Malaysian Journal of Civil Engineering 18(1) : 38-45 (2006)

A MODEL STUDY ON METALLIC STRIP-REINFORCED EARTH WALL

Iqraz Nabi Khan[1,*], Swami Saran[2]

[1] *Department of Civil Engineering, Sri Balaji College of Engineering & Technology, Benad Road, Jaipur-302013, Rajasthan INDIA.*

[2] *Department of Civil Engineering, Indian Institute of Technology, Roorkee-247667, Uttaranchal, INDIA.*

*Corresponding Author: *iqraz56@yahoo.co.in*

Abstract: A model reinforced earth wall with sand backfill of height 1.0 m has been tested in laboratory. Wooden panels were used as skin elements. Aluminium reinforcing strips of length 0.8 m were fixed to the wooden panels and instrumented with strain gauges to measure the stress distribution when the wall was subjected to surcharge free loadings and surcharge loading conditions on the backfill. The maximum tensions induced in the strips were used to determine pressure along the height of model reinforced earth wall. The test results indicated that Rankine's theory of earth pressure was close to the observed values and therefore they may be adopted in design.

Keywords: *Reinforced Earth Wall; Instrumented Strips; Surcharge Loading and Earth Pressure.*

Abstrak: Sebuah model tembok penahan tanah bertetulang setinggi 1.0 m dengan pasir sebagai tanah yang ditimbus belakang.telah diuji di dalam makmal. Panel-panel kayu telah diguna sebagai unsur permukaan. Jalur-jalur tetulang aluminium sepanjang 0.8 m dilekatkan pada panel kayu dan dipasang dengan tolok terikan untuk mengukur agihan tegasan akibat surcaj dan tanpa surcaj. Tegangan maksimum yang terhasil pada jalur tetulang telah diguna untuk menentukan agihan tekanan di sepanjang ketinggian tembok penahan tersebut. Keputusan ujikaji menunjukkan teori tekanan Rankine boleh diguna untuk tujuan reka bentuk kerana nilai yang dikira menggunakan teori ini hampir menyamai nilai yang diperolehi daripada ujikaji.

Katakunci: *Tembok Penahan Tanah Bertetulang; Jalur Terinstrumen; Pembebanan Surcaj; Tekanan Tanah.*

1.0 Introduction

Reinforced Earth Technique was systematically introduced by a French scientist H. Vidal in 1966. Reinforced Earth is a composite material which is formed by the association of soil and tension resistant reinforcing elements. The reinforcement suppresses the normal tensile strains in the soil mass through frictional interaction. Reinforced earth wall has widely been adopted due to its economy, ease of construction and flexibility in nature. The design of a reinforced earth wall should be checked for external stability and internal stability. The external stability comprises of checking the safety of the wall as a rigid block against overturning, sliding, bearing capacity failure and overall stability. In internal stability, the competency of the reinforcements provided at different heights is examined against tension and pull-out failures.

The internal stability analysis of a reinforced earth wall requires the identification of rupture surface behind the panels of the wall and during pull-out failure, and the effective length of the reinforcement contributing to the development of frictional resistance that lies outside the wedge. Further, the earth pressure distribution behind the wall is required to design the size and type of reinforcement.

Much research on reinforced earth has been carried out since Vidal (1966; 1969) coined the term “Reinforced Earth”. He systematically introduced fundamentals of Reinforced Earth Technique and discussed about the choice of soil and reinforcement, compaction, uses, risks of failure, cost and examples of field construction. Schlosser and Vidal (1969) published analytical and experimental results. Schlosser and Long (1974) carried out model study in laboratory and suggested an equation to calculate maximum tie tension. Schlosser (1978) presented state of the art and discussed the behaviour of a number of instrumented field walls built in France and other countries. Talwar (1981) conducted model studies by using concrete panels, strip reinforcement and dry sand as backfill. He did not measure tensions induced in the strips. Leshchinsky (1985) suggested design procedures for geotextile reinforced walls subjected to uniform surcharge and developed design charts for internal stability of walls. Ramaswami and Bose (1989) studied the behaviour of prototype geogrid reinforced retaining wall subjected to surcharge loading. Saran and Khan (1990) developed non-dimensional charts for seismic design of reinforced earth wall. Saran and Khan (1993) reported results of a study on a full scale 4.0 m high instrumented reinforced earth wall. Kumar and Saran (2003) reported their findings on closely spaced footings on geogrid reinforced sand. Miller and Roycroft (2004) reported four case studies on seismic performance and deformation of levees. Khan and Saran (2004) reported results of a model study on reinforced earth wall.

In this study an attempt has been made to study the behaviour of 1.0 m high model reinforced earth wall in the laboratory. Aluminium strips were used as reinforcement, dry sand as backfill and wooden panel as skin elements. Uniformly distributed surcharge was placed on the entire backfill. Reinforcing strips were instrumented with strain gauges to measure tension induced in them. Deflected position of model wall was monitored. The values of maximum tie tension developed in the reinforcing strips were used to give the pressure intensity at the location of the reinforcement, which in turn gave the observed earth pressure distribution.

2.0 Development of Test Programme

Field tests on prototype structures are always the best in any research work but economical considerations and practical difficulties either eliminate prototype tests completely or restrict their scope to a great extent. However model studies are generally less expensive and less time consuming, hence models could be used to study the effect of more parameters. Therefore, the behaviour of 1.0 m high model reinforced earth wall with wooden skin panel and reinforced with 0.8 m long aluminium strips was monitored. Uniformly distributed surcharge was placed on the entire backfill. Reinforcing strips were instrumented with strain gauges to measure tension induced into them.

2.1 Soil and Reinforcement

The soil used in this study was dry sand. The soil was classified as SP with effective size (D_{10}) of 0.185 mm and coefficient of uniformity (C_u) of 1.30. Backfill soil was deposited at a density of 16.0 kN/m^3, and relative density of 60%. The angle of internal friction, obtained from direct shear test, was 37˚.

Aluminium strips were used as the reinforcement. The aluminium strips of width 40 mm and thickness 0.3 mm were cut from aluminium sheet. The rupture strength of the aluminium strip was 41.75 N/mm width. The length of reinforcement used for the study was 800 mm, horizontal spacing was 300 mm and two vertical spacing used were 100 mm and 200 mm respectively.

2.2 Instrumentation

Instrumentation of aluminium reinforcing strips was done by pasting strain gauges on both sides of the strips. The strips were calibrated by hanging them vertically and putting weights on hanger.

2.3 Test set-up

Model tests were performed in a steel tank of size 2200mm × 1000mm × 1250mm high. It was made of steel sections. One longitudinal side of the box was provided with perspex sheet properly stiffened to avoid any bulging. The purpose of the perspex sheet was to observe the rupture surface. On one side of the tank no sheet was provided; but a stand for the dial gauge was provided. Wooden panels were used as skin elements. Surcharge load was applied in the form of sand bags, each weighing 400N placed on a 4mm thick steel plate weighing 510N and resting on the backfill surface as shown in Figure-1.

Figure 1: The test set up

2.4 Test Procedure

The procedure adopted for the construction of model was similar to that used in the field and described in the following steps:

i. The first row of skin panels, consisting of 2 side panels, 3 half panels and 2 full panels, was assembled in a line at the base of the tank and ensured plumb with a tri-square. The panels were properly placed in position so that they were properly aligned in horizontal and vertical directions. Arrangements were also made to prevent flow of sand through sides. A vertical line was also marked on perspex sheet sidewall to check its deviation from the plumb during backfilling.
ii. The backfilling of sand was done by using rainfall technique up to the level at which the first layer of reinforcement has to be laid. The height of fall 55 cm and the lift 10 cm were adopted to achieve 16 kN/m^3 density of backfill.
iii. After making the sand surface level, the reinforcing strips were laid on it and properly attached to the panels. One central reinforcing strip was instrumented with strain gauges and the leads were carefully taken to the data acquisition system.
iv. More panels were then placed in position and the sand was deposited up to the next desired height. The records of tensions induced in the central reinforcement of first layer were noted.

v. Steps (iii) and (iv) were repeated till the desired height of backfill was achieved. At every layer of filling (depending on the vertical spacing) the tensions in the central strips of lower layers were noted.
vi. Coloured sand bands were used at every 10 cm fill height to investigate the shape of failure wedge.
vii. Surcharge on the backfill was then placed in five stages, each giving an intensity of 4.8 kN/m^2. For each surcharge intensity, the tensions in all central strips were noted.

Dial gauges were installed at skin to record its movement during backfilling and application of surcharge. Pressure cells were also installed to measure earth pressure on the skin panels (Figure 2).

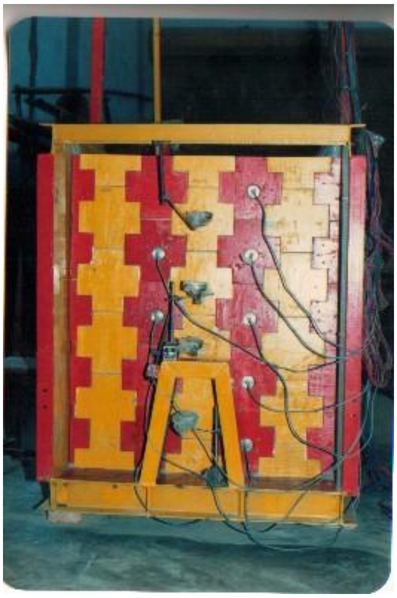

Figure 2: The positions of dial gauges and pressure cells

2.5 Tests Performed

The details of two tests performed on 1.0 m high model reinforced earth retaining wall are given in Table 1.

Table 1: Tests performed on 1.0m high model reinforced earth retaining wall

Test No	L/H	S_H (mm)	S_v (mm)	Q (kN/m^2)
1	0.8	300	100	5.1 to 24.4
2	0.8	300	200	5.1 to 24.4

where L is the length of reinforcement (0.8 m), H is the height of the model wall (1.0 m), S_H is horizontal spacing (300 mm), S_V is vertical spacing (100 mm and 200 mm), and q is surcharge in kN/m^2.

3.0 Test Results and Anaysis

As mentioned earlier, the following observations were recorded in a test.

(i) tension in the reinforcement strips, and
(ii) deformation of wall.

The tension, due to every backfill height and every increment of surcharge, was obtained at each location of strain gauge by using calibration charts. These tensions were used to draw tension curve for every strip. In this analysis, tensions corresponding to zero surcharge and 24.4 kN/m^2 were selected. The corresponding values of maximum tensions were noted. The maximum tensions have been reduced to give the pressure variation using the following relationship.

$$\text{Pressure intensity} = \frac{MaximumTension}{S_H \times S_V} \quad (1)$$

where S_H and S_V are horizontal and vertical spacing of reinforcements.

The wall deflection was monitored by installing dial gauges at different heights (Figure 2) and the wall deflection due to application of surcharge loading was also recorded. The deflection of wall after application of surcharge is very small in comparison with the deflection during construction, therefore it is not plotted separately.

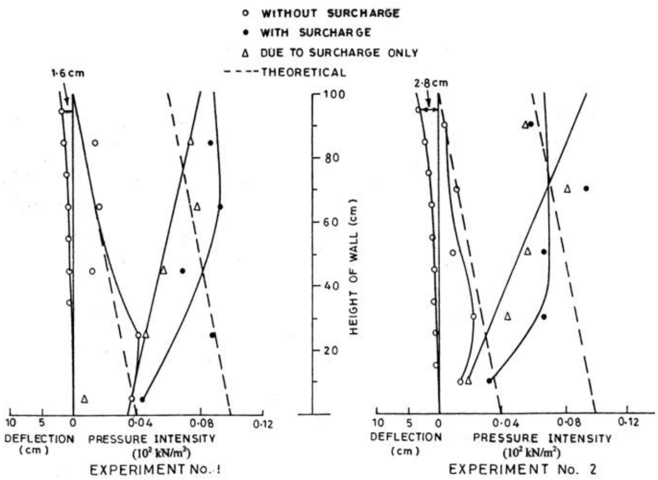

Figure 3: Pressure Distribution and Deflected Position of Model Wall.
(Measured on Perspex Sheet)

Figure 3 shows pressure distribution diagram for Experiment No 1 and 2 due to backfill only i.e. without surcharge, pressure distribution due to backfill and surcharge loading, pressure distribution due to surcharge only and Rankine's theoretical active earth pressure.

A close examination of pressure distribution diagrams, Figures 3(a) and 3(b), reveals that the observed pressures are quite close to the theoretical active earth pressure obtained by using Rankine's approach.

The deflected positions of the wall are shown in Figure 3 which clearly indicates that the deformation of model retaining wall under gravity and surcharge loads is similar to that of a rotation about a toe. However, skin elements behave as a flexible member.

No distinct breakage of colours bands was observed in the tests. It indicates that no complete failure has occurred.

4.0 Conclusions

In this study tests were performed on 1.0 m high instrumented model reinforced earth retaining wall. From the experimental work, the following conclusions can be made:

a. The results indicated that Rankine's earth pressure theory gives earth pressures very close to the observed values and therefore it may be adopted for design.
b. The deflection of the retaining wall under gravity and surcharge loads is similar to the deflection due to a rotation about the wall toe.
c. Skin elements behave as a flexible member.

Acknowledgement

The authors would like to thank Mrs Clotilda Petrus and Mrs. Caroline Peter, Lecturers, Universiti Teknologi MARA, Pulau Pinang, Malaysia, for proof readings.

References

Khan, I.N. and Saran, S. (2004) A Model Study on Reinforced Earth Wall. Proceedings International Conference on Bridge Engineering and Hydraulic Structures, 26- 27 July 2004, Kuala Lumpur, pp. 295-298.

Kumar, A., and Saran, S. (2003) Closely Spaced Footings on Geo-grid-Reinforced Sand. *Journal of Geotechnical and Geoenvironmental Engineering, ASCE,* July 2003, pp. 660-664.

Leshchinsky, D. (1985) *Design Manual for Geolextile Retained Earth Walls*. Research Report No. CE-85-51, Department of Civil Engineering, University of Delaware New York, DE-1976.

Miller, E.A., and Roycroft, G.A. (2004) Seismic Performance and Deformation of Levees: Four Case Studies. *Journal of Geotechnical and Geoenvironmental Engineering,* ASCE, April, pp. 344-354.

Ramaswami, S.V. and Bose, G.S.C. (1989) Prototype Geogrid Reinforced Retaining Wall. *Proceedings Indian Geotechnical Conference* (IGC-89), Vol. 1, pp. 411-414.

Schlosser, F. and Vidal, H. (1969) *Reinforced Earth Bulletin* de Liaison des Laboratoire Central des Ponts et Chaussees, No 411, Paris.

Schlosser, F. and Long, N.T. (1974) Recent Results in French Research on Reinforced Earth, *Journal of the Construction Division*, ASCE, Vol.100, No C.03, pp. 223-237.

Schlosser, F. (1978) History, Current and Future Developments of Reinforced Earth, Keynote Address, *Symposium on Soil Reinforcing and Stabilizing Techniques in Engineering Practice*, Sydney, pp. 5-28.

Saran, S. and Khan, I.N. (1990) Seismic Design of Reinforced Earth Wall. Proceedings Ninth Symposium on Earthquake Engineering, Roorkee, December 1990.

Saran, S. and Khan, I.N. (1993) Studies on a 4.0 m High Reinforced Earth Wall, Proceedings Third International Conferences on Case Histories in Geotechnical Engineering, St.Luis, Missouri (USA), June 1-6,1993.

Talwar, D.V. (1981) Behaviour of Reinforced Rarth in Retaining Structures and Shallow Foundation, Ph.D theses, Department of Civil Engineering, University of Roorkee, Roorkee, India.

Vidal, H. (1966) English translation of La Terre Armee, Annales des I' Institute Technique du Bâtimen et des Travaux Publics, France.

Vidal, H. (1969) English translation of text entitled La Terre Armee, as published in the Annales des I' Institute Technique du Bâtimen et des Travaux Publics, Series materials No (38), pp.259-260, July/August.