Effect of dosage of super plasticiser and water cement ratio on workability and compressive strength of reactive powder concrete

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***Abstract*-Reactive Powder Concrete (RPC) which is a new type of improved high strength concrete is a recent development in concrete technology. Because the material is intrinsically strong in compression, the stress-strain behaviour of RPC under compression is of considerable interest in the design of RPC members and accurate prediction of their structural behaviour. However, only a few studies have been undertaken on the workability and compressive strength of RPC and therefore not much published information is available. An attempt has been made in the present experimental study to determine the Effect of dosage of super plasticizer and water cement ratio on workability and compressive strength of high performance concrete. In the absence of standard mix design procedure, on the basis of data obtained from previous experimental study, specific mix proportions has been evaluated and total 42 number of mix proportion were decided and 4 specimens for each proportion were casted and tested under the action of uniaxial compression. 168 specimens were tested using a compression testing machine and workability is determined by slump cone and flow table test.**

Keywords: RPC, Compression, Workability, Super plasticizer.

I INTRODUCTION

Concrete is a widely used construction material dominating the construction industry worldwide. The use of cementitious material can be traced back thousands of years ago to Italy, Greece, ancient Egypt and the Middle East.According to Glasser world production of concrete exceeds currently 1billions tonnes per annum. Although high-strength concrete is often considered a relatively new material its development has been gradual over many years. High strength concrete is an important member of the concrete family; its first use in significant quantities in major structures was in the early 1960s in Chicago, USA. As the development has continued, the definition of high-strength concrete has changed. The concrete that was once known as high-strength concrete in the late 1970s is now referred to as high-performance concrete because it has been found to be much more than simply stronger; it displays enhanced performance in such areas as durability and abrasion resistance. High-performance concrete can be defined as an engineered concrete in which one or more specific characteristics have been enhanced through the selection and proportioning of its constituents. Densified with small particles concrete (DSP) and reactive powder concrete (RPC) have been marketed as high performance concretes in various countries. This new family of materials has compressive strengths of (170MPa to 230 MPa) and flexural strengths of (30MPa to 50 MPa).

Since the intrinsic strength of concrete is its ability to resist compressive loads, reinforced concrete members are designed to take advantage of this intrinsic strength. Therefore, the knowledge of the behaviour of concrete in compression is very important. RPC is a recent development in concrete technology. Therefore, the behaviour of RPC under compression is of considerable interest in the design of RPC members and prediction of their structural behaviour. However, only a few studies have been undertaken on the rheological and strength properties of RPC.

II Material Specification

The following materials are used for RPC and their properties and specification are described below.

a. Cement
b. Quartz Sand
c. Silica Fume
d. Super Plasticizer

2.1 Cement

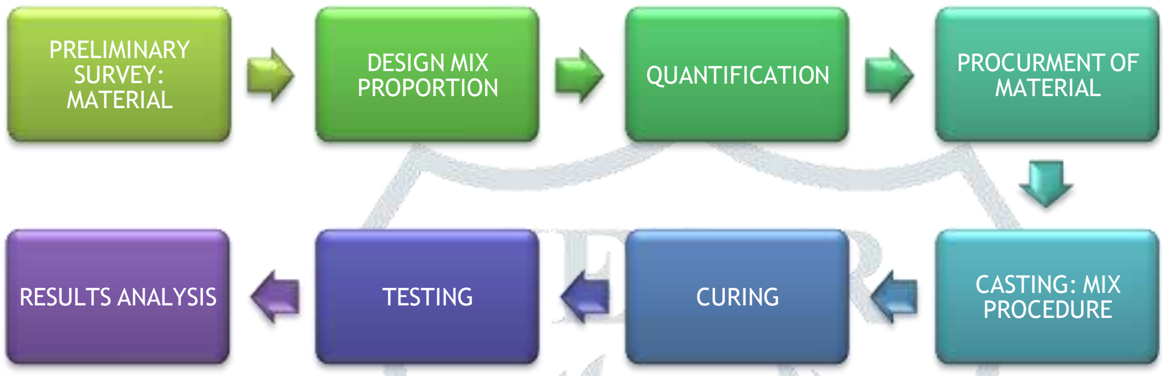
Ordinary Portland Cement of 53 grades was used for the experimental work which was locally available with brand name "BIRLA SUPER SHAKTI" Cement.

2.2 Quartz Sand:
The quartz sand was procured from "Welcome Chemical Pvt. Ltd." and the sizes of the particles of sand are ranging from 200 µm to 500 µm.

2.3 Silica Fume:
Silica fume for the project was procured from "Oriental TechximPvt.ltd." with the brand name "ORISIL Micro silica/Silica Fumes Grade 90 D".

2.4 Super Plasticizer:
The super plasticizer used in our program was Auramix-400 manufacture by Fosroc Chemicals Pvt. Ltd.

III EXPERIMENTAL PROGRAM



3.1 Design mix proportion

In this program we have kept the quartz sand cement ratio as 1.5 and the silica fume cement ratio is varied from 0.15 to 0.3.The value of water cement ratio is varied from 0.2 to 0.35. The dosage of super plasticizer depends upon the water cement ratio and dosage of other constituents. Different mix proportions used in this project are as tabulated below:-

Table 1 Design Mix Proportions

Designation	w/c ratio*	SF/C ratio**	QS/C ratio#	Super plasticizer Dosage ml
A1	0.25	0.15	1.5	6
A2	0.25	0.15	1.5	7
A3	0.25	0.15	1.5	8
A4	0.25	0.15	1.5	9
B1	0.3	0.15	1.5	7
B2	0.3	0.15	1.5	5
B3	0.3	0.15	1.5	4
B4	0.3	0.15	1.5	3
C1	0.2	0.15	1.5	15
C2	0.2	0.15	1.5	12
C3	0.2	0.15	1.5	9
D1	0.35	0.15	1.5	4
D2	0.35	0.15	1.5	5

D3	0.35	0.15	1.5	5.5
E1	0.25	0.2	1.5	7
E2	0.25	0.2	1.5	8
E3	0.25	0.2	1.5	10
F1	0.3	0.2	1.5	7
F2	0.3	0.2	1.5	6
F3	0.3	0.2	1.5	5
G1	0.35	0.2	1.5	8
G2	0.35	0.2	1.5	9
G3	0.35	0.2	1.5	10
H1	0.25	0.25	1.5	10
H2	0.25	0.25	1.5	15
H3	0.25	0.25	1.5	20
I1	0.3	0.25	1.5	8
I2	0.3	0.25	1.5	12
I3	0.3	0.25	1.5	15
J1	0.35	0.25	1.5	12
J2	0.35	0.25	1.5	10
J3	0.35	0.25	1.5	8
K1	0.25	0.3	1.5	14
K2	0.25	0.3	1.5	18
K3	0.25	0.3	1.5	20
L1	0.3	0.3	1.5	14
L2	0.3	0.3	1.5	12
L3	0.3	0.3	1.5	10

M1	0.35	0.3	1.5	14
M2	0.35	0.3	1.5	12
M3	0.35	0.3	1.5	10

Note:-

* W/C Ratio= Water Cement Ratio

**SF/C Ratio= Silica Fume Cement Ratio

#QS/C Ratio= Quartz Sand Cement Ratio

3.2 Specimen Preparation and Curing

The concrete specimens were prepared in the concrete laboratory of Department of Civil Engineering, Sinhgad College of Engineering Pune. Procedure adopted for preparing specimens is as given below.

1. Prepare test sample according to mix proportion adopted as stated in table 1.
2. The cubes are cast as specified by the IS Code.
3. In all 42 combinations of design mix were used and 4 cubes were cast on an average for each design mix proportion.
4. The size of the mould used was 70.7 X 70.7 X 70.7 mm.

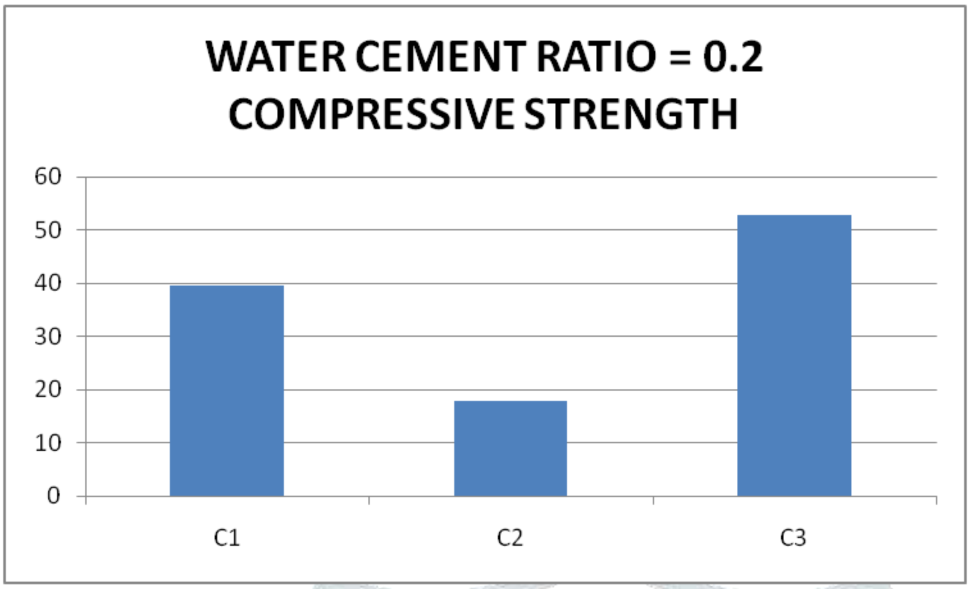
IV RESULTS AND DISCUSSIONS

The results are analysed after sorting all the results according to water cement ratio.

Table 2 Tabulated Results keeping W/C Ratio=0.2 and QS/C Ratio=1.5

Name	SF/C Ratio	Super-plasticizer Dosage	Slump	Flow Dia.	Load	Compressive Strength	Average
		ml	mm	mm	kN	MPa	MPa
C1	0.15	9	NR	NR	250	50	39.5
C1	0.15	9	NR	NR	180	36	
C1	0.15	9	NR	NR	210	42	
C1	0.15	9	NR	NR	150	30	
C2	0.15	12	NR	NR	90	18	17.75
C2	0.15	12	NR	NR	85	17	
C2	0.15	12	NR	NR	100	20	
C2	0.15	12	NR	NR	80	16	
C3	0.15	15	NR	NR	300	60	52.75
C3	0.15	15	NR	NR	235	47	
C3	0.15	15	NR	NR	270	54	
C3	0.15	15	NR	NR	250	50	

In the experimental program carried out the effect of water cement ratio and dosage of super plasticizer was taken initially as 0.2 and 9 ml respectively. For this no slump or flow was observed, also the specimen for compression testing could not be prepared properly. So the dosage of super plasticizer was increased to 12 ml with no values of slump and flow. The dosage was further increased to 15 ml without any success in the result. This test was carried out for silica fume cement ratio of 0.15 and increase in silica fume cement ratio would definitely not improve the workability condition unless higher dose of super plasticizer (>15 ml) is adopted and this would prove uneconomical. Hence, for water cement ratio 0.2 further tests were not carried out. Graph 1 for reference is given below.



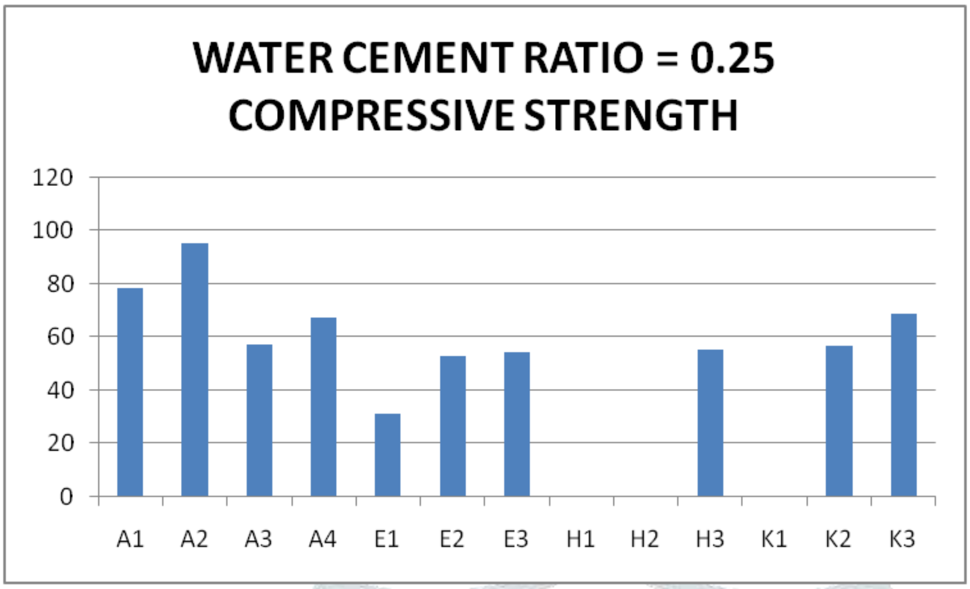
Graph 1 Compressive strength for W/C ratio 0.2

Table 3 Tabulated Results keeping W/C Ratio=0.25 and QS/C Ratio=1.5

Name	SF/C Ratio	Super-plasticizer Dosage	Slump	Flow Dia.	Load	Compressive Strength	Average
		ml	mm	mm	kN	MPa	MPa
A1	0.15	6	5	235	445	89	78.5
A1	0.15	6	5	235	375	75	
A1	0.15	6	5	235	430	86	
A1	0.15	6	5	235	320	64	
A2	0.15	7	20	285	525	105	95.5
A2	0.15	7	20	285	460	92	
A2	0.15	7	20	285	470	94	
A2	0.15	7	20	285	455	91	
A3	0.15	8	50	300	335	67	57.5
A3	0.15	8	50	300	240	48	
A3	0.15	8	50	300	315	63	
A3	0.15	8	50	300	260	52	
A4	0.15	9	30	310	340	68	67.5
A4	0.15	9	30	310	325	65	
A4	0.15	9	30	310	355	71	
A4	0.15	9	30	310	330	66	
E1	0.2	7	15	225	185	37	31.25
E1	0.2	7	15	225	160	32	
E1	0.2	7	15	225	130	26	
E1	0.2	7	15	225	150	30	

E2	0.2	8	20	245	290	58	53.25
E2	0.2	8	20	245	230	46	
E2	0.2	8	20	245	290	58	
E2	0.2	8	20	245	265	53	
E3	0.2	10	45	320	300	60	54.5
E3	0.2	10	45	320	290	58	
E3	0.2	10	45	320	270	54	
E3	0.2	10	45	320	230	46	
H1	0.25	10	NR	NR	NR	-	-
H1	0.25	10	NR	NR	NR	-	
H1	0.25	10	NR	NR	NR	-	
H1	0.25	10	NR	NR	NR	-	
H2	0.25	15	NR	NR	NR	-	-
H2	0.25	15	NR	NR	NR	-	
H2	0.25	15	NR	NR	NR	-	
H2	0.25	15	NR	NR	NR	-	
H3	0.25	20	65	320	265	53	55.33
H3	0.25	20	65	320	295	59	
H3	0.25	20	65	320	NR	NR	
H3	0.25	20	65	320	270	54	
K1	0.3	14	NR	NR	NR	-	-
K1	0.3	14	NR	NR	NR	-	
K1	0.3	14	NR	NR	NR	-	
K1	0.3	14	NR	NR	NR	-	
K2	0.3	18	NR	260	265	53	56.75
K2	0.3	18	NR	260	340	68	
K2	0.3	18	NR	260	290	58	
K2	0.3	18	NR	260	240	48	
K3	0.3	20	50	290	375	75	68.75
K3	0.3	20	50	290	380	76	
K3	0.3	20	50	290	330	66	
K3	0.3	20	50	290	290	58	

In this table we have taken the water cement ratio as 0.25 and quartz sand cement ratio as 1.5. The values of silica fume cement ratio are varied from 0.15 to 0.3. Here from the readings we could decipher that the value of compressive strength increases with the increase in workability of the concrete. Here we could also see that with the increase in the silica fume proportion the super plasticizer requirement increases, thus we could not get readings for K1. On further increase in super plasticizer dosage we could get the values for workability and compressive strength. Graph 2 for reference is given below.



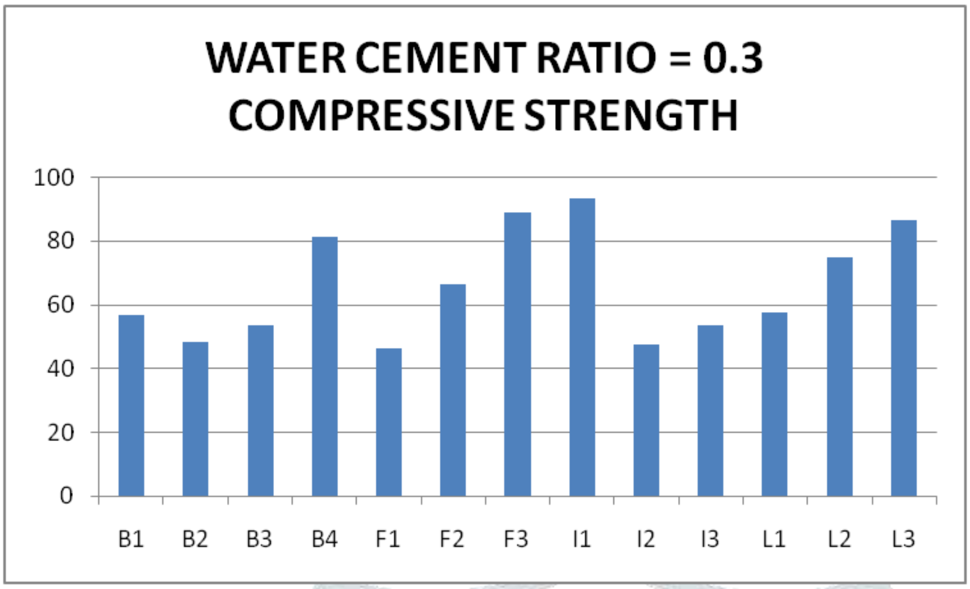
Graph 2 Compressive strength for W/C ratio 0.25

Table 4 Tabulated Results keeping W/C Ratio=0.3 and QS/C Ratio=1.5

Name	SF/C Ratio	Super-plasticizer Dosage	Slump	Flow Dia.	Load	Compressive Strength	Average
		ml	mm	mm	kN	MPa	MPa
B1	0.15	7	Collapse	420	285	57	
B1	0.15	7	Collapse	420	245	49	56.5
B1	0.15	7	Collapse	420	340	68	
B1	0.15	7	Collapse	420	260	52	
B2	0.15	5	60	340	270	54	48.25
B2	0.15	5	60	340	225	45	
B2	0.15	5	60	340	230	46	
B2	0.15	5	60	340	240	48	
B3	0.15	4	55	300	275	55	53.25
B3	0.15	4	55	300	260	52	
B3	0.15	4	55	300	250	50	
B3	0.15	4	55	300	280	56	
B4	0.15	3	15	255	390	78	81.25
B4	0.15	3	15	255	400	80	
B4	0.15	3	15	255	420	84	
B4	0.15	3	15	255	415	83	
F1	0.2	7	Collapse	395	260	52	46.25
F1	0.2	7	Collapse	395	250	50	
F1	0.2	7	Collapse	395	245	49	
F1	0.2	7	Collapse	395	170	34	

F2	0.2	6	20	325	295	59	66.25
F2	0.2	6	20	325	350	70	
F2	0.2	6	20	325	300	60	
F2	0.2	6	20	325	380	76	
F3	0.2	5	NR	275	410	82	88.75
F3	0.2	5	NR	275	445	89	
F3	0.2	5	NR	275	545	109	
F3	0.2	5	NR	275	375	75	
I1	0.25	8	NR	NR	451	90.2	93.05
I1	0.25	8	NR	NR	472	94.4	
I1	0.25	8	NR	NR	473	94.6	
I1	0.25	8	NR	NR	465	93	
I2	0.25	12	10	280	225	45	47.5
I2	0.25	12	10	280	205	41	
I2	0.25	12	10	280	240	48	
I2	0.25	12	10	280	280	56	
I3	0.25	15	25	295	260	52	53.5
I3	0.25	15	25	295	275	55	
I3	0.25	15	25	295	295	59	
I3	0.25	15	25	295	240	48	
L1	0.3	14	Collapse	365	240	48	57.5
L1	0.3	14	Collapse	365	325	65	
L1	0.3	14	Collapse	365	310	62	
L1	0.3	14	Collapse	365	275	55	
L2	0.3	12	40	320	350	70	74.5
L2	0.3	12	40	320	385	77	
L2	0.3	12	40	320	385	77	
L2	0.3	12	40	320	370	74	
L3	0.3	10	10	295	425	85	86.5
L3	0.3	10	10	295	395	79	
L3	0.3	10	10	295	470	94	
L3	0.3	10	10	295	440	88	

In this table we have kept the water cement ratio constant as 0.3 and quartz sand cement ratio as 1.5. The dosage of silica fume is varied from 0.15 to 0.3. Here we could make an interesting observation that the compressive strength value increases as the slump value decreases. This is due to silica fume which has a binding property which leads to dense packing of the concrete. Here we also found that the most efficient mix for RPC is 0.3 water cement ratio, 0.25 silica fume cement ratio, keeping quartz sand cement ratio to a constant of 1.5. This gave us a compressive strength of about 93 MPa. Thus I1 is the most efficient mix. In the readings from L1 to L3 we could see that we got a reading around 95 MPa if the dosage of super plasticizer would have been reduced to 8 ml. Here we could note that an increase in the super plasticizer dosage would lead to a decrease in compressive strength. Graph 3 for reference is given below.

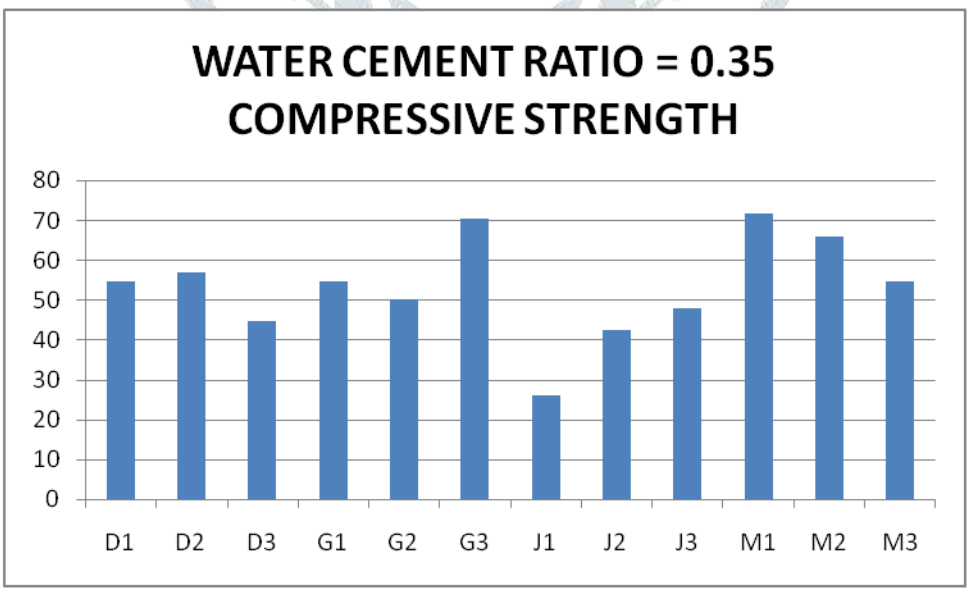


Graph 3 Compressive strength for W/C ratio 0.3

Table 5 Tabulated Results keeping W/C Ratio=0.35 and QS/C Ratio=1.5

Name	SF/C Ratio	Super-plasticizer Dosage	Slump	Flow Dia.	Load	Compressive Strength	Average
		ml	mm	mm	kN	MPa	MPa
D1	0.15	5	90	410	255	51	
D1	0.15	5	90	410	260	52	
D1	0.15	5	90	410	325	65	
D1	0.15	5	90	410	250	50	54.5
D2	0.15	4	5	325	250	50	
D2	0.15	4	5	325	285	57	
D2	0.15	4	5	325	330	66	56.75
D2	0.15	4	5	325	270	54	
D3	0.15	6	Collapse	380	200	40	
D3	0.15	6	Collapse	380	280	56	
D3	0.15	6	Collapse	380	230	46	44.5
D3	0.15	6	Collapse	380	180	36	
G1	0.2	8	20	355	265	53	
G1	0.2	8	20	355	305	61	
G1	0.2	8	20	355	200	40	54.5
G1	0.2	8	20	355	320	64	
G2	0.2	9	50	330	235	47	
G2	0.2	9	50	330	260	52	
G2	0.2	9	50	330	250	50	50
G2	0.2	9	50	330	255	51	
G3	0.2	10	Collapse	385	350	70	
G3	0.2	10	Collapse	385	325	65	
G3	0.2	10	Collapse	385	410	82	70.25

G3	0.2	10	Collapse	385	320	64	
J1	0.25	12	Collapse	NR	110	22	26
J1	0.25	12	Collapse	NR	125	25	
J1	0.25	12	Collapse	NR	150	30	
J1	0.25	12	Collapse	NR	135	27	
J2	0.25	10	Collapse	NR	200	40	42.25
J2	0.25	10	Collapse	NR	215	43	
J2	0.25	10	Collapse	NR	230	46	
J2	0.25	10	Collapse	NR	200	40	
J3	0.25	8	Collapse	NR	240	48	48
J3	0.25	8	Collapse	NR	270	54	
J3	0.25	8	Collapse	NR	230	46	
J3	0.25	8	Collapse	NR	220	44	
M1	0.3	14	Collapse	330	325	65	71.5
M1	0.3	14	Collapse	330	360	72	
M1	0.3	14	Collapse	330	335	67	
M1	0.3	14	Collapse	330	410	82	
M2	0.3	12	75	280	340	68	66
M2	0.3	12	75	280	320	64	
M2	0.3	12	75	280	350	70	
M2	0.3	12	75	280	310	62	
M3	0.3	8	60	245	265	53	54.5
M3	0.3	8	60	245	305	61	
M3	0.3	8	60	245	200	40	
M3	0.3	8	60	245	320	64	



Graph 4 Compressive strength for W/C ratio 0.35

In this table we have taken the water cement ratio as 0.35 and quartz sand cement ratio as 1.5. Silica fume cement ratio is varied from 0.15 to 0.3. It is to be noted that a decrease in super plasticizer dosage would lead to a higher compressive strength due to high water cement ratio and closed packing capability of silica fume. Due to such a high level of water cement ratio we could see that the concrete was quite sensitive to super plasticizer dosage. Even a small increase in super plasticizer dosage would lead to large changes in workability values and hence collapse in slump was observed. Graph 4 for reference is given above.

V CONCLUSIONS

1. With the increase in dosage of super plasticizer the workability of concrete increases.
2. With the increase in silica fume to cement ratio the compressive strength of the concrete increases.
3. With the increase in water cement ratio the workability of concrete increases and the dosage of super plasticizer required decreases.
4. As such there is no relation between compressive strength and dosage of super plasticizer.
5. Water cement ratio and compressive strength are inversely proportional, an increase in water cement ratio leads to a decrease in strength.
6. As we kept the quantity of quartz sand constant there was no relation found between compressive strength or workability due to quartz sand.
7. For RPC especially it was observed that even at low water cement ratio with comparatively low dosage of plasticizer, the mix though not showing workability requirements i.e. giving zero slump and zero flow was showing cohesiveness in the mix and the specimens could be cast easily and they gave a higher value of compressive strength (Ref. reading A2 and I1).
8. Overall conclusion can be made that the water cement ratio of 0.3 and silica fume cement ratio of 0.25 are giving better results as compared to the other proportions for super plasticizer dosage of 8 ml with quartz sand cement ratio of 1.5.

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