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Field experiment of fabric reinforced earth wall
Essai de chantier sur un mur en terre armée avec armature de textile

Cette communication présente un essai de chantier qui était réalisée sur un mur en terre aimée, equipée des instruments, 16 ft (4.88 m) longue, 10 ft (3.05 m) large et un hauteur projeté de 12 ft (3.66 m). Le mur était renforcé par les bands de membrane de grande puissance, produit de nylon et enrobé avec néoprène. Le mur s'écroulait lorsque la hauteur dépassait 9 ft (2.74 m); la rupture est attribuable aux allongements excessif des bands renforceur.

INTRODUCTION

Soil masses which contain small quantities of frictional material with high tensile stress for the improvement of its engineering qualities are known as reinforced earth. The concept of reinforced earth is very old and remained as craft until 1969 when Henri Vidal quantified and patented it with reference to its usefulness to practical problems. Metals, which corrode and lose strength under poor environmental conditions, have been principally used as reinforcing material. In designing of reinforced earth structure under such adverse condition, the required thickness of the reinforcing material is usually increased to compensate for losses due to corrosion. Because of the potential influence of corrosion, the U. S. Army Engineer Waterways Experiment Station (WES) used a neoprene coated nylon fabric as a reinforcing material in one of their field experiments which is described in this paper.

Components of reinforced earth wall

The major components of the experimental reinforced earth wall, shown in Figure 1, are soil backfill, reinforcing membrane strips, and face covering called skin element. The assumption used in the design of the reinforced earth wall is that the wall will move laterally during construction a sufficient amount to create Rankine active failure in the soil behind the skin element. The consequence of this movement is the mobilization of skin friction between the soil and the reinforcing strips which is essential for the internal stability of the structure. To insure adequate performance of the wall, the reinforcing ties should not fail in tension or by slippage due to lack of skin friction under applied loads.

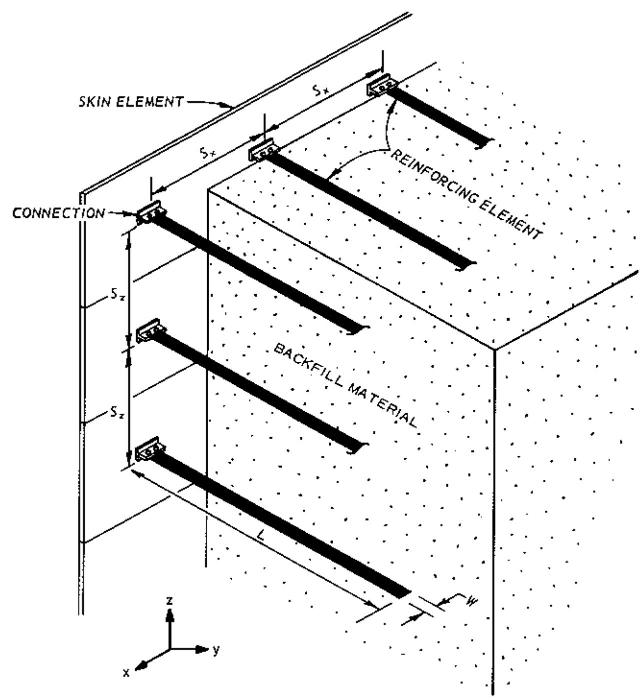

Figure 1. Schematic of major element of reinforced earth wall

Design consideration

Two design criteria, in terms of factor of safety, have been suggested [2] against tie breakage in tension and tie pullout. These two criteria are based on the assumption that the maximum tensile force in the reinforcement increased linearly with depth in a manner similar to the Rankine active earth pressure shown in Figure 2.

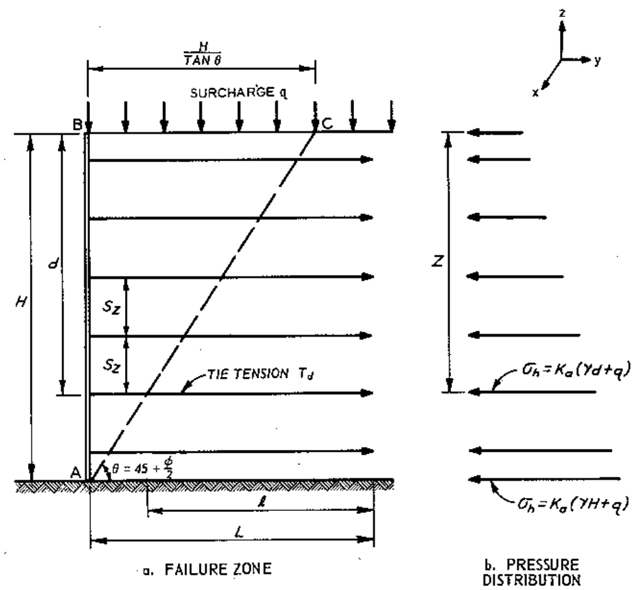

Figure 2. Pressure distribution according to Rankine theory

The factor of safety against tie breaking, FS_b, can be expressed as

$$FS_b = \frac{\sigma_y wt}{K_a \gamma H S_x S_z} \qquad (1)$$

where

σ_y, t, and w = the tensile strength, thickness, and width, respectively, of the tie as shown in Figure 1

K_a = the coefficient of active earth pressure expressed as $\tan^2 (45 - \frac{\phi}{2})$

γ = the unit weight of soil

H = the height of the wall

S_x and S_z = the horizontal and vertical spacing of the ties

ϕ = the angle of internal friction

The factor of safety against tie pullout, FS_ϕ, is expressed as

$$FS_\phi = \frac{2\ell w \tan \phi_\mu}{K_a S_x S_z} \qquad (2)$$

where ϕ_μ is the angle of friction between the reinforcing material and the surrounding soil, and ℓ is the effective length [2] which is equal to the portion of the tie which is extended beyond the Rankine failure zone as shown in Figure 2.

FIELD EXPERIMENT

A field experiment test was conducted on a reinforced earth wall 16 ft (4.88 m) long, 10 ft (3.05 m) deep, and intended height of 12 ft (3.66 m). The reinforcing strips used in the experiment were made of heavy duty nylon fabric coated with neoprene. Other detailed descriptions of the membrane are presented elsewhere [1]. Each reinforcing strip was 0.08 in. (0.205 cm) thick, 4 in. (10.16 cm) wide. and 10 ft (3.05 cm).

These strips were spaced at 2 ft (0.61 m) in the vertical direction and 4 ft (1.22 m) in the horizontal direction. The stress-strain test results conducted on a 2 in. (5.08 cm) wide specimen, Figure 3), is concave upward with

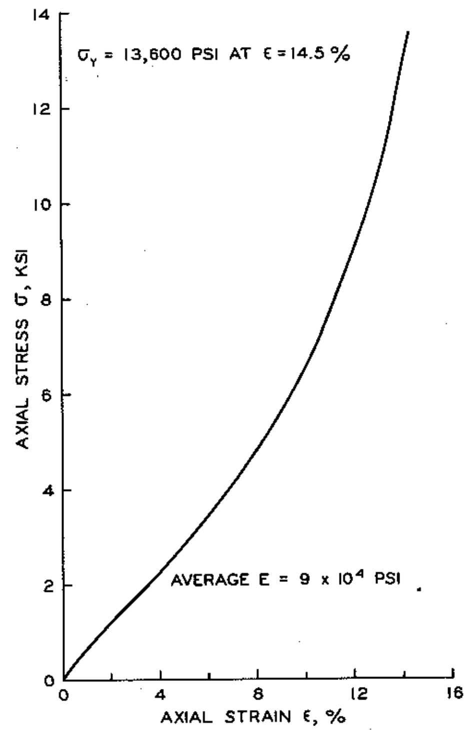

Figure 3. Stress-strain relationship for the reinforcing material

the tangent modulus, E_t, increasing rapidly when the axial strain exceeded 9 percent.

The skin element was made of Alcoa T11 high-strength aluminum panels; each panel is 2 ft (0.61 m) wide, 12 ft (3.66 m) long, and 1.6 in. (4.06 cm) thick and can be easily connected to each other by a hinge-type connection. The reinforcing ties were fixed to the skin element by a double angle connector and two 1/4-in. (0.64 cm) bolts.

The fill material used was clean concrete sand with particles ranging from subangular to angular, coefficient of uniformity, Cu, equal 2, and mean diameter, D_{50}, equal 0.5 mm. Other physical properties of the sand as G_s = 2.66, γ = 101.7 pcf (1.63 g/cm^3), ϕ = 36 deg, and ϕ_μ = 34 deg. Other properties are presented elsewhere [1].

Construction of the wall

The test area consisted of a three-sided pit excavated into a bank of silty Vicksburg loess soil.

The first two rows of the skin element were held vertically to close the front end of the pit, then the sand was dumped into the test pit in 1-ft (0.31 m) lifts and spread evenly by hand. The reinforcing strips were stretched and leveled on the surface of the sand as shown in Figure 4.

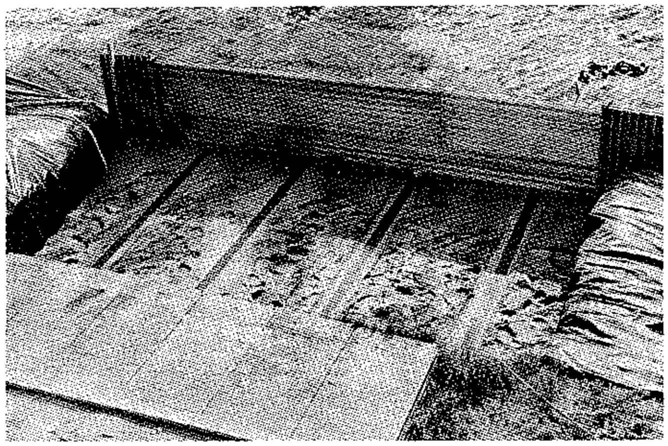

Figure 4. The reinforced earth wall during construction

Three pairs of WES pressure cells were used to measure the vertical and horizontal pressure along the center line of the structure and at a distance of 1 ft (0.31 m) from the skin element. Measurements of the lateral deformation of the skin element were also made during construction.

TEST RESULTS

Pressure cell readings were taken after placement of every 1-ft (0.31 m) lift. Comparisons between horizontal pressure cell reading and the calculated vertical pressure due to the depth of overburden is presented in Figure 5. It can be

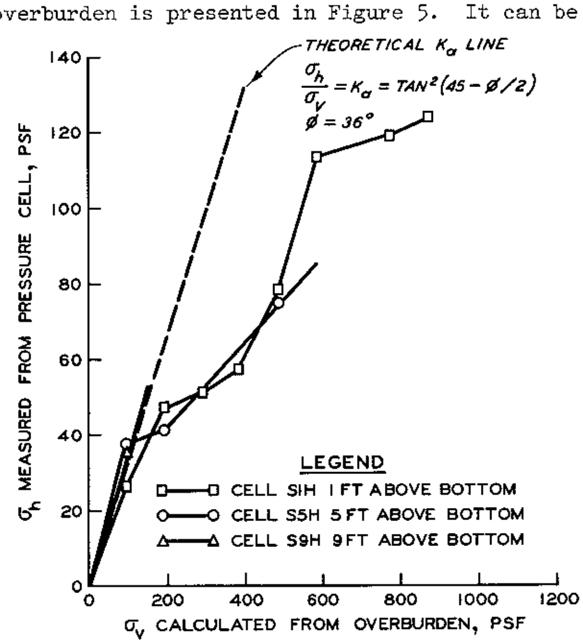

Figure 5. Comparison between the measured horizontal pressure and the vertical overburden pressure

seen that the predicted lateral pressure by Rankine theory is higher than that measured by the pressure cell. Therefore, Rankine theory should provide a conservative estimate for lateral pressure in reinforced earth wall carrying no surcharge load. The lateral deformations of the skin element were monitored directly during construction until failure occurred when the height of the wall was slightly higher than 9 ft (2.74 m). The movement of the skin element prior to failure was 2.25 in. (5.7 cm) at the bottom and 6 in. (15.2 cm) at the top. Examination of the reinforcing strips and connectors after failure showed no visible signs of defects.

Factor of safety

If we assumed that Rankine active condition prevailed then the factor of safety against tie breaking and tie pullout for the lowest tie, as expressed in Equations 1 and 2, respectively, are $FS_b = 2.38$ and $FS_\phi = 1.76$. Accordingly, the reinforced earth wall should not have failed by tie breaking or by pullout. Thus the stability of wall is not assured even though FS_b and FS_ϕ are more than unity. It is possible, however, that the failure of the wall was caused by the large deformations of the reinforcing ties which are not accounted for in the design of reinforced earth structures.

SUMMARY AND CONCLUSIONS

Based on the data collected in this study, it is concluded that the lateral earth pressure, as measured by pressure cells during construction, is less than that predicted by Rankine earth pressure theory. The stability of a reinforced earth wall is not insured even though the factor of safety against tie breaking and tie pullout were satisfied. It is possible that excessive deformation of the reinforcing ties can trigger failure.

ACKNOWLEDGMENT

The test described and resulting data presented herein were obtained from research conducted at WES. Permission was granted by the Chief of Engineers to publish this information.

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1. Al-Hussaini, M. and Perry, E., "Effect of Horizontal Reinforcement on Stability of Earth Masses," Technical Report No. S-76-11, 1976, U. S. Army Engineer Waterways Station, CE, Vicksburg, Miss.

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