Investigation on Reactive Powder Concrete and its Characteristic by using Silica Fume

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Abstract— Nowadays concrete has become more complex, it is a composite material and versatile in nature, generally the cost of the material that it contains. As the demand of high strength concrete is increasing researchers are continuously trying to develop an ultra-high performance concrete for this they have to reduce the w/c ratio, the main aim of the engineers is to achieve higher compressive strength. Reactive powder concrete is one of the cement based concrete with a developing composite material, it is classified as the combination of different mineral admixture in it. Overall it has a high durability with a greater strength than normal concrete. The main aim of this study is to investigate the characteristics of reactive powder concrete after applying different dosages of mineral admixture and its behavior under different curing condition. Mix proportion is obtaining from past published literature based on trial and error method. First part contains, different mix proportion and its comparison on the basis of compressive and flexural strength under different curing condition, it contains 7 types of mix proportion and second part contains, substituting of cement by silica fume with constant dosage of crimped steel fiber, percentage of replacement is 0%, 10%, 20%, 30%, 35%, 40%. The test gives the positive results which are discussed below at the conclusion.

Key words: Reactive Powder Concrete, Compressive, Flexural, Admixture, Ultra-High Performance Concrete

I. INTRODUCTION

Concrete which is a common material used for the development of the structure has undergone some certain limitations and become complex also. Nowadays technology is getting advanced day by day so the demand of complex design of structure is also increasing for this there is a requirement of ultra-high-strength concrete and the durability of the concrete is also matters, it is not possible for a normal concrete to gain this type of property. So the researchers developed reactive powder concrete at Bouygues laboratory in 1990 in France. Richard and Cheyrezy [1] had explained the principal of developing reactive powder concrete. The term reactive powder concrete (RPC) is classified as the concrete which has low water/binder ratio, fiber-reinforced, and have very high amount of silica content in it because to utilize the property of silica fume (pozzolanic property). Researchers said that the strength of RPC varies from 60 MPA to 400 MPA some said that they achieve the compressive strength of 800 MPA, from this it is defined that RPC is an ultra-high- strength concrete and the steel fiber used in the RPC is of small size to improve the ductility of the material. In this concrete water/binder ratio is low in order to reduce the heat of hydration of cement and to improve the sulfate resistance of the material. It contains all the material in powder form. Mahesh K Maloriya [2] studied that silica fume act as pore filler in reactive powder concrete it supports to form a compact material and directly it does not contribute with the strength. Halit yazici et.al [3] studied that the high strength of concrete is only obtained by mixing high amount of mineral admixture. Harish. K.V et.al [4] studied that to achieve high strength concrete sorting of ingredients parameters and different curing regimes plays a major role. It is also found that after temperature curing there is a thermal expansion on RPC, researchers said that it is due to the development of ettringite inside the material. Ettringite is a calcium aluminum sulfate mineral. Robert. L. Day [5] studied that this formation can ends if the concentration of sulfate is very low and also reduce by inclusion of air-entrainment void system.

The main purpose of the present research is to study the manners of material of 7 different types RPC mix proportion of which is achieve from the past literature and strength evaluation between them. Second part of the research contains replacement of cement by silica fume and strength comparison under different curing condition.

II. MATERIAL USED AND THEIR PROPERTY

Cementicious material	Used as binder	O.P.C 53 GRADE S.G = 3.15
Quartz sand	Max size 90µm	Sp.gravity= 2.59
Silica fume	Max size 90µm	Sp.gravity= 2.25
Sand	Max size 4.75mm	Sp.gravity = 2.63
Coarse aggregate	Max size 8mm	Sp.gravity=2.77
Super plasticizer	P.C based	In required amount
Steel fiber	L=35 mm , D=0.60mm	Sp.gravity= 2.8

Table 1: Material

A. *Cement*

- Initial setting time: 55 min (30 min as per IS 12269-1987)
- Final setting time: 360 min (600 min as per IS 12269-19987)
- Consistency: 32% on vicat's apparatus (IS 12269-1987)
- Soundness: 2mm (as per IS code 4031 - 1996 {Part -III}, and IS 5514-1996

B. *Silica Fume (IS 15388-2003)*

Composition	content
SiO_2	96.73%
Na_2O	0.51%
SO_3	0.2%
L.O.I	1.5%
Cl	0.07

Table 2: Silica Fume (IS 15388-2003)

C. Sand: IS 2386-1963 (part 1)

IS Sieve	% passing for	
	Zone I	Zone II
10 - mm	100	100
4.75 - mm	90 - 100	90 - 100
2.36 - mm	60 - 95	75 - 100
1.18 - mm	30 - 70	55 - 90
600 - µm	15 - 34	35 - 59
300 - µm	5 - 20	8 - 30
150 - µm	0 - 10	0 - 10

Table 3: Sand: IS 2386-1963 (part 1)

D. Steel Fiber

Steel fibers are manufactured as per ASTM-A820M
Length = 35 mm
Dia = 0.60 mm
Aspect ratio = 58

E. Super Plasticizer

MASTER GELENIUM ACE 30 JP: As per IS 9103: 1999

Aspect	Light Brown Colour
Relative Density	1.09 ± 0.01 At 25°C
Ph	>6
Chloride Ion Content	< 0.2%

Table 4: Super Plasticizer

III. EXPERIMENTAL PROGRAM

This investigation contains 7 different types of mix proportion of reactive powder concrete (RPC), mix proportion obtain from the past literature and replacing of cement from different % of silica fume the mix of which is also achieve from the past literature. The compressive strength of all these different types of mixes are compared with each other, comparison is also takes place on the basis of different types of curing condition like normal water curing for 7 and 28 days, accelerated curing for 48 hours 90 oC or we can also say that steam curing.

A. Casting

Investigation on OPC cement, mineral admixture like silica fume which has a good compatibility with cement. Quartz sand with very small particle size 0.074-0.149mm and 0.058mm are used. Super plasticizer is a high range water reducer with a specific gravity of 1.09. Steel fiber is added for it's high compressive and flexural strength which also depend upon the aspect ratio of steel fiber. Size of the cube specimen is 70x70x70mm and beam specimen is 100x100x500 respectively. Cubes and beams are prepared according to table 2 and table 3 respectively.

Mix	Cement Kg/m^3	Quartz sand Kg/m^3	Sand Kg/m^3	Silica fume Kg/m^3	Aggregate Kg/m^3	Steel fiber Kg/m^3	SP L/m^3	W/C
Mix 1	777	311	855	194	-	160	29	0.35
Mix 2	934	1030	-	234	-	-	29	0.3
Mix 3	934	618	-	234	412	-	29	0.32
Mix 4	934	721	-	234	309	-	29	0.35
Mix 5	934	618	-	234	412	186	29	0.32
Mix 6	800	375	855	150	-	160	30	0.35
Mix 7	800	375	855	200	-	160	30	0.35

Table 2: contains 7 different types of mix proportion of RPC mentioned above

Halit Yazici et al. (2008)	Cement Kg/m^3	Quartz sand Kg/m^3	Sand Kg/m^3	Silica fume Kg/m^3	Steel fiber Kg/m^3	SP L/m^3	W/C
RPCSF0	830	332	1040	0	166	29	0.32
RPCSF10	747	332	1040	83	166	29	0.32
RPCSF20	664	332	1040	166	166	29	0.32
RPCSF30	581	332	1040	249	166	29	0.32
RPCSF35	539.5	332	1040	290.5	166	29	0.32
RPCSF40	498	332	1040	332	166	29	0.32

Table 3: contains mix proportion of replacement of cement by silica fume.

IV. TEST AND RESULTS

Mix	Compressive strength @ 7 days (MPA)	Compressive strength @ 28 days (MPA)	Compressive strength @ 48 hrs 90 ^{o}C (MPA)
Mix 1	57	75	78
Mix 2	52	58	63
Mix 3	50	60	67
Mix 4	47	61	65
Mix 5	55	69	73
Mix 6	58	77	81
Mix 7	60	78	83

Table 4: contains results of compressive strength of 7 different mix proportion at different curing conditions. Cubes where tested on compression testing machine as per IS 516-1959

Mix	Flexural strength @ 28 days (MPA)	Flexural strength @ 48 hrs 90 ºC (MPA)
Mix 1	6.062	6.1822
Mix 2	5.331	5.556
Mix 3	5.422	5.729
Mix 4	5.467	5.643
Mix 5	5.814	5.980
Mix 6	6.142	6.3
Mix 7	6.182	6.377

Table 5: contains results of flexural strength of 7 different mix proportion at different curing condition. As per IS 456 (cl.6.2.2 permissible flexural strength is 0.7√fck). In case of RPC reverse engineering is taken into consideration in which grade of concrete is decided with the help of compressive strength calculation.

	Compressive strength @ 7 days (MPA)	Compressive strength @ 28 days (MPA)	Compressive strength @ 48 hrs 90 ºC (MPA)
RPCSF0	51	59	62
RPCSF10	53	63	66
RPCSF20	56	65	69
RPCSF30	64	79	82
RPCSF35	69	84	88
RPCSF40	61	76	79

Table 6: contains results of compressive strength of different % of silica fume

	Flexural strength @ 28 days (MPA)	Flexural strength @ 48 hrs 90 ºC (MPA)
RPCSF0	5.376	5.511
RPCSF10	5.556	5.686
RPCSF20	5.643	5.814
RPCSF30	6.221	6.338
RPCSF35	6.415	6.556
RPCSF40	6.102	6.221

Table 7: contains results of flexural strength of different % of silica fume

A. Graphical Representation

Graph 1 Shows that the comparison of compressive strength of different mix proportion and from graph it is found that accelerated curing gives the best result as compared to normal water curing.

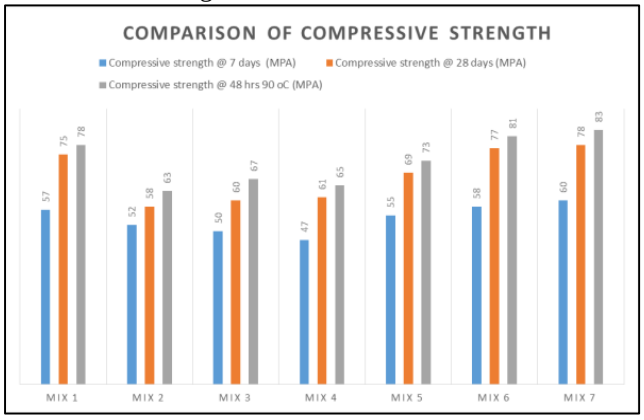

Fig. 1: Graph 1

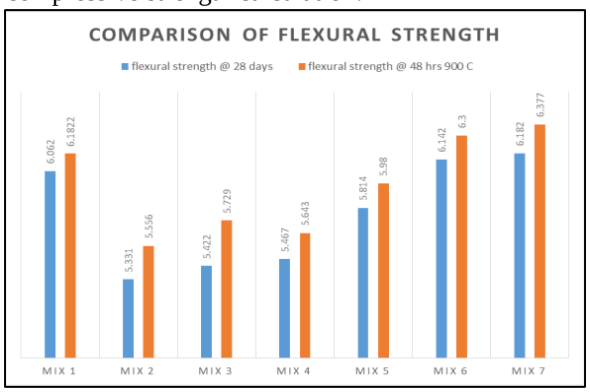

Fig. 2: Graph 2

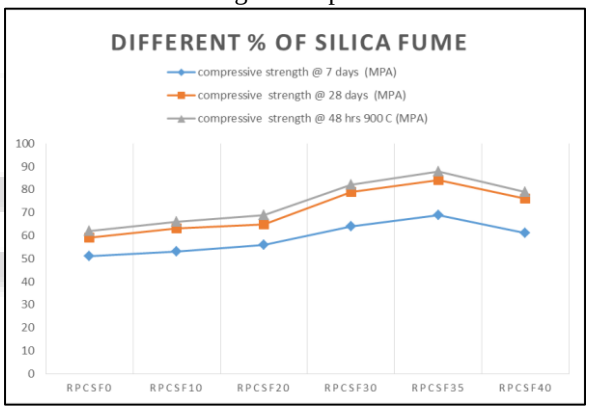

Fig. 3: Graph 3

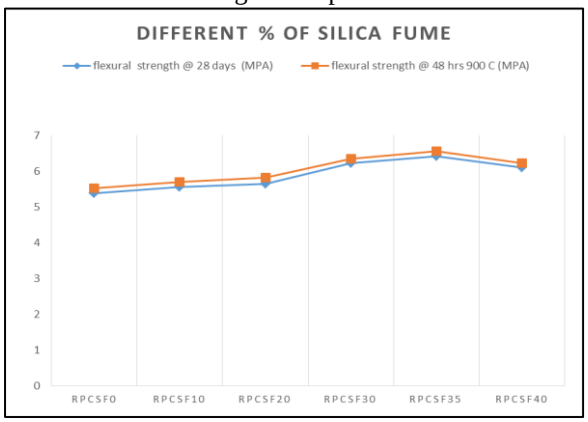

Fig. 4: Graph 4

V. DISCUSSION AND CONCLUSION

Accelerated curing gives more compressive strength than normal water curing so it is better than normal water curing, it enhance the material property of the concrete also due to its heating effect. During the test it is found that due to accelerated curing thermal expansion of the concrete takes

place, researchers says that it is due to the formation of ettringite chemical compound inside the concrete which form due to heat only.

- Over all it is said that MIX 6 & MIX 7 gives higher strength as compared to different mix proportion because it contains higher amount of binder i.e cement.
- Strength of MIX 7 is greater than MIX 6 because it contains more amount of silica fume. So, we can say that silica fume also plays a major role as a mineral admixture to achieve strength in Reactive Powder Concrete.
- Strength of MIX 5, which contain coarse aggregate of size 8mm or it is also called as a modified form of Reactive Powder Concrete is more than MIX 3 & MIX 4 which also contains coarse aggregate is due to the steel fiber in it. Steel fiber increases the ductility of the concrete.
- In MIX 1 and MIX 2, MIX 2 contains higher amount of binder but its strength is lower than MIX 1 because the amount of quartz sand or silica sand is very high in MIX 2. So, by this we can conclude that quartz sand is useful for a Reactive Powder Concrete up to a certain level only.
- In the second part of this research paper cement was replaced by silica fume, and from this research we conclude that 65% cement and 35% silica fume gives maximum strength.
- Cement was replaced by a silica fume up to a certain level only after 40% cement replacement strength gets lower down
- So, 35% of cement replacement is the highest point of the replacement from silica fume.
- Reactive Powder Concrete can be used as a retrofit material or as a repair material.

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