POST-LIQUEFACTION BEHAVIOR OF MEDIUM DENSE SILICA SAND IN LARGE STRAIN TORSIONAL SHEAR APPARATUS

Institute of Industrial Science, University of Tokyo — Student member — Nazish Ullah
National University of Computer & Emerging Sciences — Muhammed UMAR
Institute of Industrial Science, University of Tokyo — Member — Masataka SHIGA
Institute of Industrial Science, University of Tokyo — Member — Takashi KIYOTA

1. INTRODUCTION

Since Niigata and Alaska earthquake in 1964, liquefaction-induced damages have been reported after every major earthquake. It was essential to understand the mechanism of damages caused by the liquefaction. Initially, the research's focus was to investigate the liquefaction failure mechanism, predict the occurrence of liquefaction, and design remedial measures. The researchers had not paid much attention to estimate the post-liquefaction damages. However, during the last few decades, some empirical and analytical attempts have been made to assess these damages by Finn et al. (1986) and Hamada et al. (1987). Later, Vaid and Thomas (1995) investigated post-liquefaction deformation and strength characteristics. They found that even under different densities and confining pressure, the stress-strain curve becomes linear with no termination point (residual strength), which may be associated with the apparatus's technical limitations to achieve large strain.

Umar (2019) investigated the post-liquefaction behavior of Toyoura sand using modified torsional shear apparatus, described in Kiyota et al.(2008); the test results show undrained shear strength degradation with increasing cyclic strain history. Insight of undrained strength degradation in other geomaterials was necessary. Hence an attempt has been made to investigate post-liquefaction behavior of silica sand with various cyclic shear strain histories. The test results show that the shear strain history has a significant impact on the peak undrained shear strength.

2. EXPERIMENTAL OUTLINE AND METHODOLOGY

A series of tests were conducted using torsional shear apparatus to achieve double amplitude shear strain of more than 120%. Hollow cylindrical specimens of silica sand (D_{50} = 0.21mm, Fc < 0.1%, G_s = 2.617, e_{max} = 1.151, e_{min} = 0.687) with 20cm in height, 10cm outer diameter, and 6cm inner diameter were prepared by air-dried pluviation method. The specimens were kept under vacuum for 90 minutes, followed by passing enough water to achieve Skempton's B value larger than 0.96.

After isotropically consolidating to an effective confining pressure of 100 kPa, the specimens were subjected to two-stage loading. The samples were sheared cyclically under undrained conditions in the first stage until achieving the required cyclic shear strain amplitude (damage strain (γ_Δ)). Afterward, undrained monotonic loading (ML)was applied in the second stage until reaching a single amplitude strain level up to 60%.

3. TEST RESULTS AND DISCUSSION

After Umar (2019), the undrained peak shear strength is evaluated corresponding to the limiting shear strain ($\gamma_{L,SA}$) at which shear band initiates and strain localization occurs. Since the specimen behaves non-uniformly and the test results become defective after the shear band's initiation, the peak strength obtained after $\gamma_{L,SA}$ is not truly representative of the strength of the specimen. The undrained peak shear strength during monotonic loading has been presented in Figure 1(a), which shows the effect of γ_Δ on the post-liquefaction undrained peak shear strength. Each stress-strain curve is marked with the designated γ_Δ. The results reported in Fig. 1(a) show the damaging effect of γ_Δ on the undrained peak shear strength (peak point is indicated by red dot), which reduced from 201kPa to 84kPa by increasing γ_Δ from 0% to 26%.

To quantify the degree of degradation with the amplitude of γ_Δ, undrained strength degradation ratio (τ_d) is presented in Figure 1(b), which is the ratio of the undrained peak shear strength with γ_Δ ($\tau_{PL\Delta}$) to undrained peak shear strength without γ_Δ (τ_{PL}). The results show a linear correlation between τ_d and γ_Δ, suggesting that the $\tau_{PL\Delta}$ degraded to 60% of the original strength when γ_Δ= 26%. This implies that the accumulated cyclic shear strain history predominantly caused the reduction in the effective stress recovery thresholds, which can be attributed to the reduction in the soil's dilative capacity.

Figure 2(a) illustrates the variation of excess pore water pressure (EPWP) development with the increase in γ_Δ during undrained ML, and each curve is marked with the designated γ_Δ. The results reported in Fig. 2(a) show the increase in the minimum value of the EPWP from -197 kPa to -35.4 kPa with an increase in γ_Δ from 0 to 26%.

Figure 2(b) shows the relationship between the EPWP degradation ratio (r_d) and γ_Δ, whereas r_d is the ratio of the minimum peak of EPWP in undrained monotonic loading with γ_Δ (ΔU_{Cyc}) to the minimum peak of EPWP in undrained monotonic loading without γ_Δ (ΔU). The correlation depicts the influence of γ_Δ on the depletion of EPWP, the minimum peak of EPWP reduced up to 90%.

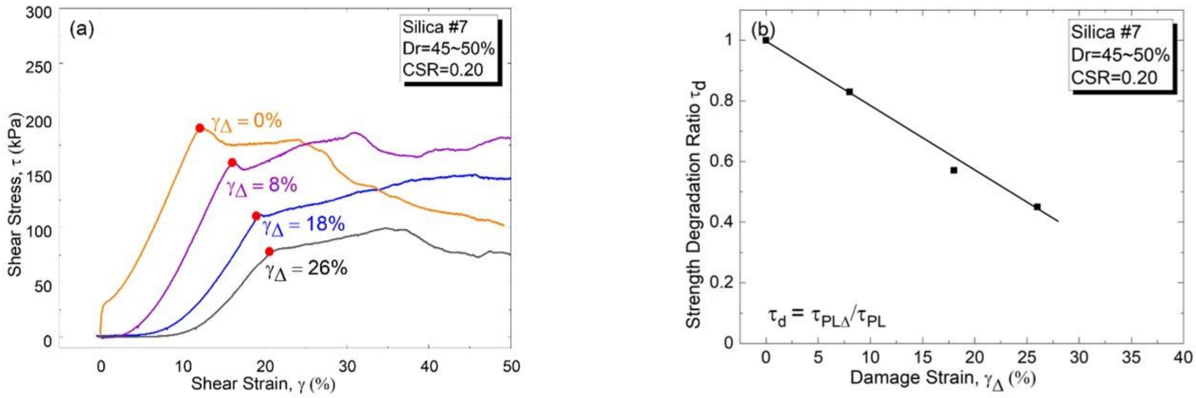

Figure 1. (a) Post-liquefaction stress-strain relationship during undrained ML loading for various γ_Δ=0~26% and (b) strength degradation ratio versus γ_Δ

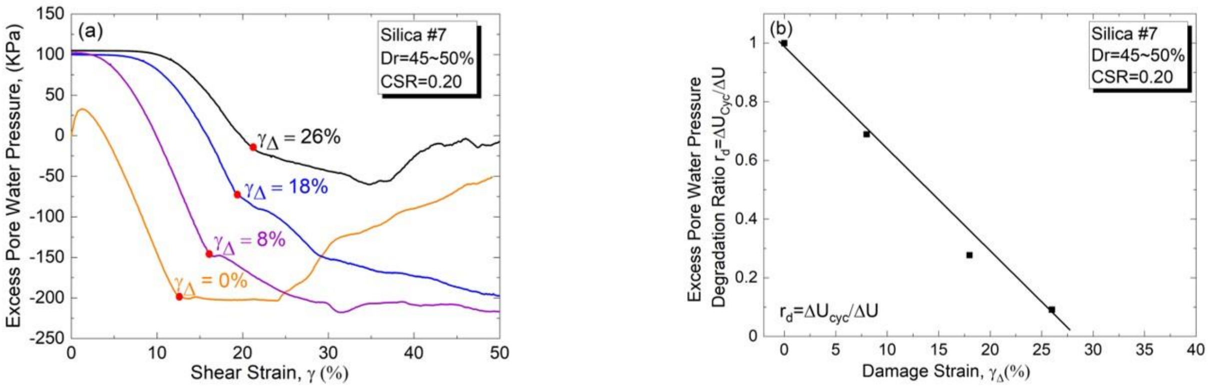

Figure 2. (a) Post-liquefaction EPWP response with shear strain for various γ_Δ=0~26% and (b) EPWP degradation ratio versus γ_Δ

CONCLUSION

The behavior of medium-dense silica sand subjected to two-stage torsional shear loading was investigated and evaluated by looking at the stress-strain relationship and excess pore water pressure (EPWP)generation responses. Following conclusions can be drawn from the test results reported.

Correlation between undrained strength degradation ratio with cyclic shear strain (γ_Δ) suggests that γ_Δ has a detrimental effect on the undrained peak shear strength. The undrained shear strength reduced up to 60% of the original strength (γ_Δ= 0%) when γ_Δ= 26%. It depicts that $\gamma_\Delta$induces softening in the sands.

Correlation between EPWP degradation ratio (r_d) and γ_Δ suggests a linear increase in the minimum value of EPWP with the increment in the amplitude of γ_Δ.

REFERENCES

Finn et al., *USC Soil Mech. Ser., 1986*; Hamada, et al, *CompUlers and Geotechnics,* 4, 1987; Kiyota et al, *S&F*, *48*(5), 2008; Umar, Doctor thesis, U. Tokyo, 2019; Vaid & Thomas, *J. Geotech Eng.*, *121*(2), 1995.

