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LEVEL CONTROL IN BUILDINGS BY MEANS OF ADJUSTABLE PILING

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The subject matter of this paper is still being experimented upon --- but due to the favorable results already obtained, it is submitted because of the importance advantages that may be obtained by the use of this system.

Since the fundamental problem which is considered herein is a result due mainly to the peculiar conditions of the sub-soil in Mexico City which is highly compressible it is very important to describe the class of soil its behavior and its constitution so that the necessity for use of the proposed system may be understood.

On the other hand as the type of soil mentioned has already been described at great length by Engineer José A. Cuevas in "Proceedings of the International Conference on Soil Mechanics and Foundation Engineering, June 22, to 26, 1936, Volume 1 Page 294, Volume 3 Page 233", and since said proceeding can be easily referred to, the description will not be repeated herein and only general ideas on the behavior of this kind of soil will be included in this paper.

The sub-soil of Mexico City consists in most of its area of the following layers:

a) A highly compressible volcanic clay layer having a depth of about 32 meters (105 ft.);
b) A thin layer of sand about 1-½ meters deep, (5 ft.);
c) Another clay layer similar to the above with a depth of about 20 meters (65 feet);
d) Another sand layer about 4 meters thick (13 ft.) and finally
e) Still another volcanic clay layer as compressible as the upper ones which has a depth which for practical purposes may be considered indefinite.

The general characteristics of this type of soil are the following:

The void ratio between 200% to 400%. Its water content varies from 150% to 400%.

A soil sample having a water content of 350%, when allowed to dry in the air in the shade reduces its volume to practically 1/8 of the original volume, as can be seen from the foregoing data and it is therefore easy to understand the conditions observed in the city of Mexico, which is subsiding all over its whole area including unloaded sections such as parks and gardens which also subside and this settlement varies between 10 and 20 centimeters per year. This settlement is not uniform but is affected very probably by the thickness of the fill which also varies in different zones in the City and it decreases in the neighbourhood of the nearby mountains. Two factors influence particularly the above mentioned settlement; the excessive pumping of water from the sub-soil and the consolidation of the various layers due to construction of buildings, as well as the soil's own weight.

PILING FOUNDATIONS.

Most buildings which have been constructed on piles in Mexico City are bearing on the first layer of sand located approximately 32 meters (105 ft.) below the ground surface. The shrinking and consolidation of the various layers of soil that are located down to the 32 meters (105 ft.) depth causes the piles to apparently come out of the surface, since their length is constant and -- they cannot shrink or be compressed proportionally to the shrinking that the same layer is being subject to. The sand phenomenon can be observed in pipes used in wells which apparently come out of the surface at a ratio proportional to the time elapsed and to their length. As a result, buildings which are supported exclusively on piles apparently rise with respect to other buildings and even when their levels are compared with those on the surface of gardens and sidewalks around them, even though such areas do not have to support loads of any importance. This relative movement of buildings erected on piles with respect to other buildings and with respect to gardens and sidewalks is from 35 to 40 millimeters (1-3/8" to 1-5/8"), per year as can be seen from the graphs showing apparent rise of the Guardiola Building in the City of Mexico in which the relative rise of the four corners is shown comparing it with levels on the Alameda Garden located approximately 300 meters (1000 ft.) away from the building.

This case is merely an example and many others can be mentioned, particularly in any one of the buildings supported exclusively on piles, such as the ones shown on photographs 1, 2 and 3, which is the Monumento to Independence, the platform of which was rebuilt for third time in 1942, and which at present shows a difference of elevation of about 50 centimeters with respect to the roadway around the monument. Photographs 4, 5 and 6 show a building on Atoyac Street which has been erected three years ago, in which it can be seen that the sidewalk is now about 15 centimeters (6") below its original level. This difference in levels correspond approximately to the figures for general subsidence given above.

Due to the great compressibility of the ground, to its expansion when the load is removed as well as to the deformation of the deep layers underlaying sand layers which support the piles, the system implying the use of piles has the following disadvantages:

1) The apparent rise of the building due to the continuous settlement of the sub-soil of the City of Mexico. This rise causes severe stresses in the building proper and in the adjacent buildings which are unfavorable for all of them. Sidewalks and access stairways have to be frequently repaired, sewer, water supply pipes, telephone and electric connections to the building are easily broken and have to be repaired. Besides the buildings themselves remain in conditions of unfavorable stability specially when the upper part of the pile is made of timber, since in such a case there is no perfect bond between the pile and the foundation.

2) The sand layer 32 meters (105 ft.) deep that is used to transmit the load from the piles is subject to uneven settlement, since it is underlain by a clay layer about 20 meters (65 ft.) in depth; this clay layer due to its own structure and due to the loads that are transmitted to it from the sand layer above, is unevenly consolidated by the pressure bulbs acting on it, and therefore this sand layer is subject to slight deformations that will cause craks and slanting of the buildings even merely on the erection of new heavy buildings nearby the one under consideration. Several of the structures erected on piles in Mexico City, show settlements in their central area when they cover a large load of ground and they also slant when heavy buildings are

PHOT. 1

PHOT. 2

PHOT. 3

PHOT. 4

PHOT. 5

PHOT. 6

located near them later on. The deformation of the sand layer 32 meters (105 ft.) below the ground surface to which the piles transmit their load, causes also the uncontrollable distribution of loads among the various piles, being increased in some of them and decreased in others.

3) The method used for construction when piles are used, is the following:

A layer of about two meters (6 ft.) is excavated until ground water is found, reaching also the depth to which old foundations of lighter and older buildings are found; this first step in excavating gives the builder a level surface from which driving of the piles can be carried on with ease; piles used for most buildings are timber sections, it being necessary to use 3 to 4 sections to make up a pile; between each one of the sections it is customary to use a bolt or a joint capable of transmitting a load of approximately one ton in tension. To bring the pile heads to the proper depth a "follower" is used, the follower is another timber section which is removed when the sections which make up the pile have reached the desired depth. Once the pile have been driven the second step in excavating is carried on so as to reach the pile heads and to allow sufficient volume under the sidewalk level for basement of the building resting on the piles. When removing the weight of the material which is taken out in the second step in excavation, the upper layers of the subsoil expand, this expansion tends to pull out the piles slightly. As the upper layers are subject to a greater expansion that the lower ones, the sections that make up each pile tend to come apart, resulting in a slight separation between the various sections of the piles; this separation varies with the different piles. Later on when the building is erected on the piles its loads will be supported initially by those piles in which joints permitted the least amount of separation between their sections, this causes unfavorable conditions both to the foundation and to the structure of the building, since some of the piles will be overloaded.

4) Due to the common practice in building foundations on pile heads, it is practically impossible to make any later adjustments or to have any control on the levels of the buildings and besides that, by using the methods which are common at present, there is an absolute lack of knowledge about the loads that are bearing on the piles at any time during the life of the building, these loads are actually changing as the supporting layer becomes deformed.

FOUNDATION BY MEANS OF ADJUSTABLE PILING.

So as to correct some of the above mentioned defects inherent in present pile foundations, a new method envolving piles which are provided on their tops with an easily adjustable mechanism, is now being tested. Said mechanism is easily adjustable above the foundation slab or above the girders or cantilevers of the foundation proper; this mechanism makes it possible to control the load that is bearing on each one of the piles and to correct the differential settlements; it also makes it possible to allow the building to descend with the ground so as to subside through the same depth that the soil has shrunk. This system can be used on a timber pile, on a concrete pile or on any other type of pile, independently of the material which may have been used in it.

The adjustable piling system can be used in two ways: one of them permits the pile to pierce through the slab and girders of the foundation by means of screws capable to support a cross tie which rests on the pile (fig. 1).

The other system allows the pile to pierce through the foundation slab only and the loads are transmitted on the pile top by foundation girders or cantilevers without piercing them. In this paper only the first system will be described, since it is believed that it will be more easily applied then the second.

The process to be followed so as to control the level of building by means of the first system is shown on figures 1 through 8, which appear at the end of this paper. Figures 1 to 7 show one of the vantilevers which make up the foundation /3/ (numbers shown between slanting lined correspond to the ones showing details in the various figures), and pile /14/ which penetrate to a predetermined level within the cantilever /3/; on top of the pile head are placed several gasket rings /1 and 2/ having the shape shown in figure 8, these gasket rings are bonded together merely with cement mortar. The pile and the gasket rings pierce through the cantilever completely until their upper part is cleared out of the upper level of the cantilever. On both sides of said pile two or more screws /6/ are embedded in the concrete by ordinary gaskets /9/ which serve as anchors in their lower end. These screws support a bridge /10/ or cross-tie through which it is possible to transmit the load of the building to the pile; thus as can be easily seen in the various figures the building is actually hung on these cross-ties which bear on the pile heads.

As can be seen in figures 1 through 7 the pile goes through the cantilevers without having any bond with it, in other works, the pile is losely fitted within the cantilever, so that the pile may slide within the hollow space left in the cantilever without friction.

In the case of deep foundations, the upper part of the pile going through the cantilever, requires the use of a tight fitting ring /13/ to prevent the ground water from flowing into the building.

Figure 1 shows the foundation resting on the pile and on the ground.

In figure 2, it can be observed how the ground has already shrunk, therefore, the foundation is resting wholly on the pile; therefore the building is actually hanging from the screws which are transmitting their load to the cross-tie bearing on the head or upper part of the pile.

Figure 3 shows how by means of nuts /7/ it has been possible to lower slowly the whole foundation until it is again bearing on the ground which has shrunk and had therefore subsided. As the foundation is lowered as can be seen in figure 3, the pile is coming into the building. Having in kind the relative movement of the soil with respect to the pile which is of the magnitude of from 30 to 40 millimeters (1-3/8" to 1-5/8") per year as shown in the graphs corresponding to the Guardiola building, it is possible to determine the length of the gasket rings which is proportional to the life which is assumed for the building after said period of time there are still other methods which are more laborious but still simple, which can be used to lower the building, such as the slicing of the pile heads to adjust is to the shape of the gasket rings.

Figures 1 and 2 assume that the pile has already penetrated into the building a vertical distance corresponding to 1½ heights of the

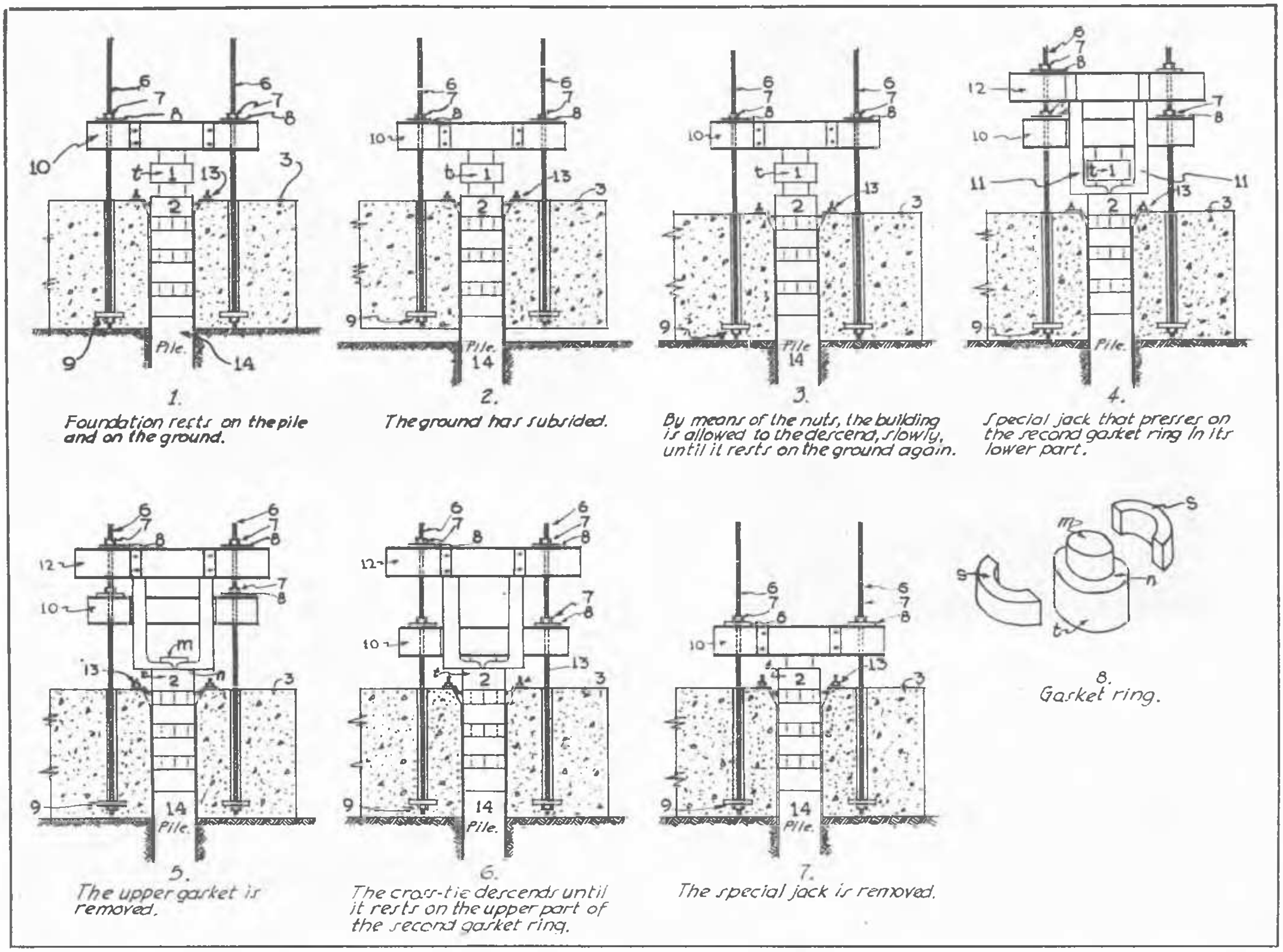


FIG. 1,2,3,4,5,6,7,8

gasket ring.

Figure 3 which shows the foundation already lowered until bearing again on the ground shows that the pile has already penetrated into the building a height corresponding to two gasket rings.

To remove the gasket rings they are built in such a way that they are capable of being in two levels. Figure 8 shows one of such gasket rings having both levels designated as "m" and "n".

The load may be applied on any one of both levels and by the use of two collar rings placed on the same gasket ring a cylindrical shape can be obtained, which may be used to improve the operation of the tight fitting joint when it may be necesaary. As these gasket rings penetrate in the building, the collar rings are removed so as to leave free the space designated "n" which is used as the supporting area for the prongs /11/ of a special jack which is anchored on the upper part of the same screws that are used to transmit the load of the building to the pile.

Figure 4 shows the special jack /12/ already in place, and this jack has 4 areas or prongs /11/ which make up a circular base to bear on the intermediate or "n" level of the gasket rings. Once the jack is in place, the nuts which can be screwed along the same anchor screws are tightened until it has been possible to apply a slightly larger load than the one which the cross-tie /10/ was applying, thus loosening the cross-tie. The nuts which were used to press on the cross-tie can then be loosened so as to make it easier for the upper part of the gasket ring bearing on the pile to come out.

Figure 5 shows the upper part of the gasket ring which was bearing on the pile already removed and in contact with the cross-tie.

Figure 6 shows how after removing the last of the gasket rings necessary, the cross-tie is again lowered so as to bear on the upper level of the second gasket ring; once in place, it is tightened by means of the nuts until it is possible to give it a slightly larger pressure than the one which is being applied by the prongs of the special jack.

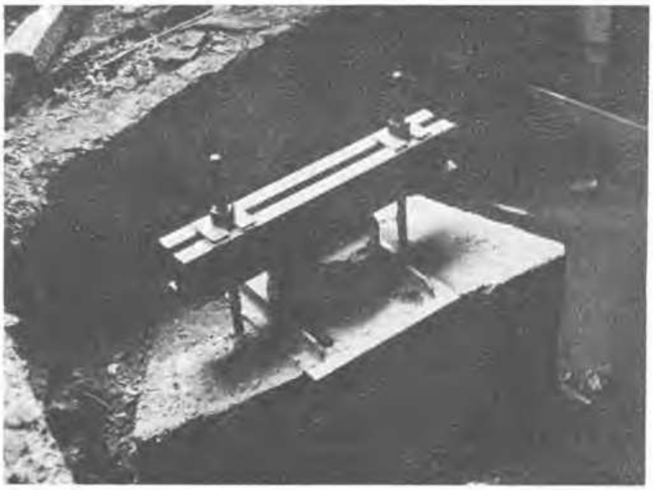
Every time that the special jack is used, it is possible, by means of a hydraulicly operated device, to determine the load that each one of the piles supports.

Another method is also being tried, which may give the load bearing on the pile as a function of the deformation observed in the screw since the screw is embedded in its lower part in the foundation, and is free in its outer length until it reaches the cross-tie.

When the cross- tie /10/ has already been able to compress the pile and thus to take all the load, the special jack /12/ is removed, and the whole system remains as shown in figure 7, in much similar conditions to the initial ones shown in figure 1.

As the approximate length of the pile is

PHOT. 7



PHOT. 8

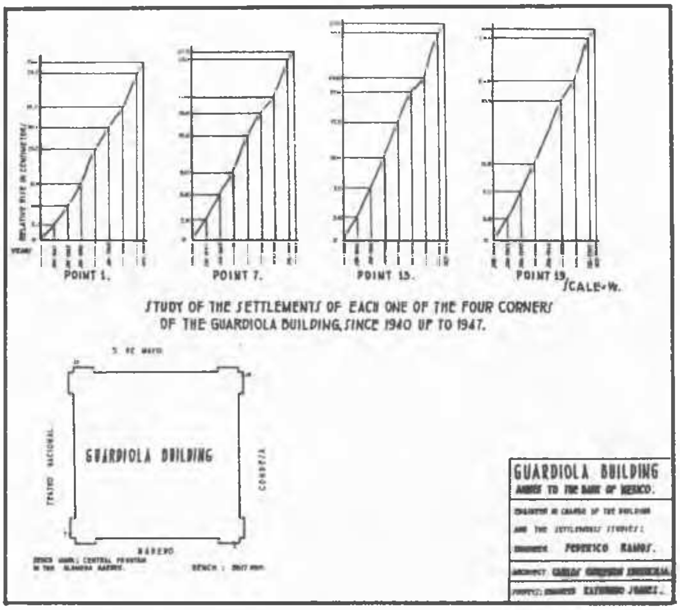


FIG. 9

about 32 meters (105 ft.), and as in the majority of cases timber piles are used, it is sufficient to apply with the cross-tie or with the special jack, a load of about two tons more than what was being applied with one or the other, so as to have an appreciable deformation in the pile, which will indicate that the cross-tie or the special jack is carrying the load. See photographs 7 and 8 of the adjustable piling.

It is believed that the advantages inherent in the foundations on piles with controllable levels are the following:

1) One or more piles can be adjusted to even up or to change their loads easily, and it will be possible to know the magnitude of the load and to keep it within specified limits.
2) It will be possible to obtain uniform levels throughout the building, it being possible to bring back to plumb a slanting building by means of simple and precise operations.
3) Since the ground is shrinking and therefore is subsiding with respect to the building, it will be possible to let the building subside without allowing it to come away from the ground surface, thus making it possible to maintain a predetermined pressure on the ground, so that piles may only have to support part of the building load, the rest being supported directly by the ground.
4) It will be possible to know the load transmitted by each one of the various colomns in the building.
5) It is possible to obtain periodically, the profile of the bearing layer in any direction wanted, thus being able to have a numerical history of the building's own deformation, and those caused by the influence of other buildings.

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