A Review on Bond Strength of GGBS Based Geopolymer Concrete

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Abstract— This article aims to discuss the literature review on Bond Strength of GGBS based Geopolymer Concrete. Concrete is the most popular material used in the construction works in which cement is the main composite. The manufacturing of cement involves the emission of greenhouse gases into the atmosphere which are responsible for global warming. Hence the researches are currently focused on various materials to replace and reducing the usage of cement. In this study Geopolymer concrete is prepared with Ground Granulated Blast furnace Slag (GGBS) with the addition of steel fibers. GGBS is the by-product produced from steel industry. Steel fibers are added to increase the tensile strength of concrete. Hence it is carry out the research on GGBS based Geopolymer concrete by used sodium silicate as alkaline activate and various factors affecting it. This paper includes the study of various GGBS and Fly ash or any other waist based Geopolymer concrete research paper and to analyse the method which respected authors used.

Keywords: Geopolymer concrete, Bond Strength, Compressive strength, ambient curing, steel fibre

I. INTRODUCTION

A. General

Concrete is the most widely used construction material in the world. Ordinary Portland Cement (OPC) has been traditionally used as the binding agent for concrete. The worldwide consumption of concrete is estimated to increase due to the increase of infrastructure in countries such as India and China. About 1 ton of carbon dioxide is released to the atmosphere during the manufacture of 1 ton of cement. Globally, the cement production contributes about 7% of the world's carbon di-oxide. The worldwide annual cement production is estimated as 2 billion tons at present and is expected to increase to 4 billion tons in 30 years from now. In order to control the effect of global warming, it is necessary to reduce the emission of CO_2 gas to the environment. The use of an alternative low-emission binding agent for concrete will help reduce the environmental impact of manufacturing of cement. Geopolymer is an alternative material that can act as a binding agent in concrete. The geopolymer binder contains no cement and thus will help enhance sustainability to construction industries.

Compressive strength itself is not the property of concrete to explain the performance of concrete. Concrete failure will always develop in weakest part of one of these three phases namely: aggregate zone, transition zone and hydrated cement paste. Thus, in order to increase the compressive strength of concrete, great care must be taken to strengthen all these three phases. It also depends on the microstructure features of concrete which govern the other properties like compressive strength, bond strength etc.

The knowledge of bond behaviour between reinforcing steel and concrete is critical to the design of reinforced concrete structures. Bond behaviour is the interaction of the reinforcing bar with the concrete. This is described as the transfer of forces from the reinforcement to the surrounding concrete by adhesion between the bar and concrete, frictional force at the interface and bearing of the ribs of deformed bars against the concrete. The adhesion depends on the bar surface condition and the type of concrete. Bond resistance is governed by several factors such as compressive and tensile strengths of concrete, the concrete cover to the bar, confinement due to transverse reinforcement, surface condition of the bar and bar geometry. Structural performance of reinforced concrete members depends on the bond between concrete and the reinforcement. The design provisions of reinforced concrete as a composite material utilize the bond strength between the two materials. The commonly used steel reinforcing bars have been developed for use with OPC concrete. Since geopolymer binder is chemically different from OPC, it is necessary to understand the bond properties between geopolymer concrete and steel reinforcement. This paper studied the bond strength of fly ash-based geopolymer concrete by using pull-out tests. A comparison is made between the bond strengths of geopolymer and OPC concretes with reinforcing steel

The literature survey related to the project bond strength of GGBS based Geopolymer Concretet was undertaken to get acquainted process adopted with the same. Technical articles published in the proceedings and other journals have been referred to determine the further scope of the work and to understand the status of each work undertaken. It has been also noted that many researches and work on GGBS based Geopolymer concrete development process.

B. Need for the Study

It is evident from current scenario that OPC is causing considerably environmental hazards such as increasing global warming by releasing greenhouse gases and enormous consumption of power and raw materials for production of OPC. Need for this study is to find the alternative of OPC to solve these problems.

To find an alternative for the OPC in concrete.

1) To reduce CO2 release and produce eco-friendly concrete mix.
2) To produce a price efficient product.
3) To produce high strength concrete than ordinary Portland cement concrete.
4) The bond strength of GPC is about four times higher than the corresponding standard concrete.

C. Bond Strength of Geopolymer Concrete

Bond stress is the shear stress that acts at the interface of bar and concrete and helps in transfer of load from concrete to steel due to adhesion, frictional resistance and mechanical resistance. Bond strength is determined by factors like surface condition of bar, concrete strength and development length. Flexural bond and anchorage bond are the two types of bond. Steel and concrete act together by flexural bond which acts along bar length. The bond at bar cut off point that causes slippage between steel and concrete is anchorage bond. The length of the extended bar in concrete to transmit force effectively from bar to concrete is known as development Length (Ld). As per IS 456.

II. LITERATURE REVIEW

An attempt has been made in this chapter to make a review of the available relevant to the topic of study. Considerable amount of literature is available on the response characteristics of GGBS based geopolymer concrete and fly ash with other waste products such as red mud, palm oil fuel ash, rice husk ash based geopolymer concrete but the literatures on the only GGBS based geopolymer concrete are very limited. Among the study done in the field of GGBS based geopolymer concrete, some of them are as follows:

Joseph Davidovits et al.(1994) stated in geopolymer concrete Geopolymerization is the main process involves a chemical reaction between alumina-silicate oxide present in source material and alkali silicates of alkaline activator solution yielding a three dimensional polymeric ring structure consisting of Si-O-Al bonds. For chemical designation, this alumina-silicate based geopolymer was named as isolated. Isolated is an abbreviation for silicon-oxo-aluminates. The isolate network consists of SiO_4 and AlO_4tetrahedral linked alternatively by sharing all the oxygenIn 1978, Joseph Davidovits coined the term geopolymer to denote a wide range of materials characterized by networks or chains of inorganic molecules. He has suggested that an alkaline activator solution could be used to react with Silicon (Si) and Aluminium (Al) present in a source material of geological origin or in by-products of several industries such as ground granulated blast furnace slag, fly ash and rice husk ash to produce binders These are fundamentally inorganic alumino-silicate polymers synthesized from a fast chemical reaction called „Polymerization‟. Due to geological origin of silicon and aluminium and polymerization reaction it is termed as geopolyme.

G. Duxson et al. (2006) stated importance of geopolymer concrete as the availability of other material and their effect for production of cement. the structures are reinforced with steel lot of steel demand is there, due to this iron production industries is more, from this industries slag is disposed and the slag is converted to ground granulated blast furnace slag (GGBS). As a civil engineer we know the problem of cement manufacture emits carbon dioxide in to the environment which is almost equal to its production. For the production of the cement lot of energy consumption is required i.e. lot of fossil fuels are consumed.

B. Vijaya Rangan et al.(2010) discuss Geopolymer concrete is made by fly ash, GGBS with alkali activation and special concrete is prepared. The energy required for the manufacture of cement based concrete is very large than the energy required for the manufacture of geopolymer cement, this is effecting the environment .Where the concrete i.e. ordinary Portland cement concrete (OPCC) is not suitable at that conditions special concrete with good durability aspect is preferred, such alternative concrete like geopolymer concrete is in needed.

Mehta et al. (2006) stated the properties of geopolymer concrete but the compression strength itself is not the property of concrete to explain the performance of concrete. Concrete failure will always develop in weakest part of one of these three phases namely: aggregate zone, transition zone and hydrated cement paste. Thus, in order to increase the compressive strength of concrete, great care must be taken to strengthen all these three phases. It also depends on the microstructural features of concrete which govern the other properties like strength, elastic modulus and durability

Deepak et al. (2010) discuss any material that contains mostly Silicon (Si) and Aluminium (Al) in amorphous form is a possible source material or binding material for the manufacture of geopolymer. Several minerals and industrial by-product materials have been investigated in the past and concluded that metakaolin or calcined kaolin, low-calcium fly ash, combination of calcined mineral and non-calcined materials, combination of fly ash and metakaolin, and combination of granulated blast furnace slag and metakaolin can be used as source materials

Hardjito et al.(2005) claims that claimed source materials like fly ash, slag (GGBS), claimed kaolin, and demonstrates a higher final compressive strength when compared to those made using non-calcined materials like kaolin clay, mine tailings, and naturally occurring minerals.

Panagiotopoulou et al.(2007) discussthe amount of dissolution of GGBS is more than the amount of dissolution of fly ash Therefore, in the present study GGBS is used as a source material which is rich in silica and alumina.

Petermann et al.(2010) suggest the activation of the selected pozzolanic material is the most significant factor in producing a mechanically-sound cementitious material via the geopolymerization process. The initial mechanism of reaction is driven by the ability of the alkaline solution to dissolve the pozzolanic material and release reactive silicon and aluminium into solution. The activators prompt the precipitation and crystallization of the siliceous and aluminous species present in the solution. OH- acts as a catalyst for reactivity, and the metal cation serves to form a structural element and balance the negative framework carried by the tetrahedral aluminium.

Xu et al.(2000) discuss about the binding properties sodium silicate material how to bind the material .the addition of sodium silicate solution(Na_2SiO_3) to the sodium hydroxide (NaOH) solution as the alkaline liquid improved the reaction between the source material and the solution. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

Nuruddin et al. (2011) stated the mixing process can be divided into two stages, dry mix and wet mix. Initially coarse aggregate, fine aggregate and GGBS will be mixed together in rotating pan mixer for 3 to 5 minutes. The alkaline solution is prepared by mixing sodium hydroxide solution with sodium silicate solution one day before making the geopolymer concrete to get the desired alkaline solution. The liquid part of the mixture, i.e., the alkaline solution, extra water and the superplasticizer, should be premixed thoroughly and then added to the dry mixture. The wet mixing can be done for 1.5 to 3 minutes. The process of mixing is depicted. Fresh geopolymer concrete is then hand mixed to ensure the mixture homogeneity. The aluminosilicate gel is highly viscous and mixing agitation can easily encapsulate air into the matrix. Mechanical vibration of the formed molds serves to reduce this potential and greatly improves the overall strength of the hardened geopolymer concrete.

Mustafa et al. (2011).Discuss curing process of geopolymer concrete can be achieved by: oven curing (30-90 °C), hot gunny curing (33-38 ºC), ambient curing (27-32ºC), and external exposure curing (39-44 ºC). Special curing techniques like steam curing at temperature of 600C for 24 hours followed by air curing in a control environment with a temperature of 23-2 ^{0}C until testing can also be followed. There is an increase in compressive strength with the increase in age for ambient cured specimens.

Vijai et al. (2014) discuss increase in compressive strength with age is very less as compared to that of specimens subjected to ambient curing for hot cured samples. The rate of increase in strength will be rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate. Therefore, heat-curing time need not be more than 24 hours in practical applications. Heat-curing can be achieved by either steam-curing or dry-curing.

Rangan et al.(2006) stated that range of temperature 25-35°C can be provided by the ambient curing conditions in tropical climates. So, in the present study the adopted curing regime is only restricted to ambient curing. As there are no standard codes established for the mix design of geopolymer concrete in any part of the world, so for the mix design process is carried on basis of some of the following thumb rules like density of concrete as 2400kg/m^{3}, quantity of total aggregates as 80% of the total constituents, coarse aggregate content as 70-75% of total aggregates.

Zongjin, Li. Et al. (2007) found that the incorporation of slag could significantly increase the compressive strength of the geopolymer at 30°C ambient curing. The incorporation of steel fibres in Geo-Concretes reduces the compressive strength at early ages. On the contrary, the splitting tensile strength, the flexural strength and the toughness increase significantly.

Susan et al. (2006) concluded the strengths and the toughness of Ordinary Portland Cement Concretes with the same proportion of binder and fibers were lesser than the Geo-concretes reinforced with steel fibres.

Sivakumar et al. (2014) stated the mechanical properties like compressive, split tensile and flexural strength will be improved with added of polypropylene fibre. Test results of Srinivasan showed that 100% GGBS binder composition with 0.25% polypropylene fibres has shown better performance.

Chanh et al. (2008) concludes that geopolymer concrete is suitable for tough environmental conditions and seawater can be used for the blending of the geopolymer cement which can be useful in marine environments and on islands short of fresh water.

Alehyen et al. (2017) stated the microstructure of geopolymer concrete shows a highly complex product morphology that consists of unreached, partially reacted, and completely reacted fly ash spheres that are surrounded by a matrix which also includes quartz crystals and mullite needles originating from the fly ash. The bigger fly ash particles are almost dissolved or reduced to smaller size at higher silica content showing denser and finer microstructure as a result of geopolymerization, which indicates a higher degree of reaction resulting in increasing compressive strength. Therefore, the compactness of the microstructure indicates the proper dissolution of Si and Al due to which good binding has been developed between binder and aggregates; resulting in higher strength of concrete. However, many of the works related to microstructure are with geopolymer concrete with fly ash as binding material. Hence it is needed to understand the microstructure property of geopolymer concrete made with GGBS. Microstructure also helps to predict the reason for the failure of concrete with durability issues in different environments.

Ganesan et al. (2013) showed from the experiments that addition of steel fibres improved the mechanical properties of GPC in the case of compressive strength, splitting tensile strength, modulus of rupture, modulus of elasticity and Poisson’s ratio at 1% volume fraction of fibres.

Amuthakkannan et al. (2013) showed the improvement in tensile, impact and flexural strength with different fibre length and fibre content of basalt fibre. But still there is need to study the effect of fibres on geopolymer concrete as many of the works concentrated only on mechanical properties for fibre reinforced geopolymer concrete.

III. Conclusion

The study of various research papers is caring out been caring out. Most of the authors is done research on GGBS and fly ash with other waist. There are many factors influencing the overall development process. These factors affect the durability, compressive strength, bond strength etc. The Geopolymer concrete exhibited high bond strength. The Bond strength of GPC is in the order of about one third of the corresponding compressive strength. The bond strength of GPC is about four times higher than the corresponding standard concrete.

The compressive strength of the geopolymer concrete made with steel fibers is higher than the geopolymer concrete made without steel fibers. It is clear that as the Na_2SiO_3 solution increases the compressive strength also increases. The load carrying capacity of the beams made with steel fibers is higher.

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