Experimental Investigation On Properties Of Self Compacting And Self Curing Concrete Using Light Weight Aggregate, Quarry Dust And Fly Ash As A Mineral Admixture

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Abstract - Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its self weight with little or no vibration effort, and which is at the same time cohesive enough to be handled without segregation or bleeding of fresh concrete. This study presents an experimental investigation on Self Compacting and Self Curing Concrete (SCCM) with fine aggregate replacement of a Quarry Dust (0, 10, 20, 30, 40%) with 10% and 15% LWA constant and addition of mineral admixture Fly Ash. Mix proportions of SCCM for M40 grade concrete were arrived. For each concrete mix nine 150×150×150 mm cubes, 150×300 mm cylinders were cast and left for Self Curing for 7, 28 and 56 days and results are compared with Self Compacting Concrete (SCC). The Slump Flow, J-Ring, UBox, L-Box and V-Funnel test are carried out on the fresh properties of SCCM and in harden concrete Compressive Strength, Split Tensile Strength were determined. The flow properties on SCC with cement, Fly Ash as additional for cementitious material and various proportions of Quarry Dust has been performed and found that the values of Slump flow, V-Funnel, UBox, L-Box and J-Ring were within the limits prescribed by EFNARC. From overall study, it was concluded that SCC with Quarry Dust found satisfactory.

Keywords - Self Compacting Concrete (SCC), Fly Ash, Light Weight Aggregates and Quarry Dust.

I. INTRODUCTION

The self-compacting concrete (SCC) is the newest innovating category of high performance concrete, characterized by its ability to spread and self consolidation in the formwork exhibiting any significant separation of constituents. Elimination of vibration for compacting concrete during placing with the use of SCC leads to substantial advantages related to better homogeneity, enhancement of working-environment and improvement in the productivity by increasing the speed of construction. One of the disadvantages of SCC concrete is its cost, associated with the use of high volume of Portland cement and use of chemical admixtures. One alternative to reduce the cost of SCC is the use of mineral admixtures such as fly ash, which is finely, divided material added to concrete during mixture procedure. When this mineral admixture replaces a part of the Portland cement, the cost of SCC will be reduced especially if the mineral admixture is waste or industrial by-product. Moreover, the use of mineral admixture in the production of self compacting concrete not only provides economical benefits but also reduces heat of hydration. SCC is not a new material, but rather new and improved way of executing the concreting operation. SCC, similar to CVC (conventional vibrated concrete), has a wide variety of properties to achieve specific targets. A wide number of definitions can be found in the literature, but all of them describe SCC in the common way: SCC is a concrete that is able to flow under its own weight and completely fill the formwork and encapsulate the reinforcement, while maintaining homogeneity and can consolidate without the need for vibration compaction. The use of SCC offers benefits in the key areas such as construction process, concrete quality, energy conservation, health and safety. There are many advantages of using SCC especially when the material cost is minimized. These include:

1. Reducing the construction time and labour cost.
2. Eliminating the need for vibration.
3. Reducing the noise pollution
4. Improving the filling capacity of highly congested structural members.
5. Facilitating construability and ensuring good structural members.

SCC consists of the same components as conventionally vibrated concrete, which are cement, aggregates and water, with the addition of chemical and mineral admixtures in different proportions.

II. LITERATURE REVIEW

Kazumasa Ozawa et. al., [1]: In this study by using different types of fly ash, he studied the workability of concrete and developed a concrete, which was more workable. It was suitable for rapid placement and had a very good permeability. Ozawa (1989) carried out experiments by focusing on the influence of mineral admixtures, like fly ash and blast furnace slag, on the flowing ability and segregation resistance of self-compacting concrete. He found out that the flowing ability of the concrete improved remarkably when Portland cement was partially replaced with fly ash and blast furnace slag. After trying different proportions of admixtures, he concluded that 10-20% of fly ash and 25-45% of slag cement, by mass, showed the best flowing ability and strength characteristics.

Nan Sua et. al., [2] : Proposed a new mix design method for self-compacting concrete (SCC), to ensure that the concrete obtained has flowability, self-compacting ability and other desired SCC properties. The amount of aggregates required is determined, and the paste of binders is then filled into the voids of aggregates. Thus by using appropriate material properties the amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer (SP) to be used are determined. Fresh properties like Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out successfully to examine the performance of produced high quality SCC. From the mix design, came to the conclusion that, this method is simple when compared to the method developed by the Japanese Ready-Mixed Concrete Association, as it is easy for implementation, simple, less time-consuming, saves cost and requires a smaller amount of binders.

Jagadish Vengala and Ranganath R.V [3] : In this study developed high performance self-compacting concrete and discussed the results of an experimental study of the fresh concrete properties. Coarse aggregate is replaced partly by fly ash which has increased the paste content and enhanced the SCC properties. The high powder content which has been advocated for development of SCC, contributed to its long-term strength and durability as it imparts a continuous hydrating system to the concrete. If the concrete is having fly ash greater than 140 kg per cum, an increase in strength of the order of 35% occurs at later ages whereas similar increase occurs in SCC mixes of high volume fly ash and the order is of 35-60%.

Naveen Kumar et. al., [4] : In this investigation is discussed the successful use of fillers other than fly ash in self compacting concrete. The available literature has been reviewed to bring out the advantages of such fillers when used in SCC. Experimental studies were done with fly ash, metakaolin and their blends as fillers in SCC. The result showed that SCC can be produced with cement content, as low as 200 Kg/m3 of concrete along with fly ash as rest of the powder. High strength SCC can be obtained by incorporation of metakaolin. With different fillers like silica fume and metakaolin a high early strength mix of around 50-70MPa can be achieved. It is also observed that as long as the paste volume constituted by the powder and water is kept unaltered, SCC can be obtained for widely differing fly ash contents or cement contents. Finally the experimental study reports that fly ash can be used in large quantities in SCC and cement can be reduced to 200 kg.

In Choi et. al., [5] : In this study special consideration was given to the investigation of the influencing of replacing either the coarse or the fine fraction of normal weight aggregates with natural light weight ones on the mechanical and rheological properties of the concrete. Slump flow and T500 values of all mixtures were found to lie within the commonly accepted limits for SCC, where as V-funnel and U-box values were satisfactory, especially for the mixtures in which the fine natural weight aggregate were partially or fully replaced by normal weight aggregate.

III. OBJECTIVES OF STUDY

1. To study the fresh properties for all mix proportions such as:

a) Slump Flow
b) J-Ring Test
c) U-Box Test
d) V-Funnel
e) L-Box

2. To determine the different strength parameters such as compressive strength, split tensile strength of the Self Compacting and Self Curing Concrete (SCCM) in comparison to Self Compacting Concrete (SCC).

Some of the terms frequently used in the present investigation are defined as follows:

- Self Compacting and Self Curing Concrete (SCCM) : It is the self compacting and self curing concrete produced by replacing coarse aggregate with 10% and 15% of light weight aggregate (LWA) and fine aggregate by 0, 10, 20, 30 and 40% of Quarry dust.
- Self Compacting Concrete (SCC): It is a composite product produced by mixing cement, fine aggregate, coarse aggregate and water in suitable proportions.
- SCCM0: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 10% of light weight aggregate (LWA).
- SCCM1: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 10% of light weight aggregate(LWA) and fine aggregate by 10% of Quarry dust.
- SCCM2: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 10% of light weight aggregate(LWA) and fine aggregate by 20% of Quarry dust.
- SCCM3: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 10% of light weight aggregate(LWA) and fine aggregate by 30% of Quarry dust.
- SCCM4: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 10% of light weight aggregate(LWA) and fine aggregate by 40% of Quarry dust.
- SCCM5: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 15% of light weight aggregate (LWA).
- SCCM6: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 15% of light weight aggregate(LWA) and fine aggregate by 10% of Quarry dust.

- SCCM7: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 15% of light weight aggregate(LWA) and fine aggregate by 20% of Quarry dust.
- SCCM8: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 15% of light weight aggregate(LWA) and fine aggregate by 30% of Quarry dust.
- SCCM9: It is the self compacting and self curing concrete produced by replacing coarse aggregate with 15% of light weight aggregate(LWA) and fine aggregate by 40% of Quarry dust.

Self-curing or internal curing is a technique that can be used to provide additional moisture in concrete for more effective hydration of cement and reduced self-desiccation. There are two major methods available for internal curing of concrete. The first method uses saturated porous lightweight aggregate (LWA) in order to supply an internal source of water, which can replace the water consumed by chemical shrinkage during cement hydration. The second method uses poly-ethylene glycol (PEG) which reduces the evaporation of water from the surface of concrete and also helps in water retention. In the present study the first method is being adopted. The use of fly ash, blast furnace slag and silica fume in SCC reduces the dosage of superplasticizer needed to obtain similar slump flow compared to concrete mixes made with only Portland cement.

IV. EXPERIMENTAL PROGRAM

In this investigation 99-cube, 99-cylinders are tested to investigate concrete compressive strength and split tensile strength of SCC with the combination of Quarry Dust, Fly Ash and light weight aggregate. All test specimens of cube with 150 mm size and cylinders with diameter 150 mm and 300 mm in length.

V. MATERIALS USED IN THIS EXPERIMENT

1) **Cement (C)**

In this experimental study, Ordinary Portland Cement conforming to IS: 8112-1989 was used. The physical and mechanical properties of the cement used are shown in Table 1

Table-1: Properties of cement

Physical properties	Results
Fineness	2%
Normal consistency	30%
Vicat initial setting time (minutes)	30
Vicat final setting time (minutes)	205
Specific gravity	3.1

2) **Light Weight Aggregate (LWA)**

It is highly porous light weight aggregate. Its density is approximately 0.25g/cm^3. It is typically light colored and translucent bubble walls.

3) **Fly Ash**

Fly ash or pulverized fuel ash is the residue of the combustion of finely ground coal used in thermal power plants. It is removed by the dust collection system as fine particle residue from the flue gases before they are discharged into atmosphere. These micron-sized earth elements consist primarily of silica, alumina and iron. When mixed with lime and water the fly ash forms a cementations compound with properties very similar to that of Portland cement. Because of this similarity, fly ash can be used to replace a portion of cement in the concrete, providing some distinct quality advantages. Fly Ash is also known as Coal Ash, Pulverized Fuel Ash and Pozzolona. Fly Ash is the most commonly and abundantly available artificial pozzolana. Large proportion of fly ash, which is produced in India, can be advantageously used in cement and concrete. It is the most widely used pozzolonic material all over the world. The importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high performance and SCC.

4) **Aggregates**

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate (FA). Coarse aggregate (CA) of maximum 12.5 mm was used. Table-3 gives the Physical properties of fine & coarse aggregate.

5) **Super Plasticizer (SP)**

Master glenium-Ace 30(JP) from BASF Bangalore was used.

Table-2: Physical properties of fine & coarse aggregate

Property	Fine Aggregate (FA)	Coarse Aggregate (CA)
Specific gravity	2.5	2.84
Fineness modulus	3.37	7.1
Surface texture	Smooth	--
Particle shape	Rounded	Angular
Crushing value	--	17.4
Impact value	--	12.5

6) **Quarry Dust**

Basalt fines, often called quarry or rock dust are by products of the production of concrete aggregates by crushing of rocks. The addition of quarry dust to normal concrete mixes is limited because of its high fineness. The addition of quarry dust to fresh concrete increases the water demand and consequently the cement content for given workability and strength requirement however potential benefits to using quarry dust is the cost having, because the material cost varies depending on the source.

7) **Water**

Ordinary portable water is used.

VI. SCC Mix Design

Several methods exist for the mix design of SCC. We have adopted Nan-Su method.

Mixing procedure for SCC is described as follows:

- Binder and aggregates are mixed for one minute.
- The 1st part (70%) of water was added and mixed for two minute.
- SP and VMA along with 2nd part (30%) of water was added and mixed for two minutes.
- The mix was stopped and discharged for SCC tests.

Table 3 - Mixture proportion for SCC (SCCM0 – SCCM9)

SCCM0, SCCM1, SCCM2, SCCM4 are constant 10% LWA and 10%, 20%, 30%, 40% replacement of Quarry Dust respectively. SCCM5 to SCCM9 are constant 15% LWA and 10%, 20%, 30%, 40% replacement of Quarry Dust respectively.

Table-3: Details of Self Compacting and Self Curing Concrete (SCCM) and Self Compacting Concrete (SCC) Specimens Considered for Strength Parameters.

Sl no	Type of concrete	Designation	Cementitious material		Fine aggregate contents		Coarse aggregate conctents	
			Cement	**Fly Ash**	**Sand**	**Quarry Dust**	**CA**	**LWA**
1	Self Compacting Concrete	SCC	79%	21%	100%	0%	100%	0%
2	Self Compacting and Self Curing Concrete (SCCM)	SCCM0	79%	21%	100%	0%	90%	10%
3		SCCM1	79%	21%	90%	10%	90%	10%
4		SCCM2	79%	21%	80%	20%	90%	10%
5		SCCM3	79%	21%	70%	30%	90%	10%
6		SCCM4	79%	21%	60%	40%	90%	10%
7		SCCM5	79%	21%	100%	0%	85%	15%
8		SCCM6	79%	21%	90%	10%	85%	15%
9		SCCM7	79%	21%	80%	20%	85%	15%
10		SCCM8	79%	21%	70%	30%	85%	15%
11		SCCM9	79%	21%	60%	40%	85%	15%

VII. RESULT AND DISCUSSION

This chapter consists of test results and discussions on workability, compressive strength, split tensile strength Self Curing Concrete (SCCM) for different fine Aggregate (Natural Sand) and coarse aggregate (LWA) replacement levels. The test results are compared with Self Compacting Concrete (SCC).

A) Properties of Fresh state SCC

The workability is measured by flow properties as per EFNARC. The values of flow properties with constant water/binder ratio for Self compacting self curing concrete for different mixes were measured.

B) Properties of hardened SCC

The properties of hardened SCC was measured in terms of Compressive Strength obtained from Compression test confirming to IS 516-1959.Tests were conducted at different curing periods of 7, 28 and 56 days. The tensile strength is one of the basic and important properties of concrete. Hence, the tensile strength of concrete is obtained indirectly by subjecting concrete cylinders to the action of compressive force along two opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from the elastic analysis. The split tensile test is carried out as per IS: 5816-1970. The magnitude of tensile stress was evaluated using the relation $\sigma SP = 2P/\pi DL = 0.637P/DL$. The results of variation in compressive strength and tensile strength with various curing periods are as shown in table and figure.

Table-4: Compressive Strength of SCCM Concrete and SCC

Sl no	Designation	Fine aggregate contents		Coarse aggregate conctents		Average compressive strength,N/mm^2 at Different ages		
		Sand	**Quarry Dust**	**CA**	**LWA**	**7 Days**	**28 Days**	**56 Days**
1	SCC	100%	0%	100%	0%	26.8	46.4	51.2
2	SCCM0	100%	0%	90%	10%	27.2	46.6	51.7
3	SCCM1	90%	10%	90%	10%	28.1	46.8	52.3
4	SCCM2	80%	20%	90%	10%	31.0	48.1	54

5	SCCM3	70%	30%	90%	10%	32.3	50.2	54.5
6	SCCM4	60%	40%	90%	10%	32.1	50	53

Sl no	Designation	Fine aggregate contents		Coarse aggregate conctents		Average compressive strength,N/mm^2 at Different ages		
		Sand	**Quarry Dust**	**CA**	**LWA**	**7 Days**	**28 Days**	**56 Days**
1	SCC	100%	0%	100%	0%	26.8	46.4	51.2
2	SCCM5	100%	0%	85%	15%	27.3	46.8	52.7
3	SCCM1	90%	10%	85%	15%	28.5	48.0	54.1
4	SCCM2	80%	20%	85%	15%	31.8	48.6	54.8
5	SCCM3	70%	30%	85%	15%	33.3	50.8	56.1
6	SCCM4	60%	40%	85%	15%	32.7	50.0	54.1

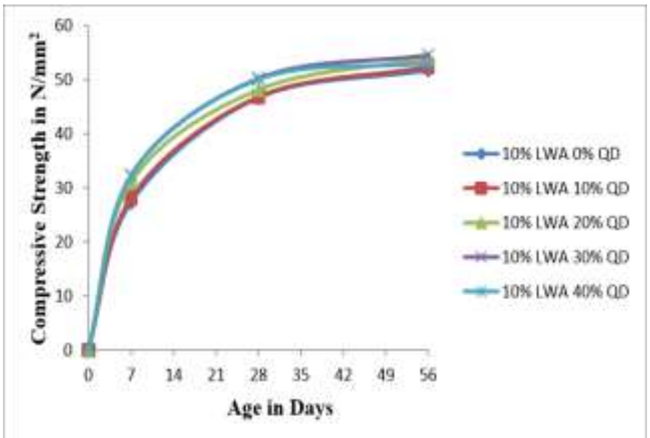

Fig-1: Compressive Strength of SCCM for all curing periods (10%LWA)

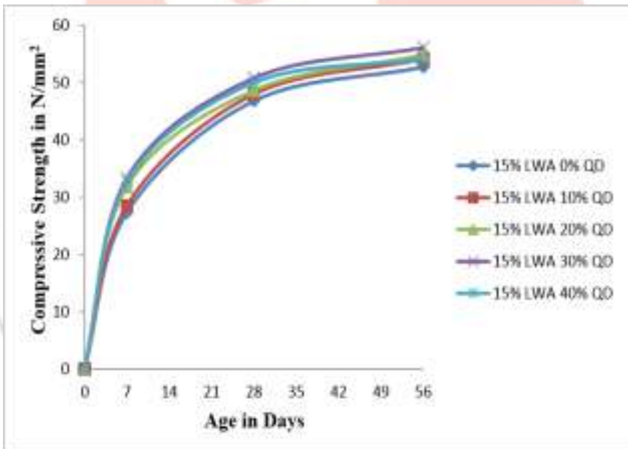

Fig-2: Compressive Strength of SCCM Concrete for all curing periods (15% LWA)

VIII. OBSERVATION AND DISCUSSION

1. By increasing the percentage of quarry dust, the compressive strength goes on increasing at all levels. The maximum strength is observed for 30% replacement of quarry dust in both cases 10% LWA and 15% LWA replacements to CA internally cured and were water sprinkled.
2. It observed that the strength increases upto 30% replacement of quarry dust. Three standard cubes each for various mixes were tested to determine 7 days, 28 days and 56 days compressive strength.
3. The increase in the compressive strength which is maximum for SCCM3 concrete is 21%, 9% ,7% at 7, 28, 56 days respectively in comparison to that of SCC (water cured) at laboratory condition.
4. The increase in the compressive strength which is maximum for SCCM8 concrete is 24%, 9% , 9% at 7, 28, 56 days respectively in comparison to that of SCC at laboratory condition.
5. The decrease in the compressive strength was generally 2-3% was observed in the compressive strength for 40% Replacement of quarry dust for SCCM9 and SCCM4 as compared to that of SCCM3 and SCCM8.
6. This shows that it is possible to use quarry dust in place of natural sand up to 40% if Cement is supplemented by the addition of fly ash and also subjected to internal curing at the point of scarcity of water and sprinkling of water by replacing with appropriate percentages of coarse aggregate with that of light weight aggregate.

7. The compressive strength substantially increased made with combination of Light Weight Aggregate and Normal Weight Aggregate.
8. The amount of increase in Compressive Strength substantially increases with increasing the portion of Normal Weight Aggregate.

Table-5: Split Tensile Strength of SCCM Concrete and SCC

Sl no	Designation	Fine aggregate contents		Coarse aggregate conctents		Average Split tensile strength,N/mm^2 at Different ages		
		Sand	**Quarry Dust**	**CA**	**LWA**	**7 Days**	**28 Days**	**56 Days**
1	SCC	100%	0%	100%	0%	2.6	3.2	3.9
2	SCCM0	100%	0%	90%	10%	2.63	3.27	3.92
3	SCCM1	90%	10%	90%	10%	2.68	3.30	4.0
4	SCCM2	80%	20%	90%	10%	2.71	3.48	4.14
5	SCCM3	70%	30%	90%	10%	2.8	3.61	4.20
6	SCCM4	60%	40%	90%	10%	2.69	3.60	4.19

Sl no	Designation	Fine aggregate contents		Coarse aggregate conctents		Average Split Tesnsile strength,N/mm^2 at Different ages		
		Sand	**Quarry Dust**	**CA**	**LWA**	**7 Days**	**28 Days**	**56 Days**
1	SCC	100%	0%	100%	0%	2.6	3.2	3.9
2	SCCM5	100%	0%	85%	15%	2.71	3.43	3.93
3	SCCM1	90%	10%	85%	15%	2.77	3.47	4.13
4	SCCM2	80%	20%	85%	15%	2.83	3.60	4.23
5	SCCM3	70%	30%	85%	15%	2.87	3.66	4.27
6	SCCM4	60%	40%	85%	15%	2.81	3.60	4.20

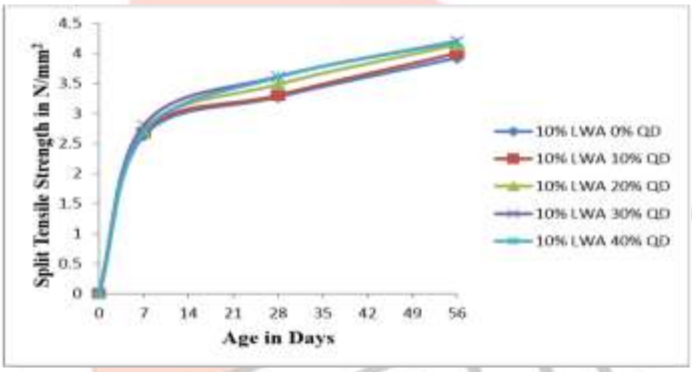

Fig-3: Split Tensile Strength of SCCM for all curing periods (10% LWA)

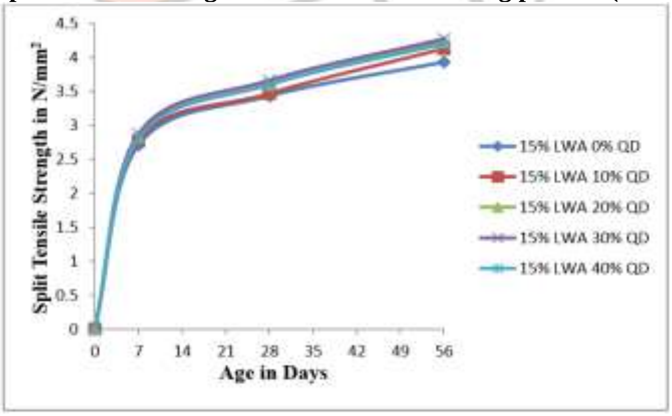

Fig-4: Split Tensile Strength of SCCM for all curing periods (15% LWA)

IX. OBSERVATION AND DISCUSSION

1. By increasing the percentage of quarry dust, the split tensile strength goes on increasing at all levels. The maximum strength is observed for 30% replacement of quarry dust in both cases 10% LWA and 15% LWA replacement to CA.
2. It can be seen that strength increases upto 30% replacement of quarry dust. Three standard cubes each for various mixes were tested to determine 7 days, 28 days and 56 days split tensile strength.
3. The increase in the split tensile strength which is maximum for SCCM3 concrete is 7%, 13% ,8% at 7, 28, 56 days respectively in comparison to that of SCC for 10% coarse aggregate replaced by LWA subjected to internal curing at laboratory condition.

4. The increase in the split tensile strength which is maximum for SCCM8 concrete is 10%, 15% , 10% at 7, 28, 56 days respectively in comparison to that of SCC for 15% coarse aggregate replaced by LWA subjected to internal curing at laboratory condition.
5. This shows that it is possible to use quarry dust in place of natural sand if Cement is supplemented by the addition of fly ash.
6. The decrease in the split tensile strength was generally 2-3% was observed in the Split tensile strength for 40% Replacement of quarry dust for SCCM9 and SCCM4 as compared to that of SCCM3 and SCCM8.
7. This shows that it is possible to use quarry dust in place of natural sand upto 30% if cement is supplemented by the addition of fly ash and also subjected to internal curing at the point of scarcity of water and sprinkling of water by replacing with appropriate percentages of coarse aggregate with that of Light Weight Aggregate.
8. The split tensile strength substantially increased made with combination of Light Weight Aggregate and Normal Weight Aggregate.
9. The amount of increase in split tensile strength substantially increases with increasing the portion of Normal Weight Aggregate.

X. CONCLUSION

The study examine the properties of freshly poured Self Compacting Concrete with fixed water cement ratio of 0.45 in which cement is added with fly ash and natural sand replaced by various percentage quarry dust in weight ratios of 0, 10, 20, 30, 40% the following observations are made:

1. The fresh properties of SCCM mixes in terms of passing ability, filling ability and segregation containing different proportions of quarry dust and light weight aggregate formed that the values are within the limits prescribed by EFNARC.
2. The results showed that the slump flow varied with replacement ratio of quarry dust for natural sand and LWA.
3. The average compressive strength of SCCM having 30% quarry dust for both 10% LWA and 15% LWA internally cured as compared to SCC water cured was increased by 9% for 28 days.
4. The average split tensile strength of SCCM having 30% quarry dust for both 10% LWA and 15% LWA internally cured as compared to SCC water cured was increased by 13% and 15% for 28 days .
5. It is been indicated that SCCM mixes at all replacement levels of quarry dust has higher compressive strength and split tensile strength subjected to internal curing with addition filler material fly ash.
6. Hence it is possible to successively utilize waste quarry dust and fly ash for replacement of natural sand and at point of scarcity of water may be subjected to self-curing by proper replacement of LWA due to its absorbed mechanical advantages.
7. The employment of waste mineral admixture and by self curing improved the economic feasibility of SCC production on a unit strength basis.

XI. REFERENCES

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