SUB-SECTION VI d

SPECIAL PROBLEMS IN FOUNDATION ENGINEERING

VI d 1

SMALL HOUSE FOUNDATION DESIGN

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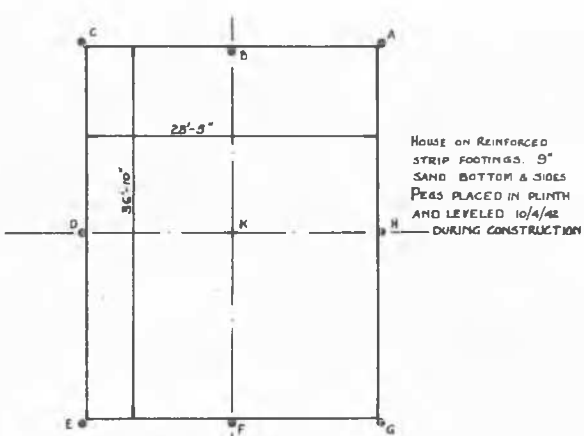
SUMMARY.

This paper deals with the design of the foundations of small buildings and houses. A theoretical approach combined with a programme of practical observation work is outlined and records of movements experienced in certain buildings are also given.

In South Africa we are faced with a high prevalence of unexplained cracking in buildings, particularly in small unframed brick structures. There are some areas where this cracking is very severe indeed and in many localities scarcely any buildings exist which have not shown cracks. These are mostly in the highveld of the Union where the line of saturation in the soil is generally fairly low. By far the worst conditions apply in areas of black turf associated with decomposition of the Upper Ecca Shales. A case of this nature is given in Fig. 1 and it will be observed that the physical properties indicate a soil high in clay fractions and with an excessive volume change with alterations of moisture content.

In the construction of buildings of this type there is generally little money available for foundation exploration and any solution which may be offered must of necessity be an inexpensive procedure. Certain bye-laws exist which are aimed at preventing cracking of this nature but it is generally true that many of these bye-laws have not provided the solution to the problem. The bye-laws are frequently restrictive and have often led to costly practice without overcoming the cracking: much confusion and frequent criticism has resulted.



FOUNDATION MOVEMENTS—STANDERTON

Peg No.	Recorded Movement cm		
	20/8/42	17/7/46	17/9/47
A	+0·06	+4·16	+4·27
B	−0·25	+4·86	+5·00
C	−0·91	+5·85	+5·48
D	−0·09	+4·38	+4·64
E	+0·15	+3·91	+3·98
F	+0·58	+3·53	+3·73
G	+0·52	+2·67	+2·97
H	+0·27	+3·25	+3·41
K	+0·28	+4·04	+4·27

PHYSICAL PROPERTIES

Sample No.	1	2	3	4
< 1·881 mm	100·0	100·0	100·0	100·0
< 0·417 "	99·6	99·4	99·2	99·8
< 0·246 "	97·8	97·8	99·0	98·2
< 0·147 "	94·7	94·0	98·0	95·0
< 0·089 "	92·7	90·0	96·8	91·4
< 0·050 "	80·8	72·8	86·8	82·8
< 0·005 "	39·0	29·6	48·8	37·2
< 0·002 "	28·8	22·8	41·6	32·8
Liq. Limit	56	55	66	75
Plas. "	21	21	24	22
P.I.	35	34	42	53
Lin. Shrink.	17	16	19	20
Shrink Lim.	11%			

FIG.1

The problem is of very great importance to the country as a whole. The new goldfields of the Orange Free State lie in one of these areas noted for severe foundation conditions and, as extensive developments are expected, it is essential that an answer be provided as soon as possible to meet the needs of this locality. Many experiments have been tried by various Building Authorities in the attempt to provide a remedy to this cracking. Structures have been built on a variety of foundations such as heavily reinforced concrete rafts, light footings directly on the surface, relatively deep footings, drained footings, etc., but no methods have yet been devised which really succeed in overcoming the cracking. A general observation of most of the cracked buildings inspected is that they appear to crack by the apparent downward movement of the corners of the structure.

It is thought that much of the cracking can be associated with volume changes in the subsoil due to changes in moisture content. The problem is much complicated by the fact that the line of soil saturation is relatively deep and it is not economically justified to carry the foundations below this line of saturation. Sufficient evidence however exists in the form of uncracked structures with foundations well above the line of saturation, to indicate that other solutions are possible. The whole question of movements of the line of saturation is considerably influenced by the nature of the site works: excavation for levelling, the interference with the natural condition of evaporation provided by the coverage of the building, trees in the immediate vicinity of the building and watering of gardens in the precints of the house, all add to the complications.

The approach adopted by the National Building Research Institute in finding a solution to the problem may be divided into four heads, namely:

A. Consideration of the structure;
B. Field Tests;
C. Theoretical Analysis on the principles of Soil Mechanics;
D. Practical fild tests;
The work which is in hand is as follows:

A. CONSIDERATION OF STRUCTURE.

Strength and deflection characteristics of various types permanent constructions are being examined and it has already been found for reinforced concrete footings with superimposed brick walls that these quantities are such as to render the beneficial effects of the reinforcing negligible. In this case a relatively strong but flexible footing is supporting a weak but rigid load and generally a plane of weakness is artificially introduced by the provision of a damp-proof course at their junction. Under these conditions the reinforced concrete foundation is still very far from its ultimate bending capacity when the supported wall is about to show its first signs of failure. It is very common practice to design elaborate reinforced footings without any consideration of the elastic properties of the composite construction.

Following on the above, an investigation to determine the tolerable degree of movements allowable in buildings, is being undertaken. The work involves computing and measuring the maximum deflections which can occur before the first cracking takes place and calculations are then made to determine the worst types of pressure distribution on the foundation which might be tolerated.

B. FIELD TESTS.

In the field, observations are proceeding on the settlements of approximately 15 small buildings erected on a variety of soils. Levels are being very carefully observed and as far as possible these are being tied into fixed bench marks on rock so that records of the absolute movements of structures can also be obtained. In the course of this work it has been disconcerting to note that some structures are showing rises instead of settlements and typical examples of two cases of this nature are given in Figures 1 and 2.

Observations are being made of the moisture changes in the subsoil and the rise and fall of the line of saturation is being recorded. Efforts are being made to relate this to the coverage provided by the building and to variations due to seasonal changes. An attempt will be made to correlate the movements of the structure with the observed changes in the line of saturation.

It is proposed that pressures cells be built into the footings of a number of test buildings and observations be made of the exact pressure distribution which actually occurs on the foundations of the buildings. This work will ultimately be connected to the theoretical maximum pressure distribution which can be withstood by the structure, when the strength and deflection of its composite elements are taken into account.
A special pressure cell employing the variation with tension of the frequency of vibration of a steel wire has been designed for this work.

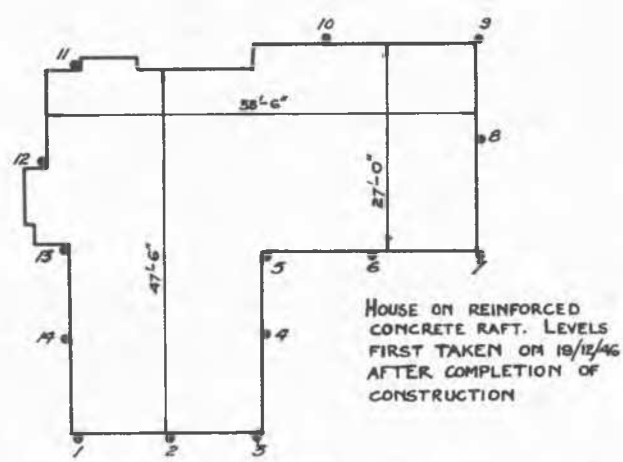
An extensive series of bearing tests are also being undertaken with a view to determining the effects of depth of founding and also the results of artificial inundation of the surface. Normal sampling of soils for laboratory examination is also being undertaken at the same time.

C. THEORETICAL ANALYSIS OF SOIL CONDITIONS.

An analysis based on the Boussinesq equations for stress distribution is being made for the subsoils of the buildings under consideration. In the laboratory the determination of the normal physical properties of the soils is proceeding and an attempt is also being made to determine the swelling pressures of each of the soils concerned. It is expected that these swelling pressures will generally be much larger than the pressures induced by the superimposed loads of the structure and an attempt will be made to formulate a theory of design based upon the swelling pressure.

D. PRACTICAL APPROACH.

Certain experimental buildings on pile and beam foundations are being constructed in order to investigate in a practical fashion the effects of depth of founding. An attempt will be made to introduce a cheap method of cast-in-situ piling and the foundation beams resting on these piles will be kept clear of the surface soil. Certain buildings with reinforced brick walls are also being erected and the question of flexible buildings such as frame structures, wooden constructions, etc., are also being looked into. An attempt is being made to determine the effects of aprons around the outside of the building, the effects of flooding the foundation site



FOUNDATION MOVEMENTS — PRETORIA

PEG No.	MOVEMENT TO 7/10/47
1	+0·21 cm
2	+0·51 "
3	+0·76 "
4	+0·56 "
5	+0·36 "
6	+0·01 "
7	−0·02 "
8	−0·02 "
9	−0·13 "
10	−0·04 "
11	−0·29 "
12	−0·26 "
13	−0·10 "
14	+0·02 "

PHYSICAL PROPERTIES

SAMPLE No.	1	2
< 1·981 mm	98·8	97·6
< 0·417 "	89·3	86·3
< 0·246 "	70·6	73·6
< 0·147 "	58·5	65·7
< 0·050 "	57·0	48·1
< 0·005 "	27·0	33·9
< 0·002 "	24·2	30·0
Liquid. Lmt.	44%	47
Plastic "	15	15
Plast. Index	29	33
Shrink. Lmt.	14	16

FIG.2

before construction, and other measures for maintaining high moisture content in the soil immediately around the building.

It will be observed that examination of the cracked buildings indicates an apparent downward movement of the corners of the structures. This would be the normal type of settlement to be expected if the shearing condition in the subsoil is the major contributing factor, and with small structures of the type considered, this condition would probably normally apply. The upward movements apparent from the levelling observations have however given the whole problem a new aspect and if, due to interference with the evaporation condition, a general rise in the line of saturation can be expected immediately under a newly erected building, it is most probable in the case of an expansive clay subsoil that the structure will also exhibit a dome shaped rise. Cracking in these cases appears to have resulted from an apparent downward movement of the corners although the absolute movements may in general be upwards.

It will be our object to try and seperate these two effects which show such apparently similar evidence. At the same time an attempt will be made to formulate simple rules for quick application by the practical builder. The investigation is necessarily a long term study and much of the work listed above has only just been started due to the recent establishment of the National Building Research Institute in South Africa. The Authors are particularly anxious to contact others who are faced with the same problems and exchange ideas and experience with those who have conducted similar work in this field.

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VI d 2

SOME SOIL RUPTURE AND SETTLEMENT PROBLEMS IN THE CONSTRUCTION OF A LOCK, AT DUFFEL

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INTRODUCTION.

The double lock of Duffel has been founded in the Boom Clay, which is a tertiary formation having in this region a thickness of more than 50 meters. Figure 1 gives a location plan of the lock, with its approach-walls. A cross-section through the lock and an other one through the approach-walls are shown in figures 2 and 3.

During the period of construction, abnormal movements occurred in some parts of the lock. For instance, the approach-walls indicated in figure 1 by shaded areas, and especially the walls 5L and 6L, have undergone important movements. At the joint between 5L and 6L, the following horizontal movements have been measured in March 1943:

at level	wall section	
	5L	6L
+ 7,00	21,3 cm	16,5 cm
- 0,20	2 cm	2 cm

These movements have reference to the vertical axis passing through the lower edge of the footing of the wall, which is located at the foundation-level - 4,00. It should be noted that against these walls the fill was completely placed.

Furthermore the walls and the floor of the locks have undergone very large vertical movements. After a general levelling of the top of the walls and of the floor of the locks, between the cross-sections $\alpha\alpha$ and $\beta\beta$ (large lock) and $\alpha'\alpha'$ and $\beta'\beta'$ (small lock), the following average vertical movements were found (see figure 1 and table I).

TABLE I.

longitudinal sections	settlement cm	rising cm
large lock.		
left wall	2	-
section AB	-	3,6
" CD	-	4,6
" EF	-	5,0
" GH	-	1,0
right wall	2,4	-
small lock.		
left wall	2,3	-
section IJ	-	0
" KL	-	1,0
" MN	-	1,6
right wall	2,0	-

It may also be interesting to notice that some longitudinal cracks were observed in the floor of the lock; this floor consists of reinforced concrete beams which were shored up between the both walls of the lock. The intervals between these beams are protected with independent concrete slabs, which had undergone an important upward movement in their median parts. Some of them show cracks. At the ends of the lock where the floor and the walls are constructed as one rigid body, no signs of movement were found. Cracks were also seen in the reinforced concrete beams of the apron on the downstream side.

After these difficulties, a thorough examination of the soil was ordered. A complete field investigation was carried out: a number of deep sounding tests and borings were made in the positions shown in figure 1. In the borings undisturbed samples were taken, and transported to the laboratory for further examination. Three piezometric tubes were placed in the backfill against the walls 5L and 6L, in order to permit the observation of the changes in the ground-water level.

The profile of the soil, as revealed by the borings, can be approximated as follows:

- upper level of the fill : + 7,00
- natural ground surface and water level : + 3,50
- from + 7,00 to + 3,50 : sandy fill