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Case Histories of Engineering Vibrations

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INTRODUCTION

The topic of this session is Engineering Vibrations. Vibrations in general are caused by a wide range of activities. These activities include natural phenomena such as earthquake and man-made vibrations such as those caused by traffic, construction activities, industrial processes and military and civilian activities. Six papers were assigned to this session making it one of the least published for this Conference. The papers submitted cover a wide range of cases in engineering vibrations. For convenience, the cases have been divided into two major categories; 1) Vibration Response Evaluation, and 2) Vibration Mitigation.

Vibration Response

Three papers have been placed into this category. Two papers, Papers 4.02 and 4.09, deal with analytical solutions to compute the response of foundations subjected to dynamic loading. The third paper, Paper 4.05, deals with the evaluation of the vibration characteristics of vibro-drive piles.

Paper 4.02 by Prakash and Tseng presents a simple analytical approach for computing the non-linear dynamic response of vertically vibrating foundations. A computer program based on the Elastic Half Space (EHS) theory analog equations was used. The computed response was compared with measured data. The predicted amplitudes are lower than the measured amplitudes for the frequency range considered. The authors state that the EHS provides a higher value of radiation damping and have proposed a modification factor to apply to the EHS estimated radiation damping. Based on several field test data, the authors have developed two equations for a radiation damping modification factor. One for surface footings and the other for embedded footings. The radiation damping modification factor has been shown to be dependent on the shear strain as defined by Prakash and Puri (1988). The authors have also demonstrated that the difference between the response obtained from frequency dependent and frequency independent stiffness and damping is not significant.

Paper 4.09 by Prakash and Nampoothiri presents a study in which the response of a block foundation subjected to coupled horizontal and rocking motion was computed based on existing analytical equations. The computations were compared with field data done by others. Frequency dependence of the stiffness and damping parameters were considered in this study. A derivation of the equations for computing the response in terms of amplitudes and the damped natural frequency was made. Apparently the response equations for amplitudes of vibration presented in this paper are different from those presented by Kumar and Prakash (1995). In comparison, the current equations produce larger values of amplitudes then those by Kumar and Prakash (1995). Based on limited field data arbitrary modifications of stiffness and damping were made to match the field test data. After these modifications a comparison of response over a given frequency range was made. A reasonable match is obtained especially at the natural frequencies. The authors acknowledge that the model has some drawbacks. These include the arbitrarily modification of the stiffness and damping parameters and the lack of enough field test data to develop rational correction factors to these parameters. The authors are pursuing these studies further. It is our opinion that more field test data are required to pursue this study further.

Paper 4.05 by Tsudoi and Matsui discusses a case history of vibratory characteristics of vibro-driven piles. Authors measured vibratory characteristics during installation of vibro-driven steel pipe piles, driven closed ended, at four sites. The vibration characteristics were studied under free penetration state without any control through the suspension of piles. Soil profiles generally consisted of silty sand to fine sand with occasional layers of silt. The vibratory behavior of the piles was monitored using a reaction force meter mounted near the pile tip. Results presented showed a linear relationship between the pile tip reaction force and the vibratory acceleration. Under the free penetration state, the authors have recommended that tip reaction force can be represented as the force of inertia minus the vibromotive force plus the weight of the pile. Based on the analysis of the measured data, the authors developed a nomograph showing relationship between specifications of vibrohammer and acceleration, pile tip reaction force, and reaction force per unit area. It is our opinion that this chart may be helpful for selection of the suitable specifications of the vibrohammer for a particular type of soil conditions.

Vibration Mitigation

Three papers have been placed into this category. Two papers, Papers 4.03 and 4.07, deal with vibration isolation using barriers and one Paper 4.04 deals with vibration damage control during demolition without isolation.

Paper 4.03 by Stuit describes a case history of reducing low-frequency vibrations due to passing of trains using concrete slab under the tracks. The site under study was located north of Amsterdam, Netherlands. Author performed numerical analysis to compute required thickness of the concrete slab. Based on the results of the numerical analysis construction of 450 mm thick concrete slab, directly under the ballast, was recommended although a thickness of 300 mm was also considered in the analysis. A full scale field test was performed over a 300 meter span of the existing track to verify the numerical computations. Soil conditions at the site consisted of soft, silty clay to clay interbedded with sand and an approximately 1 to 1.5 meter thick layer of weak peat at a depth of approximately 1.5 to 3.4 meter from the ground surface. The results presented by the author show that at the tracks, construction of concrete slab reduced the vibration velocities by approximately 50 percent for train speeds of 100 km/h and approximately 30 percent for train speeds of 140 km/h. However, the effect of concrete slab on vibration velocities was generally negligible at distances more than 15 meter from the tracks. Author is further pursuing this study to develop recommendations for reducing vibrations at distances away from the tracks.

To construct the slab, sheet pile wall was installed near the test track to retain the soil and tracks adjacent to the test tracks. Effect of existence of sheet piles wall on the vibration characteristics is not properly addressed in the paper. We believe that the effect of presence of sheet pile wall should be considered appropriately to study the effectiveness of concrete slab.

Paper 4.04 by Prosser, Manyando, Mottin and Andruska descibes a case history of vibration mitigation during demolition of Brewery Stockhouse which had common walls with other stockhouses and structures to remain operational during demolition. In addition to consideration of limiting vibrations to the adjacent structures, the main focus of the study appeared to be limiting vibrations to the existing glass-lined tanks, and underground tunnels located below the site. Maximum ambient vibrations during normal business activities were recorded at 102 locations using SSU 1000D seismographs. Maximum peak particle velocity (PPV) of 2 inch per second (IPS) was recorded during cleaning of the tanks. Based on the authors' experience with similar other projects and literature review, the maximum allowable PPV of 1 ips during demolition activities was recommended at any point. For stability of the retaining walls shared by other structures, installation of rock anchors were recommended. Authors' also developed and recommended a demolition sequence to minimize vibrations in the existing structures. Vibration measurement data provided by the authors showed that demolition was successfully accomplished with PPV's generally within the recommended value.

Paper 4.07 by Hayakawa, Kani, Matsubara, Matsui and Woods describes a case history of a study of the effectiveness of using a PC wall-piles barrier in vibration isolation. Vibration issues have acquired important status in Japan due to the enactment of two laws, the Environment Standard Law in 1993 and the Anti-Vibration Law in 1996.. The study was done using a barrier that was built alongside a road passing through some sensitive sites to assess its effectiveness in isolating vibrations caused by running trains and dropping a weight. Based on results of field measurements performed for five cases having different types of PC wall-piles, the authors have demonstrated the effectiveness of using PC-wall-piles for vibration isolation. The test sites included road construction and sheathing construction sites and the sources of vibrations included a passing freight train, a large truck and a free-falling weight similar to that used for a Standard Penetration Test. Vibrations were measured using a vibration level meter. The vertical component of vibration acceleration level (VAL) dB was measured. The PC wall-piles used were prestressed square type piles with a central hole. The barriers were built by installing the piles in succession along a line using the method known as "boring through central hollow." Measurements were conducted under different conditions to investigate the effect of filling in the hollow piles and/or grouting the spaces between piles on their performance. The measurement conditions for test site 4 are summerized in the table belowi

Peak amplitude vibration levels were recorded at all sites for the different vibration sources, sites and conditions for the five measurement conditions studied

Table 2. Measurement condition (Test Site 4)

Filling condition	Case 1	Case 2	Case 3	Case 4	Case 5
Grouting of space	exist	nothing	exist	nothing	without
Mortaring of hollow	exist	exist	nothing	nothing	PC pile

The authors observed the effectiveness of the barriers to be optimal with Case 1 (hollows filled and joints grouted) followed by Case 2, Case 3 and Case 4 (hollow not filled, joints not grouted) in that order. Based on results from this study an empirical relationship for the reduction in vibrations by the barrier was developed. Results based on this relationship were compared with data at other sites and also with data from an experiment using a FFT analyzer. A good agreement was observed over a range of frequencies between 1 to 80 Hz.. The reduction in the level of vibration by a PC wall-pile barrier can be estimated by the relationship presented in this study. The author have indicated that PC wall-pile barriers are capable of reducing vibration level by 10 to 15dB at a point just behind such a barrier and about 5 dB at 10 m away from.it. The reduction is exponentially related to the distance from such a barrier. The authors conclude that the performance of the PC wall-pile barrier can be attributed to the combined effect of the piles themselves composing a rigid body and that of the hollows in them acting as a gas cushion. It has been shown that the reduction in vibration by a barrier made of filled-in PC wall-piles can be calculated with a reasonable accuracy over a given range of frequency. Further, the authors indicate that additional reduction in vibration level by filling in the hollow of a PC wall-pile barrier has not yet been clearly identified herein and may be pursued further.

CONCLUDING REMARKS

Athough only six papers were submitted in this session, a wide range of the cases associated with engineering vibrations has been addressed. These being the computation of vibration response and the mitigation of vibration damage by isolation or other means.

There are several analytical approaches available for computing vibration response of foundations and dealing with vibration isolation and mitigation. However, there is need for the validation of these methods through comparison with case histories or measured data.

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