Effects of Recycled Fine Aggregate Content on Cementitious Mortar

Subasinghe IS, Madusanka VPS, JayasingheVRDK, Sundarapperuma SMAP, Fernando WSSR, Chandrasiriand SAKN, Karunarathne S

*Corresponding author – shiromi27@yahoo.co.uk

Abstract: Properties of the recycled fine aggregates and the suitability of the same in cementitious mortar were studied and compared with those of natural fine aggregates. The results showed that the particle size distribution of recycled fine aggregates is compatible with those of natural fine aggregates. The recycled fine aggregates had fine fraction and bulk density of 13.47% and 1407kg/m^3, respectively while those of the natural fine aggregates were 1.51% and 1453kg/m^3, respectively. Specific Gravity of recycled fine aggregates was 2.499with compared to 2.408 of Natural fine aggregates and the water absorption was 6.325% with compared to 0.71% of Natural fine aggregates. Chloride Content of recycled fine aggregate was 0.0150% with compared to 0.0005% of natural fine aggregate. Properties of mortar made fewer than five testing scenarios consisting different proportions of natural fine aggregate to recycle fine aggregate as 100%-0%,75%-25%,50% -50%, 25%-75%, and 0%-100% were compared with those of 100% natural fine aggregates. With increasing percentage of recycled aggregate content, compressive strength increased in 0.7 Water cement ratio while the workability decreased. According to the results, mortar properties could be achieved with mix proportions of 50% natural fine aggregate and 50% recycled fine aggregate, without significantly affecting the mortar properties, indicating a 50% saving of natural fine aggregates thus reducing environmental impacts and enhancing sustainability.

Keywords: Water absorption, Compressive strength, Bulk Density, Specific Gravity, Workability.

1. Introduction

With the significant technological development currently experienced worldwide, the rate of pollution and waste emission has increased immensely while demolished construction waste has begun to play a significant role in this issue. With the concept of recycling in rise, the focus has shifted to the use of recycled construction and demolished waste as an alternative for fine and coarse aggregates in the construction industry. In addition, rising demand for construction materials, increasing depletion of raw materials such as sand and aggregates plus the environmental damage from material production has led to the popularity of this concept.Although research works in

some countries had indicated that recycled fine aggregates could be used for production of mortar, it has not been researched enough in Sri Lanka to convince the Sri Lankan engineers. Thus the present study investigates the feasibility of using recycled fine aggregates as an alternative construction material in bedding mortar.

2. Materials and Methods

2.1 Preparation of Samples

A bulk sample of demolished building waste was collected from the COWAM centre site in Galle and used as the materials for testing.

2.2 Testing of fine Aggregates

Followings tests were carried out to test the fine aggregate properties of recycled fine aggregates and natural fine aggregates.

- Sieve Analysis test - (ASTM C 144-84)
- Specific Gravity and Water Absorption test -(BS 812-Part 2:1995)
- Bulk Density test - (ASTM C 29-09)
- Fine Fraction- (ASTM C117-95)
- Chloride Content-(BS 1377-Part 3:1990)

2.2 Testing of Mortar

To evaluate the properties of mortar made using recycled fine aggregates, the recycled fine aggregates were mixed with natural fine aggregates under three different scenarios.

Table 1 - Respective percentage of fine aggregates mixed for production of mortar

Scenario No :	% of Recycled Aggregates	% of Natural Aggregates
1	0	100
2	25	75
3	50	50
4	75	25
5	100	0

The properties of mortar made according to the mixed proportions given in table 1, were compared with the mortar made with 100% natural fine aggregates.

The workability of each and every mix was tested prior to the making of mortar specimens. Curing was carried out as per the BS standards after the preparation of the mortar specimens. The testing of those specimens was done for 7 days, 14 days and 28 days.

Following tests were done to determine the mortar properties.

- Compressive strength of test cubes - (BS 1377-part 2 : 1990)
- Workability of fresh mortar – (BS EN 1015-3)

3. Results and Discussion

Mortar is a mixture of compendious material, sand, and water. Aggregate is classified as course and fine. For Mortar, fine aggregate were used. In the present study the fine aggregates were varied while keeping the others as they are and,

S Karunarathne, C. Eng., MIE (SL), M.Sc.(Saitama), Ph.D.(Saitama) B.Sc. Eng. (Hons) (Moratuwa), MASCE(USA), Head of Department in Department of Earth Resources Engineering, University of Moratuwa.

IS Subasinghe,VPSMadusanka, VRDK Jayasinghe,SMAPSundarapperuma,WSSR Fernando, SAKN Chandrasiri, Final year Undergraduate students in the Department of Earth Resources Engineering, University of Moratuwa.

the variation in the properties of mortar was studied.

3.1 Properties of recycled fine aggregates

There was no significant difference between the gradation curves of natural fine aggregates and recycled fine aggregates. Gradation affects many properties such as bulk density, physical stability, permeability etc. If the fine aggregates used to produce mortar are well distributed in their sizes, it will make the mortar stronger and also less porous.

According to the results, it shows a dense gradation of approximately equal amounts of various sizes of fine aggregates. The size of sand particles and their relative proportions play an important part in determining mortar properties in both the wet and set states.(S.J.Thurston,2011)
The average results of fine aggregate properties are given in table 2.

Table 2 - Results of fine aggregate properties of Recycled Fine Aggregates (RA) vs. Fine Natural Aggregates (NA)

Aggregate Property	RA	NA
Specific Gravity	2.499	2.408
Water Absorption (%)	6.325	0.71

The specific gravity of a fine aggregate is considered to be a compute of strength or quality of the material (Yong, 2009).There is a reduction of 4% from recycle fine aggregate to natural fine aggregate with respect to table 2, hence the strength is reduced. This is due to the fact that the recycled fine aggregate contains some amounts of mortar, parts of bricks and parts of concrete surrounded by the virgin aggregate and that deleterious material which are heavier than virgin aggregates.
Water absorption of recycled aggregates is higher than that of natural aggregates probably due to higher amount of pore spaces in the recycle aggregate due to the presence of attached mortar, concrete etc.

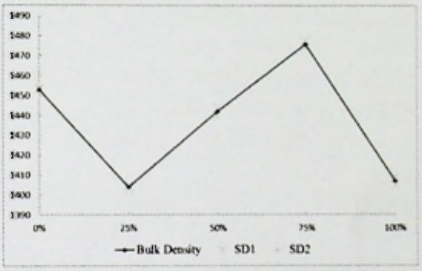

Figure 1 - Bulk density vs. Recycled aggregate %
The bulk density plays a vital role in determining the strength of mortar. According to figure- 1, it is visible that bulk densities of all five mixtures are within the range of 1400-1480 kg/m^3 while the maximum bulk density is reached at 75RA% due to the grain packing at that ratio.

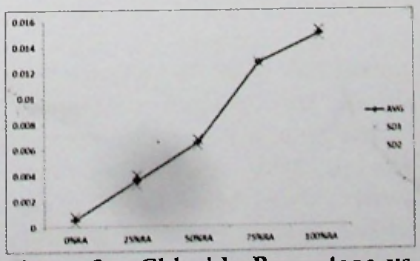

Figure 2 - Chloride Percentage vs. RA Percentage

Observing the chloride content results in Figure- 2, the lowest is 0.0005%, which is for NA while the value increases up to a highest of 0.0150% for 100% RA. When considering the basic applications for bedding purposes mixtures of up to 99%RAcontent can be used within permissible chloride content. But, when considering applications where mortar is used with embedded metals, aggregate mixtures up to 45% RA can be used without carrying out any additional washing.

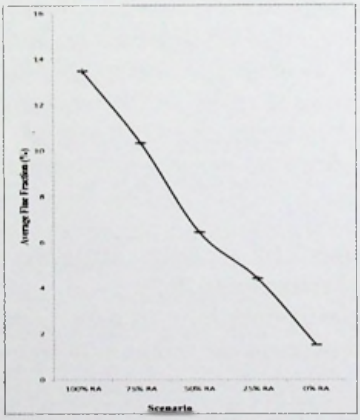

Figure 3 – Fine Fraction vs. RA percentage

When considering Figure-3, it is evident that the fine fraction (%) increases from 1.51% at 0%RA to a maximum of 13.47% at 100%RA. This high amount of fines is undesirable and, is expected to reduce the strength of mortar. According to these results, it is clear that all these recycled aggregate mortar mixes are below 30% in fine fraction and can be used as masonry mortar.

3.2 Property variation of mortar made using recycled aggregates.

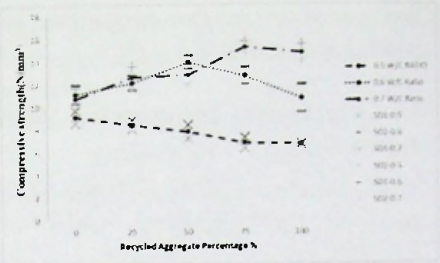

Figure 4 – Variation of compressive strength of mortar after 28 days

In Figure 4,When the 0.7 water/cement ratio data are analysed it can be seen that they change in a similar pattern by increasing up to 75% RA mixture and then on showing a dip. This may once again be due to excess water the mortars up to 75% RA contained and, then on the lack of water due to the high water absorbance by the RA. Due to the high water absorbance of RA, it showed low compressive strengths at 0.5 and 0.6 water/cement ratios.

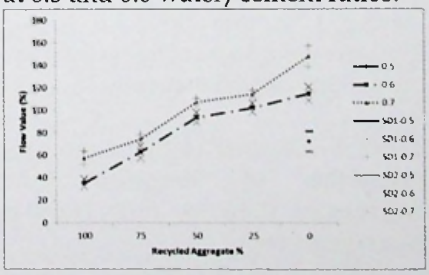

Figure 5 – Workability of mortar in 0.7 Water cement ratio

When considering the results from the workability tests for mortar, the recycled aggregates seem to reduce the workability of mortar. 0.5 water/cement ratio once again proved to be lacking water required for good mortar workability even for 100%NA. When considering the 0.6 water/cement ratio, the mortars made from 0%RA (100%NA) and

25% RA showed good workability characteristics. With the water content further increased at water/cement ratio of 0.7, Figure 5 shows that good workability can be achieved, for higher RA% in mortar in the range of 25-50%RA.

4. Conclusions

Mechanical properties of RA such as bulk density, water absorption, fine content and chloride content showed a relatively inferior quality when compared to that of natural sand. However, mortar made out of RA showed lesser impacts on the compressive strength and workability when compared to that made from 100% natural aggregates.

Mortar made by using mixtures of 50% RA with 50%NA, at water/cement ratio of 0.7, most suitable for construction purposes since it has achieved the optimum workability as well as acceptable and higher strength values than 100%NA.

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