5 LABORATORY INVESTIGATIONS

5.1 General:

Laboratory investigations were undertaken to study the mechanism involved in the process of consolidation for various size fractions of a black-cotton soil and sodium bentonite systems and to ascertain the extent to which the unbalanced electrical charges influence consolidation characteristics in general and pore pressure development and dissipation characteristics in particular.

For the systems tested in this investigation, the programme has been split up in two series of tests. First series consists of adopting consolidation testing programme in conventional size new consolidometer with pore pressure measurements at the bottom only and allowing the drainage at the top. Second series consists of consolidation testing programme in the specially designed large size consolidometer with pore pressure measurement at one-fourth, one-half, three-fourth and full height of the consolidating system, and allowing the drainage at the top.

The loading programme adopted in both the series of tests is the conventional one with 100% increase of pressure increment. Bishop's pore-pressure apparatus is used for the measurement of pore-water pressure.
5.2 Materials:

The materials for testing black-cotton soil and sodium bentonite were supplied by Engineering Research Institute, Baroda. The property data of these materials are given in Table No. 5.1 and 5.2.

From the tables, it can be seen that six soil systems with base exchange capacity of 7, 30, 57, 69, 112 and 134 are available for the study. The X-ray diffraction data on black cotton soil fractions shown in Fig. 5.1 indicate the presence of montmorillonite, kaolinite and small amounts of quartz. Similar data on bentonite clay fractions indicate the presence of mixed layered illite - montmorillonite, kaolinite and quartz.

5.2.1 Sand, Silt and Clay size fractions:

The soil was first pulverised and passed through BS Sieve No. 7. This sample was used for consolidation test for the soil. Sand, silt and clay size fractions were separated from this soil.

The sedimentation principle was used to separate the clay fractions (5 microns and 2 microns). For this purpose, about 500 gms. of air dried soil passing BS Sieve No. 7 with a little water was taken in a 10 litre bottle and the mixture was vigorously shaken on a mechanical agitator.
FIG. 5-1
X-RAY DIFFRACTION DATA
for about an hour. The bottle was then filled with distilled water to make up the volume of suspension about 10 liters. No chemical was used to bring about the dispersion of the soil grains.

The suspension thus prepared was allowed to settle after vigorous shaking. Using Stoke's law, the time required for 5 micron particles to fall a fixed height was calculated and by successive sedimentation and decantation, clay fractions were separated. Similarly, 2 micron particles were also separated. In the same manner, 5 micron and 2 micron fractions from bentonite clay were also separated. After the complete separation of the clay fractions, remaining sand and silt fractions were passed over 33 Sieve No. 300. The fractions retained on the sieve gave sand size fractions while the fractions passing the sieve gave silt size fractions. All these fractions were dried up, powdered and collected.

5.3 Testing Program:

The testing program consisted of carrying out consolidation tests in two series of tests on soil system, silt fractions, 5 micron and 2 micron clay and 5 micron and 2 micron bentonite clay fractions.

All the tests, in both the series, were carried out at common void ratios of 1.25, corresponding to the field density of soil and 1.50. In case of first series of
tests one additional value of void ratio 1.0 was also adopted to study the effects of lesser interparticle spacing for fine fractions in consolidation process.

The first series of testing program consisted of 18 tests carried out in Conventional Size New Consolidometer unit on six soil systems for three values of void ratios. In the second series of tests, however, the measurement of pore pressures at four different points in the large size consolidometer with the limitation of the equipment as discussed in Section 5.6, necessitated in all 48 tests on the six soil systems for two different values of void ratios.

For a comparative study of consolidation characteristics of soil systems having the same equivalent size of particle but with varied B.E.C. values, two additional tests were resorted to in the conventional size new consolidometer for one value of void ratio of 1.25 for two selected soil samples - Saurastra (Rajkot) Soil Sample (L.L = 42.50, P.L = 30.80) and South Gujarat (Surat) Soil Sample (L.L = 54.30, P.L = 36.40) for 2-nanometer size fractions having the B.E.C. values of 24 and 50 m.e./100 g. respectively.

Data obtained from conventional size new consolidometer, forming the first series, for void ratios of 1.0, 1.25 and 1.50 and from large size consolidometer forming the second series for void ratios of 1.25 and 1.50 have been presented
in Chapter 6.

5.4 Preparation of Specimens:

All the samples were moulded in the consolidometer rings - for the first series having 7.62 cm. (3") diameter and 1.90 cm. (\(\frac{3}{4}\"\)) height while for the second series having 22.25 cm. (8.75") diameter and 7.62 cm. (3") height and were covered at top and bottom with filter papers. The consolidometer ring was then clamped between two perforated plates and the assembly was put in a humidifier containing desired distilled water. The humidifier was connected to a vacuum pump. Saturation was ascertained by weighing the consolidometer rings.

5.5 New Set Up:

In case of standard consolidation tests, when the pore pressure measurements are desired (at bottom), the conventional consolidometer set up poses a problem of pressure leakages. For this purpose, a new consolidometer Fig. 5.2 as was developed by the author (64, 1965) is used in this investigation for the first series of tests involving measurement of pore pressures at the bottom face of the sample, Photo Plate No. 5.1.

In order to procure a complete picture of isochrones, measurements of pore pressure are desired at different
CONVENTIONAL SIZE
NEW CONSOLIDOMETER UNIT

LARGE SIZE CONSOLIDOMETER UNIT
heights of the consolidating sample. Hence, a large size consolidometer, 31 cm. (12") diameter 12 cm. - (4.75") height, was developed, Fig. 5.3, Photo Plate No. 5.2. The large size consolidometer has a recessed screwed portion at its bottom and the consolidometer ring 22.25 cm. (8.75") in diameter and 7.62 cm. (3") in height fits into this portion. The ring has, on its two right angle diameters holes of 1.0 cm. diameter at 1.905 cm., 3.81 cm. and 5.715 cm. distances from its top. The first and the third hole will lie on the same diagonal when viewed in plan. Similar holes are made in concentric positions in the outer hug or the shell of the consolidometer.

Both the consolidometers were made from cast iron and the conventional was chromium plated while large-size consolidometer was put into operation after finishings.

The loading frame for the conventional size new consolidometer has the lower arm ratio of 1 : 11 while the one used for large consolidometer has the value of 1 : 24.

5.6 Pore Pressure Measurements:

The pore pressure measurements during consolidation prove to be an important record and pore pressure measurements ( at bottom ), far possible, should always be incorporated in the consolidation testing program.
With the increased tendency for the pore pressure measurements in soil engineering testing programs, as is prevalent to-date (1971), there should be availability of equipment simple in its use and easy in its control. Attempts were directed towards the insertion of fine bore tubes and this resulted in using surgical tubes called Uterus Cannula having 2 mm. diameter and the length of 16 cm. (6\(\frac{1}{2}\) inches). The Cannula when inserted in the consolidometer will have its tip exactly at the centre of the sample placed in the consolidometer ring.

The Cannula is fitted to the valve, on a rubber seat and enters the consolidometer ring through the small rubber plugs fitting tightly into the rings. To remove the entry of air, while inserting the Cannula, small head of water is placed on the Cannula through a plastic tube connected on one end to the valve and the other to water bath. The Cannula to be provided at bottom face of the sample can be placed directly and hence does not involve the above mentioned procedure.

Bishop's pore pressure apparatus has been used in this investigation for the measurement of pore pressures. Four such units connected to different above mentioned positions would then give simultaneously the records of pore pressures at different depths. In the present investigation, the
pore pressures were measured at one point with the single pore pressure apparatus available and the test was repeated three times to complete four records of pore pressure measurements at one-fourth, one-half, three-fourth and the bottom face of the sample.

When the loading was in the low pressure range, mercury manometer was used to measure the pressure. For pressures beyond the range of manometer, manometer valve was shut and pressures were measured with a calibrated Bourdan Gauge.

5.7 Side Friction:

Side friction, forming an undesirable feature of conventional testing apparatus, does not occur in natural clay strata. The magnitude of the side friction may be decreased by the use of thinner samples which may lead to less accurate measurements of compressions. To some extent, floating ring type of consolidometer reduce the magnitude of side friction, Taylor (71, 1942).

Side Friction data as collected by Leonard and Girault (44, 1961), indicate that the rate at which side friction develops is dependent upon at least two factors:

(i) the rate of strain.
(ii) the rate of pore pressure dissipation.

Further, appreciable amount of side friction
accompanies the development of immediate compressions and therefore the friction, increasing at decreased rates, affects the rate of pore pressure dissipation.

In the present investigation, side friction is eliminated by coating the surface of the consolidometer ring in contact with the sample with frictionless grease. Use of grease containing molybdenum disulphide also helps in removing the side friction.

5.8 Method of testing:

Saturated sample from the humidifier was taken out, after getting assured that full saturation is achieved. The consolidometer ring containing the sample was then transferred to the consolidometer base. Utmost care was required in order to ensure that the sample is not disturbed during this process and no air should get entrapped between the consolidometer base and the sample. For the large-size consolidometer sample, this has been discussed in Section 5.6.

The base is connected to a valve, tested previously to about 400 p.s.i. to the Bishop's pore pressure apparatus. Every time, before starting the loading program, the apparatus was fully de-aired and the deflection of mercury in the null-indicator obtained was of the order of 3/8"
and less for about 100 to 120 p.s.i.

The loading program consisted of applying the load increments in sequence as 0.1, 0.2, 0.4, 0.6, 0.8, 1.6 and 3.2 kg/cm². The duration of increment adopted is the same as the conventional one of one day.