Hurdles with self–cured Geopolymer Composites in Indian scenario

Mayank Gupta*, N.H. Kulkarni
Shri Guru Gobind Singhji Institute of Engineering and Technology, Vishnupuri, Nanded (Maharashtra) Pin: 431 606 [India]

* mayank40gupta@gmail.com

Abstract. Ordinary Portland cement (OPC) production is boosting global warming very speedily. Therefore, geopolymer concrete is receiving huge attention as an alternative to traditional concrete because it develops without the use of OPC. Majority of the previous publications suggest that high-temperature curing required to gain higher mechanical strength and better durability properties, which is not feasible for cast-in-situ work. This obstacle has been overcome by adding calcium oxide and reducing silicon dioxide in the geopolymer. In addition, geopolymers also confront many other problems such as cost of construction, efflorescence and utilization of harmful chemical etc. that can’t be easily overcome. This literature makes an effort to identify some hurdles with the geopolymer composite in the Indian scenario. It concludes geopolymer composites will take some more time to completely replace conventional composites and requires some more improvement.

Keywords – Geopolymer, efflorescence, limitations, ambient cured, self–cured.

1. Introduction
Nowadays, construction industries are focusing on the development of green and sustainable buildings because of the high energy consumption and greenhouse gas emission by the manufacturing of OPC. The manufacturing of one-ton cement emits approximately the same amount of CO2 to the atmosphere. It was estimated that 5-8% of the global greenhouse gases production is done by the cement industry alone which is second largest in terms of greenhouse production industry [1,2]. It has also been observed that for the last two decades, the productivity of industrial and agricultural waste augmented with high leaps and bounds, which is also a concern for researchers from various fields that how it could be reduced, reused and recycle that waste. A. Pappu et al. [3] anticipated that annually 290 MT and 350 MT wastes will be generated through industry and agriculture respectively, by only India. Various government from all over the world are providing some guidelines for lowering the quantity of waste materials. Now, as a civil engineer and a resident of the earth, the production of cement has to be reduced and the use of by-products in concrete will have to increase. Hence, the majority of the researchers are endeavoring to productize green and sustainable concrete, by exploiting a variety of agricultural and industrial by-products.
Geopolymer composites to be an alternative to conventional composites in recent years, as this alternative material neglects or reduces the use of Portland cement for construction purposes. Geopolymer binders are produced by the alkali activation of aluminosilicate source materials such as fly ash (FA), ground granulated blast furnace slag (GGBFS), iron making slag, rice husk ash (RHA), red mud, cement kiln dust, metakaolin etc. Previous research reported this material has the potential to tackle the concerns of the housing sector and waste management [4–6]. The word "geopolymer" was firstly invented by Joseph Davidovits in 1978 [6]. Geopolymers are 3-dimensional frameworks of aluminosilicate inorganic polymer, constituted through polymerization of the industrial and agricultural by-products (ample with alumina and silica) in the presence of alkaline solution. Many different types of aluminosilicate materials such as feldspars, kaolinite and industrial and agricultural solid residues such as iron and steel slag, mining waste, ashes of various fields, etc. are employed in the geopolymerization process. Activation is required for geopolymers for the polymeric reaction, which could be accomplished with potassium or sodium based silicate and hydroxide alkaline compounds [6,7].

Geopolymer composites emit approximately 9% less CO2 gas compared to the conventional composites and consume waste and by-products, therefore it can be considered as green and sustainable composites [6,8], along with this geopolymer binder have various other benefits, like compressive strength more than 120 MPa, better resistance to corrosion, water, temperature, harmful acid, etc., low creep and drying shrinkage, early compressive strength, etc. [4,9,10] compared to the conventional concrete, which constraints construction industry and researchers to think that it can be a perfect alternative to ordinary concrete. The application of geopolymers in various construction fields such as urgent repairs works, nuclear waste disposal plant, road pavements, retaining wall, interlocking block, coating, concrete pipes, water tanks, boat ramps, etc. was reported by numerous authors [9–11].

On the geopolymer, composites sufficient work has been done and also reviewed by various authors and they informed that geopolymer composites can be a probable alternative of the traditional composites [4–7,9–12]. But still, geopolymer composites is not being utilized by the construction industry because of some limitations or hurdles. Therefore, the prime objective of present literature is to discuss some hurdles and limitations of the geopolymer composites, focused solely on self-cured geopolymer composites in the Indian scenario.

2. Hurdles

The key ingredient of the conventional concrete binder is cement when cement mixed with water than a uniform mix obtained, known as conventional concrete binder whereas the prime constituent of geopolymer binder is aluminosilicate rich material when this material assorted with the solution of silicate and hydroxide of sodium or potassium then a homogeneous mix attained, considered as geopolymer binder. When these binders are mixed with fine and coarse aggregates, the composite material is known as concrete. To achieve higher strength and better durability properties, geopolymer concrete needed high-temperature curing [4,13] which is the main limitation of the geopolymer concrete which is conquered by utilizing GGBFS, RHA, etc. as an aluminosilicate material [14,15]. Employing GGBFS, RHA, etc. as aluminosilicate materials have enabled the development of self-cured geopolymer concrete. But, self-cured geopolymer composite also has some other hurdles which restrict the high utilization of that material in India.

2.1 Problems with aluminosilicate material

The production of self-cured geopolymer composites required aluminosilicate material (in which calcium content is more) such as GGBFS, metakaolin, RHA, etc. These materials are not easily available in every
city of India, only some states like Jharkhand, Odisha, Karnataka, etc. are having more amount of aforementioned materials [16]. For the construction work, the client has to pay high transportation charges for utilizing the byproducts, which increases the total expense of construction. It has been observed that aluminosilicate source materials extracted from different sources do not have identical physical and chemical properties, thereby requiring different dosages of chemical activators, curing processes, etc. for each origin [9,12]. Another problem with the aluminosilicate material is the small particle size, which reduced the workability of the self-cured geopolymer concrete [4]. G. Fang et al. [17] informed that flow value and slump was reduced because of the angular particle size of the GGBFS compared to the spherical particle shape of fly ash material but the inclusion of GGBFS reduced the setting time of the mixtures. In addition to that Y.J. Patel and N. Shah [15] reported that higher surface area was also a cause for reduction of the workability because these aluminosilicate materials imbibe more water compared to the fly ash material.

2.2 Problems with alkaline activator

The alkaline activators are required for the geopolymerization of the aluminosilicate materials. The solution of Sodium/potassium hydroxide and sodium silicate were commonly used as an alkaline activator. The combination of sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) are frequently used to react prime constituents of the source materials like aluminium and silicon because the alkaline and silicate ions are more soluble with sodium hydroxide compared to the potassium hydroxide [18]. The production of the alkaline activators such as NaOH and Na2SiO3 requires 20.5 and 5.37 MJ/ kg high intensive energy which is more than the embodied energy desired for the OPC, and contribute around 60% to the overall carbon footprint [8].

Similar to the aluminosilicate materials, the availability of activators also a little bit complicated. It was observed that activators are the most expensive constituent in the geopolymer composites as sodium silicate is mostly available in liquid form, leading to increased transport charges. Other than availability, the purity or grade of these materials also influences the mechanical and durability of the self-cured geopolymer composites [19,20]. Therefore, skilled labour is necessary to obtain a perfect and homogeneous mixture which is usually impossible in India.

2.3 Problems with curing

Heat curing is necessary for geopolymer concrete to achieve the best results, which is impossible to use at the construction site [4,6,12]. Some literature [2,15,21] suggests that geopolymer composites could be developed in ambient condition by utilizing some industrial and agricultural waste like GGBFS, RHA, etc. but achieving ambient temperature (most of the researchers consider as ambient temperature 20–300C) again a constrained for regular practice, because of the temperature diversity in India, such as less than 100C in winters, more than 400C in summer and in rainy season temperature variation too high. Therefore, there is a need for more research work on the development of self-cured geopolymer concrete.

2.4 Efflorescence
The establishment of white or grey coloured salt on the surface of the concrete is considered as efflorescence when the surface is exposed to humid air. The presence of the high alkali minerals such as sodium hydroxide in the geopolymer composite originates an endogenous and spontaneous process in the wet environment, which form the efflorescence [6]. The rate of development of efflorescence in the ambient curing condition is high compared to the heat curing because the alkaline solution reduces the dissolution rate of the fly ash in the low temperature [22]. Efflorescence is not only a surface issue, but it can also be responsible for structural changes that lead to a reduction in strength [6]. Therefore, now the focus of researchers should be on the reduction of the cause of efflorescence in the self-cured geopolymer concrete.

2.5 Health and Safety

The aluminosilicate source materials and alkaline activators are the prime ingredients of the geopolymer composites and also the main cause of health issues to the persons those are present on site. Appropriate safety measures for workers such as hand gloves, mask, shoe, etc. are mandatory for working with geopolymer which is usually ignored by many construction sites in India. The alkaline activators may create different types of health issues like itching and irritation of skin, eyes and mucous membranes of the respiratory system, to the workers [2]. To work on geopolymer, the authors would like to suggest that a training program on health and safety should be mandatory for individuals who would be involved in geopolymer work.

2.6 Standard code of practices

In India, IS 456 [23] and IS 10262 [24] has been providing guidelines for the development of the OPC based concrete. However, no standard codes and guidelines are available for the production of neither for self-curing nor heat-cured geopolymer concrete, which becomes a barrier for the geopolymer composites to achieve higher mechanical properties and better durability properties on the field [4,9,25]. M.S. Reddy et al. [25] reported that there is a complexity to the preparation of the standard codes and guidelines in geopolymer composites due to the presence of several influencing factors such as concentration, dosage and quality of activators, water-to-solid ratio, pH of alkaline ingredients, the amount of aluminosilicate material, mixing time, rest periods, etc. Till date, some authors [25–28] try to develop a standard code for the Indian condition but they consider few guidelines which are used for the conventional concrete. Along with that, some researchers like [25], fixed some factors before starting the mix design process, which makes it difficult to achieve consistent results every time, particularly when the properties of raw materials vary.

3. Concluding remarks

Geopolymer composites proposing a good perspective to the employment of industrial and agricultural by-products. Past literature provides the idea that geopolymer composites may be a better alternative to traditional composites due to their superior or comparable properties. This literature focuses on the limitation or hurdles with the self-cured geopolymer composites particularly concentrate on the Indian scenario. Apart from the aforementioned issues, self-cured
geopolymer composites also have few other hurdles such as the effect and employment of the chemical admixture, long-duration durability properties, less study related to the geopolymer based structural elements, etc. The authors found that no research discuss the effect of high chemicals utilization on the health of persons who will reside or involved with a structure made with geopolymer composites. To promote the acceptance of the self-cured geopolymer composites by the citizens of India, standard codes and guidelines should be prepared, urgently. Lastly, it can be concluded that still, geopolymer composites required more time and further research to become a perfect alternative to the conventional concrete composites.

Conflict of interest

None.

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