EFFECT OF PARTICLE SIZE OF RECYCLED GLASS ON CONCRETE PROPERTIES – A REVIEW

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Abstract— concrete is the most widely used man-made construction material. Globally, the concrete industry consumes large quantities of natural resources, which are becoming insufficient to meet increasing demands. It is obtained by mixing cement, water and aggregates in required proportions. Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere. Among the greenhouse gases, CO_2 contributes about 65% of global warming. In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Some of the industrial wastes like fly ash, silica fume, blast furnace slag etc have already established their usage in concrete. Recently the research has shown that the waste glass powder can be effectively used as a cement replacement material in concrete. Waste glass when grounded to a very fine powder shows some pozzolanic properties because of silica content. This paper presents review of the literature based on the effect of particle size of recycled glass on the properties of concrete.

Keywords— Glass Powder, Pozzolanic Properties, Compressive Strength, Tensile Strength, Workability.

I. INTRODUCTION

In day today life glass is used in various forms such as bottles, jars, windows and windshields, bulbs, cathode ray tubes, etc. It is a manufactured material for human use since 12,000 BC. The glass has limited service life and after its use it is generally dump in landfills. Since glass is non-biodegradable, landfills do not provide an environmental friendly solution [1]. Hence considering the social and environmental issues there is a growing interest in recycling the waste glass. The concept of utilizing waste material for building applications has a long and successful history, which includes fly ash, slag, and silica fume. Land filled waste materials are now considered valuable commodities for use in enhancing certain properties of concrete [2].

Use of waste glass as aggregate in concrete has been attempted by many researchers. Those early efforts were thwarted by the problem of alkali-silica reaction (ASR) [3]. It resulted into reduction in workability and strength properties of concrete [4]. The reduction in the workability may b due to flat and elongated shape of glass aggregate [5]. Ankur Meena & 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. It was observed that smaller particle size of the glass powder has higher pozzolanic activity resulting in higher compressive strength of concrete. Also finer glass powder concrete has slightly higher early strength as well as late strength [6]. Today the researchers are more interested to investigate the effect of finer glass powder on strength properties of concrete.

II. CHEMICAL COMPOSITION OF CEMENT AND GLASS POWDER

After reviewing the literature based on chemical properties of glass powder and cement the chemical composition is given in Table 1.

Table 1: Chemical Composition

Composition (% by mass)	Cement	Glass powder
Silica (SiO_2)	17 - 25%	50 - 80%
Alumina (Al_2O_3)	3 - 8%	1 - 10%
Iron oxide (Fe_2O_3)	0.5 - 6%	< 1%
Calcium oxide (CaO)	60 - 67%	5 - 15%
Magnesium oxide (MgO)	0.1 - 4%	< 1.5%
Sodium oxide (Na_2O)	0.5 - 1.3%	1 - 15%
Potassium oxide (K_2O)	0.5 - 1.3%	< 1%
Potassium oxide (K_2O)	1 - 3%	Nil

A. Effect of chemical composition of cement on strength of concrete.

The raw materials used for manufacturing of cement consist mainly of lime, silica, alumina and iron oxide. 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's compound.

Tricalcium silicate and diacalcium silicate are the most important compound responsible for early strength and 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 case in most of today's cement, will tend to have a higher early strength, and allow for early formwork removal or post 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 [7].

III. EFFECT OF PARTICLE SIZE OF RECYCLED GLASS ON PROPERTIES OF CONCRETE

Many attempts have been made by various researchers to utilize waste glass as coarse aggregates, fine aggregates or as a partial replacement to cement. The investigations were done with variation in particle size and proportions; in various types of concretes. Review of their investigation is tabulated as bellow:

Table 2: Effect of particle size of glass powder on properties of concrete

Name of author with year of publication	Particle size	% replacement to aggregate/cement	Concrete mix	conclusion
Ilker Bekir Topc¸u, Mehmet Canbaz [2003]	As coarse aggregate 4mm to16mm	15%, 30%, 45%, 60%.	M20	Reduction in workability, compressive and tensile strength of concrete. In particular, the compressive strength decreased as much as 49% with a 60% of WG addition.
Tung-Chai Ling, Chi-Sun Poon, Shi-Cong Kou[2011]	5-10 mm	25%,50%,75%,100%	---	Workability of concrete increases. Compressive strength and flexural strength gradually decreases.
M. Iqbal Malik, Muzafar Bashir, Sajad Ahmad, Tabish Tariq, Umar Chowdhary[2013]	Less than 4.75 mm	10%,20%,30%,40%	M25	20% replacement of fine aggregates by waste glass showed 15% increase in compressive strength. Splitting tensile strength decreases with increase in waste glass content.
Oliveira L.A Pereira de, Gomes J.P. and Castro Santos P	as natural sand replacement,	25, 50 and 100%	M40	The compressive strength increased for 28 days the increase was 24%, 25% and 29%.The compressive strength was increased with the waste glass sand rate in concrete.
Dr Sunny O. Nwaubani [2013]	Less than 300 microns	5%,20%,30%	---	Increasing amount of glass decreases workability and compressive strength of mortar.
Dhanraj M. Patil, Dr. Keshav K. Sangle[2013]	Less than 90 microns and between 90-150 microns	10%,20%,30%	M30	At 20% replacement of cement by glass powder meets maximum compressive strength as compare to that of normal concrete.
Bhupendra Singh Shekhawat, Dr. Vanita Aggarwal [2014]	Less than 90 micron	10%,20%,30%,40%	M20	Workability of concrete mix increases with increase in waste glass content.20% replacement showed increase in compressive strength. Splitting tensile strength increases at 10% of replacement.
Shilpa Raju, Dr. P. R. Kumar(2014)	Less than 90 microns	0% to 40% with an increment of 5.	M20	As the glass content increases workability decreases. Up to 20% replacement compressive strength increases; further addition causes strength decrement.
Dr. G.Vijayakumar, Ms H. Vishaliny, Dr. D. Govindarajulu[2013]	Less than 75microns	10%,20%,30%,40%.	M20	No adverse effect has been seen on workability. Compressive strength and split tensile strength increases at 20% replacement
M.N.Bajad et. al. [2014]	Less than 75 microns	5% to 40% with an increment of 5.	M20	Higher compressive strength and tensile strength achieved when 20% cement replaced by GP. Glass powder less than 75 microns shows pozzolanic activity.
Jitendra B. Jangid, Prof.A.C.Saoji[2014]	Less than 45 microns	5% to 40% with an increment of 5.	M30	Workability of concrete decreases as percentage of glass powder increases. Compressive strength of concrete increases upto 20% replacement of glass powder. Beyond 20% replacement of glass powder the compressive strength decreases.
Ahmad Shayan & Aimin Xu [2006]	Between 10 to 15 microns	0%, 20% & 30%	M40	At 28 days, only Mix containing 20% glass powder had met the compressive strength, flexural strength and tensile strength requirement of concrete.
Gunalaan Vasudevan, Seri Ganis Kanapathy pillay[2013]	Waste glass powder (WGP0	10%, 15%, 20%.	M30	Workability of concrete increases with increase in WGP content. Compressive strength will increase with increase in WGP content. Results show higher compressive strength for 20% WGP content.
J.M. Khatib, E.M. Negim, H.S. Sohl and N. Chileshe[2012]	---	10%,20%,30%,40%	M30	Slump value increases with increase in glass powder content. Compressive strength increases upto 10% variation of glass powder further variation decreases the strength.
A. Khmiri, M. Chaabouni, B. Samet [2013]	100-80, 80-40, <40 and <20 microns	20%	---	Glass powder less than 20 microns shows pozzolanic behavior

IV. SUMMARY

By reviewing the work done by various researchers to investigate the effect of glass on strength of concrete, following are conclusions can be made:

- When waste glass is used as aggregate, it shows ASR activity which adversely affects strength of concrete.
- As the particle size of waste glass reduces it helps in enhancing strength of concrete.
- A particle size less than 75 microns show pozzolanic activity.
- Increase in glass content as cement replacement material decreases the workability of concrete.
- Recycled glass can be incorporated as cement replacement up to 20%, further increment will decrease the compressive strength, flexural strength and split tensile strength.
- Addition of recycled glass reduces the water absorption of the concrete.

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