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STUDY THE RETARDANT EFFECT OF USING DIFFERENT SUGAR'S TYPES ON SETTING TIME AND TEMPERATURE OF CEMENT PASTE

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ABSTRACT

This paper present the study of the effect of adding different sugar types such as (Granular, Caster, Brown and Beet) on setting time and temperatures of hydration of cement paste. The effect of sugar on the setting times was checked by testing numbers of cement paste samples, that produce from 35% w/c ratio and different sugar type and ratio (0.5%, 1.5%, 2.5% and 5%) by the cement weight using Vi-cat needle apparatus. While the temperatures of hydration heat were measured by using Thermocouples, and changes in the heat of hydration were clearly recognised. The results of the experimental works show that: adding any type of cane sugar (Granulated, Caster and Brown sugar) in proportion (0.5% and 1.5%) the sugar was works as a concrete retardant, but these type of sugar worked as concrete accelerator when used in proportion (2.5% and 5%). However; adding Beet sugar in proportion (0.5%, 1.5%, 2.5% and 5%) was working as a concrete retardant. On the other hand, the hydration temperatures increased by adding sugar and the high peak they reached was about 33.890C at 0.30 water ratio with 1.5% sugar content. It obvious, for all sugar type (1.5% by cement weight) was the optimum sugar proportion to retard the final setting time of the cement pastes of different w/c ratios, but the higher sugar contents cause a decrease in the final setting time. On other hand, the initial setting time was decreased and accelerated when sugar was added to the paste. As well as adding sugar to the cement paste improved it physically by reduced the cracking and the bleeding on the surface of the sample.

Key words: Final setting time, heat hydration, Initial setting time, sugar ratio, Sugar type, Vi-cat needle test.

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1. INTRODUCTION

The setting and get hardening considered general characteristic of concrete and cement paste after mixing cement with water. Usually, the final setting time is getting during 2-3 hr. depending on the temperature and the cement content in the mixture, but some big project needs for extending setting time for this reason should adding retarder admixture to concrete mixture to get the extension. Adding retardant materials to the concrete mix and cement paste, a delay in the setting time of the cement paste can be achieved. Retarding admixture forms a film around the cement grain that prevents or delays the reaction with water (Neville, 2006).

Many materials are used as a retarding admixture and sugar is one of these materials. The retardant materials extend the dormant time of cement by slowing down the rate of early hydration of C3S. The augmentation of the dormant period is commensurate to the ratio of the admixture materials that used in the mixture. In the United States, truck drivers carrying unset concrete in circumstances where adding set must be postponed regularly exploit this by adding a pack of table sugar to the concrete batch (Yasuhiko, 1972).

Khan and Baradan (2002) found that adding sugar with various types of cement (three various type of cement PKC/A42.5, PKC/B32.5 and PC42.5)had an effect on the setting time of the cement paste. The experimental work was carried out under three different conditions of curing (Relative Humidity &Temperature). Mixing sugar with cement under the normal laboratory condition (temperature = 22 ˚C and relative humidity = 60%),the effectiveness of the sugar as a retardant material was increased when the sugar content is increased in the mix and not exceeded a certain limits. They observed that sugar works as a retarder to an extent of 0.25% of cement content at ratio (32.5%) water/cement and the reducing water content leading to reduce the efficiency of sugar in delaying cement setting time. However, sugar became more effective when the sugar concentration in the mixture was increased to 0.8% by cement weight under higher curing condition (temperature =35 ˚C).Basing on the results of tests, the 0.15% sugar-content was found as optimum sugar content for retarding cement set time. Furthermore, results revealed that sugar caused a higher retardation when it added a few minutes later after mixing water and cement.

Khan (2004) added sugar as an admixture to cement paste, mixed sugar with three different types of cement. The results show that the retarder effect of sugar on setting time of cement paste depending on the dosages and the type of cement. According to his investigation, in one type of cement the sugar accelerated the initial setting time and retarded the final setting time when dosages higher than 0.25% were used. As well as, the laboratory conditions like the high temperature and low humidity accelerated the setting of cement pastes for all mixes.

Kumar (2015) found that when molasses is added to the concrete mixture it will improve the mixture’s initial and final setting times. Additionally, adding molasses to concrete improves the concrete’s workability and compressive strength. After searching for the properties of molasses, they found that its bending properties will reduce the water cement ratio in the mixture, which improves the concrete properties. Furthermore, they found that their idea is easy to apply in urban areas because molasses is available in all markets and builders already know about it. Additionally, in urban areas construction is mainly carried out by experienced builders and molasses is fairly cheap, which helps to reduce the construction budget.

Neville (1995) said that the quantity of sugar (0.2% - 1% of cement weight) can be used as inexpensive good retarder. Then he added, saying that the strength beyond 7 days increases with adding sugar but the early strength is significantly reduced.

There are multi-theory to explain the retarder behaviour of sugar when mixing it with concrete. According to (Ballieu, et. al.) there are four mechanisms to interpret the reaction between retarder and cement. Firstly, the adsorption theory and this theory depends on the assumption: the retardants admixtures form a barrier of protective thin skin around the particles of cement by adsorbed the admixtures on the surface of the cement grains. And this protective skin hinders and prevents water molecules from contacting with cement particles to hydrate them, for this reason the hydration process is being slow down. Due to the moderate hydration, no significant measure of the hydration items offering inflexibility to the cement paste will be shaped and hence the cement paste will remain plastic for a longer time. Later, when the admixture is expelled from arrangement by response with C3A from concrete or by some other way, it is uprooted and consolidated into the hydrated material, and further hydration is eliminated (Abalaka, 2011). Secondly, the nucleation theory and this theory depends on the assumption: the retardants admixtures adsorbed on the surface of C3S by the calcium hydroxide (Ca(OH)2), and poisons the growth of the calcium hydroxide nuclei C-S-H until some level of super saturation . Thus, the setting time is being extended due to increasing the concentration calcium hydroxide to super saturation level. Thirdly, the complexion theory and this theory depends on the assumption: the increasing in Ca2+, Si, Al, OH-, and Fe concentrations delay the hydrous phase of the cement paste. The availability of organic complexes with calcium ions form retarder on the cement grains. The complexes delay the formation of the of calcium hydroxide due to precipitation of those ions. The final mechanism is precipitation theory: it states that retarder reacts with the highly alkaline solution and forms new types of insoluble derivatives of that retarder. Because of that reaction, the pH of the solution increases over 12 after the first few minutes of the interaction between water and cement.

In 1983, N.Thomas and J. Birchall indicated that the retardation of hydration conducted through adsorption mechanism. They tested different types of sugar which are reducing sugars (able to donate an electron to another chemical species), non-reducing and the non-reducing sugars which have five-membered ring; they didn’t find a proof on the complexion of sugars and silicate. Results showed that the oxidized (reducing) sugars are unstable in high pH solutions and easy subjected to degradation and ring-opening, and then compound with calcium via the bidentate ligand (bidentate ligands is Lewis base that can donate a pair of electrons to a metal atom). However, the non-reducing sugars like trehalose and α-methyl glucoside are relatively inert in high pH solutions, and they can bind with a little of calcium. The non-reducing five-membered ring sugars are in between the two limits; they are stable enough in order not to undergo to degradation of ring opening, but they are adequate labile to form a half salt with Ca+-OH. Consequently, the half salt R-O--Ca+-OH composed of an immense di-saccharide or tri-saccharide molecule R-O- bonded to a pendant calcium group which can suit into a lattice site in Ca(OH) 2 or C-S-H; therefore, the large sugar molecule can successfully poison the-surface of the Ca(OH)2 and C-S-H gel.

2. MATERIALS AND METHODOLOGY

2.1. Materials

2.1.1. Ordinary Portland cement (OPC)

In the experimental work the commercial Ordinary Portland Cement OPC type CEM-II/A/LL 32.5-N, which supplied by CEMEX Company in Warwickshire, UK was used to carry out all the tests. Table 1. Shows the chemical analysis for Ordinary Portland cement.

Table 1 Chemical analysis of the Ordinary Portland Cement OPC.

Material	**CaO**	**SiO_2**	**Al_2O_3**	**MgO**		**Fe_2O_3**		**SO_3**	**K_2O**	**TiO_2**	**Na_2o**
OPC	62.34	26.64	2.44	1.57		1.75		2.59	0.72	0.39	1.53

2.1.2. Sugar

During the experiment there are four sugar types was used to perform the tests:

- Granular commercial sugar which supplied by silver spoon company, UK.
- Caster commercial sugar which supplied by silver spoon company, UK.
- Brown commercial sugar which supplied by Tate and Lyle company, UK.
- Beet Syrup which supplied by Bauckhof online company.

2.2. Methodology

2.2.1. Mixing Proportions

The setting time test was performed by using five mixing proportion which consist from Ordinary Portland Cement OPC, sugar and water. The OPC/w was constant which about (30%) and the sample that has cement and water only called Reference sample, while the sugar proportion and type was vary as shown in table 2. Reference sample (100% OPC which equivalent to 400 gm and water weight about 120gm)

Table 2 Mixing proportions used in this study

Mix ID	**OPC %**	**Sugar type**	**Sugar%**	**Sugar weight (g)**
RF	100	NO	0	0
GZ1	100	Granular	0.5	2
GZ2	100	Granular	1.5	6
GZ3	100	Granular	2.5	10
GZ4	100	Granular	5	20
CZ1	100	Caster	0.5	2
CZ2	100	Caster	1.5	6
CZ3	100	Caster	2.5	10
CZ4	100	Caster	5	20
BZ1	100	Brown	0.5	2
BZ2	100	Brown	1.5	6
BZ3	100	Brown	2.5	10
BZ4	100	Brown	5	20
BEZ1	100	Beet	0.5	2
BEZ2	100	Beet	1.5	6
BEZ3	100	Beet	2.5	10
BEZ4	100	Beet	5	20

2.3. Laboratory Tests

The experiments as following:

2.3.1. Initial and final setting time

Consistency and the initial and final setting were investigated by using Vi-cat needle apparatus. As shown in Plate 1. (VI-CAT device consists of the body of the device which made from steel and the body left steel rod which has a needle in the lower end. And the dimension of this needle is 1 mm2 cross-section and 50 mm length and this needle use to investigate (initial and final setting time). According to EN 196-3, BS 4550, which present the (Initial setting time) as the time which located between the time after the first contact of water and cement (when the mixture started) and the time when the needle with(1 mm2) cross-section give an reading (15 mm from the bottom of the mould). On the other hand, (the final setting time) is the time after the first contact of water and cement (when the mixture started) and the time when the needle with(1 mm2) cross- section does not leave any marks on the upper surface of the cement paste, (Yasuhiko, 1972).

The test was carried out by using 16 samples which consist of cement, water and sugar and the proportion of each one as shown in Table 2. And all materials are mixing manually and then placed at the mould to be ready for getting the setting times.

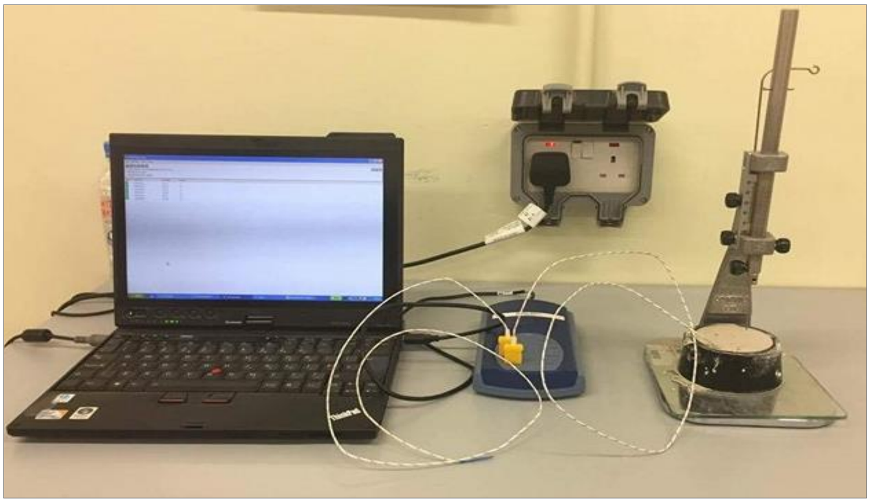


Plate 1 The test cell: Thermocouple and Vi-cat device.

2.3.2. Record the heat hydration changes

To record the hydration temperature of the cement paste, the cell that shown in Plate1. had been produced to record the temperature immediately after adding the water to the mix until finishing the setting time test. To obtain the temperature of the hydration during the test, Thermocouple device type (80PK-1) had been used which is a Teflon cable of 40 inch is ended with a mini type K thermocouple connector with 0.312-inch pin spacing. A Teflon cable consists of two different metal wires which are joined at one end to produce the sensor and linked to thermocouple capable device (PicoLog logger) at other end and the PicoLog logger was plugged into computer by USB wire as shown in Plate 2. Thus, When the sensor end of thermocouple is heated, a current is produced in thermometric circuit. This current is then correlated back to temperature. The temperature readings were collected each 5 seconds and they were displaced on computer screen which then used to present the changing in the temperature.

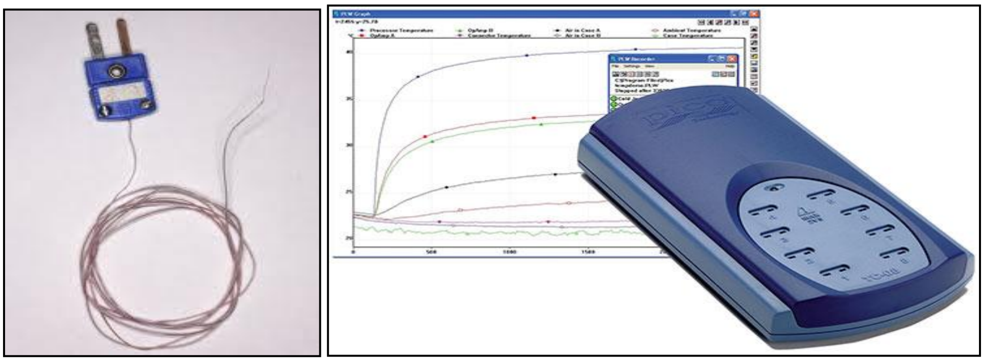


Plate 2 Thermocouple device parts.

3. RESULTS AND DISCUSSION

3.1. Setting Time Test

Figures (1, 2, 3 and 4) illustrate the changes the initial and final setting times for different sugar types (Granulator, Caster, Brown and Beet) and specific sugar proportion. The y-axis represent the time in (min), and x-axis present the sugar type that used in the experiments. Each figure has the same sugar ratio for all sample along with (RF sample with zero sugar) to discover the changes in the initial and final setting time depending on the sugar type and comparison that with RF sample. In Figure 1., the 0.5% proportion for (all specific sugar) worked as concrete retarder for the final setting time and the Granular sugar give the best time about (350 min). As well as, in Figure 2, the 1.5% proportion for (all specific sugar) worked as concrete retarder for the final setting time and the Beet sugar give the best time about (530 min).

On the other hand, Figure 3. demonstrate the accelerator behaviour of the final setting time for cement paste after adding 2.5% sugar (Granulator, Caster and Brown) and the Granulator and Brown sugar give the lowest time about (140 min). As well as, Figure 4 demonstrate the accelerator behaviour of the final setting time for cement paste after adding 5% sugar (Granular, Caster and Brown) and the Caster sugar give the lowest time about (103 min). While Beet sugar in proportion 2.5% and 5% works as retarder for the final setting time. However, the initial setting times were reduced as a result of adding sugar to cement paste as shown in Table 3.

Table 3 Summary of the results of initial and final setting times for all samples

Sugar type	Ratio	Initial setting time (min)	Final setting time (min)
No sugar	0%	122	242
Granular	0.5%	49	350
Castor	0.5%	39	310
Brown	0.5%	68	333
Beet	0.5%	33	336
Granular	1.5%	45	408
Castor	1.5%	66	436
Brown	1.5%	65	400
Beet	1.5%	87	530
Granular	2.5%	43	140
Castor	2.5%	45	190
Brown	2.5%	44	140
Beet	2.5%	31	528
Granular	5.0%	23	111
Castor	5.0%	18	103
Brown	5.0%	57	180
Beet	5.0%	110	405

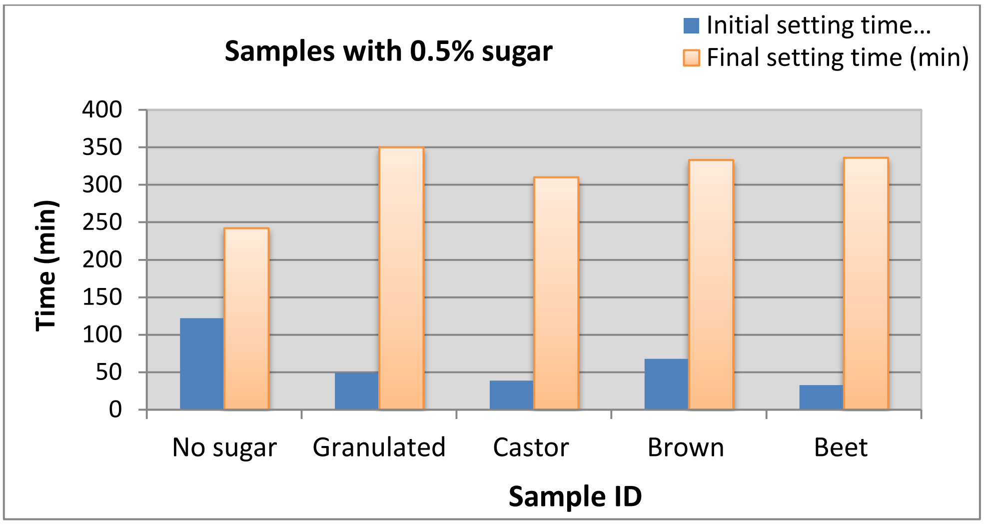


Figure 1 the Vi-cat needle results of using 0.5% sugar from different sugar type.

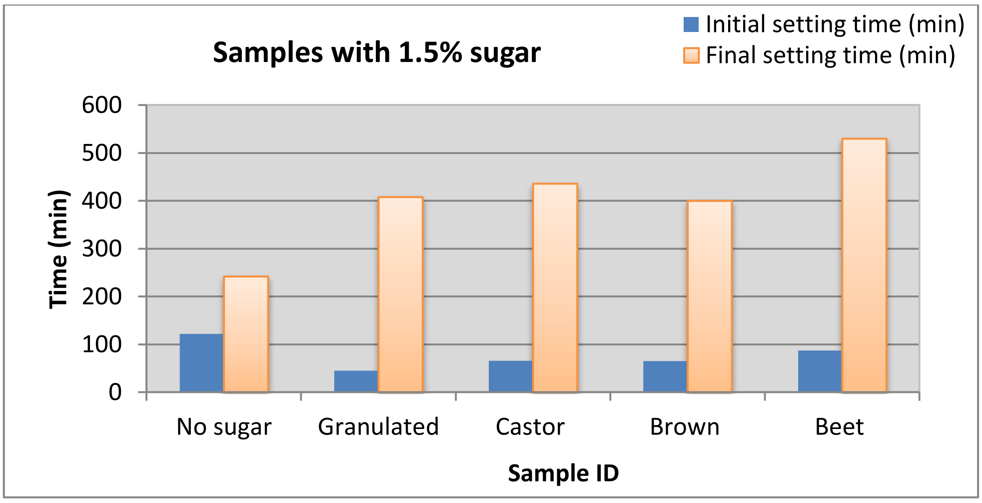


Figure 2 The Vi-cat needle results of using 1.5% sugar from different sugar type.

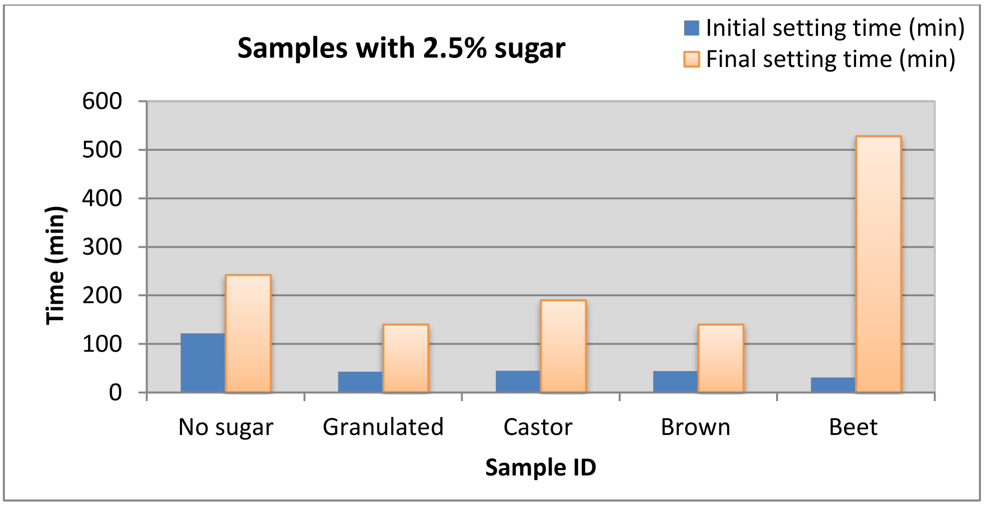


Figure 3 The Vi-cat needle results of using 2.5% sugar from different sugar type.

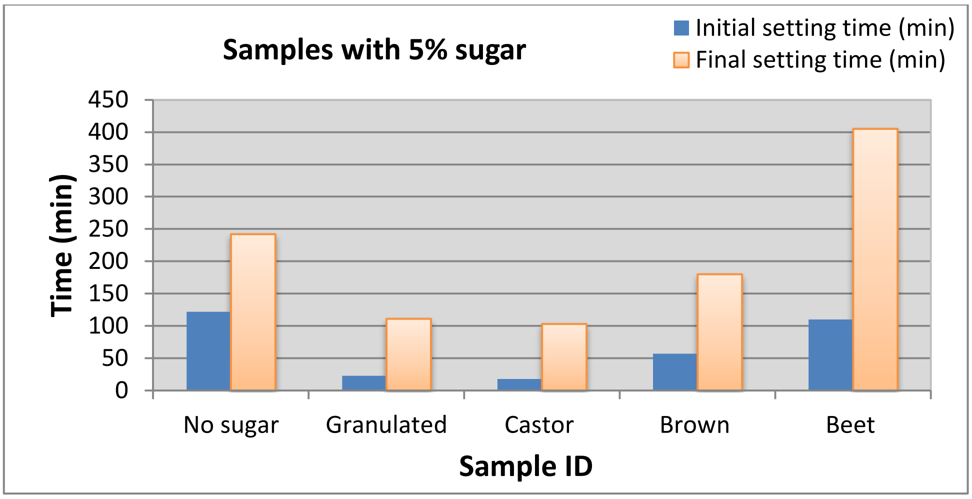


Figure 4 The Vi-cat needle results of using 5% sugar from different sugar type.

3.2. The impact of using sugar on the heat of hydration

When mixing cement with water, the process of hydration release high heating. The temperatures of hydration heat are affected by the content of sugar that is added to the mix. Figures 5, 6, 7, 8 and 9 show the differences in the heat hydration temperatures during the setting time stages. The y-axis represent the temperature in (˚C), and x-axis present the number of temperature reading during the test (the temperature taking automatically each 5 second). Figure 5. demonstrate the temperature of sample without sugar while the other Figures demonstrate the temperature for sample contain different sugar types and proportions and the orange circle in each curve present the time of finishing the test. Each curve in the same figure has the same sugar ratio for all samples. In all curves there are some disruption which refer to the starting of hydration after mixing the water with cement. After disruption period, the RF sample shows decreasing in the temperature and then still increasing until the end of the test. While the sample that contain sugar in any type or ratio after disruption period try to decrease until be constant which refer to final setting time. And the period between the disruption and the constant depending on the sugar ratio. The highest temperature was gotten from (5%) Beet sugar which about (34˚C), while the best graduation in temperature between the beginning of the mix until the final setting time was gotten from both (Granular and Brown) in proportion (0.5%) as shown in Figure 6.

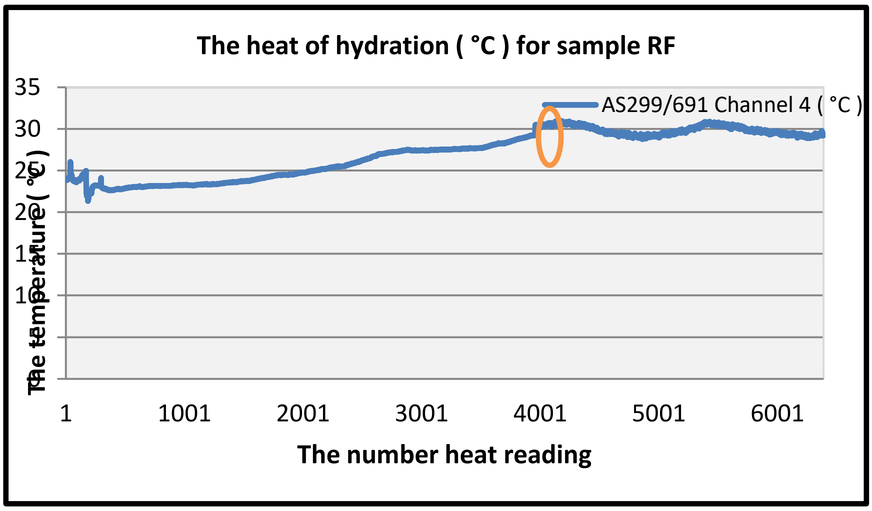


Figure 5 The changing in the heat of hydration during the setting times for sample RF.

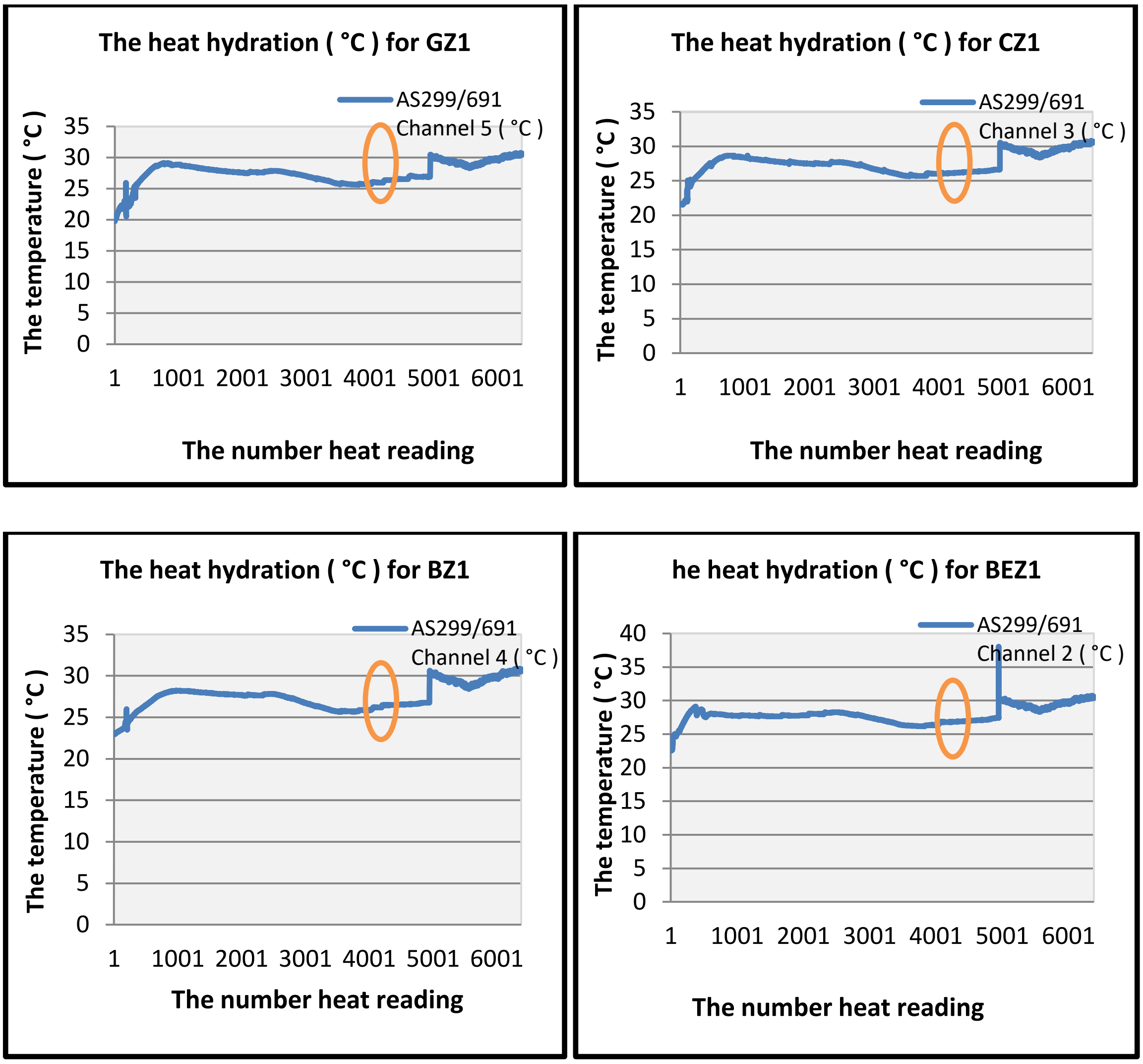
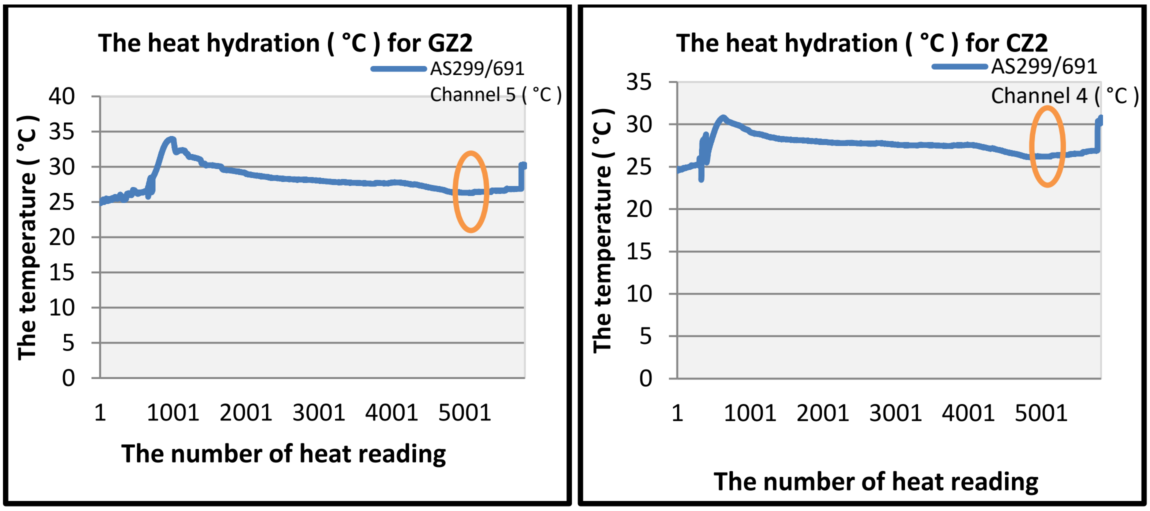


Figure 6 The changing in the heat of hydration during the setting times for samples GZ1, CZ1, BZ1 and BEZ1 with 0.5% sugar.



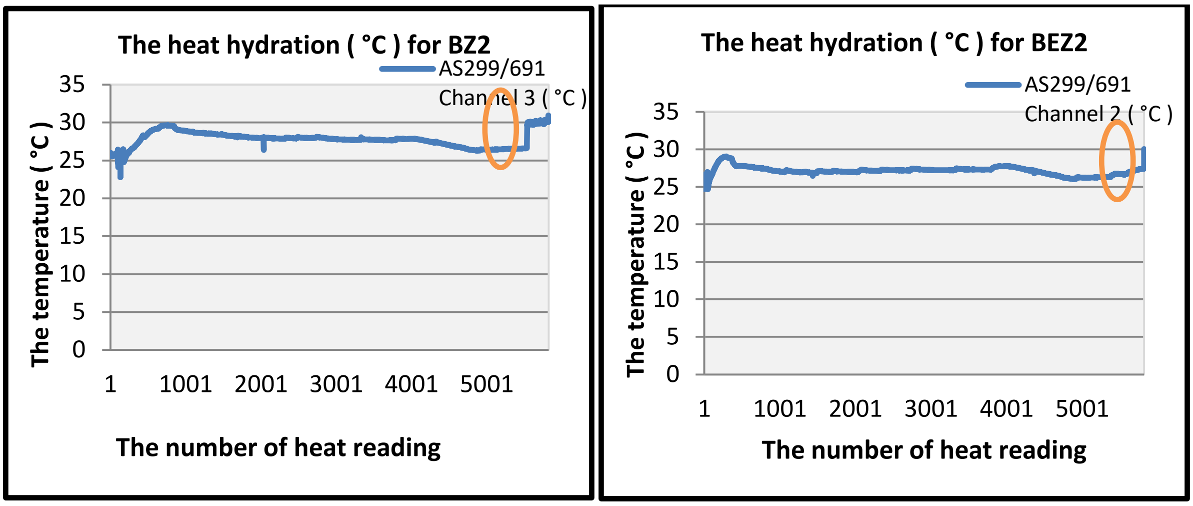


Figure 7 The changing in the heat of hydration during the setting times for samples GZ2, CZ2, BZ2 and BEZ2 with 1.5% sugar.

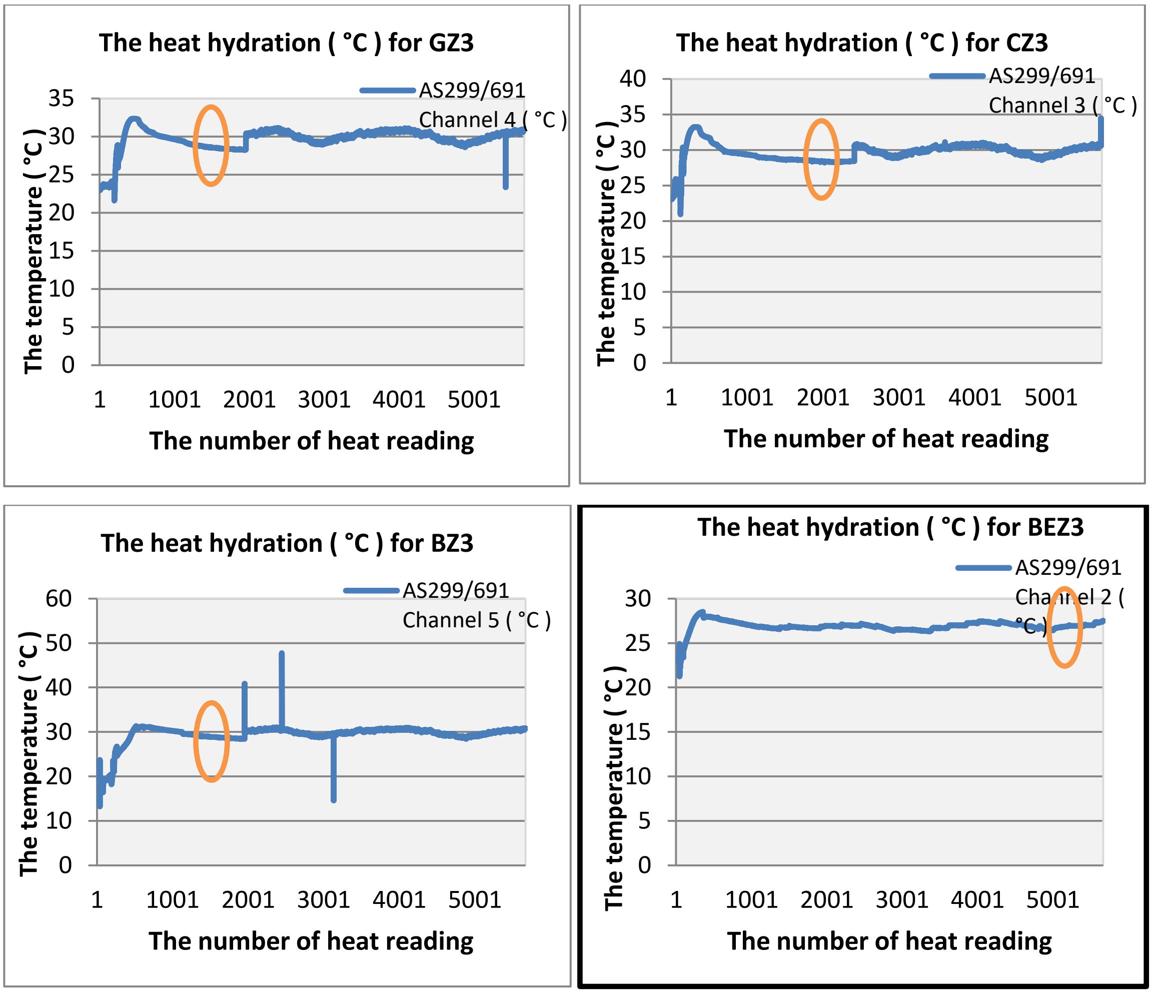


Figure 8 The changing in the heat of hydration during the setting times for samples GZ3, CZ3, BZ3 and BEZ3 with 2.5% sugar.

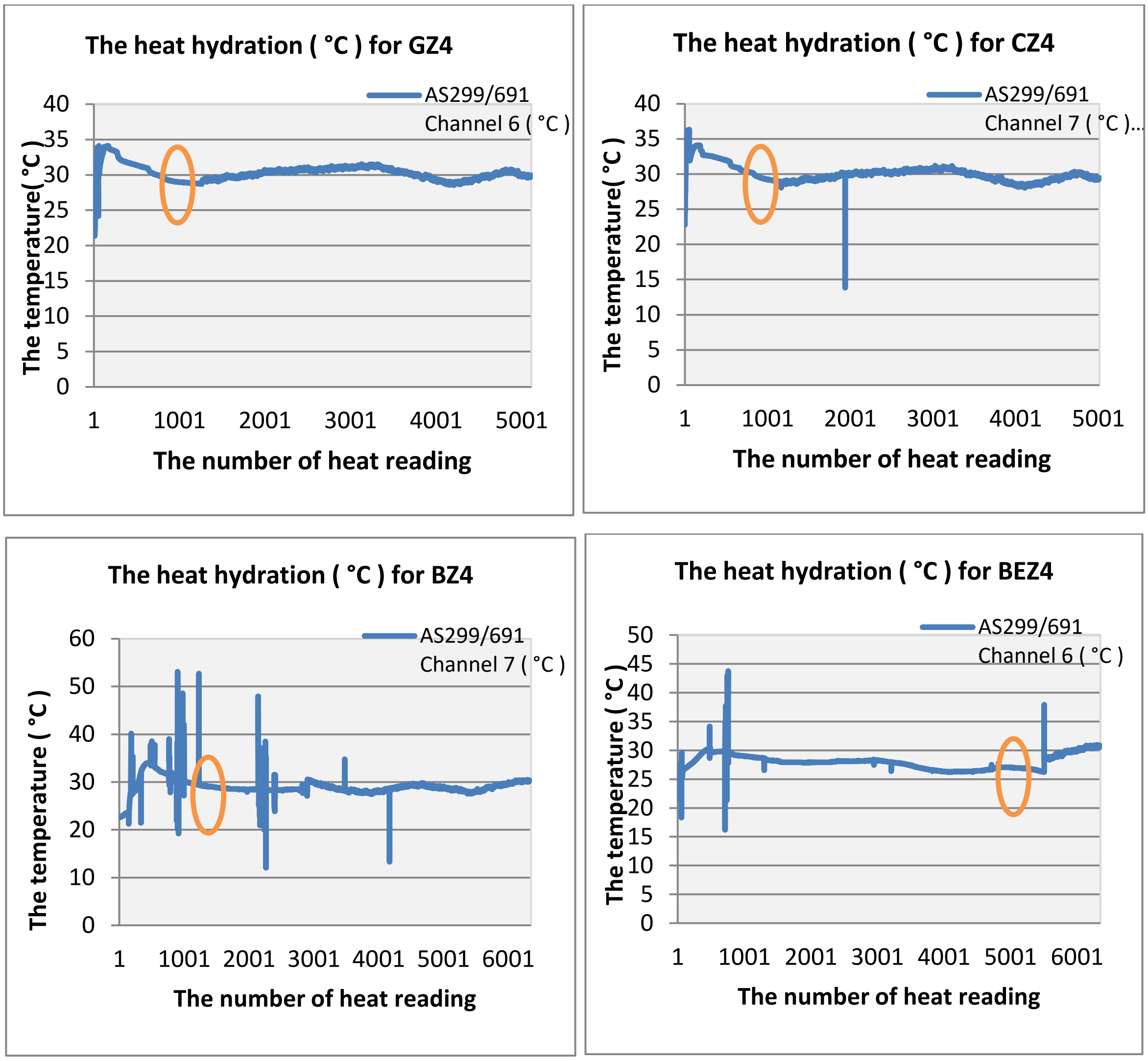


Figure 9 The changing in the heat of hydration during the setting times for samples GZ4, CZ4, BZ4 and BEZ4 with 5% sugar.

4. CONCLUSIONS

In the sum up, this paper study the behaviour and temperature during all setting stages of the cement paste after adding (Granular, Caster, Brown and Beet) sugar in proportion (0.5, 1.5, 2.5 and 5)%. This study provides a novel approach due to using the cell of getting setting time and temperature recording in the same time. As well as, the tests was showed the following:

Granular, Caster and Brown sugar when added to cement paste had two behaviours depending on the sugar proportion that used. Adding (0.5% and 1.5%) of sugar were tended to delay the final setting time, but it accelerate the initial setting time. While adding (2.5% and 5%) of sugar were tended to accelerate both the initial and final setting time.

Adding Beet sugar to cement paste works as concrete retardar, when using this sugar proportion (0.5%, 1.5%, 2.5% and 5%).

1.5% of (Granular, Caster, Brown and Beet) Sugar gave best results, because it delay the final setting time from (242 min) for RF sample to (530 min) for Beet.

Moreover, the temperature curves demonstrate many changes depending on the sugar types and proportion of sugar in the mixture. And the gradual increase in the temperature during the setting time considered more beneficial because it reduce the cracks in the concrete mass. For this reason adding (0.5%) of (Granular and Brown) considered the best proportion to reduce the physical issues of concrete.

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