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Delayed Analysis of Superplasticized Fresh Concrete

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Abstract - *Fresh analysis techniques for concrete mix can be used to check the compliance of mix proportions with specified requirements. Due to the practical difficulties related with conventional analysis techniques, the cement contents are rarely checked. Thus Rapid Analysis Machine can be used to analyze the cement content of fresh concrete. Rapid Analysis Machine is quick and considered reliable if concrete is tested within an hour of being mixed.*

Fresh concrete can be kept without setting for at least 7 days by using sugar for the determination of cement content using Rapid Analysis Machine. This technique is useful in finding the cement content of concrete mixes supplied to construction sites, which do not have ready access to a suitable fresh concrete analysis facility. The concrete containing superplasticizers can be tested using this method.

Testing was done for three superplasticizer dosages which were 0ml, 800ml and 1000ml per 100kg of cement content, respectively. The sugar percentage added to a single sample was 2% by the mass of cement content of the sample. The test were conducted for the samples with given sugar and superplasticizer dosages after three delay times, 1 hour, 24 hour and 7 days. Five samples of each sugar and superplasticizer combination were checked using Rapid Analysis Machine. The average cement content of the five samples was taken as the cement content given by Rapid Analysis Machine for a particular test.

The test results reveal that the cement content can be determined to a variation of 3.5% from actual cement content, within 7 days of initial adding of mixing, even if the fresh concrete contains superplasticizers.

Key Words: Superplasticizers, Rapid Analysis Machine, Sugar

1. INTRODUCTION

Fresh analysis techniques allow concrete to be checked for compliance of mix proportions with specified requirements. On the other hand, in many construction sites, ready access to suitable testing facilities for fresh concrete analysis is not available and a technique allowing delays in testing would make such sites to send the samples to the laboratories where these facilities are available.

Fresh concrete can be analyzed for cement content by using Rapid Analysis Machine (RAM) and for water content by quickly drying the mix to a constant weight. RAM gives quick and reliable values for cement and water contents, if the test was done within an hour after mixing [5]. Using chemicals, setting of concrete can be retarded and thereby make it possible to be tested for its cement after considerable time of mixing.

Admixtures can be used to change some of the properties of concrete. There are several types of admixtures, but in this test series it is intend to superplasticizers as they are widely used in the production of high performance concrete (HPC).

A delaying of the setting of the concrete mix can be achieved by the addition of a retarder. Sugar is proposed to be used as the retarder for keeping concrete fresh till the tests are performed.

Sugar can be used in two quantities [1],

1. In small quantities – 0.05% of the mass of concrete acts as an acceptable retarder; then the delay in setting of concrete is about 4hrs.
2. In large quantities-0.2 to 1% of the mass of cement virtually prevents the setting of cement.

Therefore in this experiment the sugar amount used was 2% of the cement mass.

Superplasticizers are long-chain polymers which can be used to improve the consistency of concrete [1]. The absorption of superplasticizers onto the cement particles deflocculates them and makes the cement pastes flowable. It helps to produce flowing concrete at lower water contents than otherwise required. However, it is suspected that the deflocculating action of superplasticizer interferes with the functioning of the chemically induced flocculating process of the RAM. In the proposed investigation such interference is studied on concrete mixes containing a naphthalene based superplasticizer.

Several brands of Portland cements with different compositions, as well as superplasticizers of different formulations carrying numerous product names are available in the market. Even though, an extensive investigation is in order to find the limitations of the delayed analysis covering combinations of most of the locally available products, due to limitation of available time, the project is confined to a single brand of cement with different dosages of single superplasticizer. The scope of the study is given in Table 1.

Table- 1. : Scope of Investigation

Sugar by mass of cement	Superplasticizer dosage (ml per 100kg of cement)								
	0			800			1000		
	Delay for the commencement of fresh concrete analysis								
(%)	1h	24h	7d	1h	24h	7d	1h	24h	7d
0%	5			5			5		
2%	5	5	5	5	5	5	5	5	5

5 — 5 samples for single test

2. ANALYSIS OF FRESH CONCRETE

In practice mistakes, errors and even deliberate actions can lead to incorrect mix proportions, and it is sometimes useful to determine the composition of the concrete at an early stage; one to be seriously considered is the cement content. Various methods of fresh analysis methods are discussed below.

The first one is Chemical Method Based on the Calcium- Ion Concentration [1]. ASTM C 1078-87 (Reapproved 1992) prescribes a chemical method, based on the calcium-ion concentration, which gives the value of the cement content in the fresh mix. Equipment and operator skills is required for this method.

The second method is Calcium Titration. US Army uses a test, which relies on the calcium titration for the cement content [1]. This test can be done in the field and takes no more than a quarter of an hour. However, the fine partials (smaller than 150µm (No.100 sieve) of calcareous aggregates cannot be distinguished from the cement.

The Pressure Filter method is developed in which the material smaller than 150 µm in the material batch. This is a likely source of error [2].

The Method using heavy liquid and a centrifuge which cement content is measured by separating the cement using a heavy liquid and a centrifuge [1]. This is not very successful, especially when the finest aggregate particles have a specific gravity not significantly lower than that of the cement.

The RAM can also be used to determine the cement content in fresh concrete [1], [2]. Approximately 8kg of concrete is put in to an elutriation column and material smaller than 600µm sieve is lifted. A part of this slurry is vibrated in the 150 µm and flocculated and the transferred to a constant volume vessel. This is weighed, and using calibration graph, cement content of the sample is determined. The whole test takes approximately 7-10 minutes.

3. RAPID ANALYSIS OF CEMENT CONTENT USING RAM

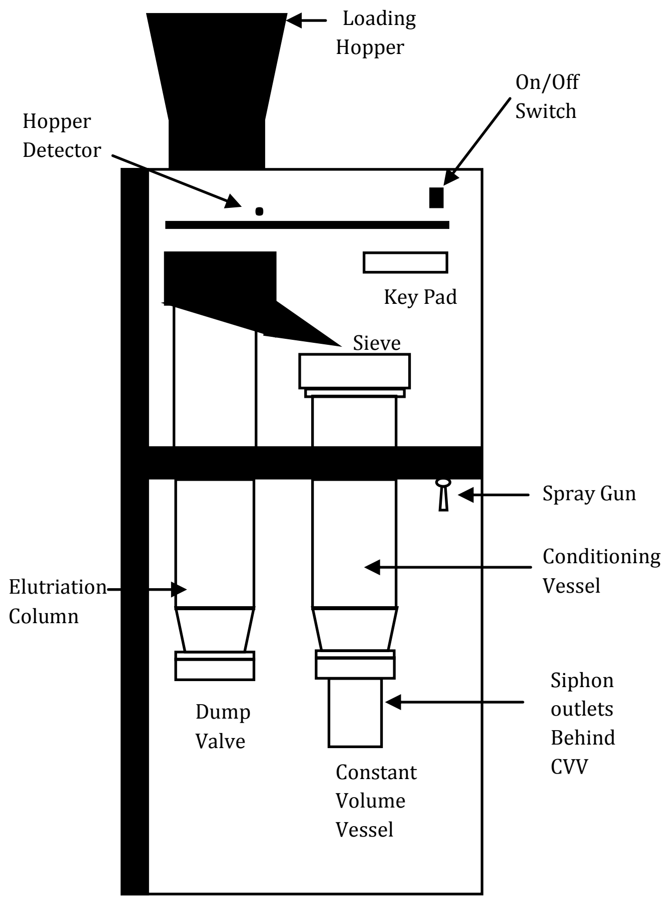

Figure 1: Components of RAM

The Figure: 2 illustrates the process of RAM. The RAM operates on the principal of physical separation. Using a high velocity water stream, all the small particles are removed from the concrete. The slurry produced by this separation is filtered to remove all the solid particles larger than 150 µm in size. Chemical agents cause the flocculation of the cement particles of the slurry in a CVV, which is weighed to determine the total cement content [6].

The operation of the RAM consists of two separate fully automatic cycles:

a. The Prime Cycle, in which the machine is primed with clean water before each concrete sample is placed in it.
b. The Auto Cycle, which is the physical separation test cycle carried out on the concrete sample.

It is not possible to initiate the AUTO cycle until a PRIME cycle has been completed. However two PRIME cycles can be carried out by mistake in succession. If this event occurs, the level of the water in the elutriation column will rise above the column height, and therefore water has to be removed before the second PRIME cycle.

When the AUTO cycle starts, water from the tank in the rear of the machine is pumped at high velocity in to the bottom of the elutriation tank. The water rises up carrying the small sized particles with it. At the sampling head, which is fitted to the top of the elutriation column, transfers 10% of the cement- water slurry to the conditioning vessel. The dump value, which is fitted to the bottom of the elutriation column, enables the remaining content to be removed at the completion of the test.

At the top of the conditioning vessel is the 150µm sieve holder which is fitted to a vibrator inside the top panel of the machine. Slurry, which comes from the sampling head, passes through the sieve to the conditioning vessel where it is mixed with flocculating agents, which enter the vessel through polythene tubes positioned below the table of the machine, by a paddle mixer.

Then the flocculated cement particles settle down in the Constant Volume Vessel (CVV) at the bottom of the conditioning vessel. Then the remaining water is siphoned out by the two siphon tubes and then a buzzer indicates the end of the test. CVV can be removed from the conditioning vessel for the weight measurement [6].

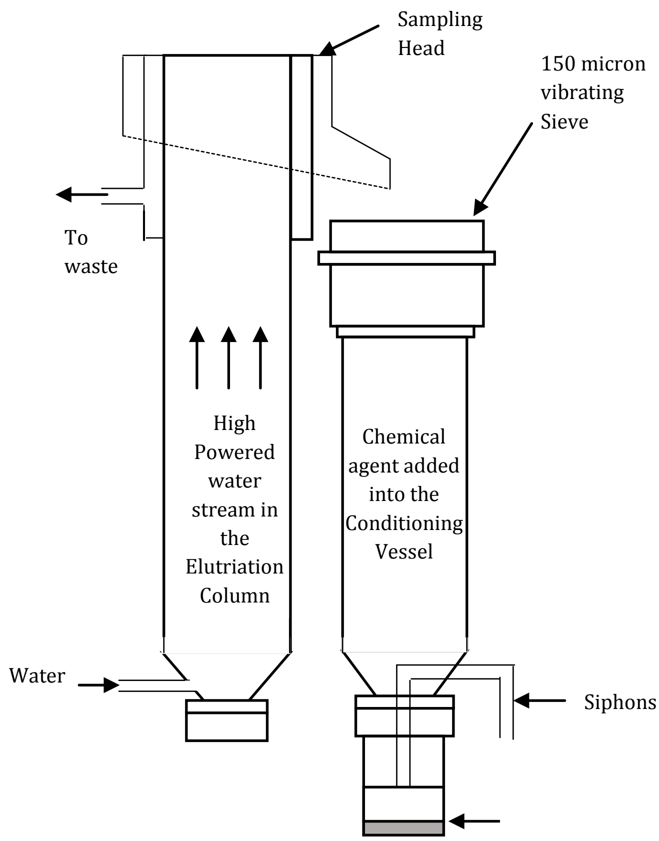

Figure 2: Process on auto c

4. METHODOLOGY

4.1. Experimental programme

The experimental programme was scheduled to carry out in following steps.

a) Testing of aggregate for
   - Specific gravity of fine and coarse aggregates
   - Specific gravity of cement
   - Wet density of the selected concrete mix.

b) Calibration of the RAM
c) Sample preparation and test for silt content of the selected mix
d) Preparation of concrete samples for the cement test
e) Analysis of the fresh concrete and the delayed analysis of fresh concrete for the cement content by RAM
f) Analysis of the results to assess the effect of delay and superplasticizer content, on the reliability of the cement content measurement.

4.2. Calibration of RAM

The RAM should be calibrated before testing of any concrete sample. This should be done using representative site material for each project. The RAM is calibrated by carrying out series of tests on concrete which is known to be silt free and which contains known amount of cement.

Silt free aggregates can be obtained by loading approximately 7kg of aggregate into the elutriation column of the machine and manually operating the pump. This washes out all the cement size particles. The selected amount of cement (0g, 750g and 1500g) was added to the aggregate for the calibration purpose.

4.2.1. Calibration procedure for 750g and 1500g

The required amount of cement (750g or 1500g) was weighed in to a container and cement was added to the approximately 7kg of clean washed aggregate. Sufficient amount of water is then added to get a workable concrete mix and was mix thoroughly. After that normal RAM test was carried out using this mix, and the results were recorded. The testing procedure was repeated using the clean aggregate collected from the dump valve until all the ten readings (five readings for single cement content) were obtained.

4.2.2. Calibration procedure for zero cement content

RAM test was carried out, using approximately 7kg of clean aggregate only, without cement. Then the CVV and its contents were weighed and the reading were recorded. This procedure were repeated until the required five set of readings were obtained.

According to the RAM Extended Hand Book [6], for any group of five readings obtained in calibration, the variability between readings in the group must be less than the values given in the Table 2.

Table- 2. Allowable Variability of CVV values

Cement content (g)	0	750	1500
Rang of CVV value for 5 results (g)	2.0	3.5	5.0

Observations of the calibration of the RAM is tabulated in Table 3 below.

The average weight of CVV (CVV value) was calculated for the relevant cement content and calibration graph was drawn with the CVV value on the vertical axis against the known cement content on the horizontal axis. The calibration line was the line joining the 750g point with the 1500g point.

Table- 3: Observations for the Calibration of RAM

		CVV Value/(g)					Avg. CVV Weight
	Trial	1	2	3	4	5	
Cement content /(g)	0	1623.6	1624.3	1623.3	1623.4	1622.8	1623.48
	750	1674	1672.2	1673.2	1673.1	1672.3	1672.96
	1500	1723.2	1724.8	1723.1	1724.1	1725.4	1724.12

Chart 1 illustrates calibration graph. From this graph the cement content corresponding to the CVV weight can be found

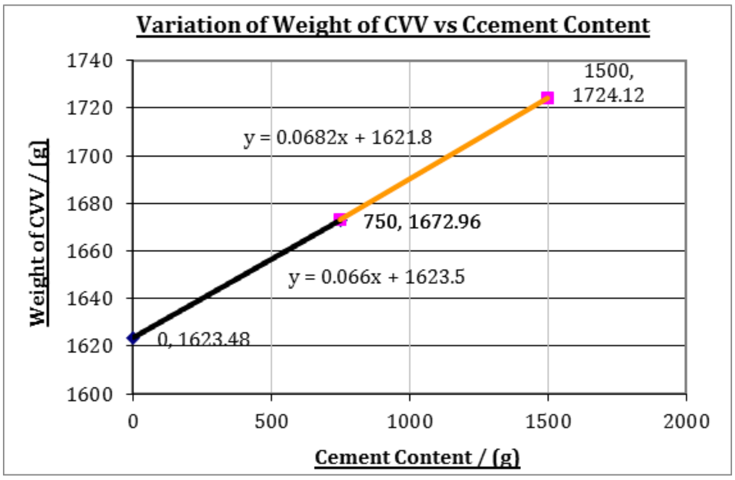

Chart 1: Calibration graph of RAM

4.2.3. Effects of silt on the cement content of a test sample

The term "silt" used in connection with the RAM test is defined as any non-cementitious material passing through a 150 micron sieve. Since silt in the mix will enhance the cement content value determined by the RAM, it is necessary to apply a correction factor, known as the silt content value or silt correction to the RAM result in order to get the true cement content.

4.2.4. Silt correction procedure

A sample was prepared which contains known cement content (ex: 1000g). The corresponding amount of fine and Coarse aggregates was complying with the nominal mix proportions of the concrete to be tested. Sufficient water was added to get a workable mix. Then test specimen was weighed. After that it was loaded to RAM and the RAM

S = Reading A- 1000g

analysis was carried out. The reading "A", corresponding to the weight of the CVV, from the calibration graph, gives the 1000g of cement plus silt. The silt content, "S" is calculated as shown below.

The test was repeated for five results where the range of results must less than 20 kg/m^3 according to the RAM Extended Hand Book. The average of the five results is taken as the Silt Content Value (kg/m^3). The true cement content was found by;

True cement content = Measured cement content - Silt content value

Table - 4: Constituents of the sample

Material	Test Mix (g)
Cement	1400
Water	798
Fine Aggregate	3430
Coarse Aggregate	2926
Total Weight of the sample	8554

After mixing of the sample the following observations were rerecorded by analyzing samples by RAM.

Table -5: Observations for silt correction using RAM

Sample No	Weight of Sample (g)	CVV Value (g)
1	8565.6	1718.4
2	8586.0	1719.8
3	8558.1	1718.1
4	8609.2	1721.4
5	8875.1	1718.6

The silt correction was calculated as shown in the Table 6.

Table- 6: Silt Correction Calculation

No Sample	Weight of Sample (g)	CVV Value + Content / (g)	A(Cement + Silt)(g)	Cement content (g)	Silt content S= A-1400 / (g)	Silt content / (kg/m^3)
1	8565.6	1718.4	1416.4	1400	16.4	4.6
2	8586.0	1719.8	1437.0	1400	37.0	10.3
3	8558.1	1718.1	1412.0	1400	12.0	3.4
4	8609.2	1721.4	1460.4	1400	60.4	16.8
5	8875.1	1718.6	1419.4	1400	19.4	5.2

Mean silt content = 8.1 kg/m^3

Range = 13.4 kg/m^3

4.3. Preparation of test sample

The experimental programme included testing of samples after 1hour, 24 hour, and 7days of mixing (Table-1). Three concrete mixes with different superplasticizer contents were tested for each delay time. Therefore five samples were checked for a certain amount of superplasticizer and certain amount of delay time. The 1hour test samples were prepared in buckets and kept in the same buckets until those were loaded to RAM. The 24hour and 7days test samples were put in to polythene bags and kept sealed till the delay period pass.

The main objective of this test was to study weather delayed analysis fresh concrete and presence of superplasticizer, affect the reliability of cement content determination using RAM. Mixing of concrete using an ordinary mixer would give samples which may not be fully homogeneous, thus cement, fine and coarse aggregates proportions in each sample may vary slightly. It is essential to have same cement and very fine aggregate content in every sample for certain amount of superplasticizer and certain time of delay, because then only values given by RAM, for the cement content, can be compared with actual cement content in that sample. Due to this reason, each sample was mixed in a bucket and the actual content was considered as the amount of cement used in that sample before mixing.

The weight of a single sample was about 8kg. Five samples were checked for a given amount of superplasticizer and a given amount of delay.

4.3.1. Material and mix proportions

The concrete mix was made from coarse aggregate (crushed rock) of 20mm size and specific gravity was 2.77 and specific gravity of fine aggregate (river sand) was 2.41 and specific gravity of Portland cement was 3.05 and Wet density of the compacted concrete was 2398.5kg/m3[3]. The silt (finer than 150 micron) content in five aggregate was about 7.7kg/m3.

The mix proportion by weight, for the selected concrete mix is as follows [4]

Cement: Water: Fine Aggregate: Coarse Aggregate

=

1: 0.57: 2.45:2.09

According to the mix proportion, weight of constituents of an individual sample is given in Table 7. The recommended dosage for the superplasticizer is in the range of 0.7-1.2L per 100kg of cement.

Table- 7: Constituents of an individual concrete sample

Constituents		**Superplasticizer Dosage (ml per 100kg of concrete)**		
		0	**800**	**1000**
Cement (g)		1308.3	1308.3	1308.3
Water (g)		745.8	745.8	745.8
Fine Aggregate (g)		3210.8	3210.8	3210.8
Coarse Aggregate (g)		2735.1	2735.1	2735.1
Sugar	For 2% of cement content (g)	26.16	26.16	26.16
	For 0% of cement content (g)	0	0	0
Superplasticizer (ml)		0	10.5	13.0

4.3.2. Mixing and sampling for 1hour test (with or without sugar)

Cement and aggregates were measured for a single sample according to the weights given in Table 7, using electronic balance and the bucket which the sample to be mixed was weighted. Then the measured constituents were filled in to the bucket and water was added to the sample and the contents were thoroughly mixed. After that the bucket and contents were weighed. Required amount of Superplasticizer was added using a burette and then the sample was mixed again. After thirty minutes of mixing, sugar was added (only for sample with sugar) to the sample and was mixed again. After 1 hour of mixing, the sample was taken to analyze using RAM. The above procedure was repeated for all five samples.

4.3.3. Mixing and sampling for 24hours and 7days tests (with sugar)

Mixing was as same as given in the above steps in the 1 hour test. After adding and mixing sugar, sample was poured to a polythene bag. All the materials from the bucket were recorded and put in to the bag. Weight of the bag and its contents was measured and sample was labelled and kept at a safe place until the delay period elapses. The above procedure was repeated for all five samples.

4.4. Analysis of samples by RAM

Steps involved in RAM analysis are as follows: Pressed the PRIME button on the keypad and waited until the GREEN LED lights. Added water to the sample bucket and stirred and place loading hopper in left hand column and poured in the sample. Used the spray gun to wash the last contents of the bucket into the hopper and also cleaned cement on the stirring rod into the hopper. Then spray cleaned the inside of the hopper, before removing it. After removing the loading hopper, pressed the automatic button on the keypad and placed a bucket under the siphon tubes. The buzzer sound came up at the end of the cycle. After that removed the CVV and dried the outside and weighted. Finally determined the cement content using calibration curve.

5. OBSERVATIONS AND RESULTS

5.1. Superplasticizer content (ml/100kg of cement) = 0ml

Table -8: Weight of CVV plus content for 1 hour test with sugar by mass of cement (%) = 0

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	7994.59	1711.70	1318.18	387.37	-1.24
2	8005.00	1714.00	1351.91	396.97	1.20
3	7936.30	1711.60	1316.72	389.84	-0.61
4	7999.40	1712.60	1331.38	391.09	-0.29
5	8005.00	1713.00	1337.24	392.57	0.08
Avg. Cement Content				391.57	

Table- 9: Weight of CVV plus content for 1 hour test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8006.6	1711.60	1316.72	386.34	-1.50
2	8024.9	1714.30	1356.30	397.28	1.28
3	8007.5	1713.90	1350.44	396.40	1.06
4	7992.5	1713.10	1338.71	401.73	2.42
5	8002.2	1714.60	1360.70	407.84	3.98
Avg. Cement Content				397.92	

Table -10: Weight of CVV plus content for 24 hours test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8033.5	1712.6	1331.38	389.40	-0.72
2	8010.0	1716.4	1387.10	407.25	3.83
3	7870.2	1711.6	1316.72	393.18	0.24
4	8022.0	1712.9	1335.78	391.28	-0.24
5	8012.7	1716.6	1390.03	407.99	4.01
Avg. Cement Content				397.82	

Table -11-: Weight of CVV plus content for 7days test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8007.3	1717	1395.89	410.03	4.53
2	8009.2	1717	1395.89	409.93	4.51
3	7985.3	1715.6	1375.37	405.01	3.26
4	7992.7	1714.7	1362.17	400.67	2.15
5	8003.8	1714.6	1360.70	399.66	1.89
Avg. Cement Content				405.06	

5.2. Superplasticizer content (ml/100kg of cement) = 800ml

Table -12: Weight of CVV plus content for 1 hour test with sugar by mass of cement (%) = 0

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8019.30	1714.00	1351.91	396.24	1.02
2	8016.20	1713.70	1347.51	395.08	0.72
3	8027.50	1713.00	1337.24	391.45	-0.20
4	8011.00	1713.10	1338.71	392.71	0.12
5	8002.60	1714.60	1360.70	399.72	1.91
Avg. Cement Content				395.04	

Table -13: Weight of CVV plus content for 1 hour test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8011.50	1712.00	1322.58	387.86	-1.12
2	8011.30	1713.00	1337.24	392.26	0.00
3	8082.50	1715.20	1369.50	398.30	1.55
4	7997.00	1715.70	1376.83	404.85	3.21
5	7999.00	1712.80	1334.31	391.99	-0.06
Avg. Cement Content				395.05	

Table -14: Weight of CVV plus content for 24 hours test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8008.30	1715.4	1372.43	411.04	4.79
2	7999.00	1712.8	1334.31	400.08	2.00
3	8013.90	1715.3	1370.97	410.31	4.61
4	7997.10	1711.3	1312.32	393.58	0.34
5	8007.60	1711.5	1315.25	393.95	0.43
Avg. Cement Content				401.79	

Table -15: Weight of CVV plus content for 7days test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8003.80	1713.5	1344.57	402.92	2.72
2	7991.40	1713.9	1350.44	405.31	3.33
3	8048.80	1715.4	1372.43	408.97	4.27
4	8025.70	1713.5	1344.57	401.82	2.44
5	8033.00	1713.1	1338.71	399.70	1.90
Avg. Cement Content				403.74	

5.3. Superplasticizer content (ml/100kg of cement) = 1000ml

Table -16: Weight of CVV plus content for 1 hour test with sugar by mass of cement (%) = 0

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8069.30	1712.40	1328.45	386.76	-1.40
2	8042.40	1713.30	1341.64	392.02	-0.06
3	8010.70	1712.10	1324.05	388.34	-1.00
4	8010.40	1714.50	1359.24	398.89	1.69
5	8010.80	1715.80	1378.30	404.57	3.14
Avg. Cement Content				394.12	

Table- 17: Weight of CVV plus content for 1 hour test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8014.20	1712.80	1334.31	391.23	-0.26
2	8025.00	1715.90	1379.77	404.28	-3.07
3	8055.80	1714.60	1360.70	397.03	-1.22
4	8022.00	1714.80	1363.64	399.61	1.88
5	8004.60	1713.40	1343.11	394.35	0.54
Avg. Cement Content				397.30	

Table- 18: Weight of CVV plus content for 24 hours test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8009.40	1710.6	1302.05	389.91	-0.60
2	8009.90	1711.9	1321.11	395.59	0.85
3	8007.50	1710.8	1304.99	390.88	-0.35
4	8008.70	1711.8	1319.65	395.21	0.76
5	8045.40	1712.4	1328.45	396.03	0.97
Avg. Cement Content				393.52	

Table -19: Weight of CVV plus content for 7days test with sugar by mass of cement (%) = 2

No Sample	Weight of Sample (g)	CVV Value / (g)	A(Cement + Silt) Content (g)	Cement Content (g)	% Error
1	8007.50	1711.8	1319.65	395.27	0.77
2	8000.10	1714.1	1353.37	405.74	3.44
3	8006.60	1712.3	1326.98	397.51	1.34
4	8028.60	1711.7	1318.18	393.79	0.40
5	8011.60	1711.6	1316.72	394.19	0.50
Avg. Cement Content				397.30	

5.4. Analysis of Data

The result obtained from RAM analysis can be grouped according to the superplasticizer content and the delay time. The variations of cement for a particular superplasticizer content and delay times are shown in Chart 2.

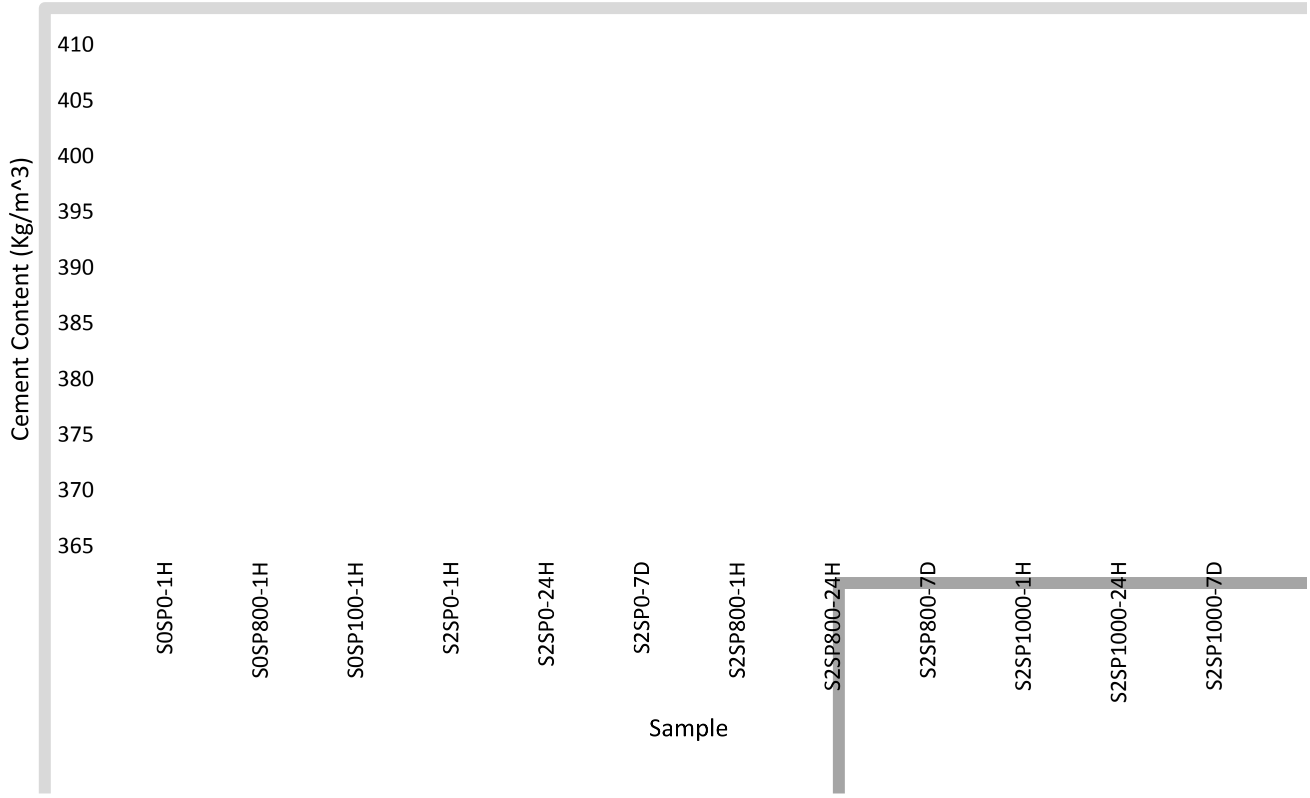

Chart -2 Variation of cement content for different delay times and different superplasticizer contents

6. RESULTS AND DISCUSSION

Table -20: Results of delayed analysis of fresh concrete

Sample	Superplasticizer content (ml per 100kg of cement)	Delay Time	Cement Content (kg/m3)			
			Actual	Sample mean	Upper Limit	Lower Limit
S0SP0-1H	0	1h	392	391.57	396.43	387.56
S0SP800-1H	800	1h	392	395.04	396.00	387.99
S0SP100-1H	1000	1h	392	394.12	401.29	382.70
S2SP0-1H	0	1h	392	397.92	401.80	382.19
S2SP0-24H		24h	392	397.82	403.23	380.76
S2SP0-7D		7d	392	405.06	398.10	385.89
S2SP800-1H	800	1h	392	395.05	400.22	383.77
S2SP800-24H		24h	392	401.79	402.56	381.43
S2SP800-7D		7d	392	403.74	396.40	387.59
S2SP1000-1H	1000	1h	392	397.30	398.19	385.80
S2SP1000-24H		24h	392	393.52	395.59	388.40
S2SP1000-7D		7d	392	397.30	398.12	385.87

The upper limit and the lower limit (95% confidence level) are calculated by a hypothesis test with (H_0: μ) = 392 kg/m^3, where 392 kg/m^3 is the actual cement content of the mix, with level of significance is set to 0.05

The Table 20 shows the results of the cement content test. The results show that the sample mean of cement content lies within the upper limit and lower limit except for 7 days tests with superplasticizer content 0 and 800ml per 100kg of cement. The superplasticizer dosage of 1000ml per 100kg of cement content also gives a sample mean which is close to the upper limit. This shows that the cement content given by this test tends to increase as the delay time increases. The variation in the cement content does not show a significant relation with the addition of superplasticizer.

If the loss of materials (even slightly) during mixing, sampling and storing can be avoided, the variations in cement content for 5 sample series can be minimized. Thus, it might be possible to get a better relationship between cement content and delay time as well as cement content and superplasticizer content.

As the cement content accuracy is of ±5% of actual value and the sample mean lies within the upper limit and lower limit for 1 hour and 24 hour tests, the method of delayed analysis of concrete containing superplasticizer contents within the range of 800-1000 ml/100kg of cement, using sugar as a set preventer, appears to be acceptable for 1 hour and 24 hour tests. The method shows no significant loss of reliability, when it is applied to analyze concrete mixes without superplasticizers, even at a delay of 7 days of mixing.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The accuracy of cement content determination by the delayed analysis of fresh concrete using RAM, is in the range of ±5% of the true cement content.

The delayed analysis of fresh concrete containing superplasticizer, using sugar as a set preventer, can perform satisfactorily using RAM up to delay time of 25hours.

The mean cement content of superplasticized concrete given by this method is tend to be marginally higher than the 5%.

The reliability of the determination of the cement content of fresh concrete that does not contain superplasticizer is within the 5% limit, even if the test by RAM is performed as late as 7days of mixing.

7.2. Recommendations

A RAM calibration test can be done, for the mixes after a delay of 7days of mixing, in order to see whether there is any effect of delay on the calibration graph.

Further tests are needed to be carried out in order to find out the effects of sampling in the field, to the variability of results in delayed analysis of fresh concrete.

Further investigation is recommended to assess the effects of different cement superplasticizer combinations on the reliability of this test.

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