C.R. Coll. Int. Renforcement des Sols. Paris 1979.

MAGYARNE JORDAN M., SCHARLE P. et SZALATKAY I.

Hungarian Institute for Building Science, Hongrie

Improvement of bedding conditions around pipes by rigid inclusions

Amélioration de l'interaction remblai-conduite par utilisation d'inclusions rigides

La déformation des tuyaux des conduites flexibles posés dans le sol dépend dans une large mesure de la qualité du remblai du radier de fondation. Des inclusions rigides posées près des tuyaux améliorent leur comportement. Des études expérimentales et des calculs théoriques approchés permettent de mettre en évidence et de déterminer cette amélioration.

Introduction

The thin-walled plastic tubes and sewers are of highly flexible structures. Their deformations depend on several factors, particularly on the bedding conditions. If the soil surrounding the tube was well compacted the unwanted flattening /the increment of the lateral diameter/ remains moderate. In consequence, the bending moments in the wall are relatively small. In loose soils the cross section of the tube may become elliptic and high stresses arise in the wall. From this point of view there is no significant difference between the two fundamental arrangements /Fig. 1, CPIM/.

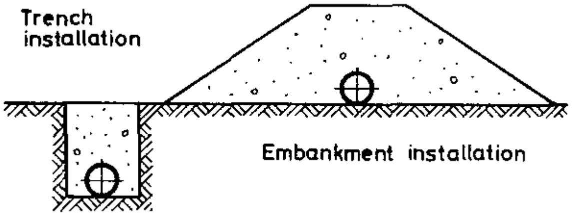


Fig.1.Main installation types of sewers

There are many ways to improve the situation. In aware of that the most plausible solution would be the appropriate compacting, the contractors often prefer to use different chemicals, concrete embeddings of mechanical constraints /for example, clamps - Fig.2./

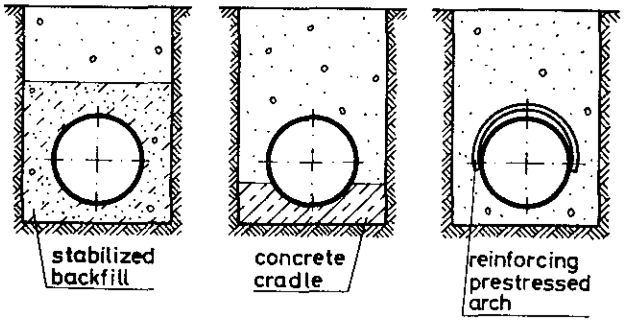


Fig.2.Bedding reinforcements

The rigidity of the bedding can be improved by using inset elements enclosed in proper distance around the pipe, too. The idea of using rigid inclusions is by no means idle considering the spontaneous practice. Its peculiarity lies in the fact that the arrangement seems to be undesignable. On the other hand, the beneficial effect of the different inclusions is a central question of interest in our days, even general principles are formulated already /McGown et al.,1978/.The aim of the authors was to get a better insight into the behaviour of the structure-soil-inclusion system and to control some intuitive expectations quantitatively. The present paper reports some results of the investigation carried out to clear up the effects to be considered here.

Mechanics of the rigid inclusions

Under vertical loading the D_V vertical diameter of the circular tube decreases, the lateral one D_L increases. As a matter of fact, the extension of the domain influenced by this effect varies with the compactness of the soil. When the soil was loose the compressing region is small but the displacements are great. In well-compacted soils the spread-off of the stresses may reach wide range but the strains remain low /Fig.3/.

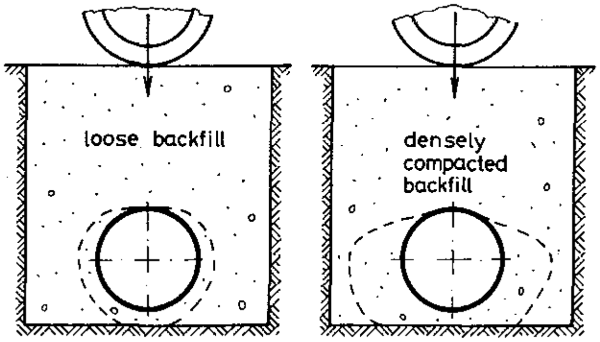


Fig.3. Domains under stress caused by the pipe deformation

The deformations of the cross section are influenced by several different factors.The most important ones are

-the effective load,

-the bending inertia of the pipe-wall,

-the stiffness of the surrounding soil.

To describe this latter one, in general the E elastic modulus of the soil is considered in spite of the well-known shortcomings of this parameter. Intuitively, it can be expected, that the - even local - increase of E results in more favourable situation for the tube.Rigid inclusions - either simple rods with rectangular cross section or more difficult, "optimized" forms /Fig.4/ - present a kinematic constraint in the surroundings of the sewer.The effectiveness of these inclusions is based on their rigidity of much higher magnitude than that of the soil and on the fact that they are placed in the domain determining the deformations.

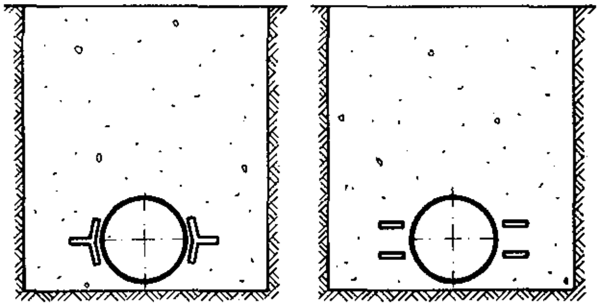


Fig.4. Rigid inclusions around the pipe

Naturally, the magnitude of this effect highly depends on the circumstances mentioned above. The inclusions may be useful in loose fillings and their use may be meaning-less in well-compacted soils.To have got a better insight into the quantitative relations experimental and numerical investigations were performed.

Experiments

To have some orienting datas a full-scale model of D=400 mm plastic tube was loaded /Fig.5/. The vertical and lateral diameters were measured, the results are shown on the Fig.6. In accordance to the expectation the ratio D_V/D_L was significantly higher when inclusions were applied, the flattening of the cross section became restricted.

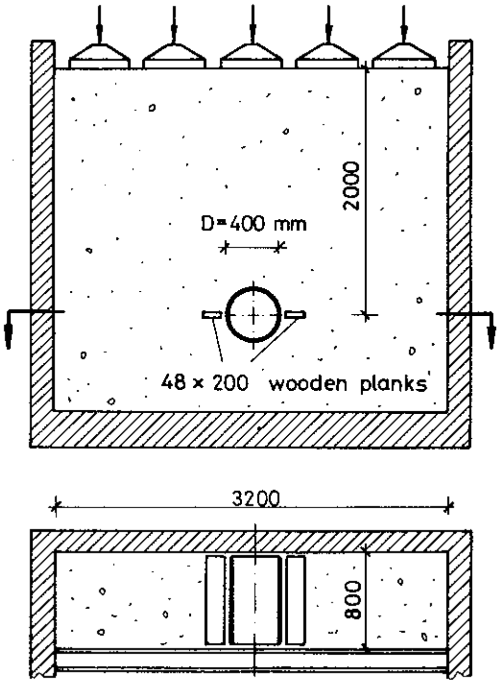


Fig.5. Arrangement of the preliminary experiment

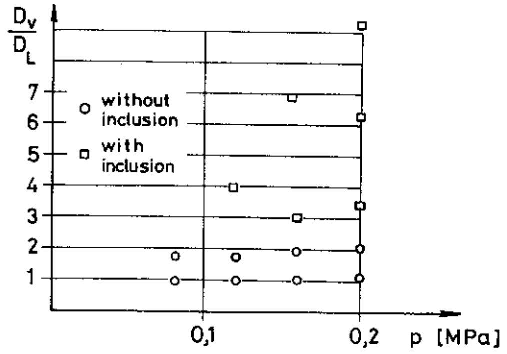


Fig.6.Relationship between the vertical and lateral diameters

A more elaborated sequence of experiments was performed in a small box of dimensions 0,9x1,2x2,4 m/Fig.7/.Three arrangements /etalon without inclusions, rectangular plank in horizontal and in vertical position/ were investigated.Three states of compactness were considered in each arrangement /Q_d/Q_m= 74,79,83 p.c.,where Q_d denotes the dry density of the soil, Q_m stands for the maximal value of Q_d/.

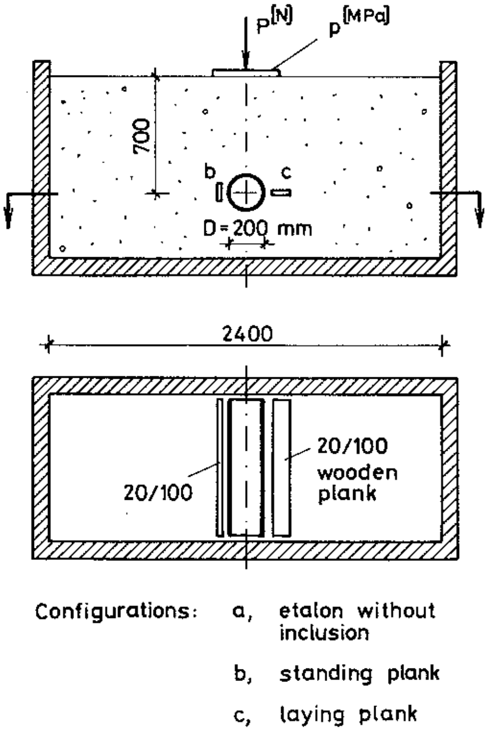


Fig.7. Arrangement of the experiments

The results, in general, verfied the hypotheses.Fig.8. shows the most well-performed case/Q_d/Q_m=79%/.All results were of similar character with some anomalies caused by experimental deficiencies. To comment quantitatively the results it is suitable to define the ration η as a measure of increase in bearing capacity of the tube:

$$\eta = \frac{P_i - P_e}{P_e} \quad \%$$

where P_i denotes the force resulting a given relative increase or decrease in the measured diameter for the cross sections with inclusion;

P_e denotes the force resulting the same increase or decrease for the etalon.

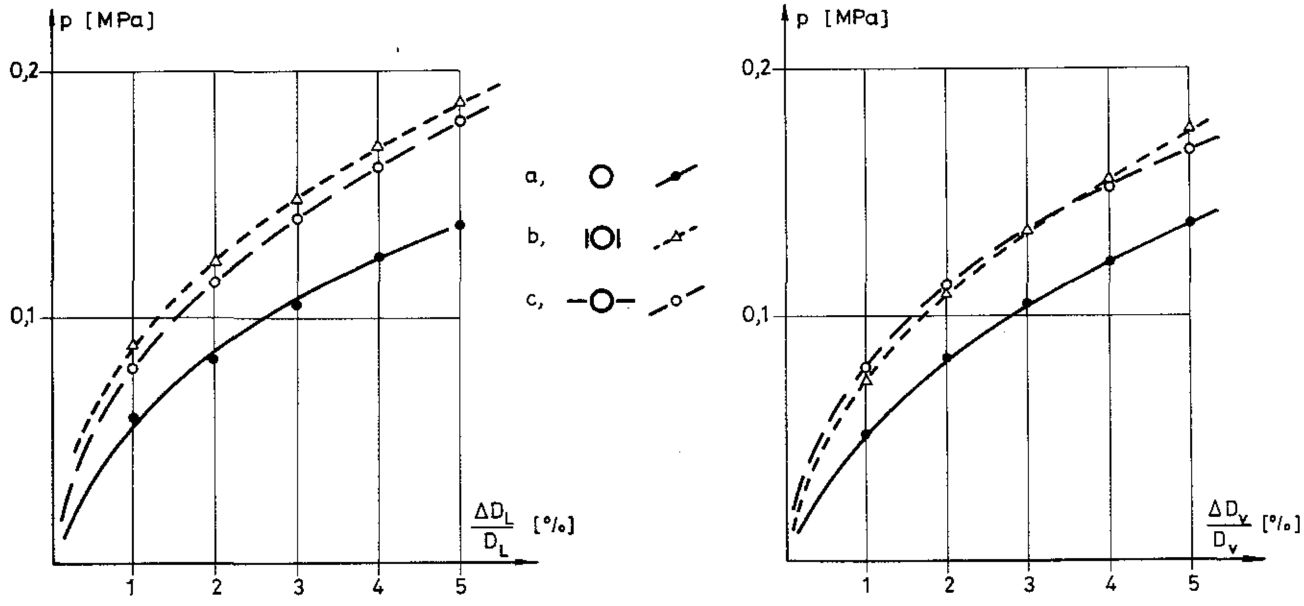


Fig.8.Experimental results for the relative density of 79 p.c.

The results for the relative compactness 73 and 79% are plotted on the Fig.9 as functions of the relative deformations

$$\frac{\Delta D_L}{D_L} \quad \text{and} \quad \frac{\Delta D_V}{D_V}$$

The increase of the bearing capacity /when it was defined in the sense given above/ is of 10-50 % in the range investigated.

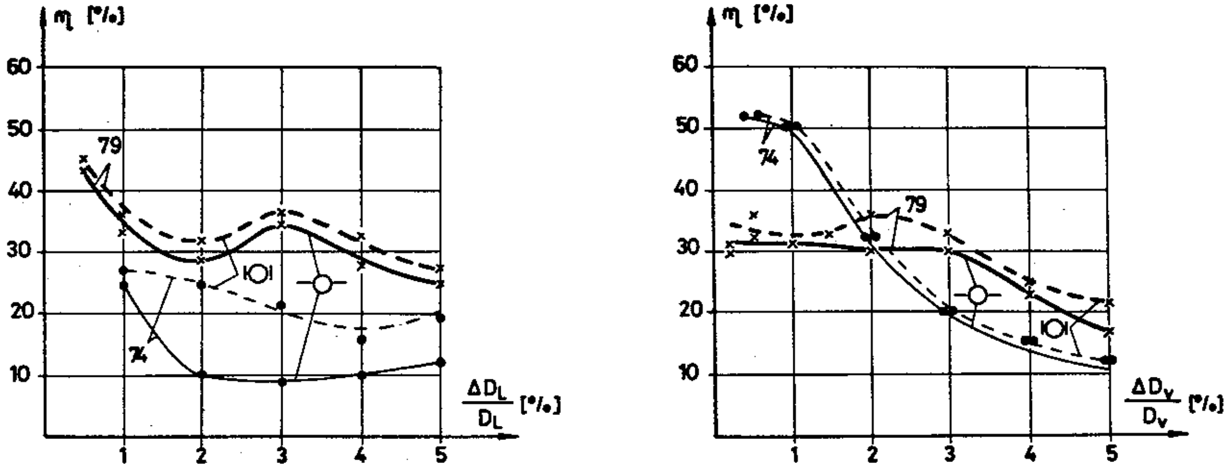
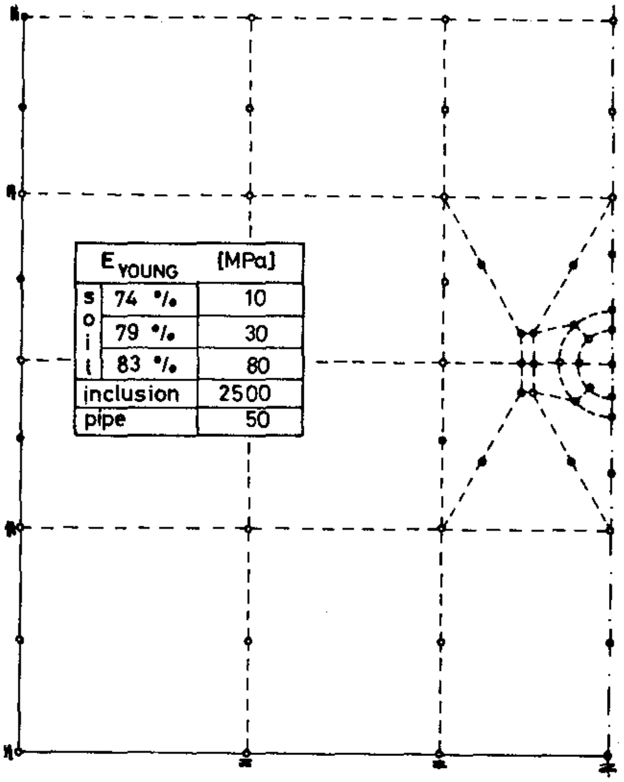


Fig.9.Bearing capacity vs relative deformations /relative densities of 74 and 79 p.c./

Numerical experiments

The use of the finite element technique is at hand in the given case. The familiar plane strain version was applied with isoparametric quadrilaterals of 16 degrees of freedom. Clearly, the physical circumstances are very difficult in the given case and the interface behaviour may highly influence the deformations /Desai, 1977/. Nevertheless, our aim was here again to get some quantitative estimation about the magnitudes and the effects of contact type were neglected.

The mesh and the physical parameters considered for the case of vertical inclusion are shown on Fig.10. To avoid the well-known difficulties caused by slender elements and to save the computer efforts the pipe wall was transformed to greater width with reduced elastic modulus.



E_{YOUNG}		[MPa]
soil	74 %	10
	79 %	30
	83 %	80
inclusion		2500
pipe		50

Fig.10. Finite element mesh for the configuration b,

The effect of the relative compactness of the soil is quite clear here and can be modelled by the appropriate use of different E moduli. The Fig.11 shows the influence of the inclusions - both configuration with inclusions resulted reduced deformations in comparison with the etalon.

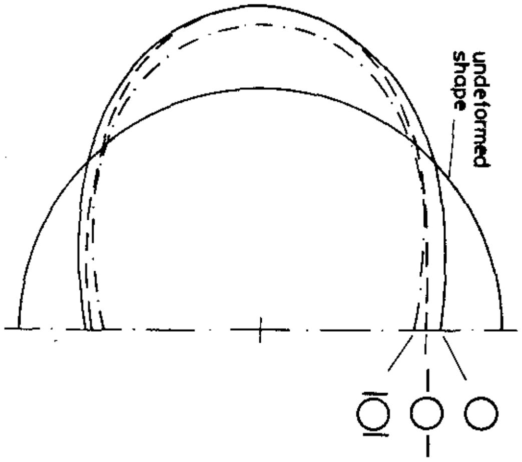


Fig.11. Deformations computed for the configurations at E_{soil}=10 MPa

Conclusions

Summarizing the experimental and numerical results it can be stated that the rigid inclusions significantly decrease the deformations. Prescribing the relative deformations higher loads of 10-50 p.c. can be permitted. The role of the inset elements is higher in loose soils - the use of the inclusions is appropriate when the compaction cannot be performed in good quality.

The shape and proper place of the inclusions can be optimized - the effectiveness depends on the distance between the tube and the element, too. The finite element technique allows for numerical estimating.

From the point of view of the technology, the build-in of the elements does not require special tools or machines. The inclusions can be of simple concrete slabs or planks. Because the material of higher quality is well arranged in this configuration theoretically the improvement of bedding conditions should be economical.No reference site performance has been carried out up to date.

References

CPIM - Concrete Pipe Installation Manual, American Concrete Pipe Assotiation, 1972.

Desai,C.S.: Soil-structure interaction and simulation problems, in Finite Elements in Geomechanics /Ed. by G.Gudehus/, Wiley, 1977.

McGown,A.,Andrawes,K.Z.,Al-Hasani,M.M.: Effect of inclusion properties on the behaviour of sand, Géotechnique, XXVIII,3,September 1978, pp.327-346