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SIGNIFICANT CONCEPTS OF SCENARIOS IN RELATION TO REVISING PROCESS OF LICENCING CRITERIA FOR SEISMIC SAFETY OF NUCLEAR POWER PLANTS IN JAPAN

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ABSTRACT

This paper deals with the necessity of objective scenario for distribution of asperity of a particular fault near by a specific point, such as a site of a nuclear power plant, and its rupture process. For the application of pseudo-Green function method to decide Design Basis Earthquake, so-called "one's recipe" has been used. It is a subjective scenario, decided by a particular seismologist or geologist according to his/her experience. In general, it is enough for our engineers, but it is necessary more study it to obtain the public understanding for seismic safety of NPPs. We are planning the OECD/NEA workshop in this coming fall in Tsukuba, Japan.

INTRODUCTION

This paper will deal with some key issues, which the author has been facing as a member of the Revising Committee on "Guideline on Licencing Criteria of Seismic Design of Nuclear Power Plants" in Japan.

Based on the facts resulted from the Hyogoken Nanbu earthquake-1995, this three years' project has been running for two years already, but we are far from the final stage. The following discussion is his personal observations on the reasons of the delay, and he likes to point out that it contains a very significant subject for engineers, especially who are working for regulatory works. To establish adequate measures against natural hazards, we assume future event. Recently a term of "scenario" was frequently used for such an assumption. For the simulation to estimate future situation, we need a set of initial condition and boundary conditions. The term "scenario" is used to call this set like usual terminology to express the story of drama and so on. This "scenario" is significant for designing and evaluating the seismic safety of NPPs.

After Northridge earthquake-1994 and Kobe earthquake-1995, the technique for numerical simulation of ground motions has been developed, and estimating of asperity and its behavior is a key to produce a future ground motions. This "asperity and its behavior" is a kind of "scenario", which is usually called as "recipe" by some researchers' group in this field. The author has been studying on the role of "scenario"

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and how to balance subjective decisions and objective engineering requirements based on this concept. He will describe his personal idea how introduce this concept for drafting the revising of guideline.

To solve such difficulties, we plan to have OECD/NEA workshop in this coming fall, November 2004 in Tsukuba, Japan.

BACKGROUND

In Japan, the revising work on the Licencing Criteria has been continuing for almost three years since June 2002. However, we are still facing several significant key issues.

Most of the significant issues are related to the new developments of seismology, and also the safety concept for public understandings, and also the reflection of the new policy of the new government, "capacity and functional requirement in code".

As known well, the technical procedure for estimating the input ground motions have been developed enough for engineering use, however, there are various opinions on how we decide the design value as the most serious peak value. The way of estimating its asperity, which is strongly related to the ground motions, has not been well established in prior to an event. Therefore, we need to define it, as the engineering philosophical view point, as well as the role of time history in design procedure. We need to show that the procedure, which we are using, is the best one for the seismic safety of nuclear power plant for the public. This is one of the key issues, and we have many other points, which we need to make assumption, that is, our subjective judgment. We call it as "scenario", and the author has been discussed it [11 [2] these several years, and here, he faces it as one of the key issues of the fundamental attitude of revising the Licencing Criteria. To obtain the agreement of the public, also we should get the agreement from other seismologists and geologists.

To get the public understanding on "Safety" of nuclear power plants, the probabilistic approach should be introduced. However, it is not clear how to estimate the probability of occurrence of future destructive earthquakes objectively.

Moreover, for the design procedure, it should be used according to PRA specialists, and Architect Institute of Japan, AIJ completed their guideline [3] for it. On the other hand, the probabilistic concept is difficult for engineers to be understood as well as for the public, if it takes a significant part of seismic design.

Now three working groups have been examining approximately thirty items like, categorizing the factor of importance, design basis earthquake, applicability of elasto-plastic design and so on. We are tying to draw out our conclusion through these discussions on recent developments in various fields related to those key issues. The details would be the subjects of the report for the committee in the future and not the subject here. During last several months, there were the some seismic events which may affect to establish the concept on the Licensing Criteria, itself.

The author deals with some key concepts obtained through the following discussions at first.

"Earthquake" is a natural phenomenon, and the seismic design must start from defining design basis earthquake. In Japan, we have been defining only two types of earthquakes, for example, in-crust earthquake was defined for a smaller magnitude M=6.5 ~ 8, which is similar to that occurs very often in California, and inter-plate earthquake, a larger magnitude $M \geqq 7.5$ or 8.0 at the trenches in the Pacific ocean mainly. The former one was called sometimes intra-plate earthquake in some documents. However, recent studies on the sort of earthquakes brought much more variations with the development of

seismology. For example, an earthquake in a slab, which should be called as “intra-plate earthquake”. This type of earthquake brought a problem of the attenuation of ground motion waves through the subducted plate from the focus. Before recognizing this type of an earthquake, the attenuation formula has much uncertainty. By taking account of high-Q characteristic of plate, we can find more accurate formula. The event, on May 26, 2003 in the North-eastern Pacific Coast brought a new fact.

The distribution of upper-bound magnitude of earthquakes in the region of Japan islands was mapped by Omote [4] as Fig.1 for the upper-bound earthquake, or the limit earthquake S_2 in 1981 for the Licensing Criteria, but it has been developed more complicated map now as Fig.2. This concept was originated by Miyamura, then, Omote established the concept for the design. Then through the paper by Matsuda, and it becomes as Fig.2 in the recent paper [5] by Kakimi and Matsuda. However, for the engineering purpose, Fig.1 in the current Licensing Criteria and Fig.2 are not much different to each other. Such a fact is a really key issue how to truncate the knowledge from seismology to engineering criteria. Back to the subject how to define the design basis earthquake, it is how to truncate our knowledge to the design criteria without loosing the significance for the safety of nuclear power plants.

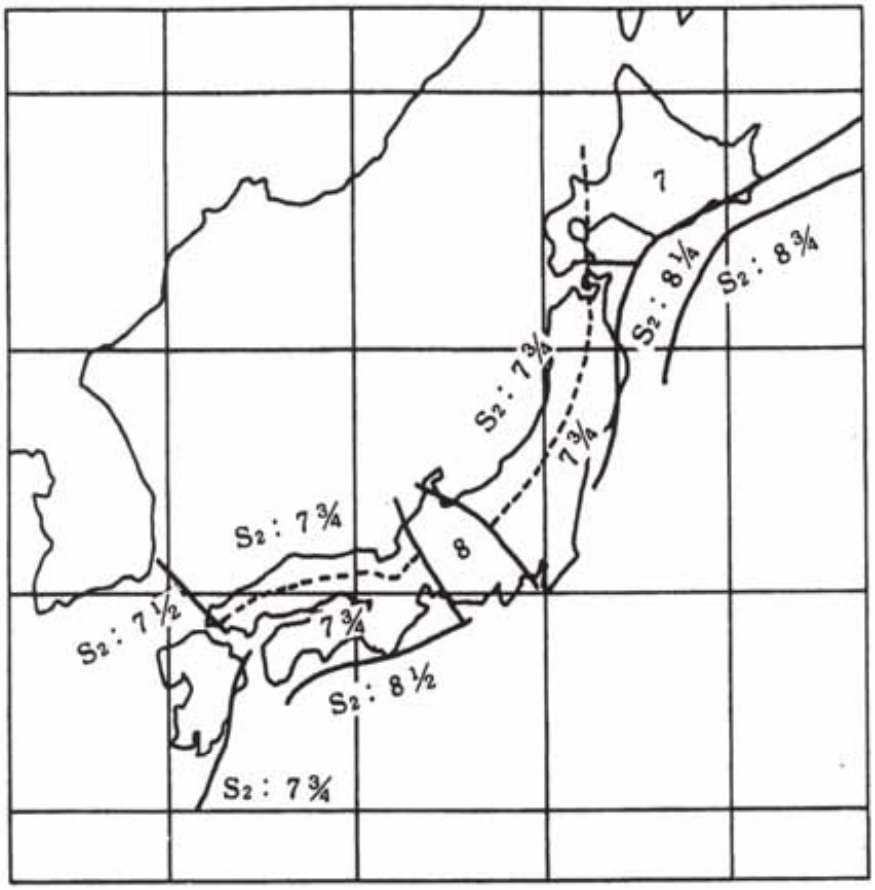


Fig.1, Omote Map (JEAG 4601-1987)

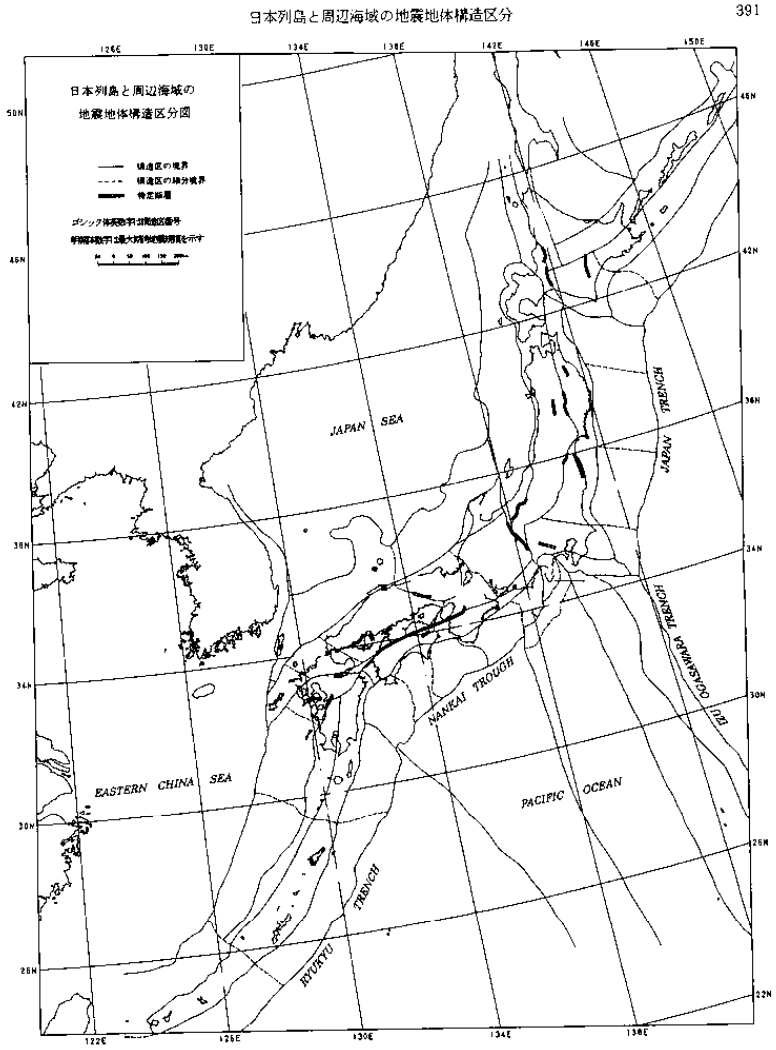


Fig. 1. Seismotectonic province map in and around the Japanese islands. Boldfaced sign is the symbol of province. Roman-type numeral represents the expected maximum earthquake magnitude (M_{max}) assigned to each province. Solid line: boundary between provinces. Broken line: boundary between subprovinces. Bar: the designated fault.

Fig.2, Map by Kakimi and Matsuda (2003)

Also DBE in Japan is usually related to an earthquake decided by such a map or undiscovered fault underneath of the site area. For a known near-field earthquake, the evaluation of a total length of segmented fault is significant. Which is separate faults or one fault should be defined regarding to a gang of lined faults on a map for engineering purpose. Upto now, if the distance of ends of two faults is smaller than 5 km, it should be handled for the design calculation as one continuous fault based on an experiences-based geological study.

However, such discussions to define the practical method for example, how to decide the design basis fault may not be necessary in the Licensing Criteria, and this might be described in the technical guideline because such a criteria, like “5 km apart”, because it is gradually changing by the current knowledge. As described the map for the maximum magnitude in a certain region has been changing as mentioned, and the distance “5 km” of two ends of separate faults has not a strong theoretical reason at this moment. Those are examples of a practical method in the technical guideline.

The principles described in the Licensing Criteria are very often one dimensional matter like a distance of both ends of two separate faults. But, if it will be related to dynamic simulation for the design, we need initial conditions and boundary condition along space and time. This might be called "Scenario". Of course, the term "scenario" is original for the literary world like drams. We, engineers, introduce this terminology to our field very often. The author likes to develop the discussion on the term "Scenario" in the following chapter, as he described in his papers [1] [2] in last several years, such as OECD/NEA workshop in Istanbul. There might be other significant issues, he will add some of them later.

SUBJECTIVE OPINIONS ON RELATION OF SEISMIC INPUTS TO PUBLIC SAFETY

As mentioned in the previous chapter, there is no standard to decide the Design Basis Earthquake as a condition to fulfill the absolute seismic safety of nuclear power plants. Most of the seismologists and the geologists have their own standards, and they are almost unanimous, however, some of them have their different opinions, which are based on the own individual belief, and mostly more serious estimation on future events. The public is supporting their opinion often, because it is understood that the condition based on their opinion should give safer situation in general.

However, the majority is different from such an opinion. Then we need to decide whether or not to follow which one. To select the majority or to consider the minority, which consists of different, individual opinions. To denine them or to employ one of them, we must explain the reason of our decision. This is the subject of "Scenario". We need the decision on how to select our scenario for our design criteria. It is very difficult to decide it based on random procedure as discussed in the following chapters. The author tries to discuss on this difficulty.

OBJECTIVE CONDITION FOR DESIGN BASIS EARTHQUAKE

Our engineers are hoping to get an objective design condition against seismic events, not only to obtain adequate design results, but also to establish good relation to public.

For a typical event, which is expecting to occur to near to a plant, the pseudo-Green Function methods is the best approach, if asperity of a specific fault could be established. Then, whether or not we can establish the asperity distribution for the worst design condition.

Then the question has been arisen, that is, how to decide the worst distribution of asperity. A time process of slipping is also unknown process in advance, but it should be clarified prior to the event in the future by the effort of geologists. Currently, this should be a random process. Back to the distribution of asperity, it should be estimated prior to the event based on knowledge on geological details of a fault. As mentioned in the Concluding Remarks, the author believes that the technology to estimate this is next ten years, if we shall have enough numbers of scientists with enough amount of financial support.

At this moment, we can't have any objective approach to decide it. Therefore, we must find some good approach to explain its objectivity to the public as well as possible.

Some seismologists are offering a figure of asperity for the future event based on his/her geological and seismological knowledge on a particular fault, so-called, "*one's recipe*". If the most of scientists, related to this, agree this proposal, it might be said "objective" in general. Even so, some few scientists or the public will oppose them, it is very difficult to persuade them, that the recipe would be a subjective offering. The author tries to discuss what a recipe, may be similar to a concept of "scenario", is, and how to be objective in the following chapters.

SCENARIO, AND ITS FUNDAMENTAL CHARACTERISTICS

The author has been discussing about the concept of the worst scenario in a previous paper [1]. Here, he tries briefly to explain as an example again. This example is on Fatal Risk Evaluation diversing the radiological materials [6], which was studied by JAERI's group. As shown in Fig.3A, this simulation analysis are divided into two measure parts, that is, leakage of radio-active sources from a containment vessel, and their divergence under a certain meteorological conditions. This seems to be quite different from a seismic problem, but it is a good example of the difficulty to produce it by Monte Carlo method.

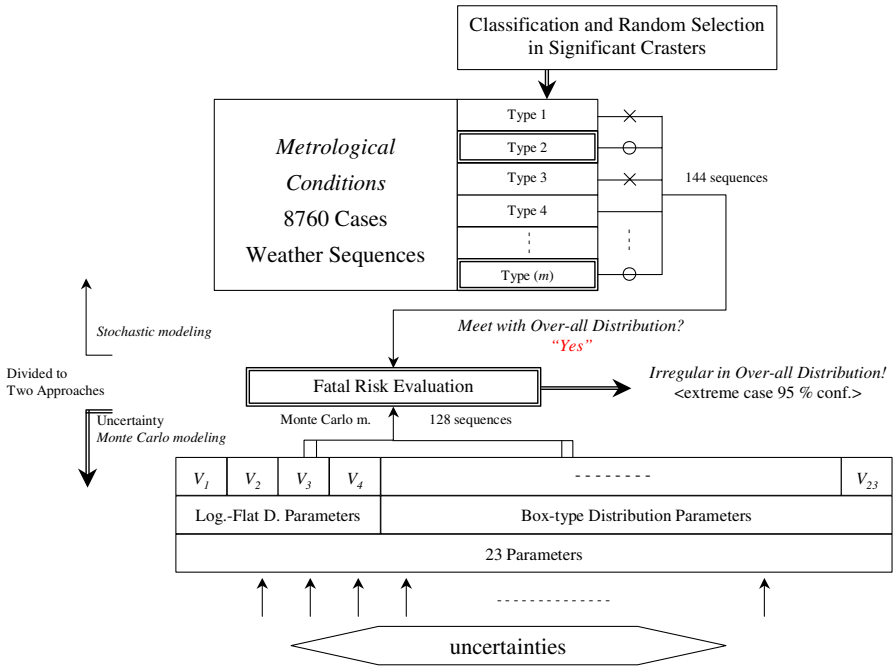


Fig.3A, Schematic Flow of Fatal Risk Analysis, [Ref. (6)]
Prepared by Shibata, based on Honma's Presentation and *Private Communication*

The amount of leakage of radioactive sources is governed by 23 parameters. And its diffusion is governed by the meteorological conditions which were described by 8,760 cases of weather sequences in the area.

At first, 128 sequences of leakages were selected from the combinations of 23 parameters with Monte Carlo method. These consequences were examined to meet with the normal distribution. However, it should be noted that the total number of a combination of 23 parameters of only two extreme case becomes $2^{23} \cong 8 \times 10^6$. A schematic relation of the extreme case of two parameters is shown in Fig.4. This means the total number of trials for Monte Carlo simulation should be, at least, the order of 10^7. Therefore this number, 128, is extremely smaller than that to be adequate number. The other side for the simulation of defusing process, to reduce the number of cases, 8,760, of meteorological conditions to meet the above number of cases, they classify the weather sequence to significant cruster in the view point of the possibility of occurrence and its actual field situation. Assumed several types of sequences to be most effective in the area for evaluating "Fatal Risk", then picked 144 sequences up from the selected types by Monte Carlo method. They checked their stochastic distribution to meet the requirement as its shape. Then they combined these two procedures, the results are almost smoothly distributed in the mean, but the

shape of 99% confidence distribution is biased as shown in Fig.3B. It comes from the second step on the selection after subjective process by crusting meteorological sequences.

Thus, it is very difficult to get a certain scenario based on a random process approach.

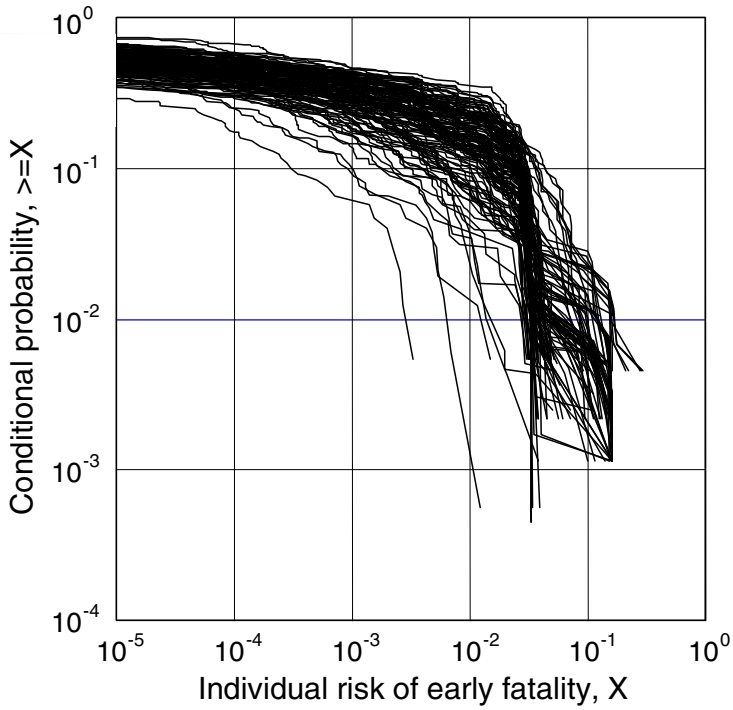


Fig.3B, Fatal Risk vs Probability [Ref. (6)]

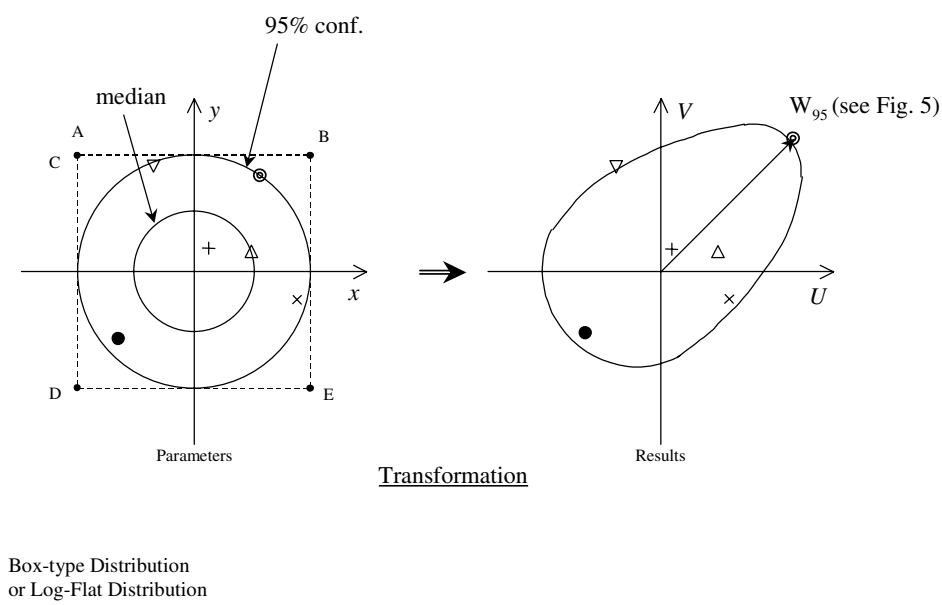


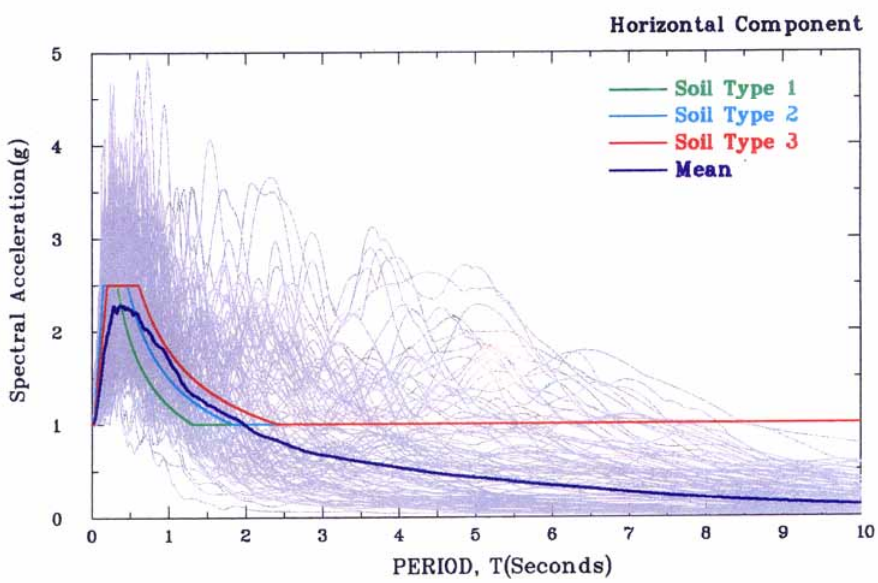
Fig.4, Monte Carlo Approach for Simulation

SCENARIO AND OBJECTIVITY

Already the author makes clear this subject in the previous chapter. Back to the term "Scenario", it comes from a story-making for a drama, which plays at a theater. A drama is, of course, the product of a writer's originality, that is, subjectivity.

Therefore, in principle, the scenario for the design basis is subjective. A rupture process of a fault might be such a scenario, and it shall be a product by a specialist to be more objective.

In some works, it is practical to generate a set of distributions of asperity as it was presented in a STS in Acapulco, there is no systematic way, in general. The 124(?) costs of simulation, which has been done by LLNL in U.S.A. and was presented in the STS, is one example. Their figure, obtained by LLNL, is similar to the cases of the response spectrums of Chi-chi earthquake in Taiwan as shown in Fig.5, but LLNL's has no model for their distribution. It is only subjective one. The discussions on searching the worst event without any reason in seismology and geology are meaningless for the engineering purpose. It is a weak point of the pseudo-Green function method.



圖四 集集大地震引發之非台北盆地測站之水平地動加速度反應譜形狀與現行建築技術規範地震設計之比較。

Fig. 5 The Response Spectra of Chi-chi Earthquake in Taiwan for their Design Basis Earthquake for the Code

APPROACH TO PREDICT FUTURE EVENT

The author believes that there would be some technical approach to estimate a distribution of asperity. One idea is to utilize a technique of deep bore hole and instrumentation in its hole. By combining oil well technique and instrumentation technique under extreme environment, we could know structures in 10~15 km depth by positive elastic wave reflection mapping. For this, the depth of bore holes may be enough to be 2~3 km.

The effort to obtain cores in fault zone has been made by USGS in USA, NIED in Japan and others. Knowledge, obtained by such positive efforts of related organizations, shall bring a practical way to estimate the distribution of asperity so as to meet our engineering necessity for predicting the time process of a future event.

CONCLUDING REMARKS AND ACKNOWLEDGEMENT

The author believes the necessity of a technique to estimate the distribution of asperity for a future event on a particular fault. It may be required some billions of US dollars, but it would be worth while to obtain the seismic safety of nuclear power plants, or to estimate and to prepare for the seismic disaster in a certain region.

OECD/NEA has decided that the Workshop for "Seismic Input" for nuclear power plants will be held in November 2004, this coming fall, in Tsukuba by organizing of NIED, National Research Institute for Earth Science and Disaster Prevention. In this three days workshop, we plan to have two Special Sessions: i) utilizing the deep bore-hole technique for deciding asperity distribution, and ii) to finding hidden faults and their lower-boundary magnitude of the event which we can find.

The author appreciates for their decision and supports of OECD; CSNI and NIED, METI in Japan and also for the co-operation of the Organizing Committee.

We expect that many related scientists and engineers will join to us.

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