University of West Hungary

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THESIS OF PHDDISSERTATION

Critical review of the application of seismic-based methods in civil engineering

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Sopron
2006.

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Programme: Geo-environmental Sciences Programme

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Preliminaries

In the last decades, the Department of Engineering Geophysics of Eötvös Loránd Geophysical Institute of Hungary has carried out several studies on surveying the causes of man-made or geological hazards. The first group includes amongst others, the localization of abandoned mines and other voids, subsidence of buildings, communal and radioactive waste disposal, while the second comprises landslides, site effects of earthquakes, etc. The demand for using near-surface seismic techniques for solving these tasks has been growing continuously. Near-surface seismic methods are based on the methodology of exploration seismics but the variability of environmental protection- and engineering applications go much beyond that of routine industrial seismic exploration. The most important differences are: in strongly inhomogeneous media, which do not follow Hooke's law, the geotechnical interpretations of data require different approaches.

The author, based on his extensive experience of in-mine geophysics, having developed seismic methods for engineering problems, believes that making the combination of shallow-seismic and geotechnical methods widely applied in geotechnical engineering is essential for the synthesis of the seismic-wave-based procedures and geotechnical tests.

Objectives

The tasks with civil engineers facing can be mostly linked to the questions regarding the structural and mechanical properties of the subsurface. Among geophysical methods, seismics based on the nature of wave propagation influenced by the elastic properties of

materials is the most useful for this purpose. However in the majority of cases the tasks are concerned with static problems, as engineers are seeking answers for breaking-point stress-strain relations, to which the physical parameters determined at seismic stress-strain conditions can give approximate solutions only.

The objectives of this dissertation are to place the seismic tests in appropriate position between in-situ and laboratory geotechnical tests. This critical analysis intends to investigate how the traditional seismic methods can be developed further to give in-situ physical parameters of rocks and soil for planning and decision making experts. Furthermore, the results of research in adapting seismic methods for geotechnical applications are highlighted, together with methodological recommendations for investigating either solid, non-layered rocks, or very loose media (soil), as well as foundation problems of buildings.

The research

In order to achieve the objectives stated above, the author describes the basis of the seismic method with special emphasis on its application for geotechnical purposes. He reviews the methods based on surface waves, the various methods used to determine the mechanical properties of rocks (for example cross-hole tests) and seismic tomography using different wave types. He also attempts to determine the position and applicability of the shallow-seismic method in the engineering sciences. For this purpose he analyses in detail the propagation of elastic waves in rocks and soils. The extent and velocity

of deformation in wave propagation are compared to those in other test methods of geotechnics, to find the applicability of seismic methods in solving engineering tasks.

Both the experimental measurements and the results are presented in the form of case histories going back over a number of years.

New scientific results

Thesis No. 1

It was found, that the place and roll of geotechnical application of seismic methods should be based on the specific level and rate of deformation induced by the propagating seismic waves in rocks and soils. Analysing the characteristics of seismic waves in different media it was established that seismic parameters – which can be associated with elasticity and strength parameters (e.g. body-wave velocities, Q-factor) – could be directly used for geotechnical calculations in connection with the interpretation of vibration measurements only. It was also proved that parameters determined from seismic stress-strain relations, and elastic constants derived from them can only be used for engineering calculations if a reduction factor is introduced, either by laboratory measurements or by some mathematical solution creating relationship between the two states of deformation.

Thesis No. 2

All seismic measurements can be regarded as in situ material tests by determining seismic parameters (e.g. velocities, Q-factor). The different mechanism of seismic

wave propagation in rock and soil result in different velocities of elastic waves. The author describes the different mechanisms of seismic wave propagation in rocks and soils as influencing velocity, and demonstrates which factors have dominant effect. The author demonstrates his thesis with examples of the effect of seismic waves both from natural and man-made environmental problems by showing the effect of composition, physical and mechanical properties and stress conditions of the media on the velocity of seismic wave propagation. In the case of soil, the composition, the fluid content and grain size are the factors mainly influencing seismic velocity.

Thesis No. 3

In the case history describing the investigation of the Üveghuta granite body selected for low- and medium radioactive waste disposal site, it has been proved that seismic methods are suitable for determining structural features and/or internal inhomogeneities of solid, non-layered media, if the dimensions of internal acoustic impedance anomalies are at least similar or larger than the wavelength. As a result of methodological research, it is shown that placing both source and receivers inside the medium can increase the resolving power of seismic methods. It was also found that methods using S-waves are more sensitive to indicate of fractures than P-waves.

The results and integrated interpretation of seismic methods are presented along a profile. The structural elements determined by different seismic methods are in interdependence of each other and supported by other non-seismic methods.

Thesis No. 4

Simple 3-phase soil models cannot describe the behaviorv of complex systems of inhomogeneous composition. Traditional in situ tests are inadequate for solving such problems because of the high sampling density necessary for approximating the variability of such a system. The author recommends the mapping of the group velocity of surface waves for the geotechnical investigation of shallow disposal sites and the suitability of subsoil characteristics for foundations. With the help of such a velocity map, soil soundings (SPT, CPT) can be located to optimum places. Their results correlate with the velocity anomalies.

In a case history connected to an environmental protection problem it is shown that the quality of loose, unconsolidated material can be characterized by wave propagation mechanism of different seismic waves, and the singularity points of the medium can be pinpointed.

Thesis No 5

Investigation methods using elastic waves for foundation studies are based on the same physical principles as those used for geological exploration. The author gives methodological recommendations for the application of methods using non-destructive procedures in built-up environments by presenting the results of his seismic and acoustic measurements. By velocity profiling of the concrete floor of an industrial building and by determining the velocity of concrete foundation blocks of long-distance transmission lines the author could prove that seismic velocities are suitable for determining the

quality and internal inhomogeneities of concrete. His results were published in the magazine “Concrete” in Hungary .

Possibilities of utilizing the results

Strength and stiffness parameters determined by different geotechnical methods and characteristic to different engineering tasks refer to different levels of deformation. By approximating them to each other, engineering design – based on subsoil-structure interaction – will become more effective and the building more economical, as compared to the present static attitude to design-and building.

The case histories, discussed above are either completed in the recent past or are still in progress. In projects belonging to the first case (i.e. the surveying of the optimum place for a radioactive waste disposal site) by handing over a report, the results are already on their way to utilization. Furthermore, if a solution has been found for a problem, the results will be applicable in many similar situations. The experience gained in Dombóvár where multi storied buildings were erected on poor quality subsoil will be applicable to many other areas of the country. Geophysical surveys before starting a building project could prevent significant later damage.