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Sustainable Performance of Glass Powder and Fly Ash in Concrete: A Review

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Abstract: ***Development of sustainable construction materials has been the viewpoint of research efforts worldwide in recent years. Concrete is a major construction material used worldwide; hence, finding alternative cementitious materials to ordinary Portland cement is of extreme importance due to high levels of carbon foot print associated with its manufacturing process. In the past few decades, many researches have been carried out on the use of glass powder and fly ash in concrete. Due to the good execution and environmental affability, fly ash and glass powder based construction materials have great potential as alternatives to ordinary Portland cement. This paper reviews the previous findings on the effects of using fly ash and glass powderwith a particular focus on recent advances in characterization, hydration mechanism, activation approaches, durability and sustainability of fly ash and glass powder as a construction material.Such effects are mainly influenced by many factors, including the particle size and optimum content of the cementitious materials, The use of high volume fly ash as a partial replacement of cement in concrete reduces environmental pollution and conserves natural subsistence.***

Keywords: Fly Ash, glass powder, pozzolanic activity, pore filler, supplementary cementitious materials

1. Introduction

Concrete is the accustomed material and it shapes our built environment. Popularity of concrete as construction material is on the three counts 1) excellent mouldable2) adequate strength and 3) amenable to the utilization of local materials as ingredients. The main purpose of this work is to provide a comprehensive review of fly ash and glass powder as a construction material worldwide.Presently, construction andinfrastructure industries are experiencing an active growthcurve owing to the world population. Consequently, the demand for concrete as anessential construction material has also extended significantly due to its enormous usage,which, in turn, increased the demand of the predominant binder in concrete- ordinary Portlandcement (OPC) [4]. The Glass powder (GP) shows an additional advantage by providing pozzolanic activity, in which the amorphous silica (SiO_2) in the GP reacts with the portlandite [$Ca(OH)_2$] generated during cementhydration and forms gels of calcium silicate hydrate (C–S–H) and it is an ideal material for recycling as it has high silica content, which is the primary requirements for a pozzolanic material [5]. The purpose of this study is to efficiently recycle waste glass, one of silica-based industrial by-products and use it as a cement alternative for sustainable construction. Using fine glass ascementitious materials has the potential to form a new pozzolanic C-S-H gel with very low C/S ratio and high amounts of alkalis (Na+K) and aluminum (Al), which could result in denser microstructure and improved strength capacity [10].While using such industrial by-product as alternatives for cement, not only there is a reduction in associated CO2 emissions, but also there are effects of decreasing the ecological impact on the environment.Waste glass and fly ash finds a numerous applications in concrete in a variety of paths and Waste glasscan be used as inert filler aggregate with larger sized particles or supplementary cementing material (SCM) with finer particle gradation[2]. Fly ash is an excellent SCM and pore filler material.It is shown that use of fly ash extremely enhanced all concrete strength after exposure to elevated temperatures due to the reaction of fly ash with $Ca(OH)_2$ decomposed at elevated temperatures [13].

2. Fresh Concrete Properties

The slump and air content shows adecreasing trend with waste glass addition due to the higherspecific surface area and particle shape [3].Greater the volume of glass powder content less will be the slump value this is due to the fact that glass powder absorbs more water. To overcome these super plasticizers may be used.

3. Mechanical Properties

The use of fly ash as a supplementary cementitious material reduces the concrete strength at early ages and a significant improvementin concrete strength was observed at the ages of 56 to 180days with elevated temperatures. This may bedue to the pore filler properties and the reaction of fly ash with $Ca(OH)_2$ decomposed at elevated temperatures [13]. Waste glass powder (WGP) offers better strength characteristics in thelong term with higher rate of strength gain.The higher strength achieved for WGP indicates the enhanced pozzolanic reactivity and pore filler properties leading to higher C-S-H formation [3]. However, at 90 days the 0.40 w/c ratio mixture with 10% fly ash shows a greater compressivestrength than the mixture with 10% glass powder, indicating that the pozzolanic reaction of fly ash is more effectivethan the secondary reaction of glass powder. This can alsobe attributed to the particle sizes of the fines used, the glass powder has only 25% of the particles finer than 10 µm, while the fly ash and cement have 30% and40%, respectively of particles finer than 10 µm [9].

4. Durability Characteristics

Durability characteristics of the concrete are the ability to resist weathering action, chemical attack, and abrasion etc., while maintaining its desired engineering properties. The highest durability factor is achieved when wasteglass powder is mixed.

4.1 Chloride transport test

The RCP test basically measures theconductivity of concrete which depends on both the pore structure and the pore solution composition. For concretes containing cementitious materials, the chemical composition of the pore solution also changes either due to the consumption of calcium hydroxide during pozzolanic reaction, or the presence of ions contributed by the cement replacement materials, both of which changes its conductivity[2]. WGP incorporation resulted in the highest chloride diffusion coefficientand correspondingly greatest penetration depth indicatingits poor performance in regards to chloride ion penetration due to its greater size and poor pozzolanic reactivity. Waste glass slag (WGS) showed the least penetrability, which is attributed to the greaterpozzolanic reaction [3]. In general, the results shows that resistance to chloride-ion penetration increased significantly as the glass powder content in the mixtures increased and the resistance increased over time due to the hydrationof the cement and GP and the filling of the concrete's pore structure [5]. Glass powder modified concretes show lower or similarRCP values in chloride ion penetration as compared to control concrete at all ages. More alkali ions are released into the aqueousphase by a certain amount of glass powder than the alkalicontribution from the same amount of cement it replaces, thus increasing the pore solution conductivity of glass powder for greater resistance[9].

4.2 Frost resistance

Freezing and thawingresistance is determined by entrained air and strength of cement matrix rather than the pore filler effect and contribution ofpozzolanic reaction. Better scaling resistance for WGP andWGS is attributed to the fine particle filling effect and pozzolanic reaction [3].

5. Porosity

Both WGP and WGS found to have positive influence in reducingthe total porosity. The reduced porosity ismost probably due to the micro filler effect [3]. Fly ash also acts as excellent pore filler with respect to its size.

6. Alkali–Silicareactivity

This test method can be usedto evaluate the efficiency of supplementary cementingmaterials in reducing the expansion due to ASR. Increase in glasspowder content reduces the expansion in concrete. The very high silica content and the low CaO content of glass powder can be expectedto play a major role in reducing the expansion.A 20% replacement ofcement by fly ash is found to limit the expansion to less than 0.10% [9]. Fly ash has a significant influence on the pore solution to mitigateASR. Firstly, fly ash reduces the alkalinity of pore solution by Alkali binding [8].

7. Moisture Transport

The fly ash modified concretes show the highest moisture intake, showing thatthe effect of dilution of cement content by fly ash has notbeen compensated by any secondary reaction at this age.The total moisture intake for the glass powder concretesare in between those for control and the fly ash modifiedconcretes. Glasspowder provides advancement in cement hydration atearly ages while fly ash is only filler at these times. Thebeneficial effects of secondary reaction of fly ash are evidentat later ages whereas the secondary reaction of the glasspowder is not as efficient as that of fly ash [9].

8. Conclusion

By consolidating the reviews of Fly ash and glass powder the following conclusions can be drawn

1) In chloride ion penetration both glass powder and fly ash modified concretes showed lower RCP values as compared to the plain concrete, especially at later ages, indicating the influence of these materials in microstructure refinement. Even with a pore solution having a slightly higher conductivity because of the presence of higher alkali content in glass powder, the glass powder modified concretes demonstrated similar or lower RCP values as compared to fly ash modified concretes of the same replacement level.
2) Good mechanical characteristics (compressive, split-tensile, and flexural strengths as well as modulus of elasticity), especially at later ages (90 days), provided by the glass powder's greater pozzolanic reactivity, higher surface area, finer particle size, and reduced total porosity
3) Enhancement of durability characteristics adsorption, resistance to chloride-ion permeability and resistance to the freeze–thaw cycles due to the improved characteristics of the pore network, the filling effect of glass particles, pozzolanic activity and the conversionof CH to C–S–H.
4) Use of glass powder supplemented with small amounts of Class F fly ash can be used to reduce the expansion due to ASR.
5) Reduction of CO_2 emissions associated with cement productionand protecting the environmental by recycling waste materials.
6) Saving the costs related to processing and disposing of wasteglass in landfills as well as reducing the price of concrete.

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