined pore structure restricts the movement of water and other aggressive agents, enhancing the concrete's resistance to moisture ingress, chemical attack, and freeze-thaw damage.

3.3 Enhanced Chemical Resistance

The pozzolanic reaction of waste glass in concrete leads to the formation of calcium silicate hydrate (C-S-H) gel, which provides improved chemical resistance. This resistance makes the concrete less susceptible to chemical degradation caused by substances such as sulphates, chlorides and acids. Concrete with waste glass as a pozzolanic material exhibits a better long-term performance in aggressive environments.

3.4 Improved Workability and Cohesion

The addition of waste glass as a pozzolanic material can enhance the workability and cohesion of concrete. Due to the fine particle size and pozzolanic nature of the waste glass, it acts as a filler material, improving the packing and lubrication of the concrete mixture. This improved workability allows for easier placement, consolidation and finishing of the concrete.

3.5 Mitigation of Alkali-silica Reaction

Alkali-Silica Reaction (ASR) is a chemical reaction that can occur between certain reactive silica minerals in aggregates and the alkalis present in cement. This reaction results in expansive cracking and deterioration of concrete. Waste glass, being an inert material, can act as a mitigating agent for ASR by replacing some of the reactive silica in the concrete mix.

3.6 Sustainability and Eco-friendliness

In addition to performance improvements, the utilisation of waste glass in concrete contributes to sustainability and eco-friendliness. By incorporating waste glass as a pozzolanic material, the consumption of cement is reduced, resulting in CO2 emissions associated with cement production. This reduction in CO2 emissions aligns with environmental goals and contributes to a more sustainable construction industry.

4. ENVIRONMENTAL BENEFITS

4.1 Waste Reduction and Recycling

Waste glass, if not properly managed, poses a significant environmental challenge. By using waste glass as a pozzolanic material in cement production, it is diverted from landfills or incineration, reducing the need for new disposal sites and minimising the environmental impact associated with glass waste. Recycling waste glass as a pozzolana in cement production promotes a circular economy by converting it into a valuable resource.

4.2 Conservation of Natural Resources

The incorporation of waste glass in cement production reduces the need for virgin raw materials, such as limestone or silica. By substituting a portion of cement with waste glass as pozzolana, natural resources are conserved, including the energy and water required for extraction and processing of raw materials. This conservation helps in preserving natural ecosystems and reducing the overall ecological footprint.

4.3 Reduced Landfill Space and Leachate Generation

When waste glass is disposed of in landfills, it occupies valuable space and can contribute to environmental concerns. Glass waste in landfills may also produce leachate, potentially contaminating soil and groundwater. Utilising waste glass as a pozzolanic material that the amount of glass waste sent to landfills, alleviating the pressure on waste management infrastructure and minimising the associated environmental risks.

4.3 Improved Air Quality

Cement production is associated with the release of pollutants, including dust, particulate matter, and potentially harmful gases. By replacing a portion of cement with waste glass as pozzolana, the production of cementitious materials can be optimised. The use of waste glass as a pozzolana reduces the overall emissions of particulate matter in to the atmosphere and ultimately improves air quality in and around cement plants, promoting a healthier environment for nearby communities.

4.4 Enhanced Durability and Reduced Maintenance

Concrete incorporating waste glass as a pozzolanic material exhibits improved durability and reduced permeability. Thisresults in longer service life for concrete structures, reduced maintenance requirements, and decreased need for repairs or replacements. By extending the life and durability of concrete, the environmental impact associated with new construction projects is minimised.

CONCLUSION

The use of waste glass as a pozzolanic material in cement production offers a sustainable solution to address environmental concerns associated with both waste glass disposal and cement manufacturing. By harnessing the pozzolanic properties of waste glass, cement producers can reduce their carbon footprint, enhance concrete performance, and contribute to a more circular economy. The addition of waste glass as a pozzolanic material significantly enhances the performance of concrete. The improvements include increased strength and durability, reduced permeability, enhanced chemical resistance, improved workability and cohesion, mitigation of alkali-silica reaction and sustainability benefits. By embracing waste glass in concrete production, the construction industry can create more resilient and eco-friendly structures while effectively utilising a valuable waste material. Further research, collaboration and implementation efforts are essential to fully exploit the potential of waste glass as a valuable resource.

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