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Initial setting time of cement using sugarcane juice as an admixture

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Abstract

Concrete is a widely used material in construction projects globally, valued for its durability and strength. Comprised of cement, sand, aggregate, and water, the addition of admixtures further enhances its properties. Cement plays a pivotal role in the hardening of concrete through a chemical process known as hydration, which occurs upon mixing with water. To tailor the setting process according to specific project requirements or environmental conditions, chemical admixtures such as retarders or accelerators are incorporated. These additives are instrumental in extending or shortening the initial setting time of cement, ensuring optimal performance. While chemical admixtures are commonly employed to improve concrete characteristics in modern construction practices, they have environmental and health implications. The study examined the effect of sugarcane juice as an organic admixture on cement's initial setting time. By analyzing sugarcane juice proportions ranging from 0% to 28% of the cement's weight. The initial setting times were precisely measured with the Vicat apparatus. All results were benchmarked. The percentages included are 5%, 10%, 15%, 20%, 25%, and 28%. All results were compared to a 0% sugarcane juice baseline. The cement's initial setting time notably decreased from 140 to 75 minutes with 5% sugarcane juice added. Progressive additions of 10%, 15%, 20%, and 25% sugarcane juice steadily reduced the initial setting time. At 28% with only sugarcane juice as the admixture, the initial setting time decreased significantly to 23 minutes. The research indicated that higher proportions of sugarcane juice speed up hydration, significantly reducing the cement's initial setting time.

1. Introduction

Concrete is an essential construction material utilized in the majority of construction activities (1). When water is added to the cement and aggregate blend, the cement initiates a reaction with the water. Under typical weather conditions, this combination solidifies and strengthens over time, resulting in concrete. Once the mixture is placed in formwork and permitted to cure, it transforms into a durable mass akin to stone. The chemical interaction between cement and water is responsible for the solidification process of this blend (2). The characteristics that determine the strength of solidifying concrete are closely tied to the microscopic structure of cement material. As a result, the formation of structures can be connected to the alterations in material characteristics that happen during the process of hardening (3).

Construction activities require strict adherence to parameters and procedures in order to achieve the desired quality outcomes. One critical factor to consider is temperature, as it significantly impacts the performance of concrete. In hot weather conditions where temperatures exceed 100°F, the hydration process of cement is accelerated, leading to faster setting times. While concrete may

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exhibit early strength development in such conditions, it is important to note that significant strength can be compromised in the long term.

Furthermore, hot weather conditions can give rise to plastic shrinkage due to rapid water evaporation from the concrete surface. Tensile stresses may be formed as a result of this within the material, ultimately leading to cracking. To mitigate these risks and ensure the longevity and durability of concrete structures, it is essential to follow precise procedures and take appropriate measures to address the challenges posed by hot weather conditions. By carefully monitoring and adjusting construction practices in high temperatures, the quality and integrity of concrete can be effectively maintained (4,5). The heat created during the concrete's shrinkage and expansion after hardening creates tensions that eventually result in tiny cracks within the concrete structure. This phenomenon is problematic when building big concrete structural elements like bridges, dams, and piers, as well as when concreting structures in hot regions in general (6,7). Similarly, concreting in cold weather can have negative effects. The volume of concrete increases as water sets in its plastic state, impacting chemical reactions. Without sufficient water, the concrete setting and hardening process are delayed, leading to the formation of numerous pores. Ultimately, this results in concrete with lower strength (4,8). The difficulties experienced when working with concrete in cold weather are caused by the negative effects of frost on recently poured concrete. When the wet concrete becomes frozen, the water used in the mixing process transforms into ice, leading to an expansion in the concrete's volume. The lack of water for chemical reactions results in a delay in the concrete's curing and solidification. The cold temperature poses challenges for the concrete's curing and hardening process, as well as the risk of freezing and thawing during the initial stages. As a result of this process, ice needles begin to form inside the concrete, which then leads to the creation of cavities when the ice melts. These cavities significantly weaken the structural integrity of the concrete and result in a significant decrease in strength. In extreme conditions, the cold temperatures can make the concrete completely useless, causing it to become weak and easily breakable. Nonetheless, if the concrete has already hardened before freezing temperatures set in, it will not cause significant structural damage to the concrete. Once the concrete has solidified properly, any water that was used in the mixing process will have either evaporated or been consumed during hydration. There will be minimal excess water in the concrete structure to freeze as the capillary voids will have contracted due to the formation of cement gel (9).

Hence, chemical admixtures are utilized to uphold the prescribed standards (10). With the exception of cement, aggregates, and water, the additional material employed in the production of concrete is commonly referred to as an admixture (11). Admixtures play a crucial role in shaping the characteristics of concrete beyond the traditional components of cement, aggregates, and water. These supplementary materials are incorporated either during or just before the concrete mixing process to tailor its properties to specific construction requirements. Admixtures are instrumental in enhancing attributes like workability while effectively addressing challenges posed by extreme temperatures (12).

Concrete possesses multiple advantageous qualities that make it a highly favorable material for construction purposes, including its binding capabilities, strength, and durability. However, its utility across diverse weather conditions in its natural state is limited due to varying setting times. To address this challenge, the use of retarders and accelerators as admixtures becomes imperative in hot and cold weather scenarios to prolong or hasten the initial setting time, respectively. This strategic application ensures optimal performance and efficiency of concrete in a range of environmental conditions (13).

Retarders and accelerators can change the way hydration occurs (14). Admixtures that effectively improve the hydration process and prolong setting times are commonly referred to as retarders (10). A retarder is a substance that delays the hardening process of cement paste, and consequently, the hardening process of cement-based materials like concrete or mortar (15). Retarders are additive ingredients that delay the concrete’s initial setting time, giving concrete operations extra time, and can be utilized to slow down the rate of hydration, heat generation, and strength development. By preventing cement from reacting with water, retarding admixtures reduce the rate of hydration (16).

Under normal weather conditions, adding water to cement causes it to set and harden. However, in certain countries, hot weather conditions can lead to challenges in the concreting process. Hot winds, low humidity, and high temperatures can accelerate the evaporation of moisture from recently laid concrete. This quick evaporation can result in early setting of the concrete, limiting the time available for proper concreting processes. Research has shown that when the temperature of cement mortar rises between 27.80°C and 45.50°C, with a water-cement ratio of 0.6, both the initial and final setting times are significantly reduced to approximately half. In such adverse weather conditions, it becomes crucial to allow for sufficient time for the proper mixing, transporting, and placing of concrete. To address these challenges, the use of retarding admixtures is recommended. By incorporating these admixtures into the concrete mix, construction projects can maintain the required workability and achieve the desired results (17,18). Accelerators are indeed a crucial type of admixture in construction projects. Their primary function is to modify the hydration process's mechanism and kinetics, resulting in accelerated setting times (19,20). An accelerator is a substance that, when mixed with grout, concrete, or mortar, speeds up the hydraulic cement hydration process, cuts down the setting time, or hastens the hardening and strengthening process (15).

It is important to acknowledge the significant role those chemical admixtures play in enhancing concrete properties, such as retarders and accelerators. However, it is evident that these additives have negative implications for the environment, primarily due to leaching. The exposure of chemical admixtures during demolition or the use of debris containing them as gravel can contribute to environmental harm. Furthermore, environmental pollution can occur during the production, storage, transportation, and usage of concrete with chemical admixtures. Given the water-soluble nature of these additives, leaching poses a significant risk to environmental health. The cost implications of utilizing synthetic admixtures also contribute to the overall disadvantages associated with their usage. In light of these limitations, there is a rising curiosity about investigating alternate bio-based admixtures that are able to effectively enhance concrete properties without causing harm to the environment. This shift towards bio-admixtures not only aligns with sustainability goals but also presents an opportunity to reduce costs compared to synthetic options. As the construction industry continues to prioritize environmental considerations, the investigation and adoption of bio-based admixtures represent a promising pathway towards sustainable concrete solutions (21- 27). When using high-performance concrete, admixture costs can sometimes exceed those of cement. Therefore, research and the development of organic admixtures are essential to the advancement of concrete technology. This underscores the importance of focusing on the development of organic admixtures over cement enhancements (28). Therefore, the creation of environmentally friendly concrete will be aided by the discovery of substitute admixtures. Globally, scientists and researchers working with concrete are working to create non-chemical admixtures that are regarded as environmentally friendly and sustainable construction materials. Green or natural admixtures can be a realistic alternative and support green building because of their abundance and simple manufacturing process. Animal products, fruit, and herpes are combined to produce these concoctions. Natural admixtures and biopolymers produced through biotechnological processes are commonly called "bio-admixtures." It appears that employing natural admixtures made from plant or fruit extracts is a reasonable choice, despite the lack of research on the topic. Studies conducted on old buildings indicate that plant extract and lime were employed in construction (29). Hence, the incorporation of natural admixtures proves advantageous for improving the characteristics of both fresh and hardened concrete. Due to their environmentally friendly nature and cost-effectiveness, natural admixtures are deemed superior to chemical alternatives (30).

The history of the use of admixtures closely parallels that of concrete and mortar. Dating back to around 3000 BC in India, various types of natural admixtures, such as molasses, fruit juices, bananas, olive oil, milk products, and others, were commonly employed. These natural admixtures were integrated into lime mortar for a variety of purposes, including accelerators like starch, fig juice, and soured milk, plasticizers such as sugar, mineral oils, and olive oils, as well as glycerol, pine resin, protein, and reducing agents like bee wax (31,32). In ancient times, herbs used as admixtures in lime mortars (29). Jaggery is a natural product, making it environmentally friendly.

Its excellent binding qualities have led to its longstanding use in construction works in India and China for centuries (23). In ancient times, jaggery was a prevalent admixture (33). In Thirrsur, Kerala, India, the ancient Vadakkunnathan temple 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 a period of fifteen days. This mixture was mixed with lime to make the plaster (29). For a very long time, the construction of the Channel between England and France used molasses(sugar), as a retardant (34). Molasses can be used as a retarder, water reducer, and grinding aid in construction materials. Molasses is a common admixture used in China in cement and concrete to reduce and retard water and also serves as a grinding aid (35).

2. Materials

2.1 Cement

When a material undergoes a chemical reaction with water and solidifies into a hard mass, it is commonly known as cement. Cement is essentially the capability of a substance to form strong bonds with other materials through a series of chemical reactions (36-38).

When calcareous (such as limestone) and argillaceous (such as clay) raw materials are subjected to high temperatures of 1400–1450 °C, clinker nodules form due to partial fusion. A specific percentage of calcium sulphate is blended with the clinker, and after finely grinding this mixture, cement is produced. Calcium sulphate, commonly referred to as gypsum, has a vital function in controlling the cement's setting process (38-40). The raw materials required for the production of cement include lime, silica, alumina, and iron oxide.

Table 1. Portland cement's approximate composition limits

Oxide	Content Percentage
CaO(Lime)	60-67
SiO_2(Silica)	17-25
Al_2O_3 (Alumina)	3-8
Fe_2O_3(Iron oxide)	0.5-6
MgO (Magnesia)	0.1-4
Alkalis	0.2-1.3
SO_3(Sulphur trioxide)	1-3

Throughout the kiln's heating process, various compounds present in the mixture react with each other, leading to the formation of a series of complex products. Among these products, four compounds are recognized as the primary constituents of Portland cement (enumerated in Table 2 along with their shortened symbols). The chemical symbols for these compounds are abbreviated for convenience in cement chemistry. For instance, CaO is represented as C, SiO_2 as S, Al_2O_3 as A, and Fe_2O_3 as F. Furthermore, in the context of hydrated cement, water (H_2O) is symbolized by the letter H.

Table 2. Portland cement's primary ingredients

Name of Compound	Oxide composition	Abbreviation
Tricalcium silicate	$3CaOSiO_2$	C3S
Dicalcium silicate	$2CaOSiO_2$	C2S
Tricalcium aluminate	$3CaOAl_2O_3$	C3A
Tetracalcium aluminoferrite	$4CaOAl_2O_3\ Fe_2O_3$	C4AF

Once hydrated, Portland cement's strength is mostly determined by the silicates, specifically C3S and C2S. These compounds have a substantial effect on the cement's overall strength and durability. On the other hand, C3A is considered undesirable in Portland cement as it provides minimal to no contribution to the strength characteristics of the cement (38). Tricalcium silicate

(C3S or alite) is recognized as the primary compound in Portland cement, constituting 50-70% of its composition. Additionally, the percentages of dicalcium silicate (C2S or belite), tricalcium aluminate (C3A or aluminate), and tetracalcium aluminoferrite (C4AF or ferrite) in Portland cement typically range from 15-30%, 5-10%, and 5-15%, respectively (39).

2.1.1 Hydration of Cement

When water is mixed with anhydrous cement or its components, the resultant reaction leads to a series of chemical changes known as hydration (39). Hydration is a fundamental chemical process involving the interaction between anhydrous compounds and water molecules, leading to the formation of hydrated compounds with distinctive properties. This reaction not only induces superfluidity in the resultant compounds but also triggers mechanical, physical, and chemical changes (41). Concrete hardens through hydration, an exothermic event involving cement and water (16). When cement and water are mixed, numerous chemical reactions occur, initiating the transformation of a workable cement paste into a durable, solid structure. This conversion process is driven by the hydration reactions between ordinary Portland cement and water molecules, resulting in the formation of various components. The complexity of this process is influenced by the initial composition of the clinker, which in turn is affected by the alterations within the cement matrices. The intricate nature of these reactions underscores the intricacy involved in the solidification of cement through hydration (42).

Hydration kinetics is usually divided into three separate stages. In the beginning, there is an initial induction period followed by a nucleation and growth stage, and finally a diffusion-controlled phase. During the diffusion-controlled phase, which lasts around 48 hours after mixing, despite being early in the hydration process, it significantly affects the hydration kinetics (43). hydration, the silicates and aluminates found in Portland cement undergo a chemical reaction with water, as a result of which a solid mass form. The hydration of silicates results in the production of calcium silicate hydrate (C-S-H) and $Ca(oH)_2$ (38).

The hydration process of ordinary Portland cement is thoroughly documented, detailing the composition of its clinker which comprises four main phases: C2S and C3S (calcium silicates), C3A (calcium aluminate), and C4AF (ferrite). The addition of calcium sulphate helps regulate the setting process of ordinary Portland cement by acting on these phases. Early hydration primarily stems from C3S and C3A, whereas the slower hydration of C2S plays a more critical role in determining the cement's later properties (44).

The chemical reactions of cement during the hydration process closely resemble those of its individual calcium silicate phases, including C3S (alite) and β-C2S (the dominant form of belite). When these phases react with water independently, they generate comparable final products, which include calcium hydroxide and calcium silicate hydrates (commonly referred to as CSH gel). The primary composition of CSH gel is typically 3CaO·2SiO2·3H2O, although there may be variations in lime: silica ratios. Given that C3S and C2S make up around 75% of Portland cement, their hydration reactions are crucial in the overall cement hydration process. Although both silicates need a comparable quantity of water for hydration in terms of weight, C3S creates three times more Ca(OH)2 than C2S. Although most cements have low levels of C3A, the way it behaves and interacts structurally with other cement phases is of great interest. When tricalcium aluminate hydrate, likely when mixed with other solid substances, produces a dark, prism-like substance in between. Typically, this substance is found as flat plates encircled by calcium silicate hydrates. When C3A reacts with water independently, it triggers a fierce reaction that causes a rapid setting and the release of significant heat, making the cement difficult to work with. The equation C3A + 6H2O = C3AH6 (tricalcium aluminate hydrate) represents a quick response. In order to avoid this unwanted situation, gypsum (CaSO4.2H2O) is added to the cement clinker. This additional ingredient encourages the creation of ettringite, which regulates the setting process of the cement. The resulting chemical process can be summarized as: C3A + 3CaSO4.2H2O + 26H = C3A3CaSO4.32H2O (also known as ettringite) (45).

The hydration of cement is a complex and multifaceted process involving many chemical and physical interactions at a microscopic level. In essence, when the unhydrated cement and the mixture's free water combine, it results in the creation of different hydrates. Portland cement is made up of important minerals like calcium silicates (C3S and C2S), calcium aluminates (C3A), and calcium aluminoferrites (C4AF). When mixed with water, it produces different hydrates such as calcium silicate hydrate (CSH), calcium hydroxide (CH), ettringite (Aft), and monosulfate (Afm). A thorough grasp of the mechanisms underlying hydration is still elusive, despite a century and more of research on the subject. It is clear that the various components' reaction rates differ greatly from one another. As such, the computer modeling of the complex interactions in a hydrating poly-mineral and poly-size mechanism is extremely intricate and requires the take-in of physical, chemical, stereological, and granular parameters. Because of these intricacies, it is crucial to move from studying the different compounds' hydration 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 process of cement involves a complex interaction of different elements, necessitating a comprehensive approach to fully understand its complexities (46).For the purpose of comprehensively understanding the cement's hydration process, it is essential to examine the four primary clinker phases: alite, belite, aluminate, and ferrite. Simplistically, the following can be used to represent how cement hydrates:

- Clinker phases + water → Hydrated phase + energy
  (High in energy (low energy (heat of hydration)
  with no water) contains water) (47)

The hydration process in Portland cement is a key aspect in understanding its setting and hardening characteristics. Initially, When Portland cement's silicates react with water, calcium hydroxide $Ca(OH)_2$, often referred to as portlandite, and calcium silicate hydrate (C-S-H) are created. The following is a representation of this reaction:

- Silicates + water → C-S-H + portlandite

Additionally, the aluminates in Portland cement react with gypsum (calcium sulfate) in the presence of water to form ettringite. This reaction can be depicted as

- Aluminate (C3A) + calcium sulfate + water → ettringite (39).

Tricalcium aluminate's two primary hydration products are ettringite (AFt) and monosulfoaluminate (AFm(MS)). Gypsum promotes ettrigite production, and in a system that contains a low calcium carbonate content, monosulfoaluminate is the typical AFm phase (48).

The solidification and firming process of tricalcium silicate (alite) is similar to that of Portland cement. This process is affected by both the ratio of water to cement and the particle size distribution. As a result, gel-like calcium-silicate-hydrate (C-S-H) and calcium hydroxide (CH) are formed. Ettringite and monosulfate are produced during the process of cement hydration. Ettringite is a compound with a columnar structure made up of calcium sulfo-aluminate hydrates (3CaO·Al2O3·3CaSO4·32H2O) and is known as an AFt-phase. In contrast, monosulfate is a type of AFm-phase compound that has a layered structure and is made up of (3CaO·Al2O3·CaSO4·12H2O). In the beginning stages of Portland cement's hydration process, Ettringite, which is the main component of AFt, is created (39). In the absence of calcium sulphate, C3A reacts rather quickly. Unlike alite, C3A does not show a noticeable slow reaction time, leading to an almost instantaneous setting. Poorly crystallized aluminum hydroxide, or AFm3, phases are formed upon initial hydration; these phases are commonly recognized as C_2AH_8 and C_4AH_{13}(39,49,50,51).

The process of cement hydration involves a complex chemical reaction that progresses through several distinct stages. The cement's hydration can be broken down into four main stages. Initially, the silicates and aluminates present in Portland cement engage in a reaction with water, resulting in the formation of a durable solid mass. Specifically, the hydration process in Portland cement is kickstarted by the interaction between silicates and aluminates with water. Aluminates, when there is water present, also undergo a reaction with gypsum (calcium sulphate) to produce ettringites, further contributing to the overall hydration process.

Stage 1:

- $C3A + 3CaSO_4 + 32H_2O \rightarrow 3CaO.Al_2O_3.3CaSO_4.32H_2O$
  (Trisulphate or ettringite)

Furthermore, the combination of silicates with water forms calcium hydroxide, which is also called portlandite Ca(OH), and calcium silicate hydrate. The main source of strength in Portland cement comes from C3S, also known as alite, which is the primary component in cement. When Alite comes into contact with water, it rapidly undergoes a reaction. The external ions of alite start to break down, releasing silicate and hydroxyl ions. Therefore, the negative charge of ions such as hydroxyl and silicate anions balance out the positive charge of Ca+ ions. As alite dissolves quickly, the liquid phase becomes saturated before surface ions have a chance to permeate through. Due to this process of hydration, the formation of CSH, also known as tobermorite, occurs. Dicalcium silicates (C2S or belite) exhibit a similar hydration process to that of alite, but their reaction occurs at a slower pace. Tricalcium silicate (alite) behaves like Portland cement in terms of setting and hardening, with its properties being influenced by the water-to-cement ratio and particle size distribution. As a result, Calcium hydroxide (CH) and C-S-H (having a gel-like consistency) are formed. The process of adding water to cement leads to the creation of ettringite, which is a type of crystalline calcium sulfo-aluminate hydrate ($3CaO.Al_2O_3.3CaSO_4.32H_2O$, an AFt-phase) with a column structure, and monosulfate, which is another type of calcium sulfo-aluminate hydrate ($3CaO.Al_2O_3.CaSO_4.12H_2O$, an AFm-phase) with a lamellar structure. In the early stages of the hydration of Portland cement, ettringite, the most significant phase of the AFt, is formed.

Stage 2:

- $2C3S + 6H_2O \rightarrow 3CaO.2SiO_2.3H_2O + 3Ca(OH)_2$
  (Calcium silicate hydrate or C-S-H) (portlandite)
- $2C2S + 4H_2O \rightarrow 3CaO.2SiO_2.3H_2O + Ca(OH)_2$
  (Calcium silicate hydrate or C-S-H) (portlandite)

Stage 3:

- $C3A + Ca(OH)_2 + 12H_2O \rightarrow 4CaO.Al_2O_3.13H_2O$
- $C3AF + 4Ca(OH)_2 + 22H_2O \rightarrow 4CaO.Al_2O_3.13H_2O + 4CaO.Fe_2O_3.13H_2O$

Stage 4:

- $2C3A + 3CaO.Al_2O_3.3CaSO_4.32H_2O + 4H_2O \rightarrow 3CaO.Al_2O_3.CaSO_4.12H_2O$
  (ettringite) (monosulfate)

Ettringite plays a significant role in the early stages of the hydration of cement, serving as the initial precipitation product. Its formation is facilitated by the interaction of calcium aluminates with gypsum in the presence of water. This process effectively impedes the setting of cement. Subsequently, the reaction between calcium trisulfate and calcium disulfate with water gives rise to calcium silicate hydrate and calcium hydroxide (portlandite). Notably, calcium silicate hydrate stands out as the predominant product of cement hydration, accounting for 60-65% of the resulting solid mass (38,39,52-55). During the initial hydration of cement, a crucial phase in AFT is the formation of ettringite (39).

2.1.2 Setting of Cement

When water is added to the cement, it creates a paste that gradually becomes stiff, resulting in the paste beginning to harden (56). Setting is the process by which cement stiffens without a significant increase in compressive strength, and typically takes place within a few hours (39). Anhydrous cement particles are dispersed, while setting refers to the process where these scattered particles come together to form a strong, connected system. Typically, this process of change is achieved through a chemical interaction that occurs when water is mixed with the cement, initiating hydration - a reaction between the cement particles and water (57).

2.1.3 Initial Setting Time of Cement

Setting time is the amount of time that concrete takes to harden after water is mixed with the cement-aggregate mixture (16). The initial time for setting is a crucial factor when working with materials containing cement. The initial time of the setting process controls the timing of the transportation schedule, the pouring and finishing of the concrete, and the consolidation of the concrete (58,59,60). The amount of time cement takes to set is incredibly important when it comes to placing concrete and conducting quality checks during the process. The duration in which the concrete sets dictate every step of the process, from mixing and transportation, to placement and finishing (61). The unhydrated cement particles dissolve in water upon the addition of water. In the first few hours, very little chemical activity is seen. During this initial phase, referred to as the induction period, hydration products lack a percolating structure, which causes concrete to behave in a roughly plastic manner with better workability. As a result, the material that is based on cement has minimal stiffness and strength, which are frequently viewed as unimportant. The products of hydration resulting from various cement particles begin to interact as the induction period comes to an end, causing the initial setting to occur. During this initial period, a cluster of hydration products begins to form, leading to the development of stiffness and strength. At this point, the material that is based on cement becomes stiff and difficult to work with (3).

The pure C3A rapidly undergoes a violent reaction with water. Therefore, the cement paste quickly becomes stiff, a process known as flash setting. Gypsum is included in the cement to avoid the occurrence of this sudden flash setting. If gypsum is absent in the cement, the tricalcium aluminate (C3A) will react very quickly, as demonstrated.

$$3Cao.\ Al_2O_3+6H2O \rightarrow 3Cao.\ Al_2O_3.6H_2O \quad (47) \qquad (1)$$

This fast-hardening property, while important for specific uses, may be inconvenient in the construction of concrete, where the concrete must be workable for a sufficient amount of time before it permanently hardens. Therefore, calcium sulfate is frequently added to cement mixes in order to regulate the aluminate phase's reaction. Gypsum (CaSO4•2H2O) is the most commonly utilized type of calcium sulfate added, but natural gypsum sources also often contain anhydrite (CaSO4). The presence of the hemihydrate form (CaSO4•0.5H2O) may occur when gypsum partially dehydrates during the grinding process. When calcium sulfate is present, it results in a notable change in the reaction behavior of C3A. Understanding and regulating these chemical reactions is essential for ensuring the effectiveness and standard of cement applications, especially in the context of producing concrete (62). Likewise, it quickly responds when exposed to calcium hydroxide, which is produced during the hydration of calcium silicates.

$$3Cao.\ Al_2O_3+ Ca(oH)_2+12H_2O \rightarrow 4Cao.\ Al_2O_3.13H_2O \qquad (2)$$

Both reactions mentioned above showcase the rapid hardening of Portland cement paste. Therefore, the calcium sulphate in the form of gypsum is added to the clinker in the grinding mill. The gypsum helps slow down the setting of cement paste, while the calcium aluminate reacts with gypsum when mixed with water to create ettringite.

$$\underbrace{3Cao.\ Al_2O_3}_{\text{Calcium Aluminate}}+ \underbrace{3(CaSO_4\ .2H_2O)}_{\text{Gypsum}}+\underbrace{26H_2O}_{\text{Water}} \rightarrow \underbrace{3Cao.\ Al_2O_3.\ 3CaSO_4.32H_2O}_{\text{Trisulphate or ettringite}} \qquad (3)$$

In reactions 1 and 2 mentioned earlier, the creation of calcium aluminate hydrate occurs rapidly, causing the cement paste to gain some strength at its initial set. The interaction between calcium aluminate and calcium sulfate, specifically gypsum, leads to the formation of ettringites. During the initial phase of the hydration process, ettringites coat the cement particles and create a thin layer on them. This film allows the particles to slide freely, causing the cement paste to stay in a plastic state (47). The inclusion of calcium ions and sulphate ions in cement paste helps regulate the flow properties of any system containing cement. The creation of ettringite is significant in determining the flow properties of cement paste. The addition of the sulphate phase is equally important to the dosage of sulphate in controlling the setting of cement. In order to form ettringite, a large quantity of Ca^{2+} ions are required as alkali sulphate cannot promote the formation of ettringite since it only provides SO_4^{2-} ions (63). Gypsum leads to the creation of an ettringite coating over the cement particles, serving to delay the rapid setting process (52). The incorporation of gypsum into Portland cement serves to prolong its setting time until a certain threshold is attained, characterized by a plateau effect. Subsequent additions of gypsum beyond this critical point exhibit minimal impact on the setting time of the cement (64). A significant correlation was observed between the production of ettringite and the rheology of cement paste. The development of ettringite seems to be positively correlated with the reduction in cement paste workability. As the cement paste's ettringite content increased, so did the impact of the additional increased ettringite on the workability of the paste. The water-to-solid ratio of the cement paste changes when low-density ettringite forms (65). Fast reaction takes place at the beginning, followed by a swift reduction in speed within a short period. Ettringite is the primary hydrated phase that is produced during the initial stages of the reaction. Following the swift phase of reaction, there is a subsequent period characterized by decreased heat generation, the duration of which is determined by the concentration of calcium sulphate within the system. After the depletion of the introduced calcium sulphate, there is a swift acceleration in the reaction rate, leading to the formation of calcium monosulfoaluminate as the predominant product stage. In cement systems, the slow reaction of C3A must continue for an extended period of time following the peak rate of alite in order to achieve the appropriate setting and hardening. The primary concern with regard to the hydration process of C3A with calcium sulphate is focused on the unexpected delay in the initial reaction. Three possible reasons exist for the observed event:

- The reaction may be impeded by the existence of the product phase ettringite as it forms a diffusion barrier on the surfaces of C3A.
- Other phases, like AFm, may also hinder the reaction in a similar way.
- The presence of certain solute species released during the dissolution of calcium sulphate may directly inhibit the reaction (39,66,67).

2.2 Use of Chemical Admixtures to Regulate the Initial Setting Time

In the beginning stages of cement hydration, there is a quick sequence of reactions between C3S and water that begins as soon as the cement is mixed with water. During this stage, there is a notable exothermic reaction, with the heat generated from the wetting process and the dissolving of C3S being key factors. Thorough chemical examinations of the solution stages have given compelling proof that C3S dissolves completely and quickly at the beginning of wetting. As the reaction continues, the pace of response decreases because a thin but continuous layer of a metastable phase called C-S-H(m), which is calcium silicate hydrate, forms quickly. This layer serves to protect the surface by preventing water from entering and stopping the release of ions from the surface. It is suggested that by the conclusion of the initial response time, this thin layer will reach a state of equilibrium with the solution. In unretarded and unannealed alite and C3S systems, the time of the delay is when the pace of hydration reaches its lowest point following the initial response, before the rapid formation of products of hydration begins. A distinct induction period is only noticeable when the chemical retarders are used or when the materials are annealed. This postponement is primarily due to a slow reaction caused by one of the mechanisms mentioned before, until it reaches a critical point, which then accelerates the nucleation and growth processes (68). The kinetics of cement hydration are significantly influenced by concrete admixtures, particularly in the early stages of inactivity. The adjustments of the intermolecular forces between ion species in the aqueous solution within the concrete appear to be the primary influence of these admixtures. Repulsive forces predominate during the solvation stage, whereas attractive forces do so during the crystallization stage. As the hydration advances, these bound force transitions result in two volumetric changes. Concrete admixture’s impact on cement reactions can be clearly observed through experiments conducted with an immersion weighing system. Accelerators cause instant shrinkage tendencies, while retarder agents cause volume expansion. A Le Chatelier-like theoretical model involving a solvation-crystallization sequence is found to be a suitable model to describe the hydration kinetics. Volume expansion happens when repulsive forces are in charge, preventing the development of strength. The dormant phase is determined by how long the swelling process takes. When volume shrinkage is visible, the hardening and strength-building process begins (69).

An essential part of the process of creating concrete is the admixture. The way an admixture reacts to cement paste influences both the paste's fluidity and the cement's stiffness (7). The admixture is important to the process of making concrete as a key ingredient. Not only does the admixture-cement paste interaction affect the cement paste's flow characteristics, but it also influences the rigidity of the cement itself (28). An admixture is an ingredient included in a concrete mix to alter or enhance the characteristics of the concrete when it is freshly poured or once it has hardened (7). Chemical additives are primarily utilized to regulate the setting time, hardening time, and flow characteristics of concrete (70). The setting time can be adjusted to speed up or slow down by using the right admixtures (12). Chemical additives manage the flow properties of newly mixed concrete. Retarders and accelerators can alter the process of cement hydration (71). 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 (72). Concrete's workability and rheological qualities are crucial; hence admixtures are typically added to the mixture to enhance these qualities. When these admixtures are applied to concrete in the recommended dose, the concrete's characteristics typically change (73). The rheological characteristic is crucial for concrete. The interaction between the admixture and cement can lead to abrupt alterations in the flow of concrete and result in varying levels of stiffness, depending on the specific combination of admixture and cement used (28,74,75,76,77).

Admixtures play an important part in the concrete production process. The characteristics of admixtures play a vital part in deciding their suitability for various applications. Table 3 displays the different types of chemical admixtures and the properties of their particles (78).

Table 3. Chemical admixtures types

Chemical admixtures	Function
Superplasticizer	To decrease the amount of water needed by 15% to 20% without compromising the workability, resulting in a strong and compact concrete
Accelerator	In cold weather concreting, accelerator is added to concrete to decrease the time it takes for the concrete to set, enabling the forms to be removed sooner
Retarder	Slowing down the hydration of cement helps to prolong the setting time, making retarders a preferred option for concreting in hot environments
Water reducing admixture	In order to attain a specific amount of workable consistency in concrete with a low water-cement ratio for a desired strength, thereby reducing the amount of cement needed
Air entraining admixture	Incorporating tiny air bubbles into concrete serves as rollers that enhance its workability. This is particularly beneficial in cold climates, as the air bubbles act as a cushion to prevent damage from expanding water during freeze-thaw cycles.

2.3 Use of Sugarcane Juice and Its Products as Admixtures

Sugarcane is a significant crop. It is grown in tropical and subtropical regions around the globe. India ranks as the second-biggest producer of this crop following Brazil. The composition of sugarcane juice includes 75 to 85% water, 0.3 to 3% reducing sugar, and 10 to 21% nonreducing sugar (79,80).

The process of tricalcium silicate (alite) setting and hardening is similar to that of Portland cement, and it is influenced by the water-to-cement ratio and particle size distribution. This leads to the formation of C-S-H (gel-like) and calcium hydroxide (CH). In the process of cement hydration, ettringite and monosulfate are formed. Ettringite is a crystalline calcium sulfo-aluminate hydrate with a column structure (3CaO·Al2O3·3CaSO4·32H2O, AFt-phase), and monosulfate is a calcium sulfo-aluminate hydrate with a lamellar structure (3CaO·Al2O3·CaSO4·12H2O, AFm-phase). During the initial hydration process of Portland cement, Ettringite is the most critical phase within the AFt mineral (39).

The microstructure of C-S-H undergoes changes when sucrose is added, impacting the formation process (81). Admixtures used to modify the characteristics of concrete include sugar and jaggery. The principal justification for the addition of jaggery and sugar as admixtures is that, as they are introduced, their adsorption creates a thin coating on top of the cement particles, delaying the hydration process. Calcium hydroxide formation will be inhibited by the generation of calcium ions, which will improve their solubility. This has led to an improvement in concrete's setting characteristics (73). By including sucrose in the cement paste, the setting process of the cement is initiated, leading to either accelerated or delayed setting based on the production of Aft (82). The number of admixtures that cause delays in setting time is crucial. In simpler terms, the extent of delay or acceleration depends on the quantity of the admixture used. Additives such as sucrose, glucose, and other substances. because of retardation and additives such as organic compounds, inorganic salts, etc. because it speeds up the cement's hydration process. Substances like triethanolamine and triisopropanolamine can speed up the process when used in small amounts (83). The slowing down of cement hydration is influenced by the amount of admixture used. The hydration of cement may be delayed by adding certain admixtures that act as water reducers, depending on how they are mixed (72). A strong relationship was found between the formation of ettringite and the flow characteristics of cement paste. The decreased workability of cement paste was directly linked to the increased production of ettringite. As the amount of ettringite in the cement paste increased, the impact of the additional ettringite on the workability of the paste also increased. The water-to-solid ratio of the cement paste shifts as low-density ettrigite is produced (65).

The large quantity of AFt was produced by adding varying amounts of sucrose solution to Portland cement. The addition of a high amount of sucrose solution to cement sped up the hydration process, thus causing the cement to set faster (84). Ettringite development in cement-based materials can be linked to both helpful and detrimental activities (48). When a small amount of sucrose, specifically 0.045% of the weight of the cement, is included, it leads to a decrease in the consistencies of Ca2+ and OH- ions, resulting in the formation of highly soluble Ettringite (Aft). Hence, the AFT is formed as a gel-like substance that coats the clinker particle surface, causing sucrose to function as a retarding agent. Increasing the sucrose content to 0.24% negatively affects the C2S and C3S hydration, as the consistency of Ca2+ and OH- speeds up the setting process, causing Aft to act more effectively. and the AFt acts like a needle to construct a network of hydration products and quicken the setting procedure. C2S and C3S are unable to produce enough C-S-H, which hinders the development of strength **(85).** Having more molasses will result in extending the duration of the induction phase. The aluminate phase's dissolution can be accelerated with a small quantity of sugarcane molasses, whereas too much may increase the formation and growth of AFt in the initial stages. The addition of 1.0% molasses accelerates the formation of AFt during the hydration of C3A and ferrite. Nevertheless, the addition of 1.0% molasses to cement paste significantly inhibits the secondary hydration of C3A and Ferrite, while also delaying the hydration of C3S (86).

The use of sugar as an additive significantly affects the cement's times for both initial and final setting. The addition of a small quantity of sugar caused a significant increase in the setting times of the cement. The addition of approximately 0.05% sugar caused the initial and final setting times of the cement to reach their highest levels. When sugar content exceeded 0.05%, the setting times started to decrease. It was found that the initial setting time of the cement decreased by a smaller amount when the sugar content was above 0.1% compared to when the sugar content was zero (87). It was discovered in the research that adding different types of sugar like granular, caster, or brown in amounts of 0.5%, 1.5%, or 0.5% can slow down the setting process of cement. Nevertheless, when included in proportions of 2.5% and 5%, all of these sugars functioned as a cement accelerator. The cement's final setting time was found to increase when sugar was added up to a certain ratio, specifically the optimal 1.5%, but decrease when added in higher amounts. The initial setting time of cement was decreased and extended by adding sugar of any kind (88).

It was found that adding up to 0.2% sugar to the cement paste caused a longer initial setting time compared to adding no sugar, and that adding up to 0.15% sugar resulted in a longer final setting time. With no sugar added, the initial and final settings took place at 120 and 349 minutes, respectively. The cement hardened in 174 minutes with the addition of 0.2% sugar, compared to 112 minutes with 0.15% sugar. The final settings took place at 491, 316, and 294 minutes by adding 0.15%, 0.2%, and 0.25% sugar, respectively (89).

3. Methodology

The sugarcane juice utilized for this study was procured from a facility located near the laboratory in Uttar Pradesh, India, which is equipped with a machine specifically designed for the extraction of sugarcane juice. The ambient laboratory temperature during the testing phase was maintained at a controlled range of [23-27°C], ensuring consistent conditions for all experimental procedures. This controlled environment is critical for minimizing variability in the results and enhancing the reliability of the data obtained. All procedures adhered to established protocols to ensure the integrity of the sugarcane juice and the accuracy of the testing outcomes. Tests were conducted using cement paste without any sugarcane juice added, as well as with various ratios of sugarcane juice to the weight of the cement.

3.1 Consistency of Cement

3.1.1 Sample Preparation

Initially, a sample consisting of 400 grams of cement is prepared. Sugarcane juice is then added at varying percentages of 0%, 5%, 10%, 15%, 20%, 25%, and 28% by weight of the cement sample. The remaining water is used to adjust the consistency of the paste. For instance, when adding 5% sugarcane juice to the cement, 20 grams of sugarcane juice are incorporated, and the consistency is adjusted using water. Interestingly, with the addition of 28% sugarcane juice, no additional water is needed, indicating that the paste consists solely of sugarcane juice.

The prepared cement pastes samples undergo testing using the Vicat apparatus in accordance with IS 4031-4 standard. This involves placing the samples in a mould and positioning them under the Vicat apparatus's plunger. The percentage of combined water and sugarcane juice is carefully noted when the plunger penetrates 5 to 7 mm from the bottom of the sample within five minutes after the addition of water and sugarcane juice to the cement.

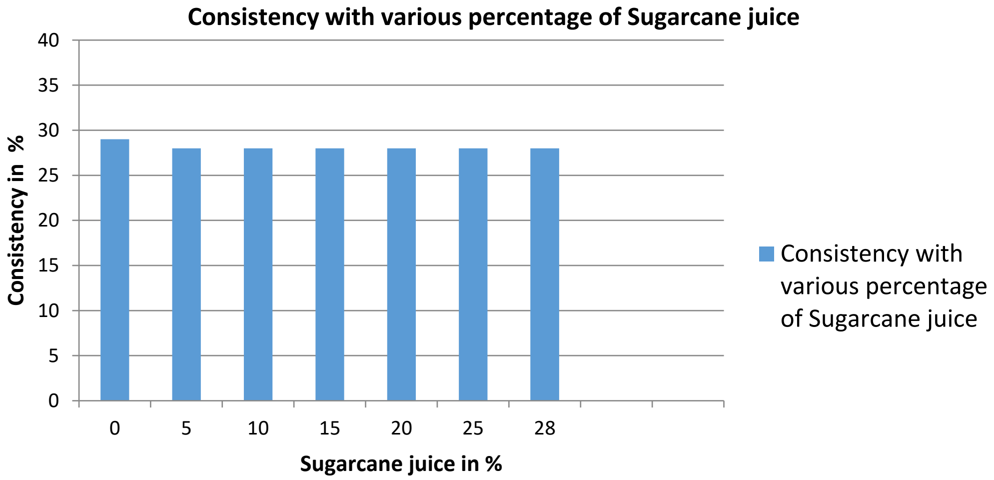

Fig. 1. Consistency with various percentage of Sugarcane juice

Table 4. Consistency with various percentage of Sugarcane juice

Percentage of Sugarcane juice (in %)	0	5	10	15	20	25	28
Consistency (in %)	29	28	28	28	28	28	28

3.2 Initial setting time of cement

3.2.1 Sample Preparation

First, 400 grams of cement is taken and different amounts of sugarcane juice are added at percentages ranging from 0% to 28% by weight of the cement (0%, 5%, 10%, 15%, 20%, 25%, and 28%). Then, 85% of the normal consistency of cement, along with water and the specified percentage of sugarcane juice, are added to the mixture. The cement paste sample is prepared and tested using the Vicat apparatus in accordance with IS 4031-5. That is to say, the samples that have been prepared are placed in the mold and positioned under the needle of the Vicat apparatus. The time it takes for the needle to penetrate 5.0 ± 0.5 mm from the bottom of the sample is then recorded.

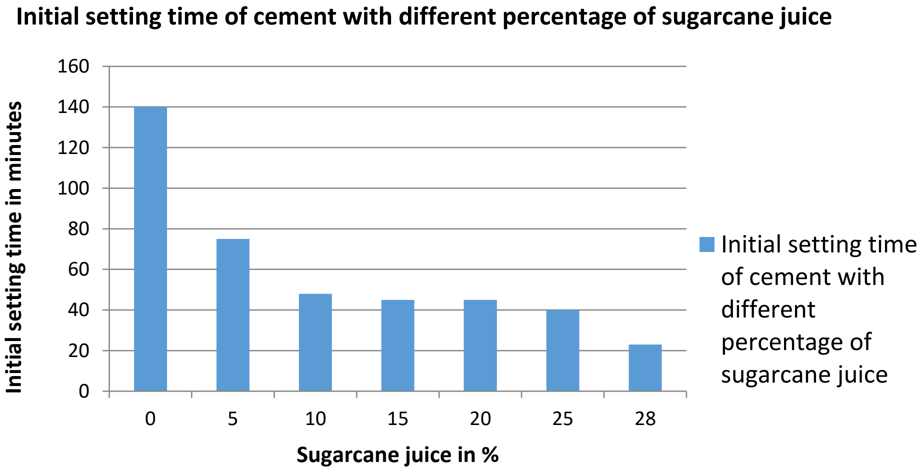

Fig. 2. Initial setting time of cement with different percentage of sugarcane juice

Table 5. Initial setting time of cement with different percentage of sugarcane juice

Percentage of Sugarcane juice (in %)	0	5	10	15	20	25	28
Initial setting time (in min.)	140	75	48	45	45	40	23

4. Results and Discussion

During the investigation, it was discovered that adding various amounts of sugarcane juice (5%, 10%, 15%, 20%, 25%, and 28%) did not significantly change the consistency of the cement paste compared to when no sugarcane juice was added. Overall, adding sugarcane juice to cement paste can considerably reduce its penetration depth or setting time. The initial setting time of cement paste decreased by 46%, 66%, 68%, 68%, 71%, and 84% when sugarcane juice was added in percentages of 5, 10, 15, 20, 25, and 28%, respectively. These findings indicate that adding larger quantities of sugarcane juice speeds up the setting process of the cement paste. If the hydration process of cement speeds up (causing the cement paste to harden rapidly), the time it takes for the cement to initially set decreases significantly. Therefore, the needle penetrates the Vicat's apparatus less when compared to the control cement paste (without sugarcane juice).

Prior research has also mentioned a decrease in setting time as a common trend. S.C.Paul and colleagues examined that the adding sugarcane juice to the cement paste caused a notable decrease in the time it took for the mixture to set. Experimentation revealed that adding higher amounts of sugarcane juice to the cement paste led to even faster setting times when compared to the standard cement paste without any sugarcane juice added. More precisely, the addition of sugarcane juice at 2, 5, 10, and 20% by weight of cement resulted in a decrease in the initial setting time of the cement by 33, 57, 70, and 90% respectively, in comparison to the regular cement paste. These results clearly show that sugarcane juice is a powerful catalyst, expediting the hardening of cement (90). The setting time was noticeably affected by the small amount of sugar added. The setting time peaked when sugar was added to 0.05% of the weight of the cement. Nevertheless, adding more sugar caused the setting time to decrease. More precisely, the addition of 0.1% sugar caused a further decrease in setting time compared to cement paste without sugar (87). In the study, it was observed that both the initial and final setting times of the cement increased as the proportions of sugar were raised. However, these setting times reached their peak when the sugar proportion was at 0.05%. Subsequently, with sugar proportions exceeding 0.08%, both setting times began to decrease. Notably, the setting time of the cement exhibited a significant drop starting from a sugar proportion of 0.2%. Furthermore, the cement's initial setting time was discovered to be only a few minutes when mixed with sugar at levels ranging from 0.8% to 1.0%(91).

5. Conclusion

Research findings from multiple scholars highlight an enduring pattern of incorporating sugarcane-derived products, including jaggery, molasses, and sugar, as additive components in the formulation of construction materials. This tradition has its origins rooted in ancient history and has managed to retain its significance, playing an important role in various modern-day applications. The results derived from these studies emphasize the substantial influence that sugarcane juice and its related by-products exert on the chemical and physical processes involved in the hydration of cement.

This specific investigation involved conducting experimental research to thoroughly evaluate and analyze the impact of incorporating sugarcane juice as an admixture in cement mixtures, aiming to understand its influence on the properties and performance of the cement formulations. The findings of this study indicate that the addition of varying percentages of sugarcane juice does not significantly affect the consistency of cement paste. Specifically, when no sugarcane juice was added (0% concentration), the consistency was measured at 29%. This value remained relatively stable with the incorporation of sugarcane juice, with consistency measurements recorded at 28% for 5%, 10%, 20%, and 25% concentrations, as well as for a 28% concentration of sugarcane juice.

However, the results unequivocally demonstrate that the inclusion of sugarcane juice in the cement mixture significantly reduces the duration required for the initial setting process of the cement. This finding suggests that while the consistency remains largely unchanged, the setting time is notably influenced by the presence of sugarcane juice, which could have practical implications for construction practices and the use of cementitious materials. In particular, as the proportion of sugarcane juice in the mixture rises, there is a significant decrease observed in the initial setting times of the cement paste, indicating a faster onset of the setting process. The data reveal a significant reduction in the initial setting times of cement paste when sugarcane juice is added in varying proportions. Specifically, incorporating sugarcane juice at concentrations of 5%, 10%, 15%, 20%, 25%, and 28% resulted in decreases of 46%, 66%, 68%, 68%, 71%, and 84%, respectively, compared to the initial setting time of the control cement paste that contained no sugarcane juice.

The results highlight the significant role played by sugarcane juice in expediting the hydration process of cement, with its effectiveness becoming increasingly pronounced when used in higher concentrations. This research holds substantial importance as it paves the way for the advancement and innovation of construction materials that prioritize both efficiency in performance and sustainability in environmental impact.

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References

[1] Memon RA, Memon FA. Experimental study on the effect of sugarcane juice as an admixture on fresh and hardened properties of concrete. Int Res J Mod Eng Technol Sci. 2022;4(5):e-ISSN:2582-5208.
[2] Otunyo AW, Koate I. Sugar cane juice as a retarding admixture in concrete production. Glob J Eng Res. 2015;14:17-23. https://doi.org/10.4314/gjer.v14i1.3
[3] De Schutter G. Influence of hydration reaction on engineering properties of hardening concrete. Mater Struct. 2002;35:447-52. https://doi.org/10.1007/BF02483131
[4] Neville AM, Brooks JJ. Concrete technology. New Delhi: Dorling Kindersley; 2006.
[5] Usman ND, Idusuyi FO, Ojo EB, Simon BM. The use of sawdust and palm kernel shell as substitute for fine and coarse aggregates in concrete construction in developing countries. J Chem Mech Eng Pract. 2012;2(3):51-62.
[6] Neville AM. Properties of concrete. 5th ed. Harlow, UK: Trans-Atlantic Publications; 2012.
[7] Li Z. Advanced concrete technology. New York, NY: John Wiley & Sons; 2011.
[8] Usman ND, Adebitan EO, Kwari JK, Gyang JB. Determination of engineering properties of locust bean waste and wild vine use in construction in Nigeria. In: SABS Conf; 2013 Oct 10-12; Nairobi, Kenya. Jomo Kenyatta Univ Agric Technol.
[9] Naqash JA, Bhat ZB, Malik MI, Ahmad S, Kumar D. Effect of accelerating admixture on properties of concrete. IOSR J Eng. 2014;4(3):48-55. https://doi.org/10.9790/3021-04314855
[10] Lea F. The chemistry of cement and concrete. 3rd ed. London, UK: Edward Arnold; 1988.
[11] Maheswari AU, Harshavardhan R, Tejas JS, Chandradeep K, Monisha SK, Padal S, et al. Utilization of sugarcane bagasse as retarder in concrete. Int J Innov Res Technol. 2021;8(3):ISSN:2349-6002.
[12] Shah DS, Shah PM, Pitroda JK. Chemical admixtures: A major role in modern concrete materials and technologies. In: Natl Conf Trends Challenges Civ Eng. 2014. ISBN:978-81-929339-0-0.
[13] Kawade A, Kamthe I, Khemalapure AB. Experimental study of effect of sugar on properties of concrete. J Struct Transp Stud. 2017;2(1).
[14] Mohamed AK, Weckwerth SA, Mishra RK, Heinz H, Flatt RJ. Molecular modeling of chemical admixtures; opportunities and challenges. Cem Concr Res. 2022;156:106783. https://doi.org/10.1016/j.cemconres.2022.106783
[15] Bureau of Indian Standards. IS 9103 (1999): Specification for concrete admixtures. New Delhi: BIS; 1999.
[16] Eloge MO, Abuodha SO, Winja MMO. The effect of sisal juice extract admixture on compressive and flexural strength of cement concrete. Eng Technol Appl Sci Res. 2021;11(2):7041-6. https://doi.org/10.48084/etasr.4030
[17] Dheenadhayalan M, Suvetha G, Monica D, Shenoi PS, Dhanasekaran R. Effect of sugarcane juice in concrete by partial replacement of water, recycled coarse aggregate and silica fume in fine aggregate. Int J Intell Res. 2016;7:ISSN:0976-9859.
[18] Khan B, Baradan B. The effect of sugar on setting-time of various types of cements. Q Sci Vis. 2002;8:71-8.
[19] Prudencio LR. Accelerating admixtures for shotcrete. Cem Concr Compos. 1998;20:213-9. https://doi.org/10.1016/S0958-9465(98)80007-3
[20] Salvador RP, Cavalaro SHP, Segura I, de Figueiredo AD, Perez J. Early age hydration of cement pastes with different types of accelerating admixtures for sprayed concrete. Cem Concr Compos. 2016;ISSN:0950-0618. https://doi.org/10.1016/j.conbuildmat.2016.02.101
[21] Faqe H, Dabbagh H, Mohammed A. Natural admixture as alternative for chemical admixture in concrete technology: a review. J Duhok Univ. 2020;23(2):301-8. https://doi.org/10.26682/csjuod.2020.23.2.24
[22] Patel GK, Deo SV. Effect of natural organic materials as admixture on properties of concrete. Indian J Sci Technol. 2016;9(37). https://doi.org/10.17485/ijst/2016/v9i37/93541
[23] Dandotiya A, Parihar RS, Jha AK. An investigational properties of concrete using jaggery. Int J Trend Sci Res Dev. 2022;6(5). Available from: www.ijtsrd.com

[24] Togero A. Leaching of hazardous substances from additives and admixtures in concrete. Environ Eng Sci. 2006;23(1):102-16. https://doi.org/10.1089/ees.2006.23.102

[25] Abdulrahman AS, Mohammad I. Green plant extract as a passivation promoting inhibitor for reinforced concrete. Int J Eng Sci Technol. 2011;3(8):6484-90.

[26] Chandra S, Eklund L, Villarreal RR. Use of cactus in mortars and concrete. Cem Concr Res. 1998;28(1):41-51. https://doi.org/10.1016/S0008-8846(97)00254-8

[27] Dwivedi VN, Das SS, Singh NB, Rai S, Gajbhiye NS. Portland cement hydration in the presence of admixtures black gram pulse and superplasticizer. Mater Res. 2008;11(4):427-31. https://doi.org/10.1590/S1516-14392008000400008

[28] Hanehara S, Yamada K. Interaction between cement and chemical admixture from the point of cement hydration, absorption behaviour of admixture, and paste rheology. Cem Concr Res. 1999;29:1159-65. https://doi.org/10.1016/S0008-8846(99)00004-6

[29] Thirumalini P, Sekar SK. Review on herb used as admixture in lime mortar used in ancient structures. Indian J Appl Sci. 2013;3(8):295-8. https://doi.org/10.15373/2249555X/AUG2013/93

[30] Mahmood HF, Dabbagh H, Mohammed AA. Comparative study on using chemical and natural admixtures (grape and mulberry extracts) for concrete. Case Stud Constr Mater. 2021;15:e00699. https://doi.org/10.1016/j.cscm.2021.e00699

[31] Chandra S. Architecture and ancient building materials in India. New Delhi: Tech Books International; 2003.

[32] Kurdowski W. Cement and concrete chemistry. Dordrecht: Springer; 2014. ISBN: 978-94-007-7944-0.

[33] Michelle S. Did our church builders use egg white as mortar ingredients? The bimolecular reason behind collecting mortar samples from historical sites. Proc Soc Philipp Archaeol. 2009;7. Available from: https://www.academia.edu

[34] Neville AM. Properties of concrete. Vol. 4. London: Longman; 1995.

[35] Olbrich H. The molasses. Berlin: Biotechnologie-Kempe GmbH; 2006.

[36] Paul SC, Van Rooyen AS, Van Zijl GP, Petrik LF. Properties of cement-based composites using nanoparticles: a comprehensive review. Constr Build Mater. 2018;189:1019-34. https://doi.org/10.1016/j.conbuildmat.2018.09.062

[37] Bahhou A, Taha Y, Khessaimi YE, Hakkou R, Tagnit-Hamou A, Benzaazoua M. Using calcined marls as non-common supplementary cementitious materials-a critical review. Minerals. 2021;11(5):517. https://doi.org/10.3390/min11050517

[38] Neville AM, Brooks JJ. Concrete technology. Malaysia: Prentice Hall; 2010. ISBN: 978-0-273-73219-8.

[39] Taylor HFW. The chemistry of cements. 2nd ed. New York: Thomas Telford Services Ltd; 1997.

[40] Singh NB, Chaturvedi S, Rai S. Chemistry of Portland cement. J Indian Chem Soc. 2003;80:319-25.

[41] Whittaker M, Dubina E, Plank J, Black L. The effects of prehydration on cement performance. In: Proc 30th Cement and Concrete Science Conf; 2010 Sep 13-15; Birmingham, UK.

[42] Lavagna L, Nistico R. An insight into the chemistry of cement-a review. Appl Sci. 2023;13:203. https://doi.org/10.3390/app13010203

[43] Bishnoi S, Scrivener KL. Studying nucleation and growth kinetics of alite hydration using µic. Cem Concr Res. 2009;39:849-60. https://doi.org/10.1016/j.cemconres.2009.07.004

[44] Taylor HFW. Cement chemistry. London: Academic Press, Harcourt Brace Jovanovich Publishers; 1990.

[45] Potgieter JH, Kaspar H. Hydration of cement. S Afr Tydskr Chem. 1999;52(4).

[46] Van Breugel K. Numerical simulations and microstructural development in hardening cement-based material. Heron. 1992;37(3):1-61.

[47] Labahn O, Amerongen CV (translator), Kohlhaas C (editor). Cement engineers handbook. 4th Engl. ed. Wiesbaden, Berlin: Bauverlag; 1983.

[48] Honorio T, Guerra P, Bourdot A. Molecular simulation of the structure and elastic properties of ettringite and monosulfoaluminate. Cem Concr Res. 2020;135:106126. https://doi.org/10.1016/j.cemconres.2020.106126

[49] Corstanje WA, Stein HN, Stevels JM. Hydration reactions in pastes C3S + C3A + CaSO4·2H2O at 25 °C. Cem Concr Res. 1973;3:791-806. https://doi.org/10.1016/0008-8846(73)90012-4

[50] Corstanje WA, Stein HN, Stevels JM. Hydration reactions in pastes C3S + C3A + CaSO4·2H2O at 25 °C III. Cem Concr Res. 1974;4:417-31. https://doi.org/10.1016/0008-8846(74)90107-0

[51] Breval E. C3A hydration. Cem Concr Res. 1976;6:129-38. https://doi.org/10.1016/0008-8846(76)90057-0

[52] Cocke DL, Mollah MYA. The chemistry and leaching mechanisms of hazardous substances in cementitious solidification/stabilization systems. In: Spence RD, editor. Chemistry and microstructure of solidified waste forms. Boca Raton, FL: Lewis Publishers; 1993. p. 187-241.

[53] Collepardi M. A state-of-the-art review on delayed ettringite attack on concrete. Cem Concr Compos. 2003;25(4-5):401-7. https://doi.org/10.1016/S0958-9465(02)00080-X

[54] Batic OR, Milanesi CA, Maiza PJ, Marfil SA. Secondary ettringite formation in concrete subjected to different curing conditions. Cem Concr Res. 2000;30:1407-12. https://doi.org/10.1016/S0008-8846(00)00343-4

[55] Wang L, Yang HQ, Zhou SH, Chen E, Tang SW. Hydration, mechanical property and C-S-H structure of early-strength low-heat cement-based materials. Mater Lett. 2018;217:151-4. https://doi.org/10.1016/j.matlet.2018.01.077

[56] Baradan B. Construction materials - II. 5th ed. Izmir: Dokuz Eylul University, Technical Faculty Publication Section; 1998.

[57] Jiang SP, Mutin JC, Nonat A. Studies on mechanism and physico-chemical parameters at the origin of cement setting. Cem Concr Res. 1995;25(4):779-89. https://doi.org/10.1016/0008-8846(95)00068-N

[58] Lee HK, Lee KM, Kim YH, Yim H, Bae DB. Ultrasonic in-situ monitoring of setting process of high-performance concrete. Cem Concr Res. 2004;34:631-40. https://doi.org/10.1016/j.cemconres.2003.10.012

[59] Zheng JJ, Zhang J, Scherer GW. Prediction of the degree of hydration at initial setting time of cement paste with particle agglomeration. Cem Concr Res. 2012;42:1280-5. https://doi.org/10.1016/j.cemconres.2012.05.020

[60] Aydin AC, Gül R. Influence of volcanic originated natural materials as additives on the setting time and some mechanical properties of concrete. Constr Build Mater. 2007;21:1277-81. https://doi.org/10.1016/j.conbuildmat.2006.02.011

[61] Pessiki SP, Carino NJ. Setting time and strength of concrete using the impact-echo method. ACI Mater J. 1988;85:389-99. https://doi.org/10.14359/2312

[62] Minard H, Garrault S, Regnaud L, Nonat A. Mechanisms and parameters controlling the tricalcium aluminate reactivity in the presence of gypsum. Cem Concr Res. 2007;37:1418-26. https://doi.org/10.1016/j.cemconres.2007.06.001

[63] Prince IW, Espagne M, Aitcin PC. Cement and Concrete Research. 2003;33(5):635-41. https://doi.org/10.1016/S0008-8846(02)01042-6

[64] Lea F. The chemistry of cement and concrete. 4th ed. London: Edward Arnold; 2006.

[65] Jakob C, Jansen D, Ukrainczyk N, Koenders E, Pott U, Stephan D, Neubauer J. Relating Ettringite Formation and Rheological Changes during the Initial Cement Hydration: A Comparative Study Applying XRD Analysis, Rheological Measurements and Modeling. Materials. 2019;12:2957. https://doi.org/10.3390/ma12182957

[66] Gaidis JM, Gartner EM. Hydration mechanisms, II. In: Skalny J, Mindess S, editors. Materials Science of Concrete, Vol. 2. Westerville (OH): American Ceramic Society; 1989. p. 9-39.

[67] Tenoutasse N. The hydration mechanism of C3A and C3S in the presence of calcium chloride and calcium sulphate. In: Proc 5th Int Symp on the Chemistry of Cement. Tokyo: The Cement Association of Japan; 1968. p. 372-8.

[68] Bullard JW, Jennings HM, Livingston RA, Nonat A, Scherer GW, Schweitzer JS, et al. Mechanisms of cement hydration. Cem Concr Res. 2011;41:1208-23. https://doi.org/10.1016/j.cemconres.2010.09.011

[69] Paulini P. Reaction mechanisms of concrete admixtures. Cem Concr Res. 1990;20:910-8. https://doi.org/10.1016/0008-8846(90)90053-Z

[70] Sakai E, Ishida A, Ohta A. New trends in the development of chemical admixtures in Japan. J Adv Concr Technol. 2006;4(2):211-23. https://doi.org/10.3151/jact.4.211

[71] Nkinamubanzi PC, Mantellato S, Flatt RJ. Superplasticizers in practice. In: Aïtcin PC, Flatt RJ, editors. Science and Technology of Concrete Admixtures. Amsterdam: Elsevier; 2016. p. 353-78. https://doi.org/10.1016/B978-0-08-100693-1.00016-3

[72] Marchon D, Flatt RJ. Mechanisms of cement hydration. In: Aïtcin PC, Flatt RJ, editors. Science and Technology of Concrete Admixtures. Amsterdam: Elsevier; 2016. p. 129-46. https://doi.org/10.1016/B978-0-08-100693-1.00008-4

[73] Kumar AVP, Venkatesh B, Prasad BBCO. Effect of sugar, jaggery & sugar cane ash on properties of concrete. Int J Sci Eng Technol Res. 2015;4(51).

[74] Nocun-Wczelik W, Trybalska B. Effect of admixtures on the rate of hydration and microstructure of cement paste. Cem Wapno Beton. 2007;6:284-9.

[75] Du L, Folliard KJ. Mechanisms of air entrainment in concrete. Cem Concr Res. 2005;35:1463-71. https://doi.org/10.1016/j.cemconres.2004.07.026

[76] Yang Q, Zhu P, Wu X, et al. Properties of concrete with a new type of saponin air-entraining agent. Cem Concr Res. 2000;30:1313-7. https://doi.org/10.1016/S0008-8846(00)00340-9

[77] Mohamed AK, Weckwerth SA, Mishra RK, Heinz H, Flatt RJ. Molecular modeling of chemical admixtures: Opportunities and challenges. Cem Concr Res. 2022;156:106783. https://doi.org/10.1016/j.cemconres.2022.106783

[78] Patel V, Shah N. A survey of high performance concrete developments in civil engineering field. Open J Civ Eng. 2013;3:69-79. https://doi.org/10.4236/ojce.2013.32007

[79] Phanikumar HK. Sugarcane juice powder by spray drying technique. Sci Tech Enterpreneur. Bengaluru: National Research Development Corporation; 2011.
[80] Swaminathan V. Food science chemistry & experimental foods. Bangalore: The Bangalore Printing & Publishing Co. Ltd.; 1995.
[81] Maria C, Garci J, Jennings H. New insights into the effects of sucrose on the hydration and microstructure of cement pastes. Cem Concr Res. 2002;32(3):393-9. https://doi.org/10.1016/S0008-8846(01)00689-5
[82] Wu J, Wang P. Mechanism of regulation set of sucrose in Portland cement. J Chin Ceram Soc. 1998;26(2):164-70.
[83] Gartner E, Myers D. Influence of tertiary alkanolamines on portland cement hydration. J Am Ceram Soc. 1993;76:1521-30. https://doi.org/10.1111/j.1151-2916.1993.tb03934.x
[84] Wang P. Formation of hydration on C3A mineral and Portland clinker with and without sucrose. J Shangh Inst Build Mater. 1994;7(2):107-17.
[85] Li Z, Song W, Liu Q, Cao L, Xu Z. Influence of sucrose on hydration process of Portland cement. Key Eng Mater. 2014;599:46-51. https://doi.org/10.4028/www.scientific.net/KEM.599.46
[86] Li W, Ma S, Zhang S, Sun X. Physical and chemical studies on cement containing sugarcane molasses. J Therm Anal Calorim. 2014;118:83-91. https://doi.org/10.1007/s10973-014-3947-4
[87] Ahmad S, Lawan A, Al-Osta M. Effect of sugar dosage on setting time, microstructure and strength of Type I and Type V Portland cements. Case Stud Constr Mater. 2020;13:e00364. https://doi.org/10.1016/j.cscm.2020.e00364
[88] Al Khafaji ZS, Ruddock F. Study the retardant effect of using different sugar's types on setting time and temperature of cement paste. Int J Civ Eng Technol. 2018;9:519-30.
[89] Kawade A, Kamthe I, Khemalapure AB. Experimental study of effect of sugar on properties of concrete. J Struct Transp Stud. 2017;2(1).
[90] Paul SC, Babafemi AJ, Miah MJ, Basit MA, Hasan NMS, Kong SY. Role of sugarcane juice as a natural admixture on setting time and hardened properties of cementitious materials. Infrastructures. 2022;7:145. https://doi.org/10.3390/infrastructures7100145
[91] Abalaka AE. Comparative effects of cassava starch and simple sugar in cement mortar and concrete. ATBU J Environ Technol. 2011;4(1).