04 Apr 1995, 10:30 am - 12:00 pm

Discussions and Replies — Session IV

Multiple Authors

DISCUSSIONS AND REPLIES
SESSION IV

Discussion on Paper Titled : "Wall Movement Modes Dependent Dynamic Active Earth Pressure Analyses Using Cracked Element" by H.Matsuzawa et. al., Paper No. 4.12.

By : Constantine A. Stamatopoulos, K&S Consulting Engineers, 5 Isavron str., Athens 11471, Greece.

The authors present a new formulation and very interesting numerical results illustrating the effect of the wall movement modes on the spread of the failure zone, and the dynamic active earth pressure (magnitude and height of the resultant) under dry conditions. The failure zone results of the numerical analysis for all modes generally follow what has been described by Whitman (1990) : that the Mononobe-Okabe (M-O) theory holds when wall movement is sufficient to mobilise fully the shear strength resistance of the soil. Accordingly, the M-O slip surface approximately coincides with the failure zone only for the larger wall rotations/deformations.

Some points of the analysis need clarification :

- The manner that deformation/acceleration was applied: Deformation was increased for given acceleration levels, or acceleration was increased for given deformation levels ?
- How was the earth pressure affected by the magnitude of wall movement ? At what deflection levels are figures 6 and 7 ?

It would be of interest to simulate with the proposed approach a whole cycle of dynamic loading by using a given wall rotational or translational spring constant, instead of a given deformation. Then, the effect of the wall stiffness on the wall pressure and the failure zone could be investigated for each mode for both directions of horizontal acceleration. If more than one cycle of loading is applied, in addition to the peak response, one could study the residual response at the end of each cycle. Results could be compared with those given by Stamatopoulos and Whitman (1990) illustrating that the failure zone gradually decreases (and thus the static earth pressure increases) as the cycle number increases.

REFERENCES

Stamatopoulos C. A., Whitman R.V. (1990), " Prediction of permanent tilt of gravity retaining wall by the residual strain method", Proceedings of Fourth U.S. Conf. on Earthquake Eng, Palm Springs.

Whitman, R. V. (1990), "Seismic design and behavior of gravity retaining walls". Design and performance of earth structures, Proceedings, GT Div, ASCE.

Discussion on Paper Titled : "Shaking Table Tests and Numerical Simulation of Seismic Response of The Seawall" by Y.Nishimura et. al., Paper No. 4.13.

By : Constantine A. Stamatopoulos, K&S Consulting Engineers, 5 Isavron str., Athens 11471, Greece.

The authors present excellent results of shaking-table tests of gravity sea walls with dry backfill both with and without breaking works. Accelerations, earth pressures, and deflections were measured continuously during shaking at some locations. Points that need clarification are the sign convention used for the earth pressures and accelerations, and at what location were the dynamic pressures measured in case 5 (see fig. 7). Earth pressure measurements would have been more complete if the initial value of the earth pressures was also recorded.

It can be noted (but was not by the authors) that the results of the shaking table tests, given in figures 5 and 7, are a perfect example of a case where the Mononobe-Okabe (M-O) and Richards-Elms (R-E) theories hold :

- A failure wedge behind the wall was observed (fig. 6).
- Deformation accumulated, and thus yielding occurred, only when the input acceleration was negative (I presume directed away from the wall) and smaller than the limit value of about -200 Gal.
- When deformation and yielding occurred the negative acceleration at the caisson remained constant at about -200 Gal not following the further decrease of the input acceleration to -400 Gal.

In addition, it is of interest to observe that negative dynamic pressures when yielding developed were less than the corresponding positive ones for similar magnitude of input acceleration and that residual pressures after shaking were practically zero.

Before predicting the response of these tests using finite elements, the dynamic earth forces could have been compared with M-O predictions, and the critical acceleration and permanent movements with R-E predictions. A rough comparison between test results and R-E predictions of movements for tests 3 and 5 is : The measured permanent displacement is about 5.5 cm=2.2 in and the measured ratio of critical to peak acceleration is about 200Gals/400Gals=0.5; the displacement corresponding to this acceleration ratio according to fig. 15 of Richards and Elms (1979) is 5 in. The difference in measured/predicted displacement may be a result of the small number of cycles applied in the tests. Integrating twice the measured difference in acceleration may give closer predictions.

In the finite-element predictions it can be observed that accelerations and displacements are predicted well, but predicted dynamic earth pressures are off for case 3. Numerical results using model "J" predict the anticipated decrease in the displacement of the caisson by the presence of the breaking works; this trend is not shown in the test results.

Test results with saturated backfill are only described briefly. Numerical predictions are not presented. Predictions of these tests will illustrate the accuracy of the numerical model for predicting the response of The Seawall.

REFERENCE

Richards R., Elms D. (1979), "Seismic Behavior of Gravity Retaining Walls", J. of the Geotech. Engrg. Division, ASCE, April.

Discussion on Paper Titled : "Earthquake Induced Displacement of Gravity Retaining Walls" by X.Zeng, Paper No. 4.14.

By : Constantine A. Stamatopoulos, K&S Consulting Engineers, 5 Isavron str., Athens 11471, Greece.

This concise paper includes an excellent discussion of factors affecting displacement of gravity walls, results of new centrifuge tests with gravity walls, and their numerical prediction. It also proposes an interesting approximate model giving the tilting of gravity walls.

The discusser agrees with comments made by the author that "for a gravity wall with dry backfill, Newmark's sliding block method can generate reasonable results about the sliding displacement". This is certainly true for the test results presented. One could also note that sliding displacement may not be the prevailing failure mode for other types of walls, which are more rigid and yielding in the active sense does not develop in the backfill.

The centrifuge test results would have been more complete if wall pressures were also measured. These would have allowed comparison of predicted and measured earth pressures. For the case with dry backfill earth pressures could have been compared with those estimated by the Mononobe-Okabe equation, that are assumed in the author's predictions to act.

The discusser agrees with the author's comment that "For a gravity wall with saturated backfill, the influence of excess pore pressure plays an important role and makes it difficult to apply a simple calculation. Comprehensive numerical simulation is needed." This is illustrated by the test results presented in the paper, and their numerical simulation. Similar dynamic centrifuge tests illustrating the same need are described and simulated numerically by Ting (1993).

For the tests with saturated backfill it would be of interest to compare pore pressure response at PP1 and PP2. As these two transducers are at the same depth but different horizontal locations, a comparison of their response may illustrate the effect of wall movement on the excess pore-pressure generation.

REFERENCE

Ting N. H. (1993), "Earthquake-Induced tilt of retaining wall with saturated backfill", Massachusetts Institute of Technology, PhD thesis, May.

Discussion on Paper Titled : "Dynamic Response of Soil Pressure on Retaining Wall" by K.Sun and G.Lin, Paper No. 4.17.

By : Constantine A. Stamatopoulos, K&S Consulting Engineers, 5 Isavron str., Athens 11471, Greece.

The authors present a new formulation and numerical analysis of the model of a vertical flexible beam retaining an elastic stratum to evaluate the dynamic soil pressures on retaining walls. It can be noted that the above model applies particularly for non-yielding (rigid) walls where a failure wedge does not develop and the Mononobe-Okabe theory of dynamic pressures no longer applies. For such walls residual horizontal forces may also exist after each cycle of dynamic shaking. For example in Andersen's centrifuge tests using tilting walls, residual forces were nearly as large as the peak forces during shaking (Nadim and Whitman, 1993). Such residual forces cannot be predicted by elastic theory. Since the Finite Element Method with appropriate elements can predict such residual forces (e.g. Nadim and Whitman, 1993), the discusser believes that the reduction of computational effort of the proposed approach may not be justified in all cases in view of the possibility of less accurate results.

Previous work on the topic of using the theory of elasticity to estimate dynamic pressures on retaining walls (e.g. Scott, 1973) could have been compared to the present work. Differences in the assumptions made in the formulation of the problem and advantages of the present approach could have been discussed.

Of particular interest to actual problems is the total magnitude and the distribution with depth of earth pressures. These quantities are not presented in the obtained solutions. Limited space may be the reason. Computed distributions of dynamic pressures with depth could have been compared with measured distributions as reported by Prakash (1981).

ERRATA : - In text : Sun and Pires, 1993 (not 1994)
- In REFERENCES : Prakash, S. ..... Proc. 1st (not 2nd) International Conference ......

Also some references are not mentioned in the text.

REFERENCES

Nadim F., Whitman R. V. (1993), "Seismic analysis and design of retaining walls", Soil Dynamics and Earthquake Engr., Seco a Pinto (ed.), Balkema.

Prakash S. (1981), "Analysis of rigid retaining walls during earthquakes", Proc. 1st International Conf. on Recent Advances in Geotech. Earthquake Engr. and Soil Dynamics, St. Louis, MO, Vol. III.

Scott R. F. (1973), "Earthquake-induced pressures on retaining walls", Proc. 5th World Conf. on Earthquake Engr., Tokyo, Japan II, 1611-1620.

Discussion on paper titled: "Dynamic Response of Soil Pressure on Retaining Wall", by K. Sun and G. Lin, Paper No.4.17.

By: Hiroyuki Watanabe, Department of Civil and Environmental Engineering, Faculty of Engineering, Saitama University, Japan.

The authors are to be congratulated for their contribution on evaluating the dynamic soil pressures acting on a flexible retaining wall.

I am very interesting in the theory which the authors proposed in this paper because the theory may be able to apply to evaluate the earth pressure acting on the underground structures such as subway, underground conduit, and so on.

In my experimental and numerical studies on the normal and shearing soil pressure acting on the underground conduit of double box RC Rahmen frame during earthquake (Watanabe and Suehiro, 1992), it has been revealed that the dynamic soil pressure acting on the side wall of the conduit shows such distribution mode as reverses in its acting direction at upper and lower parts along the wall as seen in Fig.6 measured in the experiment carried out on the model conduit buried in very shallow depth of sand as shown in Fig.7, whereas in the case buried deep, above mode of soil pressure distribution reverses also as the rigidity of conduit changes from high to low at every phase of base motion as seen in Fig.8. In the above figures Case 1 means that the conduit has lower shearing rigity than the one of soil layer, Case 2 corresponds to higher one and Case 3 does medium. The side wall of conduit buried in shallow depth of sand has similar situation to the flexible retaining wall being treated in this paper.

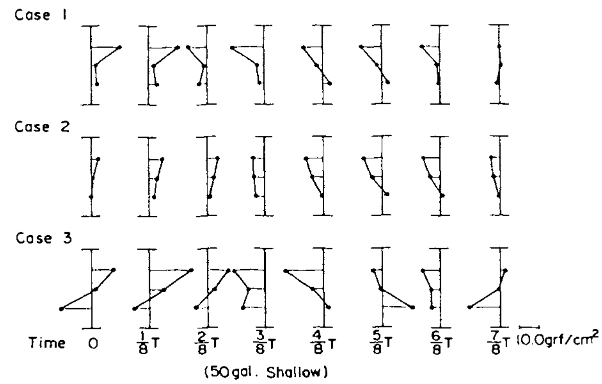

Fig.6 Time History of Distribution Pattern of Soil Pressure (Shallow)

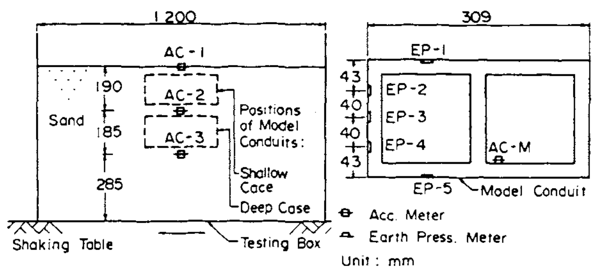

Fig.7 Arrangement of Conduits and Gauges

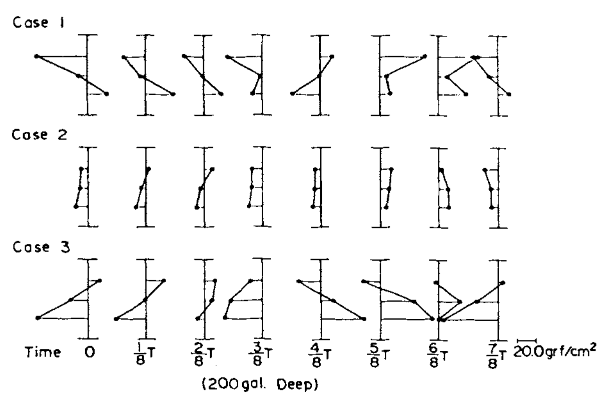

Fig.8 Time History of Distribution Pattern of Soil Pressure (Deep)

The authors show three figures concerning the effects of wall rigidity and material damping on the frequency response of soil pressure only at the top of the wall. How is the distribution mode of soil pressure along the flexible mode in your calculation?

In Eq.(10) I wonder if the double integral in the left hand side should be multiplied by ε^2. Give some comments please.

Reffences

watanabe, H. and Suehiro, T. (1992), "Ex-perimental and Numerical Studies on Dyanmic Earth Pressure acting on Side Walls of Underground Conduit", Proc. of the Tenth World Conference on Earthquake Engineering, Madrid Spain, Vol.9, pp.5427-5432.

Paper No. 4.12

Reply by Hiroshi Matsuzawa, Hemanta Hazarika and Masahiro Sugimura
Department of Geotechnical and Environmental Engineering, Nagoya University, Nagoya, JAPAN

The authors would like to acknowledge the discussion raised by Constantine A. Stamatopoulos and appreciate the suggestions made by him.

The primary objective of the analyses is to explain the generation of the seismic active earth pressure for various modes of the displacement of a retaining wall through simulation of the model tests. Compared to the conventional method of analyses, the analyses using the *Double Shear Band* formulations presented in the paper can capture well the progressive deformation characteristics of the backfill. The analyses were performed in the time domain for different level of accelerations. During the analyses, incremental displacement was applied to the wall, while a sinusoidal loading was applied to the backfill with a frequency of 3.5 Hz. In other words, the deformation was increased for a particular acceleration level.

The variation of the seismic earth pressure with wall displacement is shown in the figure below for translational movement (T Mode) of the wall. Two cases are shown in the figure, one for the static case (acceleration = 0) and the other for the seismic loading

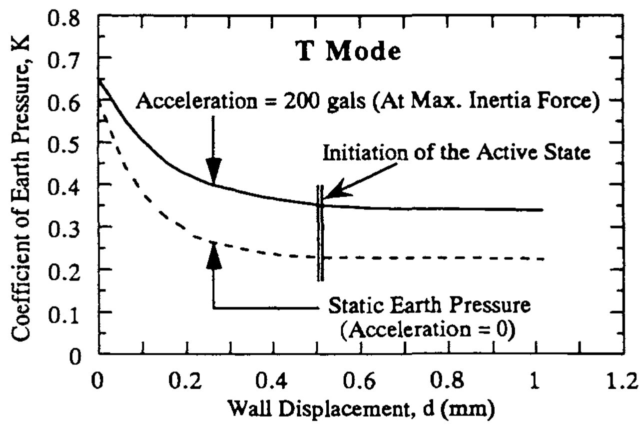

Fig. Variation of the Earth Pressure Coefficient with Wall Displacements

case (acceleration = 200 gals) when the inertia force acting on the wall is maximum. The variation shows a sharp decrease of the earth pressure at the small wall displacement, however, with increasing wall displacement the rate of decrement decreases and ultimately reaches a constant state, implying the attainment of the active state. The failure patterns of the backfill at different wall displacements were observed for a particular acceleration (Fig. 4 in the original paper). The active state has been defined to be at that stage when the backfill forms either a clear failure wedge or a banded zone of failed elements. With further increase of the displacement, the progression of the failure zone ceases. The values of Figs. 6 and 7 are corresponding to the displacements at the active state for each level of the accelerations. It was found from the analyses that even though the domain of the failure zone is affected by the acceleration levels (see Fig. 5 in the original paper), the displacements required to reach the active state were not significantly affected (about 0.5 mm for the T mode) by the same. Ichihara and Matsuzawa (1973) also arrived at similar conclusion regarding the displacement from their experiments for a retaining wall undergoing rotation about the base and translation (RB-T mode). Sherif et al. (1982), based on the static and the dynamic earth pressure experiments advanced an empirical equation for this value, which is a function of both wall height and the angle of internal friction of the granular soil. Therefore, it can be inferred that for the same angle of internal friction and for the same wall height, the displacement at the active state is independent of the acceleration.

REFERENCES

Ichihara, M. and Matsuzawa, H. (1973), "Earth Pressure during Earthquake", Soils and Foundations, JSSMFE, Vol. 13, No. 4, pp. 75-86.

Sherif, M.A., Ishibashi, I. and Lee C.D. (1982), "Earth Pressure Against Rigid Retaining Wall", Journal of the Geotechnical Engineering Division, ASCE, Vol. 108, No. GT5, pp. 679-695.

Paper No. #4.14

Reply by Xiangwu Zeng, Dept. of Civil Engineering, University of Kentucky

The author would like to thank Mr. Stamatopoulos for his interesting comments and agrees with these comments.

It would be ideal if the earth pressure on the retaining wall was measured directly during the centrifuge tests. However, after taking into account two major factors, no attempt was made to measure the dynamic earth pressure. First, there have been many experiments conducted to measure dynamic earth pressure on retaining walls mainly using shaking tables. As concluded by Seed and Whitman (1970), most experimental results show that Mononobe-Okabe theory predicts dynamic earth pressure reasonably well for walls with sufficient lateral displacement to generate full active earth pressure, which is exactly the situation in this study. Secondly, for each centrifuge test reported in the paper, there was a limit for the total number of transducers that the data acquisition system could handle. It was the author's belief that there were more uncertainty concerning the acceleration and excess pore pressure in the soil and on the wall. Therefore, the channels available for data recording were used mainly for these purposes.

The complexity of the problem for a retaining wall with saturated backfill is well demonstrated in the paper as well as by some other studies. The need for comprehensive numerical codes is obvious. The study on this problem using numerical techniques has be carried out at Cambridge University and the results will soon be published. It will show that effective stress based fully coupled numerical code can predict most of the behaviors observed in the centrifuge tests.

The author agrees that a comparison between the response of PPT1 and PPT2 will be interesting. It will help to explain qualitatively the influence of soil-wall interaction on the excess pore pressure generated in the backfill. However, a quantitative explanation is possible only through a comprehensive numerical simulation.

REFERENCE

Seed, H.B. and Whitman R.V. (1970), "Design of Earth Retaining Structures for Dynamic Loads", Lateral Stresses in the Ground and Design of Earth Retaining Structures, ASCE, pp103-147.

Discussion on Papers in Session IV: Dynamic Earth Pressures and Seismic Design of Earth Retaining Structures

By: Marshall Lew, Law/Crandall, Inc., Los Angeles, California, USA.

The state-of-the-art in analysis and design of earth retaining structures for dynamic earth pressures has made some progress since Mononobe-Okabe; however, the advances have not significantly changed the basic concepts that are still being commonly used in practice. A re-evaluation should be made occasionally to compare actual earth retaining structure performance with predicted performance in earthquakes.

The recent Northridge earthquake of January 17, 1994 provides an opportunity to do this. With the exception of crib wall systems, the writer is not aware of any engineered earth retaining wall structures that suffered failure or significant damage due to induced dynamic earth pressures. In the San Fernando Valley, peak horizontal ground motions were reported to range from 0.4 to over 1.0 g. There were many cantilevered retaining walls as well as a fair number of subterranean basement structures with walls braced by floor levels in the valley which have been subjected to these horizontal ground motions and did not exhibit failure or distress.

It is normal engineering practice in Southern California to design earth retaining structures for active earth pressures (and not for at-rest conditions). It is also not required by building code to design for dynamic earth pressures due to earthquake. If one were to re-examine these existing walls for ground motions of 0.4g or greater with a Mononobe-Okabe analysis, one would conclude that the walls would be grossly inadequate and that a new design would be substantially more massive and, in the writer's opinion, not considered economical by a large margin compared to the walls that currently exist.

This recent experience indicates that either there is a great degree of conservatism built into earth retaining systems, or dynamic earth pressures may not develop to the degree computed by standard procedures.