The Design of Shallow Foundations for Low Cost Houses in a non-Saturated Clay at Basrah, Iraq

Les fondations en surface de maisons à bon marché dans une argile non saturée, à Basrah, Iraq

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Summary

Existing houses in Basrah had shallow foundations at depths varying between 2 ft. 6 in. and 3 ft. 6 in. below ground level, with bearing pressures varying between 0·25 and 2 tons/sq.ft. in a brown clay with a liquid limit of 45-55 per cent and a plastic limit of 18-27 per cent.

Little damage was apparent as a result of soil shrinkage or swelling, despite the fact that very substantial seasonal soil moisture content changes were known to take place to a depth of at least 10 ft. below ground level.

Originally it was proposed to found the new houses at a depth of 3 ft. in conformity with local practice and in an attempt to limit seasonal movements.

Soil moisture suction and shrinkage tests, however, showed that the swelling and shrinkage of undisturbed soil was of a small order, although re-moulding or compaction greatly increased it. In undisturbed soil, therefore, it was decided to place the foundations at only 12 in. below ground level.

It is concluded that the low volume changes of the undisturbed soil result from a soil structure which is destroyed by re-moulding.

Sommaire

Les maisons déjà existantes à Basra ont des fondations de surface à des profondeurs variant de 2 ft. 6 in. à 3 ft. 6 in. sous le niveau du sol, avec des charges variant de 0·25 à 2 tons/sq.ft. dans une argile brune à limite de liquidité de 45 à 55 % et la limite de plasticité de 18 à 27 %.

Les dommages dus au retrait ou au gonflement du sol étaient faibles malgré de très notables variations saisonnières du degré de l'humidité du sol (le phénomène étant connu) à une profondeur d'au moins 10 ft. en-dessous du niveau du sol.

Il avait été d'abord proposé de creuser les fondations des maisons neuves à une profondeur de 3 ft. conformément à l'usage local en vue de limiter les mouvements saisonniers.

Les essais de succion et de retrait montrèrent, en tout état de cause, que le gonflement et le retrait d'un sol non-remanié étaient faibles, alors que le remaniement ou le compactage les augmentaient considérablement. Ainsi dans un sol non-remanié la décision fut prise de creuser les fondations seulement à 12 in. sous le niveau du sol.

D'où la conclusion suivante : les faibles changements de volume d'un sol non-remanié résultent du fait que la structure du sol n'a pas été détruite par le remaniement.

I. Introduction

In 1957 the Author was concerned with the construction of approximately 2,000 low cost terraced houses on a site on the western outskirts of Basrah, Iraq. A soil survey was carried out by means of shallow hand auger borings and laboratory tests were made upon undisturbed and re-moulded samples of soil taken from the borings, with a view to determining the maximum bearing pressure for shallow house foundations and the depth at which the foundations should be placed.

II. Geology and Climate of the Area

The site was located on the Mesopotamian Plain to the west of Basrah and within two or three miles of the Shatt-al-Arab River. The soils within the depths likely to be affected by engineering work all belong to the Recent or Holocene group of deposits. LEES and FALCON [1] have concluded that the whole Mesopotamian Plain has in Recent times been subject to a general subsidence which has from time to time enabled the sea to inundate large areas. Thus fresh and brackish water deposits occur, intercalated with deposits of marine origin.

The subsidence, both local and general, has been episodic in character, and in the intervals the depressions have tended to fill up with sediments, resulting in a slowing down or cessation of sedimentation until the next subsidence enabled further deposition to take place. The pauses or breaks in sedimentation have resulted in the formation of successive layers of sediment which make up the present alluvial plain. Owing to the shape of the depressions each layer will have a more or less irregular lenticular form. Furthermore, each layer of sediment may have been subjected to partial desiccation if, following complete infilling of a depression, an interval elapsed before subsidence enabled further sedimentation to take place. This last process could have been operative during the whole of the Recent period, since it is probable that the climate of the area has not changed appreciably since the end of the Ice Age.

In winter the weather is relatively cool with a mean minimum temperature of 4° C. and a mean maximum of 16° C. Summer temperatures rise to a mean minimum of 25° C. and a mean maximum of 44° C. The annual rainfall is 4-6 in. with 3-5 rain days a month from November to April.

III. Site Investigation

A large number of 6 in. diameter boreholes were sunk by hand auger methods to depths of up to 15 ft. in April, 1957. These boreholes revealed that the soil over the whole site consisted of a light brown or grey silty clay with a liquid limit varying between 45 and 55 per cent and a plastic limit varying between 18 and 27 per cent. The soil natural moisture content was found to be variable and no true water table was established at depths of up to 15 ft. below ground level at the time the investigation was carried out.

The site was liable to winter flooding but an earth bund wall was constructed as part of the contract, which was intended to ensure that such flooding could not recur, and flood waters which annually approached from the west of Basrah would be diverted by means of canals into the Shatt-al-Arab.

The foundations of many other houses being constructed in other parts of Basrah were examined. In addition, the foundations of a number of existing houses were exposed, examined and measured and it was found that the depth of foundations varied betweem 2 ft. 6 in. and 3 ft. 6 in. below ground level, and the bearing pressures varied between 0·25 and 2 tons/sq.ft. Little damage to existing houses was apparent as a result of soil shrinkage or swelling, despite the fact that very substantial seasonal soil moisture changes were known to take place to a depth of at least 10 ft. below ground level. There were, however, some significant exceptions, and it was possible to establish in the case of three houses which had been constructed about ten years before the investigation and which showed signs of extensive cracking, probably as a result of soil shrinkage, that they had been founded on recompacted soil. In all other respects their foundation construction did not differ from the general pattern.

Before commencing construction, it was necessary to carry out some re-levelling of the site involving shallow cut and fill. Drainage and service trenches were also being opened at various points on the site and these were left exposed for considerable periods. As the exposed soil dried it was noted that the recompacted soil appeared to shrink to a much greater extent than the undisturbed soil even though their initial moisture contents had been similar.

IV. Laboratory Tests

The unconfined compressive strength of a number of undisturbed samples of soil taken from the boreholes was determined and, in addition, the shear strength of a number of samples was determined in triaxial compression using a lateral pressure equivalent to the over burden pressure. The shear strength of the soil at its natural moisture content was found to vary between 700 lb/sq.ft. and 4,500 lb/sq.ft., and a reasonable correlation between shear strength and moisture content was established. The value of 700 lb/sq.ft. was found to be appropriate to soil at a shallow depth when saturated.

Soil suction and shrinkage tests were carried out on very carefully hand cut undisturbed specimens of soil using a suction plate technique. Further suction and shrinkage tests were made on samples of the soil remoulded and compacted to various densities. The results of a suction test on a sample of undisturbed soil and another suction test on the same sample remoulded and compacted are shown in Fig. 1. The results of a shrinkage test on an undisturbed and three shrinkage tests on remoulded soil are shown in Fig. 2. It will be seen that the effect of remoulding was apparently to increase the pF 0 moisture content and also to increase the shrinkage of the soil after wetting to pF 0. Furthermore, the shrinkage was increased by increasing the initial compacted density. For the sake of clarity only a few of the test results are shown, but the remainder gave similar indications.

V. Discussion

It was decided that the minimum practical width of foundation which could be excavated on the site was 11 in. The maximum load per foot run for the types of houses being constructed was such that the maximum bearing pressure exerted beneath a foundation of this width was 0·65 tons/sq.ft. In view of the measured shear strength of the soil in a saturated condition, it became obvious that shear failure could not result from this order of bearing pressure and it was decided that the minimum practicable width of 11 in. would be adopted as a standard throughout the site.

It was realised that significant seasonal variations in soil moisture content at shallow depths could be expected with probably significant volume changes because of the climatic extremes of the area. Initially, therefore, it seemed desirable

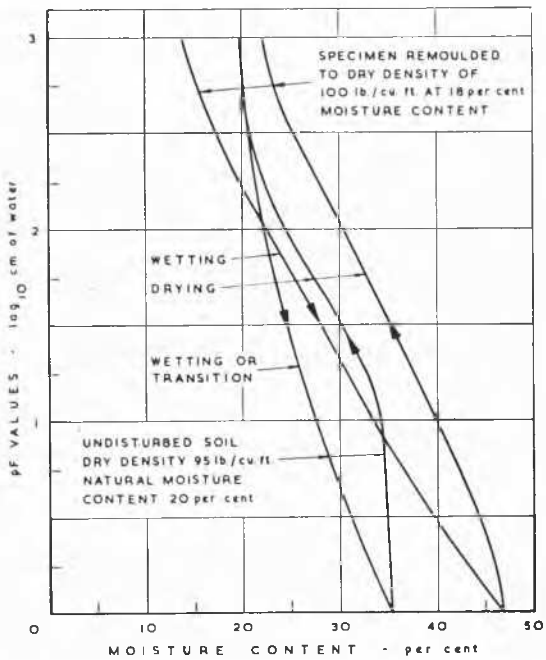

Fig. 1 Soil suction — moisture content relationships for a sample of silty clay.

Relation entre la succion et la teneur en eau d'un échantillon d'argile limoneuse.

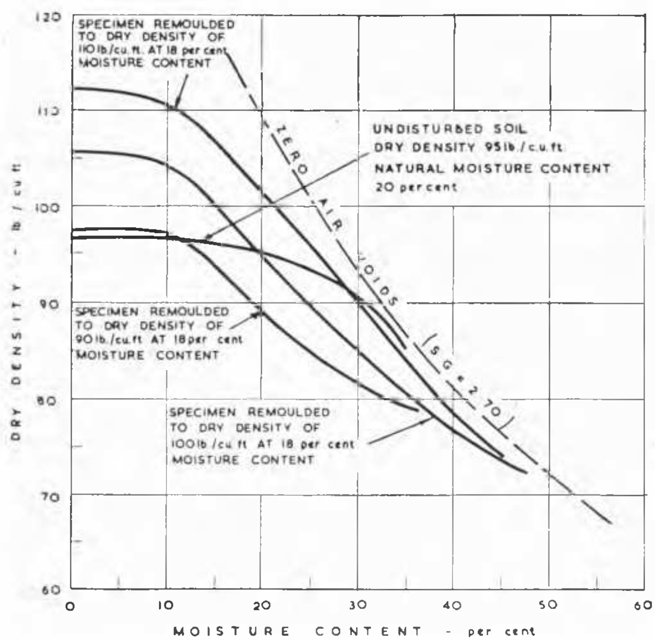

Fig. 2 Shrinkage curves for a sample of silty clay (after wetting to pF zero).

Courbes de retrait d'un échantillon d'argile limoneuse (humecté jusqu'à pF zéro).

to place the foundations at a substantial depth below ground level in order to limit any seasonal movement. Examination of the laboratory test results indicated that the drying shrinkage of the undisturbed soil was very significantly less than that of remoulded soil, probably because the undisturbed soil possessed a weak structure which was destroyed by remoulding. This was to some extent confirmed by the observations mentioned above of the relative behaviour of the undisturbed and remoulded soil during the initial cut and fill operations on the site, and also of the behaviour of existing houses in the Basrah area. The greatest possibility of damage to houses would occur when the foundations were placed in soil which had been exposed to rain and had swelled before the building load was applied. Such soil would subsequently dry and shrink with a consequent movement of the foundations. The test results indicated that the swelling of compacted soil would be much greater than that of undisturbed soil and it was therefore decided that the house foundations should not be placed in remoulded or compacted soil, but there seemed no advantage in placing them in undisturbed soil at depths below that which were required to avoid damage due to rain run-off from the roofs or local channelling during heavy rain. The foundations of the houses throughout the site were therefore placed at a minimum depth of 12 in. below ground level with the over-riding consideration that they should penetrate at least 6 in. into undisturbed soil where the houses were located in areas of fill. This decision appears to have been justified in practice, since the houses are now completed and a substantial number of them have survived two years without any evidence of damage resulting from soil shrinkage or swelling.

Examination of the typical shrinkage curves given in Fig. 2 shows that air readily enters the undisturbed soil when its moisture content is reduced slightly below the pF 0 value. This is typical of soils which possess a cemented structure and it is quite possible that this condition is applicable to substantial areas of the Mesopotamian Plain. It may well explain why large seasonal moisture content changes in the soil sub-grade beneath impervious paved areas have been reported [2] as a result of soil temperature changes, since soil moisture movements in the vapour phase can only occur in a non-saturated soil.

It was intended to continue the investigation to examine in more detail the type of soil structure which may be similar in some respects to that reported by Jennings and Knight [3] in South Africa. Unfortunately, political events in 1958 prevented site and laboratory work but it is hoped that further investigations may be undertaken in the future.

VI. Acknowledgements

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