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Construction of reinforced earth retaining structures on Ratnapura-Wewelwatte road in Sri Lanka

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ABSTRACT
This paper describes the construction of reinforced earth retaining walls using treated bamboo strips as reinforcements and used tyres as facings, and also the combination of reinforced earth and anchored tyres for retaining structures. It also discusses the advantages of these methods of construction.

1 INTRODUCTION

In modern times reinforced earth structures developed in France is an invention of Henry Vidal and widely used in the world as an alternative earth retaining system. According to historical evidence, the principle has existed in countries like China in ancient times. The reinforced structure comprises of three principal components. A selected fill ideally a free draining well graded granular material strengthened by reinforcing elements and enclosed on the exposed faces by facing units/cladding. Strips of galvanised iron, aluminium or copper are used as reinforcements and at present polymer materials and geotextiles are also in use.

At the sites where these studies were carried out, valley sideslopes of the Ratnapura-Wewelwatte (R-W) road between culverts 19/6 & 19/8 and at 23/8 had collapsed in the late 1980's due to stream cutting at the toe during the rainy season. In a normal situation in Sri Lanka, random rubble masonry walls would have been constructed at these sites in order to reconstruct and retain the road embankments. However at the first site, a reinforced earth retaining wall with treated bamboo strips as reinforcements and used tyres as facing elements, and at the second site a combination of reinforced earth and anchored tyre retaining wall were constructed on a trial basis in 1991 in order to try out the reinforced earth system and to determine whether treated bamboo strips can be used.

The technique of anchored tyre retaining wall was developed in about 1989 and over 40 structures were constructed using same. The technique involves the anchoring of a scrap tyre facing of a retaining wall to scrap tyres placed outside the active zone by tying the tyres together to form a combined system.

2 CONSTRUCTION OF REINFORCED EARTH RETAINING WALL BETWEEN CULVERTS 19/6 & 19/8 R - W ROAD

Figure 1 shows the cross section of the reinforced earth retaining wall.

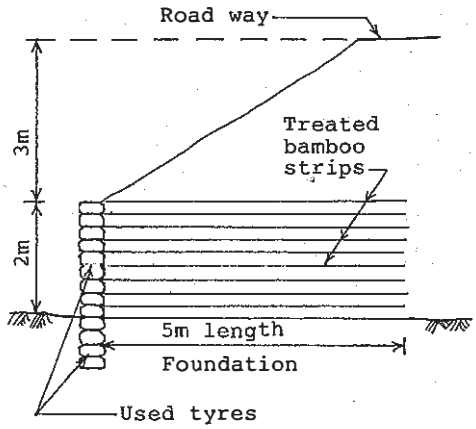

Figure 1. Reinforced earth retaining wall between 19/6 & 19/8 R-W Road

In this method, the bamboo strips were placed on a prepared foundation at intervals of about 0.3m extending from the boundary of the retaining structure towards the embankment to a length of about 5m. A set of scrap tyres were placed at the boundary of

the retaining structure to stop erosion and connected at the bottom to the bamboo strips by using nylons strings of 6mm diameter. Clayey gravel with sand having a maximum dry density under standard conditions of compaction of 1600 Kg/m³ was placed on the bamboo strips and compacted to a height of about 0.3m. This soil was also inserted fully inside the tyres and sufficiently compacted manually. Another similar set of bamboo strips were placed on the compacted soil and connected to the next set of tyres placed on top of the earlier set. This procedure was repeated to form a reinforced earth retaining structure to the required height.

A locally available most suitable material which is also inexpensive and readily available as reinforcing element in Sri Lanka is bamboo cut into strips. There are several varieties in many parts of the country which are quick growing and do not require much attention. Although there appears to be awareness of the potentialities of bamboo, very little published data is available.

Amaratunga (1970) has looked into the possibility of using bamboo strips as reinforcements in reinforced concrete in Sri Lanka and published the following data for common yellow (Dendrocalamus Strictus) and green giant bamboo (Dendrocalamus Gigan teus).

Tensile strength between nodes	90-140 MPa
Tensile strength at nodes	70-130 MPa
Tensile strength of strips	70 MPa

Using a factor of safety of 4, the permissible tensile stress of strips can be taken as 17.5 MPa.

In this retaining wall bamboo strips of about 50mm width x 4.6mm thickness were used. In order to preserve these bamboo strips, they were treated with copper sulphate solution of 3% by weight of water and keeping same immersed for minimum of 24 hours in a 5.5m long bath of the solution.

The construction of the retaining system was carried out by unskilled labour with the help of basic hand tools which are familiar to them. However to achieve the required degree of compaction of the soil layers of 100 percent maximum dry density under standard conditions of compaction for the top 450mm and 95 percent of this density below this level a plate vibrator or a vibrating pedestal roller was utilized. Although it is not theoretically required, distribution bamboo strips of the same cross section were tied to the structural reinforcing elements to form a mat. This method was adopted as a precautionary measure to avoid possible damages to main reinforcement element during compaction. The reinforcement mat was pegged to the compacted soil layer prior to placing of the subsequent layer of soil.

3 CONSTRUCTION OF COMBINED REINFORCED EARTH AND ANCHORED TYRE, RETAINING WALL AT CULVERT 23/8 R-W ROAD

At this site, a combination of reinforced earth and anchored tyre retaining wall of height varying from 2 to 3m were constructed to retain embankments of heights varying from 4 to 6m. The reinforced earth retaining wall was constructed as before. The construction of a typical anchored tyre retaining wall is described briefly in the ensuing paragraph. The details of this method will be given in a forthcoming paper (Sumanaratne, Mallawaratchie & Kulatileke, 1996).

The foundation of the anchored tyre retaining wall was taken to a suitable depth in stable ground. Scrap tyres of equal sizes were placed flat on the foundation of the retaining wall to interlock with each other and were tied together. Suitable soil was inserted fully inside the tyres and compacted sufficiently. The space between the tyres and the excavation was filled and compacted with suitable soil. This procedure was repeated by placing tyres one on top of the other, filling and compacting with soil until the foundation is firmly formed.

Another row of tyres was then placed above the ground level, tied with each other to interlock. Then they were tied with nylon ropes of suitable diameter to every other tyre and these ropes were tied to anchor tyres placed in a stable zone (passive zone). The number of tyres tied to an anchor was limited to 4. Back filling up to the top of tyre was then done using suitable fill material. This procedure is repeated until the required height was reached.

4 THE RESULTS OF TYPICAL DESIGN CALCULATIONS FOR REINFORCED EARTH RETAINING WALLS WITH BAMBOO STRIPS AND TYPICAL VALUES OF PROPERTIES USED IN SUCH CALCULATIONS.

In carrying out the construction of reinforced earth retaining walls using bamboo strips, rule of thumb methods and personal judgements were used. However, subsequently design calculations carried out in order to determine the stability of the

structure proved that the factor of safety is above the recommended standard values. This is further confirmed by the present stable and intact condition of the structures after a period of about 5 years of their construction. In doing these calculations, the following values for the properties of soil and bamboo were assumed :-

Angle of internal friction of soil= 30^0
Cohesion of soil = 0^2
Bulk density of soil = $20KN/m^3$
Co-efficient of friction between bamboo strips and soil = 0.577
Tensile strength of bamboo strips = 17.5MPa

5 ADVANTAGES OF REINFORCED EARTH RETAINING WALLS

The major advantages of the use of reinforced earth as retaining structures are :-

1. It is very flexible. Large vertical settlements and lateral movements can be accommodated and good foundation conditions are not essential.
2. Retaining structure can be made simultaneously with the fill.
3. Construction process is easy and quick and does not require specialised machinery or labour. Only standard equipment and simple construction techniques combined with locally available labour are required.
4. The use of less cohesive fill material ensures that proper drainage exists.
5. Total cost can be 40% to 50% less than that of the conventional concrete walls, random rubble masonry and gabion walls etc.
6. Apparently there is no practical limit for height or width.
7. The wall will match with the surroundings as it gets covered with vegetation after sometime.
8. Reduction in construction time.

6 CONCLUDING REMARKS

The two structures described in this paper have been successfully constructed using locally available materials like bamboo strips and scrap tyres. These methods are labour intensive with many advantages enumerated in this paper. Design calculations carried out after construction indicate that the structures are safe with the assumption of values for properties of soil and bamboo strips. These methods could be adopted ideally in countries like Sri Lanka where similar conditions prevail and advanced technology and capital intensive equipment are lacking.

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