Shear Strength of Self Compacting Concrete with Demolished Concrete Waste as Fine Aggregate

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***Abstract*—Concrete is the largest material consumed by human being second to water. The use of concrete may lead to the depletion of natural resources. Thus an alternative source should be developed to retain the natural resources to an extent. Sustainable development is one of the major problems faced by the construction industry. With the increase in demand of construction, the natural resources are depleted as well as tons of waste concrete is produced. Reuse of this waste concrete can be found as the best green solution. Here is an attempt to replace fine aggregate with Demolished Concrete Waste as Recycled Fine Aggregate (DCWRFA) and to develop a self compacting concrete (SCC) mix. Further we have studied the variation in compressive strength as well as the shear strength of the developed self compacting concrete mix. It was found that the demolished waste concrete could be efficiently used in the production of self compacting concrete with sufficient compressive strength and shear strength.**

***Keywords*— Self compacting concrete (SCC); demolished concrete waste; shear strength; EFNARC**

I. INTRODUCTION

Sustainable development can be described as a method for meeting human needs while the ability of natural systems to provide resources remains sustained. The entire society and economy depends on these resources and ecosystem to flourish. From the evolution of man, the construction industry has been consuming the natural resources. The search of betterment in the construction industry leads to the consumption of the resources to a greater extent. Consumption increased in such a way that the depletion of natural resources has become one of the greatest concern and challenge faced by the construction industry. It is found that the construction industry consumes more than 10 billion tons of aggregates and producing a constructional and demolition waste of over 1 ton annually, which depletes the resources as well as produces large amount of waste. The reuse or utilization of the waste concrete can make significant changes in the environmental issues as the concrete contains of 70% of aggregates. It was found by researchers that the recycled aggregates could be used for almost all the concrete activities. Also it can be seen that there is a significant potential for usage of demolished waste concrete as an ideal and green solution for bringing out the sustainable development in construction industry. The usage of the demolished waste concrete as the replacement for the fine aggregate makes a solution to reduce the waste concrete without reducing the strength of the concrete. Therefore the purpose of this study is to examine the strength of the concrete obtained by the replacement of fine aggregate by the demolished waste concrete and also to find the optimum replacement percentage of the demolished waste concrete.

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete. Concrete that requires little vibration or compaction has been used in Europe since the early 1970s but self-compacting concrete was not developed until the late 1980’s. Self-compacting concrete was first developed in Japan in late 1980’s. This could be regarded as a significant development in the civil engineering construction industry. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is often produced with low water-cement ratio providing the potential for high early strength, faster use of elements and structures. The elimination of vibrating equipment improves the environment on and near construction where concrete is being placed, thus reducing the exposure of workers to noise and vibration.

Now a day’s various methods are used for backfill. Western countries have already started using locally available material as backfill rather than conventional concrete. Demolished concrete waste can be effectively used to replace fine aggregate and the concrete developed with this demolished waste can be used as an effective backfill material. Since shearing occurs at the backfill region, shear strength of the developed SCC have to be checked. This experimental investigation thus emphasis the need for developing a suitable self-compacting concrete mix with addition of demolished concrete waste. The compressive strength and shear strength of the same is also determined.

II. MATERIALS

Ordinary Portland cement of 43 Grade has been used in this experimental investigation. Different physical properties of cement have been tested and verified as per Indian standards.Silicious Fly Ash was used as a supplementary cementitious material for the partial replacement of cement. Fly Ash helps in improving the cohesive properties and also reducing the cement content. Manufactured Sand was used as fine aggregates. Demolished Concrete Waste as Recycled Fine

Aggregate (DCWRFA) of 4.75mm maximum size used as replacement for fine aggregates. It is obtained from the demolished concrete cubes tested in concrete technology lab. Demolished concrete cubes were crushed in a rotating crusher and sieved. 12 mm downward sized crushed aggregates were used as coarse aggregates. High-performance super plasticizer (MasterGlenium SKY 8233 manufactured by BASF India Limited, Construction Chemicals Division.) and viscosity modifying agent (MasterMatrix 2 manufactured by BASF India Limited, Construction Chemicals Division.)were used as chemical admixtures in developing the mix. Various properties of constituent materials are given in Table 1

Table 1. Properties of constituent materials

Material	Properties	Value
Cement	Specific Gravity	3.02
	Standard Consistency	30%
	Initial Setting Time	70 minutes
	Final Setting Time	430 minutes
Manufactured Sand	Specific Gravity	2.6
	Fineness Modulus	3.9
Coarse Aggregates	Specific Gravity	2.63
	Water Absorption	0.9%
DCWRFA	Specific Gravity	2.45
	Fineness Modulus	3.78

III. EXPERIMENTAL PROGRAM AND RESULTS

A. Development of Mix Design

In this experimental investigation, six types of self-compacting concrete mixes were made to analyse the effect of replacing fine aggregates with demolished concrete wastes. Control mix of SCC was developed according to the EFNARC guidelines. Details of the mixes are shown in Table 2. In mixes R1, R2, R3, R4 and R5, the fine aggregates was replaced by DCWRFA in 20%, 40%, 60%, 80% and 100% (by weight) respectively. Quantity of materials required for making 1 m^3 of concrete was kept as constant. But in some mixes, quantity of admixtures was altered to obtain equal consistency in all mixes due to the higher water absorption of recycled aggregates. Tests for fresh state properties were carried on all mixes as per EFNARC guidelines.

B. Fresh State Properties

Filling ability, passing ability, flowing ability and segregation resistance are the characterising properties of self-compacting concrete. To characterise a concrete as a self-compacting concrete, it should have the above properties. There are various tests for determining the fresh properties of SCC. Slump flow test is for assessing the flowability and viscosity can be assessed by T_{500} slump flow test or V-funnel test. The passing ability of fresh SCC can be tested by L-box or J-ring. In this experimental investigation, fresh state properties of self-compacting concrete were tested by slump-flow test, T_{500} slump flow test, V-funnel test and L-box test as per EFNARC guidelines. Recommended values for different tests for workability purposes were given in Table 3 and obtained values for different mixes were given in Table 4.

Table 3. Recommended values for different tests

Method	Unit	Typical Range of Values	
		Minimum	*Maximum*
Slump Flow	mm	650	800
T_{50} cm slump flow	Sec	2	5
V – Funnel	Sec	8	12
L – Box	(h_2/h_1)	0.8	1

Table 4. Test results on fresh concrete

Mix	Slump Flow, mm	T_{50} cm slump flow, sec	V – Funnel, sec	L – Box, (h_2/h_1)
Control Mix	680	5	10	0.85
R1	695	5	11	0.96
R2	700	5	9	0.82
R3	710	4	10	0.93
R4	715	3	12	0.87
R5	735	4	11	1.0

Table 2. Mix proportion details

Mix	Cement, Kg	Fly Ash, Kg	Coarse Aggregates, Kg	Fine Aggregates, Kg		Super Plasticizer, Kg	Viscosity Modifying Agent, Kg	Water Content, Kg
				Normal	*DCWRFA*			
Control Mix	440	110	750	970	0	6.27	1.25	210
R1	440	110	750	776	194	6.27	1.25	210
R2	440	110	750	582	388	6.27	1.25	210
R3	440	110	750	388	582	6.27	1.25	210
R4	440	110	750	194	776	6.32	1.26	210
R5	440	110	750	0	970	6.32	1.26	210

C. Compressive Strength

For each mix, 9 cubes of size 150mm were casted. Curing of these cubes were done by water curing and tested for 7 days, 14 days and 28 days compressive strength. Compressive strength test results are given in Table 4. For SCC mixes, in which fine aggregates are replaced by DCWRFA, maximum compressive strength is obtained for mix with 40% replacement of fine aggregates. Effect of DCWRFA content on7 days, 14 days and 28 days compressive strength of different mixes are presented graphically in Fig. 1.

Table 4. Compressive strength results

Mix	Compressive Strength		
	7 Days, MPa	*14 Days, MPa*	*28 Days, MPa*
Control Mix	24.56	27.06	30.52
R1	25.84	27.12	31.63
R2	26.12	31.14	34.30
R3	23.69	26.79	31.06
R4	21.62	24.17	26.70
R5	20.78	22.58	24.78

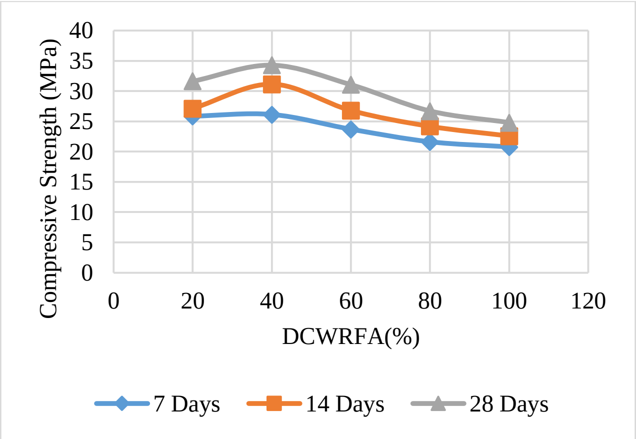

Fig. 1. Effect of DCWRFA content on compressive strength

D. Shear Strength

This method of test covers the procedure for testing specimen for longitudinal shear strength, unconfined using shear plane.

1) Test Specimen: The specimen for this test shall be cuboid with 150mm x 100mm x 100mm. Curing of these cubes were done by water curing and tested for 7 days, 14 days and 28 days shear strength.

2) Shear Device: The shear device shall consist of an apparatus in which the test specimen can be clamped and supported so that bending stress are minimized across the longitudinal plane along which the shear load is applied. Test set up was developed as shown in the Fig. 2.

Fig. 2. Shear testing apparatus

3) Placing of Test Specimen: Place the specimen in the device and tighten down the top plate. It should be ensured that the plane along which the shear load is to be applied is in line and parallel to the shear edge at both the top and the bottom. Place the rectangular steel loading block on the top of the specimen and lock them in the testing machine. Taking precautions to ensure that the loading block is centred under the spherical head, lower the head until it has made contact with the loading block.

4) Shear Testing: The load shall be applied continuously and without shock until the specimen fails. Shear testing specimen in the apparatus before loading is shown in Fig. 3. The indicated load at the failure shall be recorded. Fig. 4 shows the specimen after failure and Fig. 5 shows the shear failure plane.

Fig. 3. Specimen before loading

Fig. 4. Specimen after loading

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Fig. 5. Typical view of the failure plane

Shear stress can be calculated from the breaking load. Shear strength test results are given in Table 5. For SCC mixes, in which fine aggregates are replaced by DCWRFA, maximum shear strength is obtained for mixes with 40% replacement of fine aggregates. Effect of DCWRFA content on 7 days, 14 days and 28 days shear strength of different mixes are presented graphically in Fig. 6.

Table 5. Shear strength results

Mix	Shear Strength		
	7 Days, MPa	*14 Days, MPa*	*28 Days, MPa*
Control Mix	4.16	5.14	6.26
R1	4.22	5.17	6.59
R2	5.27	6.13	7.10
R3	3.99	5.12	5.55
R4	3.55	4.72	5.08
R5	3.08	4.09	4.85

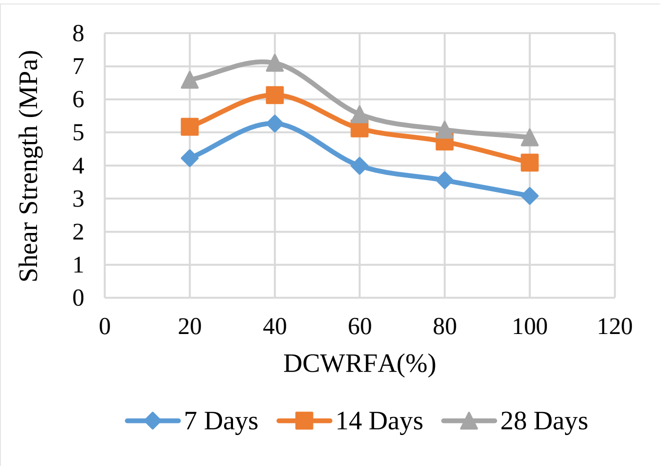

Fig. 6. Effect of DCWRFA content on shear strength

IV. CONCLUSION

From this experimental investigation, following inferences are made:

- Demolished concrete waste is an easily available material which can be significantly used in the concrete production.
- SCC mix was developed by replacing fine aggregate with demolished concrete waste as recycled fine aggregates.
- It was seen that the SCC mix developed could satisfy all the fresh state properties recommended by EFNARC guidelines.
- Maximum compressive strength and shear strength is obtained with 40% replacement of fine aggregates by demolished concrete waste as recycled fine aggregates.
- By the addition of demolished concrete waste, it was found that the strength characteristics has increased up to 40% replacement of fine aggregates by DCWRFA.
- So with the help of DCWRFA, sustainable development can be achieved.

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