International Conferences on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics

2010 - Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics

27 May 2010, 7:35 pm - 8:05 pm

General Report — Session 2

Ethan Dawson
URS Corporation, Los Angeles, CA

C. B. Crouse
URS Corporation, Seattle, WA

Fifth International Conference on
Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics
and Symposium in Honor of Professor I.M. Idriss
May 24-29, 2010 • San Diego, California

WAVE PROPAGATION, ENGINEERING VIBRATIONS AND SOLUTIONS, VIBRATIONS OF MACHINE FOUNDATIONS, BLAST, TRAFFIC AND CONSTRUCTION VIBRATIONS, AND VIBRATION ABSORPTION GENERAL REPORT ON SESSION 2

Ethan Dawson
URS Corporation
Los Angeles, California-USA 90017

C.B. Crouse
URS Corporation
Seattle, Washington-USA 98101

INTRODUCTION

This General Report presents a summary of the 16 papers accepted for Session 2 focused on wave propagation, engineering vibration solutions, vibrations of machine foundations, blast, traffic and construction vibrations, and vibration absorption. Authors of the papers originate from 14 different countries including Australia, China, the Czech Republic, Germany, Japan, India, Indonesia, Iran, Malaysia, the Netherlands, Romania, Turkey, the United States and Vietnam.

The papers include several valuable case studies where ground motion measurements are examined and compared to analytical and numerical solutions for sites with well documented subsurface conditions. In keeping with the session themes, many papers are concerned with near field ground motions including Rayleigh and Love waves propagating from a point source. Four papers deal with the classic problem of limiting damage from ground vibration due to construction (2.22), heavy traffic (2.27) and large machinery (2.11, 2.14). Three papers address ground motions and dynamic problems related to railroads, including: ground improvement schemes to reduce train induced vibrations (2.13); measurement of cyclic shear strains induced by railroad traffic and the accumulated permanent embankment deformations caused by these cyclic strains (2.06); and Winkler beam analysis of dynamic response due to a moving load (2.20).

Ten out of 16 papers include numerical analyses with the finite element method, finite difference method, or the discrete element. The discrete element analyses include a study of 'bumps' (rock bursts) due to long wall coal mining (2.03) and ground motions near the surface rupture of an earthquake fault (2.18).

Other topics addressed included constitutive models to address strain accumulation under high cycle loading, along with the laboratory tests required to determine the model parameters (2.28) and seismic isolation of buildings and other structures using a material based on scrap tires (2.07). New techniques for processing and analyzing ground vibration data are described in paper 2.10, where wavelet transforms are used to filter unwanted background noise from recorded motions before applying the spectral analysis of surface waves method.

Brief overviews of the Session 2 papers are provided in the summaries below.

SUMMARY OF RESEARCH PAPERS

Paper 2.01. NEAR FIELD WAVE TRANSFORMATION IN CLAY AND PEAT, Stefan Van Baars: This paper describes a series of simple impact tests performed, both on clay and on peat, in order to compare the current wave theory with the obtained data. The waves at the surface are measured with three 3D geophones. With this the wave propagation and the energy dissipation in three directions has been studied both for clay and peat. Since the impact produces a group of waves, only the first arrival time can easily be detected. By transferring the wave information into a 3D energy flow, also the average arrival time and the end-of-wave arrival time can be determined. The results of all tests are very similar, the short wave group splits up in three phases: the first phase consists of compression waves, in the second phase the Rayleigh waves dominate and in the last phase, remarkably, a kind of diagonal Love wave dominates. The second phase starts with a sudden flip of the particle motion due to the arrival of the second wave. In clay 78% of the energy is found in the second phase, while in peat 72% of the energy is found in the third phase.

Paper 2.03, INFLUENCE OF DISLOCATIONS ON BUMPS OCCURRENCE IN DEEP MINES Petr P. Prochazka: This paper addresses the occurrence of bumps in deep coal mines during longwall mining, one of the most serious safety issues in coal mining. Bumps are caused for various reasons, but basically are the result of accumulated energy, which is released under some unfavorable conditions. The paper studies the influence of given dislocations and their orientation in a coal seam using the free hexagon method. This method is a variant of the discrete element methods which enables a simpler calculations of stresses along the boundaries of adjacent particles (elements). Since bumps are connected with the possibility of slip along the dislocations, the dynamic response must be taken into account. The rate of mining excavation is considered by successive change of values of Eshelby's forces on the face of the side walls.

Paper 2.06, INVESTIGATION OF SHEAR STRAIN AMPLITUDE INDUCED BY RAILROAD TRAFFIC IN SOILS, by Dirk Wegener and Ivo Herle: Shear strain amplitude γ is an important quantity in dynamic soil analysis. Usually, a reduction of soil stiffness with increasing shear strain amplitude is observed in laboratory tests. An appropriate invariant of shear strain can be defined which is comparable with shear strains measured in laboratory tests. Usually, shear wave velocity c_s is determined from field or laboratory tests and the particle velocity v is obtained from vibration measurements. Afterwards, the shear strain amplitude γ is often estimated from the equation $\gamma = v / c_s$, which can be derived for the case of one dimensional wave propagation. Based on numerical analyses with FEM, the validity of the above equation for γ is checked. It can be shown that there is a clear difference between the zone close to the loading area and the zone at a larger distance from the loading area. Experimental results of vibration measurements in the field and the evaluation of dynamic soil properties due to rail traffic are presented and the impact on permanent soil deformations is discussed. Based on the results of the field measurements and the numerical calculations, recommendations on the determination of γ for dynamic analysis are presented.

Paper 2.07, GEOTECHNICAL SEISMIC ISOLATION BY SCRAP TIRE-SOIL MIXTURES, by Hing-Ho Tsang, Nelson T.K. Lam, Saman Yaghmaei-Sabegh, M. Neaz Sheikh and Buddhima Indraratna: This paper explores the use of scrap tire material for seismic isolation of civil engineering structures. Disposal of scrap tires is a significant problem and there is a need for new methods for recycling and reusing rubber tires. This paper proposes a new method of utilizing scrap tires for applications in infrastructure protection forming part of the solution strategy. The method involves mixing scrap tire particles with soil materials and placing the mixtures around civil engineering systems, for vibration absorption. The inexpensive nature of the proposed method can be of great benefits to developing countries where there are affordability issues with employing expensive resources and state-of-the-art technology for infrastructure protection. The interaction of compacted soil with interlocking rubber components exploits well known reinforced earth principles. The paper employs conventional soil-structure interaction analysis techniques for quantifying the effectiveness of rubber-soil mixtures in terms of its ability to dissipate energy and control vibrations. While deriving closed-form analytical expressions for such heterogeneous conditions is difficult, the potential of the proposed method has been demonstrated by numerical modeling to show its effectiveness and robustness as a means of protecting low-to-medium-rise buildings in an earthquake.

Paper 2.10, COUPLED CWT SPECTROGRAM ANALYSIS AND FILTRATION: NEW APPROACH FOR SURFACE WAVE ANALYSIS (A CASE STUDY ON SOFT CLAY SITE), by Sri Atmaja P. Rosyidi, Mohd. Raihan Taha, and Zamri Chik: This paper explores the use of wavelet filtering in the SASW (Spectral Analysis of Surface Waves) site investigation technique. Surface wave analysis consists of generation, measurement and processing of dispersive Rayleigh waves recorded from two or more vertical transducers. For soft clay soils, a reliable dispersion curve is difficult to obtain, particularly at frequencies below 20 Hz. Natural and artificial vibration sources may contaminate the generated surface wave data. In the paper, coupled analysis of continuous wavelet transform (CWT) spectrogram analysis based on a Gaussian Derivative function was used to analyze the seismic waves in time-frequency space. First the time-frequency wavelet spectrogram is inspected to separate the seismic response of interest from the background noise. Then a time-frequency wavelet filtering approach was used to remove noisy distortions in the spectrogram. Based on the generated spectrogram, the thresholds for wavelet filtering could be obtained. Finally, the denoised signals of the seismic surface waves were reconstructed by inverse wavelet transform, considering the thresholds of the interested spectrum. Results show that CWT spectrogram analysis is able to determine and identify reliable surface wave spectra and phase velocity dispersion curves for soft clay residual soils. This technique can be applied to problems related to non-stationary seismic waves.

Paper 2.11, VIBRATION ANALYSIS OF ROTATING FANS MOUNTED ON ADJACENT RECTANGULAR FOUNDATION BLOCKS, by C.B. Crouse and Ethan Dawson: This paper describes a numerical vibration analysis for large rotating fans at a power plant. The fans are mounted on adjacent rectangular concrete foundation blocks, 66 ft x 22 ft x 10 ft depth, with the adjacent long sides 10 ft apart. The blocks were embedded in medium dense sands and gravels with a variable shear-wave velocity profile. The purpose of the analysis was to determine whether (1) the dynamic interaction of the blocks through the surrounding soil would cause unacceptable vibratory response of the fans, and (2) the foundation stiffness criterion set by the vendor was satisfied.

Solutions were obtained using the 3-D dynamic version of the FLAC computer program, which was first used to compute the response of a single block-fan system. The introduction of the second block-fan system into the model resulted in less than 10% amplification in dynamic response of the two-block system relative to the single block-fan response, when the excitation forces of both fans were in phase (i.e. 0º lag). However, a maximum amplification of 100% was computed when the phase-angle difference in forces was between approximately 90º and 120º. The results ultimately demonstrated that the vibration and foundation stiffness criteria could be met, which would have been more difficult without the use of a 3-D numerical modeling code.

Paper 2.13, GROUND IMPROVEMENT UNDER DYNAMIC LOADING, by Dr.-Ing. M. Ittershagen: This paper describes experimental and numerical investigations of the dynamic soil-structure interaction of railway lines on soft soil. The purpose of this study was to obtain information on the influence of different soil improvement layouts and eventually to establish a design tool for railway lines on soft soil based on the additional results of a numerically supported parametric study. The principle part of the paper is the presentation of the experimental and numerical investigations.

Paper 2.14, MECHANICAL AND ACOUSTICAL VIBRATIONS OF A BUILDING GENERATED BY WEAVING LOOMS, by Ion Vlad: This paper is a case history of an investigation of building vibrations induced by weaving looms. The entire process carried out in order to solve this spectacular case of annoying vibrations is presented. Dynamic excitations and the resulting stresses in a weaving mill can affect its functioning in many different ways. Possible consequences of service vibrations include emission of acoustic waves, reduction of product quality, damage of non-structural elements (especially partition walls and cladding) and the disturbance of the activity in buildings placed in close vicinity. It is difficult to identify the influence of the vibrations on the production, on the weaving shed and on the neighborhoods. In 2004, an Italian company has rented in Romania 6000 square meters in a huge, one level industrial building, in order to lay out a weaving mill. Connected to this building there is a small five level office building having 256 square meters in plane. Two categories of weaving looms were installed, air-jet based type and rapier based type. One may say that it was another well-known classical result of the acquisition of second hand equipment. This situation was often encountered in Romania in the last twenty years due to the poor economic situation of the country and to the set up of various private companies which could not afford new equipment. It was not the case, as the Italian company supplied the weaving factory with last generation weaving looms. When the machines started to operate, severe vertical vibrations were generated in the industrial building and annoying acoustical vibrations were induced in the office building, felt especially at the fifth floor. Practically, nobody could stay for more than 10 minutes in any room of that floor. In addition, the high intensity of the vertical vibrations affected the operation of sensitive electronic equipment and, as a result, a business center located at the fifth floor closed its activity. This made the owner lose a big amount of money obtained by renting the spaces. The owner of the building, together with the Italian company, asked R.N.C.E.E.V. to identify the source of the annoying vibrations and to find a technical solution in order to avoid them. As such a case is not frequently encountered and the technical literature is very poor on the subject, the author considers it of interest to be presented.

Paper 2.15, VISCOUS DAMPING FOR TIME DOMAIN FINITE ELEMENT ANALYSIS, by Nien-Yin Chang: This paper presents a procedure for evaluation of viscous damping for time domain FEM analyses, addressing the differences between the damping scheme typically used in time domain analyses and that used in frequency domain analyses. Earthquake waves propagate mainly in a rock mass from the hypocenter to the bedrock directly underneath a monitoring station. Then, it propagates as shear waves from the bedrock to a geophone, where the surface motion is measured. For a deposit with uniform soil layers of horizontal interfaces, one-dimensional finite element analysis can be performed to analyze the dynamic responses of a horizontal soil deposit. In an ideal dynamic soil-structure interaction analysis, seismic waves are propagated from the bedrock through soils and foundations, and then to structure. Thus, it is necessary to obtain the bedrock motion from a measured surface motion registered in geophone. Conventionally the process is called de-convolution. De-convolution is treated as wave propagation in the frequency domain involving damping factors independent of the motion velocity. Time-domain analysis is usually used in assessing the effects of soil-structure interaction. The time domain analysis requires the use of viscous damping proportional to motion velocity. Thus, it is necessary to devise a method for the evaluation of viscous damping that, when used in the time domain analysis for the upward wave propagation from the bedrock back to ground surface, produces a surface motion in close agreement to the measured surface motion. This paper presents a procedure for evaluation of viscous damping from a given damping factors. This viscous damping successfully produces a surface motion in close agreement with the measured surface motion in a time domain analysis of upward wave propagation.

Paper 2.17, PROPAGATION OF SURFACE WAVES IN AN IRREGULAR GROUND BASED ON THE THIN LAYERED ELEMENT AND FINITE ELEMENT METHOD, By Hiroto Nakagawa and Shoichi Nakai: This paper explores the propagation of Rayleigh and Love waves across ground with irregular topography, using a combined method of thin layered element and finite element. The problem of wave propagation in an irregular ground is crucial when the landform is complex as in the case of Japan. This problem has been studied by a number of researchers; however, most studies were made from the viewpoint of body wave propagation and only a few dealt with surface waves. The objective of this study is to examine Rayleigh and Love wave propagation in an irregular ground based on the combined method of thin layered element and finite element. In this paper, the following conclusions are made: 1. H/V spectra of a horizontally layered medium as well as the surface wave modes can be obtained based on the thin layered element method. 2. When an incident Rayleigh/Love wave propagates toward an irregular ground, different type of Rayleigh/Love wave modes as well as body waves are generated. 3. In the microtremor wave field due to various incident surface waves, it has pointed out that the peak frequency and its height of H/V spectrum changes according to the distance from the irregularity, which is harmonious with measured results.

Paper 2.18, LARGE VARIATION IN PGA DUE TO PRESENCE OF HETEROGENEITIES IN THE SURFACE SOIL, by Mohammad Ahmed Hussain and Ramancharla Pradeep Kumar: This paper describes numerical simulation of near-field ground motions from earthquake faulting. Two dimensional numerical simulations are performed using the Applied Element Method (AEM) a variant of the distinct element method. In the proximity of an active fault, the spatial variation of peak ground motion is significantly affected by the faulting mechanism. It has been observed that near fault ground motions consists of different characteristics compared to the far field ground motions. Near fault records, in the distance range of less than 100 m from a faults are only available for a few cases. Therefore numerical simulation of ground motions for such near-fault situations is necessary. There is a need to enhance our understanding of the possible potential hazard that can be caused due to the future rupture activity by understanding the phenomenon of surface faulting. In this paper we propose numerical simulation based on discrete modeling to investigate the fault rupture propagation. Initially a two dimensional study is done for understanding the crack propagation due to various types of bedrock movement. A model of size 1000x150 m is selected for this purpose. It is observed as the stiffness of the media is decreasing, the affected surface is decreasing and also the width of the shear crack zone is decreasing. However in the dynamic analysis we can observe the significant increase in amplification in soft media. Secondly, we attempted to study the presence of boulders. Surface faulting has been examined by keeping the boulder at different positions. We find that there is an increase in the shear zone as well as the PGA on the surface when the boulder is present on the foot wall. Finally, we performed the analysis using layered media and studied the affect of crack propagation and also the variation of peak accelerations Findings from the study can be utilized to assess the damage potential of the near fault areas.

Paper 2.20, DYNAMIC BEHAVIOR OF AN ELASTIC BEAM ON A WINKLER FOUNDATION UNDER A MOVING LOAD, by Abdul Hayir: This paper is a study of the response of an elastic beam on a Winkler foundation when subjected to a moving load. The load is assumed as a moving harmonic load and the beam is considered as an infinite Bernoulli-Euler beam with constant cross-section. The Winkler foundation approach for modeling an elastic foundation is very common in practical applications, although it does not accurately represent the continuous characteristic of the foundations. In this model, only the interaction between vertical springs is considered. In the solutions of the problem, the double Fourier Transform is applied and for its inverse the Inverse Fast Fourier Transform (IFFT) is used. In the numerical example, the effect of the moving load velocity on the dynamic displacement response of the beam is discussed. The maximum deflections of the beam due to the moving load velocities are illustrated.

Paper 2.22, VIBRATIONS DUE TO DYNAMIC COMPACTION, by M. Ayşen Lav, Ercan Yüksel and Faruk Karadoğan: This paper is a case study of the ground vibrations due to dynamic compaction (DC), at a harbor site in the city of Kocaeli, Turkey. Attenuation of the vibrations were measured to determine if they might cause damage to surrounding structures, especially structures already damaged by the August 17, 1999 Kocaeli, Gölcük earthquake (M~7.4). Soils at the site were reclaimed land constructed from Hereke limestones. Measured data included vibrations induced by the tamping energy of DC, both at the vicinity of nearby structures and within the DC site. The site was surrounded by a shallow isolation trench along the land sides. Characteristics of the vibrations, such as peak values of the records, Fourier spectrum and amplitude attenuations over distance are presented. The predominant frequencies and amplitude of vibrations were compared to the related code limits to estimate the effect of vibrations on the existing structures.

Paper 2.27, ATTENUATION OF TRAFFIC INDUCED GROUND BORNE VIBRATIONS DUE TO HEAVY VEHICLES, by Ozgur L. Ertugrul and Deniz Ulgen: This paper is a case study of traffic vibrations. Numerical simulations are compared to field measurements. Traffic induced vibrations, which are transmitted through the ground, may interfere with the proper operation of vibration sensitive equipments and cause nuisance on local population. The influence of these vibrations on surrounding buildings and sensitive devices play an important role on acceptance of the projects. In this study, the main objective is the estimation of ground-borne vibration levels due to operation of heavy vehicles at two different sites where the soil type and stratification differs significantly. For this purpose, site specific vibration surveys are conducted. A series of dynamic finite element modeling analyses are performed to predict actual vibration records at measurement points. Parameters used in finite element modeling are obtained through geotechnical and geophysical surveys conducted at the site. Modeling results are in good agreement with the actual vibration levels in the considered frequency range. The frequency range of dominant structural responses due to ground borne vibrations induced by heavy vehicles is found to be between 10 Hz to 50 Hz for a single degree of freedom system with 3% damping. Calibrated finite element models are further used to predict the attenuation of vibrations with distance from the source. Slightly better wave attenuation is observed in soil site compared to the rock site.

Paper 2.28, STRESS- AND STRAIN-CONTROLLED UNDRAINED CYCLIC TRIAXIAL TESTS ON A FINE SAND FOR A HIGH-CYCLE ACCUMULATION MODEL, by Torsten Wichtmann, Benjamin Rojas, Andrzej Niemunis and Theodor Triantafyllidis: The paper presents a discussion of the isotropic elastic stiffness E in the high-cycle accumulation (HCA) model proposed by Niemunis et al. (2005). The model may be used to predict permanent deformations or excess pore water pressures in non-cohesive soils due to cyclic loading. The stress-dependent bulk modulus K was determined from pairs of drained and undrained cyclic triaxial tests on a fine sand with constant stress amplitude and with similar initial conditions. K was found in good agreement with an earlier study on a medium coarse sand where a correction for membrane penetration effects had to be applied. Undrained cyclic triaxial tests with constant strain amplitude commenced at an anisotropic initial effective stress were performed for Poisson's ratio ν. It is demonstrated that ν does not depend on amplitude, density and initial pressure. Its increase with the initial stress ratio may be disregarded for practical purposes.

Paper 2.29a, DYNAMIC ANALYSIS OF PILES UNDER LATERAL HARMONIC VIBRATION, by Mahmoud Ghazavi and Ahmad Dehghanpour. This paper presents a new mathematical approach for the analysis of a harmonically vibrating horizontal, linear, elastic uniform pile. The soil properties may vary from layer to layer. No separation is allowed at the soil-pile interface. The pile is modeled as a number of cylindrical segments connected by rigid nodes. The length of each segment is chosen such that the effects of the soil inhomogenity are accounted for. The governing differential equation for an arbitrary pile segment is obtained and solved. According to the pile support types such as pinned, fixed and free conditions, first an arbitrary appropriate value for either toe force, bending moment, rotation, or displacement is assumed. The governing differential equation is then solved from the lower pile segment to the top one. The stiffness of the whole pile-soil system will then be computed. It is shown that the slenderness ratio, the stiffness ratio and toe fixity are the governing parameters affecting the stiffness of the soil-pile system. The new analytical model, which is verified using existing numerical and analytical solutions, is more efficient than the equivalent numerical solutions for example finite element methods.

FINAL REMARKS AND TOPICS FOR DISCUSSION

The papers presented in this session cover a wide range of interesting and important topics in the area of ground vibrations. The papers include several case studies where ground motion measurements are examined and compared to analytical and numerical solutions for sites with well documented subsurface conditions. Other papers present valuable soil testing data, discuss new numerical techniques or explore new methods for processing ground motion recordings. Based on the content of the papers submitted for Session 2, the following topics are offered as possible topics for discussion:

1. Vibration and dynamic concerns for railway embankments.
2. Vibration issues for windmill foundations.
3. Advantages and disadvantages of distinct element analysis (DEM) for dynamic analyses.
4. Application of wavelet transforms for analysis and processing vibration and seismic records.
5. Soil models and procedures for computing accumulated deformation of soils due to cyclic loading.