SUSTAINABLE REUSE OF BROWNFIELD PROPERTIES IN SRI LANKA AS A GABION FILL MATERIAL

Udeni P. Nawagamuwa
Department of Civil Engineering, University of Moratuwa, Sri Lanka
Email: udeni@uom.lk
D.L. Madarasinghe , M.D.M.J. Goonatillake, H.J.D. Karunarathna,
Department of Civil Engineering, University of Moratuwa, Sri Lanka
Manjriker Gunaratne
Department of Civil and Environmental Engineering, University of South Florida, USA
Email: gunaratn@eng.usf.edu

Abstract

Sustainable reuse of Brownfield properties includes efforts to reduce the environmental impact by reusing and recycling materials generated during building construction, demolition, or renovation. The waste generated by construction and demolition industry is becoming a growing menace to the social as well as the natural environment. Even though sustainable and environmentally friendly designs are considered as current trends, a sustainable and environmentally friendly solution for the waste generated by the construction industry is still being not looked upon. In this study, the intention was to find a solution for the waste generated by the construction and demolition industry in the form of a fill material for gabions. Five waste materials such as concrete, plasters, bricks, pebbles and bricks with mortar are selected for the study and they are tested for their durability and compressive strength. These results are compared with the values obtained for rubble which is the standard gabion fill material. In addition, the environmental, economical and social feasibility of constructing gabions with waste materials are also considered, so that a proper solution could be obtained for construction and demolition waste. This application could even be considered in the North and East of Sri Lanka where there is number of damaged buildings due to 30 year old war and those buildings have to be demolished for new construction.

Keywords: Gabion, C&D waste, durability, compressive strength

1. Introduction

Sustainable reuse of Brownfield properties includes efforts to reduce the environmental impact by reusing and recycling materials generated during building construction, demolition, or renovation (EPA-US, 2008). Construction industry generates a large amount of construction and demolition (C&D) waste, in quantities that are fast increasing with economic and social development. Most construction and demolition waste are avoidable through proper planning in the design, operational, material handling and the procurement stages. Even with careful and precise planning one would expect a considerable amount of waste generated during a construction or a demolition project. Getting rid of that particular waste should be carefully done in an environmentally, socially and economically feasible manner. The existing methods of C&D waste management are mainly land filling and dumping which transforms such land to a Brownfield land. Both these methods create more social and environmental issues such as shortage of dumping areas and health hazards. Thus the main objective of this research was to find an alternative solution for the use of C&D waste, in the form of a suitable fill material for gabions.

The approximate percentages of waste materials generated in Sri Lanka are listed in the Table 1.

Table 1. Waste Percentages Generated

Waste Type	*Percentage Generated (%)*
Concrete	*21*
Mortar	*25*
Sand	*25*
Lime	*20*
Cement	*14*
Bricks	*14*
Ceramic tiles	*10*
Timber	*10*
Rubble	*7*
Steel	*7*
Cement blocks	*6*
Paint	*5*
Asbestos sheets	*3*

(Source: Attitudes and perceptions of construction workforce on construction waste in Sri Lanka – Rameezdeen, (2009))

2. Use of Gabions in Sri Lanka

Gabions have long become an established method of construction for retaining structures worldwide, providing economical and environmentally acceptable solutions. These structures are generally designed as mass gravity walls with either stepped or flush faces depending upon the requirements of the engineer. In Sri Lanka, these gabion earth retaining structures are being used for erosion control and land reclamation. Gabion fill is normally a graded fill of between 100 to 200mm in diameter with a nominal size 6% smaller or larger (Enviromesh, 2007). The grading can be tightened to 80 to 150 mm provided that the control of the grading is tight. Stones smaller than the mesh will not be contained by it. The grading is important to ensure that voids within the unit are minimized to avoid settlements. However, it has to be noted that the demand for gabion fill material is very high and hence at the moment the rubble which can be used for other construction work is used as gabion fill material. Considering the waste generated in C&D in Sri Lanka, the possible use of such waste has to be studied.

3. Collection of C&D waste and testing procedure

Initial survey was carried out in terms of availability of construction and demolition waste, C&D waste management, gabion boxes and gabion structures, fill materials for gabion boxes, standard properties of gabion fills and their test methods, etc. Then five types of C&D wastes were selected, which were concrete, plaster, bricks, pebbles and bricks with mortar as shown in Figure 1.

Figure 1: Types of test samples

Further studies were carried out on the selected waste materials in terms of percentages generated, existing uses and different attributes of those materials. As a case study, samples of the above mentioned five waste materials were collected from the “Peliyagoda Fish Market” construction site by International Construction Consortium (ICC).

The slake durability test was carried out to investigate the durability of the waste materials and the compressive strength test was done to find the strength. The slake durability test (Figure 2) was performed under three conditions which were; present available condition, after one month soaking and after two months soaking. Soaking condition was required to simulate the actual ground conditions of the gabion structure under seepage conditions. Thus some samples were soaked and another set of samples were broken into the required particle sizes under the ASTM slake durability test standards.

Figure 3: Slake durability test

Figure 2: Compressive strength test

The compressive strength testing was done using a similar procedure to the concrete cube testing process. The existing smallest gabion box sizes were 1m x 1m x 1m and 1m x 1m x 0.5m, thus it was required to construct a similar gabion box for the testing purposes. A gabion box of 300mm x 300mm x 300mm was used for the testing purposes under laboratory conditions. Then the particle size of the gabion fill material for the model was selected as explained by Enviromesh (2007). The test was done by manually loading the gabion boxes using a hydraulic jack as shown in the Figure 3. Vertical deformation and horizontal deformations in x and y directions were measured under an applied normal load using the attached dial gauges. In order to compare and analyze the results obtained from the tests, similar tests were done with rubble and the values obtained from testing rubble were considered as the reference values.

In order to compare the factor of safety against overturning, sliding and bearing capacity failure, bulk densities of the selected waste materials were also calculated as illustrated in Table 2.

Table 2. Bulk density values of gabion box with tested samples

Material	*Bulk Density(kg/m^3)*
Rubble	*1685.60*
Pebbles	*1505.68*
Concrete	*1381.00*
Plaster	*1303.66*
Bricks	*1104.80*
Bricks with mortar	*1016.40*

4. Results and Analysis

4.1 Durability aspects

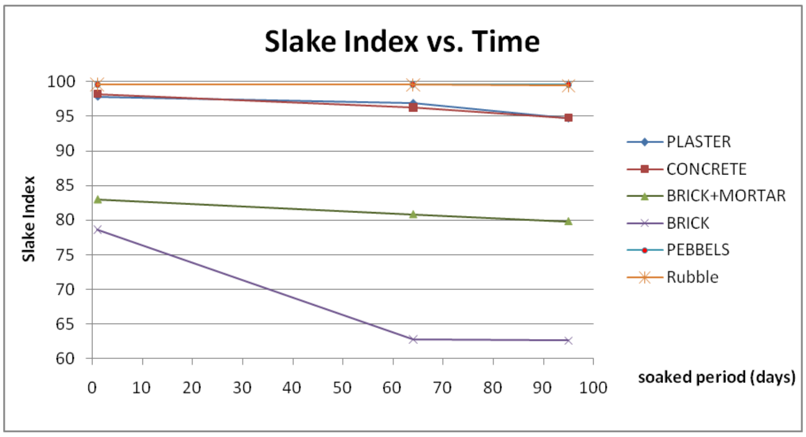

Figure 4. Slake durability test results

Slake Durability Test Results are shown in Figure 4. In order to compare the durability with the reference gabion fill properties, the slake durability indices were normalized with the slake index of rubble which is taken as the reference value. Figure 5 shows the normalized slake indices.

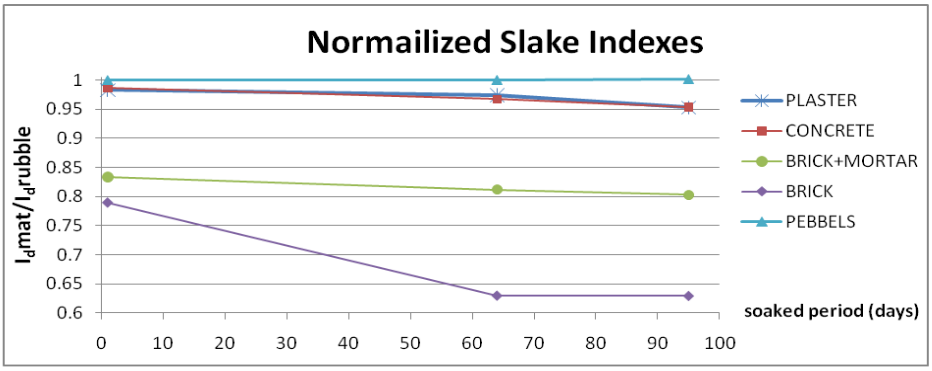

Figure 5. Normalized slake indices with respect to rubble

According to the Figure 5, pebbles have the highest ratio, which is slightly greater than the standard rubble value. Furthermore, it shows that the plaster and concrete can be identified as the next most durable material as they show slightly lower slake indexes when compared to rubble and pebbles. Bricks and bricks with mortar have the lowest durability values out of the five tested samples and hence can be identified as weak materials when considering durability aspects. Furthermore by investigating the above slake indices it was evident that the bricks and bricks with plaster show a lower reduction of durability in the duration from 60 days to 100 days soaked period.

4.2 Compressive strength aspects

Figure 6 shows the compressive stress and vertical strain relationship. The application of normal loads had to be stopped at a vertical deformation of approximately 40 mm which was identified as limiting deformation considering the dimension of the box being tested. Concrete shows that it can bear a higher load than rubble during that particular range of deformation. Plaster, brick and brick with mortar showed lower values compared to concrete. Pebbles showed the lowest strength out of the five materials. Since pebbles are broken rock material and naturally they have a high compressive strength such as rubble. The pebble samples were of rounded shape and it leads to higher voids when packing. Furthermore, the surfaces of pebble samples were smooth and this lead to slipping of pebble particles on each other when the load was applied. Due to these reasons pebbles showed higher deformation vertically when compared to other samples.

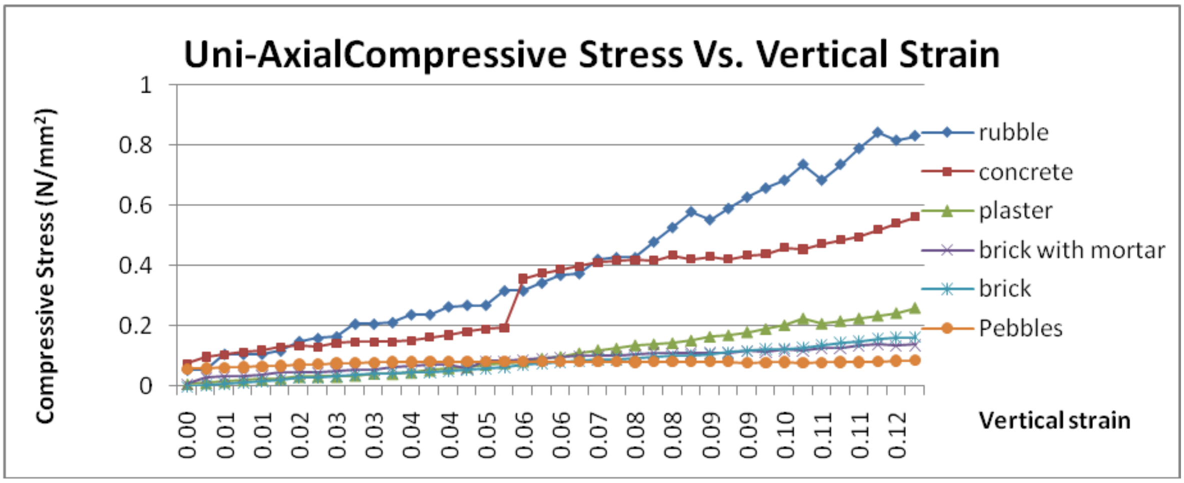

Figure 6. Uni-axial compressive stress vs strain results

4.3 Factor of Safety (FoS) aspects

Table 2 shows the bulk density values of different samples when those were packed in the tested gabion box. As FoS against overturning, sliding and bearing capacity failure is a function of the self weight of the retaining structure and when the other geotechnical conditions are considered as not varying (fixed)., bricks and bricks with mortar cannot be considered as an alternative option to rubble as a gabion fill material.

5. Conclusions and Recommendations

According to this study considering the durability, compressive strength and FoS aspects of the five selected waste materials, concrete could be considered as the most suitable for sustainable reuse as a gabion fill material. All the other four materials failed from either the durability aspect or compressive strength aspect or both.

Concrete showed similar behavior to rubble under the weathering process in the slake durability test. As far as the slake index values are concerned, concrete falls in the category of high durability. After pebbles, concrete is the most suitable material from durability perspectives. Based on the compressive strength test results, concrete showed the second best performance with respect to the vertical deformation next to rubble. In some instances it had even higher compressive strength values than rubble. However, it has to be noted that bricks and bricks with mortar had failed in all three aspects such as durability, compressive strength and FoS against different failures.

This finding could even be used in the construction sites in the war affected areas in Sri Lanka where a considerable demolition waste is available.

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