UNDRAINED RESPONSE OF SOILS UNDER VARYING PARAMETERS

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Abstract - *The undrained shear response of equally loaded isotropically consolidated saturated clay samples can be characterised by a change in the excess pore pressure generation in the sample. In this thesis work Consolidated undrained triaxial tests were performed in undrained conditions on clay specimens collected from three regions of Kuttanad in Allapuzha district for studying the effect of confining pressure. The objective of the work is to obtain data that can be used for interpretation of results for geotechnical analysis, facilitating the assessment of the over consolidation ratio with different densities and study of stress paths .The engineering properties of the clay samples are obtained and the relation between deviator stress , pore water pressure and principal effective stress ratio with varying densities and OCR is found.*

The results of this study revealed that the OCR significantly affects the pore water pressure in compacted clay samples .In normally consolidated clay the deviator stress increases with strain , whereas for over consolidated clay ,the deviator stress decreases with increase in strain. Effective stress ratio decreases with strain for normally consolidated clay and effective stress ratio increases for over consolidated clay with increase in strain. The peak strain values are obtained at 15 – 20 % strain. A suitable model is obtained for various parameters by R code software.

***Key Words*: Pore water pressure, Consolidated undrained triaxial test, OCR's (over consolidation ratio), Deviator stress**

1.INTRODUCTION

Pore fluid pressures which develop within soil masses because of both mechanical and physico-chemical effects influence the magnitude of the intergranular or effective stresses. In many cases, soil behaviour in shear and compression is controlled by the intergranular stresses. Recent construction in the world is opting for several major structures to be built on cohesive soils. Thus , structures on clayey soils undergoing repeated stresses have been subject to effect of pore water pressure increase resulting in large deformation . Positive and negative excess pore water pressures generation is related to contractive and dilative responses. Pore water pressure increase or decrease continues until it reaches critical state (known as steady state for undrained tests).The over consolidation ratio (OCR) is a parameter, which is related to historical changes in the state of stress in the subsoil.

The paper presents interpretation for results of geotechnical analysis, taking into account the assessment of the over consolidation ratio. Here the densities of the soil specimens are varied and the corresponding OCR variation is found with respect to other parameters .

1.1 METHADOLOGY

In this study, clay samples from three regions of kuttanad , ie, Edathua , Thalavady and Kidangoor is taken and consolidated undrained test in triaxial apparatus was done in the Soil Mechanics Laboratory of the Department of Civil Engineering in Saintgits college of engineering ,pathamuttom , Kottayam. In a consolidated undrained triaxial test (CU) , the specimen is allowed to consolidate in the first stage and drainage is permitted till the consolidation is complete. In the second stage when the specimen is sheared , no drainage is permitted. It is also called a R test.

The soil specimens were compacted by hand tamping. The soils were tested in a series with different OCRs ,ie,2, 2.5 and 10 and effective consolidation stresses, 50 , 100, 150 and 500 kPa. Prior to shearing, the specimens were isotropically consolidated by several small loading increments up to the maximum effective confining pressure, so as to complete primary consolidation on the specimens. The overconsolidated specimens were later unloaded to the desired effective confining pressure σ_c to achieve the required OCR .Again the density is varied and specimens were tested with different OCR's and effective consolidation stresses .The testing program encompassed three over consolidation ratios (OCRs), 2 , 2.5 and 10 . The results of this study revealed that the OCR significantly affects the pore water pressure in compacted clay samples. The samples were made free from roots , organic matters etc. clayey samples were air dried for experimental purpose.

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Table -1: Physical properties of clayey soil

Sl no	Properties	Thalavady TV	Edathua ED	Kidangoor KR
1	Moisture content , w	81.8 %	110 %	98 %
2	Specific gravity,G	2.22	2.27	2.35
3	Cohesion , C	11 kN / m²	21 kN / m²	23 kN / m²
4	Angle of internal friction ,ø	3º	5º	4º
5	Amount of clay	52 %	65 %	53 %
6	Amount of silt	40 %	15 %	22 %
7	Amount of sand	8 %	20 %	25 %
8	Uniformity coefficient , Cu	70	10	30
9	Compression index , Cc	1.157	1.225	30
10	Liquid limit, LL	81 %	172 %	98 %
11	Plastic limit, PL	21 %	69.9 %	25 %
12	Plasticity index, PI	60 %	102 %	73%
13	Maximum dry density ,MDD	1.34 g/cc	1.29 g/cc	1.26 g/cc
14	Optimum moisture content, OMC	35 %	29 %	33.5 %
15	Organic content	7.05 %	7.27 %	6.54 %

2. TYPICAL TEST RESULTS OF CLAY SAMPLE

In this study mainly three densities are taken for test ie, 1.29 g/cc , 1.24 g/cc and 1.22 g/cc. For each density five confining pressures are applied ,ie, 0.5 bar , 1 bar , 1.5 bar and 5 bar and corresponding graphs are drawn.

Fig -1 (a) :Clay sample after test

Fig -1 (b): Clay sample

EDATHUA SAMPLE – DENSITY 1.26 g/cc

NCC(normally consolidated clay)

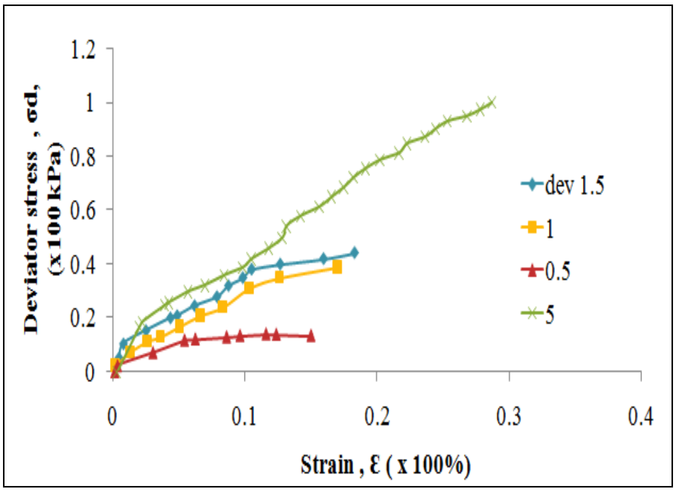

Fig -2(a) : Deviator stress Vs Strain

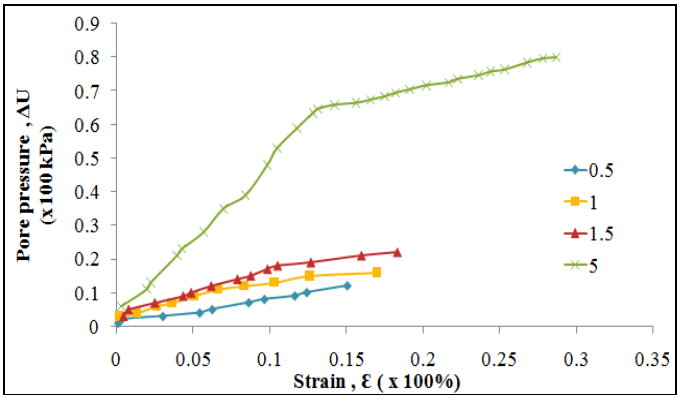

Fig 2(b) : Pore pressure Vs Strain

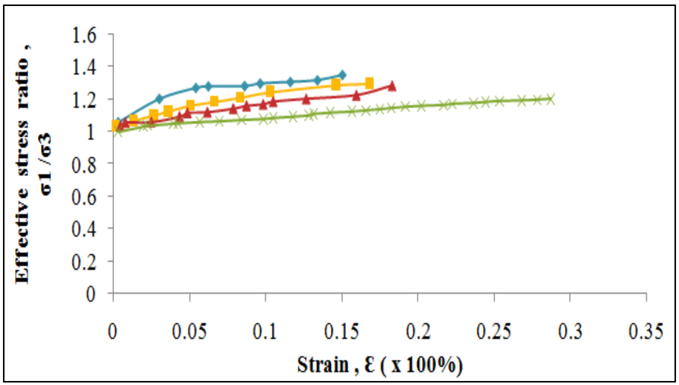

Fig 2(c) : Effective stress ratio Vs Strain

EDATHUA SAMPLE – DENSITY 1.24 g/cc

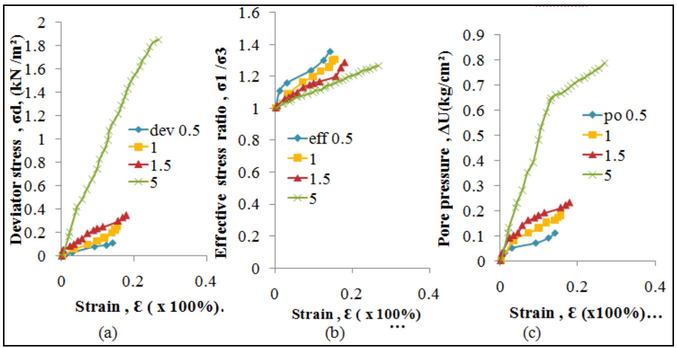

Fig -3(a): Deviator stress Vs Strain **Fig 3(b)** : Effective stress ratio Vs Strain **Fig 3(c)** : Pore pressure Vs Strain

EDATHUA SAMPLE – DENSITY 1.22 g/cc

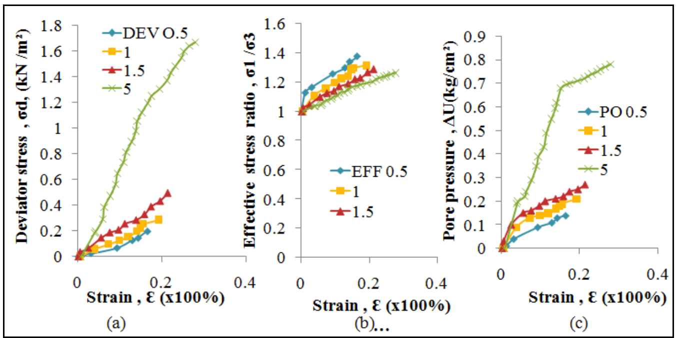

Fig -4(a): Deviator stress Vs Strain **Fig 4(b)** : Effective stress ratio Vs Strain **Fig 4(c)** : Pore pressure Vs Strain

From the above interpretations it is seen that , as the density increases , the deviator stress and pore pressure increases with strain for normally consolidated clay (NCC) as shown in fig 2(a),2(c), 3(a), 3(c), 4(a) and 4(c) .Effective stress ratio also increases with strain but ,decreases as confining pressure increases and density increases, as shown in fig 2(b),3(b) and 4(b). The pattern of the graph is same for all the clay samples , ie , for Thalavady and Kidangoor according to their densities.

3. EFFECT OF OCR ON CLAY SAMPLE

EDATHUA SAMPLE – DENSITY 1.26 g/cc

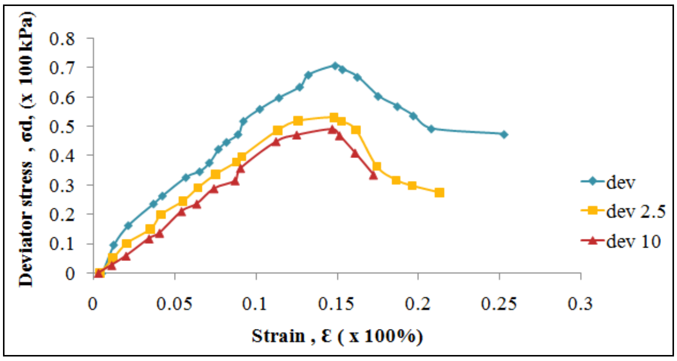

Fig -2(a) : Deviator stress Vs Strain

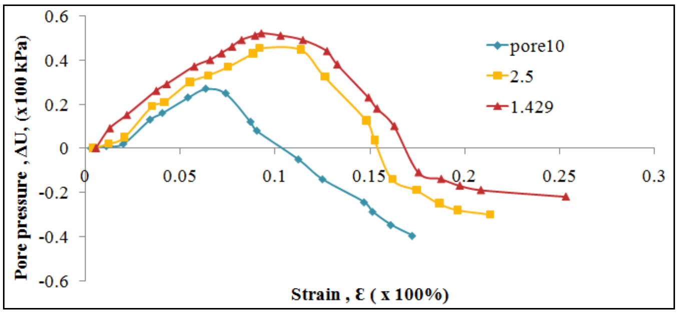

Fig -5(b) : Pore pressure Vs Strain

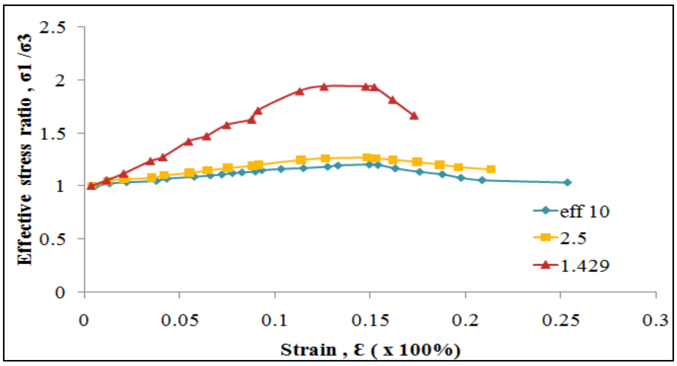

Fig -5(c) : Effective stress ratio Vs Strain

The effect of the OCR on the normalized pore water pressure, Δu , is presented in Fig. 5(b). The value of Δu is consistently lower at a higher OCR. For a high-OCR, pore water pressure typically increases to become a positive pressure and then decreases to negative. However, for a normally consolidated specimen, the pore water pressure generally develops as a positive value and increases with an increasing level of Δu. This result is most likely because at a high OCR, the soil structure of compacted clay has a lower capacity for volume reduction in undrained conditions, which translates into a negative pore water pressure buildup. The concepts for the pore pressure behaviour in overconsolidated (OC) clay were drawn mainly from Mitchell (1976), and an explanation of why the pore water pressure is negative in overconsolidated clays during cyclic loading was given in Dobry and Vucetic (1987).

Number of particle bonds increases with the OCR because of the larger maximum past pressure, σ_3, at the time the bonds were formed. However, the closer proximity of clay particles under this larger σ_3, causes greater repulsion forces. The attraction forces existing between particles and at the bonds and the repulsion forces between particles and the pore water pressure must be at all times in balance with the imposed total vertical stress. More specifically, in OC clay, the larger repulsion forces are counteracted by numerous particle bonds. In constant-volume, undrained conditions, this results in negative pore water pressures.

4. STRESS PATHS

The stress path is the change in horizontal stress as the pore pressure changes .There are mainly two coordinates , ie , $p= (\sigma_1 + \sigma_3)/2$ and $q = (\sigma_1 - \sigma_3)/2$ from this the effective stress coordinates of the stress points p' and q' are given by p'= (p-u)and q' = q. Lambe (1964,1967)and Lambe and Whitman (1969)have demonstrated the usefulness of the stress path as a method for solving practical geotechnical problems involving stability and deformation.

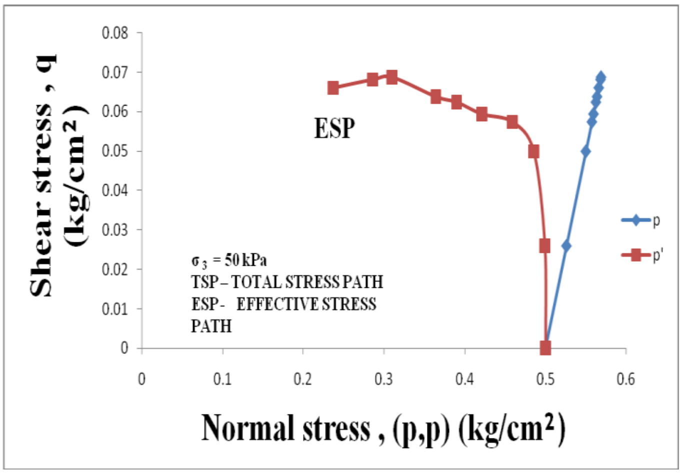

Fig- 6(a): Total and effective stress path for confining pressure = 50 kPa

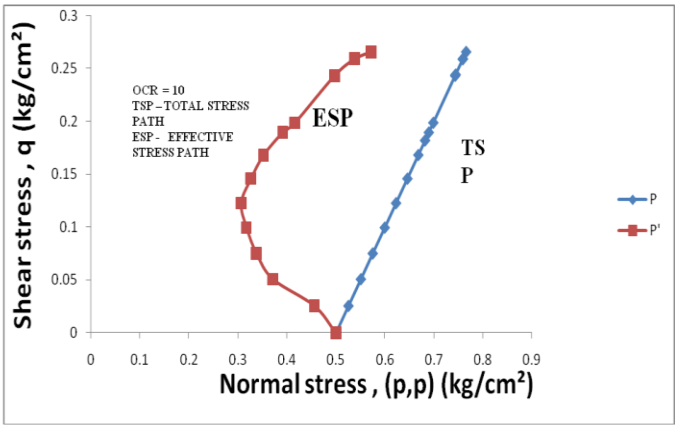

Fig 7 (b): Total and effective stress path for OCR = 10 (OCC)

In a normally consolidated clay, TSP for axial compression at constant cell pressure is a straight line inclined at 45º and ESP lies to the left because σ'= (σ-u)as in fig 7(a).The pattern of TSP and ESP are same for 100 , 150 and 500 kPa confining pressures. In an over consolidated clay ,TSP is same as normally consolidated clay , since the axial compression is done in constant cell pressure.ESP is to the left while starting because pore water pressure is positive and then as the pore water pressure increases it becomes negative as shown in fig 7 (b) and the pattern is same for OCR = 2 and OCR = 2.5.

5. R CODE STATISTICAL ANALYSIS

Multiple linear regressions is done in this project. The model having a single study variable and many explanatory variables called multiple linear regression models.

```
den<-c(1.26,1.24,1.22)
strain<-c(0.183,0.2145,0.1793)
devi<-c(0.439,0.4153,0.2983)
eff<-c(1.337,1.2866,1.2754)
pore<-c(0.27,0.25,0.23)
da<-data.frame(den,strain,devi,eff,pore)
pairs(da)
```

```
lm(pore~devi+den+eff+strain, data = da)

##
## Call:
## lm(formula = pore ~ devi + den + eff + strain, data = da)
##
## Coefficients:
## (Intercept)         devi          den          eff       strain
##  -9.900e-01   -3.065e-15    1.000e+00           NA           NA
```

Fig 8(a): Regression analysis of normally consolidated clay by unconsolidated undrained test

Equation obtained is :

Pore pressure = -3.065 X 10 ^(-15) deviator stress + 1 x 10 ^ (0)density – 9.900 x 10 ^(-1)

```
den<-c(1.26,1.24,1.22)
strain<-c(0.1482,0.0882,0.0756)
devi<-c(0.5307,0.5132,0.481)
eff<-c(1.265,1.2566,1.243)
pore<-c(0.47,0.43,0.41)
da<-data.frame(den,strain,devi,eff,pore)
```

```
pairs(da)
```

```
lm(pore~devi+den+eff+strain, data = da)

##
## Call:
## lm(formula = pore ~ devi + den + eff + strain, data = da)
##
## Coefficients:
## (Intercept)        devi         den         eff      strain
##      -2.828      -1.361       3.190          NA          NA
```

Fig 8(b):Regression analysis for OCR variation by unconsolidated undrained test

Equation obtained is :

Pore pressure = -1.361 x 10 ^(0) deviator stress + 3.190x 10 ^ (0)density – 2.828x 10 ^(0)

Strain and principal effective stress ratio does not have much effect in this concept.

3. CONCLUSIONS

Consolidated undrained, triaxial test were conducted on clay samples from three regions to study the response of density and OCR variation. The tests encompassed three OCRs (1.429, 2.5,and 10) and four confining pressures thus allowed for a preliminary evaluation of the effect of the OCR on density and pore water pressure response.

We can conclude form test that, Peak deviator stresses at failure strain level are increasing with increase in the density of samples, but the pore pressures decreases with increase in the densities irrespective of all confining pressures surrounded by the sample. Clay samples moulded at low densities possess high contraction behaviour and exhibit less resistance to shear loads when to compared at high densities irrespective of all confining pressures. The reduction in mean effective normal stress is increasing with decrease in the density of clay samples. Effect of confining pressure is to be expressed in terms of normalised stress ratios due to the test samples are subjected to different pressures. Peak deviator stress ratios are decreasing with increase in the confining pressures, but the pore pressures increases with increase in pressures irrespective of all density of samples.

As OCR value increases , the deviator stress values increases to a point and then decreases . Pore pressure increases and then becomes negative as OCR values increases. Principal effective stress ratio increases as OCR value increases with density. From the regression analysis the following observations are obtained :

- **EDATHUA NCC**

Pore pressure = -3.065 X 10 ^(-15) deviator stress + 1 x 10 ^ (0)density – 9.900 x 10 ^(-1)

- **EDATHUA OCR VARIATION**

Pore pressure = -1.361 x 10 ^(0) deviator stress + 3.190x 10 ^ (0)density – 2.828x 10 ^(0)

- **KIDANGOOR NCC**

Pore pressure , Δu= -1.311 x 10 ^(-12) σ_d+ 1x 10 ^ (0)density – 1.02x 10 ^(0)

- **KIDANGOOR OCR VARIATION**

Δu= -1.749 x 10 ^(-14) σ_d+ 1.5x 10 ^ (0)density – 1.37x 10 ^(0)

- **THALAVADY NCC**

Δu= -0.3425 x 10 ^(0) σ_d+ 0.3955x 10 ^ (0)density – 0.4072x 10 ^(0)

- **THALAVADY OCR VARIATION**

Δu= 1.515 x 10 ^(-13) σ_d+ 3x 10 ^ (0)density – 3.25x 10 ^(0)

The relations will be useful not only for single person but also for the government agencies, who are involved in construction of building work and other structures in the study area.

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