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Effect of Sugar on Setting-time and Compressive Strength of Ordinary Portland cement Paste

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Abstract: The use of sugar to delay setting of cement at construction site seems reasonable as it is cheap and readily available. But, addition of sugar has inevitable implications not only on setting time but also on compressive strength of cement paste. So, its effect needs to be well-understood for better control over its use. Test samples prepared by using 53 grade OPC cement and sugar in increasing proportion did not show a fixed result. Addition of sugar 0.07% by weight of cement resulted in 3 hours and 35 minutes delay in total setting time and around 4% increase in strength of cement. But, sugar content above 0.13% by weight of cement reduced setting time and sample was marked with cracks at the surface while hardening.

Keywords: *OPC-Ordinary Portland cement, Setting time, Compressive Strength*

Introduction:

Almost all civil engineering works are site work based but the procedure to perform these works are derived in a controlled lab i.e. parameters temperature, humidity are controlled ;hence in actual practice desired quality may not be achieved and also many a times , it may not be possible to follow exact set of procedure. Concreting in hot weather i.e. above 100°F accelerates the early hydration of cement and produce concrete having high strength at early ages, but the later strength is reduced considerably. Further, the rapid evaporation of water causes plastic shrinkage (cracks developed before the concrete has hardened) in concrete and subsequent cooling would cause tensile stresses and cracking (IOE. Manual on Concrete Technology). Similarly, concreting in cold weather is also detrimental. If water of plastic concrete sets , then overall volume of concrete increases and also delays the setting and hardening of the concrete as no water is available for chemical reaction ;ultimately resulting large volume of pores and hence low strength is gained(Neville, Concrete Technology).Hence in order to maintain the standard condition, admixture are used. Retarders are admixture that extend the hydration induction period, thereby lengthening the setting times(Lea).Sugar ,carbohydrate derivatives , soluble zinc salts ,soluble borates exhibits retarding action(Neville, Concrete Technology).Lea,1988-Sugar falls under the category of 'coating ' admixture ;in the presence of water a cement particle sends out a swarm of calcium ions into the surrounding water and any substance capable of immobilizing or delaying this surge will also slow down the interchanges between the water and the particle, thus retarding the hydration process.

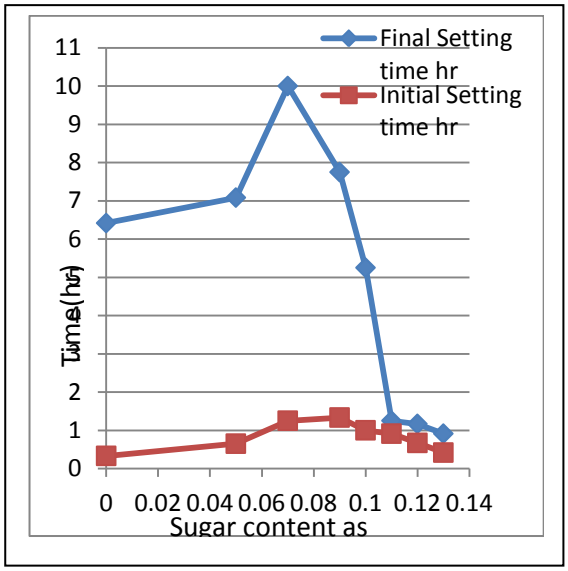
Methodology:

53 grade OPC cement sample was taken to perform the test. Sugar used to perform the experiment was sucrose crystals ($C_{12}H_{22}O_{11}$); it was dissolved in required amount of water. In order to determine the Consistency and setting time of cement paste vicat apparatus, conforming to IS: 5513-1976, was used. The test was performed conforming to IS. The standard consistency of a cement paste was recorded as amount of water added that permits 5 to 7 mm penetration of vicat plunger from the bottom of the vicat mould (IS:4031(Part 4)1988).Similarly setting time was measured as per IS:4031(Part 5),1988-initial setting time as the period elapsed between the time of adding water to the cement to the time when needle fails to pierce the mould by 5±0.5mm;final setting time as period elapsed between the time of adding water to the cement to the time when the annular ring fails to make the impression on the mould as the final setting time. The test was conducted at a temperature of 27±2°c and the relative humidity within 65±5%.

Strength of prepared cement mortar is determined by cube crushing test .In accordance with IS: 4031(Part 6) sample cubes were prepared to record compressive strength at 3 and 7 days respectively from the day of preparation. Standard Sand (IS: 650-1966) was taken in 3 parts with 1 part of cement to prepare 1:3 cement mortar. The percentage of water required to prepare mortar was obtained as total weight of sand and cement multiplied by summation of a quarter of consistency of cement and a constant 3. Numerically,

%of water required =Total weight *(Consistency (in %)/4+3).

***Figure 1**: Test for setting time of cement.*



***Graph 1**: Variation in setting time of cement paste on adding sugar.*

***Table 1**: Data recorded for setting time of cement*

S.N	Sugar content as % of weight of cement	Initial Setting time hr (in min)	Final Setting time hr(in min)
1	0	0.33(20)	6.417(385)
2	0.05	0.65(39)	7.083(425)
3	0.07	1.25(75)	10(600)
4	0.09	1.333(81)	7.75(465)
5	0.1	1(60)	5.25(315)
6	0.11	0.912(55)	1.25(85)
7	0.12	0.67(40)	1.167(70)
8	0.13	0.417(25)	0.912(55)

Data Analysis Setting -time test from the above table, it can be inferred that with the addition of sugar in cement both initial and final setting time of cement can be delayed up to certain sugar content. Required result was achieved at 0.07 % of sugar content in cement paste: initial setting time was delayed by 55 minutes and final setting time was delayed by around 215 minutes (3 hours and 35 minutes).About 0.05% of sugar by mass of cement will delay the setting time by about 4 hours (Neville, Concrete Technology).While increasing sugar content up to 0.1% setting was not attained in fixed pattern, in a way it was unpredictable. Above 0.1% of sugar content the final setting time of the cement was drastically shortened: it was acting like an accelerator, final setting time was obtained in around 1 hour. At very low dosage of sugar, it retards, but again their performance can be unpredictable and at high dosages 'flash setting' may be induced (Lea 1988). The specimen with above 0.1% sugar was characterized by cracks at the surface and color was black from earlier greyish sample. It is essential soundness is within permit else it would lead to disruption of the cement paste (Neville, Concrete Technology).

***Figure 2:** Picture showing cracks on surface of sample having sugar of 0.13% by weight of cement*

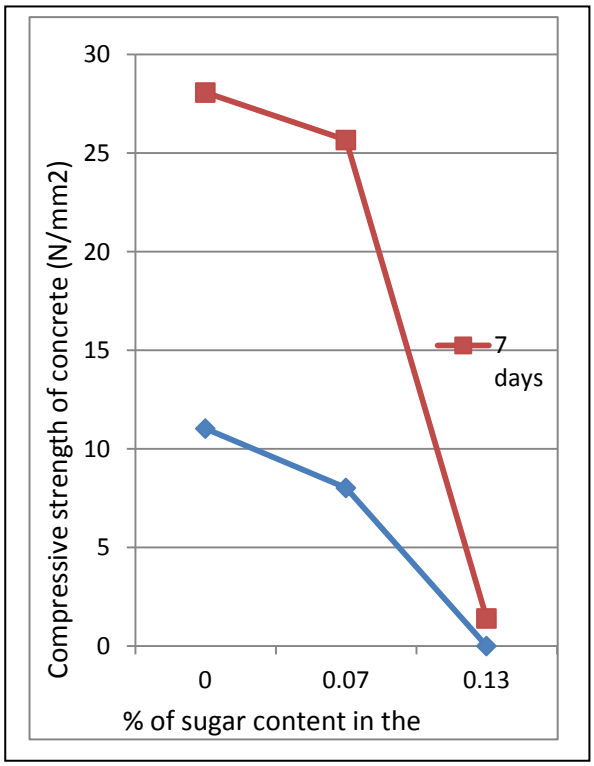
Compressive Strength test Sample cubes were prepared and average of the recorded strength was plotted in Table 2. Compressive strength test was performed at sugar content of 0%, 0.07% and 0.13% and strength was noted at 3 and 7 days respectively.

***Table 2**: Average Compressive strength*
Graph of the observed compressive strength of the cement mortar is plotted as below.

S.N	Sugar content as % of weight of cement	Average Compressive Strength (N/mm^2)	
		3 days	7 days
1	0	11.03	17.05
2	0.07	8.02	17.65
3	0.13	0	1.40

Conclusion:

Sugar when used in correct proportion acts as retarder but when it is used in excessive amount it reverse its property i.e. acts as accelerator. So it should be used in proper supervision. An amount of 0.07% by weight of cement is found to delay both the setting time and also shows around 4% increase in compressive strength. Sugar above 0.13% by weight of cement accelerated the setting time with nominal gain in initial strength. Excessive volume expansion was noted in the sample as cracks were formed in the sample itself. So a careful use of sugar can be economical in comparison to commercially available set retarders.



***Graph 2:** Compressive strength of cement mortar. From the graph it can be inferred that addition of sugar retards the early strength gain but there is no much difference in overall strength gained. When sugar is used as a controlled set retarder, the early strength of concrete is severely reduced but beyond about 7 days there is an increase in strength of several percent compared with a non-retard mix (Neville 2006).*

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