Effects of flow gate and flow pipe as countermeasures against uplift of a sewage manhole

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1. Introduction

Damage on underground structures has been frequently initiated by liquefaction of soils during earthquakes. Uplifting of sewage manholes is one of the typical and striking damage pattern observed in the areas being strongly hit by large earthquakes. During the construction of manholes, the ground is excavated with a width of about 2 m. After placing manholes, the excavated area is replaced with sandy material. Soil investigation of the replaced sand after earthquakes has revealed that the sands are relatively loose and easy to liquefy. It has been concluded, therefore, that the uplift of the manholes occurs due to the liquefaction of the replaced sand. In order to mitigate the uplift for future earthquakes, a manhole with flow gates and flow pipes as a part of pipe connection (Fig. 1) has been proposed. The flow gate and flow pile guide pressured water into a manhole to dissipate the excess pore water pressure in the replaced sand. The effect of proposed countermeasures is verified through the centrifuge model tests conducted in the present study.

2. Centrifuge model tests

A series of centrifuge tests were performed under the centrifugal acceleration of 20 g (g is the acceleration due to gravity) with a rigid soil container of 450 × 150 × 300 (L × W × D) (mm) (model scale). A typical model set up is shown in Fig. 2 with location of sensors; 7 accelerometers (A1~A7), 6 pore water pressure transducers (P1~P6), and 2 displacement transducers (D1~D2).

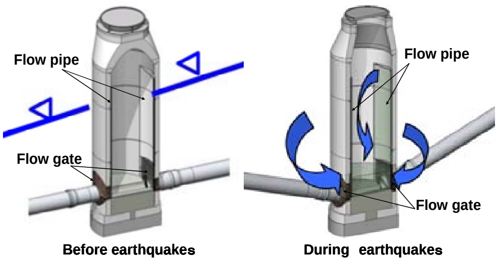

Fig.1. Flow gates and flow pipe as countermeasure

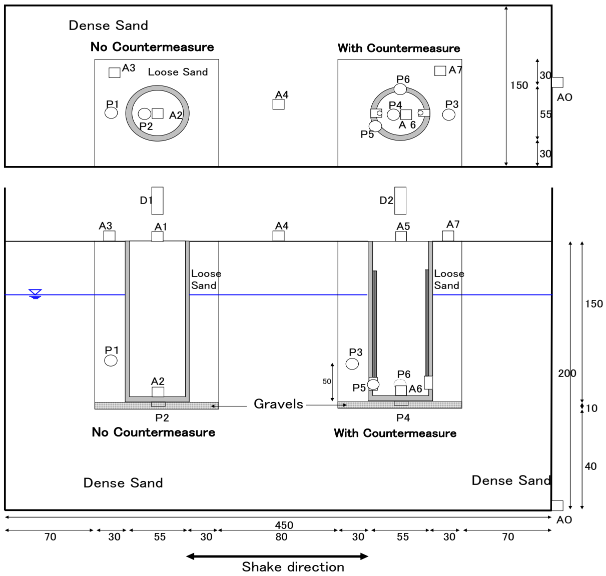

Fig. 2. Model setup

The model is scaled down to 1/20. Model manhole with outer diameter of 55 mm, length of 150 mm and a wall thickness of 5 mm was made from a hollow aluminum column in model scale. The soil profile consisted of uniform silica sands. It has been widely used in previous research and its mechanical behavior is well documented. The maximum and minimum void ratios are 1.19 and 0.79, respectively, and average diameter (D_{50}) is 0.15 mm.

First, the model container was filled up with the sand compacted until relative densities of 85~90 % is achieved. Then, the ground was excavated with a volume of 100 × 100 × 160 (L × W × D) (mm) to place the manholes on gravels of 10 mm thickness. Lastly, by water pluviation method, loose sand deposit of the relative densities of 35~40 % was made in the excavated volume. The manhole in prototype scale has an outer diameter of 1,100 mm, length of 3,000 mm and a wall thickness of 100 mm. Two model manholes, one without countermeasure and the other with countermeasure, were shaken simultaneously to investigate the effects of countermeasure. Model No. 1 has no countermeasure (see Fig. 3). Countermeasures employed in the study consist of model No. 2 and 3 (see Fig. 3). Model 2 has flow gates of diameter 10 (mm), while model No. 3 has that of 15 (mm) in prototype scale.

Common input acceleration shown in Fig. 4 was applied in a series of tests. It has frequency of 1.25 Hz and the

Keyword: Liquefaction, Manhole, Uplift, Centrifuge Model Test, Earthquake
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maximum amplitude of about 600 Gal in prototype scale.

3. Results of centrifuge model tests

Fig. 5 and 6 show time histories for model No. 1 and 2. Uplift of the manhole is started at onset of liquefaction of sand fill [Fig. 5 (a-b) and Fig. 6 (a-b)]. Pore water pressure at the bottom of manhole [P2 and P4: Fig. 5(c) and Fig. 6(c)] did not reach to the initial vertical effective stress.

The effects of flow gates are shown in Fig. 6(d) and (e). The maximum excess pore water pressure of P5 [Fig. 6(d)] is slightly smaller than that of P6 [Fig. 6(e)]. It indicates the dissipation of excess pore water pressure through flow gates.

Fig. 7 summarizes uplift amount of manholes, and Table 1 shows details of uplift amount, settlement of sand fill, and dissipated water level in a manhole. As shown in Fig. 7, uplift amounts of model No. 2 and 3 are smaller than that of No. 1, and model No. 3 whose flow gate diameter is 15 mm gives the smallest uplift. From Table 1, one may notice that larger uplift amount is associated with larger surface settlement of sand fill.

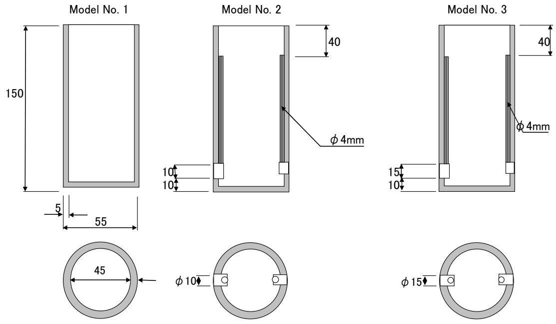

Fig. 3. Manhole model and countermeasures

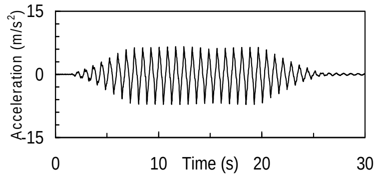

Fig.4. Input acceleration recorded at the shaking table

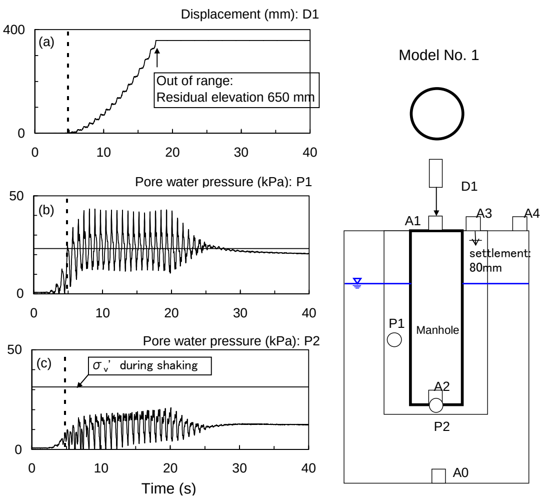

Fig. 5. Measured time histories of model No. 1

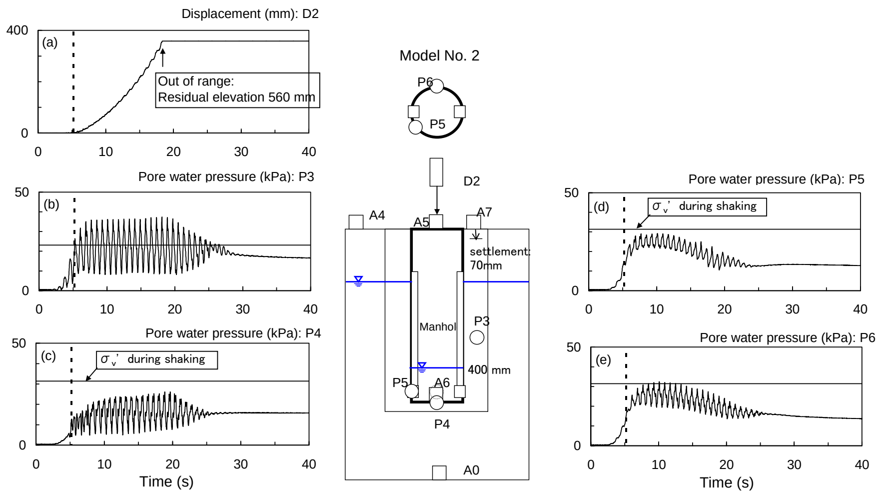

Fig. 6. Measured time histories of model No. 2

Table 1. Uplift amount of manholes

Model No.		Water level	Uplift amount of Manhole (mm)		Settlement of sand fill (mm)		Water in Manhole (mm)	
			With countermeasure	No countermeasure	With countermeasure	No countermeasure	With countermeasure	No countermeasure
1	2	G.L. -1m	560	650	70	80	400	0
1	3	G.L. -1m	460	820	60	100	280	0

4. Conclusion

In order to verify the applicability of countermeasures against uplift of manholes, a series of centrifuge model tests were performed. Proposed countermeasures consisted of flow gates and flow pipe to guide pressured water into a manhole. The applicability of the countermeasures was verified through centrifuge model tests by comparing response of the case with no countermeasure. Although uplift amount was reduced by the proposed method, the amount of uplift may be still too large when it is applied in practice. Hence, further investigation for effective countermeasures is required.

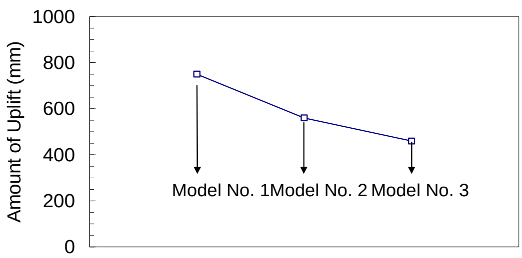

Fig. 7. Amount of uplift of manholes

References

Yasuda, S., and Kiku, H. (2006). "Uplift of Sewage Manholes and pipes during the 2004 Niigataken-Chuetsu Earthquake" Soils and Foundations, Vol. 46, No. 6, 885-894.