Strength Parameters of SCC Using Fly-Ash and Quarry-Dust

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Abstract – *Self compacting concrete is a flowing concrete that spreads through congested reinforcement, fills every corner of the formwork, and is consolidated under its self-weight. SCC requires excellent filling ability, good passing ability, and adequate segregation resistance. In recent years many researches has been carried out to utilize the waste materials like Fly-Ash in place of cement and Quarry Dust in place of sand as alternative material to reduce the cost of construction. In the present study the strength characters on SCC in replacing both cement and FA together by Fly-Ash and Quarry Dust respectively. Partially replacing Cement with Fly-Ash and high percentage replacing Quarry- Dust with Fine aggregate with admixture.*

***Key Words*: Self compacting concrete, Segregation, Fly-Ash, Quarry Dust, Admixture.**

1.INTRODUCTION

SCC was first developed in 1988 so that durability and workability of concrete structures can be improved. Investigations for establishing a rational mix-design method and self-compatibility testing methods have been carried out from the viewpoint of making it a standard concrete. The creation of durable concrete structures requires adequate compaction b skilled workers. The solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of SCC, which can be compacted into every corner of a formwork, purely by means of its own weight and without need of compaction.

1.1 Mechanism for Achieving Self Compact Ability

The method for achieving self-compact ability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. Okamura and Ozawa employed the following methods to achieve self-compact ability.

- Limited coarse aggregate content.
- Low water-powder ratio.
- Limited Use of super plasticizer.

1.2 Mix Proportioning Procedures of SCC

No standard methods for designing SCC mixtures (Okamura 1995) could be to date; there is no American Concrete Institute (ACI) standard mixture design method for Self Compacting Concreting (SCC), as there is for conventional concrete. There have been guidelines for mixture proportions published in various works, yet there is no definitive or standard mixture design to date.

The various mix design procedures available for SCC are

- Rational mix design.
- Nan-Su, et al, method.
- Japanese method.
- European Method of practice.
- Sedan et al. [LCPC, Paris] method.
- Gomes Ravindra Getto etal method.
- Particle packing method.

Table 1.2.1 gives the list of test methods for workability properties (Malhotra 1995 & Bartoos 2000) of SCC based on EFNARC Specification and guidelines. Table 1.2.2 gives the list of methods for workability properties of SCC based on EFNARC specification and guidelines. Table 1.2.3 gives the typical acceptance criteria for SCC

Table 1.2.1: EFNARC Specification and Guidelines

Sl. No	Method	Property
1	Slump flow	Filling ability
2	T50cm slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel at T5Min	Segregation resistance
6	L-box	Passing ability
7	U-box	Passing ability
8	Fill box	Passing ability
9	GTM Screen Stability test	Segregation resistance
10	Orimet	Filling ability

Table 1.2.2 Workability Properties of SCC and Alternative test methods

Property	Test methods	Field	Modification of test according to maximum size of Aggregate
	Lab mix design	Quality control	
Filling ability	Slump flow	Slump flow	None
Filling ability	T-50CM slump flow	T-50CM slump flow	None
Filling ability	V-Funnel	V-Funnel	Maximum 16mm
Passing ability	L-box	J-ring	Different openings in L-box
Segregation resistance	GTM-Test	GTM-Test	None
Segregation resistance	V-Funnel at T-5 min	V-Funnel at T-5 min	None

Table 1.2.3 Typical acceptance criteria for SCC

Sl. No	Method	Unit	Typical Range of Values	
			Min	Max
1	Slump flow	mm	600	800
2	T50 cm Slump Flow	sec	2	5
3	J-ring	mm	0	10
4	V-funnel	sec	8	12
5	V-funnel at T5 minutes	sec	0	3
6	L-box	(h2/h1)	0.8	10
7	U box	(h2-h1)	0	30
8	Fill box	%	90	100
9	GTM Screen stability test	%	0	15
10	Orimet	sec	0	5

1.2 Properties of Fresh SCC

Filling ability:

"It is the ability of SCC to flow into and fulfill completely all spaces within the formwork under its own weight". SCC flows under its own weight, filling formwork and flowing around recesses or embedded objects without leaving voids. As it is very fluid, it can flow considerable distances horizontally and upwards to fill vertical elements from the bottom. SCC can be pumped into column and formwork from the bottom through special valves, eliminating the use of craned skips, platforms etc.

Passing ability:

"It is the ability SCC to flow through right openings such as spaces between steel reinforcing bars without segregation and blocking." The passing ability enables SCC, containing the appropriate aggregate grade, to flow around congested reinforcement without affecting the homogeneity of the concrete.

Resistance to Segregation:

"It is the ability of SCC to remain homogeneous in composition during transport and placing". Segregation is observed as surface bleed water and formation of surface mortar laitance. These are as undesirable in SCC as in traditional concrete. In SCC, segregation resistance is the most difficult fresh property to achieve. The most critical manifestation of segregation is the separation of mortar from the coarse aggregate fraction even though full compaction is achieved. This can cause settlement of coarse aggregate in deep sections, together with blocking, which can prevent the free flow of concrete around the concrete the reinforcement. Owing to SCC s cohesive nature and in spite of its high fluidity, there is no internal settlement of coarse aggregate.

2. METHOLODOGY

Study of strength parameters on the Fly-Ash and Quarry Dust self compacting concrete replacing Fly-Ash with Cement at four different levels (10%, 20%, 30% & 40%), and Quarry Dust with sand at four different levels (10%, 20%, 30% & 40%). Obtained strength parameters are compared with Conventional SCC of M60 Grade of concrete for different curing periods.

Strength parameters:

Experimental studies are carried out to understand the strength characteristics of Fly-Ash & Quarry Dust SCC. The compressive strength, split tensile strength of Fly-Ash and Quarry Dust concrete is compared with Conventional SCC.

Constant Parameters:

- Grade of Concrete: M60
- Water Cement ratio (W/C):0.32 (obtained from mix design)
- Size and Number of specimens:
- Cube specimen size 150mm x 150mm x 150mm for compressive tests.
- Cylinder specimen size 150mm diameter and 300mm long for split tensile tests.

Variable parameters:

Fly-Ash: The Fly-Ash is replaced by cement in four different levels of 10%, 20%, 30% & 40%.

Quarry Dust: The Quarry Dust is replaced by natural sand in four different levels of 10%, 20%, 30% & 40%.
Curing period: The specimens of compressive strength i.e. cubes are cured at 28 days and specimens of split tensile strength i.e. cylinders are cured at 28 days.
Super plasticizer: Super plasticizer Glenium B233 is used to maintain the workability with constant water binder ratio. Dosage is adjusted with in permissible limits such that concrete to maintain the required workability.

Table 2.1 No. of specimens of conventional SCC, Fly-Ash and Quarry Dust for Compressive strength**.**

Sl. No	Concrete	Quantity of		Designation	Curing Period In days 28
1	Conventional SCC	Cement 100%		C	3
2	Replacement of Fly-Ash with Cement	**Cement**	**Fly-Ash**		
		90%	10%	A1	3
3		80%	20%	A2	3
4		70%	30%	A3	3
5		60%	40%	A4	3
6	Replacement of Quarry Dust with Natural Sand	**N-Sand**	**Q-Dust**		
		90%	10%	B1	3
7		80%	20%	B2	3
8		70%	30%	B3	3
9		60%	40%	B4	3
Total No of cubes					27

Above No of specimens of conventional SCC, Fly-Ash and Quarry Dust with same composition are made for Split Tensile strength.

3. RESULTS AND DISCUSSION

It consist of test result and discussion on strength parameters such as flow ability, filling ability(V-Funnel),Passing ability (L-box), compressive strength, split tensile strength and flexural strength of FLY-ASH& RCP SCC for four different replacement levels of cement with FLY-ASH that is 10%, 20%, 30%, 40%, and natural sand with RCP with four different levels of replacement that is 10%,20%30%,40%, The study has been made for differential curing period curing period of 28days.

3.1 Flow ability

The dosage of super plasticizer is made restricted to 0.7% based on the mass cone method with water binder ratio of 0.45 to get the value within the permissible codal value. The slump value of SCC for Conventional SCC and different level of Fly-ash & Quarry-Dust has been tabulated in table 6.1.

From Table 3.1.1 and Fig 3.1.1, 3.1.2, following observations are made with respect to the slump values of SCC with different replacement of FLY-ASH and QUARRY-DUST.

Table 3.1.1 Slump Values

Concrete Designation	% Replace FLY ASH	CEMENT	Designation	Water binder ratio	Slump value in mm
Conventional	0%	0%	C	0.45	703
Cement replacement with fly ash	10%	90%	A_0	0.45	695
	20%	80%	A_1	0.45	693
	30%	70%	A_2	0.45	689
	40%	60%	A_3	0.45	687
	Q-Dust	N-sand			
Sand replacement with Quarry Dust	10%	90%	B_0	0.45	686
	20%	80%	B_1	0.45	683
	30%	70%	B_2	0.45	679
	40%	60%	B_3	0.45	676

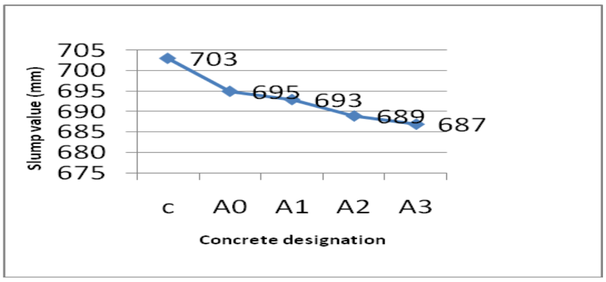

Fig 3.1.1: Slump Flow of SCC in replacement of Fly-Ash with Cement.

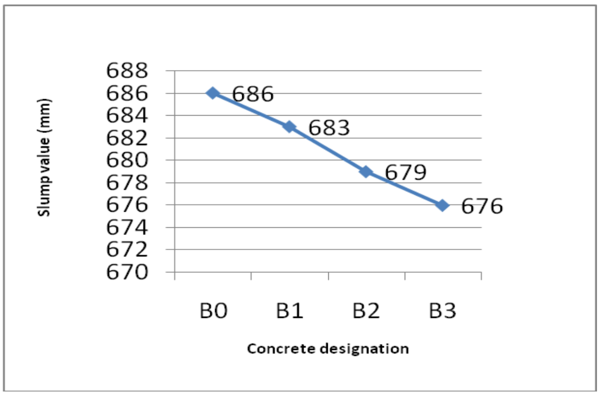

Fig 3.1.2: Slump Flow of SCC in replacement of Quarry-Dust with Sand

- The slump value reduces with the increase in percentage of Fly-Ash. For 40% FLY-ASH SCC compared to conventional SCC(c), the slump value reduces from 703mm to 687mm.
- And also the slump value reduces with the increase in percentage of Quarry-Dust. For 40% of Quarry-Dust SCC compared to Conventional SCC(c), the slump value reduces from 703mm to 676.
- Hence from the above observation it is observed that presence of Fly-Ash and Quarry-Dust will reduces the slump.

3.2 Filling Ability (V-Funnel)

The V-funnel test is to assess the viscosity and filling of self-compacting concrete. The test is not suitable when the maximum size of the aggregate exceed 20mm. if SCC shown segregation then flow time increases significantly.

For V-funnel test the flow time should be between 8 and 12 second. The results of fresh properties of SCC mixes are tabulated in the table 3.2.1 & plotted in fig 3.2.1, 3.2.2

Table 3.2.1: V-Funnel Value

Sl. No	Concrete	Quantity Of		Designation	V-Funnel value in sec
1	Conventional SCC	Cement 100%		C	9.05
2	Replacement of Fly-Ash with Cement	**Cement**	**Fly-Ash**		
		90%	10%	A1	9.28
3		80%	20%	A2	9.60
4		70%	30%	A3	9.69
5		60%	40%	A4	9.76
6	Replacement of Quarry Dust with Natural Sand	**N-Sand**	**Q-Dust**		
		90%	10%	B1	9.84
7		80%	20%	B2	9.93
8		70%	30%	B3	10.02
9		60%	40%	B4	10.17

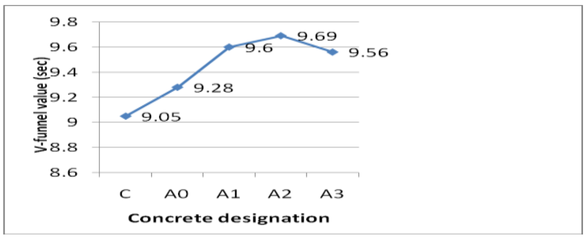

Fig 3.2.1: V Funnel Values of SCC in replacement of Fly-Ash with Cement

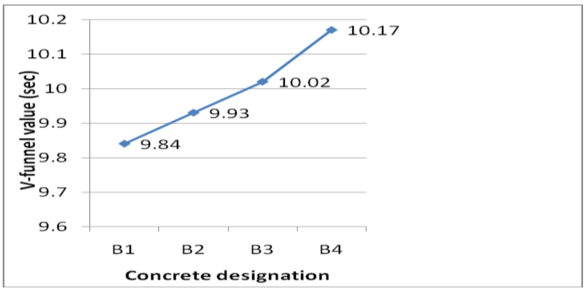

Fig 3.2.2: V Funnel Values of SCC in replacement of Quarry-Dust with Sand

Following observations are made with respect to the V-funnel value of concrete with different replacement of Fly-Ash and Quarry-Dust:

- The V-funnel value increases with the increase in percentage of Fly-Ash & Quarry-Dust also with the increase in the percentage of Quarry-Dust. This may be the presence of FLY-ASH & Quarry-Dust increases the viscosity of the concrete.
- For 40% of Fly-Ash SCC compared to Conventional SCC the V-funnel value varies from 9.05 sec to 9.76 sec.
- For 40% of Quarry-Dust SCC compared to Conventional SCC the V-funnel value varies from 9.05 sec to 10.17 sec.

3.3 Passing ability (L-box)

The test is conducted to assess the flow of concrete and also the extent to which the concrete is subjected to blocking by reinforcement (H_2/H_1, blocking ratio).

The European Union research team suggested a minimum acceptable value of 0.8 to 1.0, which give some indication of case of flow. The value are tabulated in Table 3.3.1 & plotted in fig 3.3.1

Table 3.3.1: L-Box Values

Concrete	Quantity of		Designation	Compressive strength in n/mm² 7days	28days
Conventional SCC	Cement 100%		C	38.89	60.36
Replacement of Fly-Ash with Cement	**Cement**	**Fly-Ash**			
	90%	10%	A1	28.60	31.56
	80%	20%	A2	18.92	32.26
	70%	30%	A3	15.48	33.67
	60%	40%	A4	15.10	32.91
Replacement of Quarry Dust with Natural Sand	**N-Sand**	**Q-Dust**			
	90%	10%	B1	33.85	40.93
	80%	20%	B2	31.11	41.28
	70%	30%	B3	30.21	42.63
	60%	40%	B4	28.74	41.94

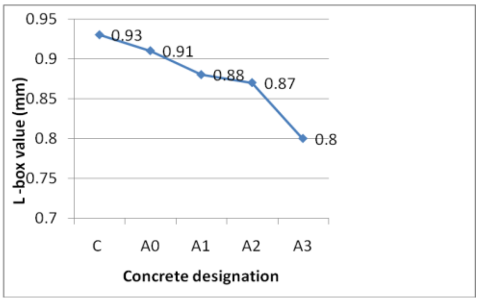

Fig 3.3.1: L-Box Values of SCC in replacement of Fly-Ash with Cement

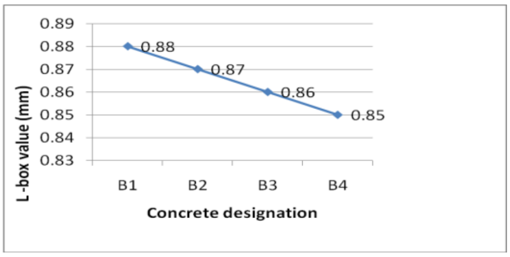

Fig 3.3.2: L-Box Values of SCC in replacement of Quarry-Dust with Sand

From Table 3.3.1 & fig 3.3.1 & 3.3.2 following observation are made

- With the increase of FLY-ASH in SCC the consistency of flow reduced with 40% FLY-ASH. In SCC the H_2/H_1 ratio varies from 0.93 to 0.86 of the conventional SCC.
- With the increase of Quarry-Dustin SCC the consistency of flow reduced with 40% Quarry-Dust In SCC the H_2/H_1 ratio varies from 0.93 to 0.85 of the conventional SCC.
- Hence the FLY-ASH contributes more in the reduction of consistency of flow in compared to Quarry-Dust.

3.4 Compressive Strength

The test results of compressive strength of M60 grade FLY-ASH, RCP Self compacting concrete for different Curing period of 7 and 28 days. The compressive strength of standard cube size 150m × 150mm × 150mm is calculated using the formula.

$$F = P/A$$

Where, F = Compressive strength of concrete in N/mm²
P=Ultimate load resisted by concrete in Newton
A=Cross sectional area of cube specimen in mm

Table 3.4.1: Compressive strength of conventional SCC, four different replacements of Fly-Ash and Quarry Dust with respect to different curing periods

Concrete	**Quantity of**		**Designation**	**H_1 IN CM**	**H_2 IN CM**	**H_2/H_1 Ratio**
Conventional SCC	Cement 100%		C	9.0	8.4	0.93
Replacement of Fly-Ash with Cement	**Cement**	**Fly-Ash**				
	90%	10%	A1	9.1	8.3	0.91
	80%	20%	A2	9.3	8.2	0.88
	70%	30%	A3	9.3	8.1	0.87
	60%	40%	A4	9.2	8.0	0.86
Replacement of Quarry Dust with Natural Sand	**Sand**	**Q-Dust**				
	90%	10%	B1	9.4	8.2	0.89
	80%	20%	B2	9.3	8.1	0.88
	70%	30%	B3	9.0	8.0	0.86
	60%	40%	B4	9.0	7.9	0.85

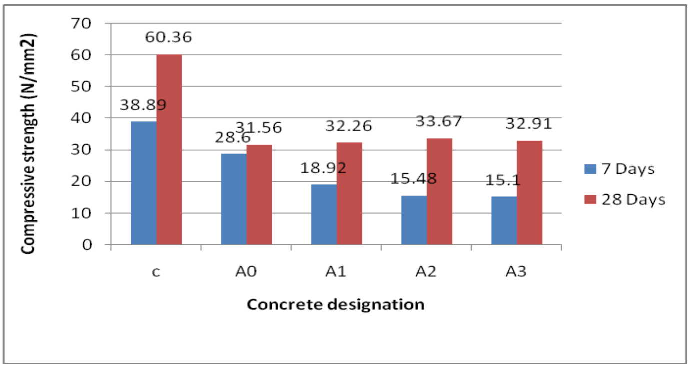

Fig 3.4.1: Compressive Strength Values of SCC in replacement of Fly-Ash with Cement

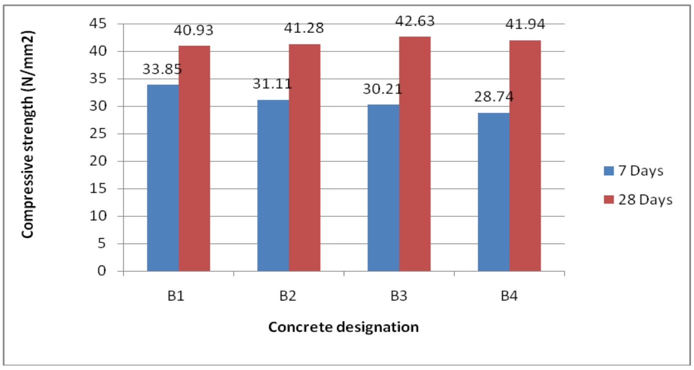

Fig 3.4.2: Compressive Strength Values of SCC in replacement of Quarry-Dust with Sand

From table 3.4.1 and fig 3.4.1 and fig 3.4.2 following observation are made

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Concrete	**Quantity Of**		**Designation**	**Split strength in N/mm²** 28days
Conventional SCC	Cement 100%		C	4.10
Replacement of Fly-Ash with Cement	**Cement**	**Fly-Ash**		
	90%	10%	A_0	3.66
	80%	20%	A_1	3.48
	70%	30%	A_2	3.75
	60%	40%	A_3	3.15
Replacement of Quarry Dust with Natural Sand	**Sand**	**Q-Dust**		
	90%	10%	B_1	3.39
	80%	20%	B_2	3.22
	70%	30%	B_3	3.90
	60%	40%	B_4	2.97

- The SCC with FLY-ASH attains significantly strength only after 28 days of curing Compared to Conventional SCC.
- The compressive strength of SCC with 40% replacement of Fly-Ash varies between 33.67 to 32.91. Whereas compressive strength of conventional SCC is 60.36 N/MM².
- The compressive strength of SCC with 40% replacement of Quarry-Dust varies between 42.63 to 41.94, whereas compressive strength of conventional SCC is 60.36 N/MM².
- The concrete with different percentage of Fly-Ash attains significantly strength only after 28days of curing compared to 7 days curing periods.
- The concrete with different percentage of Quarry-Dust attains significantly strength only after 28days of curing compared to 7 days curing periods.
- Hence from the observation replacement of 40% of both Fly-Ash and Quarry-Dust has more influence in reduction of strength compared to Conventional SCC.

3.5 Split Tensile Strength

The test result of split tensile strength of M60 Grade concrete Cylinder of standard size 150mm Diameter end 300mm long cylinder specimen of FLY-ASH &RCP self compacting concrete & Conventional concrete for different curing period of 28 days are tabulated in Table 6.5

The split tensile strength of concrete is given by the formula

$$FCS = 2P/\Pi dl \text{ N/MM}^2$$

Where P=Failure load of specimen

D=Diameter of the cylinder in mm

L=Length of the cylinder in mm

FCS= Failure strength N/MM²

The variations of split tensile strength with four different percentage of Fly-Ash, Quarry-Dust and Conventional SCC (c) with different curing period.

Table 3.5.1 : Split tensile strength of conventional SCC mix with four different replacement of Fly-Ash and Quarry-Dust with respect to differential curing period

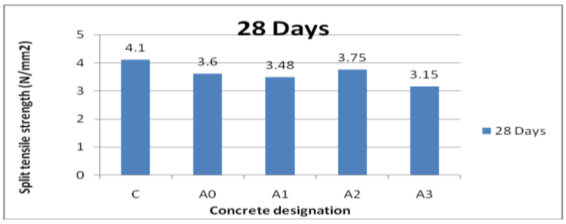

Fig 3.5.1: Split tensile Strength Values of SCC in replacement of Fly-Ash with Cement

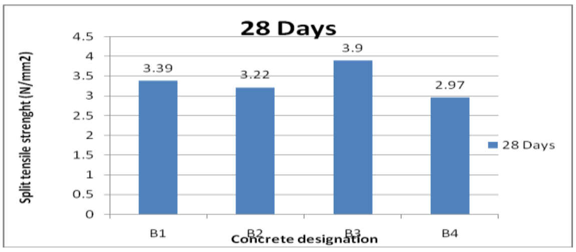

Fig 3.5.2: Split tensile Strength Values of SCC in replacement of Quarry-Dust with Sand

From the table 3.5.1 following observations are made:

- The SCC with FLY-ASH and Quarry-Dust attains significantly strength only after 28 days of curing Compared to Conventional SCC.
- The split tensile strength of SCC for different replacement levels of Fly-Ash (10%, 20%, 30%, & 40%) varies between 52.08 N/mm² to 51.90N/mm², compared to conventional SCC(c) is 4.10 N/mm².
- The split tensile strength of SCC for different replacement levels of Quarry-Dust (10%, 20%, 30%, & 40%) varies between 3.90 N/mm² to 2.97 N/mm², compared to conventional SCC(c) is 4.10 N/mm².

- Hence when Fly-Ash is in 30% it will give better strength as compared to 10%, 20% and 40% of SCC and also when Quarry-Dust is in 30% it will give better strength as compared to 10%, 20% and 40% of SCC.

- Hence from the observation replacement of 40% of both Fly-Ash and Quarry-Dust has more influence in reduction of strength compared to Conventional SCC.

4. CONCLUSIONS

- Fly-Ash contributes in the reduction of agricultural waste that is the main cause of environmental problems agricultural countries. On the other hand it is an approach to improve the quality of concrete without using other costly additives such as Silica fume, GGBS and Rice Husk Ash.
- Due to the presence of fly-ash in SCC required strength of SCC is obtained after 28 days of curing unlike normal concrete which attains the strength at 7 days, due to the reason that fly-ash is regulate the cement content so as to reduce the heat of hydration. When heat of hydration is reduced strength development at early age is also reduced.
- The presence of Fly-Ash reduces the slump, with increase in quantity of fly-ash in SCC's the reduction in slump also decreases. The replacement of Fly-Ash is also further reduces the slump (from Table No. 3.1.1). This could be due to the absorption of porous structure of Fly-Ash and also due to the high percentage of fines in fly-ash it goes to shrinkage.
- The replacement of Fly-Ash and Quarry-Dust in different levels (10%, 20% & 40%) has more influence in reduction of compressive strength, split tensile strength as compared to 30% of Fly-Ash and Quarry-Dust and also compared to conventional SCC.
- However the SCC with Fly-Ash and Quarry-Dust reduces the strength (From Table No. 3.4.1 & 3.5.1), these could be due to that Fly-Ash does not act as Cement replacement because of its low reactivity. And also Quarry-Dust does not act as Sand replacement because of low fines particles.
- The percentage reduction of strength of SCC with 10%, 20% & 40% of both fly-ash and quarry-dust has showed poor results, when compared to 30% of fly-ash and quarry-dust and conventional SCC.
- 30% replacement of Fly-Ash and Quarry-Dust was to be performed better than the other proportions. So we can recommend that using only cement and sand, replacement should be used along with cement and sand.

4. SCOPE OF FUTURE STUDY

Following recommendations are made for future studies to improve and to explore the current work for the development of SCC using Fly-Ash and Quarry-Dust as replacement materials.

- Investigations to study the shrinkage and bond properties of Fly-Ash and Quarry-Dust SCC.
- Characterization studies on Fly-Ash and Quarry-Dust the samples from different sources so that they can be standardized for better application as alternate material.
- Improve the mix by modifying the various constituents to observe the changes of physical changes.
- This study only used one type of admixture. It is recommended to use different types of admixtures whether it's influences the properties of concrete.
- Same work can be done for different grades of concrete.

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