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Numerical and experimental examination of the reinforced earth retaining wall in fenyeslitke

Dimensionnement et expérimentation du mur en terre armée de fenyeslitke

A l'occasion de la construction d'un mur en terre armée à FENYESLITKE, on a pu procéder à des expérimentations sur la tension dans les armatures, la déformation du mur et le frottement entre l'armature et le sol. Les résultats ont montré qu'un modèle élastique ne représente pas convenablement le système sol-métal, et que le frottement se modifie pendant la construction. Il a été également noté que l'on peut utiliser, pour la construction en terre armée, des remblais de qualité médiocre.

Both conventional theories and advanced mechanical models include more or less uncertainty in the computation of the strip forces.It might be due to the fact that we have no perfect knowledge about the mechanical interaction of the soil-strip composite material.Studying the tensile force distribution and frictional condition for in-situ

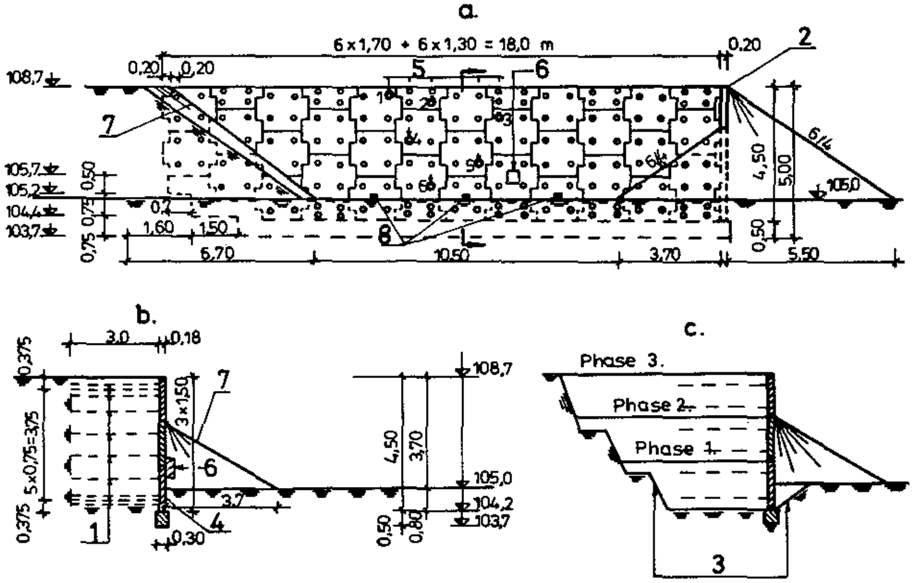

Fig.1.General view, cross section and constructing stages of the wall

1 - strips, 2 - reinforced concrete board, 3 - slope before construction, 4 - facing, 5 - measuring strips, 6 - instrumentation box, 7 - slopes joining the wall, 8 - drainage

walls, having an adequate numerical model for the estimation of the stress distribution may contribute to a more appropriate and economic design method. This paper presents a wall subjected to an experimental and numerical examination.

General description of the wall

The main dimensions had been estimated by Schlosser-method / 1 / published earlier /Fig. 1./. It's height is 4,50 m, total and free lenght are 18,0 and 10,5 m, respectively. Mild steel strips, having a lenght of 3,00 m, a width of 100 mm and a thickness of 3,5 mm, were laid down in x = S = = 0,75 m vertical and horizontal spacings. /Corrosion term 1,5 mm had been assumed/. Backfill material consisted of fine sand with 30 p.c. silt / U = 11, d_{eff} = 40 /. Facings were prefabricated of reinforced concrete. Seven strips in different levels were instrumented with strain gauges, tensile forces and deformation of the face were measured during the construction and after it was finished. Construction system was usual, compacting process of every layer in the backfill had been continued until 95-97 p.c. modified Proctor-density was reached.

For design and finite element analysis soil moduli and frictional coefficients between the soil and strip had been measured in laboratory. Values of the initial modulus varied between E_i= 8,0-12,0 MPa/80-120 kp/cm^2/ depending on the magnitude of the all-round pressure corresponding with the horizontal stress of the backfill in various height. Friction coefficient between the soil and steel given by a simple shear-box is $f_{so/st}$ = 0,5 ./Internal frictional angle for the soil: $\phi = 34^{\circ}$./

Finite element representation

Calculation was carried out by finite element method and using the composite anisotropic elastic parameters introduced by Romstad et al. / 2 /. Unit cell concept was adopted to calculate the elastic constants of the reinforced soil. Having established all geometric parameters of the structure and elastic properties of the soil and steel it is easy to obtain the stress-strain relationship in the form of

$$\sigma = A \varepsilon \, , \qquad /1/$$

in which A has nine a_{ij} coefficients since the wall exhibits plane strain response.

The finite element mesh /Fig.2./ modelling the cross-section of the wall and its environment has 78 rectangular elements and 273 nodes. Boundary condition was considered by spring supports, and spring constants were assumed $k=10^7$ MPa in magnitude.

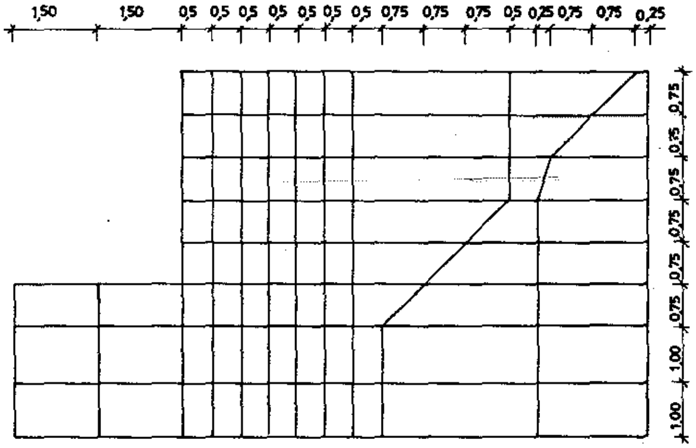

Fig.2.Finite element mesh for the wall and its environment

Constructing process was taken into consideration.Three different stages can be separated according to the Fig.1c, each of them representing an incremental height of H=1,5 m in the backfill-facing-reinforcement system. Not only the finite element mesh but the soil and composite properties and loads, due to the self-weight of the fill, change in the phase 1,2 and 3.Results of the measurement are evaluated in a similar manner.

Results

In Fig.3. measured and calculated tensile force distributions are seen and it can be stated that they differ considerably from each other. The highest calculated value is about three times of the measured one /at the lowest strip levels/, however, on the upper levels experimental maximum value of the strip forces approach to the theoretical ones. Fig.3a. illustrates results for three construction phases according to which in the distribution curves are similar. Fig.3b shows tensile force distribution in the case when the total height is reached. Strip force according to the conventional examination of the internal stability decreases because of the frictional resistance and, therefore, triangular strip force distribution occurs. In our cases the curve fitting on the extreme values can not be characterized by the tangential line started from the toe with an initial inclination of angle $45^{\circ}+\emptyset/2$ to the horizontal direction.

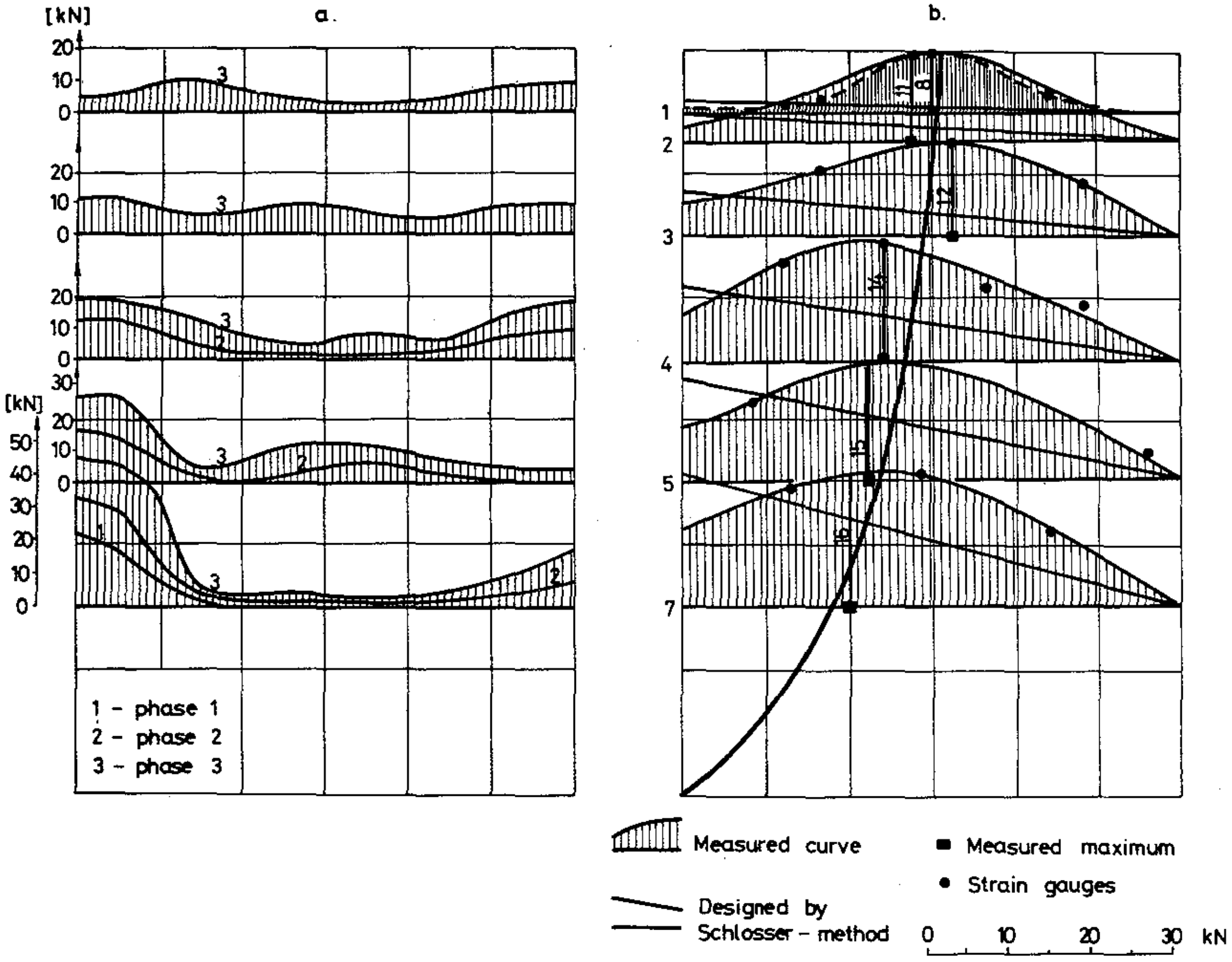

Fig.3.Tensile force distribution

a - by the finite element method
b - by site measurements

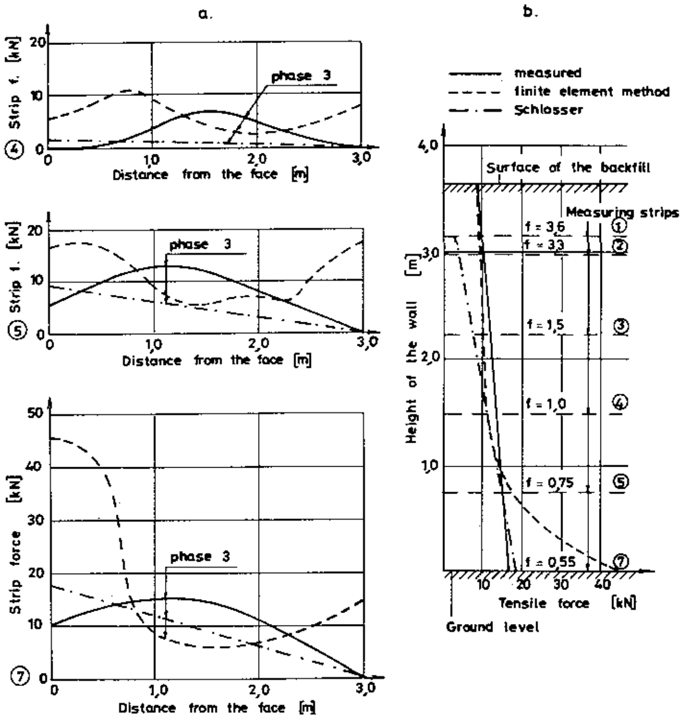

Fig.4.Comparative results for the strip forces and frictional coefficients

a - tensile forces in measuring strips 7, 5 and 4,

b - maximum values and frictional coefficients according to the measurement plotted against the wall-height

Comparative diagrams in Fig.4a contain tensile force distribution for the three reinforcing levels given by the conventional design, the finite element method and the measurement.Extreme values do not coincide: where the measured maximum is, the computed minimum exists.In Fig.4b the highest values as well as the frictional coefficients originated from the measured data can be compared in every measuring strips. The latter were estimated by supposing constant distribution of the frictional resistance mobilized along the tie lengths in the "passive zone".

Measured displacements are about two or three times higher than that of the computed ones. The ratio of the measured distortion to the computed value is four /Fig.5/.

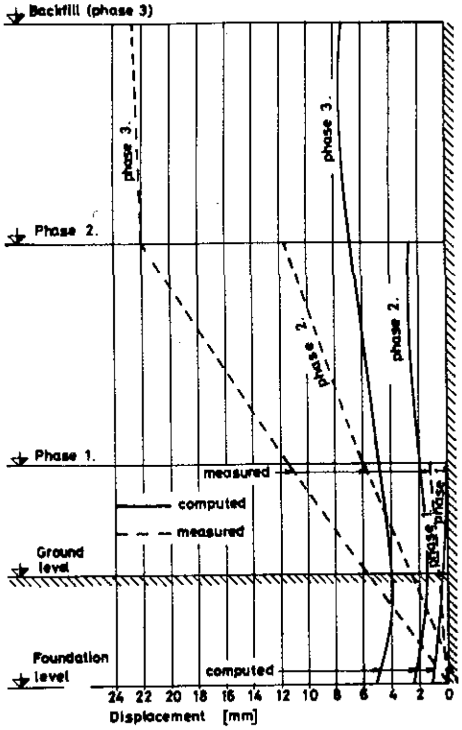

Fig.5. Displacement of the wall during construction

Conclusions

1. The greatest measured tensile force /in the lowest strip/ is almost equal to one given by conventional methods, in which it is supposed that maximum value can be obtained from active earth pressure acting on the facing area pertained to the respective strip.

2.Finite element calculation underestimates the horizontal displacements of the facing whilst overestimates the maximum tensile force.It concludes reasonably from the fact that not only elastic but plastic /frictional/ displacements between the soil and the strips occur, therefore the interaction criterium has, mostly in the higher deformation zone, limited validity. Taking only elastic physical equations into consideration results give much higher values in the strip forces than they are in actual. It is the further task to develop this method in that direction where this inadequacy can be eliminated.

3. Frictional interaction is affected by not only roughness of the strip surface or cross section of the ties / 3 /, but it is influenced by the magnitude of the deformation, too. In the upper zone, where relative distortions are smaller, laying fold or unevenness in the strips cause 6-8 times increase in the frictional resistance compared to the value measured in the laboratory. On the contrary, the lower part of the backfill-strip system undergoes a significant deformation, consequently the strips become "planished" or "levelled-up", therefore frictional resistance converges to the surface frictional coefficient, i.e. to the laboratory value.

To sum up the results it can be stated that in the upper part of the wall elastic stress state predominates, whilst in the lower levels slipping occurs between the soil and strips. Going upwards along the height of the wall the finite element analysis, implying unit cell concept, gives better approach to the value of the measured tensile force. Since in general cases the lowest strips are dimensioned this elastic mechanical model might result an unnecessary overestimation.

Beside these mechanical considerations this structure is a pregnant example for building a reinforced earth retaining wall by using transitional fill material, e.g. fine sand, silty sand, etc., which is predominant in Hungary.

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