Report of the JSME Research Committee on the Great East Japan Earthquake Disaster

Chapter 1

Lessons Learned from the Disaster
—An Overview—

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Abstract

In this chapter four lessons learned through research are presented in the form of proposals. These were arrived at through extensive discussions between the committee members about what we, as mechanical engineers, can learn from the disaster and what we can contribute to society as a result. The four proposals are summarized as follows.

I To develop the approach to system integration of large scale systems.

II To review how the design basis is determined and how we can prepare for events beyond the scope of the design basis.

III To better inform the public about risks associated with new products.

IV To incorporate the lessons learned into our codes and standards, and foster engineers with the skills to tackle disaster related tasks, with the aim of passing these lessons on to future generations.

Keywords: Tohoku Region Pacific Coast Earthquake, Great East Japan Earthquake Disaster, Tsunami, System Integration, Design Basis, Beyond Design Basis, Risk Communication, Codes and Standards

1. Introduction

Through the activities of the working groups (WGs) we have compiled many data about damages caused by the Great East Japan Earthquake Disaster and have learnt many lessons as a result. The members of the WGs worked with great motivation, and the results of their research are summarized in the groups' reports and proposals, the details of which are given in the following chapters. When we read these reports and proposals, we find that the contents cover various areas of mechanical engineering and provide many well justified suggestions for the field's progression, particularly for preparing against earthquakes that may strike in the future. The worth of the present report stems directly from the value of the reports and proposals of each WG.

The scale of the Tohoku Region Pacific Coast Earthquake, tsunami and resulting disaster was so huge that it is impossible for the committee to consider all the areas within mechanical engineering. Therefore, the reports and proposals of the WGs describe only some aspects of mechanical engineering. The problem yet to be solved is what we, as engineers and researchers working in the field of mechanical engineering, can learn from this disaster and what messages we should send to the public. To this end, as the research of the WGs was concluding, we, the committee members, started considering these issues and through extensive discussions arrived at four proposals which are summarized below and presented in detail in the following sections.

I To develop the approach to system integration of large scale systems.

II To review how the design basis is determined and how we can prepare for events beyond the scope of the design basis.

III To better inform the public about risks associated with new products.

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IV To incorporate the lessons learned into our codes and standards, and foster engineers with the skills to tackle disaster related tasks, with the aim of passing these lessons on to the next generation.

2. Proposal I To develop the approach to system integration of large scale systems.

In large scale systems such as nuclear power plants, knowledge is integrated from various fields of science and technology. It has been proven that this integration can cause vulnerability to disasters such as earthquakes and tsunamis. In order to overcome these weaknesses, it is necessary to develop the approach to system integration of large scale systems through the training of specialists who overview the entire system, identify the weak points, and introduce the safety measures required. With this in mind, engineers and researchers who are engaged in mechanical engineering, especially the members of the JSME, should work towards efficient systematization in the field of "design science".

In most of the proposals presented by the WGs, it is highlighted that the weak points are a result of differing specialist knowledge between the experts involved. For example, mechanical engineers have not paid much attention to the threat of tsunamis in the past because they consider it to be an issue addressed in the field of civil engineering. However, the accident at the Fukushima nuclear power plant revealed many instances, such as securing a back-up power supply and ensuring that rooms can be made water tight, in which mechanical engineers could have prepared against the tsunami. It is areas such as these that are particularly affected by catastrophes. Such problems cannot be solved by specialists of any one field; we need to collect and systematize knowledge from many areas.

Generally, researchers at universities are interested in highly specialized and advanced fields. They are not so eager to incorporate perspectives from other fields. However, knowledge of system integration, in terms of design, manufacturing and operation, can be accumulated through experience in industry. For example, in the car and electronics industries of Japan, the understanding of such concepts is very high, allowing Japanese companies to compete as world leaders in their markets.

On the other hand, for industries such as nuclear power or aerospace/aeronautics, in which very large scale systems are developed, we cannot say that the understanding of system integration in Japan is sufficient. For mass-produced products like cars and electronic devices, we can accumulate knowledge through experience and repetitions of experiments. This is of course difficult for large scale systems, especially if the experiments are conducted on the same scale as the system. Recently, engineering simulations have shown the potential to overcome the difficulties inherent to such experiments. In order for engineering simulations to be really useful, an approach through which they can validly describe the behaviors of real world systems has to be established.

When the development of a large scale system begins, a team composed of specialists from many different fields is assembled. The project then progresses through the concurrent works of these specialists. In this case it could be useful to adopt the approach of program/project management to overview and manage the progress of the project. It is also essential to employ an external risk management team who oversee the project as well.

The approach to system integration can be structured in terms of the following levels:

- Individual level: research and systematization of system integration
- Team level: progression of the project
- Organizational level: policy making and being accountable for the public
- National level: implementing codes and standards and granting permissions for project go-ahead
- Global level: global standardization and business

The proposals made in the reports of the WGs concern aspects of all of these levels.

In the JSME, activities are often lead by academic researchers whose main interests lie in well recognized branches of science. As a result, there have been few motivated individuals that have challenged the approach to design science. The achievements of the majority of researchers can be put into practical use by incorporating them into codes and standards; however, most academic researchers are predominantly interested in writing and publishing papers in established journals, and lack interest in contributing in this way. Academic researchers should take more interest in the ways in which their research can directly benefit society.

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On the other hand, engineers working in industry gain experience of system integration in their daily work. Such experience may be useful for improving the approach to the system integration. Considering this, the JSME will encourage activities through which industry based engineers can combine and share their varying experiences with academic researchers and discuss how to improve, and ultimately systemize, the approach to system integration.

The committee would like to propose that the JSME promote such activities more actively. This proposal can also be adopted by companies, national laboratories and other engineering societies that are involved in the development of large scale systems.

3. Proposal II To review how the design basis is determined and how we can prepare for events beyond the scope of the design basis.

In the design of industrial products, the first step is to determine certain specifications. In terms of safety, the specifications are usually arrived at by estimating the maximum value of external loads that the product will be subjected to. It is difficult to estimate such forces for natural hazards such as earthquakes and tsunamis; thus, it is possible that the estimated maximum loads can be exceeded in extreme cases. Therefore, the following two steps need to be taken:

(1) Better estimating maximum loads and determining the design basis.

(2) Preparing for catastrophes beyond the scope of the design basis.

The lessons learned from the 3.11 disaster are that we, as mechanical engineers, should inform the public how the design basis (specifically the safety requirements) is determined and how we can prepare for accidents beyond the scope of the design basis, so that the above procedures are accepted by society.

These lessons should be applied to all large scale systems, not only nuclear power plants, but also chemical plants, railroad systems and so forth.

As for (1), the estimated values, which outline the design basis or safety requirements, are determined through assessment by a group of specialists. Assessments of this sort are made by considering the balance between the function, safety and cost of the product. The details are usually quite in depth and are therefore not accessible to the public. It is merely stated that the product is safe because the design basis was determined by specialists.

The specialists know that there is some chance, albeit very low, that the applied load exceeds the estimated value. Therefore, society should be made aware how the design basis was determined and what can be done to prepare for events not accounted for in the design basis. It is important that the design basis be accepted by society; to this end, the design basis should be determined through communication between the specialists and society, and set at a level recognized as an “acceptable risk”.

Engineers and researchers who are involved in the manufacture of industrial products should be clear that the products can never be absolutely safe. They should understand that acceptance of the product ultimately lies with society, based on the balance between risk and benefit.

As for (2), such approaches have been called “design in depth” in the field of nuclear engineering. In nuclear power plants, the design in depth with the following five levels has been recommended by the IAEA:

① Preventing the occurrence of accidents
② Preventing the expansion of accidents
③ Mitigating the effects of accidents
④ Countermeasures against severe accidents
⑤ Disaster prevention measures

In these five levels, ①～③ are known as design basis accidents (DBA) of which very careful regulation is carried out in Japan by the government. It was believed that events related to levels ④ and/or ⑤, which are known as beyond design basis accidents (BDBA), could never occur because the levels ①～③ were implemented extensively. In Japan this belief has been termed the “myth of absolute safety”. In the case of the Fukushima Daiichi nuclear power plant (1F), the measures of ①～③ failed to cope with the tsunami, and

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severe accidents followed by core melt-down occurred, resulting in the release of a large amount of radioactive materials into the environment, forcing the people living near the site to evacuate. The effects of the disaster were magnified because level ④ and ⑤ measures were not in place adequately.

The lesson learned from the accidents that occurred at 1F is that the extent to which measures against disasters are taken should be decided by society. We have to develop engineering strategies to prevent such damage. From this point on, the important considerations are to (a) determine the safety requirements for a given estimated risk, (b) present it to society, (c) concur with society on a critical damage level that cannot be exceeded, and (d) prepare for catastrophes that will exceed that level by implementing both hardware and software countermeasures.

4. Proposal III To better inform the public about risks associated with new products.

Engineers engaged in manufacturing products should predict the risk associated with and the benefit offered by a new product in the planning stage. They should make this information available to the public so that the product can be deemed acceptable. In short, they should learn the following two skills:

(1) Risk management: accurately predicting risk and preparing for it.
(2) Risk communication: informing society of risks in a way that is understandable, with the aim of gaining society's acceptance.

These skills are necessary not only for individual engineer/researcher but also for organizations such as universities, companies and governments.

The committee would like to propose that the JSME tackle this problem earnestly, provide society with the necessary information in a timely manner, and ultimately seek acceptance from society.

In modern society, people enjoy the benefits of highly advanced science and technology in the form of products used in their daily lives, but do not always understand the fundamental scientific and technological concepts behind them. As such concepts span a broader range and become more in-depth, it becomes increasingly difficult to understand them. As a result, people accept the fundamentals of science and technology without an understanding of them, which is left to the specialists, and place their interest only in the value and benefits of using the product.

As described in the previous section, when planning a new product, it is necessary to determine specifications related to the safety requirements. For example, we have to estimate the maximum external load that the product will be subjected to over its life. Specialists who design products know that situations are possible in which these critical values are exceed, although the probability is low. However, people use the products with total peace of mind* because they have confidence in the specialists claims of safety and security and are unaware that such a possibility exists. Therefore, if an accident does happen, it is difficult for the specialists to explain why or how the accident happened, and may lose credibility as a result.

The reason why nuclear power plant accidents are particularly problematic compared with incidents occurring in other more general machines and structures is the release of radioactive material into the environment. We have to recognize that the amount of radioactive material released in the 1F disaster was far over the amount allowed by society. On the other hand, it is very difficult for people to understand the explanations given by specialists concerning the health risks for humans caused by exposure to very low levels of radiation. Misunderstandings cause other social problems such as the spread of inaccurate information. It is hence the duty of the specialists to accurately and plainly inform the public so that people are aware what is true and what is not true. This will be of particular importance when decisions are made regarding the future operation of nuclear power plants and the best energy strategy for Japan.

Generally, when a new product is created as a result of newly developed technologies, the users desire it be secure and safe. Specialists try to meet these demands and reassure the users. However, the meanings of "secure" and "safe" are different. The former expresses peace of mind, which is subjective, while the latter is a concept

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that can be defined objectively and scientifically. It is needless to say that people desire a product to be “absolutely safe”; however, it is not necessarily the case that the specialists’ assurances of safety and security mean this demand has been met. The specialists should not assure safety in black and white terms. They should explain that every product is designed in terms of threshold values based on safety requirements, i.e., the design basis, and that there exists the possibility that accidents outside the scope of the design basis may occur. Furthermore, they should also explain that they prepare for such accidents, and that this makes the product “safe”.

Conventionally, engineers are content to communicate with each other within their own societies and circles, but lack motivation to communicate with the public. However, the 1F accident has made it clear that the benefits and risk associated with a new product should be available to the public in an accurate and easy to understand manner. In short, they should learn the following two skills:

(1) Risk management: accurately predicting the risk and preparing for it.

(2) Risk communication: informing society of risks in a way that is understandable, with the aim of gaining society’s acceptance.

For risk management, approaches have been developed in various fields of engineering. For example, probabilistic risk assessment (PRA) is applied in the field of nuclear engineering. Engineers should learn these approaches as part of their basic education.

As for risk communication, engineers have not yet tackled this problem earnestly because they are of the opinion that it is more a matter for experts such as social psychologists.

However, technology is now so extensively integrated into society that engineers need to be able to communicate effectively, i.e., develop the skills of engineering/science communication. Furthermore, organizations such as the JSME should send messages to the public that are well discussed and agreed upon, that is, through a voice representative of the entire organization. It is necessary for the JSME to systematize the process through which this is done.

*In Japanese, there is a word, “anshin”, that is difficult to translate into English. One interpretation is “peace of mind”, as used in this document. Furthermore, there is no word for “risk” in old Japanese; we have imported the word and its concept from English and write it as “risuku” in Japanese characters. However, even now people are not accustomed to dealing with and thinking in terms of risk. Most Japanese people are content to become “anshin” following the words of specialists or governments, instead of assessing the risk themselves.

5. Proposal IV To incorporate the lessons learned into our codes and standards, and foster engineers with the skills required to tackle disasters, and ultimately pass these lessons on to the next generation.

In order to apply the lessons learned from the Great East Japan Earthquake Disaster to mitigate the effects of earthquakes in the future, the committee would like to propose that the JSME promote the practice of incorporating the results of research into the codes and standards that the JSME contributes to setting.

The committee also would like to propose that the JSME foster specialists, especially young engineers, with the talent and skills necessary to tackle disasters and eventually hand these lessons down to the next generation.

Although there were many facilities and plants that sustained damage as a result of the Great East Japan Earthquake Disaster, it was found from the research of the WGs that some of them succeed in preventing a disaster because effective safety measures were taken in advance, based on the lessons learnt from previous disasters, or because they were constructed using the stronger earthquake-proof design outlined by the technical standards that were improved following the Hanshin-Awaji Earthquake. The proposals of the WGs have thus highlighted the importance of continually learning from disaster research and improving our codes, standards and manuals as a result.

Japanese engineers must be willing to examine and constitute codes and standards themselves instead of

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importing them from western countries. Most Japanese engineers are of the mindset that the codes and standards have been constituted by someone other than themselves, which is sufficient for them to follow the rules in Japan; codes and standards have actually been constituted by the Japanese government since the Meiji period. It is now the time for Japanese engineers to modernize their way of thinking. Furthermore, it is important that engineers working in the private sector, who understand the application of technology to the manufacturing process, lead the discussions with academic societies to arrive at new, up-to-date codes and standards. Conventionally engineers from industries have had difficulty to contribute to the setting of codes and standards because they may stand to benefit financially from certain outcomes. However, the committee recommends this no longer be the case and that academic societies should create an environment in which discerning engineers from the private sector can take part in discussing codes and standards without any prejudice.

On the other hand, it is necessary for academic researchers to apply the findings of their research to the setting of the codes and standard; this is an important way through which they can contribute to society. Most researchers are satisfied publishing papers in well established journals. They are not interested in improving codes and standards because it is laborious and they don't recognize it is as an important academic activity. Academic societies need to actively dissuade researchers from this point of view. Researchers should be aware that the results of research and technological development can contribute to society through incorporation into codes and standards. At present the motivation for such work is not high because doing so is not recognized in terms of career progression, compared with publishing papers. Therefore, it is necessary to create an environment in which academic society rewards such contributions.

The committee believes it is of the utmost importance to train and foster engineers, especially young engineers, to have the skills necessary to prevent or mitigate the effects of disasters that may happen in the future.

Torahiko Terada, a famous physicist in the Meiji period, pointed out in his book, "Tsunami and Human Beings", that the reason why people who experienced multiple tsunamis in their lifetime could not avert disaster lies in the fact that the intervals with which natural disasters like earthquakes and tsunamis occur are so long in comparison to the average human life, they didn't remember their prior experience of the disaster. He went on to say that it is important for people to try to remember such experiences in order to help avoid disasters in the future. While the frequency of earthquakes that damage machines and machine systems is once every several years or even once every few decades, the frequency of events like the Great East Japan Earthquake Disaster is much lower. It is said that earthquakes of this magnitude occur once every thousand years. Therefore, it is important to keep current the knowledge and lessons learnt from past events. To this end we must foster engineers, especially young engineers, to promote research for improving safety measures by continuously utilizing this knowledge, and ultimately hand it down to future generations. It is not enough to simply prepare manuals. Actual training is important to increase peoples' ability to cope with disasters.

The committee would like to propose that the JSME coordinate an effort from the academic, governmental and industrial sectors, and organize the results of the research obtained by the WGs into codes and standards that will help prevent and mitigate the effects of disasters to come. The committee also proposes that the JSME encourage the fostering and training of young engineers so that they gain the skills to tackle disasters in the future.

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