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LPA : AN EXPERT SYSTEM FOR LIQUEFACTION POTENTIAL ANALYSIS

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ABSTRACT

This article presents an expert system for assessing liquefaction potential, based on a correlation between observed behaviour in previous earthquakes and the properties of the ground, basically determined by in situ tests (SPT and CPT).

KEYWORDS

Expert system; liquefaction potential; earthquakes; in situ tests; Knowledge Engineering.

INTRODUCTION

It is not easy to evaluate the liquefaction potential with an acceptable degree of accuracy, using methods based on observed behaviour in previous earthquakes and on ground properties determined through in situ tests. In fact, a considerable number of soil and earthquake dependent variables are involved, whose influence is considered in different ways, depending on which of the various methods of analysis is applied.

As a result of the above, in most cases it is complicated to aprioristically determine which is the most suitable method. This means the problem must be dealt with by real experts, especially in boundary cases given that deterministic-type conventional computer programs do not exist for solving it. In the light of this, the article presents the computer program LPA : an expert system for analyzing liquefaction potential.

EVALUATION OF THE LIQUEFACTION POTENTIAL

The works by Armijo et al. (1994) and Armijo (1995) outlines the advantages of analysis methods based on recorded data from past earthquakes, concerning ground behaviour and its properties, especially regarding in situ test information. Such methods are well described in that works.

Figure 1 shows the typical general plan for assessing liquefaction potential, following the methods mentioned. In this plan, the first stage involves determining the sites and the ground layers for the
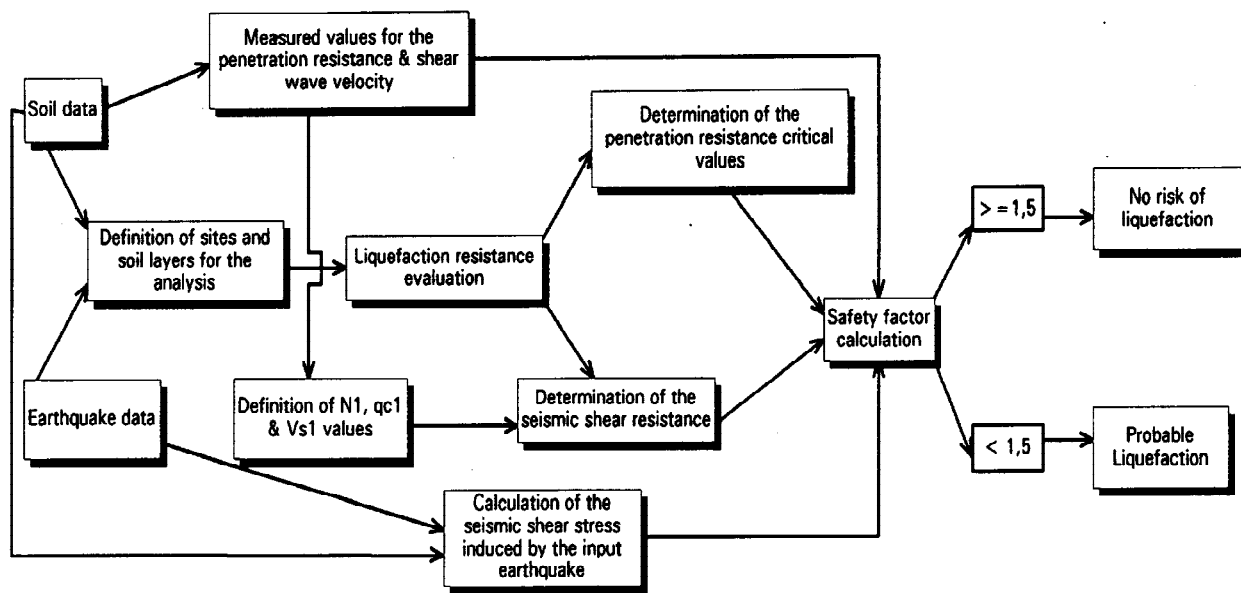
FIG.1.   Typical general outline for the liquefaction potential analysis.
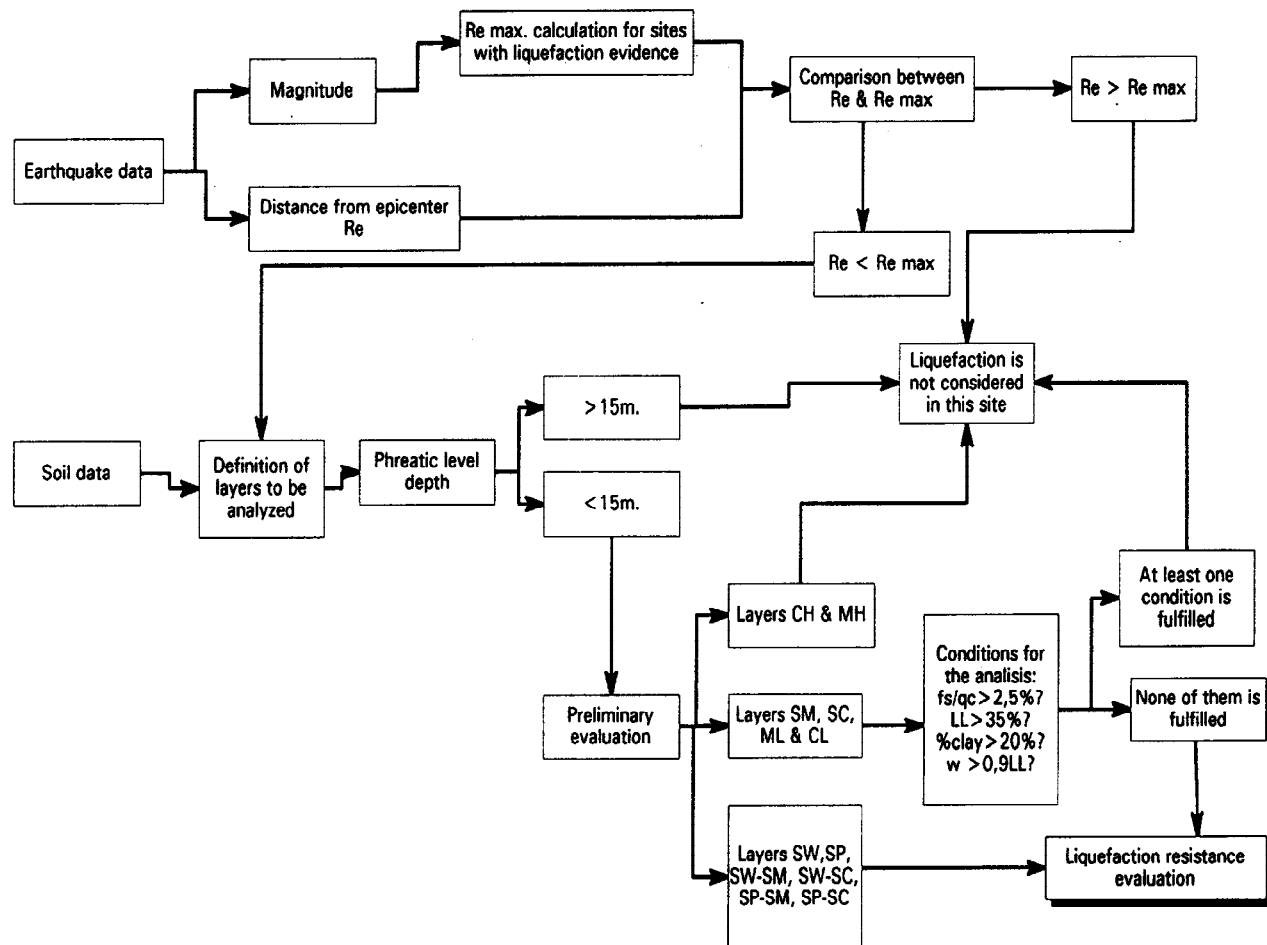

FIG.2.   Definition of sites and soil layers for the analysis.

analysis on the basis of the soil data and the design earthquake data. Figure 2 shows how this process is carried out.

The following stage, as summarised in Fig.3, concern the liquefaction resistance evaluation, i.e., calculation of the seismic shear strength (τ_l / σ'_v), as a function of N_1, q_{cl} and V_{sl}, or determining the critical values of the penetration strength (N_{crit} and q_{ccrit}). The first case requires prior obtaining of the parameters referred to, for the purpose of which the procedure indicated by the corresponding authors must be followed. (Armijo, 1995).

Finally, comparisons are made of both the τ_l / σ'_v determined and the seismic shear stress induced by the design earthquake, τ_d / σ'_v, calculated in a simplified manner, and also the values N_{crit} and q_{ccrit} calculated and the measured values of N and q_c.

APPLICATION OF KNOWLEDGE ENGINEERING

Many variables, depending on the ground and earthquake characteristics, are involved in evaluating the liquefaction potential. Owing to this, the problem is generally complex, and a considerable number of methods are available to tackle it. These methods vary not only in the correlation observed behaviour-in situ soil properties, on which they are based, but also on the way in which the influence of each of the variables mentioned is taken into account.

In the case of the basic correlation to determine liquefaction resistance, the differences arise mainly from the volume of the database considered and the variation range of the parameters included therein. The main databases used to date, are summarized in the work by Armijo (1995). As regards the way in which the various methods take into account the influence of the problem variables, the differences become important on consideration of such earthquake characteristics as magnitude (M) and ground properties like the content and quality of fines.

Due to the drawbacks mentioned in the preceding paragraph, the basic conclusions were established for clean sands and earthquakes of about M= 7.5, this being the situation for which the largest number of records exist. A generalization can be made by applying a series of corrective factors, which vary according to the method chosen.

From what is explained above, it can be deduced that to assess potential liquefaction with a required degree of accuracy, all the possible methods would have to be applied, depending on available earthquake and ground data, and the corresponding safety factors (SF) would have to be calculated. According to the experience acquired, it can be confirmed that there is no liquefaction risk if all methods yield SF $\geq$ 1.5, and that otherwise, the possibility does exist. In the latter situation, when some of the methods give SF ranging from 1-1.5, a greater analysis is required to establish the reliability of the method, in the variation band of the data concerning the specific problem.

At present, deterministic-type conventional computer programs are not available to solve this problem, and an expert is required to make decisions on the basis of criteria developed from prior experience. Consequently, this problem belongs to the sphere of Knowledge Engineering, and is ideal for the application of a program of the socalled expert system type (ES).

In the light of the above, this article presents an ES, named LPA, for assessing liquefaction potential, on the basis of observed ground behaviour recorded from past earthquakes together with the ground properties, especially when these have been determined in real environmental conditions, i.e., in situ.
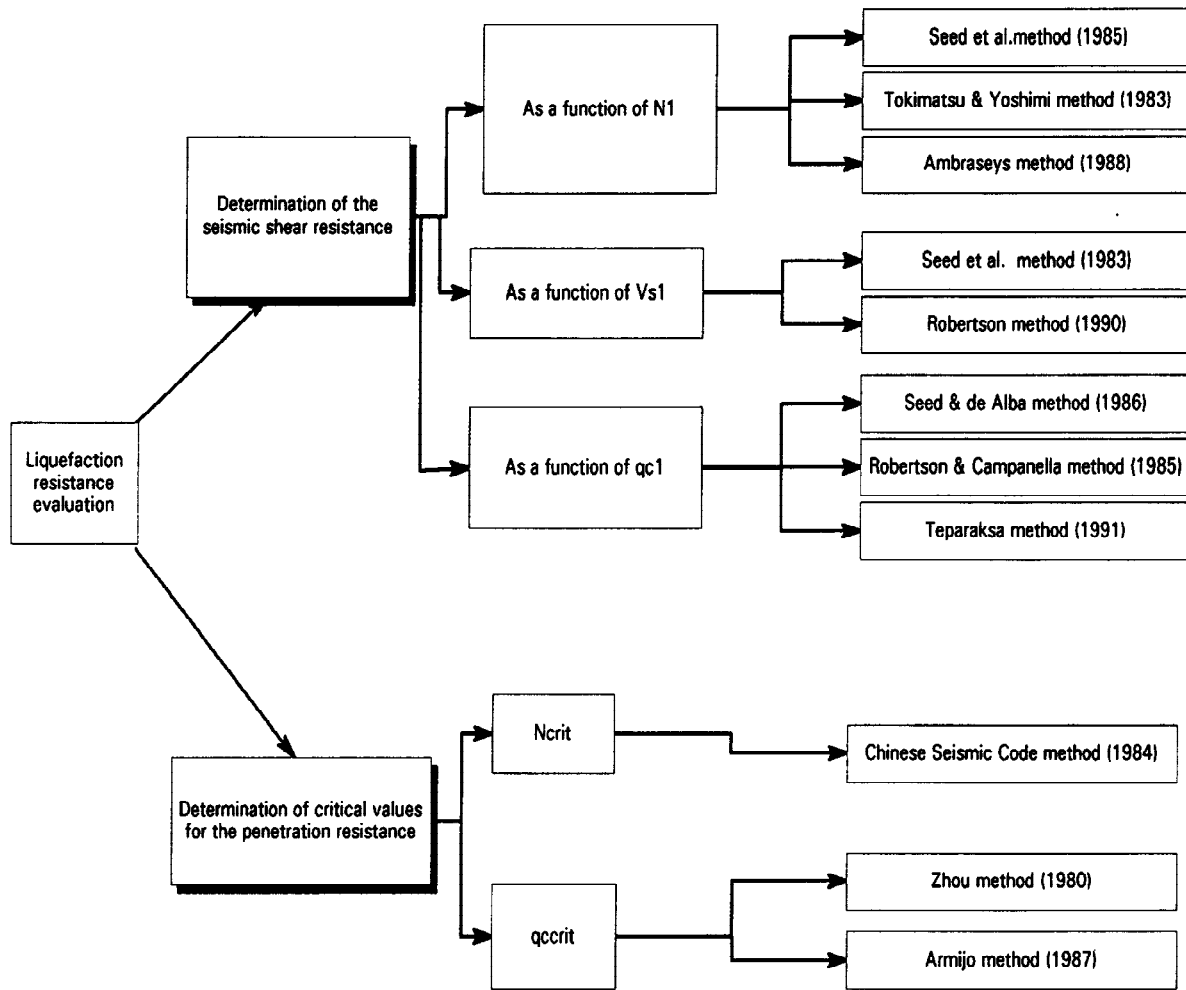
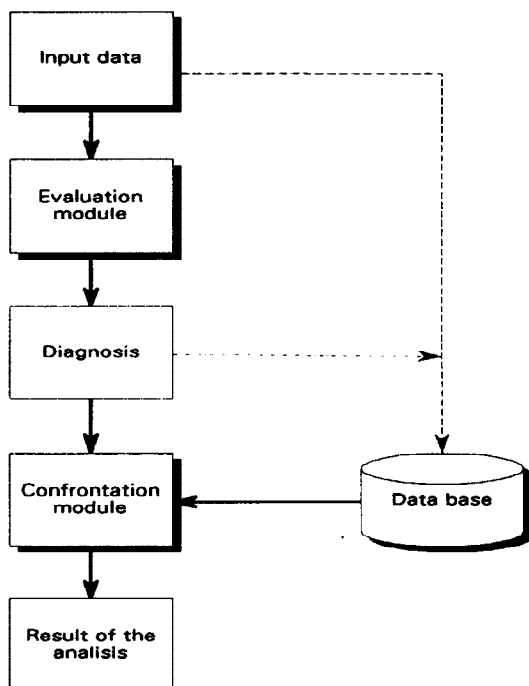FIG.3.   Liquefaction resistance evaluation (Armijo et al., 1994).

FIG.4.   Diagram showing how the expert system works.

EXPERT SYSTEM DEVELOPED

The expert system has been developed using the Kappa PC tool. The philosophy of this tool is oriented towards objects, allowing in this way the inheritance of properties and the dynamic creation and/or destruction of objects and relations.

The representation of knowledge is done by means of the classical rule frame : IF (premise), THEN (hypothesis) and DO (actions). The system has a forwards-backwards mode of reasoning and the inference strategies are dynamically defined.

The designed ES basically consists of three well-defined modules. These modules are as follows (Fig.4):

* Input data module (Fig.5): it uses the graphics interface to show a ground section which reveals the different layers clearly defined, together with their depths and a summary of their index and state properties, plus the corresponding values of the N(SPT), q_c (CPT) and V_s (cross-hole and spectral analysis of surface waves). This graph also shows the design earthquake data (M,I, a_{max} and epicentral distance, Re).

An initial analysis leading to determining the layers and places where an assessment of the liquefaction potential can be carried out, by following the diagram that appear in Fig. 2. A similar procedure is also used to find out where preliminary corrections to the data are needed in order to obtain normalized penetration strength and shear wave propagation velocity values, according to Armijo (1995).

* Evaluation module (Fig.6): it contains the set of rules facilitating the evaluation or diagnosis itself. The rules have basically been defined to allow a diagnosis from the available data, in such a way that they are triggered as the imposed conditions are fulfilled and the associated actions are carried out.

The system contains all the existing assessment methods, and applies them on the basis of the data incorporated, as shown in Fig.3. When the data prove insufficient for suggesting one of the methods mentioned, the system reports this deficiency and indicates what additional information is required.

Using de data from the above analysis, it proceeds to calculate the safety factors, according to the processes indicated in Fig. 1. It considers that there is no liquefaction risk in the following situations :

- SF $\geq$ 1.5
- 1.3 $\leq$ SF < 1.5 and N_1 (or equivalent values of q_{c1} or V_{s1}) $\geq$ 20
- 1.3 $\leq$ SF < 1.5 and N_1 (or equivalent values of q_{c1} or V_{s1}) < 20 if the diagnosis is confirmed by the confrontation module.

* Confrontation module (Fig.7): the purpose of this module is to combine the diagnosis obtained with the database included in the system. This database contains information concerning the geotechnical properties of the sites that showed evidence of liquefaction in the past and the characteristics of the earthquakes involved. Thus, possible similarities and differences can be analyzed regarding the diagnosis made and the real cases which have occurred, on the basis of a previously defined range of variation of the ground properties and the characteristics of the earthquake.

Once the aforementioned process is completed, the system presents the overall result, showing at the same time : a) how this was reached, b) the methods applied and c) the safety factor values obtained, and, in some cases, a weighting of them, on the basis of direct comparison with the database information.
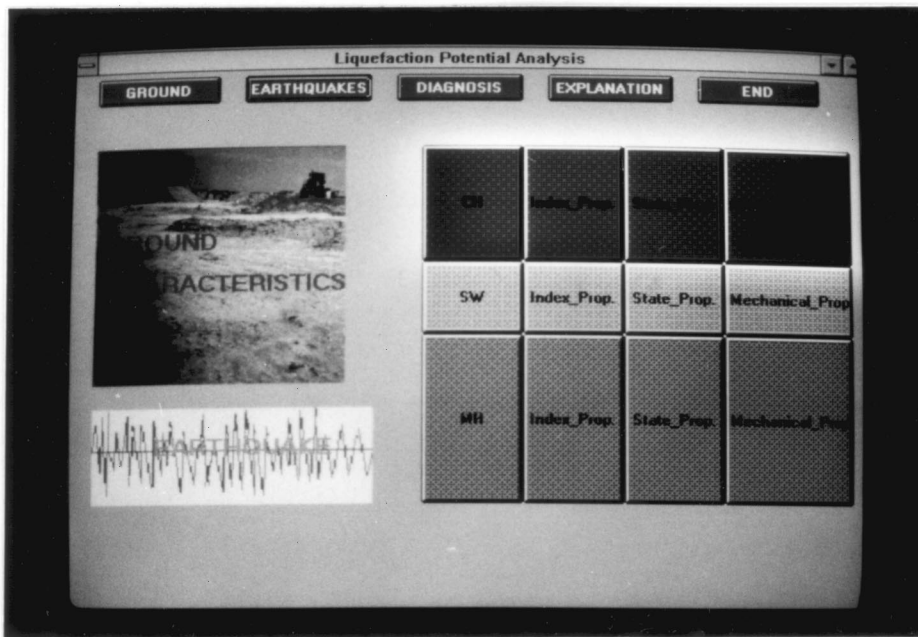
FIG.5.   Photograph of the screen showing an example of the data presentation by means of the corresponding buttons (input data module).
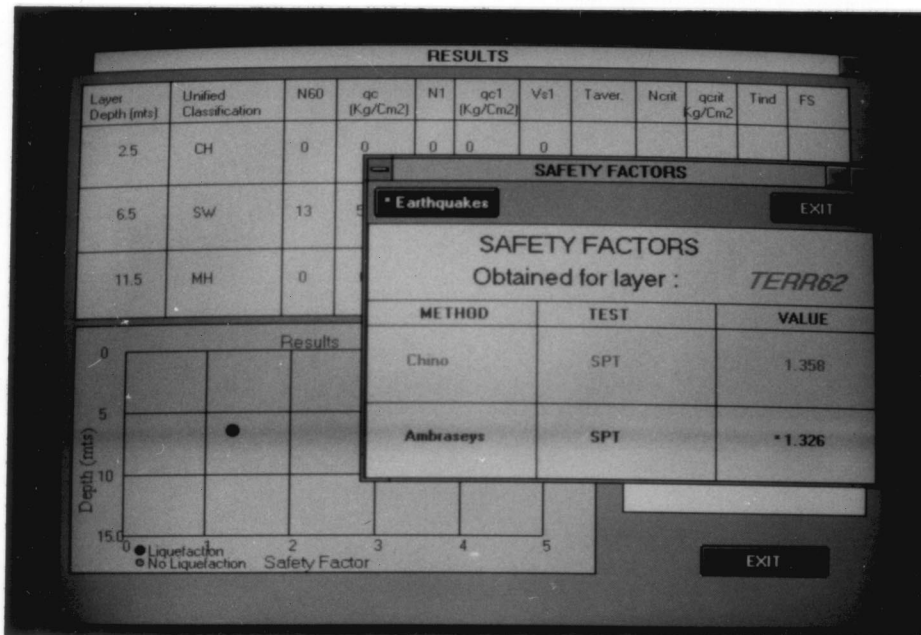

FIG.6.   Photograph of the screen showing the results of a diagnostic an the safety factor values obtained (superimposed window).

Furthermore, it makes an entry in the database for every site analyzed, which includes the ground and earthquake characteristics, together with the diagnosis made. Such data will serve to make a comparison between the predicted and observed behaviour, should an earthquake later affect the study site. Therefore, it is possible to provide dynamic experience through this system, with a view to making more reliable future predictions.
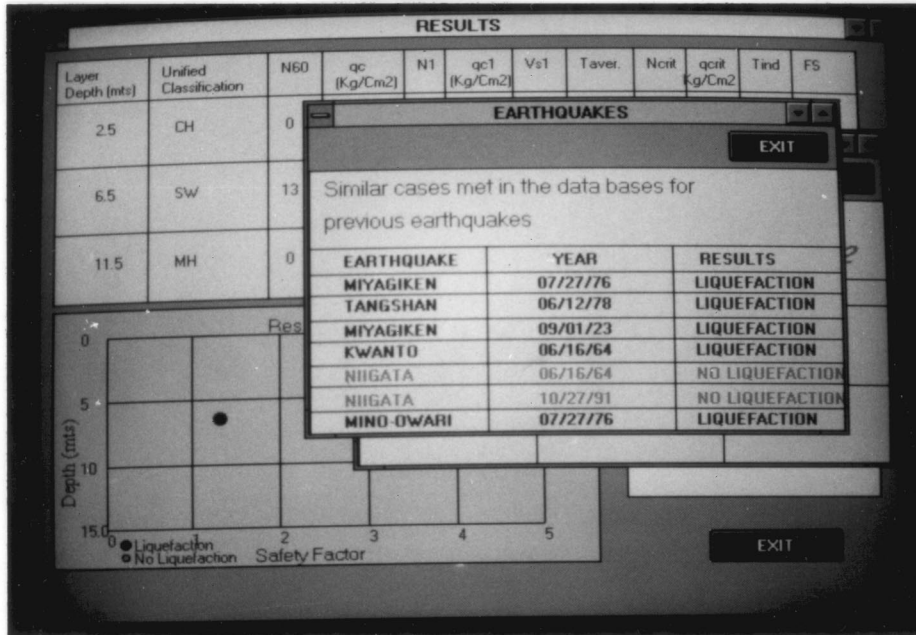

FIG.7.   Photograph of the screen showing similar cases met in the databases by the confrontation module for a verification of the diagnosis made by the evaluation module (Fig.6).

VERIFICATION OF THE EXPERT SYSTEM

To check the efficiency of this ES, it was applied to well-documented cases which form part of the database of the authors of this paper.

The cases are taken from about twenty sites where evidence of earthquake-induced liquefaction has been recorded in San Juan-Argentina (23/11/77) and Mexicali-Mexico (15/10/79 and 08/06/80). This verification stage was completed with promising results.

CONCLUSIONS

The expert system LPA, presented in this paper, constitutes an efficient tool for liquefaction potential assessment based on observed behaviour in previous earthquakes and on ground properties determined through in situ tests. It uses all existing methods, on the basis of available data, and it is capable of weighting the results obtained, applying its own dynamic criteria.

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