Project Study for Seismic Engineering
for
Chemical and Petrochemical Plant

Final Report

November 2012

Japan International Cooperation Agency (JICA)

Japan Consulting Institute (JCI)
Chiyoda Corporation
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Contents

Abbreviation Table

General	
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASEAN	Association of South - East Asian Nations
ASME	American Society of Mechanical Engineers
ANSI	American National Standards Institute
BCP	Business Continuous Plan
BP	British Petroleum
ERP	Emergency Response Plan
GDP	Gross Domestic Product
IBC	International Building Code
IHI	Ishikawajima Harima Heavy Industries Co., Ltd.
JAIC	Japan Asia Investment Co., Ltd.
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standard
JEA	Japan Electric Association
JGA	Japan Gas Association
JGC	JGC Corporation
JPI	Japan Petroleum Institute
KHK	Koatsu-gasu Hoan Kyokai
NEHRP	National Earthquake Hazards Reduction Program
SINOPEC	China Petrochemical Corporation
SNI	Indonesian National Standard
SNIP	System of Normative Documents in Construction, Basic Principles（Russia）
TEC	Toyo Engineering Corporation
TEMA	Tubular Exchanger Manufacturers Association, Inc.
TKP	Tecnip-Coflexip
UBC	Uniform Building Code
UNDP	United Nations Development Programme
USGS	U.S. Geographical Survey

Technology	
BEDD	**Basic Engineering Design Data**
BR	**Butadiene Rubber**
bpd & b/d	**Barrel per day**
CCR	**Continuous Catalyst Regeneration & Reforming Unit**
CDU	**Crude Distillation Unit**
DCU	**Delayed Coking Unit**
DEG	**DI Ethylene Glycol**
DOP	**Dioctyl phthalate**
EB	**Ethylbenzene**
EDC	**Ethylenedichloride**
FCC	**Fluid Catalytic Cracker**
FPG	**Formosa Plastics Group, Taiwan**
HDPE	**High Density Polyethylene**
HDS	**Hydro Desulphurization Unit**
LCOHTR	**LCO Hydrotreater**
LLDPE	**Linear Low-Density Polyethylene**
MEG	**MONO Ethylene Glycol**
MMI	**Modified Mercalli Intensity**
MSK	**Medvedev-Sponheuer-Karnik scale**
NHT	**Naphtha Hydrotreating Unit**
OX	**Ortho-xylene**
PET	**Polyethylene Terephthalate**
PFY	**Polyester Filament Yarn**
PGA	**Peak Ground Acceleration**
POY	**Partially Oriented Yarn**
PP	**Polypropylene**
PS	**Polystyren**
PSF	**Polyester Staple Fiber**
PTA	**Purified Terephthalic Acid**
PVC	**Polyvinyl Chloride**
PX	**Para-xylene**
RFCC	**Resid Fluid Catalyst Cracking**
SD	**Scientific Design**
SM	**Stylene Monomer**
SMS	**Short Message System**

STG	**Steam Turbine Generator**
TPA	**Terephthalic Acid**
UCC	**Union Carbide Corporation**
UPS	**Uninterruptible Power System**
VCM	**Vinyl Chloride Monomer**
VDU	**Vacuum Distillation Unit**
Vietnam	
DMC	**Dike Management Center**
DSTE	**Department of Science, Technology and Environment**
IBST	**Institute of Building Science & Technology**
Lilama	**Vietnam machinery Installation Corporation**
MOC	**Ministry of Construction**
MONRE	**Ministry of Natural Resources and Environment**
PDC	**Petro Vietnam Processing and Distribution Company**
PPC	**Pha Lai Thermal Electric Joint Stock Company**
PVGAS	**Petrovietnam Gas Company**
PVN	**Petrovietnam**
VAST	**Vietnam Academy of Science and Technology**
Indonesia	
AMI	**PT Amoco-Mitusi PTA Indonesia**
ASC	**PT Asahimas Chemical**
B&B	**Bakri & Brothers**
BGC	**Petrochina Betara Gas Complex**
BMKG	**Metrological Climatological and Geophysical Agency**
BNPB	**National Agency for Disaster Management**
BPPT	**Bandan Pengkajian dan Penerapan Teknologi, The Agency for the Assessment and Application of Technology**
CAP	**PT Chandra Asri Petrochemical Tbk**
IKPT	**PT. Inti Karya Persada Tehnik**
MCCI	**PT. Mitsubishi Chemical Indonesia**
NIODC	**National Iranian Oil Refinery & Distribution Co.**
PUSKIM	**Research Institute for Human Settlements, Agency for Research and Development, Ministry of Public Works**
SMI	**PT Styrindo Mono Indonesia**
SIM	**PT Satomo Indovyl Monomer**
SAU	**Sulfindo Adiusaha**

SEJ	**PT Showa Esterindo Indonesia**
TPPI	**PT Trance-Pacific Petrochemical Indotama**
Philippines	
ASEP	**Association of Structural Engineers, Philippines**
BPI	**The Bank of The Philippine Islands**
DPWH	**Department of Public Works and Highway**
FIC	**First In Color Inc.**
JGSH	**JG Summit Holdings**
JGSP	**JG Summit Petrochemical Corporation**
NSCP	**National Structural Code of Philippines**
OCD	**Office of Civil Defense, Department of National Defense**
PHIVOLCS	**Philippine Institute of Volcanology and seismology**
PNOC	**Philippine National Oil Company**
PPI	**Philippine Polypropylene Inc.**
PRII	**Philippine Resin Industries Inc.**
PSPC	**Philipnas Shell Petroleum Corporation**
SMC	**San Miguel Corporation**

Summary

1 Background and purpose of the study

Japan is one of the prominent countries that are prone to be caused and damaged by earthquakes frequently and therefore the seismic design for industrial plant facilities and petroleum refining and petrochemical plants (regarded as “plants” henceforth) is indispensable. The plant manufacturers and engineering companies in Japan have made an effort to improve design procedures for earthquake-resistance plants and have accumulated the knowledge on technologies. On March 11, 2011 many petroleum refineries and petrochemical plants in Eastern Japan suffered serious damages by the Great East Japan Earthquake and Tsunami. Taking this disaster into consideration, the necessity of improving the design method for earthquake-resistance plants has been freshly recognized, and the seismic assesment and reinforcements, etc. for the existing plants in each district have been also carried forward. By making the best use of these experiences and technologies in Japan, the improved seismic technologies will be expected to be transferred to overseas plants suitably in the future.

Based on the above background, JICA study has been carried out in accordance with the following purposes.

a) To investigate whether Japanese seismic technologies are able to be introduced into the developing countries appropriately.

b) To investigate whether these transferred seismic technologies are able to contribute to improve the seismic safety plant facilities and progress the level of the seismic technologies in the developing countries.

And from study results, the proposal for the possibility of future technical cooperation in the seismic technologies and the disaster prevention technologies to the target countries and the reference country is made.

2 Outline of study results

Three times surveys for the target countries of Vietnam and Indonesia, and reference country of Philippines, have been carried out. Regarding seismic law systems, seismic technologies including seismic design codes and disaster prevention technologies for petroleum refining and petrochemical plants, the present conditions and needs in their countries have been grasped, and in addition the future direction of the technical cooperation has been studied.

2.1 Plant seismic technology and disaster prevention plan in Indonesia

It is confirmed that the observation system (warning system etc.) and the disaster prevention organization have been well provided as Indonesia has experienced big earthquakes in the past. With regard to the plant seismic design code in Indonesia, its own seismic design code for building is applied to the structures such as pipe racks and so forth, which are similar to building structures. On the other hand, the applicable parts of US seismic design code (UBC: Uniform Building Code) is also applied to any plant facilities besides the above structures at present. Since the severe earthquake and tsunami disaster in Aceh, the disaster prevention organization/system and seismic technology have been reinforced in Indonesia.

Although infrastructures such as buildings, highways, and bridges can be built based on the seismic design by itself, some of seismic designs for plants are still forced to depend on overseas engineering companies. There are many large-sized petroleum refinery, natural-gas-liquefaction, and petrochemical plants in Indonesia. However, most of them have been designed and constructed by overseas engineering companies or domestic major engineering companies such as Rekayasa. These domestic companies have collaborated with overseas plant engineering companies, such as Japanese engineering companies to improve seismic technology.

For earthquake and tsunami observation system in Indonesia, BMKG (Metrological Climatological and Geophysical Agency) which corresponds to the Meteorological Agency in Japan has been promoting an active interchange of technology among agencies including Japan to improve its technology level. BMKG is also responsible for preparing " Earthquake Hazard Map" in order to make an amendment of seismic design code. As for disaster prevention plan, BNPB (National Agency for Disaster Management) is making the best effort to improve education system for disaster prevention.

Taking up suggestion by the study team, they get into an opinion that Indonesia has to have its own unified seismic design code for plants in Indonesia. PUSKIM started preparation to set up a new committee to establish the new seismic design code for plants, cooperating with other ministries and government offices. In the future Indonesian needs is further improvement of the seismic design code for plants and personnel training for seismic design engineers.

2.2 Plant Seismic technology and disaster prevention plan in Vietnam

Since Vietnam has rarely experienced big earthquake and tsunami disasters until now, the government offices and enterprises seldom seem to be conscious of earthquake disaster prevention, and to be interested in seismic technology. However the occurrence of a strong earthquake (Magnitude 5.7~7.0) in Northern Vietnam and a tsunami in the Manila Trench has been already predicted. Therefore the following items might be needed in Vietnam in the future.

a) Provision of the code and guidelines for plant seismic design and earthquake disaster prevention
b) Personnel training for seismic design engineers in its own country
c) Establishment of organization and system for earthquake disaster prevention

Since overseas plant engineering companies have mostly made a seismic design for large-sized plants in Vietnam, domestic seismic engineers have not been educated in the country yet. Therefore, it is recognized that the number of seismic engineers is substantially insufficient and personnel training for domestic seismic design engineers might be needed. It is predicted that domestic seismic engineers will have more opportunities to make a seismic design for plants by themselves corresponding the higher demand of energy in the future. Accordingly, it is suggested that campaign enlightenment of necessity for plant seismic technology should be given priority firstly in order to be recognized that seismic technology and personnel training for seismic design engineers is essentially needed in Vietnam in the future.

At present the general architect seismic design code, which was amended in 2006 based on the Eurocode and was published, is not applicable to plants as a suitable seismic code. Therefore the improvement of seismic design code for plants will be needed in future.

2.3 Plant Seismic technology and disaster prevention plan in Philippines

Since Philippines has experienced a lot of damages, such as earthquakes, volcanic eruptions, typhoons, and floods until now, organization and system for natural disaster prevention have been improved with the interchange of technology among overseas countries including Japan. Since overseas plant engineering companies have mostly made a seismic design and constructed large-sized plants in Philippines in a similar way, domestic seismic engineers have less opportunities to be brought up on the job training and as a result domestic seismic engineers have not been educated in the country yet.

Although there are a few of branched domestic engineering companies which are making a seismic design as an engineering center of overseas companies, most of design and construction works have been practically conducted by overseas engineering companies. In result, it seems that any domestic engineering companies do not make a seismic design for domestic plants in Philippines.

As the seismic design code (NSCP2010) for building structures is provided based on UBC and some parts of UBC is applicable to seismic design for plants, NSCP2010 is applicable to seismic design for any facilities other than piping.

In these circumstances, ASEP (Association of Structural Engineers, Philippines) is deeply interested in Japanese law system specialized in seismic design for plants. It is said that ASEP might have an intention to study introduction of Japanese law system to its own country in cooperation with DPWH (Department of Public Works and Highway).

2.4 Dissemination activity by seminars in the three countries

At each seminar held in three countries, there were about 70 participants and a discussion about each subject was made earnestly. Since at the first seminars held in Indonesia and Vietnam, the subjects were selected from wide and general topics as shown below so that participants with various kinds of background may understand them;

- Outline of seismic technology in Japan
- Law system for plant seismic design in Japan
- Plant disaster prevention system in Japan

At the second seminars held in Indonesia, Vietnam, and Philippines (the first seminar in Philippines), the subjects were selected from more deep and specialized topics. The following themes were prepared taking requests of participants of the 1st seminar into consideration;

- Practical seismic assesment evaluation method and result
- Earthquake risk management in consideration of Life Cycle Cost
- Comparison of the example results designed for plants in accordance with the national seismic design codes in Japan, Indonesia, Vietnam, and Philippines
- Practical disaster prevention system of the oil refinery in Japan, etc.

As a result, it was recognized through seminars that participants were substantially interested in the seismic technologies for plants in Japan.

According to the questionnaire at seminars (see Appendix VIII), there were lots of the requests for holding seminars by JICA continuously. There were also many requests that the measures for personnel training of seismic engineers and improvement of seismic design codes should be studied in future. Most of the participants took part in seminars and studied plant seismic technology and disaster prevention technology for the first time. The necessity for plant seismic countermeasures had been freshly recognized by the participants.

2.5 Plant observational results in Indonesia, Vietnam, and Philippines

The simplified seismic assesment evaluation results of the plants observed in Indonesia, Vietnam, and Philippines have been described in Chapter 3, Chapter 4, and Chapter 5 respectively.

Based on each result, the applied seismic design code, the contractor name, start-up time, and simplified assesment evaluation result are shown in Table -1. The plants observed at this study, such as petroleum refining and petrochemical plants and LPG plant were large-scale, and were designed and constructed by overseas engineering companies. As a result, there was not any particular problem. However, the No. 1 plant of Pha Lai coal fired thermal power plant in Vietnam started in 1983 and it was designed and constructed by the former Soviet Union, and a seismic design was also made by the former Soviet Union norm. As observational results, the defect was found in earthquake prevention measures for plant piping and ceiling, and the aged deterioration of plant was also found out.

In Philippines, there are both of old and new plants in the Bataan Refinery of Petron. At the old plant, replacement is now in progress. The plant was designed and constructed by the old owner Esso and it is conjectured that the applied code was UBC in those days (different from the present UBC). It was also found out that the old plant had maintenance problems such as steam leakage and insulation broken off.

Table-1 Simplified seismic assesment evaluation results for plants observed at this study

The Results of Plants Seismic Survey in Vietnam、Indonesia and Philippines						
	Vietnam			Indonesia		Philippines
Plants observed	Petrovietnam Dung Quat Refinery	Power plants (Old&New)	PVGas LPG Receiving Terminal	Jambi Betara Gas Plant	Mitsubishi Chemical	Petron Bataan Refinery
Applied Code	UBC1997	Russia & Japan,Korea	TCXDVN375	UBC1997	SNI	UBC/Esso /Mobil
Contractors	JGC	Sumitomo Corp.	POSCO Engineering	Chiyoda	JGC	n.a.
Year started	2009	1983/2000		2005	1991	1973
Observational Results	Good	Old: To be further studied New:Good	Under construction	Good	Good	Old: To be further studied New:Good

(Data source: Drawn up by Study team)

2.6 Comparison of disaster prevention organization and relevant laws and so forth in Indonesia, Vietnam, and Philippines

The disaster prevention plans in three countries, Indonesia, Vietnam, and Philippines are summarized in Table -2. The example of Japan is also put together and shown in this table.

Each basic law is provided and each corresponding organization is clarified in three countries respectively.

In Vietnam, the law of the Ministry of Construction for an earthquake is also prescribed. When Northern Vietnam had a severe earthquake in 2000, the Ministry of Construction coped with the disaster quickly in accordance with this law.

Table- 2 Comparison of disaster prevention in three countries

Comparison of Disaster Prevention Plan in Viet Nam, Indonesia and Philippines

	Viet Nam	Indonesia	Philippines	Japan
a) Basic Law	Law on Water Resource Law on Dyke Ordinance on Flood and Storm Control	Law No. 24 Year 2007 on Disaster Management	Disaster Risk Reduction and Management Act 2010	Disaster Counter-measures Basic Act
b) Responsible Government Organization	Prime Minister (Ministry of Agriculture and Rural Development, The Central Committee for Flood and Storm Control (Disaster Management Dept./Dike Management for Tsunami)	National Agency for Disaster Management	Department of National Defense	Cabinet Office
c) Covering Disaster	Natural Disaster	Natural & Accidental Disasters	Natural Disaster & Terrorism	Natural & Accidental Disasters

(Data source: Drawn up by study team)

The plant disaster plan is included in Table -2. Especially in Indonesia and Philippines, the basic law and the corresponding organization have been well established and an earthquake disaster is definitely included in Covering Disaster.

On the other hand, in Vietnam, although there is a relevant law, the law has been provided mainly based on flood prevention. And the measures for earthquake prevention have not been sufficiently taken in practice though the law has a few of description about an earthquake.

Therefore, it is necessary to improve the earthquake- resistance measures further in Vietnam in the future.

2.7 Common problems in Indonesia, Vietnam, and Philippines

As results of investigating the information acquired from deliberations with main counterparts at this study, the held seminars, the observed plants, and domestic study in Japan, the following items were recognized as common problems.

(1) The number of seismic design engineers, especially for petroleum refining and petrochemical plants is insufficient in all three countries. On the other hand, the seismologist, the observatory, and so forth are substantially supplied in cooperation with overseas countries, including Japan.

(2) It has been found that there is no norm about the seismic design for piping in the seismic design codes of three countries. Since piping is apt to suffer a heavy damage from an earthquake, it is suggested that Japanese seismic design code for piping should be introduced and applied to three countries without delay.

(3) The large-sized plants such as Petrochina and Mitsubishi Chemical in Indonesia, Petrovietnam in Vietnam, and Petron in Philippines were designed and constructed by the Japanese and the South Korean plant engineering companies and any defect for seismic measures was not found out.

There must be so many small-sized chemical and petrochemical plants in three countries. Such small and medium plants are not always constructed by engineering companies in overseas developed countries, so that it is assumed that there are insufficiencies of seismic measures for the plants.

(4) Economic development is remarkable in three countries and the stable supply of energy is an important issue for three countries. Since Vietnam and Philippines do not necessarily have sufficient resources in their own countries, both countries have to import LNG as a power-generation fuel similarly to Japan. Pipeline for supplying own country with LNG is also planned in Indonesia. Therefore, it is predicted that the demand of LNG receiving terminals will be increased and the suitable seismic design code and design manuals for storage tanks should be provided in the future.

2.8 Potential needs of seismic engineering in Indonesia, Vietnam, and Philippines

As results of investigating the information acquired from deliberations with main counterparts at this study, the held seminars, the observed plants, and domestic study in Japan, Table-3 is summarized in terms of potential needs of plant seismic technology in three countries.

From this table, the following items were recognized as potential need of plant seismic technology in three countries.

(1) Table-3 shows that Vietnam most needs the future provision of seismic engineering and disaster prevention technology. Since Vietnam has experienced neither a severe earthquake nor tsunami until now, improvement of seismic technology has not been well developed.

(2) On the other hand, due to earthquakes frequently caused in Indonesia, Indonesia is establishing the correspondences and measures against earthquakes nationally. Moreover, plant engineering companies such as Rekayasa grow within the country and they have acquired seismic technology in cooperation with foreign plant engineering companies. Some of them are able to manage to design and construct by themselves.

Table-3 Potential Needs of plant seismic technology in three countries

Potential Needs of Plants Seismic Technology

	Indonesia	Viet Nam	Philippines
Cooperation for Bring up of Seismic Engineers Resources	○ (Middle)	◎ (Large)	◎ (Large)
Cooperation for Enhancement of Seismic Design Capability	○	◎	◎
Cooperation for Evaluation & Capability of Seismic Diagnosis	○	◎	◎
Cooperation on Disaster Prevention	○	◎	○
Other Seismic Tech. Cooperation (Power Plant /LNG Storage)	◎	◎	◎

(Data Source: drawn up by Study team)

3. Recommendations for plant earthquake disaster prevention in developing countries

JICA study has been carried out in the purpose to investigate whether Japanese seismic technologies are able to be introduced into the developing countries appropriately, and to investigate whether these transferred seismic technologies are able to contribute to improve the seismic safety plant facilities further and progress the level of the seismic technologies in the developing countries.

According to the results of the study, the preparation of the seismic design codes and standards for plant facilities and the seismic assessment of the existing plant facilities could be assumed as the recommendations of seismic disaster prevention. In addition, establishment of codes and standards in Japan is examined by committee in which experts in private companies are appointed, and it is thought that making of a structure also contributes to the development of institution in developing countries.

For plant earthquake disaster prevention in the target countries, the concrete technical cooperation items are selected as follows;

a) Introduction of seismic design codes and standards for plants

b) Seismic assessment of existing plants

Judging from the needs of concerned personnel in the target countries and the possibility of technical cooperation from Japan, it is considered that these proposals are able to contribute to improve the seismic safety of plant facilities and to progress the level of seismic technologies in the target countries. If plural technical cooperation items are required at the same time, it is preferable that the priority should be given to the technical cooperation item having higher possibility of introducing Japanese seismic design methods.

3.1 Analysis of target countries and possibility of technical cooperation

3.1.1 Indonesia

Indonesia is affluent in energy resources and it holds a number of plant facilities. In the future, the construction of modification or expansion for these plant facilities can be expected. Since the seismic design methods of non-building structures such as plant facilities in Indonesia code has not been included into the scope of the present code. PUSKIM is currently preparing for a new committee to develop plant seismic design code, understanding sufficiently the necessity for seismic design code for plants. In Indonesia, since some of the domestic engineering companies have already made a seismic design for plants using UBC by themselves, Indonesia has the highest technical level of seismic design among three countries. For development of human resources including seismic engineer training, conduct seminars, workshops, the cooperation is supposed to be done in the process of development of seismic design codes and standards for plants and seismic assessment for the existing plants.

3.1.2 Vietnam

Although "375 TCXDNV:2006 ‘Design of Structures for Earthquake Resistance’" has been provided based on "Eurocode (1998-1 BS-EN: 2004)", the code has not been spread widely yet.

"TCXDNV375: 2006" is planned for applying to plant facilities under design at present, but the application seems to be difficult since Eurocode itself is not intended to be applied to plant equipments(for example; towers, vessels, spherical tanks, and so on) except storage tanks.

IBST and MOC (Ministry of Construction), which are the supervisory authority to provide seismic design codes, are showing positive attitude to prescribe a seismic design code for plants, and there seems to be very high possibility to adopt Japanese seismic design code for plants as Vietnamese code. In addition, the construction of plants may be expected in the future based on the development of resources on coast and petroleum refining and petrochemical industries.

3.1.3 Philippines

NSCP (National Structural Code of Philippines) 6th Edition-2010 has been prescribed in accordance with UBC, and plant facilities are also recognized as target structures (non-building structure) in the code. ASEP which is the association in charge of the provision of seismic design code for buildings in Philippines, and they are considering the introduction of seismic design methods based on Japanese seismic design codes and standards of plant facilities. ASEP is an organization for structural engineers, and it may not be predicted whether it is possible for ASEP to promote a new seismic design code by working on government agencies.

It is suggested to find out if Philippines are going to introduce seismic design methods based on Japanese codes and standards, and then cooperation is to be implemented for the development of plant seismic codes and standards as well as the seismic assessment on the existing plants.

3.2 Contents of the expected cooperation

As a result of the study for the three countries, the following cooperation is assumed.

1) Development of seismic design codes and standards for plants

Three target countries have seismic design codes for building structures based on Eurocode and UBC. It is said as a result, seismic design codes for general building structures are prepared, but seismic design codes for plant facilities are not in hand. In Philippines, plant structures are included in the intended facilities of the present seismic codes, but there is possibility to introduce Japanese seismic design codes for plant facilities including piping. The organizations and institutions related to design codes in the target counties acknowledge the necessity of development of plant seismic codes. So, technical cooperation for development of plant seismic design codes and standards is required.

When the government develops the plant seismic design codes, support by overseas experts is necessary, such as support for development of the codes, for formulation of education scheme to engineers in the private companies, and for compliance program after codes developed. There is a certain area where Japan is able to contribute.

In Japan, committee is established including members from experts of the private companies, when seismic design codes and standards are developed. Introduction of the committee system is also useful and available in those countries.

2) Seismic assessment for the existing plants

After the development of plant seismic design codes and standards, seismic assessment by engineers in the country with support of Japanese experts is required to check seismic performances of the plants. By execution of seismic assessment, it will be available to know the actual situation of the plants for the seismic performances. And in the next step, it is expected to implement seismic upgrading project, such as introduction of concrete seismic equipments, renovation to earthquake-resistant structure, and others.

3.3 Cooperation of provision of seismic design code and standards for plants

In Indonesia, Vietnam, and Philippines, some of the agencies which are in charge of providing seismic design codes for buildings, are showing intension to prescribe new seismic design codes for plants. In accordance with their needs, it is recommended to give technical support to introduce Japanese seismic design code into the target countries.

3.3.1 Study and provision of codes and standards to be introduced

There are a plenty of seismic design codes and standards in Japan, important ones are the High Pressure Gas Safety Law, Fire Service Act and Building Standard Act. Support for drafting of seismic design code for plants in the target countries will be necessary based on Japanese “Seismic Design Code of the High Pressure Gas Facilities” of METI (Ministry of Economy, Trade and Industry) and “Seismic design procedure of flat-bottomed tanks and related things” of Fire Service Act. For building structures, specialists in Japan will adjust making use of the existing seismic design code and standards for building structures in the target countries. (The specialists of seismic motions, towers, tanks, piping, structure, and foundations, etc. will perform works including domestic and overseas matters.)

In Japan, when seismic design codes and standards are developed, the government establishes a committee consists of experts and specialists. The members of academy and of private companies are included in the committee, and constitution and revision of rules and codes are made based on discussion of the committee. The committee system is considered to introduce those countries to make sustainable effect to the countries.

It is preferable to conduct cooperation to the target countries for human resource development on governmental officials and engineers in parallel as well as technical transfer, such as workshop and OJT (on the job training) in Japan, at the time of introduction of seismic codes and standards.

Instruction and support of the study work will be required for approval and license for using the codes and standards (draft), after introduction of codes and standards. (The specialists of seismic motions, towers, tanks, piping, structure, and foundations, etc. will perform works including domestic and overseas matters.)

Through the cooperation, increase of engineering business opportunities, and enhancement of chance of introducing plant facilities such as vessels, tanks and piping to developing countries will be expected.

3.3.2 County-by country support

(1) Indonesia

PUSKIM is currently preparing for a new committee to develop plant seismic design code. It is necessary to find out whether Indonesia may introduce Japanese seismic design codes and standards for plants. If not, it may be difficult to introduce Japanese seismic technologies and equipments practically.

(2) Vietnam

Taking it into consideration that IBST and MOC (Ministry of Construction) is showing a positive attitude to provide seismic design code for plants, and seismic design code for buildings has not been widely used, it may be considered to codify seismic design code of plants as a whole including seismic design procedure for buildings.

(3) Philippines

In Philippines, plant structures are included in the present seismic design codes and standards. Putting Japanese codes on the present Philippines code is technically available. But it is necessary to find out how Philippines consider about introduction of Japanese seismic design method based on Japanese codes. Educational activities will be necessary not only to practical business level, but to policy level. If required, the basic course seminars will be supplied by judging the technical level of the participants.

3.4 Cooperation about enforcement of seismic assessment for existing plants

Concrete plant is not identified in this study, but, in order to verify seismic performance of existing plants, it is necessary for engineers in Japan and the target countries to select existing plants and perform seismic assessment. It is required that seismic design codes and standards have been established before implementing the projects. It is adequate that the seismic assessment will be carried out by using Japanese seismic design codes and standards, because Japanese ones are the most advanced for earthquake damage prevention. In the enforcement of seismic assessment, conducting technical transfer such as OJT in Japan and engineer education for personnel training in parallel will be preferable.

3.4.1 Correspondence measures for each country

(1) Indonesia

There are many existing LNG production plants and drying up in gas field may cause the conversion of existing production plants into receiving facilities. Since this conversion can be studied as a target of seismic assessment, it is expected that the demand for seismic assessment of existing plants will be increased in future. In addition, there are a lot of chemical plants which require seismic assessment, too.

(2) Vietnam

The construction of many energy-related plants may be expected in the future and chemical plants and oil tank terminals can be appropriate as targets.

(3) Philippines

Many existing chemical plants and oil tank terminals are expected to be targets for seismic assessment. There are many old and new plants in Bataan refinery of Petron and they seem to be suitable as targets of seismic assessment.

3.5 Characteristic and advantage of Japanese seismic design codes

Characteristic and advantage of Japanese seismic design codes for plant facilities are listed below.

(1) Importance classification for plant facilities

In IBC and Eurocode, only one value of coefficient of importance factor is given to whole plant facilities. However importance classification based on Japanese seismic design codes is applied to each facility which has severe risk in plant facilities and each importance factor is given to each facility depending on its own risk.

In Japanese seismic design code, the importance factors are decided by the distance between the facility keeping safety and every plant facilities and by the quantity of dangerous materials possession, and the facilities which have high risk against vicinity increase safety around the plant site by being designed to withstand increased seismic design load.

(2) Two levels design method

In IBC and Eurocode, a design spectrum of the earthquake ground motions, in which design target is to keep away from collapse, is given. And the design seismic load is calculated by the spectrum, and these methods are called one step design method using the allowable stress design. On the other hand, two levels design methods of seismic design codes are adopted in Japan. Using two levels design methods, the facilities are designed in order to keep the following seismic performance.

1) Concerning the earthquake with higher probability of occurrence during in-service period of facilities, facilities are designed on the basis of elastic design method so that facilities may remain in a possible state of reuse after the earthquake.
2) Concerning the largest earthquake, the facilities are designed on the basis of elasto-plastic design method in order to absorb earthquake energy by plastic deformation, and a leak of the content fluid is prevented, although residual deformation is permitted, and the safety of the plant is ensured.

(3) Presentation of the seismic design method for every plant facilities

For example, spherical tanks, towers and vertical/horizontal tanks, etc. of concrete seismic design method is not shown in IBC and Eurocode, but in the Japanese seismic design codes and standards, seismic design method in consideration of the vibration characteristics of each facility is shown in the seismic design standard.

(4) Examination of necessity of seismic design for piping

Piping is one of the most important facilities at plants especially chemical and petrochemical plants. In IBC and Eurocode and the related standard, the seismic design of piping is not prescribed in detail. In Japan, the seismic design method of piping was newly standardized based on the experience of suffering from the damage of the piping by the Great Hanshin and Awaji Earthquake.

(5) Influence evaluation of liquefaction of ground

Japanese seismic design code and standard have a characteristic to be able to design considering influence of the liquefaction of the ground such as ground subsidence, a lateral movement of the ground and the sinking of facilities. This method is applicable to seismic evaluation of seismic assessment for existing facilities. This is a characteristic of Japanese seismic design standard not to be included in standards of the United States (IBC) and the Europe (Eurocode), too.

(6) Applicability to seismic design of LNG facilities

Japanese seismic design code studied at this time is applicable to LNG receiving terminals. The demand of LNG receiving terminals is expected to increase in the future.

3.6 Expected benefits and effectiveness

Regarding to cooperation to developing countries on seismic design codes and seismic technologies, although there are seismic design code for general buildings in the target countries, seismic design code for plants can be provided based on Japanese seismic design code by technical cooperation. Concerning design and construction of plants, it is supposed that Japanese seismic design technology is also used in common. And its practical activities are seismic assessment.

(1) Benefit in the target countries

1) Reinforcement of the preparation for earthquake disasters of the country concerned is performed by introducing Japanese seismic design code with superiority including importance classification and two levels design method, etc.

2) Decision making of introduction and acquirement of Japansese seismic technology leads to technological assistance and technology interchange, so that the level of earthquake proofing knowledge and the level of the seismic technology in the target countries are raised as a whole and development of codes and related organization, personnel training are also promoted.

3) At the private company level, a lot of business orders and jobs from Japan and overseas countries may be expected by acquiring Japanese technique and holding the ability to carry out jobs of Japanese company.

4) By getting information of seismic safety on plant facilities through seismic assessment, it is available to strengthen seismic security and seismic disaster prevention as a whole country.

(2) Benefit in Japan

1) In a project of construction and the remodeling of plants in the target countries, Japanese engineering companies can increase the possibility to join projects from an early stage setting design ground motion and seismic design method. And it will be possible to enhance business opportunities on the projects by demonstrating higher technology level in practice.

2) By bringing up the domestic engineers who can understand Japanese seismic codes and seismic technologies, human resources can be secured as a business base of Japanese company and business cooperation relation can be established.

3) By introducing Japanese technology, local subsidiaries of Japanese engineering companies and apparatus makers increase the possibility to join various local projects and as a result international competitiveness can be maintained.

Chapter 1 Introduction

1.1 Background and purpose of the study

In Japan as one of countries with most frequent earthquakes in the world, seismic design is indispensable for industrial facilities and plants. Plant manufactures and engineering companies in Japan are concerned to design earthquake-proof plant facilities and have been building up its know-how and technologies. Putting these experiences and accumulated technologies in Japan to overseas, seismic assessment and other appropriate seismic technologies are expected to be introduced to countries where risks of seismic hazard may be estimated.

Other than Japan, there are many countries with frequent earthquakes in the world, namely, China, Indonesia, Iran, Afghanistan, Turkey, Mexico and so on. Vietnam, to whom Japan is one of main donation country for economic assistance, is expected to construct many petrochemical and chemical plants, since petroleum and natural gas development will proceed in future. There was no report of the earthquake in the past, but UNDP report “HAZARD FACT SHEET: The possibility of earthquakes and tsunamis in Vietnam, 24 March 2011 “ says that Vietnam has possibility to have earthquakes of Magnitude 5.7 – 7 class in future. In those countries, it is supposed that seismic design is not implemented yet, although it is ordinary conducted in advanced level in Japan. And once a large earthquake hits the country, severe disasters may occur such as a blaze case in Cosmo Oil Co., Ltd. in the Great East Japan Earthquake.

The purpose of the study is to examine the possibility to introduce appropriate seismic technologies to those countries, applying Japanese plant engineering technologies and experiences. And it is expected to contribute to enforce industrial infrastructure in the countries with frequent earthquakes.

Main target field in the study is chemical and petrochemical plants, including refinery plants, considering to influences and sufferings by the earthquake. The industry is considered to cause a) affection to securement of commodities essential to life (gasoline, kerosene, and so on), b) high risk on fire blaze, explosion, noxious fume, and so on, to surrounding area, c) influences to marine pollution as many of chemical and petrochemical plants have been built in sea coast area.

1.2 Basic policy of the study

1.2.1 Study on seismic technologies in Japan

In Japanese laws and regulations system as well as standards and disaster prevention plan, a number of administrative units are engaged. And the system is spread from the central government to the local government. And different code and standard which are suitable to certain facilities are necessary, because the plant facilities are composed of a number of equipments with special feature.

The study is deemed to be a basic study to examine necessity and measures of future cooperation to developing countries. Therefore, the study on the seismic technologies in Japan was conducted to the following items.

(1) Laws and regulations create interest to seismic technologies:

Chemical and petrochemical plants store or treat large volume of high-pressure gas, poisonous materials and deleterious substance, so that they are controlled under various laws. Such laws differ according to chamber, piping and so on. (Tank, piping, etc. as plants element are regulated by different laws.) So requirements in those laws and standards are investigated.

(2) Disaster prevention plan, security and disaster prevention countermeasures:

Laws regarding to security and disaster prevention countermeasures and earthquake disaster prevention for chemical and petrochemical plants, there are " Disaster Measures Basic Law ", " Large-Scale Earthquake Countermeasures Law " and " Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities ". In addition, disaster prevention plan constituted by local governments are related to plant facilities. Information on these laws is investigated.

(3) Plant design technologies:

Chemical and petrochemical plant facilities are revised in accordance with improvement by technical innovation and revision of seismic design codes. Based on lesson learned by fire disaster in Cosmo Oil Chiba refinery caused by the Great East Japan Earthquake, legislation for related matters is considered. This kind of new movement is also investigated.

(4) Revision of laws and regulations followed by the past earthquake, and development of technologies:

In the past, when disaster happened caused by earthquake and tsunami, revision of laws and standards was conducted in disaster prevention viewpoint. And corresponding technologies were developed and applied. The information on the past cases of earthquakes and revision of institution, including the most recent disaster case of the Great East Japan Earthquake, are investigated.

1.2.2 Study on the target countries

The target countries of the study are Indonesia, Vietnam and Philippines for comparison. A lot of earthquakes happened in Indonesia and Philippines. In Vietnam, they had almost no suffering by large earthquake in the past, but there are forecasts of large one in future. There are differences in each country in its laws and regulations and disaster prevention schemes. And more, understanding and vision against earthquake differs.

The following items were studied in the tree countries for seismic technologies for the plant.

(1) Past earthquake and tsunami, accidents and risks
(2) Laws and regulations, seismic code for plants.
(3) Disaster prevention plan, security and disaster prevention measures on plants.

Based on the information collected in the study, damage simulation analysis on the plant was conducted for the assumed scale of earthquake.

In addition, understanding of actual condition of plant seismic design in each country, check of plant seismic technology level, and verification of necessity and requirements were conducted. In doing so, examination of appropriate technologies from Japan, study on the possibility of revision or review of laws, regulation and standards were conducted.

1.3 Local survey and educational seminar

In the local survey, the study team assumed governmental bodies related to laws and regulations for seismic matters, organizations related to disaster management, private companies and plants. Also identifying a candidate of the counterpart of this study beforehand, the study team visited the counterpart, the related organizations and firms. The items on study are laws and regulations, seismic standards and codes, disaster prevention plan, disaster management and systems, the present situation of the seismic design.

The local surveys were conducted three times. And the member is as follows.

Name	Field in charge	First survey	Second survey	Third survey
Takashi SATO	Team leader/Plant engineering	○	○	○
Takashi NOTO	Seismic system		○	○
Masami OSHIMA	Seismic technology	○	○	○
Toshio ISHIGURO	Refinery		○	○
Moritaka KATO	Petrochemical/Chemical		○	○
Tetsuya SUGITA	Coordinator(own account)	○		

1.3.1 The first local survey

The first local survey was conducted from April 8, 2012 to April 21. Main services are as follows.

(1) The study team visited governmental organizations, research and development institutions and private companies related to construction for the study, explained the purpose of the study, and collected data and information on seismic system, standard and codes and disaster prevention plan and so on.

(2) To make the second survey more efficient, the team discussed the related organizations and fixed the places to be visited. Especially, the candidate factories and plants are fixed. Some of the plants gave the team acceptance to visit.

(3) Joint hosting partner to hold the educational seminar was identified and discussed theme and contents to be presented in the seminar.

(4) The team called for participation to the seminar when they visited organizations.

All of three countries have deep interest in the study, especially may offer to cooperate the seminar was made to the team. This study started without any previous or preliminary study. Regardless of the situation, the team could fix the joint hosting partner in early stage. It gave a large influence to accomplish the purpose of the study

1.3.2 The second local survey

The second local survey was conducted from June 3, 2012 to July 7. Main services are as follows.

(1) Educational seminars were held in Vietnam and Indonesia.

In Vietnam, the seminar was held with cooperation of IBST (Institute for Building Science and Technology). Around 60 people from the Ministry of Construction, research and development institutes, universities, a refinery company and others attended the seminar. In Indonesia, on the other hand, the seminar was held with cooperation of Agency for the Assessment and Application of Technology (BPPT), around 70 people from BPPT, governmental bodies, private companies attended.

(2) The plant survey (3 factories in Vietnam, 2 factories in Indonesia and 1 factory in Philippines) was conducted and simplified seismic assessments were done.

In Vietnam, the team visited Petrovietnam Dung Quat refinery, Phalai Power Station and PVgas LPG terminal. In Indonesia, the team visited Petrochina Betara Gas Complex and Mitsubishi Chemical Merak factory. In Philippines, only one factory of Petron Bataan refinery was visited by the team.

(3) During the visit, the team called for the participation of the next seminar, and made interview for any requirements or needs for the coming seminar expected to hold in August.

(4) The team also collected necessary and related data and information for laws and regulations, seismic standard and codes, disaster prevention plan, disaster management and system for plants.

Interests for the seminar in three countries were high, and the attendants absorbed information and knowledge in a positive manner. On the contrary, private companies are in position to place an order for the construction of the plants to reliable overseas engineering companies, so that they had no consciousness on this point.

1.3.3 The third local survey

The third local survey was conducted from August 19, 2012 to September 8. Based on the investigation and analysis made in the previous survey, the followings are made.

(1) The educational seminars are held in Indonesia, Vietnam and Philippines.

As well as the previous seminars done in Indonesia and Vietnam, with cooperation of the local joint hosting partners, the educational seminars were held. The contents of the seminar were reflected of the requirements and the result of the study in the first and the second survey. In the Philippines, it was the first time of the seminar, and the Association of Structural Engineers of Philippines, Inc. (ASEP) had a role of the joint hosting partner. In the seminar, outline of seismic technologies for the plants, detailed contents of the seismic design, and others were introduced. It was in wide range for beginner and experts.

(2) Considering the situation of the three countries examined during the survey, the team exchanged opinions with related organizations and the seminar attendants on requirements and needs for seismic technologies for the plants, assuming possibility of technical assistance by Japan.

Chapter 2 Plant Engineering and Seismic Technology in Japan

2.1 Plant engineering and seismic technology

Plant engineering for Chemical and Petrochemicals are methodology for design and construction for petroleum refinery, petrochemicals and general chemical plants. For instance, it is technology how to superintend and manage, securing budget, quality, and time for delivery. Naturally, the design and construction in consideration of a customer's request, law observance in a plant location country (site), environment, and safety are called for.

In particular, design, construction, and operation are asked for sufficient consideration for earthquake and tsunami in earthquake-prone country like Japan, and Vietnam, Indonesia and Philippines which are the target countries of the investigation in this Study. Of course, observing the law and code of countries concerned in design and construction shall be needed, and the examination of international code and standard is needed in developing countries.

The flow of typical plant engineering is shown in Figure 2.1-1. In the case of plant engineering, and especially large-scale projects, various forms exist between a customer and an ordering contractor. For example, in the case of the developing country, when a customer is not enough equipped with the capability, an owner’s contractor who is implementing project management and supervising, instead of the customer exists, and it manage and superintend the plant engineering company. When it has sufficient management / supervisor ability for a customer like Japan, the customer and the plant engineering companies do direct talks, and implement design and construction. As shown in Figure 2.1-1, there are several steps as a general engineering flow. As for these step(s), it is common that job is rather implemented in simultaneously and in parallel rather than is proceeded in order.

- Feasibility Study (FS)
- Basic Engineering
- Detail Engineering
- Procurement & Fabrication
- Construction-Start up & Operation.

Especially when seismic design are called for in the stage of Engineering, the applicable regulation and code are decided in FS and/or basic engineering works in terms of civil, architecture, mechanical design and electric and instrumentation design. And detail engineering is carried out based on these.

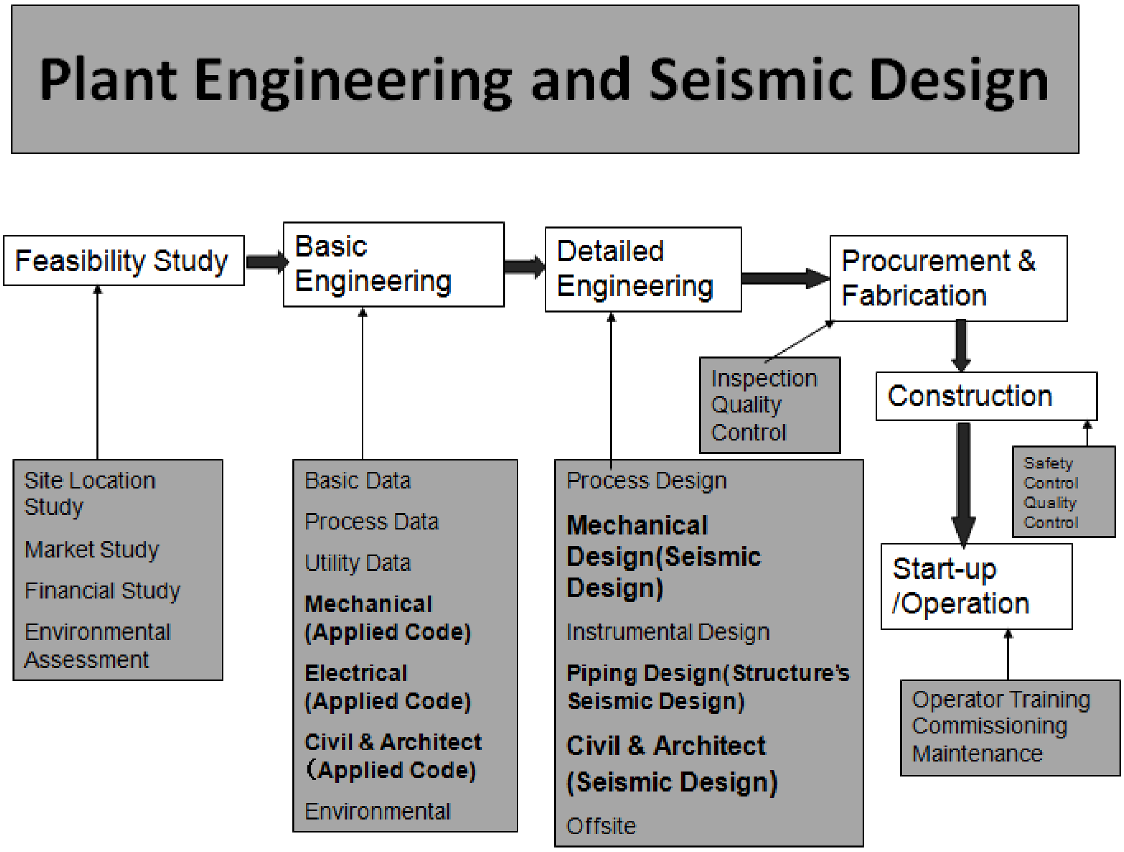


Figure 2.1-1 Block flow of plant engineering

(Data Source: Made by Study team)

It is shown in Figure 2.1-2 how seismic design from the plan of plant, design to operation stage is implemented. In the stage of planning, the viewpoint of seismic measure is considered in terms of site selection, process selection, and examination for cost and products. In addition to the design from the functional side of the plant equipment in a design or a construction phase, examination for the safety design or the disaster prevention design is made. Furthermore, even if it starts production step, sufficient maintenance check, employee education, emergency drill, measures, etc. are taken.

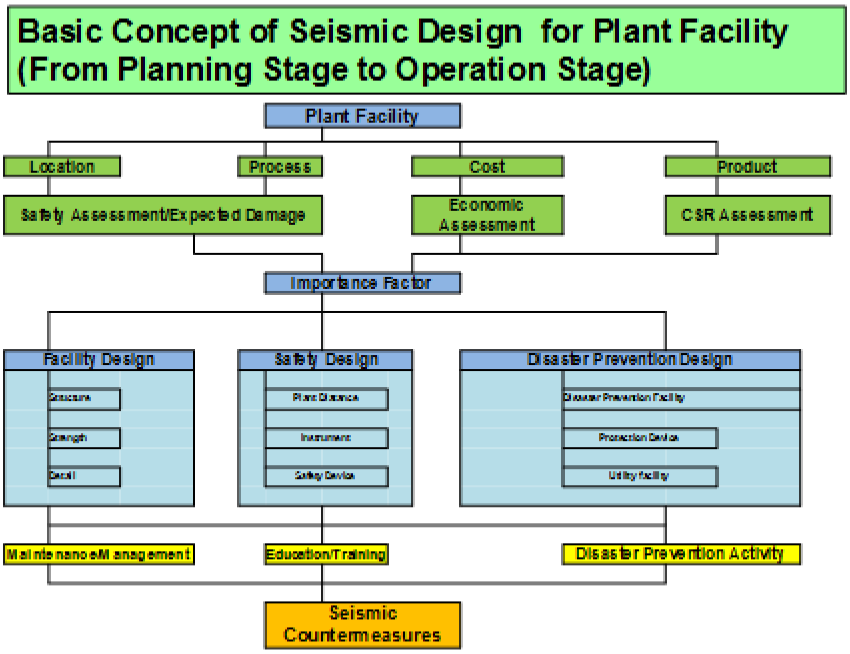


Figure 2.1-2 Concept of seismic design

(Data source: The seismic design for chemical plants)

2.1.1 Applicable seismic design code for plant facilities

The applicable seismic design codes for plant facilities are shown on Table2.1-1.

Table2.1-1 Code and standard for seismic design

Category	Standard, Recommendation	Issued	Date of issue
Archtecture	Design standard of steel structure (SI system)	Architectural Institute of Japan	Feb. 2002
	Recommendation for Limited State Design of Steel Structures	Ditto	Sep. 2002
	Standards for Structural Calculation of Steel Reinforced Concrete Structures	Ditto	Nov. 1999
	Standards for Structural Calculation of Steel Reinforced Concrete Structures	Ditto	Jan. 2001
	Recommendations for Design of Building Foundations	Ditto	Oct. 2001
	Recommendations for Design of Tower Type Steel Structures	Ditto	Sep. 1980
	Recommendations for Seismic Design and Construction of Building Structures	The Building Center of Japan	Sep. 1997
	Recommendations for Design and Construction of Chimney Structures	Ditto	Nov. 1982
Petrolium Refinery, Petrochemical	Recommendations for Seismic Design of High Pressure Gas Facilities	The High Pressure Gas Safety Institute of Japan	
	Performance Assessment of Seismic Level 2 (Guidance)	Ditto	Feb. 2003
	Performance Assessment of Seismic Level 2 (Example)	Ditto	Feb. 2003
	Performance Assessment of Seismic Level 1 (Seismic Design Facilities, Foundations)	Ditto	Nov. 1999
	Performance Assessment of Seismic Level 1 (Piping)	Ditto	Nov. 1999
	Design of Vertical Vessels Supported by Skirt (JPI-7R-35-04)	Japan Petroleum Institute	2004
	Calculation of Stresses in Horizontal Vessels (JPI-7R-52-96)	Japan Petroleum Institute	1996
	Saddle Supports for Horizontal Vessels (JPI-7R-53-09)	Japan Petroleum Institute	2009
	Pressure Vessels (JIS B 8270)	Japan Industrial Standards Committee	1993
	Welded Steel tanks for oil storage (JIS B 8501)	Japan Industrial Standards Committee	1995
Gas	Recommendation of Spherical Gas Holders	The Japan Gas Association	Jun. 1988
	Recommendation of seismic design of gas facilities on tall buildings	The Japan Gas Association	Nov. 1987
	Recommendation of underground LNG storage tank	The Japan Gas Association	Aug. 2002
	Recommendation of aboveground LNG storage tank	The Japan Gas Association	Aug. 2002
	Recommendation of LPG storage tank	The Japan Gas Association	Jun. 1992
	Recommendation of Seismic Design of Production Facilities	The Japan Gas Association	Aug. 2001
	Recommendation of Water Sealed Gas Holder	The Japan Gas Association	Mar. 1982
	Recommendation of Seismic Design of Gas Pipeline	The Japan Gas Association	Mar. 1982
	Recommendation of Seismic Design of High Pressure Gas Pipeline	The Japan Gas Association	Mar. 2004
	Recommendation of Seismic Design for Liquefaction of High Pressure Gas Pipeline	The Japan Gas Association	Feb. 2002
Electric Power	Recommendations for Seismic Design for Nuclear Power Plant (JEAG 4601-1987)	The Japan Electric Association	1987
	Recommendations for Seismic Design for Nuclear Power Plant- Importance Factor, Allowable Stress (JEAG 4601Annex-1984)	The Japan Electric Association	Sep. 1984
	Standard for Seismic Design for Fired Power Plant (JEAG 3605-2004)	The Japan Electric Association	Nov. 2004
	Recommendations of Seismic Design for Substation (JEAG 5003-1999)	The Japan Electric Association	Mar. 1999
	Guidelines of Seismic Design for Captive Power Plant	The Japan Electric Association	Mar. 1981
Water Supply	Recommendations of Seismic Design for Water Supply Facilities	Japan Water Works Association	1997
Civil	Guidelines for Concrete	Japan Society of Civil Engineers	2002
	Specifications for Highway Bridges	Japan Road Association	Mar. 2002
	Recommendations of Design for Common Utility Duct	Japan Road Association	Mar. 1986
	Technical Standards and Commentaries for Por and Harbour Facilities in Japan	The Port and Harbours Association of Japan	Apr. 1999
	Design Standards for Railway Structures and Commentary (Seismic Design)	Railway Technical research Institute	Oct. 1999

(Source: Masami Oshima, No. 04-24 Seminar for Design Procedure of Chemical Plant considering the Environment and Safety, (3)Seismic design for Chemical Plant, Japan Society of Mechanical Engineers, 2004.6.10)

Major facilities of the plant are in towers and tanks, piping and related to these supporting structure and foundation. Seismic design code for high pressure gas equipment applied above a certain size are, subject to "High Pressure Gas Safety Act" and "Act on the Securing of Safety and the Optimization of Transaction of Liquefied Petroleum Gas" within these facilities of the. Seismic loading of applied standards, foundation and supporting structure seismic design method of vertical cylindrical storage tank and horizontal cylindrical storage tank, spherical storage tank, flat bottom cylindrical LPG storage tank and piping system has been presented on such standards and support them. How the Building Standard Law applies mutatis mutandis for seismic design method applied to foundation or supporting structure. In addition, storage of dangerous goods pursuant to the provision of Fire Services Act or seismic design method shown in the notification for the specifics of the technical standards on hazardous materials regulation is applied flat bottom cylindrical storage tank handling is. Overview of seismic design code and basic concepts of these shear design method described below.

2.1.2 Basic concept of seismic design petroleum refinery and petrochemical plant

2.1.2.1 Countermeasures for earthquakes and seismic design

The meaning of seismic design is “to design the equipment and piping of the plant not to be broken when the quake hit”. However, only the strength design undertaken as a seismic design is not an effective seismic design. The seismic design should be performed as a part of countermeasures for earthquakes from plant construction planned to start of operations. The concept of countermeasures for earthquakes is shown on Figure 2.1.4-1. According to this, be in designing countermeasures for earthquakes categorize of importance and to conduct various types of design based on its seismic importance. To reasonably attempts to grant the seismic performance of the chemical plant, classified facilities standards properly, consider hazard facilities and social importance, or protection of property from markup is used. That is, a theory to seismic try and design that have a set level of seismic performance seismic importance each and divided by seismic importance individual chemical plant equipment, piping, etc., depending on its seismic importance on seismic performance levels. The design-based seismic importance classification is the following.

Mechanism design: to prevent damage caused by damage to or destruction of the respective facilities.

Safety design: abnormality occurs during an earthquake to maintain safety as a whole plant.

Disaster Prevention design: to prevent the occurrence of disasters and expanding.

The determinant of seismic importance that is required on the seismic design is shown in Figure 2.1.2.1-1. Associated with the system, and ensure the safety area as today's seismic design makes the seismic importance classification criteria based on the "damage assessment and evaluation" and the primary goal. This idea is fundamental concept stemming from the seismic design of nuclear power plants and incorporated in the fundamental concept of seismic design of plants.

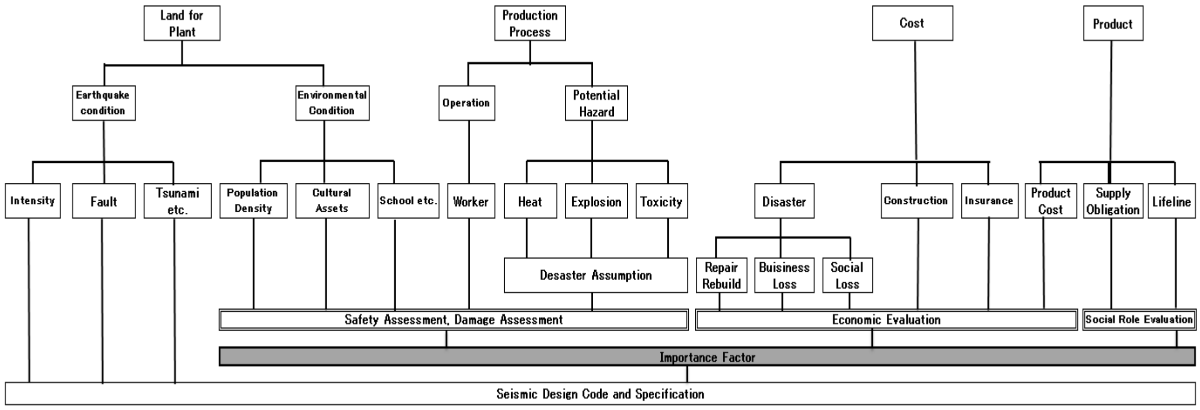


Figure 2.1.2.1-1 Evaluation items on seismic importance

(Source: Midori Shibata: Seismic Design of Chemical Plant, Maruzen, 1986.5)

2.1.2.2 Concept of seismic load on seismic design

The concept of amplification of seismic motion and keywords in the seismic design of the plant to propagate structures from the ground is shown on Figure 2.1.2.2-1. The set up method of typical seismic load include linear Static Analysis method and Modified seismic coefficient method. That set seismic load first, to acting as a design seismic intensity data as shown in the simplest Linear Static Analysis method directly in the center of gravity. Also in the seismic load calculation method on the other hand, currently apply to plant structure's response equipment on the ground and set the base intensity as shown in Figure 2.1.2.2-1, according to the onsite amplification, and Modified seismic coefficient method (seismic load calculation method considering vibration characteristics of input seismic motion and structure and determine the response magnification factor) will set the magnification factor to calculate the design seismic intensity. Into large earthquakes occurring earthquake itself to design for seismic motion, however, measured input seismic motion has been assumed until now, in recent years, and that observation input seismic motion is more than great actualization of, and only rarely and often occur during the earthquake, was to enable two types of seismic load from these application of seismic design for seismic design for seismic load to meet earthquake in traditionally all facilities subject to seismic design, earthquake for further comprises the seismic load (the secondary design) also applied.

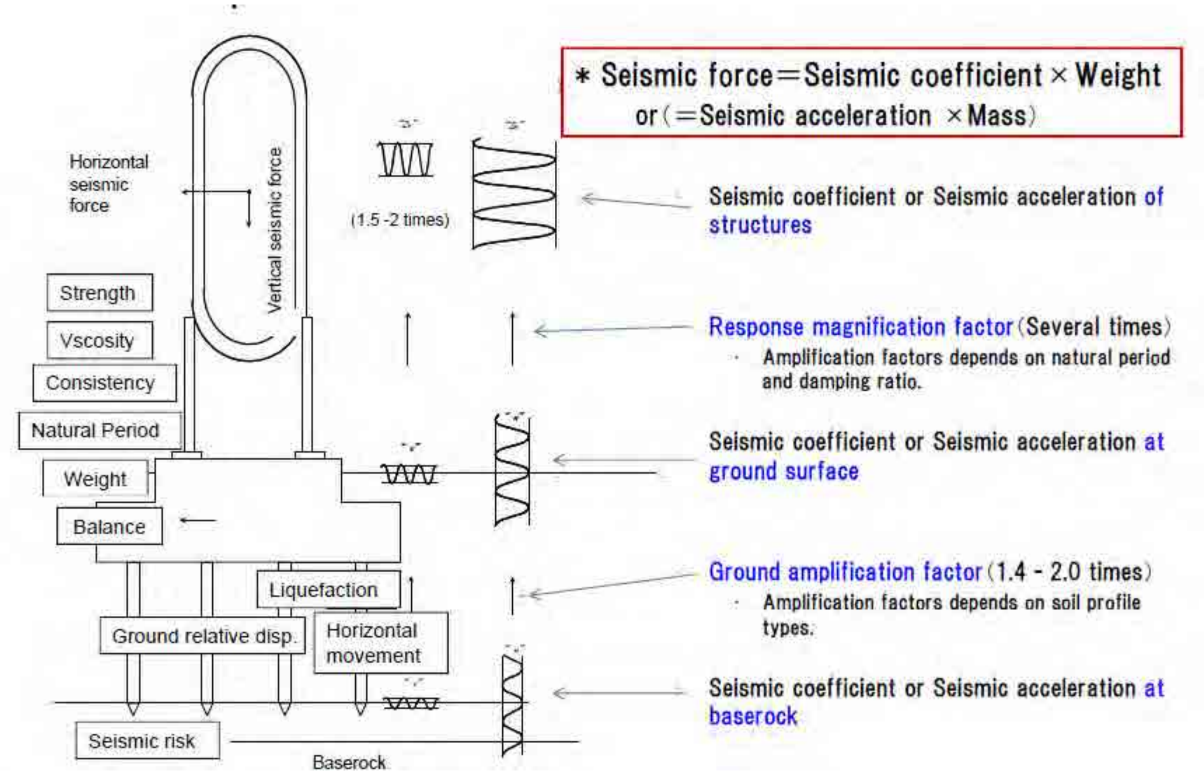


Figure 2.1.2.2-1 General idea of Seismic Load and Keywords for Seismic Design

(Source：Masami Oshima, Series Change and Development of Seismic load, No.6 Seismic design of chemical plant, Earthquake disaster prevention, No. 195, pp21-29, 2004)

However, relations between seismic load and allowable stress are relative on seismic design system. Double seismic load makes the equivalent result of double the allowable stress in stages to evaluate the stresses occurring in the facility, as a design against earthquake forces. Be aware to the relationship between the two, to compare the level of seismic safety in different criteria is determined policy as a seismic design system.

2.1.3 Seismic design code for high pressure gas facilities

The basic concept of seismic design code for high pressure gas facilities is as follows.

(1) Applicability

The old code covered seismic design structures including towers and tanks and its supporting structure and foundation. But the modified code is expanded to the piping and its supporting structures and foundation and a part of seismic disaster prevention facilities.

(2) Category of Seismic Importance

To minimize the damage to the outside of the facilities due to the loss of its function or damage of the plant, the categorization of seismic importance is provided for the towers and tanks, piping system and its supporting structures and foundations based on the intensity of the effect to the outside.

(3) Category of Seismic base Earthquake

Two types of design earthquake are provided. Category 1 Design base Earthquake and to evaluate the seismic acceleration or the intensity of seismic design of structures based on earthquake motion, Category 2 Design base Earthquake and earthquake motion to assess the effect of sloshing for flat bottomed cylindrical storage tank.

(4) Level of Seismic design Earthquake

According to the provisions of the basic disaster management plan, stipulates the following two seismic design earthquake ground motion levels. How to set the earthquake level is shown in Figure 2.1.3-1.

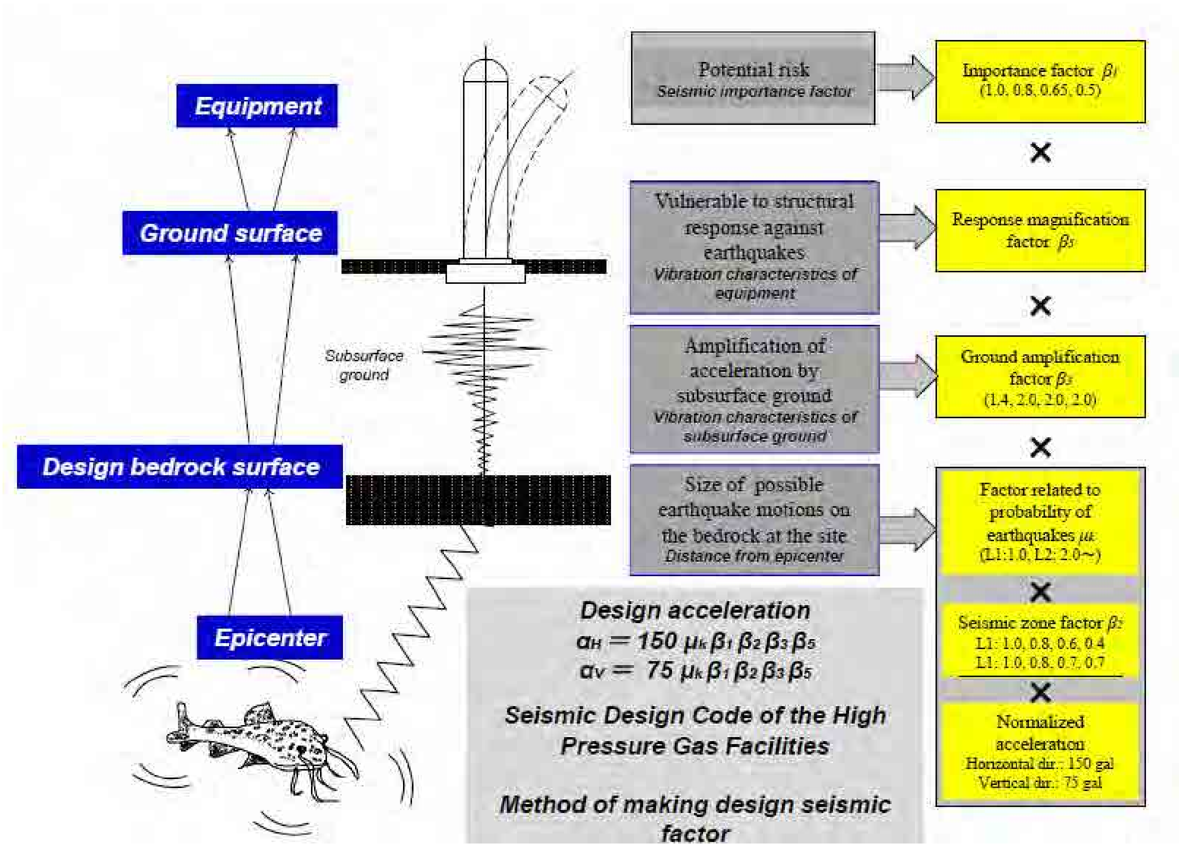


Figure2.1.3-1 Method of making design seismic factor

(Source : Masami Oshima, Series Change and Development of Seismic load, No.6 Seismic design of chemical plant, Earthquake disaster prevention, No. 195, pp21-29, 2004)

The level 1 earthquake is defined the earthquake with a probability of about 1 to 2 times during the selected period, the maximum surface maximum acceleration 300 gal and then level 2 earthquake defines a lower probability during a selected period and high levels of seismic level 1 has more than doubled in the strength of the earthquake.

(5) Response Analysis

Linear Static Analysis method is used for smaller-scale equipment, seismic importance is low. For the facilities with high seismic importance or the large scale facilities with lower seismic importance, Modified seismic coefficient method or mode analysis method is applied.

(6) Seismic Performance

Seismic design code stipulates that the seismic design structure with high seismic importance should be provided the certain seismic performance for the following two levels of seismic design earthquakes. The basic flow of seismic design is shown on Figure 2.1.4-1.

a) Level 1 Earthquake:

No detrimental deformation and the high pressure gas tightness in the seismic design structure should be kept for the level 1 earthquake. To avoid serious trouble in the seismic design of structures, the structures generally should be kept within elastic range design (allowable stress design).

b) Level 2 earthquake:

The high pressure gas tightness of the structure should be kept under the level 2 earthquake and its deformation of foundation. The seismic design structure should be designed not to destroy or collapse and affect the human life under the terminal strength design condition.

2.1.4 Notification for the specifics of the technical standards on hazardous materials

Main equipment of the facility which would be subject to seismic design per the Notification for the specifics of the technical standards on hazardous materials of the Fire Services Act is a piping for transfer facility and Outdoor Storage Tank with capacity 1,000 kl and over.

(1) Applicability

Large Outdoor Storage Tank with capacity 1,000 kl and over

Piping for transfer facility

(2) Category of Seismic Importance

Not categorized seismic importance
The most sever factor of 1.0 is applied for all the facilities which is equivalent Category Ia on the seismic design code for high pressure gas facilities.

(3) Earthquakes to be considered

Two design seismic intensities are stipulated. Both horizontal and vertical direction of design seismic intensity is hydrodynamic pressure acting on bottom of tank and side wall of the tank and tank body inertial force and also to evaluate the sloshing caused by horizontal seismic of sloshing hydrodynamic pressure.

(4) Level of Earthquake for Seismic Design

In accordance with the basic disaster prevention plan, the following 2 level of earthquakes are specified. The earthquake motion is calculated with seismic zone factor, ground factor and response factor considering the natural period of tank.

The seismic design intensity level for evaluation is 300 gal at ground surface which is equivalent of level 1 earthquake on the seismic design code for high pressure gas facilities. The seismic design intensity level for the calculation of required horizontal strength is 1.5 times of the seismic design intensity level for the evaluation of allowable stress which is equivalent of level 2 earthquake on the seismic design code for high pressure gas facilities.

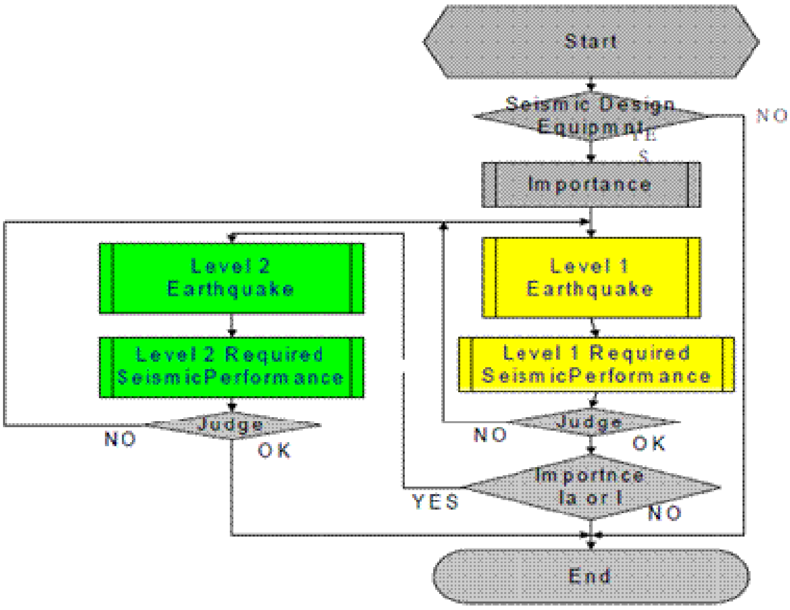


Figure2.1.4-1 Basic Flow Chart of Seismic Design

(Source : Masami Oshima, Series Change and Development of Seismic load, No.6 Seismic design of chemical plant, Earthquake disaster prevention, No. 195, pp21-29, 2004)

(5) Response Analysis

The evaluation of seismic design stress is conducted by the modified seismic coefficient method. The evaluation of horizontal strength is conducted by ultimate strength design method.

The evaluation of semi-large outdoor storage tank with capacity less than 1,000kl, equipment and disaster prevention facility is conducted by the linear static analysis method. The evaluation of underground piping is conducted by the seismic deformation method.

(6) Seismic performance

The standard stipulates that the facility to be satisfied the seismic performance under the following two seismic design conditions.

a) Seismic design intensity for the evaluation of seismic design stress:

The facility should be designed to prevent such extent of deformation or damage that occur the leak of oil. The tank should be evaluated the seismic horizontal and vertical stresses and also the liquid load and load by the sloshing.

b) Seismic design intensity for calculation of required horizontal strength:

The tank should be designed not to leak the oil by the destruction. The design allows the elastic deformation and confirms that the required horizontal stress will not exceed the horizontal strength of material at the design seismic intensity.

2.1.5 Building standard law

For the facilities do not apply the seismic design code for high pressure gas facilities or notification for the specifics of the technical standards on hazardous materials, the building standard law which is applied for general building structures is commonly applied. The outline of seismic design is as follows:

(1) Applicability

Buildings, structures such as chimneys

(2) Categorize of seismic importance

Not categorized seismic importance

(3) Earthquakes to be considered

Stipulates one the seismic motion for seismic design

(4) Level of Earthquake for Seismic Design

For the primary and secondary design, it stipulates two seismic design earthquake ground motion levels. Amplitude is set from the seismic zone factor and ground factor. And 1.0 as well as standard shear coefficient (the coefficients corresponding to the base shear for the building) need strength more than 0.2 in secondary design of calculation, in the first phase. If cannot say seismic intensity relative to the peak response magnification factor is expected in the number of which is how much clearer, even if response magnification factor 2.5 acceleration that 80 gal at ground level in the first phase (surface intensity, 5 less than 0.8, Japan Meteorological Agency seismic intensity on the floor), as well as on the second phase design of 400 gal (surface intensity then 0.4, Japan Meteorological Agency seismic intensity level 6 +) would be to consider that each degree of earthquake.

(5) Response Analysis

The seismic design stress is evaluated by the modified seismic coefficient method, and the natural horizontal strength is evaluated by the terminal strength design method.

(6) Seismic performance

The standard stipulates that the facility to be satisfied the seismic performance under the following two seismic design conditions.

a) Primary design：

To prevent the destruction of building by the small and medium size earthquake, the applied stress to the part of building is designed less than the allowable stress of the material.

b) Secondary design:

To prevent the collapse of building by large scale earthquake, the design method allows the plastic deformation of structure. The horizontal stress applied to the material at the ultimate design earthquake is checked not to exceed the allowable strength of material by the response analysis.

The comparison of applicability and calculation method of each standard is summarized on the Appendix IV.

2.2 Safety and disaster management plan on Petroleum Refinery and Petrochemical Plant

Japan stipulated in disaster management organization, disaster management plan, disaster prevention and preparedness, and disaster emergency response and disaster recovery and rehabilitation, etc. as the basis for general disaster preparedness disaster countermeasures basic act and based on this disaster management operation to create a designated government organizations and designated public corporations, based on the basic disaster management plan has been created by the central disaster management council as management areas at the top and the basic disaster management plan have a plan. In addition, petroleum refinery and petrochemical plant safety, laws relating to disaster management and countermeasure of the Earthquake as disaster countermeasures basic act, the act on special measures for large-scale earthquakes, act on disaster prevention in Petroleum Industrial, is given. Disaster management plan indicated in these laws, and disaster management plan related to disaster management operation plan, basic disaster management plan for petroleum refinery and petrochemical plant, safety and disaster relationships including the requirements for the management system and systematically investigated.

2.2.1 Disaster countermeasures basic act

(1) Outline

With regard to disaster management to protect the land and people's life, health or property from disaster, establish necessary system throughout the State, local governments and other public institutions, to clarify where the responsibility to create a disaster management plan, disaster prevention and preparedness, and disaster emergency response, disaster recovery and disaster financial measures on the management aims to determine the basic disaster preparedness and other necessary thereby, and promotion of comprehensive and systematic disaster management administration, thereby contributing to ensuring the welfare of the public and the maintenance of social order.

(2) Composition of Act

- Chapter 1 General Rules（Article 1 ‐ 10）
- Chapter 2 Organization on Disaster Management
  - Section 1 Central Disaster Management Council（Article 11 ‐ 13）
  - Section 2 Disaster Management Council of Local Government（Article 14 -23）
  - Section 3 Major Disaster Management Headquarters and Extreme Disaster Management Headquarters（Article 24 ‐Article 28-6）
  - Section 4 Dispatch of Staff at the Disaster（Article 29 - 33）
- Chapter 3 Disaster Management Plan（Article 34 - 45）
- Chapter 4 Disaster prevention and preparedness（Article 46 - 49）
- Chapter 5 Disaster emergency response
  - Section 1 General Rule（Article 50 - 53）
  - Section 2 Transmission of Warning etc.（Article 54 - 57）
  - Section 3 Precaution and Evacuation（Article 58 - 61）
  - Section 4 First-aid Treatment（Article 62 - 86）
- Chapter 6 Disaster Recovery（Article 87 - 90）
- Chapter 7 Financial Measures（Article 91 - 104）
- Chapter 8 State of Disaster Emergency（Article 105 ‐ 109-2）
- Chapter 9 Miscellaneous Regulation（Article 110 - 112）
- Chapter 10 Penal Regulation（Article 113 - 117）
- Additional Rule

2.2.2 Act on special measures for large-scale earthquakes

(1) Outline

To protect people's lives, bodies and assets from disasters caused by a massive earthquake, earthquake observation system, specifying the Earthquake Countermeasure against strengthening regional development Countermeasure of Earthquake emergency response measures and matters related to Earthquake Countermeasure systems by special measures Earthquake Countermeasure-related matters and other Earthquake Promote the Countermeasure against strengthening and also shall be in legislation enacted to ensure the maintenance of social order and public welfare purposes. "Earthquake Countermeasure against strengthening decision regional nomenclature", aka "Evaluation Committee" installed prediction in 1979 as just before the earthquake.

(2) Composition of Act

The principal composition of acts is as follows;
Article 1 Object
Article 3 Designation of the areas for intensified measures against the earthquake
Article 4 Implementation of survey and observations pertaining to strengthening regional earthquake strengthening
Article 5 Earthquake Basic Disaster Management Plan
Article 6 Strengthen Plan for Earthquake Countermeasure
Article 7 First aid plan for Earthquake Countermeasure
Article 9 Warning Declaration
Article 10 Establishing of Earthquake Disaster Warning Headquarters
Article 15 Establishing of Prefectural and Municipal Earthquake Disaster Warning Headquarters
Article 21 First aid treatment of Earthquake Countermeasure and its responsibility of execution
Article 22 Duty of Resident
Article 23 Direction of municipality
Article 28 Report of Evacuation
Article 31 Execution of Earthquake Countermeasure Drill for strengthen area
Article 33 Promotion of Scientific and Technical Research

2.2.3 Act on disaster prevention in petroleum Industrial

(1) Outline

In large factories of petrochemical complex on handling highly volatile disaster should happen once on handle which has been poisonous and deleterious substances, such as oil or toluene (chlorine, caustic soda, etc.), that aspect unlike other disasters, human, physical, and economic damage is enormous. So basic matters concerning the prevention of the accidents by Fire Service Act (1948), High Pressure Gas Safety Act, Disaster Countermeasures Basic Act and other synergy with disaster prevention law by petrochemical complex "special Disaster Management areas" and promotes various measures to stop disasters, disasters have been elsewhere, etc., from people's lives, Intended to protect physical and property (including complex itself of course).

(2) Composition of Act

・Chapter 1 General (Article 1 - 4)
・Chapter 2 Registration and Guidance for new facility, etc. (Article 5 14)
・Chapter 3 Disaster prevention and preparedness for Designated Entity (Article 15 ‐ 22)
・Chapter 4 First Aid Treatment for Disaster（Article 23 - 26）
・Chapter 5 Organization and Plan for Disaster Management(Article 27-32)
・Chapter 6 Provision of Green Belt, etc. (Article 33-37）
・Chapter 7 Miscellaneous Regulation（Article 38-48）
・Chapter 8 Penal Regulation（Article 49-52）
・Additional Rule

2.2.4 Basic disaster management plan

(1) Outline

Basic disaster management plan is a basis for disaster reduction activities prepared by central disaster management council based on disaster countermeasures basic act.

Disaster management Operation plan is a plan made by each designated government organization and designated public corporation based on the basic disaster management plan.

Local disaster management plan is a plan made by each prefectural and municipal disaster management council, subject to local circumstances and based on the basic disaster management plan.

The major contents;
・Establishment of Disaster Management Organization
・Promotion of Disaster Management Projects
・Early and Appropriate Disaster recovery and rehabilitation

·Promotion of Scientific and Technical Research on Disaster Management
·Basic Policy for Strategic Items on Disaster Management Operation Plan of Central and Local Government

(2) Composition of Plan

1) Natural Disaster

・Earthquake Disaster Countermeasures
・Tsunami Disaster Countermeasures
・Storm and Flood Countermeasures
・Volcano Disaster Countermeasures
・Snow Disaster Countermeasures
・Accident Disasters
・Marine, Aviation, Railroad, Road, Nuclear, Hazardous Materials, Large-scale Fire, Forest Fire

2) Countermeasures

・Disaster prevention and preparedness
・Disaster emergency response
・Disaster Recovery and Rehabilitation

3) Responsibility and Duty of Stakeholders

・National Government
・Local Government
・Residents

2.2.5 Disaster management operation plan

(1) Outline

Disaster management Operation plan is a plan of each governmental sector prepared by each designated government organizations based on Basic Disaster Management Plan per Disaster Countermeasures Basic Act. Cabinet Office prepares “Cabinet Office Disaster Management Operation Plan”.

【Main point of Cabinet Disaster Management Operation Plan】
·Cabinet Disaster Management Operation Plan is a disaster management plan for the scope of Cabinet office prepared based on Disaster Countermeasures Basic Act36-1.

· The plan includes the strengthen plan of Countermeasures for Tokai Earthquake, Tonankai/Nankai Earthquake and Trench type earthquake near Japan Trench/Chishima Trench based on Act on Special Measures for Large-scale Earthquakes Article 6-1.

2.3 Current trends of earthquake resistance technology, facilities and design regarding plant facilities

The extent of the damage which occurred by the Great East Japan Earthquake, March 11th 2011, had been investigated by the following committees;

- The Ministry of Economy, Trade and industry
- The Fire and Disaster Management Agency of the Ministry of Internal Affairs and Communications.

And the reports in terms of the countermeasures against earthquakes and tsunamis for the high-pressure gas facilities had been issued by the same committees. Enhancement for the countermeasures against earthquakes and tsunamis for the regional disaster prevention plan had also been issued. The damage of the plant facilities based on above reports, the status quo of the earthquake resistance technology and the task of the design are summarized in this section.

2.3.1 The status quo of the earthquake resistance technology in terms of the damage of the plant facilities occurred by the Great East Japan Earthquake

During the 2011 off the Pacific coast of Tohoku earthquake, some high-pressure gas facilities suffered from fire and explosion damage, and at the tsunami inundation areas, various high pressure gas facilities and containers were destroyed and their contents leaked.
Summary of the damage of plant facilities and status quo of earthquake resistance technologies are as follow;

(1) Summary of damages of plant facilities

1) The extent of the damage in three prefectures of the Tohoku region
(Iwate, Miyagi and Fukushima prefecture)

a) Damaged business establishments by earthquake and tsunami

The return rate on a questionnaire addressed to the business establishments in the three prefectures of Tohoku region was totally 49% (1,817 of 3,730 questions). Approximately 20% of them reported damages by this earthquake and tsunami. The breakdown of the disaster type of the 389 business establishments which had been damaged by the Great East Japan Earthquake are as follows;

- The damage caused by the earthquake: 45% (176 facilities)

- The damage caused by the tsunami: 22% (85 facilities)
- The damage caused by the earthquake and the tsunami: 8% (31 facilities)

b) Damage classification of high-pressure gas facilities etc.

Main damages of high-pressure gas facilities which had been suffered by the Great East Japan Earthquake are as follows;

- collapse or breakage of administration buildings: 129 case
- deformation or breakage of pipings or valves etc.: 98 case
- collapsed or broken of container depots etc.: 66 case

c) Inundation depth of business establishments by tsunami

Maximum inundation depth of administration buildings was more than or equal to 20 meters. And the depth from more than 5 meters to less than 10 meters had been the most number of inundation depths. Details are as follows;

>20m: 3 cases, 15 to 20m: 10 cases, 10 to 15m: 15 cases, 5 to 10m: 47 cases,
2 to 5m: 30 cases, 1 to 2m: 13 cases

d) The outflow situation of high-pressure gas facilities and the container caused by the tsunami

Concerning the number of outflows caused by this tsunami, there were far greater outflow cases of the container (114 cases) than the outflow of facilities (tankage : 14cases, high-pressure gas lorry: 14 cases).

2) The extent of the damage of industrial complex

The questionnaire to the establishments had been carried out about the extent of the damage of high-pressure gas facilities caused by this earthquake and tsunami. Out of 158 reporting establishments, 42 reported damages. Of these, fire or explosion accidents were four cases in total. Details are as follows;

- The damage by the fire of the LP gas shipping facilities of oil refinery in Miyagi prefecture,
The fire and the explosion accident of the LP gas shipping facilities of oil refinery in Chiba prefecture,
Two fire accidents at the facilities caused by above Chiba's accident.

(2) The status quo of the earthquake resistance technologies

1) The damage status caused by strong ground motion of the plant facilities applied to the instruction and the earthquake resistant design code

a) As a result of investigation, the following things became clear. Most of the facilities which complied with the notification or the seismic design standard were not damaged in the extent of the design earthquake.

b) The facilities which suffered strong ground motion exceeding the design earthquake preserved the Level 2 required seismic performances (preserved airtightness).

c) The facilities which suffered strong ground motion exceeding the Level 2 earthquake preserved the Level 2 required seismic performances (preserved airtightness).

d) In the spherical reservoirs which were complying with the notification, 3 cases suffered damage of the rupture of the brace. Thus, the instruction and the earthquake resistant code had an adequate effect in this earthquake, except the brace rupture of those spherical reservoirs examining separately.

- Ground motion in the extent of the design earthquake
  under a leak test by filling water condition, not in normal operating conditions: 1 tank
- Ground motion in excess of the design earthquake
  under a leak test by filling water condition, not in normal operating conditions: 1 tank;
  liquefied butane storage tank: 1 tank (gas did not leak)

e) Summary

Even for the facilities that are not required to conform to the instruction and the seismic resistant design code, serious damage did not occur except for breaks in the braces of the spherical reservoir. There is a reason to believe that the facilities which suffered strong ground motions by this great earthquake had a certain level of the earthquake resistance performance. Because the business operators had done the earthquake resistance design to be based on ways of thinking of the Building Standard Low voluntarily even if it was before enforcement of the instruction and the earthquake resistant design code.

2) The summary of the damage by the ground motion such as the facilities that are not required to conform to the seismic resistant design code

a) About the damage such as the facilities that are not required to conform to the seismic resistant design code, the most of the damage were 46 cases of the piping, and then were 23 cases of the regenerator and next were 13 cases of the anchor bolts.

b) 12 cases of the damage of the piping were suffered by liquefaction. The characteristics of the damage are as follow.

- The strong ground motion that most of damage really received was in excess of the Level 2 earthquake.
- Seven leaks occurred.
- As for the breakdown, a leak due to the damage of the regenerator was one case and leaks due to the damage of the piping were six cases. However, these were slight leaks.

(3) Summary of the evaluation for the status of the damage due to liquefaction

Most of the damage due to the liquefaction occurred under the conditions when the actual ground motion was lower than the Level 2 earthquake. Thus, it seems that the damage of the liquefaction was strongly affected by the effect of the ground property of the facilities rather than the ground motion itself. Incidentally, in the piping which had installed bellows at the middle, there were some cases were the contents leaked from the vicinity of connections of bellows after being deformed by the liquefaction. It is thought that these leaks occurred for the following; the damage caused by the fatigue of the vicinity of connections of bellows with the expansion and contraction involved in the temperature change of the piping had been actualized and the damage expanded by excessive deflection involved in the liquefaction.

2.3.2 The future task of earthquake-resistant design based on lessons learned from the Great East Japan Earthquake

Except for three breaks in the braces (diagonal brace of the legs) of the spherical reservoir, including the fire and explosion at Chiba Refinery of Cosmo Oil Co., Ltd, there were no accidents or damage which required new regulations such as a revision of the seismic resistant design code. (Note: As for the accident at Chiba Refinery of Cosmo Oil Co., Ltd. separate measures including new requirements for the company and all the oil industry have already been implemented). On the other hand, among the facilities that are not required to conform to the seismic resistant design code, 90% of them (in case of piping systems) (hereinafter called “existing facilities”) would be found lacking/inadequate to code should the code apply.

The following measures should be taken, based on the above situation.

Regarding the brace of the spherical reservoirs, the seismic resistant design code should be revised and ways to reinforce them should be considered;

Regarding the status of conformity of existing facilities to the seismic resistant design code, the business operators should confirm and disclose them on their financial statements. The central and local government should follow up with them;

The business operators should conduct survey on the risk of soil liquefaction and implement countermeasures against it;

Based on the discussion by the Headquarters for Earthquake Research Promotion, revision of regional coefficients and other figures in the seismic resistant design code should be considered.

The summary of "How to advance in the future regarding to the measures against earthquakes and tsunami" shown in "Report of Measures for High-pressure Gas Facilities, etc. against Earthquakes and Tsunami, Based on Lessons Learned from the Great East Japan Earthquake" by Ministry of Economy, Trade and Industry are as follow.

(1) About the additional countermeasures to the business operators

Measures against earthquake and tsunami shown in the “Report of Measures for High-pressure Gas Facilities, etc. against Earthquakes and Tsunami, Based on Lessons Learned from the Great East Japan Earthquake” are minimum requirement for high-pressure gas facilities regarding earthquake and tsunami. Should local government see fit to enhance stricter rules than the minimum required, such as construction of shelters or preservation of existing ones, business operators shall collaborate accordingly.

(2)About the voluntary correspondence of the business operators and the spread of specific countermeasures

It is expected that the business operators take measures based on the request of the local government and the latest scientific knowledge and techniques positively, not to wait for the revision of laws and ordinances, because nobody knows when natural disasters occur. In addition, every industry should prepare the guidelines about specific countermeasures such as measures for the overturning of the high pressure gas reservoir which depends on the shapes.

(3) About the improvement of the law and the standard

The technical standards for the functions for the preservation in safety environment and the regulations of protection of danger against tsunami will be established/revised sequentially from 2012 by government.
In addition, subjects which need technical studies will be discussed with specialists from 2012.

- the assessment method for strength of the bracing
- the assessment method of the influence of the wave force of tsunami

(4) The confirmation of the compatibility of the notification and the earthquake-resistant design standard by the business operators

As for the particularly notable thing in various investigations, many of the high-pressure gas facilities were not complying with the compatibility of notification or the seismic design standard.
To improve the above situations, the business operators, the local governments, and the government have to complete the task shown below steadily.

-The confirmation of the compatibility of the notification, and the publication with securities reports by the business operators
-The comprehending of the status of the above investigation by the local government
-The publication of the compatibility confirmation results by the government

- It is important to implement these countermeasures adequately by following up the progress by council etc. in the future.

2.4 The instance of the accident caused by past earthquake and tsunami, and the later legal system and standard establishment and technological change

2.4.1 Instance of the damage, and the change of the enactment and the revision of the laws and standards

2.4.1.1 The instance of past damage

(1) The instance of the damage caused by tsunami

The damage caused by the tsunami occurs in the sea area, the estuary, the sea mingled with fresh water area such as lakes close to the shore, and the land inundated district. The damage level is decided whether the land can be reused or not. The current speed and the fluid force which are major factor of the damage outbreak are decided by the height of the wave and the depth of the flood of the tsunami. The characteristic of the damage caused by the tsunami has various configurations as follows, the damage caused by the huge fluid force; only flooded; the long-time inundation, and so on.

As damage caused by the tsunamis, there are casualties, house and building damage, disaster prevention facilities damage, infrastructure (social infrastructure facilities) damage, lifeline damage, industrial damage, fire damage, oil or dangerous materials outflow damage, jetsam damage, shore forest damage, topography change damage, and so on.

The summary of the major tsunami and the damage related to the plant facilities caused by the tsunami which occurred in recent years are shown in the following.

1) Tsunami and the characteristics

-1- The 1983 Nihonkai-Chubu Earthquake Tsunami

This tsunami was caused by the 1983 Nihonkai-Chubu Earthquake occurred on May 26, at 11:59:57 local time, it had a magnitude of 7.8 on the moment magnitude scale. The hypocenter was off shore of the west of both Akita and Aomori prefectures. This was the most massive tsunami since the Niigata Earthquake Tsunami (1964) in the Sea of Japan side. Maximum run-up height of more than 14m was observed at smooth sandy beach shores. The death toll was about 100 persons. This tsunami re-sparkled the discussion about problems related to the plate boundary of the eastern edge of the Sea of Japan that were pointed out just before Niigata Earthquake Tsunami. In addition, this tsunami occurred immediately after the introduction of the concept of natural disaster reduction. This tsunami was produced the problems such as the responsiveness of the tide gauge for the short period tsunami, soliton division at the coast with gradually shoaling beach, phenomenon of the wave called the edge bore, and effect of energy dissipater with maritime forest. And these were with the main task of the next tsunami study.

-2- The 1993 Southwest-off Hokkaido Earthquake Tsunami

This tsunami was caused by the 1993 Southwest-off Hokkaido earthquake occurred on July 12, at 22:17:12 local time, it had a magnitude of 7.8 on the moment magnitude scale. The hypocenter was off shore of the west of Okushiri island. A maximum run-up of 31.7m was recorded on the western part of the island near Monai. This was observed in the V shape valley that the width and the riverbed to rapidly change. The death toll was 142 persons. The characteristics of this tsunami are as follow:

Several minutes after the earthquake, a first tsunami wave with more than 10m height invaded. There was a location that reached a run-up height of 20m on the east coast of the Okushiri at the shade from the wave source,

Inferno caused by the tsunami occurred in the Aonae area at the south end of Okushiri Island,

And the water level declined of 40-50cm for more than 30 minutes before the tsunami invasion in several places of the west coast of main land of Hokkaido.

This tsunami were produced several problems such as the insufficient tsunami warning, the neighboring area tsunami could not be explained from the earthquake data, and the lack of the three-dimensional model for analysis.

-3- The 2003 Tokachi-Oki Earthquake Tsunami

This tsunami was caused by the 2003 Tokachi-Oki Earthquake occurred on September 26, at 4:50:07 local time, it had a magnitude of 8.0 on the moment magnitude scale. The hypocenter was off shore of Tokachi in Hokkaido. The maximum wave height was 4.0m. There was no casualties caused by the tsunami (however two persons were reported missing). The two characteristics of this tsunami are as follow. The wave behind the first one became larger than the first waves at Kushiro and Urakawa. The tsunami ran-up 11km in Tokachi River.

-4- The 2011 off the Pacific coast of Tohoku Earthquake and Tsunami

This massive tsunami was caused by the 2011 off the Pacific coast of Tohoku Earthquake occurred on March 11, at 14:46:23 local time, it had a magnitude of 9.0 on the moment magnitude scale. The hypocenter was off shore of Miyagi prefecture. The first wave invaded at 14:50 that was immediately after occurrence of earthquake (14:46), and the biggest wave invaded approximately 30 minutes after the earthquake occurred. From the off shore of north Iwate prefecture to the off shore of Fukushima prefecture, the height of tsunami was recorded from 2.6m to 6.7m. And the maximum wave height was recorded at off the coast of Kamaishi in Iwate prefecture.*1

*1: In the investigation of tsunami by Japan Meteorological Agency, more than 9.3m height at Soma in Fukushima prefecture and more than 8.6m height at Ayukawa in Ishinomaki were observed.

In addition, as for the depth of the inundation, depths between 10m and 15m were recorded in the Sanriku Coast (from the north of Iwate prefecture to the Oshika Peninsula in Miyagi prefecture), and approximately a 10m depth was recorded at the bayside of Sendai to Soma. As for the run-up height, the maximum height of more than 40m was recorded in Miyako of Iwate prefecture and the tsunami run-up traces more than 10m were confirmed from Fukushima to Iwate. The death toll caused by the earthquake, tsunami and the aftershocks were totally 15,866 persons (as of 2012 July 4).

Characteristics of this tsunami are as follow: the damage caused by the tsunami had been extensive, the biggest tsunami invaded after the first wave, there was a tsunami which was observed six hours after the first wave, and the inferno caused by the tsunami occurred. As for the inferno caused by the tsunami in Kesennuma, dangerous materials which flowed out of a tank destroyed by a tsunami attached to jetsam and washed away by it were ignited, and burning jetsam were cast ashore at the coast which was inundated by a tsunami, and the inferno grew biggest. In addition, instance of delay and interruption of the refuge was caused by underestimating of the tsunami observation results and the delay of the additional information announced by Tsunami Warnings/Advisories and Information. The improvement of the tsunami warning is considered, and the reconsideration such as the size or the damage assumption of the tsunami assumed by three motion earthquakes of Tokai-Tonankai-Nankai is pushed forward by this tsunami. In addition, a master plan for disaster prevention of Central Disaster Prevention Council was revised, basic ways of thinking to assume the tsunami of two levels, and considering measures against tsunami disasters were shown.

2) Damage of plant related facilities caused by tsunami

The damage summary of plant related facilities in Japan caused by the tsunami are as follows.

a) Major damage of the facilities related to power plant

-1- The 1983 Nihonkai-Chubu Earthquake

All of the 53 persons who worked at the construction site of the caisson off shore of Noshiro thermal power plant fallen in the sea, 24 persons of them died.

-2- The 1993 Southwest-off Hokkaido Earthquake

A small scale thermal power plant on the west shore of Okushiri Island was damaged by inundation.

-3- The 2011 off the Pacific coast of Tohoku Earthquake

The nuclear reactors of unit 1 – 3 in the Fukushima Daiichi nuclear power station of Tokyo Electric Power Company were urgently shut downed by this earthquake. As outside power supply cut off, the emergency diesel generator in the basement started up. However, it was broken down by the inundation caused by the tsunami. All electric sources were lost by damage or outflow of many facilities such as electric facilities, pumps, fuel tanks, and so on. For this reason, inside of the nuclear reactor, the nuclear fuel pool could not be cooled down. Pressure vessel, containment vessel, and piping in the nuclear reactor had also been damaged by the meltdown of the nuclear fuel. All this combined created the largest nuclear accident in history.

b) Major damage of the petroleum and the dangerous materials facilities

-1- The 1944 Tonankai Earthquake Tsunami: The 1944 Tonankai earthquake occurred at 13:35 local time on 7 December with estimated magnitude of 7.9. The heavy oil tank in Nikito of Mie prefecture was carried approximately 300m away. The tank was empty at that time.

-2- The 1946 Nankaido Earthquake Tsunami: The 1946 Nankaido earthquake occurred at 4:19 local time on 21 December with estimated magnitude of 8.0. The tank in Kuki of Owase was carried away, and its oil spilt.

-3- The 1964 Niigata Earthquake Tsunami: The 1964 Niigata Earthquake occurred at 13:01 local time on 16 June with a magnitude 7.5. One of the piping of oil storage tanks cracked, and the gasoline it contained leaked. The blowout groundwater by the liquefaction and run-up sea water by the tsunami accumulated around the tank, and the leakage oil spread on it. Five hours after the earthquake, fire occurred and explosions could be heard. This fire spread to the leakage oil on the water, and the fire induced explosions to other tanks.

-4- The 1968 Tokachi-Oki Earthquake Tsunami: The 1966 Tokachi-Oki Earthquake occurred at 9:48 local time on 16 May with a magnitude 7.9. The mobile lubricator in the warehouse of the Port of Kamaishi was overturned by driftwood which had broken through an iron shutter, and fire occurred. However, the fire did not lead to conflagration because it was found early.

-5- The 1983 Nihonkai-Chubu Earthquake: The light oil tank which has the capacity 130kl was carried approximately 10km away, and the containing oil spilt. In the Port of Akita, snapping of the loading arm and bending of the gang way occurred in the middle of unloading from the tanker. However, a major catastrophe was avoided due to early action.

-6- The 2011 off the Pacific coast of Tohoku Earthquake: The 167 tanks in outdoor tank storage facilities were damaged by the tsunami. The damage types were outflows, shiftings, overturns, and deformations. The tanks, the foundation of oil retaining wall, and the ground were scoured by the tsunami. Thus, the damages were not only on the foundations but also on slopes or breakages of the tank. In addition, damages such as outflows, shiftings, ruptures, and snappings were occurred in the piping which connects to the tank. In Kesennuma, out of 23 tanks of the outdoor tank storage facilities 22 were carried maximum 2.4km away. The dangerous materials which spilt out of tanks destroyed by the tsunami ignited these burning jetsams were cast ashore into inundated areas and resulting in greater inferno.

(2) The damage instance of the earthquake

The outline of the major earthquake which occurred in recent years and damage instance of the plant facilities which were caused by earthquake are shown below.

Table 2.4.1.1-1

Earthquake Name	Outline	Damage instance of plant facilities	
		Stricken area (Horizontal	Extent of the damage
Niigata Earthquake 1964 M7.5	Damage of the ground liquefaction ・incline, subsidence (310 buildng) ・fountain, sand boiling earthquake damage ・completely destroyed building: [illegible]	Niigata City (160 - 250gal)	・Incline and subsidence of the oil tanks and the plant facilities caused by the extensive liquefaction ・Extencive leakage of oil and fire accident ・There is no damage in ground improved tanks and plants in vibro-floatation method of construction.
Miyagi Eathquake 1978 M7.4	Damage of landslide and collapse of filling area ・the land developed for housing which was developed in the hill country ・andslide and collapse of filling area ・completely destroyed building: 1,183 ・dead: 27 presons	the Port of Sendai, Shiogama area	・Three of the bottom plate of the oil tanks suffered crack, and leakage of oil occurred ・There was no damage in ground improved tanks in vibro-floatation method of construction by the liquefaction. ・Gas leak frequent occurrence by the slack of the flange and the crack of the piping.
		Ishinomaki City (280gal)	・On the neighboring ground, liquefaction occurs ・There was no damage in the tanks on the ground which improved in sand compaction pile method.
Nihonkai-Chubu Earthquake 1983 M7.7	Earthquake damage (small) Damage of tunami and ground liquefaction (large)	the Port of Aomori (115gal)	・Maximum 30cm of subsidence in 20 tanks were occurred by liquefaction ・There was no damage in the tanks on the ground which improved in sand compaction pile method.
		the Port of Akita (209gal)	・The tanks in the south area suffered few cm subsidence by liquefaction, however there was no leakage.
Hyogoken-Nanbu Earthquake 1995 M7.2	Earthquake damage ・the shear destruction of the column in RC building ・collapse of middle floor and 1F ・collapse of highway ・rupture of lifeline ・gound liquefaction (large) ・completely destroyed building: 104,906 ・dead: 6,433 presons	the Port of Kobe (more than 500gal)	・The damage of the harbor structure by the liquefaction is enormous. ・Many of the tanks suffered subsidence by liquefaction, however there was no leakage. ・Leakage accident occurred by liquefaction at the flange coupling part of high pressure gas piping system.
Tokachi-Oki Earthquake 2003 M8.0	Earthquake damage ・gound liquefaction (large) ・completely destroyed building: 104	Tomakomai City (100 - 200gal)	・Damage occurred in a specific tank of the majority by sloshing ・The submergence of the floating roof ・The ring fire occurred in the crude petroleum tanks ・The the whole surface of fire occurred in the naphtha tank

(Source: Encyclopedia of Earthquake, Second Edition, popular edition, Asakura Publishing Co., Ltd., March 2010)

2.4.1.2 The change of establishment and the revision of law and the standard

In facilities such as oil refineries, various facilities are mixed. Thus the earthquake resistant design is carried out based on each law and standards, because the applicable law and standards to each plant facility are different. The change of establishment and the revision of law and the standard which applied to plant facilities such as High Pressure Gas Safety Act, Fire Service Act, and the Building Standard Law are shown in Table 2.4.1.2-1.

Table 2.4.1.2-1 The change of various earthquake resistant code

Year		Major Eartnquake	Building Standards Act	High Pressure Gas Safty Act	Fire Survice Act
1923	T12	Great Kanto Earthquake (Mj7.9)			
1924	T13		Urban Building Law		
|	|				
1950	S25		Order for Enforcement of the Building Standards Act (Cabinet Order No.338)		
|	|				
1952	S27	Kern County Earthwuake (Ms7			
1959	S34				Regulation of dangerous materials
|	|				
1964	S39	Niigata Earthquake (Mj7.5) Alaska Earthquake (Ms8.4)	Seismic Cord for High-Rise Building in Japan (AIJ)		
1968	S43	Tokachi-Oki Earthquake (Mj7.			
1970	S45				
1971	S46	San Fernando Earthquake (Ms6.5)			
1972	S47				
1973	S48		Revision of Seismic Cord for High-Rise Building in Japan(AIJ)	(Seismic Design Standard for the High Pressure Gas Facilites in Kanagawa Prefeture)	
1974	S49	NOTICE: Mj: JMA Magunitude Ms: Surface Wave Magnitude Mw: Moment Magunitude		Guidelines for the Safty and the Privention of Disaster in Petrolem Industrial Complexes	Notification to determine the item of the technical standard about the regulation of dangerous materials (No.99)
1975	S50				
1976	S51				
1977	S52				Amendment of the notification (No.22)
1978	S53	Miyagi Earthquake (Mj7.4)			
1979	S54			(Amendment) Report on seismic design standard for the plant facilities (KHK)	
1980	S55		Amendment of Order for Enforcement of the Building Standards Act (Cabinet Order No.196)		
1981	S56			Seismic design standard for the high pressure gas facilities (Notification No.515)	
1982	S57				
1983	S58				Amendment of the notification (No.11
1984	S59	Nihonkai-Chubu Earthquake (Mj7.7)			
1985	S60	Mexico Earthquake (Ms8.1)		(Operative procedures for seismic design standard for the high pressure gas facilites in Kanagawa prefeture)	
|					
1988	S63			(Guidelines for the judgment of seismic performance for high pressure gas piping	
1989	H1	Loma Prieta Earthquake (Mw6.9)			
1990	H2			(Seismic Design Standard for the High Pressure Gas Facilites in Kanagawa Prefeture)	
1991	H3				
1992	H4				
1993	H5	Kushiro-Oki Earthquake (Mj7.8) Southwest-Off Hokkaido Earthquake (Mj7.8)		(Amendment)	
1994	H6	Northridge Earthquake (Mw6.7) Offshore Sanriku Earthquake (Mj7.5)			
1995	H7	Hyogoken Nanbu Earthquake (Mj7.2)			Amendment of the notification
1996	H8				Amendment of the notification
1997	H9			Amended Seismic design standard for the high pressure gas facilities (No.141)	
1998	H10				
1999	H11	Kocaeli Earthquake (Mw7.5)			Amendment of the notification
2000	H12	Western Tottori Earthquake (Mj7.3)	Amendment of Order for Enforcement of the Building Standards Act (Notification No.1457)		
2001	H13	Geiyo Earthquake (Mj6.4)			
2002	H14			(Amendment)	
2003	H15	Miyagi Earthquake (Mj7.0) Tokachi-Oki Earthquake (Mj8.0)			
2004	H16				
2005	H17	Off the West Coast of Northern Sumatra (Mw9.1)			Amendment of the notification

(Source：Made by Study team)

As a major flow of the changes of the earthquake-resistant design for the plant facilities are as follows. The first stage was applied seismic design method in the Building Standard Low for plant facilities by analogy. And the next stage was the preparation stage of seismic design method for each plant facilities. Finally, the notification of High Pressure Gas Safety Act was established including seismic design method for various plant facilities. In addition, the code was revised introducing the 2 step earthquake assessment after the 1995 Hyogoken Nanbu Earthquake. And the piping system was including in the object of seismic design facilities. At the present, the extent of the code was expanded.

2.4.2 The assessment item reflected to the low, and the change of the assessment method

(1) Amendment of the Seismic design code for high pressure gas facilities

By the 1995 Hyogoken Nanbu Earthquake, the phenomenon and the damage instance that were not seen in previous earthquake disasters were seen. Therefore, the seismic design code for high pressure gas facilities (the notification of Ministry of International Trade and Industry No.515, hereinafter called "old seismic design notification") that was enforced in 1981 was amended based on the earthquake in the notification of Ministry of International Trade and Industry No.143 (hereinafter called "amendment seismic design notification") as the countermeasure. The summary of the extent of damage caused by the 1995 Hyogoken Nanbu Earthquake and the contents of amendment are as follows.

1) The extent of damage caused by the 1995 Hyogoken Nanbu Earthquake

The characteristics related to major damage of the high pressure gas facilities are as follows.

-1- There was little damage at the facilities of the towers and the tanks target for the High Pressure Gas Safety Act.

-2- As for the seismic design structures which was designed after old seismic design notification established, those were hardly damaged even after having experienced the 1995 Hyogoken Nanbu earthquake.

-3- The leak accidents from the flange coupling part occurred in high pressure gas piping system. In this reason, evacuation advisory for neighboring inhabitants was given. The conditions photograph around the tank valve which became the leakage point is shown in Figure 2.4.2 -1.

-4- The damage such as the crack and the opening of the oil protective wall was remarkable.

-5- Damaged facilities such as the instrumentation and control facilities, the utility facilities, and so on were confirmed.

As described above, the earthquake damage of the high pressure gas facilities was limited to the facilities except "seismic design structure targeted for the seismic design determined by old seismic design notification". These damages were estimated to be caused by the ground deformation such as the lateral flow or the subsidence with the liquefaction of the ground. The condition of the ground deformation at the damaged site was shown in Figure 2.4.2-2.

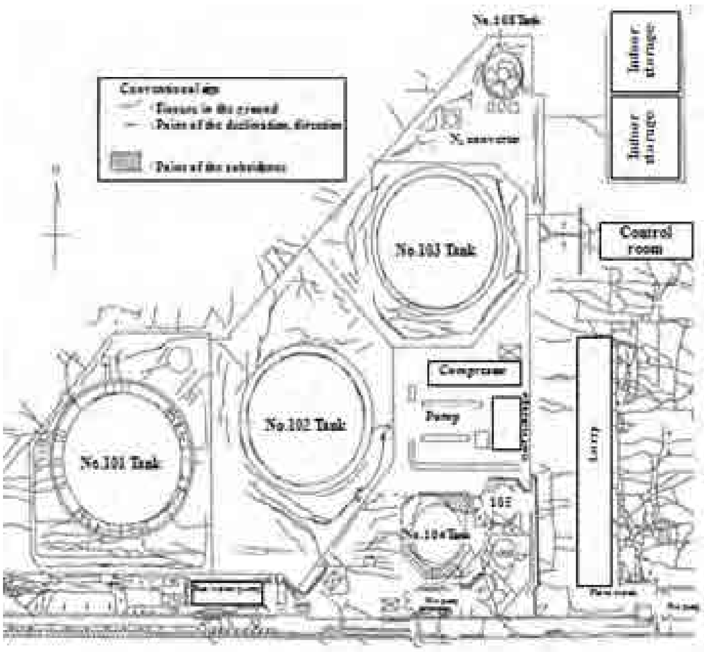


Figure 2.4.2-1 Leakage point of the valve of LPG Tank

Figure 2.4.2-2 The condition of the ground deformation at the LPG Tank site

(Source of both above Figure: the Institution for High Pressure Gas Safety: “LP gas storage facilities with Southern Hyogo Prefecture earthquake. Interim report on Gas leakage investigation.”, 1995)

2) Outline of amendment seismic design notification (1997)

-1- The piping system was included in the seismic design structure targeted for the seismic design. In addition, earthquake emergency shut-off valve was added as earthquake prevention facilities.

-2- The level of the earthquake to consider as design was divided into 2 step as Level 1 earthquake and Level 2 earthquake. The assessment of Level 2 required seismic performance by Level 2 earthquake was required to all the facilities that importance factor is Ia or I.

-3- The design method of foundation for the ground deformation and the design method of piping system by foundation movement were shown.

Above outline of amendment was the countermeasure for the phenomenon of gas leakage from flange connection caused by ground deformation of liquefaction.

In the amendment seismic design notification, Level 1 earthquake (design earthquake in the old seismic design notification, probable strongest earthquake in service life of the facilities) was not revised, because the seismic design structures which was designed after old seismic design notification issued were hardly damaged even after having experienced the 1995 Hyogoken Nanbu earthquake. And as for the additional Level 2 earthquake (additional design earthquake by amendment, probable strongest earthquake with low probability), the seismic design method which has the purpose of adding the ductility to the structures satisfied with the Level 1 required seismic performance was adopted.

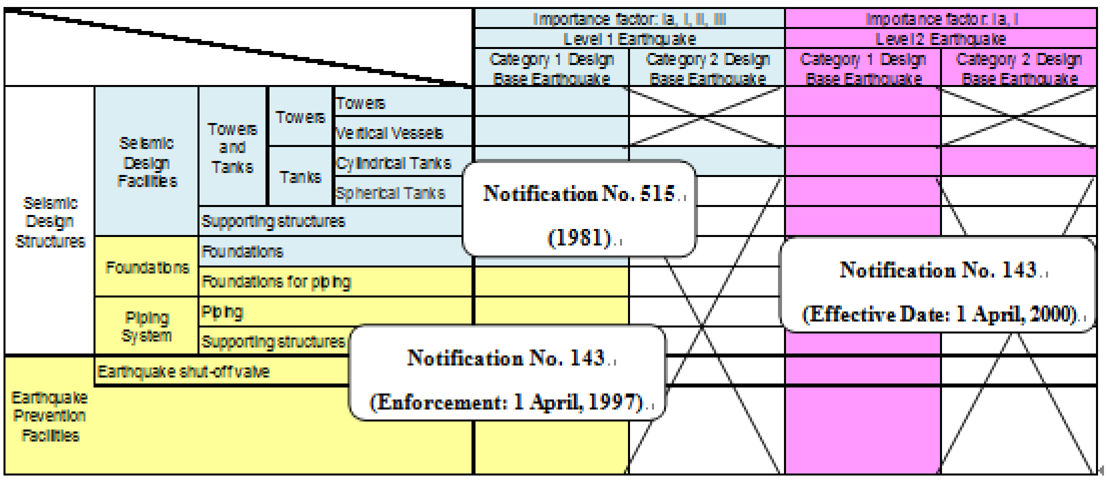


Figure 2.4.2-3 Scope and facilities of application of seismic design notification
(Source: made by Chiyoda Advanced Solutions Corporation)

(2) Notification to determine the item of the technical standard about the regulation of dangerous materials

As for the outdoor tank storage facilities, whenever serious damage was caused by accidents and earthquakes, the reconsideration of the standard has been performed as well as the structure which applied to the High Pressure Gas Safety Act. In the following, the change of the countermeasures for the earthquake and the accident of the outdoor tank storage facilities which applied the Fire Services Act are described. In addition, as for "Notification to determine the item of the technical standard about the regulation of dangerous materials" issued 1974, the change of the evaluation method and the evaluation category reflected to the seismic design are shown in Table 2.4.2 -1.

1) Application notice No. 52 of May 20, 1975

The date of the accident: 28 December, 1974
Location: Mitsubishi Oil Mizushima refinery of Okayama prefecture
Damage: Heavy oil leaked by crack of the weld of the heavy oil tank
Measures and Requirements: The Fire Services Act was drastically revised in 1979. The technical standards of provision for outflow of the foundations of tank, the main body, oil protection wall, and so on were prescribed in details. And the regular overhaul inspection to measure differential settlement was required.

2) Application notice No. 137 of October 20, 1978, Application notice No. 169 of December 25, 1979

The date of the accident: June 12, 1978
Location: the Tohoku Oil Sendai refinery
Damage: The contents leaked from the outdoor tank storage facilities by the Miyagi offing earthquake
Measures and Requirements: Early completion of the repair of the existing oil protection wall and the setting of the oil protection wall was promoted in October of the year. Furthermore, the execution of the general inspection, repair, and the safety measures of the open storage tank space was required in December of the year after the accident. In addition, it was demanded that the safety inspection used horizontal seismic intensity 0.4 or more. In the safety measures, the nonproliferation of the oil spill and the rainwater invasion hedge to below the bottom plate of the tanks were required.

3) Application notice No. 51 of May 31, 1983, Application notice No. 89 of September 29, 1983

The date of the accident: May 26, 1983
Location: Akita thermal power plant of Tokyo Electric Power Service

Damage: The ring fire by the sloshing of the containing liquid in the open storage tank caused by the 1983 Nihonkai-Chubu Earthquake
Measures and Requirements: The operative notice about earthquake measures of the outdoor tank storage facilities was given. And for the promotion of earthquake measures of the outdoor tank storage facilities, the operative notice about ensuring safety of the draining pipe at the bottom of the tanks, the floating roof, and the piping and the earthquake countermeasures of the corridor between the tanks were given in September of the year. Using materials other than metal for the weather shield was required, because the cause of the ring fire was a contact and a collision with the facilities which the floating roof and side plate inside were provided with.

4) Application notice No. 69 of July 12, 1984

The date of the accident: 17 December 1979, 21 May and 4 June 1984
Damage: the fire failure of the tanks under the overhaul inspection
Measures and Requirements: The instruction about the reconsideration of the in-house safety standards and the operation standard and also exhaustiveness of accident prevention measures were given.

5) Application notice No. 125 of October 15, 1996

The date of the accident: 17 January, 1995
Damage: The various damages such as the cracking and buckling of the fire extinguishing water tanks, the falling of the corridor between the outdoor tank storage facilities, the leakage of the dangerous materials by the overturning of the tanks at the outdoor tank storage facilities were caused by the 1995 Hyogoken Nanbu Earthquake that occurred on 17 January, 1995.
Measures and Requirements: The reinforced concrete water storage tanks shall have the strength that is equal to fire prevention water tanks or to prevent a leak of water even they are cracked. The steel tanks shall have the strength more than or equal to the open storage tank if that setup is on the ground, and also more than or equal to the underground storage tank if that setup is in the ground.

6) Application notice No. 16 of January 21, 2002

The date of the accident: 27 June, 2001
Location: Oil refinery in Takaishi of Osaka prefecture
Damage: Leakage of the crude petroleum
Requirements: As for the draining pipes were difficult to access easily dismantled mechanism and accessible places for easy inspection are required.

7) Application notice No. 67 of May 15, 2002

The date of the accident: June to December, 2001
Damage: Leakage of the contents, 4 cases
Requirements: Exhaustiveness of inspection to the side plate and the inside of the tank

8) Enforcement notice No. 14 of January 14, 2005

The date of the accident: 26 May, 2003
Location: Oil refinery in Tomakomai of Hokkaido
Damage: The fire of the floating roof tank, the submergence of the floating roof, extensive of spillovers oil were caused by the 2003 Tokachi-Oki Earthquake.
Measures and requirements: The regulation about ensuring seismic performance for floating roof was issued. The structural calculation method for seismic strength of floating roof was added. The regulation about structural performance of floating roof was issued.

9) Application notice No. 227 of October 3, 2005

The date of the accident: 19 February, 2005
Location: Oil refinery in Oita prefecture
Damage: After the oil leaked on the floating roof, the floating roof was submerged.
Requirement: Exhaustiveness of the safety measures for the floating roof.

10) Application notice No. 235, No. 142 of October 19, 2007

The date of the accident: October 2006 to October 2007
Damage: Spillovers of dangerous materials into the inside of the floating roof, the slant of the floating roof, the submergence of the floating roof
Requirement: Exhaustiveness of the prevention measures against the extraordinary occurrence for the inside of the floating roof, make complete the emergency measures system

11) Application notice No. 350 of September 30, 2008

The date of the accident: 16 January, 2008
Location: Open storage space of Osaka prefecture
Damage: The floating roof was damaged by loading ladder abnormalities, the detention of the dangerous materials on the floating roof, and the leakage of the dangerous materials from the down pipe connection into the inside of the oil protection wall

Requirement: the inspection of the wheels of the loading ladder was added in the inspection item of the periodic inspection.

12) Application notice No. 52 of March 28, 2011

The date of the accident: 11 March, 2011
Damage: Serious damage suffered by the 2011 off the Pacific coast of Tohoku Earthquake.
Requirement: As for the dangerous materials facilities which suffered from earthquake disasters, the quick inspection that whether or not adapts to a technical standard based on the Fire Services Act. As for the dangerous materials facilities where abnormalities were found, perform appropriate measures.

Table 2.4.2-1 The change of the assessment method for seismic design

revised year	main revised point	remarks
1977	Add the classification of the tanks which applied to antiqua statuta (old law) or applied to amendment The adoption of the modified seismic coefficient method Add the assessment for the sloshing	
1983	Add the vertical seismic coefficient	
1995	The adoption of the plastic design (objected to the tanks which applied to antiqua statuta) Add the assessment of the ground liquefaction	
1996	The adoption of the plastic design (objected to the tanks which applied to amendment)	
1996	The establishment of the seismic design standard for the semi-specified outdoor tank storage facility	
2005	The introduction of the correction factor depending on the regionalization by the long period earthquake The establishment of the seismic design standard of the single deck floating roof objecting the regulation condition	

(Source：Made by Study team)

Chapter 3　Seismic Technology for Plant in Indonesia

3.1　Petroleum, petrochemical and chemical industries in Indonesia

The following Table 3.1-1shows the general information of Indonesia.
The Indonesian GDP growing rate fell down to 4.63% in 2009 because of the world-wide economical crisis, however, after that it has been keeping at a good rate of 6% level.

Table 3.1-1　Outline of Indonesia

<table>
<tr><th>Economic Index</th><th colspan="2">Static</th><th colspan="4">Remarks/Sources</th></tr>
<tr><td>Area</td><td colspan="2">1.89 mil.㎢</td><td colspan="4">(Slightly less than 5 times of Japan) Ministry of</td></tr>
<tr><td>Population</td><td colspan="2">241 mil.</td><td colspan="4">Foreign Affairs</td></tr>
<tr><td>Growth rate of Population</td><td colspan="2">1.18%</td><td colspan="4">IMF World Economic Outlook Databases (04/2012)</td></tr>
<tr><td>GDP</td><td colspan="2">846 bil.US$</td><td colspan="4">World Population Prospects by UN (2008)</td></tr>
<tr><td>GDP/person</td><td colspan="2">3,509 US$</td><td colspan="4">IMF World Economic Outlook Databases (04/2012)</td></tr>
<tr><td>Foreign Reserves</td><td colspan="2">56.3 bilUS$</td><td colspan="4">IMF World Economic Outlook Databases (04/2012)
(01/2008)</td></tr>
<tr><td rowspan="2">GDP</td><td>2006</td><td>2007</td><td>2008</td><td>2009</td><td>2010</td><td>2011</td></tr>
<tr><td>5.50%</td><td>6.35%</td><td>6.01%</td><td>4.63%</td><td>6.20%</td><td>6.46%</td></tr>
</table>

(Source : Made by JCI based on the above sources)

3.1.1　Petroleum industry in Indonesia

Indonesia is the largest oil producer in ASEAN and they can export the natural gas at present, however, as for the crude oil, they are in excess of imports. In order to meet the dwindling oil production and the growing domestic demand, they intend to give density to the export of petroleum products by construction of the new export-oriented refineries and the development of alternative energy of the petroleum. It aims the effective use of resources and expansion of the acquisition of foreign currency, but most projects have not progressed because of the economic and political turmoil.

National Oil Company PT Pertamina has separated the six affiliate refineries in October 1998 as the first step of privatization and made them independent profit centers and/or strategic units respectively. PT Pertamina has drawn the blueprint to increase the refining capacity up to 1.503 million bpd by 2017 and to establish the self-sufficiency organization in conjunction with renewable energy systems, however, the implementation of the project has been delayed. Indonesia is a growing market and gathering attracted attention from Asian countries and the Middle East but they can’t proceed to the next step.

(1) Dumai/Sungai Pakning Refinery (Processing Unit-II)

In the middle of Sumatra, there are two Refineries called Unit-II altogether which has 122,000bpd CDU in Dumai and 50,000bpd CDU in Sungai respectively.
Ishikawajima-Harima Heavy Industries (IHI) has been constructed Dumai Refinery.
Dumai Refinery has a plan to revamp the CDU enhance to 80,000bpd in around 2014.

(2) Musi (Plaju) Refinery (Processing Unit-III)

In the Southern of Sumatra, there are two refineries called Musi Refinery altogether which are Plaju Refinery and Sungei Gerong refinery located near Palembang, and the total CDU capacity is 127,000bpd (max. 135,600bpd) with CDU units. There is a plan to revamp CDU unit by 2012 and enhance refining capacity up to 138,000bpd. Furthermore, they are considering the enhancement of 50,000bpd CDU capacity in around 2014 with cooperation of SK Energy of South Korea.

(3) Cilacap/Wonokromo Refinery (Processing Unit-IV)

In Java, there are two Refineries in Cilacap and Wonokromo. They are in a long distance but the tow of them are positioned as Processing Unit-IV and called Cilacap Refinery. The feature is while the eastern Wonokromo refinery is the smallest refinery in Indonesia with CDU capacity 2,000bpd, Cilacap in the middle of Java has become the largest refinery in Indonesia with CDU capacity 348,000 bpd.

(4) Balikpapan Refinery (Processing Unit-V)

This refinery has the capacity 253,600 bpd CDU unit (Max. 263,800bpd) in East Kalimantan.

(5) Balongan Refinery Processing Unit-VI)

It started the operation in September 1994 as EXOR-1 (Export Oriented Refinery-l). CDU unit Capacity is 125,000bpd.

(6) Sorong (Kasim) Refinery (Processing Unit-VII)

It was constructed as EXOR-2 (Export Oriented Refinery-2) in Kasim followed to Balongan, which is 100,000bpd CDU unit as the core facility.

(7) LEMIGAS・Cepu Refinery

LEMIGAS-Research and Development Centre for Oil and Gas Technology is a national research and development institute located in Cepu, Java, and it is the only company managing refinery in Indonesia other than Pertamina. CDU capacity is 3,800bpd.

(8) TPPI's Tuban Refinery

Tuban refinery is belonged to PT Trance-Pacific Petrochemical Indotama (TPPI). At early stage of the establishment, they aimed to construct ethylene cracker plant as the second one in Indonesia, but the plan was broken down. National Oil Company Pertamina joined in October 2001 and supplying condensate to Tuban as a raw material. They abandoned the original plant of construction of ethylene cracker, they are now only operating a 100,000 bpd condensate splitter and operating an aromatic extraction unit.

(9) New construction plan of Banten Refinery

There is a plan to establish a joint venture company named PT Banten Bay Refinery, whose shareholders are Pertamina (40%) and National Iranian Oil Refinery & Distribution Co.,Ltd. (NIODC) (40%), and Petro Field (M) Sdn Bhd of Malaysia (20%). The plan of PT Banten Bay Refinery is the construction of 300,000bpd crude oil processing refinery at Banten, the port city of West Java.

(10) Tuban Refinery Construction Project in East Java by joint venture of SINOPEC.

SINOPEC will construct and operate the refinery and Pertamina will support and cooperate.
The plan is to build a crude oil processing capacity 200,000bpd refinery in Tuban, East Java.

3.1.2 Petrochemical and Chemical Industries in Indonesia

(1) Petrochemical Complex in CAP/Cilegon Industrial Zone

PT Chandra Asri Petrochemical Tbk (CAP) constructed a naphtha cracking furnace and started full operation in September 1995 at Anyer of West Java. The main products are 550,000 t/y Ethylene by ABB Lummus process, 243,000t/y propylene by the same process, and thermal cracked gasoline 216,000t/y.

The derivatives are supplied to customers, such as PENI and Tri-Polyta, in Merak Industrial Zone, including Anyer, Cilegon, Merak and Bojonegara, through the underground pipeline of about 18km total length as raw materials required for each customers.

In addition, PT Chandra Asri Petrochemical Tbk completed and started 200,000 t/y LLDPE / HDPE by Unipol process in June 1995, and also 100,000 t/y HDPE by Showa Denko technology in July 1995 in a series. Toyo Engineering Corporation. (TEC) constructed the plants including the cracking furnace. Capacity of LLDP has been increased to 220,000 t/y later.

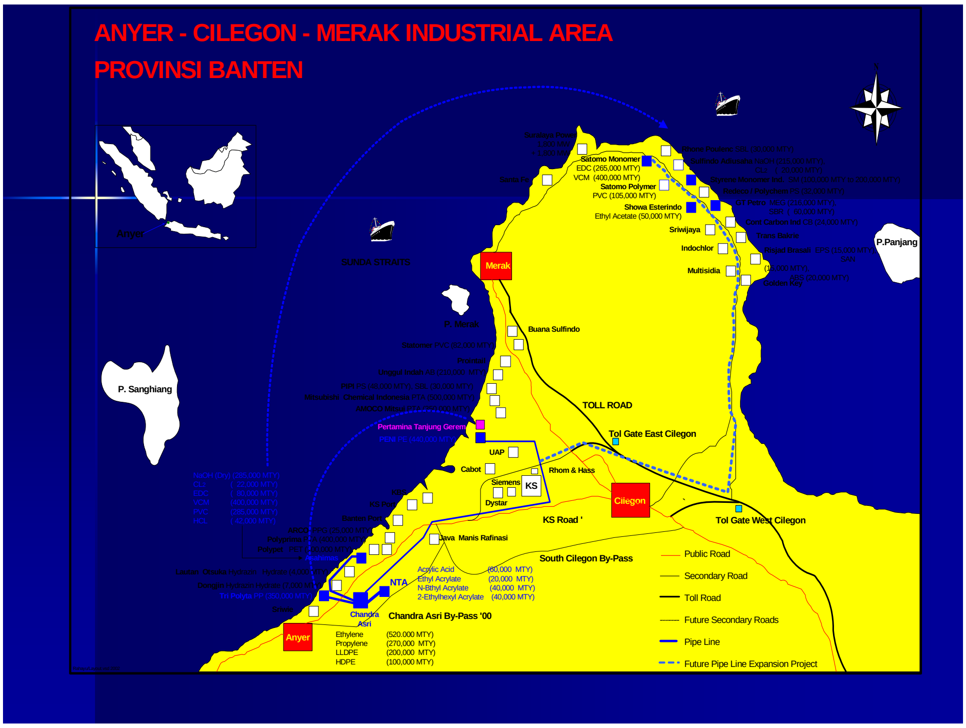


Figure 3.1.2-1　　Cilegon & Merak Industrial Zone

(Source : Seminar document by PT Chandra Asri)

The Following Figure shows the products flow chart of the Petrochemical Complex of PT Chandra Asri.

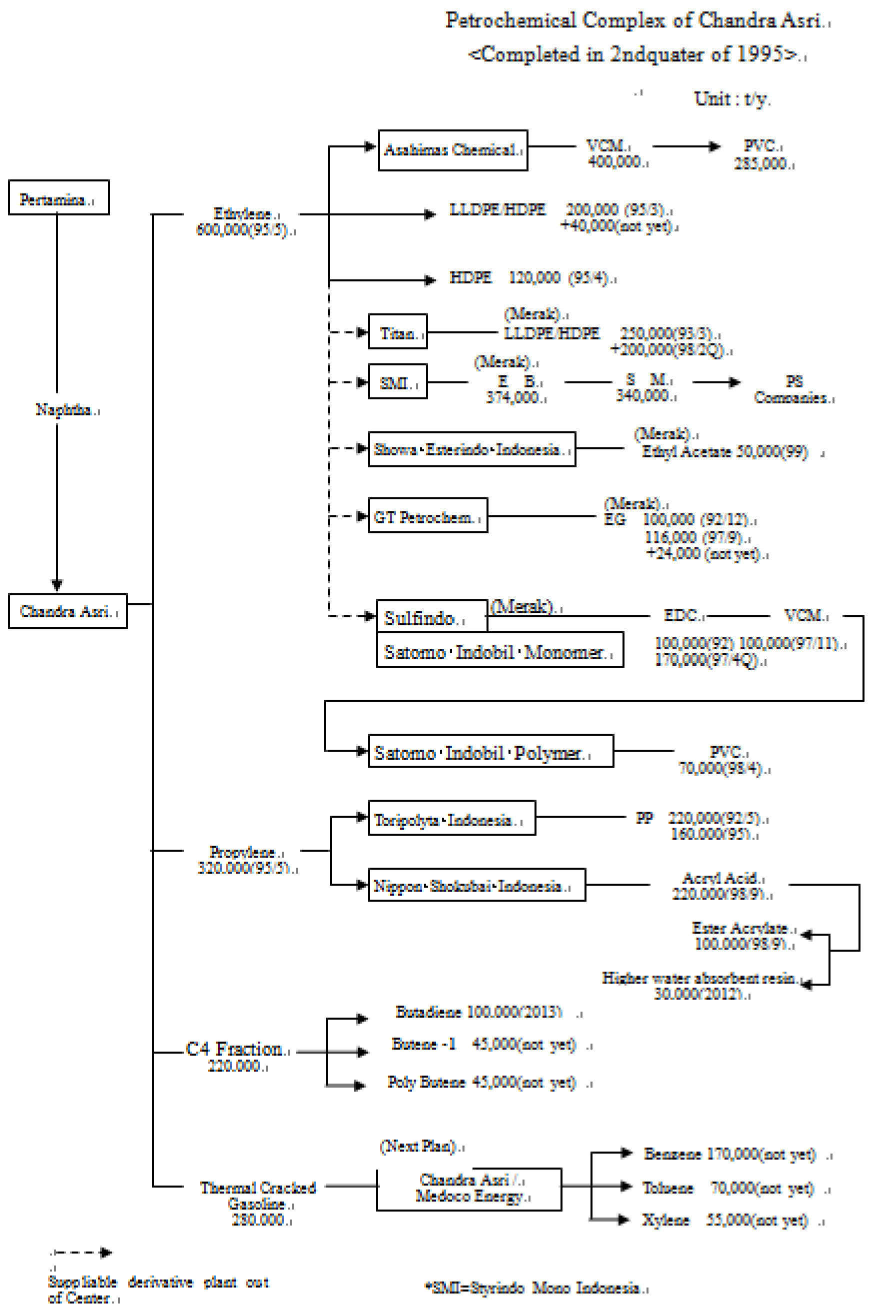


Figure 3.1.2-2 The petrochemical Complex of the PT Chandra Asri

(Source : Asian Petrochemical Industry Version 2011)

(2) Petrochemical Complex plan of TPPI/Tuban

The plan was to construct the second petrochemical complex in Indonesia in Tuban, eastern Java, by PT Trance-Pacific Petrochemical Indotama (TPPI) and PT Tuban Petrochemical Industries (Tuban Petro), and the naphtha cracking furnaces to produce 700,000t/y (550,000 t/y initially) ethylene and 280,000t/y propylene is the core plant.
Despite started the construction aiming mechanical completion in October 1999, the construction was suspended in November 1997 at the stage of 45% completed in the olefin plant and 64% completed in the aromatic plant because of the deterioration of the funding. After that, 100,000bpd condensate splitter and aromatics extraction unit were completed in February 2006 and finally the organization have been completed to produce1.10 million t/y kerosene, 189,000 t/y diesel fuel, paraxylene (PX) 500,000 t/y, 120,000t/y ortho-xylene (OX) and 100,000t/y toluene in place. However, they initially started with running about 60 % operation rate and gradually increase the operation rate.

(3) PT Polychem Indonesia

The old name was Yasa Ganesha Puma, and it is the chemical company to whom the Indonesian largest tire manufacturer Gajah Tungal invested 50% and the only mono ethylene glycol (MEG) manufacturer in Indonesia. Singapore investment fund, Garibaldi Venture Fund Ltd, acquired the company and changed the name from PT Petro Chem to the current name and restarted.
In December 1992, 88,000 t/y MEG facility was completed in Bojonegara near Merak West Java and started the operation from the beginning of the next year. Samsung Engineering has constructed with Scientific Design process (SD). And currently, there are 2 lines of units with 216,000 t/y capacity. In addition to 9,500t/y DEG and 450t/y TEG, 30,000t/y ethoxylates with SD technology have been commercialized in accordance with the increase of the lines in 1999. (Constructed by Samsung Engineering, Korea).
The company has established an integrated production system of 45,000t/y Polyester Polymer tip, 43,800t/y short fiber polyester, 63,000t/y POY in Tangerang West Java.
They also operate an integrated production system of 24,850t/y Polyester Polymer tip, 42,000t/y short fiber polyester, 38,150 t/y filament-yarn in Karawang.

(4) PT Styrindo Mono Indonesia (SMI)

SMI was established in June 1990 as a specialized producer of styrene monomer (SM). Equity structure was originally former Tomen Corporation (currently Toyota Tsusho Corporation) 68.42%, Bimantara Group 15.79%, Salim Chemicals 10.53%, former Idemitsu Oil and Chemical (currently Idemitsu Kosan) 5.26%. In April 2007, the Ethylene center company Chandra Asri acquired all the shares of the company to be a subsidiary.

SMI constructed 100,000t/y SM by ABB Lummus process in Bojonegara, near Merak in west Java, and started commercial operation at the end of 1992. (Constructed by Toyo Engineering Corporation (TEC))

Initially, feedstock ethylbenzene (EB) had been imported。 In 1996, the process moved to an integrated production system by completion of 110,000 t/y EB plant by Mobil-Bad Co., Ltd. The current capacities are 400,000 t/y SM and 440,000 t/y EB respectively.

Chandra Asri is also aiming production of aromatic extraction and is planning the next expansion.

(5) PT Asahimas Chemical (ASC)

ASC is the largest chlor-alkali producer in Indonesia established in September 1986.

The equity structure is Asahi Glass Group 52.5%, Rodamas and Ableman Finance 18% each, Mitsubishi Corporation 11.5%.

In June 1988, 130,000 t/y caustic soda production facilities by IAZECJ system of Asahi Glass (Ion-exchange membrane method) started in Anyer, west Java, and then in August 1989, 30,000t/y EDC, 150,000t/y VCM and 70,000 t/y vinyl chloride resin (PVC) started the commercial operation as chlor-alkali plant. (All plants were constructed by Chiyoda Corporation.)

Current capacities are 380,000 t/y caustic soda electrolysis equipment, 400,000 t/y with 2 lines VCM, 240,000 t/y with 3 lines PVC and 285,000 t/y with 3 lines PVC.

The raw material ethylene is bought from not only an ethylene center Chandra Asri but also imported from Saudi PETROKEMYA and the spot market by each of the one thirds and they enhance competitiveness.

In addition, there is a plan to increase caustic soda electrolysis equipment to 500,000 t/y until the first quarter of 2013.

(6) PT Satomo Indovyl Monomer (SIM)

SIM is a VCM producer whose equity structure is Sulfindo Adiusaha (SAU), the manufacturer of electrolytic soda 51%, Sumitomo Corporation 25%, Brenswick, an investment company in Hong Kong owned by the Salim Group 24%. SIM has established an integrated production system for the production of PVC and EDC – VCM (SIP).

Located in Bojonegara, west Java, SIM produces 265,000 t/y EDC and 100,000 t/y VCM including 70,000t/y PVC of SIP. SIM established the integrated production system as downstream facilities of 215,000 t/y electrolytic caustic soda facility. (Krehs constructed.)

Feedstock Ethylene is supplied by Chandra Asri.

(7) PT Showa Esterindo Indonesia (SEI)

SEI was established in August 1997 as a specialized producer of ethyl acetate, 67% share owned by Showa Denko, 30% CV Indo Chemical in local, 14% Tomen, 5% Chin-Ron CLP in Singapore.

SEI completed 50,000 t/y ethyl acetate plant (Max. 70,000 t/y) in the land adjacent to SMI in Bojonegara, west Java and the plant started operation in March 1999. Adopted the ethylene direct oxidation method (The own technology of Showa Denko). (IHI received the order and constructed.)

(8) PT Mitsubishi Chemical Indonesia

The company is a specialized producer of high-purity terephthalic acid (PTA) established in March 1991, 57.4% owned by Mitsubishi Chemical (former Mitsubishi Kasei), 25.5% by Bakri & Brothers of local conglomerate (B & B), 17.1% by Japan Asia Investment Company (JAIC). This company is located at adjacent lands of Ungal Indah in Merak, west Java and has 640,000 t/y PTA plant of Mitsubishi technology. (JGC Construction)

(9) PTMC-PET Film Indonesia (former Bakri Dia-Hoylle)

This company is the joint venture of Mitsubishi Chemical and Hoechst AG, and is a specialized producer of PET chip and film established in May 1995. The share is 95% owned by Wheel Hoechst (currently Mitsubishi Chemical Polyester Film) and 5% by BKC. They produce 250,000 t/y PET film and 520,000 t/y polymerized PET chips in Merak. (Constructed by Hitachi Construction and Samsung Engineering)

(10) PT Amoco-Mitsui PTA Indonesia (AMI)

The company is a specialized producer of high-purity terephthalic acid (PTA), 50% owned by BP Amoco Chemicals, 45% by Mitsui Chemicals, 5% by Mitsui Co., Ltd. They produce 420,000 t/y PTA by Mitsui/Amoco process in the land adjacent to PENI in Merak, west Java. (Chiyoda Corporation received the order and constructed.)

(11) PTPET Nesia Resindo

This company is a specialized producer of PET resin for bottles established in December 1994, 47.1% owned by Toray group, 41.6% by Mitsui Chemical group, 5.8% by local investor, 5.5% by Mitsui Co., Ltd., and produces 75,000 t/y PET resin for bottle in Tangerang.

(12) PT Polysindo Eka Perkasa

The company is a producer of PTA and polyester fiber, 69% owned by Multikarsa Investama of Texmaco Group, the largest India-based fiber maker in Indonesia. They produce 350,000 t/y PTA by Esatman Chemical process in Karawang, west Java located about 60km east of Jakarta, and produce also 330,000 t/y polyester fiber yarn in Karawang and in Semarang, middle Java. Their advantage is that they can consume their products by their own.

(13) PT Polyprima Karyareksa

The company is a specialized producer of PTA in Napan Group, and produces 420,000 t/y PTA in Cilegon, west Java. (John Brown (currently Kvaerner) and Daelim Industrial Co., Lt. (Korea) constructed)

3.2 History of earthquakes and tsunami, damages and future risks

3.2.1 Earthquakes and Tsunamis

(1) Geological and geographical environment in Indonesia

Figure 3.2.1-1 shows the plate tectonic setting around Indonesia. In the south area, the Indian Ocean-Australian Plate moves at a velocity of 6cm/year and forms the Sunda Trench along the line of Sumatra and Java by subducting under the Eurasian Plate. In the east area, plate moves at a velocity of 11 cm/year compressed by Philippine Sea Plate and the Pacific Plate, the tectonic setting is very complicated. Therefore, the earthquakes are frequent from the past in Indonesia.

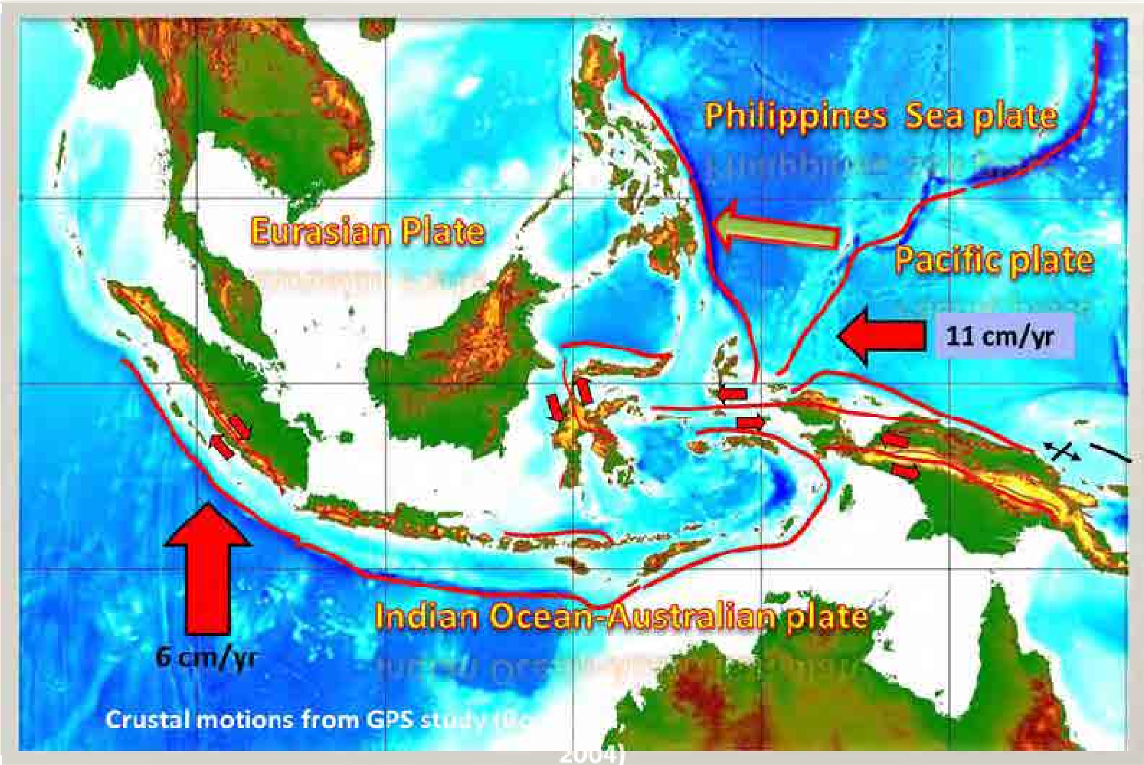


Figure 3.2.1-1 Geological and geographical Environment of Indonesia

(Source : Meteorological Climatological and Geophysical agency of Indonesia (BMKG））

(2) Previous seismic data in Indonesia.

Seismic activities in Indonesia from 1973 to 2011 are shown as red points in Figure 3.2.1-2. There have been many large and small earthquakes, and the epicenters are located along the subducting boundaries formed by the tectonic plates.

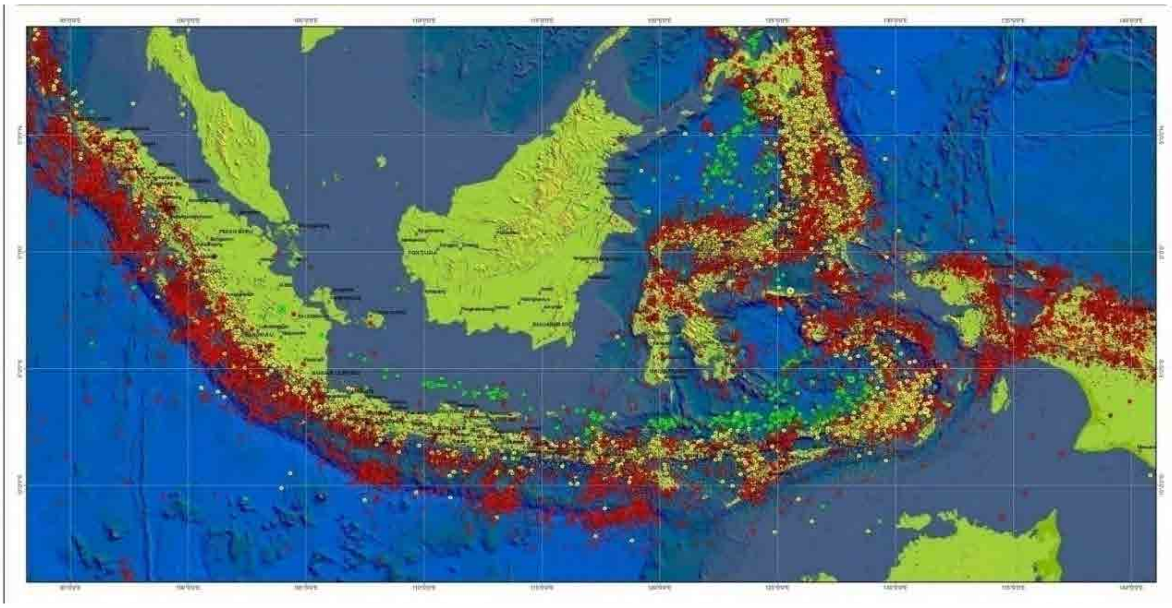


Figure 3.2.1-2 Earthquake activity in Indonesia（1773～2011）

（Source: Meteorological Climatological and Geophysical agency of Indonesia (BMKG））

Figure 3.2.1-3 shows the past large earthquakes and earthquakes with tsunami. A public institution in Indonesia picked up especially large earthquakes within the earthquake experiences. Large earthquakes (yellow points) occur more than once a year, and large earthquakes with tsunami (red points) occur about once every two years.

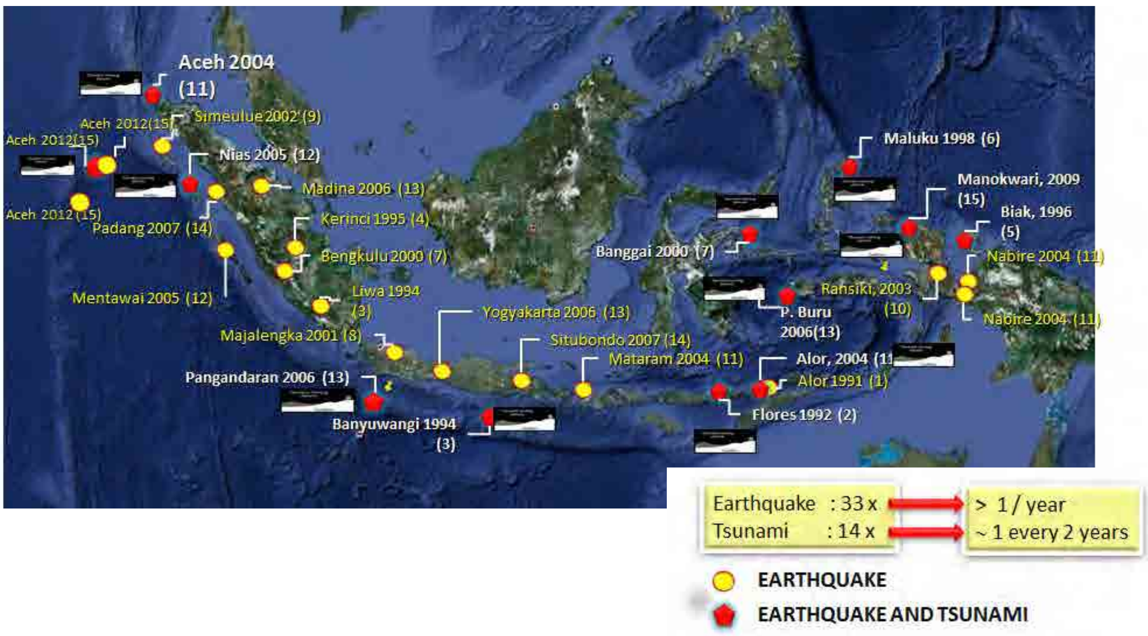


Figure 3.2.1-3 Big Earthquake and Earthquake with Tsunami in Indonesia

（Source: Meteorological Climatological and Geophysical agency of Indonesia (BMKG））

In addition, the following Table 3.2.1-1 is made by the study team based on Figure 3.2.1-3 and shows the location of earthquake, year and whether or not with tsunami by zone.

Table 3.2.1-1 The history of Earthquake in Indonesia

No	Earthquake Zone	year	Epicenter	Tsunami
1	North Sumatra	2002	Simeulue	
2		2004	Aceh	Yes
3		2005	Nias	Yes
4		2006	Madina	
5		2007	Padang	
6		2012	Aceh	Yes
7		2012	Aceh	
8		2012	Aceh	
9	Middle Sumatra	1995	Kerinci	
10		2005	Mentawai	
11	South Sumatra	2000	Bengkulu	
12		2007	Bengkulu	
13		1994	Liwa	
14	West Java	2001	Majalengka	
15		2006	Yogyakalta	
16		2006	Pangandaran	Yes
17	East Java	1994	Banyuwangi	Yes
18		2004	Mataram	
19		2007	Situbando	
20	Eastern Indonesia (Western sea area of Papua New Guinea)	1991	Alor	
21		1992	Flores	Yes
22		1996	Biak	Yes
23		1998	Maluku	Yes
24		2000	Banggai	Yes
25		2003	Ransiki	
26		2004	Alor	Yes
27		2004	Nabire	
28		2004	Nabire	
29		2006	P.Buru	Yes
30		2009	Manokwari	Yes

（Source : Made by investigation team based on the data by Meteorological Climatological and Geophysical agency of Indonesia (BMKG））

In North Sumatra, since the Sumatra-Andaman earthquake off the coast of Aceh occurred in 2004, massive earthquakes have occurred at a high level. Earthquakes with tsunami are characterized by concentration along the Sunda Trench and in the eastern part of Indonesia (western sea area of Papua New Guinea).

3.2.2 Damages caused by earthquakes and tsunamis

The data of the "Occurrence of the earthquake and tsunami in Indonesia" by a public institution in Indonesia has been shown in the previous section. Table 3.2.2-1 summarizes the data based on the information in Japan, US and others, taking into account of “The extent of damage caused by the earthquake and tsunami in Indonesia”.

The massive earthquakes with big damage have occurred in Sumatra. On the other hand, in the region of the eastern reef island, massive earthquakes occurred sporadically, but large to middle-class earthquakes occurred so often. Data is suggesting that even the small and medium-sized earthquake, they often have been accompanied by the tsunami.

Table 3.2.2.-1 Magnitude of Earthquake and Damage situation

No.	Day/Month/Year of Earthquake	Epicenter	M	Remarks (Source:*2)	Source
Northern Sumatra					
1	1935/12/28	-	7.7-8.1	-	*2
2	2002/11/2	-	7.4	-	*1
3	2004/12/26	Off shore of Aceh Sumatra/Andaman Earthquake	9.1	Dead/Missing: More 283,000 The injured: Half a million After this, Great Earthquake occurred so often in Indonesia	*1 *3
4	2005/1/1	Off shore of west coast	6.7	-	*1
5	2005/2/26	Simeulue	6.8	-	*1
6	2005/3/28	Just west side of No.3	8.6	Dead/Missing: 1300-1700 Damaged in wide area	*1 *3
7	2005/4/10	Mentawai	6.7	-	*1
8	2005/5/14	Nias	6.7	-	*1
9	2005/5/19	Nias	6.9	-	*1
10	2005/7/5	Nias	6.7	-	*1

No.	Day/Month/Year of Earthquake	Epicenter	M	Remarks (Source:*2)	Source
11	2005/11/19	Simeulue	6.5	-	*1
12	2006/5/16	Nias	6.8	-	*1
13	2007/9/12	Mentawai	7.9	-	*1
14	2008/2/20	Simeulue	7.4	-	*1
15	2009/8/16	Mentawai	6.7	-	*1
16	2010/4/7	Off shore of west coast	7.8	The injured: A little Small Tsunami	*2
17	2010/5/9	-	7.2	-	*1
18	2012/4/11	Off shore of west coast	8.6	Dead: A dozen	*1
19	2012/4/11	Off shore of west coast	8.2		*1
Middle of Sumatra					
20	2010/10/25	Off shore of west coast	7.5-7.7	Dead/Missing: More than 700 Tsunami: In Mentawai	*2
Southern Sumatra					
21	2000/6/4	-	7.9	Dead/Missing: More than 100	*1
22	2004/7/25	-	7.3	-	*1
23	2007/3/6	-	6.4	-	*1
24	2007/8/5	-	8.5	Dead/Missing: 2 Small Tsunami	*1
25	2007/9/12	Bungle province	8.5	Dead: 25	*3
26	2007/9/20	-	6.7	-	*1
27	2007/10/24	-	6.8	-	*1
28	2009/9/30	-	7.5	Dead/Missing: 1200 – A few thousand The injured: many Great damage in Badan	*2
29	2009/10/1	-	6.6	-	*1
Java					
30	1943/7/23	Off shore of the middle of Java	7.6-8.1	Dead:210 Damaged in Yogyakalta	*2
31	1994/6/6	-	7.8	Dead:More 27 Tsunami	*2
32	2006/5/26	-	6.3	Dead:5800 The injured: More	*1 *3

No.	Day/Month/Year of Earthquake	Epicenter	M	Remarks (Source:*2)	Source
				than 30,000 70-80 % of Building destroyed	
33	2006/7/17	South- east of java	7.7	Dead/Missing: More than 850 Tsunami	*1
34	2007/8/8	-	7.5	-	*1
35	2009/9/2	West Java	7.0	Dead:81 Missing:47	*1 *3
Eastern Area of Indonesia					
36	1932.5.14	Molucca Sea	8.0-8.3	Dead;5～many	*2
37	1938/2/1	Banda Sea	8.5	Big Tsunami	*1
38	1948/3	Ceram Sea	7.9	-	*2
39	1950/11/2	Banda Sea	7.4-8.1		
40	1963/11/04	Banda Sea	7.8-8.2	-	*2
41	1965/1/24	Ceram Sea	7.6	-	*1
42	1971/1/10	Irian Jaya	7.9-8.1	-	*2
43	1976/6/21	Papua	7.1	-	*1
44	1977/8/19	Sumbawa Sumbawa Earthquake	8.2-8.3	Dead/Missing:180, Big tsunami	*2
45	1979/9/12	Irian Jaya	7.5-7.9	Dead:15	＊2
46	1992/12/12	Flores Island Flores Earthquake	7.8	Dead/Missing More than 2500、 Tsunami :Max25m	*1
47	1996/2/17	Irian Jaya	8.1-8.2	Dead/Missing :170 Big Tsunami （6-7m）	*2
48	1996/6/17	Flores Sea	7.3	Dead/Missing :14 Small Tsunami	*2
49	1998/11/29	Ceram Sea	7.7	Dead: 40, Tsunami	*2
50	2001/10/19	Banda Sea	7.5	-	*2
51	2002/10/10	Irian Jaya	7.6	-	*1
52	2003/5/26	-	7.0	-	*1
53	2004/1/28	Ceram Sea	6.7	-	*1
54	2004/2/5	Irian Jaya	7.0	-	*1
55	2004/2/7	Irian Jaya	7.5	-	*1

No.	Day/Month/Year of Earthquake	Epicenter	M	Remarks (Source:*2)	Source
56	2004/11/26	Papua	7.1	-	*1
57	2005/3/2	Banda Sea	7.1	-	*1
58	2006/1/27	Banda Sea	7.6	-	*1
59	2006/3/14	Ceram Sea	6.7	-	*1
60	2007/11/25	Sumbawa Area	6.5	-	*1
61	2009/1/3	Northern shore of Papua (New Guinia)	7.4	-	*1
62	2009/2/11	Kepulauan Talaud	7.2	-	*1
63	2009/8/28	Banda Sea	6.9	-	*1
64	2009/11/8	Sumbawa Area	6.6	-	*1
65	2009/10/24	Banda Sea	6.9	-	*1
Northern part of Indonesia					
66	1938/5/19	Celebes	7.6-7.9	Dead: many	*2
67	1939/12/21	Celebes	7.8-8.6	-	*2
68	1996/1/1	Celebes	7.6	Dead:8, Tsunami	*2
69	2005/2/5	Celebes	7.1	-	*1
70	2005/2/19	Celebes	6.5	-	*1
71	2000/5/4	Celebes	7.4-7.6	Dead/Missing :50	*2
72	2008/2/25	Kepulauan Mentawai Area	7.2	-	*1
73	2008/11/16	Minahasa Celebes	7.4	-	*1
74	2009/10/7	Celebes	6.8	-	*1

(Source : Made by investigation team based on the data by

*1 USGS Home Page, Magnitude 6.0 and Greater

*2 G-ma Area Research Series／E-005, Main big Earthquake in the World)

*3 Asian Disaster Reduction Centre)

3.2.3 Future risks

Based on the past seismic disasters shown above, the Indonesian government divides the country into six Zones depending on the degree of risk (Figure 3.2.3-1). The red area is the most dangerous.

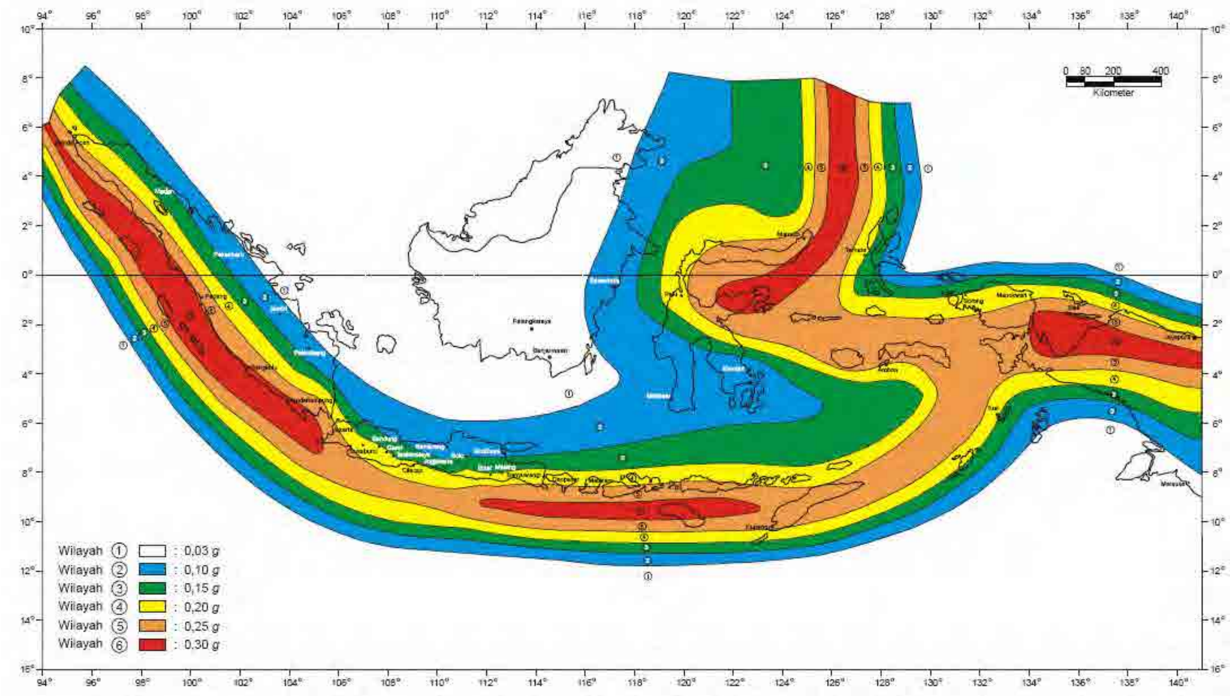


Figure 3.2.3-1 Seismic Hazard Map of Indonesia (SNI-03-1726-2002)

(Source: Research institute for human settlements, agency for research and development ministry of public works – Indonesia (PUSKIM))

The area of the Trench around the western coast of Sumatra is the most high-risk area, and the 100 years Seismic Gap Hypothesis is proposed (Figure 3.2.3-2). According to this hypothesis, the earthquake of about magnitude 7.9 is expected in the future 100 years around off the coast of Aceh in the northwestern Sumatra because the stress has been released by the super massive earthquake (magnitude = 9.1) in 2004. On the other hand, massive quakes of about magnitude 8.5 are forecasted to occur in southern area of around the Sunda Strait, which is located between Sumatra and Java.

The Seismic Moment Rate based on GPS data around the Sunda Strait is shown in Figure 3.2.3-3.

The red area is more stressed, and earthquake-prone.

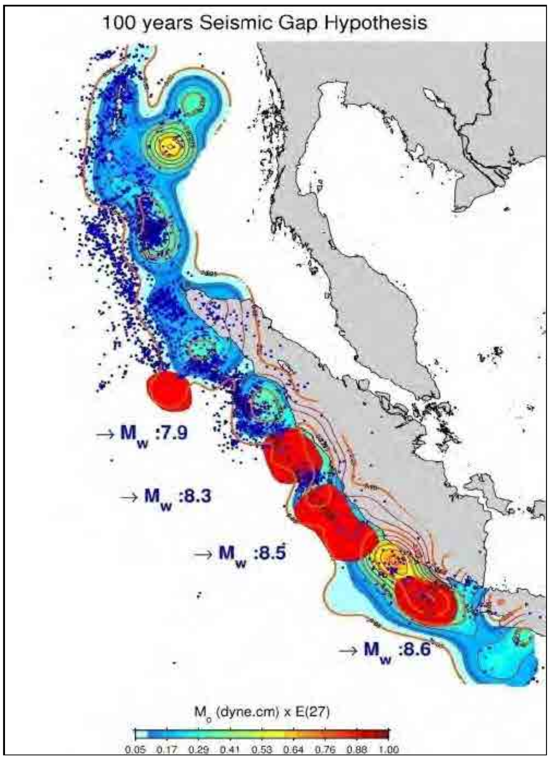


Figure 3.2.3-2 Seismic Gap Hypothesis by 100 yeas unit (Source: BPPT)

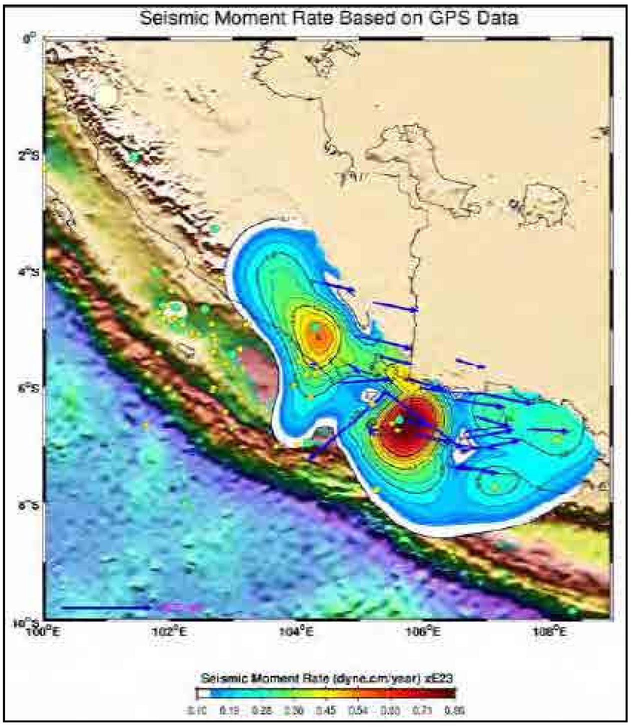
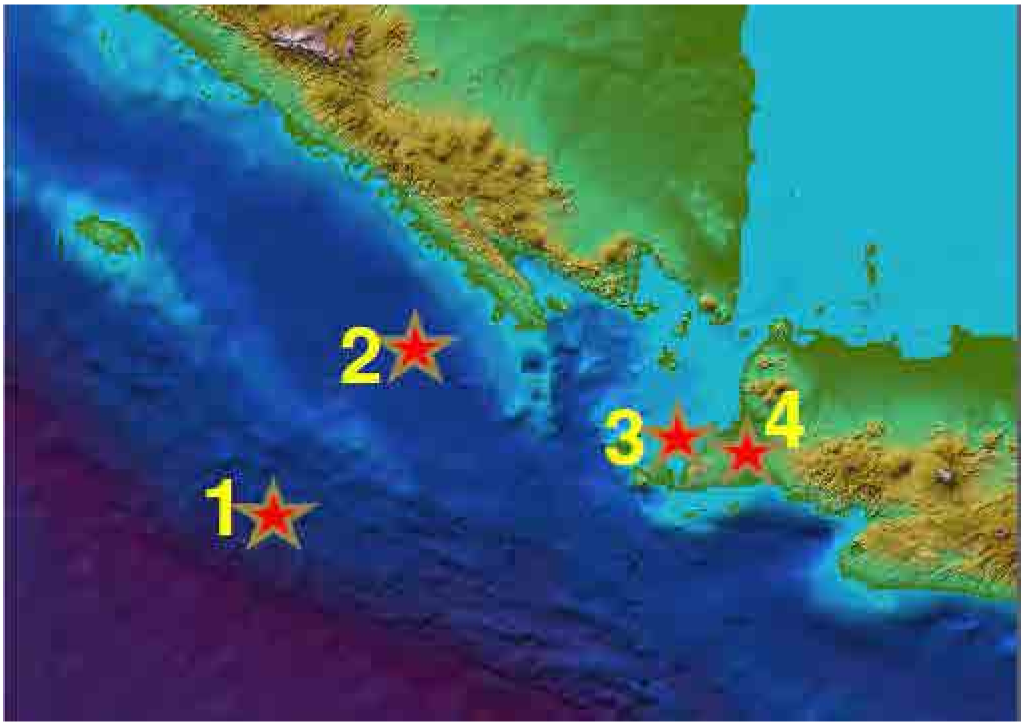


Figure 3.2.3-3 Seismic Momentum Rate By GPS Data （Source: BPPT）

The largest industrial area in Indonesia, Cilegon & Merak Industrial Zone (Figure 3.1.2-1), faces to the Sunda Strait. Four case studies have been carried out in the event of a seismic occurrence around the Sunda Strait where the ground is under stress (Figure 3.2.3-4).



Skenario	Mw	Epicenter		L (km)	W (km)	D (m)	Strike	Dip	Slip	Depth (km)
1	8.6	102.94	-6.89	300	80	10	320°	145°	83°	10
2	8.6	104.13	-6.22	300	80	10	320°	105°	83°	60
3	7.5	105.44	-6.50	100	40	7	215°	8°	83°	10
4	7.5	105.91	-6.67	100	40	7	215°	8°	83°	10

Figure 3.2.3-4 Study on seismic Scenario around Selat Sunda

（Source : BPPT）

Although magnitude has not been stated, Figure 3.2.3-5 is a simulation of propagation situation of the tsunami by every 5 minutes, in a case when the earthquake has occurred in the area around 7 degrees south latitude and 105 degrees east longitude.

Tsunami is forecasted to reach to Merak after 1 hour and 15 minutes and to Eretan after approximately 4 hours and 10 minutes.

The size and height of the tsunami will be related to the magnitude and terrain.

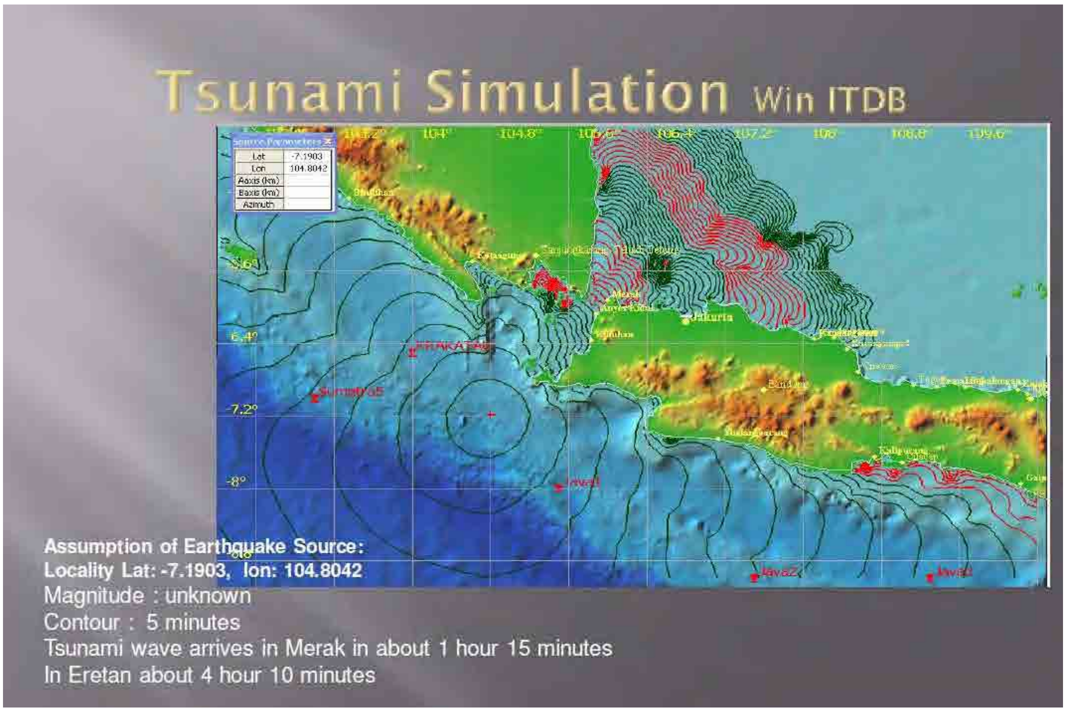


Figure 3.2.3-5 Tsunami Simulation around Selat Sunda （Source : BPPT）

In Indonesia, volcanic activity, along with the frequent occurrence of earthquakes, is also active as well as in Japan. The volcano Krakatoa, which is famous for the great eruption in the past, is located at the center of the Sunda Strait.

As a result of discharging large amounts of ejects with the earthquake at the great eruption of May 20, 1983, wide caldera was generated. Tsunami occurred at the same time and 36,417 people died in the great eruption.

3.3 Seismic code for petroleum refinery and petrochemical plant in Indonesia

(1) History of seismic code

Seismic design code and standard of the Indonesia is based on UBC (Universal Building Code) of the United States, and UBC seismic design load including seismic is based on idea of ASCE7-2010 (Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers). The latest version of SNI-02-1726-2002 is currently in revision work. Revision of Earthquake Zone Mapping in each area is enacted.

(2) Structures to be applied of Seismic Design Code

Structures under application of seismic design code TSNI-02-1726-2002 is buildings and structures under the jurisdiction of the Department of Public Works. Tank and similar plant facilities are under the jurisdiction of the Ministry of Industry, and the following US standards shall apply.

Pressure vessel	:	UBC (Zone factor SNI)
Tank	:	API650 Appendix E
Piping	:	ASME B31.3

(3) Earthquakes to be considered

The seismic design code of Indonesia (SNI-1726-2002) categorizes the country into 6 seismic zones from the PGA of 0.03g to 0.3 g by Indonesian PGA map. PGA of each seismic zone was categorized by 4 soil conditions from 0.04 g to 0.38g. To calculate the design PGA, the seismic response factors are stipulated for the 6 categories of seismic zone and 3 conditions of soil based on the reproduction period 500 years of earthquake.

Reference is made to the Appendix I "Indonesian Seismic Design Code (SNI-1726-2002" for more detail including the following items.

(4) Seismic Performance to be provided

Five type of importance factor is stipulated for the importance of building. The reduction factor depending on the degree of ductility of structures is applied.

(5) Design Method

Design method of standard building structure is applied.

(6) Evaluation Method

Evaluation is conducted by comparing allowable stress calculates structure based on shear and lateral force applied to members.

3.4 Disaster prevention planning & organization and security for plants

3.4.1 Hazard map of earthquake

In Indonesia, the government has drawn the seismic hazard map and promotes awareness to peoples. The first version was made in 1983 and thereafter revised several times, and currently used one is the Indonesian seismic hazard map (SNI-03-1726-2002) made in 2002 (Figure

3.2.3-1). It is now under further revision. For details, such as the transition from the past, are described in section 3.6.1 hereafter.

3.4.2 The early warning system for earthquake and tsunami

In Indonesia, 160 broadband seismometers have been installed as the early warning system and network have been formed (Shown in Figure 3.4.2-1 below).

The net work has been constructed along the earthquake-prone area, or so as to surround it.

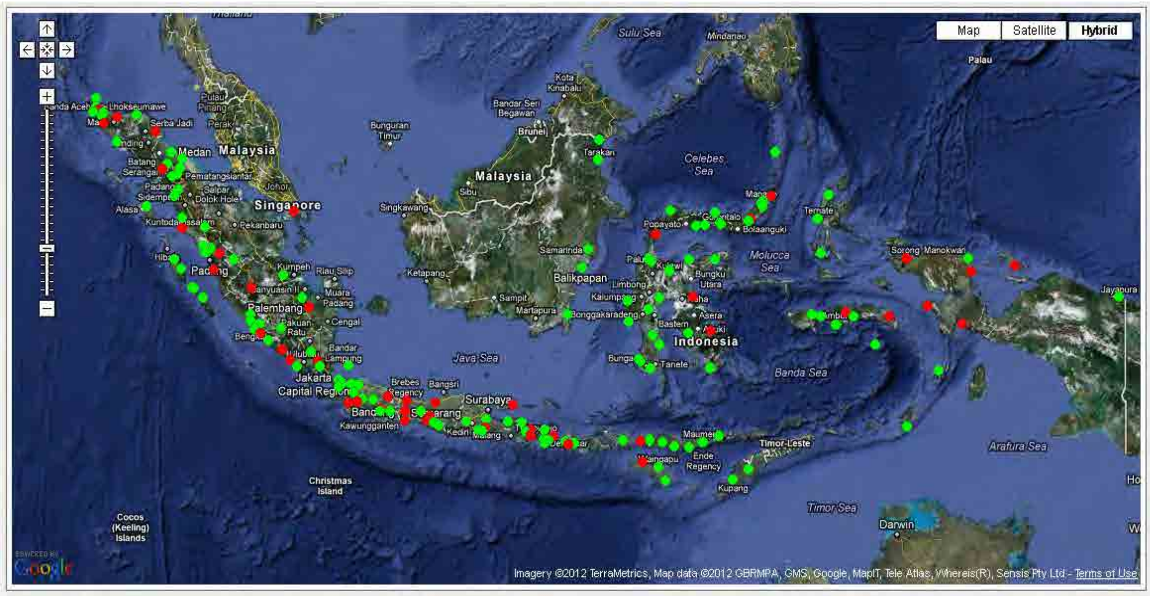


Figure 3.4.2-1 Seismometern Network System of 160 stations in Indonesia

(Source : BMKG)

3.4.3 Examples of disaster countermeasure in some companies

(1) PetroChina International Jabung Ltd (Betara Gas Complex)（Gas processing business）

1) Outline of the business

The company is located to 50km northeast of Jambi in central Sumatra in the straight-line distance. They integrate gas fraction from a number of surrounding gas field and carries out fractionation and refining. Fractions of raw material gas are C1, C2, C3, C4 and condensate and contains about 40% of CO_2 with no H_2S and amine processing has been required.

Production volume : As Liq. …23,000bpd

As Gas …100MMSCFD

2) Earthquake history and seismic Countermeasure

- There are some kinds of disaster such as earthquake, other natural disasters and fire, and the biggest concern is earthquake as a company located in the central part of Sumatra.
- In Sumatra, there are active volcanoes on the Indian Ocean side, and rain flows straight to the Malacca Straits side. The plant is located at the middle area of rivers and the ground is not the alluvium and is relatively solid.
- When the tsunami occurred by the great earthquake (M = 9.1) in Aceh of North Sumatra in 2004, the plant was under construction. The information about the quake was unknown but there was no damage by tsunami because the plant site was located at the other side of Sumatra.
- When earthquake (M = 8.5) in Bengkulu occurred in 2007, the plant was in operation and towers and vessels were shaken violently because the plant site was located only 200 ~300km away from the epicenter. There was no damage such as deformation, displacement and leakage in the building structures, towers and vessels, piping and pipeline. Although soil was soft clay but there was no liquefaction. Problem in well of gas, located 100km away, was doubted but there was no problem by the results of the investigation.
- The pile foundation has been adopted for the foundation of the plant.
- UBC 1997 Standard has been applied to the seismic design.

3) Disaster Prevention Countermeasure

- As the country's disaster prevention countermeasures, Indonesian Government Regulation has been established.
- As for the factory, Emergency Response Plan (ERP) has been established.
- Field Manager will usually determine the shutdown of the plant, however, in case of emergency, anyone can press the button for the shutdown. In that case, block and depress the plant at first, then evacuate employees. When the plant shut down, it has to be reported to MIGAS which is the supervisory authority in the circumstances.

(2) PT. Mitsubishi Chemical Indonesia（MCCI）（Merak plant）

1) Outline of the business

The plant is the first factory among Mitsubishi overseas factories and located on the coast of Merak in Cilegon, in the peninsula of 110km west of Jakarta. At the time of construction, there was no Infrastructure and it was the entirely grass roots plant in which all electricity, water and other utilities were developed in house.

More than 50 companies in chemical industry mainly, are located in this coastal region. These include the affiliates of Chandra Asri, Asahi Kasei, Mitsui Chemicals, Showa Denko and Nippon Steel Chemical, and so on.

Shinko Plantec is also located there in engineering field. As a recent topic, POSCO is planning an integrated steelworks and Lotte has also plans of refinery. The penetration of Koreans is remarkable.

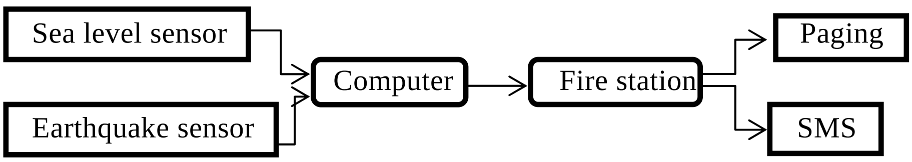
Site area of MCCI = 34ha, Production = 600,000 t/y PTA , 600,000 t/y PET.

2) Earthquake history and seismic countermeasure

- Major earthquake has never felt in this area. Related to the tsunami, there is a legend of a tsunami of 30 m height by the explosion of a submarine volcano.
- As far as MCCI knows, there is no plant that has the problem of the structure in petroleum refining and petrochemical plant in this area.
- JGC made the BEDD (Basic Engineering Design Data) of TPA facilities in 1990.
- The MCCI has the comparison table of seismic design criteria (provisions of Japan, examples of existing plants in Japan, the design conditions of the plant in Indonesia) and has a strong interest for earthquake resistance.

3) Disaster Prevention Countermeasure

- Scenarios for natural disasters and emergency response are set as follows.
- After Earthquake and Tsunami in Aceh in 2004, MCCI has established the "Earth Quake & Tsunami Warning system" in 2005. The outline of flow is as follows.



And they also take the following responses by the level of earthquake.

Level :1	20 gal>	Operation continued
Level :2	20 gal <= <40 gal	Continue to operate if there is no damage
Level :3	40 gal <= <79 gal	Process stop, Utility operation
Level :4	80 gal <=	Total Shut down

- Emergency shutdown of the plant is carried out manually but it never has been stopped in the previous operation. SMS alarms sometimes.
- As a countermeasure against tsunami, simulation has been implemented by assuming the water flooded area in depth of 5m and 10m.

The escape route and place have been decided and training is performed.

4) Others

- With respect to maintenance, safety inspection related to the pressure vessels etc. is not ruled by laws or regulations.
- MCCI has been conducting a periodic inspection once a year on the same level in Japan but every two years in recent years. In Indonesia, maintenance is performed by the owner in a various intervals such as four-year or five-year from each time of the lowest level failure.

(3) PT REKAYASA INDUSTRI Engineering & Construction : Head Office（Engineering）

1) Outline of the business

REKAYASA is the leading integrated engineering company in Indonesia, and the main business is the design, procurement and construction of gas, oil and petrochemical plants.

2) For seismic design of non-building structures in Indonesia

- Although there is no description of the seismic resistance design method for non-building structures, such as pressure vessels, tanks, piping etc, in the Seismic Resistance Design Standard for Buildings (Standard Perencanaan Ketahanan Gempa Untuk Struktur Bangunan Gedung) or SNI-02-1726-2002, which is the seismic design code of Indonesia. The following information has given as the actual situation of the seismic design of these non-building structures.

  * Only Zone factor is in accordance with SNI-02-1726-2002. Chose the Zone from the UBC, which is equivalent Zone factor to that of the SNI-02-1726-2002. After then, calculation has been done along the UBC, by using the internationally and commercially available design software.

  * Tanks are calculated along API 650 Appendix E, and piping is along ASME B31.3.

- As for the differences of response spectra between SNI-02-1726-2002 and UBC, the maximum response scale factor of both SNI-02-1726-2002 and UBC are the same, but the extent of the maximum response scale factor can be different, that means the difference between SNI-02-1726-2002 and UBC comes out in case of more than 40 m height structure.

  In that case, the building structures shall be amended and the pressure vessels shall be designed along UBC. The customer hopes to apply UBC.

3.5 Investigation of actual seismic design

In Indonesia the national seismic design code SNI-1726-2002 (the latest edition was issued in 2002) exists. That was established with reference of American standards such as UBC or IBC. Therefore, Indonesian seismic design code is consistent with UBC. Accordingly it is possible to design non-building structures against seismic loads applying UBC, although SNI-1726-2002 does not cover non-building structures.

REKAYASA, who is one of largest engineering companies in Indonesia, said that they usually do seismic design of building and non-building structures using international commercial software, which does not cover Indonesian seismic design code, applying UBC with equivalent zoning factor and soil factor to Indonesian code. There are some small differences between SNI-1726-2002 and UBC on seismic response curves at longer vibration period. Structural engineers usually add some modifications in such a case. But pressure vessel engineers neglect the differences because such differences are negligibly small.

Thus, seismic design of plant facilities in Indonesia is actually done applying UBC. However, engineers in Indonesia are not confident about continuous using of UBC, because UBC is an old code and it has not been revised since 1997.

Draft of revised edition of SNI-1726-2002 was issued in 2010 but it has not been authorized.

3.6 Simulation for damage of plants due to estimated seismic load and improvement plan

The study team investigated the seismic design codes and the seismic hazard maps in Indonesia, estimated the damage of the plants designed by these codes and maps, and analyzed problems and recommended plans for improvement.

3.6.1 History of seismic design code for plants and seismic hazard map

Seismic design code for plants has not been established in Indonesia. History of seismic design code for buildings and seismic hazard map is as follows.

(1) PPTI-UG-1983 “Indonesian Earthquake Resistant Design Code for Building”
- Hazard Map：Refer to Figure3.6.1-1. In this reference zoning is shown but values of PGA are unknown.

(2) SNI 03-1726-1989 “Earthquake Resistant Design Method for Houses and Buildings”
- We do not get this standard.

(3) SNI 03-1726-2002 “Seismic Resistance Design Standard for Buildings”
- Design Code : This code was established with referring to UBC 1997.
- Hazard Map : Refer to Figure3.6.1-2

(4) Working for revision of this code is pushed forward, and drawing up of draft is completed.
- Design Code : This code will be revised with referring to latest IBC.
- Hazard Map : Refer to Figure3.6.1-3. This map is opened to the public at 2010, but not used for seismic design.

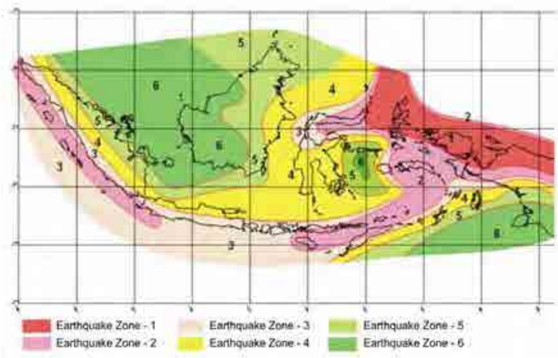


Figure 3.6.1-1 PPTI-UG 1983 PGA Map
（source:"Summary of Study:Development of Seismic Hazard Maps of Indonesia for Revision of Hazard Map in SNI 03-1726-2002"）

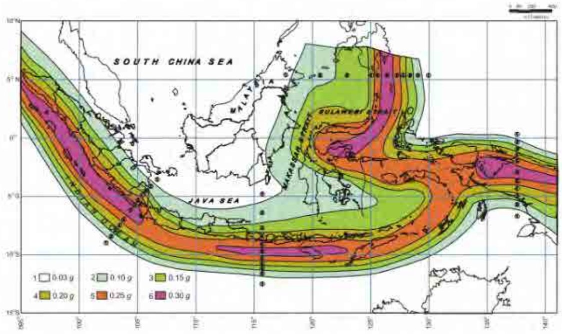


Figure 3.6.1-2 SNI-1726-2002 PGA Map
Exceedance probability 10％ between 50 yrs（return period 475 yrs）
（ source: "Seismic Resistance Design Standard for Buildings"）

Figure3.6.1-3 PGA Map Revised at 2010

Probability of exceedance 10％ between 50yrs（return period 475yrs）

（source: "KEMENTERIAN PEKERJAAN UMUM"）

3.6.2 Outline of seismic design code

In the seismic design of the ordinary buildings, the study team used to calculate the lateral force on the buildings due to the design earthquake and select the structural members of the building.

The outline of the calculating method of the lateral force acting on the building due to earthquake is shown in Attached document I of SNI-1726-2002. In this code, the lateral seismic design force is prescribed from five parameters as follows.

(1) Peak ground acceleration at the top of the seismic bedrock[1)] is given in the PGA of the seismic hazard map. (refer to Figure3.6.1-2)

(2) Seismic response factor indicates earthquake amplifying at the outer layer of the ground, and is given in the function of the soil profile type and the first natural period of the structure. (refer to Figure3.6.2-1)

(3) Importance factor indicates charging an extra of the seismic force, and is given for the usage category of the structure.

(4) Seismic reduction factor indicates reducing of the seismic force, and is given for the ductility2) of the structural system.

(5) Total weight of the building including an appropriate portion of the live load.

1) seismic bedrock : rock with hard stiffness that is not affected by amplification and dispersion of vibration at the outer layer of the ground.

2) ductility : performance absorbing seismic energy by the character that the material of the structure is plastically deformed.

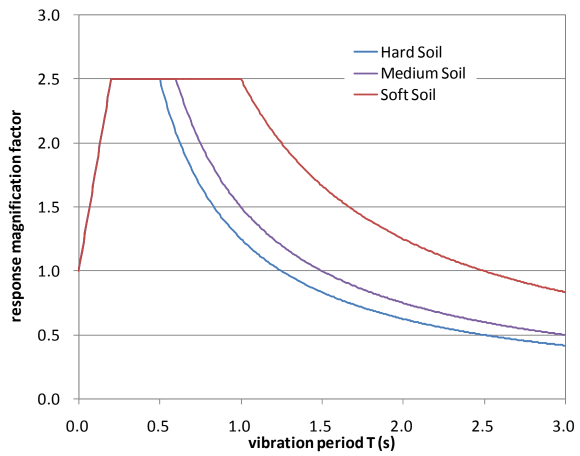


Figure3.6.2-1 Response Magnification Factor of the Seismic Design Response Spectra

3.6.3 Prediction of the damage

Among the five parameters at 3.6.2 which prescribe the lateral seismic design force, (1)～(4) are prescribed by the seismic design code. For the factor (1) the study team compares the history of the PGA map and for the factor (2)～(4) the study team compares the design base shear expressions between SNI and ASCE 7-05 (American Society of Civil Engineers). Then we will predict possibility of the damage from the magnitude of the design base shear (total lateral force at the base).

(1) Hazard map has been revised on the latest seismic observation and seismology investigation, and the values of PGA become larger. Therefore when the PGA values are different between old and new seismic hazard maps of the site, there is some possibility of no fitting in the latest map. So it is desirable for the plants designed by the older map to check seismic performance and plan adequate reinforcement.

(2) As the study team has no older seismic design codes than 2002 edition, it is not declared whether there is the seismic performance of the plants designed in these codes. However, in these codes values of PGA may have been further less and no engineering knowledge about items of 3.6.2(2)～(4) may have been adopted. Therefore seismic performance of the plants designed in these codes may be worse than those designed in 2002 edition.

(3) Structural type and framing system of some plant structures or equipments are not applicable to the building seismic design code. So it is desirable to build up design the code for them referring to the foreign seismic code applicable to plants.

(4) For some of the plant structures or equipments their usage categories are not applicable to the building seismic design code. When the damage of their plants may have a bad influence on the safety at the circumstance, importance factor depending on the extent of the risk is considerable at the seismic design. However, as such influence is not considered in the building seismic design code, it is desirable to build up the code considering such influence.

3.7 Level check of plant seismic technologies in Indonesia

In the earthquake and Tsunami observation system of Indonesia, BMKG (Metrological Climatological and Geophysical Agency) equivalent to the Meteorological Agency of Japan, are carrying out the technology exchange with Japan and other foreign countries. Moreover, in plant engineering companies like REKAYASA and IKPT(PT Inti Karya Tehnik), they have implemented more or less seismic design and construction for plants. These companies have collaborated with Japanese or overseas plant engineering companies in the past and also presently, and they have aimed at improvement in technology. However, in LNG, oil refineries, and large-scale petrochemicals plants, design and construction works of the plant are made in the combination of overseas contractors and the domestic plant engineering companies still now. Moreover, about disaster prevention plan, there is the organization like BNPB (National Agency for Disaster Management), and the organization to disaster prevention has been established. Thus, Indonesian people have deep concern for seismic engineering because of an earthquake-prone country in Indonesia.

Since Indonesia is the earthquake-prone country where also volcanic activity is active fundamentally, there are many scholars and researchers who get interested in earthquake, and they are eager for the creation of seismic code, and amendment. And many large-sized oil refineries, natural-gas-liquefaction plants, and petrochemical plants exist in Indonesia. However, those mostly were designed and constructed by major engineering companies like overseas plant engineering companies or domestic REKAYASA. Moreover, in those plant engineering companies, each equipment is designed by the engineers of each department using the application of the seismic design code of the United States like UBC and using international design software. Therefore, the engineers in charge have been working with little attention to the seismic design code of Indonesia itself. And there is problem of discrepancy between Indonesian code and actual seismic design. It is necessary to provide the seismic design code for non-building structure.

3.8 Enlightenment activities for seismic measures

3.8.1 Outline of seminars

（1） The First Seminar

Date： June 20, 2012

Venue： Conference room of BPPT

Subject： The following four themes were presented by JICA team with an emphasis on introduction of disaster prevention and seismic technology of Japan for broad participants.

-1- Outline and Plan of the JICA Project

-2- Overview of Japanese Seismic Technologies

-3- Japanese Seismic Laws and Codes for Plant Engineering

-4- Disaster Management in Japan

On the other hand, a more specific review of tsunami and earthquake in seismic design codes in the Indonesia observation system, selection of LPG Terminal, was presented from Indonesia side.

Participant : 65

Q & A : The questions were raised actively, on the presentation of Japanese side, such as seismic design criteria for the model of soil liquefaction, seismic design code for underground storage tank, equipment stopping criteria on earthquake, BCP standard and prevention of secondary disasters were raised actively.

(2) The Second Seminar

Date : September 7, 2012

Venue : Conference room of BPPT

Subject : The mission presented the following four themes based on previous research findings from more tangible subjects.

-1- Insight about the JICA Seismic Technology Study Project

-2- Proposal of Seismic Design Methods for Plant Facilities in Indonesia and Introduction of Seismic Assessment Methods for Existing Plant Facilities in Japan

-3- Comparison of seismic design results based on various national codes

-4- Disaster Prevention System of Refineries in Japan

The themes on directly related to business were presented from Indonesian companies such as seismic design factor from Pertamina and petroleum chemical plant disaster from Chandra Asri.

Participant : 70

Q & A : Discussion is made actively on themes such as Pertamina, seismic assesment and seismic engineers develop methods of disaster prevention system. Because the date was Friday, time constraints, it could not be carried out disaster-related questions and answers.

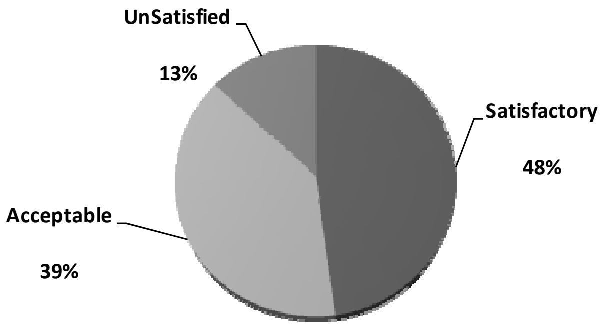
3.8.2 Summary of questionnaire on seminar

The questionnaires were distributed to the participants at registration process at this seminar and recovered it at the end.

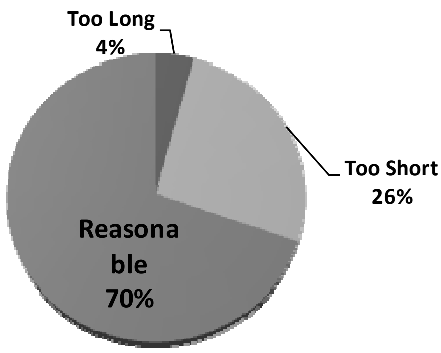
(1) The First Seminar

1) Summary of Questionnaire

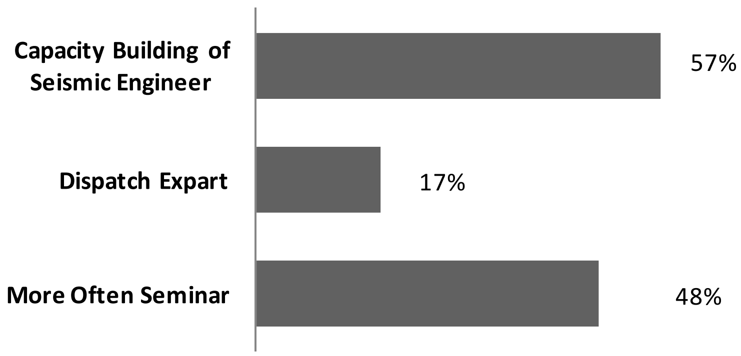
① Content of Seminar：



② Length of Seminar：



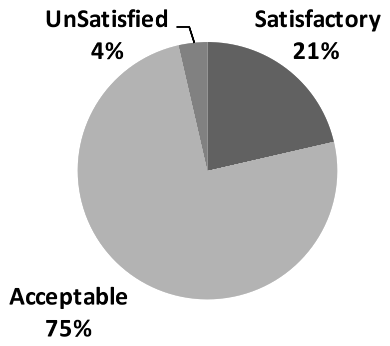
③ Request to Japanese cooperation：



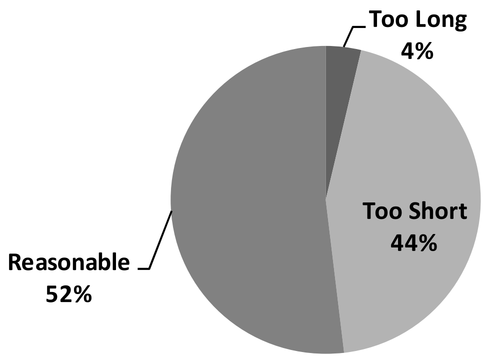
(2) The Second Seminar

1) Summary of Questionnaire

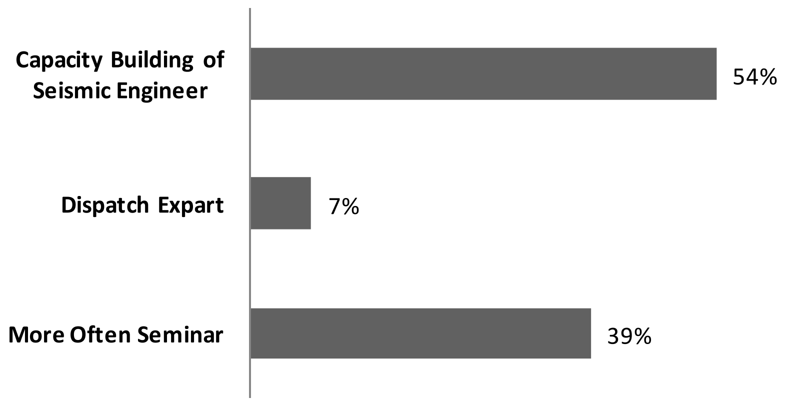
① Content of Seminar:



② Length of Seminar：



③ Request to Japanese cooperation:



3.8.3 Summary of seminar

Nearly 70 participants attended to the first seminar held on June 20 in Indonesia, and active discussion has been made. The broad and general themes of seismic technology understandable to a broad audience were introduced. The contents included fundamentals, therefore, some experts requested to know more state of art Japanese technology. In the second seminar held on September 7, the study team conducted more specific disaster prevention system technology in Japan, law used in seismic risk management considering seismic diagnostic procedures, Life Cycle Cost, and design effects due to seismic design criteria for the three countries, the Japanese oil refinery and petrochemical plant design and construction, seismic design standards, refinery in response to the request. It is evident that they are interested in Japanese seismic technology through the two seminars. The summary of answer on the questionnaire of seminar is in the Appendix VIII. There are comments by the attendants said that latest technology was included, contents was adequate, it was short of time, it was not enough discussion and talk time. There were a lot of opinions that they expect of more frequent seminars.

3.9 Needs and requests in Indonesia

In Indonesia, from the result of the questionnaire, they want to hold more frequent seminars like the seminars held during the study. When JICA study team held the seminar in Jakarta, WIRATMAN & Associates which is an authority of the seismic design code and engineering of the buildings in Indonesia stated the opinion that Indonesia had to own seismic design code for Petroleum and Petrochemicals plants which was unified code even in Indonesia. There were the following comments from PUSKIM, Bandong, when the third mission visited PUSKIM;

- There is no seismic design code for Petroleum and Petrochemicals plants in Indonesia.
- In future, it is necessary for Indonesia to introduce seismic design code for Petroleum and Petrochemicals plants, and personnel training is also required.
- PUSKIM is responsible for the newly provision for the seismic design code for Petroleum and Petrochemicals plants. From now on, PUSKIM is ready to set up a new committee to establish seismic design code for Petroleum and Petrochemicals plants, cooperating with other ministries and government offices. In that case, they expect very much a specialist of JICA and discuss together with them.

As described beforehand, the seismic design code in Indonesia does not include non-building structure, such as pressure vessel, piping, and tank which are plant components. And it does not mention about design procedures. However, if UBC is applied, seismic design for non-building structure can be applied. Since UBC is the design criteria known well internationally, it is comparatively easy for obtaining the calculation program by which design calculation is possible. It is not practical to perform design and procurement on the plants by engineers of the developing country where a large project planned. It is necessary to develop designers or the manufacturers of equipment internationally. In that kind of capacity building, it is desirable that the seismic design code or standard is internationally acceptable. Comparing to the Indonesian seismic design code and UBC, they are not perfectly coincidence in detail. However, because Indonesian code was prepared by UBC base from the first, there is small inconsistency on the calculation using seismic load of UBC, which is equivalent to Indonesian code. Rather than that, it is a realistic method. Moreover, the engineers who are actually designing in Indonesia do not feel any inconvenience. They just have to verify the equivalence of the Indonesia standard and UBC standard project by project. The establishment of the method on verification and proposing it are also required.

Although it is required that all of the Japanese excellent seismic design code introduces into Indonesia national code and the actual seismic design in business. The seismic design code of UBC or ASME/ANSI is not enough in term of piping, it is meaningful to complement them by the Japanese seismic design code.

Regarding the seismic engineers resource development, it is necessary to bring up the instructors who will in future instruct and educate young seismic design engineers, that is, “Trainer’s Training”. Consequently a lot of young seismic engineers become possible to do their works by themselves.

Chapter 4　Seismic Technology for Plant in Vietnam

4.1　Petroleum, petrochemical and chemical industries in Vietnam

The following Table 4.1-1shows the general information of Vietnam.

The Vietnam GDP growing rate has been kept on 8 % level until 2007, however, after 2009 when the world-wide economical crisis occurred, it has been fallen down and can not recover to the former level yet even at this moment.

Table 4.1-1　General information of Vietnam

Economic Index	Static	Remarks/Sources				
Area	329,241㎢	Ministry of Foreign Affairs				
Population	89.32mil.	IMF World Economic Outlook Databases (04/2012)				
Growth rate of	1.15％	World Population Prospects by UN (2008)				
Population	1,22.7bil.US$	IMF World Economic Outlook Databases (04/2012)				
GDP	1,374 US$	IMF World Economic Outlook Databases (04/2012))				
GDP/person	20bil.US$	(01/2008)				
Foreign Reserves						
GDP	2006	2007	2008	2009	2010	2011
	8.23％	8.46％	6.31％	5.32％	6.78％	5.89％

(Source : made by JCI based on the above sources)

4.1.1 Petroleum industry in Vietnam

The second refinery plan in Nghi Son is in progress following the Dung Quat first oil refinery now in operation. In addition, there are more likely to the possibility of third and fourth refinery plans. Other than those, there are also small-scale plans and key of the plan is construction funds and ensuring of supply of processing crude oil.

The figure 4.1.1-1 shows the status quo and future plans of oil and gas fields, its treatment facilities and petrochemical plants of Vietnam.

(1) Saigon Petro・Cat Lai Refinery

Vietnam's only simplified refinery established in 1986 as a public enterprise under the Ho Chi Minh City People's Council.　The nominal capacity is 7,000 bpd (350,000 t/y). Processing the light low-sulfur crude oil and condensate imported from Thailand.

(2) Petro Vietnam Oil Corporation

The company was established in June 2008 in the form that PetroVietnam Trading

Corporation (Petechim), a subsidiary of PetroVietnam, to relief and merger PetroVietnam Processing and Distribution Company (PDC), and they engaged in import and export of petroleum products, such as crude oil and retail.

It has 7,200-8,000 bpd condensate distillation apparatus and the gasoline blending apparatus in BaRia-Vung Tau, about 60km southeast of Ho Chi Minh City. Condensate is used as a raw material to produce 270,000 t/y gasoline (and 92 RON83) and 26,000 t/y diesel.

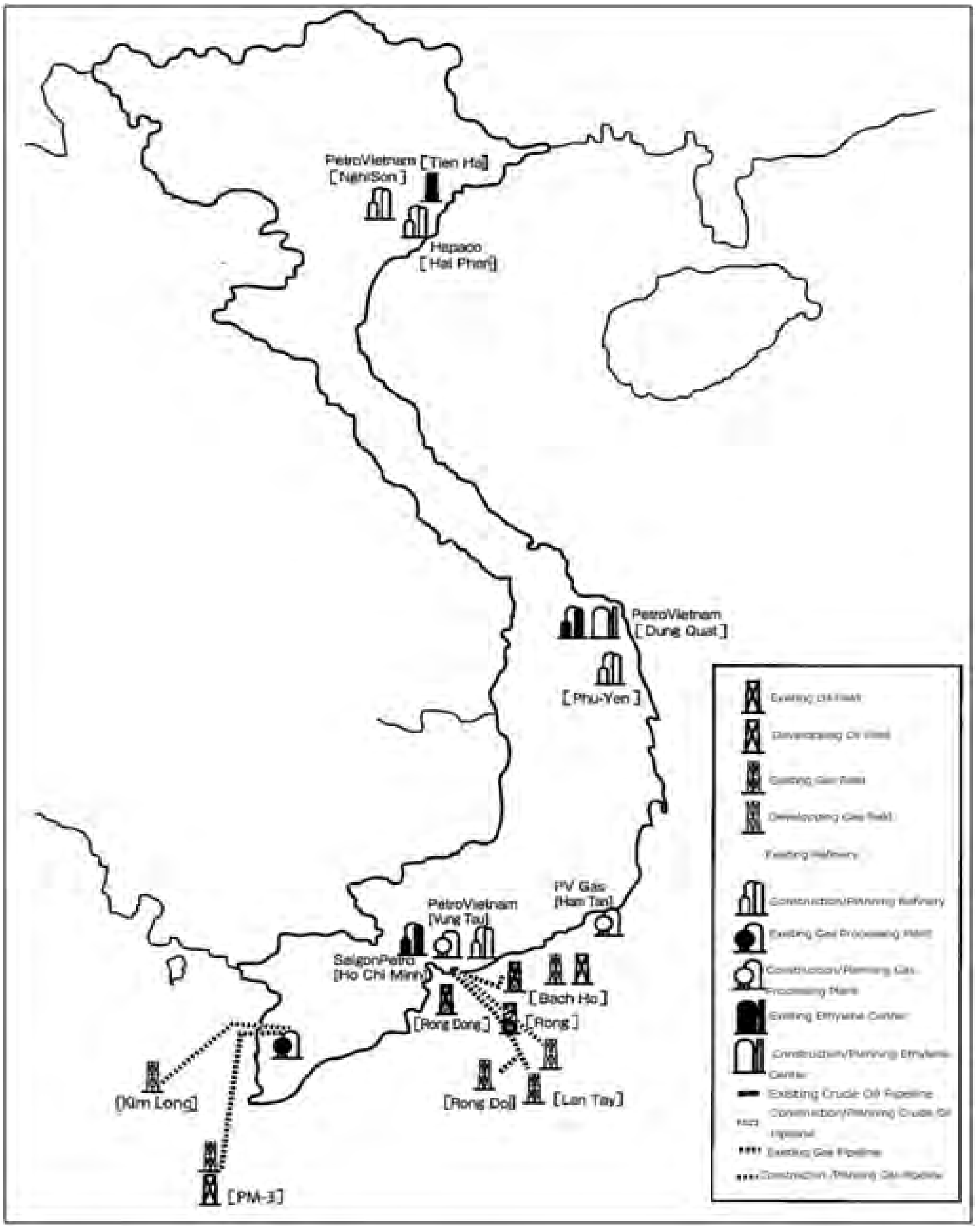


Figure 4.1.1-1 Current situation and plan of Oil and Gas field and its processing units and Petrochemical plants in Vietnam

(Source : Petroleum and Petrochemical Industry in East Asia Ver.2011)

(3) Petro Vietnam・Dung Quat first refinery

Petro Vietnam promoted the plan. Management company of the current first refinery is Binh Son Refining and petrochemical Company, a subsidiary of Petro Vietnam.

Dung Quat refinery has crude oil processing plant (148,000 bpd Capacity), crude oil tank (65,000 m3X6units), 8km pipeline system and shipping facilities in the sites of approximately 350ha located at Dung Quat area in Quang Ngai province, approximately 850km southeast of Hanoi.

Domestic crude oil such as Doi Moi and Bach Ho is exported as much as possible and required sweet crude oil for processing is imported from Kikeh and Miri of Malaysia, Azeri Light of Azerbaijian and ESPO of Russia through such as BP.

In order to respond to 2 oil type, Sour (High sulfur content) and Sweet (Low sulfur content), atmospheric distillation unit (CDU), naphtha hydrodesulphurization unit / continuous regenerating catalytic reforming unit (NHT / CCR), isomerization unit, residual oil fluidized-bed catalytic cracking unit (RFCC), LCO hydrotreating equipment (LCOHTR), sulfur recovery unit (SRU) and furthermore for manufacturing high quality gasoline (for Ron92), there are two refining units.

The below chart is a list of major equipments and products flow diagram.

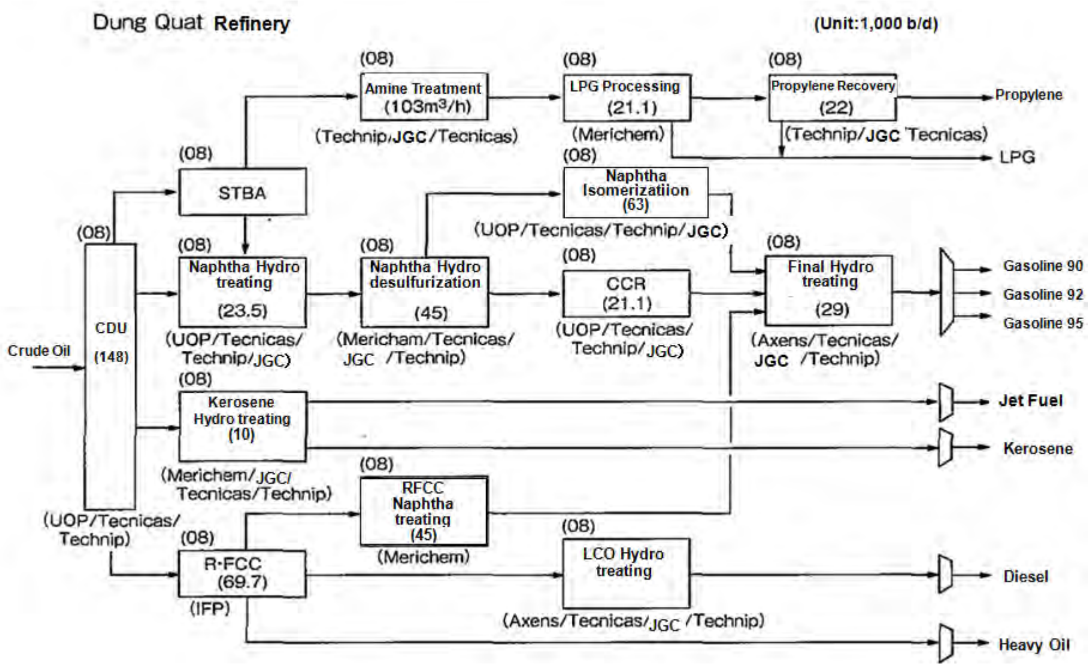


Figure 4.1.1-2 Products flow diagram of Dung Quat Refinery
(Source : Petroleum and Petrochemical Industry in East Asia Ver.2011)

Table 4.1.1-1 Major equipments of Dung Quat Refinery

<Dung Quat Refinery> (unit:bpd)

Plant	Capacity	License	Engineering	Compld.
CDU	148,000	UOP	Technicas/Technip/JGC	2008
RFCC	69,700	IFP	-	2008
RFCC naphtha treatment	45,000	Merichem	-	2008
LCO Hydrotreating	1,320,000/y	Axens	Technicas/JGC/Technip	2008
STBA	-	-	-	2008
Amine treatment	$103m^3/h$	-	Technicas/JGC/Technip	2008
LPG treatment	21,100	Merichem	-	2008
Propylene recovery	22,000	-	Technicas/JGC/Technip	2008
Naphtha Hydrotreating	23,500	UOP	Technicas/Technip/JGC	2008
Naphtha Hydrodesulfurization	45,000	-	Technicas/JGC/Technip	2008
Naphtha Isomerization	65,000	UOP	Technicas/Technip/JGC	2008
CCR	21,100	UOP	Technicas/Technip/JGC	2008
Sulfur recovery	5 t/d	UOP	Technicas/JGC/Technip	2008
Sour water stripper	81.6 t/d	-	Technicas/JGC/Technip	2008

(Source : Petroleum and Petrochemical Industry in East Asia Ver.2011)

(4) The second refinery plan of Nghi Son in northern part of Vietnam

This is a joint venture project of the second refinery under the configuration of Petro Vietnam 25.1%, Idemitsu and Kuwait Petroleum Europe BV each side 35.1% and Mitsui Chemicals 4.7%.

The plan is to construct a 200,000 bpd crude oil processing refinery (about 10 million t/y) until 2015 at the Nghi Son Economic Zone in Thanh Hoa province Tinh Gia area, approximately 125km south of Hanoi,

In addition to domestic crude oil, Dubai crude is also assumed to be processed and the installation of secondary processing unit, such as vacuum distillation unit, residual oil catalytic cracker (R-FCCU), CCR, and hydrocracking unit, is also planned.

As downstream petrochemical projects, 300,000 t/y polypropylene (PP) due to the recovery of propylene from a R-FCC, phenol, paraxylene (PX) with aromatic extract, High-purity terephthalic acid (PTA) are planned.

Furthermore they decided to introduce the Axens technology (France) for RFCC and light kerosene desulfurization apparatus and have entered into a basic design contract.

(5) The third refinery plan of Long Son in southern part of Vietnam

National oil company PetroVietam is planning a joint venture with foreign capital with the approval in September 2006.

It is expected to construct at least the same scale as the first and the second of crude oil processing refinery, and also they plan to integrate 500,000-550,000 t/y ethylene cracker which uses condensate as a raw material. In the downstream, of course general-purpose resins, such as polyethylene (PP) and polypropylene, is in the running for the project and BR of synthetic rubber is as well.

(6) The fourth refinery plan of HaTinh province

FPG(Taiwan) has proposed the fourth project. The plan is to construct a 300,000bpd new refinery at the Vung Ang Industrial Park (1Z) with1,591ha area in Ha Tinh province and integrate 1.4 million t/y petrochemical complex here. There is also a plan to construct a 500MW thermal power plant and cover the necessary electricity.

(7) Vung Ro refinery plan in Phu Yen province

There is the Vietnam's first 100% foreign capital refinery plan which UK Technor Star Management Ltd., plans to build. It is a joint venture refinery with Russian Telloil at Vung Ro Bay in Phu Yen province.

The plan is to construct a 4 mil. t/y (about 80,000bpd) oil processing refinery in the land of 40ha size at Hoa Tam, Phu Yen province. The plans to double to 8 mil. t/y (about 160,000bpd) later. The configuration of the secondary processing equipments was decided, such as 4,000 bpd Vacuum distillation unit (VDU), 1,000 bpd Delayed Coker (DCU), 600bpd catalytic reforming unit (CCRU), hydrotreatment unit of jet fuel and diesel, residual oil desulfurization unit and 1,000 bpd catalytic cracking unit (FCCU).

(8) Petrolimex/Sinopec joint refinery plan

Petrolimex is planning the construction of a petrochemical integrated type refinery by joint venture with (Sinopec Corp) Co., Ltd. in Khanh Hoa province.

The location is about 400km to the south from Dung Quat first refinery, and the construction of 10 million t/y (about 208,000 bpd) crude oil processing capacity refinery is planned.

4.1.2 Petrochemical and chemical industry in Vietnam

There is no ethylene crackers as the core of the petrochemical in Vietnam.

Current situation is in the first stage as “The formative period of petrochemical industry before the construction of an ethylene plant ".

Although the second stage is positioned as “The period of establishing core domain of the petrochemical industry," and its completion will be regarded around 2020, the factories of downstream sector have already started as follows and the foundation is being laid.

(1) Alkyl benzene sulfuric acid (Raw material of synthetic detergent)

Soft Chemical started at 12,000 t / y in 1997 and doubled to 24,000 t / y in 1998.

(2) Dioctyl phthalate (DOP) (Plasticizer for PVC)

LG Vina Chemical started at 40,000 t /y in 1997.

(3) Poly vinyl chloride (PVC)

TPC-Vina Chemical started at 80,000 t / y in 1998 and to 190,000 t / y in 2010.
Hitachi Zosen built with Tosoh technology.
Raw material VCM is imported from Thailand.

(4) Polypropylene (PP)

PP started as a downstream of the first refinery Dung Quat in 2010.

(5) Polyester short fiber and Nylon 6 resin

120,000 t/y Polyester short fiber started during 2004-2005 by FPG (Taiwan) and 47,000 t/y of Nylon 6 resin scheduled to start operations in 2010.

(6) High-puriy terephthalic acid (PTA) & Phenol

Mitsui Chemicals is planning as a downstream of Ngi Son second refinery in 2015.

4.2 History of earthquakes and tsunami, damages and future risks

4.2.1 Earthquake and tsunami

(1) Geological and geographical environment in Vietnam

Although there is no major structural cause of earthquakes such as trench in Vietnam and the occurrence of earthquakes is smaller compared to the neighboring countries, there are many faults in the north of Vietnam and it is estimated that maximum magnitude (M) 7 class earthquakes will be occurred. On the other hand, there are factors of occurrence of damages by earthquakes which will occur in around area.

As for this matter, an Institute of United Nations (UN) is alarming about the earthquake in north Vietnam and tsunami in the middle area in the report dated March 24, 2011.

This report is about the investigation of earthquake and tsunami in Vietnam implemented by the Program Coordination Group for Natural Disaster & Emergency of United Nations.

According to this report, Vietnam is located in the southeastern part of the Eurasian plate and at the same time located between the Indian plate, the Philippine Sea plate and the Australian plate. However, it is deviated from the boundary parts of these plates and it is estimated that the impact of the earthquake will be limited compared to neighboring countries such as Myanmar.

On the other hand, though there are no epicenter of massive earthquake in the northern Vietnam, precautions must be taken in the mountainous area which is close to the plate boundary. Magnitude 4 class weak earthquakes have occurred in Hai Phong of the coastal area.

Some faults have been confirmed around the Red River, the Mã River and the Lai Châu province - Điện Biên province area. These fault lines are totally several hundred kilometers length and the average movement rate (The average movement of the strata and terrain formation faults from the time of the formation of faults until now.) is 0.5 – 2 mm/year. It is estimated that magnitude 5.7 - 7.0 class earthquake may be possibly occurred at fault segments of this length.

According to the Vietnam Global Physics Institute and Earthquake Information and Tsunami Warning Center, the cause of current frequent earthquakes in Vietnam is due to the complex activities of the Lai Châu - Điện Biên fault, the Mã River fault, the Son La fault, the Hong River fault zone, the Ca River fault zone, and the 109-110 degree East Longitude line fault zone.

Figure 4.2.1-1 shows the geological and geographical environment which will affect to Vietnam and red points represent the past epicenters, and the main causes of the earthquakes and the consequential tsunamis are as follows: .

1) Ryukyu Trench (1a)
2) Manila Trench (2abc)
3) Subducting boundary near the Palawan island (3)
4) Fault zone in the Vietnam Sea (9)

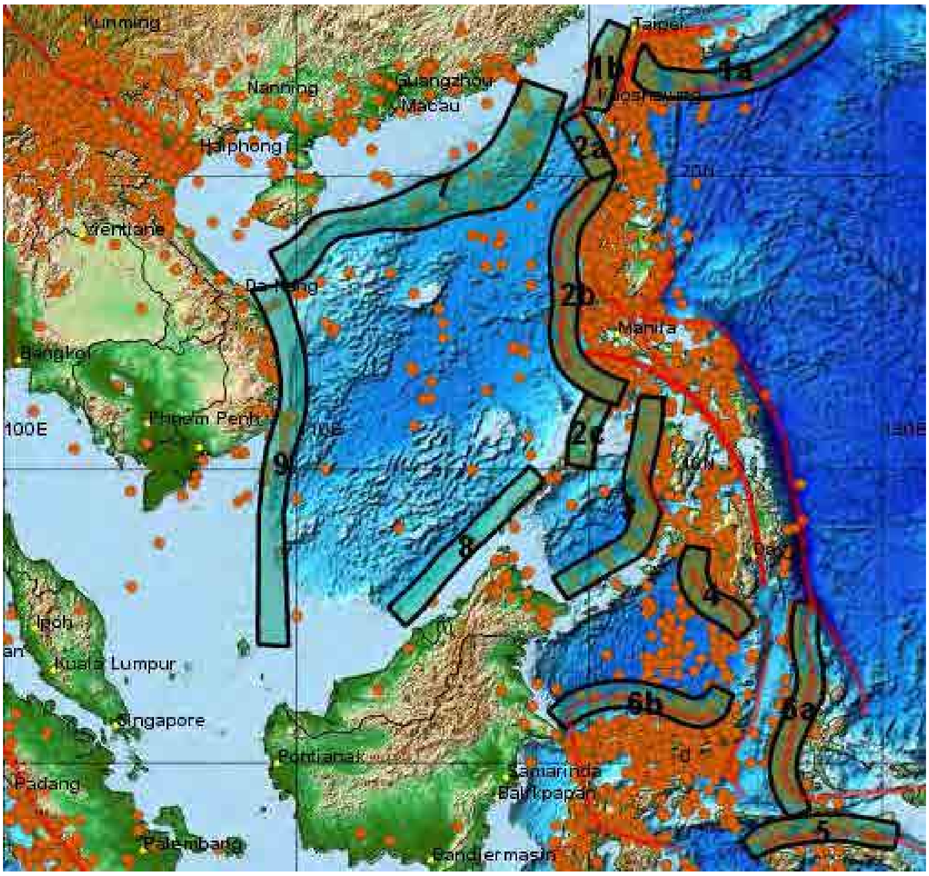


Figure 4.2.1-1 Geological and geographical environment of Vietnam
(Source : Seminar document by Vietnam Academy of Science and Technology(VAST))

(2) Seismic activity in Vietnam

According to the Vietnam Institute for Building Science & Technology (IBST), earthquakes have not occurred frequently.

Earthquakes larger than magnitude 3 have occurred 1,645 times from 114 to 2005 (Nguyen Dinh Xuen 2005). But from 1900 to 2001, following three large earthquakes have been observed in Vietnam.

* The Điện Biên Phu earthquake in November 1935 (M6.8, northern Vietnam)
* The Tuan Giao earthquake in June 1983
(M6.7, Northern Vietnam the Mã River fault zone)
* The Điện Biên Phu earthquake in February 2001
(M5.3, Laos/Near Yunnan in China)

In 2005, at least five earthquakes were observed in the northern, central and southern Vietnam. The past epicenters in Vietnam are shown in Figure 4.2.1-2.

It is obvious that the epicenters are concentrated in the northern Vietnam. In fact, from 1900 till 1995, 2 earthquakes with magnitude 5.6-6.0 and the seismic intensity (that is a measure of the effects of the earthquake on the buildings and structures) 7, 13 earthquakes with magnitude 5.1- 5.5 and intensity 7, and more than 100 earthquakes with magnitude 4.6-5.0 and intensity 6-7 have occurred in Vietnam. The Hontro earthquake in 1923 (M6.1) was accompanied by volcanic activity. In the southern Vietnam, although less frequently, earthquakes of magnitude 5-5.9 occurred several times, and that of more than magnitude 6 occurred one time at the undersea fault .

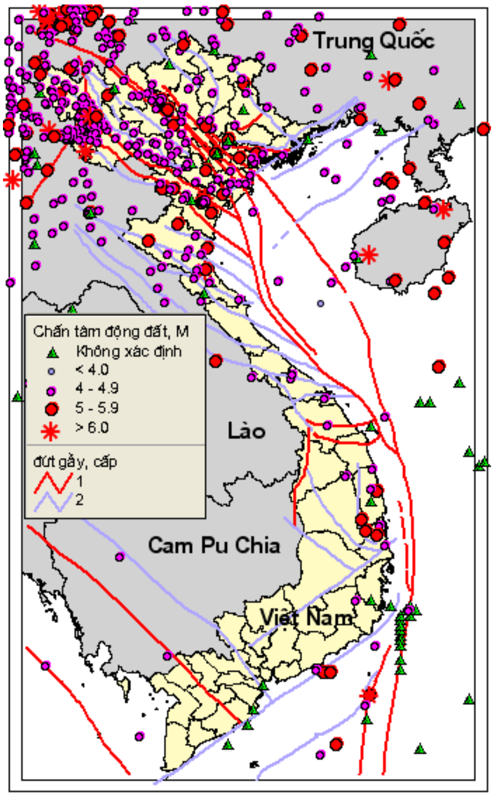


Figure 4.2.1-2 Earthquake activity data in Vietnam
(Source : Seminar document by Vietnam Academy of Science and Technology(VAST))

4.2.2 The damages caused by earthquakes.

In Vietnam, seismic data and specific information about the damages are less than expected, but respective situations about major earthquakes are as follows.

(1) The Tuan Giao earthquake on 24 June 1983

* Site of occurrence: Lai Chau province, 400 km northwest from Hanoi.

* Earthquake size : Magnitude 6.7
* Damage situation : Many houses suffered damage and collapse during the Earthquake (Figure 4.2.2-1 and 4.2.2-2).
Resident of 3-5 floors of buildings felt the quake.

Figure 4.2.2-1 A collapsed house by Tuan Giao earthquake on 24 June 1983
(Source : The seminar document by IBST)

Figure 4.2.2-2 A collapsed house by Tuan Giao earthquake on 24 June 1983
(Source : The seminar document by IBST)

(2) The Điện Biên Phu earthquake on 19 February 2001

* Site of occurrence : Nam Oun (Laos), about 15 km from Điện Biên Phu city.
*Earthquake size : Magnitude 5.3
*Damage situation : The quake damaged almost all masonry structures in the region and injured 4 people but no one was killed.

* Aftershock	: Hundreds of aftershocks (The strongest magnitude 4.9.)
* Impact	: The quake had very severe social and economic impact on the people and the local government in the region, such as homeless people, panic, anxiety. Consequently, this earthquake motivated the government to pay attention to the seismic design and the prevention of seismic disaster (Figure 4.2.2-3, 4.2.2-4).

Figure 4.2.2-3 A collapsed masonry structure by Dien Bien Phu (DBP) earthquake on 19 February 2001 (Source : The seminar document by IBST)

Figure 4.2.2-4 A collapsed masonry structure by Dien Bien Phu (DBP) earthquake on 19 February 2001 (Source : The seminar document by IBST)

These earthquakes revealed the necessity for the study of the resistance to seismic activities in Vietnam where many high-rise buildings have been constructed, and were clear reasons for the immediate issuance of the Current Vietnamese Earthquake Design Code in December 2006.

4.2.3 Future risks of tsunamis

As well as earthquakes, tsunamis are threats to Vietnam, which has a long coastline.

(1) Causes of tsunamis and their effects

Tsunamis in Vietnam have been generated by seismic activities in the following areas as described in 4.2.1.

* Ryukyu Trench
* Manila Trench
* Subducting boundary near the Palawan Island
* Fault zone in the Vietnam Sea

The UN report on earthquakes and tsunamis in Vietnam notes it is unlikely that tsunamis do severe damage to Vietnam, and there have been no tsunami damages so far. But the possibility for an occurrence of tsunami is pointed out in the central coastal area of Vietnam.

Tsunamis generated by earthquakes in the seismic zone in the western Philippines and Manila Trench are threats to Vietnam, and if an earthquake of magnitude over 8 occurs in Manila Trench, it is inevitable that a tsunami arrives at the central coast of Vietnam. Furthermore, the central coast will be damaged by a tsunami if an earthquake of magnitude over 8 in the area from the northern Luzon to the southern Taiwan, or that of magnitude over 8.8 in the Ryukyu Trench occurs.

There are over 270,000 residents in the area, and countermeasures against tsunamis are necessary. Meanwhile, tsunami damages as large as mentioned above are not supposed to occur in the northern and southern Vietnam.

(2) Estimation of tsunami traveling

According to the trial calculation by the Institute of Geophysics (Vietnam Academy of Science and Technology), if an earthquake of magnitude 8.8 occurs at Manila Trench, the arrival time and the height of the tsunami are as shown in Figure 4.2.3-1 and Figure 4.2.3-2, respectively.

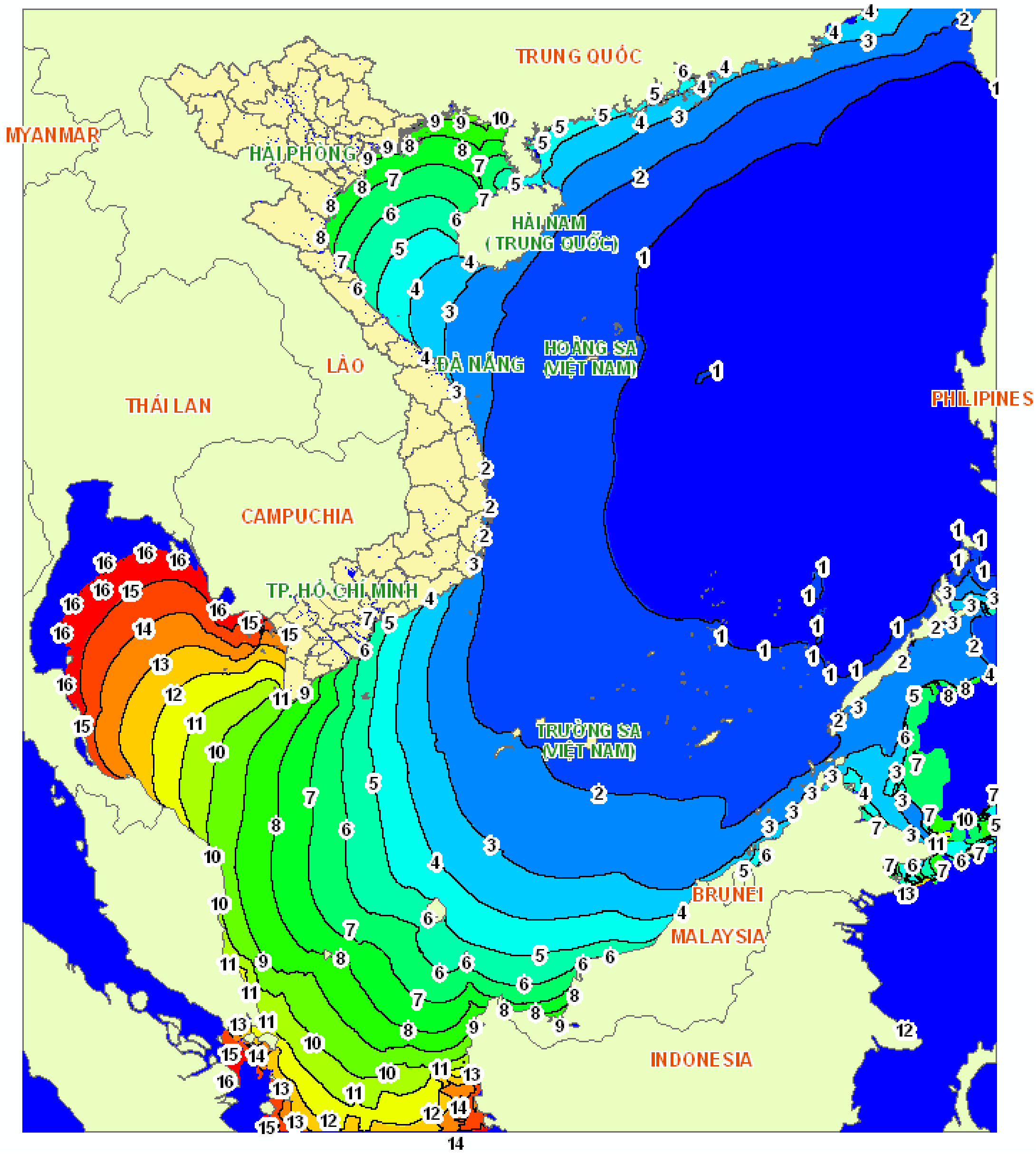


Figure 4.2.3-1 Tsunami traveling time (Hrs)

(Source : Seminar document by Vietnam Academy of Science and Technology (VAST))

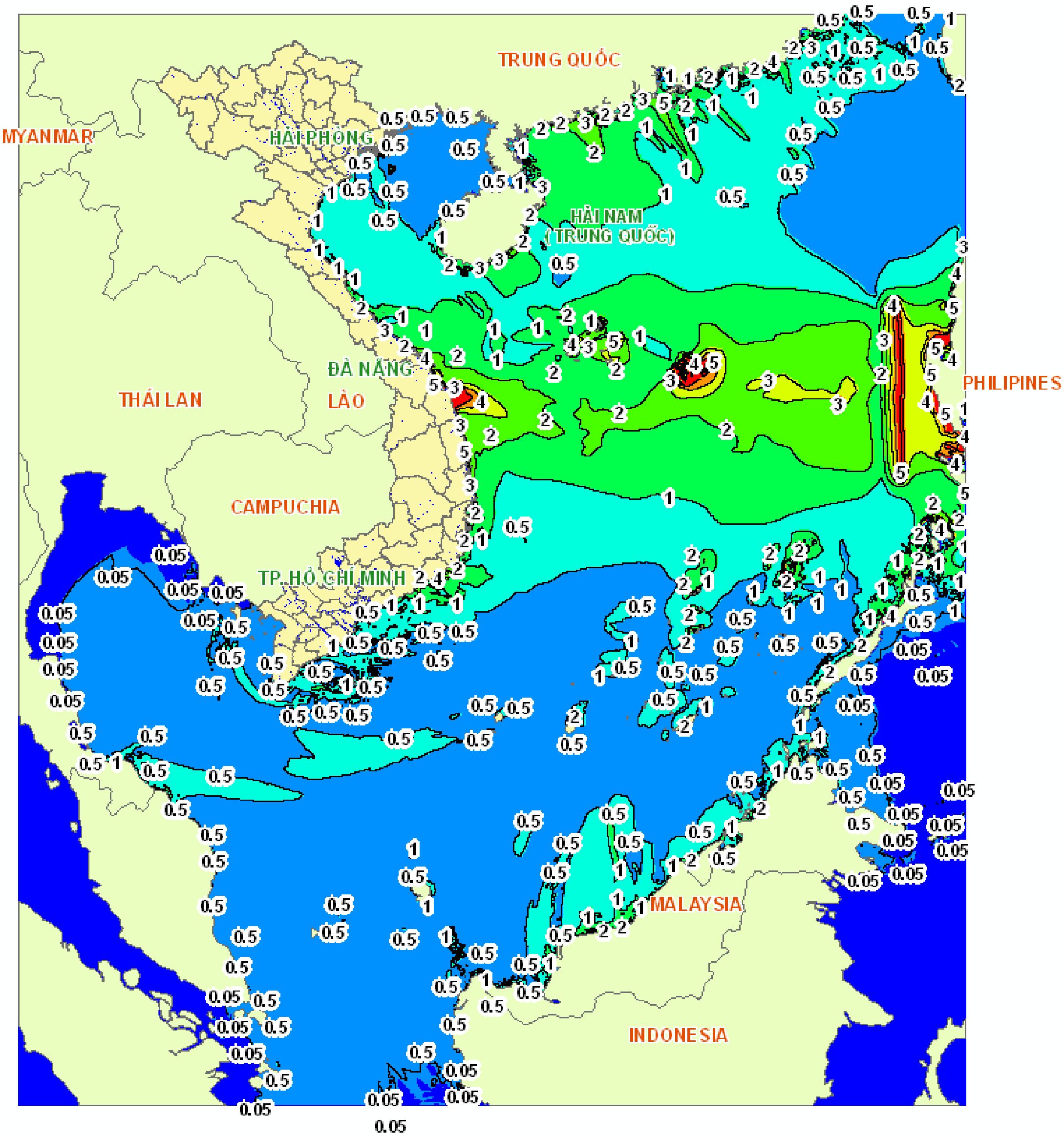


Figure 4.2.3-2 The height of tsunami (m)

(Source : Seminar document by Vietnam Academy of Science and Technology (VAST))

On the coastline of central Vietnam, the area around the Dung Quat refinery on the shortest distance from the Manila Trench is supposed to be damaged by a tsunami of 3-5 meters in height about two hours after the occurrence of the earthquake.

4.3 Seismic design code for petroleum refinery and petrochemical plant in Vietnam

(1) History of seismic code

Vietnam did not hold its own seismic design code until 2006. Until then, seismic forces had been decided by MSK-64 scale. Areas of seismic structural design has been done by National Geographical Survey Institute (belongs to National Center for Natural Science and Technology). Seismic design code of all kinds, such as Russia CNIP II 7 - 1981 and Uniform Building Code (UBC) has been used. New seismic design code based on code Euro in 2006, have been established.

(2) Structures applied seismic design code

Structures applied of the Seismic design code TCXDVN 375:2006 are buildings and other structures, and they are parted to Part 1 and Part 2. And the relationship with Eurocode is as follows.

Part1: General rules, seismic actions and rules for buildings (equivalent for EN 1998-1)
Part2: Specific provisions for foundations, retaining structures and geotechnical aspects (equivalent for EN 1998-5)

(3) Earthquakes to be considered

Surface seismic intensity applied in seismic design code of Vietnam TCXDVN 375:2006 that divide the nation into the four tiers. For calculating the designed maximum ground acceleration, stipulates reproduction period 500 years of earthquake 5 kinds of elastic response spectral parameters based on depending on the ground. Detailed explanation including the below items are to be referred the Appendix II Seismic Design code in Vietnam TCXDVN 375:2006.

(4) Seismic performance to be provided

Depend on the importance of building, five kinds of importance factor is provided. Behavior Factor depending on its type for steel structures is provided. Also, depending on the degree of ductility reduction factor adjustment is stipulated.

(5) Response analysis method

Linear Static Analysis method is applied for the response analysis.

(6) Evaluation method

By calculating the shear stress applied for the basis of the structure and horizontal force applied for each structural member, then comparison is made with allowable stress of the structural materials.

4.4 Disaster prevention planning & organization and security for plants

4.4.1 Hazard map of earthquake

In 1996, 1000 years period Earthquake Hazard Map shown in Figure 4.4-1 has been made.

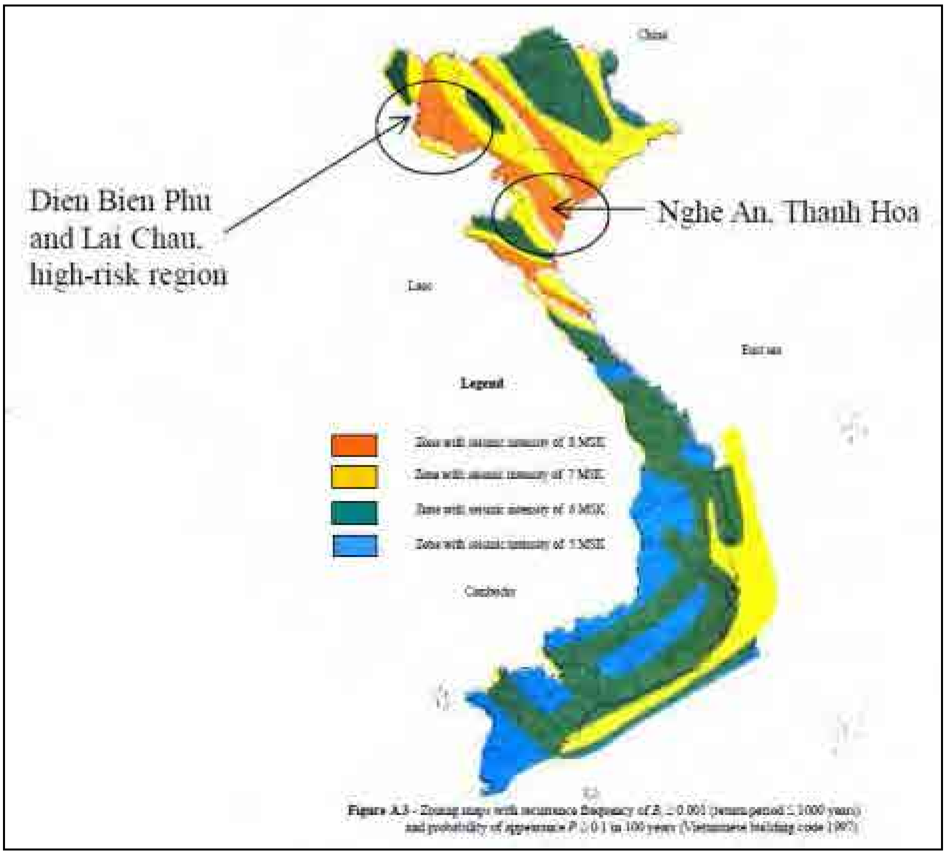


Figure 4.4-1 1000 years period Earthquake Hazard Map
(Source : Seminar document by IBST)

4.4.2 Establishment of seismic network

"Vietnam Project 2009-2014" has been launched in Vietnam. The seismic network of Vietnam was established and the following measures were planned. (See Figure 4.4-2)

1) 30 Broadband stations in real-time
2) Service provided for data obtaining and data processing method from "Earthquake Information and Tsunami Warning Center", located in the Institute of Geophysics of Hanoi.
3) 6 Broadband stations from the seismic network of Ho Chi Minh City

Figure 4.4-2　Vietnam Seismic Network（Vietnam Project 2009-2014）
(Source : Seminar document by Vietnam Academy of Science and Technology (VAST))

4.4.3 Examples of disaster countermeasure in some companies

(1) Dung Quat refinery

1) Outline of their business

- The refinery is located on the seafront of about 50km to the west of the Quang Ngai, The Capital of the Quang Ngai province in central Vietnam and it has 148,000bpd oil refining capacity (approximately 6.5 million t/y as crude oil).
- Summary of the site and major plant units is as follows.
  * Refinery on-site facilities, off-site facilities and utilities facility : 110ha
  * Crude oil tank, flare : 42ha
  * Product tank : 36ha
  * Water tank, waste water treatment, piping : 4ha
  * Internal pipeline : 40ha
  * Port facilities : 135ha
  * Main units: CDU, RFCC, CCR (Platformer) and ISOMAX (Naphtha Hydro Treater)
  * The port facilities are including 1.6Km breakwater and with standable to the 10m high waves.
  * The water depth is 18m and crude oil is transported by 110,000 tons (dead weight) tankers. Sea berth is located off the coast of the shipyard, a few kilometers away from the refinery, and is accepting crude oil. 190,000 tons VLCC is also considered in the Future.

2) Earthquake history and seismic Countermeasure

- Only typhoon is assumed as a disaster, and there is no damage by flood, earthquake, tidal wave and tsunami.

  The west side is the mountains, the east side is sea and the central part is low in Vietnam and, in case of heavy rain, the water level of the river rises in the central portion, and residents worry about it.
- 5-6 typhoons invade refinery in a year. The refinery was attacked by a level 11 large one in 2009. (Level 11 was based on Vietnam standard). The plant is designed to withstand to wind speed 160km/hr. Tank level has been confirmed everyday as a countermeasure.
- UBC 1997 has been adopted as the seismic design standard.
- Design standards of pressure vessels and piping is ASME.

3) Disaster prevention Countermeasure

- No accidents for three years since its start up of the operation.
- The following items have been established as emergency response scenario.

* Fire
* Explosion
* Flood
* Earthquake
* Other natural disasters

- There are Law and Regulation on disaster in Vietnam. Particularly important matter to refinery is the weather forecast and refinery keeps closely contact with National & International Weather forecasting system.
- Dung Quat oil refinery has established the early warning system for earthquakes. The dangerous situation is already known that if an earthquake occurs off the coast of Philippines, 5m height tsunami will reach to Vietnam coast in 2-3 hours, however, the dangers will be avoided because there is a bank of 30 ~ 40m on the beach.
- The refinery has a self-generating system (An boiler STG of 22-24MW, made in Jap) for the power outage. Power supply is covered by self-generation system and electricity will be received from National Grid during the Shut down Maintenance.
  It has also the UPI System for Safety Shut Down.

(2) Petro Vietnam Gas （LPG Terminal）

1) Outline of their business

Nam Con Son Basin terminal is located about 90 km to the southeast of Ho Chi Minh City which receiving dry gas, LPG and condensate sent from the sea. 2BMC/yr capacity unit constructed in 1995and 7 BMC/yr capacity unit constructed in 2002 are under operation and 7 BMC /yr capacity third unit is currently under construction.

Main facilities are two double shell tanks of 30,000 ton capacity with 40m diameter, 50 m height and flat bottom, two sphere shape tanks with 21 m diameter, pipe rack, ground flare, fire water tank and etc.

2) Earthquake history and seismic countermeasure

- As located in the southern part of Vietnam, the risk of earthquakes is low.
- The earthquake load for Seismic design of LPG terminal which is currently under construction is determined by the response spectrum method.
  The standard response intensity is 0.042 x 1.25 (importance factor) = 0.055.
  Piping should be considered a horizontal acceleration of 0.05G, and also be taken into account the displacement caused by the earthquake.
- The ground is the fill with fine sand up to 4m underground and the 80 ~ 90m soft clay under the fill. Pile foundation is adopted and the length of the pile is 45m. Water level is -2m to the ground and the height from the sea level of the bottom of the tank is 4m.

3) Disaster prevention countermeasure

- Although considering fire, earthquake, typhoon, there is almost no experience of earthquake.
- As for the tsunami, no worry has been taken because the site is located on the river Thi Vei, near the mouth of the river, and it is not directly facing to the ocean. The ground level is 4m from the sea level.
- As for the tank fire, Water Curtain and Foam System have been established. There is no regulation for the safety distance between tanks in Vietnam and the International Standard 510 has been adopted.

(3) Pha Lai Thermal Electric Joint Stock Company (PPC)　(Coal power Station)

1) Outline of their business

PPC is located about 50 km to the east-northeast of Hanoi and has old and new two coal fired power plants. Older No.1 plant was designed and constructed in 1983 by the former Soviet Union and the capacity of electricity generation is 440 MWh with 4 units of boiler. The newer No.2 plant was constructed by ODA of Japan in 2000, Sumitomo Corp. was the contractor, and the capacity of electricity generation is 600 MWh with 2 units of boiler. Coal as fuel is transported through river from domestic coal mines which is 50-60 km away from PPC plant site. The Power Station is a subsidiary of EVN (Electricity of Vietnam) and generated power is sent to the National Grid. Because 40 years past since its completion, IBST provides rehabilitation services and the staff regularly stays at the plant.

2) Earthquake history and seismic countermeasure

- There is a possibility of damage caused by the earthquake because PPC is located in the northern part of Vietnam, however, there is no experience to be affected by the earthquake. Wind disaster (typhoon) is considered as the most likely occurring disaster.
- As for the design standards, Russian standard has been applied to No.1 plant. Standard of several countries have been applied to No. 2 plant in terms of equipment purchase. MMI scale 7 based seismic design has been also implemented by a Korean company.
- The ground is hard and piling is not required except the end of the facility where partially the pile foundation is necessary because the stratum is inclined toward its direction.

3) Disaster prevention countermeasure

- The scenario for disaster prevention at the time of the earthquake has neither been made, nor significant plant modifications have been carried out up to now.

- There is the Disaster Management Plan in the factory.

4) Others

- Supervisory authorities are as follows.
    * Environment-related matters are by local governments
    * Technical problems are by Ministry of Environmental Science (MONRE)
    * Civil engineering and construction related matters are by The Ministry of Construction
    * Boilers are by EVN
- Intervals of regular shut down and maintenance are determined by law, every three months for level, every two years for level 2 and every four years for level 3.

4.5 Investigation of actual seismic design

Before 2006, there is no national code for seismic design. In 2006, Vietnamese seismic design code TCXDVN 375 was issued. It was established with reference of Eurocode 8. And it does not cover non-building structures similarly to Eurocode 8.

UBC was applied to Dung Quat refinery whose operation was started in 2009, because the design of the plant was started before 2006. There is no refineries or petro-chemical plants to which Vietnamese seismic design code applied. To Nghi Son refinery which is now under planning by Japanese companies, Vietnamese seismic design code TCXDVN 375 shall be applied. However, detailed application methods are not yet established.

Because the design of these refineries and petro-chemical plants including seismic design were mainly done by foreign companies, Vietnamese engineers and governments are not familiar with the detail design method for plants. The background of such a situation is a fact that Vietnam has no experiences of serious seismic hazards. Especially in southern area, they have not even feel seismic vibrations.

4.6 Simulation for damage of plants due to estimated seismic load and improvement plan

The team studied the seismic design codes and the seismic hazard maps in Vietnam, estimated the damage of the plants designed by these codes and maps, and analyzed problems and suggested plans for improvement.

4.6.1 History of seismic design code for plants and seismic hazard map

Seismic design code for plants is not established in Vietnam. History of seismic design code for buildings and seismic hazard map is as follows.

(1) "Building Code for Vietnam 1997"

- Regulation for Seismic design is not found.
- Seismic design code is shown as MSK-64 Seismic Intensity Scale. Refer to Figure 4.6.1-1, Table4.6.1-1.

(2) TCXDVN 375:2006 "Design of Structures for Earthquake Resistance"

- This code was faithfully converted from Eurocode 2005 (BS-EN 1998-1:2004), and modification points are referred seismic hazard map and importance factors.
  Refer to Figure 4.6.1-2 for the hazard map.

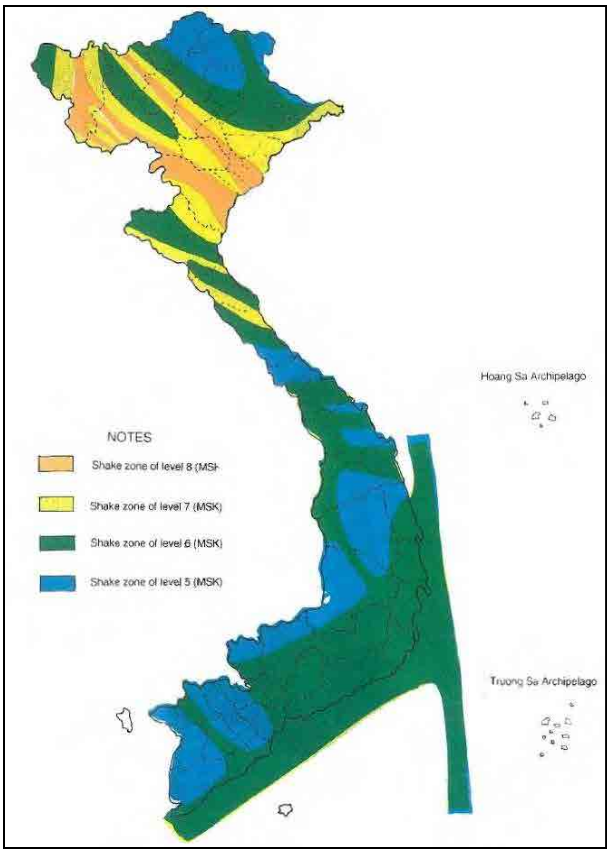


Figure 4.6.1-1 Shake Zoning Map MSK-64 of Building Code for Vietnam 1997
Repeated frequency B1>0.002, cycle T1<500 years
Shake appeared probability P>0.1 within the time of 50 years

(source:"Building Code for Vietnam 1997")

Table 4.6.1-1 MSK-64 Seismic Intensity Scale

(source:"Wikipedia")

class	extent o shaking	acceleration
I. Not perceptible	Not felt, registered only by seismographs. No effect on objects. No damage to buildings.	
II. Hardly perceptible	Felt only by individuals at rest. No effect on objects. No damage to buildings.	
III. Weak	Felt indoors by a few. Hanging objects swing slightly. No damage to buildings.	<12gal
IV. Largely observed	Felt indoors by many and felt outdoors only by very few. A few people are awakened. Moderate vibration. Observers feel a slight trembling or swaying of the building, room, bed, chair etc. China, glasses, windows and doors rattle. Hanging objects swing. Light furniture shakes visibly in a few cases. No damage to buildings.	
V. Fairly strong	Felt indoors by most, outdoors by few. A few people are frightened and run outdoors. Many sleeping people awake. Observers feel a strong shaking or rocking of the whole building, room or furniture. Hanging objects swing considerably. China and glasses clatter together. Doors and windows swing open or shut. In a few cases window panes break. Liquids oscillate and may spill from fully filled containers. Animals indoors may become uneasy. Slight damage to a few poorly constructed buildings.	12-25gal
VI. Strong	Felt by most indoors and by many outdoors. A few persons lose their balance. Many people are frightened and run outdoors. Small objects may fall and furniture may be shifted. Dishes and glassware may break. Farm animals may be frightened. Visible damage to masonry structures, cracks in plaster. Isolated cracks on the ground.	25-50gal
VII. Very strong	Most people are frightened and try to run outdoors. Furniture is shifted and may be overturned. Objects fall from shelves. Water splashes from containers. Serious damage to older buildings, masonry chimneys collapse. Small landslides.	50-100gal
VIII. Damaging	Many people find it difficult to stand, even outdoors. Furniture may be overturned. Waves may be seen on very soft ground. Older structures partially collapse or sustain considerable damage. Large cracks and fissures opening up, rockfalls.	100-200gal
IX. Destructive	General panic. People may be forcibly thrown to the ground. Waves are seen on soft ground. Substandard structures collapse. Substantial damage to well-constructed structures. Underground pipelines ruptured. Ground fracturing, widespread landslides.	200-400gal
X. Devastating	Masonry buildings destroyed, infrastructure crippled. Massive landslides. Water bodies may be overtopped, causing flooding of the surrounding areas and formation of new water bodies.	400-800gal
XI. Catastrophic	Most buildings and structures collapse. Widespread ground disturbances, tsunamis.	>800gal
XII. Very catastrophic	All surface and underground structures completely destroyed. Landscape generally changed, rivers change paths, tsunamis.	

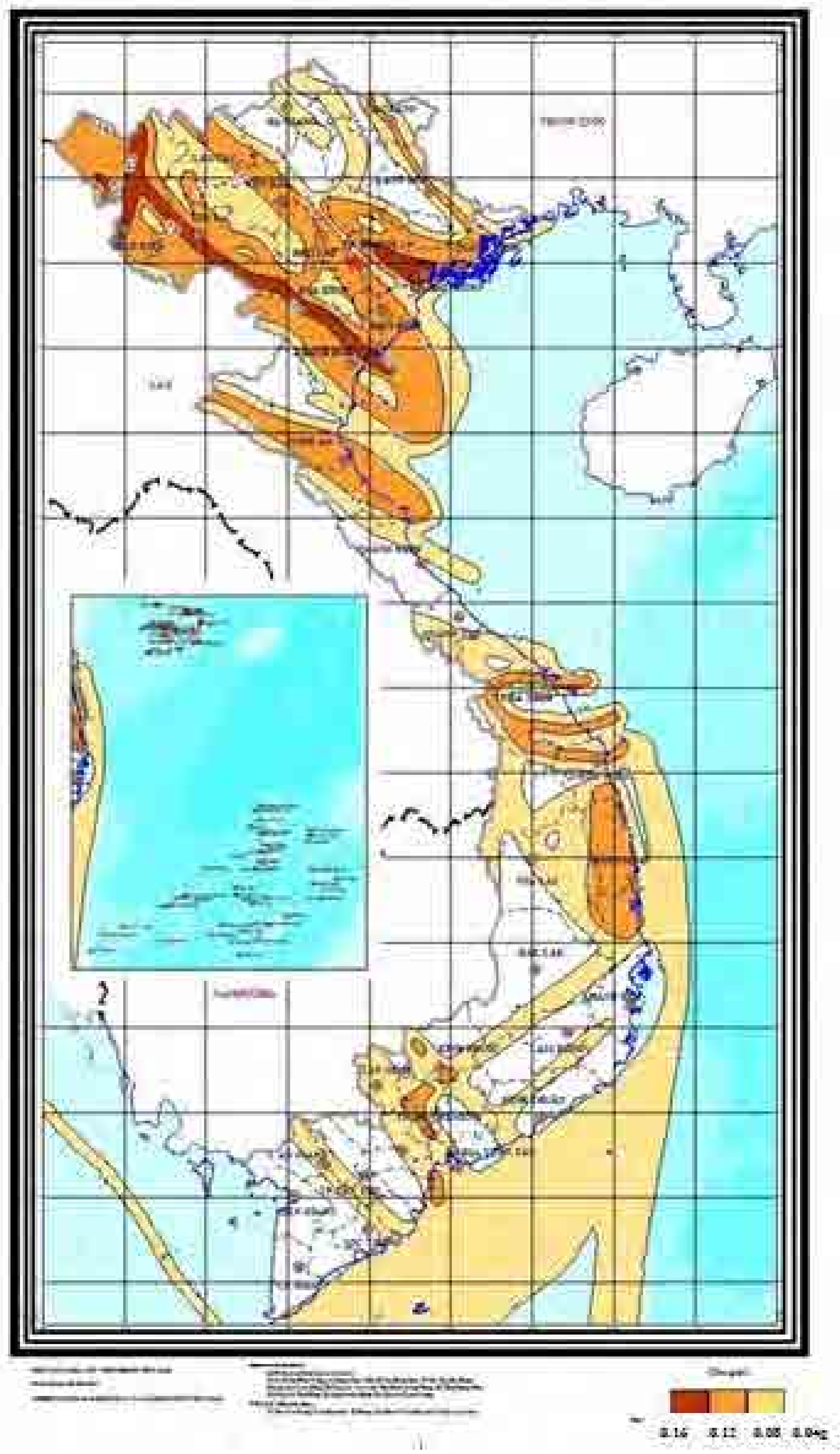


Figure 4.6.1-2 Ground acceleration zone map with return period of 500 years for ground type A on the whole territory of Vietnam
(TCXDVN 375:2006)
(source:"Design of Structures for Earthquake Resistance")

4.6.2 Outline of seismic design code

In the seismic design of the ordinary buildings, we use to calculate the lateral force on the buildings due to the design earthquake and select the structural members of the building.

The outline of the calculating method of the lateral force acting on the building due to earthquake is shown in appendix II of TCXDNV375:2006. In this code the lateral seismic design force is prescribed from five parameters as follows.

(1) Peak ground acceleration at the top of the seismic bedrock is given in the PGA of the seismic hazard map. (refer to Figure 4.6.1-2)

(2) Seismic response factor indicates earthquake amplifying at the outer layer of the ground, and is given in the function of the soil profile type and the first natural period of the structure. (refer to Figure 4.6.2-1)

(3) Importance factor indicates charging an extra of the seismic force, and is given for the occupancy type of the structure.

(4) Seismic reduction factor indicates reducing of the seismic force, and is given for the ductility of the structural system.

(5) Total weight of the building including an appropriate portion of the live load

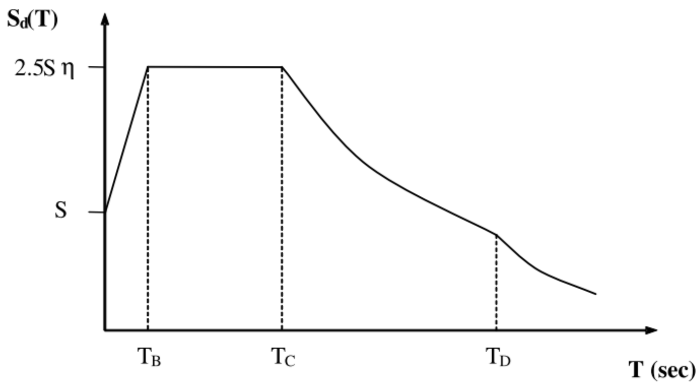


Figure 4.6.2-1 Design Response Spectrum
(source:"TCXDVN 375:2006")

4.6.3 Prediction of the damage

Among the five parameters at 4.6.2 which prescribe the lateral seismic design force, (1)～(4) are prescribed by the seismic design code. For the factor (1) we will compare the history of the PGA map and for the factor (2)～(4) we will compare the design base shear expressions between SNI and ASCE 7-05. Then we will predict possibility of the damage from the magnitude of the design base shear (total lateral force at the base).

(1) The seismic hazard map was revised in 2006, and the peak values of PGA were two or three times greater than the previous map at the middle or south region. As it is not so large, there are no problems if the wind design load exceeds the seismic loads. However as we hear that seismic load is not considerable usually in this region, it is desirable to verify whether the seismic load is critical in the seismic design.
(2) There were no seismic design codes in Vietnam before 2006, and it was rule to apply the foreign codes, if necessary. For the plants designed at the time, it is desirable to examine the procedure of the seismic design, and check the seismic performance, if necessary.
(3) For some of the plant equipments their structural system types are not applicable to the building seismic code. So for those equipments it is desirable to build up the procedure for correcting the seismic force by the ductility of them.
(4) For some of the plant structures or equipments their usage categories are not applicable to the building seismic design code. When the damage of their plants may have a bad influence on the safety at the circumstance, Importance factor depending on the extent of the risk is considerable at the seismic design. However, as such influence is not considered in the building seismic design code, it is desirable to build up the code considering such influence.

4.7 Level check of plant seismic technology

According to the IBST (Institute of Building Science & Technology) and the Ministry of Construction, in Vietnam, there was not enough seismic engineers. It seems that contractors, such as Japan, South Korea, and the U.S., have received the order of design and construction of large plants in the country, and there was small chance to carry out the projects by Vietnamese engineers. There is no work place where their ability can be utilized even if they study quakeproof engineering in Japan, and they replace job, or there is also an example turned to the department of measures against typhoon. Plant construction in the energy field will increase in connection with the economic development in future, and legal provision and opportunity to actually perform design and construction will increase. It is considered that energy scarcity arises and it is forced to specifically depend on import of LNG with economic growth etc. in the future. It is actually LPG company of Petrovietnam is planning construction of LNG tank and they came to the study team to have consultation in terms of applying Code. Moreover, about disaster prevention plan, there is still no organization which carries out as a leading player, and it is necessary to prepare organization/system for future disaster. Although Dike Management Dept. of the Ministry of Agriculture and Forestry has jurisdiction which takes the measures against tsunami, the alarm system for disaster prevention is only installed in limited part of the seashore in Da Nang, the middle area of the Vietnam. For covering all the coastlines, their budget is insufficient.

4.8 Enlightenment activities for the necessity of plant seismic measures by seminars

4.8.1 Outline of seminars

(1) The First Seminar

Date : June 6, 2012

Venue : Conference room of IBST

Subject : The following four themes were presented by JICA team with an emphasis on introduction of disaster prevention and seismic technology of Japan for broad participants.

-1- Outline and Plan of the JICA Project

-2- Overview of Japanese Seismic Technologies

-3- Japanese Seismic Laws and Codes for Plant Engineering

-4- Disaster Management in Japan

On the other hand, introductory presentation on earthquake observation system and outline of seismic technology in Vietnam was presented from the Vietnam side.

Participant : 58

Q & A : The questions were raised actively, on the presentation of Japanese side, such as relation between design seismic intensity and reappearance period, soil liquefaction, seismic load wind load and explosion load for structure design, measures of entity against national disaster prevention plan, and disaster prevention facilities in Japan.

(2) The Second Seminar

Date : August 22, 2012

Venue : Conference room of IBST

Subject : The mission presented the following four themes based on previous research findings from more tangible subjects.

-1- Insight about the JICA Seismic Technology Study Project

-2- Report of Study Results and Introduction of Seismic Assessment Methods for Existing Plant Facilities in Japan

-3-Application of Vietnamese seismic design code to plant facilities

-4- Disaster Prevention System of Refineries in Japan

Two themes were presented by Vietnamese side concerning the seismic strength of precast concrete by IBST and ground motion prediction in Vietnam by University of Transport and Communication.

Participant： 74

Q & A : The questions were raised actively on the presentation of Japanese side, such as a cause of damage to refineries in the great east Japan earthquake, security measures for residents who live in adjoining facilities, evaluation of soil and foundation on seismic response, seismic evaluation of underground structures, organization plan of " proposed Seismic Technology Center" and seismic design code for piping in Vietnam.

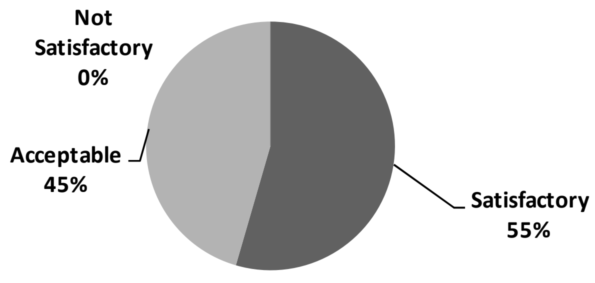
4.8.2 Summary of Questionnaire on Seminar

The questionnaires were distributed to the participants at registration process at this seminar and recovered it at the end.

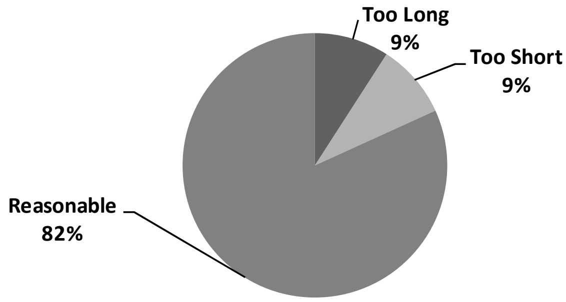
(1) The First Seminar

1) Summary of Questionnaire

① Content of Seminar：



②Length of Seminar：



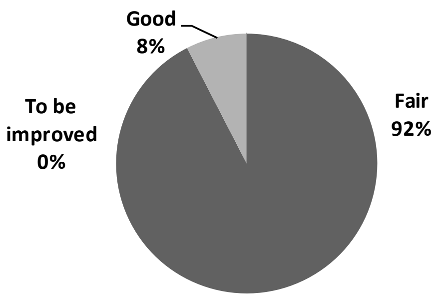
③ Attendance to the future JICA seminar：

Will attend : 100%

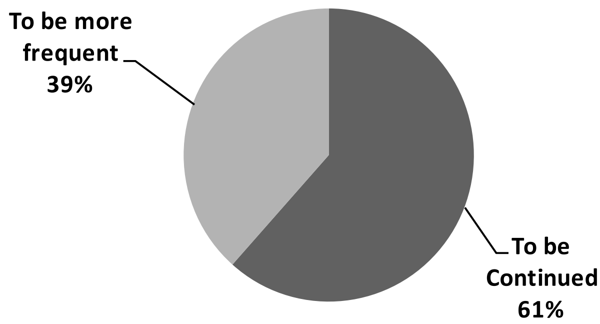
(2) The Second Seminar

1) Summary of Questionnaire

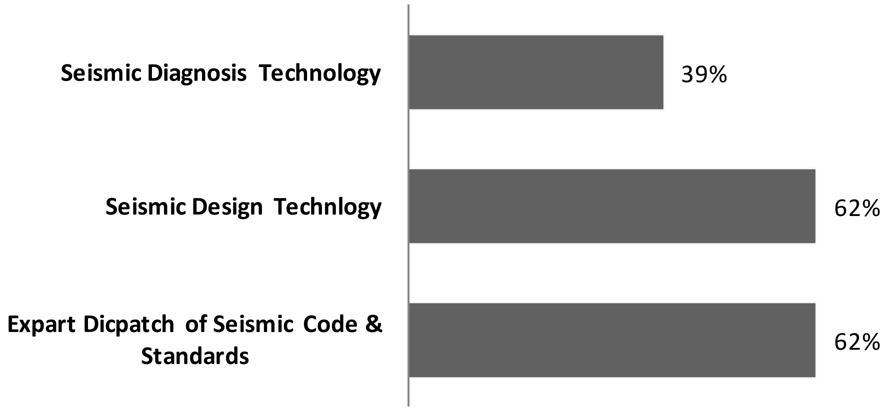
① Content of seminar:



② JICA seminar on seismic technology:



③Future Japanese cooperation:



4.8.3 Summary of seminar

Nearly 60 participants participated in the first seminar held on June 6 in Vietnam, and active discussions were held. The themes from Japanese side were the Japanese seismic technology and systems. In panel discussion, lots of questions were raised by eager participants who remained in place, and the discussion was continued beyond the schedule. There were a lot of opinions and encourages that seminars are held more frequently in the questionnaire (attached). Themes for broad audience were selected based on broad and shallow of seismic technology. The fundamentals of seismic technology also included, so some expert had an opinion to know more Japanese state of the art technology. In response to the requests in the first seminar, the themes in the second seminar, which was scheduled on August 22, included their requirements. They are, Japanese seismic design code and standards for design and construction of refinery and petrochemical, seismic risk management, design effects due to seismic design criteria for the three countries and detailed seismic assessment method considering the low Life Cycle Cost and actual disaster prevention system in Japanese refinery, etc. In the second seminar, answer of everyone was in satisfactory or in appropriate, reflecting requests by the attendance of the first seminar. 100% of the answer on the questionnaire wanted continuation of the seminar. The comments said that more participation from civil and architectural engineering society and private companies would be expected, and that continuation of corporation with JICA in the field of seismic technology in Vietnam would be expected.

4.9 Needs and request in Vietnam

According to the IBST in Vietnam, they have to increase seismic engineers, and they want to have opportunity to study about Japanese technology in terms of plant seismic design and construction technology. Moreover, when IBST newly makes the seismic design code corresponding to plants for Vietnam, they show the intention and interest that the IBST itself will become a counterpart or responsible organization.

When the 3rd mission discussed with the IBST, they reconfirmed that they would like to proceed the matters "step by step basis", collaborating with JICA from now on. As to IBST, not only government officials but private company engineers needs to raise their capability. They intend to involve Petrovietnam for the realization of these plans. The IBST also shows their intention of future cooperation that their Seismic Department is possibly strengthened for the human development, and that they are expected to have the technical assistances from Japan. Regarding the seismic engineers resource development, it is necessary to bring up the instructors who will in future instruct and educate young seismic design engineers, that is, “Trainer’s Training”. Consequently, by doing so, it will give a broad base on seismic engineers by self education in sustainable manner.

There is a tendency to be insufficient recognition on the necessity for earthquake resistance technology and disaster prevention plan among people. Since a serious disaster was not experienced until now, there is no preparation for disaster.

In the seminar, there were many questions about seismic technology and engineering, on the other hand, there seems to be a lack of knowledge about disaster prevention plan and also a lack of general knowledge on the earthquake. Therefore it is necessary to have plants disaster prevention disseminations activities as well as seminars on plant seismic design technologies.

Chapter 5 Seismic Technology for Plant in Philippines

5.1 Petroleum, petrochemical and chemical industries in Philippines

The following Table 5.1-1shows the general information of Philippines.

GDP growth rate in Philippines had been stable at around 5% by 2008, then, it has been unstable from the influence of global economic recession in 2009.

GDP growth rate in Philippines has been about 5% in the past, and it fell down to fairly 1% in the world economic crisis. Subsequent economic situation seems to be a little unstable.

Table 5.1-1 General information of Philippines

Economic Index	Static	Remarks				
Area	299,404㎢	(about 80% of Japan) Ministry of Foreign Affairs				
Population	95.86mil.	IMF World Economic Outlook Databases (04/2012)				
Growth rate of Population	1.82%	World Population Prospects by UN (2008)				
GDP	213bil.US$	IMF World Economic Outlook Databases (04/2012)				
GDP/person	2,223US$	IMF World Economic Outlook Databases (04/2012)				
Foreign Reserves	36.1bil.US$	(01/2008)				
GDP	2006	2007	2008	2009	2010	2011
	5.24%	6.62%	4.25%	1.15%	7.63%	3.72%

(Source ： JCI)

5.1.1 Petroleum industry in Philippines

In Philippines, since Chevron Philippines Inc. (Former name was Caltex Philippines Inc.) closed the Batangas refinery in 2003, 2 refineries, e.g. 180,000bpd Limay refinery of Petron Corp. and 120,000 bpd Tabangao refinery of Pilipinas Shell Petroleum Corp., have been continuing production.

After giant food and beverage company, San Miguel Corp (SMC), got Petron Corp from Ashmore Group of UK, they acquired ExxonMobil's oil refining businesses in neighboring Malaysia and have been laying the foundation to set up the reverse offensive to Petronas.

(1) Petron Bataan refinery

Petron Corporation had been a subsidiary of SEA Refinery Holdings B.V. (SEA B.V.) who was the member of Ashmore Investment Management Group of United Kingdom, and now is a subsidiary of San Miguel Corp's who holds 68.0% shares

Bataan refinery is located in Limay of Bataan Peninsula, 146km away from the capital Manila, and completed in April 1961 and currently processing 180,000 bpd crude oil by 3 CDUs.

Table 5.1.1-1 is a list of main plant facilities of the Bataan refinery.

(2)PSPC / Tabangao refinery

Pilipinas Shell Petroleum Corporation (PSPC) is a joint venture between oil major Royal Dutch/Shell group and local capitals. The Largest shareholder is Shell Petroleum Company and has invested 67.6%.

This refinery started operations in 1962 at Tabangao of Batangas, about 120km south of Manila and currently it is composed with 110,000 bpd CDU as the core facility, 24,000 bpd hydrocracking unit, 50,000 bpd desulphurization unit (HDC), 28,000 bpd naphtha hydrodesulfurization unit and 17,000 bpd catalytic reforming unit.

Table 5.1.1-1 Main facilities of the Bataan refinery

PETRON / Bataan Limay (Unit:bpd)

Plant	Capacity	Additional	License	Engineering	Completed
CDU (No.1)	45,000	-	-	-	1961
CDU (No.2)	85,000		JGC	JGC	1972
CDU (No.2)	15,000	-	Daelim Industrial	Daelim Industrial	1997
CDU (No.3)	35,000	-	JGC	JGC	1980
CDU	-	20,000	Not yet	Not yet	Not yet
Vacuum Distillation	31,000	-	JGC	JGC	1972
Vacuum Distillation	32,000	-	JGC	JGC	1989
FCC	10,000	-	UOP	Daelim Industrial	2008
FCC	-	10,000	-	-	2011
SCC recovery	140,000	-	UOP	Daelim Industrial	2008
Catalytic reformation	17,000	-	ER&E	JGC	1972
RFCC	17,000	-	-	Daelim Industrial	1998
Aromatic extraction	-	-	UOP	Daelim Industrial	2009
Benzene	22,800 t/y	-	-	-	2009
Toluene	150,000 t/y	-	-	-	2009
Xylene	220,000 t/y	-	-	-	2009
Hydrodesulfirization (Naphtha, Kerosene)	30,500	-	ER&E	JGC	1972
Ditto (Naphtha)	19,000	-	-	Daelim Industrial	1998
Ditto (Diesel)	18,000	-	ER&E	JGC	1972
Ditto (Diesel)	6,,000	-	ER&E	JGC	1989
Ditto (Gasoline)	10,,000	-	-	-	2005
Merox (Kerosene)	10,000	-	JGC	JGC	1989
Merox (Kerosene)	16,000	-	JGC	JGC	1990
Sulfur recovery	71 t/d	-	-	Daelim Industrial	1998
Hydrogen	10 MMcfd	-	-	-	-
Jet fuel	2,100	-	-	JGC	1977
Naphtha Isomerization	6,000		UOP	Hyundai Eng.	2005

(Source : Petroleum and Petrochemical Industry in East Asia Ver.2011)

5.1.2 Petrochemical and chemical industry in Philippines

Petrochemical related industries in Philippines was mainly smaller ones, e.g. plastic compound such as PVC and polystyrene, and most of the products and raw materials have been imported from abroad except PVC, PS and a part of domestic products, and domestic production of PP started in 1997 and then polyethylene also in 1998. However, they were limited to the downstream plastics businesses by private companies of local chemical makers and foreign manufacturers. Philippine National Oil Company (PNOC), who has been aiming the construction of an ethylene-center time and again since 1980s, they still can not set up the Petrochemical complex plan.

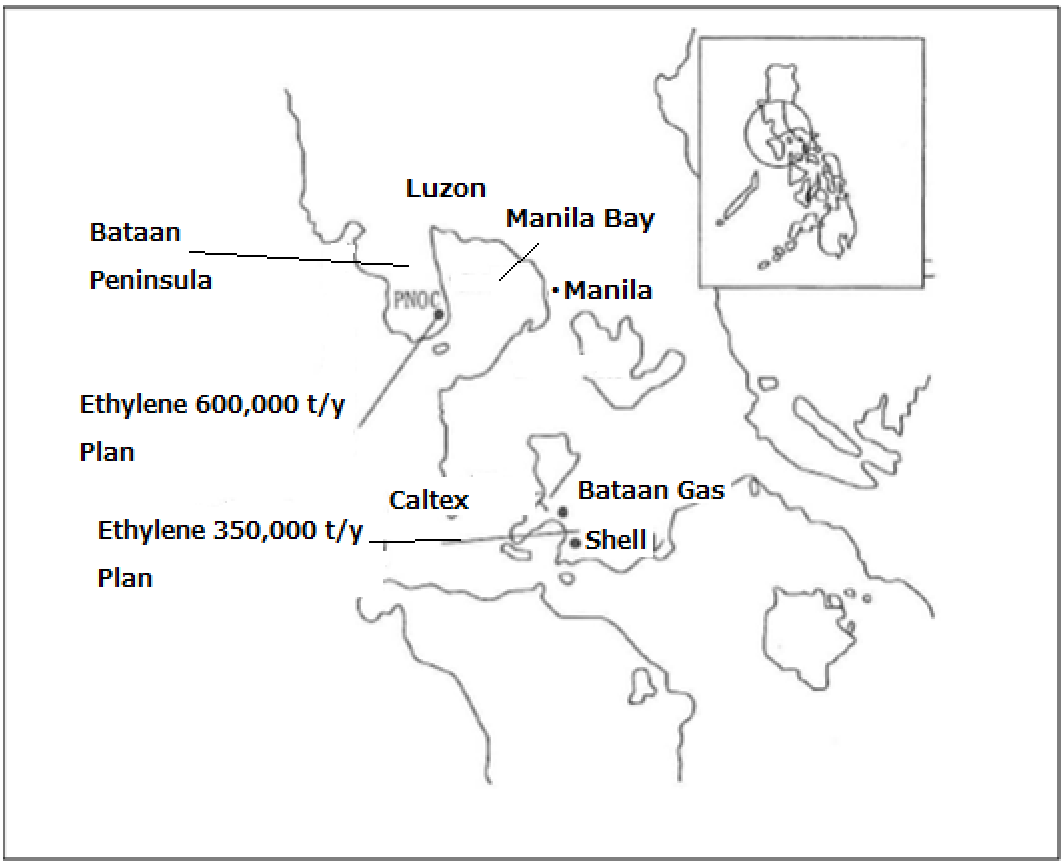


Figure 5.1.1-1Petrochemicalo Pants in Philippines

(Source : Petrochemical Industry in Asia Version 2011)

(1) Petrochemical complex plan in Batangas Island

JG Summit Petrochemical Corp. (JGSP) plans to build a petrochemical complex as the first ethylene cracker in Philippines.

The plan is to construct a naphtha cracker including 18,000 t/y ethylene, 189,000 t/y propylene (218,000 t/y gasoline, 150,000 t/y and 28,000 t/y heavy oil as co-product) but has been delayed and estimated to be early 2014.

(2)JG Summit Petrochemical Corp. (JGSP)

JGSP was established by 80 % of JG Summit Holdings (JGSH) and 20% of Marubeni

Corp. and has been producing polyethylene and Polypropylene (PP) since 1998.

The 200,000 t/y LLDPE / HDPE by Unipol method of old UCC (now Dow Chemical) technology was completed in Batangas in the second half of 1997 and has entered into operation. The 180,000 t/y PP by Unipol method has also started in June 1998.

The raw material, ethylene and propylene have been imported from Singapore and the operation rate was remained around only 50 %.

(3)Philippine Polypropylene Inc. (PPI, former Petrocorp)

PPI has completed the construction of 160,000 t/y PP plant by BASF method, which was adjacent to the ethylene cracker of POC, in December and they have expanded to 225,000 t/y in March 1999.

Though the PP plant was forced to stop operation from the high cost of raw materials, it started to operation again in February 2011 by receiving FCC recovery propylene from the refinery because Petron became the parent company.

(4)Philippine Resin Industries Inc. (PRII)

PRII was a PVC manufacturing company which was established as a joint venture investment Mabuhay Vinyl Corp. 49%, Tosoh and Mitsubishi Corporation 20% each, The Bank of The Philippine Islands (BPI) 11% in July 1994 and currently, Mitsubishi Corporation and Tosoh 50-50.

PRII started commercial operation of 70,000 t/y PVC resin plant by Tosoh technology at PPDC-Petrochemical Park of Bataan Peninsula in October 1998 and expanded to 100,000 t/y by the de-bottlenecking in December 2000. Raw material VCM has been imported from Tosoh plant in Japan.

Tosoh has completed 12,000 t/y compound facility in the Lima Technology Center Industrial Park near Manila in March 1999,

(5)D&L Industries Inc.

This company started as a chemical trading company in 1971 and produces polystyrene (PS), unsaturated polyester resin, plasticizer and has also produced oleochemical.

They have introduced the general-purpose resin compound technology from Japan Pigment and have affiliated Farst In Color Inc. (FIC) who is operating Manter-Batch, and also imports engineering plastics and solvents.

They are producing 21,000 t/y GP and IHI grade PS in Quezon near Manila.

5.2 History of earthquakes and tsunami, damages and future risks

5.2.1 Earthquake and tsunami

(1) Geological and Geographical Environment in Philippines

Philippine is sandwiched between two deep trenches, Manila Trench and Philippine Trench (Figure 5.2.1-1).

Manila Trench is an oceanic trench located from southwest off shore of Taiwan in the east part of South China Sea to west side of Luzon and the trench reaches a depth of about 5,000 meters, in contrast with the average depth of the South China Sea of about 1,500 meters. It is created by subduction, in which the Eurasian Plate of west side subducts to under Philippine Sea Plate of east side. Manila Trench causes frequent earthquakes in this area and also causes volcanic activities in Luzon. On the other hand, Philippine Trench is located from southeast of Luzon to the northeast off shore of Halmahera through east side of Mindanao and the trench reaches a depth of maximum over 10,000 m. This trench is the boundary of Sunda Plate (part of the Eurasian Plate) and Philippine Sea Plate and Philippine Sea Plate is subducting under the Eurasian Plate.

Philippines seems to be floating between two subducting zone.

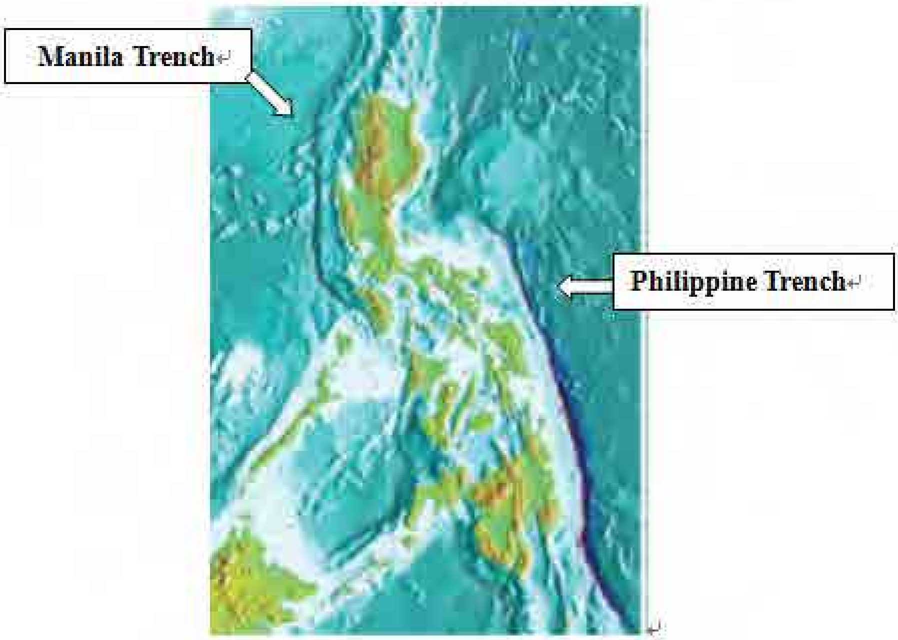


Figure 5.2.1-1 Geological and Geographical Environment in Philippines
(Source : Philippine Institute of Volcanology and Seismology (PHIVOLCS))

(2) Past seismic data in Philippines

The past seismic activity in Philippine are shown in Figure 5.2.1-2.
In Philippines, there has been no massive earthquake as much as occurred in Indonesia, but small and medium-sized earthquakes have frequently occurred.
The epicenters concentrate especially on Manila Trench and Philippine Trench.

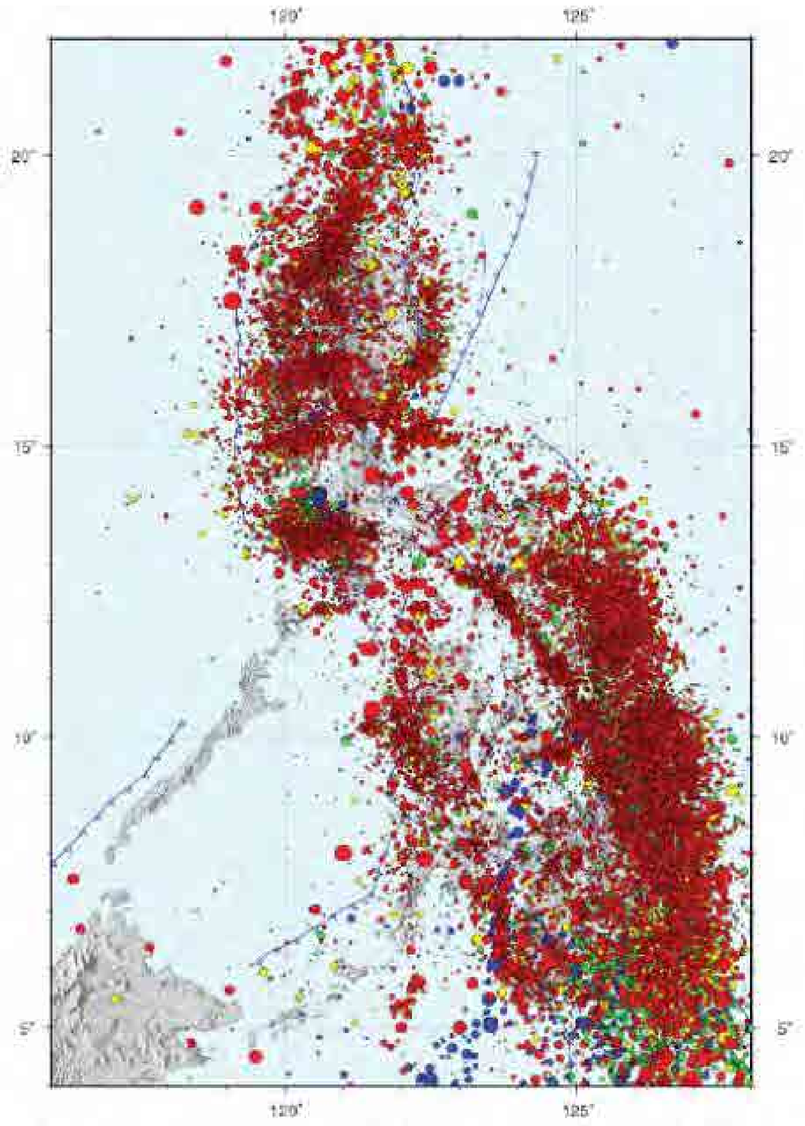


Figure 5.2.1-2Epicenters in Philippines
(Source : PHIVOLCS)

5.2.2 Damages caused by earthquakes and tsunamis

(1) USGS Data etc.

Large earthquakes in Philippines have occurred only twice on Luzon, but frequently on Mindanao, which is located near Philippine Trench.

Damages are summarized in the Table 5.2.2.2-1.

Table 5.2.2-1－The list of Damages

No.	Day/Month/ year of Earthquake	Epicenter	M	Situation (Source:*2)	Source
1	1934/2/14	Luzon	7.6-7.9	-	*2
2	1942/5.14	Mindanao	7.9-8.2	-	*2
3	1943/5/25	Mindanao	7.7-7.9	-	*2
4	1948/1/24	Middle of Philippines	8.2-8.3	Dead: 70	*2
5	1952/3/19	Mindanao	7.6-7.9	-	*2
6	1976/8/16	Mindanao (Mindanao Earthquake)	7.9	Dead/Missing :180 Tsunami in Moro Gulf	*1
7	1990/7/16	Luzon (Philippine Earthquake)	7.7	Dead/Missing :1700-2400	
8	1992/5/17	Mindanao	7.5	-	*2
9	1994/11/15	Middle of Philippines	7.1	Dead/Injured :200 Tsunami (*3)	*3
10	2001/1/1	Mindanao	7.5	-	*1
11	2002/3/5	Mindanao	7.5	-	*1
12	2003/11/18	Samal Island	6.5	-	*1
13	2004/10/8	Dhindoro Island	6.5	-	*1
14	2007/8/20	Philippines Island chain area	6.4	-	*1
15	2008/3/3	Philippines Island chain area	6.9	-	*1
16	2009/10/4	Mindanao（Moro Gulf）	6.6	-	*1
17	2010/7/23	Mindanao（Moro Gulf）	7.6	Deep Earthquake	*1
18	2010/7/23	Mindanao（Moro Gulf）	7.3	-	*1
19	2010/7/23	Mindanao（Moro Gulf）	7.4	-	*1
20	2012/2/7	Middle of Philippines（Cebu）	6.8	Dead:43, Many Injured（*4）	*1

(Source : *1 USGS Home Page , Magnitude 6.0 and Greater

*2 G-ma Area Research Series / E-005, Main big Earthquake in the World

*3 Wikipedia / Chronology of Earthquake

*4 AFP BB News)

5.3 Seismic design code for petroleum refinery and Petrochemical plant in Philippine

(1) History of seismic code

Philippines have been preparing seismic design code for buildings referring to United States Code since 1976. The newest is NSCP (National Structural Code of Philippines) 6th Edition-2010. Application of the code is minimum requirements. The endorsement by DPWH (department of Public Works and Highway) is necessary.

(2) Structures applied seismic design code

Building structures, Non-building structures

(3) Earthquakes to be considered

Seismic design code of Philippines categorized two stage of earthquake zone with peak ground acceleration (PGA) of 0.2g and 0.4g which is stipulated in the PGA map of Philippines.

Peak ground acceleration (PGA) is corrected by soil type, response ratio depends on soil type and natural period of the structure, importance factor and reduction factor depend on the degree of ductility.

Detailed explanation including the below items are to be referred the Appendix III, "Seismic Design Code in Philippines".

(4) Seismic performance to be provided

The seismic design code of Philippines stipulates the calculation methods for each specific structures.

(5) Response analysis

Linear static analysis is applied for the response analysis.

(6) Evaluation method

By calculating the shear stress applied for the basis of the structure and horizontal force applied for each structural member, then comparison is made with allowable stress of the structural materials.

5.4 Disaster prevention planning & organization and security for plants

5.4.1 Hazard map of earthquake and tsunami

The figure 5.4-1 below shows the distribution of active faults and trenches in Philippines. Receiving the strong compressive pressure from the plate subduction zone of two trenches, a large active fault is running along the center line of Philippines and a number of small active faults are also present in reef islands, and it is clearly understood that the ground is unstable and earthquake-prone.

(Trenches are displayed by purple lines and Active faults are by red lines.)

In addition, the figure 5.4-2 below shows the areas vulnerable to tsunami.

Tsunamis have been occurred causing by 40 earthquakes since 1958 in Philippines.

Blue lined area is region prone to tsunami historically. Other green lined and red lined areas have been also pointed out the possibility and it suggests clearly that all shorelines of reef islands belonged to Philippines are exposed to the risk of tsunami in case of earthquake.

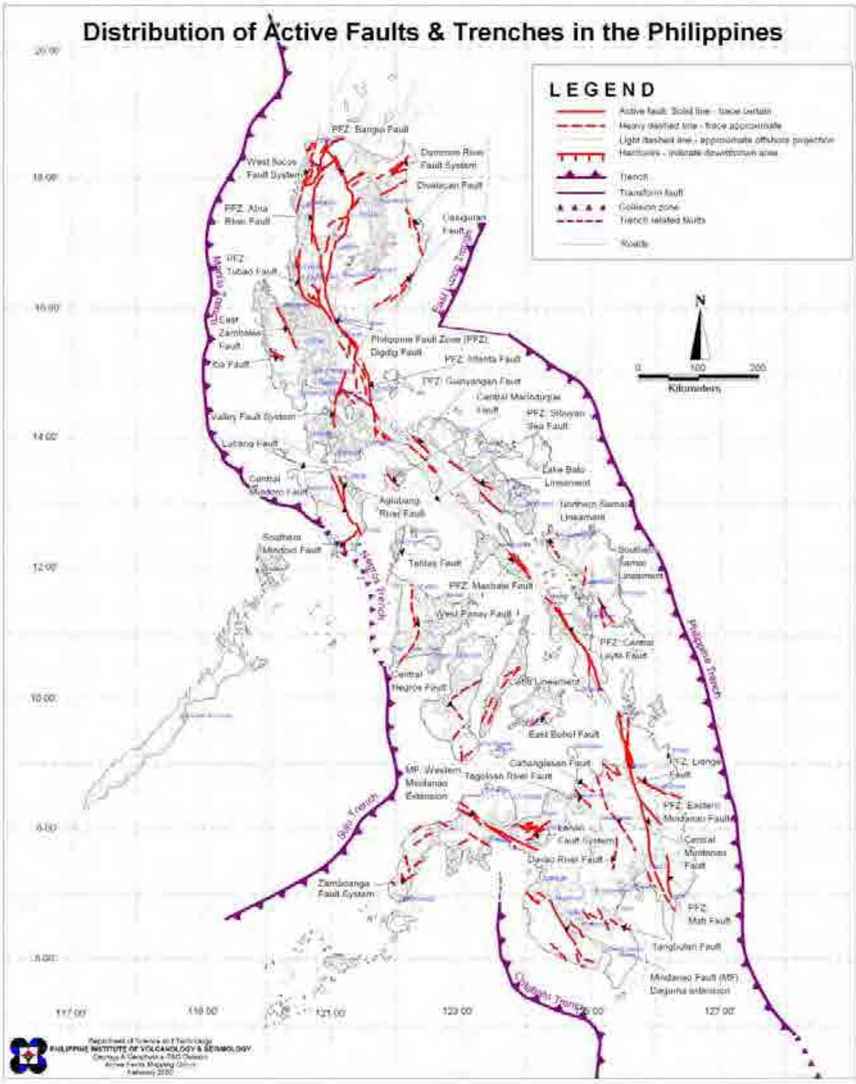


Figure 5.4-1 the distribution of active faults and trenches in Philippines
(Source : PHIVOLCS)

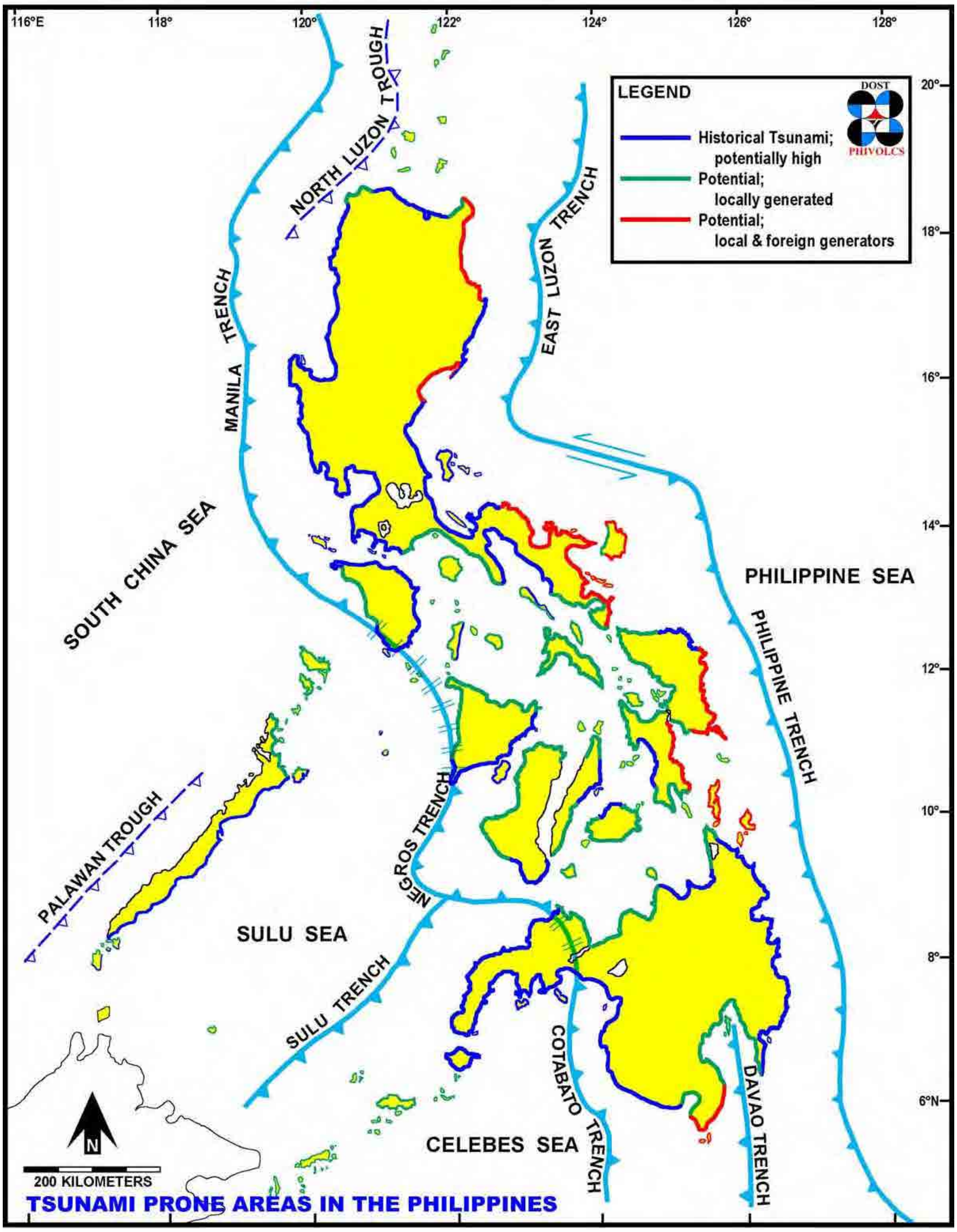


Figure 5.4-2 The areas vulnerable to Tsunami
(Source : PHIVOLCS)

5.4.2 Seismic network

The following figure 5.4-3 shows the Disaster Observation Network in Philippines including earthquakes and volcanic activities and the current status is as follows.

(1) "Earthquakes and Volcanos Observation Network Improvement Project " has been promoted by Japanese Government.

Phase I (2000) / Phase II (2004)

1) Installation of 67 Network stations
  - Installation of seismic observatory
  - Installation of volcanic activity observatory
  - Installation of nine broadband stations

2) Measures to strengthen the future
  - Replacing the computer
  - Additional two stations for remote control observatory
  - Expansion of the system to 85 stations as total

(2) Broadband seismometers and seismographs will be installed at 10 stations out of existing 30 satellite telemetry seismic stations in the activity of the Science and Technology Cooperation, that is “The Project to enhance the monitoring ability of earthquake and volcano in Philippines and to promote the use of disaster prevention information”, in 2010-2014. In addition, seismic intensity early flash reports system will be developed with the help of warning system of the Internet.

Figure 5.4-3 Disaster Observation Network in Philippines(Source : PHIVOLCS）

5.4.3 Examples of disaster countermeasure in some companies

(1) Petron Bataan Refinery

1) Outline of their business

This refinery is located in Limay of Bataan Peninsula about 146km away from the Capital Manila. It has been completed and started in April 1961. This refinery was first owned by ExxonMobil and through capitals of the Philippine Government and Ashman of Saudi Arabia, and finally the beer company San Miguel owned about half of the shares in 2012. Currently, they have totally 180,000 bpd capacity with 3CDUs. The specification of sulfur content in petroleum products has been stipulated by the Philippine Government and it is settled to be Max.5PPM by the European standard, it is very severe specification. Therefore, they also carried out hydrodesulfurization.

2) Earthquake history and seismic Countermeasure

- Manila Trench is the causes of earthquakes, but the refinery is located away from the trench and is at Manila Bay side which is across the mountains of Bataan Peninsula and at the opposite side of the trench. Concerns about earthquake and tsunami are not so big.

- As natural disasters in the past, there was a shaking by the eruption of Mount Pinatubo in 1991 but no seismic activity. At that eruption time, though a large amount of volcanic ash fell estimated to 20 ~ 30cm on the road, there was no affection to the plants.

- The most threat of natural disaster is Typhoon. Since it comes at least 20 times in a year, refinery staff has been in contact with Meteorology Bureau accordingly.
  As the countermeasure, when equipments and materials likely to be blown up by the strong wind, they are to be put into the house. The liquid level in the tank shall be raised up and the Pier is closed. The wind speed design value to Typhoon is 232km/hr.

- This refinery site is 240ha and uses the slope from the mountains to the sea. The purification process is located 40m above sea level and the site has no worry about the big wave, Tsunami and flood.

- There are many lightning in June and July. The lightning rod and foam extinguishing facility has been settled against the tank ring fire.
  Though tank ring fire caused by lightning can occur once a year, they have been able to deal adequately. Lightning comes certainly but earthquakes rarely occur.

- Based on the standard specification of Exxon Mobil(EM), the United States Standards such as ASME / ANSI, API and TEMA have been applied.

- Seismic Design has been designed on the basis of UBC. Current standards have been modified based on the initial one, but the latest standards have been applied at the time of expansion. Though the oldest facility currently in operation was built in 1973, the standard is not out of fashion.
  When UBC was revised in 1989, rehab (Re-use, Revamp, Re-design) has been implemented during 1999 to 2000. The pile has also been exchanged at that time.

- The maximum design wind speed is 232 km / hr and the wind load is dominant than seismic load in the structural design.

- Though there is no capital tie with Exxon Mobil now, the technology consultant contract with the Exxon Mobil Corporation has been entered into, and the design, maintenance and operation have been conducted based on the latest specification of

EM. EM answers the questions, if questions will be submitted.

- Ground is good and the mountain side is being built on the base directly. The structures near the sea are pile foundation. Pile length is 20m ~ 25m. Soil bearing capacity of the foundation can be taken 107kPa.

- Seismograph has not been installed.

3) Disaster Prevention Countermeasure

- The following countermeasures to disaster have been developed.
  * Environment : Waste Water treatment, Sour Water facility, Sulfur Recovery Unit, PFCCU, Flue Gas Desulfurization unit etc.
  * Fire-safety and Disaster Prevention:
    Fire fighting pipe systems,
    Heat Sensor Automatic Foam Pouring System,
    Ring-shaped Sprinkler for spherical tank, fire brigade etc.
- AS for Scenarios for emergency response, guidelines of plant operation along with the disaster level (level 1, 2) have been prepared. The acceptance of crude oil shall be stopped at level 2.

- Emergency Response Plan (Shutdown Manual) has been prepared.
  Operators have to be stand-by even at the weekend in rotation. The paging system and the siren have been installed in the field. Every operator has a handy phone.

- At the time of emergency, Executive Vice President, in the top of the organization chart, has the responsibility as the head, and the head of the Safety, Health, Environment & Facility department shall lead in practice.

4) Others

- As for laws and regulations concerning the conservation and maintenance of the plant, there are provisions of the local government, and it is necessary to overhaul high-pressure towers and vessels maximum every 5 years. As for Hydrogen system, inspection is required every 18 months.

- As for Fire/Electricity/Buildings, there is a regulation of the central government.

- As for the leak test of the plant, government inspectors attend once a year. This is under the jurisdiction of the Department of Labor.

- The check before operation is necessary to the new plant.

5.5 Investigation of actual seismic design

In Philippines the national seismic design code, National Structural Code of Philippines (NSCP) (the latest edition of 6th edition was issued in 2010) exists. That was established with reference of American standards such as UBC or IBC. Therefore, Philippines seismic design code is consistent with UBC. And NSCP also covers non-building structures. Accordingly it is possible to design non-building structures against seismic loads applying UBC.

In applying UBC to plant facilities in Philippines, the equivalent UBC's zoning factors to the construction site must be selected from tables on UBC. And calculation is done in accordance with UBC.

5.6 Simulation for damage of plants due to estimated seismic load and mprovement plan

The team studied the seismic design codes and the seismic hazard maps in the Philippines, estimated the damage of the plants designed by these codes and maps, and analyzed problems and suggested plans for improvement.

5.6.1 History of seismic design code for plants and seismic hazard map

Seismic design code for plants is not established in Philippines. History of seismic design code for buildings and seismic hazard map is as follows.

(1) "National Design Code of Philippines (NSCP), Volume 1, Forth Edition 1992"
- This code was established with referring to UBC.
- Refer to Figure 5.6.1 for the hazard map.

(2)"National Design Code of Philippines (NSCP), Volume 1, Fifth Edition 2001"
- The skeleton of seismic design was not revised except for the soil profile categories.
- Seismic hazard map was not revised.

(3)"National Design Code of Philippines (NSCP), Volume 1, Sixth Edition 2010"
- The skeleton of seismic design was not revised.
- Seismic hazard map was not revised.

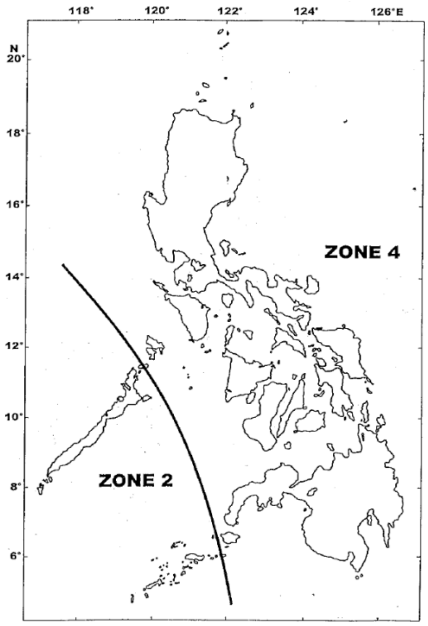


Figure 5.6.1 PGA Map of NSCP
(source:"National Design Code of Philippines (NSCP), Volume 1, Forth Edition 1992")

5.6.2 Outline of seismic design code

In the seismic design of the ordinary buildings, the study team used to calculate the lateral force on the buildings due to the design earthquake and select the structural members of the building.

The outline of the calculating method of the lateral force acting on the building due to earthquake is shown in Attached document I of NSCP Sixth Edition 2010. In this code, the lateral seismic design force is prescribed from five parameters as follows.

(1) Peak ground acceleration at the top of the base rock is given in the PGA of the seismic hazard map. (refer to Figure 5.6.1)

(2)Seismic response factor indicates earthquake amplifying at the outer layer of the ground, and is given in the function of the soil profile type and the first natural period of the structure. (refer to Figure 5.6.2)

(3)Importance factor indicates charging an extra of the seismic force, and is given for the occupancy type of the structure.

(4)Seismic reduction factor indicates reducing of the seismic force, and is given for the ductility (performance of the plastic deformation) of the structural system.

(5)Total weight of the building including an appropriate portion of the live load

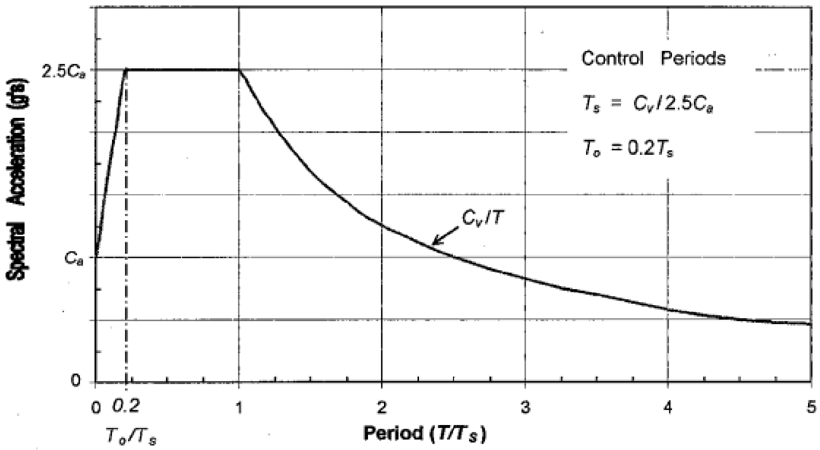


Figure 5.6.2　Design Response Spectrum
(source : “NSCP Sixth Edition 2010”)

5.6.3　Prediction of the damage

Among the five parameters at 5.6.2 which prescribe the lateral seismic design force, (1)～(4) are prescribed by the seismic design code. For the factor (1) the study team compares the history of the PGA map, and for the factor (2)～(4) the study team compares the design base shear expressions between NSCP and ASCE 7-05 (American Society of Civil Engineers). Then we will predict possibility of the damage from the magnitude of the design base shear (total lateral force at the base).

(1) The seismic hazard maps in NSCP1992, 2001, 2010 are exactly the same. It is desirable to consider whether it is necessary to revise the hazard maps incorporating the latest seismic observation and investigation data.

(2)The seismic reduction factor corresponding to the ductility has been decreased in NSCP1992, 2001, 2010, and the seismic load has been increased. Therefore when the value of this factor corresponding to the structural system type has been decreased significantly, there is some possibility of no fitting in the latest code. So it is desirable for the plants designed by the older code to check seismic performance.

(3)As the study team has no older seismic design codes than 1992 edition, we don’t declare concerning the seismic performance of the plants designed in these codes. However, the seismic performance may be poor furthermore.

5.7　Level check of plant seismic technology

In Philippines, there is the surveillance of volcanic activity, and Observation of earthquake and tsunami, etc.　These are performed by PHIVOLCS (Philippine Institute of

Volcanology and Seismology) and OCD (Office of Civil Defense, Department of National Defense) corresponding to disaster. These organizations are conducting the technology exchange with Japan and other foreign countries. It seems that, however, there is no domestic plant seismic engineering company. The overseas contractor is taking charge of the large plant related to energy here. ASEP (Association of Structural Engineers, Philippines), who has a role as co-organizer of the seminar, is saying that they are taking charge of building-related design criteria, and they have sufficient knowledge in Philippines. It seems that there are few plant seismic engineers. The basic design including the seismic design of oil refinery and the petrochemical plants in Philippines is performed by the overseas engineering companies. The seismic design code used in the country is U.S. standards including UBC, and the design is performed by the commercial software in which they are incorporated. It is thought that contractors in Philippines are inexperienced in the application of the seismic design for non-building structure like plant equipment.

5.8 Enlightenment activities for the necessity of plant seismic measures by seminars

5.8.1 Outline of seminars

Date : August 29, 2012

Venue : Metropolitan Club, Makati city

Subject : Mission presented the following 4 themes for the first time seminar in Philippines.

-1- Insight about the JICA Seismic Technology Study Project

-2- Overview of Japanese Seismic Technologies and Introduction of Seismic Assessment Methods for Existing Plant Facilities in Japan

-3- Comparison of seismic design results based on various national codes

-4- Disaster Prevention System of Refineries in Japan

The principal themes of earthquake observation system, seismic design code and disaster prevention plan and organization in Philippines were presented by Philippine side.

Participant : 44

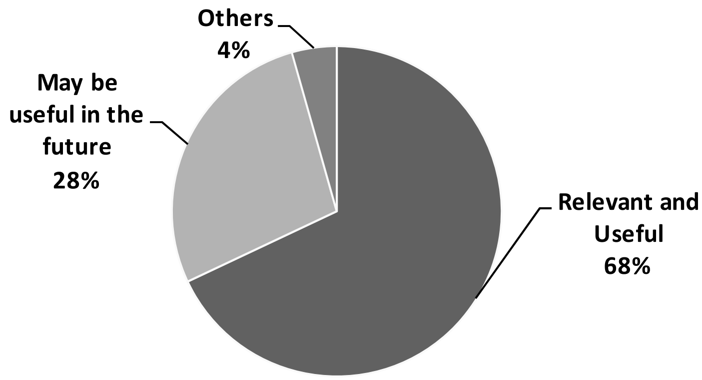
Q & A : Main question on the Japanese side presentations were, how to train seismic design engineers, importance factor and related equipment, importance factor of the LNG tanks, wall thickness and overturning moment, countermeasure for refinery fire.

5.8.2 Summary of Questionnaire on Seminar

The questionnaires were distributed to the participants at the registration at this seminar and recovered it at the end.

1) Summary of Questionnaire

-1- Content of Seminar：



5.8.3 Summary of seminar

There are about 45 participants in the first seminar, and active discussion was made in Philippines. There were many opinions from the questionnaire that they wanted to hold a seminar more frequently. Since it was the first seminar held in Philippines during the study, there was the presentation which touched a little on the basic seismic engineering. In the presentation, the team introduced the three-country comparison for the seismic design code, the law system in Japan, disaster prevention of Japan, especially the disaster prevention system of petroleum refineries. ASEP stated that the law system about the seismic design and disaster prevention for petroleum refinery and petrochemicals plants is more required, and they are paying attention to the law system of Japan. ASEP has an intention to perform examination whether law system of Japan in the future can be introduced. ASEP said that they would like to receive Japanese specialist's assistances on the occasion of the introduction for Japanese law system.

Even in the field of personnel training, since a Philippines markets-oriented plant engineering company does not exist in Philippines, it will be necessary to raise engineering works, architectural engineers, and mechanical engineers. From the questionnaire (refer to the Appendix VIII), there was also the opinion of the purport that many participants want to continue and carry out the same kind of seminar.

5.9 Needs and requests in Philippines

ASEP, who was co-organizer of the seminar, stated that the law system about the seismic design and disaster prevention for petroleum refinery and petrochemicals plants is required, and they are paying attention to the law system of Japan. In the stance of the expert on plant engineering, ASEP has opinions as follows.

- It is necessary in Philippines that the low system related to seismic design and disaster prevention for refinery and petrochemical.
- They are concerned to Japanese law system.
- In future, it is necessary to introduce Japanese law system.
- Since capability of ASEP is limited for making codes and standards, cooperation with DPWH (Department of Public Works and Highway) will be necessary.

Bring-up a large number of plant seismic engineers is the greatest needs, and from the result of the questionnaire of the seminar, many participants expected to continue seminars on plant seismic design technologies.

Chapter 6 Summarization of Plant Earthquake Prevention Problems and Proposal from Japanese Standpoint

6.1 Comparison of disaster prevention organization, relevant laws, and so forth in Indonesia, Vietnam, and Philippines

The disaster prevention plans in three countries, Indonesia, Vietnam, and Philippines have been described in Chapter 3, Chapter 4, and Chapter 5 respectively. Their results are summarized in Table 6.1-1. The example of Japan is also put together and shown in this table.

Table 6.1-1 Comparison of disaster prevention plan in three countries

Comparison of Disaster Prevention Plan in Viet Nam, Indonesia and Philippines

	Viet Nam	Indonesia	Philippines	Japan
a) Basic Law	Law on Water Resource Law on Dyke Ordinance on Flood and Storm Control	Law No.24 Year 2007 on Disaster Management	Disaster Risk Reduction and Management Act 2010	Disaster Counter-measures Basic Act
b) Responsible Government Organization	Prime Minister (Ministry of Agriculture and Rural Development, The Central Committee for Flood and Storm Control (Disaster Management Dept./Dike Management for Tsunami)	National Agency for Disaster Management	Department of National Defense	Cabinet Office
c) Covering Disaster	Natural Disaster	Natural & Accidental Disasters	Natural Disaster & Terrorism	Natural & Accidental Disasters

(Data Source: Drawn up by Study team)

Each basic law is provided and each corresponding organization is clarified in three countries respectively. The plant earthquake disaster is classified into natural disaster in Covering Disaster of Table 6.1-1.

Especially in Indonesia and Philippines, the basic law and the corresponding organization have been well established and an earthquake disaster is definitely included in Covering Disaster.

In Vietnam, the basic law and the corresponding organization have been built up, too and the law of the Ministry of Construction for an earthquake is also prescribed. When

Northern Vietnam had a severe earthquake in 2000, the Ministry of Construction coped with the disaster quickly in accordance with this law. However, the present law has been provided mainly based on flood prevention. Although there is a few of description about an earthquake in the law, the measures for earthquake prevention have not been sufficiently taken in practice. Therefore it is necessary to establish and improve the earthquake-resistance measures further in the future in Vietnam.

6.2 Comparison of seismic technology and disaster prevention technology in Indonesia, Vietnam, and Philippines

The aspect of seismic technology and disaster prevention technology is studied in 6.2 and the results are described as follows.

6.2.1 Plant observational results in Indonesia, Vietnam, and Philippines

The simplified seismic assesment evaluation results of the plants observed in Indonesia, Vietnam, and Philippines have been described in Chapter 3, Chapter 4, and Chapter 5 respectively.

Based on each result, the applied seismic design code, the contractor name, start-up time, and simplified assessment evaluation result are shown in Table 6.2.1-1.

In Vietnam, the petroleum refining plant started in 2009 was designed and constructed by JGC Corporation. It was made a seismic design by UBC (American specification) and is now in operation well. Pha Lai coal burning thermal power plant has the following two plants.

No. 1 plant : started in 1983 and designed & constructed by the former Soviet Union

No.2 plant : started in 2000 and designed & constructed by Japan and South Korea

No. 1 plant was built based on the seismic design by the former Soviet Union norm. As observational results, the defect was found in earthquake prevention measures for plant piping and ceiling, and the aged deterioration of plant was also found out. LPG plant of PVGas is under construction by South Korea and TXCDVN375 code is to be applied.

In Indonesia, the gas plant of Petrochina Betara was designed and constructed by Chiyoda Corporation. It was made a seismic design by UBC. MERAK Plant of Mitsubishi Chemical Corporation was designed and constructed according to SNI code by JGC Corporation. The observational results of both plants were good.

In Philippines, there are both of old and new plants in Bataan Refinery of Petron. At the old plant, replacement is now in progress. The plant was designed and constructed by the old owner, Esso and it is conjectured that the applied code was UBC in those days (different from the present UBC). It was also found out that the old plant had maintenance problems such as steam leakage and insulation broken off.

The plants observed at this study such as petroleum refining and petrochemical plant and LPG plant were large-scale, and were designed and constructed by overseas engineering companies. As a result, there was not any particular problem.

Table 6.2.1-1 Simplified seismic assessment evaluation results for plants observed at this study

The Results of Plants Seismic Survey in Viet Nam, Indonesia and Philippines						
	Viet Nam			Indonesia		Philippines
Plants visited	Petrovietnam Dung Quat Refinery	Power plants (Old&New)	PVGas LPG Receiving Terminal	Jambi Betara Gas Plant	Mitsubishi Chemical	Petron Bataan Refinery
Applied Code	UBC1997	Russia & Japan,Korea	TCXDVN 375	UBC 1997	SNI	UBC/Esso /Mobil
Contractors	JGC	Sumitomo	POSCO Engineering	Chiyoda	JGC	n.a.
Year started	2009	1983/2000		2005	1991	1973
Observational Results	Good	Old: To be further studied New:Good	Under construction	Good	Good	Old: To be further studied New:Good

(Data Source: Drawn up by Study team)

6.2.2 Comparison of the minimum required thicknesses of a tall tower designed in accordance with the national seismic design codes in Indonesia, Vietnam, and Philippines

An earthquake-proof for plants is generally dependent on the severity of the applied seismic design codes. Based on the investigation results of seismic design codes applied to petroleum refining and petrochemical plants, the minimum required thicknesses of a tall tower, which is one of the typical instruments in plants was calculated on trial. A tall tower is the center of plant system in various plants such as a process reactor and is also large-sized and must be assumed to suffer a lot of damage from disasters.

The calculation result shows that the earthquake-proof for a tall tower is dependent on the minimum required thicknesses as might be expected.

As a result of investigation on seismic design codes in Indonesia, Vietnam, Philippines, USA, and Japan, applicable scope for each seismic design code for petroleum refining and petrochemical plants is as shown on Table 6.2.2-1.

Table 6.2.2-1 Applicable scope of seismic design codes

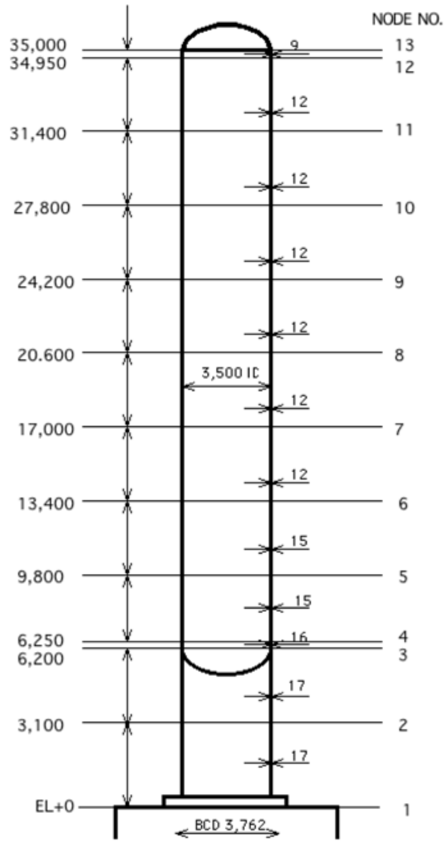
<table>
<tr><th>Facilities</th><th>Japan</th><th>USA</th><th>Viet Nam</th><th>Indonesia</th><th>Philippines</th></tr>
<tr><td>Building structures</td><td>The building Standard Act</td><td rowspan="4">ASCE 7 (or UBC, IBC)</td><td rowspan="2">TCXDVN 375</td><td rowspan="2">SNI-02-1726</td><td rowspan="4">NSCP</td></tr>
<tr><td>Non-building structures similar to building</td><td rowspan="4">High Pressure Gas Safety Act</td></tr>
<tr><td>Non-building structures</td><td rowspan="3">(NONE)</td><td rowspan="2">(UBC)</td></tr>
<tr><td>- Pressure vessels
- Heat exchangers</td></tr>
<tr><td>- Piping</td><td>ASME B31 E</td><td>(NONE)</td><td>(NONE)</td></tr>
<tr><td>- Storage tanks</td><td>Fire Service Law</td><td>API 650 Appendix E</td><td>EN 1988-4</td><td>(API 650 Appendix E)</td><td>(API 650 Appendix E)</td></tr>
</table>

Note: Code names with parenthesis mean de-facto standards. They are not specified by national codes but are applied in those countries,

(Data Source: Drawn up by Study team)

In order to study the effects of seismic loads specified by the national seismic design codes on the actual thicknesses of shell and supporting skirt, the minimum required thicknesses against design loads including seismic load were calculated on trial for the sample tower shown in Figure 6.2.2-1.

As shown in Table 6.2.2-1, seismic design codes in Vietnam and Indonesia can be applied to building structures. On the other hand, they cannot be applied to non-building structures that are the majority of plant facilities. Since it might be difficult to determine the required sizes of components against seismic loads if the seismic design codes were strictly applied, some necessary factors for the trial calculation such as importance factors are assumed based on the actual design results.



Design Pressure: 0.35MPa

Design Temperature: 150C

Material

Shell: SA516 Gr.70 (C.S.)

Head: SA516 Gr.70 (C.S.)

Skirt: SA516 Gr.70 (C.S.)

Natural Period: 0.61 sec

Damping Factor: 3%

Pressure Vessel Design Code:

ASME Section VIII division 1

Operation Weight: 1,474 kN

Corrosion Allowance: 3.0mm

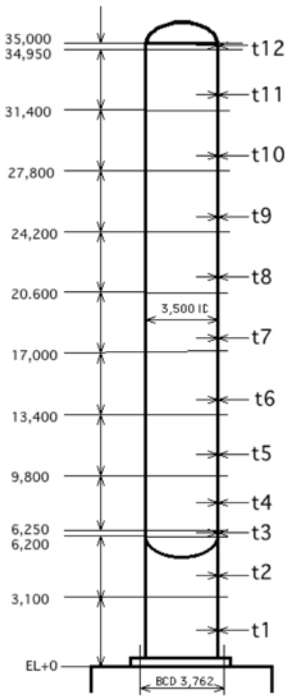
(for pressure parts)

Figure 6.2.2-1 Calculation Model for seismic design of a tall tower
(Data Source: Drawn up by Study team)

It is assumed that the construction site is located at the area where the design seismic acceleration is the highest in each country and that the soil condition has the highest response to the natural period of the model tower.

As results of calculation, the minimum required thicknesses are shown on Table 6.2.2-2.

Table 6.2.2-2 The minimum require thicknesses of shell and skirt of a tall tower



	Japan	Viet Nam	Indonesia	Philippine
t12 (mm)	9	9	9	9
t11 (mm)	12	12	12	12
t10 (mm)	12	12	12	12
t9 (mm)	12	12	12	12
T8 (mm)	12	12	12	12
t7 (mm)	12	12	12	12
t6 (mm)	12	12	12	12
t5 (mm)	15	12	12	12
t4 (mm)	15	12	12	12
t3 (mm)	16	12	12	12
t2 (mm)	17	13	14	11
t1 (mm)	17	13	14	11
Natural period (s)	0.61	0.69	0.68	0.71
Ope. Wt (kN)	1,437	1,388	1,394	1,377

(Data Source: Drawn up by Study team)

In case of Japan, thicknesses of pressure parts under the level of 13.4 m are governed by seismic loads. However, in cases of other three countries, only thicknesses of supporting skirts are governed by seismic loads. In result, the sequence of the required thicknesses of supporting skirts is shown as Japan, Indonesia, Vietnam, and Philippines in order of thickness.

Taking it into consideration that seismological conditions and seismic design requirements are different each other among those countries, it is suggested that simple comparison should not be made with ease. However, the results of Table 6.2.2-2 might be useful for obtaining the outline of the difference of seismic design codes and magnitudes of the seismic loads among those countries

6.3 Common problems in Indonesia, Vietnam, and Philippines

As results of investigating the information acquired from deliberations with main counterparts (BPPT in Indonesia, IBST in Vietnam, and ASEP in Philippines) at this study, the held seminars, the observed plants, and domestic study in Japan, the following items were recognized as common problems.

(1) The number of seismic design engineers, especially for petroleum refining and petrochemical plants is insufficient in all three countries. On the other hand, the seismologist, the observatory, and so forth are substantially supplied in cooperation with oversea countries, including Japan.

(2) It has been found at this study that there is no norm about the seismic design for piping in the seismic design codes of three countries. Since piping is apt to suffer a heavy damage from an earthquake and there is also no norm about the seismic design for piping in USA and EU codes, it is suggested that Japanese seismic design code for piping should be introduced and applied to three countries without delay.

(3) Since the plants observed by the second mission survey were large-sized and were designed and constructed by the Japanese and the South Korean plant engineering companies, any defect for seismic measures was not found out by the simplified seismic assesment evaluation.

However there must be so many small-sized chemical and petrochemical plants in three countries. Therefore it seems that it is necessary to check the actual sufficiency of seismic measures for plants, including small-sized plants in the near future. Similarly to Japan, it is very difficult for small-sized plants in three countries to take useful seismic measures by making an investment without expecting any practical business merit. Accordingly establishment of relevant law and regulation, and campaign enlightenment of necessity for seismic measures should be given priority firstly. In addition, it is necessary to study the actual damage caused by an earthquake and assume how much the damage is and check if the present design and construction may be sufficiently correspondent to the assumed damage. In this way, more necessary seismic measures should be further developed in the future.

(4) Economic development is remarkable in three countries and the stable supply of energy is an important issue for three countries. Since Vietnam and Philippines do not necessarily have sufficient resources in their own countries, both countries have to import LNG as a power-generation fuel similarly to Japan. Pipe line for supplying own country with LNG is also planned in Indonesia. Therefore, it is predicted that the demand of LNG Storage tanks will be increased and the suitable seismic design code and design manuals for storage tanks should be provided in the future.

6.4 Potential needs of seismic technology in Indonesia, Vietnam, and Philippines

Table 6.4-1 is summarized in terms of potential needs of plant seismic technology in three countries. From this table, the following items were recognized as potential need of plant seismic technology in three countries.

(1) Three countries need cooperation for personnel training, such as seismic design engineers, seismic design capability, and evaluation & capability of seismic assesment. It seems to be unexpected that necessity result of Indonesia in Table 6.4-1 is middle, ○. However, taking it into consideration that cooperation from JICA is well organized and developed in Indonesia, it does not necessarily follow that the demand for seismic technology is low in Indonesia.

(2) Since Vietnam has less experience of earthquake hazard, disaster prevention measures in Vietnam is less organized and developed as compared with those in Indonesia and Philippines. Therefore need of cooperation in Table 6.4-1 is large,◎.

(3) Three countries need the concrete seismic technology cooperation (Power plants and LNG storage tanks).

(4) Table 6.4-1 also shows that Vietnam most needs the future provision of seismic engineering and disaster prevention technology. Since Vietnam has experienced neither a severe earthquake nor tsunami until now, improvement of seismic technology has not been well developed.

(5) On the other hand, due to earthquakes frequently caused in Indonesia, Indonesia is establishing the correspondences and measures against earthquakes nationally. Moreover, plant engineering companies such as Rekayasa grow within the country and they have acquired seismic technology in cooperation with foreign plant engineering companies. Some of them are able to manage to design and construct by themselves.

Table 6.4-1 Potential Needs of Plant Seismic Technology in three countries

Potential Needs of Plants Seismic Technology			
	Indonesia	Viet Nam	Philippines
Cooperation for Bring up of Seismic Engineers Resources	○ (Middle)	◎ (Large)	◎ (Large)
Cooperation for Enhancement of Seismic Design Capability	○	◎	◎
Cooperation for Evaluation & Capability of Seismic Diagnosis	○	◎	◎
Cooperation on Disaster Prevention	○	◎	○
Other Seismic Tech. Cooperation (Power Plant /LNG Storage)	◎	◎	◎

(Data Source: Drawn up by Study team)

6.5 Expected counterparts for future cooperation in Indonesia, Vietnam, and Philippines

Outline of major governmental or public organizations visited and covered by study team is as follows.

6.5.1 Indonesia

(1) The Research Institute for Human Settlement, the Ministry of Public Works (PUSKIM : Pusat Penelitian dan pengembangan Permukiman)

PUSKIM is one of four institutes under the Ministry of Public Works, and is in charge of research and development applying science and technology on human settlement. PUSKIM also drafts seismic design code on building structures, and it is expected to strengthen the capability.

(2) Agency for the Assessment and Application of Technology (BPPT : Badan Pengkajian dan Penerapan Teknologi)

BPPT is the largest institute in Indonesia that is in charge of development and evaluation for energy, disaster and earthquake, transportation, space development, and so on. At this study, dissemination activity was carried out in cooperation with BPPT as a seminar hosting partner. BPPT has more comprehensive strength in various of fields, but it may not suitable for settle standards and codes in seismic technologies. BPPT may have more important role in the development of human resources and dissemination of the technologies.

(3) Metrological Climatological and Geophysical Agency (BMKG : Badan Meteorologi, Klimatologi, dan Geofisika)

BMKG has a similar role of the Meteorological Agency in Japan. BMKG controls observation of earthquake and tsunami, and its alarm system. There are 10 local observation centers in Indonesia. BMKG was also very supportive to the study team.

(4) National Agency for Disaster Management (BNPB : Badan National Penanggulangan Benchana)

BNPB was established in February 2008 as an organization for general disaster prevention adjustment, and design of disaster prevention scheme in Indonesia. In precaution, in emergency, and after disaster happened, BNPB in charge of disaster prevention work in each stage, and works with local disaster agencies.

In the industrial fields, there are the Ministry of Industry and the Ministry of Energy and Mineral Resources. The study team came into contact with both of them and explained the purpose of the study and asked for cooperation. In results cooperation could not be accepted since they are not in charge of seismic standards and codes. In fact, ministries related to construction may be mainly engaged with the institutions and standards. Nevertheless mutual understanding between study team and both Ministries will have to be further promoted for future cooperation.

6.5.2 Vietnam

(1) Vietnam Institute for Building Science and Technology (IBST)

IBST is the institute under the Ministry of Construction and is in charge of research and development of construction and establishment of construction codes and standards. By instruction of the Ministry of Construction, IBST developed TCXDVN375:2006 based on Eurocode 8. Since IBST is showing intention to develop a seismic code for plants, IBST is expected to strengthen the capability.

(2) Department of Science, Technology and Environment, Ministry of Construction (DSTE)

DSTE is a department for science, technology and environment in the Ministry of

Construction. IBST is in position to develop codes and standards, while DSTE is in charge of instruction. DSTE has understanding that Northern Vietnam is the earthquake area with middle risk level and seismic technology, personnel training, and technical assistance are needed.

(3) Institute of Geophysics, Vietnam Academy of Science and Technology (VAST)

VAST has a role to conduct survey on natural science and technology development. They manage science technologies, drafts and plans for socio-economic development, human resources training, and others. In VAST, there are 30 institutes and 5 non-academic units. Institute of Geophysics is one of the 30 institutes, and survey for earthquake activities is also one of the roles of VAST.

The Ministry of Industry and Trade and the Ministry of Energy in Vietnam hold jurisdiction over industrial and power fields. In this study, the study team contacted two ministries, but they did not accept the visit, since they are not in charge of seismic matters. In the process of cooperation such as human development between Japan and Vietnam, it might be necessary to deepen understanding of importance of seismic technologies as well as enlightenment to private companies.

6.5.3 Philippines

(1) Office of Civil Defense, Department of National Defense (OCD)

OCD manages natural disasters as well as terrorism. The Director of OCD works as a chairman of the National Disaster Risk Reduction and Management Council (NDRRMC). OCD is now implementing anti-earthquake measure program in cooperation with JICA.

(2) Philippine Institute of Volcanology and Seismology (PHIVOLCS)

PHIVOLCS is governmental institute under the Department of Science and Technology. PHIVOLCS is engaged with observing earthquakes, volcanoes and tsunamis, judging the information and informing the related organizations.

(3) Association of Structural Engineers of Philippines, Inc. (ASEP)

ASEP drafts National Structure Code as a lower agency of Civil Engineering Society. In the study, ASEP made cooperation with the study team to hold seminars, and is deeply interested in seismic technologies and standards. ASEP has capability to develop construction codes, and it is said that ASEP is one of the candidate for future cooperation. But, for the development of the standards, the Department of Public Works and Highways (DPWH) has right to approve it. Therefore cooperation with DPWH may be needed in future.

The Department of Trade and Industry, the Department of Energy, and the Department of Environment and Natural Resources may be related to industrial fields. But the study team could not visit them since none of the ministries is in charge of seismic matters.

It is suggested that ASEP is one of the hopeful candidate as a counterpart for future cooperation in Philippines and further study and discussion about counterparts should be kept. In the process of cooperation such as human development between Japan and Philippines, it might be necessary to deepen understanding of importance of seismic technologies as well as enlightenment to private companies.

Chapter 7 Recommendations for plant earthquake disaster prevention in developing countries

JICA study has been carried out in accordance with the following purposes.

a) To investigate whether Japanese seismic technologies are able to be introduced into the developing countries appropriately
b) To investigate whether these transferred seismic technologies are able to contribute to improve the seismic safety plant facilities and progress the level of the seismic technologies in the developing countries.

According to the results of the study, the preparation of the seismic design codes and standards for plant facilities and the seismic assessment of the existing plant facilities could be assumed as the recommendations of seismic disaster prevention. In addition, establishment of codes and standards in Japan is examined by committee in which experts in private companies are appointed, and it is thought that making of such a structure also contributes to the development of institution in developing countries.

For plant earthquake disaster prevention in the target countries, the concrete technical cooperation items are selected as follows;

a) Introduction of seismic design codes and standard for plant facilities
b) Seismic assessment of existing plant facilities

Judging from the needs of concerned personnel in the target countries and the possibility of technical cooperation from Japan, it is considered that these proposals are able to contribute to improve the seismic safety of the plant facilities and to progress the level of the seismic technologies in the target countries. If plural technical cooperation items are required at the same time, it is preferable that the priority should be given to the technical cooperation items having higher possibility of introducing Japanese seismic design method.

7.1 Analysis of the target countries and possibilities of technical cooperation

7.1.1 Indonesia

Indonesia is affluent in energy resources and it holds a number of plant facilities. In the future the construction of modification or expansion for these plant facilities can be expected. The Committee of PUSKIM has a plan for introducing the concept of the ASCE-2009（American Society of Civil Engineers）into the new seismic design code of SNI 03-1726-2010 which is seismic design code for buildings based on the UBC-1997 originally, and is now applying for its approval to the Ministry of Public Works. However the plan has not met with its approval yet. Since the seismic design methods of non-building structures such as plant facilities in Indonesia code has not been included into the scope of the present code. Taking up suggestion by the study team, PUSKIM is currently preparing for a new committee to develop plant seismic design code, understanding sufficiently the necessity for seismic design code for plants. In Indonesia, since some of the domestic engineering companies have already made a seismic design for plants using UBC by themselves, Indonesia has the highest technical level of seismic design among three countries and has achieved the technology level in which domestic engineers are able to study plant seismic design code and make a seismic design for plants based on UBC by themselves. Since seismic design procedure for plants including non-building structures is not defined in the present Indonesian seismic design code, BPPT is enthusiastically collecting technical information about plant seismic design. Since Japan is the only country that has the seismic design standard for piping, it is suggested that Japanese seismic design code for plants can be transferred to Indonesia. In future, it is advisable that Japanese seismic design code for plants can be introduced into the existing code in Indonesia appropriately. In this case, it is assumed that besides introducing Japanese seismic design code for plants into the design code only for plants, seismic design code for building structures which is now under revision based on ASCE7, might be applied as the design code only for general building.

Therefore, first of all assumption is necessary to adopt Japanese seismic design code in plant and engineering field, under conditions of using UBC in practice in Indonesia. For development of human resources, including seismic engineers training, conduct seminars, workshops, the cooperation is supposed to be done in the process of development of seismic design codes and standards for plants and seismic assessment for the existing plants.

7.1.2 Vietnam

Although "375 TCXDNV: 2006 ‘Design of Structures for Earthquake Resistance’" has been provided based on "Eurocode (1998-1 BS-EN: 2004)", the code has not been spread widely yet.

"TCXDNV375: 2006" is planned for applying to plant facilities under design at present, but the application seems to be difficult since Eurocode itself is not intended to be applied to plant equipment (for example; towers, vessels, spherical tanks, and so on) except storage tanks . Although the seismic code has been provided in this way, the code has not been sufficiently applied in practice yet.

As a matter of fact, PVGAS is now planning LNG plant, but domestic engineers are not able to fully understand the present seismic design code in their own country. And they asked for the interpretation of the present code at plant visit by study team.

IBST and MOC (Ministry of Construction), which are the supervisory authority to provide seismic design codes, are showing positive attitude to prescribe a seismic design code for plants, and there seems to be very high possibility to adopt Japanese seismic design code for plants as Vietnamese code. In addition, the construction of plants may be expected in the future based on the development of resources on coast and petroleum refining and petrochemical industries.

In conclusion, Vietnam has the most appropriate situation to develop plant seismic design codes and standards, and seismic assessment on the existing plant. Cooperation for comprehensive technical cooperation plan will be available in the future. Since seismic design level is not sufficient to provide seismic design code for plants, it is suggested that personnel training to the governmental officials, experts in the institution and engineers in private companies will be executed for plant design, during the transfer of Japanese seismic design code for plants to Vietnam.

7.1.3 Philippines

NSCP (National Structural Code of Philippines) 6th Edition-2010 has been prescribed in accordance with UBC, and plant facilities are also recognized as target structures (non-building structure) in the code. Therefore, without piping, the seismic design procedures for plant facilities are prepared in the code. Accordingly it may be possible to make a seismic design of plants by using the current code. ASEP which is the association in charge of the provision of seismic design code for buildings in Philippines, and they are considering the introduction of seismic design methods based on Japanese seismic design codes and standards of plant facilities. ASEP is an organization for structural engineers, and it may not be predicted whether it is possible for ASEP to promote a new seismic design code by working on government agencies.

Although Philippines is not rich in energy resources and does not hold so many plants, it is expected to construct LNG plants at which LNG is imported to secure energy resources in the future.

It is suggested to find out if Philippines are going to introduce seismic design methods based on Japanese codes and standards, and then cooperation is to be implemented for the development of plant seismic codes and standards as well as the seismic assessment on the existing plants.

7.2 Contents of the expected cooperation

As a result of the study for the three countries, the following cooperation is assumed.

1) Development of seismic design codes and standards for plants

Three target countries have seismic design codes for building structures based on

Eurocode and UBC. It is said as a result, seismic design codes for general building structures are prepared, but seismic design codes for plant facilities are not in hand. In Philippines, plant structures are included in the intended facilities of the present seismic codes, but there is possibility to introduce Japanese seismic design codes for plant facilities including piping. The organizations and institutions related to design codes in the target countries acknowledge the necessity of development of plant seismic design codes. So, technical cooperation for development of plant seismic design codes and standards is required.

When the government develops the plant seismic design codes, support by overseas experts is necessary, such as support for development of the codes, for formulation of education scheme to engineers in the private companies, and for compliance program after codes developed. There is a certain area where Japan is able to contribute.

In Japan, committee is established including members from experts of the private companies, when seismic design codes and standards are developed. Introduction of the committee system is also useful and available in those countries.

2) Seismic assessment for the existing plants

After the development of plant seismic design codes and standards, seismic assessment by engineers in the country with support of Japanese experts is required to check seismic performances of the plants. By execution of seismic assessment, it will be available to know the actual situation of the plants for the seismic performances. And in the next step, it is expected to implement seismic upgrading project, such as introduction of concrete seismic equipments, seismic upgrading of earthquake-resistant structure, and others. The details are described in 7.4.

7.3 Cooperation of development of seismic design codes and standards for plants

In Indonesia, Vietnam, and Philippines, some of the agencies which are in charge of providing seismic design codes for buildings, are showing intension to prescribe new seismic design codes for plants. In accordance with their needs, it is recommended to give technical support to introduce Japanese seismic design code into the target countries.

7.3.1 Cooperation for introduction of seismic codes and standards

There are a plenty of seismic design codes and standards in Japan, important ones are the High Pressure Gas Safety Law, Fire Service Act and Building Standard Act. Support for drafting of seismic design code for plants in the target countries will be necessary based on Japanese “Seismic Design Code of the High Pressure Gas Facilities” of METI (Ministry of Economy, Trade and Industry) and “Seismic design procedure of flat-bottomed tanks and related things" of Fire Service Act. For building structures, specialists in Japan will adjust making use of the existing seismic design codes and standards for building structures in the target countries. (The specialists of seismic motions, towers, tanks, piping, structure, and foundations, etc. will perform works including domestic and overseas matters.)

In Japan, when seismic design codes and standards are developed, the government establishes a committee consists of experts and specialists. The members of academy and of private companies are included in the committee, and constitution and revision of rules and codes are made based on discussion of the committee. The committee system is considered to introduce those countries to make sustainable effect to the countries.

It is preferable to conduct cooperation to the target countries for human resource development on governmental officials and engineers in parallel as well as technical transfer, such as workshop and OJT (on the job training) in Japan, at the time of introduction of seismic codes and standards

Instruction and support of the study work will be required for approval and license for using the codes and standards (draft) after introduction of codes and standards. (The specialists of seismic motions, towers, tanks, piping, structure, and foundations, etc. will perform works including domestic and overseas matters.)

Through the support of cooperation, increase of engineering business opportunities, and enhancement of chance of introducing plant facilities such as vessels, tanks and piping to developing countries will be expected.

7.3.2 Country-by-country support

(1) Indonesia

PUSKIM is currently preparing for a new committee to develop plant seismic design code. It is necessary to find out whether Indonesia may introduce Japanese seismic design codes and standards for plants. If not, it may be difficult to introduce Japanese seismic technologies and equipments practically.

In case of introducing, considering the fact that the seismic design code for building revised and applied for approval two years ago has not been approved yet, it may be long way even if the discussion started. Therefore, it will be good way to provide seismic design code for plants as a guideline, not as a code, and offer it firstly and after that disseminate the guideline in practice in Indonesia.

(2) Vietnam

Taking it into consideration that IBST and MOC (Ministry of Construction) is showing a positive attitude to provide seismic design code for plants, and seismic design code for buildings has not been widely used, it may be considered to codify seismic design code of plants as a whole including seismic design procedure for buildings.

(3) Philippines

In Philippines, plant structures are included in the present seismic design codes and standards. Putting Japanese codes on the present Philippines code is technically available. But it is necessary to find out how Philippines consider about introduction of Japanese seismic design method based on Japanese codes. Educational activities will be necessary not only to practical business level, but to policy level. If required, the basic course seminars will be supplied by judging the technical level of the participants.

7.4 Cooperation about enforcement of seismic assessment of existing plants

Concrete plant is not identified in this study, but, in order to verify seismic performance of existing plants, it is necessary for engineers in Japan and the target countries to select existing plants and perform seismic assessment. It is required that seismic design codes and standards have been established before implementing. It is adequate that the seismic assessment will be carried out by using Japanese seismic design codes and standards, because Japanese ones are the most advanced for earthquake damage prevention. In the enforcement of seismic assessment, conducting technical transfer such as OJT in Japan and engineer education for personnel training in parallel will be preferable.

By carrying out seismic assessment, the situation of seismic performance of plants in the target countries can be grasped and as the next stage, it may be expected that seismic assessment results is useful for planning for the introduction of concrete earthquake-proof instruments and the modification for earthquake-proof structures and so forth in practice.

7.4.1 Corresepondence measure for each country

(1) Indonesia

There are many existing LNG production plants and drying up in gas field may cause the conversion of existing production plants into receiving facilities. Since this conversion can be studied as a target of seismic assessment, it is expected that the demand for seismic assessment of existing plants will be increased in future. In addition, there are a lot of chemical plants to be taken seismic assessment, too.

(2) Vietnam

The construction of many energy-related plants may be expected in the future and chemical plants and oil tank terminals can be appropriate as a target.

(3) Philippines

Many existing chemical plants and oil tank terminals are expected to be a target for seismic assessment. There are many old and new plants in Bataan refinery of Petron and it seems to be suitable as a target of seismic assessment.

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7.5 Characteristic and advantage of the Japanese seismic design codes

Characteristic and advantages of seismic design codes for plant facilities in Japan are listed below.

(1) Importance classification for plant facilities

In IBC and Eurocode, only one value of coefficient of importance factor is given to whole plant facilities. However importance classification based on Japanese seismic design codes is applied to each facility which has severe risk in plant facilities and each importance factor is given to each facility depending on its own risk.

Regarding the plant facilities (such as flammable gas container and a toxic gas, etc.) which have high possibility to threaten the safety around plant site when a plant is damaged by an earthquake, it is desirable to add an extra load to the seismic design load depending on the degree of the risk. In the Japanese seismic design code, the importance factors are decided by the distance between the facility keeping safety and every plant facilities and by the quantity of dangerous materials possession, and the facilities which have high risk against vicinity increase safety around the plant site by being designed to withstand increased design seismic load.

In other words, the seismic design based on IBC and Eurocode have only one importance factor for all facilities in one plant site, and so all facilities become to have same seismic strength. However, the influence of the leak due to the damage of the facilities varies according to the risk of contents and its volume. Therefore, by carrying out the seismic design by the importance classification of the Japanese standard, achievement of the reduction of the risk at plant facilities can be made suitably.

(2) Two levels design method

In IBC and Eurocode, a design spectrum of the earthquake ground motions, in which design target is to keep away from collapse, is given. And the design seismic load is calculated by the spectrum, and these methods are called one step design method using the allowable stress design. In other words, seismic loads for the design to prevent collapse are reduced by multiplying by the reduction coefficient, which is different depending on the structural specification, and perform the design in the elasticity range, and the physical understanding of this reduction coefficient is difficult.

On the other hand, two level design methods of seismic design codes are adopted in

Japan. Using two levels design method, the facilities are designed in order to keep the following seismic performance. An objective for two level earthquake ground motions become clear so that after the seismic event of the earthquake level which users experienced 1 or 2 times during a period of use, the facilities are able to use without repair, and at the seismic event of the rear maximum earthquake level, they are prevented from leak of contents. It is easy to use this method as an aim of the seismic assessment.

1) Concerning the earthquake with higher probability of occurrence during in-service period of facilities, facilities are designed on the basis of elastic design method so that facilities may remain in a possible state of reuse after the earthquake.

2) Concerning the largest earthquake, the facilities are designed on the basis of elasto-plastic design method in order to absorb earthquake energy by plastic deformation, and a leak of the content fluid is prevented, although residual deformation is permitted, and the safety of the plant is ensured.

Using IBC and Eurocode, the plant facilities are designed to be evaluated by the two levels of design condition, which are a level to prevent collapse and a level to remain in use, by only one level of design seismic force, hence if there is not the collapse of plant facilities, and degree of remain damage does not become clear after a seismic event the plant facilities may collapse at next seismic event. However, using Japanese two levels design method, it is easy to grasp damage degree and the degree of reuse after earthquake, because two levels of seismic performance are defined and the seismic performance can be evaluated using two levels of design seismic loads. Here, the two levels design is as follows;

a) The design to remain in use without repair after the event against the earthquake experiencing once during service period

b) The design to minimize damage even if plant facilities are destroyed against big ocean-trench earthquake and near-field earthquake

(3) Presentation of the seismic design method for every plant facilities

For example, spherical tanks, towers and vertical/horizontal tanks, etc. of concrete seismic design method is not shown in IBC and Eurocode, but in the Japanese seismic design codes and standards, seismic design method in consideration of the vibration characteristics of each facility is shown in the seismic design standard.

(4) Examination of necessity of seismic design for piping

Piping is one of the most important facilities at plants especially chemical and petrochemical plants. In IBC and Eurocode and the related standard, the seismic design of piping is not prescribed in detail. In Japan, the seismic design method of piping was newly standardized based on the experience of suffering from the damage of the piping by the Great Hanshin and Awaji Earthquake.

(5) Influence evaluation of liquefaction of ground

Japanese seismic design code and standard have a characteristic to be able to design considering influence of the liquefaction of the ground such as ground subsidence, a lateral movement of the ground and the sinking of facilities. This method is applicable to seismic evaluation of seismic assessment for existing facilities. This is a characteristic of Japanese seismic design standard not to be included in standards of the United States (IBC) and the Europe (Eurocode), too.

(6) Applicability to seismic design of LNG facilities

Japanese seismic design code studied at this time is applicable to LNG receiving terminals. The demand of LNG receiving terminals is expected to increase in the future.

7.6 Expected benefits and effectiveness

Regarding to cooperation to developing countries on seismic design codes and technologies, although there are seismic design code for general buildings in the target countries, seismic design code for plants can be provided based on Japanese seismic design code by technical cooperation. Concerning design and construction of plants, it is supposed that Japanese seismic design technology is also used in common. And its practical activities are seismic assessment.

(1) Benefit in the target countries

1) Reinforcement of the preparation for earthquake disasters of the country concerned is performed by introducing Japanese seismic design code with superiority including importance classification and two levels design method, etc.
2) Decision making of introduction and acquirement of Japansese seismic technology leads to technological assistance and technology interchange, so that the level of earthquake proofing knowledge and the level of the seismic technology in the target countries are raised as a whole and development of codes and related organization, personnel training are also promoted.
3) At the private company level, a lot of business orders and jobs from Japan and overseas countries may be expected by acquiring Japanese technique and holding the ability to carry out jobs of Japanese company.
4) By getting information of seismic safety on plant facilities through seismic assessment, it is available to strengthen seismic security and seismic disaster

prevention as a whole country.

(2) Benefit in Japan

1) In a project of construction and the remodeling of plants in the target countries, Japanese engineering companies can increase the possibility to join projects from an early stage setting design ground motion and seismic design method. And it will be possible to enhance business opportunities on the projects by demonstrating higher technology level in practice.
2) By bringing up the domestic engineers who can understand Japanese seismic codes and seismic technologies, human resources can be secured as a business base of Japanese company and business cooperation relation can be established.
3) By introducing Japanese technology, local subsidiaries of Japanese engineering companies and apparatus makers increase the possibility to join various local projects and as a result international competitiveness can be maintained.