ICSBE2016-230

UTILIZATION OF FINE FRACTION OF CONSTRUCTION AND DEMOLITION MASONRY WASTE FOR MORTAR

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Abstract: Construction and demolition waste plays a major role of the waste production in developing countries and there is scarcity of natural resources also, due to rapid development projects. This research is focused on the utilizing Construction and Demolition (C&D) masonry waste as a replacement of sand in mortar. Objective of this study is to investigate the performance of mortars having different replacement ratios of C&D masonry waste and determine the best proportion of the C&D waste for the mortar which can be used as plaster. Crushed C&D masonry waste was collected from the Construction Waste Management Centre (COWAM), which is located in Galle. A sieve analysis test was performed to determine particle size distribution of C&D masonry waste. Bulk density, workability, flexural strength, compression strength, water absorption and fire resistivity were experimentally investigated. Bulk density of C&D masonry waste was 18% lower than that of the river sand. Bulk density of fresh and harden conventional mortar had higher values than sand replaced mortars. Workability of the mortar decreased when increasing the waste content. The flexural strength and compression strength were maximized at 10% and 20% sand replacement levels, respectively. Water adsorption of sand replaced mortars was higher than the conventional mortar. It was found that with the presence of C&D masonry waste in the mortar, the higher resistance to the fire.

Keywords: C&D waste; mortar; masonry; physical performances; utilization

1. Introduction

In the developing countries, mega scale development projects have been started, more projects are to be expected in future and several projects are already completed. Construction and Demolition (C&D) waste form construction projects are inevitable. However waste cannot be illegally disposed. Finally all these C&D waste is accumulated rapidly in to the land. Illegal disposal methods of C&D waste are increased creating lot of financial, social and environmental problems which can be affected on future developments. In addition, disposal cost represents about 0.5% of a house's total construction cost or more than [1] including the cost of transporting, handling and tipping charges and cost of consequential losses. On the other hand, there is a scarcity of several limited natural resources such as sand which is costly and mining processes also create lots of problem to the environment.

Most of the developed countries have implemented proper management systems for C&D waste but it is not possible to use the same in other developing countries due to different composition of the waste, lack of technology, lack of resources and financial limitations. In the literature there are several C&D waste management methods which help to utilize the waste. However, these studies have been mostly focused on coarse fraction of C&D waste [2]. Several of characteristics, namely workability, bulk density, flexural strength, adhesive strength, compressive strength, shrinkage and water retentivity of mortar with C&D concrete waste and ceramic waste have been studied in Nenoa [3] and Silva [4], respectively. Some improvements with the sand replaced mortar with these wastes have been found. Based on the literature, it seems to be possible to use recycled aggregates in mortars but the limitations of use and the optimal content to be adopted depend on the nature of the recycled material and its chemical composition.

This research investigates the performance of the recycled C&D masonry waste added plaster by determining characteristics of the samples having various percentage of C&D masonry waste. Optimum proportion of C&D masonry waste for the mortar which can be used as plaster by replacing the sand will be determined.

2. Materials and methodology

2.1 Raw materials

Galle municipal council area was selected as the study area because composition of C&D masonry waste is all most same within a small country like Sri Lanka. Rameezdeen [1] had found the construction waste composition (Figure 1) and demolition waste composition (Figure 2) within Galle municipal council. Among the waste accumulated in Galle municipal council, a large amount of C&D waste consist with brick and masonry waste.

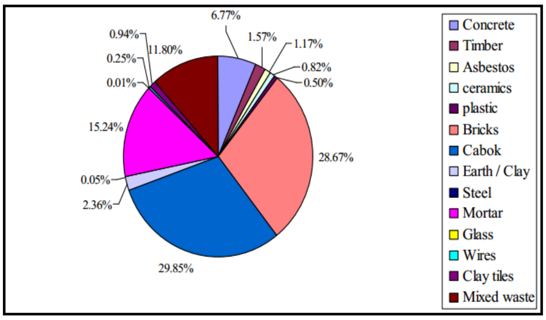

Fig 1: Demolition waste composition

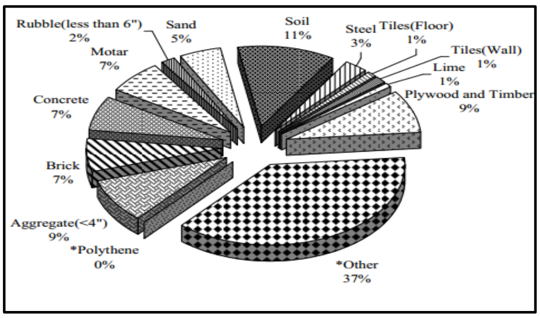

Fig 2: Construction waste composition

C&D masonry waste was collected from Construction Waste Management Centre (COWAM) which is located in Dadalla, Galle. Sieved fine masonry aggregate samples were selected from this site for the current study. River sand, ordinary Portland cement and pipe borne water, provided by National Water Supply and Drainage Board (NWSDB) were used as other raw materials to prepare test specimens.

2.2 Preparation of specimens

Different C&D masonry waste replacement of sand (i.e., 0%, 10%, 20%, 30% and 40% of volume) to the mortar was used. The mortar type M (1:5 cement, sand) [5], which is largely used in Sri Lanka, was used for this research. Mortar cubes and prisms were made according to the testing procedures. Cube specimens having the size of 50mm×50mm×50mm were cast to conduct water adsorption test, compression test, durability test and fire resistivity test. Prism specimens having the size of 160 mm x 40 mm x 40 mm were prepared for the flexural strength test.

2.3 Laboratory Experiments

Laboratory experiments were performed for raw materials, fresh mortar and harden mortar.

2.3.1 Raw materials

Sieve analysis test was performed for C&D masonry waste and river sand as specified in ASTM C 136 [6] to determine particle size distribution. A sample of dry aggregate of known mass was separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

The bulk density test was carried out as specified in ASTM C-29 [7] by weighing the known volume of sample.

2.3.2 Fresh mortar

2.3.2.1 Workability test

The workability test was carried out according to ASTM C 1437 [8], because the ability of accurate determination of the workability is very essential for mortar. In addition, density test was conducted for fresh mortar.

2.3.3 Harden mortar

2.3.3.1 Compression test and Flexural test

Specimens for compression test were cured for required time period (i.e., 24hrs, 3days, 7days, and 28days) as in ASTM C109 [9]. The specimens were placed carefully in the compression testing machine below the centre of the upper bearing block and load was added until failure. Using the load at the failure compression force was determined. Six samples were tested from each replacement ratio of sand.

The flexural strength was determined by three point loading of a prism specimen as specified in BS EN 1015-11[10]. At the point of failure flexural strength was determined as in Equation 1. Where b and d are the internal dimensions of the prism mould, l is the distance between the supporting rollers.

$$f = \frac{1.5\,Fl}{bd^2} \tag{2}$$

2.3.3.2 Water adsorption test

Water absorption test was performed as specified in ASTM C1403 [11]. At the age of 28 days ±12 hrs from the time of casting, the specimens were removed from the moisture tight plastic bag and dry in a ventilated oven at a temperature of 110±5°C for not less than 24 hrs. All the specimens were placed in the uptake container(s) with their top faces, as cast, in contact with the specimen supports.

2.3.3.3 Fire resistivity test

After curing 28 days, cubes were dried at room temperature and are kept in an oven at a temperature of 100°C and 300°C for 18 hrs to conduct the fire resistivity test. The samples were monitored and weight of the samples was measured.

2.3.3.4 Durability test

Durability was determined by the compressive strength test. Each specimen was exposed to solutions of 10% Sodium Sulphate (Na_2SO_4) and 10% Magnesium Sulphate ($MgSO_4$) in water and was tested at 60 days after 28 days initial curing of specimens in water as performed in [12].

In addition to above tests, bulk density of harden mortar was also determined by weighing the dry 50mm× 50mm× 50mm cubes.

3. Results and Discussion

3.1 Properties of raw materials

3.1.1 Sieve analysis test

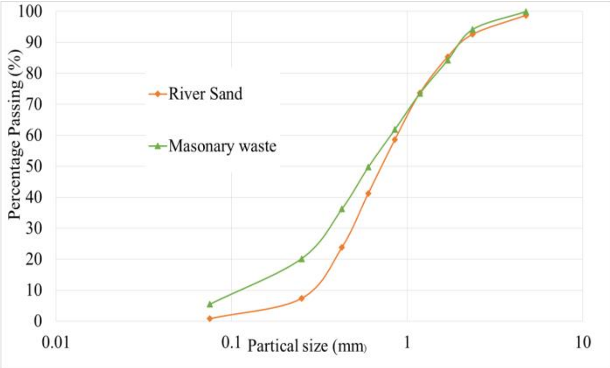

Fig 3: particle size distribution

Particle size distribution is shown in Figure 3.It can be seen that fines percentage of river sand is 1%, while masonry waste is 5%. This indicates fine percentage of recycled aggregates is higher than that in natural river sand.

3.1.2 Bulk density test

Bulk densities of river sand and C&D masonry waste are listed in Table 1.

Table 1: Bulk density of raw materials

Material	Bulk density (kg/m^3)
Sand	1512
C&D Masonry waste	1238

Bulk density of masonry waste was 18% lower than the river sand. Consequently, working with C&D masonry waste is easier than river sand due to the lesser self-weight.

3.2 Properties of fresh mortar

3.2.1 Bulk density

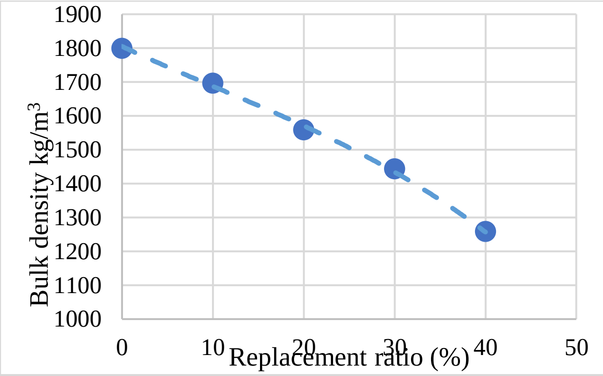

Fig 4: Variation of bulk density of fresh mortar

It can be seen from figure 4 that bulk density of fresh mortar decreased when increasing the waste content, since bulk density of recycled fine aggregate is lower than the conventional aggregate, such as river sand.

3.2.2 Workability test

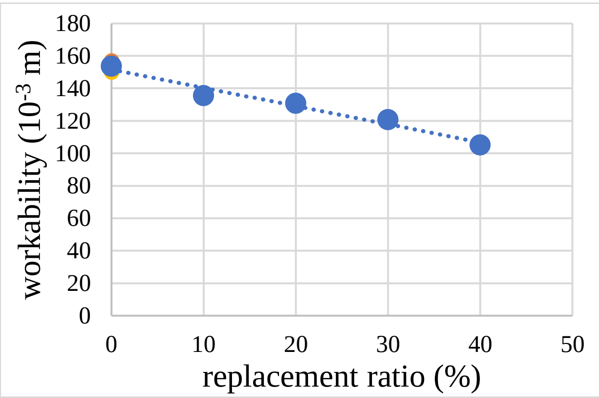

Fig 5: Workability of mortar

Figure 5 shows that workability of mortars containing recycled C&D masonry waste decreases when increasing the waste content. This would be attributed by the greater porosity of the recycled C&D masonry waste than that of river sand. This further indicates mortars containing recycled masonry waste need more mixing water to reach the same level of workability as conventional mortars. Silva [4] and Nenoa [3] also found that the larger the incorporation of C&D ceramic and concrete waste, respectively, the more mixing water needed. It is well established that C&D wastes with greater porosity and surface area per unit volume absorb more water and therefore they make the resulting mortar more consistent [3].

3.3 Properties of harden mortar

3.3.1 Bulk density

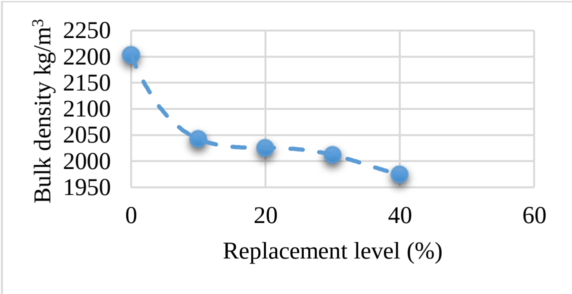

Fig 6: Variation of bulk density of harden mortar with C & D masonry waste replacement level

In harden mortars, the bulk density reduces when recycled C&D masonry wastes are incorporated into the mix as in Figure 6. The mortar having 10% replacement ratio reduces the bulk density in 7%. When increasing the waste content further, bulk density gradually decreased; the mortar having 40% replacement ratio reduce the bulk density in 10%. Silva [4] also found that the dry bulk density of the hardened mortars containing recycled C&D brick waste with ceramic material was 8% lower than that of mortar made with natural sand.

3.3.2 Compression test and flexural test

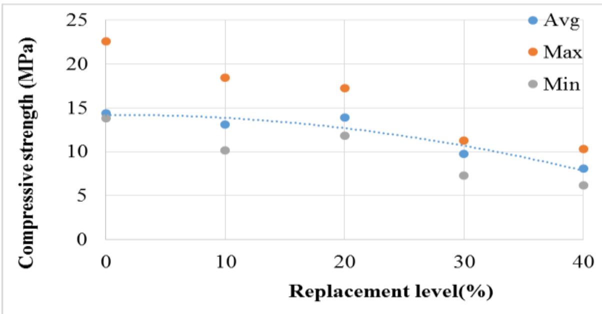

Fig 7: Variation of compressive strength with C & D masonry waste replacement level

However in the BS 5628-1 [13] the compressive strength for the 1:5 mortar is defined as 4 MPa and the compressive strength of 40% replacement ratio also has the value more than 4 MPa. Therefore mortar with 40% replacement of sand also can be recommended in terms of compressive strength (Figure 7). However, the effect of reduction of compressive strength can be neglected, since it was a small value and large compressive forces may not apply for the plaster.

In masonry waste, no considerable portion of sand particles are available and it consists with crush brick particles which having the low strength may cause to reduce the compressive strength of the sand replaced mortar than the conventional mortar. Dillman [14] also generally found that when increasing the C&D waste *(without separating)* content, compressive strength decreased.

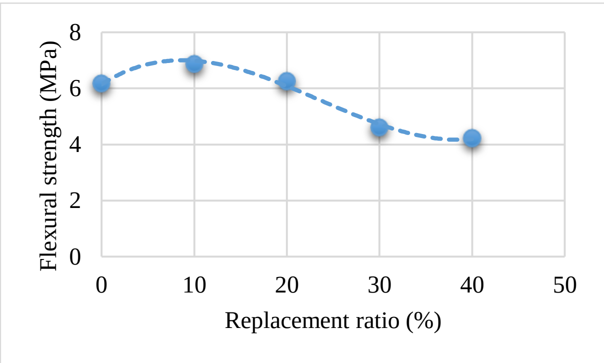

Fig 8: Variation of flexural strength with the C&D waste replacement ratio

Flexural strengths at the age of 28 days are shown in Figure 8. In terms of flexural strength the optimum mix proportion is 10% replacement of sand having 11% improvement than the conventional mortar mixture. However 20% replacement of sand has the approximately same flexural strength as conventional mortar. Improvement of flexural strength properties are effective for plaster to resist the lateral forces induced by the wind and forces due to cracking.

3.3.3 Water adsorption test

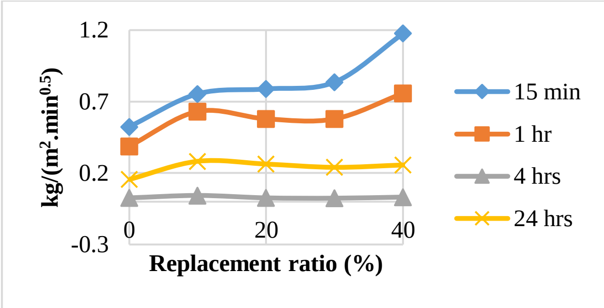

Fig 9: Variation of water adsorption rate with the replacement ratio

Figure 9 shows the variation of water adsorption with C&D masonry waste replacement level. It can be seen that replacement of sand with brick waste caused an increase of water absorption by capillary action. 30% replacement of sand shows the minimum water adsorption by comparing with other replaced mixtures; it also increased water adsorption by 54%, when comparing with conventional mortar.

3.3.4. Fire resistivity test

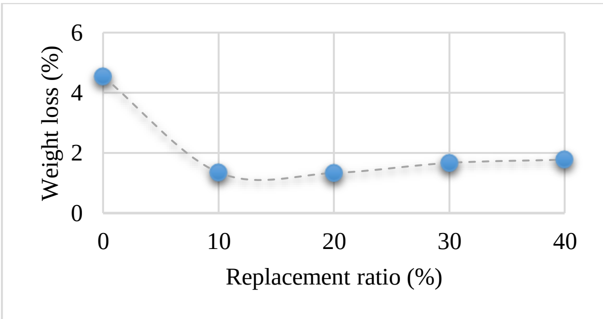

Fig 10: Weight loss variation with the C&D waste replacement ratio

As shown in Figure 10 there is a weight reduction in mortar cubes in different temperatures. Highest weight reduction was occurred in the conventional mortar. At 30% and 40% replacement ratios, the 40% improvement of fire resistivity was found. The optimum mixture in terms of fire resistivity is the mortar with 20% replacement ratio.

4 Conclusions

The performed tests allowed conclusions to be drawn on the feasibility of replacing fine natural aggregates (sand) with fine particles of construction and demolition masonry waste. Throughout the testing sequences, reference mortar without recycled aggregates and mortars with replacement ratios of 10%, 20%, 30% and 40% were used. Constant composition, water cement ratio and aggregate size distribution were kept and allowed the following conclusions.

C&D masonry waste had similar particle size distribution and lower bulk density when comparing with the natural sand.

Bulk density of fresh conventional mortar had higher values than replaced mortars. Workability and the bulk density of the mortar decrease when increasing the C& D masonry waste content.

Compressive strength was optimum at 20% replacement ratio flexural strength was optimum at 10% replacement ratio. 30% replacement of sand showed the minimum water adsorption properties, although it was approximately same for the 20% replacement of sand. Fire resistivity was improved by 40% compared to the conventional mortar, for 40% replacement ratio. At 20% replacement level of mortar, the 30% improvement of fire resistivity was found.

The study clearly indicates the 20% replacement of sand with C&D masonry waste had the more improved characteristics such as workability, bulk density, compressive strength, water adsorption, flexural strength and fire resistivity, than the conventional mortar.

In the present, large amount of sand is needed for the plastering work. With this replacement ratio, considerable amount of C&D masonry waste can be utilized as mortar for plaster with minimizing the effect on the environment by reducing the waste disposal areas and sand mining activities.

References

[1] Rameezdeen, R., 2004, Strategy for Sustainable Construction and Demolition Waste Management in Galle, Sri Lanka, University of Moratuwa, Katubedda, Sri Lanka.

[2] Kuosa, H., 2012, Reuse of recycled aggregates and other C&D wastes, VIT Technical Research Centre, Finland.

[3] Nenoa, C., Britoa, J., and Veigab, R., 2013, Using Fine Recycled Concrete Aggregate for Mortar Production, DECivil-IST, Technical University of Lisbon, Av. Rovisco Pais, 1049-001, Lisbon, Portugal.

[4] Silva, J., Brito J. and Veiga, M.R., 2010, Recycled red-clay ceramic construction and demolition waste for mortars production, DECivil-IST, Technical University of Lisbon, Av. Rovisco Pais, 1049-001, Lisbon, Portugal.

[5] ASTM C136, 2014, Standard Standard Specification for Mortar for Unit Masonry, ASTM International, West Conshohocken, USA.

[6] ASTM C136, 2001, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, ASTM International, West Conshohocken, USA.

[7] ASTM C29, 2003, Standard Test Method for Bulk Density ("Unit Weight"), ASTM International, West Conshohocken, USA.

[8] ASTM C1437, 2007, Standard Test Method for Flow of Hydraulic Cement Mortar, ASTM International, West Conshohocken, USA.

[9] ASTM C109, 2002, Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens), ASTM International, West Conshohocken, USA.

[10] BS EN 1015-1, 1999, Determination of flexural and compressive strength of hardened mortar, Brussels, Belgium.

[11] ASTM C1403, 2000, Standard Test Method for Rate of Water Absorption of Masonry Mortars, ASTM International, West Conshohocken, USA.

[12] Ravikumar, C.M., Sreenivasa, M. B., Raheem, K.A., Prashanth, M. H. and Sekhar M.V., 2013,'Reddy Experimental Studies on Strength and Durability of Mortars Containing Pozzolonic Materials', International Journal of Advanced Structures and Geotechnical Engineering, 2(2), pp. 45-49.

[13] BS 5628-1, 2005, Code of Practice for the Use of Masonry, BSI Group, UK.

[14] Dillman, R. (1998) "Concrete with recycled aggregate", International symposium: "Use of recycled concrete aggregate", Concrete Technology Unit, University of Dundee, Scotland, Thomas Telford Books, pp. 239-253.