Dynamic characteristics of a liquid filled egg-shaped tank

Autor(en): **Uno, Kiyoshi / Takanishi, Teruhiko / Naritomi, Masaru**

Objekttyp: **Article**

Zeitschrift: **IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht**

Band (Jahr): **13 (1988)**

PDF erstellt am: **21.06.2024**

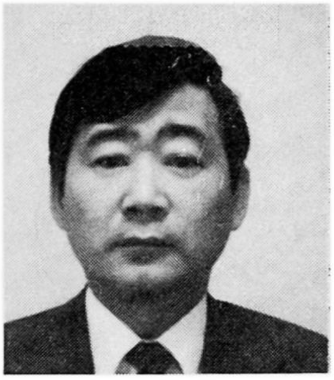
Persistenter Link: https://doi.org/10.5169/seals-13065

Dynamic Characteristics of a Liquid Filled Egg-Shaped Tank

Caractéristiques dynamiques d'un réservoir ovoïde plein

Dynamische Einwirkungen einer Flüssigkeit in einem eiförmigen Wassertank

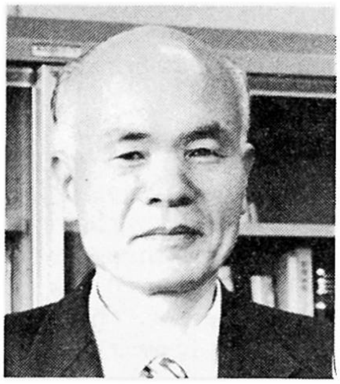
Kiyoshi UNO
Assoc. Prof.
Kyushu Univ.
Fukuoka, Japan



Teruhiko TAKANISHI
Prof. Dr.
Kyushu Inst. of Tech.
Kitakyushu, Japan

Masaru NARITOMI
Dr. Eng.
Kyushu Univ.
Fukuoka, Japan

Seima KOTSUBO
Prof. Dr.
Kyushu Kyoritsu Univ.
Kitakyushu, Japan



SUMMARY
When an Egg-shaped tank is constructed in Japan, pile-group foundation is used in order to resist the effect of earthquakes. It is difficult to analyse the response of tank, liquid and foundation reaction during earthquakes. We proposed approximate equations for the calculation of dynamic liquid pressures in the Egg-shaped tank during earthquakes.

RÉSUMÉ
La fondation par groupe de pieux est utilisée pour des réservoirs ovoïdes au Japon, afin de résister aux effets des tremblements de terre. Il est difficile d'analyser le comportement du réservoir, du liquide et de la fondation pendant les tremblements de terre. Les auteurs proposent des équations approximatives pour le calcul des pressions dynamiques du liquide dans le réservoir ovoïde lors de séismes.

ZUSAMMENFASSUNG
Beim Bau von eiförmigen Wassertanks wird in Japan zur Aufnahme der Erdbebeneinwirkungen auf Pfahlfundationen zurückgegriffen. Die Berechunung des dyanmischen Verhaltens von Tank, Flüssigkeit und Pfahlgruppe ist relativ schwierig. Es werden Näherungsgleichungen zur Bestimmung der dynamischen Flüssgigkeitsdrücke im eiförmigen Behälter vorgestellt.

1. INTRODUCTION

The Egg-shaped tank shown in Fig.1 is developed in West Germany and it is more effective on sewage purification than that of a cylindrical tank. Recently many tanks of this type have been constructed in West Germany. When the Egg-shaped tank is constructed in Japan, pile-group foundation is used in order to resist the effect of earthquakes, which in turn makes it difficult to analyse the response of the tank, liquid and foundation system subject to earthquakes.

The purpose of this study is to propose the approximate equations for evaluating the dynamic liquid pressures of the Egg-shaped tank during earthquakes. Through the results of this calculation, the value of moment at the top of the pile can be easily obtained.

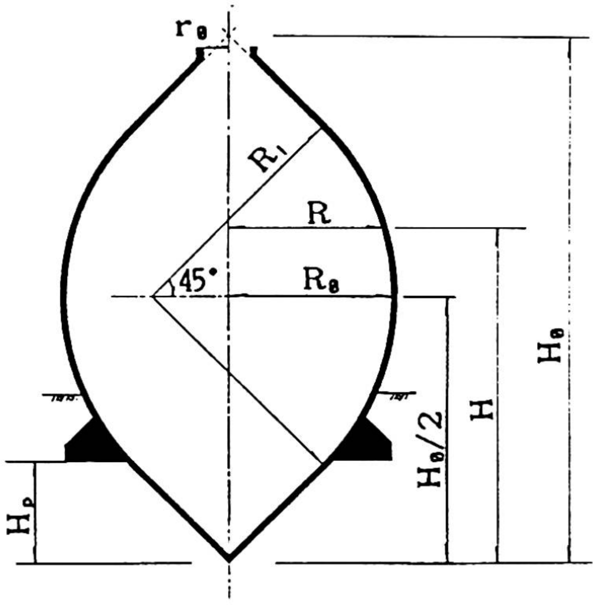


Fig.1 Egg-shaped tank

2. METHOD OF ANALYSIS

Dimensions of three Egg-shaped tanks constructed in Japan are shown in Table 1. The ratio R_0/H_0 falls in the narrow range between 0.301 and 0.315 for all three cases so that the shapes of these tanks are considered similar to each other. Since the values R_0^3 and $(H_0/2)^3$ are nearly equal to the ratios of volume(V) of each Egg-shaped tank, it is known that the standard of the shape can be set up from the ratio R_0/H_0. H_p is the height from the bottom of the Egg-shaped tank to the top of the pile, as is indicated in Fig.1. Dynamic liquid pressures can be separated into impulsive part, which depends on short period component, and sloshing part which depends on long period component. Since it is difficult to analyse these two types of dynamic liquid pressures exactly, the transfer matrix proposed by Sogabe is used for calculating the dynamic liquid pressures.

Table 1 Dimensions of the Egg-shaped tank

		CASE 1	CASE 2	CASE 3
R_1	(m)	10.600	15.550	13.065
R_0	(m)	6.800	10.900	9.180
r_0	(m)	1.000	2.500	2.495
H_p	(m)	4.000	5.000	4.474
$H_0/2$	(m)	11.200	17.340	14.541
R_0/H_0	(m)	0.304	0.314	0.315
V	(m³)	1748.0	6863.0	4000.0

3. RESULTS AND PROPOSED EQUATION

3.1 Impulsive Liquid Pressures (Pi)

Since the value of impulsive liquid pressures increases in proportion to the acceleration and the height of liquid surface(H), the proposed approximate equations for α_i and H_i/H_θ are written in the following form

$$\alpha_i = 0.27(H/H_\theta) + 0.73 \quad 0.9 \leqq H/H_\theta$$
$$= 1.08(H/H_\theta) \quad 0.5 \leqq H/H_\theta < 0.9 \quad \cdots\cdots\cdots (1)$$

$$H_i/H_\theta = 0.25(H/H_\theta) + 0.26 \quad 0.8 \leqq H/H_\theta$$
$$= 0.50(H/H_\theta) + 0.06 \quad 0.5 \leqq H/H_\theta < 0.9 \quad \cdots\cdots\cdots (2)$$

where α_i is the coefficient of added mass and H_i is the height of the loading point of impulsive liquid pressures. Figure 2 shows $\alpha_i - H/H_\theta$ and $H_i/H_\theta - H/H_\theta$ relationships. Using these values, impulsive liquid pressures(Pi) and the moment(Mi) at the top of the pile can be given as follows

$$P_i = \rho \alpha_i V_H \omega_i^2 A_i \quad \cdots\cdots\cdots (3)$$

$$M_i = P_i (H_i - H_p) \quad \cdots\cdots\cdots (4)$$

where ρ is the density of liquid, V_H is volume of liquid, ω_i is the natural circular frequency and A_i is amplitude of displacement.

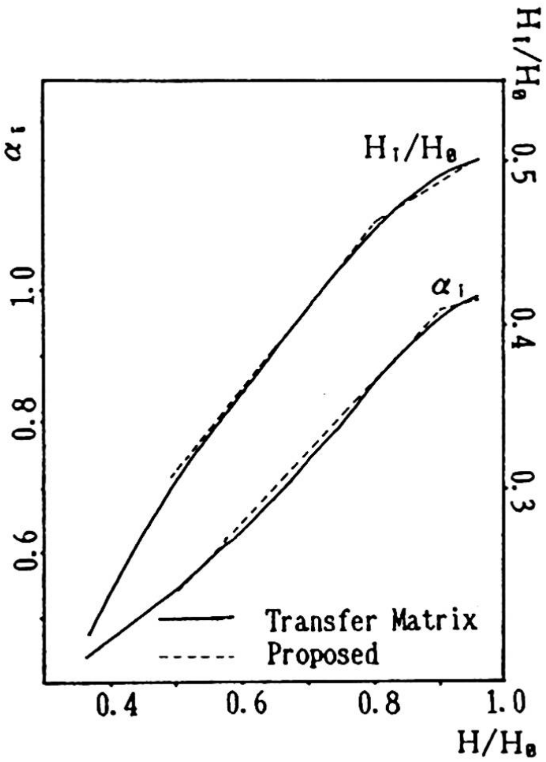


Fig. 2 $\alpha_i - H/H_\theta, H_i/H_\theta - H/H_\theta$ relationships

3.2 Sloshing Liquid Pressures (Ps)

Since sloshing liquid pressures are under the influence of the first vibration mode, the proposed approximate equations are obtained for the first vibratinal mode. The proposed approximate equations for α_s, H_s, T_s, β_s, are written in the following form

$$\alpha_s = 0.37 - 0.40(H/H_\theta)^3 \quad 0.5 \leqq H/H_\theta \quad \cdots\cdots\cdots\cdots\cdots (5)$$

$$H_s/H_\theta = 0.8(H/H_\theta) \quad \cdots\cdots\cdots\cdots\cdots (6)$$

$$T_s/R_\theta^{0.5} = 1.10(R/R_\theta) + 0.40 \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (7)$$

$$\beta_s = 0.27/\{1.0 - (H/H_\theta) + 0.67\} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (8)$$

where α_s is the coefficient of added mass, H_s is the height of the loading point of sloshing liquid pressures, T_s is the natural period and β_s is the participation factor.

Figure 3 shows $\alpha_s - H/H_\theta$ and $H_s/H_\theta - H/H_\theta$ relationships. $T_s/R_\theta^{0.5} - H/H_\theta$ relationship and $\beta_s - H/H_\theta$ relationship are presented in Fig.4 and Fig.5, respectively.

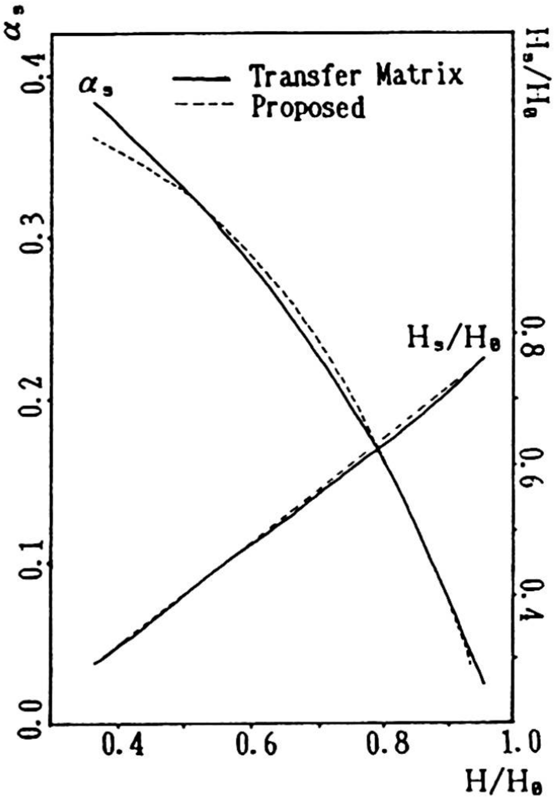


Fig.3 $\alpha_s - H/H_\theta, H_s/H_\theta - H/H_\theta$ relationships

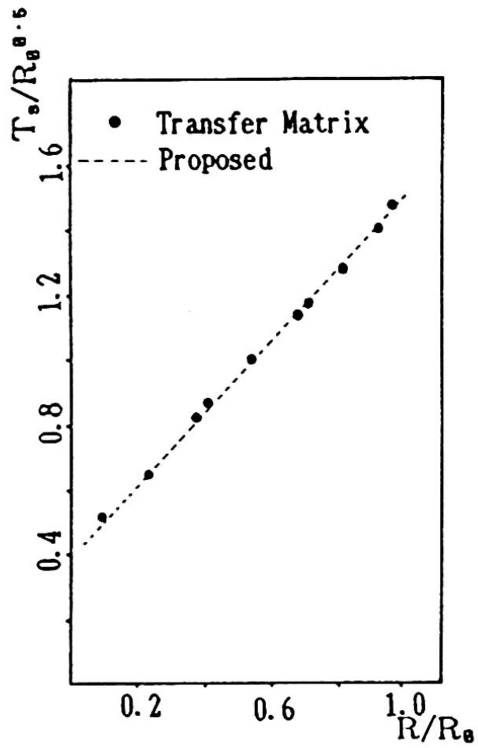


Fig.4 $T_s/R_\theta - R/R_\theta^{0.5}$ relationships

Using these values, sloshing liquid pressures(Ps), the moment at the top of the pile(Ms) and the maximum vertical displacement of free-surface(Wmax) during earthquakes can be given as follows

$$P_s = \rho\, \alpha_s V_H \omega_s^2 A_s \quad \cdots\cdots (9)$$

$$M_s = P_s\,(H_s - H_p) \quad \cdots\cdots (10)$$

$$W_{max} = \beta_s S_A / \omega_s^2 = \beta_s A_s \quad \cdots (11)$$

where ω_s is the natural circular frequency, A_s is the amplitude of earthquake displacement for ω_s and S_A is the amplitude of acceleration for ω_s. Figure 6 shows $M_i - H/H_\theta$ and $M_s - H/H_\theta$ relationships when the amplitude of input earthquake acceleration is 100 cm/s^2.

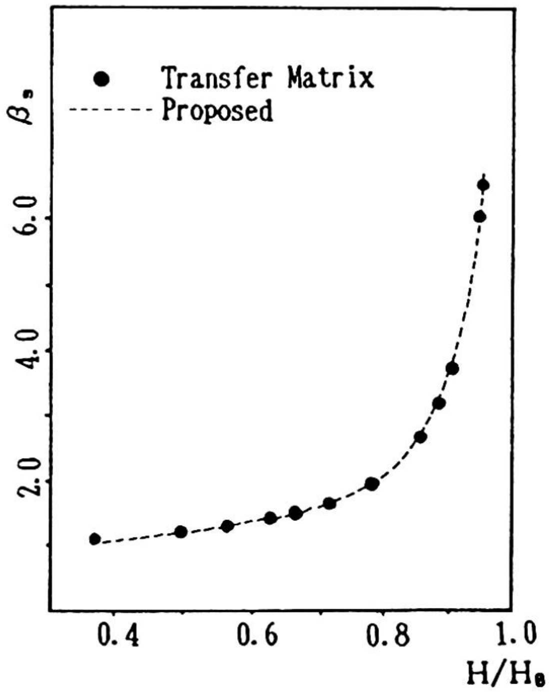


Fig.5 $\beta_s - H/H_\theta$ relationships relationships

4. CONCLUSIONS

The results are useful for aseismic design of the pile-group foundation. When comparing our proposed results with those of the transfer matrix, the accuracy is quite satisfactory, and the dynamic liquids' characteristics of the Egg-shaped tank can be easily given.

It is essential for aseismic design of the Egg-shaped tank to evaluate the moment at the top of the pile-group foundation. The proposed equations are readily used to estimate this moment.

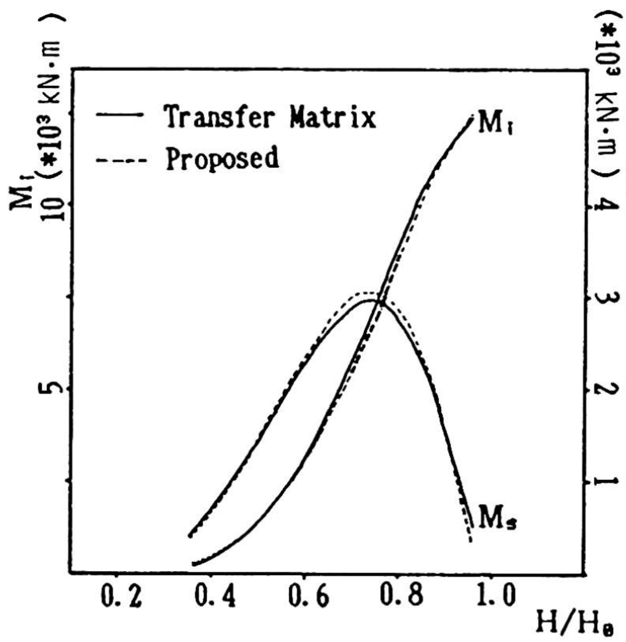


Fig.6 M_i - H/H_0, M_s - H/H_0 relationships

REFERENCES

1. Sogabe K., Shigeta T. and Shibata H., A Fundamental Study on the Aseismic Design of Liquid Storages, Report of the Institute of Industrial Science, March 1977.

2. Abramson,H.N. ed., The Dynamic Behavier of Liquids in Moving Containers, with Applications to Space Vehicle Technology, NASA SP-106 1966.

3. Housner,G.W., Dynamic Pressures on Accelerated Fluid Containers, Bulletin of the Seismological Society of America Vol.47, No.1, 1957.

4. Graham,E.W. and Rodriguez,A.M., The Characteristics of Feul Motion Which Affect Airplane Dynamic, Journal of Applied Mechanics, Vol.19, No.3, September 1952.

5. Cambra,F.J., Earthquake Response Considerations of Broad Liquid Storage Tnaks, University of California Earthquake Engineering Research Center Report Number UCB/EERC-82/25, November 1982.

6. Budiansky,B., Sloshing of liquids in Circular Canals and Spherical Tanks, Journal of the Aero Space Sciences, Vol.27, No.3, March 1960.

7. Dokuchaev,L.V., On the Solution of a Boundary Value Problem on the Sloshing of a Liquid in Conical Cavities, Journal of Applied Mathmatics and Mechanics(PMM), Vol.28, No.1, 1964.

8. Nakayama T., and Washizu K., Nonlinear Analysis of Liquid Motion in a Container Subjected to Forced Pitching Oscillation, International Journal for Numerical Methods in Engineering, Vol.15, 1207-1220, 1980.

9. Aslam,M., Finite Element Analysis of Earthquake Induced Sloshing in Axisymmetric Tanks, International Journal for Numerical Methods in Engineering, Vol.17, 159-170, 1981.

10. Liu,W.K. and Ma,D.C., Coupling Effect Between Liquid Sloshing and Flexible Fluid-Filled Systems, Nuclear Engineering and Design, Vol.72, 345-357, 1982.

11. Abramson,H.N., Dynamic Behavier of Liquid in Moving Container, Applied Mechanics Review, Vol.16, No.7, July 1963.

Leere Seite
Blank page
Page vide

Leere Seite
Blank page
Page vide