# III－160 EFFECTS OF CYCLIC PRESTRAINING ON STIFFNESS OF GRAVEL IN TRIAXIAL COMPRESSION

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**INTRODUCTION:** Dong et al. (1992) and Tatsuoka and Dong (1992) showed that for a gravel, a large degree of cyclic prestraining (**CP**) applied in triaxial compression changes considerably the stress-strain relation during the subsequent monotonic triaxial compression; i.e., compared to those of the virgin specimen, the initial stiffness at the beginning stage decreased, whereas as the stress level increased, the tangent stiffness increased drastically with a negligible change in the peak strength. Herein, the change of tangent and elastic moduli due to **CP** will be examined in detail.

**TEST RESULTS:** The specimens were 30cm in diameter and 60cm in height. The testing methods and the material properties are described in detail in Dong et al. (1992) and Tatsuoka and Dong (1992). **Fig. 1** shows typical relationships between $q=\sigma_1-\sigma_3$ and $\varepsilon_1$ of two monotonic loading (**ML**) tests (one virgin and one prestrained specimens). The features of **CP** specimens described in the above may be noted.

The tangent Young's modulus $E_{tan}$ during **ML** and the peak-to-peak equivalent Young's modulus $E_{eq}$ during small unload/reload cycles are plotted against $\varepsilon_1$ during **ML** or $q/q_{max}$ in **Figs. 2 through 7.** The following points may be commonly seen from these figures:

(1) The initial stiffness at very small strains less than about 0.001% immediately after the start of **ML** of a **CP** specimen was smaller than the initial stiffness $E_{max}$ of the corresponding virgin specimen. Further, even up to $\varepsilon_1$ of about 0.1%, $E_{tan}$ was also smaller for a **CP** specimen than for the virgin specimen. These trends increased as the degree of **CP** increased.

(2) As the strain or stress level increased, the value of $E_{tan}$ of each **CP** specimen soon started increasing as opposed to the continuous decrease for the virgin specimens, and subsequently it caught up with that of the corresponding virgin one. $E_{tan}$ of **CP** specimen could increase to a very high value (even up to more than 3 times of the value of $E_{max}$ of the virgin specimen) near $q/q_{max}$ equal to $(X+Y/2)_{max}$ (the highest stress level during **CP**) (see **Fig. 7**). Exceeding that stress level, $E_{tan}$ started decreasing very sharply. Note also that in **Figs. 5 and 7**, stress levels near $q/q_{max}=(X+Y/2)_{max}$, $E_{tan}$ of the **CP** specimen was almost the same as the elastic Young's modulus $E_{eq}$ defined for the unload/ reload cycle at that stress level. This means that during **ML**, the **CP** specimen behaved almost purely elastically at this high stress level.

(3) For the virgin specimens, the elastic stiffness $E_{eq}$ increased as the strain or stress level increased. This rate of the increase could be approximately predicted by assuming that $E_{eq}$ be proportional to $\sigma_1^{0.4}$ or $\sigma_1^{0.5}$. The powers 0.4 and 0.5 are often observed for granular materials. However, at any stress level, the value of $E_{eq}$ of any of the **CP** speci-

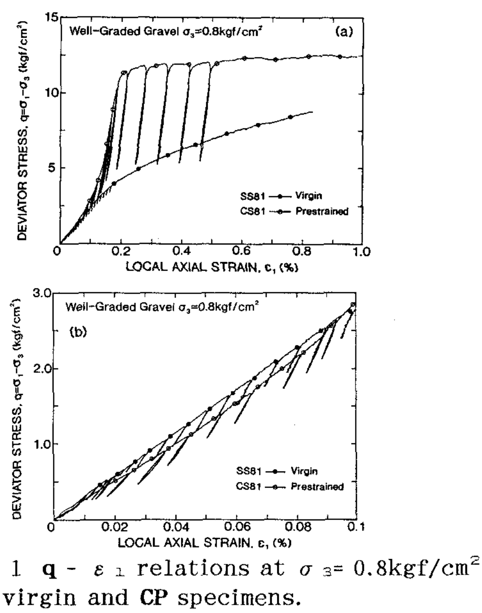


Fig. 1 **q** - $\varepsilon_1$ relations at $\sigma_3$= 0.8kgf/cm$^2$ for virgin and **CP** specimens.

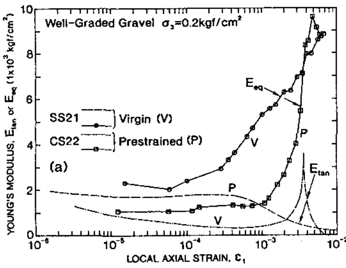


**Fig. 2** $E_{tan}$ and $E_{eq}$ versus $\varepsilon_1$ during ML, $\sigma_3$= 0.2kgf/cm².

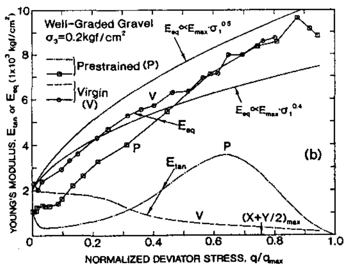


**Fig. 3** $E_{tan}$ and $E_{eq}$ versus $q/q_{max}$, $\sigma_3$= 0.2kgf/cm².

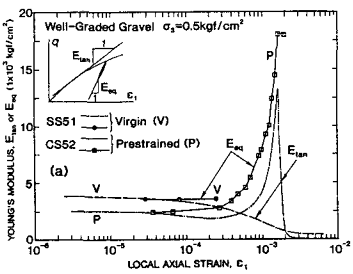


**Fig. 4** $E_{tan}$ and $E_{eq}$ versus $\varepsilon_1$ during ML, $\sigma_3$= 0.5kgf/cm².

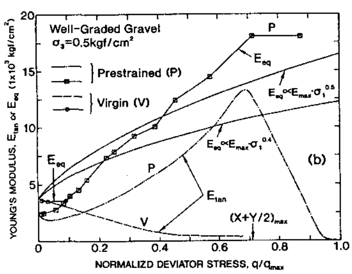


**Fig. 5** $E_{tan}$ and $E_{eq}$ versus $q/q_{max}$, $\sigma_3$= 0.5kgf/cm².

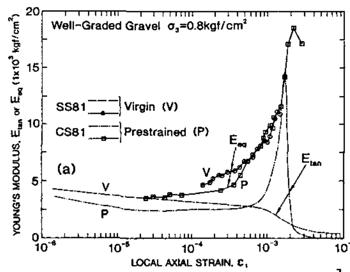


**Fig. 6** $E_{tan}$ and $E_{eq}$ versus $\varepsilon_1$ during ML, $\sigma_3$= 0.8kgf/cm².

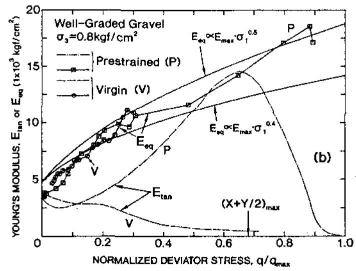


**Fig. 7** $E_{tan}$ and $E_{eq}$ versus $q/q_{max}$, $\sigma_3$= 0.8kgf/cm².

mens did not exceed that of the corresponding virgin specimen. This means that the elastic stiffness at any stress level did not increase by **CP**, while it may have decreased at lower stress levels.

**CONCLUSIONS:** When compared to the virgin specimen of gravel, due to cyclic prestraining (**CP**), the deformation of gravel during the subsequent monotonic loading (**ML**) became much more recoverable; i.e., for a given small stress increment, a much larger ratio of recoverable strain increment to total strain increment (even nearly unity in some cases). After **CP**, the tangent Young's modulus $E_{tan}$ during **ML** decreased at very low stress levels. However, as the stress level increased, $E_{tan}$ increased drastically and became much larger than that of the virgin specimen, and near the highest stress level during **CP**, the **CP** specimen exhibited the largest tangent modulus, which could be almost the same as the elastic modulus at that stress level. This result suggests that some specific anisotropic structure was formed by **CP**. Most importantly, the elastic stiffness at any stress level did not increase by **CP**.

**REFERENCE:** Dong,J., Tatsuoka,F., and Sato,T.(1992): Effects of cyclic prestraining on stress-strain behaviour of gravel in triaxial test, Proc. 27th Japan National Conf. on SMFE, Kochi. Tatsuoka,F. and Dong,J.(1992): Effect of cyclic prestraining on deformation characteristics of gravel in triaxial compression, Proc. 47th Annual Conf. of JSCE, Vol.III.