every two days until it had reached equilibrium. The time to equilibrium was approximately four weeks.

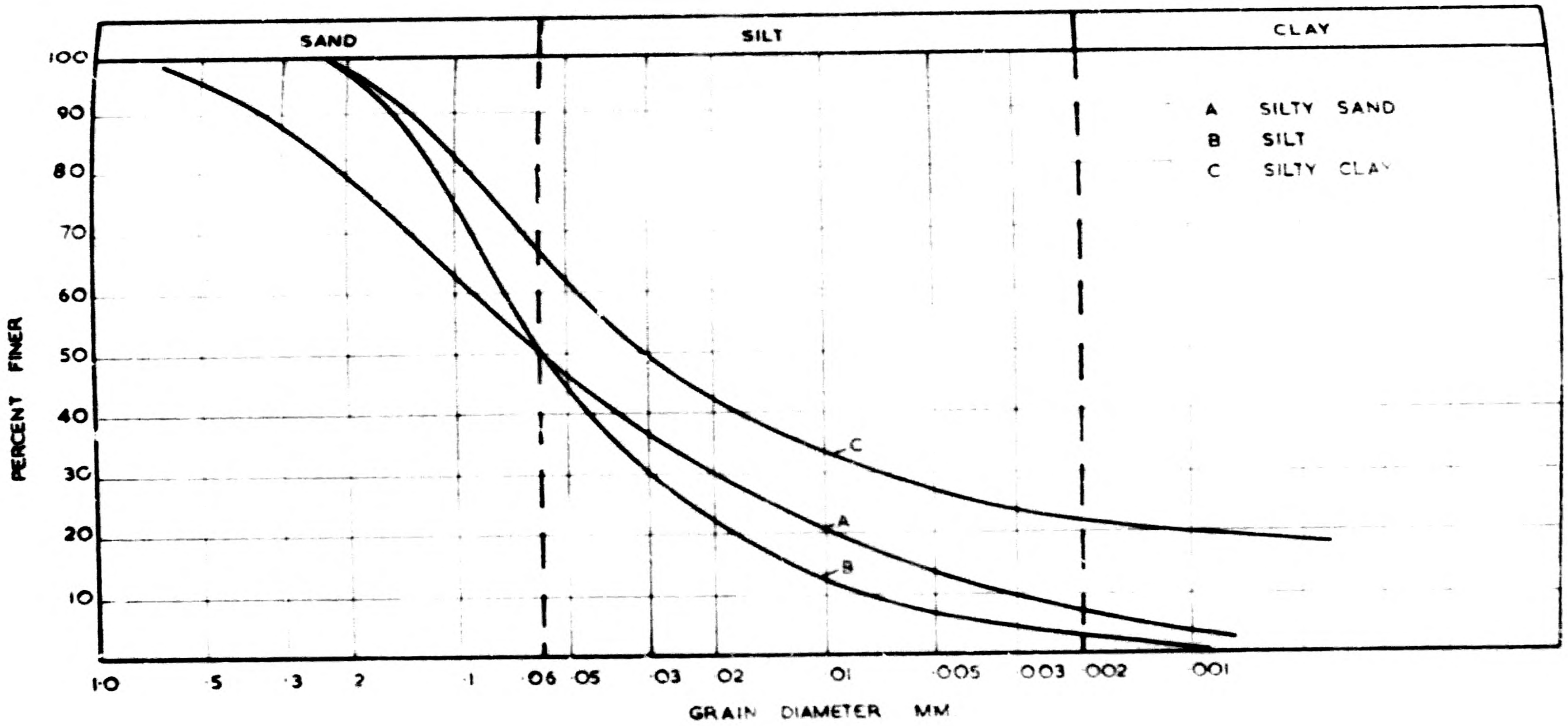
After the sample had reached equilibrium its ends were trimmed flat and its overall dimensions were carefully measured. The specimen was then weighed and placed in the high pressure all round compression apparatus between air dry end plates. The specimen was subjected to an all round consolidation test with the increments of load applied at 24 hour intervals. The maximum applied load was 32.4 tons/squ.ft. At the end of the test the specimen was removed, weighed, oven dried and weighed again.

Four specimens were tested as above. The initial pressure deficiencies of the four samples were pF 3, pF 3.5, pF 4 and pF 4.5. In fig. 6.9 is shown e: log p curves for three of the four samples together with the virgin consolidation curve obtained by performing an all round consolidation test on a sample initially at the liquid limit. No e: log p curve was obtained for the sample at pF 4.0 as the test was spoilt by a leak in the rubber membrane. Also shown on fig. 6.9 is the e: pF curve for the material.

6.8 Consolidometer tests on silty sand at various initial degrees of saturation

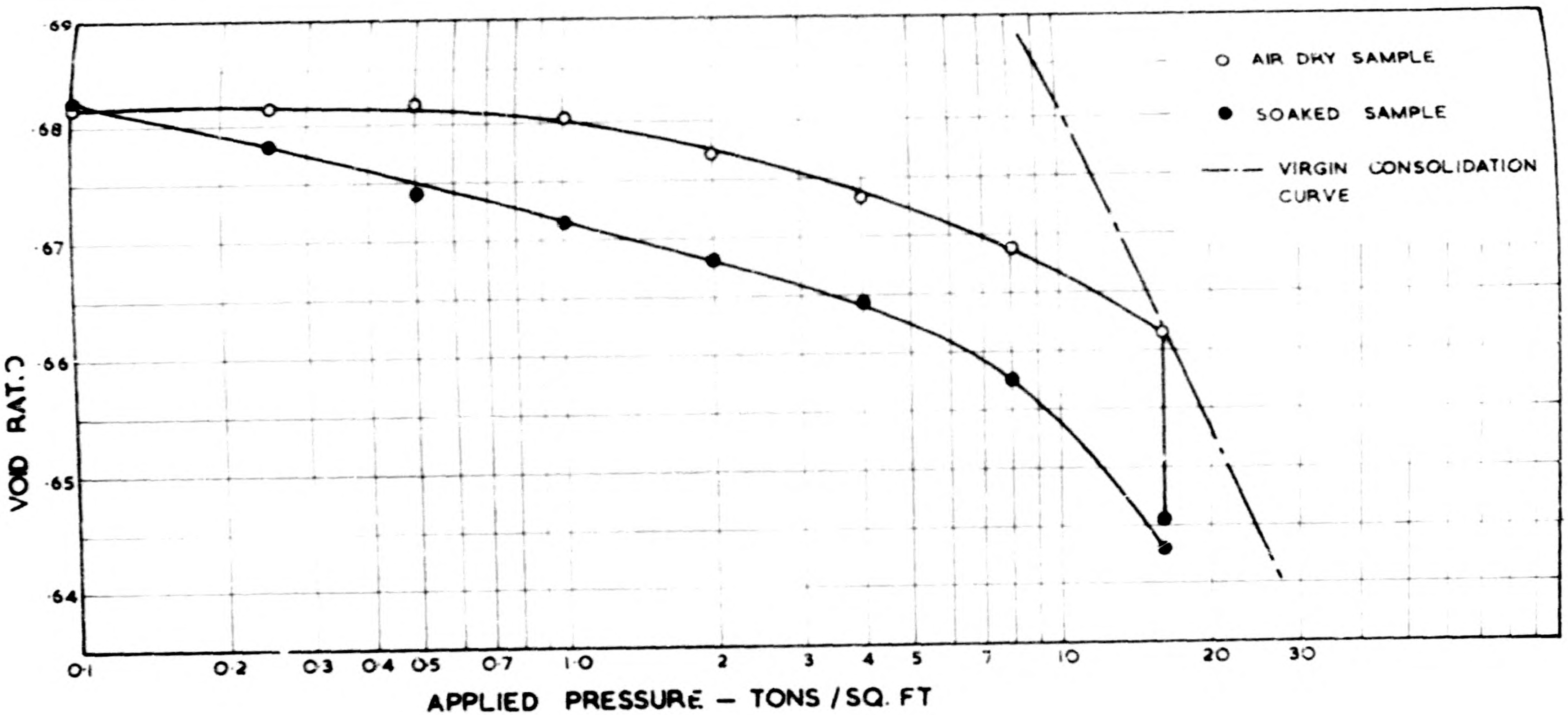
The samples were thoroughly remoulded at the liquid limit and shaped in 3½ inch diameter by 1¼ inch high moulds. The specimens were dried in the atmosphere to various moisture contents and then placed under bell jars for a few days to allow time for equilibrium of moisture throughout the sample. The samples were then tested in the consolidometer at various initial degrees of saturation. Loading was taken up to 16 tons/squ.ft. at which point the samples were soaked.

Four samples having initial degrees of saturation of 69.5%, 49.4%, 40.7% and 36.3% were tested. (An additional sample was brought to approximately 30% saturation [illegible] at zero applied load and then consolidated by means of applied loads.) The e: log p curves for the five specimens together with the virgin compression curve for the material are shown in fig. 6.10.



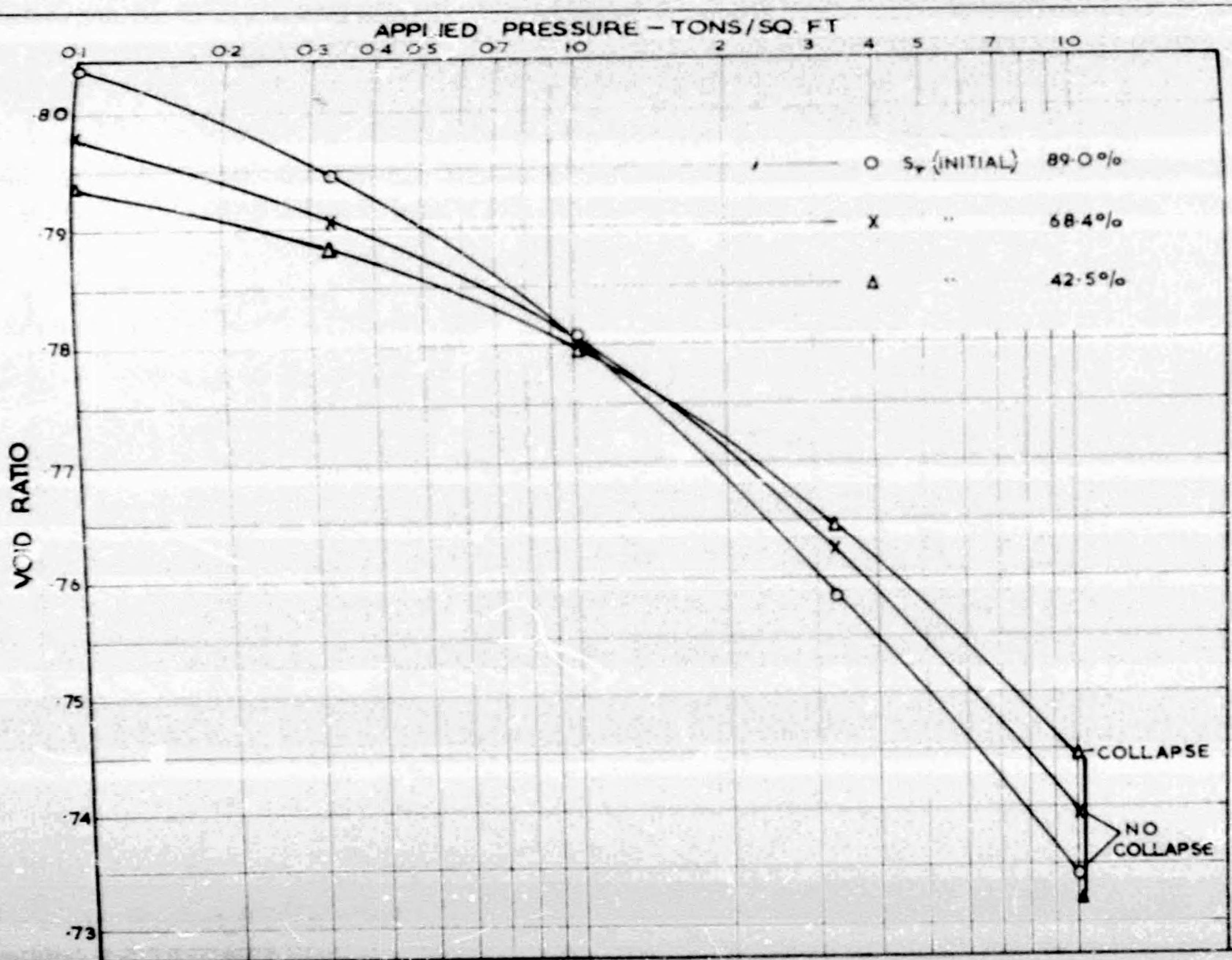
GRAIN SIZE DISTRIBUTION CURVES

FIG. 6.1



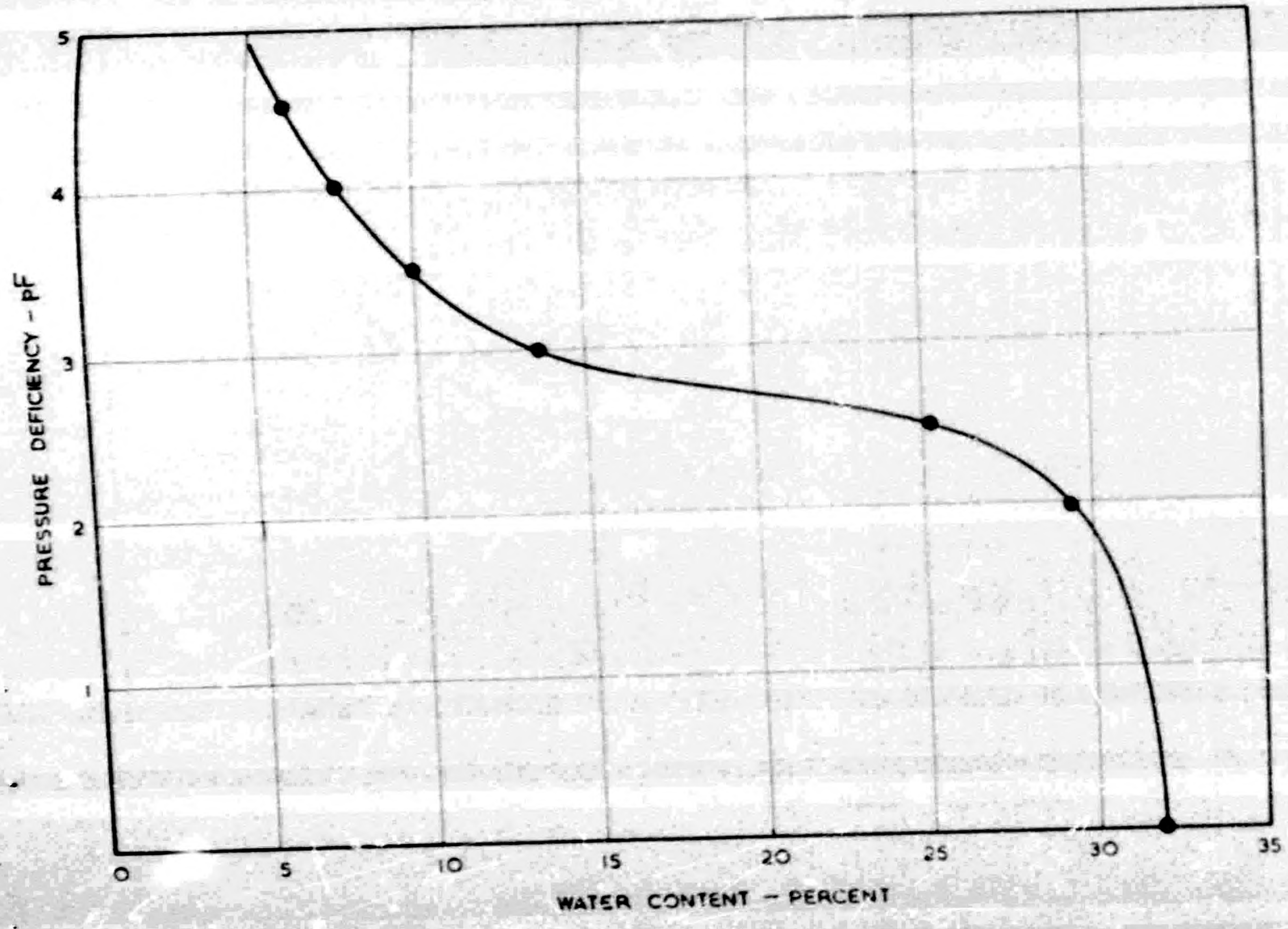
DOUBLE CONSOLIDOMETER TEST ON VERY COMPACT SILT

FIG 6.4



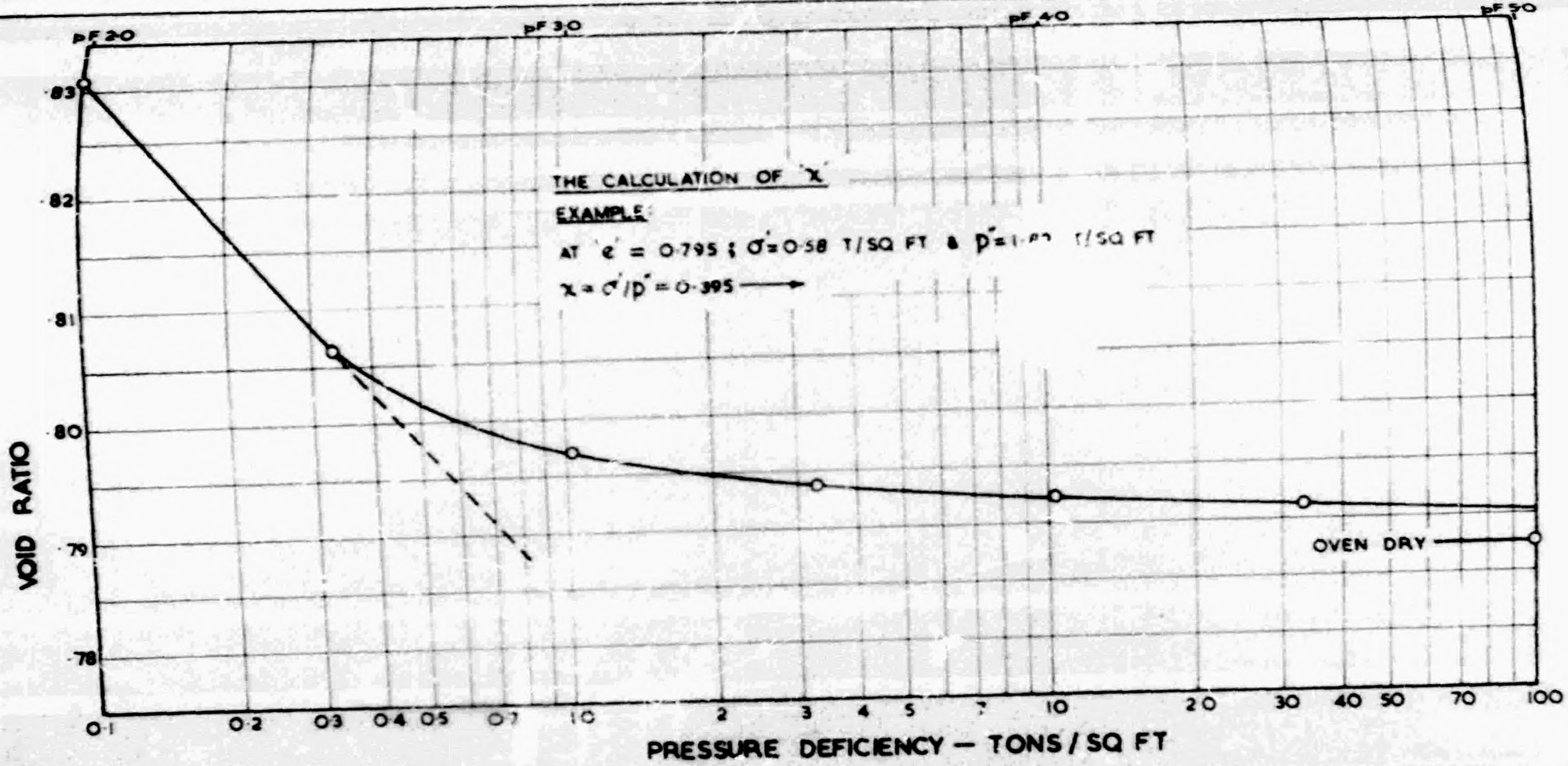
ALL ROUND COMPRESSION CURVES FOR SILT AT VARIOUS INITIAL DEGREES OF SATURATION

FIG 6.6



pF MOISTURE CONTENT CURVE FOR SILT

FIG. 6.7



RELATIONSHIP BETWEEN PPESSURE DEFICIENCY
AND VOID RATIO FOR SILT

FIG. 6.8

CHAPTER VII

ANALYSIS AND DISCUSSION OF TEST RESULTS

7.1 Compression tests on silt

It can be seen from fig. 6.2 that the e: log p curve for the sample which was soaked at 0.1 ton/squ.ft. joins up with the virgin compression curve at an applied load of approximately 4 ton/squ. ft. Thereafter the curve is almost coincident with the virgin line. This behaviour is consistent with classical consolidation experience which has shown that a precompressed soil will return to a unique 'virgin' compression curve if it is re-compressed.

The air dry specimens are very much more incompressible with respect to applied pressures than the saturated specimen. Instead of joining up with the virgin curve the e: log p curves for the air dry silt actually cross it.

The compression curve for the saturated silt is in terms of effective stress. However the compression curve for the air dry silt is in terms of applied stress because the positive effective stress component due to the pressure deficiency in the soil is unknown. Although the effective stress conditions in the air dry soil are indeterminate we can definitely say that, at a specific void ratio, the effective stress in the soil must be greater than the applied load acting on the soil. It can be seen from fig. 6.2 that the void ratio of the air dry silt is always <u>greater</u> than the void ratio of the saturated silt at any specific applied load. This is clearly contrary to the principle of effective stress which implies that the void ratio is determined only by the effective stress in the soil. If the silt were to have behaved in accordance with the principle of effective stress the void ratio of the air dried sample should have been <u>less</u> than the void ratio of the saturated sample at a specific applied load.

Fig. 6.2 shows that in every case when the samples were soaked under constant applied load they underwent additional settlement or 'collapsed'. The phenomenon of collapse was discussed in chapter IV where it was shown that such behaviour is contrary to the principle of effective stress.

The results of the consolidometer tests on air dry silt soaked at constant void ratio (see fig. 6.3) offer further evidence that the normal concept of effective stress is not valid for the material. If the principle of effective stress were valid for the material it could be expected that soaking at constant volume would involve an increase in applied stress σ. This increase in applied stress should be approximately equal to the magnitude of the pore pressure $\chi.p''$ relieved as a result of soaking. However the results show that in order to retain constant volume during soaking it is necessary actually to <u>reduce</u> the applied load.

An important observation can be made from figs. 6.2 and 6.3. Allowing for small errors in determining the initial void ratios of the specimens it can be seen that the silt returns to a unique saturated compression curve on soaking. This behaviour appears to be independent of the method of soaking or the value of applied load at which soaking was initiated.

The double consolidometer test on a compact silt shows the same characteristics, only to a lesser degree, as the tests on the loosely packed silt (see fig. 6.4). The material is far less compressible under changes in applied pressure deficiencies than under externally applied loads. Also when soaked under conditions of applied load the material 'collapses' to a saturated compression line which is unique for the material at its specific initial condition of applied load and stress history. It can therefore be deduced that even in a compact condition the air dry silt does not obey the principle of effective stress.

(i) <u>All round compression tests on air dry silt.</u>

The stress conditions set up in a partly saturated soil during a laterally confined compression test are very complicated. Quite apart from secondary edge effects the sample is subjected to a complex shear condition resulting from the differences in magnitude of the major and minor principal stresses. Hilf (1956) explains the collapse effect, discussed above and in chapter IV, purely on the basis that saturation of the soil releases a certain amount of the confining stress and the sample fails in shear with the result that it undergoes additional settlement. Wagener (1960) points out that if collapse of structure were due only to the shear stress set up as a result of differences in principal stresses then at small applied loads no collapse would occur. However it has been observed (Knight 1960, Wagener 1960) that even at very small applied loads collapse still takes place.

The only really satisfactory way to test whether collapse of structure is due to shear stresses, which can be accounted for by the principle of effective stress, or by structural changes, which cannot be accounted for in this way, is to test the soil in equal all round compression, i.e. equal principal stresses so that no shear stresses are developed. The results of such a test on air dry silt are shown in fig. 6.5.

It can be seen that the soil behaviour in equal all round compression is very similar to the behaviour in laterally confined compression. As was observed in the consolidometer test, the air dry silt is much less compressible with respect to applied loads than the saturated silt. Moreover, on soaking under a given applied load, the soil undergoes a rapid reduction in volume and 'collapses' to a unique saturated compression curve. Clearly the behaviour of the soil cannot be explained by the action of shear stresses developing from differences in principal stresses as postulated by Hilf. The only reasonable explanation for the collapse phenomenon seems to be the one offered in chapter IV.

(ii) Triaxial compression tests on silt at various degrees of saturation : The purpose of these tests was to determine approximately at what degree of saturation the 'collapse' effect begins to manifest in the silt. The results (see fig. 6.6) show that at 68.4 percent saturation there is no collapse on soaking under load. However at a degree of saturation of 42.5 percent there is a clearly defined collapse. It can be concluded that for degrees of saturation greater than about 50 percent the soil behaves in accordance with the principle of effective stress. Below this value, however, the silt exhibits behaviour which cannot be accounted for by the principle of effective stress.

(iii) Conclusions : The results of the tests discussed in this section indicate that, as regards volume changes, fine granular materials do not behave in accordance with the principle of effective stress below a critical degree of saturation. The behaviour of the soil can be explained by the effects, on the stability of the soil structure, of high curvature menisci acting at grain contact points. In a dry state the soil grains form rigid arches bonded together by the above mentioned menisci. These bonds resist micro shearing effects imposed by additions of applied stress. If, however, the soil is soaked while under load the bonds are removed, the effective shear resistance between grains is reduced and the grain structure collapses to a more stable arrangement. During compression, under saturated conditions, collapse of grain structure still occurs but it takes place progressively.

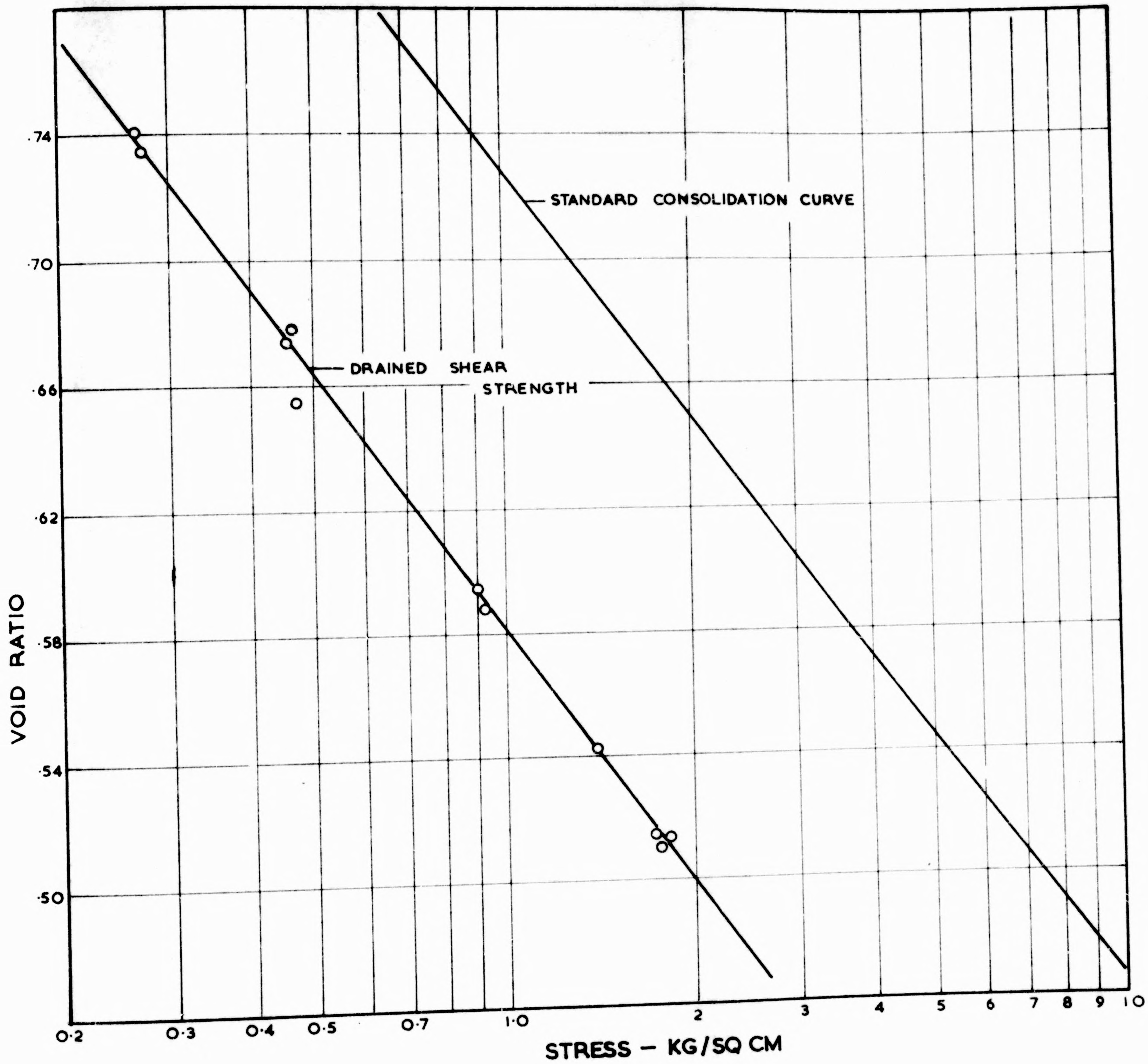
The above discussion reveals that compression of fine grained soils takes place mainly by slipping and rolling of particles and only to a small degree by grain distortions. In chapter I a method of calculating the angle of undrained shearing resistance of a granular posed by Bishop and Eldin (1950), was discussed. ...ned assumed that compression of the soil ... resulted only from grain distortions. It was ... that compression might also result from the displacement of grains and Bishop and Eldin's ... was modified accordingly. The work presented ... section indicates that compression due to ... and rolling of grains is the more correct ...ion for a soil composed of fine quartz particles.

...ight (1960) has carried out a detailed study of ...cture of collapsing soils. He has shown that in ... the soils possess a large amount of clay, usually ... which forms bridges between larger quartz ... On wetting un... load the bridges break ... collapse of structure results. The tests just ... show that collapse of structure is by no means ... to sandy soils which contain a relatively high ... of clay but can also occur in purely granular

...lysis of pF: moisture content and pF: void ... Relationships for Silt.

...pF: moisture content plot shown in fig. 6.7 is ...ical of a granular material. The initial steep ... represents the part where the menisci form at ...face of the soil. At the point where the curve ... flattens the air-water interfaces have been ... the soil and a considerable part of the ...filled pores are emptied. The final portion ... curve bends upwards shows that considerable ... in tension are required to remove water from ... which have formed at each grain contact

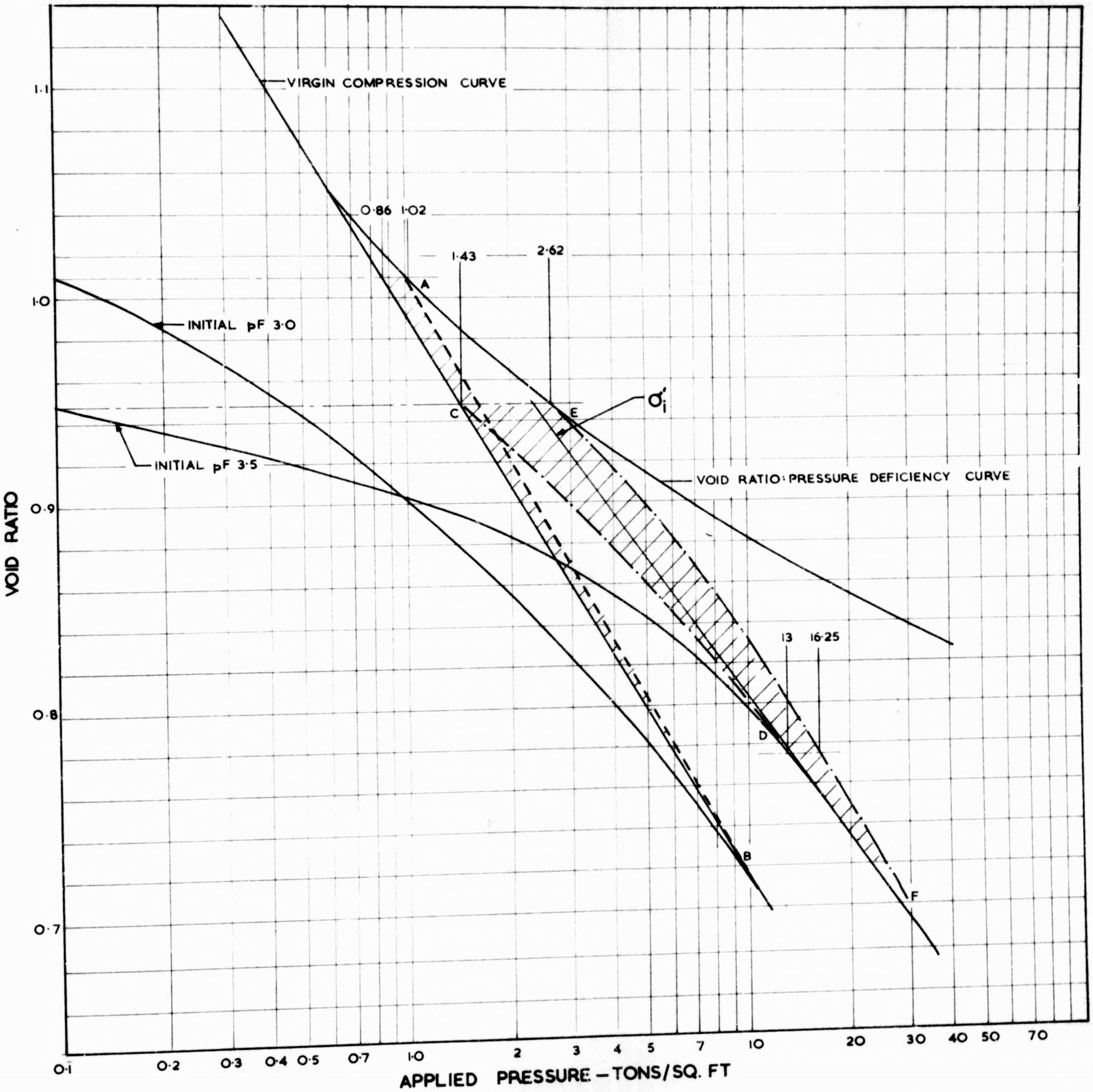
...can be seen from the pF: void ratio plot in ... that initially the void ratio decreases ...with increase in pressure deficiency. However ...of about 3.5 the rate of change of void ratio ...decreases. This corresponds approximately to ... which ...saturation occurs. From this



THE RELATIONSHIP BETWEEN VOID RATIO AT FAILURE AND SHEAR STRENGTH FOR ZURICH TALUS CLAY

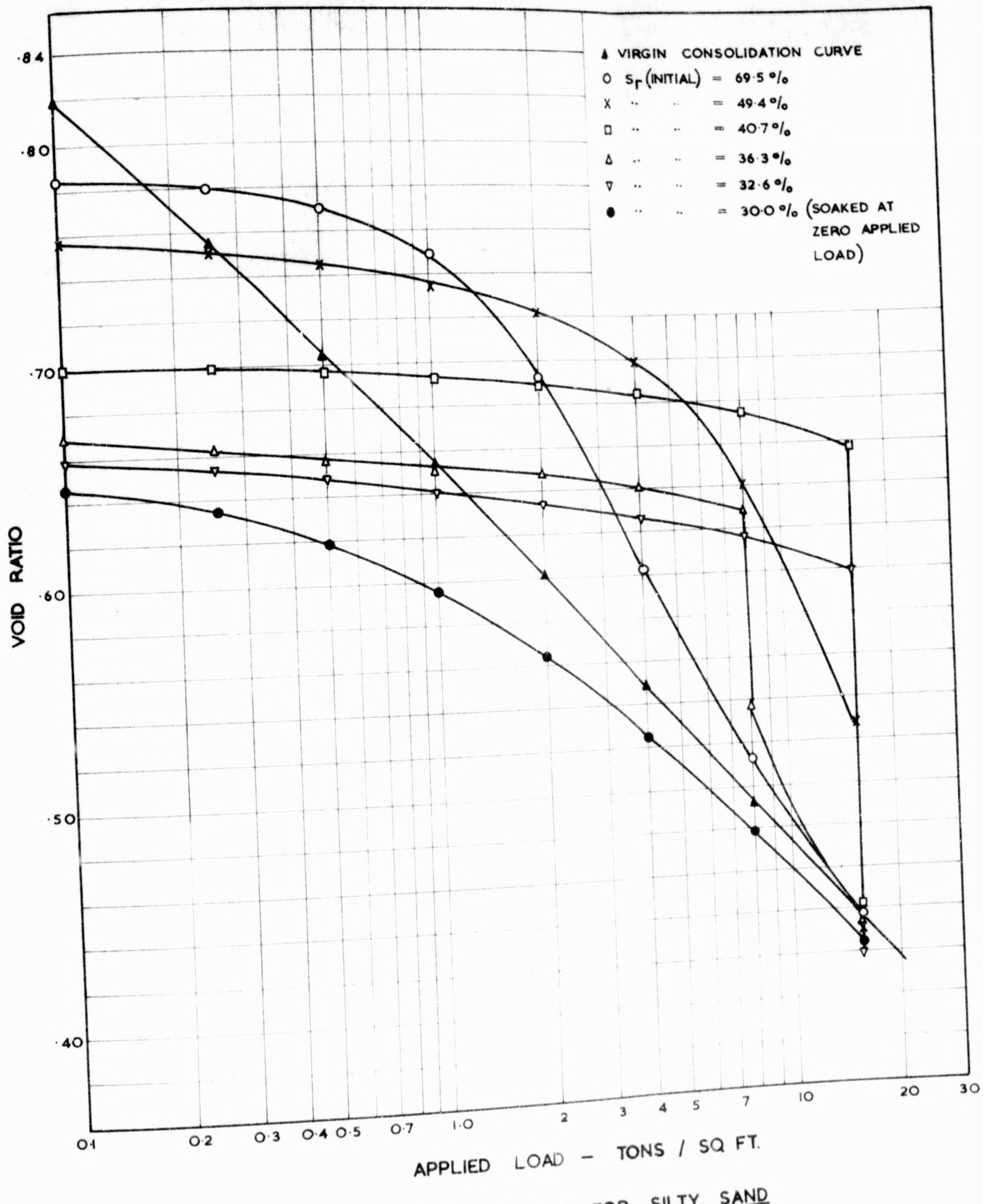
AFTER BJERRUM (1954)

FIG 8.1



ENVELOPES OF POSSIBLE INTERGRANULAR STRESSES FOR TWO SAMPLES OF PARTLY SATURATED SILTY CLAY COMPRESSED UNDER ALL-ROUND APPLIED LOADS

FIG. 7.6



CONSOLIDOMETER CURVES FOR SILTY SAND AT VARIOUS INITIAL DEGREES OF SATURATION

FIG. 6.10