Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 2 (1936)

Artikel: The artificial consolidation of embankments

Autor: Loos, W.

DOI: https://doi.org/10.5169/seals-3369

VIII 12

The Artificial Consolidation of Embankments.

Verdichtung von Brückenrampen.

Le tassement artificiel des remblais.

Regierungsbaurat Dr. Ing. habil. W. Loos,
Berlin.

In major engineering works carried out during the last few years increasing importance has been attached to the artificial consolidation of embankments, especially where these form the approaches on either side of large bridges. The length, height and width of such embankments has increased on account of the

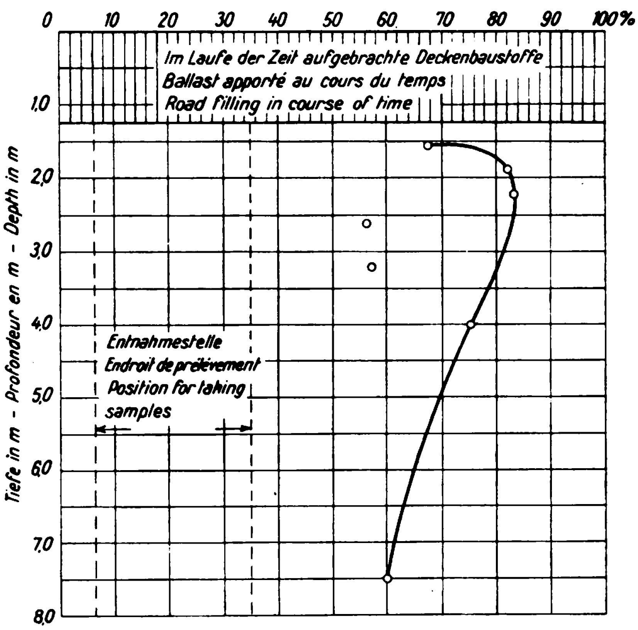


Fig. 1.
Neisse-Ziegenhals road.

much more ample location now adopted, involving large radii and easy gradients, flyover crossings, approaches to motorways, etc. The time now available for construction is in most cases shorter than formerly, and it is no longer practicable to rely on embankments being left for some time to settle before the paving is added in the hope that meanwhile the settlement will have attained its limit; moreover, the great increase in the weight and speed of vehicles which has now taken place, makes it inadmissible to regard mere delay as a sufficient guarantee of consolidation.

Attempts have been made to ascertain the amount of settlement that has already taken place under roads and embankments already carrying traffic. It

Fig. 2.

was established, for instance, under the effect of railway traffic, that an embankment formed in the year 1923 from more or less non-uniform sand had attained 60 % of its total range of consolidation, while a neighbouring embankment formed at the same time from the same sand had consolidated only between 10

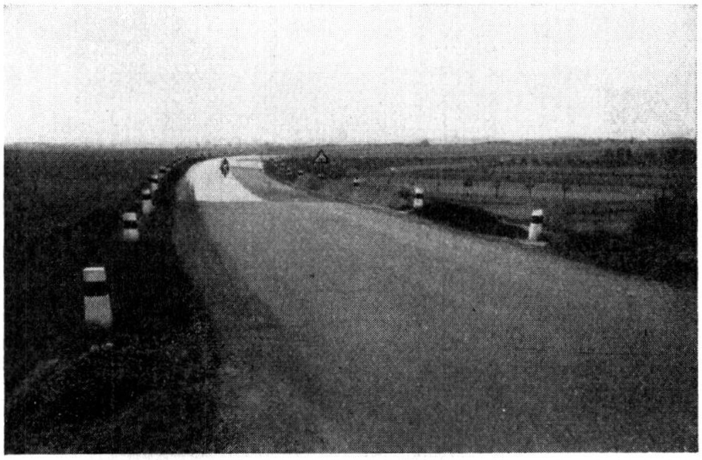


Fig. 3.

and 30 % in the course of 12 years. A roadway embankment a hundred years old formed from weakly binding non-unifom sand had attained a consolidation of 60 to 80 % (Fig. 1). The requisite amount of consolidation depends to a great extent on the granulation of the material, but in the case of roads a consolidation as uniform as possible approximating to 50 % should be insisted upon, and this is more than can be accomplished by wind and weather alone.

I.

1) The reason why the consolidation of tipped embankments is often not uniform is that the newly filled material is apt to attain a denser stratification,[1]

[1] *Hertwig:* Bodenverdichtung, „Die Straße" 1934, N° 4, pp. 106—108.

usually known as settlement, and also, in yielding ground, the fact that the embankment imposes heavy loads on the strata of the existing subsoil.

2) Delayed settlements, which may be particularly dangerous in the case of expensive road pavings, may also occur through excessively steep slopes; through the slow yielding of sticky soils; through the formation of shrinkage cracks due

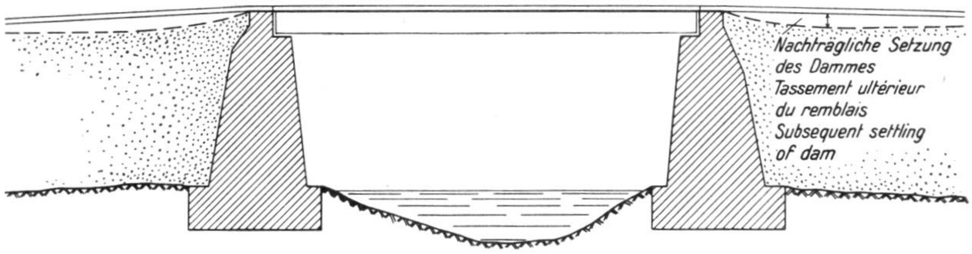


Fig. 4.

to drought being followed by that of wide rain gullies and partial slips; through frost effects; through swelling due to increase in the water content (known as spring slips); and through slackening due to weathering.

3) The blows and vibration due to traffic shake the sand together, giving it a smaller pore content. Water carries fine material into the hollows between the large grains, or into the gaps between stone packing where, as used frequently to be the practice, such material has been deposited with a view to protecting the embankment.

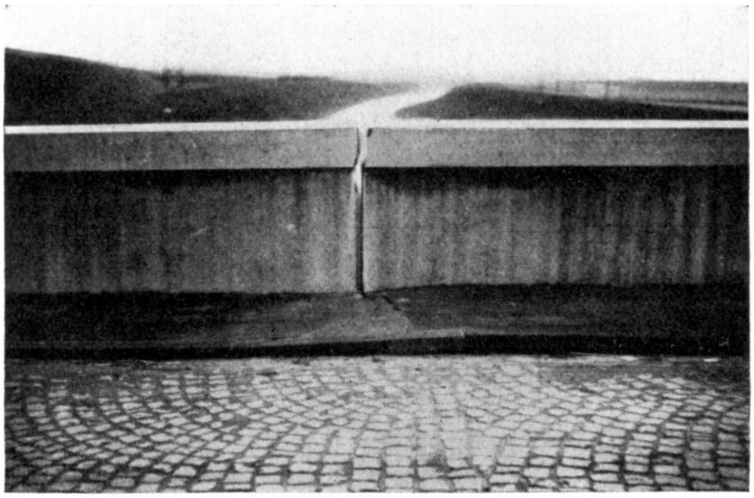


Fig. 5.

These phenomena result in the following defects:

In the case of *railways* there is the necessity for constant packing such as may be seen in Fig. 2, at the level of the ballast after a settlement has taken place, and this is perceptible as a bad transition when passing from the embankment on to the bridge. In the case of *roads* the defect takes the form either of damage to the paving which may often occur repeatedly, or of settlements (Figs. 3, 4, 5). These effects are particularly notable when the foundations of the bridge are deep while the embankment is of a yielding nature (Fig. 6).

II.

Remedial Measures:

1) Determination of what degree of consolidation is necessary in the material available for filling.

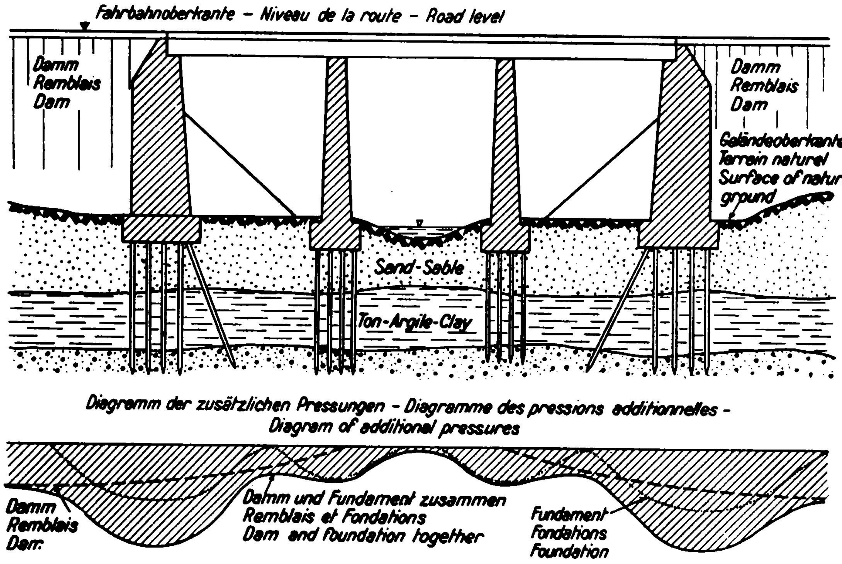


Fig. 6.

Diagrammatic longitudinal section.

This is a very difficult point to decide, as at present only a few observations are on record, while moreover some foresight must be exercised to make allo-

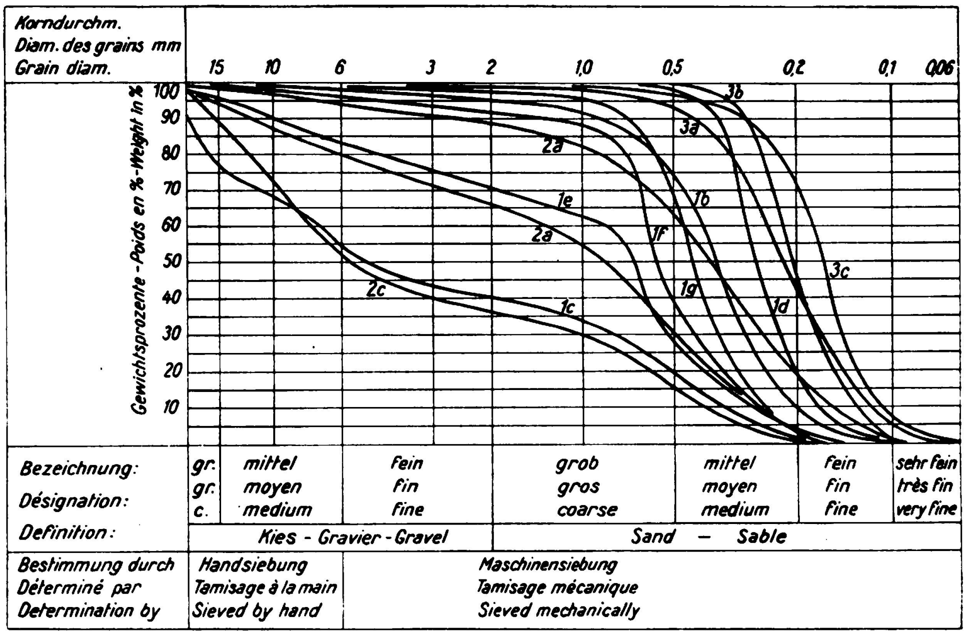


Fig. 7.

Grain size curves.

wance for future increases in the weight and speed of traffic. Two attempts to determine this amount have already been mentioned in the introduction (Fig. 1).

It should be mentioned, also, that it is not possible to produce relatively dense sand by mixing together several different sands on the site; proposals of this kind are often made (consider, for instance, Figs. 7 and 8), but it is in fact

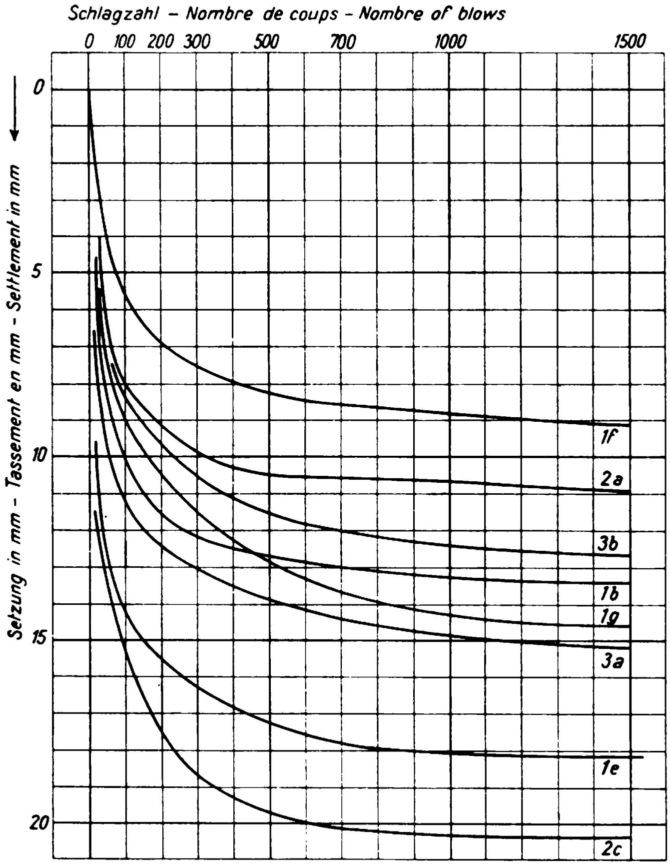


Fig. 8.
Filling by vibration under a fixed number of blows. (The tests 1e, 2c were carried out with the large cylinder).

impossible, on the site, to ensure an intimate mixture. The author's experiments have related mainly to sandy soils and have been aimed at determining the principles underlying these relationships. Ultimately the *maximum* amount of consolidation is not so important as *uniformity*, whereby damage to the pave-

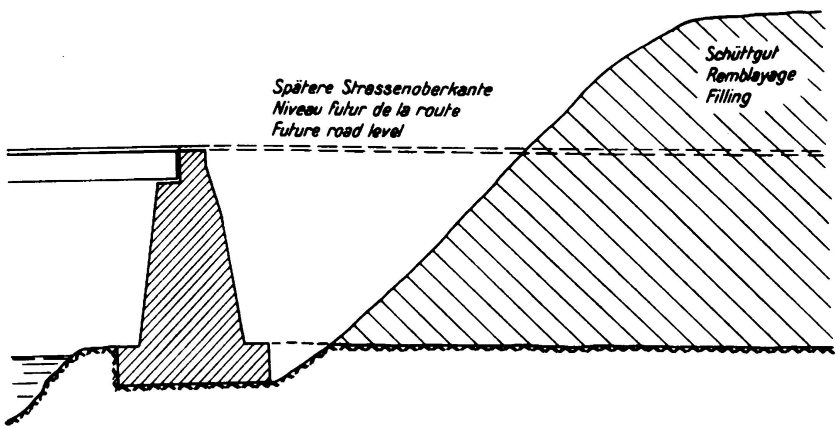


Fig. 9.

ment may be avoided. The conclusion is that 50 to 70 % of the attainable consolidation is to be desired, varying in accordance with the granulation of the filling material.

2) As already indicated, the necessary amount of consolidation is not the same for every type of ground (Fig. 8). It is advisable to carry out a few preliminary experiments on the material taken from the source which is to be used in the work, in order to determine the amount of consolidation attainable.[2]

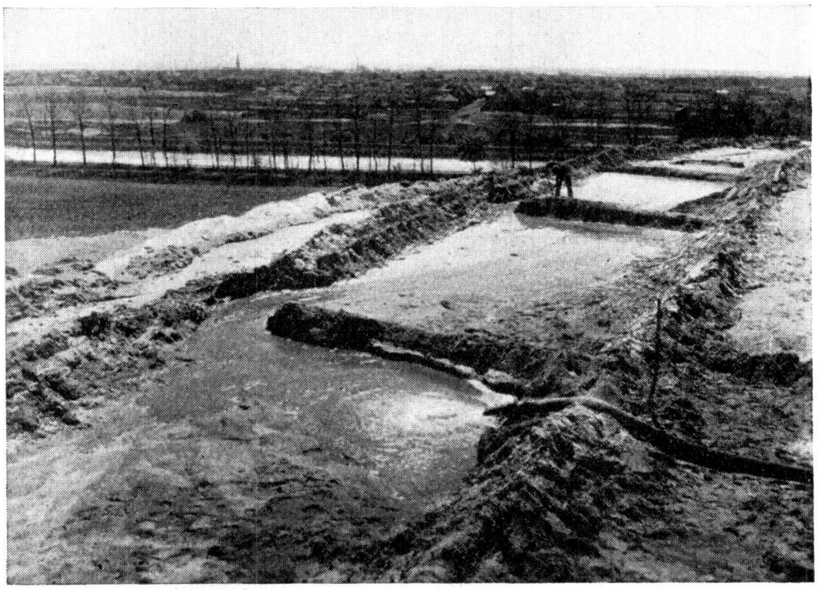


Fig. 10.

3) Working procedure at the site. The procedure must often differ fundamentally according as the ground is of a binding or of a non-binding nature, and

Fig. 11.

in the latter case according as the sand is uniform or otherwise. With a binding soil there is scarcely any way of reducing the time of consolidation required by

[2] *Loos* and *Lorenz:* Verdichtung geschütteter Dämme — 1st Report, „Die Straße", 1934/4. *Loos:* Verdichtung geschütteter Dämme — 2nd Report, „Die Straße", 1935/13. *Müller* and *Ramspeck:* Verdichtung geschütteter Dämme — 3rd Report, „Die Straße", 1935/18.

the ground, except by lengthy pre-loading where possible. The disadvantage in this respect is that the wedge of filling material immediately behind the abutment cannot, as a rule, be completed until the last moment. It is possible, of course, to bring the material which is to be used for this as close as possible and allow

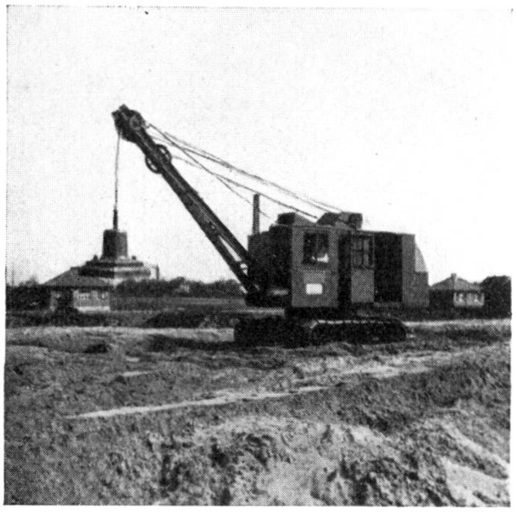


Fig. 12.

it to stand on the embankment (Fig. 9) with a view to pre-loading the subsoil. Mechanical work will produce a breaking up of lumps and sods so as to avoid any large cavities, but it will not be possible to press out the pore water. With this object rolling, stamping and placing of the layers not more than 25 cm deep at a time is advantageous.

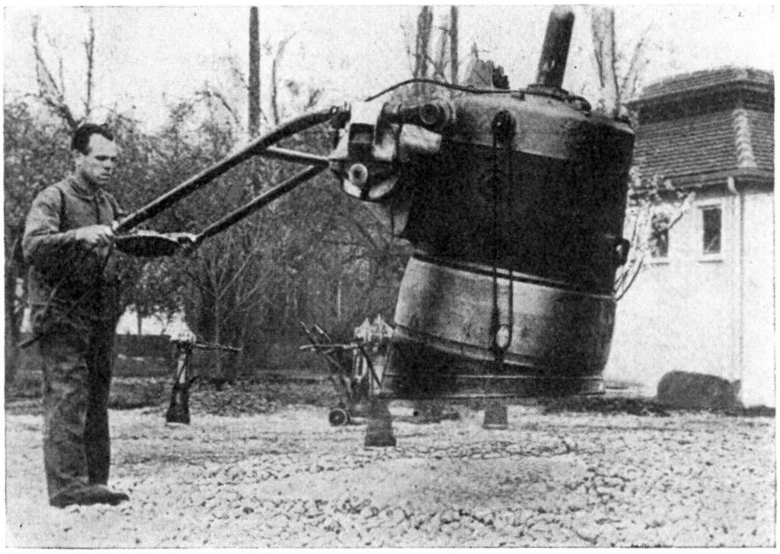


Fig. 13.

1000-kg. Delmag Frog in operation.

Rock fills are very difficult to consolidate. Such material is often used as a filling for embankments in the construction of railways and motor roads in mountainous country; heavy stamping is the only thing that can be done, but there are scarcely any experimental observations on the matter, as sampling is very difficult. The risk, however, is usually small, provided that no finer material

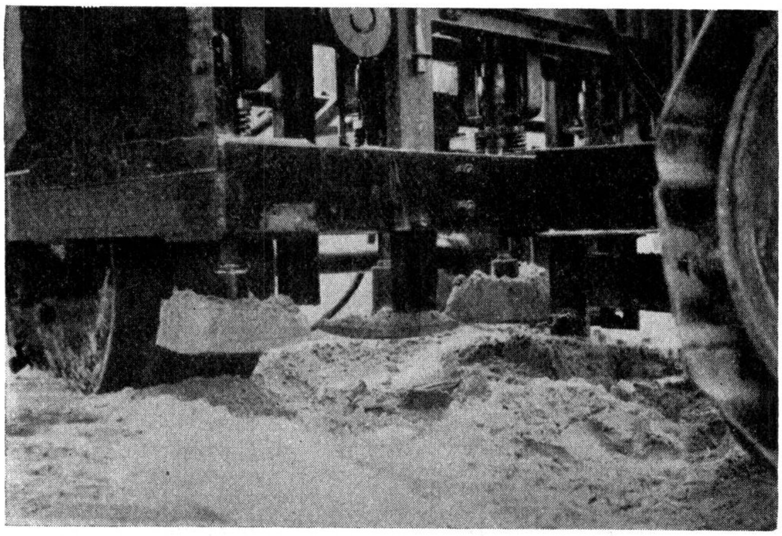


Fig. 14.

is placed over the cavities between the large stones which may penetrate into the spaces between them.

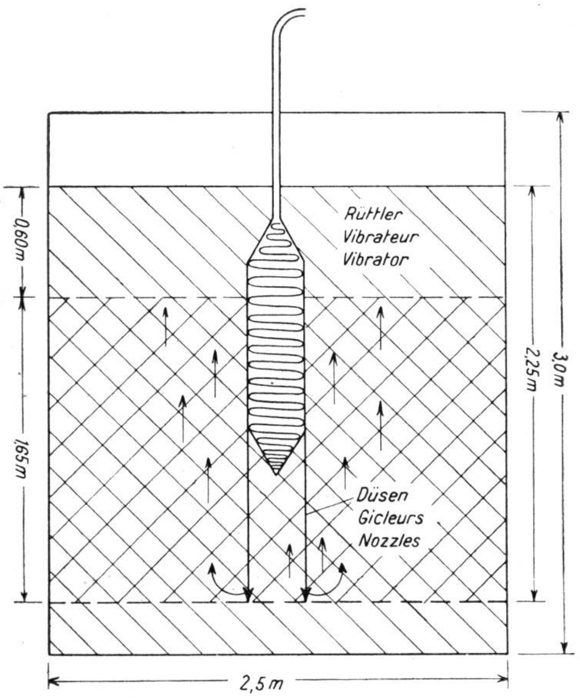


Fig. 15.

Settlement of soil. Model tests with loose filling and internal vibration. Settlement of filling 74 %.

In sandy soils a number of methods have been tried:

a) Silting, which gives only a moderate amount of consolidation.

b) Washing into place, which is a method particularly favoured in canal construction (Fig. 11).

c) Stamping with a plate (Fig. 12).

d) Stamping with explosion-driven frogs (the Delmag frog) (Fig. 13).

e) The use of stamping machines which comprise a number of stampers, actuated electrically, by steam or by compressed air (Fig. 14).
f) The vibration process (Fig. 15).
g) The Losenhausen pendulum machine (Fig. 16).
h) Special form of rollers having ribs or attachments to prevent slipping.

Fig. 16.

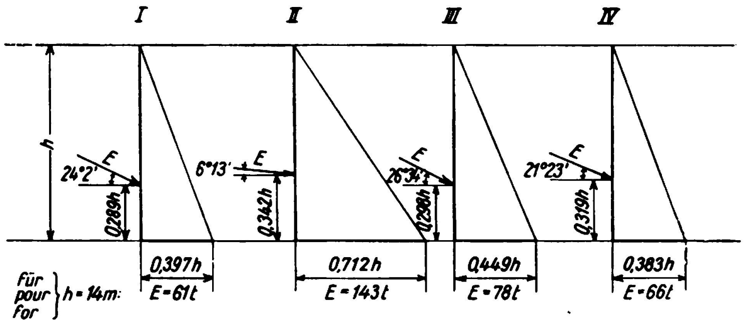
Details of the procedure to be followed in consolidating and testing are given at greater length in the literature already cited.

Special attention is to be paid to those portions of the embankment which are fairly close to the bridge or abutments, and here — even where artificial

Fig. 17.

consolidation is adopted — it is desirable that the paving should at first be temporary and provisional, especially if a long period of settlement is anticipated (Fig. 4). In this way the heavy shocks resulting from the abrupt settlement of the approaches and being apt to be experienced by road vehicles may be avoided.

4) The method of consolidation which it is proposed to adopt should be borne in mind when designing the abutments. Great care is needed, because heavy



I	II	III	IV
Filling damp loosely filled =1,57 t/m³ 5,4 % content of water.	Water level coinciding with level of filling =2,05 t/m³ 36,9 % content of water.	Water level below measuring plate =1,78 t/m³ 6,2% content of water.	Sand dried. =1,77 t/m³ No water content.

Fig. 18. Earth pressure tests with artificial subsoil water levels.

stamping may be necessary which will increase the earth pressure and hydrostatic pressure (Fig. 18); moreover almost any consolidating process has the effect

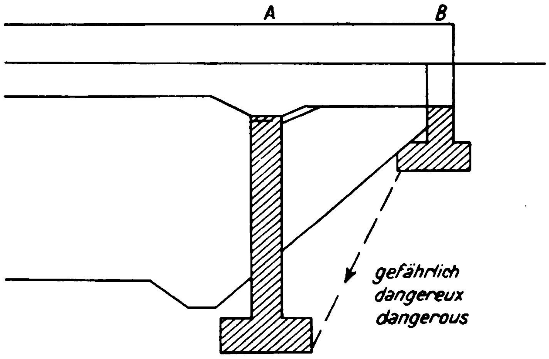


Fig. 19.

of temporarily reducing the internal angle of friction and therefore of increasing the earth pressure, particularly if the abutment is afterwards set back (Figs. 19

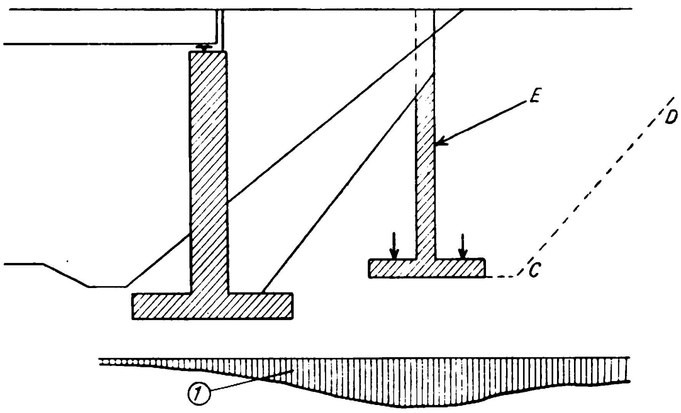


Fig. 20.

(1) Settlement possible through subsequent filling and vibration of bank.

and 20). Especial care is called for when making use of very hard soils such as sandy or chalky marls, etc., which, when exposed to the air, are apt to disintegrate and flow away even without an addition of water (Fig. 21). In such materials the angle of internal friction is very small and the earth pressure correspondingly great.

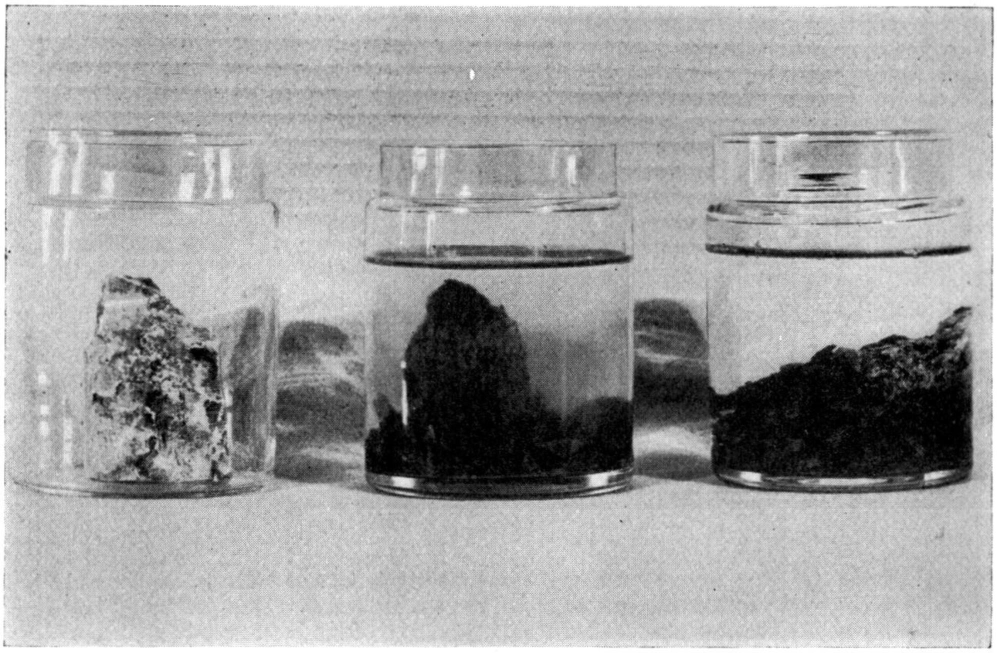


Fig. 21.

Close to the bridge the only acceptable practice, therefore, is to deposit the fill in very shallow layers and to consolidate it with very small stampers not exceeding 500 kg in weight, even in cases where further away the embankment has been formed by depositing layers 1 m deep.