boulders, sands and stone carried down by glacier. It is also not fertile [1]

Kalomato soil found in Kathmandu valley is formed by lacustrine deposit. Because of its high swelling and shrinkage characteristics, *Kalomato* soil has been a challenge to the engineers since long. It is very hard when dry, but loses its strength completely as humidity penetrates the soil. *Kalomato* soil is made up of varying properties of minerals like Montmorinolite and kaolinite, chemicals like Iron Oxide and Calcium Carbonate and organic matter like humus. [2] *Kameromato* soil found in Ghattekhola, Kaski is also a residual deposit. Very few researches are done till date on the *Kameromato*, so its detailed geotechnical investigation is yet to be carried out. Chemical compositions of Kameromato samples of Kamerotar area of Bhaktapur primarily include clay minerals having MgO and K_2O with SiO_2 and Al_2O_3. On the other hand, the amount of Fe_2O_3, Na_2O and CaO in fine clay sample is found to be lower than in bulk. [3]Red soil is a tropically weathered soil with a high concentration of sesquixides of iron and/or alumina. It has correspondingly low content of alkalis and alkaline earths. It exists in wide range of chemical composition. Silica content varies from low to medium and exists usually as kaolinite, whenever it is found in substantial amount. The presence of iron oxides in various states of hydration gives red soil a range of colors. [4]

Consolidation is the gradual reduction in volume of a fully saturated soil of low permeability due to drainage of some of the pore water, the process continuing until the excess pore water pressure set up by an increase in total stress has completely dissipated. Consolidation theory is required for predicting both magnitude and rate of consolidation settlements to ensure serviceability of structures founded on a compressible soil layer. Terzaghi’s theory of consolidation makes certain assumptions about the consolidation process. He asserts that soil is homogeneous and fully saturated, solid particles and pore water are incompressible, flow of water and compression of soil are one dimensional (vertical), and strains are small. Darcy’s law is valid at all hydraulic gradients, but the most important assumption is that the coefficient of permeability and the coefficient of volume compressibility remain constant throughout the consolidation process. It is known that consolidation process is accompanied by decrease in void ratio which leads to decrease in coefficient of permeability. Effect of decrease in coefficient of permeability on time rate of settlement and pore water pressure needs to be investigated. The settlement rate and pore water pressure dissipation rate are mainly controlled by permeability of soil. Both laboratory and field tests show that permeability is varied during the loading and consolidation process. The variation of C_V with pressure has not received much attention. Review of some available data in past shows C_V is not constant but varies with consolidation pressure. An examination shows that C_V increases with consolidation pressure for kaolinite but decreases with consolidation pressure for montmorillonite. This inconsistency in the variation of C_V with consolidation pressure for different soils needs reconciliation.

This paper takes into account the change in coefficient of permeability with varying consolidation on three different fine grained soils of Nepal.

A. *Problems and issues*

- Life of different structures in Kathmandu valley and other places of Nepal built over fine grained soil are usually underestimated with constant coefficient of consolidation. Decrease in coefficient of consolidation with time decreases the settlement rate and increases the life of structures.
- Decrease in void ratio and subsequent decrease in the coefficient of permeability followed by slower dissipation of pore water pressure accompainies consolidation. This, in turn, makes it difficult to predict bearing capacity of soil.
- Different types of soil have different settlement patterns which largely depend on varying coefficient of consolidation. Hence comparative study of different types of fine grained soil is a must.

II. METHODOLOGY

A. *Soil Sampling Technique*

Open excavation were carried out. Undisturbed and disturbed samples were collected in thin walled sampler tubes. Sampling tubes were sealed at both ends by using wax and plastic to preserve moisture content. All the sample tubes were kept in a container and covered with wet jute bag followed by a plastic sheet to preserve the natural state of the samples.

Location of sample collection:
Kalomato - Chardobato, Bhaktapur Building site
Ratomato - Chormara,Nawalparasi
Kameromato - Ghatte Khola, Kaski

Fig. 1. Soil Sampling

B. *Soil Testing Method*

Soil testing included various testing methods to determine index, properties and consolidation characteristics of soil. Coefficient of consolidation was determined from consolidation test.

a) Consolidation Test

This test was performed to determine magnitude and rate of volume decrease that a laterally confined soil specimen undergoes when subjected to different vertical pressures.

Fig. 2. Consolidometer

Undisturbed Samples were extruded from sampling tube and cut with trimming tools to a cylindrical shape with 5.9 cm diameter and 2 cm height. Specimen was weighted and recorded, which was further used for determination of water content of the soil. Three different samples of undisturbed specimen were prepared and tested using consolidation test.

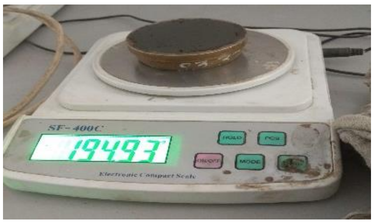

Fig. 3. Undisturbed soil sample

Extensive consolidation test procedure was deployed. Firstly, soil specimen was collected using consolidation metal ring. The ring was confirmed to be clean and dry and its weight, inner diameter and height were measured using weighing balance and calipers respectively. The metal ring was then pressed into the soil sample using hand and it was then taken out with soil specimen. As the soil specimen should project about 10 mm on either side of metal ring, excess soil content was trimmed on top and bottom of the rings using knife, spatula and fine metal wires. This excess soil was later used to measure the water content of soil sample.

For measuring the water content of the soil sample, firstly it was confirmed that the ring did not contain any soil on its outer part and weight of the metal ring with soil specimen was recorded. Then two porous stones were taken and saturated by boiling them for 15 minutes and submerging between 4 to 8 hours in distilled water. Consolidometer was then assembled by placing the parts of consolidometer from bottom to top in the following order: bottom porous stone, filter paper, specimen ring, filter paper and top porous stone. Loading pad was placed on top of the porous stone and the consolidometer was eventually locked using metal screws provided.

The whole assembly was mounted on a loading frame and centered such that the load applied was axial. Then initial trail load was applied which did not allow any swelling in the soil. In general, 5 kn/m^2 initial load was applied. The load was left until there was no change in dial gauge reading for at least 24 hours and final reading of dial gauge for initial load was recorded.

First load increment of double load was applied and stop watch was started immediately and readings from the dial gauge were recorded at various time intervals. In general, readings were taken at 0.25, 1, 2.5, 4, 6.25, 9, 12.25, 16, 25, 30 minutes, 1, 2, 4, 8, 24 hours.

In general, primary consolidation of soil (90% of consolidation) was reached within 24 hours. Hence, readings were recorded up to 24 hours.

Fig. 4. Dial gauge

Second load increment which was double the first load was applied and the same procedure was repeated as mentioned for the first load. Similarly double load increments was applied till 7 days and the same procedure was repeated. After the seventh day, increment of load was stopped and the reading was taken after every 24 hour for 3 to 9 months.

Finally, the assembly was removed from the loading frame and dismantled. The specimen ring was taken out and excess water was wiped out, after which the specimen ring weighted and recorded. The specimen was eventually placed in an oven and its dry weight was specified and recorded.

Calculation for Consolidation Test of Soil

Height of solids, $H_s = W_s/(G*\gamma_w*A)$

Height of Voids, H_v = H-Hs

Void ratio, $e = H_v/H_s$

Graphs of dial gauge reading vs. logarithm of Time were plotted to determine the coefficient of consolidation.

III. Results And Discussion

A. Grain Size Distribution

Figure 5 shows the detail grain size pattern of various soil samples tested. Hydrometer analysis done for finer particles of *Ratomato*, *Kalomato* and *Kameromato* shows 58 %,16 % and 8.5 % of clay particles (i.e., finer than 0.002 mm) respectively.

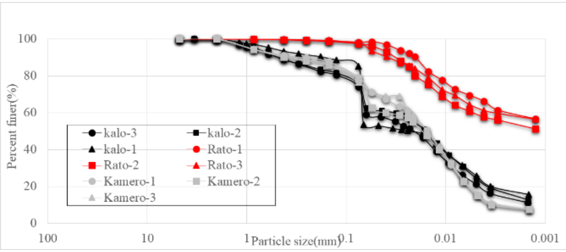

Fig. 5. Grain Size Distribution

B. Position of soil in Plasticity Chart

Figure 6 reveals the relationship between liquid limit and plasticity index (Casagrande's Plasticity Chart). Soil samples of *Ratomato* and *Kalomato* lie below A-line, whereas that of *Kameromato* lies above A-line.

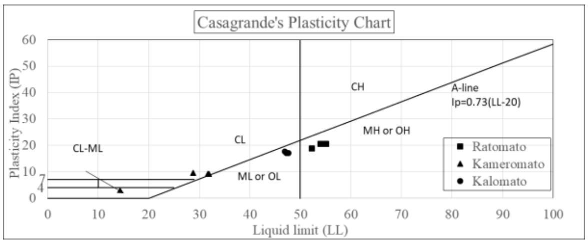

Fig. 6. Plasticity Chart

C. Activity

Figure 7 shows the activity of different samples tested based on plasticity index and percentage of clay fraction. Lines having slope of 0.75 and 1.4 (i.e., A=0.75 and A=1.4) and passing through origin are reference lines for classifying the soil. Based on this, *Ratomato* was classified as inactive and *Kalomato* and *Kameromato* were classified as normal active soil.

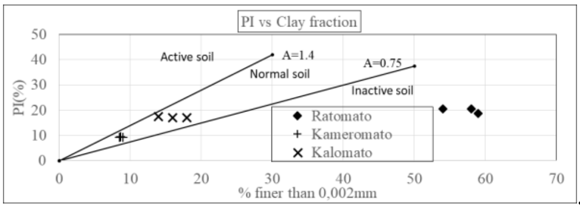

Fig. 7. Relationship between Plasticity index and Percentage of Clay Fraction

D. Basic Geotechnical properties

Detail description of various soil samples tested are presented in Table 1.

Table.1. Geotechnical Properties of three soils

Description	Ratomato	Kalomato	Kameromato
Liquid Limit	55.08	47.23	31.89
Plastic Limit	34.51	30.09	22.70
Plasticity Index	20.57	17.14	9.19
Shrinkage Limit (Lab)	22.55	19.01	20.55
SL(Casagrande'chart)	24	19	20
Sp.gravity	2.55	2.45	2.66
Clay fraction(%)	58	16	8.5
Organic content(%)	0.67	1.95	0.35
Soil type	MH	ML	CL
Natural(w%)	30.33	35.53	20.69
Liquidity Index(IL)	-0.18	0.78	-0.16
IL(Classification	Hard	V.soft to soft	Hard
Activity	0.35	1.07	1.08

E. Consolidation Test

Figure 8 shows the coefficients of consolidation (C_v) of *Kameromato, Kalomato* and *Ratomato*. The value of C_V for *Kameromato* varied from $2.46*10^{-7}$ m^2/min to $9.16*10^{-5}$ m^2/min. For *Kalomato* the value varied from $5.55*10^{-7}$ m^2/min to $9.13*10^{-6}$ m^2/min. Likewise, for *Ratomato* the value of C_v varied from $4.92*10^{-7}$ m^2/min to $3.28*10^{-6}$ m^2/min. Consolidation test was performed for 7 days where the load varied from 0.904 ton/m^2 to 57.856 ton/m^2 while maintaining one load for 24 hours.

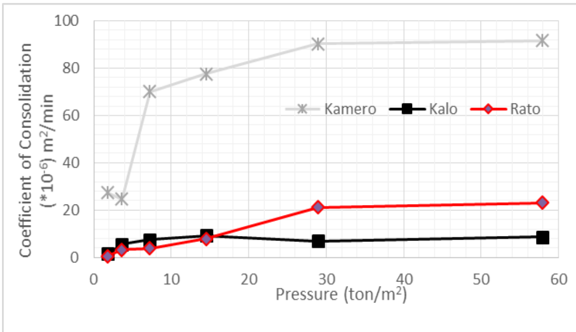

Fig.8. Coefficient of consolidation of three soil

F. Variation of Coefficient of Consolidation

Figure 9 shows the change in coefficient of consolidation of Kameromato and *Kalomato* within a period of 90 days at constant load intensity of 57.586 ton/m^2. The graph shows that there is significant decrease in C_V for both *Kameromato* and *Kalomato*. The value of C_V for *Kameromato* decreased from $9.15*10^{-5}$ m^2/min to $4.81*10^{-5}$ m^2/min which was 47.5%. Similarly for *Kalomato*, C_V decreased from $8.73*10^{-6}$ m^2/min to $3.4*10^{-6}$ m^2/min which was 53%.Similarly, variation of coefficient of consolidation of *Ratomato* in a period of 270 days. The value of C_V varied from $2.31*10^{-5}$ m^2/min to $6.52*10^{-6}$ m^2/min which was 71.79 %. At the end of 3 months final water content of kamero mato and kalo mato was 20.34% and

32.4% respectively. For rato mato at the end of 9 months final water content was 23.16%.

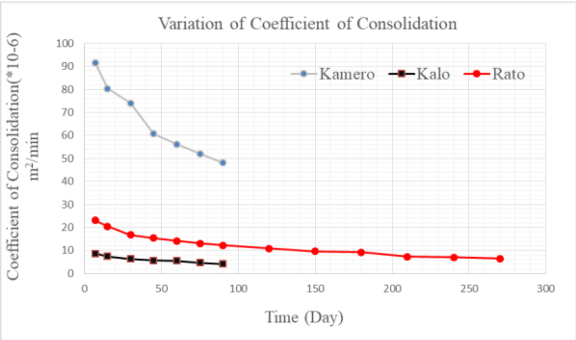

Fig. 9. Variation of coefficient of consolidation of Kameromato, Kalomato and Ratomato

G. *Mineralogical composition*

Minerals found in *Kameromato*, *Kalomato* and *Ratomato* did not possess pure chemical composition. Detailed mineralogical identification and quantification showed that chlorite was the major constituent of *Kameromato* (60%), also shown in Figure 10. Figure 11 shows quartz as the major element for *Kalomato* (60%) and protoenstatite as the second major element (26%). Similarly, Figure 12 shows quartz as the major mineral in *Ratomato* (80%). Mohs value of quartz is 6 which makes *Ratomato* and *Kalomato* hard. Mohs value of chlorite is 2.5 which is comparatively lower than that of quartz. This makes *Kameromato* soft in comparison to *Kalomato* and *Ratomato*. Percentage of quartz was found to be more in *Ratomato* than in *Kalomato*. This makes coefficient of consolidation of *Ratomato* more than that of *Kalomato*. Figure 11, Figure 13 and Figure 15 shows the mineral peak identification of kamero mato, kalo mato and rato mato respectively

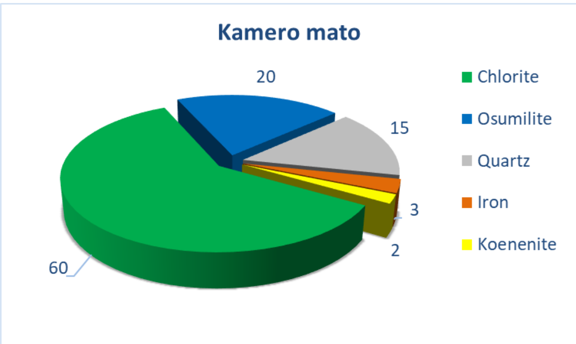

Fig.10. Kameromato Minerals

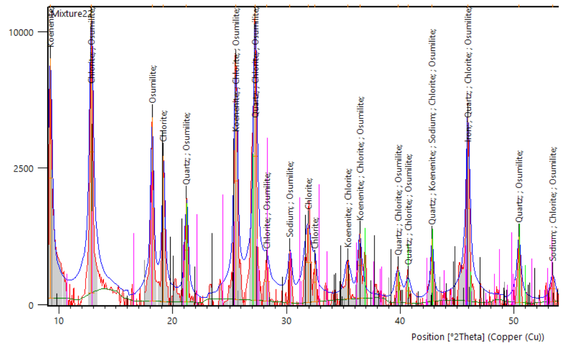

Fig. 11. Kamero mato peak identification

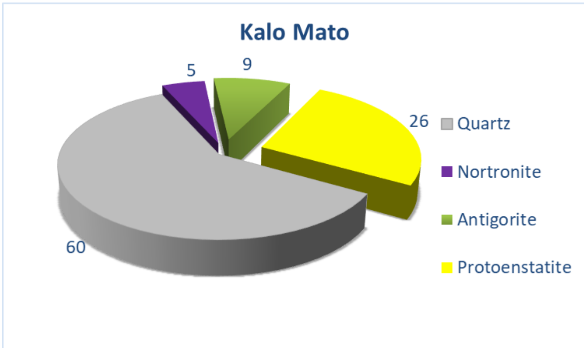

Fig. 12. Kalomato minerals

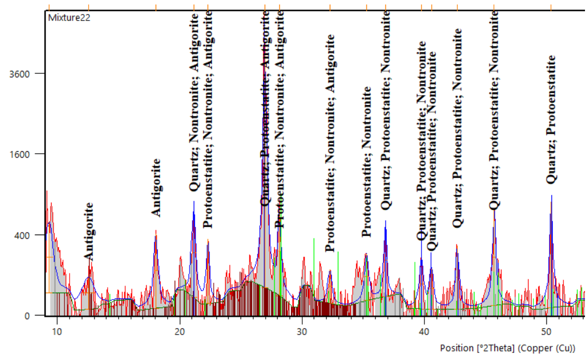

Fig. 13. Kalo mato peak identification

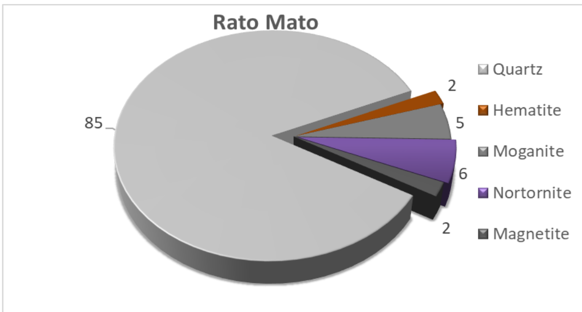

Fig.14. Ratomato Minerals

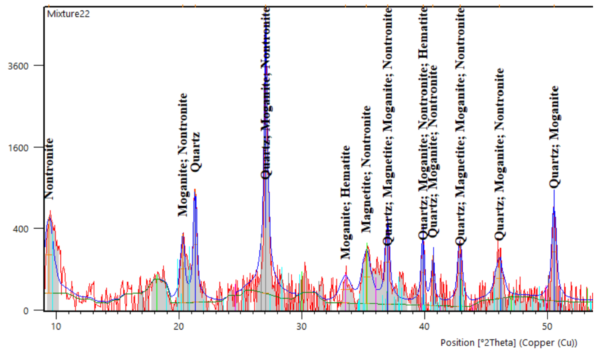

Fig. 15. Rato mato peak identification

IV. CONCLUSION

Results of the study indicate that the coefficient of consolidation is not constant but varies with the change in consolidation pressure and also with time. Significant change in coefficient of consolidation of *Kameromato* and *Kalomato* was witnessed which was 47.5% and 53% respectively within a period of 3 months at a constant consolidation pressure of 57.586 ton/m^2. Similarly for *Ratomato*, the change was 71.79% in a period of 9 months. Hence, it can be concluded that the effect of decrease in void ratio at later time of consolidation leads to decrease in coefficient of consolidation. The variation in C_v thus may mislead in predicting the actual settlement of the structure. A detailed study is required to find the change in C_v of different soil types at different consolidation pressures.

Based on the detail mineralogical identification, quantification and Mohs values, quartz content is more in *Ratomato* and least in *Kameromato*. Major minerals found in Ratomato are hard, while those found in *Kalomato* are moderately hard and those found in *Kameromato* are soft, as its major mineral (chlorite) has low Mohs value. The reason behind higher value of Cv for *Ratomato* in comparison to *Kalomato* is the availability of higher concentration of quartz in it.

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