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Potential use of Construction and Demolition Waste Materials as Fine Aggregate in Self-Compacting Concrete

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Abstract

River sand being most preferred and widely used fine aggregate in concrete, with urbanization and industrialization the demand for river sand in construction industry has given rise to a situation where extensive availability of river sand has decreased, price has increased and causing extensive environmental problems. In recent times researches are being carried out to find a suitable alternative for fine aggregate. On the other hand, construction industry is generating lot of wastes in various phases of construction and during demolition, the disposal of these materials is also creating environmental damage. In the present investigation an attempt has been made to find an effective way to tackle these problems in construction industry. The rigid waste materials such as waste glass, ceramic waste, waste mortar, granite and concrete blocks were collected and finely grounded to be used in varying replacement levels of 0%, 30%, 70% and 100% in self-compacting concrete (SCC) of grade M30. Mix design was done according to Nan-Su method. Characterisation of mixed rigid waste materials was confirmed to zone II. The plastic property tests on SCC indicated decrease in workability with increase in replacement level. From compressive strength test result, it was noted that 30% replacement gave maximum strength than control SCC concrete, however the strength at 70% and 100% replacement levels were comparable with control mix.

Key words: *Rigid waste, Alternative material, Fine aggregate, Compressive strength, SCC.*

INTRODUCTION

In making of concrete, river sand is the most preferred and widely used fine aggregate constituting 35% to 45% by mass of total aggregates. River sand is product of natural weathering of rocks over a period of millions of years. Currently sand mining has disastrous environmental and social impact, such as river bank erosion, river bed degradation, deterioration of river water quality, river buffer zone encroachment, reduction in ground water infiltration, illegal mining, increase in cost and non-availability. It is well known that aggregates are used as fillers to provide skeletal framework to concrete. The use of river sand as fine aggregate in concrete is historic and has evolved over a period of time due to its easy availability along river beds. However, with the changed environmental stipulations has led to imposing ban on mining, which has resulted in creating pressure on the supply of sand to meet the demand of fast pace construction thereby increasing in price. With the change scenario search for an alternative material has begun with the research being carried out by using all the possible alternative materials [1, 2].

Infrastructure development in India is accelerating. The construction industry has contributed as estimate 670,778 crores to national GDP in 2011-12 (a share of around 8%) [3]. This huge developmental activity has led to problems relating to increase in cost, waste such as building rubble, concrete lumps at construction and demolition site. In India, the waste from construction industry is estimated to be about 12 to 14.7 million tonnes per annum. The Central Pollution Control Board estimates a current solid waste generation as 48 million tonnes per year of which construction industry account for 12 to 14.7 million tonnes. Management of such high quantum of waste imparts pressure on system. Estimated waste generation during construction and renovation work is 40-60 kg/m^2 and 40-50 kg/m^2 respectively, whereas demolition of buildings yields 500 and 300 kg/m^2 of waste, for pucca and semi-pucca buildings respectively [1]. The physical properties of rigid waste material such as specific gravity, fineness modulus are comparable with the fine aggregates. It was observed from literature that limited work has been carried out on utilization of these materials in SCC. Most of the researchers have used only one type of material for replacement and found encouraging results. This paper presents an attempt has been made to use combination of different rigid waste materials such as waste glass, ceramic waste, waste mortar, granite and concrete blocks used as replacement for river sand as fine aggregate in SCC.

MATERIALS

Characterisation of material is an important stage in the mix proportion of concrete. Engineering properties of materials plays a vital role in properties of concrete. The following materials were used in the current investigation.

a) **Cement:** Ordinary Portland cement of 43 grade (Zuari Cement) confirming to IS: 12269-1987 was used in the present investigation, the specific gravity was 3.15.
b) **Fine aggregate:** Natural River Sand was procured from nearby construction site which was confirming to Zone II of IS 383: 1970, with specific gravity of 2.63 and fineness modulus of 2.98.
c) **Coarse aggregate:** Crushed angular coarse aggregates confirming to graded condition of IS 383:1970 was used in the present investigation. The specific gravity was found to be 2.65. A maximum size of 12.5mm was used.
d) **Fly ash:** In order to avoid segregation and also as filler material Fly ash is required for SCC. In present investigation Class-F type, obtained from Raichur power plant with specific gravity of 2.15 was used in SCC.
e) **Superplasticizer (SP):** In the present investigation GLENIUM B233 an admixture of a new generation based on modified polycarboxylic ether, confirming to IS 9103:1999 was used in SCC to achieve desired workability.
f) **Viscosity Modifying Agent (VMA):** VMA is used for producing concrete enhanced viscosity, superior durability and in controlled bleeding. In the present investigation GLENIUM STREAM 2 a premier ready-to-use liquid VMA specially developed for production of SCC was used, which was confirming to IS 9103:1999.
g) **Rigid Waste Materials:** Various rigid C&D waste material were obtained from C&D site, all the waste materials were ground and sieved with 4.75 mm IS sieve individually and stored separately, following rigid materials were used,

Glass Waste: It is widely used as manufactured products such as sheet glass, bottles, glassware and vacuum tubing. Glass is an ideal material for recycling. In the present investigation waste glass was collected from demolition site at the campus. The specific gravity was found to be 2.51 with a fineness modulus of 3.06.

Ceramic Waste: Ceramic wastes are generated during the process of dressing, polishing and demolition, these materials were collected and crushed. The specific gravity was found to be 2.46 with a fineness modulus of 3.43.

Mortar Waste: Mortars are typically made from a mixture of sand, a binder, and water. Mortar wastes are generated from the building constructions during plastering, laying of bricks and demolition process, these materials are collected and processed to use them as fine aggregate. The specific gravity was found to be 2.58 with a fineness modulus of 2.67.

Waste Granite Powder: Granite pieces obtained from the polishing units, demolished wastes were collected, crushed and properties were found. The specific gravity was found to be 2.73 with a fineness modulus of 2.63.

Concrete Blocks: The blocks contain mainly aggregates which can be used as fine aggregate, physical properties were found. The specific gravity was found to be 2.74 with a fineness modulus of 2.64.

h) Blending of rigid C&D waste

In order to use these materials as fine aggregates they have to be blended properly. Since from the gradation it was observed that waste glass and ceramic wastes did not confirmed to zone II, whereas remaining materials confirmed to zone II. Hence in the present investigation as a first trial 10% of glass powder, 15% of ceramic powder with other materials 25% each were mixed, which did not confirm to zone II. After carrying out several trials it was found out that blending in equal proportion of 20% of all materials resulted in specific gravity of 2.54, fineness modulus of 2.84 and confirming to zone II of IS 383:1970.

METHODOLOGY

a) Particle size distribution:

Sand was being dried in the air and sieved with a set of sieves between 4.75 mm to 0.15 mm, which was according to IS 383:1970. The grading curve was plotted and fineness modulus was found out by sum of cumulative percentage weight retained on each sieve was divided by 100.

b) Mix Proportioning

A mix of M30 was designed as per Nan-Su method [5], to arrive at final mix proportions, water binder ratio (w/b) was varied from 0.3 to 0.35. The Packing factor from experiment was obtained as 1.14 for a volume ratio of fine aggregate to total aggregates which was 53%. Finally, a mix proportion with w/b ratio of 0.32 was obtained after several trial mixes. The replacement levels of river sand were done with rigid waste materials at 0%, 30%, 70% and 100%. The identification of mix proportion and quantity of materials for concrete mixes are given in table 1.

Table 1 Quantity of material for different mixes

Mix Designation	**SCC/0**	**SCC/30**	**SCC/70**	**SCC/100**
w/b ratio	0.32	0.32	0.32	0.32
Cement (kg/m^3)	214.28	214.28	214.28	214.28
Fly ash (kg/m^3)	330	330	330	330
River sand (kg/m^3)	849.2	594.44	254.76	0
Rigid waste (kg/m^3)	0	254.76	594.44	849.2
Coarse aggregate	681.1	681.1	681.1	681.1
Water (lit/m^3)	174.2	174.2	174.2	174.2
SP %	1.3	1.3	1.3	1.3
VMA %	0.18	0.18	0.18	0.18

Where, SCC/0 is controlled concrete, SCC/30 is concrete with 30% replaced rigid waste material, SCC/70 is concrete with 70% replaced rigid waste material, SCC/100 is concrete with 100% replaced rigid waste material.

c) SCC Plastic properties

In order to investigate the effect of replacement of rigid waste materials on workability various tests like slump flow, T_{50} cm test, J ring, V funnel test, L box test and U box test were conducted on fresh concrete, these tests were conducted within 30 minutes of mixing.

d) Compressive Strength of test and controlled specimens:

The compressive strength tests were carried out at the end of different curing periods of 7, 14 and 28 days on 200T capacity compression testing machine on both test specimens and controlled specimens, for each test three specimens were used to study the hardened property of concrete. The test was carried out according to IS 516:1959 [33].

RESULTS AND DISCUSSION

a) Grain size distribution:

After processing the rigid waste materials, sieve analysis was carried out according to IS 383:1970 [31], from the results the particle size distribution curves were plotted for different materials.

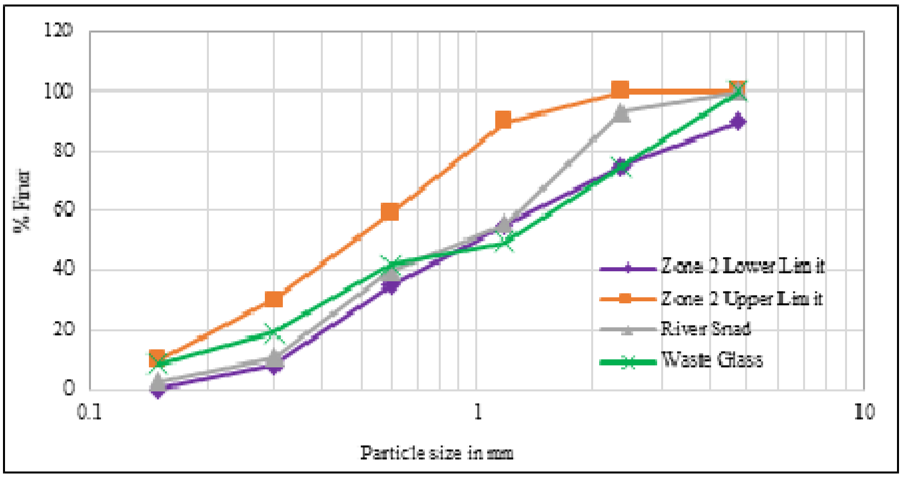

Figure 1 Grain size distribution curve for waste glass in comparison with river sand.

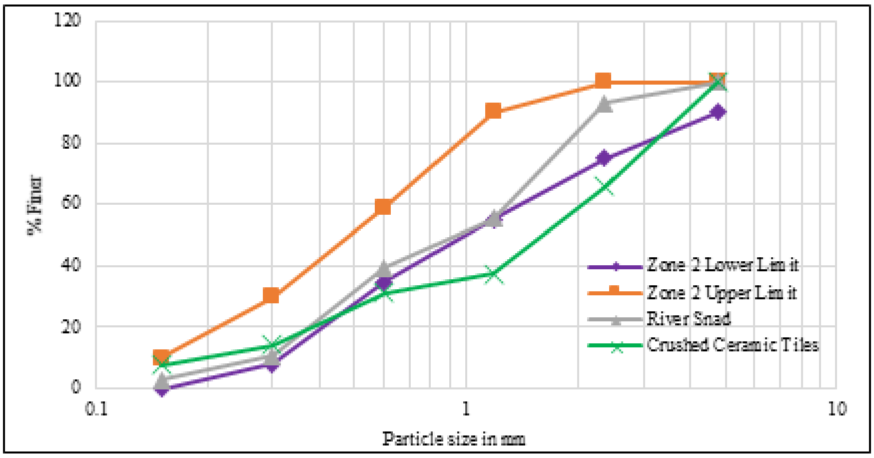

Figure 2 Grain size distribution curve for ceramic tiles in comparison with river sand.

From the gradation curves figure 1 and figure 2 it was observed that waste glass and crushed ceramic tiles did not confirm to zone II of IS 383:1970. Indicating need for proper care to be taken during blending.

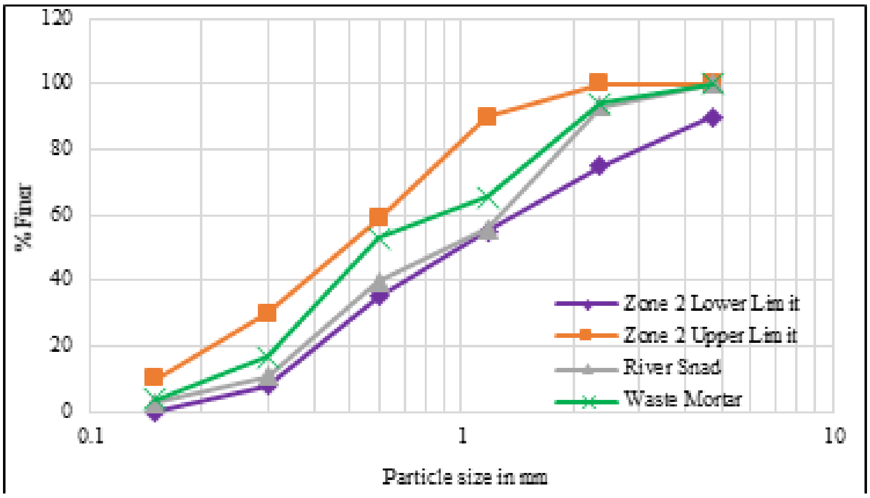

Figure 3 Grain size distribution curve for mortar waste in comparison with river sand.

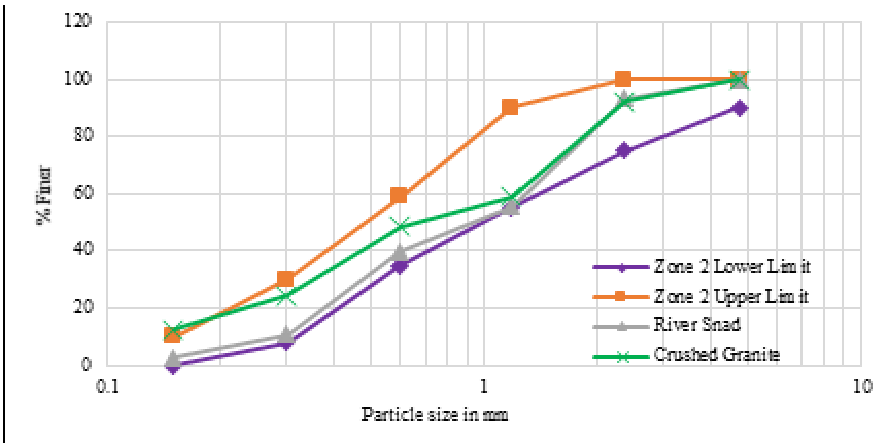

Figure 4 Grain size distribution curve for waste granite in comparison with river sand.

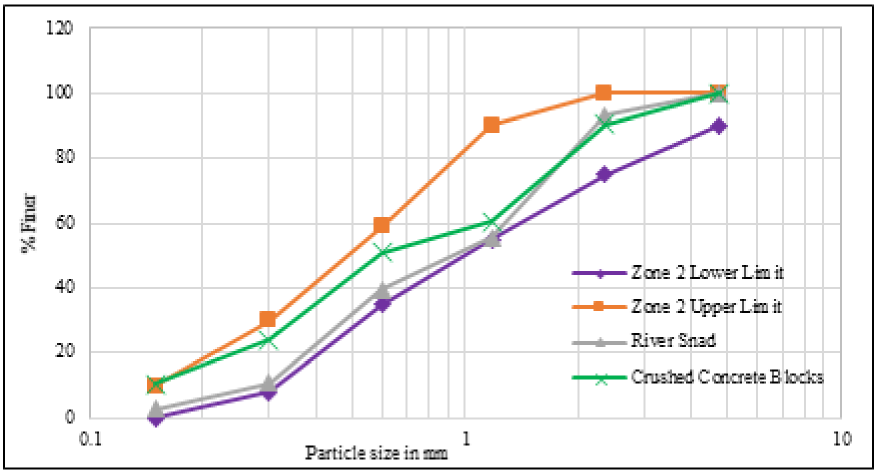

Figure 5 Grain size distribution curve for concrete blocks in comparison with river sand

From the figure 3, figure 4 and figure 5 it was observed that waste mortar, crushed granite and crushed concrete blocks confirmed to zone II gradation of IS 383:1970.

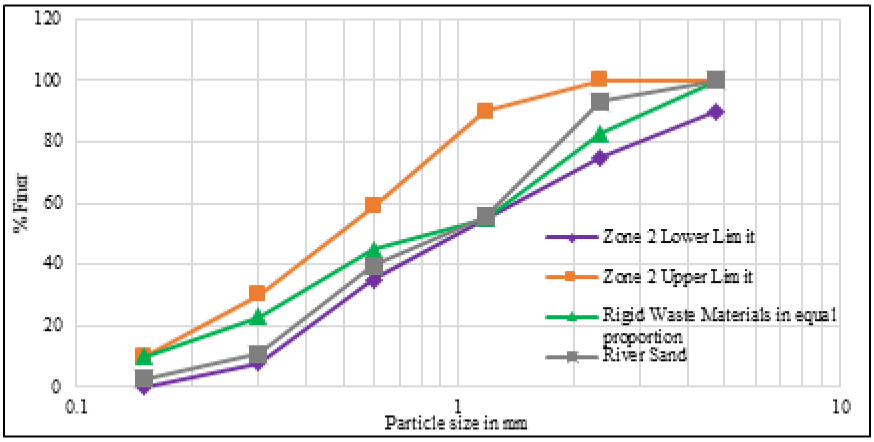

Figure 6 Grain Analysis for all waste materials in equal proportion in comparison with river sand

From the figure 6 it can be clearly observed that all rigid waste materials mixed in equal proportion confirmed to zone II gradation of IS 383:1970. Hence it can be inferred that proper gradation for waste materials has to be done, so as to get the required gradation.

b) SCC Plastic Properties

The test results on SCC for different replacement levels are tabulated in TABLE 2 along with acceptable limits followed by Japan Society of Civil Engineers (JSCE).

From the test conducted on workability it was noted that with the increase in replacement levels there was decrease in workability for same w/b ratio, SP and VMA content. However, these values were well within acceptable limits.

Table 2. Various SCC plastic property test results for different replacement levels in SCC.

	SCC/0	SCC/30	SCC/70	SCC/100	Limits
Slump flow (mm)	760	755	730	660	600-800
T_{50} cm (sec)	2.2	2.5	3.2	4.6	2-5
J ring (mm)	1	1	2	4	0-10
V Funnel (sec)	8	9.6	10.9	12	4-12
L box (mm)	0.9	0.87	0.72	0.65	0.8-1
U box Diff in Height (mm)	2	3	10	12	0-30

c) SCC Hardened Properties

The average compressive strength at the end of 7, 28 and 56 days are tabulated in TABLE 3.

Table 3 Average Compressive strength results at different curing periods.

	7 Days (MPa)	28 Days (MPa)	56 Days (MPa)
SCC/0	16.66	48.68	50.87
SCC/30	13.44	47.5	51.45
SCC/70	17.06	47.38	49.12
SCC/100	14.96	46.8	50.29

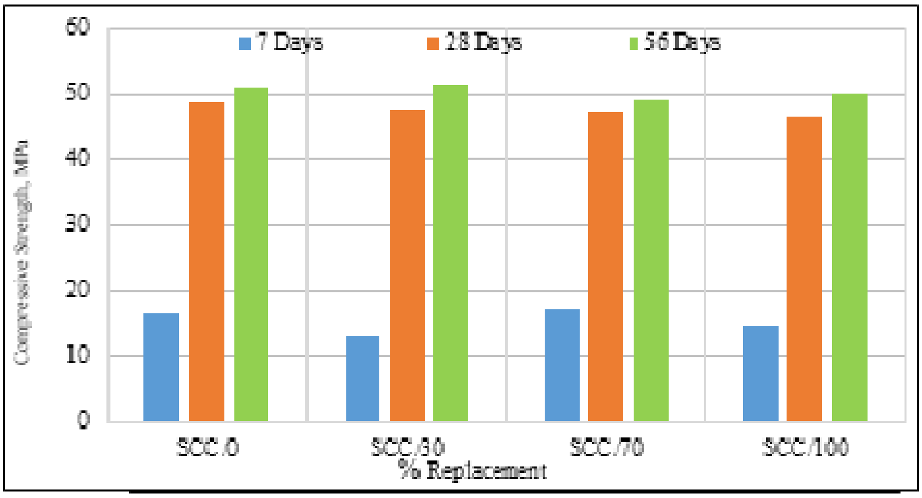

Figure 7 Compressive strength values for various replacement levels with age

From the overall results it was observed that 30% replacement of river sand by rigid waste materials gave more strength than SCC/0 with increase in curing period. Also with increase in curing period both 0% and 100% replacement gave a consistent value.

OBSERVATIONS AND CONCLUSIONS

1. When rigid waste materials were used as replacement for fine aggregates, there was a decrease in workability. The decrease was observed at 70% and 100% replacement levels; however, these decreased workability values were within acceptable limits.
2. Packing factor is one of the main criteria when Nan-Su method used for mix proportioning of SCC, which has to be evaluated by actual investigation.
3. Proper care needs to be taken during blending of different materials so as to avoid undesirable grading and to obtain grading curve within the required zone.
4. Suitable mechanised crushing techniques needs to be developed which can take care of variety of rigid wastes materials and to obtain desired consistent and gradation.
5. At 7 days SCC/70 gave highest strength of 17.06 MPa, which was 2.4% higher than SCC/0, whereas SCC/30 and SCC/70 was 19.3% and 10.2% lesser than SCC/0 respectively.
6. At 28 days SCC/0 gave the highest strength of 48.68 MPa, whereas SCC/30, SCC/70, SCC/100 was lesser by 2.42%, 2.74% and 3.86% respectively.
7. At the end of 56 days SCC/30 gave highest strength of 51.45 MPa which was 1.14% more than SCC/0, however SCC/0 and SCC/100 showed a consistent results indicating progressive strength development in SCC/100. But SCC/70 showed 3.44% lesser value than CC.
8. However, from the overall results of compressive strength it was observed that strength was consistent even at 100% replacement and all the strength were more than the design strength.

This results were not observed in any of the research carried out on rigid waste material as replacement for fine aggregates.

9. Since the results of compressive strength were higher than designed strength, reduction in cement content can be investigated and a suitable mix design procedure can be evolved.
10. The availability of rigid waste material is not same from all the site, hence various combinations of these materials has to be carried out to obtain best suitable proportion.
11. The use of waste materials in concrete for partial and full replacement proves to be an alternative material for depleting natural river sand and also helps in safe & effective disposal of waste material rather than dumping them.

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