Movement of Small Houses Erected on an Expansive Clay Soil

Mouvement de maisons basses bâties sur un sol argileux expansif

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Summary

The paper describes an investigation of the movement of small houses erected on an expansive clay soil of the Central Texas area. A description of the soils and climatic conditions that have caused trouble in the Central Texas area is given and a record of the movements of the foundations of two houses—one house erected on ordinary spot footings and the second house on a "honeycomb" foundation. The "honeycombed" foundation is constructed by turning the structural clay tile in such a manner that the lateral expansion of the soil can enter the openings in the tile. It is well known from laboratory investigations that when expansive soils are permitted to expand a slight amount the swelling pressures are greatly reduced. The idea of the "honeycombed" foundation is to permit the lateral swelling of the soil hoping that it will reduce the pressures that are developed. Graphs showing the movement of the houses and contour of equal expansion are shown. Also, pressure cell readings have been made to determine both the lateral and horizontal pressures developed on these foundations.

The tentative conclusion reached is that these soils expand lifting the structures considerably due to the taking up of water. Also, there is an indication of considerable horizontal movement or wave action of the soil as shown by the contours of equal settlement.

Sommaire

Cette communication décrit des observations concernant les mouvements constatés dans les fondations de maisons construites sur un sol argileux expansif de la région centrale du Texas. Les caractéristiques des terrains et les conditions climatiques qui ont suscité des désordres dans la région du Texas sont données, ainsi que les résultats des nivellements des fondations de deux maisons – l'une d'elles bâtie sur des socles isolés et l'autre sur une base «alvéolaire». La base «alvéolaire» est formée en plaçant la brique creuse de construction de manière à permettre l'expansion latérale du sol dans les trous. On sait par des expériences de laboratoire que la pression de gonflement diminue largement quand on permet aux sols expansifs une petite augmentation de volume. La base alvéolaire a justement pour but de permettre le gonflement latéral du sol afin de réduire les pressions verticales qui s'y développent. Des courbes indiquant le mouvement des édifices et les courbes d'égale expansion sont tracées. On a employé des cellules manométriques pour obtenir les pressions latérales et horizontales développées dans ces fondations.

La conclusion donnée à titre de suggestion est que ces sols expansifs soulèvent les structures qui sont considérablement affectées par l'absorption d'eau. Les courbes d'égal soulèvement montrent un mouvement horizontal important conjugué avec les mouvements verticaux et donnent l'impression que les maisons sont soumises à l'action de vagues.

Fig. 1 House No. 1. Honeycombed Foundation
Maison No 1. Fondation alvéolaire

Expansion of and contraction of bentonitic or colloidal clays in the southwestern part of the United States has caused tremendous damage to structures where foundations have been placed on these materials. These soils are not limited to this area but are found in many sections of the world where expansive soils combined with seasons of high rainfall intensity which are followed by seasons with little or no rainfall, develop conditions which result in foundation troubles. During the process of expansion enormous pressures are developed if the clays are confiend. Swelling pressures exceeding 30,000 pounds

Fig. 2 House No. 5. Spot Footings
Maison No 5. Semelles isolées

per square foot have been measured in our laboratory, however, the usual swelling pressures of these clays range from 2,000 to 12,000 pounds per square foot. It has also been observed in the laboratory that if the clays are permitted to expand a small amount when taking up moisture the swelling pressures are greatly relieved.

The clays are badly fissured and the fissures have slickened-sided surfaces. Liquid limit ranges from 37 to 104 with an average of approximately 60 and the plasticity index ranges from 22 to 81 with an average above 40. Because of the fissures encountered in the clay it is very difficult to make unconfined compression tests that will not be influenced by the fissures. However, the soils are, as a rule, very stiff to hard and will support heavy loads although the general practice is not to put high loads on the soils because the possibility of soften-

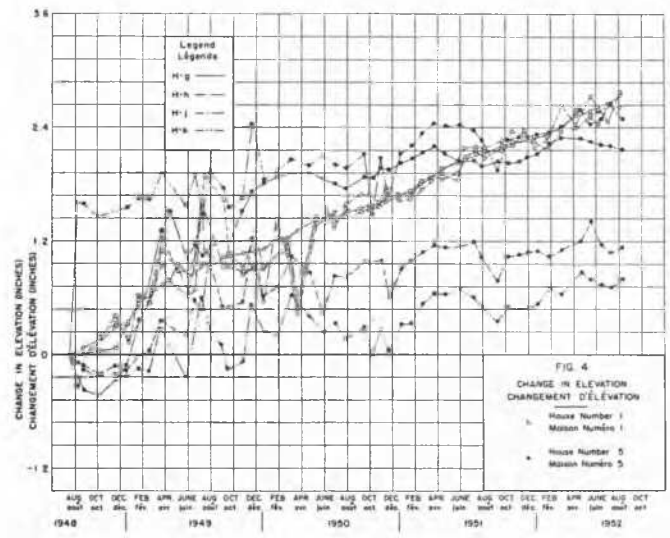

Fig. 4 Change in Elevation
Variation d'élévations

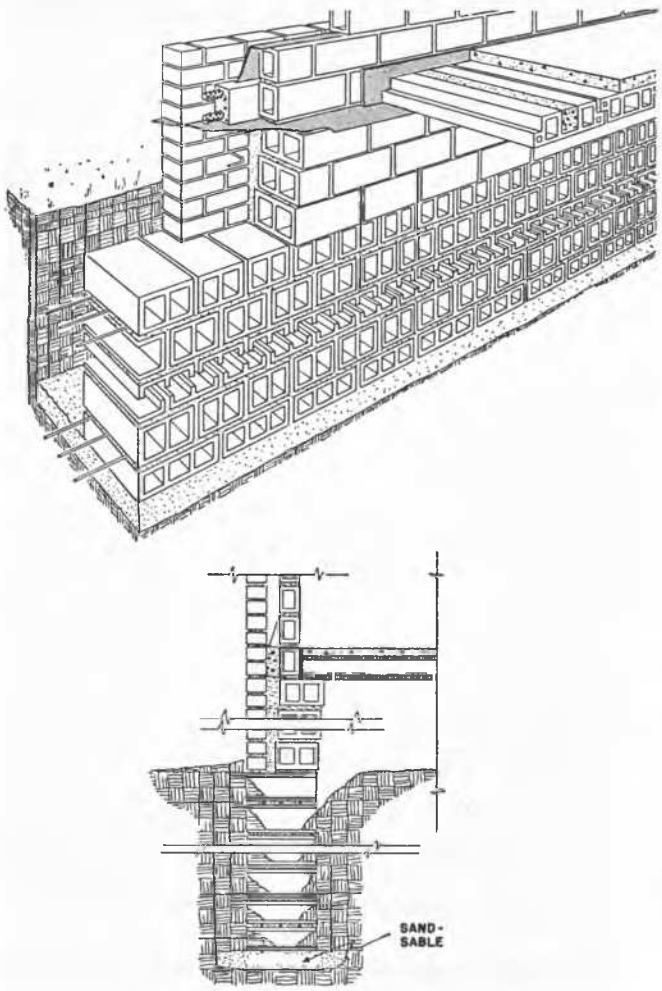

Fig. 3 Perspective and Section of the Honeycombed Foundation
Vue en perspective et coupe de la fondation alvéolaire

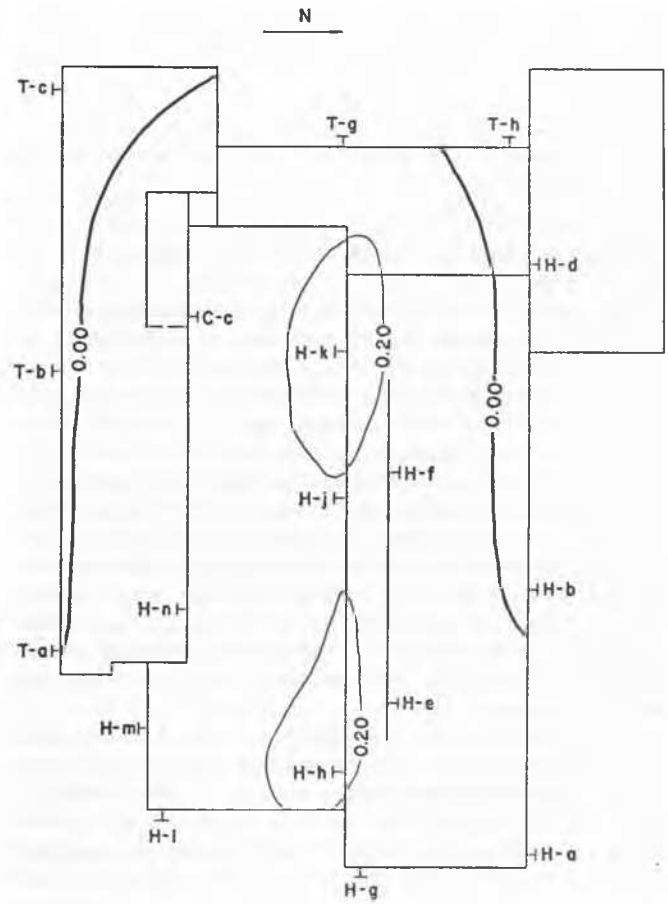

Fig. 5 House No. 1. Elevation Contours October 25, 1948. Contour Interval: 0.20 in.
Maison No 1. Cote d'élévation 25 octobre 1948. Intervalles des contours: 0.20 pieds

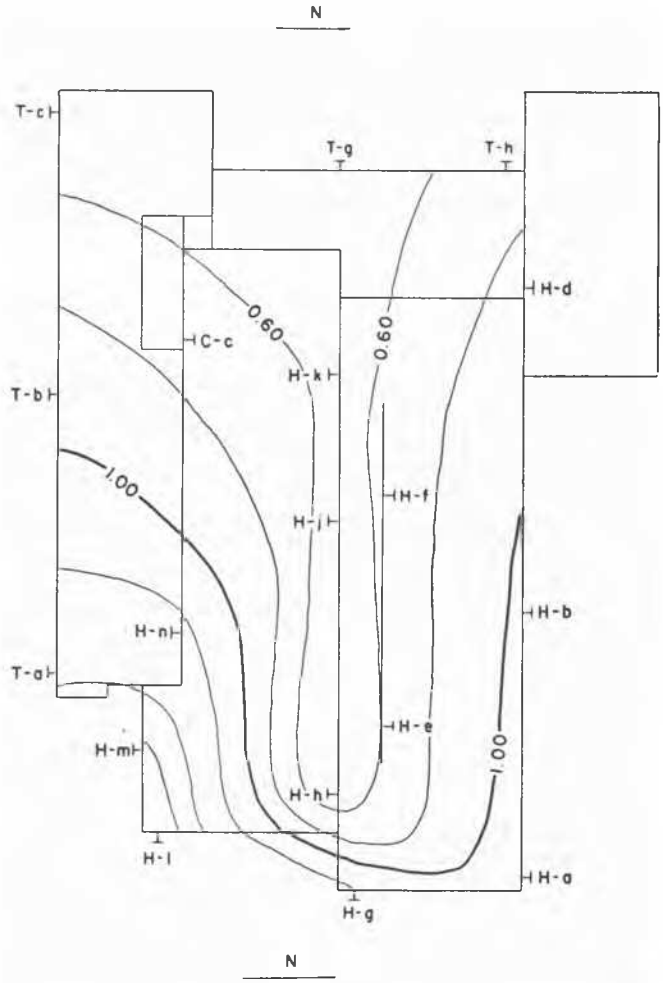

Fig. 6 House No. 1. April 11, 1950. Contour Interval: 0.20 in.
Maison No 1. Cote d'élévation 11 avril 1950. Intervalles des contours: 0.20 pieds

ing when moisture is available. This is true particularly in the fissured areas.

Because of the troubles encountered, many attempts have been made to produce a satisfactory footing on these soils. In this connection the Acme Brick Company of Fort Worth, Texas, has erected six houses in Austin, Texas, five of which are made of ceramic materials and the sixth a frame house. These houses were designed and constructed by the Acme Brick Company for certain research conducted by The University of Texas' Bureau of Engineering Research. The houses are all the same size and shape and contain approximately 2,000 square feet of floor space. Foundation investigations included vertical movements of the houses, measurements of vertical and horizontal pressures and moisture determinations of the soils. Fig. 1 hows House No. 1 which was constructed of ceramic material and Fig. 2 shows House No. 5 which was the frame structure.

As stated earlier it has been found that when these expansive clays are permitted to expand a small amount when taking up moisture the swelling pressures are greatly relieved. This idea was used in the design of the foundations for the ceramic houses. The so-called "honeycombed" foundation was developed in which clay tile were turned so that open ends were exposed to the soil in the trenches. When the soil expanded laterally it could push into these openings and thus relieve the swelling pressure. Fig. 3 shows the "honeycombed" foundation and indicates how the soil might push into the openings of the tile. The foundations were carried from depths of $3\frac{1}{2}$ to 9 feet below the surface on the various houses. The frame house (House No. 5) was placed on concrete piers on spot footings which were carried $3\frac{1}{2}$ feet below the surface of the ground.

Vertical movements of these houses are determined by means of precise levels and a water level device referenced to benchmarks which were carried down to rock. Fig. 4 shows the vertical movements of a series of points near the central section of each house. The location of these points are shown on the contours of equal settlement which are given in Fig. 5 through 10. The lines with the solid dots are for House No. 5 and it will be noted that point *H-j*, which is almost the center of the residence, went up over one inch almost immediately after readings were started, and continues at a very high elevation. Other points on this residence showed some initial settlement although they have continued to rise after the initial period, also it may be seen that there is considerable differential movement in this house. This resulted in floors being out of level, and doors and windows sticking. For several months, on House No. 5, almost every week the carpenters had to cut off the tops or bottoms of various doors in order to close them. The open circles represent the movements of House No. 1 which is the all-ceramic structure. All points on this house have continued to rise since its erection although in numerous cases there were rather violent movements of certain points. These movements appear to tie in with moisture changes al-

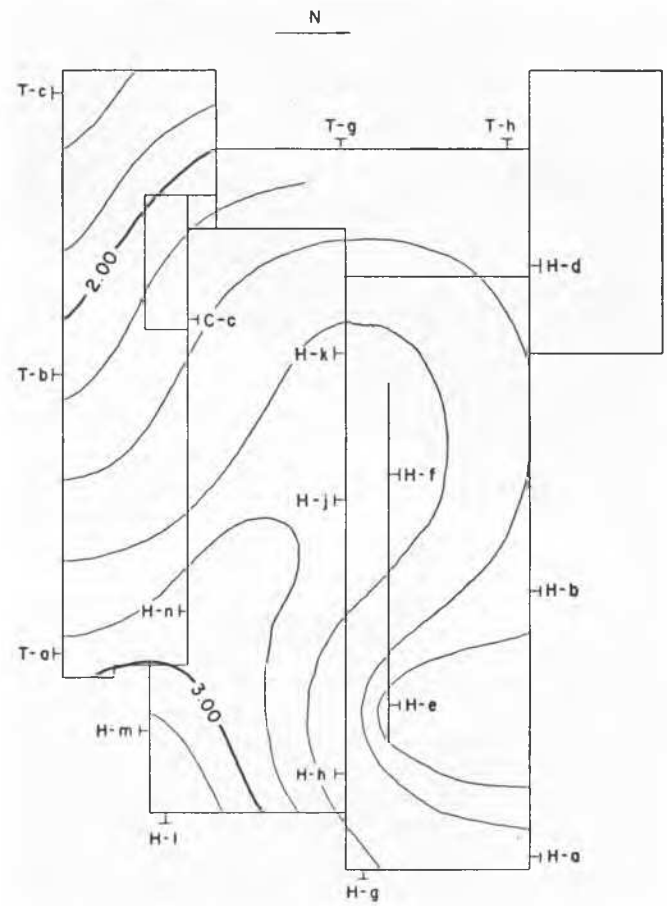

Fig. 7 House No. 1. Elevation Contours July 23, 1952. Contour Interval: 0.20 in.
Maison No 1. Cote d'élévation 23 juillet 1952. Intervalles des contours: 0.20 pieds

though there is some question because of conditions that will be explained under moisture determinations. As can be seen from these curves the houses have risen over 2½ inches since construction and the movement is still in an upward direction.

The contours of the equal settlements of these houses are of particular interest because they show the movements of the soil at various locations from time to time. Contour plots are made each month on each house, but space will permit the showing of only a few in this report. Fig. 5, 6 and 7 show the contours of ceramic House No. 1 from shortly after construction was started until recently. In October of 1948 the house showed two rather high points near the center of the structure and other points being somewhat lower. In April of 1950 this house showed a high point at the southeast corner, but a lower trench near the central section of the structure. In July of 1952 the high point was again at the southeast corner but a tendency for a ridge to form toward the central portion of the house. For the past several months the contours have been quite similar to those shown in Fig. 7 while the earlier contours indicated a possibility of a wave action in the soil. At the present time it appears that this has ceased or does not exist. Fig. 8, 9 and 10 show contours of House No. 5. Here in most cases the high point is near the center of the structure although in October of 1950 a high point existed near the southeast corner. The contours of House No. 5 do not indicate the wave action of the soil as clearly as the earlier contours of House No. 1.

Vertical and horizontal pressures are measured on the ceramic foundations by means of the U.S. Waterways Experiment Station pressure cells, commonly called the Vicksburg cells. These cells were placed underneath and along the sides of the "honeycombed" foundations. Fig. 11 shows the pressures that have developed in the soils at House No. 1. At the top of the figure are the lateral pressures that were measured at various depths along the sides of the foundation. These pressures have been rather slow in developing because of the fact that loose fill was placed in the trenches beside the foundation and most of the expansion of the soil has resulted in compaction of the loose fill, also in some cases undoubtedly the soil has pushed into the openings in the tile. Of particular interest is cell No. 15 along the north wall. This cell was placed in the center of a 3-foot square plate which would not permit the soil to enter the openings in the tile. It will be seen that immediately high pressures developed in this cell, and these high pressures have continued since the earlier readings, however, recently cell No. 9 which is attached directly to the tile has developed higher pressures than cell No. 15. The lower section of this curve shows the vertical pressures developed under the foundations of House No. 1. The vertical pressures under the south wall have been much higher than those under the north wall. The Natural ground slopes toward the south and all footings were carried to the same elevation, therefore the north footings of this house were carried considerable deeper than those on the south side. The footings on the north wall being approximately 6 feet below the natural grade while on the south the footings are 4 feet below the natural grade. It is probable that the north footings being deeper have reached less disturbed soil and therefore have not developed the higher

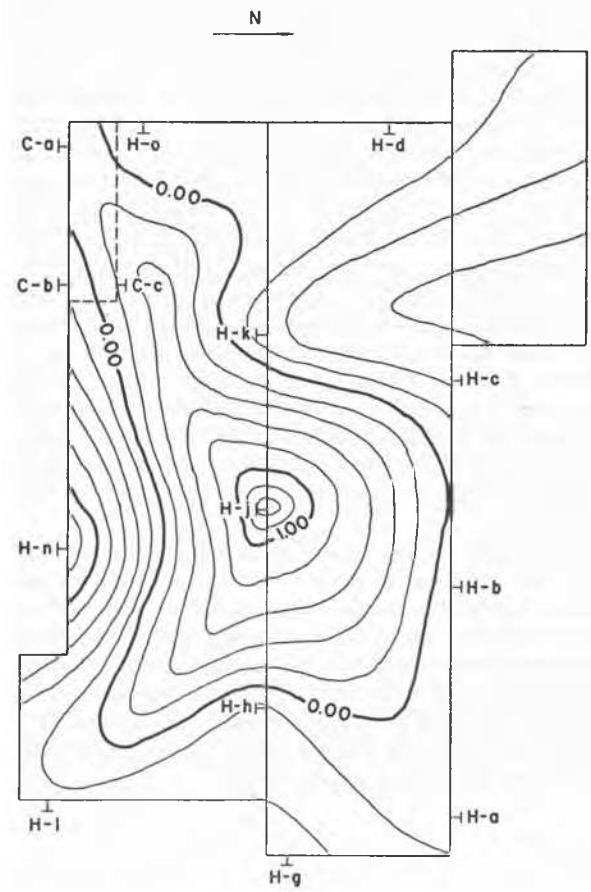

Fig. 8 House No. 5. Elevation Contours October 22, 1948. Contour Interval: 0.20 in.
Maison No 5. Cote d'élévation 22 octobre 1948. Intervalles des contours: 0,20 pieds

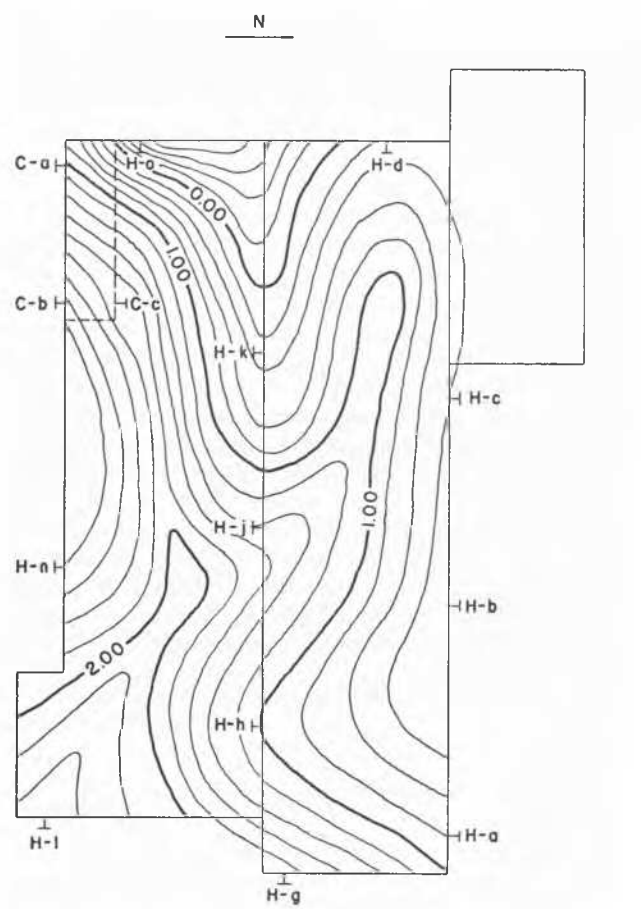

Fig. 9 House No. 5. Elevation Contours October 3, 1950. Contour Interval: 0.20 in.
Maison No 5. Cote d'élévation 3 octobre 1950. Intervalles des contours: 0,20 pieds

vertical pressures that are shown along the more shallow south footings. This difference does not show in the lateral pressures along the north and south wall. The lateral pressures, however, are developing from loose backfill and not from the natural soil as are the vertical pressures.

Attempts were made to measure moisture changes in the soils by means of various moisture blocks. Plaster of Paris, nylon and fiberglas blocks were installed under the foundations of all the houses. In no case have dependable moisture readings been obtained from any of the blocks, therefore, all our moisture determinations are made from borings. While earlier borings indicated considerable variation in the moisture content, after a few months all the soils were virtually saturated. Free water has risen in all the holes to within 2 to 3 feet of the surface in all the recent borings in spite of the fact that we have had one of the most severe droughts in history. Since the completion of the houses, considerable water has been available from the watering of the lawns and shrubs and apparently all the moisture the soil can take up is available. Unfortunately borings cannot be made near the central portion of the houses and we are unable to check the moisture in these areas.

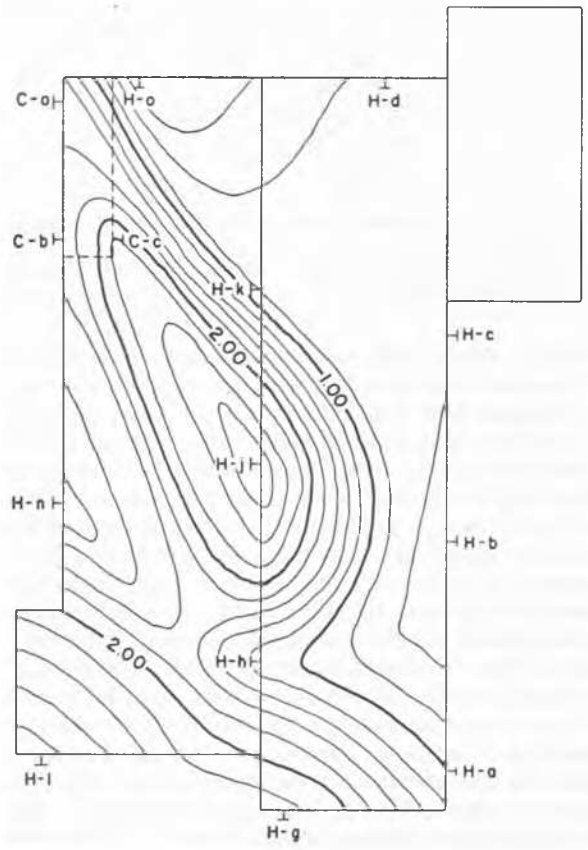

Fig. 10 House No. 5. Elevation Contour July 25, 1952. Contour Interval: 0.20 in.
Maison No 5. Cote d'élévation 25 juillet 1952. Intervalles des contours: 0,20 pieds

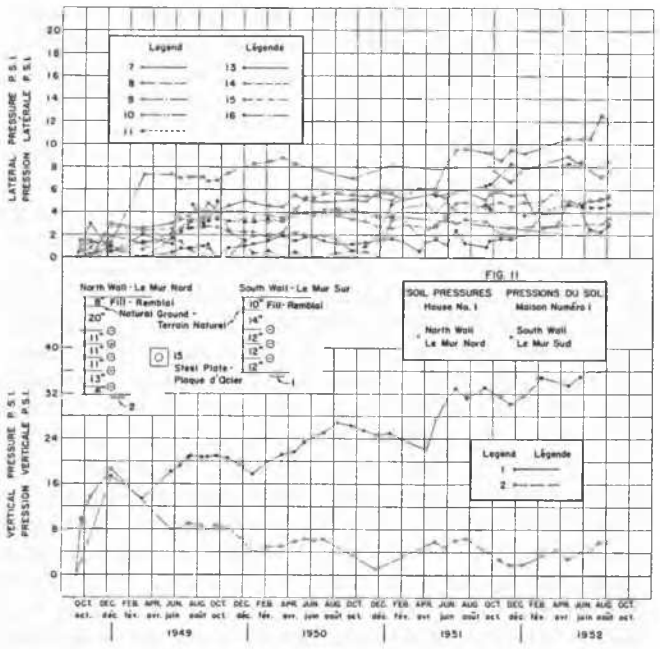

Fig. 11 Soil Pressures
Pression du sol

In spite of the large vertical movements and considerable differential movements of the ceramic houses in this project there has been very little cracking of the walls. In fact we wonder at the very small amount and small sizes of the cracks that have developed. This is undoubtedly due to construction features that were developed by Mr. *Demarest* of the Clay Products Association of the Southwest. He has attempted to build ceramic houses that were as flexible as possible so that when movements do develop, there will be little or no damage. He has attempted to build a house that, like a prize fighter, rolls with the punches, and this is one of the most promising solutions for the small residence. At the present time we are not in a position to say that the "honey-combed" foundation is the answer to the problem of small homes on expanding clays, in fact, we are not in a position to say that it is at all successful because we are unable to separate the excellent results that have been obtained. These may be caused by the "honeycombed" foundation or by the flexible type of construction and the writer is inclined to believe that the latter feature is more important than this type of foundation, however, future investigations may determine the answer to this question.

It is the intention of the Bureau of Engineering Research to carry on these readings for several years or at least until we go through a very wet season where abundant water will be available at all times to the soil, although present indications are that even though there was an excessively wet season it would make little difference in the results as apparently sufficient moisture has been available to expand the clay soil. The question is how long will this expansion continue and what will be the ultimate rise of the structure?