International Journal of Advanced Science and Technology
Vol. 29, No. 08, (2020), pp. 1868- 1877

# Effect of E-Log σ' Behaviour of Compacted Fine Grained Soils Having Different Clay Mineralogy

**H. S. Prasanna and Basavaraju**

***Abstract**: Compressibility criteria of fine- grained soils possess a major challenge because of its complex physio chemical behavior due to the presence of clay mineral that it is kaolinite and otherMontmorillonite.Theconstruction sites having adequate safe bearing capacity and minimum degree of settlement it is facing major problems for the industry at large to have constructions on compacted fine-grained soils having different clay mineralogy altogether.The structure constructed on such embankments have to be controlled effectively for settlements throughout the time .It is imperative that the compressibility behavior of compacted fine-grained soils with reference to clay mineralogy is having more qualitative approach. In the present research attempt has been made to study compressibility character of fine-grained soils having different clay mineralogy altogether .It is observed that the soils compacted for same placement densities for having different e-log σbehavior by virtue their different initial water contents.Equilibrium void ratio on wet side compacted state at any effective consolidation stress is always more than that the dry sides which highlights the role of placement conditions and soil fabric an e-log σbehavior .Clay mineralogy place a vital role in the behavior of an e-log σ curves .*

## I.INTRODUCTION

The three most important properties of soil mass are compressibility, shear strength and permeability. These are useful in the design and analysis of dams, retaining walls, soil foundation systems. Among these three, compressibilityis one of the owing to the fact that number of quality construction areas available for construction is becoming a major issue for the construction factory. It is imperative that, the construction has to be done on soil's having low bearing capacity which issusceptible to major settlements. Developing grounds for such structure at large gain lot of importance from engineering safety of such structures.

However, it has been worked beyond doubt that, by imparting mechanical energy to suit the ground conditions to one's needful. It is important to note that enhancement of bearing capacity and minimizing the possible settlements within permissible limits are the governing factors in addition to magnitude of energy, type and availability of soil. It is observed that, type and availability of soil (coarse grained soil) is becoming scare at large. It is this status, forcing the construction industry to use the fine-grained soils for ground improvement applications. It is worthy to note that, the compaction behavior of coarse-grained soils is a physical phenomenon, whereas for fine-grained soils it's a physico chemical phenomenon. The role of clay mineralogy i.e., presence of clay minerallike Kaolinite in Kaolinitic rich soils other clay mineral i.e., montmorillonitic soils plays a vital role which governthe monitoring mechanisms @ large. For the present experimental study, an attempt has been made to study the compressibility behavior of fine-grained soils with reference to clay mineralogical composition.

## II. LITERATURE REVIEW

Many researchers in the past attempted to correlate γdmax and OMC of fine-grained soils for different energy levels and the methods of finding γdmax and OMC (McRae (1958), Hilf (1956) Jumikis (1958), Ring et al (1962) and Wang and Huang (1984)). Benson and Trost (1995) have conducted the permeability tests on thirteen compacted clays for different compaction energies. Blotz et al (1998) has explained about an empirical method, for evaluating γdmax and OMC of clayey soils for different energy levels.

Sridharan et al. (2000) have studied about the data related to plastic limit, γdmax (plastic limit) and γdmax (OMC) for light compaction effort. It has been brought out that the role of the compactive energy and how the compaction characteristics are affected. Over a long period of field experience, it has been realized that role of compaction characteristics like γdmax and OMC for modified proctor, reduced standard proctor and reduced modified proctor gains a lot of impetus from method of construction and longitivity and economics point of view.

Peck et al., (1967) has discussed that, the decreasing in void ratio leads to decrease in both K and Mv in rapid manner and the ratio of K /mv also and hence $C_V$ is constant for different consolidation pressures.

In general geo-technical engineering practice, the consolidation process of soils has been followed by three steps,

a) Immediate settlement or initial settlement
b) Primary consolidation
c) Secondary consolidation.

Fine-grained soils are extensive complex natured materials containing a huge amount of flaky-shaped dispersed particles of <2 micron diameter of size, which is being influenced by different physical, mechanical and physico-chemical process. Because of the complex compressibility of fine-grained soils having different consolidation stress over a period of time, with particular reference to clay mineralogy, the present experimental work attempts to analyze the compressibility behavior of fine-grained soils with respect to clay mineralogy.

ISSN: 2005-4238 IJAST

## III. MATERIALS AND METHODS

Nearly thirty soils from different locations in Mysore and Chamarajanagar districts were subjected to preliminary laboratory investigation involving liquid limit and free swell tests. Their liquid limits were determined using Casagrande percussion method (IS: 2720 - Part 5, 1985), and the nature of their clay mineralogical composition was judged by the free swell ratio method (prakash et al., 2004). Finally four field soils were identified to be used for the present experimental investigation based on clay mineralogy.

The experimental investigation has been conducted on two field soils-one kaolinitic and the other montmorillonitic, having lower liquid limit range ($W_L$ < 50%) and on two field soils-one kaolinitic and the other montmorillonitic, having higher liquid limit range ($W_L$ >50%).

- Soils having low liquid limit range
    1. Field soil from Bogadi, Mysuru (passing 425 µm sieve), Chamarajanagar district, which contains kaolinite as the predominant clay mineral.
    2. Field soil from Nanjangud, Mysuru District (passing 425 µm sieve), Mysuru district, which is a montmorillonitic predominant soil.
- Soils having high liquid limit range.
    1. Field soil from Kollegala (passing 425 µm sieve), Chamarajanagar District, which contains Kaolinite as the predominant clay mineral.
    2. Field soil from Kuderu (passing 425 µm sieve), Chamarajanagar District, which appears to contain Montmorillonitic as the predominant clay mineral.

The physical properties of the soils studied are given in the table 1.

**Table 1: Physical Properties of Soils Studied**

| Sl. No. | Soil | Specific Gravity | Atterberg Limits and Index properties | | | | | | | FSR | Clay Mineralogy | Grain Size Distribution:% | | | | IS classif-ication | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Casagrande Methods | | | | | | Cone Penetrometer Method | | | | | | | | |
| | | | Liquid limit ($w_L$): % | Plastic limit ($w_P$): % | Plasticity index ($I_p$): % | Shrinkage limit ($w_S$): % | Shrinkage Index ($I_s$): % | Distilled Water | Kerosene | | | Clay size % | Silt size % | Sand Size % | Gravel % | | |
| 1. | Bogadi Soil | 2.6 | 46 | 22 | 24 | 13.7 | 32.3 | 44 | 50 | 1.3 | Kaolinitic | 13 | 16 | 71 | - | CI | K-Soil |
| 2. | Nanjungudu Soil | 2.65 | 46 | 23 | 23 | 18.7 | 37.3 | 39 | 35 | 1.3 | Montmorillinitic | 7.5 | 19.5 | 60.5 | 12.5 | CI | M-Soil |
| 3. | Kollegala soil | 2.74 | 55 | 26 | 29 | 15.9 | 39.1 | 43 | 54 | 1.11 | Kaolinitic | 37.0 | 34.5 | 28.5 | - | CH | K-Soil |
| 4. | Kuderu soil | 2.85 | 54 | 26 | 28 | 11.5 | 42.5 | - | - | 1.42 | Montmorillinitic | 39.0 | 21.0 | 40.0 | - | CH | M-Soil |

A. *Consolidation tests on compacted soils*

A. *Sample preparation for consolidation testing*

The consolidation tests were done at three levels of initial moulding water contents –corresponding to $\gamma_{d\ max}$(i.e. OMC), 0.95 $\gamma_{d\ max}$on dry of optimum and 0.95 $\gamma_{d\ max}$on wet side of optimum. The soil sample is compacted for the optimum moisture content and maximum dry density in the consolidation ring and it is positioned in the consolidation cell. The fixed ring type consolidation cell was used for the experimental work with drainage on both sides and availability of conducting the falling head hydraulic conductivity test also on the soil sample. The ring is having the diameter of 60 mm and height is 20 mm.

B. *Load – deformation - time measurements for compacted soils*

Consolidation tests were conducted according to IS: 2720, Part 15 (1986).

The soil samples are equilibrating under the seating stress. M-soil sample exhibited swelling on addition of water into the consolidation cell. In such cases, time-swelling readings were recorded till the equilibrium was reached. The samples are loading from 6.25 kPa (after the permeability measurements were taken) to 1600 kPa with an increment ratio of one. Under each consolidation stress increment, time - compression readings were recorded till the near equilibrium state was reached.

## V. RESULTS AND DISCUSSIONS

**Effect of placement condition**

Figs.1 through 4 represent the e-logσ' curves of K and M soils belonging to the low liquid limit ($W_L$ = 46 %) group respectively. Each of these two figures contain three e-log σ' curves–one corresponding to the soil at optimum compacted state, one corresponding to the soil compacted to 0.95 $\gamma_{dmax}$ on the dry of optimum and the other soil on the wet of optimum compacted to 0.95 $\gamma_{dmax}$. Following observations can be made from these illustrations.

The soils compacted to the same placement density (i.e., 0.95 $\gamma_{dmax}$) show different e-log σ' curves by virtue of different initial water contents adopted during compaction.

The e-log σ' plots of the wet side compacted soil are lying above the soil compacted on dry of optimum side. This means the equilibrium void ratio on compacted soil of wet side of optimum placement condition, the effective consolidation stress levels are always more than that of the dry side compacted soil. Even though this similar behaviour is exhibited by both K and M soils, the controlling mechanisms in both the cases are different.

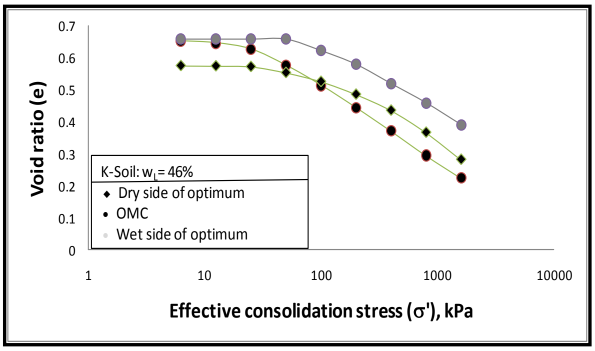


**Fig. 1: e-log σ' plots of K-soil for Light Compaction under different placement conditions**

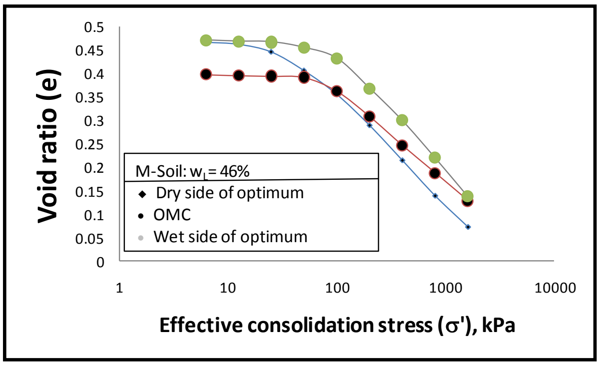


**Fig. 2: e-log σ' plots of M-soil for Light Compaction under different placement conditions**

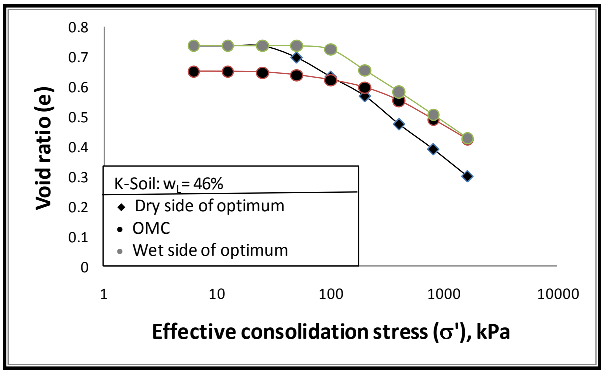


**Fig. 3: e-log σ' plots of K –soil for Heavy Compactionunder different placement conditions**

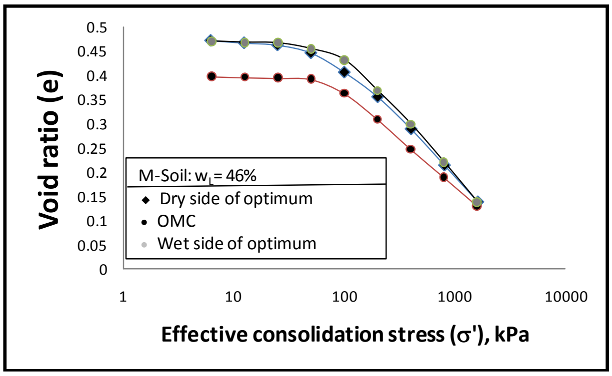


**Fig. 4: e-log σ' plots of M-soil for Heavy Compactionunder different placement conditions**

In general, on the dry of optimum side, the soil fabric structure is flocculent type compared with optimum and wet of optimum side. On wet of optimum side, the soil fabric is dispersed type. In K-soil, flocculent fabric on the dry of optimum side is susceptible to break down even at lower effective consolidation stresses resulting in more compression, which is evident from Fig. 1. In M-soil, due to the presence of relatively more oriented fabric, which is favourable for the full development of diffused double layer, the inter particle repulsive forces develop. This leads to more equilibrium void ratio on the wet side of optimum under any effective consolidation stress.

Similar observations were made for e-log σ' curves for soils subjected to heavy compaction tests (Figs. 3 and 4).

Figs. 5 and 6 represent the e-log σ' curves of soils of high liquid limit ($W_L$ = 55%) group namely k-soil and m-soil respectively.

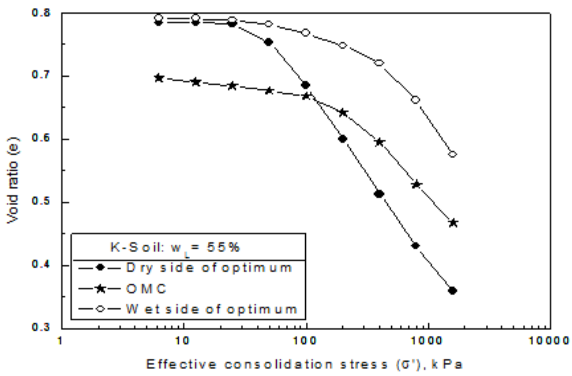


**Fig. 5: e-log σ' plots of K-soil for Light Compactionunder different placement conditions**

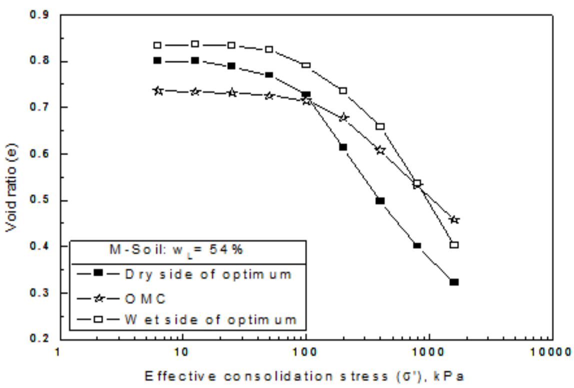


**Fig. 6: e-log σ' plots of M-soil for Light Compaction under different placement conditions**

These soils also have their e-log σ' curves compacted on the wet and dry of optimum states. In Fig. 5, the e-log σ' curves of K-soil corresponding to compacted on dry and wet of optimum states appear to be almost identical. The dominance of inter particle repulsive forces due to relatively more oriented fabric on the wet of optimum side, which results in the higher equilibrium void ratio (e) under any effective consolidation stress level can be seen from e-log σ'curves of M-soil (Fig. 6). Similar observation were made for e-log σ'curves for soils subjected heavy compaction test (Fig. 7and 8).

ISSN: 2005-4238 IJAST

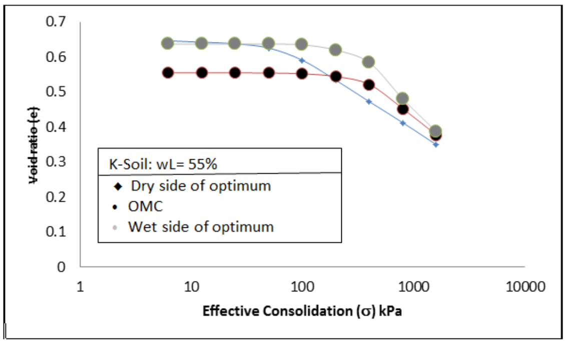


**Fig. 7: e-log σ' plots of K-soil for Heavy compaction under different placement conditions**

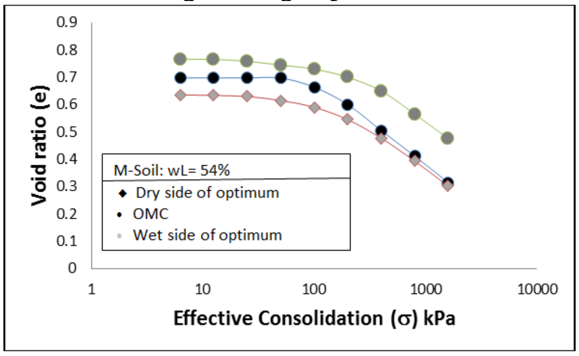


**Fig. 8: e-log σ' plots of M-soil for Heavy compaction under different placement conditions**

The void ratios of soil samples with different placement conditions are normalized using the void ratio at seating effective consolidation stress (i.e. at 6.25 kPa), and these normalized void ratios are plotted against log σ'. Figs. 9, through Figs.12shows ($e/e_{6.25}$) v/s log σ' curves for the soils of low liquid limit ($W_L$ = 46%)and high liquid limit ($W_L$ = 55%)groups respectively subjected light compaction tests. Compacted on dry of optimum side, optimum and wet of optimum side respectively, Figs. 13, through Fig.16 illustrate ($e/e_{6.25}$) v/s log σ' plots for the soils having high liquid limit($W_L$ = 55%) subjected to heavy compaction test. From these illustrations, it is clear that, the dry side compacted soil sample will compress more than the wet side compacted soil sample and soil sample compacted at OMC.

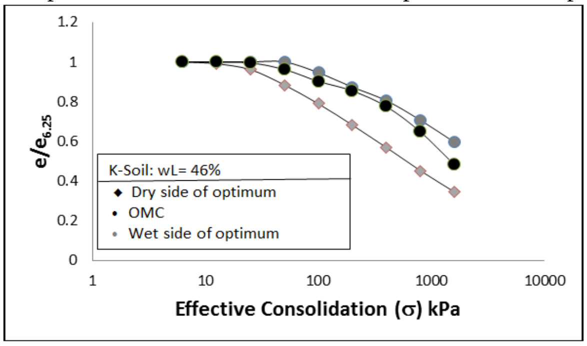


**Fig. 9: $e/e_{6.25}$ v/s log σ' plots of K-soil for Light Compaction under different placement conditions**

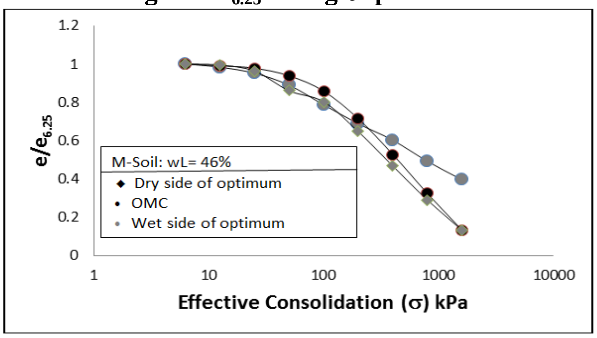


**Fig.10: $e/e_{6.25}$ v/s log σ' plots of M-soil for Light Compaction under different placement conditions**

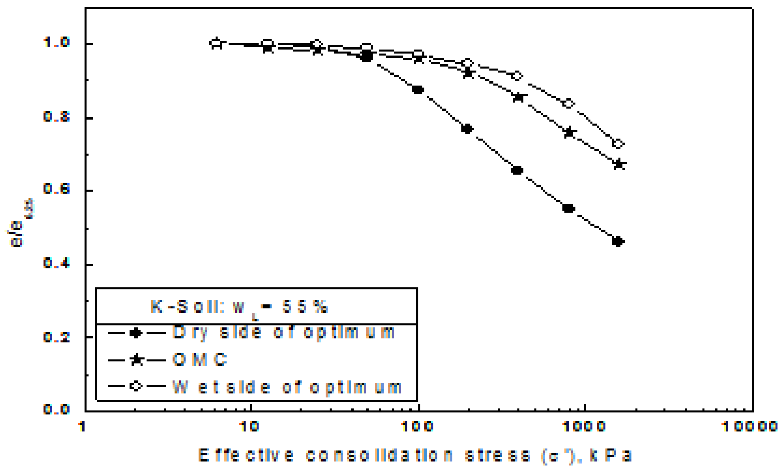


**Fig. 11: e/e$_{6.25}$ v/s log σ' plots of K-soil for Light Compaction under different placement conditions**

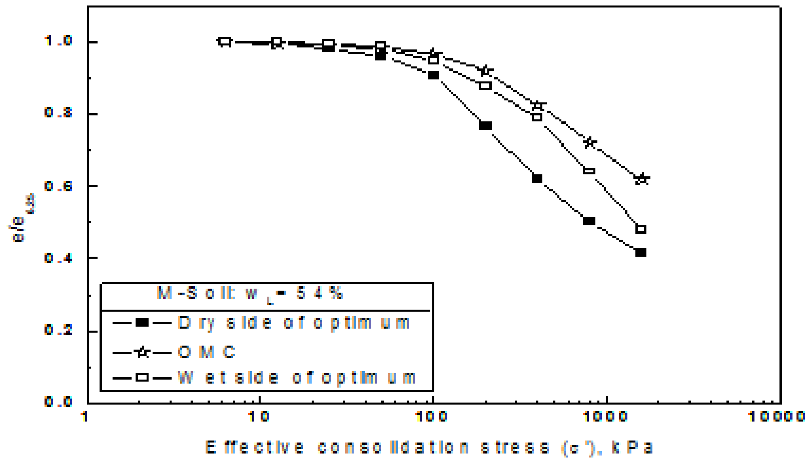


**Fig. 12: e/e$_{6.25}$ v/s log σ' plots of M-soil for Light Compaction under different placement conditions**

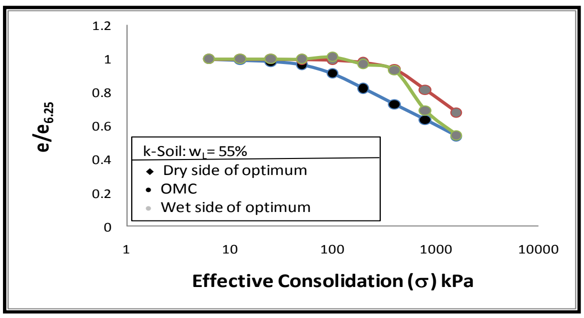


**Fig. 13: e/e$_{6.25}$ v/s log σ' plots of K-soil for Heavy Compaction under different placement conditions**

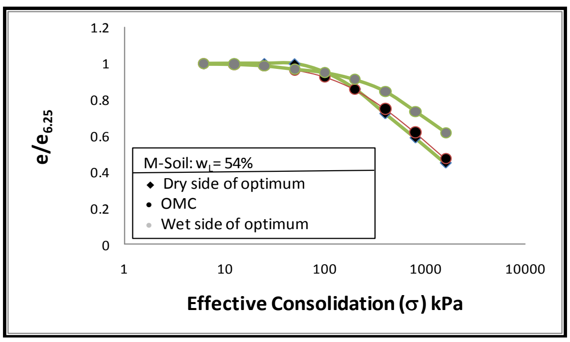


**Fig. 14: e/e$_{6.25}$ v/s log σ' plots of M-soil for Heavy compaction under different placement conditions**

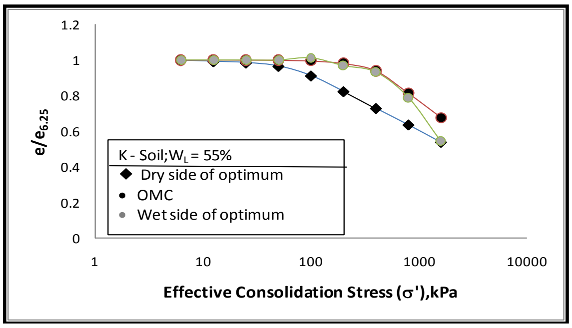


**Fig. 15: $e/e_{6.25}$ v/s log σ' plots of K-soil for Heavy compactionunder different placement conditions**

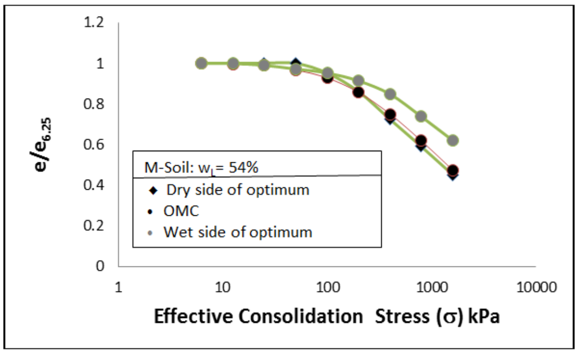


**Fig. 16: $e/e_{6.25}$ v/s log σ' plots of K-soil for Heavy Compactionunder different placement conditions**

**Effect of clay mineralogy**

The soils with different liquid limits were controlling the compressibility behavior, the e-log σ' curves of both K-soil and M-soil should have been identical when placement conditions are identical. This is due to fact that the soils of having identical low liquid limit group, exhibit different e-log σ' curves rule out the liquid limit as the controlling parameter. It suggests that, the clay mineralogical composition is the dominant mechanism which controls the soil behavior.

Figures 17 through Fig. 22 shows variation of e-log σ' curves for K and M soils having same liquid limit ($W_L$ = 46%) group subjected for both energy levels (light and heavy) under different placement conditions.

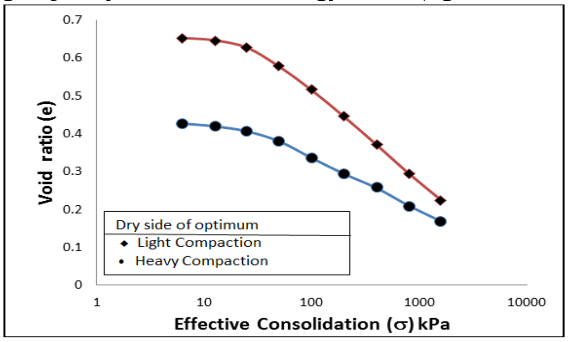


**Fig. 17: e-log σ'plots of K soils (Low liquid limit group)for light and heavy compaction energy levels (dry side of optimum)**

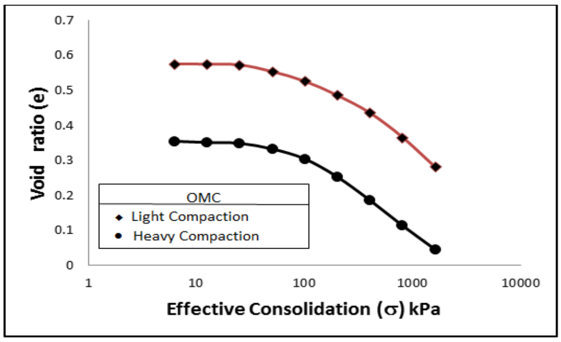


**Fig. 18: e-log σ' plots of K-soils (Low liquid limit group) for light and heavy compaction energy levels (OMC)**

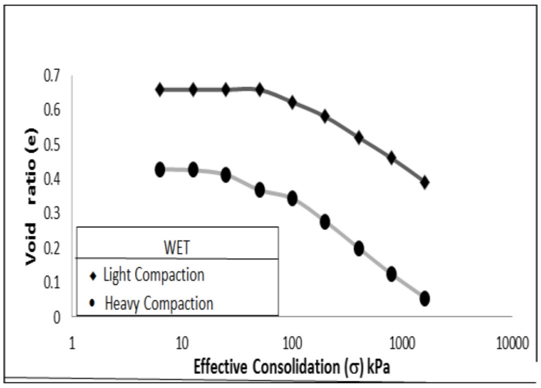


**Fig. 19: e-log σ' plots of K soils (Low liquid limit group ) for light and heavy compaction heavy energy levels (wet side of optimum)**

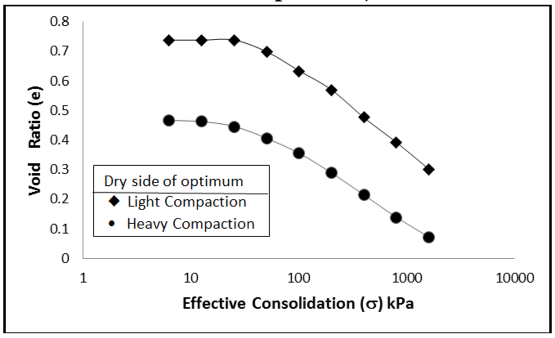


**Fig. 20: e-log σ' plots of M soils (Low liquid limit group) for light and heavy compaction energy levels (dry side of optimum)**

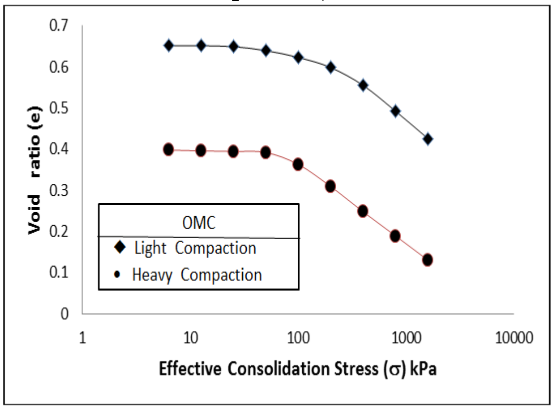


**Fig. 21: e-log σ'plots of M soils (Low liquid limit group)for light and heavy compaction energy levels (OMC)**

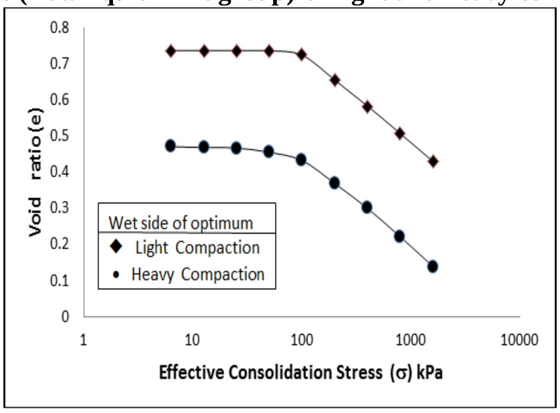


**Fig. 22: e-log σ' plots of M soils (Low liquid limit group) for light and heavy compaction energy levels (wet side of optimum)**

Figures 23 through 28 shows the variation of e-log σ' curves for K and M Soils of same high liquid group subjected to both light and heavy compaction tests for different placement conditions.

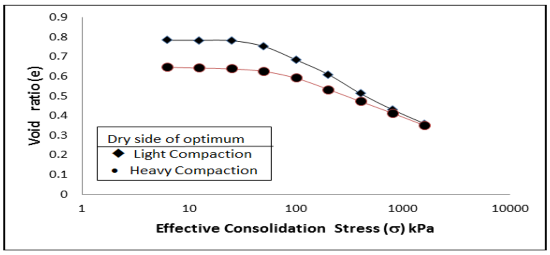


**Fig. 23: e-log σ' plots of K soils (High liquid limit group) for light and heavy compaction energy levels (dry side of optimum)**

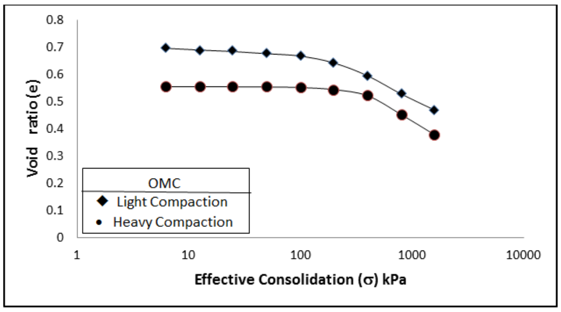


**Fig. 24: e-log σ' plots of K soils(High liquid limit group) for light and heavy compaction energy levels (OMC)**

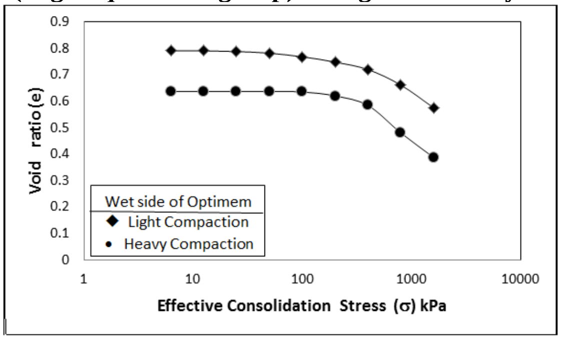


**Fig. 25: e-log σ' plots of K soils (High liquid limit group) for light and heavy compaction energy levels (Wet side of optimum)**

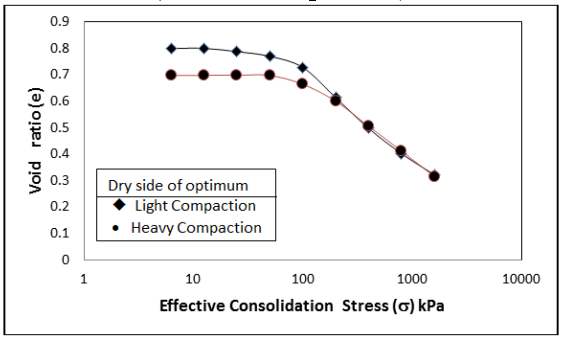


**Fig. 26: e-log σ' plots of M soils (High liquid limit group) for light and heavy compaction (dry side of optimum)**

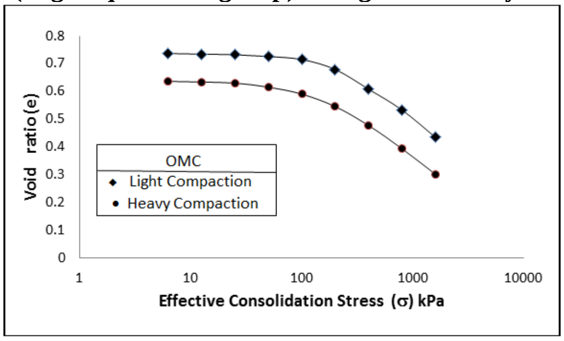


**Fig. 27: e-log σ' plots of M soils (High liquid limit group) for light and heavy compaction energy levels(OMC)**

ISSN: 2005-4238 IJAST

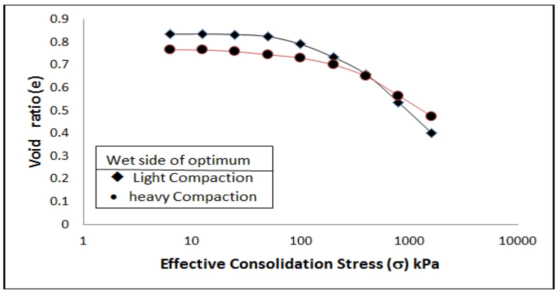


**Fig. 28: e-log σ' plots of M soils (high liquid limit group) for light and heavy compaction energy levels (wet side of optimum)**

From these figures i.e., figures 17 through 22 (e-log σ' curvesfor light compaction tests) and figures 23 through 28 (e-log σ' curvesfor heavy compaction tests),the following observations can be made.

The equilibrium void ratio for the seating consolidation pressure of 6.25 kPa of K and M soil for light compaction energy level is always more than heavy compaction energy levels i.e., more K soils and less in M soils.

Higher equilibrium void ratio of M soil at lower effective consolidation stresses than that of K soil indicates the dominance of double layer repulsion over the effect of flocculent fabric exhibited by K soil.

The above discussion indicates the effective of clay mineralogical composition and compactive energy of soils on their e-log σ' behavior.

## VI. CONCLUSIONS

Based on the detailed experimental investigation on compacted fine-grained soils having different clay mineralogy, the following observations can be made.

The soils compacted @ same placement densities have different e- log σ behaviour by virtue of different initial water contents.

Equilibrium void ratio on wet side compacted state @ any effective condition stress is always more than that of the dry state which highlights the role of placement conditions and soil fabric on e-log σ behaviour

Clay mineralogy plays a vital role in the behaviour of e-log σ curves i.e., higher equilibrium void ratio of montmorillonitic soils at lower effective consolidation stress than that of Kaolinitic soils indicates the dominance of double layer repulsion over flocculent fabric effect exhibited by Kaolinitic soils.

## VII. REFERENCES

1. Sridharan, A. (1991), 'Engineering behaviour of fine-grained soils – A fundamental approach', *Indian geotechnical journal*, Vol.21, No. 1, pp. 1-136.
2. Sridharan, A. and VenkatappaRao, G. (1973), 'Mechanism controlling volume change of saturated clays and the role of effective stress concept',*Geotechnique*, Vol. 23, No.3, pp. 359-382.
3. Rao, S.M. and Sridharan, A. (1985), 'Mechanism controlling volume change behaviour of kaolinite', *Clays and Clay Minerals,* Vol. 33, pp. 323-328.
4. Sathyanarayana Murthy, N. (1986), Factors and mechanism controlling volume change behaviour of fine-grained soils,Ph.D., thesis submitted to Indian Institute of Science, Bangalore, India.
5. Bowles, J.E., (1997), Foundation analysis and design, 5th edition, *The McGraw Hill Company,Inc. New York.*
6. Burmister(1951), 'The application of controlled test methods in consolidation testing', pp. 83-89.
7. Sridharan, A. Abraham, B.M. and Jose, B.T. (1991), 'Improved technique for estimation of preconsolidation pressure',*Geotechniqe,* Vol. 41, No. 2, pp. 263-268.