A topic on the seismic design criteria for a nuclear power plant in Japan

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A sequence of discussion on seismic design criteria at Ooi nuclear power plant is described for discussion in this session. It took place after my presentation at 2015 JpGU (see 'Maximum-class’　Japan Sea tsunami scenarios are less than maximum-class, e0002 KAGAKU Nov. 2016 Vol. 86). This presentation aims to present an example on how things have been going on among earth science community, Nuclear Regulatory Authority, and power companies in Japan.

Keywords: seismic design criterion, nuclear power, earth science community

Design Basis Ground Motion reduces seismic safety of NPP: Proposal of *Earthquake Ground Motion for Defense in Depth*

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DBEGM (Design Basis Earthquake Ground Motion) prescribed in Japan's NRA’s (Nuclear Regulation Authority) New Regulatory Requirements is insufficient to accomplish seismic safety of NPPs (nuclear power plants). This is because, in terms of the IAEA's (International Atomic Energy Agency) concept of Defense in Depth in nuclear safety, DBEGM is used merely for seismic design of NPP facilities in Level 1 (prevention of abnormal operation and failures), Level 2 (control of abnormal operation and detection of failures) and Level 3 (control of accidents within the design basis), not having any responsibility for Level 4 (control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents). As an example, in case of Sendai NPP's Units 1 and 2 operated by Kyusyu Electric Power Co., Inc., DBEGM Ss-1 (maximum horizontal acceleration 540 Gal) and Ss-2 (maximum horizontal acceleration 620 Gal) are only short-period and short-duration with small CAV (Cumulative Absolute Velocity), which is considered important in the United States, and probably very insufficient to defend additional emergent facilities and human activities of Level 4 against large ground accelerations, velocities and displacements of short to long periods and long duration times due to, for example, the anticipated *M* 9-class giant Nankai trough earthquake, which is ignored by Kyushu Electric and NRA. Therefore, I propose to establish a new earthquake ground motion, say, EGMDD (Earthquake Ground Motion for Defense in Depth), which important facilities and infrastructures of NPPs should withstand from Level 1 through Level 4. EGMDD should be formulated by taking into account both large earthquakes just beneath NPPs and great earthquakes distant from plants having annual exceedance probabilities of 10^{-4} to 10^{-6}, and should have broad-band spectrum from short-period to long-period and long duration times. Formulating a proper EGMDD for a certain NPP is a trans-scientific problem. So, it should be decided through exhaustive discussions in such an organization as CLI (Commission Locale d'Information) in France, in which a nuclear utility concerned, municipalities with and without the plant, inhabitants, earthquake scientists and engineers, plant makers, regulation authority, etc, will participate.

Keywords: nuclear power plant, design basis earthquake ground motion, defense in depth, trans-science, earthquake ground motion for defense in depth, local commission of information

Rigid rotation of outer Southwest Japan and its implication for the safety of Ikata Nuclear Power Plant

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After the severe accident at the Fukushima Daiichi Nuclear Power Plant in 2011, the examination system of the nuclear power plants in Japan was renovated; now the conformity to the new regulation is examined by the Nuclear Regulation Authority, Japan. The documents of the meetings are open to the public via the website at http://www.nsr.go.jp/disclosure/committee/yuushikisya/tekigousei.html; the scientists can check the appropriateness of the examination if they want to do so. However, because earth scientists are so busy, they will not view the documents unless they are forced to do so. I was also one of those people who did not have enough time to open those documents, however, I recently had a chance to read the documents about the design ground motion of the Ikata Nuclear Power Plant. What I found there was that part of the process of strong motion evaluation is not reasonable. One of those problems will be presented in my presentation. The problem is not related to the simulation of strong ground motion; it is rather related to tectonics. Therefore, the topic is not so closely related to my own specialty. My intention here is to attract the attention of the specialists to this important problem. I hope this presentation will stimulate discussion among specialists of tectonics.

The evaluation process of the design ground motion of Ikata Nuclear Power Plant can be found in a document submitted by the Shikoku Electric Power Company to a meeting on March 20, 2015 (http://www.nsr.go.jp/data/000100928.pdf). Because the Median Tectonic Line is located in front of the power plant site, its activity is considered in the evaluation of the design ground motions. In this process, the dip angle is basically assumed to be 90 degrees and its uncertainty is considered. However, although the dip angle of 30 degrees is considered in the north-dipping case where the source fault is far from the power plant, the dip angle of no less than 80 degrees is considered in the south-dipping case where the source fault is close to the power plant (page 55). It looks like the power company intentionally avoided the critical case.

The Geospatial Information Authority of Japan shows a map of crustal deformation (http://www.gsi.go.jp/kyusyu/test.html), where the outer Southwest Japan is rotating anticlockwise; this movement is in agreement with the occurrence of the 2016 Kumamoto earthquake. The animation shows that Ikata Nuclear Power Plant belongs to a region of contraction. Although the power company says that the site is located in a transition zone from a right-lateral faulting to a normal faulting in another document submitted to the same meeting (https://www.nsr.go.jp/data/000100933.pdf), the fact is that the site is located in a contraction zone; the right-lateral faulting will accompany reverse faulting rather than normal faulting.

The question is whether the fault is north-dipping or south-dipping. If we assume a reverse faulting along a north-dipping plane, it will be in conflict with the long-term uplift of the southern side of the Median Tectonic Line. Therefore, a reverse faulting along a south-dipping plane is likely to occur with the right-lateral movement. Therefore, it is not appropriate to focus on north-dipping plane.

It should be noted that this discussion does not imply that the northwest oriented crustal movement of Western Shikoku will entirely be contributing to a large event along the Median Tectonic Line; most of it will be canceled by huge subduction earthquakes along the Nankai Trough. However, it should be noted that the rotation of outer Southwest Japan is in agreement with the occurrence of the 2016 Kumamoto earthquake. Therefore, the rotation may cause a big earthquake along the Median Tectonic Line which is in consistent with the rotation, that is, a right-lateral earthquake with significant dip slip. The occurrence

of such an earthquake may be approaching due to the accumulation of strain with the subduction of Philippine Sea Plate.

Keywords: nuclear power plant, design ground motion, Median Tectonic Line, dip angle, crustal deformation, reverse fault

Uncertainty in Risk and Social Decision Making: A case study of nuclear safety regulation

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Social decision making on Risk
Any science and technology has potential risk on society. How large risk society can accept is, of course, a decision by the society. But any risk assessment has inherent uncertainty. How to deal with such uncertainty must be clarified in social decision making process. Otherwise, such decision making will not gain enough public trust.
Risk assessment is typically done by scientific/technical experts. It is often the case that there are wide disagreements on the result of risk assessment. At the end, however, experts who are involved in decision making play critically important role, it is essential that there is social trust in those technical experts and the process in which final decision is made. Especially, there should be a clear understanding on how to deal with such uncertainty.
Next, decision on "acceptable risk" must be made. It is often the case that risk does not be eliminated to zero, it is necessary to decide how much risk can be acceptable. This decision cannot be done only by scientific/technical experts. It is desirable that users of such science/technologies, or stakeholders who would be exposed to such risks, would be involved in such decision making. It is often difficult, in reality, to involve such actors in decision making, and thus decision made by the regulatory authority sometimes is not socially acceptable.
In short, 1) there is always uncertainty in risk assessment and thus it is important to have trust in experts involved in decision making and in the decision making process, 2) since risk cannot be eliminated to zero, decision on "acceptable risk" had better to involve stakeholders in addition to scientific/technical experts. In order to gain public trust, transparency of such decision making is essential.

Issues on Nuclear Safety Regulation (Basis earthquake ground motion)
From viewpoints made above, let us discuss social issues associated with nuclear safety regulation, in particular on basis earthquake ground motion. The following is a brief description of what happened in the case of Ohi nuclear power plant licensing process.
Assessment of basis earthquake ground motion during the licensing process of Ohi nuclear power plant was done based on conventional "Irikura/Miyake method" by both Kansai Electric and regulatory authority (Nuclear Regulation Authority: NRA). And NRA decided that it satisfied the regulatory standards and that allow operating license for Ohi nuclear plant.
However, earthquake expert such as Prof. Shimazaki, pointed that such decision was inappropriate considering new data from Kumamoto Earthquake in 2016, and that the prediction by Irikura/Miyake method had too much uncertainty to make a decision.
NRA confirmed its own decision despite the argument made by Prof. Shimazaki, saying his argument was based on "biased data setting". And declared that there is no need to change its decision on Ohi nuclear power plant.
This case illustrates the various important issues involved in uncertainty in risk assessment and how to deal with such uncertainty.
First, there are disagreements over the "new data" based on the Kumamoto Earthquake. According to Dr. Hiroyuki Fujiwara, an expert on earthquake movement, "it is necessary to consider such uncertainty…prediction based on the 'Irikura/Miyake method' may show too much width (uncertainty),

and it is not clear how regulatory process deals with such wide uncertainty.” On the other hand, NRA said that uncertainty is considered by taking account of the length of geological fault during the process of assessment.”
In addition, such disagreements over the risk assessment were linked to the social decision on restart up of Ohi-reactor. As a result, it generated social mistrust, including a speculation that NRA wanted to avoid reevaluation of decision to allow restart up of Ohi. Lack of transparency between the risk assessment and the final decision to allow restart up the reactor may be the reason of such speculation and mistrust. It is essential to involve non-technical experts as well as stakeholders in such decision making.

Conclusion
Based on the above example, it can be concluded that 1) when there is a disagreement among experts in risk assessments, especially on uncertainty, it is important to make clear how such uncertainty can be deal with during the decision making, 2) when the risk assessment can lead to larger social decision making, it is important to clarify the criteria of such decision making and to have enough transparency in decision making. It should be recognized that enough trust cannot be gained only by scientific/technical experts and thus there is a need to involve other important stakeholders as well.

Keywords: risk assessment, uncertainty, social decision making, public trust

Active structure and capable faults in Oma Nuclear Power Plant, Aomori, northern Japan

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Tectono-geomorphic investigations clarify that submarine active fault has played important roles in the acute uplift of the northwestern part of Shimokita peninsula. The Oma Nuclear Power Plant is under construction in this seismo-tectonically active area. There are many capable faults in the site of the plant. The S-10, S-11, cf-1, E29, and E33 faults cut and deform marine terrace sediments (MIS 5e to MIS 5c in age). Such unstable area is not the right ground for nuclear power facilities. Following scientific on-site safety inspections, we should build the facilities with engineering safeguard against the possible incidents.

Keywords: tectonic landform, submarine active fault, capable fault, Shimokita penisula, Oma Nuclear Power Plant

Problems on the volcanic hazard simulation for safty evaluation of the nuclear power plant site

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Japanese electric power companies(EPCs) have been submitting materials for safety reviews of their nuclear power plants(NPPs) to the National Regulatory Authority(NRA). Among the submitted materials, we are able to find volcanic hazard assessment results for NPP sites based on the applications of volcanic hazard simulation programs and models. Among them, Titan2d is a program for pylocrastc flow simulation and Tephra2 is a simulation program for fallout of volcanic ejecta from a volcanic column. Mogi’s model is an assessment formula for ground deformation induced by internal stress change of magma reservoirs. However, applications of the programs and formula by EPCs show inappropriate or wrong use of them when physical process and boundary conditions for them are concerned and resultant volcanic hazard assessments must be almost meaningless for safety review of NPPs.

Keywords: Titan2d, Tephra2, Mogi's Model

Can we identify all possible source faults?

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I have been devoted to study of crustal deformation with space-borne synthetic aperture radar during recent years. The lessons I learned in this study is that earthquake source fault is complex.For example, source faults in the sequence of earthquakes in New Zealand since 2010 are its representative. Parallel faults rutptured during the April 2010 Iwaki, Fukushima earthquake. Furhtermore, the lower bound of M6.4 above that surface rupture appears may be questionable for practical use. We detected clear discontinuities in phase in interferogram that covers source region of the northern Ibaraki earthquake (M6.1) on March 19, 2011. Considering pattern of observed crustal deformation, it is reasonable that rupture reached the Earth's surface. Furthermore, we observed similar crustal deformation during an earthquake of M6.3 on December 28 in the same area. Discontinuity in phase were also identified at the almost same location. It is obvious that earthquakes of similar size recurred at a shorter interval than 6 year in such a narrow area. Based on these experience, I am skeptical about the rationality on the calculation of ground motion with limited number of sources.

It is easy to reject these observational facts as exceptions. Earthquake science has developed probably by seeking universality that are common in many examples and sophisticating it; i.e. finding law by focusing average in probability distribution. However, is it OK for discussion on construction of nuclear power plants in which people must consider long tail distribution? On the other hand, to what extent we should consider "exceptional" events mentioned above or events that have not occurred? It is regrettable that I do not have answer to these questions. I expect discussion among community of earthquake science today.

Keywords: source fault, crustal deformation, nuclear power plant

Predictability in earthquake science and its uncertainties

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Prediction of future seismic phenomena with a reasonable accuracy is one of the important goals of seismology. However, in recent years it becomes a general agreement in the seismological community that accurate prediction of location, time, and size of large earthquakes is impossible at least for now.
In addition, the 2011 Mw9.0 Tohoku-oki earthquake revealed that long-term forecast of seismic activities also have large uncertainty. Under such circumstances, the emergency act against the large earthquake along the Nankai Trough is now being discussed in a governmental working group and the emergency response based on earthquake prediction shall be changed. It should be rigorously questioned if there is any information available before the occurrence of a big earthquake. These experiences brought us important lessons about the nature of seismic hazard that predictability of earthquake science in present-day is highly limited and that it is of essential to take such a large uncertainty into account in protection of important facilities such as nuclear power plants. It should be also noted that the degree of uncertainty is often underestimated as long as such evaluation depends on our limited experience.

Keywords: earthquake, predictablity, uncertainty

Interaction and Gap between Science and Engineering in Risk Governance: Perspectives of Science and Technology Studies

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It has been discussed how to deal with the incertitude of expertise regarding the risks of natural disasters and complex artifacts. We have recognized the limit of our knowledge and humble attitude for these risk is now appreciated, while we cannot stop the best effort to protect our people and society from those risks. We have to face this ambivalent to utilize our expertise to decision-making and practice of risk-management, which is to be kept as fine states –that is the goal of risk governance.

In this context, science (scientists) and engineering (engineers) could collaborate each other, but could have tension between them at the same time, because they have different mission and purpose: science (scientists) define their mission as knowledge production itself, while engineering (engineers) have to solve the problem and show the solution for their clients.

If their expertise suggests any warning of risks such as disaster risk, scientists may try to share their concern with other stakeholder in society. In this case, their advice could often include risk avoidance strategy to deal with that risk. Engineers, on the other hand, they understand that their mission includes risk management by nature of engineering, and would not try to exclude other options of risk treatment: risk reduction, sharing and retention. It is optimization problem for them to deal with risk, with all of four options of risk treatment, and the risk avoidance is sometimes the least priority option for them, because the choice implies their defeat, in a sence.

Also, on the effect of engineering measures, engineers understand that it is a combination of their efforts and external conditions to reduce risk under the tolerance level, but scientists tend to think the best pair of maximum anti-disaster engineering measures and the preferable external condition could result in the least risk for us.

These fundamental differences in their principles to face the disaster risks could be amplified through complex interactions in risk governance mechanism and could lead serious miscommunication among them. It could result in the unacceptable dysfunction in society.

In this presentation, some perspectives of science and technology studies (STS) on this topic will be introduced taking the cases of controversy on seismic risk of nuclear facilities including the topic of “basis ground motion” and other to discuss the interactions and the gap between science (scientists) and engineering (engineers). The ideas to solve/mediate the issue and prevent further social dysfunction would be suggested.

Keywords: Science (Scientists), Engineering (Engineers), Risk Governance, Social Dysfunction

History of design basis earthquake ground motion for nuclear power plants in Japan

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I would review a history of design basis earthquake ground motion (“the design ground motion” hereafter) for nuclear power plants in Japan. The first official guidelines of design ground motion established in 1978, when a number of nuclear power plants had already been constructed or in operation. The plants were designed in 1960s without the earthquake risk evaluation based on the plate tectonics theory.
In the 1978 guidelines, the design ground motion S1 expected by strongest possible nearby earthquakes and the design ground motion S2 expected by unrealistically strong earthquake with consideration of earthquakes in the last 50,000 years. The facilities of class A should be in an elastic deformation by the S1 motion and those of class As should maintain its safety. Updates of the 1978 guidelines had not been initiated until we experienced the devastating Kobe earthquake in 1995. The guidelines were updated in 2006. While a basic policy of the 2006 guidelines was not much different from the 1978 guidelines, the design ground motion is unified to Ss from S1 and S2 in the 1978 guidelines. An earthquake fault model was introduced to evaluate ground motion. Estimation period of fault activity was elongated from 50,000 to 130,000 years. Surprisingly a tsunami risk was introduced for the first time in the 2006 guidelines in spite that the tsunami disaster had occurred frequently by great thrust earthquakes in Japan. The power companies had a duty to examine whether existing plants fit to the 2006 guidelines and to reinforce when necessary. The 2011 Tohoku giant earthquake led to the severe accident of the Fukushima Daiichi power plant, for which the power companies stated “totally unexpected” . The accident strongly indicated that further and severer update was required. In 2013, new guidelines were defined. Although the government and power companies emphasize that the new guideline is severer in the world, there are still debates whether the new guidelines are reasonably severe for the nuclear power plants in Japan, where earthquake activity is extremely high in the world.

Keywords: Nuclear power plant, design basis earthquake ground motion