Prediction of behavior of soft soil under critical state and its comparison with constitutive model

1Sonia Ray, 2Harapriya Panda, 3P.K.Pradhan, 4C.R. Mohanty
1RITE Khurda Odisha
2Thakur college of Engineering Mumai,India
3,4VSSUT Burla Odisha,India

Abstract— Any type of soil have its own structural arrangement. Generally soft soil such as clay consists of two phase mixture of particles and water and they exhibit very complex behavior when applying load on it. This complex behavior can be divided as elastic and elasto-plastic. Therefore critical state theory and different constitutive model like Modified Cam Clay (MCC) is used to describe the challenging problem of transition zone from elastic to elastoplastic behavior. This paper shows experimental determination of stress-strain behavior of soft soil by conducting triaxial tests in both drained and undrained condition with confining pressure 100kpa, 200kpa and 300kpa. This paper also discuss yield surfaces of soft soil with five MCC model parameters.

Index Terms— constitutive model, model parameters, triaxial test, yield surface.

I. INTRODUCTION

The soil generally found near the pond and river bed is classified as soft soil like clay. These soft clays are belong from the group of fine grained soil and exhibit low shear strength and high compressibility. In order to explore the undrained and drained behavior of soft soil, a suitable constitutive model of soil that is MCC model successfully explain the stress-strain behavior has to be employed. Because of complex behavior of clay the elastic soil model is not enough for explaining its behavior. Therefore many elasto-plastic soil models have been proposed in past decades. The first critical state model which describes the behavior of soft soil, the Cam-Clay (CC) and Modified Cam Clay(MCC) were formulated by researchers at Cambridge University. The early development of soil modeling are often referred to Critical State Of Soil Mechanics (CSSM) was introduced by Scholfield and Worth (1968). The CSSM explains three well known concept that is the critical state line (CSL), normalization with respect to pre-consolidation pressure and the state boundary surface(SBS) . Drucker (1956,1961) proposed a model known as elastic-plastic model for the strain-hardening behavior of a soil [1]. Roscoe et al (1958) was the first to discuss the soil behavior in triaxial tests and the yield surfaces of soil.

Roscoe et al (1963) was proposed a complete mathematical model of soil behavior and called as Cam-Clay model [2] [3]. Roscoe and Burland (1968) developed the Modified Cam Clay model, which considers both plastic volumetric strain and plastic shear distortion. This model successfully reproduces the major deformation characteristics of soft clay. The main improvement of MCC model from CC model is the prediction of the coefficient of the earth pressure at rest for one dimensional normal compression [4].

A satisfactory constitutive model is one which shows the complete material behavior for all stress and strain paths and the model parameters should be determine through a reasonable number of tests. The number of parameters required in such model can range from two to over twenty parameters. The theory of soil behavior known as critical state soil mechanics was developed from the application of the theory of plasticity. Most of the formulations in critical state models have been carried out in the conventional triaxial stress space [6].

This paper mainly discusses undrained and drained shear strength of soft soil by conducting conventional triaxial tests. This triaxial tests were conducted with confining pressure of 100kpa, 200kpa and 300kpa. The purpose of this test is to find out the stress-strain behavior of soil and analyze it with MCC model. With the application of this MCC model, yield surfaces of soil are drawn by matlab coding.

II. EXPERIMENTAL PROGRAMME

2.1. MATERIALS USED

In order to obtain the geotechnical characteristics and the stress-strain behavior the soils were collected from different location of Sambalpur district in the state of Odisha. The soils were collected from a depth of 3to 5 meters and were air dried before the commencement of experiments.
2.2. TESTS FOR PHYSICAL PROPERTIES

Initially experiments were conducted to find out different properties of soil such as index properties, grain size distribution etc. then triaxial test were conducted with drained and undrained condition to investigate stress-strain response of soil.

<table>
<thead>
<tr>
<th>Index property</th>
<th>Experimental value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid limit</td>
<td>21.8</td>
</tr>
<tr>
<td>Plastic limit</td>
<td>17.9</td>
</tr>
<tr>
<td>Plasticity index</td>
<td>3.9</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.68</td>
</tr>
<tr>
<td>Soil type</td>
<td>Silt</td>
</tr>
<tr>
<td>USCS</td>
<td>ML</td>
</tr>
</tbody>
</table>

2.3. TRIAXIAL TESTS

2.3.1. Consolidated undrained test

After air drying, collected sample was sieved through 425µ sieve and the weight of sample to be used for specimen preparation was found out. The samples were prepared in a mould of 38mm diameter and 76mm length. Triaxial tests were conducted on three identical specimen at confining pressure 100kpa, 200kpa and 300kpa. In this test no drainage is allowed during the application of deviator stress.

2.3.2. Consolidated drained tests

The preparation of specimens were same as that of undrained triaxial tests. They were kept for consolidation for 24 hours. In this test drainage is permitted so that full consolidation occurs.

III. TEST RESULTS AND ANALYSIS

3.1. MODELLING

The experimental results of triaxial tests and the selection of model parameters are discussed here. This paper also discusses the comparison study of experimental results and the MCC model prediction. The parameters of MCC model are: λ - the slope of the normal compression line and CSL in v-lnp’ space, κ - the slope of swelling line in v-lnp’ space, M - slope of CSL in q-p’ space, N – the specific volume of normal compression line, μ - poisson’s ratio. The yield function for Modified Cam-Clay often written as

\[ f = q^2 - M^2 (p' + \sigma_0^V - p') \]

The model parameters obtained from conventional triaxial consolidated undrained and drained test were mentioned in table number 2 and 3 respectively. The comparision study of stress-strain behavior of experimental values obtained from both drained and undrained tests with the application of MCC model and also their respective yield surfaces using matlab programming are shown in figs 1.1(a) to 2.3(c)

<table>
<thead>
<tr>
<th>sample number</th>
<th>λ</th>
<th>K</th>
<th>M</th>
<th>N</th>
<th>μ</th>
</tr>
</thead>
<tbody>
<tr>
<td>100kpa</td>
<td>0.29</td>
<td>0.05</td>
<td>1.22</td>
<td>3.3</td>
<td>0.3</td>
</tr>
<tr>
<td>200kpa</td>
<td>0.25</td>
<td>0.05</td>
<td>1.22</td>
<td>3.21</td>
<td>0.3</td>
</tr>
<tr>
<td>300kpa</td>
<td>0.23</td>
<td>0.04</td>
<td>1.22</td>
<td>3.24</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Fig -1.1(a)

Fig -1.1(b)

Fig -1.3(a)
Table – 3 (parameters used for modeling triaxial consolidated drained test)

<table>
<thead>
<tr>
<th>sample number</th>
<th>( \lambda )</th>
<th>K</th>
<th>M</th>
<th>N</th>
<th>( \mu )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample at 100kpa</td>
<td>0.17</td>
<td>0.03</td>
<td>1.15</td>
<td>2.69</td>
<td>0.3</td>
</tr>
<tr>
<td>200kpa</td>
<td>0.12</td>
<td>0.02</td>
<td>1.15</td>
<td>2.51</td>
<td>0.3</td>
</tr>
<tr>
<td>300kpa</td>
<td>0.15</td>
<td>0.03</td>
<td>1.15</td>
<td>2.74</td>
<td>0.3</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

This paper mainly addresses on the undrained and drained shear strength of soft soil. The test data were plotted in terms of the stress-strain invariants defined by the MCC model.

From the analysis and comparison of the numerical and experimental test data, it was found that in undrained case of sample is not satisfactory or not simulated to the MCC prediction. Because of pore water pressure it was noted that the MCC model lacks the undrained component of shear strain.

In drained case it was noted that the MCC model adequately predict the stress-strain response based on shear strain versus deviatoric stress plots.

The model parameters was found out and this model shows the critical state or the failure point of the soil sample satisfactorily after initial yielding.
In the future, the research can be carried out for coarse-grained soil by adopting MCC model to know the response. The MCC model prediction can also be analysed for cohesionless soil by labrotary testing from direct shear test and can be plotted by using plaxis software for which the model analysis will be better.

REFERENCES


