Experimental study on void ratio characteristics of sand-finesmixture
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Abstract: Void ratio characteristics of sand-fines mixtures have been investigated in this study. After result analysis of 54 specimens, conclusions are summarized, which shows that most fine-sand mixtures reach extreme value of $e_{\text{max}}$ and $e_{\text{min}}$ at the fines content of 30% to 50%. It is found that 3rd degree polynomial equations are appropriate to illustrate void ratio characteristics of sand-fines mixture. And the uniformity coefficient of sand plays an important role in determining the reduction of $e_{\text{max}}$ and $e_{\text{min}}$ with fines content.

Keywords: Fine-sand mixture; Maximum void ratio; Minimum void ratio; Uniformity coefficient

1 INTRODUCTION

Sand is commonly considered as a natural granular material, and always is described by the parameters of sand particles, grain-size distribution, void ratio, mineralogy, fines content and so on. The most meaningful measures of packing behavior, representing the states of densest and loosest random packing of sands, are the maximum void ratios $e_{\text{max}}$ and minimum void ratios $e_{\text{min}}$ (Panayiotopoulos, 1989). A lot of studies on these two parameters have been taken and mainly focused on clean sand (Selg and Ladd, 1973), such as, relation between the material properties and $e_{\text{max}}$ or $e_{\text{min}}$ of sands (Miura et al., 1997), the use of void ratio range for sand classification and so on (Shimobe and Moroto, 1995; Cubrinovski and Ishihara, 1999). Effects of fines on $e_{\text{max}}$ or $e_{\text{min}}$of sands have been studied to examine the influence of fines on undrained behavior of sands (Thevanayagam, 1998). Moreover, other studies show that 3rd degree polynomial equations are reasonable to estimate the variation of minimum and maximum void ratios for fine-sands mixtures (Y.Yilma, 2009).

This study was taken to test and characterize the packing behavior of fine-sand mixtures by evaluating the parameters of $e_{\text{max}}$ and $e_{\text{min}}$, which is one part of collaborative research carried out by geotechnical group of Kyushu University and Kyushu Electric Power Company, which is focused on the capillary ability of sandy soil mixed with different content fines. Some experiment results and findings are also present in this paper.

2 MATERSITIED TESTED

The fines, on the other hand, have various degrees of uniformity and commonly contain percentage of clay size particles, and are considered as nonplastic material (Cubrinovski, M., Ishihara, K., 2002). In this study, two kinds of fines named fine1 and fine 2, are mixed with four sands with the name of sand A, sand B, sand C and Sand D, respectively. The particle size distribution curves of six samples are shown in Fig.1, while grading and void ratio properties of them is given in Table 1. As testmaterial, fines 1 and fines 2 are bought from The Association of Powder Industry Process and Engineer, Japan, sand A is Japanese standard sand for geotechnical experiment, Toyoura sand, and B, C, D sands are collected and recomposed from Masa soil of Japan.

![Particle size distribution curves of 6 samples](image)

Table 1. Grading properties of sands and fines used

<table>
<thead>
<tr>
<th>Soil type</th>
<th>$e_{\text{max}}$</th>
<th>$e_{\text{min}}$</th>
<th>$D_{90}$(µm)</th>
<th>$C_u$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.436</td>
<td>0.837</td>
<td>227.81</td>
<td>1.97</td>
</tr>
<tr>
<td>B</td>
<td>1.596</td>
<td>0.700</td>
<td>196.61</td>
<td>4.74</td>
</tr>
<tr>
<td>C</td>
<td>1.119</td>
<td>0.827</td>
<td>1998.23</td>
<td>1.59</td>
</tr>
<tr>
<td>D</td>
<td>0.969</td>
<td>0.492</td>
<td>892.94</td>
<td>3.99</td>
</tr>
<tr>
<td>1</td>
<td>1.149</td>
<td>0.667</td>
<td>25.03</td>
<td>1.93</td>
</tr>
<tr>
<td>2</td>
<td>1.410</td>
<td>0.615</td>
<td>24.97</td>
<td>4.67</td>
</tr>
</tbody>
</table>

3 TESTING RESULT AND ANALYSIS

3.1 Testing result

Fines 1, 2 samples are respectively mixed with other four sand samples A, B, C, D, individually at 0%, 10%, 20%, 30%, 40%, 50%, 75% and 100% by dry mass. In this way, 54 different sand-fine mixtures specimens are formed. Maximum and minimum void ratios have been determined according to the procedure stipulated by Japanese Geotechnical Society (JGS). Variations of $e_{\text{max}}$ and $e_{\text{min}}$ for all the composite soils, are shown in Fig. 2 and Fig. 3 respectively.
As shown in Fig.2 and Fig.3, it’s indicating that, $e_{\text{max}}$ and $e_{\text{min}}$ of six sand-fines mixtures initially decreases with the fines content increase from 0% to 30%. Moreover, these two parameters rapidly increase while the fines content increase from 50% to 100%. $e_{\text{max}}$ and $e_{\text{min}}$ approximately reach their extreme values at the fines content of 30% to 50%. Similar results have been addressed in the studies by Lade, P. V. et al (1998). But the curves of B+1 and B+2 have distinguishing characteristics comparing to the former six soils, as fines content increase.

(1) Most fine-sand mixtures reach minimal value of $e_{\text{max}}$ and $e_{\text{min}}$ at the fines content of 30% to 50%, and comparing to fine gradation, sand gradation is more sensitive for $e_{\text{max}}$ and $e_{\text{min}}$.

(2) This study verifies that void ratios of mixtures may be determined reasonably well using appropriate 3rd degree polynomial equations as function of fines content.

(3) Reductions in $e_{\text{max}}$ and $e_{\text{min}}$ have the liner relation to the uniformity coefficient of sand, and the reduction isn’t clear as uniformity coefficient reaches approximately 5.

![Fig.2. Variation of $e_{\text{max}}$ with fines content](image)

![Fig.3. Variation of $e_{\text{min}}$ with fines content](image)

![Fig.4. Variation in reduction of $e_{\text{max}}$ and $e_{\text{min}}$ versus uniformity coefficient of sand](image)

3.2 Analysis

It’s found from Fig.2 and Fig.3 that 3rd degree polynomial equation is exactly describing the relation between fines content and void ratio parameters, and the fit indexes are more than 90% for all the curves. The relationship of $e_{\text{max}}$ or $e_{\text{min}}$ with fines content is affected by the grain size distribution, in particular, by that of sand. To quantify the results, the reduction in $e_{\text{max}}$ and $e_{\text{min}}$ between 0% and 30% fines content is plotted versus uniformity coefficient of sand in Fig.4, where the reduction is denoted by $e_1$ and $e_2$. Noted that $e_1$ and $e_2$ reduce as the liner relation to the uniformity coefficient of sand. And there is no clear reduction in $e_{\text{max}}$ and $e_{\text{min}}$ when uniformity coefficient reaches approximately 5, which is the reason for the distinguishing characteristics of B+1 and B+2 mixtures.

4 CONCLUSIONS

Based on the result and analysis of void ratio test of fine-sand mixtures, the following conclusions can be summarized:

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REFERENCES


