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Review Article

Review of the Effect of Grinding Aids and Admixtures on the Performance of Cements

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Grinding aids (GAs) are polar chemicals introduced in cement mills in either liquid or powder form to improve on mill grindability efficiency. Studies have shown that some GAs not only help in grinding efficiency but also play vital roles in improving the product particle size distribution, product ability to flow in the mill, grinding energy reduction, and improvement on the separator efficiency. This review investigated the impacts of the GAs on the performance of some properties of cement when used as either mortar and/or concrete. The influence of the GAs incorporation in cement grinding on properties such as workability and setting times of the placed concrete and/or mortar has been covered in this review. The performance of GAs on ordinary portland cement (OPC) and blended cements with other supplementary cementitious materials such as pozzolana, fly ash, and slag has also been discussed. This is in view to tapping the maximum benefits of using GAs in cement production and use. This review work established that GAs have a positive influence on mill performance when properly applied. It further established that blended cements work better when dosed with additives such as GAs and/or quality improvers when compared to OPC. The review work demonstrated that some superplasticizers help in lowering the water demand in highly blended pozzolanic-based cements. The review finally recommended that the future course of action in the production of blended cements should apply GAs. This is in order to help produce highly replaced blended cements that are sustainable.

1. Introduction

Grinding aids (GAs), also called grinding additives are introduced in liquid or solid form in the ball mill or vertical cement mills during grinding because of their anticipated merits. They can be divided into amines and their salts, polyalcohols, lignosulfonates, fatty acids, and fatty acid salts based on their chemical makeup [1]. Their addition in cement can greatly improve the grindability of the materials without necessarily hampering the cement performance [2]. Currently, triethanolamine (TEA), triisopropanolamine, ethylene glycol, glycerol, and other specified organic materials are among the compounds utilized as cement GAs. TEA is the most popular among them [3]. However, the choice of a grinding aid for use in in order to improve cement properties like strength should be based on strong investigation through research because the performance of different GAs is different [2]. There are many benefits accrued from the use of GAs. They include reduced energy consumption, increased grinding efficiency, improved powder flowability, binder strength development, and increased rate of particle size reduction [1, 4]. Reduction of the energy consumed in comminution has the benefit of helping lower the greenhouse gas emission. As a result, enhancing the efficiency of the grinding process by incorporation of GAs becomes a critical concern that should be considered [5]. The GAs have therefore been introduced in cement manufacturing to promote energy saving advantage [6, 7]. The incorporation of GAs in cement production can be viewed to have an integrated goal of producing cement with improved fineness and flowability at a reduced energy consumption [8].

Factors like electrostatic charge, high cement temperature, weathered (aged) clinker, rough surface balls, and moist in the mill can cause the cement to agglomerate above the balls [9, 10]. According to Moothedath and Ahluwalia [11] van der Wall forces are the dominant forces responsible for the interparticle attraction for cement particles that are very close to one another. Cement particles agglomeration is one of the contributors to the reduced efficiency of most cement grinding units [12]. Cement manufacturers continue to prioritize the agglomeration phenomena, emphasizing the need for GAs where they allows for the partial neutralization of surface charges of cement particles arising from cement grinding [10]. GAs incorporation in cement grinding enhance enlargement of the separation distance between cement particles as they get adsorbed on the surface of cement particles which reduces agglomeration and ball coating [11]. Adsorption of the grinding aid on the cement particles also discourage cohesive forces between cement particles during grinding thereby hindering cement particles agglomeration [4]. Grinding aid does not only impact positively in cement grinding, but also effectively reduces compaction and agglomeration during cement storage [4].

An admixture is defined as a substance introduced into the concrete/mortar before or during the mixing process. They do not include the main concrete or mortar components like water and cement. Admixtures can be mineral or chemical. Some examples of chemical classifications of admixtures include air entraining, water reducers, set retarders, and superplasticizers (SP). Mineral admixtures on the other hand entails the following; pozzolana, grouting admixtures, waterproofing admixtures, air detraining admixtures, bonding admixtures, corrosion suppressing admixtures, gas forming admixtures, coloring admixtures, and alkali aggregate inhibiting admixtures [13].

Admixtures have proved to remain unaffected by other components of concrete or mortar mixture once incorporated in a concrete or mortar mixture. For instance, the influence of the SP on either fresh or hardened properties of the cementitious mixture is independent of other components such as water, aggregates, hydraulic cement, and fiber reinforcement [14]. The ultimate objectives of employing admixtures are to either maintain or improve one or more performance characteristics of concrete [15]. Each admixture is designed to serve a specific purpose. However, at times a given admixture can affect one or more properties of concrete because of their chemistry [14].

Pozzolana, an example of mineral admixture, is defined as a siliceous and or an aluminate rich substance possessing little or no valuable cementitious properties but which when finely divided, chemically reacts with calcium hydroxide at ordinary temperatures and under moist conditions to form cementitious properties possessing compounds [16, 17]. The compounds formed are similar to those that form when hydraulic portland cement hydrate. Pozzolana incorporation in cement facilitates the improvement not only of its physical properties but also its mechanical properties of the concrete [18]. Pozzolanic materials have entirely been used in the partial replacement of cement in concrete and mortar through their use in making blended cement. A lot of attention has been put on byproducts from agriculture, industrial wastes, and naturally occurring clay materials [16].

SP on the other hand are among the chemical admixtures added in small doses into concrete during or immediately after mixing. They are aimed at reducing water demand requirements, increasing workability, and also help in reducing the cement content [19]. They are crucial components for creating concrete/mortar that is more immune to ingressive agents therefore making it more durable. This is because such concrete/mortar would require less water which translates to reduced permeability and porosity. They can also be used to lessen the amount of clinker in concrete per unit volume while keeping the water-to-clinker ratio constant (or low enough) to ensure durability. This facilitates the use of blended cement with higher clinker replacement levels [20].

A lot of air pollution has been realized as a result of ordinary portland cement (OPC) production. This is because of the much energy required in the kiln when producing clinker while not negating the much energy needed in grinding of clinker, gypsum, and other components in a ball mill to produce cement. In view to reducing the amount of energy required (in clinker production by calcination and cement comminution in the ball mill) much investigation has been done on the feasibility of using different SCMs and filler materials to reduce the OPC clinker in the OPC cement. More importantly, GAs have been researched upon in evaluating their efficacy in making cement production sustainable. Incorporation of SCMs and GAs helps not only in reducing the energy requirements but also directly or indirectly help in improving the cement mortar/concrete properties. However, little work has been done on the negative effect arising from improved cement fineness accrued from the use of GAs in cement production.

The current paper is a review of the importance of GAs and SP in concrete and mortar. Exclusive discussion has been provided on how GAs enhance grinding especially in blended cement production and performance. The importance of blended cement over the OPC especially on environmental sustainability has also been discussed. The use of SP in offsetting the challenges associated with the action of GAs in cements to help in the manufacturing and construction sectors has also been discussed.

2. Mechanism of GAs

The grinding process occurs in two ways; attrition and breakage. It is therefore important to investigate the roles of GAs in these two processes. Adsorption of the GAs on the particles being ground reduces both the surface energy of the material and the material resistance to scratching which enhances finer grinding through attrition. Conversely, breakage is not enhanced under the normal grinding processes. This is because breakage involves crack initiation and propagation where the crack propagation velocities in the normal

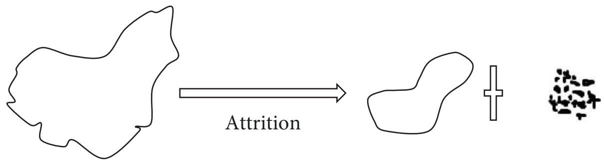

Figure 1: Attrition of cement particles during grinding.

grinding process are very high. This hinders diffusion of the GAs in the crack tips at these very high velocities [11]. Therefore, the incorporation of the GAs in cement grinding only influences the attrition path shown in Figure 1.

The mode of action of GAs in improving the properties of cement is not fully understood [5]. However, the proposed mechanisms are mostly pinned on two principles: first, the impact on particle distribution and material flow qualities; and second the chemical–physical influence on individual particles, for instance, surface energy reduction [21, 22]. The flow properties of cement can be understood by examining the dispersion mechanisms of GAs.

Organic molecules disperse cement particles during grinding via two primary mechanisms. The gas phase transfer and the surface contact transfer are the primary mechanisms described by Mishra and Zurich [5]. Simple grinding experiments in a closed batch mill have demonstrated this phenomenon. For example, different alcohols with boiling temperatures lower than the grinding temperature have greatly shown improvement in grinding efficiency. This is because of their great volatility. This property, makes them to be weakly adsorbed so weakly such that they can be smelt even on cold cement. As a result, it must be considered that they are diffused, either partially or entirely, through the gas phase. Other polymers like polycarboxylate ethers (PCEs) which vaporize irreversibly remain intact to enhance the dispersion of cement particles only through surface contact transfer. GAs that have boiling temperatures slightly above the grinding temperatures do disperse the cement particles through gas phase transfer and surface contact transfer [5].

Based on the chemical–physical influence on the individual particle principle, the GAs mechanism can envisage the following: firstly, GAs facilitate adsorption between microcracks of particles as shown in Figure 2(a). By doing so, they provide foreign ions or molecules to shield unsaturated charges of crack sections, hence inhibiting fracture surface healing and making fractures easier to extend. Second, GAs molecules adsorb on the surface of cement particles and form an adsorption film as shown in Figure 2(b). This reduces the free energy and interfacial tension of the powder surface and prevents the particles from clumping together or agglomeration [3].

Adsorption of GAs molecules helps lower the particles' surface energy which reduces the fracture resistance of the solid matter [23]. This has the direct advantage of easing the fracturing of cement particles thereby promoting grindability. Basically, GAs get preferentially adsorbed on cement particle surfaces created by the breakage of electrovalent linkages in Ca–O or Si–O, resulting in reduction of surface energy forces [24, 25].

Organic GAs have functional groups of OH^- and $-NH_2$ which do not have any clear relationship in the working of a grinding aid. These functional groups lead to electrostatic bonding with the covalent bonds (van der Wall forces) on the fractured cement particles. This is very important to deterring agglomeration of the cement particles [21, 22]. The functional groups also play the role of dispersion to prevent fine particle agglomerating, improving powder dispersion, and grinding efficiency. Furthermore, the more dispersion from the GAs, the more compact the GAs build the adsorption layer in the particle [3].

GAs act by hindering the interaction of the positive and negative charges developed when the crystal structure of the materials is destroyed in the grinding process. They therefore interact with the surface of the cement particles by forming layers that prevent the particles from sticking together [1]. A group of largely used SP, the polycarboxylic acid esters have proven to be good GAs. This has led to a possible intuition that the additional contribution of organic GAs such as alkanolamines and glycols does not necessarily originate from only electrostatic screening, but also through steric or chemical interactions with the individual cement particles [26].

3. Contributions of Grinding Aids

Addition of GAs in cement is normally done as the percentage mass of the cement in the range of 0.01%–0.1% [1]. Their addition normally comes with a couple of advantages aligned at promoting the cement quality. The use of GAs can improve grinding efficiency, reduce water usage, improve material's ability to flow, and decrease the particle size distribution of the grinding products among other contributions [21]. Besides these merits, GAs produce effects on the setting time and the rate at which strength is developed during cement hydration [8]. More importantly, the influence GAs on the cement properties affiliates its performance to the cement composition. This is because cement composition in terms of its oxides greatly influences cement paste properties like setting and strength [17].

Mixing of GAs with the material to be comminuted produces a finer product at the same production rate or a higher production rate at the same product fineness [27]. However, this advantage of the GAs should be considered subject to several factors that have been found to influence clinker grindability. The first factor is the amount of belite (C_2S) and alite (C_3S) in a given clinker where clinkers rich in C_2S resist grinding while those rich in C_3S become easy to grind. The second factor is the size of alite and belite crystals, it is evident that the bigger the crystals, the harder the clinker. Third, the presence of impurities such as magnesium oxide, sulfate, and potassium oxide do affect grindability where these impurities are thought to influence the crystalline structure of the alite phase. Finally, the possibility of clinker coating the balls of the mill and the mill linings [28].

Small amounts of GAs can effectively reduce the cement particle size and at the same time increase the specific surface area of the cement, an important property that is used as a measure of the cement quality [10, 29]. The oppositely

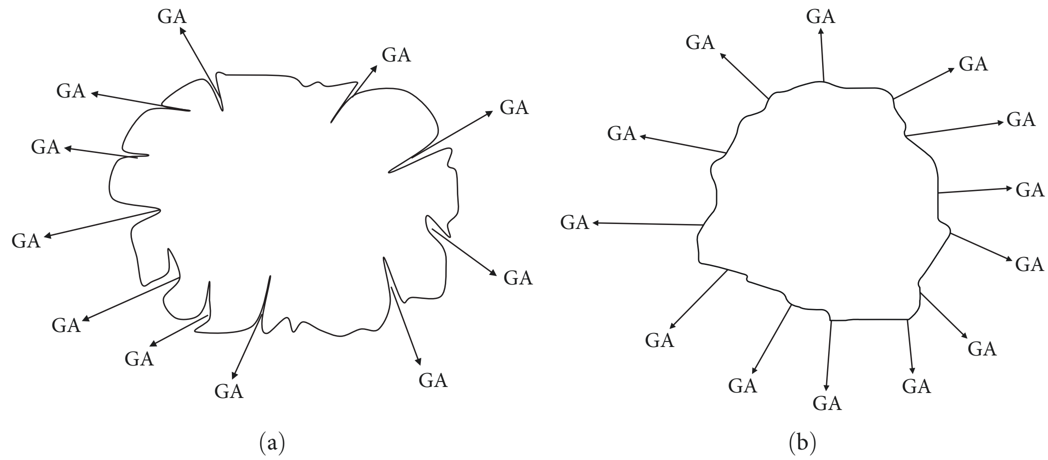

FIGURE 2: (a) Shows the adsorption of grinding aids particles between microcracks. (b) Shows the adsorption of grinding aids particles on the surface of cement particles.

charged cement surfaces formed during grinding are attracted to each other and hence agglomerate [1, 30]. GAs are mostly positively charged. They act by partially neutralizing these surface charges on the cement particles and thus hindering their agglomeration [6, 25]. This advantage promotes improvement of the cement-specific surface area.

The importance of GAs in countering agglomeration not only becomes significant in cement grinding but also during storage. This makes loading and offloading of cement easier and also reduces the hanging behavior of the cement silo wall [2]. Agglomeration of cement particles is caused by the interaction of the ionic charges developed during grinding as discussed by Kapeluszna and Kotwica[1]. It is expected that this phenomenon persists even during cement storage thereby hindering compaction during storage.

Morphology of cement particles is one of the basic elements of cement particle characteristics that affects cement fluidity, water consumption for consistency, and cement strength [31]. The cement particles become more uniform and dispersed, and the shape of the particle tends to be more circular. This is according to the cement's morphology when processed with the use of GAs. It therefore suggests that the circularity of these cement particles increases. The increase in particle size circularity is a favorable property because it facilitates improvement in the powder's fluidity and cement's comprehensive performance [3].

The fineness of cement defines the grinding extent of the cement clinker alongside gypsum and other materials in the milling machine [32]. Cement properties are highly influenced by the cement fineness, a property that is determined by the grinding process [29]. The use of cement GAs facilitates the improvement of cement fineness [33, 34].

Compressive strength, one of the most important properties of concrete/mortar, is affected by the cement fineness. Experimentally, it was revealed that a cement mixture with a lower amount of clinker, and ground along with a grinding aid produced a cement product that had a higher compressive strength than the standard mixture [34]. Therefore, it reveals that incorporation of GAs in cement grinding has added advantage of reducing the clinker factor and thereby making cement production sustainable. GAs inclusion in cements blended with supplementary cementitious materials (SCMs) affect the reactivity of such cements. This is because the order in which these cements react not only depends on the mineral composition but also the physical characteristics and more importantly the specific surface area [25]. For instance, increase of cement fineness improves the early strength of blended cements [35]. This increase in strength in the blended cements can be due to enhanced breakage of the Pozzolana particles from their unreactive crystalline form to the reactive amorphous form as observed by Yao et al. [36].

According to Ehikhuenmen et al. [32] while assessing the influence of cement fineness on the structural properties of concrete observed that increase in cement fineness directly increased the compressive strength. This concurs with the argument that incorporation of the GAs during cement comminution increases fineness and or surface area of cement particles, hence compressive strength improvement. Fine cement produces good early strength in concrete/mortars. This is associated with the role of mechanical activation through grinding which leads to faster rates of formation of hydration products [37]. The finer the particles, the larger the surface area and hence accelerated reaction with the water which leads to increased hydration. Increasing the limestone powder fineness in OPC replacement for instance has a direct effect of increasing compressive strength [38]. Intergrinding of the blended cementitious materials in the presence of GAs gives more positive results of compressive strength than when these materials are ground separately [39].

Almost all GAs have the capacity of improving the compressive strength of cement [33]. GAs are good at increasing both the early and late compressive strength [2]. The degree of cement hydration is typically thought to have the greatest impact on early strength, but the microstructure of cement hydrates should be given greater consideration for late strength. It has however been established that besides the degree of hydration, other factors could play a role in compressive strength development. This is because despite of the low heat of hydration measured, a cement produced with the help of grinding aid recorded higher values of compressive strength. It has therefore been concluded that GAs accelerate the rate of C_3A and C_4AF through chelating interaction with Ca^{2+} and Fe^{2+} and hence accelerate the rate of SO_4 consumption [6].

The setting time of cement made with GAs is normally modified [40]. A commonly used grinding aid, TEA for instance, has the capacity to act as a setting time regulator [25, 41]. This is because of the ability of some GAs to influence the hydration behavior of the cement by increasing cement fineness. It was observed that both the initial and final setting time of coarser cement to be late compared to finer cement. This was attributed to reduced hydration in coarser cement [29]. Depending on the dosage level, TEA can either retard or accelerate the cement hydration [10] in order to effect the initial setting time. This implies that most GAs have an impact on the mortar setting time.

However, it has been observed that an increase in cement fineness leads to a direct increase in the water requirement for normal consistency to enhance workability [10, 37]. An increase in water demand in mortar and or concrete has the importance of forming more hydration products and hence improvement of the late compressive strength [42]. In spite, of this advantage, other properties such as, setting time, porosity, and permeability toward aggressive agents are affected negatively. For instance, an increase in water-to-cement (w/c) ratio increases the permeability of concrete and or mortar [43]. Ingress of aggressive ions due to increased permeability would later reduce the mortar and or concrete qualities like strength and durability among others. This becomes one of the major loophole in the application of GAs in the improvement of the cement mortar/concrete properties. There is need therefore, to explore of a viable way to harness the GAs benefits while at the same time preserving the concrete/mortar integrity and durability. Hence, there is a need to assess the role of SP in this challenge.

4. Mechanism of Action of Superplasticizers

SP consist of a hydrophilic end and a hydrophobic group, that is, a water repelling group with and some polar groups. The polar groups in the chain get adsorbed on the surface of cement grains. The nonpolar end on the other hand projects outward from the cement grain. The SP molecules align themselves around the cement particles forming a watery shell. These molecules are attracted to the cement grains on one side and water molecules on the other side. This makes them to create a lubricating film around the cement particles on one side and water molecules on the other. The end goal of the SP use is the dispersion of the cement particles in order to lower the amount of water required to form a workable concrete. The dispersion by these SP can be explained as a result of electrostatic repulsion or steric hindrance due to the cement particles interacting with the SP and concrete mixing waters. The magnitude of the electrostatic repulsion and steric hindrance by the SP is essentially influenced by the type and molar masses of the SP [23].

Dispersion by electrostatic repulsion is due to the zeta potential, a surface charge produced by the grinding of the cement. Adherence of the SP molecules on the cement particles leads to an obvious reduction in the zeta potential and consequently establishes negative charges in the cement particles. The negative charges developed between the cement particles and the SP lead to cement particles deflocculating because of electronic repulsion. With time, the electrostatic charge declines as the hydration process occurs. Decrease in electrostatic charge later on leads to flocculation of the cement's hydration products. Dispersion by electrostatic repulsion is influenced by the composition of the concrete solution phase and the amount of the SP adsorbed by the cement particles. The dispersion is normally higher when the adsorption is high. Lignosulfonate-based plasticizers (first-generation SP) specifically lead to dispersion employing this mechanism [44, 45]. This is because of the adsorption of negatively charged SO_3^-, which induces reduction in the zeta potential thereby produces like charges on the cement particles.

On the other hand, dispersion by steric hindrance has been found to manifest in carboxylate SP [46]. Research reveals that the zeta potential responsible for dispersion in the case of these SP is much lower [44] and that the cement particle almost appear neutral [45]. In this scenario, only steric hindrance can stand to explain the dispersion of the cement particles. A study that was performed on the zeta potential produced by polycarboxylate (PC) based SP and sulfonate-based plasticizers showed that the PC SP produced almost negligible zeta potential compared to the sulfonate-based SP [47]. Dispersion by steric hindrance observed in the PC SP is caused by the presence of neutral sidelong ether chains. In these SP, the negatively charged anionic groups gets attached to the cement particle surface while the long ether chains themselves remain extending from the other end of nonattachment at the cement. These long ether chains from the cement particles delay their flocculation into large and irregular cement particles agglomerates.

The effectiveness and performance of SP differs from one SP to another and from one scenario to another. Among the factors affecting the SP performance include the SP type, the concrete composition, and the temperatures during mixing [48]. Many researchers have established a connection between the various polycarboxylic SP efficiency and their chemical structures, namely the kind, length, and arrangement of their main chain and side chains as well as the presence of functional groups. It seems widely accepted that the number and length of side chains affect the effectiveness of a given polycarboxylic SP, with short side chains having a marginal effect on cement paste fluidization [49]. The presence of certain kinds of groups like the hydrophilic ones in the SP structure enhances its effectiveness. Certain arrangements like the simultaneous adsorption of the main chain at the cement particle surface can boost the steric effect of the synthetic plasticizer. This could be achieved by changing the side chain's structure to include hydrophilic hydroxyl (OH) or oxyethylene (OCH_2CH_2) groups rather than hydrophobic methoxy groups (OCH_3). According to some tests, the longer the chain is in PCE plasticizers, the greater the dispersion will be, but the fluidity will also decrease. Therefore, short-chains need to be added to it as well in order to stop the flowability decline. The use of polyethylene glycol with various chain lengths in the synthesis of PCE is thought to provide products with a high level of fluidity and mobility due to the mixed long and short chains, which promote the SP performance.

5. Effect of Excess Mixing Water and Role of Superplasticizers

Water is an important ingredient in a concrete mix [50, 51]. Water activates cement and other cementitious materials, and hence the term "hydration." This is due to the fact that water molecules do both chemically and physically mix with the minerals in cement, producing heat as the products of the chemical reaction dissolve and subsequently precipitate in a watery environment [43].

The proportion of water to cementitious materials used in concrete production affects a number of its properties. It is evident that the compressive strength of concrete increases with increasing water-to-cement (w/c) ratio and vice versa. However, this comes with a disadvantage of reduced concrete density [52]. The density decreases due to reduction in the aggregates content as water replaces them. Normally, water content mass in freshly laid concrete translates into the porosity of the hardened concrete [43] impacting both strength and durability. The increase in the amount of mixing water in ultrafine cement in order to improve the paste performance has itself come with defects like slow setting and hardening and low early strength among others [53]. The amount of water in the fresh mixture (coupled with the subsequent pore space in the hardened mass) does not only affect the strength but also the durability of concrete. However, shrinkage and workability are also proportional to water content in a cement mixture, where workability relates exponentially to the water amount [43]. The challenges associated with cement production prompt us not to continue producing concrete of low quality which would then produce low-durability structures [54]. To some extent, this could be enhanced by reducing the amount of mixing water in a given concrete mix.

Reducing the water content will make the cement mortars more dense, which improves the paste's strength and durability [55]. Reducing amounts of water in concrete on the other hand reduces its workability severely [56]. Water-to-cement ratio of 0.4 could be sufficient for hydration of cement [55] but at this w/c ratio the concrete mixture would not present optimum workability. The ideal concrete therefore requires the minimum amount of water possible but this is limited by the fact that the cement particles readily flocculate in the presence of water to deter workability.

The increased amount of water is normally adopted in concrete to produce a workable concrete that has accelerated hydration and hydration products [55]. The increased amount of water adopted on the other hand produces a more porous material. Depending on the concrete composition (that is the sand and the filler materials), concrete at increased w/c ratio may be achieved. However, other negating factors associated with too much water in the concrete such as bleeding and segregation may manifest. Reducing the amount of mixing water in concrete would in one way help to increase the concrete durability while on the other hand it negatively would affect the workability and flow properties of the concrete. The compressive strength enhancement at a reduced water/cement ratio can be explained by a critical look at the kinetics of cement hydration. In this sense, the w/c ratio is viewed as the distance between the identical cement particles within the cement paste. When the amount of water is very low, the identical cement particles are normally very close to each other and the hydration products from adjacent particles grow and interact to form mechanical bonds. The center of the cement particle that is not hydrated at this reduced w/c ratio also takes part in high compressive strength enhancement [54].

In order to counter difficulties encountered at reduced w/c ratio, SP would serve this purpose. SP are high range water reducing admixtures that help to make the concrete material workable for placing and handling [57]. SP work by dispersing the water present in the concrete mix to achieve a workable concrete. They are the most important admixtures in enhancing concrete performance [58]. SP are the most prevalent admixtures that are a point of concern when fabricating high-performance concrete. The advantage of the SP can be explained in two dimensions, first to decrease water content in order to boost mechanical strength, lower permeability, and improve durability; and second to evenly distribute cement particles with water to improve uniformity and workability [44].

SP use therefore improves the characteristics of concrete in both its fresh and hardened stages [48]. SP in concrete for instance help improve the workability of a given concrete at a reduced w/c ratio [58]. Generally, using a SP will lower the tendency to bleed as a result of the decrease in water content. Nevertheless, if the w/c ratio is preserved, SP has a propensity to extend the period of concrete setting since more water will be made available in the concrete mixture. SP help to keep the concrete in a liquid state for a longer amount of time and therefore the risk of drying shrinkage decreases when concrete is being transported to the job site. At the optimal amounts of SP, the increase in the setting time becomes significant because this offers sufficient time for the concrete to be transported to the construction site in instances where the concrete demands to be fabricated in this manner.

Reduction in the mixing water has also an advantage of improving the permeability properties of the concrete because the porosity of concrete reduces when the amount of mixing water reduces. This is important because exposure of a more porous concrete/mortar to severe environmental pose problems such as attack by aggressive agents, which may lead to their durability compromise. The aggressive agents would easily ingress to this particular concrete facilitated by increased concrete porosity due to the increased w/c. This hiccup in concrete production requires reducing the amount of mixing water during the concrete/mortar production with the help of the SP. In addition, the rate of carbonation slows down when the ratio of water to cement increases when SP disperse more water in the cement mixture.

SP enhance compressive strength in concrete essentially by reducing the amount of mixing water. The strength enhancement by a SP is deeply dependent on the w/c ratio where the strength increases when the w/c ratio decreases. SP not only offer the advantage of enhanced strength at this reduced w/c ratio, but also increased concrete workability. The increase in compressive strength with increasing SP dosage under normal conditions is an indication of continued strength gain for SP dosage. By improving the efficiency of compaction to create denser concrete, the application of SP boosts compressive strength in the case of cured concrete. Reduced w/c ratio by the SP promotes strength development in the concrete because the compressive strength gain in concrete has an inverse relationship to the amount of the mixing water [59].

However, it has been noted that the dosage of the SP has a variety of effects on the compressive strength of concrete. When SP is added in excess of what is necessary, concrete/mortar strength is significantly reduced and worsens as dosages rise [48]. Based on the fact that the concentration of SP is different, comparison performance of any should be made based on the amount of solids, but not the total mass [60]. The hydration process will not only remain unaltered by the addition of SP, but the increased amount of water from the deflocculating cement particles will accelerate it. Therefore, increasing the dosage will increase the amount of water trapped and enhance cement hydration. Although increasing the admixture dosage would increase compressive strength, there is still a highest limit that should be used. Increased dosages will only weaken the compressive strength after dosages exceed this threshold. This issue manifests as a result of bleeding and segregation brought on by overloading of SP, which affects the cohesiveness and homogeneity of the concrete. Thus, compressive strength will decline beyond this optimum threshold.

6. Conclusion

The enhanced effect of grinding aid and SP in improving the concrete/mortar properties for the desired application is paramount. Introduction of GAs in cement grinding improves both the fresh and hardened paste properties. This is because GAs influence the hydration behavior by accelerating it. Improvement of hydration rate directly improves the setting time which favors both the early and late strength in concrete and/or mortar.

Based on the findings of this review paper, it is important that future research works consider the feasibility test of GAs application especially in the production of sustainable blended cements. The role of GAs in the blended cements should be geared to achieving more clinker replacement in the blended cements. This is because the cement strength is improved which will help lower the clinker amount in cement production. The improvement in strength is directly linked to the improved particle size reduction, and to hydration rate acceleration all this cumulating to strength development. To curb the challenge of increased water demand especially in pozzolana cement production, SP should be incorporated. This should be considered without overlooking the efficiency and mechanism of operation of different SP because these factors really affect the SP performance.

Data Availability

No data has been collected firsthand for use in this work.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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