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DEFORMATION OF BRICK-WORKS DUE TO SINKING OF FOUNDATION

(Examination on models)

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Rupture caused by water, damages in mining works and overcharging the ground produce subsidence under brick-works. Breaches become visible, great deformations are caused, in critical circumstances even building-walls are demolished. Till now the reciprocal effect between the subsidence and owing to this the deformation was not systematically treated in the literature. To the scientifically trained observer breaches in brick-works are but seldom accessible. Usually the plaster covering the breaches is superficially mended by the builder, house- or apartment-owner.

Physical conditions as firmness(strength), binding of bricks and the use of brick-chips, system of mixing the mortar, strength and solidity of mortar and walls, soil-mechanical- and underground-conditions cannot be seen on the already finished object. In our Institute there were experiments made on model-brick-works.

On this behalf a special table was constructed which instead of the plate had a system of vertically movable ledges. Above these tires brick-walls of small model-bricks (instead of the normal 6:13:27 cm size 6:13:27 mm) were layed consisting of two vertically crossed part of walls.

The strength of the brick-work was ½ , 1 , 1½, 2 , 3 bricks
crossed by ½, 1, 1½, 2. 3 bricks
in all possible manners. (There were 14 combinations).

The model brick-walls were of 3 different kinds of mortar:
pure lime-mortar (1 lime, 3 sand)
lime-cement-mortar (1 cement, 1 lime, 6 sand)
pure cement-mortar (1 cement, 3 sand)
that is each combination of brick-bindings with each kind of mortar. In that way 42 model walls were constructed. We were unfortunately not able to pursue to the last consequences our experiments on sandgrains.

With the aid of the movable tires we were able to imitate subsidences and undulations of any kind of breadth and depth below the model brick-work. To be as near as possible to the reality a lever was applied to the stronger model-walls to imitate the charging (loading) of this part of wall with parts of walls, roof-construction, etc.laying on top. The weaker walls were mostly uncharged (unloaded) partition-walls (Fig. 1).

There were to test the following problems:

1) Influence of strength of walls concerning breaches resp. deformation.
2) Influence of the kind of mortar concerning breached resp. deformation.
3) Influence of the binding concerning breaches resp.deformation.
4) Influence of the length of subsidence concerning breaches resp. deformation.
5) Influence of the depth of subsidence concerning breaches resp. deformation.
6) Influence of the strength of bricks concerning breaches resp. deformation.
7) Influence of the strength of mortar concerning breaches resp. deformation.
8) which strength is essentially authoritative with deformation (shearing stress,flexure, tensile strength).
9) is it possible to derive from the deformation of brick-works the soil-mechanical conditions of ground?
10) is there a reciprocal functionary effect between the deformation of brickworks and the subsidence?(conform to the analytical geometry).

We shall examine a part of these experiments as follows; that is on model brick-works with lime-mortar which because of its small strength of mortar admits greater deformations.

The crossings of walls were;
wall of ½ strength of brick with wall of ½ strength of brick
wall of ½ strength of brick with wall of 1 strength of brick
wall of 1 strength of brick with wall of 1 strength of brick
wall of ½ strength of brick with wall of 1,1½ strength of brick
wall of ½ strength of brick with wall of 2 strength of brick

The loading (charging) was done at different gradations; the size of charge is visible on the enclosed drawings, as well as on the photographs the proceedings of the breaches,their succession, form and strength, so that a nearer description is not necessary. (fig. 2, 3, 4, 5, 6, 7, 8, 9.)

In explaining the above mentioned and examined problems the following can be said:

ad 1) The strength of brick-walls has so far its influence on the formation of breaches as breaches in thin walls are earlier caused than in thicker ones, in spite of the inflexible binding of both of it. In addition to that the stronger wall was loaded the thinner one not.

ad 2) The biggest deformation was observed applying pure lime-mortar, the smallest using pure cement-mortar which is easily comprehensible becaause of the drawing- and shearing stress of cement-mortar.

ad 3) Constructing the model brick-walls we often acted contrary to the binding-rules in order to approach closer to reality. The joints of bricks were not removed according to rules and in some places cut across vertically two or three times. There were vértical gaping breaches. It can generally be said that brickworks which are strictly made according to binding-rules resist better against deformation. All kind of bindings with more sliders ("Laeufer") than bind-beams (girders) were more resistant against deformation.-

ad 4) If the length of subsidence remains the
ad 5) same the influence of the depth of subsidence cannot be fixed.

ad 6) Using the load there seldom arised breaches on the bricks. The model bricks have similar to the bricks of normal stress-firmness about 100 to 150 kg/cm^2. The brick-firmness has no particular influence as to the deformation.

ad 7) The mortar-strength has a decisive influence on deformations. Using first-class cement-mortar breaches only were apparent when strongly loaded. A loosening of the brick-works was not noticable as it is when lime-mortar is used.

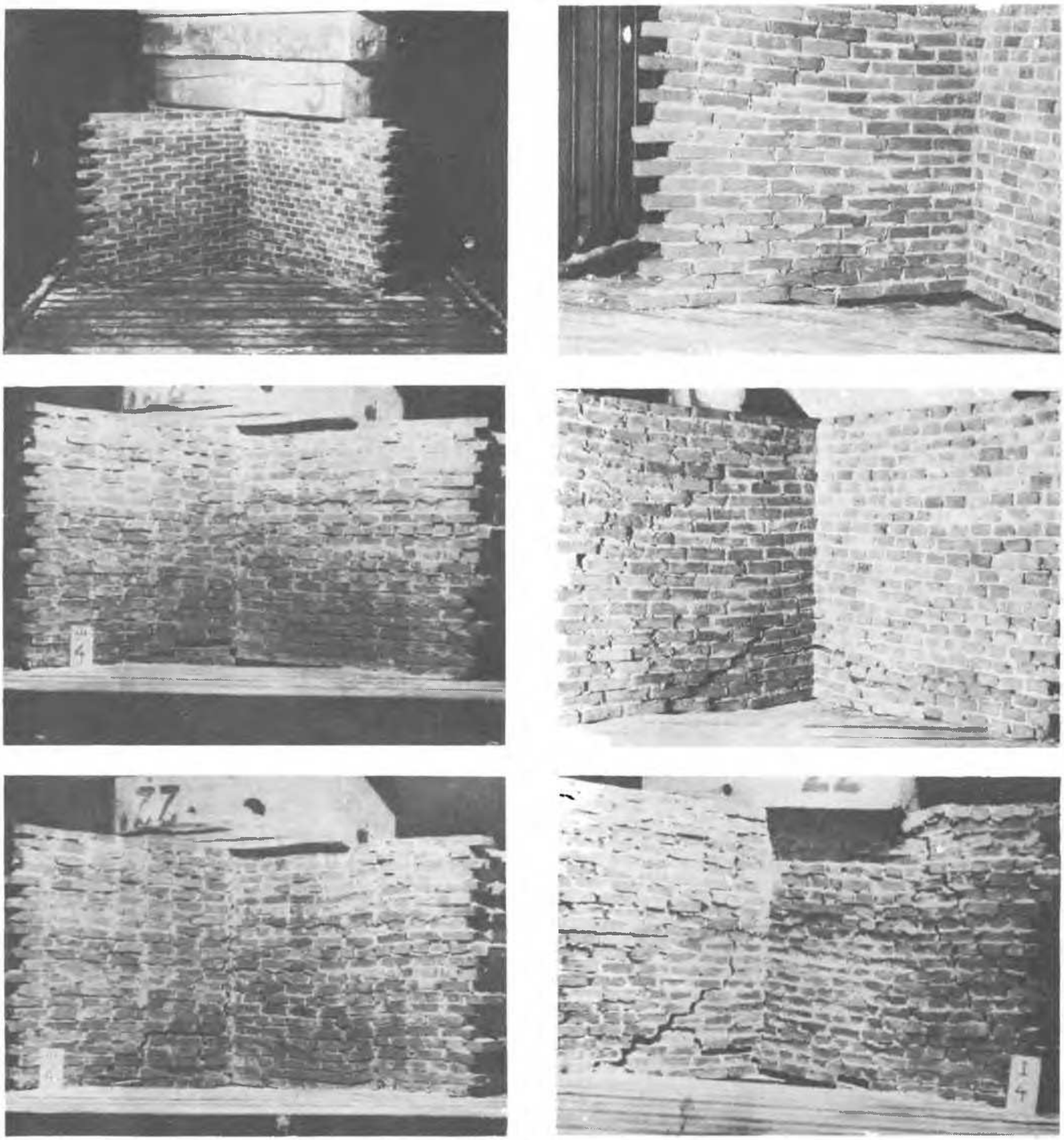


FIG. 1

ad 8) Concerning demolitions the stress- and shear firmness of mortar has its importance. With first-class standard-bricks (100 kg/ cm^2) the strength has no influence.

ad 9) We cannot conclude to a clear reciprocal influence.

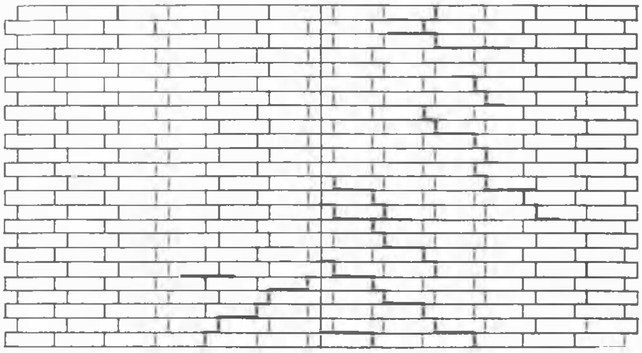
ad 10) Although the first and the lower breaches correspond with the length of subsidence the deformation afterwards is so arbitrary and casual and depends on other kinds of factors (strength of mortar, binding of bricks, etc.) that it is not possible to give an exact picture of function of the subsidence and deformation of brick-works.

A general lawfulness which is characteristic to all kinds of loading and deformation can be concluded as following:

a) the strength of bricks is greater than that of mortar. The brick-works come to a break in the mortar in form of steps (graduated).

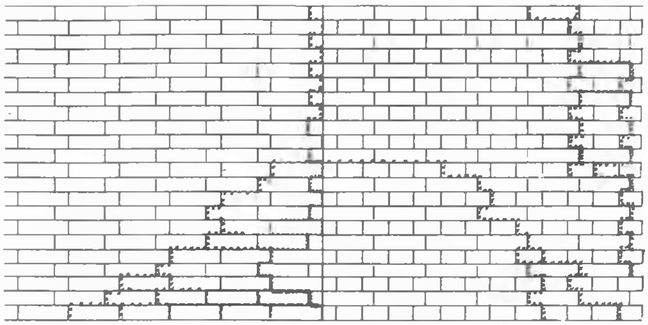
b) the breaches which arise above the movable tires (between the stable ones) don't indicate a general vault-effect (Gewölbewirkung)

c) the breaches follow the lines of mortar-



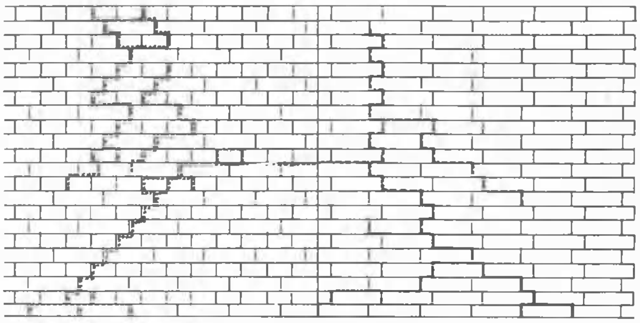
Load 3 kg/cm^2

FIG. 2



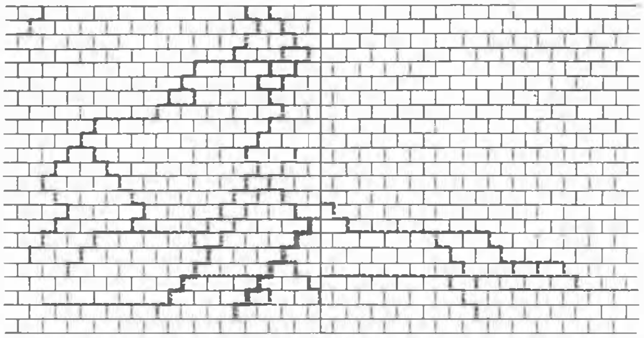
Load 8 kg/cm^2

FIG. 6



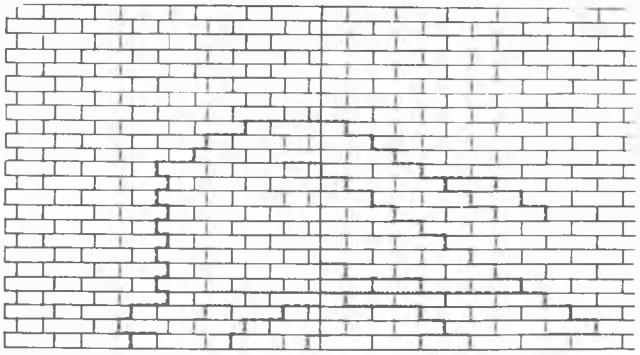
Load 9 kg/cm^2

FIG. 3



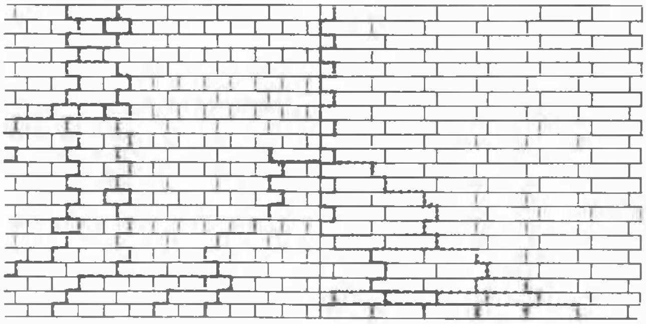
Load 10 kg/cm^2

FIG. 7



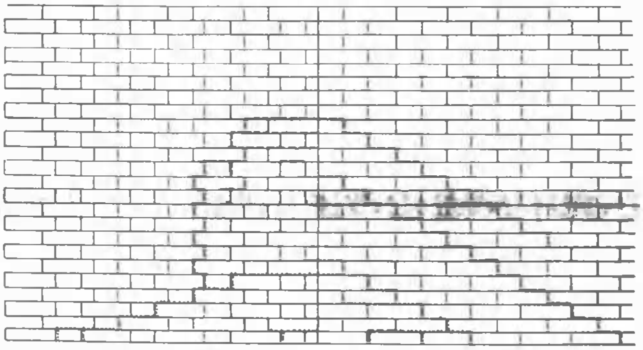
Load 5 kg/cm^2

FIG. 4



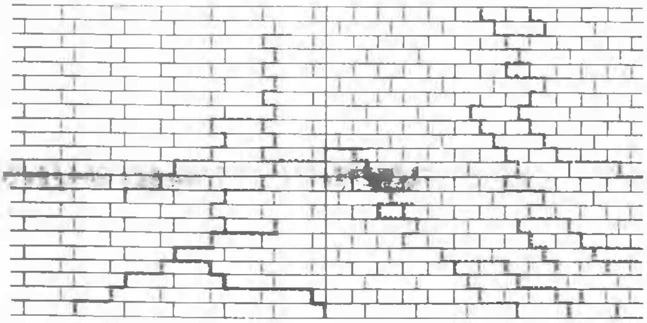
Load 9 kg/cm^2

FIG. 8



Load 4 kg/cm^2

FIG. 5



Load 10 kg/cm^2

FIG. 9

joints; they nearly always are in form of steps (graduated); the brick is seldom cut through.

d) there is no question of regular angles of the breahces. The angle of breaches is solely due to the junction of bricks.

e) traversing vertical breaches (also in zig-zag-lines) point to horizontal dislodging in different places.

f) parallel step-lines cause a loosening of brick-junction (not monolitical as with beton-beams). It would be wrong to speak of the effect of beams and to take under consideration the height of brick-works respectively the momentum of inertia (Traegheitsmoment) of the wall-transversal fracture.

g) Above the space of subsidence there are again and again horizontal breaches to be seen which means exhaution of the tensil strength of mortar (Erschoepfung der Zugfestigkeit des Moertels).

h) Beside of breaches which have the tendency of vault-breaches there are sometimes breaches of entirely opposite direction. This can be explained by the fact that there has been a horizontal- and vertical shifting which caused the loosening of the whole system.

i) Depending on local condition of strength of the mortar there result wedge-like substances. The course of breaches can not be explained by the course of the main tension-trajectories (Hauptspannungstrajektorien).

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A PROBLEM OF FOUNDATION ON LOAMY SOIL IN SUBTROPICAL COUNTRIES

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In this article a special question of foundation on loamy soil will be dealt with, common to all countries (subtropical) where there are separate rain period and a rainless season in course of a year. During the rain period, loamy earth is more and more soaked, while during the rainless period it is dried out to a water content of a few percent only. This change of humidity in the earth is associated with a change of its volume and has a remarkable influence on foundations. The author of this article has had the opportunity of observing these influences on foundations in Palestine in the course of more than 20 years.

Like in other countries there are other foundation problems in Palestine, as for instance the general settling of buildings, although this is not a major problem here. Only a few observations have been made so far in this respect, and this is not the problem to be dealt with in this article. Our question is generally described above, and its significance is the periodical yearly rise and settling of the upper layers of the earth according to the change of its water content, causing cracks in walls of buildings when the earth expands or shrinks. It may be observed that more cracks are caused through expansion than through shrinkage.

As the problem of foundations on loamy earth in countries as represented in this article is strongly influenced by the special features of the subtropical climate, let us start with these.

Diagram (1) shows the quantities of rain during a period of 10 years and the distribution of rain per month. x) It can be seen that the rain season in Palestine lasts only about four months, with a small rainfall during the months preceding and following this period. The other months are not only practically rainless, but the evaporation is relatively higher than in countries with moderate climates. Evaporation varies considerably in different parts of Palestine.

There is a double influence of rainwater on the water-content of the soil. First, the surface of the earth is wetted directly. Lower layers of the earth are subsequently soaked when the rainwater penetrates. Secondly, there is an indirect influence on the water content of the earth through the changing level of the ground water, i.e. the "water-table". Diagrams 2 and 3 show a typical course of the water-table during the same period of years as in diagram 1. They were drawn from observations made on wells in the Haifa Bay area in Palestine. The depth of the water-table was 3-4 metres. One curve gives the ground water level in sandy soil and the other in loamy earth. The relation between the water-table and rainfall is obvious. Specially the ascending branch of the curves is strongly influenced by the rainfall figures, while its descending part is less so.

A periodicity of one year can be stated, and another periodicity can be seen during a number of years. Consequently the water content in the layers above the water-table changes according to the rising or falling ground water.

Foundations are influenced by the change of volume in the loamy earth. Therefore the relation between water content and volume will be shown.

Diagram (4) gives the change of volume of clay as a function of its water content. The diagram is derived from another one by Bourry 1). The linear change is approximately one third of the cubical change i.e. about 7% maximum. With the addition of sand to the clay this percentage decreases. It can be stated that the curve is not a straight line and that the minimum of volume is already reached with a water content of 12%.

The shrinkage of loamy earth during the dry period (summer and autumn) can be observed in the form of cracks in the upper layers of the soil. According to the composition of earth these cracks are smaller or larger and at

x) Taken from records of observations near Haifa.