RELATIONS BETWEEN LIQUEFACTION RESISTANCE AND SHEAR WAVE VELOCITY AS AFFECTED BY AGING OF SAND DEPOSITS

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Aging effect is one of the significant factors, which effectively influences liquefaction resistance, because of not only the cementation but mainly due to the rearrangement of particles and interlocking grains and infilling affiliated with deposits formed during prolonged period of time. Troncoso et al. (1988) indicated that the ratio of liquefaction resistance of old-aged tailing materials over freshly reconstituted laboratory specimens reaches up to the order of 3.5, without considering any soil indices such as shear wave velocity. On the other hand, Andrus and Stokoe (2000) presented the chart in which is determined the liquefaction and the non-liquefaction sites based on many case histories, using the correlation of cyclic resistance and shear wave velocity, which is based on the resistance of liquefaction in young Holocene deposits, without considering age. In this paper, relations between liquefaction resistance and shear wave velocity of sand deposits are proposed under aging effect.

In this study, “cyclic reference strain” or “cyclic yield strain”, as an index property in cyclic loading, is proposed to differentiate between new and old age deposits in the relations of cyclic resistance ratio and shear wave velocity. With respect to cyclic reference strain, the large value of that does exhibit ductile behaviour, in contrast, the small value can soundly be representative of brittleness. Similarly, old age deposits may show brittle behavior whereas the soil with a short history of deposition may have ductile response. The relation between cyclic yield strain, ε_{ay}, liquefaction resistance, R_L, and shear wave velocity, V_{s1}, is expressed in Eq. (1).

$$\varepsilon_{ay} = \frac{R_L . P_a}{G_{01}} = \frac{R_L . P_a}{\rho / g . V_{s1}^{\;2}} \qquad (1)$$

For this purpose, the area of Asahi city in Chiba prefecture has been considered, which were affected by liquefaction induced by the 2011 East-Japan Earthquake, which is along the coastal line of Pacific Ocean. In order to investigate this area, undisturbed samples were extracted from soil holes drilled at several locations. Then, the values of shear wave velocity and cyclic resistance ratio were determined by the cyclic triaxial apparatus which is equipped with a new device to measure the shear wave velocity. Few outcomes of these experiments are shown in Table 1, along with corresponding cyclic reference strain calculated by Eq. (1). For each of new or liquefied deposits and old non-liquefied deposits, as distinguished in Table 1, a curved line is drawn in the form of R_L =a $Vs_1^{\,2}$ with particular cyclic reference strain, which passes through average points in the scattered plots of data (Figure.1). In conclusion, based on the aforementioned interpretation, the cyclic yield strain is proposed as being index property relevant to distinguish sandy deposits in terms of their age of deposition in the chart of cyclic resistance ratio versus shear wave velocity. It is suggested, therefore, that when using the chart of R_L versus V_{S1} based on in-situ measurements of V_{S1}, multiple curves related to age of the deposit in question are to be established separately and used accordingly for estimating the resistance to liquefaction for each deposit accounting to its age.

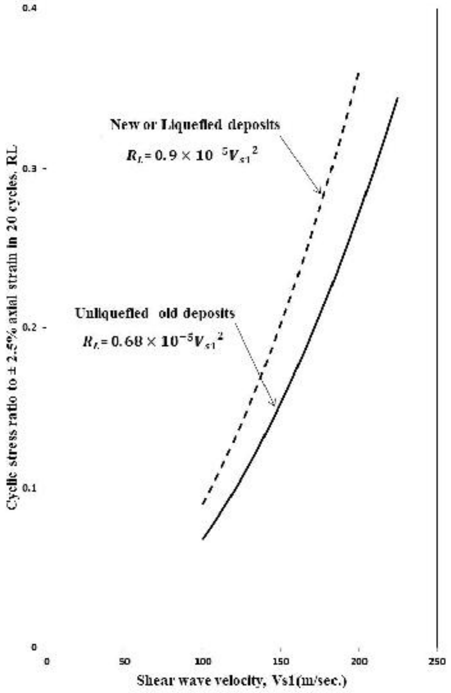

Figure 1. Multiple curves related to age of the deposit

Table 1. Undisturbed samples from Asahi

Sampling site	Age	Depth (m)	σ'v (kPa)	N-value	N_1-value	FC (%)	Vs (m/s)	Vs_1 (m/s)	G_{01} (MPa)	R_L	$\varepsilon_{cy} = \frac{R_L \cdot Pa}{G_{01}}$
HG-S-1 (S-1)	As^{ℓ}	2.0-3.0	25	4	6	11.8	L 127 F 110	L 180 F 156	L 59.5 F 47.6	0.23	L 3.86×10^{-4} F 4.83×10^{-4}
SN-S-1 (S-1)	$Fill^{\ell}$	1.0-2.0	20	5	11	1.9	L 121 F 100	L 181 F 149	L 61.9 F 41.7	0.35	L 5.65×10^{-4} F 8.39×10^{-4}
SN-S-1 (S-10)	Ds^{n}	24.0-26.1	215	23	16	9.0	L 211 F 220	L 174 F 182	L 57.8 F 66.3	0.24	L 4.15×10^{-4} F 3.62×10^{-4}
SN-S-2 (S-6)	As^{n}	13.0-14.0	115	26	24	5.0	L 209 F 220	L 202 F 182	L 76.3 F 84.8	0.23	L 3.01×10^{-4} F 2.71×10^{-4}

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