Assessment of soils compaction using multichanel analysis of surface wave

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ASSESSMENT OF SOILS COMPACTION USING MULTICHANEL ANALYSIS OF SURFACE WAVE

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ABSTARCT
The shear properties of soils are of fundamental interest in civil or environmental engineering, particularly for designing building foundations or predicting site effects in seismic hazard studies. Dynamic compaction improves the soils mechanical characteristics obtained by in-situ investigations (cone penetration tests (CPTs). Vs profiles obtained by inversion of surface wave before and after compaction have allowed a good evaluation of the compaction performance and demonstrate the potential of this technique in geotechnical investigations

Key-Words: Surface waves, Shear velocity, Rayleigh wave, Inversion, Compaction.

EVALUATION DU CAMPACTAGE DES SOLS A L'AIDE D'ANALYSE SPECTRALE DES ONDES DE SURFACE

RESUME
Les propriétés de cisaillement des sols sont d'un intérêt fondamental en génie civil ou environnemental, notamment pour la conception des fondations de bâtiments ou pour prédire les effets de site dans les études d'aléa sismique. Le compactage dynamique améliore les caractéristiques mécaniques des sols mesurées *in-situ* (pénétromètre statique ou CPT, « cone penetration test »). Les profils de Vs obtenus par inversion des ondes de surface avant et après compactage ont permis une bonne évaluation de son efficacité et démontre le potentiel de cette solution en géotechnique.

Mots-clés : Ondes de surface, Ondes de cisaillement, Ondes de Rayleigh, Inversion, compaction

INTRODUCTION

Evaluation of soil geotechnical parameters is a preliminary task to be conducted either for designing building foundations, or for studying site effects in seismic hazard evaluation. Both of these applications show the importance of knowing soil elastic properties, which govern its behavior in presence of natural or human solicitations. Shear-wave velocity (*Vs*) is usually taken as a good indicator of the elastic behavior of soils, and is classically estimated from cross-hole measurements. In order to avoid such destructive – and expensive – testing, we study here the possibility to estimate the *Vs* distribution with depth by using Spectral Analysis of Surface Waves (SASW) method. The determination of *Vs* profiles from Rayleigh waves is attractive since their propagation velocity, i.e. the phase velocity *Vph*, highly depends on the stiffness-depth profile.
Several inverse methods used seismology has already been proposed to resolve such a problem. Dorman and Ewing (1962) used surface wave to determine elastic properties of the crustal-mantle structures. Engineering problems were tackled in Nazarian and Stokoe (1984) where a hammer is used as impulsive source for generating Rayleigh waves while ground motions are recorded from two seismic sensors. The dispersion is afterwards derived from the spectrum of recorded vertical motions. Addo and Robertson (1992) also used the same approach and validated the method on six different sites by comparing SASW inverted results

and cone penetration tests data. Gabriels et al. (1987) improved the method by taking into account higher modes of Rayleigh waves and by increasing the distance between source and sensors. Recently, Xia et al. (1999a) proposed an inverse method based on Levenberg-Marquart technique. The Linearized Least-Squares (LLS) technique used here is adapted from Hermann (1987) and was already tested in Bitri et al. (1998).
The purpose of this paper is to present and discuss the results of surface wave method for the assessment site compaction.

FIELD ACQUISITION AND RESULTS

The project is located at the site of an old glass factory, near Givors (France). The site was occupied for over a century of industrial activity. The plant was dismantled recently and new construction-type industrial buildings are provided. To build these structures, a technique for improving soil has been considered by the designers. This is the technique of dynamic compaction "high energy" was chosen as an alternative to deep piles to address the dual problem of soil with low mechanical properties and by environmental stress resulting from a chemical residual impact of soil and water In fact, deep piles could impact the water resource, blending the superficial polluted soil and water with the deep ones.

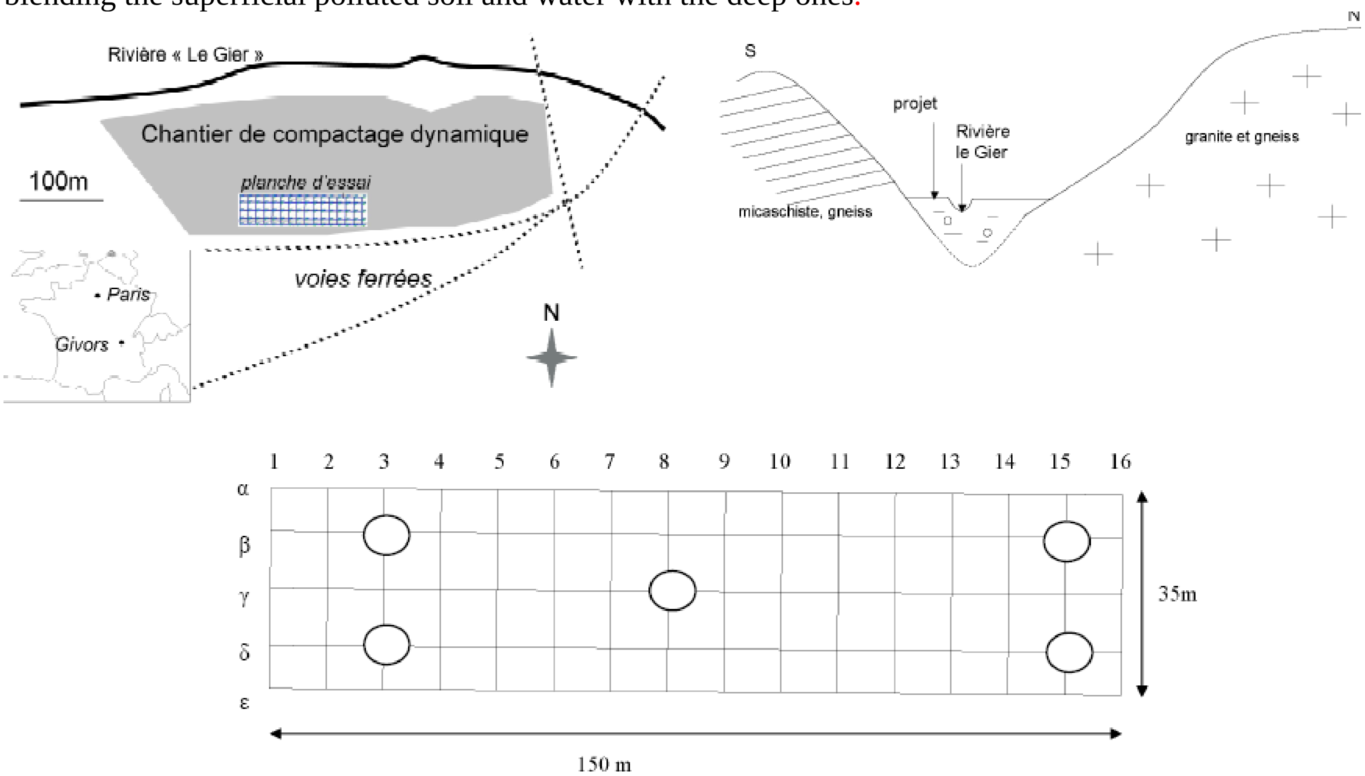

Fig.1: Location map of project (top left) and schematic geological cross-section (top right) Bottom, location and plan view of the test board. The five circles indicate the position of the static penetrometers

The Vs initial model before compaction was established in September 2009 along 4 linear lines. To increase the speed and efficiency of data recording and thereby keep acquisition costs down, a multichannel seismic cable has been designed and manufactured. It consists of 24 takeouts at fixed 2m intervals. Each takeout is attached to a single self-orientating, gimbals-mounted, vertical geophone. To help ensure proper coupling, each gimbal geophone is housed in a heavy casing (~1 kg). To damp the motion of the sensor around its rotational axis, the inside of the casing is filled with viscous oil. The seismic cable is towed behind a vehicle. A 24-channel Geometrics Stratavizor seismograph was used to record impacts of

10kg hammer seismic source. The source-to-nearest-receiver offset was 4m, while the source stations were separated by 10m along the seismic lines. The record length was selected as 1024 ms at 1 ms sample interval. The data required for inversion are the values of phase velocity as a function of frequency and surface wave mode. Phase velocity dispersion curve (phase velocity versus frequency) were determined using the slant-stack method in common shot gathers, followed by a 1-D Fourier transform over the intercept time to obtain the wave field in the f-v plane.

The surface wave investigations were carried out in the end of October 2009, after heavy dynamic compaction process on the same lines in order to verify the effect of compaction.

A seismic shot gather before and after compaction is presented in figure 2a, with the related dispersion curves showing the fundamental mode (Fig.2b).

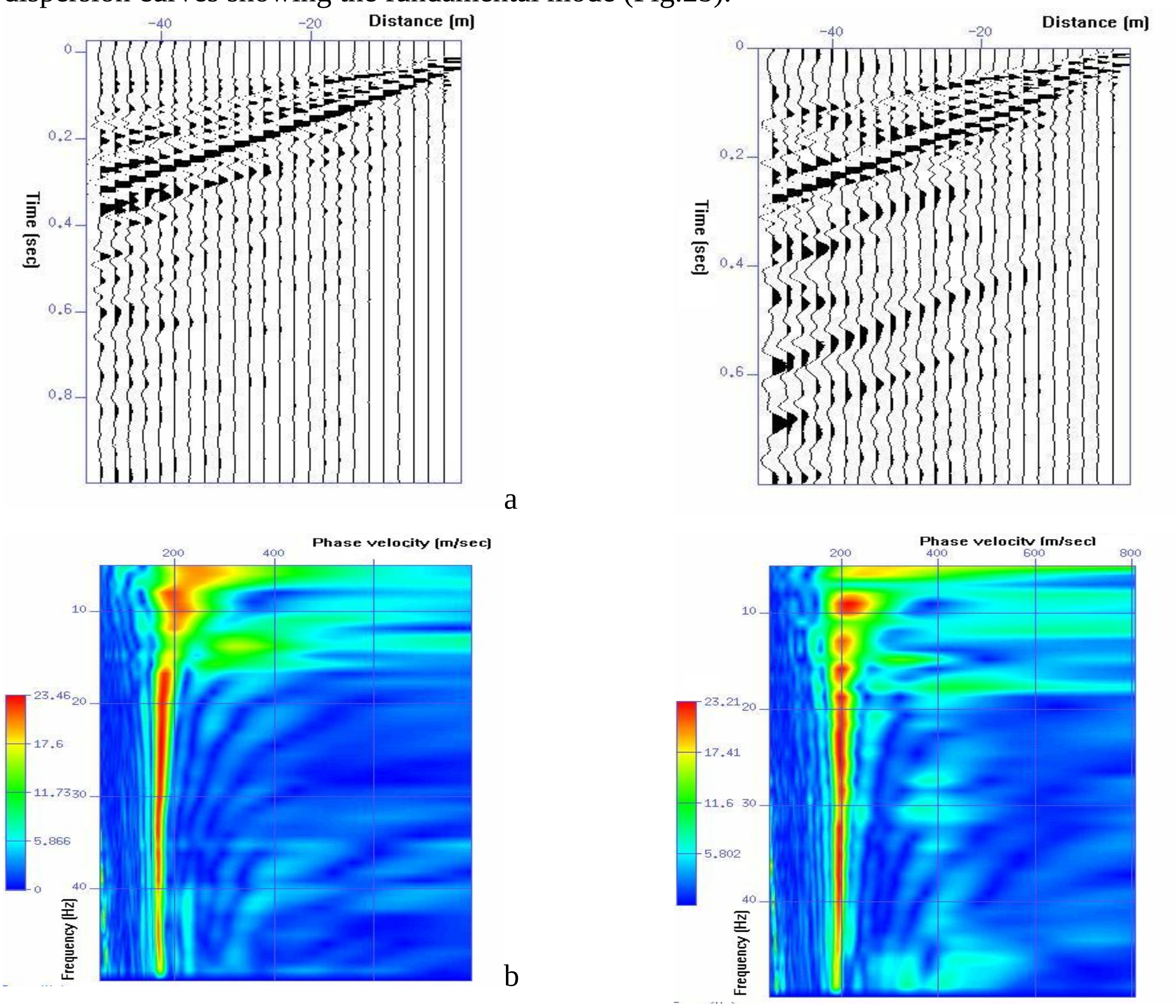

Fig 2: a) Typical shot gather before and after compaction and b) the related dispersion diagram with clear fundamental Rayleigh mode.

The initial model for inversion was calculated with an empirical relation already used by (Xia et al., 1999). Ten iterations for inverting velocities and ten more for inverting layers thickness were necessary to converge to the final model

A 2D contour plot of the shear-wave velocity field was produced by gathering all the velocity profiles into sequential order, according to half shot station. Figure 3 shows the difference of results after and before the compaction. As shown in figure, shear velocity increases of about 40-50m/s after compaction for the depth up to 7m. The same results were obtained by geotechnical investigations (heavy dynamic penetrometer)

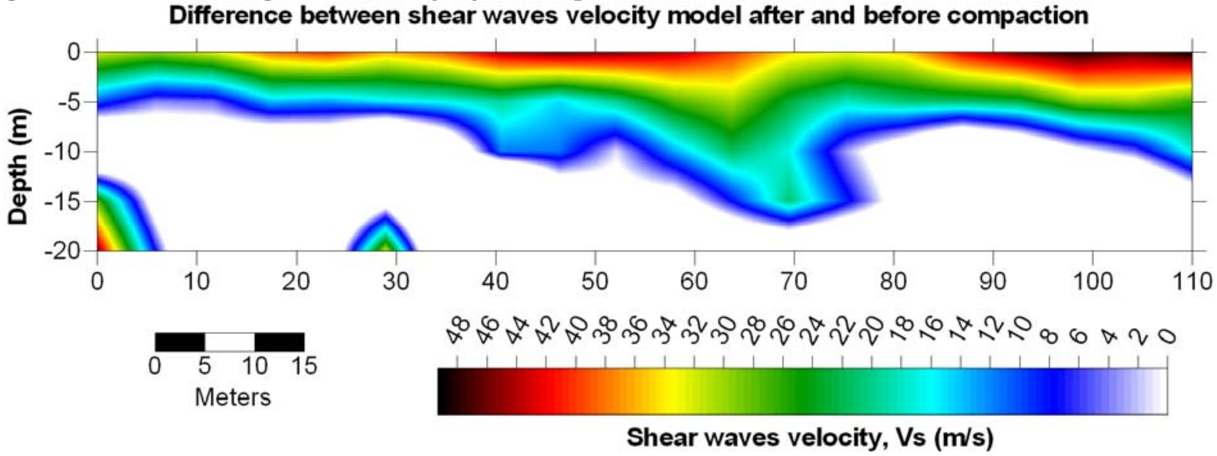

Fig.3 Difference between shear wave velocity model (line a) after and before compaction.

CONCLUSIONS

Nonintrusive multichannel surface wave method presents a great interest in geotechnical investigation as it offers the potential to determine the shear wave profiles from the surface allowing the characterization of soils in their in situ state. This can be used as an alternative to the penetration tests for assessment of compaction. In the Givors site the shear wave velocity increase by 22% after the heavy dynamic compaction. The results show a net increase up to 7m and little or no significant at greater depth.

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