A STUDY ON THE CHARACTERISTICS OF GEOPOLYMER MORTAR

Dr. Irfan Kalal
Assistant Professor
Department of Civil Engineering
Shri Jagdishprasad Jhabarmal Tibrewala University,
Chudela, Jhunjhunu, Rajasthan

Abstract

Concrete experts have lately been using breakthrough geopolymer technology to generate new environmentally friendly construction materials. Geopolymer mortar (GPM) is created via the method of geopolymerization, which involves producing a geopolymeric binder by the alkali-activation of a precursor that is rich in aluminosilicate. This is done by utilizing alkali activators at room temperature and adding fine aggregates of sand. The properties and applications of geopolymer mortar are the subject of interest among civil engineers and material scientists. This is due to its remarkable attributes and its potential to address the sustainability issue of carbon dioxide emission caused by the current production process of ordinary Portland cement (OPC). Geopolymer mortar also offers advantages such as the ability to incorporate various waste materials in the manufacturing of geopolymer products. This article provides a summary of the latest characteristics of geopolymer mortar, including its workability, setting time, and surface temperature. The results showed that the geopolymer mortar has significant potential and many applications for use in eco-constructions. It might serve as a viable alternative to traditional cement in the future.

Keywords: *Geopolymer, Geopolymer Mortar, Characteristics.*

Introduction

Cement is a commonly used synthetic binder in conventional construction, with a high demand for producing building materials. According to reports, around 1 ton of cement is produced per capita each year. The Chinese cement industry has seen significant expansion, resulting in China being the world's largest producer of cement. Conventional OPC is manufactured by the method of "two grinding and one calcining," which involves employing limestone, clays, and other materials as sources. The temperature during the calcination stage of this process may reach a high values. Essentially, the current method of producing OPC not only uses limited natural rocks and minerals to generate a large amount of energy by heating limestone, but it also releases carbon dioxide gas, which is a major greenhouse gas, into the sky. The OPC industry in China annually utilizes around 1 billion tons of limestone, 180 million tons of clay, 50 million tons of iron powder, 100 million tons of coal, and 60 billion kilowatt-hours of energy. Each ton of OPC pro duction emits 1 kilogram of sulfur dioxide (SO_2), 2 kg of nitrogen oxides (NO_x), and 10 kg of dust, along with about 0.810 ton of carbon dioxide (CO_2). As a result, the manufacture of OPC requires a significant amount of energy, consumes a large amount of natural resources, and has a strong negative impact on the environment. The production of OPC is significantly expanding in response to the increased need for urbanization to accommodate the rapid population growth. The OPC sector alone contributes around 4 billion tons of total CO_2 yearly, accounting for approximately 7% of world

CO_2 emissions. The current difficult situation has compelled concrete engineers to seek an alternate binder to Ordinary Portland Cement (OPC) with a sustainable approach, which is an urgent need at this time. Researchers are motivated to create a practical geopolymeric binder as a substitute for OPC in order to reduce eco-pollution by limiting CO_2 emissions, as well as other harmful gasses and dusts. Researchers are now developing novel GP-composites by totally or partly replacing OPC with geopolymeric binder, which is considered very promising.

The introduction of geopolymer technology may be attributed to the pioneering work of French scientist Davidovits in 1979. The individual produced a novel inorganic amorphous aluminosilicate enclosure material with a three-dimensional structure by activating raw materials rich in alumina and silica, sourced from industrial or geological origins, at room temperature. This material was given the name "Geopolymer" by the individual. GPs have a ceramic-like structure and have similar chemical properties to zeolite. Rapidly, it solidifies at normal room temps, acquiring significant initial mechanical strength along with exceptional long-lasting durability. GPs, or geopolymer products, are innovative materials created by activating alumino-silicates such as fly ash, metakaolin, ground granulated blast furnace slag, etc., utilizing minimal energy under ambient temperature and pressure conditions. The features of GP-properties primarily rely on factors such as chemical composition, amount of glassy phase, concentration of soluble silicon and aluminum, particle size distribution, and presence of inert particles in the source materials.

The amount, morphology, fineness quality, chemistry, and mineralogical structure of the basic materials in the glassy phase significantly impact the activity of the aluminosilicate sources. The basic materials must include spherical glass beads with an amorphous structure, which have the remarkable ability to easily release aluminum with little water need. The alkali liquid often used in GP-production consists of sodium silicate (Na_2SiO_3), also known as water glass, together with sodium hydroxide (NaOH) and/or potassium hydroxide (KOH). During the process of GP-curing, the temperature is often higher than the surrounding temperature, ranging from 60° to 100°C, and requires a curing time of 24 to 28 hours. After undergoing heat curing, the GP may be stored for curing at room temperature (RT). In recent years, extensive research on green infrastructure materials and advancements in GP-technology has led to increased attention in geopolymer mortar as a potential replacement for conventional OPC-mortar. Many researches focused on studying the preparation process and features of GPM. The primary objective of this work is to highlight the latest advancements in the study of the physical characteristics of GPMs.

Methodology

Authors conducted extensive searches using several search engines and databases such as Research gate, Science Direct, Google Scholar, Scopus, and Web of Science. They acquired many publications related to the different types of raw materials used in the manufacturing of GPM. A comprehensive database was created by extracting all the necessary data from prior articles.

According to Yan and Sagoe-Crentsil's examinations, the addition of waste paper sludge to mortar mixtures in a dried state significantly altered the flow behavior of the mixture because the sludge absorbed water from the mortar mix, resulting in a noticeable decrease in the properties of the mortar flow. While it is possible to use CFBC (circulated fluidized bed combustion fly) bottom ash in place of the finer aggregates in GPM, doing so will result in a lower flow value than using regular sand. When Kabir et al. added metakaolin (MK) as a binder; they found that the microstructure of the POFA was porous and spongy, and that the finer size of the MK particles contributed to the reduction in the propensity of flow. Additionally, increasing the GGBFS decreased GPM flow. Increases in GGBFS amount will result in a decrease in the number of spherical particles and the development of non-spherical particles in FA. In order to create GPMs using styrene-butadiene (SB) latex, Lee used slag and FA. Then, he conducted a flow test, which revealed that the alkali activator solution increased the flow value while the coarser bottom ash and SB latex dose had little to no effect. Deb investigated the effect of silica nanoparticles on the flow ability of new GPMs and reported that the use of silica nanoparticles reduced the flow value in three series mixtures of GPM, which could be attributed to the accelerated reaction and the increasing water requirement of the nanoparticles. According to Laskar and Talukdar's findings, alkali activator type clearly affects how well GPM works and mixtures that use Na-hydroxide as an alkali activator exhibit superior workability compared to those that use a combination of Na-hydroxide and Na-silicate.

Setting Time

From a practical standpoint, the setting time of new mortar is crucial as it establishes the acceptable duration for mortar transportation, casting, and compacting. Using the "Vicat needle" gadget in accordance with ASTM C 807-13 and BS EN 480-2 standards, one may check the times for setting. The first time of setting may be measured from the time when the mortar mix was made ready to the time when the needle inserts to the depth of 4 mm from the base of the plate, and the final setting time may be evaluated when the needle went into the depth of 2.5 mm. The ratios of alkali solution to FA and Na-silicate to Na-hydroxide showed almost equal effects on setting times in the context of FA-based systems.

Both the early and final setup times of GPMs may see a considerable decrease in the augmentation of Na-hydroxide's molarity. Furthermore, Phoo-ngernkham et al. suggested that the greater Na-hydroxide concentrations would make it more difficult to establish GPMs on time. According to Malkawi et al., the amount of sodium is the primary factor affecting the setting time because changes in the molarity of sodium hydroxide may change the ratio of sodium to silica. The amount of calcium has a significant impact on the GPM setting times. Shorter early and ultimate setting periods may result from the higher calcium content. According to Laskar and Talukdar's report, the new GPM that used just Na-hydroxide as the alkali activator solution took longer to set than the new GPM that used both Na-hydroxide and Na-silicate.

According to Al-Majidi et al., GGBFS content has a significant impact on the timings for establishing GPMs. The setup time drastically decreased as the amount of GGBS was increased. While the setting time increased gradually with increasing doses of nano-silica, the introduction of silica nanoparticles shortened the periods needed to establish GPMs with a molar concentration of 12 M.

To create GPMs, OPC may be used alone or in combination with other promotional items. OPC-mortar often takes longer to set up than GPM. When OPC content rose, there was a progressive decrease in the mortars setting times, indicating the impact of OPC. In their investigations into the setting periods of GPMs, Phoo-ngernkham et al. and Hanjitsuwanet al. combined bottom ash and cementitious calcium carbide residue as substrate materials. The results showed that increasing the dosage of bottom ash replaced by calcium carbide residue resulted in a discernible reduction in the times needed to set the GPMs. The GPM containing the Ca-carbide residue showed a slower setting time compared to the GPM mixed with OPC.

Surface Temperature of Fresh Geopolymer Mortar

Because of the more intricate exothermic chemical processes involved in the geopolymerization process, the temperature of the fresh state GPM during the mixing process was much higher than that of the typical OPC-mortar. Jumrat et al. used an infrared thermometer to monitor the fresh GPM's surface temperature immediately after mixing for mortars. They then repeated the temperature readings after 1, 2, 3, 4, 5, 6, 12, and 24 hours, respectively. The temperature of the mortar sample was monitored while observing from a distance. The findings showed that GPM has the highest temperature immediately after mixing and that the temperature decreases with time, becoming particularly noticeable after three hours.

Kotwal et al. used a digital stem type thermometer to measure the temperature of fresh GPM in compliance with ASTMC 1064. They observed that the temperature of the fresh GPM ranged from 32°C to 54°C. More Na-silicate and Na-hydroxide was found to raise the temperature of the mortar; however, as the quantity of fine aggregate increased, the temperature was observed to trend downward.

Conclusion

The overview pilot came to the conclusion that the construction and infrastructure industries have been most drawn to using aluminosilicate as an alternative building material in recent times due to its excellent properties such as fluidity, segregation and/or bleeding, outflow rate and time, and kinetics of temperature of fresh GPM. Because fresh GPM uses wastes as raw materials and has exceptional cohesion and cost-effectiveness, it has several applications. The GPM's workability, consistency, flow, temperature in its fresh form, and setting time all pointed to acceptable limits for this innovative building material. High early strength, durability, workability, and good-quality adhesion are among the exceptional fresh state qualities of a range of GPMs made using a variety of materials as base materials that provide results that are acceptable. Because geopolymer technology often has a smaller carbon footprint and requires less energy to operate, GPMs assist reduce carbon dioxide emissions and relieve global warming.

As a result of this review study's finding that GPM is considerably practicable in terms of new qualities, it will help to advance its establishment as an eco-friendly, user-friendly, and reasonably priced infrastructure material that may eventually function as an OPC system substitute.

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