SHEAR MODULI OF STRAW FIBER REINFORCED ADOBE

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1. Introduction

Adobe houses are being used since the beginning of the civilization. Two characteristics: brittle and weak in tension, however, have limited their use and caused most losses of human lives during earthquakes in developing countries. Recently, the development of straw fiber reinforced adobe (SFRA) has provided a technical basis for improving these deficiencies (Islam & Watanabe, 2001). It had been showed that straw is effective in improving both the ductility and toughness. The fact behind the improvement is that the straw fibers transmit the stress across the cracked surface and prevent the cracks from opening. However, the seismic response of adobe masonry structures showed to be non-linear (Asencios et al., 1993). Nevertheless, it is necessary to determine the strain dependent dynamic properties of SFRA. This paper presents the strain dependency of shear modulus of SFRA and effect of straw content (SC) on this property.

2. Soil Selection and Sample Preparation

To get an idea about the contents of adobe material, old adobe specimens collected from Bangladesh and Iran were analysed. However, samples were prepared by mixing locally available Japanese standard clay (Acadama clay: G_s=2.65, LL=145%, PL=67%, PI=78%), sand (Toyoura sand: G_s=2.64, D_{50}=0.18 mm, U_c=1.3), bentonite (G_s=2.514, LL=232%, PL=31%, PI=201%) with a weight ratio (w/w) of 2.5: 1.0: 0.6 to attain a similar composition of old adobe. This mix is termed in this study as 'soil-sand' mixture. Grain size distribution of the 'soil-sand' mixture along with those of old adobe specimens from Iran and Bangladesh are presented in Figure 1. The grain distribution of 'soil-sand' is almost similar to that of old adobe.

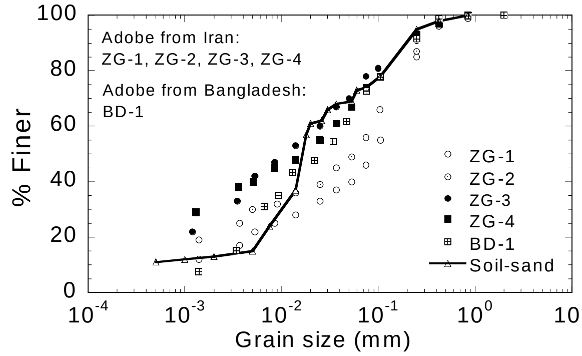

Fig. 1. Grain size distributions of old adobe and 'soil-sand'.

The details of specimen preparation are available in Islam & Watanabe (2001).

3. Cyclic Uniaxial Loading Test

With a view to study the dynamic properties of SFRA four groups of specimens were tested under multi-stage uniaxial cyclic loading condition. About 10 different amplitudes of cyclic stress were used for each test and in every stage 5 cycles were applied. Specimens were prepared by mixing 'soil-sand' mixture with different straw content of 1 cm length (Table 1). Mean values of dry density, void ratio, and final water content of the tested specimens are presented in Table 1. A typical shear stress-strain relationship is presented in Figure 2.

Table1: List of sample groups and physical properties.

Sample group	Straw content SC (%)	Straw length (cm)	Dry density (kN/m^3)	Void ratio e	Water content (%)
SC-1	0.5	1.0	10.60	1.44	9.5
SC-2	1.0	1.0	9.82	1.65	11.5
SC-3	1.5	1.0	10.10	1.66	8.5
SC-4	3.0	1.0	9.20	1.84	10.0

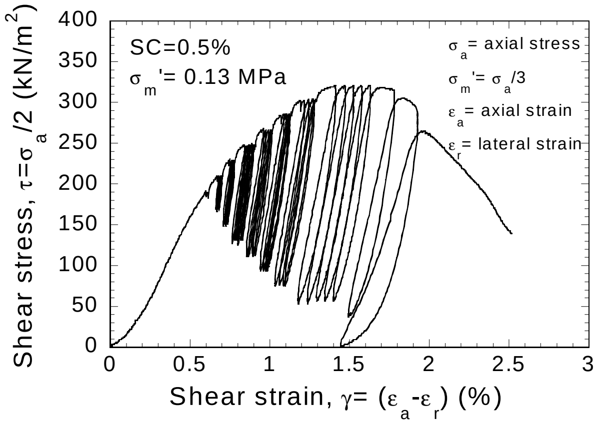

Fig. 2. Typical shear stress-strain relationship.

4. Test Results

Shear modulus for the specimens of group SC-1, are plotted with the variation of shear strain amplitude in Figure 3a. It can be seen that initial shear modulus (G_0) cannot be identified directly. However, by using Hardin and Drnevich (1972) model (HD model) G_0 can be determined from the following relationship

$$\frac{1}{G} = \frac{1}{G_0}\left(1 + \frac{\gamma}{\gamma_r}\right) \quad (1)$$

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where, γ_r is reference shear strain. By plotting 1/G vs. shear strain amplitude, G_0 for all the specimens was determined for different mean effective stresses. G_0 is often approximately expressed by the empirical equation as follows (Hardin and Black, 1969)

$$G_0 = KF(e)(\sigma_m')^n \qquad (2)$$

where, F (e) is void ratio function, $\frac{(2.97-e)^2}{1+e}$, σ_m' is mean effective stress. K and n are constants that are to be determined for SFRA. By plotting log-log of $G_0/F(e)$ vs. σ_m' (Figure 3b), the following relation can be obtained for SFRA of 0.5% SC.

$$G_0 = 954F(e)(\sigma_m')^{0.52} \qquad (3)$$

Therefore, it can be said that K=954 and n= 0.52 for SFRA of 0.5% straw content. In Table 2, HD model parameters for all cases are presented. Therefore, by knowing the straw content for the particular soil type, G_0 can be determined easily. Figure 4a shows the G/G_0 relation with shear strain amplitude for mean effective stress 0.065 MPa. It shows that with the increase of SC, G/G_0 relation shifts to the right. It means that with the increase of SC the rate of degradation of G/G_0 decreases. Figure 4b depicts that with the increase of SC G_0 decreases. It is also noticed that the decrease of G_0 is sharp in the region of SC from 0.5% to 1.0%. For SC beyond 1.0% to 3.0%, the decrease of G_0 is not significant.

Table 2. HD model parameters.

Sample group	F (e)	K	n
SC-1	0.959	954.0	0.52
SC-2	0.657	725.0	0.38
SC-3	0.645	680.0	0.41
SC-4	0.449	654.0	0.30

5. Conclusions

Shear modulus of SFRA depends on shear strain level and mean effective stress, which can be approximately correlated by HD model. It is observed that with the increase of SC, G_0 of SFRA decreases. However, with the increase of SC reference shear strain increases, which might be due to the increase in ductility with SC. Since straw is softer than soil, G_0 decreases with the increase of SC. The increase of void ratio and micro-cracks with the increase of SC might be other reasons for decreasing G_0. Thus, straw or any other natural fiber of good tensile strength and fewer voids may be better for improving the seismic resistance of adobe material.

References

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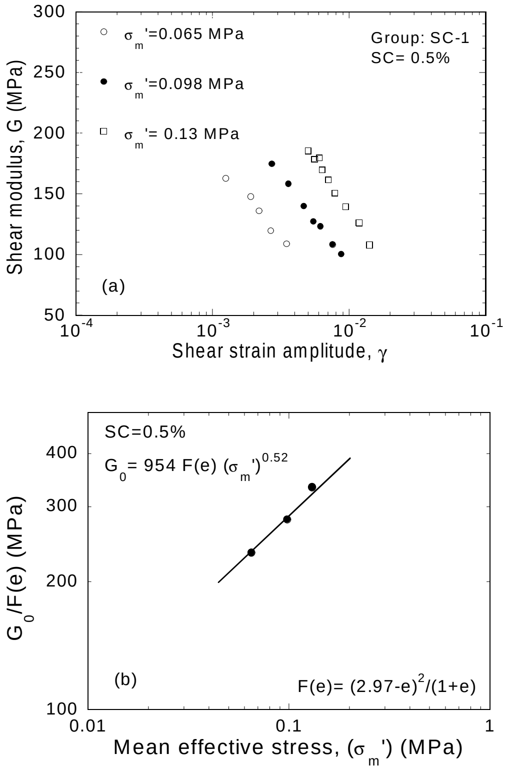

Fig.3. (a) G ~ γ relation, (b) $G_0/F(e)$ ~ σ_m' relation.

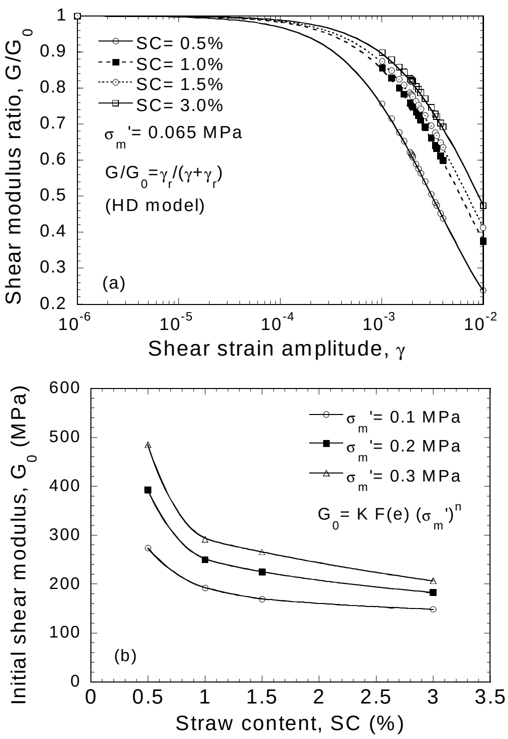

Fig. 4. (a) G/G_0 ~ γ relation, (b) G_0 ~ SC relation.