Determination of safety distances and source monitoring during land seismic acquisition

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Summary

During land seismic acquisition, field conditions make it necessary to take into account the manmade and natural environment. The use of artificial seismic sources, whether explosive or vibroseis, creates strong ground motion of amplitude and frequency that can damage the environment. Moreover, the presence of obstacles induces a stand-off distance which introduces holes in the fold coverage that will degrade the seismic imaging quality.

Thus, the goal of land seismic acquisition is twofold: acquiring data aimed at good seismic imaging whilst not damaging the environment. The use of available standard reference charts is not optimal as it will define cautiously large safety distances usually too conservative. In addition, their use does not ensure that arguments or lawsuits can be avoided in case of damage.

In this paper, we describe a two-pass methodology that can be included in land seismic acquisition in order to answer simultaneously these safety and quality issues. Only a small team and few facilities are required, with marginal additional cost and easy implementation. The first step of the methodology is dedicated to a calibration of sources and ground motion response for the study area. It gives response reference curves and allows us to specify the final acquisition scheme. Once the acquisition is started, the second step consists in implementing the method on most sensitive areas, and performing a full monitoring of effective ground motion simultaneously with seismic production recordings.

This methodology has been developed and validated on several acquisition surveys since year 2000.

Introduction

Seismic land operations are taking place more and more in an industrialized environment or in inhabited areas. Therefore, special measures aimed at limiting the effects of seismic emissions on assets, installations and property have to be taken during the acquisition of a seismic survey. In industrial zones, it is necessary to implement these controls. But at the same time, it is essential to ensure that the quality of the final seismic imaging is optimized as that is the first goal for any seismic acquisition.

State of the art

Usually, during acquisition, seismic contractors apply safety distances between the source and the object(s) to be preserved. Such information was supplied, until very recently, through standard charts made available to the industry by the International Association of Geophysical Contractors (IAGC). These values were derived from experimental in situ trials on selected sites throughout the world, but did not necessarily reflect the specificities of the area in which a survey would be conducted. Therefore, they do not optimally match the nature of the propagation media where the planned seismic survey will take place. Moreover, safety distances could easily be cautiously enlarged to avoid any damage, thus reducing the fold coverage locally. Consequently, the final imaging can be drastically hampered.

Methodology

Objective of the study

Our methodology proposes the association of a small field team with some light equipment in order to optimize the production source emission through a controlled measurement of its effect on constructions and installations. The key approach is to derive a calibrated learning curve depicting the response of local geology to the emitted energy levels defined at survey planning level which are going to be sent into the ground.

Theory

The method needs to produce quantitative orders of magnitude of the seismic signal, which are compatible with the resistance of the neighboring constructions. It also needs to be accepted by third parties who need to be convinced of the methodology of integrating site specificities, refining acquisition parameters and performing real-time monitoring.

For this purpose, the field methodology relies on special equipment such as 3 component sensors, a small independent recorder and a standalone computer. The experiment is conducted generally by two specialists from a service company who will compute the results with accuracy and reliability. The end product consists of two types of curves which will be used during the survey:

- The particle peak velocity versus the reduced distance graph (equations 1 and 2) from which distances and yields can be extrapolated. This is well adapted for explosive sources, as introduced for French mining blasts studies (Chapot, 1981). From this reference, the derived phenomenological law appears in the form of :

$$V = k \cdot (D / \sqrt{Q})^{e} \qquad (1)$$

Introducing the reduced distance $D_r = D / \sqrt{Q}$, it becomes:

$$V = k. D_r^e \qquad (2)$$

where "k" et "e" are parameters to be estimated and related to local geology conditions, V is the ground motion velocity, Q the explosive yield and D the distance between source and velocimeter. Chapot's work was mainly conducted on mining blasts experimentations. As we use the same type of explosives in seismic surveys, but with the aim of propagating the maximum seismic energy, we have confirmed through several studies that the Chapot's diagram and derived laws are still valid and useable (*see figure 1*). The only difference is that particle velocities are faster than those measured on mining operations.

- The particle peak velocity versus distance graph for every source power allows us to decouple the distance from the emitted energy source (*see figure 2*). This is mostly to be applied in the vibroseis method, since the source is a long duration energy emission.

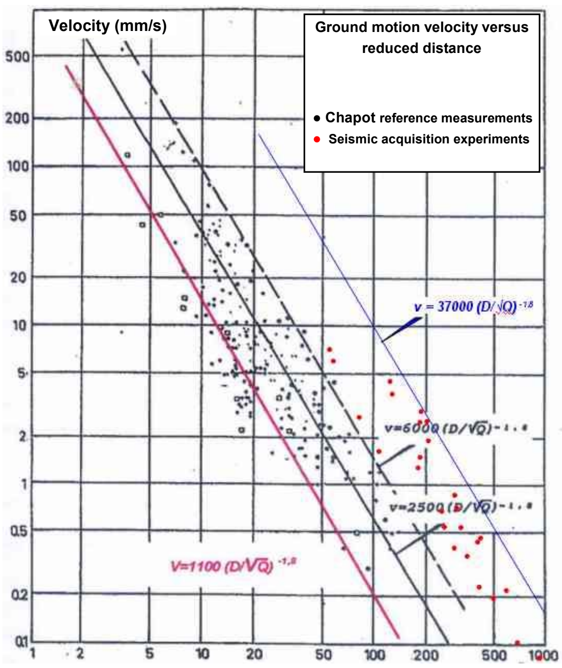

Figure 1: original Chapot's diagram with seismic acquisition experiment added (red dots).

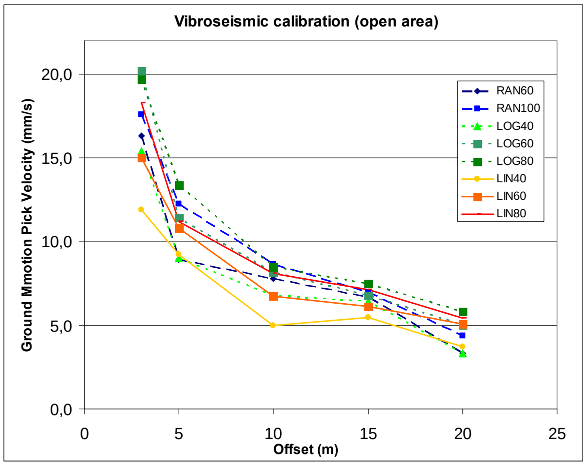

Figure 2: Example of decoupled diagram for vibroseis calibration. Color codes represent type and power of tested sweeps.

Production

The methodology is implemented by a specialized company whose services will encompass the interpretation of the results obtained and a recommendation on exclusion zones to put in place. Their work needs to be synchronized with the seismic contractor activity from whom the source will be captured during the initial testing phase. A calibration curve will be first produced in a nearby terrain free of obstructions (definition of the source response to local geology) (*see figure 3*).

This curve can then be used to fine tune the stand-off distances to a specific target (flow line, installation, construction or monument). Once the limit value is known, it can be used during acquisition for real-time monitoring based on a series of 3 component geophones placed near the object to protect.

Recent evolution of sensors (3 component accelerometers) and recording systems (featuring integrated QC while recording more than several thousands of recording channels simultaneously) means that this monitoring can also be implemented on the active acquisition swath.

In any case, the calibration phase yields reference curves that can be applied in order to respect the threshold enforced by local laws (French government 1986 and 1994; ISO 4866-1990) **(***see figure 4*). A warning system must be introduced to the production plan so that acquisition parameters can easily be adapted if the sensor flags a risk of reaching this threshold.

Figure 3: Calibration phase in free area.

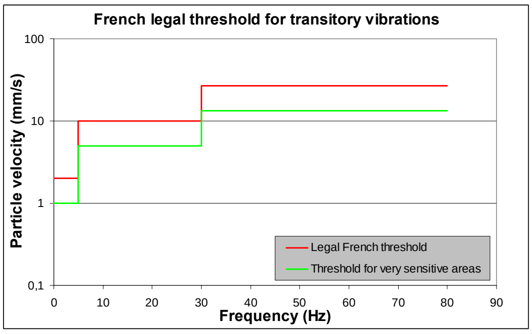

Figure 4: Example of local threshold (legal).

Application and examples

Since year 2000 we have used this methodology in various countries, in the Middle-East, North Africa and Europe. Different situations made it necessary to ensure the acquisition parameters would not induce any damage on obstructions, such as:

- industrial zones: refinery, chemical plant, water dispatcher, gas and oil pipes,
- agricultural facilities: irrigation channels, isolated farms and water wells
- other property and assets: old houses, dry-stone or cob walling huts, historical classified monuments (*see figure 5*).

Figure 5: Monitoring installation in a church.

Prior to each calibration trial, the inventory of all sensitive areas was made. According to the calibration phase performed when using explosive charges, vibroseis or both, production parameters are mapped indicating all parameter specified such as stand-off distance, explosive charge and depth, sweep type, nominal power or vibrator drive (*figure 6*).

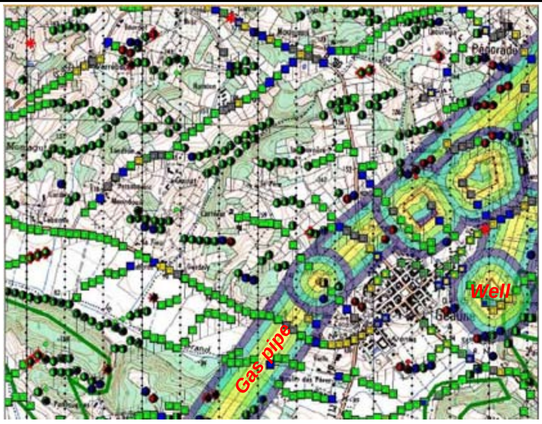

Figure 6: Map example of final source parameters (color dots) to be use and specific sensitive areas (color lines).

In the case of damage supposedly caused by the seismic acquisition, it is also easy to refer to initial measurements of the calibration phase.

The fold coverage was optimally designed while crossing villages and towns even in the presence of sensitive constructions or historical heritage.

Conclusions: Perspective and industrial impact.

Although some additional preliminary trials may be necessary, it is not a significant drawback as these operations can be conducted at the same time as the startup main technical validation of the seismic crew. Generally, these operations cost less than one day of acquisition at standby rate. Thanks to the calibration curves, one of the advantages is the capability of avoiding excessive ground motion in sensitive areas, and in an unfavorable case, to take an option when the ground motion threshold is about to be exceeded. Thus, temporary halts of the seismic production can be avoided and, when occurring, will be strongly minimized in time.

At the same time, the calibration curves give the capability of designing source parameters suitable for any complex area. This will optimize source positions and will yield data for seismic imaging in locations where it would not be possible otherwise using a standard acquisition design.

It is clear that this methodology is therefore a good trade-off between field safety constraints and final optimal data quality.

Further to the validation of several acquisition surveys so far, this methodology based on a calibration stage followed by real-time monitoring can be included in any acquisition survey where sensitive areas will be met. In addition to final seismic data quality, it also provides useful reference material in case of suspected damages or biased charges against the seismic contractor. Accurate and reliable measurements performed by an independent service company give a relevant diagnostic which can be delivered thanks to most appropriate acquisition parameters. This approach is of paramount importance in case of a contentious situation.

Acknowledgement

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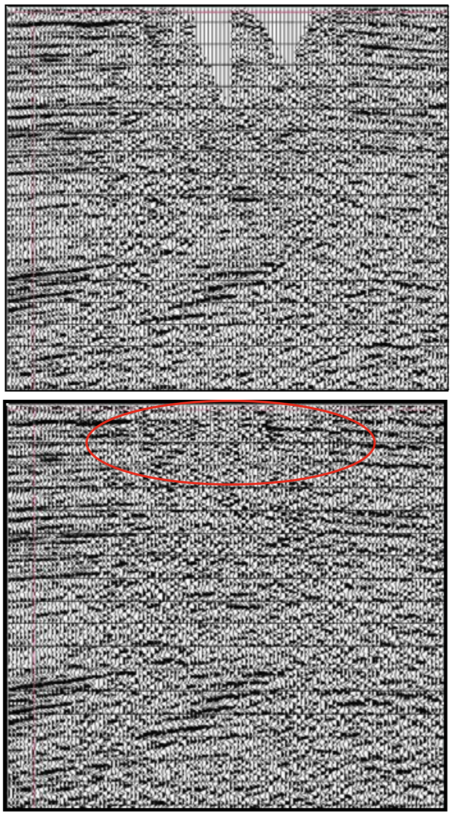

Figure 7: Effect on preliminary stack section using the source acquisition pattern optimization (bottom) compared with standard safety distance acquisition (top).

EDITED REFERENCES

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