Review on Effect of Immersion Time on the Performance of Glass Fibre Reinforced Concrete with Glass Powder Immersed in Water

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Abstract: Concrete is the most widely used construction material in the world. It constitutes cement, aggregates and water. Production of cement causes emission of carbon dioxide and leads to global warming. Usage of cement in concrete can be reduced by partially replacing it with a suitable material. Glass powder is a waste material, which shows pozzolanic property. Dry or water immersed glass powder can be used as cement replacement in concrete. Calcium and sodium ions are formed when glass powder dissolves in water. Concentration of sodium ions decreases with immersion time as it bonds with silicon dioxide on the surface of glass powder particles. Increase in strength of concrete is obtained from the double effect of the development of pozzolanic reaction due to the increase of the free ions in the water before mixing with the concrete and the packing filling effect of glass powder. Fibre addition in concrete improves the engineering properties of concrete such as tensile strength, flexural strength, impact, fatigue and abrasion resistance, deformation capability, toughness and load bearing capacity after cracking. Glass fibre reinforcement in concrete results in higher flexural and tensile strengths as compared to normal concrete. This paper aims to review the literatures on glass powder in concrete and glass fibre in concrete. Glass powder and glass fibre in concrete enhances the mechanical properties of concrete.

Keywords — ***Durability properties, Glass powder, Glass fibre, immersion time, Mechanical Properties, Pozzolanic property.***

I. INTRODUCTION

Sustainable construction has great importance in the current situation. Sustainable concrete can be developed by using blended cement, supplementary cementitious materials etc. The main component of glass is silica. Use of grinded waste glass in concrete as partial replacement of cement will be an important step towards the development of sustainable concrete. Glass in its powdered forms is expected to undergo pozzolanic reactions with cement hydrates, forming secondary Calcium Silicate Hydrate (C–S–H).

Usage of water immersed glass powder can form more C-S-H in concrete, which is due to the hydrolysis of glass powder in to free ions of SiO_2, CaO and Na_2O in the water. When glass powder is added to water more sodium ions are formed due to the higher mobility of sodium ions compared to calcium ions. But the concentration of sodium ions will decrease as a function of immersion time as it bonds with the silicon dioxide on the surface of glass powder particles. The double effect of the development of pozzolanic reaction due to the increase of the free ions in the water before mixing with the concrete and the packing filling effect of glass powder will cause early development of compressive strength.

Usage of glass fibre in concrete improves compressive strength, tensile strength, ductility etc of concrete. Glass fibre reinforced concrete has many advantages such as lightweight, fire resistant property etc. Incorporation of glass fibre and water immersed glass powder in concrete may enhance the properties of concrete in terms of strength and durability.

II. REVIEW ON GLASS POWDER IN CONCRETE

Ghahremaninezhad et al. (2015) studied the effect of industrial by product recycled glass powder, consumer by-product recycled glass powder and fly ash on the mechanical and durability performance of concrete. They conducted concrete compressive strength and observed an increase in compressive strength with increase in industrial by-product recycled glass powder. But the compressive strength of concrete containing consumer by-product recycled glass powder concrete decreased with increase in glass powder content at earlier ages and increased with increase in glass powder content at later ages. From the rapid chloride permeability test they found that the addition

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of industrial by-product recycled glass powder and consumer by- product recycled glass powder with 5%, 10%, 15%, and 20% replacement levels reduced chloride permeability of concrete compared to the control concrete at all ages except for concrete modified with 5% consumer by-product recycled glass powder at 28 days of curing. Also reduction in chloride permeability values increased with increase in replacement levels of cement with glass powders.

Aboshama A Y et al. (2016) analysed the utilization of waste glass powder in the production of cement and concrete. They evaluated the pozzolanic activity of glass powder and properties of glass powder blended cement as concrete additive. They found that glass powder had pozzolanic characteristic and the use of glass powder had significant effect on setting time and cement expansion. Cement replacement up to 15% enhanced the properties of concrete modified with glass powder. Replacement of cement with 15% glass powder reduced the water absorption and void ratio. They found that glass powder fulfils the limits of class F and class C artificial pozzolanic materials. The increase of glass powder content in concrete increased the slump. They also found that use of glass powder more than 15% as cement replacement decreased the 28 day compressive strength.

Zheng K (2016) discussed the pozzolanic reaction of glass powder and its role in controlling the alkali silica reaction. He found that pozzolanic reaction of glass grains leads to a significant increase in sodium concentration in pore solution. The sodium concentration in pore solution for hydrated blend with fine glass powder reaches 730 mmol/l at 120 d, which is even higher than that of alkali solution (0.6 M NaOH) for acceleration of alkali silica reaction. So, chances of alkali silica reaction will be less.

Islam G. M. S et al. (2017) evaluated the performance of waste glass powder as partial replacement of cement for sustainable concrete practice. They analysed the chemical properties of both clear and colored glass. They determined the chemical analysis of glass and cement samples using Xray fluorescence (XRF) technique and found minor differences in composition between clear and colored glasses. They found a slight increase in mortar flow with increase in glass addition while a minor effect on concrete workability. Also they found that, with 20% replacement, there is an increase of 2% compressive strength than control concrete. Also 20% glass addition can save 14% cost of construction from cement itself and it will reduce production and release of 18% carbon dioxide in the environment.

Ismail S I et al. (2017) studied the effects of glass powder on the properties of concrete by conducting series of test for two constant quantities of cement, 350 and 400 kg per cubic meter. They concluded that there is an improvement of concrete strength at the age of 56 days with a value of 8% for 350 kg cement with 15% glass powder and 12% for 400kg cement with 12.5% glass powder. For normal concrete without plasticizer, the workability decreased with increase in rate of glass powder. But in case of using glass powder with water reducer, increased strength of concrete simultaneously with an improvement of workability was found.

Elaqra H et al. (2018) studied the rheological and mechanical properties of two types of cement by partially replacing it with different percentages of glass powder (0, 10, 20, 25 and 30%).They observed two trends in compressive strength, from 2 days to 28 days and from 28 days to 1 year. At early ages of 2 days and 7 days, there is substantial difference between compressive strength of control mix and other mixes. At 14 and 28 days, the difference in compressive strength is smaller as the pozzolanic reactivity of ions released from the glass powder increases. After 90 days 10 and 20% glass powder mixes showed compressive strength higher than the control mix and 25% glass powder mix showed compressive strength similar to the control mix.

Ke G et al. (2018) investigated the effects of different percentages and particle sizes of waste glass powder on alkali–silica reaction (ASR) expansion of cementitious composite bar. They found that waste glass powder with particle size less than 300 μm exhibits an excellent mitigation effect on ASR expansion. With larger content and smaller particle size, the mitigation effect of waste glass powder on ASR expansion gradually increased. Also waste glass powder with the particle size ranging from 38 to 53 μm showed the lowest ASR expansion at the different curing ages and the best effective mitigation effect on ASR expansion of cementitious composite.

Elaqra H A et al. (2019) proposed a new mixing method for glass powder as cement replacement in concrete and studied its effect on mechanical behaviour of concrete. They partially replaced cement with different percentages and the mixing was done in two ways. In conventional mixing method, they added glass powder with the cement and aggregates and in new mixing method, they dissolved the glass powder in water before adding it to cement and aggregates. They got higher compressive strength at 20% cement replacement and it is more in case of new mixing method. Also the mixes with higher glass powder content showed lesser porosity and water absorption rates. They concluded that the increase in compressive strength can be related to the hydrolysis of the glass powder into free ions of SiO_2, CaO and Na_2O in the water which causes the formation of more CSH.

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Abo-Hasseira A B et al. (2019) discussed the effect on mechanical properties of concrete containing glass powder immersed in water for different time interval. They investigated the mechanical properties by adding glass powder in different percentages with different immersion times. They found that the early compressive strength of concrete is due to the double effect of the development of pozzolanic reaction due to the increase of the free ions in the water before mixing with the concrete and the packing filling effect of glass powder. Also, the densification of the transitional zone between the cement paste and the aggregate leads to higher compressive strength.

Du S et al. (2019) experimentally studied the effect of glass powder in concrete based on compressive strength, elastic modulus, creep of concrete, and the internal microstructure is also determined by mercury intrusion porosimetry, scanning electron microscope and nanoindentation techniques. They concluded that the use of glass powder reduces the compressive strengths and elastic modulus at the early ages, but the use of glass powder content less than 20% increases the compressive strengths and elastic modulus at the later ages and it also reduces creep. From SEM images and pore structure analysis, they concluded that the use of glass powder content less than 20% can effectively improve the internal microstructure of concrete at the later ages due to the pozzolanic reaction and microfiller effect of glass powder. Also glass powder content beyond 20% degrades the microstructure of concrete.

III. Review on Glass Fibre in Concrete

Akca et al. (2015) conducted an experimental study to compare the mechanical properties and fracture behaviour of basalt fibre reinforced concrete and glass fibre reinforced concrete. They added four different volume fractions (0.25, 0.5, 0.75 and 1%) of glass fibres and basalt fibres and prepared glass fibre reinforced concrete and basalt fibre reinforced concrete respectively. They observed the highest compressive strength of 67.6 MPa at 0.75% glass fibre in glass fibre reinforced concrete. The compressive strength of plain concrete was 63.4 MPa. There was no increase in flexural strength of concrete after the addition of 0.50 volume fraction of glass fibre. An increase of 50% fracture energy is observed at 1% volume fraction of glass fibre.

Deo S V (2015) conducted a parametric study of glass fibre reinforced concrete. He studied the effect of glass fibre and loading on the durability of concrete. To know the effect of loading on structures under service, on the durability of concrete, He loaded cubes to 60 % of the expected ultimate load, as it open the cracks already existing in the concrete and create more cracks.He found an increase in strength parameters and a reduced slump in glass fibre reinforced concrete. He concluded that the durability of concrete could be increased by addition of a small dose of 0.025 % of glass fibre by weight of cement.

Khan M M et al. (2017) discussed and compared the effect glass fibre and glass powder in concrete based on strength parameters. They used glass powder in different percentages from 10 to 20 and added glass fibre in 1.5 and 2% by weight of cement. They concluded that both glass fibre and glass powder can be used to enhance the strength properties of concrete, but glass fibre concrete gives better strength and workability than glass powder concrete. they found maximum compressive strength at 1.5% glass fibre in glass fibre concrete and they found the optimum percentage of glass powder as 15 in glass powder concrete.

Kasagani H et al. (2018) discussed the effect of graded fibres on stress strain behaviour of glass fiber reinforced concrete in tension. Different percentages of fibre with different lengths are added to the concrete. Short length fibres primarily control the propagation of micro cracks, and improve the ultimate strength whereas, long length fibres arrest the macro cracks and improve the post crack deformation of concrete. They conducted optical microscopic study and an image analysis technique to examine the failed specimens of glass fibre reinforced concrete for the purpose of studying the effect of graded fibres on tensile strength. The results of image analysis showed that the strength of fibre reinforced composite are dependent on the fibre efficiency characteristics. They found that graded fibres improved the workability of glass fibre reinforced concrete. Also they found that short length fibres contributed more tensile strength but long length fibres contributed more deformation capacity.

Ali B et al. (2019) investigated the influence of different percentages of glass fibres on mechanical and durability properties of concrete mixes containing different percentages of recycled aggregates. They produced three types of concrete mixes using 0% RCA, 50% RCA and 100% RCA, in each of these three mixes, 0.25, 0.5, 0.75 and 1% volume fractions of glass fibres are added. The compressive strength of concrete mixes containing NCA (0% RCA) increased up to a glass fibre content of 0.75% volume fraction. They conducted the split tensile strength test and found increase in tensile strength up to 0.75% glass fibre content in the case of concrete mixes containing NCA. They conducted the flexural strength test of concrete and found significant increase in flexural strength of concrete in the case of concrete mixes containing NCA. But flexural strength decreased with increase in glass powder content in the same case.

IV. Conclusions

From the literature review following conclusions are drawn. The use of 15% glass powder as cement addition increased the compressive strength by 15%[2]. The use of glass

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powder up to 10% increased the mortar compressive strength by 9%[2]. Concrete modified with glass powder exhibited improved resistance to chloride permeability [9]. Concrete containing glass powder resulted lesser compressive strength than control mix at earlier ages and more compressive strength than control mix at later ages. But concrete containing water immersed glass powder showed more compressive strength than control mix at all ages. This is due to the pozzolanic activity of glass powder. In case of concrete containing glass powder, pozzolanic reaction takes place at later ages. But in case of concrete containing glass powder immersed in water, pozzolanic reaction starts at earlier ages due to the dissolution of ions[1,7]. The concrete tensile strength modified with glass powder is about 9-13% of compressive strength[2]. Short length fibres(3mm+6mm) contributed more tensile strength to concrete[2].Concrete containing 0.25% glass fibre content increased the flexural strength by 26%[4].

Water immersed glass powder when added to concrete contributed early compressive strength. Alkali resistant glass fibre when added to concrete gave better strength and durability properties. So the incorporation of water immersed glass powder and alkali resistant glass fibre together in concrete may give a sustainable concrete with better strength and durability properties.

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