Relative Density and Undrained Cyclic Shear Strength of Decomposed Granite Soil "Masado"

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INTRODUCTION

In recent years, liquefaction of reclaimed landfill due to large earthquakes has become an increasingly serious problem. The materials used in coastal reclaimed landfills mostly consist of seabed sands, dredged clays and residual soils quarried from mountainous areas and transported to the reclamation sites. During the 1995 Great Hanshin-Awaji earthquake, areas reclaimed with Masado, or decomposed granite, suffered severe damage due to liquefaction. Since this earthquake event, Masado has been recognized as a material susceptible to liquefaction and many experimental studies, such as those performed by Hyodo et al. (1998)[1], have shown that reclaimed Masado is a crushable material. The purpose of this study is to investigate the effects of relative density, confining pressure, and method of specimen preparation on the liquefaction strength of Masado.

Table 1　Physical properties of materials

Sample	ρ_s(g/cm^3)	e_{max}	e_{min}	d_{50}(mm)	U_c
Port Island Masado	2.624	0.967	0.493	0.58	20.81
Shimonoseki Masado	2.664	1.144	0.583	0.56	9.71
Iwakuni Masado	2.643	1.042	0.616	0.33	6.68
Toyoura Sand	2.640	0.973	0.635	0.20	1.33

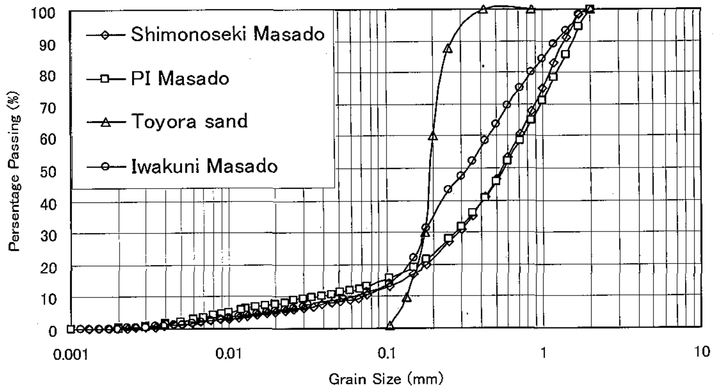

Fig. 1 Particle size distribution curves

MATERIALS AND TESTING METHOD

Masado samples were collected from Port Island, Shimonoseki and Iwakuni (Japan) for laboratory testing. Fig.1 shows the grain size distribution curves of these decomposed soils, along with that of Toyoura sand. Masado soils have wide range of particle size, from 2 mm to less than 0.001mm. On the other hand, Toyoura sand is uniformly graded. Table 1 shows the physical properties of all the Masado soils used in the present investigation, as well as those of Toyoura sand. In this study, the maximum and minimum void ratios were obtained based on Japanese Geotechnical Society (JGS) Standards.

Reconstituted triaxial specimens with 50 mm diameter and 100 mm high were prepared by both dry deposition and water sedimentation methods. In both methods, Masado was poured gently into the mould in layers; in some cases, a cylindrical block weighing 2.3 kg was placed on top as weight. Each layer was then given uniform blows by a wooden mallet to achieve the desired initial relative density. CO_2 was percolated through the specimens prepared by dry deposition method. Samples were saturated by applying back pressure and the saturation time was maintained until the 'B' value was more than 0.95. After this, the specimens were isotropically consolidated to confining pressure of σ_c'=100kPa. After primary consolidation, the specimens were subjected to stress-controlled cyclic loading under undrained conditions until the double amplitude axial strain (ε_{DA}) reached 5%.

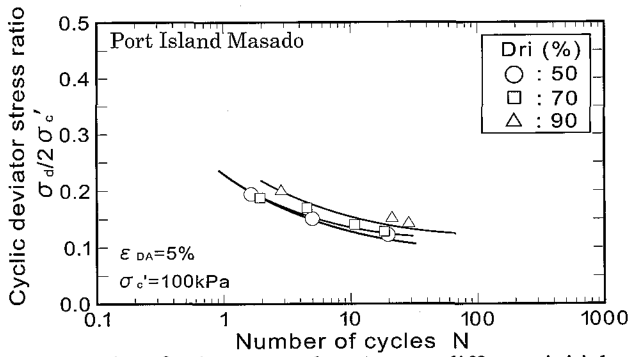

Fig. 2 Liquefaction strength curves at different initial relative densities for Port Island Masado.

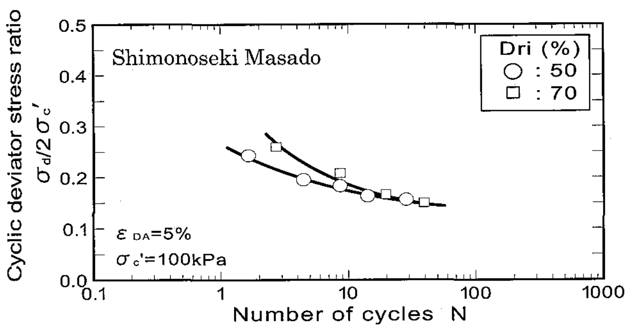

Fig. 3 Liquefaction strength curves at different relative densities for Shimonoseki Masado.

EFFECT OF RELATIVE DENSITY

To investigate the effect of initial relative density, a series of undrained cyclic triaxial tests were carried out at various initial relative densities on all the three Masado soils at σ_c'=100 kPa and f = 0.1 Hz. Initially, specimens prepared by dry deposition method were considered. Fig. 2 shows the liquefaction strength curves for Port Island Masado at D_{ri}=50, 70 and 90%. (corresponding to post- consolidation relative density of D_r=82.4%, 95% and 104.6%, respectively) The cyclic shear stress ratios at N=20 cycles (R_{20}) for this Masado were R_{20} = 0.123, 0.13 and 0.146 for D_{ri}=50, 70 and 90%, respectively. It is noted that there is a small increase in R_{20} with increase in initial relative density. Fig. 3 shows the results for Shimonoseki Masado at D_{ri}=50 and 70% (corresponding to post- consolidation relative density of D_r=85.3% and 92.5%, respectively). The results indicate that there is no change in strength for this range of relative densities considered. Fig. 4 corresponds to those of Iwakuni Masado at D_{ri}=50, 70 and 80% (corresponding to post-consolidation relative density of D_r=88.6%, 99% and 101.2%, respectively). This Masado has an average R_{20} = 0.116 and there is no change in R_{20} with relative density. Note from Figs. 2-4 that liquefaction strength is independent of initial relative density in the range D_{ri}=50~70%, while a small increase in R_{20} is observed in the range of D_{ri} = 80~90%. For practical purposes therefore, it can be considered that there is no change in R_{20} for samples with initial relative density ranging from D_{ri} =50~90%.

In view of the above, specimens of Iwakuni Masado were prepared with water sedimentation technique at initial D_{ri} = 90, 110 and 130%, (corresponding to post-consolidation relative density of D_r=95.1%, 111% and 138.6%, respectively). Note that water sedimentation technique simulates in the laboratory the field deposition of reclaimed lands. Moreover, this technique results in higher initial relative density - the minimum relative density that can be achieved without applying any energy is about D_{ri}=90% while the maximum relative density was D_{ri}=130%. Cyclic tests were conducted with σ_c'= 100 kPa and f = 0.1 Hz. Fig. 5 shows the liquefaction strength curves. The R_{20} can be read from the figure as 0.135, 0.169 and 0.296 for D_{ri} = 90, 110 and 130%, respectively, indicating an increase in R_{20} with initial relative density. Thus, there is considerable increase in R_{20} for specimens with initial relative densities D_{ri} >100%.

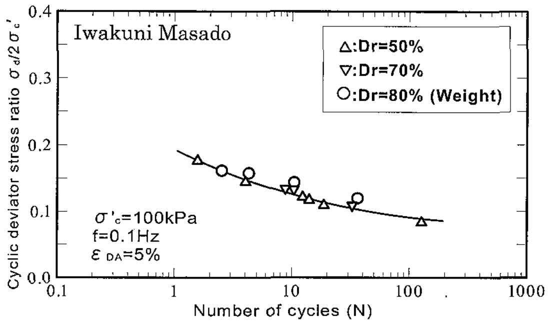

Fig. 4 Liquefaction strength curves at different initial relative densities for Iwakuni Masado.

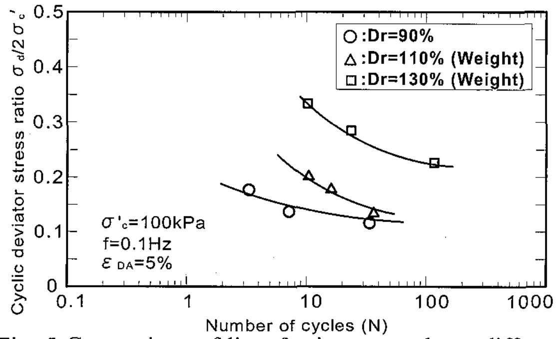

Fig. 5 Comparison of liquefaction strengths at different relative densities for Iwakuni Masado prepared by water sedimentation method.

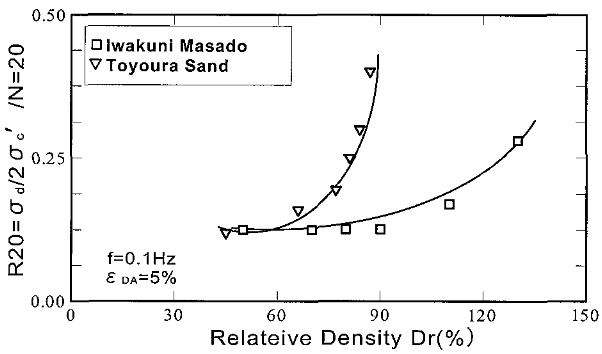

Fig. 6 Comparison between R_{20} of Iwakuni Masado and Toyoura sand with respect to initial relative

Fig. 6 shows the result in terms of the relation between relative density and R_{20} for Iwakuni Masado and Toyoura sand. The R_{20} of Toyoura sand increases rapidly when the relative density is in the vicinity of 90%. On the other hand, the R_{20} of Iwakuni Masado was still increasing even when the relative density was over 130%. Thus, the methods of obtaining the maximum and minimum void ratios, which are conventionally performed in dry condition, may not be applicable for Iwakuni Masado. Due to the large compressibility of saturated Iwakuni Masado after drainage and consolidation, special methods of determining the maximum and minimum void ratios are necessary.

CONCLUSIONS

1. For samples prepared by dry deposition method, the liquefaction strength of Masado was independent of initial relative density.
2. Water sedimentation method of sample preparation resulted in higher initial relative density than dry deposition method, with the possibility of the initial relative density exceeding D_{ri}=100%.
3. For samples prepared using water sedimentation technique, liquefaction strength increases with increase in relative density.

REFERENCE

1) Hyodo, M., Hyde, A.F.L. and Aramaki, N. 1998. Liquefaction of crushable soils, *Geotechnique*, Vol. 48, No. 4, pp. 527-543.