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## Sugarcane juice and its bi-products have effects on the setting of cement when used as bio-admixtures

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### Abstract

Concrete is a basic building material used all over the world for constructions and large-scale projects. The constituents of concrete include sand, aggregate, cement, and water. In addition to these ingredients, the additive is utilized to improve the properties of concrete. Cement plays a major role in setting or hardening. Hardening is caused by hydration, which is the chemical reaction between cement and water. It is essential to adjust the pace of the setting procedure to account for the particular needs and weather conditions. Admixtures of chemicals are employed to accomplish this. As a result, chemical admixtures like retarders or accelerators can be used to change the initial setting time of cement. Chemical admixtures are frequently employed in construction projects to enhance the characteristics of concrete.

Chemical admixtures, on the other hand, are hazardous to both the environment and human health. Sugarcane is entirely natural, harmless to humans, and has no adverse effects on the environment. This study examines how cement setting time is affected by the use of sugarcane juice and its by-products as bio-admixtures.

**Keywords:**-Bio-admixtures, Chemical admixtures, Cement, Hydration, Initial setting time

## 1 Introduction

Concrete is used in practically every construction project (1). Concrete is made by blending water, cement, and aggregates. The cement reacts with the water, and under typical weather conditions, the mixture solidifies and hardens over time. After being placed into formwork and cured, the mixture solidifies into a stone-like structure. This hardening process results from the chemical interaction between cement and water (2). The cementitious material's microstructure is intrinsically connected to the engineering characteristics of hardening concrete. Thus, during the hardening process, changes in the characteristics of the material can be connected to the development of Structure (3). Construction tasks can be finished by adhering to particular norms and regulations, such as temperature. Strict adherence to detailed instructions will result in the necessary quality level. The cement hydration process speeds up when work is done in temperatures above 100°F. Concrete often increases strength initially but then visibly loses strength as the temperature rises. Plastic shrinks as a result of water vapour evaporating quickly. The concrete then cracks as a result of tensile strains building up (4,5). Similarly, cold climates can have an impact on concrete work. As the water sets in the original state of the material, the amount of concrete increases. Concrete's setting and hardening processes are slowed down when water is absent because it alters the chemical reactions that take place. As a result, a large number of pores are created, which eventually reduce the concrete's strength(4,6). The effects of frost on recently laid concrete are the reason behind the difficulties in cold-weather concrete operations. The water used to mix the wet concrete freezes and turns into ice, increasing the volume of the concrete overall. The setting and hardening of the concrete are delayed by the lack of water for chemical reactions. The low temperature interferes with the concrete's ability to set and harden and increases the likelihood of early freezing and thawing. This process causes ice needles to start forming inside the concrete, which causes cavities to form when the ice melts. The structural integrity of the concrete is seriously jeopardised by these voids, which also significantly reduce strength. In extreme conditions, the effects of low temperatures can completely degrade concrete, causing it to crumble and become brittle (7). Therefore, even if concrete has many advantageous properties that make it perfect for construction operations, like binding, strength, and durability, it cannot be used in every type of weather. Depending on the weather, concrete can take different amounts of time to set at initially (8). Consequently, the chemical admixtures are utilized in order to uphold the specified criteria (9). As a result, chemical admixtures like retarders and accelerators are used to change the concrete's initial setting time in response to changing weather. This holds true in

both warm and chilly weather conditions (8). An admixture is anything that is added to concrete other than cement, aggregates, and water (10). Anything added to concrete that is mixed in during or right before its preparation that isn't cement, aggregates, or water is referred to as an admixture. According to the needs of the construction, an admixture is used to control the properties of the concrete. Admixtures are used to fix the problems caused by extremely hot or cold weather and to enhance the properties of concrete, such as its ease of workability (11). Admixtures, such as retarders and accelerators, can influence the hydration process (12). Retarders are admixtures that prolong setting times and aid in hydration (9). A material known as a retarder is one that slows down the setting of cement paste and other materials like mortar and concrete that contain cement (13). Accelerators, another major admixture, are frequently used to change the mechanism and pace of hydration. Accelerators are used to reduce the amount of time required for the setting process (14,15). It is evident that in order to improve the qualities of concrete, chemical admixtures—such as accelerators and retarders—are necessary; however, these admixtures induce leaching and are bad for the environment. The ecosystem suffers when chemical admixtures are discovered, when a building is torn down and its debris is disposed of, or when its granules are turned into gravel. The chemical admixtures are problematic for the environment since they dissolve in water. The manufacturing, transportation, storage, and use of chemical admixtures in concrete all lead to environmental contamination. Due to these limitations, more research is being done on bio-admixtures to lower the price of synthetic admixtures. Utilizing a superior substitute for chemical admixtures is essential in order to add qualities to concrete without endangering the environment (16,17,18,19,20,21,22). Sometimes the cost of the admixture in high-performance concrete is more than the cost of the cement. Thus, for the enhancement of concrete, the development of bio-admixtures is more crucial than the development of cement (23). Therefore, it is preferable to use bio-admixtures to improve the characteristics of both fresh and hardened concrete. Because they are more affordable and environmentally friendly, bio-admixtures are preferred over artificial admixtures (24). Thus, the development of environmentally sustainable concrete will be aided by the discovery of substitute admixtures. Worldwide, scientists and researchers working with concrete are attempting to develop non-chemical admixtures that are regarded as environmentally friendly and sustainable building materials. Natural or green admixtures can be a realistic alternative and enable green building because of their abundance and simple manufacturing process. Herpes, fruit, or animal products are combined to produce these concoctions. Biopolymers and naturally occurring admixtures produced through biotechnological processes are commonly called "bio-admixtures." Utilizing natural

admixtures based on plant or fruit extracts seems like a good choice, despite the lack of research on the topic. Studies on old buildings indicate that plant extract and lime were employed in construction (25). The usage of admixtures has a very similar historical background to that of mortar and concrete. In India, bio-admixtures such as molasses, bananas, fruit juices, dairy products, and olive oil were widely used around 3000 BC. In India, a number of naturally occurring admixtures were utilized to make lime mortar, including glycerol, pine resin, protein, reducing agents (bee wax), and plasticizers (sugar, mineral oils, and olive oils) (26,27). In ancient times, plants were utilized as a bio-admixture in lime mortars. The ancient Vadakkunnathan temple in Thirrsur, Kerala, India, was renovated using jaggery, powdered shells, and various kinds of nine plants. A palm leaf manuscript found at the Padmanabhapuram Palace identified the various plaster mixture compositions used in the repair work at Fort Vettimurichakotta, East Fort, West Fort, Pazhavangadi, Puthen Street, Virakupurakkotta, and Sreevaraham in India. Palm jaggery was mixed with a variety of fruits, herbs, and a particular type of cactus, and the concoction was left to ferment for 15 days. This mixture was mixed with lime to make the plaster (25). In ancient times, jaggery was a popular bio-admixture (28). Molasses, or sugar, was used as a retarder for a long time during the construction of the England-France Channel (29). Molasses can be used as a water reduction, retarder, and grinding aid in construction materials. In China, molasses is commonly utilized as a grinding aid and as a bio-admixture for cement and concrete to reduce and retard water (30).

## **2. Materials**

### **2.1 Cement**

The term "cement" refers to a material that reacts with water to generate a solid, lasting mass. Cement is generally defined as any substance's ability to make bonds with other compounds via a variety of chemical processes (31,32,33). When a mixture of calcareous (like lime stone) and argillaceous (like clay) raw materials is heated to a high temperature, approximately 1400–1450 °C, partial fusion occurs, resulting in the formation of clinker nodules. To make cement, clinker and some calcium sulfate are mixed together and finely processed. Calcium sulfate regulates the setting process. And the term "gypsum" is commonly used to describe it(33,34,35). Raw ingredients such as lime, silica, alumina, and iron oxide are predominantly utilized in the production of Portland cement.

### **Table-1**

Oxide	Content Percentage
CaO or (Lime)	60 to 67
SiO <sub>2</sub> or (Silica)	17to25
Al <sub>2</sub> O <sub>3</sub> or (Alumina)	3to8
Fe <sub>2</sub> O <sub>3</sub> or (Iron oxide)	0.5to6
MgO or (Magnesia)	0.1to4
Alkalis	0.2to1.3
SO <sub>3</sub> or (Sulphur trioxide)	1to3

As these compounds react with one another throughout the kiln's heating process, a multitude of complex products are produced. Four compounds—whose shortened symbols are shown in Table 2—are the primary ingredients of Portland cement. Cement scientists use short notations, as C for CaO, S for SiO<sub>2</sub>, A for Al<sub>2</sub>O<sub>3</sub>, and F for Fe<sub>2</sub>O<sub>3</sub>, to make their descriptions of each oxide simpler. In a similar vein, the letter H stands for the component H<sub>2</sub>O in cement that comprises water molecules.

**Table-2**

Compound's Name	Composition of	Abbreviated
Tricalcium silicate	3CaOSiO <sub>2</sub>	C <sub>3</sub> S
Dicalcium silicate	2CaOSiO <sub>2</sub>	C <sub>2</sub> S
Tricalcium aluminate	3CaOAl <sub>2</sub> O <sub>3</sub>	C <sub>3</sub> A
Tetracalcium aluminoferrite	4CaOAl <sub>2</sub> O <sub>3</sub> Fe <sub>2</sub> O <sub>3</sub>	C <sub>4</sub> AF

The silicates (C<sub>3</sub>S and C<sub>2</sub>S in particular) are important because they give hydrated Portland cement its strength. C<sub>3</sub>A is an undesirable component of Portland cement. The strength of the cement is essentially unaffected by the C<sub>3</sub>A (33). Alite, or tricalcium silicate, is another name for C<sub>3</sub>S, is a key ingredient in Portland cement. It makes up between fifty and seventy percent of the cement. Portland cement is composed of roughly 15–30% dicalcium silicate, sometimes referred to as belite, 5–10% tricalcium aluminate, sometimes known as aluminite, and 5–15% tetracalcium aluminoferrite, sometimes referred to as ferrite (35).

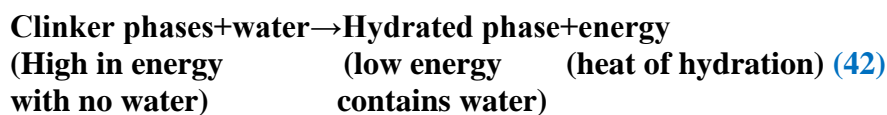
### 2.1.1 Hydration

Hydration refers to the alterations that occur when water comes into touch with either dry cement or its constituent parts (35). Super fluidity is produced via the hydration process, which is the chemical reaction that forms hydrated compounds from anhydrous substances and water molecules. A variety of mechanical alterations as well as chemical and physical modifications

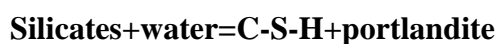
occur as a result of the contact between non-hydrated substances and water molecules (36). Numerous chemical reactions occur when cement and water are combined directly. Consequently, a solid mass is formed from the workable cement paste. Hydration is the process by which regular Portland cement, together with water molecules, go through several simultaneous chemical reactions. This is where complexity lies in the synthesis of various components. Its complexity depends on the original clinker composition, which is directly impacted by the alterations taking place inside the cement structures (37). Hydration kinetics are often divided into three phases. There is an induction phase at the beginning. There is then a growth and nucleation intermediate stage, followed by a subsequent diffusion-controlled phase. Even though the diffusion-controlled period in this case only lasts for around 48 hours after mixing, it is still extremely early in the hydration process and has a significant impact on the hydration process's overall kinetics (38). It is commonly known that ordinary Portland cement hydrates. A single  $C_3A$  phase, or calcium aluminate; two  $C_2S$  and  $C_3S$  forms of calcium silicates; and one  $C_4AF$  phase, or ferrite, comprise the clinker of ordinary Portland cement. To regulate the setting of regular Portland cement, calcium sulfate is mixed into these stages. The cement's subsequent features are mostly influenced by  $C_3S$  and  $C_3A$  hydration, whereas  $C_2S$  hydration occurs more slowly (39). The distinct calcium silicate phases,  $\beta$ - $C_2S$  (the predominant form of belite) and  $C_3S$  (alite), exhibit physical behaviours in cement that are very similar to each other after hydration. Similar end products, calcium hydroxide and calcium silicate hydrates, or CSH gel, are produced by both phases when they separately react with water.  $3CaO \cdot 2SiO_2 \cdot 3H_2O$  makes up the majority of the content of CSH gel, while alternative lime: silica ratios may also function. The hydration processes of  $C_3S$  and  $C_2S$  are crucial in the process since they make up over 75% of Portland cement.  $C_3S$  produces three times more  $Ca(OH)_2$  than  $C_2S$ , despite the fact that both silicates need the same amount of water to hydrate by weight. Although  $C_3A$  is present in very small amounts in most cements, its properties and interactions with other cement phases are of great interest. An opaque, prismatic interstitial substance is produced by tricalcium aluminate hydrate, most likely in conjunction with other solid minerals. This chemical is typically observed as flat plates surrounded by calcium silicate hydrates. On its own,  $C_3A$  reacts violently with water, causing a flash set and significant heat release that makes the cement unusable. The equation for this quick reaction is  $C_3A + 6H_2O = C_3AH_6$  (tricalcium aluminate hydrate). Gypsum ( $CaSO_4 \cdot 2H_2O$ ) is combined with the cement clinker to stop this unwanted setting. Ettringite is formed in response to this addition, regulating the cement's setting time. The resulting reaction is as follows:  $C_3A + 3CaSO_4 \cdot 2H_2O + 26H = C_3A \cdot 3CaSO_4 \cdot 32H_2O$  (ettringite) (40). Cement hydration is a complex and multidimensional

process that involves a multitude of microscopic-scale chemical and physical interactions. Basically, different hydrates are formed as a result of the reaction between the unhydrated cement and the free water in the mixture. With the help of water, Portland cement—which contains important mineral components like calcium silicates ( $C_3S$  and  $C_2S$ ), calcium aluminates ( $C_3A$ ), and calcium aluminoferrites ( $C_4AF$ )—forms several hydrates, such as calcium silicate hydrate (CSH), calcium hydroxide (CH), ettringite (Aft), and monosulfate (Afm). A thorough grasp of the mechanics behind hydration is still difficult, despite a century and more of research on the subject. It is clear that the various components' response rates varied greatly from one another. As such, the computer modelling of the complex interactions in a hydrated poly-mineral and poly-size system is very complicated and requires the take-in of physical, chemical, stereological, and granular parameters. Because of these intricacies, it is necessary to move from studying the hydration of individual compounds to studying the clinker hydration phenomenon. This means that the problem must be explained in terms of the entire hydration process.

In conclusion, the hydration of cement is a complex interaction of multiple variables that necessitates a full understanding of its nuances (41). Examining the four main clinker phases—aluminate, ferrite, belite, and alite—is necessary to have a complete knowledge of the hydration process. Cement hydration can be represented in the simplest possible way as follows:



Portland cement first gets hydrated as a result of silicates and aluminates reacting with water. Silicates react with water to produce calcium silicate hydrate and calcium hydroxide ( $Ca(OH)_2$ ), which is commonly referred to as portlandite.



Ettringites are formed when aluminates and gypsum (calcium sulphate) come into contact with water.



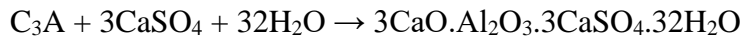
In the absence of calcium sulphate,  $C_3A$  responds rather quickly. Unlike alite,  $C_3A$  does not show a noticeable sluggish reaction time, leading to an almost immediate setup. Poorly crystalline aluminium hydroxide, or  $AFm_3$ , phases are formed upon first hydration; these phases are often recognized as  $C_2AH_8$  and  $C_4AH_{13}$  (35,43,44,45).

The chemical reaction that hydrates cement is complex. The cement's hydration process occurs in four distinct phases, which can be used to show how the process works: During the hydration



process, the silicates and aluminates in the Portland cement react with the water to produce a hard substance. When silicates and aluminates react with water, Portland cement first hydrates. When aluminates and gypsum (calcium sulphate) come together with water, ettringite formation results.

#### Phase 1



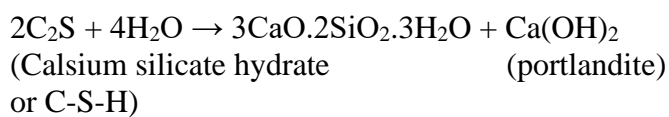
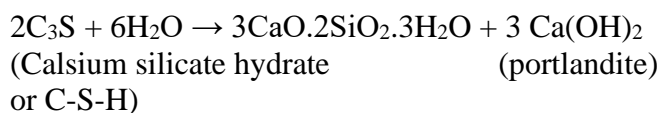
(Trisulphate or ettringite)

Moreover, silicates and water react to produce calcium silicate hydrate and calcium hydroxide ( $Ca(OH)_2$ ), often known as portlandite. The main ingredient in cement, alite, sometimes referred to as  $C_3S$ , is mostly responsible for determining the strength of Portland cement. When Alite comes into contact with water, it reacts immediately. Ions on the surface of alite start to break down and release silicate and hydroxyl ions.  $Ca^+$  ions have a positive charge, but this is balanced by the negative charge of ions like silicate and hydroxyl anions. Because alite dissolves in the liquid phase faster than surface ion diffusivity, the liquid phase oversaturates. And this hydration results in the creation of the CSH, or tobermorite.

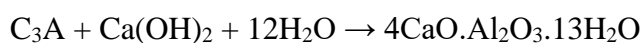
Belite, or dicalcium silicates, or  $C_2S$ , hydrates gradually in a manner akin to that of alite.

Tricalcium silicate, or alite, undergoes a similar solidification and firming process to Portland cement. Particle size distribution and the water-to-cement ratio both affect this process. As a result, calcium hydroxide (CH) and gel-like calcium silicate hydrate (C-S-H) are created. Cement hydration produces ettringite and monosulfate. Ettringite is a crystalline substance with a column structure that is made up of hydrates of calcium sulfo-aluminate ( $3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot 32H_2O$ ) and is known as an AFt-phase. In contrast, monosulphate is a molecule in the AFm-phase that has a lamellar structure and is made up of ( $3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot 12H_2O$ ). Ettringite, the main phase of AFt, forms during Portland cement's initial hydration process.

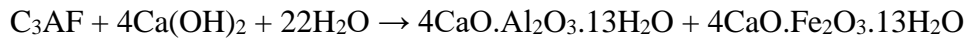
#### Phase 2



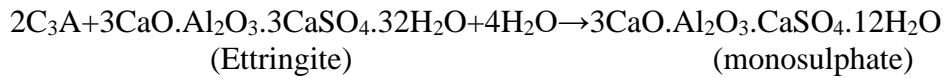
#### Phase 3







Phase 4



Ettringite is usually the first material to form during the hydration process of cement. When gypsum and calcium aluminates combine with water, ettringite formation occurs. The formation of ettringites delays the setting of cement. In the next step, calcium hydroxide (portlandite) and calcium silicate hydrate are created when calcium trisulphate and calcium disulphate are combined with water. The principal product formed during cement hydration is calcium silicate hydrate, comprising roughly 60–65% of the solid mass generated(33,35,46,47,48,49).

### 2.1.2 Setting of cement

Cement and water are combined to create a paste that gradually becomes stiffer, which is the first step in the cement setting process (50). Cement stiffens without appreciably increasing its compressive strength during initial setting, which takes place in a few hours (35). The process of setting transforms a suspension of dispersed anhydrous cement particles into the connected particles that strengthen the structure. Water added to cement usually causes a chemical reaction known as hydration. This system of transformation is produced by a reaction between the water and the cement particles (51).

The addition of calcium and sulphate ions to the cement paste regulates the rheology of any cementitious system. Cement paste rheology is significantly impacted by the production of ettringite. Just as important as sulphate dosage in regulating cement setting is sulphate phase insertion. Ettringite cannot form without large numbers of  $Ca^{2+}$  ions because alkali sulphate only gives  $SO_4^{2-}$  ions, which is inadequate to cause ettringite to form (52).

### 2.1.3 Initial Setting time of cement

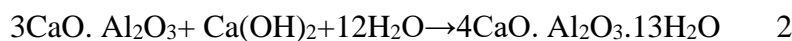
Applying materials that contain cement requires careful consideration of the initial setting period. The initial setting time determines the concrete installation procedure, concrete finishing process, transportation schedule, and concrete consolidation (53,54,55 ). The time that cement takes to set initially is important for both the placement of the concrete and the quality checks that are made while it is being placed. All concrete operations, such as mixing, shipping, pouring, and finishing, are governed by the initial setting time (56). Particles of unhydrated cement are mixed with water after being added. There is not much chemical activity

seen in the first several hours. With no percolating structure in hydration products, this early stage, called the induction period, causes concrete to exhibit a roughly pliable behaviour with greater workability. As such, the material made of cement has minimal rigidity and strength, which is sometimes considered negligible. The end of the induction period signals the start of the initial setting when hydration products from different cement particles interact. It is during this setup stage that stiffness and strength development begin with the production of a percolating cluster of hydration products. This is the point where the cement-based material becomes rigid and non-workable (3). When pure C<sub>3</sub>A combines with water extremely quickly, vibrant reactions take place. This results in an instantaneous solidification of the cement slurry; this process is called flash setting. The cement is combined with gypsum to prevent this flash setting. It is shown that when there is no gypsum in the cement, the tricalcium aluminate, or C<sub>3</sub>A, reacts rather quickly.

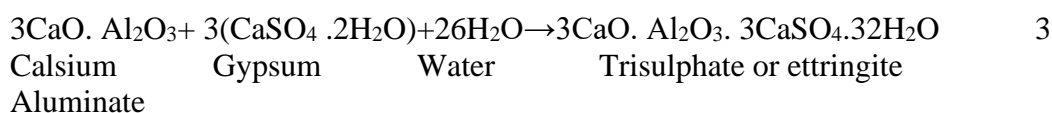


Although important in some situations, this quick-setting property could be unfavourable in concrete building, where a suitable window of workability is needed before the concrete sets irreversibly. Therefore, calcium sulphate is frequently added to cement mixtures to control the aluminate phase's reactivity. Although anhydrite (CaSO<sub>4</sub>) is usually found in natural gypsum sources, gypsum (CaSO<sub>4</sub>•2H<sub>2</sub>O) is the most widely utilized form of added calcium sulphate. During the grinding process, gypsum may partially dehydrate, resulting in the presence of the hemihydrate form (CaSO<sub>4</sub>•0.5H<sub>2</sub>O). The reaction pattern of C<sub>3</sub>A changes significantly when calcium sulfate is present. For cement applications to be effective and high-quality, especially when it comes to producing concrete, it is essential to comprehend and manage these chemical interactions (57).

Similar to this, it reacts fast in the presence of calcium hydroxide, which is a result of hydration of calcium silicates.



The two reactions listed above demonstrate how quickly Portland cement paste sets. Consequently, gypsum in the form of calcium sulphate is combined with clinker in the grinding mill. And gypsum functions as a retardant in cement paste; ettringite is produced when water is supplied through a reaction between gypsum and calcium aluminate;



In steps 1 and 2, the calcium aluminate hydrate develops rapidly, and the cement paste has some strength consistent with its initial setting. First, ettringites are produced by the reaction of calcium aluminate and calcium sulphate, often known as gypsum. During the initial hours of hydration, these ettringites coat and form a thin coating on the cement particles. Because the particles may still glide past one another through this layer, the cement paste maintains its plastic state (42). The speedy setting process of cement is slowed down by gypsum because it forms an ettringite coating on the cement grains (46). There was a substantial correlation seen between the generation of ettringite and the flow behaviour of cement paste. It seems that ettringite formation and cement paste workability decrease are positively correlated. As the amount of ettringite in the cement paste increased, so did the effect on the paste's workability. Cement paste has a different water-to-solid ratio when low-density ettringite develops (58). During the first phase, there is a rapid reaction, and within a few minutes, the rate decreases quickly. During the initial reaction, the primary hydrate phase produced is ettringite. A low heat output phase follows this quick reaction phase, and how long it lasts depends on how much calcium sulfate is in the system. With calcium monosulfoaluminate being the main product phase, the reaction rate quickly increases once again once the additional calcium sulphate has been completely consumed. To guarantee adequate setting and hardening in cement systems, the slow response period of  $C_3A$  must persist long after the major rate peak of alite. What causes the initial reaction to abruptly slowdown is the main question regarding the hydration mechanisms of  $C_3A$  in the presence of calcium sulphate. Three possible explanations exist for the phenomena that has been observed:

1. By forming a diffusion barrier at the  $C_3A$  surfaces, the product phase ettringite may impede the reaction.
2. Using a similar method, it's likely that other phases, like Afm, may also obstruct the reaction.
3. The adsorption of specific solute species generated during the breakdown of calcium sulfate may directly block the process (35,59,60).

### **3 Use of Chemical admixtures to regulate the initial setting time**

As soon as  $C_3S$  and water come into contact, a quick succession of reactions start to happen during the first stage of cement hydration. The breakdown of  $C_3S$  and the heat generated during the wetting process are two important exothermic reactions that characterize this phase. Comprehensive chemical examinations of the solution phases have yielded compelling proof that  $C_3S$  dissolves uniformly and quickly during the initial wetting seconds.

The forming of a continuous, thin, metastable layer of calcium silicate hydrate phase, called C-S-H(m), occurs quickly, which causes the reaction rate to drop as the reaction does. By limiting the flow of water and preventing the surface's detaching ions from diffusing, this layer functions to passivate the ground. The hypothesis is that at the conclusion of the initial reaction time, this thin layer will have reached equilibrium with the solution.

For both alite and C<sub>3</sub>S systems that are not retarded or annealed, the delay time represents the moment after the initial reaction when the rate of hydration is at its lowest before the hydration products start to rise quickly. When chemical retarders are introduced or materials have undergone annealing, a distinct induction period is only noticed. Until a critical threshold is achieved, which causes the nucleation and growth processes to accelerate, the delay is primarily explained by the slow reaction caused by one of the previously described mechanisms (61).

Admixtures for concrete are essential for affecting the cement hydration kinetics, particularly in the early inactive phase. These admixtures appear to have the most effect on the intermolecular interactions between the different ion species in the aqueous solution inside the concrete. Attractive forces predominate during the crystallization stage, whereas repulsive forces rule during the solvation phase. With increasing hydration, these bound force transitions result in two different volumetric changes. Concrete admixtures have a noticeable effect on the cement's response, as demonstrated by trials conducted using an immersion weighing system. Accelerators cause quick tendencies toward shrinkage, while retarding agents cause volume growth. A theoretical model that fits the hydration kinetics is one that is akin to Le Chatelier's and includes a solvation-crystallization sequence. Any development of strength is impeded by the volume expansion that takes place when repulsive forces maintain control. The length of the latent phase is determined by the length of the swelling process. As soon as volume reduction is apparent, the hardening and strengthening process begins (62).

An essential part of the concrete-making process is the admixture. The cement's stiffness is influenced by the admixture's reaction to the paste, in addition to the paste's fluidity (63). Chemical admixtures play a major role in controlling the fluidity, setting, and hardening times of concrete (64). The setting time can be controlled by adding the right admixtures to increase or decrease its speed (11). Freshly mixed concrete's rheological behaviour is controlled by chemical admixtures. The cement hydration process can be changed via retarders and accelerates (65). The quantity of admixture applied can affect how quickly cement hydrates. Some admixtures can be used as water reducers to delay the hydration of cement; this depends on the mixing ratio (66). The rheological characteristic is essential for concrete. The interaction between the cement and admixture can cause sudden variations in the concrete's stiffness and fluidity, depending on the composition (67,68,69,70).

### **3.1 Use of sugarcane juice and its bi-products as bio-admixtures**

One of the most important crops is sugarcane. Worldwide, tropical and subtropical regions are suitable for its growth. India is the second-largest producer of the crop, after Brazil. Sugarcane

juice is composed of 75–85% water, 0.3–3% reducing sugar, and 10–21% nonreducing sugar (71,72). The addition of sucrose modifies the formation process as well as the microstructure of C-S-H (73). The addition of sucrose to cement paste initiates the process of cement setting, often known as acceleration or retardation. Depending on how much Aft is produced, there will either be acceleration or retardation (74). In other words, acceleration and retardation are dose-dependent, and the doses of bio-admixtures that cause retardation are crucial. Retardation is brought on by added sugars, glucose, and other substances. Cement hydration is accelerated by bio-admixtures such as inorganic salts, organic compounds, and so on. Bio-Admixtures like triethanolamine and triisopropanolamine function as accelerates when applied at low dosages (75). Cement hydration rate is dependent on bio-admixture amount. Depending on the mixing ratio, certain bio-admixtures used as water reducers may cause the cement to hydrate more slowly (76). A considerable amount of Aft was generated when different proportions of the sucrose solution were combined with Portland cement. When a high volume of sucrose solution was added, the cement's hydration process quickened, hastening the cement's setting (77). A higher molasses content lengthens the induction phase. A lower molasses content of sugarcane may hasten the dissolution of the aluminate phase, whereas a higher molasses content may facilitate the early stages of Aft nucleation and development. A 1.0% molasses content accelerates the production of Aft from the hydration of  $C_3A$  and Ferrite; however, the cement paste hydration with 1.0% molasses significantly inhibits the second hydration of  $C_3A$  and Ferrite and delays the hydration of  $C_3S$  as well (78). Upon adding sucrose, which accounts for 0.045% of the cement's weight, the consistencies of  $Ca^{2+}$  and  $OH^-$  are decreased and Aft (Ettringite) is generated. As a retarding admixture, sucrose is used because the Aft coats the surface of the clinker particles and appears as a gel-like result. When the amount of sucrose is increased to 0.24%, the hydration processes of  $C_2S$  and  $C_3S$  are clearly poisoned by it, and the consistency of  $Ca^{2+}$  and  $OH^-$  accelerates the setting process since the Aft now acts like a needle (79). A substantial correlation was seen between the development of ettringite and the flow behaviour of cement paste. The loss of workability of cement paste has been discovered to be directly connected with the production of ettringite. As the ettringite content of the cement paste increased, so did the effect of the additional ettringite on the paste's workability. The water-to-solid ratio of the cement paste changes as a result of low-density ettringite formation (58). Cement setting periods, both initial and final, are significantly affected by the bio-admixture of sugar. The setting times increased significantly if a modest amount of sugar was added to the cement. When roughly 0.05% sugar was added, the cement's initial and final setting times increased to their maximum values. On the other hand, the setting times shortened

when the sugar content exceeded 0.05%. It was found that the initial setting time of the cement decreased less when the sugar concentration was higher than 0.1% (80). According to the research, adding sugar in any form in 1.5%, or 0.5% ratios had the impact of delaying the setting of cement. This included brown, granular, and caster sugars. Still, all these sugars worked as cement accelerators when added in 2.5% and 5% ratios. Results indicated that adding sugar up to a certain ratio—the optimal 1.5%—rose the cement's final setting time, but adding more sugar caused the cement to set faster. All types of sugar also caused a reduction in the initial setting time of cement (81). The cement paste's initial setting time was found to rise with up to 0.2% sugar added, while the final setting time increased with up to 0.15% sugar added. The initial and final settings happened at 120 and 349 minutes, respectively, with 0% sugar addition. When 0.2% sugar was added, the cement set in 174 minutes, but when 0.15% sugar was added, it took 112 minutes. The final settings took place at 491, 316, and 294 minutes, when 0.15%, 0.2%, and 0.25% of the sugar were added (8).

#### 4 Conclusion

The aforementioned research suggest that the hydration process and setting time of cement are impacted by the addition of sugarcane juice and its by-product. By slowing down the hydration process, a small amount of sugarcane juice and its by-products extends the cement's setting time. Larger quantities of sugarcane juice and its derivatives, on the other hand, speed up the hydration process and shorten the cement's setting time.

Previous studies also discovered the similar tendency.

A small amount of sugarcane molasses increases the fluidity of cement mortar while slowing the setting and hardening of cement paste; an excessive amount of molasses speeds up these processes (78). The cement paste's setting time was greatly shortened by the bio-admixture of sugarcane juice. Higher amounts of sugarcane juice in the cement paste, according to experiments, led to even faster setting times than the controlled cement paste that didn't contain any sugarcane juice. After adding 2, 5, 10, and 20% sugarcane juice by weight of cement, respectively, the initial setting time of the cement was shortened by 33, 57, 70, and 90% in comparison to the controlled cement paste. These results unequivocally demonstrate that sugarcane juice accelerates the cement-setting process (82). Different amounts of sugar were added to the cement paste: 0%, 0.04%, 0.05%, 0.06%, 0.07%, 0.10%, 0.20%, 0.30%, 0.40%, and 0.5% by cement weight. Tests conducted under standard settings on the cement paste setting times revealed that, in comparison to adding 0% sugar, adding up to 0.25% sugar increased the cement's initial and final setting times. The initial and final setup times at 0%

sugar were 143 and 204 minutes, respectively. The initial and final setting periods were increased to 260 and 649 minutes, respectively, for 0.25% sugar. Both setting times drastically decreased when the sugar content surpassed these percentages. The initial setting happened at 42 minutes, and the final setting happened at 72 minutes, at 0.30% sugar. The two settings were at 0.40 to 0.50% sugar for 20 and 40 minutes, respectively (83).

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