Unstable zone of sand-silt mixture using static triaxial tests

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Flow liquifaction in which large deformation produces can occur when the shear stress required for static equilibrium of soil mass is greater than the shear strength of soil in its liquified state. Flow slides triggered by monotonic loading have been observed by natural soil deposits and man made fields. Present work deals with the identification of unstable zone of sand with fines content using static triaxial tests. A series of undrained monotonic triaxial compression tests were conducted on reconstituted saturated samples of clean sand with variation in silt content as 0 %, 15 %, 25 % and 35 %. The influence of different parameters such as relative density, confining pressure and fines content on deviator stress and excess pore pressure was investigated. It was observed that the limiting fines content and relative density played a vital role in deciding the undrained behavior of a mixture of sand and silt. The zone between effective stress failure line and peak pore pressure line was regarded as an unstable zone which increased with fines content up to the limiting fines content.

Keywords: triaxial test, unstable zone, sand silt mixture, undrained.

INTRODUCTION

Instability has been observed to occur for saturated loose sand under undrained conditions and for saturated medium to dense sand under strain-controlled conditions. The term instability refers to a behaviour in which large plastic strains are generated rapidly owing to the inability of a soil element to sustain a given load or stress. In recent years, instability has been considered as one of the failure mechanisms that lead to flow slides or collapse of granular soil slopes in a number of case studies (Sheffield dam and Lower San Fernando Dam). The behavior of silty sandy soils such as hydraulic fills, landfills or alluvial deposits not clearly known during earthquake. Therefore, a thorough understanding of unstable behavior of silty sand is needed. the objective of the this work is to investigate the effect of fines on the unstable zone.

EXPERIMENTAL INVESTIGATION

The clean sand used in these experiments was silica sand obtained locally and has been classified as SP according to the unified soil classification system (USCS). Silt used in this study is non plastic and obtained from quarry dust. Fig. 1 indicates grain size distribution curves of clean sand, silt and various sand silt mixture. The index properties of clean sand and silt are shown in Tab. 1.

<table>
<thead>
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<th></th>
<th>G</th>
<th>D50</th>
<th>D10</th>
<th>D90</th>
<th>( \gamma_{\text{max}} )</th>
<th>( \gamma_{\text{min}} )</th>
<th>( e_{\text{max}} )</th>
<th>( e_{\text{min}} )</th>
<th>( C_u )</th>
<th>( C_s )</th>
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</thead>
<tbody>
<tr>
<td>Sand</td>
<td>2.416</td>
<td>0.28</td>
<td>15.16</td>
<td>13.98</td>
<td>0.745</td>
<td>0.609</td>
<td>2.24</td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>2.751</td>
<td>0.042</td>
<td>15.70</td>
<td>11.91</td>
<td>1.175</td>
<td>0.753</td>
<td>3.6714</td>
<td>1.1633</td>
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</table>
The tests were conducted on clean sand and mixture of sand-silt at 30% and 50% relative densities for three confining pressures of 60 kPa, 120 kPa and 240 kPa with varying silt content as 15%, 25% and 35%. Total twenty four tests were conducted on 50 mm diameter and 100 mm height cylindrical sample (H/D = 2) using moist placement method of sample preparation.

![Grain size distribution curve](image)

Fig.1 Grain size distribution curve

**TESTING PROCEDURE**

After specimens were prepared, their caps were placed and sealed with ‘O’ rings. A negative pressure of 10 kPa was applied to the specimens to reduce disturbance during removal of split mould and triaxial cell installation. When the cell was filled with water a confining pressure of 50 kPa was applied to the samples. The saturation of the specimen was done by applying CO$_2$ and back pressure technique. The control of saturation is done by means of Skempton’s pore pressure parameter B, ($\Delta\mu/\Delta\sigma$). After completion of saturation process, the confining pressure was slowly increased to provide desired effective confining pressure (i.e. 60 kPa, 120 kPa, 240 kPa). All the samples were isotropically consolidated and loaded at the strain rate of 1.25 mm/min. For each confining pressure load, displacement, pore pressure and volume change were recorded using data acquisition system during the test after every 5 second. All the tests were conducted up to maximum axial strain of 20%.

**RESULTS AND DISCUSSION**

**Effect of confining pressure**

The variations in peak deviator stress and excess pore pressure generation with increase in confining pressure for clean sand as well as sand with silt content of 15%, 25% and 35% is shown in Figs. 2 and 3. It is observed that as the confining pressure increases deviator stress as well as peak pore pressure increases for all the cases studied. It is also seen that maximum value of deviator stress has been observed for clean sand. Similar behaviour is observed for specimens prepared with 50% relative density.
Effect of silt content

The effect of fines content on peak deviator stress of specimens prepared at 30% and 50% relative density with increase in silt content from 15%, 25% and 35% at various effective confining pressures is as shown in Figs. 4 and 5.

As the fines content increase, peak deviator stress decreases up to limiting fines content after that peak deviator stress increases. Addition of fines reduces value of peak deviator stress before limiting fines content because fines do not participate in capacity of carrying load. Addition of fines beyond the point of limiting fines content changes behaviour of soil from sand dominated to silt dominated. For maintaining same relative density, soil needs to be compacted densely in specimen with fines content more than limiting fines content. So, load carrying capacity increases for sand with 35% silt content. Similar behaviour is observed for specimens prepared at medium dense state (50%). (Fig. 5).

UNSTABLE ZONE

In order to classify the liquefaction behavior of soil, Pathak and Dalvi (2011) have established unstable zone plotted between $K_f$ line and peak pore pressure line on effective stress path plot. Unstable zone has been obtained by plotting effective stress path for all three confining pressures for each relative density for each percentage of fines content. $K_f$ line is plotted based on the maximum shear stress value for each of the test. Peak pore pressure line is plotted using $p'$ and q values corresponding to peak pore pressure point.
Unstable zone for clean sand and clean sand with 25% silt is shown in Figs. 6 (a) and (b). It is observed that as fines content increase up to limiting fines content, unstable zone becomes wider. Further increase in fines content beyond limiting fines content, narrows down the unstable zone. This may be an effect of excess pore water pressure, as fines content increased to limiting fines content (25%) excess pore water pressure increases.

![Unstable Zone Clean Sand (RD = 30%)](Fig. 6 (a))

![Unstable Zone Sand + 25% Silt (RD = 30%)](Fig. 6 (b))

**Fig. 6** Variation of unstable zone with increase in fines content at relative density RD=30 %

Similar trend of unstable zone obtained for specimen prepared at relative density 50% as that at relative density 30%.

**CONCLUSION**

From the present study following conclusions are made:

1. As the confining pressure increases peak deviator stress and excess pore water pressure increases for clean sand and sand silt mixture.
2. For both loose and medium dense specimens, peak deviator stress decreases as fines content increases up to limiting fines content. Further increase in fines content increases the peak deviator stress value.
3. Unstable zone of sand-silt mixture widens as fines content increases up to limiting fines content. Further increase in fines content narrows down the unstable zone for relative density 30% and 50%.

**REFERENCES**


