PETRIK P.M.
Research Institute of Civil Engineering, Bratislava, Czechoslovakia.

Development of stresses in reinforcement and subgrade of a reinforced soil slab

Développement des contraintes dans l'armature d'une plaque en terre armée et dans le sol sous-jacent

RESUME.

La communication présente les essais sur modéles réduits qui ont été conduits á fin de déterminer la relation entre la charge appliquée et les contraintes développées dans une plaque en terre armée et dans sa sol de fondation. En présence de l´armature dans une chaussée, il se produit, dans le sous-sol, un abaissement des contraintes horizontales. Sous l´action de la charge appliquee les éllipses de contraintes s´applatissent ce qui entraine la diminution des contraintes de cisaillement. En conséquence, les déformations verticales deviennent plus faibles et les modules de déformation augmentent.
Les essais sur modéles réduits ont montré qu´en vue d´obtenir l´effet statique il faut que la résistance de l´armature mise en oeuvre dans une plaque en terre armée dans une chaussée chargée par véhicules de 15 t á pression de contact de 0,6 MPa doit dépasser 20 kN . m^{-1} . En cas des tissus synthétiques, cette résistance dans le tiers bas des courbes contrainte - déformation doit étre supérieure á kN . m^{-1}. Comme caractéristique de qualité d´un tissu synthetique ont peut considérer sa capacité de supporter pendant une longue période le chargement cyclique sans perdre ses caracteristiques de filtration.

INTRODUCTION

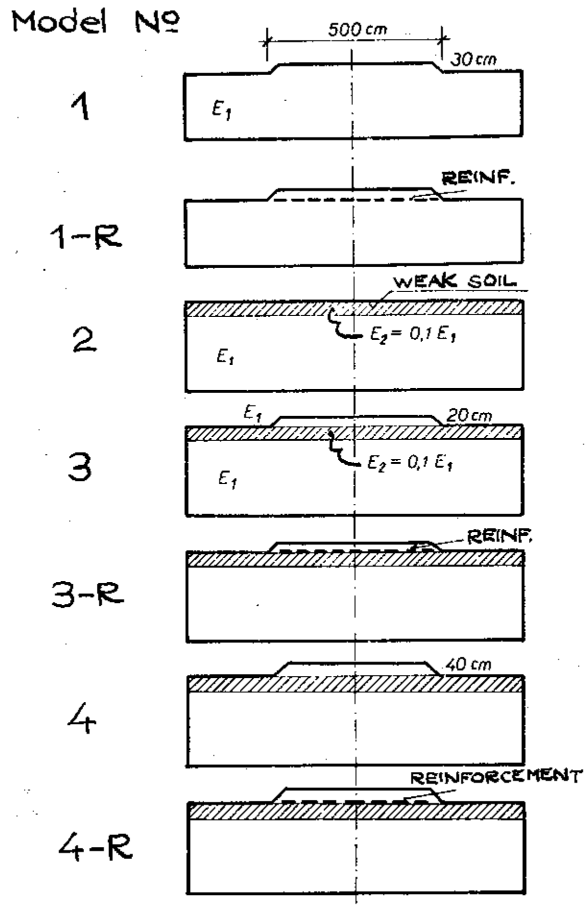
Since 1974 Czechoslovakia have been embedded in subgrade of road structures about 150 thousand s.m. of various synthetic textiles. The experience from those structures is different. At the evaluation of field tests it appeared that further spreading of use of synthetic textiles in road construction is impeded among others also by the ignorance of the optimum design of strength and deformation characteristics of synthetic reinforcement required. Therefore, in 1975 at the Research Institute of Civil Engineering in Bratislava was started a laboratory research into behaviour of a reinforced earth slabs. We may call so any compacted earth embankement laid on reinforcement resistant to tension.

LABORATORY EQUIPMENTS

For measuring the development of stresses in the surroundings of the reinforced earth slabs a pin model 100 x 50 x 3 cm was chosen. Reinforcement was modelled with aluminium foils. Though this type of model is tridimensional it is to be considered as bidimensional with an equivalent material which for a suitable choice of model material and small deformation can represent phenomena of non-linear elastoplastic deformations appearing in the case of exceeding of the lower plastic limit of materials. Most problems occured in the case of looking for model material which would suitably represent the yielding, weak subgrade layer of the road system. At the same time it was necessary to obtain the ratio of deformation moduls of road structure to the yielding layer of 1 : 10. More than 40 alternative materials were tested. At the looking for the model material of the weak layer we tried to obtain a material with such a relative deformation curve which is similar to that of the basic material of the pin model we used / steel pins / and has 10 times higher values of relative deformations. We find to model it in the whole course of the loading conditions examined $E_1 : E_2 = 1 : 10$, where E_1 is the deformation modulus of steel pins and E_2 the modulus of the non-bearing layer. The final model material chosen meeting best our requirements consisted of steel pins and two types of polyethylen pipes. The deformation curves of both materials were homothetic for the whole extent of the loading examined. The stress of reinforcement was measured with strain gauges. The stress in subgrade was read by means of box receivers of normal forces 9 x 12 x 30 mm with strain-gauges. The deformation modulus of the receivers was 30 times higher than that of the modeled subgrade.

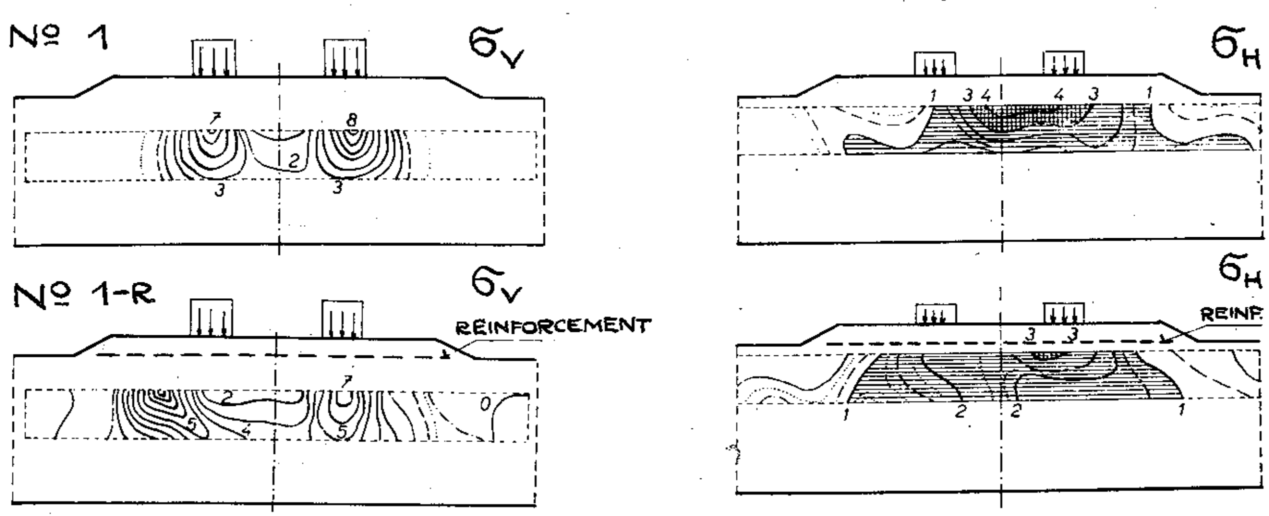
RESULTS OF MODEL MEASUREMENTS

The horizontal and vertical stresses in subgrade were measured by means of 60 box receivers arranged in 4 rows one below the other. From the values obtained in this way isobars were established of vertical and horizontal subgrade stresses. Road systems in Fig. 1 were examined. A serie of such figures was established, examples if which may be seen in Fig. 2 and 3. Here are represented vertical and horizontal stresses in subgrade when in the structure surface a contact stress of 0,82 MPa was induced. In this figures may be well seen the influences of reinforcement upon the decrease of horizontal stresses in subgrade though we didn´t manage to assure an axially symmetrical development of stresses. It is due to a change in the direction of the vertical load action during test in consequence of non-homogenity of model materials and of force vector field of subgrade.
By the analysis of the isobars of subgrade stresses we arrived at the conclusion that curing to embedding of reinforcement in the road body structure, arises a moderate increase in vertical stresses under an important decrease of horizontal stresses in subgrade. By reinforceing a flattening of the ellipses of stress in the vast sphere of subgrade takes place. At the same time arises a decrease in shear stresses and merely of shear deformations bringing about an increase in the subgrade deformation modulus.



Accounted road systems

Fig. 1



Isobars of vertical and horizontal stresses in the subgrade of road-systems No 1 and 1-R.

Fig. 2

According to model measurements the stress of reinforcement of the earth slab, when in the structure surface is induced a contact stress of 0,82 MPa corresponding 1,3 times to the Czechoslovak 15 t design vehicle, develops in conformity with Tab. I.

Simultaneously with the measurements of stresses in reinforcement and at selected points in subgrade, also the vertical deformation of the whole system was ascertained. From the values obtained in this way were deduced the relative values of deformations moduli of the road systems examined in Tab. II. From the analysis of these values results the following :

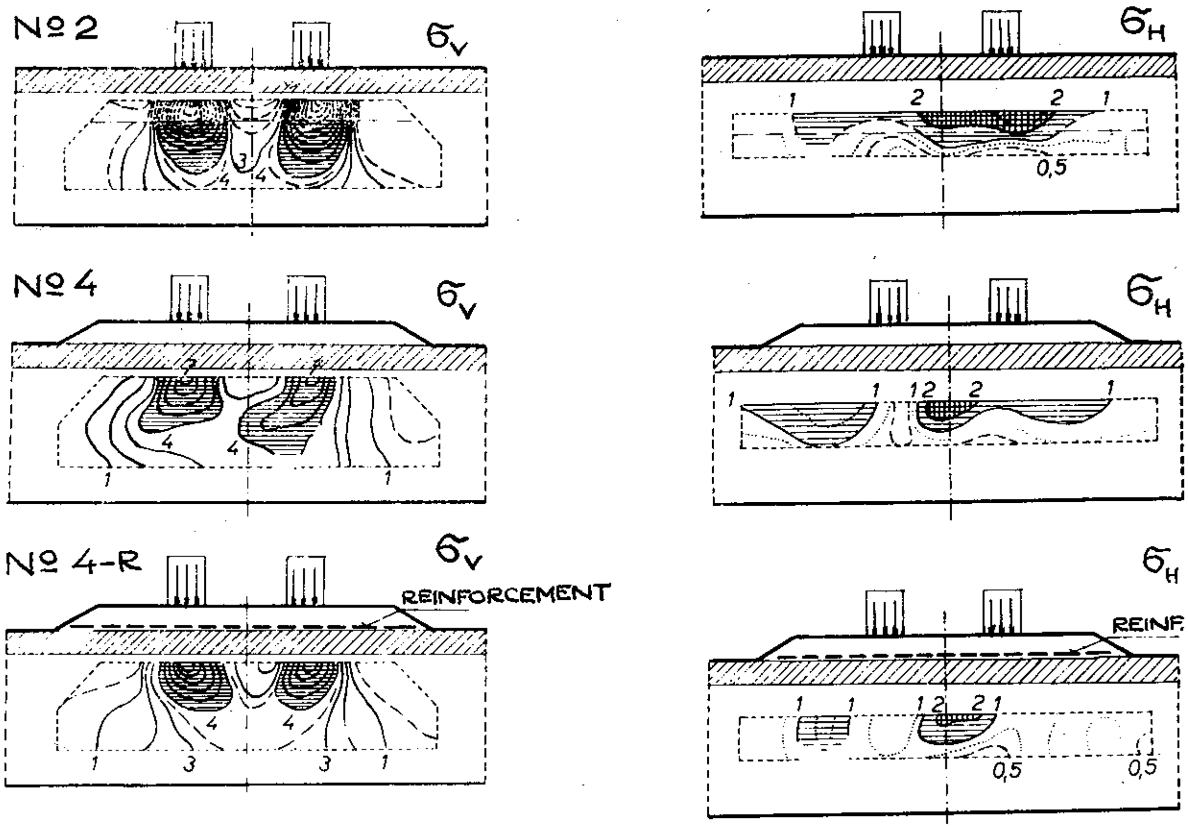
a/ for a road system with a homogeneous comparatively bearing subgrade the influence of one-row reinforcement is positive till the contact load of the system surface reaches 0,82 MPa. The deformation modulus of subgrade due to reinforcement increases as much as to the double. In the case of a larger load the influence of reinforcement disappears.

b/ for a system with low-bearing subgrade the utilization of the positive influence of reinforcement is efficient for all loading stages. The deformation modulus of subgrade with reinforcement increases three-times.

c/ for a road system with a low-bearing layer in subgrade with a thickness of to 50 cm the increase of thickness of the reinforced earth slab exceeding 30 cm is statically not efficient.

CONCLUSION

In the paper is shown the influence of reinforcement upon the stress development in subgrade by means of model measurements. With reinforcing the pavement subgrade arises a decrease in horizontal stresses in subgrade. Consequently under loads the stress ellipses flatten occasioning a decrease of the maximum shear stresses. Herewith a decrease in the overall deformations and an increase in deformation moduli of subgrade is brought about. It is caused by the distributing action of reinforcement. We recommend to use as reinforcement for earth slabs in road construction synthetic textiles of sufficient strenght which besides the static function of theirs are able to act against suffosion assuring herewith a long-term conservation of unchanged properties of road structure soils. The strength of road reinforcement designed for loading with 15 t vehicles with e contact pressure of 0,6 MPa shall exceed 20 kN . m^{-1}.



Isobars of vertical and horizontal stresses in the subgrade of road-systems No 2,4,4-R.

Fig. 3

Road system	Description of the reinforced earth slab	Maximum tension of reinforcement obtained kN . m^{-1}
1 - R	Sand and gravel slab 30 cm thick on subgrade of the same quality	13,2
2 - R	Sand and gravel slab 20 cm thick supported by a 42 cm thick low-bearing subgrade layer	18,7
3 - R	Slab 40 cm thick supported by a 42 cm thick low-bearing subgrade layer	21,3

Tension of the reinforcement. Tab. I.

Stages of loading of road system surface /MPa/	Road system type						
	Homogeneous subgrade		With a low-bearing subgrade layer				
	No 1	reinforced 1 - R	2	3	4	reinforced 3-R	4-R
0,23 - 0,41	1,00^x	0,88	1,00^xx	3,27	3,20	3,00	3,54
0,41 - 0,61	0,59	1,02	0,57	1,93	3,87	4,85	5,85
0,61 - 0,82	0,53	1,02	0,67	0,82	0,84	2,60	2,95
0,82 - 1,02	0,26	0,34	-	-	-	-	-

Notes : e.g. the Š 706-RT vehicle is a 15 t Czechoslovak design vehicle, which has a contact stress on the surface of 0,65 MPa

x For the model No 1 the value of 1,00 correspondes to 49 MPa

xx For the model No 2 the value of 1,00 correspondes to 15 MPa

Relative values of deformation moduli of the road systems examined. Table II.

Statically efficient fabrics embedded in roads shall have accordingly a strength higher than 20 kN . m^{-1} in the lower third of the stress-deformation curves of theirs. The characteristic of quality of fabrics is a steep stres-deformation curve as well as the ability of supporting for a long period the cyclic loads referred to for unchanged filtration capability.

In the case of utilization of roads with unreinforced earth slab without hard pavement it is necessary to prevent traffic canalisation by thorough maintenance of the surface layers of road. Conversely a decrease in the efficiency of reinforced earth slab or even damaging of reinforcement and thereby full deterioration of road may arise.