CHAPTER VIII

SUMMARY OF FINDINGS

The post Terzaghi developments in consolidation theories could be classified into three distinct approaches namely, Rheological, Analytical and Physical. The success of Rheological models demands that the material is homogeneous, isotropic and stress path independent. For material exhibiting large strains the principle of superposition is deprived of its validity. Hence from consideration of the nature of the soil material, as observed, the working of this versatile rheological approach has its own limitations. The consolidation phenomenon in soils cannot be tackled by mathematical treatment based on gross idealization. The consolidation problem is different from the elasticity problem and is not adequately solved by simply satisfying a heat conduction type equation. One of the distinct feature of the consolidation phenomenon is the occurance of large volume changes during the process. A physical process, however, attractive it may be, loses its value if it cannot be mathematically exploited to evaluate the parameters for the engineering analysis. A clearer picture of the phenomenon is possible if a proper linkage between the physico-chemical characteristics of clays and analytical procedure is established. The Lagranian mathematical scheme followed by McNabb (1960) and Gibson et al (1967) is versatile. A differential equation of Parikh and Verma (1970) for the present work is derived from fundamental consideration based upon the above mathematical treatment. The stress strain time relationships for clay mineral, pore fluid and soil skeleton are accounted in the quantity P. The equation has a form identical to the differential equation for the nonsteady one dimensional flow of heat through moving media against Terzaghi classical concept of heat flow through isotropic bodies. Taking P as a constant, a solution of the differential equation is obtained.by Laplace Transform technique. A Fortran Programme on IBM-1402 is used to compute theoretical relationships. The proposed theory is seen to agree adequately with experimental observations. The constant 'P' of the equation emerges as a weighted factor to account for the deviation from Terzaghi's idealizations. It is suggested that it will be worth while to obtain the solution of the differential equation taking P as some function of t. The confirmation of the proposed theory against isochrones is a further step.

The degree of exposition of any physical process depends on the degree of exactitude of the experimental set-up. Major factors that influence the measurement of consolidation characteristics are sample disturbance, side friction and inadequacies in the measuring systems. The present investigations show that deposition of uniform slurry at double liquid limit consistency in a pot produce a uniform sample, the smearing of silicone grease to contacting surfaces help minimise side friction, and continuous maintenance and calibration of measuring devices ensure precise readings. The use of electronic equipments demand stable electric power, constant temperature conditions and utmost vigilance for zero defects. Conventional Casagrande set-up provides a simple and accurate enough arrangement even for research studies. The hydraulically pressurised Rowe type set-up is particularly better suited for pore pressure measurements and drainage control. The measurements of local deformations and pore pressures within the clay bed employing radiographical techniques are worth a pursuit.

The summary of findings of present experimental investigations are :

A. Clay Mineral

Montmorillonite clays of expanding lattice type exhibit distinct consolidation characteristics compared to illitic and kaolinitic clays of nonexpanding lattice types.

(i) Bentonite shows slow initial rate of consolidation unlike kaolinite and illite.

(ii) Bentonite displays a higher degree of secondary compression compared to kaolinite and illitice

(iii) Kaolinite and illite reveal almost constant rate of consolidation as against Bentonite throughout the process of consolidation.

(iv) Bentonite deviates most from Terzaghi theory while kaolinite and illite tend towards it.

(v) The magnitude of rate of consolidation is in descending order of kaolinite, illite and Bentonite at all loads.

(vi) The pressure-void ratio relationship of normally consolidated Bentonite has a characteristic hump which is more or less absent in normally consolidated kaolinite and illite.

The distinctive behaviour of Bentonite can be attributed to the predominant repulsive potential in the clay-water system and rigid plastic nature of the oriented water.

B. <u>Fabric Structure</u>

Consolidation characteristics of flocculated clays - edge to face configuration and dispersed clays - face to face configuration are contarary to each other.

(i) Flocculated clay tends to show a decrease in the rate of consolidation at the initial stages of consolidation tidation while dispersed clays of both kaolinite and Bentonite tend to show an increase.

(ii) Dispersed clays exhibit principally primary consolidation while in the flocculated clays secondary compression is predominant.

(iii) Flocculated clays lie farther below Terzaghi theory while dispersed clays fall near to it.

(iv) Both flocculated and dispersed clays both kaolinitic and montmorillonitic approach respective constant values of rate of consolidation at higher loads.

(vi) The overall effect of either dispersing or flocculating agents becomes dormant at higher loads.

A comprehensive picture of the process of deformation can be had by visualizing that it consists of two distinct phenomena. One is the sliding and lifting of plate shaped particles leading to breakage of link bonds pressing out the pore water which is a predominant phenomenon in dispersed clays. Another is the breaking up of the link bonds at edge to edge or edge to face proximity. This preceeds the first phenomena particularly in well developed flocculated clays.

C. Degree of Saturation

Clays compacted nearer to or drier to OMC are similarly different in characteristic to saturated clays while clays at wetter of OMC behave almost identically as saturated clays.

(i) The rate of consolidation of clays compacted nearer to or drier to OMC indicates a slight decrease in the rate of consolidation while those at wetter of OMC show slight increase at initial stages of consolidation under moderate loadings.

(ii) At lighter pressures no consolidation is noticeable in clays compared at drier of OMC or at OMC. Rate of consolidation remains constant throughout the process at higher pressures.

(iii) Degree of primary consolidation increases with the increase in the moulding moisture content.

(iv) Drier clays lie above Terzaghi theory while wetter fall below it.

(v) The magnitude of rate of consolidation is in the descending order of moulding moisture content.

(vi) The nature of the pressure-void ratio relationships of kaolinite at any water content remains similar but that of Bentonite becomes characteristically steep for clays compacted at dry of OMC.

The explanation lies in the fact that at dry side of OMC, water thirst prevails, at wet side of OMC air is inoccluded state and at OMC air ceases to flow out.

D. Stress History

(a) Influence of Loading and Unloading :

Consolidation characteristics of kaolinitic clays alter with progressive cycles of loading and unloading depending on the mode of load application.

(i) Rate of consolidation increases with progressive loading and unloading cycles at the initial stages particularly under lighter loadings.

(ii) Degree of secondary compression diminishes with each cycle of loading and unloading.

(iii) Tendency is to deviate further below Terzaghi theory with successive cycles.

(iv) The magnitude of the rate of consolidation increases with the number of loading and unloading cycles for the same load intensity irrespective of any mode of load application.

(v) Pressure-void ratio relationships indicate large irreverisible deformation and very little elastic recovery under all the loading and unloading modes.

(vi) Hysteresis loop formed by decompression and recompression are almost parallel among themselves for a particular set. The area of successive hysteresis loops progressively decreases with each further loadihg and unloading cycle.

The phenomenal changes occuring in energy levels of clay water system as a result of loading and unloading cycles govern the process of deformation.

(b) Influence of Load Intensity

Consolidation phenomenon in kaolinite tends to become predominantly of primary nature with higher intensity of loading.

(i) Rate of consolidation shows rapid increase throughout the process of consolidation at stress increment ratio greater than four.

(ii) The degree of secondary compression diminishes progressively with increasing intensity of loading.

(iii) The deviation from Terzaghi theory becomes larger with higher load intensity.

(v) Pressure-void ratio relationships show a characteristicly steep curve as the load intensity is raised.

(iv) The magnitude of rate of consolidation increases with higher increment stress ratio.

The guiding point is that at lower load intensity, physico-chemical forces predominate the influence of which is obscured under higher intensity of loading.

E. Drainage Path

(a) Orientation of Drainage Path :

Vertical or inclined or horizontally oriented kaolinite clay samples indicate no appreciable distinction in the consolidation characteristics.

(i) Rate of consolidation remains almost unchanged throughout the process of consolidation.

(ii) The degree of secondary compression is not influenced by orientations.

(iii) The deviation from Terzaghi theory is that usually observed in vertical samples.

(iv) The magnitude of rate of consolidation decreases rather rapidly under lighter pressures but at higher pressures it becomes constant irrespective of the nature of orientations.

(v) Pressure-void ratio relationships are of identical nature for all orientations.

The argument to explain the ineffect on the consolidation characteristics is that the effect of drainage length and interfacial grip gets mutually nullified.

(b) Length of Drainage Path :

Thicker samples exhibit primary consolidation behaviour of Terzaghi conception.

(i) Rate of consolidation is a constant throughout the process of consolidation.

(ii) The degree of secondary compression is negligible in thicker samples.

(iii) Practically at all loads thick samples conform to Terzaghi theory.

(iv) The magnitude of rate of consolidation is higher in thick samples.

(v) Pressure-voids ratio relationships of thicker samples show an initial hump.

The significant point is that the dominating self weight generates pore water pressures and the consolidation proceeds fundamentally as hydrodynamic lag. The clue to consolidation response is mainly contained in the nature of clay lattice structure, interaction in clay water system and link formations at various contacts.

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