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Utilization of Glass Powder as a Partial Replacement of Cement and Its Effect on Concrete Strength – A Review

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Abstract: *Abstract—Glass is an amorphous solid that has been found in various forms for thousands of years andhasbeenmanufacturedforhumanusesince12,000BC.Glassisone of theversatilesubstancesonEarth, usedinmanyapplicationsandinawidevarietyofforms,fromplainclearsglasstotemperedandtintedvarieties, and so forth. It is generally dumped in landfills after usage.As glass is non-biodegradable material, landfillsdonotprovideafriendlyenvironment.Manyattemptsweremadetousewasteglassinconcreteindustry asareplacementofcoarseaggregateandfineaggregatebuttheperformancewereunreliablebecauseofstrength regression. As glass powder with particle size less than 75mm possess pozzolanic properties, past investigation reveals that glass powder can be effectively use as a partial replacement of cement. Experimental Investigations showsapositiveresultbyenhancingthecompressiveandtensilestrengthofconcrete.Workabilitydecreaseswith incrementinglasspowdercontent.Areviewonutilizationofaglasspowderasapartialreplacementofconcrete and its effects on compressive and tensile strength of concrete is shown in thispaper*

Keywords: *compressive strength,glass powder pozzolanic properties, tensile strength,workability*

I. Introduction

The rapid urbanization is creating a shortfall of conventional building construction materials due to limitedavail- ability of natural resources. On the other side energy utilized for the production of conventional building construction materials pollutes air, water and land. In order to fulfill the increasing demand for the energy efficient building construction materials there is a need to adopt cost effective, environmentally appropriate technologies and upgrade traditional techniques with available local materials. The energy required to reuse the recyclable material is less than that of virgin materials [1]. Glass is a common product that can be found in different forms: bottles, jars, windows and windshields, bulbs, cathode ray tubes, etc., thus became integral part of our life. These products lifetime is very short and generally disposed off after its usage. The present method still istolandfillmostofthenon-recyclableglass.Sinceglassisanon-biodegradablematerial,theselandfillsdonot constituteanenvironmentalsolution[2]andmustberecycledinordertoavoidenvironmentalproblemsrelatedto their stockpiling or landfilling.

Utilization of waste glass has attracted construction industry worldwide due to consumption of concrete in large quantity for widespread construction sites [3]. Use of waste glass as aggregate in concrete has been attempted by many investigators. Those early efforts were thwarted by the problem of alkali-silica reaction (ASR), which was not well understood[4].FurtherstudiesinthisfieldshowsthattheproblemofASRisnotrestrictedtoglassaggregate concrete. It can occur in conventional concrete also. As this is a long-term problem and may take years to manifestitself,itisingeneraldifficulttopredictthepotentialreactivityofnaturalaggregate,andareliableaccelerated test method is needed. ASR is uncertainty in regular concrete but glass aggregates are generally subjected to ASR. Hence glass is an ideal aggregate to study the ASR phenomenon and to search for methods to avoid it or to mitigate its detrimental consequences [5]. Finally through studies led to the conclusion that use of waste glass as coarse aggregates did not have significant effect on workability and strength but decreases the slump, air content and fresh weight of concrete [6]. But Byars, E. A. et al, has pointed out that the main deficiency of incorporating waste glass aggregates, either in form of coarse or fine fraction, is the resultant Alkali-Silica Reaction (ASR) which undermines strength of concrete. Although mineral additives such as PFA or GGBS are also used in concrete mix to suppress Alkalis Silica reaction, the feasibility of long term use of glass aggregates is questionable [7], [8]. AnkurMeena&Randheer Singh investigated the effect of particle size of glass powder on strength of concrete. Glass powder with particle size ranging from 150μm to 100μm, and 100μm to 50μm, were used in the investigation.Itwasobservedthatsmallerparticlesizeoftheglasspowderhashigheractivitywithlimeresulting in higher compressive strength of concrete. Also finer glass powder concrete has slightly higher early strength as well as late strength[9].

Shilpa Raju and Dr. P.R. Kumar observed that Glass powder shows pozzolanic activity when particle size is less than 75μm whereas experimentation was carried out using glass powder of size 45μm. The test results showedenhancementincompressivestrength.Itwasconcludedthattheenhancementinstrengthwasduetovery finely ground glass powder which may be acting as excellent filler or may have sufficient pozzolanic properties to serve as partial cement replacement. It was also observed that the effect of ASR reduces with the replacement percentage[10].

II. Physical Properties And Chemical Composition Of Cement And Glass Powder

2.1. Physical properties:

Table 1: Physical Properties

Physicalproperties	Cement	Glass powder
Specificgravity	3-3.2	2.42 -3.01
Fineness	<90 μm	< 75μm
Colour	Grey	White

2.2. Chemical composition

Table 2: Chemical Composition

Composition (% bymass)	Cement	Glass powder
Silica (SiO2)	17 - 25%	50 - 80%
Alumina (Al2O3)	3 - 8%	1 - 10%
Iron oxide (Fe2O3)	0.5 - 6%	< 1%
Calcium oxide (CaO)	60 - 67%	5 - 15%
Magnesium oxide (MgO)	0.1 - 4%	< 1.5%
Sodium oxide (Na2O)	0.5 - 1.3%	1 - 15%
Potassium oxide (K2O)	0.5 - 1.3%	< 1%
Sulphur trioxide (SO3)	1 - 3%	Nil

III. Strength Of Concrete

Strength of concrete is its resistance to rupture under the action of various types of forces. It may bemeasure in number of ways such as, strength in compression, strength in tension, strength in shear or strength in flexure. The compressive strength of concrete is one of the most important and useful properties of concrete. It is used as qualitative measure for other properties of hardened concrete. Therefore, the concrete making properties of various ingredients of mix are usually measured in terms of the compressive strength[11].Strengthofconcretedependsonvariousparameterssuchasw/cratio,qualityandcontentofcement,chemical composition of cement, ratio of cement to aggregates, age and curing conditions, grading of aggregates with its surface texture, shape, size, strength and stiffness[12].

Similarly strength of concrete is very much influenced by the chemical composition of cement along with its particle size. Chemical composition has an important relationship to fuel consumption, kiln operation, clinker formation and cement performance [13]. Fineness of cements has increased mainly to increase concrete early strength[14].

IV. Effect Of Chemical Composition Of Cement On Strength Ofconcrete

Therawmaterialsusedformanufacturingofcementconsistmainlyoflime,silica,aluminaandironoxide.These oxides interact with one another in the kiln at high temperature to form more oxide compound. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement. The oxides present in the raw materials when subjected to high clinkering temperature combine with each other to form complex compounds which are termed as Bogue'scompound.

Tricalciumsilicateanddicalciumsilicatearethemostimportantcompoundresponsibleforearlystrengthand late strength of concrete simultaneously. In modern cement together they constitute 70-80% of cement while contents of C_3A and C_4AF have decreased slightly. The calculated quantity of the compound in cement varies greatly even for a relatively small change in the oxide composition it becomes absolutely necessary to closely control the oxide composition of the raw materials. High C_3S content (low C_2S content) lead to much faster hydration rate contributes to higher early strength gain. Thus, cement with higher proportion of C_3S, as is the caseinmostoftoday'scement,willtendtohaveahigherearlystrength,andallowforearlyformremovalorpost tensioning. C_3A liberate a large amount of heat during the first few days of hardening and together with C_3S and C_2S may somewhat increase the early strength of hardening cement. Low % of C_3A cement is more resistant to sulfates. C_4AF contributes very slightly to strength gain and contribute to the colour effects that makes cement gray[15].The mechanical properties of hardened cement depend more on the physical structure of the hydration than on the chemical composition of the cement [11].

V. Effect Of Glass Utilization On Compressive And Tensile Strength Of Concrete

Glass is an amorphous solid that are found in various forms for thousands of years and has beenmanufactured for humanusesince12,000BC.Glassisone ofthemostversatilesubstancesonEarth,usedinmanyapplicationsandin a wide variety of forms, from plain clears glass to tempered and tinted varieties, and so forth.Glassisaninertmaterialwhichcouldberecycledandusedmanytimeswithoutchangingitschemicalproperty[16].Henceinterestoftheconstructioncommunityinusingwasteorrecycledmaterialsinconcreteisincreasing. Manyattemptshavebeenmadebyvariousresearcherstoutilizewasteglassascoarseaggregates,fineaggregatesas a partial replacement of cement with variation in particle size having different proportions and in various types ofconcretes.

Reviewsoftheirexperimentationsfortheuseofwasteglassinconstructionfieldaregivenintabularizeform in table3.

Table 3: Reviews of their experimentations

Name of author with year of publications	Form of Glass, particle size and % replacement to cement	Concrete Mix	Conclusion
C Meyer et.al.[1998]	as coarse aggregates	__	Efforts were thwarted by the problem of alkali-silica reaction (ASR), which was not well understood
Meyer C. and Baxter S [1999]	as coarse aggregates	__	Glass almost an ideal aggregate to study the ASR phenomenon and to search for methods to avoid it or to mitigate its detrimental consequences
C. Meyer, N. Egosi, and C. Andela[2001]	as coarse aggregates	__	Use of waste glass as coarse aggregates did not have significant effect on workability and strength but decreases the slump, air content and fresh weight of concrete
Byars, E. A. et [A-2004] & [B-2004]	as fine & course aggregates	__	Main deficiency of incorporating WG aggregates, either in form of coarse or fine fraction, is the resultant Alkali-Silica Reaction (ASR) which undermines strength of concrete. The feasibility of long-term use of glass aggregates is questionable.
EsraaEmam Ali &Sherif H. Al-Tersawy [2012]	as fine aggregates 0% - 50%.	M40 M50 M60	The compressive strength, splitting tensile strength, flexural strength, and static modulus of elasticity decrease with the increase of recycled glass content. Poor contact between the cement matrix and the recycled glass, attributed to the decrease in bond strength between the cement paste and the recycled glass.
Sunny O.N. et. al. [2013]	as fine aggregates < 300 µm 5,20 & 30%	M20	Grind glass could enhance the properties of the final concrete product if used at the right level of replacement Water absorption increased with increased glass powder content.
AnkurMeena&Randheer Singh [2012]	as cement replacement (150-100)µm & (100-50)µm	M20	Smaller particle size of the glass powder has higher activity with lime resulting in higher compressive strength. Finer glass powder concrete had slightly higher early strength as well as late strength
Jitendra B.J et. al. [2014]	as cement replacement < 90 µm. 5 - 40%	M30	Strength point of view, replacement of GP shows positive results and 20% rep, gives higher strength Workability decreases as percentage of GP increases.
RahmatMadandoust& Reza Ghavidel [2013]	as cement replacement 75µm 0% - 20% GP and 0% - 20% RHA	M30	Concrete containing 10% GP and 5% RHA as cement replacements can be adopted as an optimal combination. In short term, the compressive strength enhancement for con.G10.R05 is lower than that of conventional concrete but shows the results of higher pozzolanic activity in long term activity Tensile strength will be increased with age due to the higher pozzolanic activity.
Shilpa Raju & Dr. P. R. Kumar [2014]	as cement replacement 45µm 0 - 40%	M20	Glass powder shows pozzolanic activity when particle size is less than 75µm. Enhancement of compressive strength Very finely ground glass has been shown to be excellent filler and may have sufficient pozzolanic properties to serve as partial cement replacement ASR appear to be reduced with finer glass particles, with replacement level

VitoldasVaitkevicˇius et. al.[2014]	as cement replacement 25.80µm QP/GP0 QP/GP100 QP/GP100SF/GP100 SF/GP100	—	Glass powder, when milled to particle size of cement, benefits the structure and properties of ultra-high performance concrete. Glass powder increases dissolution rate of Portland cement, thus hydration process is accelerated. Compressive strength (221 MPa) was observed in composition with combination of silica fume and glass powder.
Ahmad Shayan&AiminXu [2006]	as cement replacement >10µm - <15 µm 0%, 20% & 30%	M40	Both GP and glass aggregate can be used together in 40 MPa concrete without any adverse reaction.

VI. Conclusion

By reviewing the work done by various researchers to investigate the effect of glass on strength of concrete, the following conclusions are made:
1.Strength of concrete reduces when glass particle are used as fine aggregate in concrete.
2. Strength of concrete increases with reduction in particle size of glass powder.
3. Glass powder with particle size less than 75 micron shows the pozzolanic properties.
4. Compressive and tensile strength of conventional concrete increases when glass powder is used as partial replacement of cement. It is observed that the strength of concrete is optimum at 20 – 25% partial replacement of cement.
5. In self-compacting concrete strength properties as well as workability reduces with increase in content of glass powder.
6. Workability is found to be decreases in all types of concrete with increase in glass powder.

VII. Future Scope

It is recommended for future studies that the research on use of glass powder is require to extend to a wider perspective in order to know the actual behavior and effective utilization of glass powder which gives an idea to study more parameters and different governing effect of glass powder on engineering properties of fresh and hardened concrete. Hence future work can be extended as follow:
1. To know the effect of different type of glass powder on concrete strength
2. Effect of glass powder on high strength concrete.
3. Effect of glass powder on strength of concrete with various w/c ratios.
4. Effect of glass powder on strength of concrete with combination of glass powder with different strengthening agent.
5. To know the exact reason behind the increment in strength of concrete.
6. To know the effect of glass powder on bond strength between inter-materials and between materials and steel.

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