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Enhancing Concrete Setting Time with Sustainable Innovation - Utilizing Apple Juice as a Retarder Agent

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Abstract – *Admixtures are group of chemicals or minerals that are added to modern concrete, in order to modify the traditional mix in accordance to the requirements and site demand. Various researches and investigations are being executed to add different chemicals and materials to this group. Construction activities are carried through a laid down procedures and parameters including temperature, humidity and placing environment. Concreting in hot weather condition, is limited to the maximum concrete temperature to 35 ºC. Concreting above this range results in early hydration of cement and thus produces concrete with early gain of strength and latterly reduction with the age gain. The increased surrounding temperature results in rapid evaporation of water causing water reduction within the concrete matrix thus cause associated plastic shrinkage, un-hydrated cement within the matrix and subsequent cooling causing tensile stresses and cracking. Chemical admixture categorized as Retarders, come a solution to this problem. The addition of chemicals from this group delays the initial setting time allowing the time for mixing, transporting and placing. This study seeks to investigate the impact of sugar on the properties of cement. The sucrose crystals were used as the source of sugar in this experimental investigation. Various sugar concentration, by weight of cement were added to the cement paste, and the impact over the setting time was monitored. Additionally the compressive strength of the cement with modified altered water-sugar concentration were investigated. This experimental investigation demonstrated that the optimum dosage of apple juice, greatly altered the setting time of cement and the mechanical strength of cementitious materials as well. This study advocates for the innovative use of apple juice as a retarder in the construction industry, offering a dual benefit by not only enhancing construction processes but also economically empowering farmers through the generation of a substantial yield of ungraded apples.*

Key Words:
Compressive Strength, Retarder, Sugar, Setting Time.

1. INTRODUCTION

Maintaining workability is one of the essential criteria during the concreting operation - transportation, handling and placement. Workability can be loosed due to various factors viz insufficient mixing time, excessive water content, incorrect cement content, improper aggregate grading, temperature effect at the time of concreting operation and other ambient conditions. During the transportation of Ready Mix Concrete, to longer distances workability retention also arises a challenge. Admixture categorized under Retarders, serve the purpose of maintaining workability by delaying the hydration process. Elevated temperatures also accelerate the setting time of concrete, leading to alteration in desired workability condition along with the increase in water demand and a higher risk of thermal cracking. To mitigate such type of issue in the construction industry, use of retarders is recommended y the concrete practitioners. Retarders are chemical admixture that slow down the hydration rate of cement within the concrete, such that the concrete remains in plastic and workable for a prolonged duration, providing necessary time for placement and finishing. By the inclusion of retarders in such conditions better control over the concrete mix is obtained along with the reduction of the associated impact over the workability. Various types of retarders both organic and inorganic are available for the utilization, with different mechanisms for retarding the hydration rate. The chemical mechanisms underlying the retarding effects are explored in depth in studies by Smith et al. [1] and Brown and Jones [2], offering insights into their particular impacts on cement hydration. Scholars have investigated several forms of retarders, such as gluconates, organic acids, and lignosulfonates, assessing their influence on the mechanical and rheological characteristics of concrete mixtures. Garcia and Lee [3] point out that retarders have a major impact on how long it takes for concrete to set. Better workability is made possible by this extension, which is also essential in situations when lengthy placement or transit times are needed. Johnson and Wang's [4] research delves deeply into the impact retarders have on early-age strength. Understanding how retarders influence strength development is crucial for improving concrete mix designs and guaranteeing the intended performance. Retarders are widely employed in hot weather concreting as a countermeasure against the temperature-induced acceleration of setting. According to Young [5], set-retardation may primarily result from a delay in the

hydration of tricalcium silicate caused by organic admixtures adhering to the calcium hydroxide nuclei. Concrete setting time is also largely influenced by the type of cement used and the amount of additive added, according to Kandhari [6]. Retarders are widely accepted in the literature as an efficient and workable way to improve the performance of concrete, especially in harsh environmental circumstances especially in hot weather concreting practice. Through the numerous methods outlined below, retarders obstruct the process of hydration.

Adsorption on Cement Particle - When retarders are added to the cement matrix, they wrap around the cement particle, forming a protective layer inhibiting water from reaching to the cement particle within the concrete matrix consequently slowing down the dissolution of cement initiated by the hydration reaction.

Complex Formation – Ions involved in the hydration reaction form complexes. The cement particles' reactivity is changed as a result of this contact, which delays the production of hydration products.

Ion Exchange - In ion exchange reactions, retarders have the ability to compete with ions necessary for cement hydration. The hydration reactions are delayed by this competition, which increases the setting time.

Surface Charge Modification - Retarders have the ability to alter the cement particles' surface charge, which can affect the electrostatic forces that propel the hydration process. This alteration could allow the cement and water to interact at a slower pace.

Delay of Nucleation & Growth - Retarders may impede the hydration products' nucleation and development, halting the concrete's quick setting. Strength can now be developed more gradually as a result.

It's essential to remember that a retarder's particular process may vary depending on its chemical structure. Retarders such as lignosulfonates, gluconates, citrates, and derivatives of tartaric acid are frequently employed. The design of the concrete mix, the surrounding environment, and the intended setting time all influence the retarder selection. While retarders are necessary in some construction situations, it's important to carefully monitor their dose in order to attain the appropriate setting time without sacrificing the concrete's final strength and durability. While apple juice finds its use in various culinary applications. However its chemical composition can promote its utility beyond kitchen. One of the constituents is the Sugar in the apple, harnessing the presence of this component in the apple juice can lead to its utilization as Retarder in cement concrete. The elevated sugar content in apple juice acts as a retardant by impeding the setting and hardening processes of concrete. It's crucial to remember that adding apple juice to concrete is an unusual method, and in order to preserve the structural integrity of the material, considerable thought should be given to aspects like dose and long-term durability. In this innovative experimental exploration of utilizing the apple juice in construction industry, underscores the potential for unexpected solution in the diverse field. An estimated one-third of the world's food supply is lost or squandered annually. Approximately 20–40% of all fruits and vegetables in developing countries and 10-15% in developed countries are lost during the value chain's post-harvest phases as a result of inadequate food handling procedures and a lack of technology (Gustavsson et al, 2011). It is estimated that a shocking 3000000 tonnes of apple waste are being generated every year[8]. Kashmir being among the north-western Himalayan states on India is the major apple producing state of India. Similar huge amount of apple waste generated during the harvesting stage poses a public health hazard, though low percentage of the waste is being utilized the rest goes to landfills, polluting the environment. During the biodegradation, it helps microbes to grow thus decreasing the available nitrogen in the soil. If this land filling is encountering the water, the dumped apple will start an unpredictable fermentation process while rotting releasing methane, contributing to the green house gases. Harnessing the potential of waste apples by converting them into juice can serves as an effective means of utilizing this agricultural byproduct as a retarder in construction practice. Offering a sustainable alternative, transforming waste apples into juice not only maximizes their utility but also provides a safe and eco-friendly solution for the disposal of agricultural waste. Consequently, the objective of the present work was to highlight the influence of apple juice on the setting time and strength of cement, leading towards selection of an optimal dosage of sugar as an alternative retarder. This innovative development may lead to economic advantage in the region, by producing admixture from this waste horticultural product leading to hard earned foreign exchange.

2. MATERIAL

2.1 Cement

Locally available Ordinary Portland Cement, Grade 43 was used for this experimental investigation. The cement was fulfilling IS:8112-1989 specifications. Cement bag was checked for freshness by checking manufacturing date on bag.

2.2 Sand

Standard sand conforming to IS: 650-1991 is used for preparing moulds for conducting compressive strength of cement. Standard sand consisting of well graded sand of quartz, light grey or whitish in color procured through supplier from Tamilnadu.

2.3 Water

Tap water supplied through municipal means free from particles and good for drinking was used for the mixing.

2.4 Apple Juice

Apple purchased from local market, locally cultivated in the region was used for this experimental finding. Juice was extracted from the same.

Cement
OPC
43 Grade

Indian
Standard
Sand
Grade III
Particle Size

Indian
Standard
Sand
Grade II
Particle Size

Indian
Standard
Sand
Grade I
Particle Size

Figure -1: Raw Material

3. EXPERIMENTAL PROCEDURE

3.1 Perpetration of Apple Juice

Apple purchased from local market, were thoroughly washed by tape water to remove any dirt or pesticides. The apples were cut into small chunks, these chunks were feed through the juicer according to the manufacturer's instructions. The extract obtained needs straining, which was done by using a cheesecloth over fine mesh strainer and collected to be used later in the experimental program.

Figure -2: Preparation of Apple Juice

3.2 Quantitative Analysis of Sugar Content in Apple Juice

Sugar content was determined by using Benedict's Solution method. Water bath was prepared and brought to boil. In the test tube, mix a small amount of the apple juice with Benedict's Solution, which contains copper sulfate and sodium citrate. Place the test tube in the boiling water bath and let it react for a specified time, typically around 5 minutes. The presence of reducing sugars in the apple juice causes a color change in the solution, ranging from blue to green, yellow, orange, or even brick red, depending on the concentration of sugar. After the reaction, observe the color change and compare it to a color chart for quantification.

3.3 Calculation of Setting Time

As per the Indian Standard (IS 4031: Part 5), the setting time of cement is determined using the Vicat apparatus. The initial setting time is the duration elapsed between the time water is added to the cement and the moment the Vicat needle makes no discernible impression on the cement paste and ceases to penetrate. The final setting time is the period between the addition of water and the point at which the needle, with a larger attachment, makes only a slight impression on the paste, and the needle does not penetrate more than 1 mm

into the cement. The tests are conducted under controlled conditions of temperature and humidity, and the results help assess the suitability of cement for various construction applications.

3.4 Calculation of Compressive Strength

Initially take 300gms of cement and 900gms of standard sand and add water equal to ((P/4)+3)% of combined mass cement and sand. Were P is the normal consistency value of the cement utilized. The following samples were prepared by alerting the water quantity by replacing the water fraction by the extracted juice.

The mix obtained is then filled in the cube moulds of size 70.6 mm x 70.6 mm x 70.6 mm. The samples were demoulded, coded after 24 hours and placed for curing in the curing tank with controlled conditions. The respective samples were tested for compressive strength in the compressive testing machine after 7,14 and 28 days. The substitution of apple juice was done by varying percentage of 5%, 10%, 15% and 20% by weight of cement.

4. MIX & SAMPLE PREPRATION

The mix were prepared with 43 grade of OPC cement, for neat concrete the water quantity was 34% of the weight of cement. Moreover few other mix were prepared by substitution the water fraction by the apple juice. For calculating the setting times the cement fraction was mixed with the water or water and apple juice respectively. The setting time of the cement mix was made with replacement of water by 5%, 10%, 15% and 20% apple juice by weight of cement.

For calculating the compressive strength of cement with and without the apple juice fraction – added into mix by weight of cement. The ratio of cement to sand is 1:3 which has the following particle size distribution of Smaller than 2 mm but greater than 1 mm : 33.33% Smaller than 1 mm but greater than 500 µ : 33.33% Smaller than 500 µ but greater than 90 µ : 33.33%. The water quantity added to the mix is calculated as (0.25P + 3)% of combined weight of cement and sand, mixed uniformly until the mixture of uniform color is obtained (P is the consistency of cement).

Additionally, alteration of the mixing water quantity was altered by substituting the water by apple juice fraction by weight of cement in accordance to Table 1.

Figure -3: Sample Preparation – Compressive Strength Test

Table -1: Mix Proportion

Mix	Cement (grams)	Sand (grams)	Apple Juice		Water (grams)
			%	grams	
Mix - 1	200	600	0	0	88
Mix - 2	200	600	5	10	78
Mix - 3	200	600	10	20	68
Mix - 4	200	600	15	30	58
Mix - 5	200	600	20	40	48

5. RESULT & DISCUSSION

5.1 Physical Test with Cement

Initially the cement sample were physically test for ensuring the cement meets the required specifications. Finess Test (IS 4031-Part 1: 1996) by dry sieving to determine the particle size of cement and Standard consistency test (IS:4031 - Part 4: 1988) to find the moisture content which is required to produce the cement paste of standard consistency. The results obtained for the cement sample have been tabulated in Table 2.

Figure -4: Physical Test of Cement – Finesse & Consistency

Table -2: Physical Test of Cement – Results

Investigation	Result
Color	Grey
Fineness	4.67 %
Consistency	32%

5.2 Sugar Content of Apple Juice

Benedict's Test gives the indication of the presence of reduced sugar in liquid. The color change occurred due to the reduction of copper (II) ions in the Benedict's solution by the reducing sugars present in the apple juice.

The extracted juice when tested with Benedict's solution turned the solution to Brick Red color showing the presence of high concentration of reducing sugar.

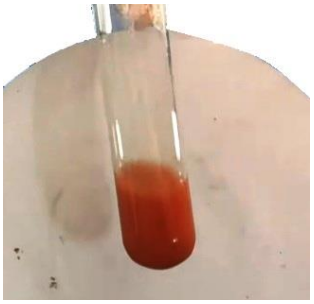

Figure -5: Color change for apple juice with Bendetic Reagent

5.3 Setting Time of Cement Mix

Cement paste by gauging 400 grams of cement with water quantity of 0.85 times the consistency value is used to prepare the cement paste for investigating the setting time. However in this experimental investigation the water quantity to be added is divided into to fraction with major being the tap water and the remaining smaller fraction being the apple juice calculated with respect to percentage weight of cement, as tabulated in Table -2. The initial setting time and the final setting time comprise the two halves of the setting time. when the elasticity of cement paste begins to decline. Initial setting time is defined as the amount of time that passes between adding water to the cement and when it first sets.

Figure -6: Initial Setting Time - Vicat apparatus with needle.

Figure -7: Final Setting Time

Vicat apparatus with annular attachement.

When the paste hardens to the point when the annular attachment to the needle under standard weight merely leaves an impression on the hardened cement paste, it is said to have reached the final setting time.

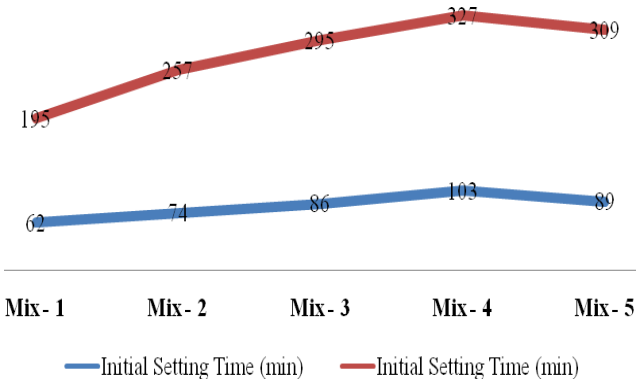

Chart -1: Setting Time Analysis

As observed from Chart - 1, the plotted data indicate with the addition of apple juice modification within the cement setting time values was noted. The maximum setting time of 5 hr 27

minutes was attained with Mix-4 with 15% of apple juice concentration with only 3 hr 17 minutes with no apple juice addition. As Figure 2 illustrated the initial and final setting time increase with the increase in apple juice concentration however after 15% addition the trend was reversed. Retarding effect caused by the addition of apple juice may be attributed to the retention of water by the induced sugar thus interfering in the cement hydrate crystal growth . Also the addition of sugar can have a cooling effect on the concrete mix, influencing the setting time of cement and lowering temperature can slow down the hydration reactions.

5.4 Compressive Strength of Cement

Chart - 2, illustrates the variation of the compressive strength in accordance to the various mix proportions. The tabulated data is the average value of the 3 samples tested for each day of age respectively. Marginal variation in the compressive strength can be observed with the addition of the apple juice. Initially with the incremental dosage of apple juice the compressive strength increased with the maximum being obtained in Mix-40 containing 15% apple juice by weight of cement content.

Figure 8: Compressive Strength of cube specimen in CTM

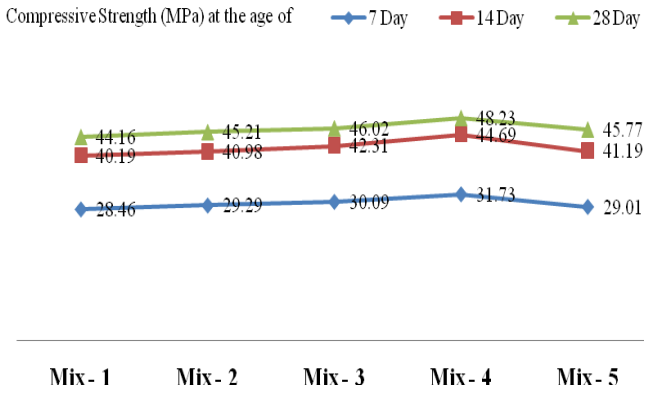

Chart -2: Compressive Strength (N/mm²)

From the plot of compressive strength data, it can be observed that there is no significant reduction in the compressive strength. The maximum gain of 9.2% has been observed in the mix with reference to the neat mix, in Mix -4 which contained 15% of apple juice. However with the further increase in the apple juice concentration the strength values started to decrease. According to Neville et al. [9], the use of sugar as a retarder significantly lowers the concrete's early strength for all ages however, the strength then increases for all ages. The quick-setting is the cause of the early strength decline. Retardation occurs when the amount of SCJ rises, increasing strength. The aforesaid fact is supported by the current study's findings. The gain in the strength may be attributed to the extended setting time of cement , allowing more time for the cement particle to hydrate and form the crystalline structure resulting gain in the strength.

6. CONCLUSIONS

From this experimental study following conclusion can be drawn:

- The addition of Sugar juice to cement mix had the ability of modify the fresh and hardened properties.
- By introducing apple juice in the cement mix, the setting time can we enhanced, showing the retarding effect over the setting of cement. Thus recommending apple juice as an alternate to retarder admixture.
- The optimum dosages of 15% of apple juice had the ability of delaying the final setting time of cement by 6.7%.
- Apple juice substitution, had the impact over the compressive strength of cement as well. The incremental value of apple juice concentration increased the compressive strength linearly upto the optimum value of 15% showing a maximum gain of 6.7% with respect to reference concrete.
- The abundance of apple in Kashmir, and utilization of lower grade of apple for this purpose in construction industry is of economic advantage in terms of savings in the foreign exchange used to import retarding agents for the industrial purpose.

7. FUTURE SCOPE

Effect on the durability of concrete due to potential issues such as increased permeability and reduced resistance to chemical attacks need to be investigated.

8. ACKNOWLEDGEMENT

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