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Does Geopolymer Concrete have the Scope of Effective Utilization in Rigid Pavements? - A Definite Review

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Abstract

Rigid pavement construction primarily resorts to the utilization of concrete incorporating cement as the integral material. The carbon footprint associated with cement production engendered the conception of modern binders in the construction industry. Furthermore, the substantial amount of waste generation in conjunction with the rapid depletion of natural resources conceived its effective utilization in the pavement sector. Geopolymer concrete (GPC) is the modern binder whose scope in rigid pavement construction is being studied extensively considering its sustainability and performance. Although research portrays comprehensive study on various wastes as the aluminosilicate source for synthesizing geopolymers, yet its application in rigid pavements is rather a newer approach as compared to structural members especially in the Pavement Quality Concrete (PQC) layer. This review presents a precise scenario of GPC utilization in pavements and is definite and specific in terms of its representation. The idea of this article is to introduce the readers to an alternative binder that is relatively contemporary and effective when used in rigid pavement construction.

Keywords: Geopolymer Concrete; Rigid pavements; Curing; Flexural strength

Introduction

Sustainable construction practices are the need of the hour. Any initiative fostering the reduction of carbon footprint leading to global warming is of unequivocal relevance. With ever-increasing demand driven by environmental protection and subsequent waste re-utilization, several initiatives have been undertaken in the construction industry to effectively utilize them as alternate binders. The primary material constituent for producing geopolymer concrete (GPC) is the activation of an alumina-silicate source using alkaline hydroxides and silicates [1]. Geopolymerisation basically involves a three-step mechanism commencing with the dissolution of silica and alumina from the source materials followed by coagulation and gelation of the dissolved materials which subsequently polymerizes to form 3-D networks of silica aluminates structures [2]. Structures may be in the form of polysialate (Si:Al=1), polysialate siloxo (Si:Al=2), and polysialate disiloxo (Si:Al=3). The geopolymerisation reaction mechanism is depicted in (Figure 1). The constitutional role of the alkaline activators is to activate the source components like fly ash (FA), Ground Granulated Blast Furnace Slag (GGBS), Silica Fume (SF), Red Mud (RM), Glass Powder (GP), etc. Thus, it may be inferred that the geopolymeric system is fundamentally re-utilizing the supplementary cementitious materials and takes a way forward towards sustainability and eco-friendliness [3].

Performance Analysis of Geopolymer Concrete

Aguilar et al. [4] investigated the compressive and flexural strength development of metakaolin-based geopolymer concrete and reported the formation of dense microstructure and a solid interfacial zone. The developed strength was well within the requisite standard specifications. He et al. [5] observed an interesting shift from ductile to brittle failure for longer cured RM-based geopolymeric binders. Moreover,

RM-GP exhibited stabilized strength values after 21days of curing as compared to 7days of metakaolin (MK)-GP blends. It has been further reported that RM can be a probable source modifier owing to its high pH value, richer alumina content, and leaching characteristics [6]. Geopolymerisation is accelerated due to the adequate reaction of the activator with activated alumina contributed by RM [7]. It has been reported that the enhanced geopolymerisation reaction could be achieved when the curing temperature is between 40˚C- 85˚C [8]. The mechanical properties and strength development of geopolymer concrete are primarily dependent on the curing temperature and are directly proportional. [9]. Research on fly ash-based geopolymer systems exposed to curing at elevated temperature exhibited almost six times the compressive strength obtained from ambient cured specimens at 7 days and nearly double strength increment at 28 days [10]. This method of curing is apt for precast geopolymer specimens. Hence, to overcome the challenges of site application of oven-cured geopolymer concrete, research is now being oriented towards the production of this modern concrete at ambient temperature. The age of curing is a significant parameter influencing the compressive strength developed. For oven-cured specimens, increased curing time had a negligible effect on compressive strength improvement but was a vital criterion for ambient-cured specimens [11]. Though a significant number of studies based on the utilization of wastes had been conducted in the past, yet there is a lack of clear understanding of how the different curing techniques can affect the performance properties of mix prepared by varied combinations of the recycled wastes.

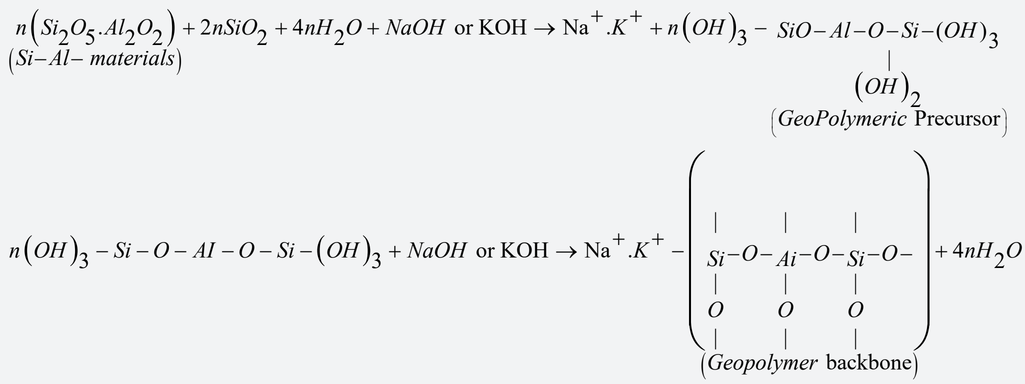

Figure 1: Reaction mechanism of geopolymer formation.

Sustainable use of Geopolymer Concrete in Pavement Layers

The recycling of industrial wastes in the geopolymer matrix, contributes to environmental balance and stability. Literature has shown promising results of geopolymer concrete performance with regards to strength and durability, exhibiting higher strength, better resistance to elevated temperature, limited shrinkage, dense microstructure, and enhanced performance in acidic and sulphate medium. It may be contemplated that the stresses induced in concrete pavements are predominantly flexural. Therefore, designing mixes based on flexural strength criterion is considered for rigid pavement construction. The minimum characteristics flexural strength of concrete shall not be less than 4.5MPa unless otherwise specified [12]. Comprehensive studies have reported that geopolymeric binders are capable of attaining the desired strength when designed considering the influence of strength affecting parameters precisely.

For pavements, consideration of durability is obligatory in predicting the service life since they are exposed outside, often in harsh environments. Various researchers have studied the durability properties of rigid pavements through resistance to acid attack, alkaline silicate reaction, and freeze and thaw cycles [13-15]. Particularly, the resistance of geopolymers to sulfuric acid has been examined due to the frequent exposure of concretes to acid rain, sewage, and sulfur-rich soils [16,17]. The majority of the past research works included durability studies on metakaolin-FA-GGBS based geopolymer concrete with limited literature on synthesis using RM and other wastes.

Conclusion

Geopolymeric binders have paved a new way in the construction of rigid pavements not only by addressing the problems associated with sustainable construction but also through evident enhanced performance. The acceptance of this modern binder by the industry faces multiple challenges because of misconceptions associated with the cost analysis and improper handling of chemicals. The primary objective should be focused on bridging this gap through extensive research and industry-academia interface.

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