Behaviour of Self-Compacting Concrete at Various Levels of Replacement to Fine Aggregate by Pond Ash and Quarry Dust

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Abstract: ***Self-compacting concrete has gained high demand in construction practices. Currently the problems faced in production of concrete includes high demand of cement, cost of cement and concrete making materials, pollution, excessive extraction of natural river sand etc. Because the sand is being extensively extracted from the river bed deposits, it is depleting at a faster rate, hence it is necessary to find an alternative material such as pond ash thermal power plant waste and waste from the stone quarries like quarry dust in the SCC production. This dissertation work deals with the study of partial replacement of natural fine aggregate by pond ash and quarry dust for achieving free flowing characteristics of concrete by using specially formulated super plasticizer. Mix design is done at replacement levels of 0 to 30% (at an interval of 10%) by keeping cementatious content constant as 500kg/m3 and water content 200liters. The main objective of the research work is to determine the optimum percentage replacement of fine aggregate by pond ash and quarry dust in production of SCC. For this study two SCC mixes were prepared (PQSCC20, PQSCC30) and were compared with normal self-compacting concrete (NSCC00). Fresh properties of these mixes were studied by conducting T-Slump, T500mm-slump, L-Box, U-Box, V-funnel & V5min-Funnel test according to EFNARC guidelines. Hardened properties of the mixes were studied by conducting compressive strength test & split tensile strength test. Water absorption properties of the mixes were studied by weight test. 20% replacement to fine aggregate by pond ash and quarry dust was found to be optimum. Fresh properties of all the mixes were satisfying according to EFNARC specifications. Compressive strength and split tensile strength of PQSCC20 was found to be 35.85N/mm2 and 3.09N/mm2 respectively for 28 days. Water absorption of PQSCC20 was found to be less than limiting value (0.5).***

Keywords: self-compacting concrete, fly ash, pond ash, quarry dust, admixture, etc

1. Introduction

Self-compacting concrete (SCC)

Self-compacting concrete (SCC) does not require vibration and compaction while placing of concrete. SCC was first developed in Japan(1980) and popular in 2000 while SCC is used in prefabricated products, and ready mixed concrete (RMC).SCC refers rapid rate of concrete placement, so it takes lesser construction time and easy to flow congested reinforcement. SCC having higher strength because of less concrete voids and high level of homogeneity. It gives early strength for providing low water-cement ratio and earlier demoulding.SCC is suitable for where the availability of skilled labour is less, congested areas, lack of compaction and curing and high strength required for structures. Superplasticizer provides to achieve passing and filling ability in SCC. SCMs (supplementary cementing material) fly ash, silica fume, GGBS, these are improves the strength and durability properties in SCC.Self-compactability mainly affected by mix proportions and material characteristics, so standard mix design procedure will required for SCC. The benefits of SCC over normal concrete (NVC) is more, it reduces the labour requirement, transportation, placement and vibration. SCC does not need any vibrators it reduces the noise level, energy consumption and gives better form work, better aesthetic views with good surface finishing.

Fly ash

Fly ash is residue of coal combustion collected from electrostatic precipitator. It is pozzolanic or mineral admixture and widely used all over world. Now a day's fly ash is common ingredient in concrete, for making of high strength and greater performance of concrete. Its benefits are not only for properties of concrete that also for minimizes the environmental pollution. The fly ash particles are spherical form and this type of particles reduces water demand and improves the flowability.

Classification of fly ash
Class F: It is produced by burning of bituminous coal, in this type calcium oxide (CaO) content is less than 5% and this class having pozzolanic characteristics only.
Class C: It is occurred by burning of sub-bituminous coal, calcium oxide (CaO) content is greater than 10% and its having pozzolanic and cementatious properties.

Pond ash:

Pond ash is also residue of coal combustion collected from bottom precipitator. The coal ash waste is in the form of coarse granulated is called pond ash and its colour is grayish-black. Particle size is 1 micron to 600 micron. While using of pond ash as partial replacement with sand pond ash gradation shoud meet with zone 4 requirements of fine aggregate.In concrete the second largest consumed material is fine aggregate (sand). Now a day's the availability of sand is decreases so using partial replacement of sand by pond ash and leave aggregates for future generation.

Quarry dust:

It is the by- product of granite rocks, produced while processing granite stones which are broken down in the form of coarse aggregates at different sizes. QD increases deformability and passing ability of fresh state concrete in SCC. It reduces the fine aggregate requirement also reduces the environmental problems. Quarry dust is used for building materials like tiles, light weight aggregate, bricks, autoclave blocks etc. QD is mainly used in highways as a surface finishing material. Additional dosage of quarry dust requires more water, least permeability it affects the workability of concrete.

2. Literature Review

S.M.Waysal, *et al.*,[1] (May 2014),in their paper entitled "Effect on Concrete Properties By Replacement of Sand as Pond Ash", International Journal of Strucural& Civil engineering Research. (IJSCER) ISSN: 2319-6009 Volm3, No2,. Here he studied the pond ash as partial replacement with fine aggregate in self-compacting concrete, and this paper shows sand is replaced by pond ash at (0,20,40,60,80, and 100)% by weight.. And they used BV plasticizer of dosage 0.21% to 0.25%. They determined compressive strength at 7,28,56 days. In this 0 to 100% replacement of sand the optimum percentage was found up to 40% replacement of sand by pond ash. The compressive strength of 7,28,56 day's are observed that 20% of sand replacement is increases the compressive strength compared to normal self-compacting concrete, but compressive strength decreases with increasing in pond ash replacement up to 40 to 100% replacement. And they conclude that in initial period the pond ash gets slower strength, about 40% replacement of pond ash with sand increases in split tensile strength for remaining replacement will be decreases the split tensile strength.

K. S. Johnsirani, *et al.*,[2] (June 2013), in their paper entitled "Experimental Investigation on SCC Using Quarry dust", Here they studied the quarry dust as partial replacement with fine aggregate at (0,25,50,75 and 100)% , and they used mineral admixture like fly ash. And each mixes prepared 45 cubes and 45 cylinder's casted and cured. Tests are conducted for determining fresh and hardened properties of SCC. Here they conclude use of mineral admixture like fly ash is avoids the requirement of VMA (viscosity modifying agent). New generation of super plasticizers reduces the cost of VMA. In this SCC0%, SCC25%, and SCC50% with w/c ratio of 0.4% gives good results in fresh state and these are within the limits, above this quarry dust increases the water demand because quarry dust is high fineness. SCC 25% series shows good performance in both fresh and hardened properties after conducted test on hardened properties at (3,7,28 day's). Greater than 25% replacement of quarry dust with sand this will be decreases the strength criteria.

Abdul Razak.B.H, *et al.*,[3] (NOV 2015) in their paper entitled "Impact of Quarry dust and Fly ash on the Fresh and Hardened Properties of Self Compacting Concrete",studied the importance of fly ash is used as a pozzolanic material as partial replacement to cement. Quarry dust is used for partial replacement with sand, in this study to investigate partial replacement of fine aggregate by quarry dust in various percentages and also the effect of partial replacement of cement by fly ash at the time of preparation of SCC. Coarse aggregate of size 20mm maximum size and minimum powder content up to 400kg/m^3 without VMA is used. Super plasticizer (poly carbolic ether) is used to obtain SCC properties in fresh state. Here the results shows 20% partial replacement of fly ash with cement it shows the similar result as that of concrete with no fly ash addition.

RatchayutKasemchaisiri, *et al.*,[4] in their paper entitled "Properties of Self Compacting Concrete Bottom ash As a Partial Replacement of Fine Aggregate" here they studied that bottom ash replacement with normal sand at (0,10,20 and 30)% by weight. In this paper water to powder ratio is fixed to 0.31, in this bottom ash properties are comparing with test results of self-compacting concrete mixed with control manner of both bottom ash and river sand. Here experimental results shows that L-box passing ability and slump flow of the self-compacting concrete with bottom ash reduced. At 10% replacement of bottom ash with fine aggregate improves the 56 day's compressive strength due to pore refinement effect and also increases the porosity. The durability properties are good at 10% replacement of bottom ash with fine aggregate as compare to control self-compacting concrete due to higher porosity.

Bharati Ganesh, *et al.*,[5] in their paper entitled"Rheology Of SCC With Pond Ash As Partial Replacement To Fine Aggregate"here theystudied the pond ash is partial replacement with fine aggregate in SCC, in this the cementatious content is taken as 400kg/m^3, pond ash replacement levels are (0,10,20,30,40,50)% by weight. In this paper they concluded it is able to obtain SCC mixes, replacing sand by pond ash up to 50% satisfies the rheological specifications as per EFNARC. Important observation made in the experiment work that is dia of SCC gradually increased only up to 20% replacement level of sand by pond ash. But comparing to normal SCC the rheological properties are good and satisfies up to 20% replacement of sand by pond ash. The 30% replacement gives variation of strength to nearly 10% for the cementitious content. A 50% replacement of pond ash reduces the strength up to 25% in SCC at low cementitious content of 400kg/m^3, because of additional water added forconcrete due to absorption of pond ash, and water drained out later because of self draining property of pond ash.

MohdHaziman Wan Ibrahim, *et al.*,[6] (FEB 2016) in their paper entitled "Bottom ash is Potential Use in Self Compacting Concrete As Fine Aggregate"here they studied the potential use of bottom ash as replacement with fine aggregate in the production of mortar and concrete. They studied different characteristics of bottom ash and then effective utilization of bottom ash in construction industry and promoting green culture and good development. Researchers concluded that overall study about bottom ash the previous paper shows the effective use of bottom ash as partially or fully replacement with fine aggregate gives different strength results thus here they conclude, longer curing period of pond ash SCC gains increase in strength because of pozzolanic reaction of pond ash. Paper found out

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

that the replacement level 10%, 20%, 30% of bottom ash gives better performance in concrete or mortar. Bottom ash required larger water content to achieve workability, but higher water-cement ratio decreases strength.

3. Objective of the Project

a) Main objectives

1. To partially replace the Fine Aggregates with pond ash & quarry dust in self compacting concrete.
2. To obtain the Strength characteristics of SCC with partial replacement of fine aggregate by pond ash & quarry dust.
3. Utilization of industrial wastes in the production of concrete and thereby reducing the cost of production of concrete.

b) Specific Objectives:

1. To study fresh properties of self-compacting concrete with partial replacement of fine aggregate by pond ash & quarry dust.
2. To study hardened properties of self-compacting concrete with partial replacement of fine aggregate by pond ash & quarry dust.
3. To study the water absorption of NSCC00, PQSCC20 and PQSCC30 by weight test.
4. To minimize the use of cement by partially replacing it with fly ash.
5. To Compute the optimum percentage replacement of fine aggregate by pond ash and quarry dust & also to study the effect on strength.
6. Minimizing the utilization of natural river sand and maximizing the utilization of pond ash & quarry dust for concrete production.
7. To study the properties of NSCC and PQSCC by comparing the test results.

4. Materials Used and Methods

Materials used for the present investigation on self-compacting concrete are.

1) Cement (opc 43 grade).
2) Fly ash (class F).
3) Pond ash.
4) Natural river sand
5) Quarry dust
6) Coarse aggregates (10mm and down).
7) Super plasticizer (master glenium).
8) Water.

Cement: Ordinary Portland cement (OPC) 43 grade JK cement is used and it was procured from cashutec, properties of which were tested in laboratory are given in table-1.

Table 1: Characteristics of Cement

Brand of cement	Jk cement
Type of cement used	43grade , OPC
Normal consistency	32%
Initial setting time	45 minutes
Final setting time	400 minutes
Fineness (sieve analysis)	8.50%
Compressive strength(Mpa)	
3days	19.38 Mpa
7days	27.50 Mpa

Fly ash (class F): It is procured from RTPS as per confirming to IS 3812 part1 and 2-2003. Various tests are conducted on fly ash as per confirming to IS 1727-1967 and it was used as powder content in SCC. Characteristics of fly ash is given in table-2.

Table 2: Characteristics of Fly Ash

Colour	Whitish grey
Form	Powder
Specific gravity	2.08
Moisture	0.30%
Residue on 45 micron seive	15.70%
Fineness (m^2/kg)	349

Super plasticizer: Super plasticizer leading a main role in workability of concrete. Here we used poly carboxylic based **Master glenium 233B** super plasticizer, and it is recommended by BASF chemicals.

Water: Clean and portable water satisfying to IS 456:2000 is used for preparingconcrete.

Pond ash: Pond ash is also procured from RTPS. The tests were conducted confirming to IS:1727-1967 (reaffirmed 2008). Pond ash physical properties are given in table-3.

Table 3: Characteristics of Pond Ash

Colour	Grey
Form	Crystalline
Specific gravity	1.99
Water absorption	20%
Residue on 45 micron seive	79%
Fineness(m^2/kg)	164

Natural river sand: This river sand was taken from Krishna river bed near KadlurRaichur district. It was confirming to IS:383-1970 (zone II) and its specific gravity 2.60 is used. The tests are conducted in cashutec laboratory, given in table-4.

Table 4: Characteristics of fine aggregates

Specific gravity	2.6
Water absorption	5%
sieve analysis	
Sieve sizes	Percentage passing
4.75mm	98.8
2.36mm	95.6
1.18mm	68.2
600 microns	42.4
300microns	2.2
150 microns	0

Quarry dust: Quarry dust is collected from near Guddeballur quarry Raichur district, and characteristics are given in table-5.

Table 5: Characteristics of Quarry Dust

SL No	Properties	Results
1	Specific Gravity	2.53-2.60
2	Bulk Density	1722-1815 kg/m^3
3	Aborption	1.3-1.6
4	Fineness	12-15
5	Moisture	----

Coarse aggregates (10mm and down): Coarse aggregates are taken from Guddeballur quarry Raichur district. And coarse aggregate tests are done in cashutec laboratory. Coarse aggregate shows important role in SCC, fresh properties of SCC mainly depends on these aggregates. Characteristics of coarse aggregates are given in table-6.

Table 6: characteristics of coarse aggregates

Specific gravity	2.6
Water absorption	0.90%
sieve analysis	
Sieve sizes	Percentage passing
40.00mm	100
20.00mm	100
12.5mm	80
10.00mm	25
4.75mm	0

Fresh& hardened properties of self-compacting concrete test methods

Properties	Test methods(laboratory)
Filling ability	Slump flow
	T_{50cm} slump flow
	V-funnel
Passing ability	L-box
	U-box
Segregation resistance	V-funnel at 5mins
Strength property	Compressive strength
	Split tensile strength

Table 7: Percentage variations of Pond Ash & Quarry dust used in each Mix.

Material	NSCC (0%)	PQSCC (20%)	PQSCC (30%)
Cement	350	350	350
Fly ash	150	150	150
Water	200	200	200
Pond ash	-	143.87	215.77
Quarry dust	-	187.20	280.8
Coarse aggregate	670	670	670
Sand	939.7	563.83	375.88

Table 8: Mix designation details

NSCC (0%)	Scc with 0% replacement to fine aggregates.
PQSCC (20%)	Fine aggregate replacement by pond ash (20%) and quarry dust (20%) in SCC.
PQSCC (30%)	Fine aggregate replacement by pond ash (30%) and quarry dust (30%) in SCC.

Table 9: Details of specimens cast for compressive strength test

Details of specimen	Cementitious content in kg/m^3	Specimen designation	Mix designation C:FA:CA:W	No of specimens casted at curing period in days		
				7	14	28
Cube (150*150*150) mm	500	NSCC (0%)	1:1.87:1.34:0.4	3	3	3
		PQSCC (20%)	1:1.78:1.34:0.4	3	3	3
		PQSCC (30%)	1:1.75:1.34:0.4	3	3	3
Total numbers of specimens				9	9	9

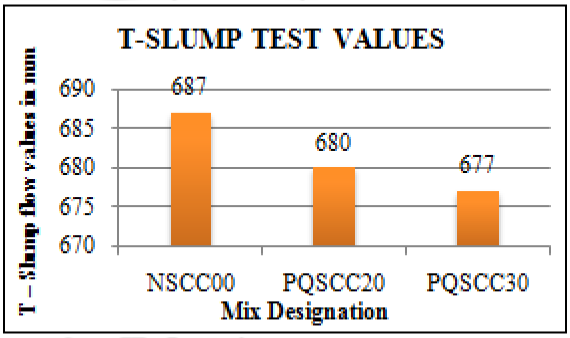
Table 10: Details of specimens cast for split tensile test

Details of specimen	Cementitious content in kg/m^3	Specimen designation	Mix designation C:FA:CA:W	No of specimens casted at curing period in days
				28
Cylinder (150*300) mm	500	NSCC (0%)	1:1.87:1.34:0.4	3
		PQSCC (20%)	1:1.78:1.34:0.4	3
		PQSCC (30%)	1:1.75:1.34:0.4	3
Total numbers of specimens				9

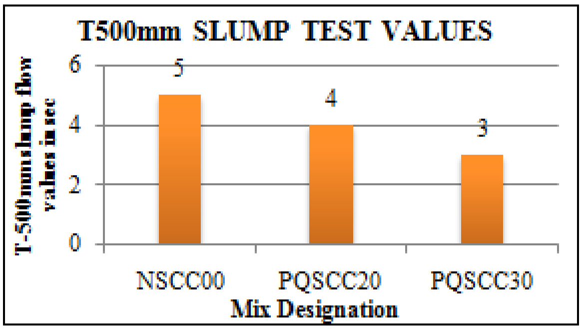
5. Results and Discussions

Table 11: Fresh property ranges of SCC as per EFNARC specification

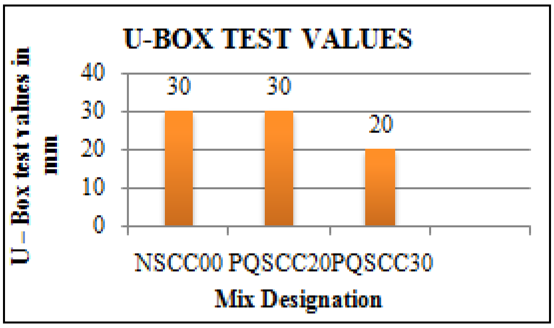
SL No	Method	Unit	Typical range of values	
			Minimum	Maximum
1	Slump flow	Mm	650	800
2	T_{50cm} slump flow	Seconds	2	5
3	V-funnel	Seconds	6	12
4	V-funnel at T_{5min}	Seconds	0	+3
5	L-box	(H_2/H_1)	0	1.0
6	U-box	$(H_2\text{-}H_1)$ mm	0	30



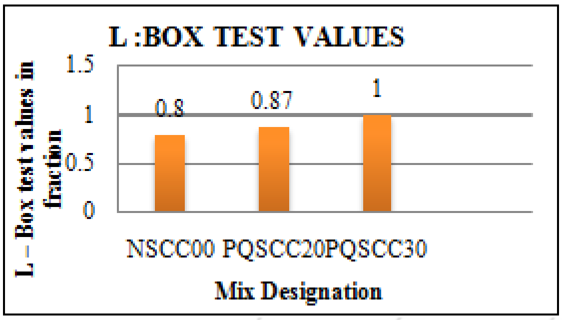
This test is conducted for determining filling ability of SCC and results are shown in above graph. This test results shows filling ability is achieved in both replacement levels NSCC00 and PQSCC20 but PQSCC30 has lesser filling ability compared to other two mixes, because of self-draining property of pond ash.



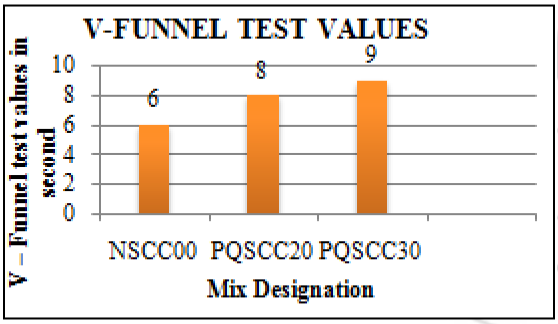
This test is carried out for measuring filling ability of SCC, test results are shown in above graph. The test results shows good filling ability in all three mixes according to EFNARC specifications.



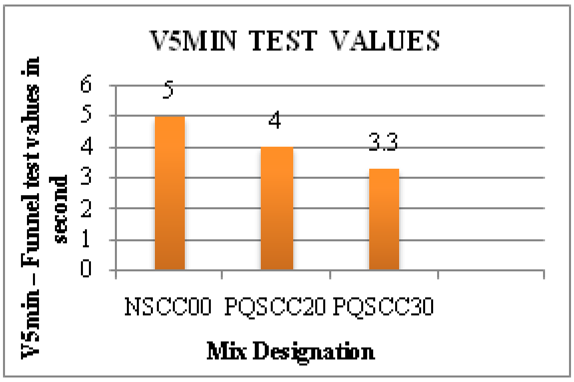
U-Box test is conducted to measure the passing ability of SCC, test results are shown in above graph. Results of all the three mixes are within the range as per EFNARC specifications.



L-Box test is conducted to measure the passing ability of SCC, from above graph test results for passing ability of NSCC00, PQSCC20 are within the limiting value, and here PQSCC30 reaches maximum value as per EFNARC specifications.

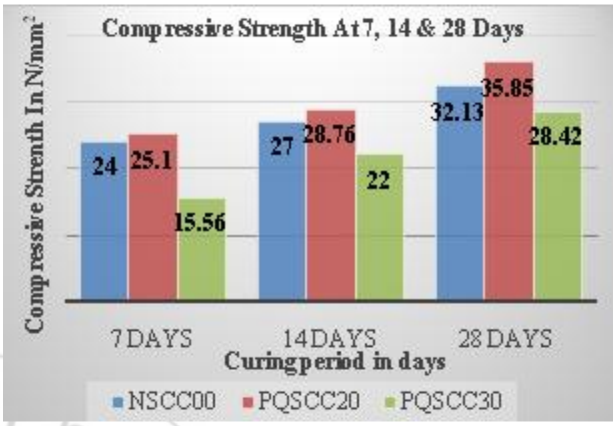


Vfunnel test is conducted to determine filling ability of SCC and test results are shown in above table-17. Filling ability of NSCC00, PQSCC20 and PQSCC30 are within the limiting value according to EFNARC specifications.

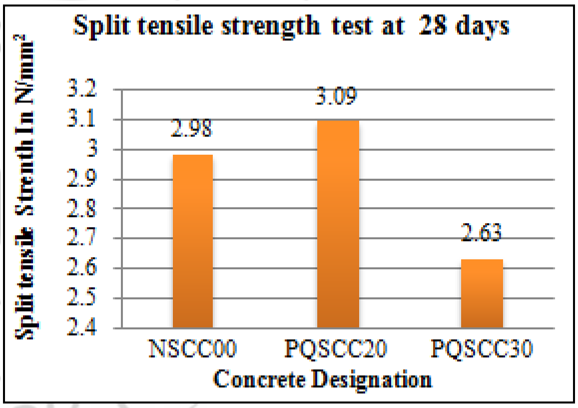


V_{5min} test is conducted to determine the segregation resistance property of SCC and test results are shown in above table-18. Segregation resistance value of NSCC00, PQSCC20 and PQSCC30 are within the limiting value according to EFNARC specifications.

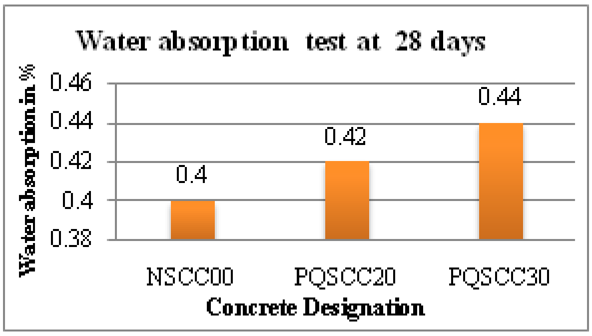
SCC hardened property test results and discussions:



From the above graphical representation we note that strength value of PQSCC20 (25.1N/mm^2) is higher than NSCC00 (24.0N/mm^2) & PQSCC30 (15.56N/mm^2) at 7 days curing period, similarly test results for PQSCC20 are higher at 14 and 28 days curing period.



The above graphical representation shows that split tensile strength value of PQSCC20 (3.09N/mm^2) is greater than that of NSCC00 (2.98N/mm^2) and PQSCC30 (2.63N/mm^2) respectively. Further increase in replacement level of fine aggregate by PA & QD split tensile strength is decreasing gradually.



From the above graph we can see that water absorption value for all the mixes NSCC00 (0.4), PQSCC20 (0.42) and

PQSCC30 (0.44) are within the range i.e 0.5, but increase in replacement level of fine aggregate by pond ash and quarry dust increases the water absorption value due to porous nature of pond ash.

6. Conclusions

From the experimental investigation on Self Compacting concrete the following conclusions are made.

1) The fresh properties at all replacement levels of NSCC00, PQSCC20 and PQSCC30 satisfy with the values as per EFNARC guidelines. Variation in fresh property values of PQSCC30 is more as compare to PQSCC20 because of bleeding and segregation.
2) The test results of the hardened concrete shows, the compressive strength & split tensile strength for NSCC00, PQSCC20 and PQSCC30 are 32.13N/mm^2 & 2.98 N/mm^2, 35.85N/mm^2& 3.09N/mm^2, 28.42N/mm^2& 2.63N/mm^2 respectively for 28 days.
3) Water absorption test results shows less in NSCC00 as compare to PQSCC20 and PQSCC30 mix. The PQSCC30 shows more water absorption as compare to PQSCC20 but it is in the limiting value.
4) The use of mineral admixture as a replacement of cement by fly ash 30% shows improvement in the strength and water absorption properties of concrete.
5) By observing compressive strength & split tensile strength values we can conclude that PQSCC20 is the optimum mix.
6) PQSCC20 with powder content 500kg/m^3 and water content 200kg/m^3 satisfies all fresh and hardened properties. Hence it is best replacement to normal self-compacting concrete.
7) In self-compacting concrete fine aggregate replaced by pond ash & quarry dust up to 20% gives good results. But in case of 30% replacement of PA & QD there is high decrease in the compressive strength and split tensile strength values, this is due to the porous nature of pond ash which makes concrete light & porous.
8) By observing the cost comparison details we can conclude that SCC can be made economical by partially replacing the natural fine aggregates by pond ash and quarry dust.

7. Scope for Further Study

1) This dissertation study can be further extended for analyzing the properties of SCC with partial replacement of fine aggregates by PA & QD, using viscosity modifying agent.
2) For further extended study, properties of SCC along with pond ash can be replaced to fine aggregate by varying the sizes of coarse aggregate.
3) For future study on SCC can be done by varying the coarse to fine aggregate ratios.
4) This research can be further continued to analyze the durability characteristics of SCC with partial replacement of fine aggregate by PA and QD.
5) For further extended study on SCC can be done by inducting pozzolanic materials such as bagasse ash, rice husk along with PA & QD as a partial replacement for fine aggregate.
6) For further study, fly ash could be replaced with cement in SCC at different percentage levels.

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