Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 100 (2016) 43816-43821

ISSN: 2229-712X

An experimental study on self compacting concrete by the replacement of fine aggregate with quary dust

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ARTICLE INFO

Article history:
Received: 24 October 2016;
Received in revised form:
19 November 2016;
Accepted: 29 November 2016;

Keywords
Self-Compacting Concrete,
Quarry Dust,
Fly Ash,
Silica Fume.

ABSTRACT
This study introduces a test examination on self-compacting concrete (SCC) with fine total (sand) substitution of a Quarry Dust (QD) (0%, 25%, half, 75%,100%) and expansion of mineral admixtures like Fly Ash (FA) and Silica Fume (SF) and synthetic admixtures like super plasticizers (SP). After every blend arrangement, 45 3D shapes examples and 45 chambers examples are thrown and cured. The examples are cured in water for 3, 7 and 28 days. The droop, V-channel and L-Box test are done on the new SCC and in solidify concrete compressive quality and split elasticity qualities are resolved. Endeavors have been made to examine the properties of such SCCs and to explore the appropriateness of Quarry Dust to be utilized as fractional trade materials for sand in SCC.

1. Introduction

Solid that streams and settles because of its own weight without isolation and draining are called Self-Compacting Concrete (SCC). As of late SCC has increased more extensive applications as it diminishes the day and age of development. It can fill the congested formwork of fortification without the utilization of outside vibrator SCC has a few focal points over Normally Vibrated Concrete (NVC). It can stream effortlessly in congested support at bar section intersections. SCC enhances the sturdiness of solid structures.

In SCC, no vibration is required for the compaction. It streams like "Nectar" and subsequent to setting it has an extremely smooth surface. SCC and NVC comprises of a similar constituent components to be specific concrete, totals and water, with the expansion of compound and mineral admixtures in changing extents. SCC blends typically contains super plasticizer in type of high range water reducer (HRWR) and consistency altering added substance (VMA). In the SCC utilization of super plasticizers (HRWR) keeps up the ease; VMA gives strength of the blend, bringing about high resistance against dying.

Quarry cleans are frequently alluded to as quarry or shake tidy, a by-item in the generation of solid totals amid the devastating procedure of rocks. This buildup for the most part speaks to short of what one percent of aggregate total creation. In typical solid, it would build the water request and thusly the bond content for given workability and quality prerequisites. In this manner, the effective use of quarry tidy and fly fiery debris in SCC could transform this waste material into a significant asset.

This paper will cover the usage of quarry clean as a major aspect of the fine total and gives perception on its similarity with super plasticizers and fly fiery debris in SCC blends.

II. Problem Definition and Goal

Get a blend extent for SCC utilizing quarry clean as an incomplete substitution to Natural fine total (NFA).

To concentrate on the consolidated results of utilizing quarry tidy and Fly Ash in such SCCs.

To ponder the workability and quality attributes of SCC by utilizing quarry clean as incomplete substitution of fine total and fly powder for bond.

This paper will show data viewing impact of quarry clean as incomplete trade for fine total on the workability and quality improvement of different Fly Ash adjusted SCC blends.

The current test examination on Self Compacting Concrete will show the likelihood of utilizing stone crusher squander/Quarry Rock Dust as incomplete substitution for regular fine total in the SCCs blend. The extents of the study are as per the following:-

1. To study the effectiveness of paritial replacement of fine aggregate in SCC. The quarry dust to be utilized as partial replacement has been taken from local availability.
2. The study involved using experiments related to the workability and strength of concrete cube, cylinder and prisms.
3. All the experiments in this study focused on laboratory experiment. The effectiveness of the use of quarry dust is based on the replacement percentage of Quarry waste with river sand.

III. Literature Survey

Vast quantities of wastes are generated from aggregate quarrying industry. Some of these quarry wastes have been used to serve different purposes. The most common use is in the construction of highways and roads.

"Celik, T. and K. Marar (1996)[1]" Reported the effects of partial replacement of fine aggregate with crushed stone dust (particle size less than 75 microns), it was observed that slump value decreased as the percentage of dust content increased. Also for higher dust contents, the compressive strength, flexural strength, and impact resistance decreased gradually where as absorption increased.

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The use of quarry sand is generally limited due to the high cement paste volume needed to obtain an adequate workability. The amount of additional paste content depends on texture, shape, grading, and dust content of the sand. The increase of water demand of concrete mixtures produced by the adverse effects of texture and shape of quarry sand can be minimized by using a HRWR.

"Nagaraj and Zahida Banu[8] (1996)" produced concrete using rock dust as a substitute to natural sand. They studied the consequence of rock dust on the strength and workability of concrete. They have examined the effect of replacement of fine aggregate in cement concrete by quarry dust and manufactured sand. It was observed that sand and 50% quarry dust combination gives higher strength when compared than the conventional concrete due to the sharp edges of stone providing stronger bond with cement compared to the rounded shape of ordinary sand.

"Ho et al [3] (2002)" He utilized quarry dust in SCC. They used quarry dust as a partial replacement of cementing material. Limited research has been conducted in the area of flowing concretes incorporating quarry waste as a partial or full replacement to river sand. Researchers and investigators have shown keen interest in using quarry dust as fine aggregate in concrete.

Naidu et al (2003a) [9] Naidu et al (2003a) have conducted an experimental study to examine the behavior of partial replacement of river sand with quarry waste in the compressive strength and pull-out force of concrete. Four types of concrete, with two water-binder ratios of 0.40 and 0.45 were undertaken in this study. Replacement proportion of 20% natural sand with quarry waste was practiced in all the concretes except in the controlled concrete mix.

All concretes were cured by dry air in the curing room at 20ºC, and their compressive strength and pull-out force were measured on the 7th, 14th, 28th and 56th day. Test results indicate that concrete incorporating quarry dust and without the inclusion any mineral admixture exhibited a lower compressive strength but a higher pull-out force than the controlled concrete at all ages.

Khatib[5] 2004 concluded that when fine recycled aggregates was used as a partial replacement to natural fine aggregates in concrete and when the free water/cement ratio was kept constant for all the mixes, the 28-day strength of the concrete developed at a slower rate as compared to reference mix.

Raman et al[10] (2005) reported on the effect of quarry waste as partial replacement to natural sand along with mineral admixtures in concrete.The study indicated that 20% partial replacement of natural fine aggregate with quarry dust can be utilized in concrete mixes.

III. Proposed Work

The methodology adopted for the study achieves the objectives and aim of work as described.

The use of stone crusher waste as partial replacement of fine aggregate on the Flow –ability and strength characteristics of fly ash based self compacting concrete will be investigated. The mixing procedure for the SCC will be as per IS 10262-2009.

The experimental work planned in this investigation consisted of mix proportioning of M40 grade fly ash induced self compacting concrete with quarry dust. The use of mineral admixture is as per the recommendation provided by EFNARC. The methodology adopted for experimental work includes

- Mix proportioning for SCC to achieve high flow ability without segregation and bleeding using chemical admixture and fly ash.
- Quarry dust as fine aggregate will be used, in different dosages to study the flow ability and strength of the mix proportions.
- Slump flow test, V-Funnel test and L-Box test will be conducted to find out the ability to pass, ability to fill and resistance to segregation of SCC.
- The test results will be compared with the limits of European standards recommended by EFNARC.
- Hardened concrete tests will be conducted to determine the strength characteristics of SCC.

Engineering Properties for Scc

SCC and traditional vibrated concrete of similar compressive strength have comparable properties and if there are differences, these are usually covered by the safe assumptions on which the design codes are based.

Tests Requirments For Scc

The main characteristics of SCC are the properties in the fresh state. The mix design is focused on the ability to flow under its own weight without vibration, the ability to flow through heavily congested reinforcement under its own weight, and the ability to retain homogeneity without segregation. SCC can be designed to fulfill the requirements regarding density, strength development, final strength and durability. Due to the high content of powder, SCC may show more plastic shrinkage or creep than ordinary concrete mixes. These aspects should therefore be considered during designing and specifying SCC. Special care should also be taken to begin curing the concrete as early as possible.

The concrete mix can only be classified as SCC, if it has the following characterized:

1. Filling Ability

The ability of fresh concrete to flow into mould and fill all spaces within the formwork, under its own weight.

2. Passing Ability

The capacity of the fresh mix to flow through confined spaces and narrow openings such as areas of congested reinforcement without segregation, loss of uniformity or causing blockings. In defining the passing ability, it is necessary to consider the geometry and density of the reinforcement, the flow ability/filling ability and the maximum aggregate size. The defining dimension is the smallest gap (confinement gap) through which SCC has to continuously flow to fill the formwork. This gap is usually but not always related to the reinforcement spacing.

3. Segregation Resistance

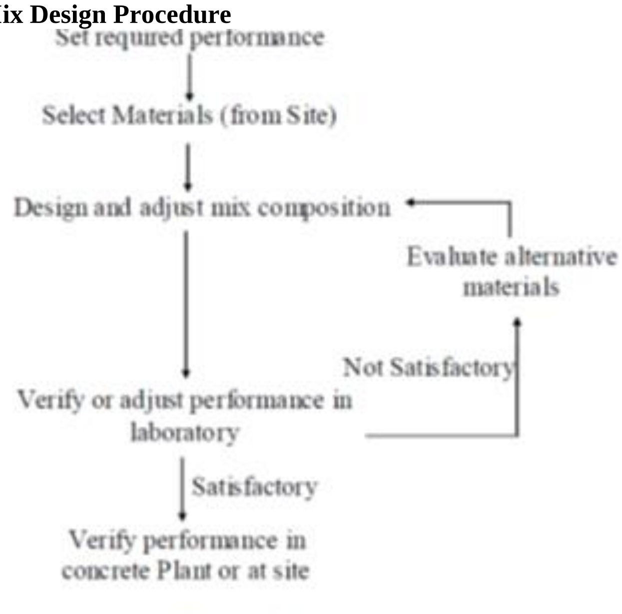
Segregation resistance is fundamental for SCC in-situ homogeneity and quality in composition while in its fresh state. SCC can suffer from segregation during placing and also after placing but before stiffening. Segregation which occurs after placing will be most detrimental in tall elements but even in thin slabs, it can lead to surface defects such as cracking or a weak surface. A concrete mix can only be classified as SCC if the requirements for all three characteristics are fulfilled.

In the event that satisfactory performance cannot be obtained, then consideration should be given to fundamental redesign of the mix.

IV. Experimental Setup

Since concrete is a three phase system containing volume of solid, volume of water and volume of air, it is mixture of so many heterogeneous material like coarse aggregate, fine aggregate, mineral admixture, chemical admixture, cement and water. Establishing a rational mix proportioning of the above mentioned material is the main aim to achieve SCC.

Mix Design Procedure



Mix design selection and adjustment

In the event that satisfactory performance cannot be obtained, then consideration should be given to fundamental redesign of the mix.

Six mixes with partial replacement of quarry dust for fine aggregates were prepared. In all fifty four cube samples of fly ash induced self compacting concrete with six different weight percentages of quarry dust (0%, 10%, 20%, 30%, 40%, and 50%) were cast to study the effect on compressive strength at 3,7, 28 days. The various flow-ability tests on SCC are stipulated as per standards mentioned in EFNARC. Further, thirty six cylindrical and prism specimen of fly ash induced self compacting concrete with six different weight percentages of quarry dust (0%, 10%, 20%, 30%, 40% and 50%) were cast to study the split tensile strength and flexural strength of fly ash induced self compacting concrete. The experimental investigation and the test procedure adopted to study the performance of fly ash induced self compacting concrete with Quarry Dust as Fine Aggregate will now be described in detail.

Material Properties

The materials used for the experimental program are cement, river sand, coarse aggregate, quarry dust, fly ash, super plasticizer and water were locally available at the institute vide the construction agencies working in the institute. The succeeding subsections describes in detail about the materials used.

Cement

The Cement used was Jaypee Ordinary Portland Cement (OPC) of grade 43 conforming to IS: 8112-1989. The various laboratory tests confirming to IS: 4031-1996 (PART 1 to 15) specification was carried out and the physical properties were found as such:

Fly Ash as Cementesious Material

Fly ash samples (fig 1) taken from NTPC Visakhapatnam is used in this study. Fly ash was not processed and, used as received. The sample satisfied the requirements of IS 3812(Part I).

Table 1. Physical properties of cement.

Sl no.	Physical Properties	Observed values for cement
1	Specific Gravity	3.15
2	Initial Setting (minutes)	30 min
3	Final Setting (minutes)	600 min
4	Consistency (%)	30%
5	Fineness %	2.56

Fig 1.Fly ash sample.

Table 2. physical properties of fly ash

Sl no.	Physical Properties	Observed values for fly ash
1	Specific Gravity	2.2
2	Initial Setting(minutes)	45 min
3	Final Setting(minutes)	280 min
4	Consistency (%)	35
5	Fineness	3.68

Fine Aggrigates

The Fine Aggregate used in this project is natural river sand. Following are the physical properties of the river sand.

Table 3. characteristics of Fine aggregate

Property	value
Specific gravity	2.63
Fineness modulus	2.60
Water absorption	2.56

Quarry Dust

Table 4. Characteristics of Quarry dust

Specific gravity	2.75
Water absorption	0.85%

Fig 2. Quarry dust sample

COARSE AGGREGATE

Locally available crushed stone with 20 mm graded size have been used as coarse aggregate. The physical properties for the coarse aggregate as found through laboratory test are

Table 5. characteristics of Coarse aggregate

Test property	Natural coarse aggregate
Specific gravity	2.87
Water absorption	0.25%
Aggregate crushing (%)	24
Aggregate impact (%)	29

Chemical Admixtures

Polycarboxylic ether based super plasticizer with viscosity modified admixture supplied by BASF India limited with a brand name of MasterGlenium SKY 8630/8632 (fig: 4.3) was used in the present research work. Master Glenium SKY 8630/8632 is an admixture of a new generation based on modified Polycarboxylic ether which produces Smart Dynamic Concrete/ Self Compacting Concrete with inbuilt Viscosity Modifying admixture. The properties as obtained from the manufacturer are shown in table below

Table 6. Chemical properties.

Aspect	Light brown liquid
Relative density	1.08 ± 0.01 at 25ºC
pH	≥ 6 at 25ºC
Chloride ion content	< 0.2%

Fig 3.Chemical admixtures

V. Test Results.

Six mixes with partial replacement of standard sand with quarry dust were prepared. For all SCCs mixes the fly ash percentage replacement to cement was fixed at 30% by weight of cement.

In all fifty four cube samples of fly ash induced self compacting concrete with six different weight percentages of quarry dust (0%, 10%, 20%, 30%, 40%,and 50%) were cast to study the effect on compressive strength at 3,7,28days. The various flow ability tests on SCC are stipulated as per standards mentioned in EFNARC.

Further, thirty six cylindrical specimen and thirty six prisms of fly ash induced

Self compacting concrete with six different weight percentages of quarry dust (0%, 10%, 20%, 30%, 40%, and 50%) were cast to study the cylindrical compressive strength and split tensile strength of fly ash induced self compacting concrete.

The results herein will be used to study the various properties of SCCs mixes with quarry dust.

Fifty four cube samples, thirty six cylindrical specimens and thirty six prisms for M40 grade of fly ash induced SCC have been tested in laboratory. All the specimens were cast with fly ash percentage replacement to cement at 30% by weight of cement. Further, the water to powder ratio for all mixes were maintained at 0.36. Super plasticizer dosage for all the mixes were 2.2% by weight of cement. A comparative study is carried out to study the effect of quarry dust on properties of SCC. Four properties of concrete namely flow ability, compressive strength, and split tensile strength has been selected for study.

WORKABILITY TEST RESULTS

Workability is the primary requirement of SCC. The various aspects of workability characteristic are

- Flow ability.
- viscosity
- passing ability and
- segregation resistance

The various flow ability tests conducted in lab where as per EFNARC (2002) and the
test conducted were Slump Flow Test, L-Box Test and V-Funnel Test.

The results of the slump flow tests of fly ash induced SCC with quarry dust as fine aggregate are presented in table 7 and comparative study with varying percentage of quarry dust is shown graphically in fig 4

Table 7. Workability test Results.

Mix no	% QD	slump flow test (t in sec)		L value(h_2/h_1)	v (t in sec)
		500mm	700 mm		
1	0	2	4	0.8	10.8
2	10	2.2	6	0.8	10.6
3	20	3	8.6	0.8	10.5
4	30	1.6	7.8	0.96	8
5	40	2.4	11.5	0.8	9
6	50	2	9	0.86	10

The slump flow varied between the ranges of 650 – 725 mm. A minimum slump flow of 650 mm is generally recommended for SCC.

The effect of Quarry dust on the flow ability of SCC is evident from figure 4. This shows that, at 30% replacement of fine aggregate by quarry dust the time of flow in slump flow test and in V Funnel test was observed to be minimum.

The lower results at higher percentage of recycled fine aggregate is attributed to the fact that, there is reduction in the free water content in the SCC mix due to high water absorption of quarry dust. In all the six SCCs mixes, No segregation and bleeding were observed.

However all the three flow ability tests were within the acceptable limits of EFNARC (2002). Moreover, the fresh concrete properties obtained from slump flow, V-funnel test, L-box provided the same trend for all SCC mixes.

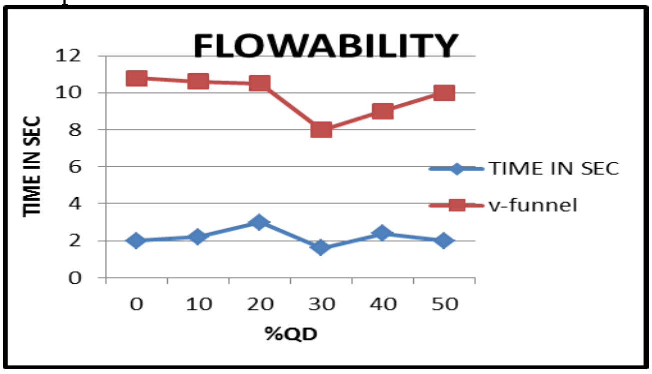


Fig 4. Flow ability results.

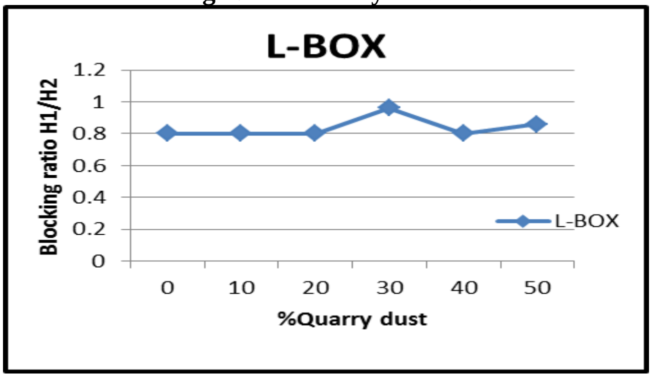


Fig .5 %QD (vs) Blocking ratio.

Compressive Strength Test Results

Cube specimens prepared for compressive strength were tested in laboratory and different crushing strengths were found which are substantiated in table 8. The results of cube compressive strength test are also shown graphically in fig 6

Table 8. Compressive Test Result.

Mix no	% QD	Compressive strength(Mpa)		
		3days	7days	28days
1	0	13.71	20.57	42.86
2	10	14.63	21.51	43.02
3	20	15.71	22.7	43.65
4	30	17.32	25.28	46.82
5	40	15.20	22.79	44.68
6	50	14.46	21.47	43.83

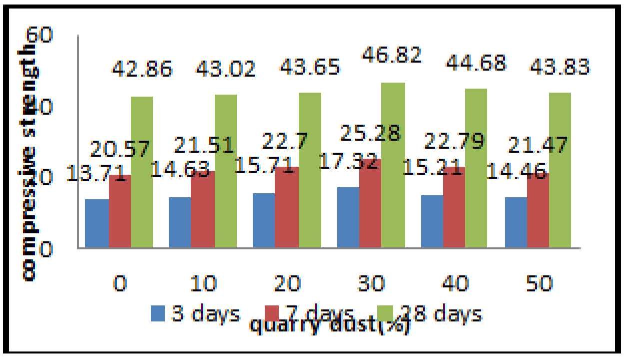


Fig 6. Compressive strength

Examining the strength at 28 days age it can be seen that increasing the quarry dust content from 0% to 20 % has caused increase in compressive strength by 2% as compared to reference mix.

But when the quarry dust replacement was increased to 30%, the compressive strength increase was almost 10%.An increase in quarry dust content from 30% to 50% reduced the compressive strength by 8% when compared to 30% replacement of quarry dust with river sand. This may be accredited to the fact that the surface area of the recycled fine aggregates requires more cement than natural fine aggregate to cover the surface. Further increase in percentage replacement of quarry dust with river sand resulted in remarkable loss in compressive strength

Split Tensile Strength Test Results

The splitting-tensile strength of concrete is an important mechanical property that greatly affects the size and extent of tension related failure behavior, such as flexural cracking in beams.

The cylinder specimens were tested for split tensile strength at an age of 28 days. According to IS-5816-1999 Split Tensile Strength of Concrete method of Test, the tensile strength was determined. The splitting-tensile strength of concrete is an important mechanical property that greatly affects the size and extent of tension related behavior, such as flexural cracking in beams.

Table 9. Split Tensile Test Result.

Mix no	% QD	Split Tensile strength		
		3days	7days	28days
1	0	1	1.5	3.14
2	10	1.09	1.62	3.22
3	20	1.19	1.71	3.29
4	30	1.25	1.85	3.43
5	40	1.27	1.87	3.71
6	50	1.29	1.88	3.62

Fig. 7 shows the 3,7,28 days splitting tensile strengths of the SCC specimens. It can be observed that the values of cylinder splitting-strength range between 3 and 4 Mpa, From Fig. 8, it is clear that the splitting-tensile strengths of quarry dust SCC mixtures are increasing. The increase was almost 10% at 30% replacement while it was almost 15% at about 50% replacement.

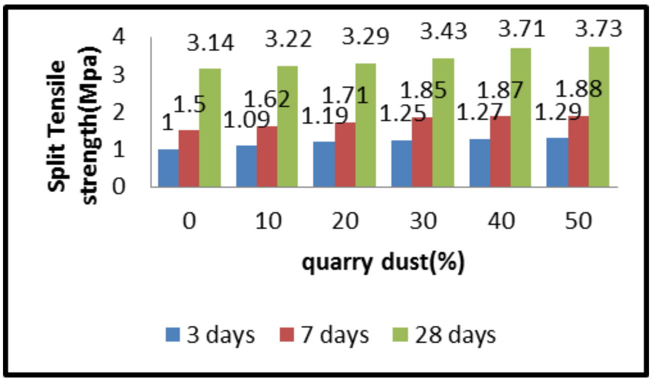


Fig 8 split tensile strength

After assessing the evaluated results of both compressive strength and split tensile strength it is found that the rate of increase in compressive stress is less as compared to the split tensile strength

This may be accredited to the fact that the particles of quarry dust are sharp edged which help in providing better bond with cement and thus resulting in resulting in higher strength.

Flexural Strength Test Results

Prisms were prepared for flexural strength was tested in laboratory and different flexural strengths were found which are substantiated in table 10. The results of prisms flexural strength test are also shown graphically in fig 9.

Table 10. Flexural Test Result.

Mix no	% QD	Flexural strength(Mpa)		
		3days	7days	28days
1	0	2.6	4.58	5.7
2	10	2.9	4.7	5.85
3	20	3.21	4.9	5.90
4	30	3.4	5.28	6.20
5	40	3.2	5.10	6.10
6	50	3.1	4.92	5.9

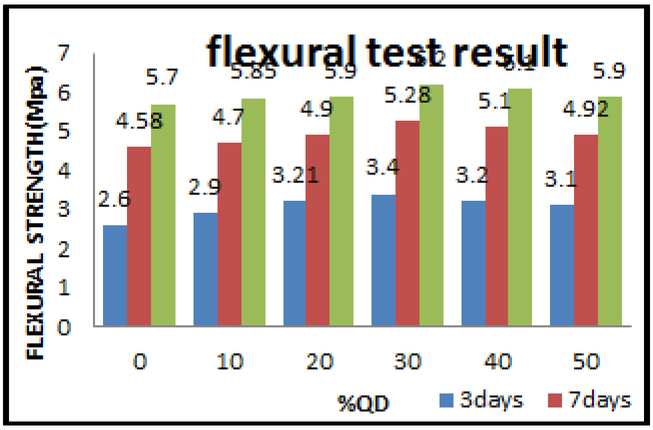


Fig 9. flexural strength.

Examining the strength at 28 days age it can be seen that increasing the quarry dust content from 0% to 20 % has caused increase in flexural strength by 3% as compared to reference mix.

But when the quarry dust replacement was increased to 30%, the flexural strength increase was almost 8-9%. An increase in quarry dust content from 30% to 50% reduced the flexural strength by 5% when compared to 30% replacement of quarry dust with river sand.

Further increase in percentage replacement of quarry dust with river sand resulted in remarkable loss in flexural strength.

VIII. Conclusion

- The slump flow varied between the ranges of 650-725mm. At 30% partial replacement of fine aggregate by quarry dust minimum flow time of 1.6sec and 8 sec was observed in slump flow and v-funnel test respectively.
- However all the three workability tests were within the acceptable limits of EFNARC.
- For compressive strength test with increase in percentage partial replacement of fine aggregate with quarry dust at 10%, 20% and 30%, observed the increase in compressive strength by 1%, 2% and 8% respectively. Further with increase in percentage partial replacement of fine aggregate with QD at 30 to 40% and 30 to 50% decreased the strength gradually by 5% and 7% respectively.
- Similarly in case of split tensile test with increase in percentage partial replacement of FA with QD at 10%, 20%, 30%, 40% increased the strength by 2%, 4%, 8%, 15% respectively. Further with increase in partial replacement from 40 to 50% has decreased the strength by 2%.
- Similarly for flexural strength test increase in strength by 2%, 3% and 8% are observed with increase in partial replacement of FA with QD at 10%, 20% and 30% respectively. Further with increase in partial replacement from 30% to 40% and 30 to50% has decreased the strength by 2% and 5% respectively.
- From all the results and points discussed above it can be concluded that the fly ash and quarry dust replacement showed the desirable results that can suggest the usage of the quarry dust as replacement of sand.
- From overall view it can also be concluded that the partial replacement of quarry dust beyond 30%, there will be decrease in the compressive strength and flexural strength values of cube and prism specimens where as in case of split tensile test decrease in strength is observed with partial replacement of FA by QD beyond 40%.

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