

Discussion session: Lessons, issues, needs and prospects

P.-Y. Bard

LGIT (Observatoire de Grenoble) and Laboratoire Central des Ponts-et-Chaussées, Paris, France

ABSTRACT: The main lessons of Turkey Flat and Ashigara Valley experiments, as they were discussed by panelists and by the floor, are summarized. Are presented successively a) what has been learned, b) the important remaining issues, c) the future of Turkey Flat and Ashigara Valley experiments and d) some recommendations for other future experiments.

INTRODUCTION

After the presentation of the two blind prediction experiments (referred to in the following as TF - Turkey Flat - and AV - Ashigara Valley -), the aim of the discussion session was to emphasize their key and weak points, and the lessons to be learned for the future experiments as well as for the prediction of site effects in engineering studies. This discussion was open first by a panel of well-known scientists and engineers, who were all deeply involved in either experiment as organizers or predictors: Dr. Tucker, Prof. Liam Finn, Dr. Donovan, Dr. Paolucci, Prof. Irikura, and Dr. Iai. Each of them delivered an opening statement pinpointing the main outcomes, from his personal viewpoint, of these two blind prediction experiments. The discussion was then open to the floor, which resulted in very vivid exchanges with the panel members, and provided many interesting comments.

The following lines are trying to summarize all these contributions, ordering them in four main sections around the following topics: a) what has been learned in these experiments? b) what are the remaining issues? c) what may further be gained from AV and TF experiments, concerning both the past predictions and the expected strong events at both sites? and d) what should the future experiments focus on, and where might they be located?

LESSONS

Average performance of predictions

It appeared clear for all the participants, that these experiments have shown once again that surface motion undergoes large changes over short distances. It was confirmed by the

numerous instrumental recordings that, although these changes do vary from one event to another, this scatter remains limited enough to justify the attempts to predict such local effects. One of the major outcomes of the blind tests was to point out that presently available methods, in an average, perform "reasonably well" in predicting the local effects. In particular, 1D models, despite their simplicity, proved to provide satisfactory results for both TF and AV sites, corresponding to very different geologic conditions (simple and stiff in one case, complex and soft in the other).

Despite this satisfactory "accuracy" of the average predictions, a general trend to overestimating the surface motion on sediments was noticed; this may come from some numerical problems in some computations, but also from inaccuracies in the standard geotechnical model (too small damping values for TF site for instance).

Large variability of predictions

Both experiments show that the predictions from different individuals exhibit a significant variability depending not only on the numerical approach, but also on the predictor himself. This should prompt "predictors" to be modest and cautious in drawing detailed quantitative conclusions from their results, especially as they prove to be, on the average, much more confident in their results than they are entitled to be: TF experiment clearly revealed that the actual uncertainty of numerical results is much larger than "blindly" estimated by the predictors.

In addition, despite the general "average" agreement between predictors, it was observed that a single method using a single code may provide very different results when used by different authors; reasons for that have not yet

been analysed, but may have to deal with deconvolution and choice of the input motion, or with translating the standard geotechnical model into a code-specific computer model. This unexpected outcome draws attention on the need to specify not only the kind of numerical approach that is followed, but also the details concerning its application to the site under study.

Importance of geotechnical measurements

These two experiments also showed that the responsibility for the predictions uncertainty or inaccuracy does not lie on the computing side only, but is also tightly linked with the interpretation of geotechnical and geophysical surveys. Predictions for KS1 site in AV experiment very clearly emphasized the fact that S wave velocity structure has a crucial importance on the surface motion, and, in particular, that small changes in the shallow structure (concerning for instance the thickness of very soft layers) may induce huge changes in surficial response. Two important lessons are ensuing: the format adopted for TF and AV experiments is good if one wants to validate the whole methodology of site effect estimation; it is not so well suited, however, to check the validity of the computing codes, since their output also depends of the validity of the (geotechnical) input. Moreover, it was observed both in AV and TF experiments that geotechnical engineers in charge of the definition of the standard geotechnical model, had to face some choices for which they had to make use of their "professional judgement", *i.e.* of some subjective feelings who may vary from one individual to another: one therefore has to be cautious both in conducting geotechnical surveys, and in interpreting the resulting data.

Miscellaneous

Finally, from an engineering point of view, an interesting result of these two sets of observations concerns the significant high frequency amplification on thin soft soils, at least at small to moderate acceleration levels: this soil amplification effect is well accepted in the engineering community in the *low frequency* domain, but is often controversial for higher frequencies (above 3 Hz). Such observations are very important for moderate seismicity areas with **moderate levels of motion, where nonlinear effects may be overestimated, and soil amplification underestimated.**

REMAINING ISSUES

Input motion

It has been shown at AV site that a significant part of the scatter in the *observed* spectral ratios between sediment and rock sites is due to

variations in the "input" rock motion over short distances. Such variations are probably related both to source radiation effects and to short wavelength heterogeneities in shallow rock; it is not possible presently, however, to quantify this variability in a reliable way, nor to answer two important questions: what is the limiting site to site distance beyond which it becomes tricky to study site effects by means of spectral ratios ? and at which distance from the earthquake generating fault is it legitimate to investigate the effects of surficial geology independently from the source processes ? The expected moderate or large events at Parkfield and Odawara might provide very useful information in that last respect, but already existing data cannot.

Soil non-linearities

Another big issue regarding site effects estimation is related with the importance of dynamic non-linearities in soil behaviour. This issue could not be addressed till now at TF site, and results concerning AV "mainshock" still correspond to short duration and moderate amplitude signals, so that non-linear models could not be fully tested. In addition, several participants mentioned that the geotechnical measurements were too strongly oriented towards simple linear-equivalent models, so that basic parameters for more sophisticated truly non-linear models were not available.

Another arising issue concerns the variations of damping with frequency. Whereas the whole geotechnical engineering community believes that viscoelastic damping in soils may be considered, for practical purposes, as frequency independent, a number of seismologists and geophysicists are questioning this affirmation, based, in particular, on comparison between theoretical spectral ratios and observed ones, and would favor a quasi-linear increase of quality factor with increasing frequency. Would this latter hypothesis prove true, damping measurements should be done in the frequency band of interest, which would imply the development of new measurement techniques.

Local geometrical diffraction effects

For both sites, incorporation of geometric 2D or 3D diffraction effects in the models did not significantly improve the fit with actual observations. However, at AV site, the instrumental observations do exhibit significant differences between EW and NS spectral ratios for KS1 and KS2 sites, which cannot be explained by 1D models. As a consequence, several attendants, who were not only numericians but also experimentators, drew attention on the impossibility to conclude right now that geometrical effects are insignificant, and/or that 2D and 3D models are not necessary in site effect studies (at AV site for instance, there might exist lateral variations in the shallow velocity

structure, along the longitudinal axis of the valley, which were not looked for during the geotechnical investigations).

The need therefore remains for further investigations in other sites, where geometric effects would be expected to be important; for instance, surface topography amplification effects have been reported in many, sometimes spectacular, instances, and yet this effect is neither well understood, nor *a fortiori* accounted for in site specific hazard studies. In a related respect, it is to be noticed that anisotropy effects have never been addressed thoroughly in engineering applications, and they should perhaps deserve some investigations.

Engineering applications

One of the initial and key questions which grounded these international experiments concerned the cost-effectiveness of the various existing methods for the estimation of site effects. It did not receive any answer, and we still cannot say, even for particular sites like AV or TF, whether it is better to perform simply an instrumental estimation of site effects, or to conduct a geotechnical survey (to which precision level?) and to run simple computer programs...

From another point of view, the observed scatter both in the measured and predicted spectral, even though it is limited to a factor of 2 to 3, is still very large when engineering decisions are to be made: the consequences in terms of cost or safety are considerable. And no methodology exists that allows to account for this scatter in a rational way.

FUTURE OF AV AND TF EXPERIMENTS

In-depth post analysis of past predictions

Everybody agreed on the fact that the "blind" statistical analysis of the TF and AV predictions already performed was a necessary first step. Everybody also agreed, however, that a lot of information and perhaps understanding may be further gained from a thorough examination of these predictions. Several particular items were repeatedly suggested for in-depth examination:

- interviewing the predictors to grasp the basis and the specificities of their methods and models.

- analysing the basic reasons for the scatter in 1D (linear and linear-equivalent) results (control motion, computer model, time step, etc...).

- looking carefully at the methods and or models that gave good results, and also on those that gave very wrong results.

- trying to get new, *a posteriori* estimates from the predictors, and comparing their scatter with the initial, blind one.

- trying to set up some measurement of the

quality of the predictions, that would be more satisfactory than the simple comparison of peak values, and would include both time and frequency domain comparisons.

In addition, although these experiments were mainly designed to check numerical methods, their results may also be used to check the capabilities of instrumental methods based either on weak motion records or on microtremors. In particular, it would be interesting to investigate how time-domain predictions could be achieved based on instrumental spectral ratios, and how they compare with actual observations.

Besides these technical or scientific issues, these two experiments provide a very good opportunity to start a cost-effectiveness analysis of the various methods, including not only the numerical but also the instrumental approaches.

It was realized, however, that such further analysis represent a huge amount of work, which seems too heavy for the Californian and Japanese institutions who already achieved a considerable and outstanding work for the successful organization of these 2 blind experiments. Given the expected benefits, it was therefore strongly recommended by all the attendants that such post-analyses be funded by research agencies, in close cooperation with the Californian and Japanese host institutions.

Recommendations for expected strong events

Since these expected strong events should stress the surficial soils well beyond their "viscoelastic" domain, the main issue to be investigated concerns the non-linear behaviour. Checking as objectively as possible the non-linear models would require some further geotechnical measurements, in order to feed the computer programs with the appropriate parameters; the design of these geotechnical tests should be done in tight connexion with numericians, who very often need much more than the curves describing the variations of shear modulus and damping with deformation.

From another point of view, the expected events correspond to nearby, extended sources. Given the possible sensitivity of surface effects on azimuth and incidence angles, as well as on rupture heterogeneities, it would be interesting to install some more sensors very close to the existing ones, so as to better identify the nature of the wavefield. But it was simultaneously realized that such a densification of existing arrays would be costly, and would transform these "blind prediction" test sites into "site effect" test sites, which was not the original purpose.

Finally, it might also be interesting to couple these site amplification studies with investigations concerning liquefaction, which would probably imply to add some piezometers to the existing accelerometers.

RECOMMENDATIONS FOR FUTURE INTERNATIONAL EXPERIMENTS: FOCUS, LOCATION.

Interest

These two past blind experiments sometimes give the uncomfortable feeling of raising more questions than providing answers; however, their interest and value were not questioned at all, and all participants agreed on the necessity to go on by encouraging the establishment of new experiments on other sites, in addition to the detailed post-analysis of past TF and AV predictions,

All participants realize that it may be uneasy to maintain the enthusiasm of *volunteer* predictors, since the outstanding quality of both TF and AV experiments has already set up a very high level of excellence, which will be difficult to be surpassed or even kept. One way to succeed would be to focus on specific and intriguing issues, not fully addressed by these first two experiments.

Focus

Several participants mentioned that TF and AV sites were not, from a purely geotechnical point of view, ideal sites for a blind prediction test: TF corresponds to shallow, stiff soil category, which is not the worst category for site effects, while AV, though much softer, has a too complex geological structure. As a consequence, in their mind, given the recent observations on Mexico City clay and on San Francisco Bay mud, the attention should be focused on "S4" like sites with an as simple as possible geological structure.

A few other participants also stressed the need for investigations on effects of surface topography, which is now not accounted for in the vast majority of earthquake regulations.

Finally, some people suggested the idea of setting up a purely numerical experiment which would provide an objective comparison of the numerous numerical codes, without any "contamination" by any error in the geotechnical model, and where the effects of the incident wave field could be well controlled. Another, complementary test of numerical models was proposed, based on centrifuge experiments with well controlled materials and boundary conditions.

No priority was given among all these - strongly wished - new prediction experiments.

Location

Several attendants presented their intention to organize a blind prediction experiment; the sites proposed during the session are located in Macedonia, Turkey, Italy, and Mexico. For some of these sites (Macedonia, Mexico), instrumental arrays have already been installed and operated for several years, and it is known that important

local effects do occur. However, this site list is by no means exclusive, and the responsibility of endorsing a given site for the establishment of a new international experiment belongs to the IAEE/IASPEI joint committee only.

Quality control

Whatever the focus and nature of future experiments, and given the growing number of candidate sites for new experiments, several participants repeatedly expressed their wish for the establishment of quality requirements and/or assessments which would allow a better control of both the experiment and the predictions:

- on one side, the geotechnical measurements should include a minimum number of lab and in situ tests, with a minimum redundancy. The listing of the required measurements was not discussed, and should be established by the IAEE/IASPEI joint committee on effects of surface geology.

- on the other side, the quality of the predictions should be measured in some way; post-analysis of past predictions for TF and AV sites should help in that respect.

CONCLUSION

At this point, some may legitimately feel that we are drowned with information, and still starving of knowledge. As the next international prediction experiment will probably not start immediately, we have time to digest the two past experiments, through a thorough analysis of individual predictions. Such a maturation will help in establishing priorities between the - numerous and important - remaining issues concerning the estimation of site effects. The new experiments in coming years could then be planned and coordinated efficiently so as to optimize, as much as possible, their benefit not only for the seismological and engineering communities, but, mainly, for the continuously growing number of humans that live in exposed sites. Rememberings of Mexico City drama, and awareness of the existence of many potentially similar situations throughout the world, should keep us deeply concerned, and anxious to reach the initial goals of these blind tests.

ACKNOWLEDGEMENTS

The author tried to stick to the words and thoughts that were actually expressed during this discussion session. However, the above lines are certainly also biased by his personal views: he therefore apologizes if some participants feel that their contributions are not well accounted for in this summary text.