Development of a countermeasure against soil liquefaction by driving wooden piles

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1. Introduction

Wood is a sustainable construction material. It has been used for thousands of years. It has low embodied energy compared to many other building materials, and it serves to sequester carbon. In the last decade, alternative building materials have begun to gain prominence in the marketplace due to environmental concerns, durability issues, and misconceptions about using wood. The fact is, untreated wood has huge environmental benefits over other building materials. It is completely biodegradable,uses less energy to process than steel, concrete, aluminum, or plastic, and is 100% renewable.

2. Test Procedure

The purpose of performing shaking table tests as part of this research was twofold. First, the tests were designed to confirm the effect of improvement of the ground. Secondly, to reveal the difference of the effect of improvement between three types of sands..

Sand was ejected sand due to liquefaction collected from Urayasu city and physical properties of sand are shown in Table 1. Figure 1 shows the particle size distribution of sand. Grain size of Toyoura and Tonegawa is almost the same, Toyoura has 0% fine fraction whereas Tonegawa has 8% and Urayasu sand has 43% fine fraction.

Many researchers used Toyoura sand for liquefaction experiments. However, Toyoura sand is very special sand compare with natural sand(Tonegawa and Urayasu) on the point that there is no fine particle in Toyoura sand. For this reason, experiment using natural sand such as Urayasu sand is needed to notify in actual field condition.

The testing platform measures 76 cm x 28 cm in plan and 40 cm deep and thickness of ground was 30cm. GSL(ground surface level) & GWL(ground water level) are at same level(as shown in Figure 2). Frequency of input motion was 5Hz in uniaxial direction[1]. Wave amplitude is increased every step. Initial relative density of the ground was 60%(using minimum method). Wooden piles used in experiments have diameter of 1cm and length of 25cm. Intervals between piles is 3D and 4D. Piles are pushed 1 cm into the ground then stop then again pushed 1cm then stop and so on.

3. Relationship between Input acceleration and cumulative settlement

Figure 3 shows the relationship between amount of cumulative/total settlement and input acceleration. With the increase of density and by using wooden piles, settlement is decreased. Settelement by 3D is smaller than 4D, therefore 3D is more effective for Urayasu sand.

Table 1: Physical Properties of Samples

Physical Properties	Symbol	Units	Toyoura	Tonegawa	Urayasu
Density	ρ_s	g/cm^3	2.645	2.734	2.705
Minimum density method (JIS)	$\rho_{dminJIS}$	g/cm^3	1.341	1.112	0.954
Maximum void ratio method (JIS)	e_{maxJIS}		0.972	1.459	1.835
Maximum density method (JIS)	$\rho_{dmaxJIS}$	g/cm^3	1.637	1.496	1.352
Minimum void ratio method (JIS)	e_{minJIS}		0.616	0.827	1.001
Maximum density (minimum method)	ρ_{dmaxmm}	g/cm^3	1.637	1.700	1.640
Minimum void ratio method (minimum)	e_{minmm}		0.616	0.608	0.649
Maximum grain size	D_{max}	mm	0.42	4.75	2
Fine fraction	P_f	%	0	8	43
50% particle diameter	D_{50}	mm	0.18	0.18	0.089
Uniformity coefficient	U_c		1.6	2.1	4.3
Liquid limit	w_L	%	—	—	—
Plastic limit	w_P	%	NP	NP	NP
Plasticity index	I_p		NP	NP	NP

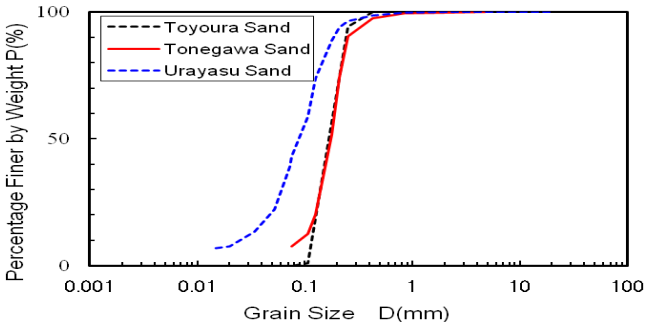

Figure 1: Gradation curves of samples

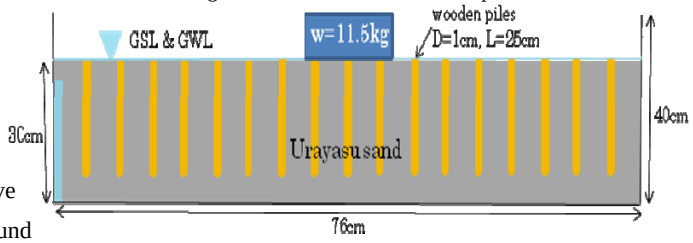

Figure 2: Schematic sketch of shaking table test

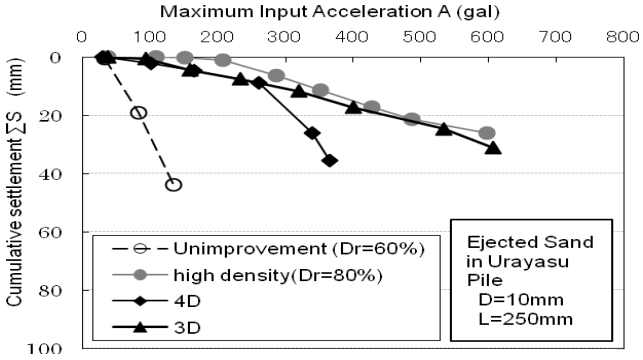

Figure 3: Relationship between cumulative settlement & input acceleration

Key Words: Wooden Piles, Shaking Table Test, Groung Improvement, Urayasu Sand

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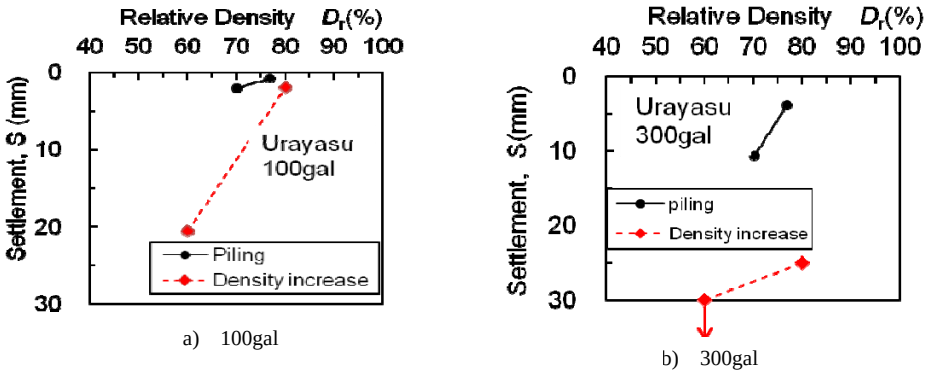
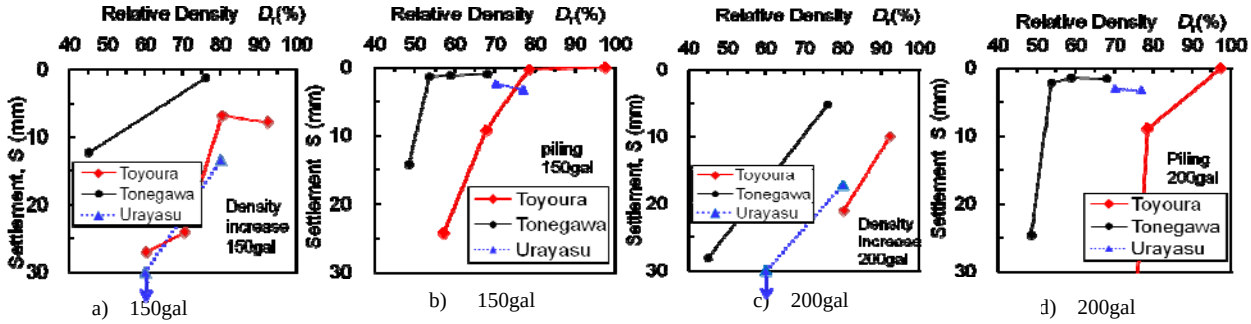


a) 100gal b) 300gal

Figure 4: Relationship between relative density and settlement of Urayasu sand



a) 150gal b) 150gal c) 200gal d) 200gal

Figure 5: Relationship between relative density and settlement in the Urayasu, Toyoura and Tonegawa sand

4. Settlement and relative density of Urayasu sand

Figure 4 shows the relationship between density and settlement of weight (structure) in Urayasu sand. Density was calculated by assuming that sand particles do not move vertically. If relative density of ground is increased, settlement is going to decrease. With the increase of 20% relative density of Urayasu sand, there is 99% reduction in settlement as shown in figure 3(a) by red line. On the other hand, by using wooden piles, subsidence reduction effect becomes larger with smaller pile interval i.e. 3D has more prominent effect than 4D and tighten the relative density closer to 77% (density of ground between piles) and almost negligible amount of settlement as shown in figure 3.

5. Comparison of effects of settlement with three types of sands

Figure 5 shows the relationships between the settlement compared with the relative density of ground in Urayasu, Toyoura[2)] and Tonegawa[3)] sands. If density is increased then there is more subsidence effect on Urayasu and Tonegawa sands as compared to Toyoura sand in piling condition. In particular the difference among three is larger in the case of density increase method. It means the effect of piling and density increase between piles is more in natural sands (Urayasu & Tonegawa) as compared to Toyoura sand. The reason may be that both these sands have fine particles (43% & 8% respectively). If there are fine particle between soil particles then it is more easy to relocate the positions of particles to achive the state of maximum strength and becomes one structure when wooden piles are inserted, compared to those without fine grained particles. As a result, it can be concluded that natural sand/actual ground is expected to have more effect against subsidence as compared to Toyoura sand.

6. Conclusion

Sand (Urayasu and Tonegawa) behaviour is more evident as compared to Toyoura sand, so if this method is used in field, the sand behaviour will be more realistic and it will give more efficient results.

7. References

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2) Motoyama H., Numata A., Momohara I., Nagao H., Hamada M. and Yoshida M.(2011): Relationship between interval of tree trunks piling and effect of liquefaction measures due to small-scale shaking table test, The 66th JSCE Annual Meeting Proceedings, CS13, pp.19-20. (in Japanese)

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