Construction of a full-scale wrapped face geogrid reinforced wall using recycled construction and demolition waste as backfill material

Santos, E.C.G.
University of Brasilia, Brasilia, Brazil
Palmeira, E.M.
University of Brasilia, Brasilia, Brazil
Bathurst, R.J.
Royal Military College of Canada, Kingston, Canada

Keywords: full-scale, reinforced wall, recycled construction and demolition waste, backfill material

ABSTRACT: The economical and technical advantages provided by reinforced soil walls are decisive to the needs of economical, safe and short construction time solutions. On the other hand, the demand for renovation and/or reform of urban environments have promoted a distinguished waste generation. Nowadays, construction and demolition wastes are perceived as significant proportion of urban solid waste. In this scenario, the use of recycled construction and demolition waste as backfill material appears to be an interesting option to incorporate sustainable development into the reinforced soil wall technique. In order to investigate this proposal, an instrumented full-scale wrapped face geogrid reinforced wall was constructed using recycled construction and demolition waste as backfill material. Even though the drawing of definite conclusions requires a deeper investigation for this innovative proposal, the post-construction results show a satisfactory performance of the wall.

1 INTRODUCTION

The modern Civil Engineering demands not just constructions which comply with technical and economical needs. Besides these factors, nowadays, engineers must be concerned on the environmental aspects/impacts of the material and the techniques used on constructions.

In this context, the accelerated development of the economy with the consequent need for renovation and/or reform of urban areas have brought out the production of construction and demolition waste (CDW), which constitutes a significant proportion of municipal solid wastes.

Although important studies have been carried out on the application of recycled construction and demolition waste (RCDW), their proposals are mainly focused on production of aggregates for the use in concrete and pavement construction (Santos & Vilar 2008).

Based on the drawback facts listed above as well as on interesting perspective for the use of this waste in geotechnical structures, a research programme to investigate the performance of reinforced soil structure using RCDW as backfill material started in 2009 at the University of Brasilia, Brazil.

This work presents post-construction facing displacements, earth pressure at the base of the wall and reinforcement strain results of a full-scale geogrid wrapped face reinforced wall constructed using RCDW as backfill material.

2 MATERIALS AND METHODOLOGY

2.1 Recycled Construction and Demolition Waste (RCDW)

The material used in this investigation consisted of the product of the crushing process of CDW (mixed materials with soil, brick, and small particles of concrete). RCDW were sampled at the CDW Recycling Plant of Brasília-DF, located at Jockey's Landfill. Usually, this material is used by the local government as cover of unpaved roads.

Table 1 presents the main geotechnical parameters of the RCDW tested. Because of the presence of coarse grained particles in RCDW (Figure 1), a large-scale direct shear equipment was necessary for the determination of the backfill shear strength parameters. Thus, the dimensions of the shear box used were 800x800x450mm.

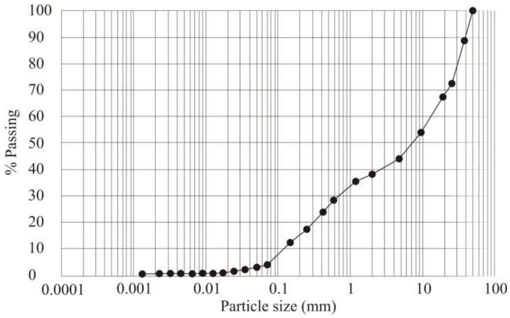

Figure 1. RCDW grain size distribution.

Table 1. Geotechnical properties of RCDW.

Parameter	Value
Specific gravity, Gs, (g/cm^3)	2.74
Liquid limit, w_L, (%)	35
Plastic limit, w_P, (%)	28
Maximum dry unit weight, γ_{dMax} (kN/m^3)	16.9
Optimum water content, w_{ot}, (%)	18
Friction angle, ϕ, (°)	38
Cohesion, c, (kN/m^2)	14

2.2 *Geosynthetic Reinforcement*

The geogrid used as reinforcement for the wall in this investigation consisted of a polyester core encased in a tough PVC sheathing. Table 2 summarizes the main reinforcement mechanical properties.

Table 2. Reinforcement mechanical properties.

Mechanical properties	Value
Longitudinal tensile strength (kN/m)	20
Transverse tensile strength (kN/m)	9
Maximum tensile strain (%)	12

2.3 *Facilities and Instrumentation*

The UnB Retaining Wall Field Test Facility is capable of testing full-scale walls up to 4.0 m high by 3.7 m wide by 7.25 m deep. The test facility is located outdoors at the Foundation, Field Test and Geosynthetic Experimental Field area. The facility can contain up to 214m^3 of backfill material. Figure 2 shows an overview of the test facility.

The wall was constructed within the test facility with isolation, from the side boundaries, of a central running length of the wall face. This procedure has been adopted at Royal Military College of Canada (RMC) in successful long-standing program on construction of full-scale reinforced soil walls. Additional procedures were necessary to protect the instrumentation devices against mechanical damage during the wall construction.

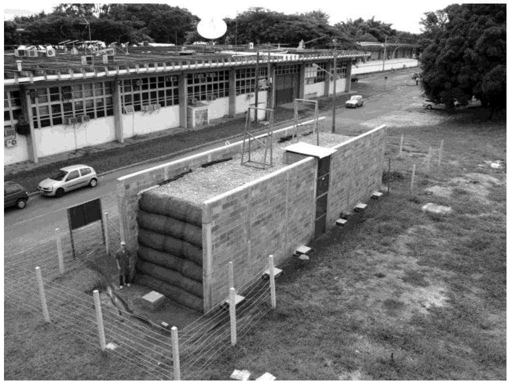

Figure 2. Reinforced wall test facility.

Horizontal and vertical earth pressures were measured by 13 earth pressure cells (EPC) located on the wall base (200mm above the first reinforcement layer) and within the backfill material (Fig. 3).

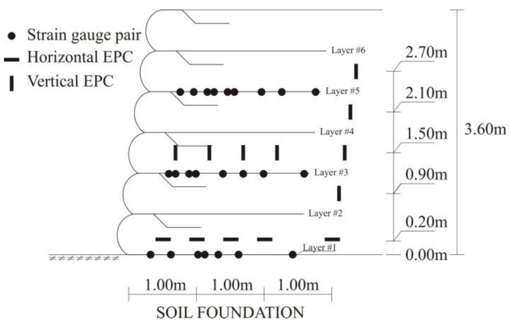

Figure 3. Wall instrumentation profile.

Geogrid strains were measured using 96 high elongation strain gauges attached directly to the geogrid. The whole geogrid instrumentation assembling was carried out at RMC, following the technique adopted for PET geogrid instrumentation.

In order to measure strain at different locations, strain gauge pairs were installed on reinforcement layers # 1 (bottom), #3 (at an elevation of about 33% of the wall height) and #5 (at an elevation of about 66% of the wall height). Every two pairs were placed at distinct longitudinal ribs, but at equal distances from the wall facing. Each strain gauge pair (bottom and top) was monitored separately in order to investigate the eventual compressive and/or tensile effort at the pair location. Figure 4 shows the instrumentation scheme of geogrid layer #3.

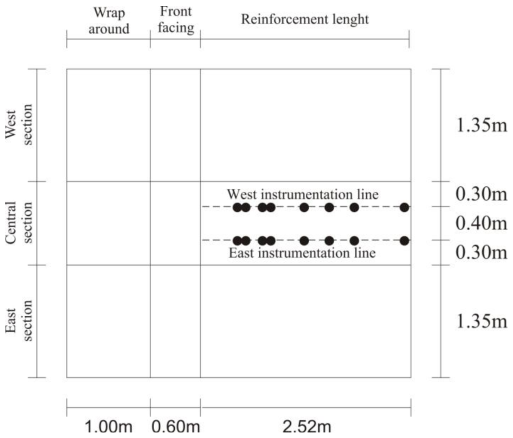

Figure 4. Strain gauge installed on layer #3.

2.3 Construction Procedure

In either side of the central instrumented section (Fig. 4) there is a 1.35 m external section constructed in an identical fashion. These three wall sections are named according to their cardinal orientation as West, Central and East. This configuration allows for the instrumented portion of the wall to approach a plane-strain condition, free from side wall effects, as far as practical.

A sidewall friction reducing system was obtained by covering the whole internal wall of the test facility with polyethylene sheets interspersed with lubrication (liquid silicone). A total of 3 polyethylene sheets in the lubrication system were used. The internal wall treatment, combined with the isolation of the one meter central column of reinforced soil, proved successful for plane strain conditions to prevail (Bathurst et al. 2009).

The wall construction process was conducted using the moving formwork technique, which is a common method for the construction of wrapped-faced walls in the field.

The construction procedure consisted of placing and compacting the backfill material in 200 mm lifts. A manual compaction roll of 1.45 kN was employed to provide a light compaction and satisfactory surface regularization. Near to the face, a hand tamping cylinder was used to reduce the effects of the compaction on wall facing displacements. Table 3 shows the main wall characteristics.

Table 3. Mainly wall characteristics.

Characteristics	Value
Height (m)	3.6
Facing batter (º)	13
Reinforcement spacing (m)	0.6
Reinforcement length (m)	2.52

The total construction time was 29 days. The construction history is shown in Figure 5.

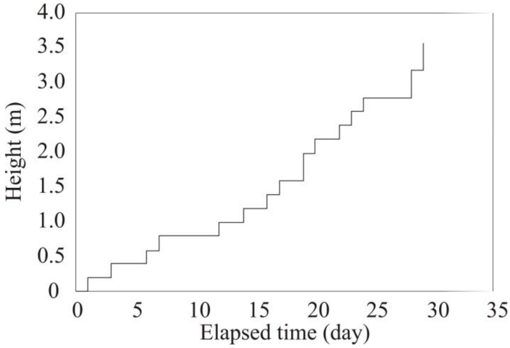

Figure 5. Construction history.

3 RESULTS

3.1 Bulk unit weight and moisture content

Measurements during wall construction yielded to an average backfill bulk unit weight of 17.78 kN/m^3, with a standard deviation of 0.59 kN/m^3 and a moisture content of 6.61%, with a standard deviation of 0.27%. Figures 6 and 7 summarize the results of bulk unit weight and moisture content obtained, respectively.

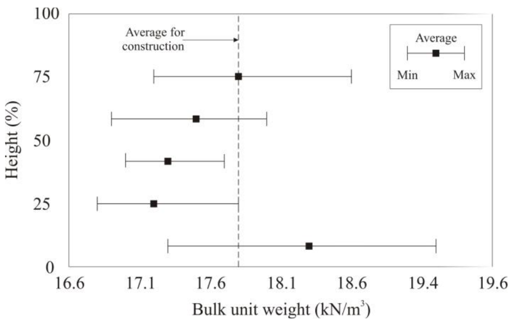

Figure 6. Bulk unit weight along the wall height.

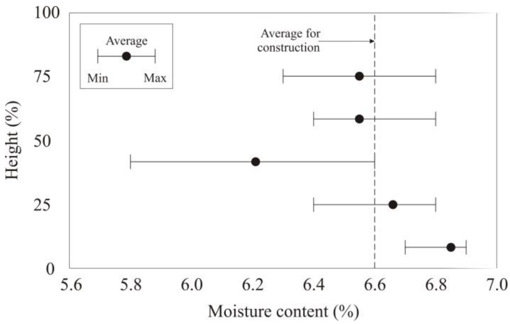

Figure 7. Moisture content along the wall height.

Outward displacements of the wall face during construction were measured. The maximum post-construction face displacement measured with respect to formwork position was approximately 106.5 mm, recorded at the layer #4 elevation (55% of the wall height). Figure 8 shows the post-construction face profile.

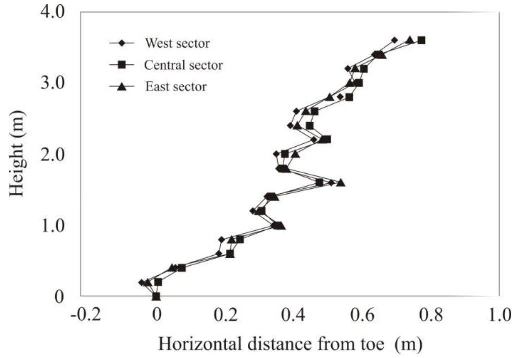

Figure 8. Post-construction face profile.

The variation of vertical earth pressure along the base of the wall (200 mm above the first reinforcement layer) is presented in Figure 9. It was observed a decrease of vertical stresses up to a distance from the wall face of 60% of the reinforcement length. After this point, the vertical pressure increases reaching the value γH beyond the reinforced mass.

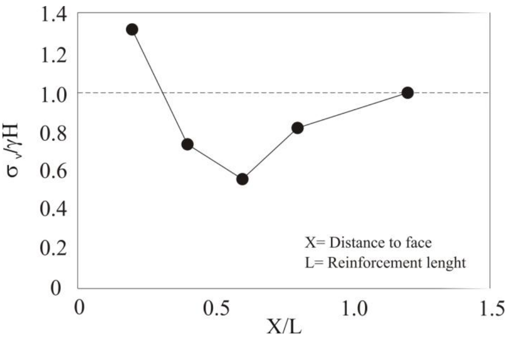

Figure 9. Vertical stresses along the wall base.

The strains measured in the top of reinforcement layers are shown in Figure 10. The presence of coarse elements in the backfill seems to influence the variation of tensile strains along the reinforcement length.

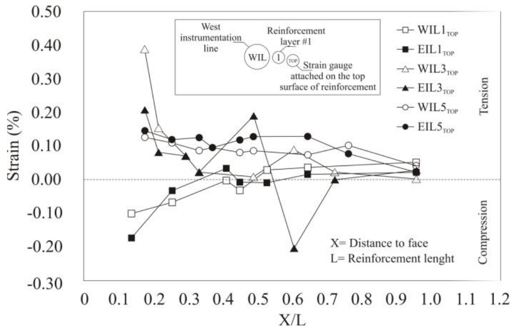

Figure 10. Strain measured in the top of reinforcement layers. (See also Fig. 3 and Fig. 4).

4 CONCLUSION

The use of RCDW as backfill material seems to be a promising solution, capable of complying with the economical and environmental requirements of modern societies.

Although post-construction results show a satisfactory behaviour of the instrumented wall, the authors believe that further investigation is required on the use of RCDW as backfill material in combination with geosynthetic reinforcement. A relevant practical issue is the possibility of damage of the reinforcement due to the aggressive nature of RCDW. Further research is in progress on this and on other aspects of the use of RCDW and geosynthetic reinforcement in reinforced walls.

ACKNOWLEDGEMENTS

Funding for the research programme described here has been provided by CNPq, FAP-DF and CAPES. The authors would like to acknowledge the contribution of the Geotechnical Research Group at RMCC, FURNAS, EMBRE, REFORSOLO, ORIGINAL, HUESKER, OBER, LINEA G, TORC, LINEA JR, ASCOLE, MULTISERVIÇOS, CAENGE.

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