COMPATIBILITY ANALYSIS OF CEMENT WITH SUPERPLASTICIZERS

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Objective Of Work

- To determine the compatibility between cement and super-plasticizer by measuring the flowability of the cement paste.
- Fabrication and arrangement of test equipment.
- Determination of saturation dosage .
- Determination of saturation dosage for change in w/c ratio for the same combination of C-SP.
- Analysis of behavior of C-SP couple for different w/c ratio.
- Development of compatibility equations.

Need Of Study

- The increase in types in multitude of brands of chemical admixtures and cement are available in the market.
- The cement composition and its properties vary in the world; it has not become an easy task for admixture manufacturer to ‘match’ its products with any specific type of cement.
- This has created confusion among users to use which type of cement with which type of super-plasticizer and with how much dosage.
- Consequently, there may exist some problems of incompatibility of C-SP.

Need Of Study contd…..

- The use and quantity of super-plasticizer is generally based on trial and error method because of an incomplete understanding.
- It becomes essential to evaluate each C-SP combination.
- This study is a step to determine the solution against this difficulty to select the most efficient couple of C-SP and optimum dosage.

Introduction

- Due to the change in composition within same grade or type of cement, super-plasticizers are not showing the same extent of improvement in fluidity.
- Some cement brand show higher fluidizing effect with a super-plasticizer than other cement brand with same super-plasticizer.
- There is neither the problem with cement nor with that of super-plasticizer.
- The fact is that they are just not compatible to show maximum fluidizing effect due to the change of composition or so.

Introduction contd…..

- The use of super-plasticizer reduces the w/c ratio for making concrete of higher workability which increases strength and durability.

- An admixture can be effective or not, depends upon various factors such as
  - Chemical family of SP,
  - Chain length,
  - Dosage of admixture,
  - Temperature,
  - Molecular weight of the polymer
  - Particle size distribution and composition of cement.

- The concrete made with low water- cement ratio require such suitable and compatible super-plasticizer which can adopt the behavior of cement and can also impart high workability.

Introduction Contd…..

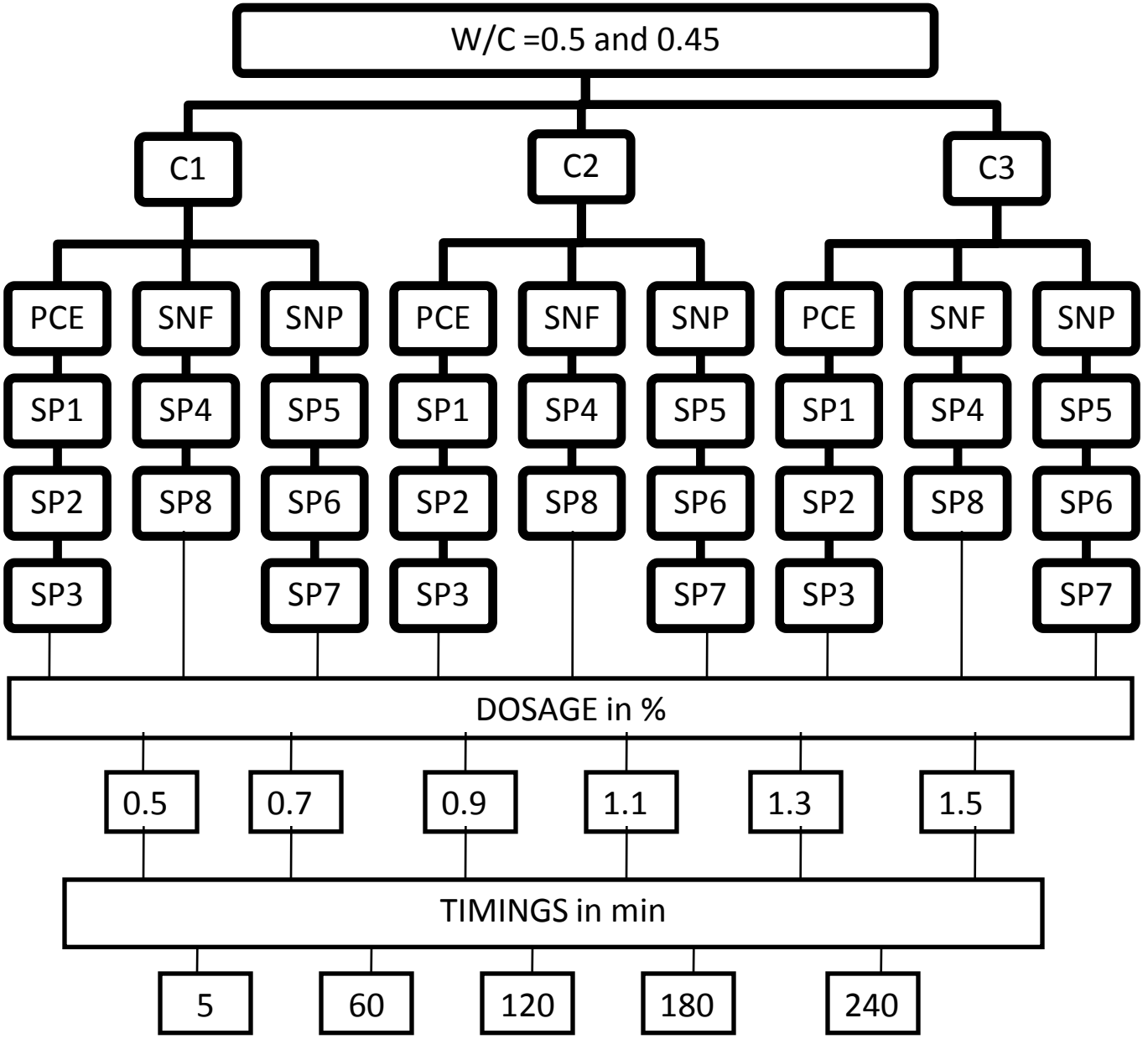
- It is very difficult to ensure that an admixture produces all the desirable effect with cement A would do the same with cement B.
- Problems arising due to compatibility issues are often mistaken for problems with concrete mix design, because of the lack of information about the subject amongst practicing engineers.
- Admixture manufacturers have started formulating project specific chemicals, to overcome the problem. But this is only short term solution.

Work Till Minor

- Fabrication and arrangement of test equipment.
- Determination of saturation dosage for C-SP couple for 0.5 w/c ratio.
- Determination of saturation dosage for change in w/c ratio for the same combination of C-SP.
- Analysis of behavior of C-SP couple for different w/c ratio.
- Development of compatibility equations.

Fabricated Marsh Cone Apparatus

Flow Chart For Experimental Program



Work Post Minor

- Fabrication and arrangement of test equipment.
- Determination of saturation dosage for C-SP couple for 0.5 w/c ratio.
- Determination of saturation dosage for change in w/c ratio i.e. 0.45 w/c for the same combination of C-SP.
- Development of compatibility equations.
- Analysis of behavior of C-SP couple for different w/c ratio.

Combination of testing

PRE- MINOR EXPERIMENTATION COMBINATION			POST- MINOR EXPERIMENTATION COMBINATION		
w/c ratio= 0.5			**w/c ratio= 0.45**		
C1- SP1	C2- SP1	C3- SP1	C1- SP1	C2- SP1	C3- SP1
C1- SP2	C2- SP2	C3- SP2	C1- SP2	C2- SP2	C3- SP2
C1- SP3	C2- SP3	C3- SP3	C1- SP3	C2- SP3	C3- SP3
C1- SP4	C2- SP4	C3- SP4	C1- SP4	C2- SP4	C3- SP4
C1- SP5	C2- SP5	C3- SP5	C1- SP5	C2- SP5	C3- SP5
C1- SP6	C2- SP6	C3- SP6	C1- SP6	C2- SP6	C3- SP6
C1- SP7	C2- SP7	C3- SP7	C1- SP7	C2- SP7	C3- SP7
C1- SP8	C2- SP8	C3- SP8	C1- SP8	C2- SP8	C3- SP8

METHODOLOGY

TEST PROCEDURE

1. w/c ratio= 0.45
2. Take 2 kg of cement in bowl
3. Add 0.9 litre of water (as w/c ratio= 0.45)

METHODOLOGY

STEP -4

STEP -5

STEP -6

4. Add 10ml of SP1 super-plasticizer. (i.e. 0.5% of cementitious material)
5. Mix them thoroughly with hand or mechanical mixer for 2 min.
6. If hand mixing is done, the cement slurry should be sieved through 1.18 sieve to avoid formed lumps to choke the funnel orifice.

METHODOLOGY

STEP -7

STEP -8

STEP -9

7. Take one litre of cement slurry and pour it into the funnel by closing the orifice with the help of rubber stop or finger.
8. Close it for that time, for which the reading has to be taken i.e. 5min, 60min….so on.
9. Start a stop watch and simultaneously remove the finger. Note down the time taken in seconds, for the complete flow out of the slurry.

METHODOLOGY

10. Repeat the above steps with 0.7% , 0.9% , 1.1% ,1.3%, 1.5% dosages of super-plasticizer for 60min,120min,180min, 240min.

11. Plot the graph between Marsh cone time and dosages of super-plasticizer.

12. The dose at which the Marsh cone time is lowest is called the saturation point. The dose will be the optimum dose for that combination of cement and super-plasticizer.

Observations cement (c1), w/c =0.45

%age of plasticizer	SP1				
	5 min	60 min	120 min	180 min	240 min
0.5%	69.53	151.78	162.36	172.22	197.06
0.7%	51.62	109.23	136.83	153.64	179.84
0.9%	34.85	79.47	121.39	139.3	157.69
1.1%	32.79	76.71	109.46	128.43	142.56
1.3%	31.58	74.28	108.77	126.58	139.17
1.5%	29.89	73.47	106.95	123.88	137.25

%age of plasticizer	SP2				
	5 min	60 min	120 min	180 min	240 min
0.5%	61.42	89.51	94.68	99.14	103.74
0.7%	49.81	71.46	81.33	87.21	95.03
0.9%	43.36	63.79	72.48	81.44	87.15
1.1%	38.14	58.08	67.52	73.8	81.22
1.3%	37.29	56.53	63.78	69.97	77.14
1.5%	36.74	55.79	62.67	70.09	75.87

%age of plasticizer	SP3				
	5 min	60 min	120 min	180 min	240 min
0.5%	57.22	96.51	103.44	118.74	127.18
0.7%	51.82	81.38	92.19	102.68	109.96
0.9%	46.43	74.29	83.36	94.79	99.06
1.1%	43.71	62.56	71.44	86.35	91.46
1.3%	39.87	52.62	69.25	84.55	87.23
1.5%	38.54	50.89	68.52	83.48	85.88

%age of plasticizer	SP4				
	5 min	60 min	120 min	180 min	240 min
0.5%	58.76	146.54	160.81	181.34	195.09
0.7%	49.85	107.65	121.17	139.54	152.75
0.9%	33.78	79.37	98.86	104.68	121.12
1.1%	31.63	73.44	81.27	93.74	106.77
1.3%	30.27	71.38	75.62	84.44	98.51
1.5%	29.52	69.97	73.04	82.39	96.66

Observations contd… cement (c1), w/c =0.45

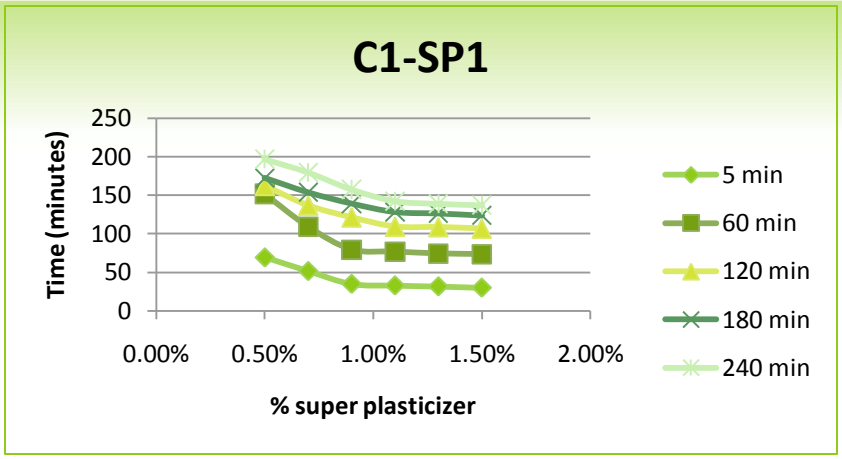
%age of plasticizer	SP5				
	5 min	60 min	120 min	180 min	240 min
0.5%	98.43	182.36	194.66	210.24	217.81
0.7%	81.35	165.49	181.79	192.46	197.74
0.9%	73.22	149.57	158.36	173.29	178.58
1.1%	61.11	118.43	139.24	156.33	167.28
1.3%	59.72	115.02	121.38	132.19	165.08
1.5%	57.21	113.65	119.81	129.97	161.77

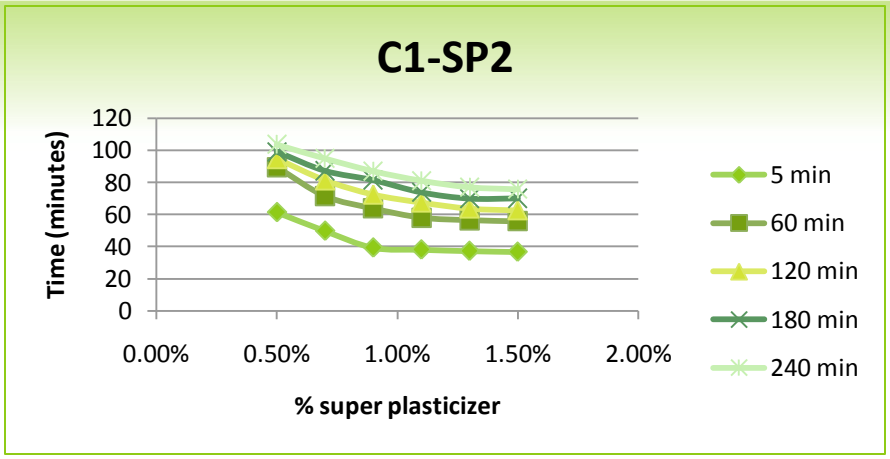
%age of plasticizer	SP6				
	5 min	60 min	120 min	180 min	240 min
0.5%	74.18	149.28	163.34	171.45	187.72
0.7%	53.22	131.47	142.53	153.68	168.41
0.9%	39.82	114.08	130.29	142.21	157.54
1.1%	38.59	109.85	121.36	128.58	145.27
1.3%	38.12	107.58	119.92	125.89	141.88
1.5%	37.28	106.37	117.46	123.35	139.16

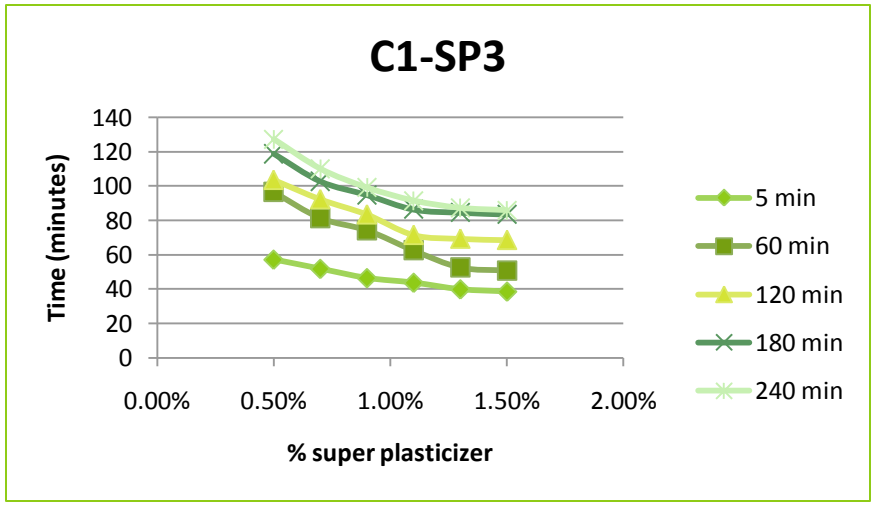
%age of plasticizer	SP7				
	5 min	60 min	120 min	180 min	240 min
0.5%	47.13	110.2	135.11	157.49	183.19
0.7%	39.27	69.33	79.68	94.86	101.55
0.9%	31.83	52.25	62.82	78.05	84.95
1.1%	27.62	41.46	57.35	63.91	67.58
1.3%	25.87	39.38	51.46	57.83	65.46
1.5%	25.03	40.41	49.71	56.69	63.89

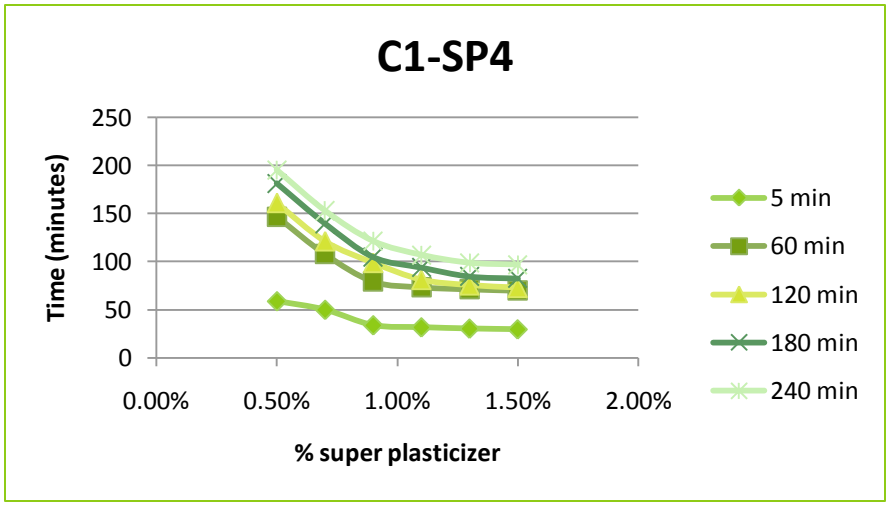
%age of plasticizer	SP8				
	5 min	60 min	120 min	180 min	240 min
0.5%	41.46	156.24	168.8	181.17	201.09
0.7%	34.25	114.55	127.47	141.46	172.85
0.9%	27.68	84.47	98.65	112.44	141.52
1.1%	21.73	75.24	82.37	91.24	104.17
1.3%	20.37	73.48	76.02	85.44	99.51
1.5%	19.82	71.77	74.64	85.39	98.86

Graphs And Results - C1

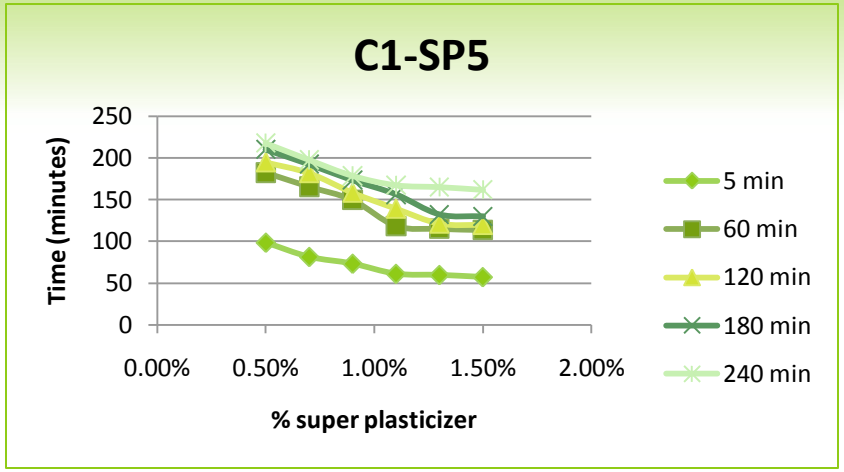


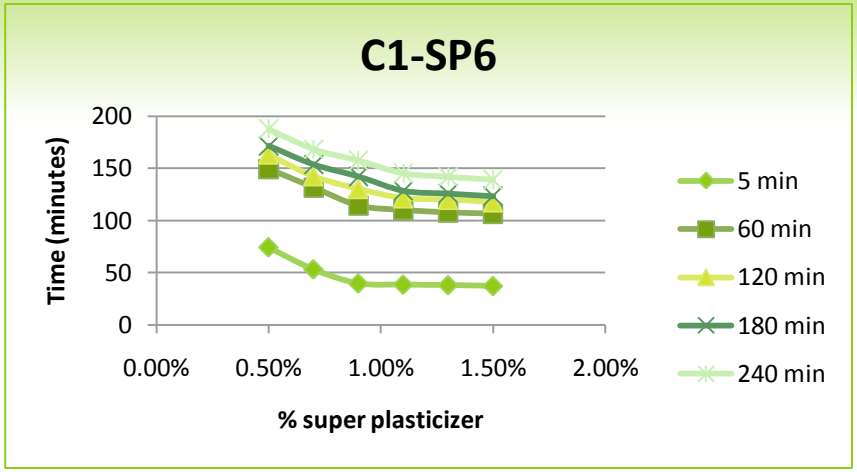


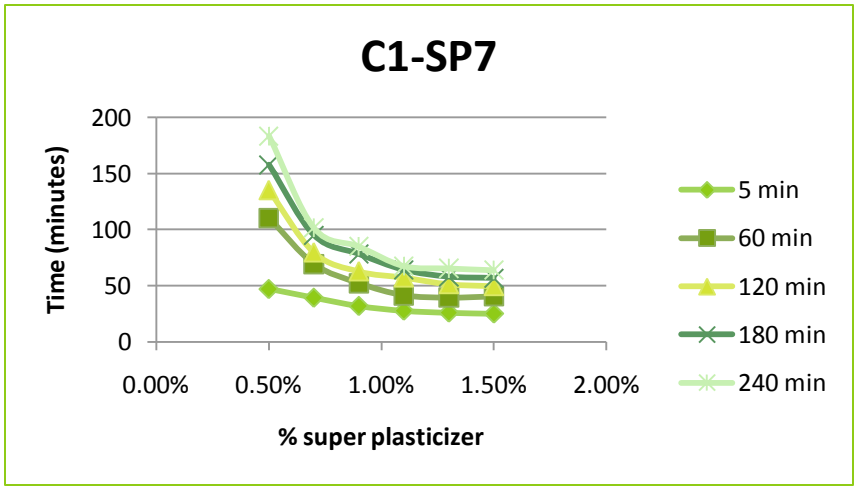


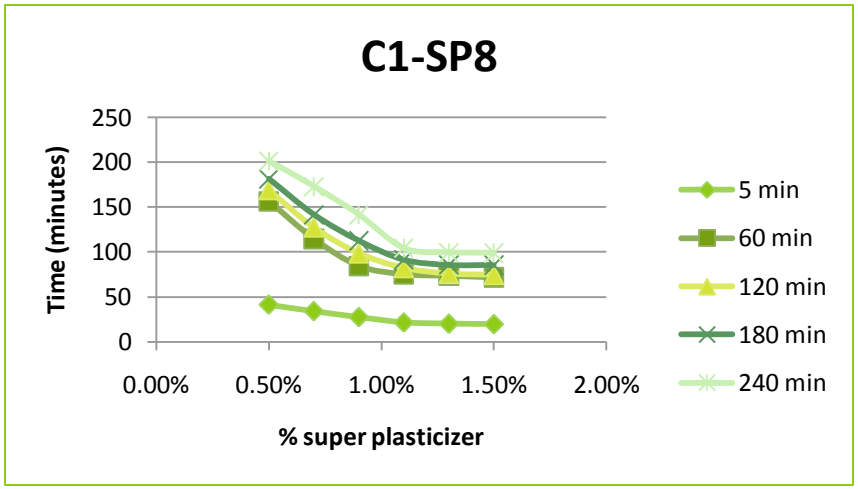


Graphs and Result - C1









Observations cement (c2), w/c =0.45

%age of plasticizer	SP1				
	5 min	60 min	120 min	180 min	240 min
0.5%	91.73	106.31	118.53	137.56	185.76
0.7%	84.55	94.51	105.42	122.68	140.37
0.9%	73.61	84.83	97.73	105.44	109.24
1.1%	59.2	78.09	93.28	96.87	101.49
1.3%	53.36	78.64	91.82	94.16	97.82
1.5%	52.79	77.13	90.49	93.65	96.27

%age of plasticizer	SP2				
	5 min	60 min	120 min	180 min	240 min
0.5%	59.24	70.71	85.68	97.23	116.17
0.7%	47.35	63.84	69.62	81.27	101.18
0.9%	37.59	52.92	61.31	72.38	90.33
1.1%	34.63	49.04	54.63	64.46	78.62
1.3%	33.28	47.36	52.33	63.71	69.83
1.5%	31.86	46.13	51.62	62.86	67.39

%age of plasticizer	SP3				
	5 min	60 min	120 min	180 min	240 min
0.5%	47.81	71.28	80.44	97.14	119.08
0.7%	39.75	59.12	69.88	76.62	91.26
0.9%	37.62	51.47	64.32	67.74	83.66
1.1%	32.03	44.78	58.22	61.29	77.54
1.3%	31.57	43.41	53.93	57.43	73.64
1.5%	30.79	42.85	52.86	56.78	71.81

%age of plasticizer	SP4				
	5 min	60 min	120 min	180 min	240 min
0.5%	53.24	72.38	81.18	93.79	101.53
0.7%	49.82	64.29	69.92	84.57	93.69
0.9%	41.64	52.81	58.86	71.94	82.28
1.1%	33.48	48.33	51.66	63.87	73.72
1.3%	32.42	46.63	49.13	58.34	69.07
1.5%	31.77	45.21	48.38	56.98	68.55

Observations cement (c2), w/c =0.45

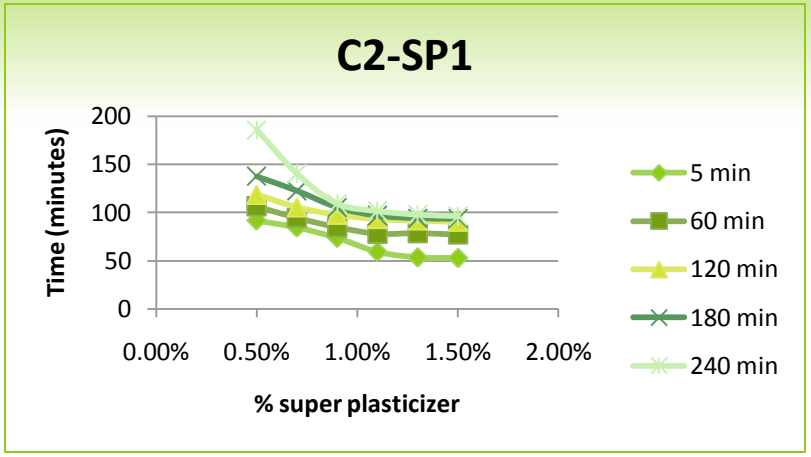
%age of plasticizer	SP5				
	5 min	60 min	120 min	180 min	240 min
0.5%	89.41	129.98	159.58	179.77	190.63
0.7%	76.93	94.59	138.02	161.85	171.96
0.9%	66.04	72.61	103.83	142.74	159.63
1.1%	65.33	70.94	91.39	118.52	124.42
1.3%	64.73	69.46	89.11	93.33	101.34
1.5%	64.13	68.89	88.24	92.79	99.67

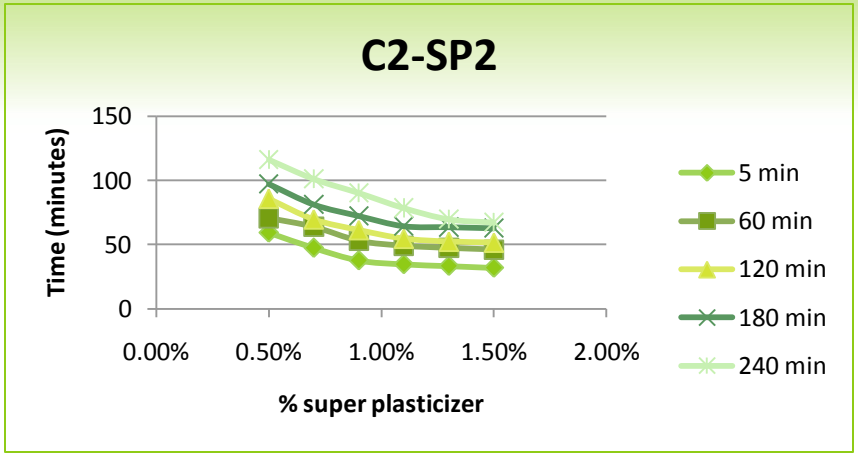
%age of plasticizer	SP6				
	5 min	60 min	120 min	180 min	240 min
0.5%	53.46	72.82	91.27	115.06	127.36
0.7%	41.53	61.73	79.81	93.38	101.33
0.9%	34.64	55.24	64.68	78.82	92.57
1.1%	29.44	46.14	58.92	63.66	84.42
1.3%	28.38	45.47	49.84	59.03	72.29
1.5%	26.87	45.63	47.18	58.74	70.88

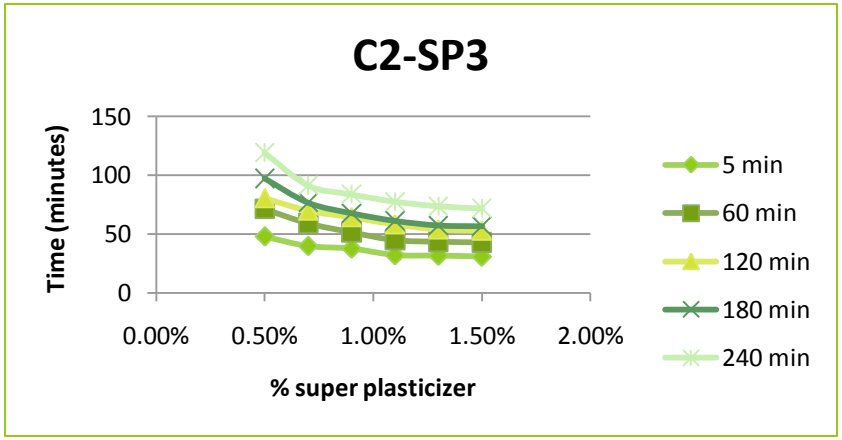
%age of plasticizer	SP7				
	5 min	60 min	120 min	180 min	240 min
0.5%	79.7	143.22	156.82	173.91	197.38
0.7%	51.29	123.77	141.37	162.28	179.87
0.9%	34.93	90.25	111.19	149.36	161.25
1.1%	29.41	81.79	92.24	128.64	153.94
1.3%	28.58	79.51	89.85	115.39	151.48
1.5%	26.65	77.12	87.34	114.73	148.96

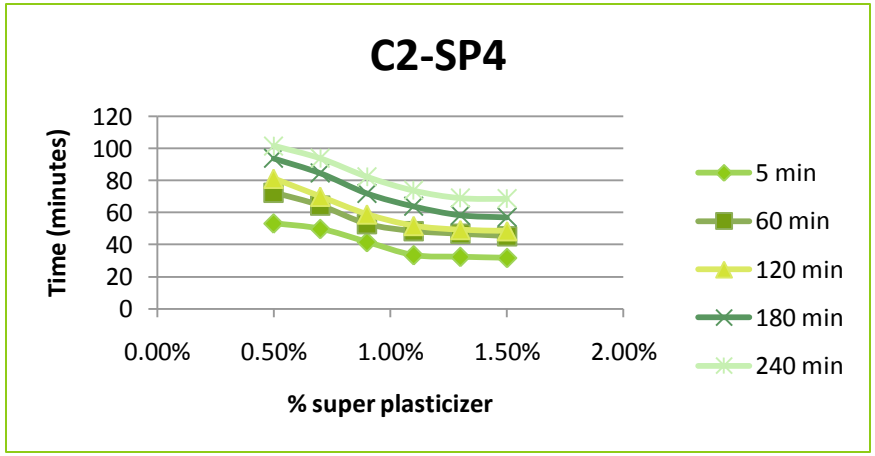
%age of plasticizer	SP8				
	5 min	60 min	120 min	180 min	240 min
0.5%	65.17	157.83	171.62	189.03	211.27
0.7%	52.97	132.66	162.94	170.58	199.05
0.9%	41.75	113.21	149.33	153.46	178.24
1.1%	39.68	110.14	137.49	142.17	159.79
1.3%	38.36	109.79	131.34	139.88	157.23
1.5%	37.09	107.38	129.52	138.37	156.77

Graphs And Result - C2

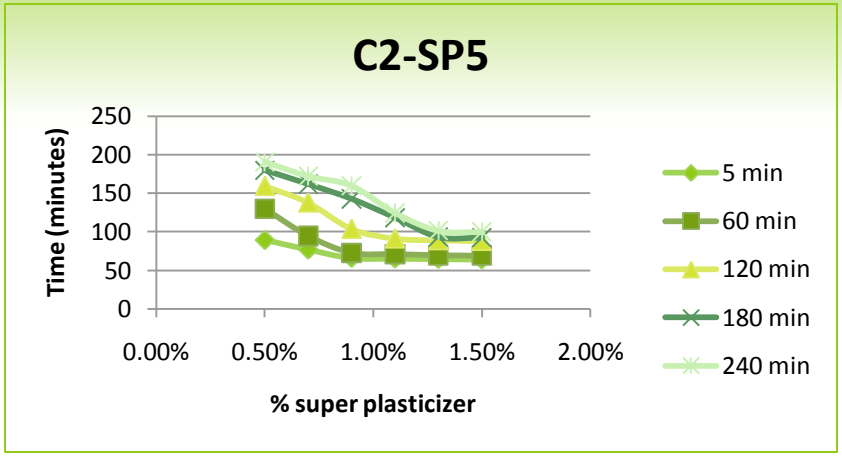


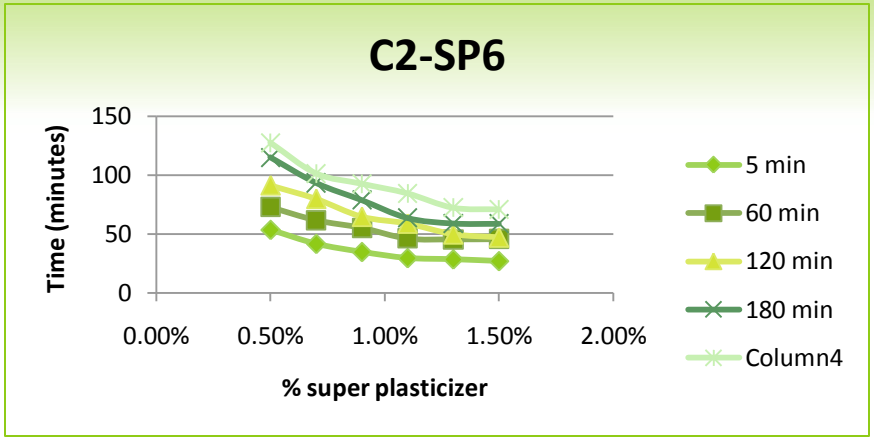


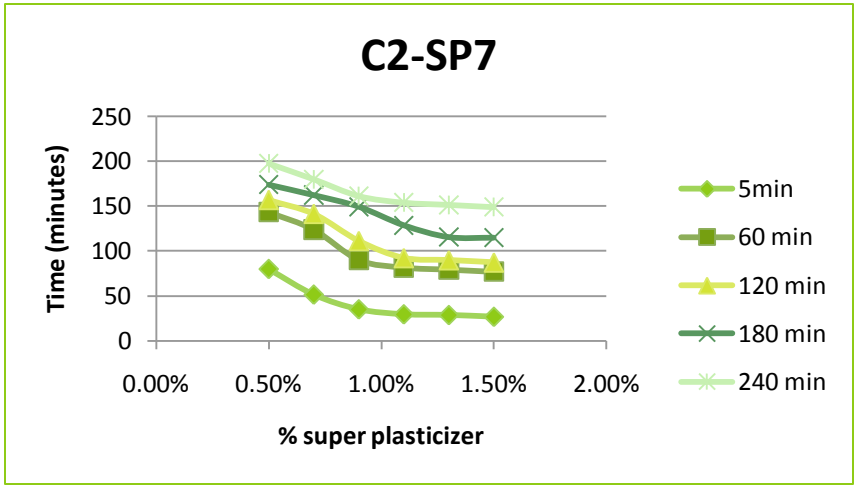


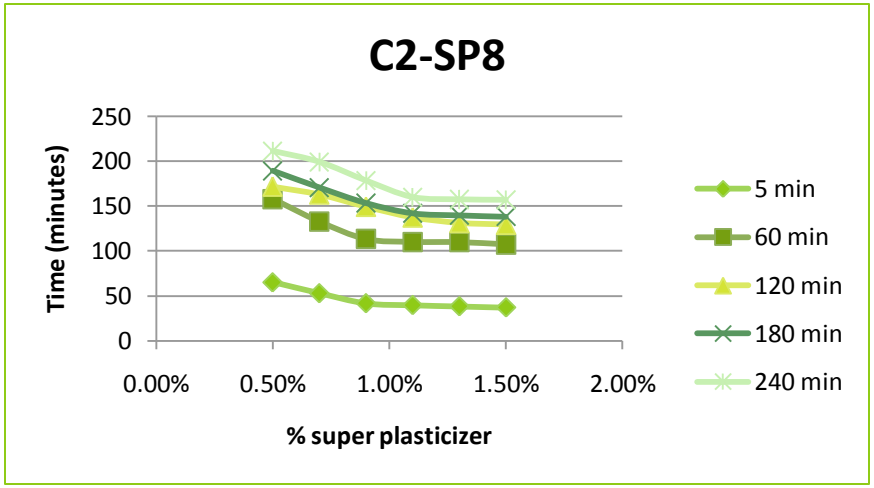


Graphs And Results - C2









Observations cement (C3), w/c =0.45

%age of plasticizer	SP1				
	5 min	60 min	120 min	180 min	240 min
0.5%	48.86	65.59	82.23	97.37	Sample set. No Flowability.
0.7%	40.08	55.93	71.94	83.88	
0.9%	33.27	45.94	54.86	67.62	
1.1%	31.42	43.67	51.79	56.29	
1.3%	31.36	41.16	49.04	53.51	
1.5%	31.48	40.27	47.47	51.06	

%age of plasticizer	SP2				
	5 min	60 min	120 min	180 min	240 min
0.5%	34.26	41.52	45.37	50.17	55.07
0.7%	29.47	33.63	36.92	41.56	49.82
0.9%	25.72	27.04	31.39	35.31	41.23
1.1%	24.66	25.23	28.21	31.85	36.44
1.3%	23.76	24.46	27.48	30.77	33.58
1.5%	23.41	23.81	26.69	29.68	32.23

%age of plasticizer	SP3				
	5 min	60 min	120 min	180 min	240 min
0.5%	35.63	40.73	44.41	49.38	53.03
0.7%	33.29	37.55	40.34	44.81	46.24
0.9%	31.4	33.17	37.72	40.48	43.47
1.1%	30.89	31.62	34.16	36.26	41.32
1.3%	30.13	30.97	33.77	35.31	40.41
1.5%	29.94	30.22	32.86	34.92	39.77

%age of plasticizer	SP4				
	5 min	60 min	120 min	180 min	240 min
0.5%	43.52	54.77	66.34	89.45	101.14
0.7%	39.68	49.6	60.56	72.73	91.62
0.9%	36.41	43.89	53.48	61.45	80.13
1.1%	33.6	40.23	43.79	51.09	68.52
1.3%	32.26	37.48	41.42	48.24	64.41
1.5%	31.91	37.03	40.84	47.75	62.88

Observations cement (c3), w/c =0.45

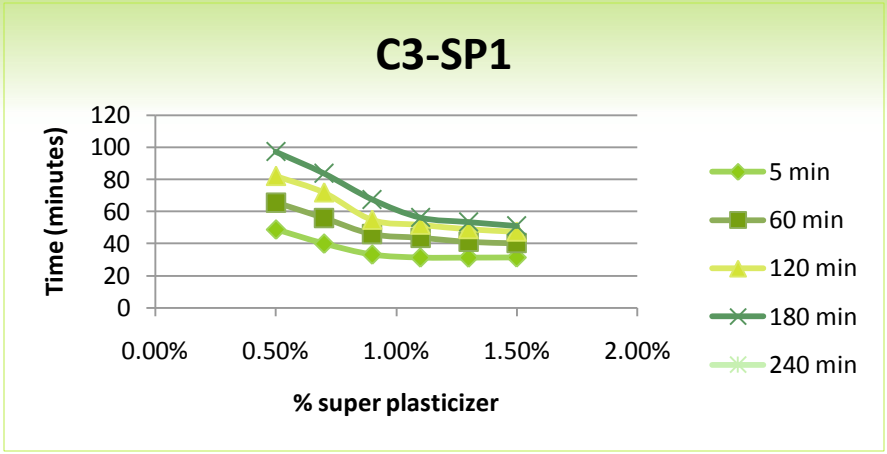
%age of plasticizer	SP5				
	5 min	60 min	120 min	180 min	240 min
0.5%	69.31	78.85	91.79	119.16	129.81
0.7%	57.78	63.46	82.51	106.74	119.02
0.9%	54.23	57.68	69.26	89.77	101.51
1.1%	51.69	54.39	64.58	78.46	85.61
1.3%	50.12	52.11	60.69	74.35	82.18
1.5%	49.79	51.87	61.53	73.27	79.46

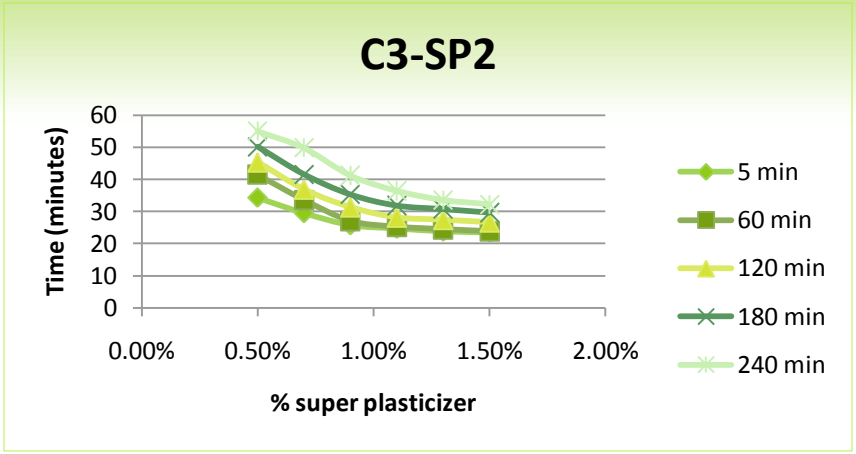
%age of plasticizer	SP6				
	5 min	60 min	120 min	180 min	240 min
0.5%	48.57	54.72	61.48	65.83	73.29
0.7%	41.62	49.41	57.39	60.74	67.55
0.9%	35.82	42.37	48.26	54.33	58.39
1.1%	34.95	40.52	46.65	51.29	55.56
1.3%	33.87	38.04	44.77	48.82	51.53
1.5%	33.17	37.64	43.48	47.68	50.24

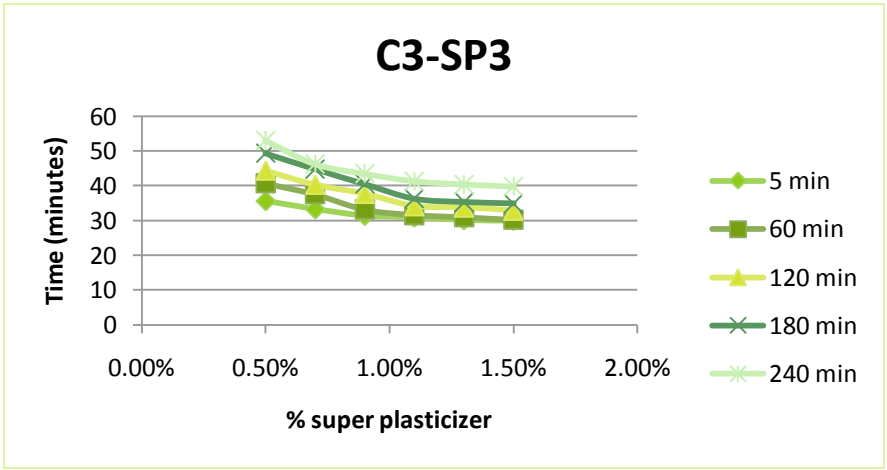
%age of plasticizer	SP7				
	5 min	60 min	120 min	180 min	240 min
0.5%	43.65	49.56	55.54	61.47	72.43
0.7%	38.69	45.44	50.35	54.62	63.67
0.9%	34.51	37.93	42.24	47.86	56.94
1.1%	30.5	33.36	36.63	40.18	48.23
1.3%	29.41	30.81	34.78	37.22	45.56
1.5%	28.98	31.08	33.53	36.47	43.74

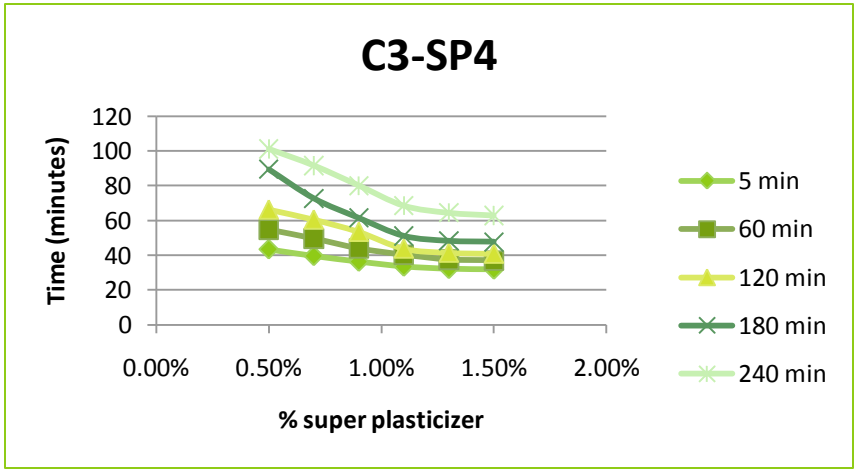
%age of plasticizer	SP8				
	5 min	60 min	120 min	180 min	240 min
0.5%	58.99	65.36	78.9	94.26	119.21
0.7%	54.12	59.39	70.49	86.73	107.18
0.9%	51.67	54.58	62.66	76.62	93.94
1.1%	50.18	52.57	58.81	70.03	89.88
1.3%	48.71	50.32	56.27	67.68	85.47
1.5%	47.94	49.76	55.16	65.46	84.28

Graphs And Result - C3

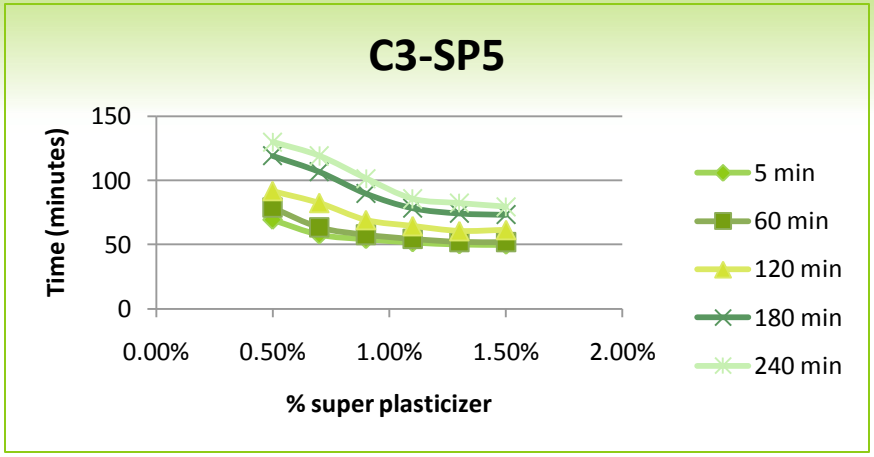


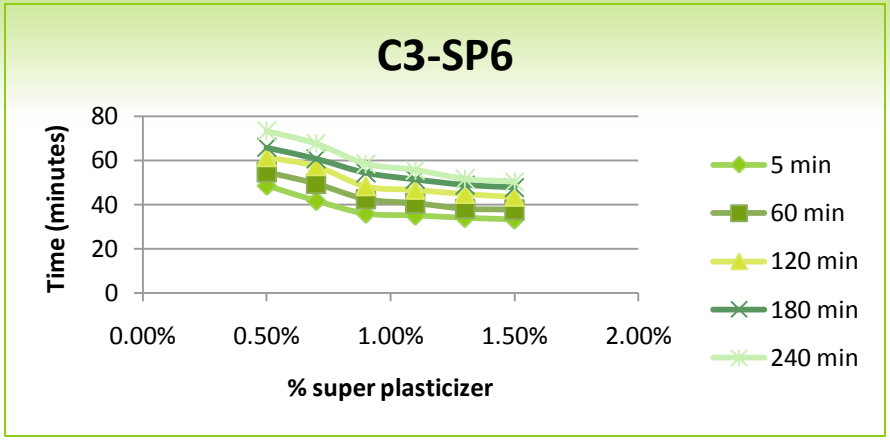


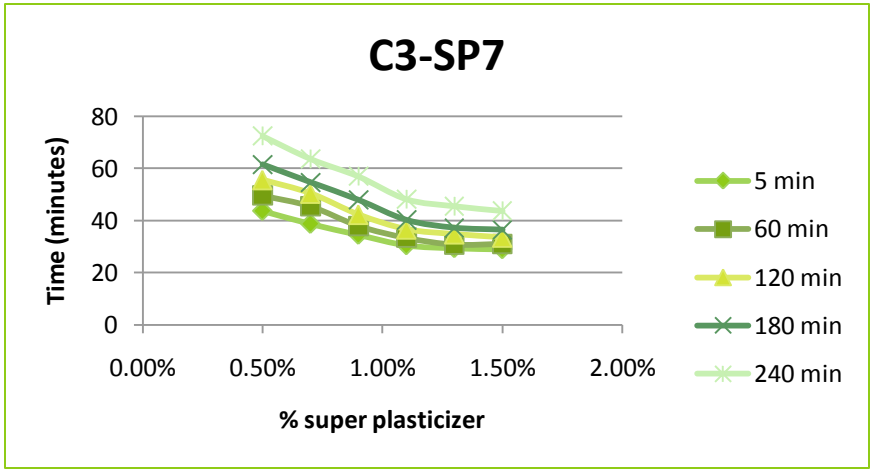


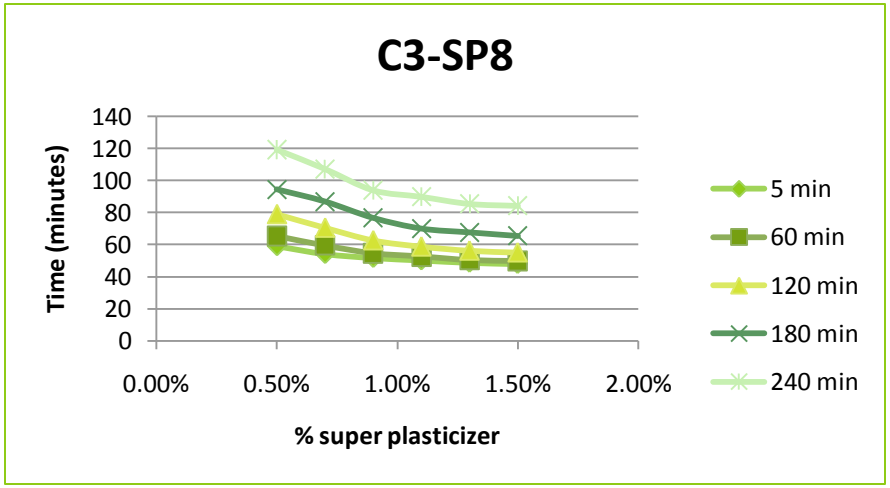


Graphs And Result - C3









Development Of Equations

1. Determine the optimum dose of each super plasticizer of particular chemical family at different flow time for particular cement.

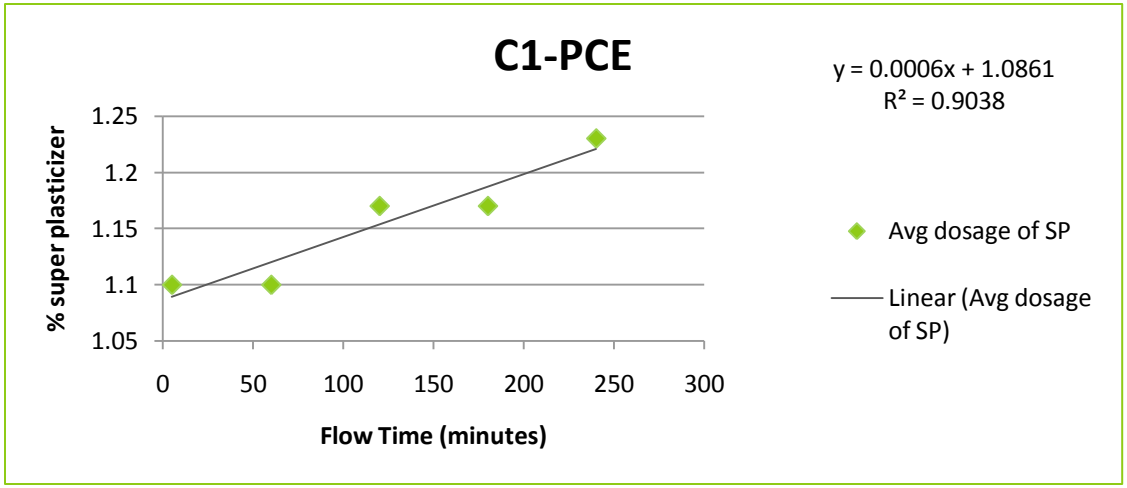
2. Take the average of optimum dose of super plasticizer.

Example :- *Chemical Family* - Poly Carboxylate Ether (PCE)[SP1, SP2, SP3]
Cement C1 , w/c = 0.45

Time in Minutes	Optimum Dose of super-plasticizer in % (PCE Family)			Average
	SP1	SP2	SP3	
5 min	0.9	1.1	1.3	1.1
60 min	0.9	1.1	1.3	1.1
120 min	1.1	1.3	1.1	1.17
180 min	1.1	1.3	1.1	1.17
240 min	1.1	1.3	1.3	1.23

Development Of Equations

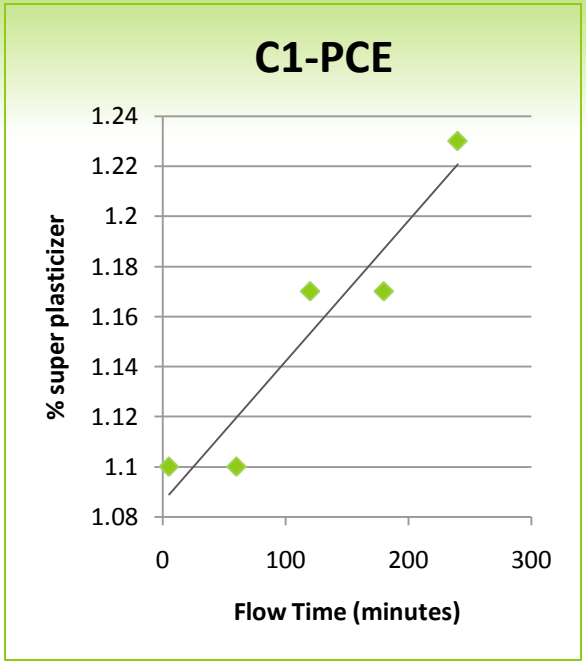
3. Plot the graph between average of optimum dose and flow time using the plot trend line feature of excel and determine the equation for trend line.

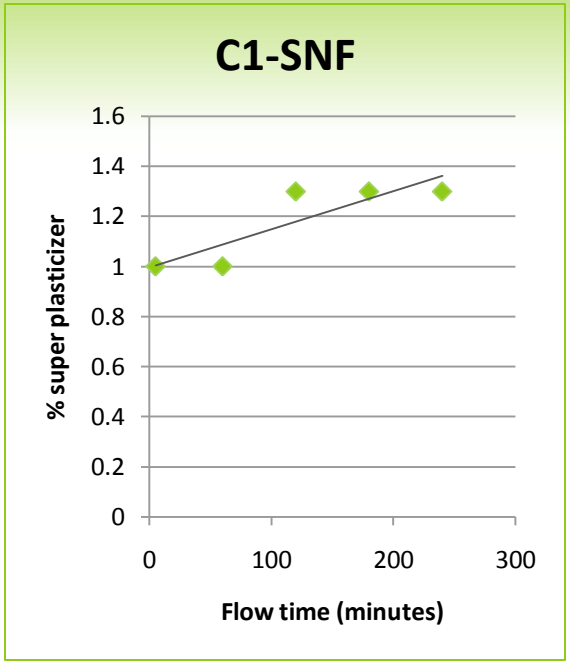


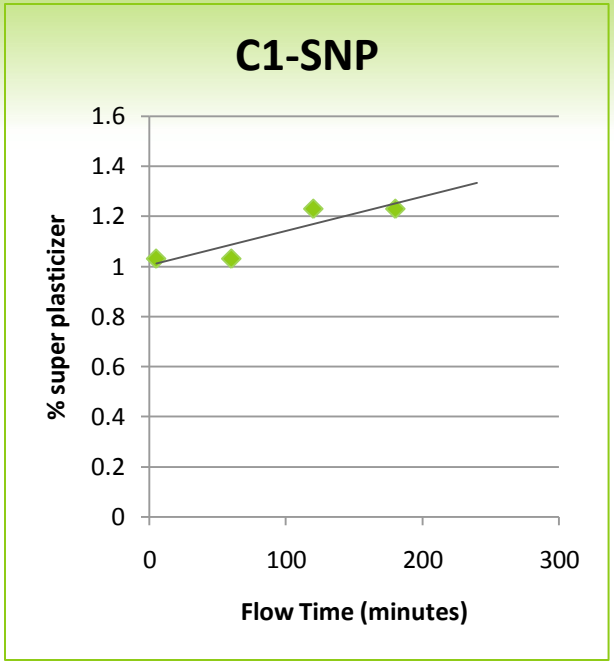
y = 0.0006x + 1.0861

Time in minutes	Optimum Dose of super-plasticizer in %			Average
	SP1	SP2	SP3	
5 min	0.9	1.1	1.3	1.1
60 min	0.9	1.1	1.3	1.1
120 min	1.1	1.3	1.1	1.17
180 min	1.1	1.3	1.1	1.17
240 min	1.1	1.3	1.3	1.23

Equations for C1, w/c = 0.45





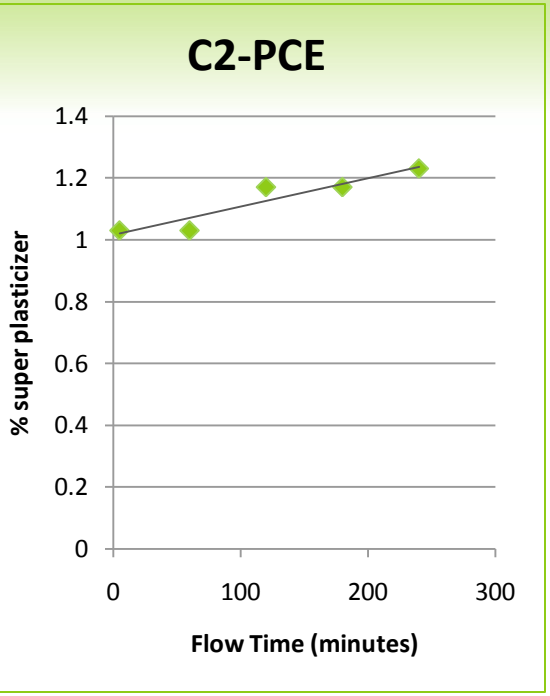


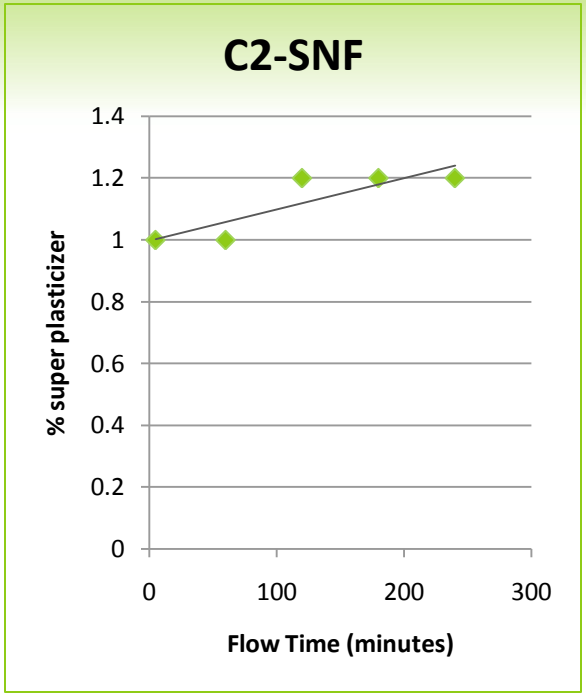
y = 0.0006x + 1.0861

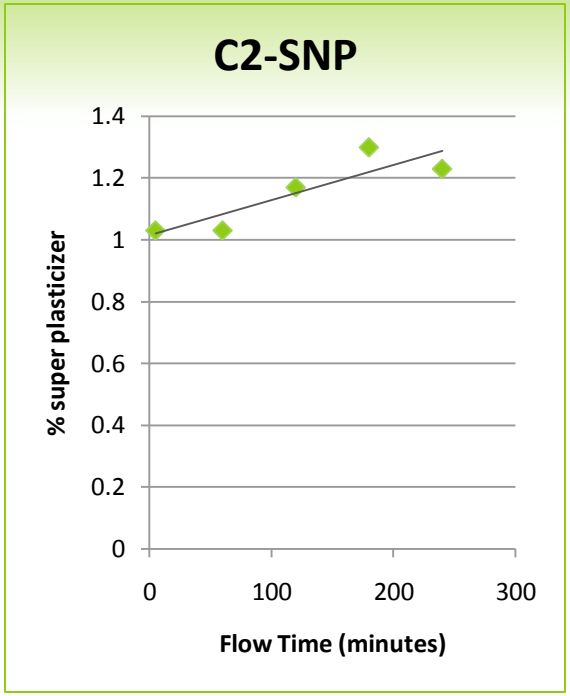
y = 0.0015x + 0.9955

y = 0.0014x + 1.0047

Equations for C2, w/c = 0.45





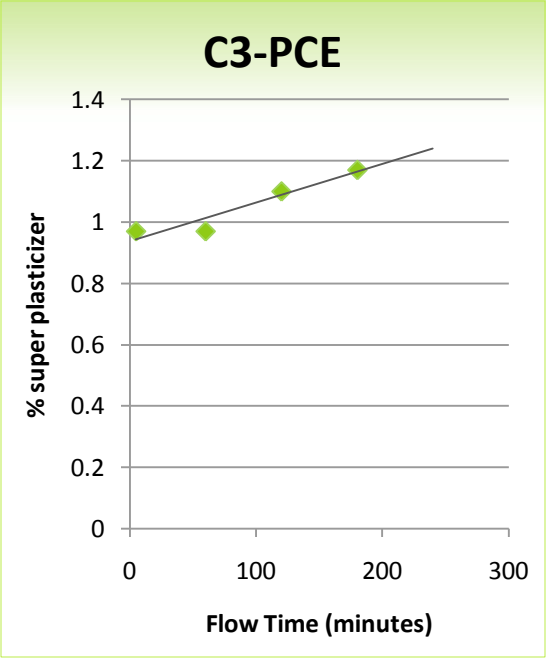


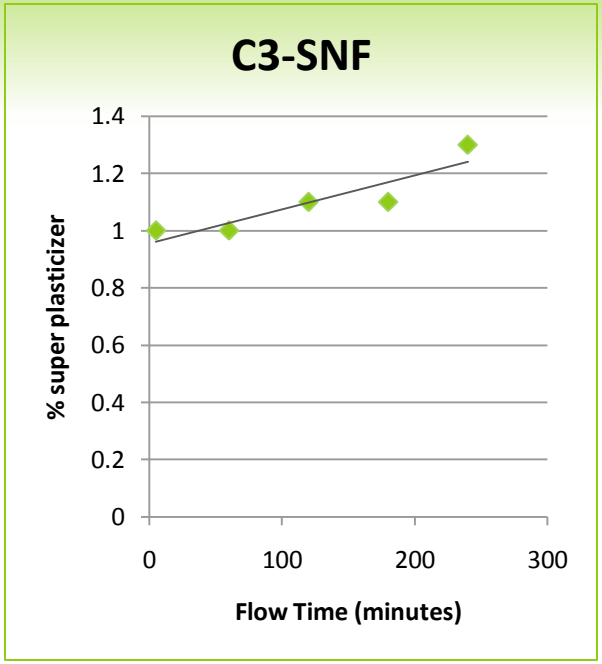
y = 0.0009x + 1.0151

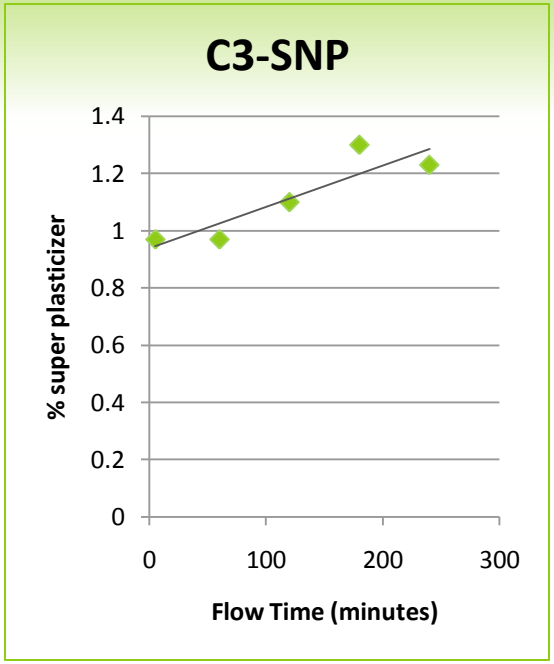
y = 0.001x + 0.997

y = 0.0011x + 1.0144

Equations for C3, w/c = 0.45





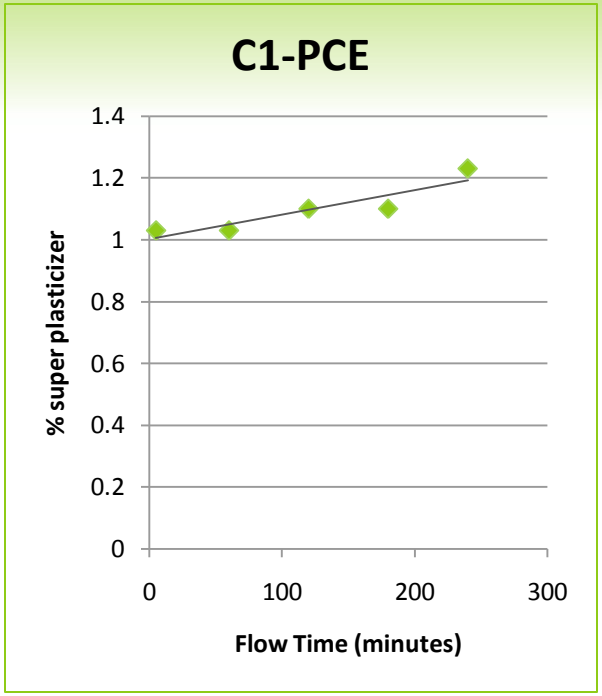


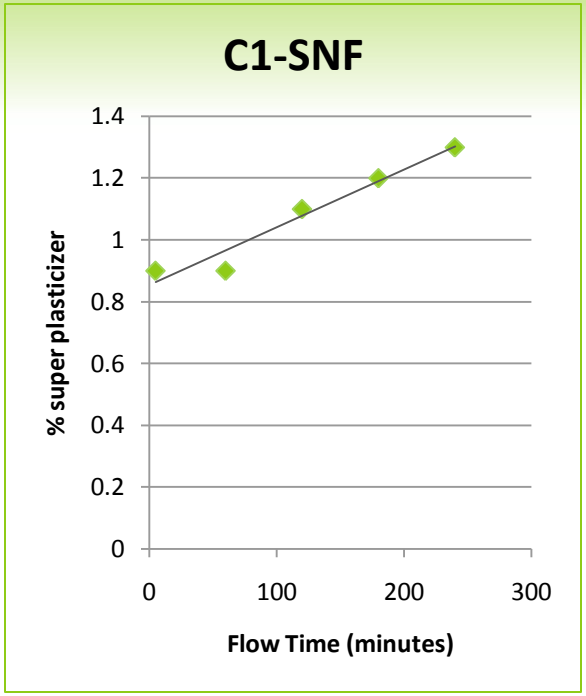
$y = 0.0013x + 0.868$

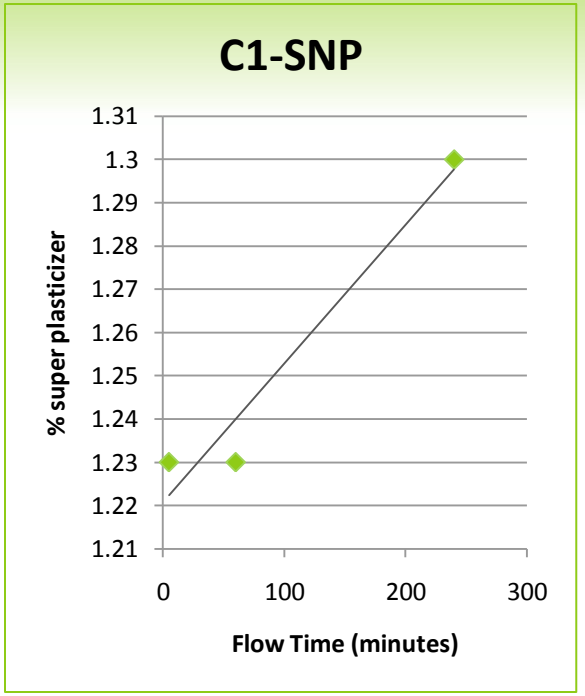
$y = 0.0012x + .9958$

$y = 0.0014x + 0.9393$

EQUATIONS FOR C1, w/c = 0.5





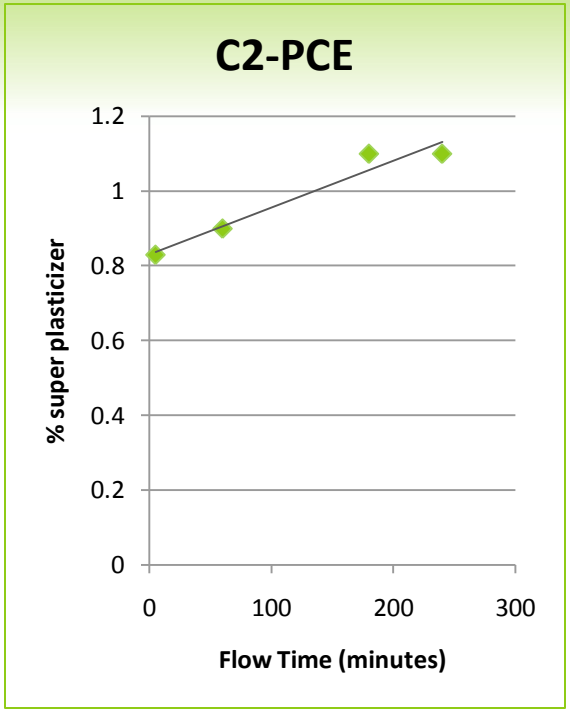


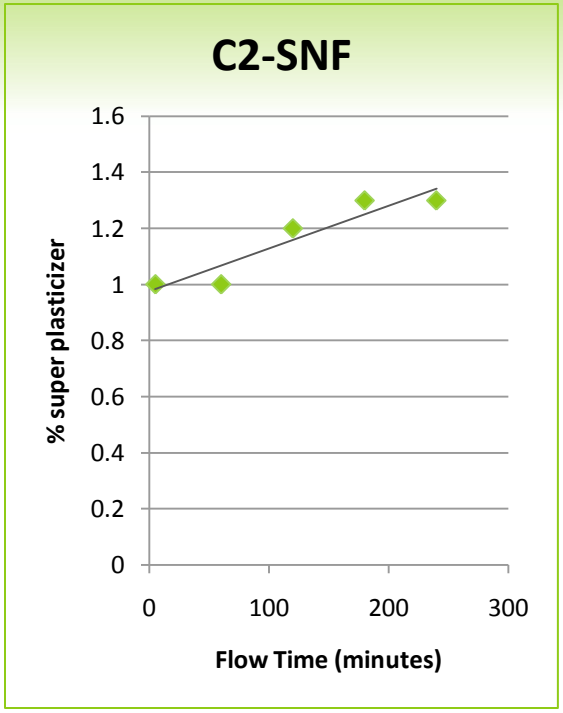
$y = 0.0008x + 1.0012$

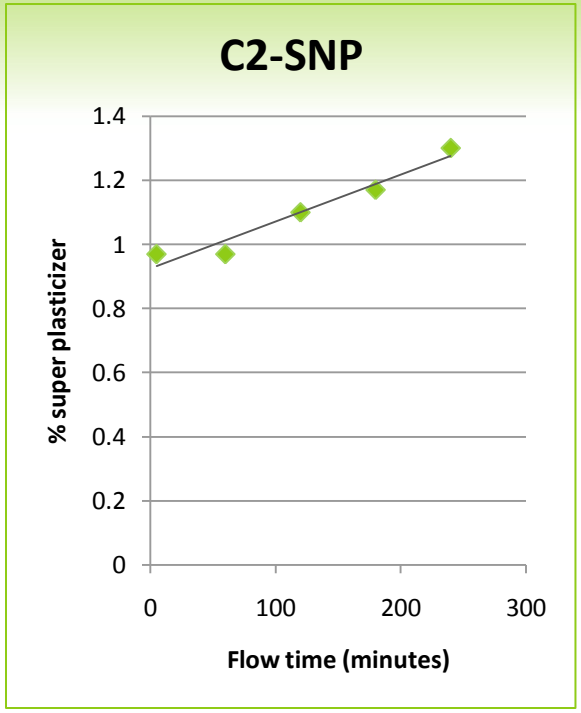
$y = 0.0019x + 0.8538$

$y = 0.0003x + 1.2208$

EQUATIONS FOR C2, w/c = 0.5





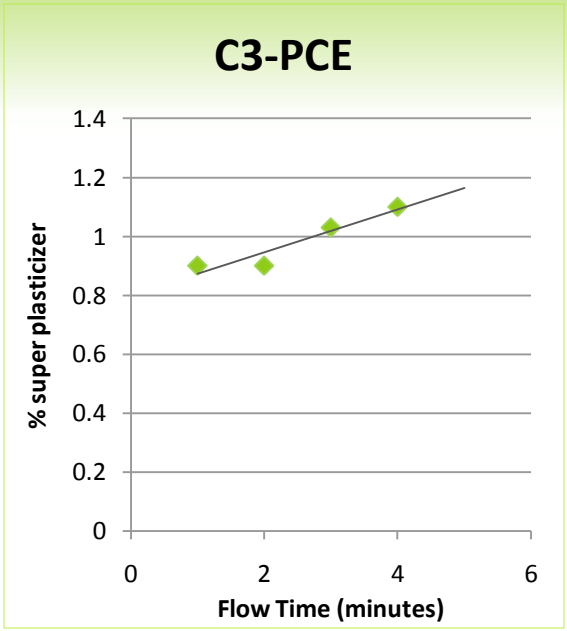


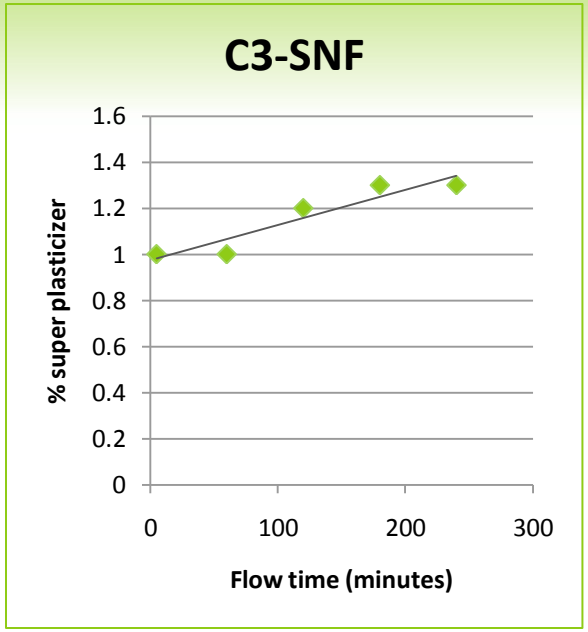
y = 0.0013x + 0.8305

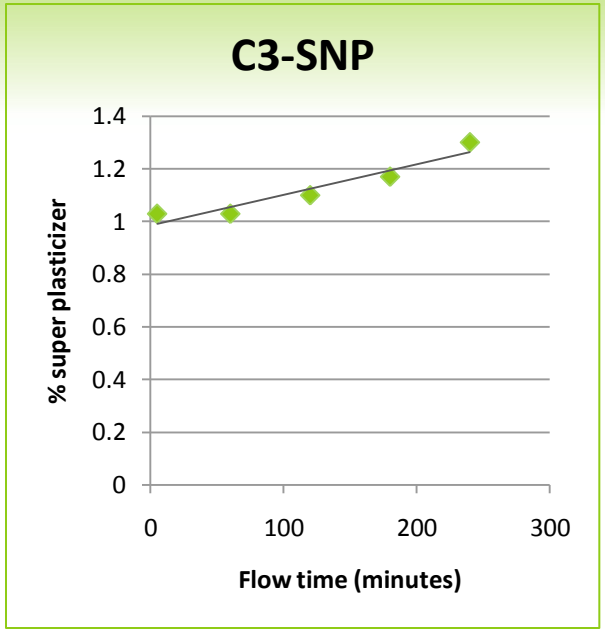
y = 0.0015x + 0.9751

y = 0.0015x + 0.925

EQUATIONS FOR C3, w/c = 0.5







$y = 0.0013x + 0.938$

$y = 0.0015x + 0.9751$

$y = 0.0012x + 0.9859$

Summary of table of constants

Determined Compatibility equations are in the Linear form
i.e. **ax+b**

Upcoming table is concluded on the basis of previous equations and thus helpful for the users to determine the equations for suitable C-SP couple.

- Column (1) of table shows the w/c ratio,
- Column (2) represents Cement- Super-plasticizer combination,
- Column (3) and (4) shows the value of constants ‘a’ and ‘b’, respectively.

Summary of table of constants

Equation :-

y = ax+b

'y'= Optimum dose of Super-plasticizer

'x'= Time in minutes

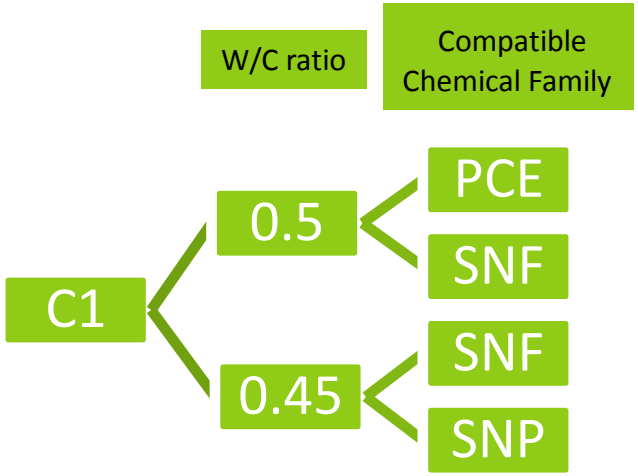
Example :
C1-PCE ,
w/c = 0.45.
a=0.0006
b=1.0861

Equation :
y = .0006x+1.0861

W/C ratio	Cement - Super-plasticizer couple	a	b
0.45	C1-PCE	0.0006	1.0861
0.45	C1-SNF	0.0015	0.9955
0.45	C1-SNP	0.0014	1.0047
0.45	C2-PCE	0.0009	1.0151
0.45	C2-SNF	0.001	0.997
0.45	C2-SNP	0.0011	1.0144
0.45	C3-PCE	0.0013	0.868
0.45	C3-SNF	0.0012	0.9558
0.45	C3-SNP	0.0014	0.9393
0.50	C1-PCE	0.0008	1.0012
0.50	C1-SNF	0.0019	0.8538
0.50	C1-SNP	0.0003	1.2208
0.50	C2-PCE	0.0013	0.8305
0.50	C2-SNF	0.0015	0.9751
0.50	C2-SNP	0.0015	0.925
0.50	C3-PCE	0.0013	0.938
0.50	C3-SNF	0.0015	0.9751
0.50	C3-SNP	0.0012	0.9859

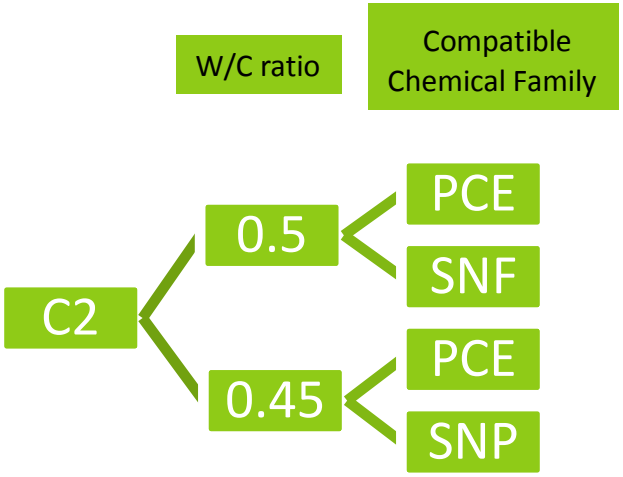
Conclusion

- For the cement C1 (w/c=0.5), SP1, SP4 and SP8 are most compatible combination among all the combinations. Super-plasticizer with chemical base PCE (SP1) and SNF (SP4 and SP8) is most compatible as compared to super-plasticizer with SNP base.
- For the cement C1 (w/c=0.45), SP4 and SP7 are most compatible combination among all the combinations+. Super-plasticizer with chemical base SNF (SP4) and SNP (SP7) is most compatible as compared to super-plasticizer with PCE base.



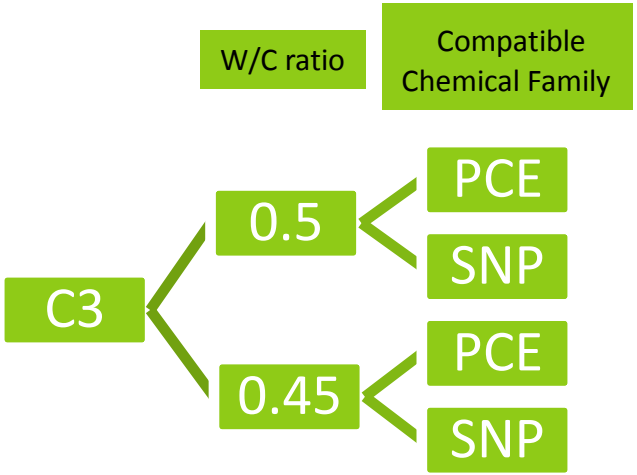
Conclusion

- For the cement C2 (w/c=0.5), SP2 and SP8 are most compatible combination among all the combinations. Super-plasticizer with chemical base PCE (SP2) and SNF (SP8) is most compatible as compared to super-plasticizer with SNP base.
- For the cement C2 (w/c=0.45), SP1 and SP5 are most compatible combination among all the combinations. Super-plasticizer with chemical base PCE (SP1) and SNP (SP5) is most compatible as compared to super-plasticizer with SNF base.



Conclusion

- For the cement C3 (w/c=0.5), SP2, SP3 and SP5 are most compatible combination among all the combinations. Super-plasticizer with chemical base PCE (SP2 and SP3) and SNP (SP5) is most compatible as compared to super-plasticizer with SNF base.
- For the cement C3 (w/c=0.45), SP2, SP3 and SP7 are most compatible combination among all the combinations. Super-plasticizer with chemical base PCE (SP2 and SP3) and SNP (SP7) is most compatible as compared to super-plasticizer with SNF base.



Conclusion contd….

- The method and calculations for fabrication of Marsh Cone test apparatus may be used for future experimental work.
- The saturation dosages have been determined experimentally which has been used for various combinations of cement and super-plasticizer to establish mathematical equation for practical use in field.

Scope for future work

- This study can also be performed on different types of cement and brands with various chemical family and brands of super-plasticizers available in the market to establish the compatibility between them, also for different water-cement ratio.
- Consequently, equations for finding saturation dosage can also be derived.

THANK YOU FOR ATTENTION