Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.III)

4-3-13

ESTIMATION OF EFFECT OF PREVENTING MEASURES FOR UPLIFT OF MANHOLE DUE TO LIQUEFACTION

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SUMMARY

The objective of this study is quantitative estimation of effect of preventing measure for uplift of the manhole due to liquefaction based on the experimental works. As the prototype of the lifeline the pipeline with a manhole for electric power supply is adopted in this study. Gravel drain method was selected as the preventing measure referring the authors' results of the previous study. In the series of the experiments the effect of the gravel drain was investigated comparing the results for several different region for improved ground by gravel. As the results of this study, quantitative relation between the uplift of the manhole due to liquefaction and the region of the improved ground by gravel were made clear by the experimental results and simplified calculation.

INTRODUCTION

Damage of buried lifelines due to liquefaction of saturated sandy layers was observed in 1964 Niigata earthquake and 1983 Nihonkaichubu earthquake in Japan. The failures of the buried lifelines cause many effects on lives and require long time to recover those functions. The damage was typically observed in lifting, sinking, bending out and breaking of them especially at locations near manholes, pipe-joints and boundaries of subsurface soils. Several experimental studies on buried pipeline subjected to liquefaction have been performed to find out the relation between the ground acceleration and strains of the model buried pipes during seismic liquefaction (Ref. 1 and 2). Effect of liquefaction to the manhole and buried pipeline were investigated by Kawamura et al and Takada et al (Ref. 3 and 4). Results of these studies pointed out the possibility of the uplift of the manhole due to liquefaction. On the other hand the experiments on the effective preventing measures of buried pipeline for liquefaction has been carried out by Ohishi et al and Kawamura et al (Ref. 5 and 6). These studies suggested that the gravel drain is the one of the effective preventing measures. In this paper the relation between the region of the improved ground and amount of the uplift of the manhole are investigated by the experiments and simplified calculation.

EXPERIMENTAL PROCEDURE

As the prototype of the lifeline the buried conduit for electric power supply is adopted in this study. The cross section of the pipeline are 0.9 m wide and 1.2 m high. The dimensions of manhole are 3.1 m in width, 3.7 m in height and 9.6 m in length. The value of unit weight of the pipeline is 1.9 $tonf/m^3$ and nearly equals to the saturated unit weight of the sand layer though the unit weight of manholes is relatively smaller than the one of soil layer. The dimensions of the model pipeline are one twentieth of the prototype. The unit weights of the model pipeline and sand layer are kept as same as the prototype to make clear the effect of the buoyancy during liquefaction due to the difference of the specific gravity. The value of Young's modulus of model pipeline is 3,300 kgf/cm^2 which is one fortieth of the one of the prototype to make easier to measure the strains and displacements of the models. A schematic diagram of the model is shown in Fig.1.

Kiso sand was used in the experiment and the physical properties of the sand is as follows. The specific gravity is 2.65, the maximum grain size is 2 mm, the minimum grain size is 0.15 mm, the effective grain size, D_{10} is 0.26 mm and the coefficient of uniformity is 1.89. It is considered that the loose saturated layer composed of this sand may easily liquefy during earthquake. The maximum void ratio is 0.856 and the minimum is 0.611. The coefficient of peameability corresponding to the maximum void ratio is 0.06 cm/sec and the coefficient to the minimum is 0.03 cm/sec. In the experiments sand was contained into the soil bin stored with water in order to put the fill into as close to the saturated state as possible. In the series of the tests the density was adjusted as Dr=40%.

To investigate the suitable range of the improved ground to prevent the uplift of the manhole due to liquefaction, the model was set up in the saturated sand layer as shown in Fig.1. In the series of the tests the width of the gravel drain surrounding the manhole w, and the thickness of the gravel drain under the manhole h, are changed as shown in Table 1. The length of the gravel which covers the joint between the manhole and the pipe section , b, was 50 mm in each test. Small gravel whose diameter is 3 to 5 mm are used as the material for gravel drain. The improved region of the ground by the gravel was covered with 0.5 mm wire mesh to avoid mixture of two materials.

In the experiments horizontal harmonic oscillation is applied to the soil box whose dimensions are 70 cm in width, 60 cm in height and 160 cm in length as shown in Fig.1. The direction of the vibration is perpendicular to the axis of the model pipe section which is buried in the saturated loose sand layer. The magnitude of the acceleration is increased linearly up to 300 gal during 30 seconds. During liquefaction tests accelerations of the soil bin and the model structure, displacements and strains of the model, pore water pressures and earth pressures, etc are measured as shown in Fig.1.

TEST RESULTS

In the experiments the boundary conditions between the pipes and the manhole are rigid. Both ends of the pipes are fixed. The fix condition corresponds to the case where the liquefaction of sand layer occurs in a narrow region. Measured values are divided into static component and dynamic component. Static component represents the mean value of a maximum value and a minimum one during one cycle. Dynamic component corresponds to the amplitude. Concerning on the vertical displacements of the manhole the static component dominates compared with the dynamic one where positive values imply the uplift of the manhole. On the other hand dynamic component of the horizontal displacement of the manhole are relatively larger than the static one.

Fig.2 shows the build up of excess pore water pressure which are measured at the bottom of the manhole during horizontal oscillation. When the gravel drain is not installed as in Case 1, the ratio of excess pore water pressure to the effective normal stress at the bottom of the manhole ,U becomes up to 1 ,

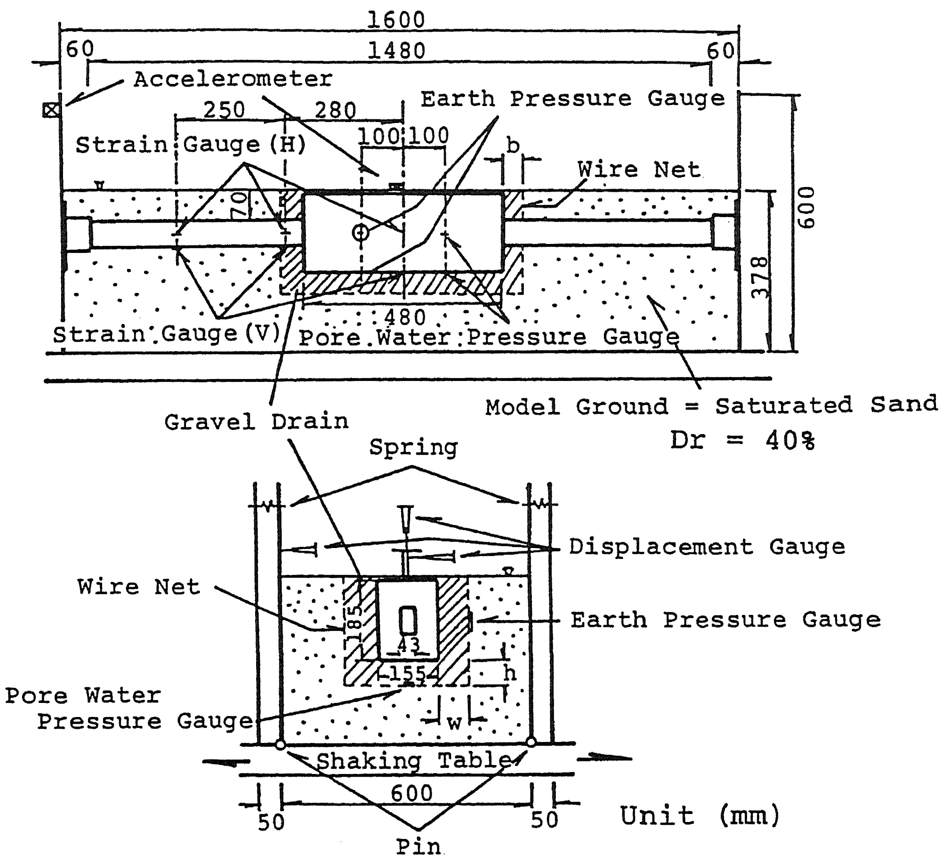

Fig.1 Schematic Diagram for the Model Manhole and Gravel Drain Layer

Table.1 Experimental Condition for Range of Gravel Drain Layer

Case \ Range	w	h	b
1	0	0	0
2	25	0	50
3	50	0	50
4	25	50	50
5	50	50	50
6	75	50	50

that indicates liquefaction of the sand layer. When the width of improved ground by gravel is 75 mm and the thickness of the gravel under the manhole is 50 mm as in Case 6, the ratio is less than 0.20. It means that the gravel drain works well as the preventing measures for liquefaction surrounding the manhole.

Fig.3 shows the vertical movement of the manhole during the horizontal vibration. When the gravel drain does not exist as in Case 1, the manhole is lifted upward more than 20 mm. On the other hand the uplift of the manhole has not been observed in Case 6 where the improved region of the ground is large. This implies that the gravel drain is the effective measure to prevent the uplift of the manhole due to liquefaction. The relation between the uplift of the manhole during the vibration and the improved area of the ground are shown in Fig.4. According to the increase of the width of the improved ground by gravel w, the uplift of the manhole becomes small. Especially in the case where w=75 mm, the uplift is completely prevented.

SIMPLIFIED PROCEDURE TO ESTIMATE THE UPLIFT OF THE MANHOLE DUE TO LIQUEFACTION

When the forces acting on the manhole are assumed as a concentrated load as shown in Fig.5, the uplift of the manhole is calculated by the following equation.

$$Y = (Pm \times L^3) / 6EI \qquad (1)$$

where Y : Uplift of the manhole
L : A half of the total length of the pipe
E : Young's modulus of the pipe
I : Moment of inertia of cross section of the pipe
Pm : Concentrated Load

Pm is calculated by the equations 2 and 3, using the uplifting force acting against the bottom of the manhole Um and the side wall friction between the manhole and gravel drain F. The friction is obtained by the weight of the gravel Wg and uplifting force acting on the gravel drain Ug, as shown in Fig.6.

$$Pm = Wm - Um + 2 \times F \qquad (2)$$

$$F = Wg - Ug \qquad (3)$$

where Wm : Weight of the manhole

The comparison between the experimental results and estimated values for the uplift of the manhole are shown in Fig.4. The continuous line represents the estimated values for the case where the gravel drain was not set under the manhole. Dotted line is the estimated results for the case where the thickness of the gravel drain layer h is 50mm. The estimated values coincide well with the experimental results. It is suggested that the increase of the width of the improved ground is more effective than the increase of the thickness of the drain under the manhole.

CONCLUSIONS

As the results of the tests followings are made clear.

(1) Gravel drain is effective to prevent the uplift of the manhole due to liquefaction.

(2) The quantitative relation between the uplift of manhole and the region of the improved ground by gravel drain were made clear based on the experiment and simplified calculation

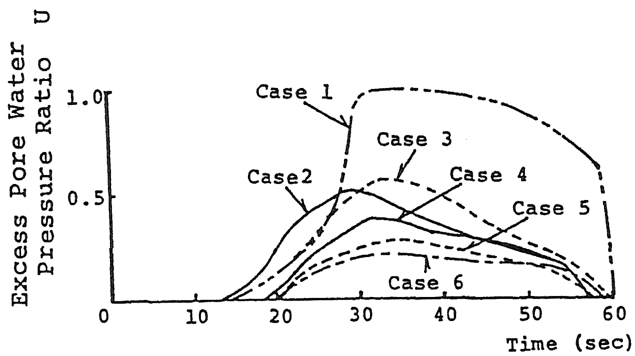

Fig.2 Time History of Excess Pore Water Pressure at the Bottom of the Manhole

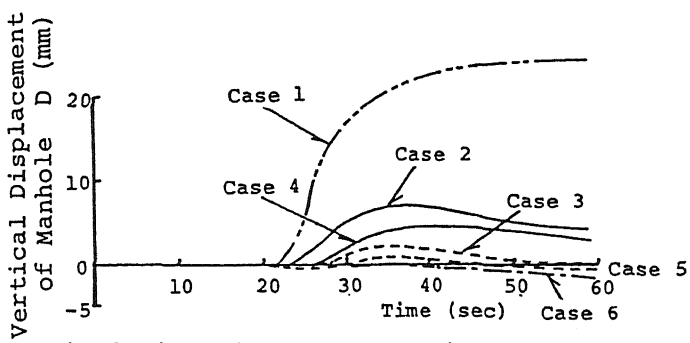

Fig.3 Time History of Vertical Displacement of the Manhole

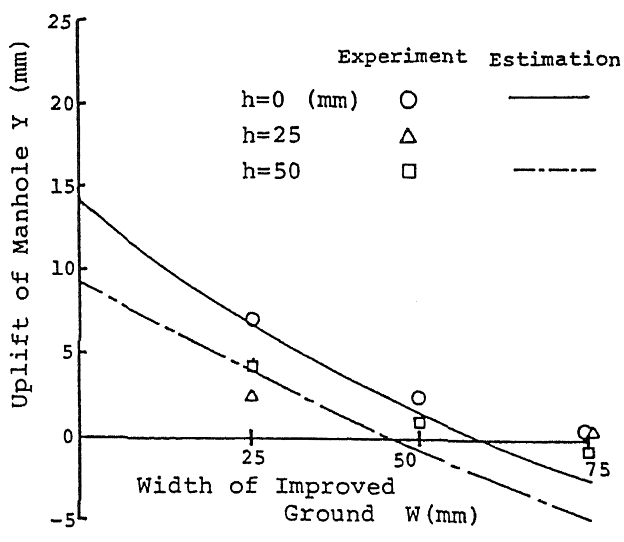

Fig.4 Relations between the Uplift of the Manhole and the Region of the Improved Ground

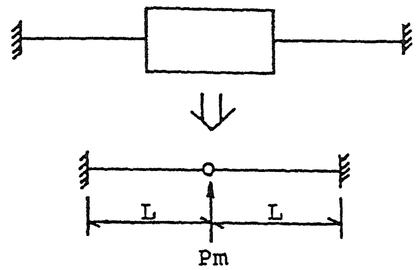

Fig.5 Model for Calculation

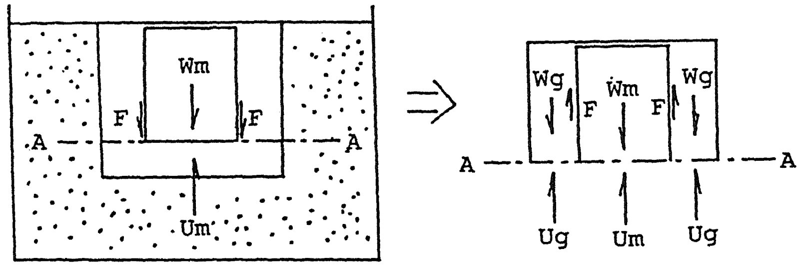

Fig.6 Forces Acting along the Horizontal Plane through the Bottom of Manhole

ACKNOWLEDGMENTS

In performing the shaking tests a great amount of labor works were offered by many colleagues in the soil mechanic laboratory of Toyohashi University of Technology. The authors wish to express their thanks to them. The authors sincerely express their appreciation to Supplementary Grant from Ministry of Education, Science and Culture, Grant No. 58-46-0156 from 1983 to 1985 FY, and Commissioned Grant from Chubu Electric Power Co. Inc. for 1984 to 1986 FY.

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