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An experimental study on the performance of a prototype reinforced earth embankment

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ABSTRACT: This paper presents a study on the performance behaviour of a prototype reinforced earth embankment during construction as well as when the structure is subjected to additional loading after its completion.

1 INTRODUCTION

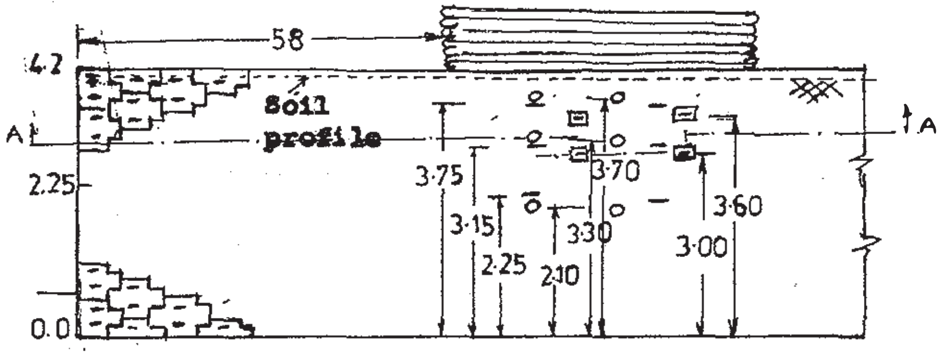
Soils, as it exists insitu, if found suitable are used as foundation material to support various civil engineering structures. If not soil borrowing and soil replacement may become necessary which may not be economical, such situations stimulated new thoughts in civil engineerings, leading to development of a number of ground improvement techniques, which can be classified as:-

a. Ground improvement by insitu soil treatment.
b. Ground improvement by soil reinforcement.

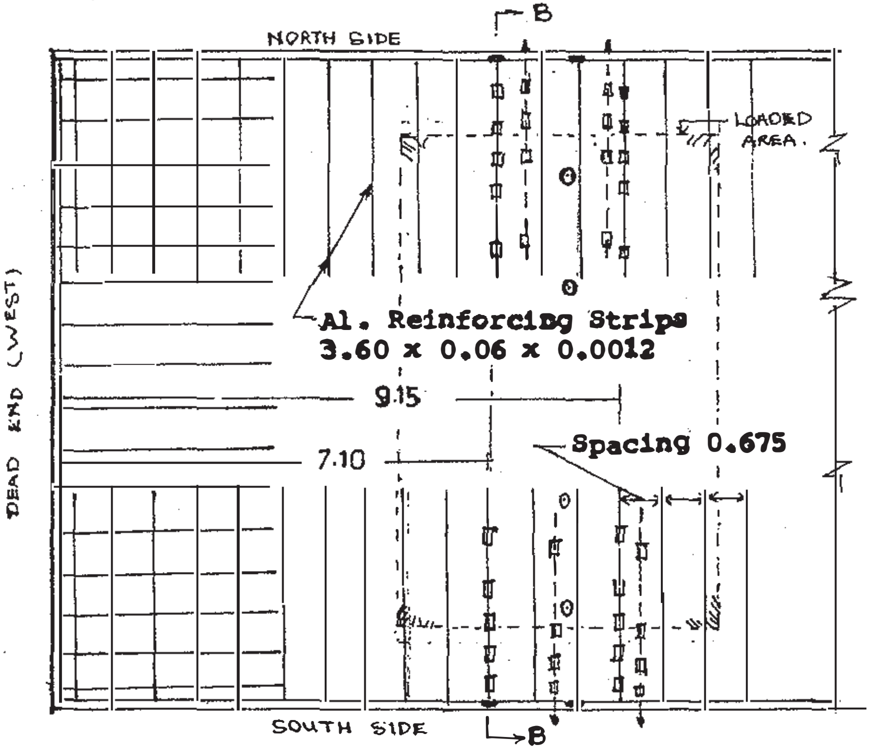
The technique of inclusion of metallic or organic reinforcements into soil to improve its strength is named as reinforced earth or reinforced soil. This technique of soil reinforcement was practiced since ancient times in the crude form, until Nineteen sixties, when Henry Vidal(1966) proposed certain design methods for reinforcing soil, by the association of two materials (i.e.) the backfill material and, the reinforcements results in a new composite coherent material termed as Reinforced Earth. Consequently several model studies were initiated by several research workers (See Schlosser and Vidal (1964) in order to formulate some design procedures for the construction of reinforced earth structures. Several attempts were made to cover the problem of switching from model to actual structures (See Venkata-Ratnam etal(1980)),but they were either not fully instrumented nor they were subjected to actual surface area loads.In order to study the performance behaviour both during construction and under applied surface area loads.A reinforced earth embankment of 4.5m hight, 10.5 wide and 75.0m long was constructed.This embankment was instrumented and tested under surface area loads. The results obtained are presented in this paper.

2 EXPERIMENTAL PROGRAMME

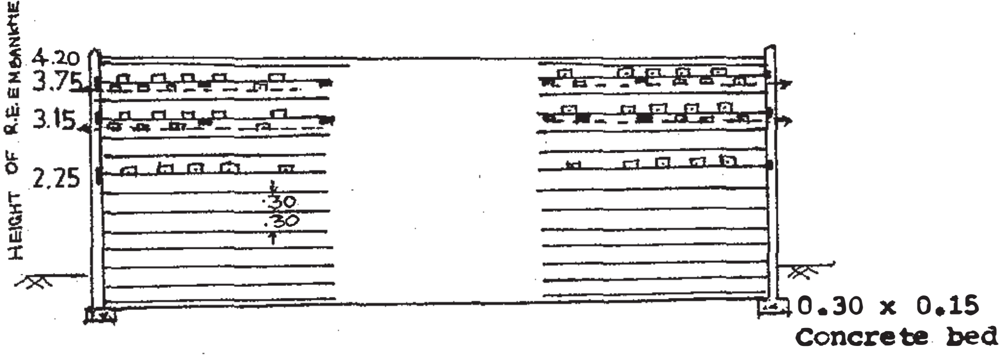
Model studies do provide cost effective and convenient research tool, but pose the problem of exact scaling of certain parameters of the actual structure, such as stress level, wall friction, gravity stresses, method of construction etc.(Al.Hussaini etal)(1978)).Hence in order to over come this practical difficulty and to study the performance of the reinforced earth wall, and compare it with its predicated behaviour when subjected to surface area loads, a proto-type reinforced earth embankment of 4.2m high with vertical faces and 10.5m wide and 60m long approach ramp with a slope of 1 in 15 on eastern side which joins the 7.0 meters wide B.T.Road, has been designed and constructed.Two types of skin elements were used for the construction of reinforced earth embankment.



SIDE VIEW OF REINFORCED EARTH EMBANKMENT



PLAN ON AA OF REINFORCED EARTH EMBANKMENT



SECTION ON BB OF REINFORCED EARTHEN EMBANKMENT

Fig.1. Prototype Reinforced earth Embankment
REC Warangal, India.

a. G.I. semi elliptical skin elements of size 240x25 and 0.10 cm thick
b. RCC cruciform panels with interlocking edges of overall size of 90x60 and 8.0cm thick and weighing about 85 kg. each.

The approach ramp, is provided with G.I. semi elliptical skin elements from 0 to 30m length and RCC cruciform panels, are used for the balance portion of ramp and level portion.

Locally available morum soil with a uniformity coefficient of 3.0 and an angle of internal friction of 35°, at a density of 1.89 gm/cc has been used as backfill. Considering various factors like, availability, of the material, low cost, and durability, two different materials, one of Aluminium of size 360.0x60x0.12cm in the level portion, (in which the instrumented test zone is located) and another of G.I. (plain) of size 240x6.0x0.10cm in the approach. The tensile strength was determined from Houns-field tensometer and were found to be 3600 and 1450 kg/sq.cm. for GI and Aluminium strip, respectively. The value of coefficient of internal friction as determined by direct shear test (of size 30 x 30 x 15 cm) was 23° and 20° for aluminium and GI strip respectively.

2.1 Construction

The site of the embankment was cleared of bushes and other organic matter. The soil profile consists of Black cotton soil for the top 2.0m depth, underlaying it was poorly graded gravel. The earth was excavated upto a depth of about 0.65m below G.L. and a concrete bed (1:3:6 min) 30cm wide and 15cm thick was provided for the full length of the reinforced earth wall facing, Fig.1.C. Four different types of skin elements were used in the erection or reinforced earth wall with concrete panel facing. The concrete panels, which were castin moulds at site have been erected in position, and the first course of skin elements, which consisted of half and full panels (90x30cm) and (90x60cm) alternatively having a flat base have been erected in position on the top of the concrete bed. The soil was then filled up in thickness of 17 to 18cm compacted to a finished thickness of 15.0cm. The compaction was done by 2.5 tonne roller operated manually. The compaction upto a distance of 0.30m from the inside face of panel was done by hand ramming. Necessary care was taken while compacting at the edges. The reinforcing strips were connected by means of two 6.3mm in dia. M.S. bolts & nuts to the projecting ends of the GI stub of 'Σ' shaped embedded in the concrete skin elements. The second course of panels comprising full panels, as placed on top of the first course, M.S. rods of 6.0 mm Ø were placed in the dowel hole provided in the elements to check plumb line. The soil was later filled upto a height of 33cm and compacted to a finished thickness of about 30cm, this procedure was repeated till the final height is reached. The top row consisted of full and half panels alternatively, having flat surface on the top.

In case of metallic skin elements, the G.I. sheet was cut to required size, and moulded using a specially prepared moulding device to obtain the semi-elliptical shape of required size. Similar procedure as mentioned earlier was adopted, except, that each vertical joints in successive layer of skin elements were kept staggering.

To obtain the performance data, during construction as well as under applied surcharge load, the following parameters were measured:-

a. The lateral deformations of the reinforced earth walls was measured from guide post, erected for this purpose. In the test zone, two guide posts on either side of the reinforced earth wall, were installed, these two were connected by GI wire to facilitate the measurement of lateral deformation at every strip location in a grid pattern.
b. The lateral earth pressure on panels were measured by means of 100mm Ø brass earth pressure cells (diaphragm type) placed on the inside face of the skin elements and kept flush with the panel surface. These are kept at distances of 7.10m and 8.45m

from the dead end and at an elevation of 2.10, 3.30 and 3.90m. The location of pressure cells are shown in fig.1.

c. To study the variation of tensile stress along with reinforcing strips, selected reinforcing strip placed on both sides of the embankment at height of 2.25m, 3.15m and 2.75m and at distances of were instrumented, with five bakelite electrical resistance type strain gauges distributed over the length of the strip. See fig.4 for further details.

The surface area load are applied centrally on the top surface of embankment. Edge distances of the loaded area from the either side of the panels was 1.5m (Ref.fig.1). This surface area load was applied over an area of 8.0m x 5.0m by means of dead weights, in increment of about 8.5-9.0 ton each. Before applying the load the initial readings of the lateral measurements of the wall, the tensile stress in the strips, the stresses in the reinforced earth mass and the lateral pressures on the skin elements were recorded.

3 PRESENTATION AND DISCUSSION OF RESULTS

3.1 Lateral Deformation

The bottom row of panels orginally kept vertical, remained vertical at the end of construction. However, the panels did deform by about 23mm at a height of about 2.25m and deformation increased with height reaching a maximum average of about 11.00mm at the top of 4.2m height. The loads were measured underneath the loaded area in panel no.10, 11, 12, 13, 14 and 15 on eitherside of the embankment. For an applied load of 35.65 ton, the lateral deformation at 4.05, 3.75, 3.45, 3.15, 2.85, 2.55, 2.25, 1.95, 1.65, 1.35 and 1.05 height of the wall are, 0.6, 0.7, 0.8, 0.5, 0. 0.4, 0.3, 0.3, 0.2, 0.1, 0.0 and 0.0mm respectively on the southern side of panel no.12. Similary the values for the applied load of 76.78 and 104.62 tons are shown in fig.2. The maximum lateral deformation of 12m and 15mm was observed on the Southern and Northern side respectively under the applied load of 104.62 tonnes.

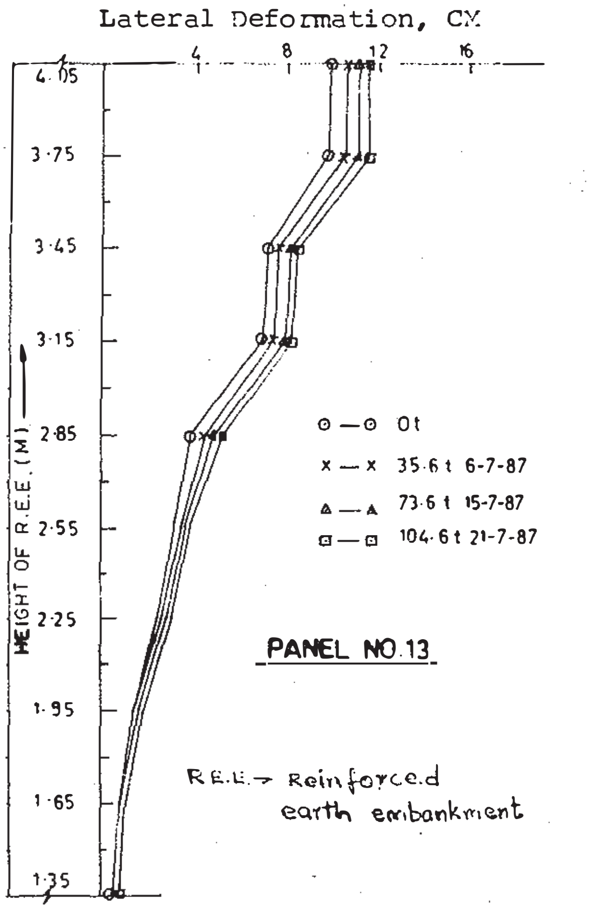


Fig.2 Lateral deformation of R.E.E.

3.2 Lateral Pressure

The lateral pressures recorded at 2.10, 3.30 and 3.90m height at a distance of 7.10 from the dead end, in panel no.11 was 0.45, 0.15 and 0.035 kg/sq.cm.respectively, at the end of construction on the southern side. The measured values, were about 1.2-1.5 times the computed value. This may be due to some times gap, during construction, (which is reflected in the increased value) and also due to compaction effect, close to the vicinity of pressure cells. The measured lateral pressure under various applied surcharges are plotted in fig.3 these pressures, were converted into equivalent height of embankment, and plotted in fig.3. (panel no.13).

3.3 Tensile Stress Distribution

The tensile strain in the strips were recorded from the digital

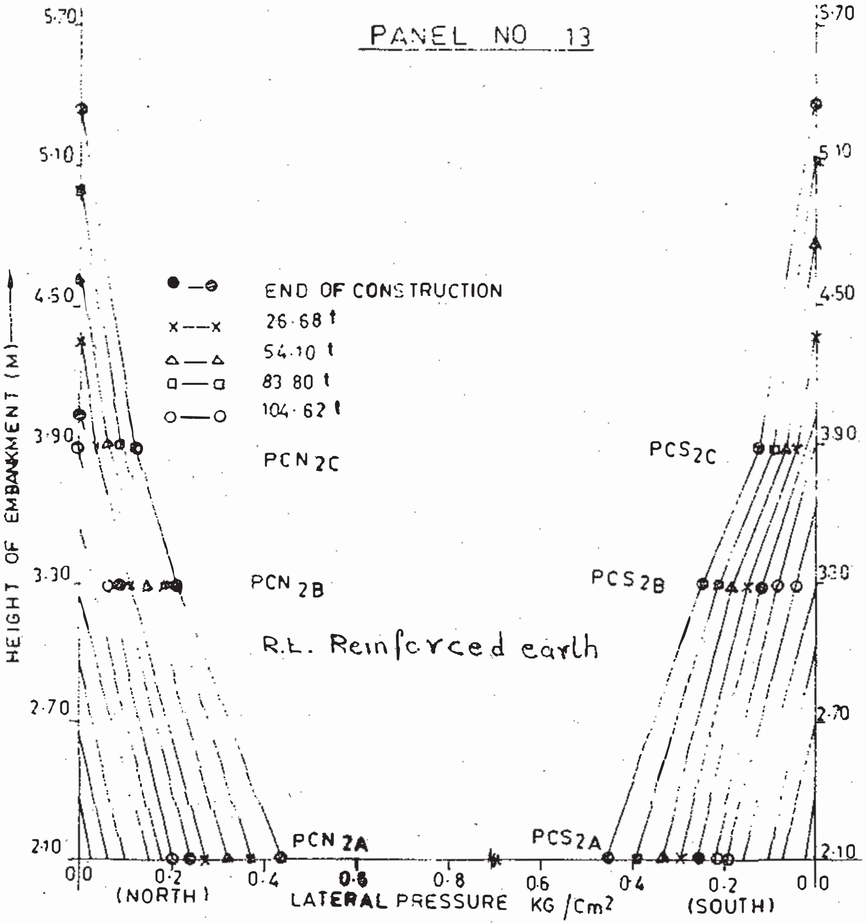


FIG.3. LATERAL PRESSURE ON R.E. WALL DUE TO SOIL AND SURCHARGE

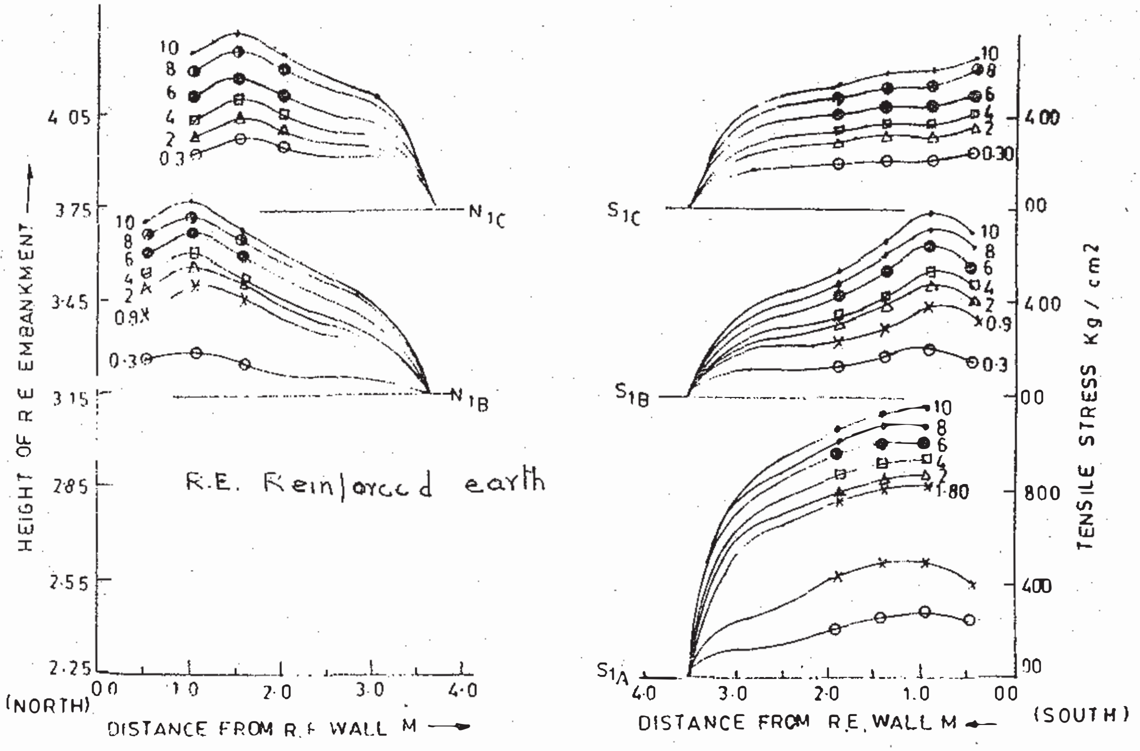


FIG.4. TENSILE STRESS DISTRIBUTION IN STRIPS DUE TO SOIL AND SURCHARGE

strain indicator, for each height of fill of the embankment. Knowing the Young's modculus of the strip material, and the strain recorded from the unit, the tensile stress was determined by using Hooke's Law. Adopting this technique, the stress in various strips both during construction and under applied loads were determined and are plotted in fig.4. for both sides of the embankment. From the figure it is observed that the tensile stress varied from the panel end to the free end of the strip. The maximum was observed to be at a distance of 1.0m from the panel end, and continuously decreased to zero, at the free end. The maximum tensile stress is found to be within middle third length of the strip, both during construction and under applied load.

4 CONCLUSIONS

During construction, the lateral displacement of wall was found to increase above a height of 2.25m. This was due to non provision of temporary supports. In practice, temporary supports may be used for maintaining vertical alignment.

The lateral moment at the end of construction was of 2.3% the height of the embankment. The increase in deformation under the maximum surcharge load was only 0.5% of the height of the embankment. The lateral deformation is found to be maximum between 0.8 and 1.0H, where H is the height of embankment.

The lateral pressures on the skin elements, at the end of construction were about 1.2-1.5 times the predicated value. However, under the applied loads, the recorded pressures were about 1.10-1.15 times the theoretical value.

The tensile stress is varying between zero at the free end of the strip, and reached a maximum value at intermediate point(within middle third portion of the strip) and then tends to decrease towards the location of skin element.

The tensile stress distribution is somewhat parabolic both during construction and under applied loads.

5 ACKNOWLEDGEMENT

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