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EXPERIMENTAL STUDY ON STRENGTH BEHAVIOUR OF SELF COMPACTING CONCRETE USING RECYCLED AGGREGATES

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ABSTRACT- The construction of modern structures alarming the attention of use of materials with improved properties in respect of strength, stiffness, toughness and durability. Concrete is one of the most widely used construction material having several advantages such as high strength, good mould ability and high durability. The major disadvantages of concrete are its poorer tensile strength and lesser ductility (toughness). Conventional concrete used in building construction and engineering applications requires compaction to attain strength, durability and homogeneity. The typical method of compaction, by vibration, generates delays and additional costs in projects and could pose a serious health hazard due to noise pollution in and around construction sites. Self Compacting Concrete (SCC) is a concrete which is highly flowble, can flows readily into place, fill the formwork without any compaction and without undergoing any significant segregation. Recycling is the act of processing the used material for creating a new useful product. Construction and Demolished waste also generate Recycled Aggregate (RA). Such a Recycled Aggregate proved to be a reliable alternative to Natural Aggregates (NA) in concrete. There is a growing need for renovation from a usual consumption based society to a sustainable society owing the natural environment pollution, exhaustion of natural resources and as decreasing capacity of disposal facilities for final waste. Use of aggregates from Building Demolished Waste (BDW) in structural concrete is definitely an important stride. Use of RA in developing SCC is certainly a novel thought towards achieving a sustainable concrete. There is a pressing demand for the use of Recycled Aggregate in recent concretes, as sustainability is given the highest importance in today's world. This has necessitated the make use of Recycled Aggregates in SCC and fibre based SCC. Hence Reinforced Self Compacting Concrete using Recycled Aggregate with fibres may be a potential material in construction. In order to clearly understand the performance of such a concrete, there is a call for to study the stress-strain and flexural strength behaviour. The present study focuses on flexural bond strength behaviour of Fibre Reinforced Self Compacting Concrete by replacing the natural Aggregate with Recycled Aggregate. BDW is used as coarse aggregate in the concrete, with an aim to achieve sustainable concrete.

Key words: Recycled Aggregates, Self Compacting Concrete, Blast Furnace Slag,

INTRODUCTION

Self-Compacting Concrete (SCC) may be defined as a concrete which is able to flow in the interior of the formwork, filling it in a natural manner and passing through the reinforcing bars, flowing and consolidating under the action of its own weight (Okamura 1997). Main intention behind the development of SCC originally was simplifying casting operation in huge Civil Engineering constructions, where difficult concrete flow or high percentage of reinforcement. Presently it became clear, though, that the vast productivity increase allied to SCC technology also habilitates it as a good resolution for building construction, precast production and other relevance (Lofgren 2005).

The fresh SCC necessities are mainly recommenced to the filling ability, the passing capability and the resistance to segregation. These properties are assessed at the time of mix design, based on a number of tests on fresh samples with different apparatus (EFNARC 2002). Self Compacting capacity of concrete mainly depends on the performance level reached by the fresh mix.

The introduction of steel fibers in SCC is another issue of attention in the concrete technology. Steel fibers attest to have the potential to increase the post-cracking energy absorption capacity of cement based materials, enhancing the ductile character of concrete structures behavior, mainly of those with high redundant supports (Barros and Figueiras 1998).

The advantages associated to the reinforcement of steel fibers to concrete mixes may be united with the ones ensuing from the self compacting ability concept of concrete, with the formulation of steel fiber reinforced concrete mixes exhibiting self compacting ability. The ensuing material is, in this work, designated by Steel Fiber Reinforced Self Compacting Concrete (SFRSCC). As compared to conventional concretes, SFRSCC presents clear technical reward in terms of costs/benefits ratio. However, There exist, some drawbacks allied to the SFRSCC formulations and the most relevant one is associated to the strong perturbation effect formed by steel fibers on the flowing capability of fresh concrete.

Recycling is the act of processing the used material for creating a new useful product. Construction and Demolished waste also generate Recycled Aggregate (RA). Such a Recycled Aggregate proved to be a reliable alternative to Natural Aggregates (NA) in concrete.

There is a growing need for renovation from a usual consumption based society to a sustainable society owing the natural environment pollution, exhaustion of natural resources and as decreasing capacity of disposal facilities for final waste. Use of aggregates from Building Demolished Waste (BDW) in structural concrete is definitely an important stride. Use of RA in developing SCC is certainly a novel thought towards achieving a sustainable concrete.

OBJECTIVES AND SCOPE OF STUDY

1. The present study focuses on flexural bond strength behaviour of Fibre Reinforced Self Compacting Concrete by replacing the natural Aggregate with Recycled Aggregate.
2. BDW is used as coarse aggregate in the concrete, with an aim to achieve sustainable concrete.

LITERATURE REVIEW

Extensive research works are being carried out globally using various types of materials. Sonebi et al (2003) reported that the structural performance of full scale beams cast using conventional concrete and Self Compacting Concrete using steel fibers. A total of eight beams of class C35 and C60 were cast and tested. His investigation concluded that the maximum moment capability of SCC60 beams was considerable as compare to RC60 beams.Ganesan et al (2006) reported an experimental study which consists of casting and testing of 18 SFRSCC flexural elements. His study concluded that all the theoretical models are available in the literature were found to undervalue the maximum strength of SFRSCC beams. He recommended that alterations are required in these models to condense the range of the predictability of the maximum moment of SFRSCC members.Moncef Nehdi and Jennifer Duquette Ladanchuk (2004) studied about the effects of fibre permutations on the workability and ability of SCC to flow around obstacles, its compressive & flexural strengths, flexural toughness & post first crack behavior. Their intention was not to optimize FRSCC mixtures but quite to identify the synergistic effects of hybrid fibres in FRSCC that can provide for such optimization in future. Their investigations evident that all mixtures containing combinations of steel fibres had higher loads at first crack than that of mixtures consist only one type of steel fibre. This may probably because of fibres with different shapes and lengths could give better control in the micro mechanics of crack formation at different levels strain than single type of fibres. Hemanth et al (2007) proposed SCFRC application in pre-stressed concrete beams. SCFRC mixes had greater normalised tensile strength than the conventional fibrous concrete mixes for the same fibre factor. Jiong, Hu, Texas State University-San Marcos, has carried out a preliminary study has been conducted to evaluate the viability of using recycled concrete aggregate (RCA) in self compacting concrete (SCC). A.N.Dabhade et al (2012), was carried out using workability test, compressive test, bulk density test, split tensile test, water absorption, impact value test, crushing value test, Fineness modulus. There were total of 6 batches of concrete mixes, consists of recycled aggregate replacement from 0% to 100% with 20% increment. The results indicated that the compressive strength and tensile strength increased gradually up to 20% of recycled aggregate. C. Sumanth Reddy et al (2013) was studied experimentally about the mechanical and durability properties of the various grades M_{20}, M_{40} and M_{60} with recycled aggregate combinations of 0%, 25%, 50% and 100%. Results showed that as much of 25% of aggregates may be replaced without any considerable consequences.

RESEARCH SIGNIFICANCE

Utilization of recycled aggregate in new concrete production has been increasing gradually due to the environmental and economic considerations. However, information on the quality of recycled aggregate concrete is still scarce. This study attempts to examine the influence of recycled aggregate on strength of Fibre Reinforced Self Compacting Concrete. This study is an attempt to provide very useful information for the practical use of recycled aggregate in advance concrete production.

MATERIALS & PROPERTIES

CEMENT

Cement is produced by calcining at high temperature an intimate mixture of siliceous, aluminous and calcareous substances and crushing the resulting clinkers to a fine powder. The properties of cements may depend on the process of manufacture, the chemical composition and the degree of fineness to which they are ground. When the water is added to the cement, a chemical reaction takes place as a result the cement paste first sets and then hardens like mass to a stone.

AGGREGATES

Fine aggregates and coarse aggregates build up the massiveness of a concrete mixture. Sand, natural gravel and crushed stone are used largely for this purpose. Recycled aggregates are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air cooled blast furnace slag and bottom ash are also permitted.

In terms of size, there are two broad categories of aggregate as below:

1) Coarse Aggregate- Retained over 4.75 mm IS Sieve.
2) Fine Aggregate - Passing through 4.75 mm IS Sieve.

WATER

Adding water with a cementitious material forms a cement paste as a result of hydration. The cement paste fastens the aggregate together, fills voids and makes it, flow more freely. Poorer water to cement ratio will give up a stronger& more durable concrete; while more water may give a free flow concrete with a greater slump. Impure water used in concrete may cause tribulations when setting or in causing untimely failure of the structure.

SUPER PLASTICIZER

Super plasticizer is indispensable for the creation of SCC. The role of SP is to impart a high degree of flow ability and deformability, however the high amounts generally associate with SCC can lead to a high extent of segregation. Conplast SP 430 is utilized in this project, which is a product of FOSROC Company having a specific gravity of 1.222. Super plasticizer is a chemical compound which is used for increase the workability without addition more water i.e. spreads the given water in the concrete throughout the concrete mix which results a uniform mix. SP improves superior surface expose of aggregates to the cement gel. Super plasticizer acts as a lubricant among the materials. Generally in order to increase the workability the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same

MINERAL ADMIXTURES

BLAST FURNACE SLAG

All over the world there is an escalating focus on the want of recycle and to more fully utilise co-products of industrialized processes in an attempt to conserve our limited natural resources. Technical assessment supported by field experience has revealed that co-products such as blast furnace slag have, in many applications, characteristics suitable to replace or supplement and improve traditional materials used.

FLY ASH

Fly ash is a residue result from the burning of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. The composition differs with type of fuel burnt, load applied on the boiler and type of separation. The fly ash consists of spherical glassy particles ranging from 1 to 150 micron in diameter and also passes through a 45-micron sieve. The ingredients of fly ash are mentioned below.

Silicon dioxide ----- SiO_2 --- 30 – 60 % ,Aluminum oxide ----- Al_2O_3 --- 15 -30 %,Unburnt fuel ----- (Carbon) --- up to 30 % ,Calcium oxide ----- CaO --- 1-7% ,Magnesium oxide --- (MgO) --- small amounts ,Sulpher trioxide ----- (So_3) --- small amounts

FIBRES

Steel fiber of diameter 0.92mm, fiber had a specific gravity and a tensile strength of 7.850 and 331Mpa respectively. The major variables used in the study are three different aspect ratios such as 15, 25 and 35 and the consequent lengths are 13.8mm, 23 mm and 32.2mm respectively. Three different percentage of volume fraction of steel fibers such as 0.5%, 1.0% and 1.5% and the matching weights are 39.25, 78.50, and 117.75 kg/m3 respectively.

RECYCLED COARSE AGGREGATES (RCA)

Destruction of aged and deteriorated construction and traffic infrastructure, and their replacement with new ones, is a common phenomenon today in a major part of the world. The major reasons for this condition are changes of purpose, structural decline, reorganization of a city, extension of traffic directions, growing traffic load and natural disasters. A probable solution to these troubles is to recycle destruction concrete and produce a substitute aggregate for structural concrete in this mode shown in fig.

MIX PROPORTION, M30 MIX

CEMENT (KG)	SAND (KG)	COARSE AGGREGATE (KG)	WATER
465.85Kg	915.69 Kg	719.47 Kg	191.00
1	1.96	1.54	0.41

LIMITS ON SCC MATERIAL PROPORTIONS

	HIGH FINES	VMA	COMBINATION
Cementations (kg/m3)	450-600	385-450	385-450
Water/Cementations material	0.28-0.45	0.28-0.45	0.28-0.45
Fine aggregate/Mortar (%)	35-45	40	40
Fine aggregate/Total Aggregate (%)	50-58	--	--
Coarse aggregate / Total mix (%)	28-48	45-48	28-48

RATIOS OF MIX PROPORTIONS BY WEIGHT:

MIX	W/C	% OF STEEL FIBRES	CEMENT	FA	CA	RCA	FLY ASH	GGBS	MICRO SILICA	SP 430 DOSAGE	VMA DOSAGE
SCC	0.41	0.05	1.00	3.81	3.00	0.00	0.55	0.40	0.01	0.05	0.007
SCC_25% RCA	0.41	0.05	1.00	3.81	2.75	0.25	0.55	0.40	0.01	0.05	0.007
SCC_30% RCA	0.41	0.05	1.00	3.81	2.70	0.30	0.55	0.40	0.01	0.05	0.007
SCC_35% RCA	0.41	0.05	1.00	3.81	2.65	0.35	0.55	0.40	0.01	0.05	0.007
SCC_40% RCA	0.41	0.05	1.00	3.81	2.60	0.40	0.55	0.40	0.01	0.05	0.007
SCC_45% RCA	0.41	0.05	1.00	3.81	2.55	0.45	0.55	0.40	0.01	0.05	0.007
SCC_50% RCA	0.41	0.05	1.00	3.81	2.50	0.50	0.55	0.40	0.01	0.05	0.007
SCC_55% RCA	0.41	0.05	1.00	3.81	2.45	0.55	0.55	0.40	0.01	0.05	0.007
SCC_60% RCA	0.41	0.05	1.00	3.81	2.40	0.60	0.55	0.40	0.01	0.05	0.007

RESULT, DISCUSSION AND CONCLUSION

The rheological properties are assessed by using rheology tests such as Filling, Passing and Segregation resistance. When coarse aggregate is replaced with RCA, a lower dosage of Super plasticizer is required to maintain the same filling ability. T_{50} times indicate the viscosity of highly flowable concrete mixes. Lower time indicates greater flowability. The T_{50} was influenced by the dosage of water and super plasticizer. V funnel test was performed to assess the flowabilty and stability of the SCC.

MIX	SLUMP FLOW (MM)	T50CM SLUMP FLOW (SEC)	V-FUNNEL (SEC)	V-FUNNEL $T_{5\ MINUTES}$ (SEC)	L-BOX H_2/H_1
SCC	705	4.76	8	1.62	0.92
S- RCA 25%	702	4.52	9	1.75	0.91
S- RCA 30%	696	4.36	9	1.89	0.89
S- RCA 35%	691	4.24	10	1.99	0.89
S- RCA 40%	682	4.10	10	2.08	0.85
S- RCA 45%	675	4.00	10	2.19	0.83
S- RCA 50%	666	3.78	11	2.33	0.80
S- RCA 55%	659	3.53	11	2.65	0.77
S- RCA 60%	654	3.36	12	2.99	0.75

COMPRESSIVE STRENGTH

MIX	7-DAYS COMPRESSIVE STRENGTH (N/MM^2)	28-DAYS COMPRESSIVE STRENGTH (N/MM^2)
SCC	**31.80**	**43.70**
SCC_25% RCA	31.11	41.48
SCC_30% RCA	31.56	42.07
SCC_35% RCA	**32.15**	**44.15**
SCC_40% RCA	31.26	43.56
SCC_45% RCA	30.96	42.37
SCC_50% RCA	30.67	41.63
SCC_55% RCA	30.07	40.74
SCC_60% RCA	28.89	40.44

It is observed that the optimum strength gained after 7 and 28 days curing period is at 35% replacement and the lowest strength at 60% replacement of RCA with coarse aggregate. The comparison of 7 and 28 days compressive as well as split tensile strength for various water cement ratio is shown in Table.

Split Tensile Strength

Specifications	7-days Split tensile strength (N/mm^2)	28-days Split tensile strength (N/mm^2)
SCC	2.84	**3.56**
SCC_25% RCA	2.49	3.11
SCC_30% RCA	**2.89**	**3.70**
SCC_35% RCA	2.76	3.41
SCC_40% RCA	2.48	3.26
SCC_45% RCA	2.24	3.11
SCC_50% RCA	2.31	2.96
SCC_55% RCA	2.14	2.67
SCC_60% RCA	2.04	2.52

It is observed that the optimum strength gained after 7 and 28 days curing period is at 30% replacement and the lowest strength at 60% replacement of RCA with coarse aggregate. The comparison of 7 and 28 days compressive as well as split tensile strength for various water cement ratio is shown in Table.

Flexural Strength

Specifications	7-days Flexural Strength (N/mm^2)	28-days Flexural Strength (N/mm^2)
SCC	2.86	**3.85**
SCC_25% RCA	2.52	3.41
SCC_30% RCA	**2.89**	**4.00**
SCC_35% RCA	2.77	3.56
SCC_40% RCA	2.56	3.40
SCC_45% RCA	2.33	3.11
SCC_50% RCA	2.14	2.81
SCC_55% RCA	2.08	2.81
SCC_60% RCA	2.03	2.67

In the present , the replacement of coarse aggregate was replaced with RCA in the range of 25% - 60% at an increment of 5%. From the various experiment results, the following conclusions are drawn.

1. It is found that as the natural aggregate replaced by RCA, the strength of the concrete decreases.
2. Use of the waste aggregate in the new concrete as the recycled concrete aggregate reduces the environmental pollution as well as providing an economic value for the waste material and water absorption of RCA is higher than natural aggregate.
3. There is an increase in the strength of FRSCC when the coarse aggregate was replaced by RCA at 30-35% than other mixes. This also reduces the coarse aggregate content by increasing the RCA thus reducing the further cost of SCC mixes developed.
4. Therefore, based on the test results, it is recommended that the RCA can be replaced with natural aggregate 30% to 35%.

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