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EARTHQUAKE DISASTER MITIGATION AND EARTHQUAKE RESISTANT STRUCTURAL DESGIN IN KOREA（アジアにおける防災交流を考える・・神戸市とソウル市を例にして）

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EARTHQUAKE DISASTER MITIGATION AND EARTHQUAKE RESISTANT STRUCTURAL DESGIN IN KOREA

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ABSTRACT

Because Korean peninsula has been experienced seldom destructive earthquakes for the past 300 years, the Korean government has not seriously considered preparing the well developed earthquake risk management system until the end of 20th century. After the Hyogoken Nambu earthquake struck the Kobe City in January 1995, the Korean people were shocked at the consequences of the earthquake disaster. And since 1995, the Korean government has begun to establish the earthquake disaster prevention and countermeasures very intensively.

In this presentation, the efforts to mitigate earthquake disaster by the Korean government and the other agencies related to the earthquake science and engineering are introduced including Earthquake Risk in Korea, Government Policy for Management and Earthquake Risk, Seismic Design Concept in Korea, Earthquake Response Plan and the Research Activities in Korea.

1. INTRODUCTION

It is considered that Korea is a safe area from the peril of earthquakes because it is located away from the tectonic boundary and does not belong to an active seismic region. However, historical records show that there occurred huge earthquakes several times in the past 2000 years and they claimed human casualties and serious property damages. Also they show some descriptions indicating the occurrences of huge earthquakes which triggered destructive damages with ground fissures, surface depression, liquefaction and landslide.

The devastating Hyogoken-Nambu earthquake of January 17,1995 in Japan sent mental shock waves that awakened the public concern about the possible earthquake disaster in Korea. Many seismologists pointed out that a disastrous earthquake might occur at any time soon. The government began to realize that preparatory measures had to be implemented at national level.

Immediately after the Yeongweol earthquake in December 1996, the Korean Government announced active earthquake countermeasure plans including research plans for the development of seismic design criteria and long term research plans for the accurate evaluation of the seismic hazard in Korea. EESK was entrusted the task to develop seismic performance requirements and code systems for the facilities under jurisdiction of the Ministry of Construction and Transportation.

Seismic Risk can be defined as a combination of Seismic Frequency and consequence of earthquake, or as a combination of seismic hazard and vulnerability of structures. For example, a non-seismic designed structure may have very high vulnerability, and the overall risk can be significant, even though it is located in a moderate seismic region like as in Korea. While a well-designed structure in high seismic region according to proper seismic design codes, may have low vulnerability and its risk can be very low. [1] Seismic vulnerability of a structure can be reduced through the active promotion of research and development on seismological science and engineering technology.

And the preventive action to reduce these vulnerabilities may be composed of the following five sets of interlinked actions;

1. Risk Assessment including creation of Hazard Map, Installation and Replacement of Earthquake Monitoring Systems.
2. Upgrading seismic design criteria and Improvement of Seismic Performance of Existing Structures
3. Emergency Measure for Earthquake Disaster
4. Accompanying Earthquake Disaster Prevention including Information, Training and Education of Personnel
5. Scientific and Technological Research Program

2. EARTHQUAKE RISK IN KOREA

2.1 Seismic Hazard Map of Korean Peninsula [2]

Because it is not possible to predict not only the exact time and place, when and where an earthquake will occur, but also we cannot estimate its magnitude and intensity, the first procedure to estimate the seismic damage more precisely must be the refinement and improvement of seismic hazard maps. The seismic hazard maps for the Korean Peninsula (Fig. 2.1) is made based on the historical (Fig 2.2) and instrument data (Fig. 2.3). And the instrumental data can also categorized in two groups; the early (1905-1943) and recent instrumental data. Considering short collecting period of instrumental data from 1905, the historical data is very important to understand the long-term seismic characteristics in Korean Peninsula [3].

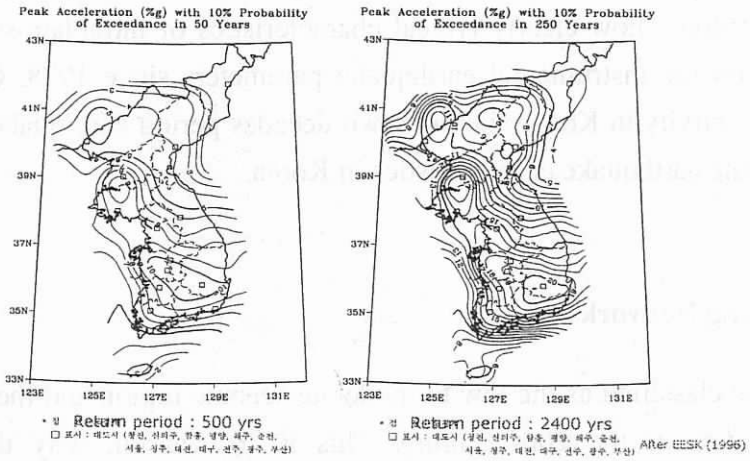


Figure 2.1 Seismic Hazard Map of Korean Peninsula

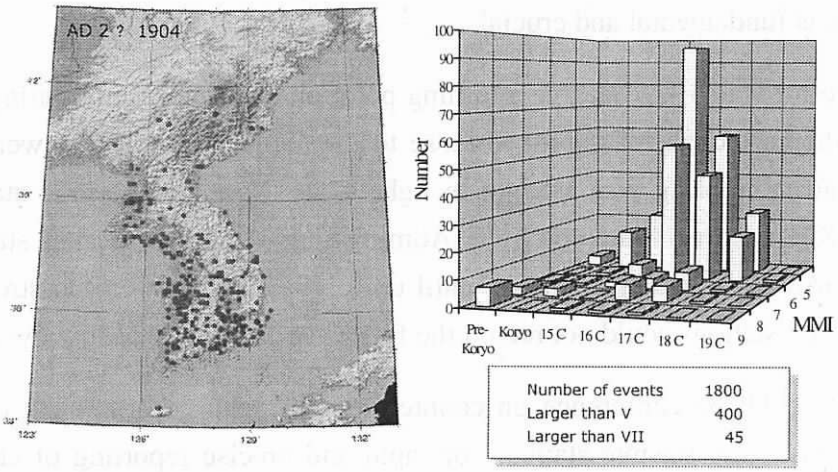
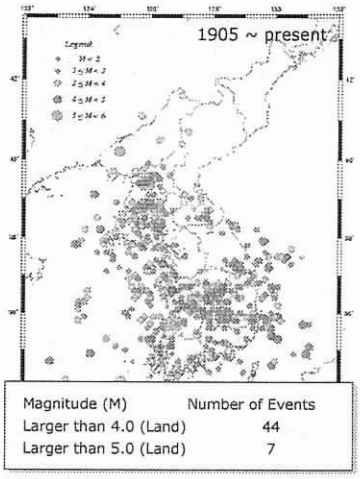


Figure 2.2 Historical Earthquakes in Korea



MAJOR EARTHQUAKES

Name	Year	Magnitude	Remarks
Ssang-gye-sa	1936	5.1	• Wounded : 5 • Damaged Houses :113
Sokri-san	1978	5.2	
Hong-seong	1978	5.0	• Wounded : 3 • Damaged Houses :118
Euju	1980	5.3	
Sariwon	1982	5.1	
Yeong-weol	1996	4.5	
Gyeong-ju	1997	4.2	

Figure 2.3 Instrumental Earthquakes in Korea

The analysis results of the earthquake data in Korean peninsula observed by KMA (Korea Meteorological Administration) show clearly typical characteristics of intraplate-seismicity. KMA has been reported based on the instrumental earthquake parameters since 1978. Considering the meager intraplate-seismic activity in Korea, the only two decades period earthquake information is not enough to understand the earthquake characteristics in Korea.

2.2 Earthquake Monitoring Network [3]

Korean peninsula might be classified as the low to moderate seismic region and there have seldom been destructive earthquakes in the 20th century. This is the reason, why the facilities of instrumental observation have not been well-prepared and the number of seismic station was very limited until now. But based on dozens of disastrous earthquakes in historical records and several medium-sized instrumental earthquakes, some of Korean seismologist expects the possibility of huge earthquakes in future. To predict the possible occurrence of disastrous earthquake, the instrumental observation is fundamental and crucial.

The Kyungju earthquake on May 1997 became a turning point on earthquake monitoring at Korea. After the epicenter of the earthquake was proved close to the Wolsung nuclear power plant, the status of national seismic monitoring was brought to light. Only 12 analog seismic stations with vertical component at KMA(Korea Meteorological Administration) and 12 digital stations with three component at KIGAM were under operation until up to 1997. There were no strong motion stations and even the digital stations could not record the full wave-forms due to low dynamic range.

After the prime Minister held the conference on countermeasure against earthquake monitoring, KMA must exchange into digital seismic stations for rapid and precise reporting of earthquakes, KIGAM expand seismic stations for seismological research, and KEPCO (Korea Electrical Power Corporation) also secure its own stations for the safety confirmation of nuclear power plants.

Seismic instrumental monitoring in Korea divided into three categories based on its principal usage: nuclear-test verification, earthquake seismology and earthquake engineering.

Array network, located at the north-eastern part with 26 borehole stations, was constructed for verification and Korea Institute of Geoscience and Material Resources (KIGAM) has used it with broad-band seismic stations for reliable automatic determination of earthquake location.

Due to rapid development of electric engineering, the dynamic ranges of sensor and A/D converter are wider but their actual dimensions are smaller. Even if the discrimination between pure seismology and engineering is usually based on whether sensor is velocity type or not, it becomes obscure since both velocity and accelerometer sensors tend to be installed together at the same station. In Korea, if both sensors are installed together, the station is called as the standard station. Except for array network, KIGAM has 24 velocity-type stations including 8 standard stations. Korea Meteorological Administration (KMA) is responsible for public announcement of the earthquake occurrence, so KMA has 27 standard stations and 15 stations with only an accelerometer sensor.

For the confirmation of earthquake safety, Korea Electric Power Corporation (KEPCO) constructed 8 standard stations around 4 nuclear power plants (NPP) and Korea Institute of Nuclear Safety (KINS) is operating an accelerometer station on the free field inside NPP. Many universities plan to construct borehole broad band stations inside campus and Kyungsang university already finished it together with KIGAM.

Due to the recent reinforcement of seismic design codes for building and civil infrastructures by the Ministry of Construction and Transportation, many companies are planning to construct engineering-prone stations for quantitative measurement of earthquake damage: KEPCO for thermoelectric power plant, Korean Water Resource Corporation for dams, Korea Gas Corporation for decompression terminals, Korea Highway Corporation for long span bridges and Incheon International Airport Corporation.

3. GOVERNMENT POLICY FOR MANAGEMENT OF SEISMIC RISK [4]

3.1 Government Policies for Disaster Prevention

Until now many nations has established the comprehensive earthquake risk management system for earthquake response measures. The comprehensive earthquake risk management system consists of 4 measures - Earthquake Forecast, Earthquake Early-Warning System, Earthquake Design and Earthquake Response System. Earthquake Forecast Technologies are not matured yet and Earthquake Early-Warning System is neither practical nor cost-effective in Moderate and Low seismic region. Therefore, Earthquake Design and Earthquake Response System are adopted in

Korea as the comprehensive earthquake risk management system. Buildings and Infrastructures in Korea should be designed in two Limit State Levels, Service limit state level and Ultimate limit state level. And earthquake response system is to develop the capability of making the basic function of nation maintained and recovering rapidly from the damage in the event of huge and rarely-occurring earthquakes allowing slight damage and no collapse in structures.

In order to reduce future damage and losses before disaster strikes, many projects are being implemented since 1995 after the Korean government promulgated " The Law on the Natural Disaster Countermeasures"; The Projects of "upgrading Seismic Design Criteria for 26 Facilities" completed 21 facilities and 5 facilities in process by Ministry of Construction and Transportation. By the law, the Korea Infrastructure Safety and Technology Corporation was established in 1995, which has been surveying and evaluating the Actual Conditions of 26 Facilities in 2000-2006 and established the "retrofit measures for facilities specified in NDCA (Natural Disaster Countermeasures Act).

In 1996 The Natural Disaster Prevention and Countermeasure Headquarter was established, which is the main body in Korea to control and provide the required measure against the Earthquake Disaster Prevention and Countermeasure in nationwide.

As the first academic society relating to the earthquake engineering, the Earthquake Engineering Society of Korea was established in November 1996.

And to meet the national demand, KOSEF (Korea Science and Technology Foundation) founded KEERC (Korea Earthquake Engineering Research Center) in 1997.

3.2 Government Organization

The National Disaster Prevention and Countermeasures Headquarter (NDPCH) was established under MOGAHA to supervise the entire operation of preventive program. It is responsible for preparing preventive measures against disasters, controlling disaster situation, implementing recovery plans, formulating mid- and long-term plans and promoting international cooperation.

The staffs of Civil Defense and Disaster Prevention Bureau (CDDPB) are closely linked to NDPCH and they are from three key divisions, the Disaster Planning Division, the Disaster Preparedness Division, and the Rehabilitation Division.

Also, local Disaster Prevention and Countermeasure Headquarters work with the Disaster Prevention Team of Water Control Division in the Construction and Transportation Bureau at the provincial level.

At the city, county and district levels the Disaster Prevention Team of the Construction Division works with local Disaster Prevention and Countermeasures Headquarter.

When a disaster strikes nationwide, forty-nine officials from twenty agencies including the Ministry of Construction and Transportation (MOCT) operate in a state of emergency and deliver appropriate and comprehensive management of the situation.

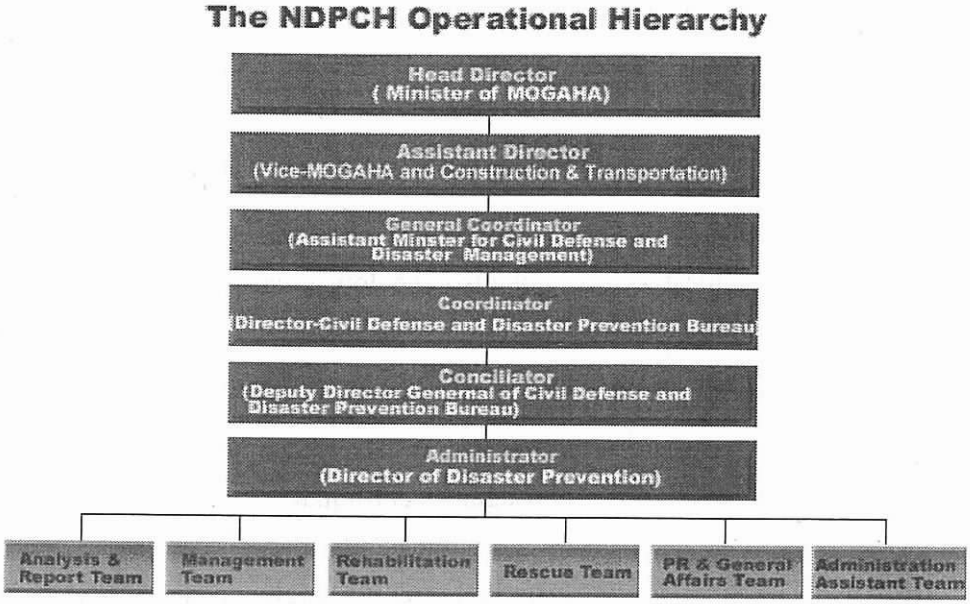


Figure 3.1 National Disaster Prevention and Countermeasures Headquarters

The disaster prevention plans are composed of the basic five-year disaster prevention plan and the yearly disaster prevention action plan. In addition, the regional plan by the local government and detailed action plan devised by various agencies such as the Korea Water Resources Corporation, the Korea Electric Power Corporation, and etc. constitute the overall disaster prevention plans.

The five-year Plan (1997 - 2001) pursues three main goals and ten strategies based on the idea of Life Free from Disasters. The three main goals of the Fifth Basic Disaster Prevention Plan are: (1) the establishment of comprehensive response system against the natural disasters focusing on the preventive countermeasures, (2) the establishment of disaster prevention information system and scientific formulation of disaster prevention policies and (3) promotion of international cooperation and prepare for the reunification of two Korea.

4. Seismic Design Concept in Korea [2, 5]

4.1 History of Seismic Design Codes in Korea

From the tragic consequences of the recent big earthquakes such as the Northridge Earthquake (1994), the Hyogoken Nambu Earthquake (1995), JiJi Earthquake(1999) and Turkey Earthquake(1999), we realized that even modern seismic codes cannot prevent building collapse

and human losses.

Therefore, the seismic vulnerability assessment of existent buildings and civil infrastructures and the seismic safety of old towns and new developed big cities are becoming more highlighted parallel to developing new seismic design standards and codes for the new buildings.

To mitigate the earthquake disaster, the prediction of a destructive earthquake through the historical and instrumental data may be the most urgent problem, which we have to be faced. After performing the earthquake safety assessment, seismic resistance standard and code can be defined based on the earthquake activities in Korean Peninsula and its economic capability. The requirements of not only the structural safety, but also the low construction cost are the basic conditions to develop the new seismic design codes.

For the first time in Korea, the seismic load was considered in the design codes, when seismic design requirements were included into the Building Standard Law System in 1988. New buildings of 6 stories or higher are required to be designed against earthquake load. Requirements for the seismic design of highway bridges were introduced into the standard specifications for the highway bridges in 1992. There exist seismic design criteria for dams, high-speed railway bridges and tunnels. The seismic design has been applied to nuclear power plants from the beginning of the nuclear industry in early 1970's.

However, still there were many kinds of facilities that do not have their own seismic design codes. Moreover, the existing ones had serious shortcomings such as disparity in Seismic Zoning, Seismic Coefficients, Design Response spectrum. More seriously the Performance Objectives and Design Principles were different from code to code.

After Hyokogen Nambu earthquake, the Ministry of Construction and Transportation in Korea entrusted EESK the task to develop new seismic design code for the facilities under its jurisdiction late 1996.

4.2 Two-Level Seismic Design Code System

EESK proposed a radically new code system. The underlying concept is similar to the performance-based design criteria. However the idea was evolved from the seismic design regulatory system for nuclear power plants. The unique structure of the present code system is that it consists of two-level design criteria; the high level and the low-level. Figure 4.1 describes the outline of the code system.

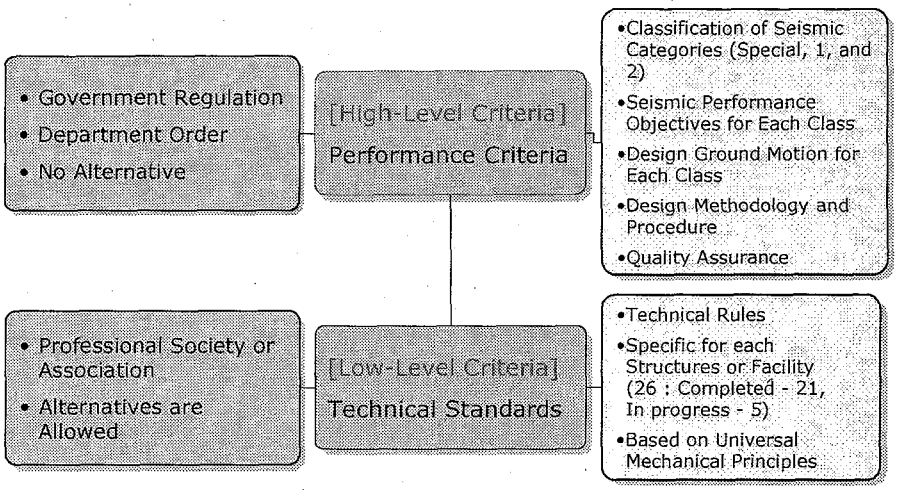


Figure 4.1 Two-Level Seismic Design Code

The high level criteria are basically seismic performance requirements. And the low ones are technical rules to achieve the required seismic performance objectives. The coordination and adjustment of the seismic performance objectives and design principles across diversified facilities can be accomplished best at the conceptual level.

Fundamental requirements on the quality assurance and those on the seismic instrumentation are included in addition to the conventional requirements. The main contents of the high-level criteria are listed as follows:

1. Classification of seismic categories
2. Seismic performance objectives
3. Design ground motion
4. Behavior limit states
5. Fundamental requirements on the seismic design, analysis, and the quality assurance
6. Authorized specifications and standards
7. Fundamental requirements on the seismic instrumentation

By incorporating the high-level criteria into the law system, the protection of the society from the earthquake risk can be more strongly imposed and the balance in protection level can be achieved.

Two seismic performance levels are defined for the seismic objectives. The facilities are classified into three categories according to the importance. The performance objectives are given in Figure 4.2. With historical records, Korean researchers started to construct the seismic hazards map from 1985 and after some revisions, they completed the maps in 1996. These maps provide the basic information for the investigation, the revision, and the new regulation of the earthquake design standards. These maps indicate the peak acceleration with 10% exceeding probability in 5, 10, 20,

50, 100, 250, 500 years, or the average return periods of 48, 95, 190, 475, 950, 2373, 4746 years. Figure 4.3 shows the peak acceleration with 10% exceeding probability in 50 years in Korean peninsula.

Return Period (yr.)	Performance Level	
	Operational	Collapse Prevention
50	Category 2	
100	Category 1	
200	Special	
500		Category 2
1000		Category 1
2400		Special

Figure 4.2 Performance Objectives

Category 1: Ordinary Structures and Facilities

Category 2: Important Structures and Facilities

Special: Safety Critical Structures and Facilities

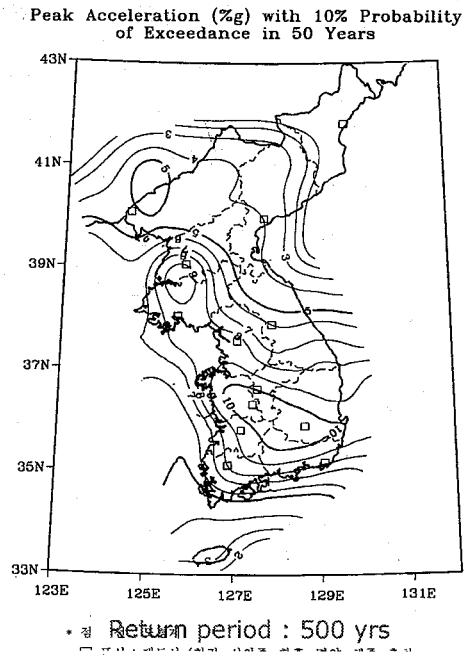


Figure 4.3 The Peak Acceleration with 10% Exceeding Probability in 50 Years in Korean Peninsula

4.3 Present Research on Seismic Design Criteria in Korea

The currently used seismic design codes are very similar to the design codes developed in the

regions of high intensity seismic zones and have unreasonable seismic detailing. However, as pointed out recently by some researchers, the structural response under low intensity ground motion will be very different from those expected under high intensity ground motion. It is highly probable that the structures may not experience its full plastic deformation at all if they are adequately designed for the conventional loads. In that case, it is very unrealistic to design the structures under the assumption that they will experience its full inelastic deformation.

As the first step toward development of seismic design procedure for moderate seismic region, it is very important to find out how the structures will behavior to the moderate earthquakes without any special seismic detailing and what amount capacity the conventional structure have. In order that they may survive the maximum credible earthquake without collapse, they need to have seismic detailing for the moderate degree of ductility potential. It has been found by many researchers that the seismic design concept based on the limited ductility will be very appropriate in moderate seismic regions.

Therefore, realizing the potential benefits of this approach, the earthquake engineering community of Korea is now concentrating its research capacity on the limited ductility seismic design method at present for the development of design concept and detailing in moderate seismic region (Fig. 4.4).

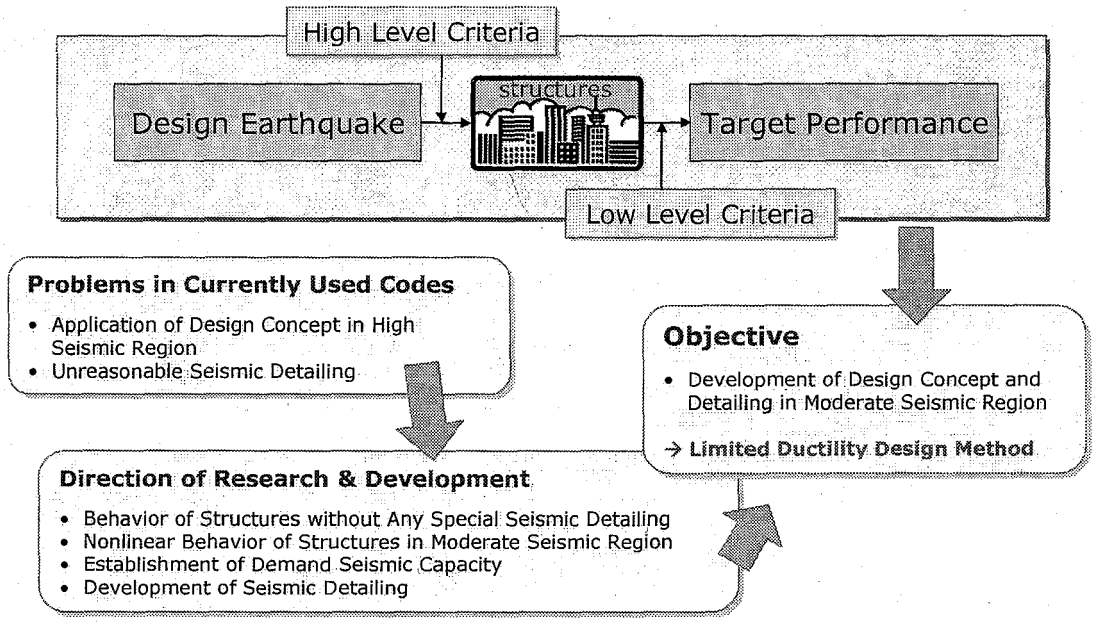


Figure 4.4 Present Research on Seismic Design Criteria in Korea

4.4 Future Direction of Seismic Design Concept [6]

The traditional seismic design codes are based on the deterministic design concepts such as the force-based seismic design and the displacement-based seismic design. In the force-based seismic design, structures are necessary to have the certain ultimate strength to resist earthquake load. Considering the energy dissipation from the nonlinear behavior of structure with R-factors, the

traditional elastic linear theory for the seismic analysis is generally used. Displacement-based seismic design method was significant from the point of view of providing the opportunity to move the focus of the seismic design from the design loads to the capacity of structures. Displacement–based design method eliminates the questionable effect of R-factors in the force-based seismic design concept and regulates the capacity of structures with displacement.

These seismic design concepts could not help being reconsidered due to the encounter of excessive economic losses during the recent earthquakes, Loma Prieta in 1989, Northridge in 1994 and Kobe in 1995 so on. The switchover in fundamental principles and philosophy of deterministic seismic design became necessary and multiple Performance-Based Seismic Design (PBSB) was suggested as an alternative.

The PBSD is the seismic design that requires a structure to satisfy four performance levels on 4 design earthquake levels as shown in Figure 4.5 and summarized as the seismic design which is aimed not in a single performance but in multiple performance such as fully operational, functional, life safety and near collapse performance level.

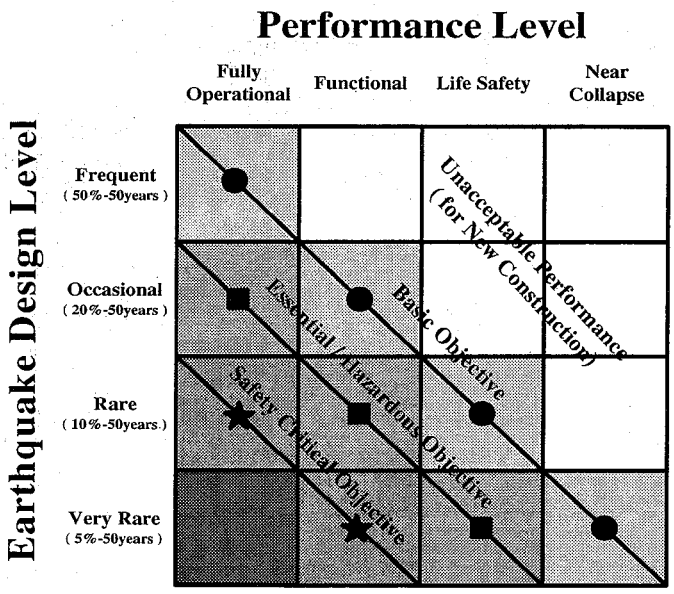


Figure 4.5 Vision 2000 Performance Objectives

It is sure that PBSD overcame the limit of the conventional deterministic seismic design in that it could predict how structures would behave in response to various possible earthquakes. However, it is not certain yet which level of the controlled risk and how serious the social consequences from the PBSD can be. This question will be asked more seriously when the objects are infrastructures. As infrastructures have the characteristic of large spreading social effects, when they are damaged or collapsed by natural disasters, it can not be regard as appropriate response to earthquake action to predict what their own performance level over only a certain limit state is.

Advanced from the simple combination of the intensity of various earthquakes and the limit states

of a structure, a more active alternative seismic design concept can be proposed, if it can suggest in an engineering standpoint what the damage scale of the structure and the social spreading effects are. Risk based seismic design method is expected to be able to satisfy this condition in the point that RBSD includes the controllable components of PBSD and the utility components such as environmental impact, social impact, cost parameters and operational parameters etc.

In this concept of risk-based earthquake engineering, KEERC plans to develop and systemize innovative seismic disaster prevention techniques suitable to moderate seismic regions, and to provide the framework and strategic techniques of national disaster prevention of infrastructures. KEERC also plans to advance national seismic engineering techniques to international level and to improve, on the basis of it, international competitiveness of domestic industry.

5. EARTHQUAKE RESPONSE PLAN [4]

5.1 Earthquake Response System in Korea

Disaster Emergency Countermeasures is consisted of the pre-earthquake disaster emergency plan, implementing pre-earthquake disaster emergency plan, the post-earthquake emergency plan and dealing with unconfirmed rumors [7].

One of the important measures for the Earthquake Disaster Mitigation is the timely and proper preparation before the occurrence of an earthquake.

In the pre-earthquake disaster emergency plan for destructive earthquake, the following components should be included:

1. The Structures of Earthquake Disaster Emergency Organizations and their Action Plans
2. Guarantee of Exigency Traffic roads and Communication Means
3. The Budget for Rescuer, Relieve, Medical Care and Rehabilitation
4. Urgent Restoration Plan for Buildings, Life Lines, Communication Facilities and Public Infrastructures
5. Secure the Personnel, Material and related Supplies
6. Preventing Plan against Secondary Disasters such as Epidemics and Corpse Treatment
7. Education against Earthquake Disaster
8. Disaster Evaluation

Another effective approach to earthquake disaster reduction is to improve efforts of rescue in

disaster-stricken areas. In Korea, the task for rescue is undertaken through the role of NDPCH to organize and coordinate the efforts of various related official and volunteer organizations to implement the pre-earthquake disaster emergency plan including collection and dissemination of the earthquake disaster information, control the traffic, evacuation and temporary shelters plan, life necessaries supply, medical cares, emergency resettlement of the victims, appeal for help from in land and foreign countries and so on.

As a matter of course, the local government in areas suffered from earthquake should establish the budget plan and implement the recovery measures according to the local seismic disaster situation.

5.2 Disaster Recovery Procedure

After prediction for destructive earthquake by the Meteorological Administration through earthquake information transmission procedure shown in Figure 5.1, the Council Central Civil Defense (CCCD) can declare that the predicted area enters the emergency period of imminent earthquake. The National Disaster Prevention and Countermeasure Headquarter (NDPCH) and Natural Disaster Headquarters organized by Provincial and Municipal Local governments mobilize social forces to make measures for disaster relief and rescuer in accordance with pre-planed earthquake emergency response plan (See Figure 5.2). Figure 5.3 shows the national Disaster Recovery Procedure in Korea.

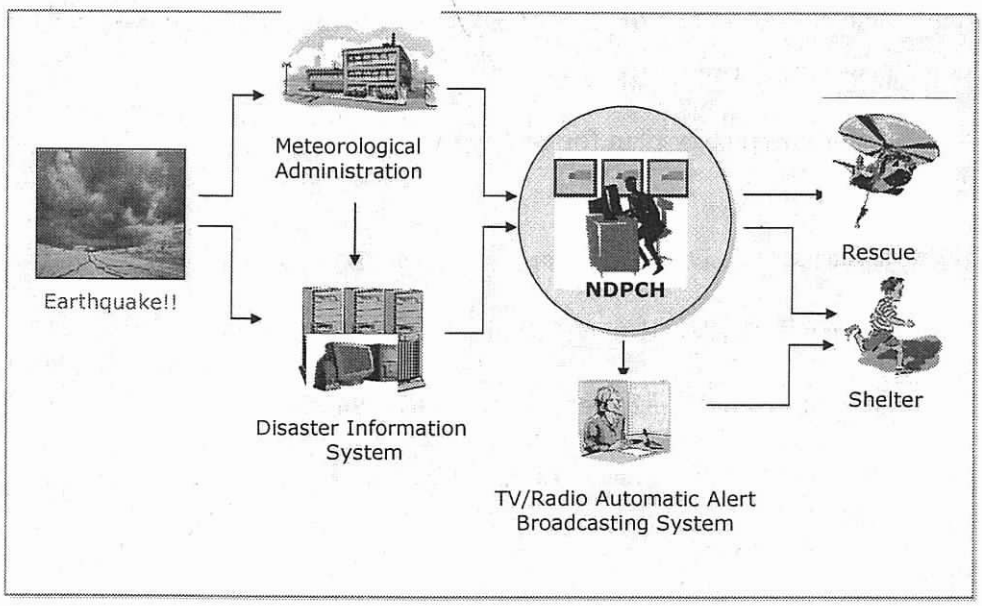


Figure 5.1 Earthquake Information Transmission

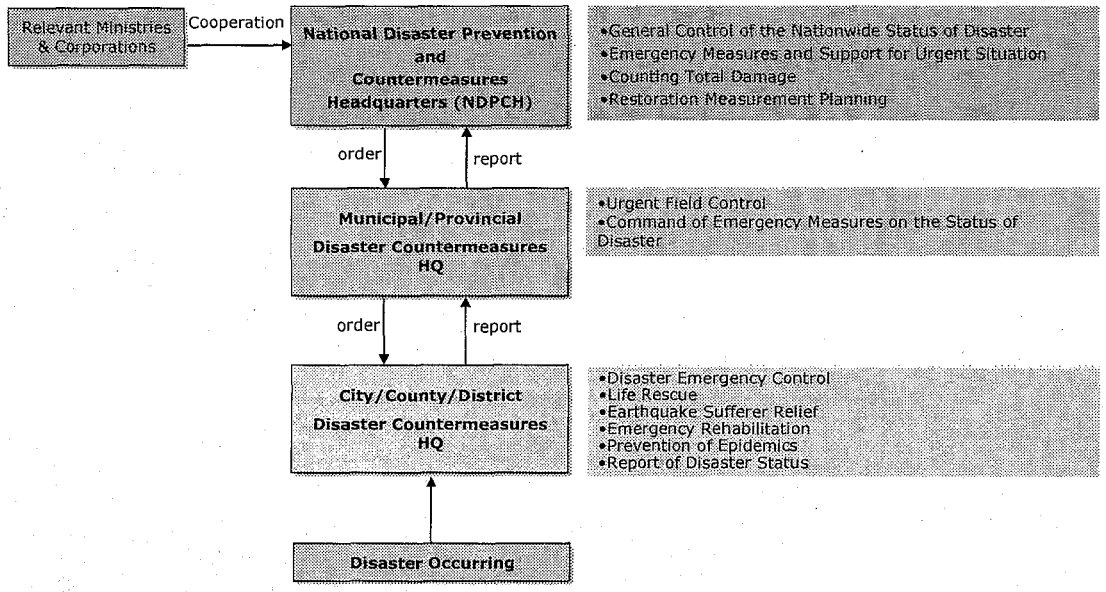


Figure 5.2 Disaster Emergency Countermeasures

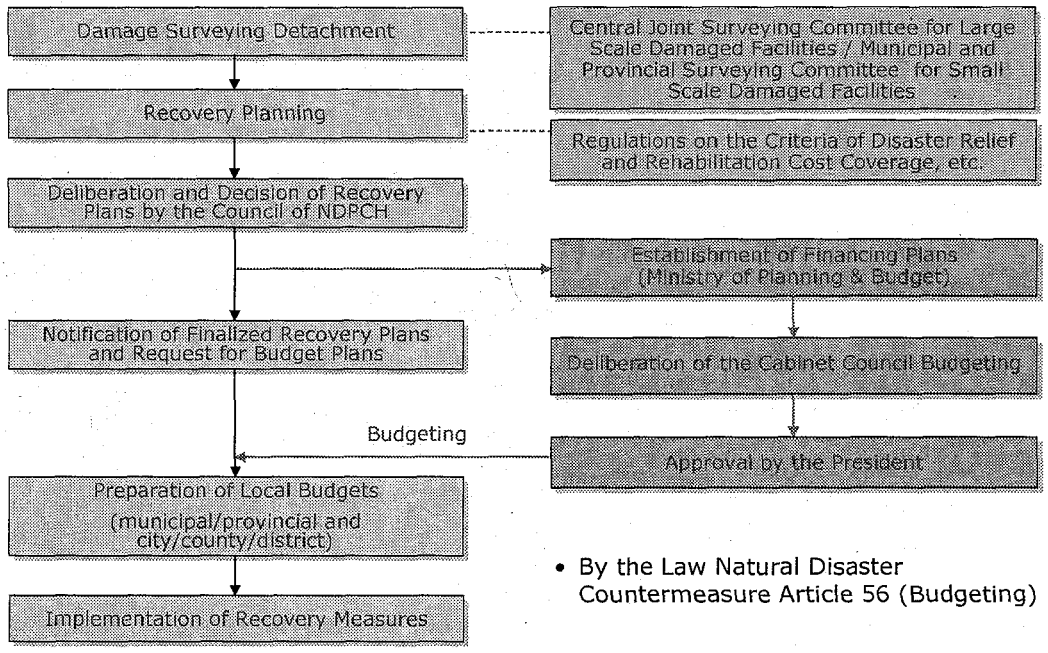


Figure 5.3 Disaster Recovery Procedure

5.3 Concept of Rapid Response System

Rapid response system is a kind of post-earthquake response system organized for the rapid and efficient execution of disaster emergency countermeasures. Presently, this system constitutes the fundamental of earthquake response plan adopted or being developed by the developed countries in the field of seismic technology, USA and Japan etc.

This system consists of Seismic Observation Network, Real Time Observation Network, Damage Assessment Database and Response Scenario Database. In particular, the earthquake damage assessment is not prepared in Korea yet and is going to be studied by researchers in KEERC [8].

The objectives of this system are providing the Foundation of Decision-making and Judgment for Rapid Early Stage Response, Efficient Distribution of Human and Material Resources, Minimization of Earthquake Damage and Rapid Restoration Work and Preliminary Data for Earthquake Preparation Planning.

The earthquake damage assessment means the estimation of the magnitude and range of the damage occurred in a target district by scenario earthquake. Damage assessment database can be constructed by a number of scenario earthquakes.

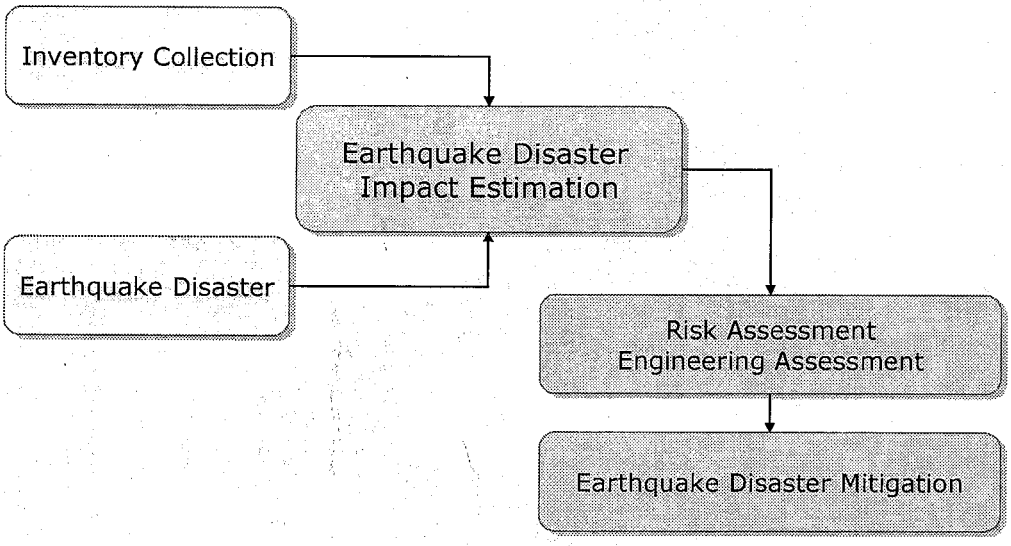


Figure 5.4 Procedure of Earthquake Disaster Assessment

Earthquake disaster assessment procedure is shown in Figure 5.4. Using the distribution of ground motion intensity, and the inventory collection to construct the database about buildings, infrastructures, transportation facilities, lifelines etc and the database necessary for the indirect damage assessment about population distribution, industrial facilities status etc., the earthquake disaster impact can be estimated. The risk and engineering assessments can be executed by the developed operational software to calculate the physical damage and socio-economic loss and by the GIS software for the database construction, management and display.

As an example, Structure Damage Assessment Flowchart is shown in Figure 5.5. First, the Distribution of ground motion intensity in target district is calculated using virtual earthquake source and constructed into database. By inputting the distribution of ground motion intensity into the vulnerability function, the probability of structure damage stage can be calculated. Ground motion Analysis Procedure by Virtual Earthquake Source is described in Figure 5.6.

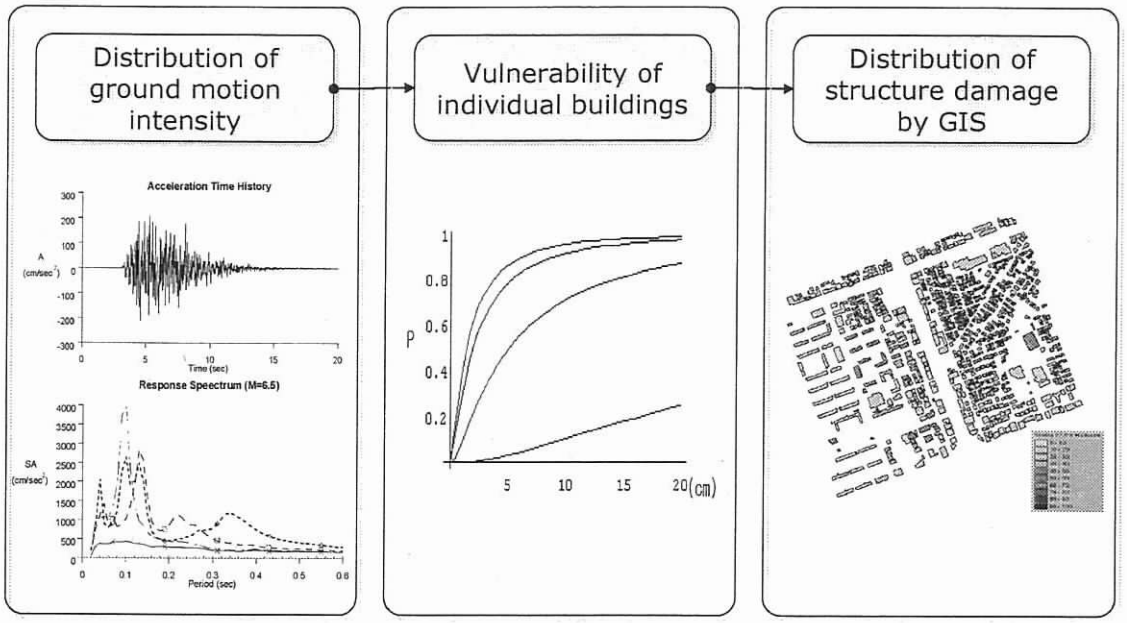


Figure 5.5 Structure Damage Assessment Flowchart

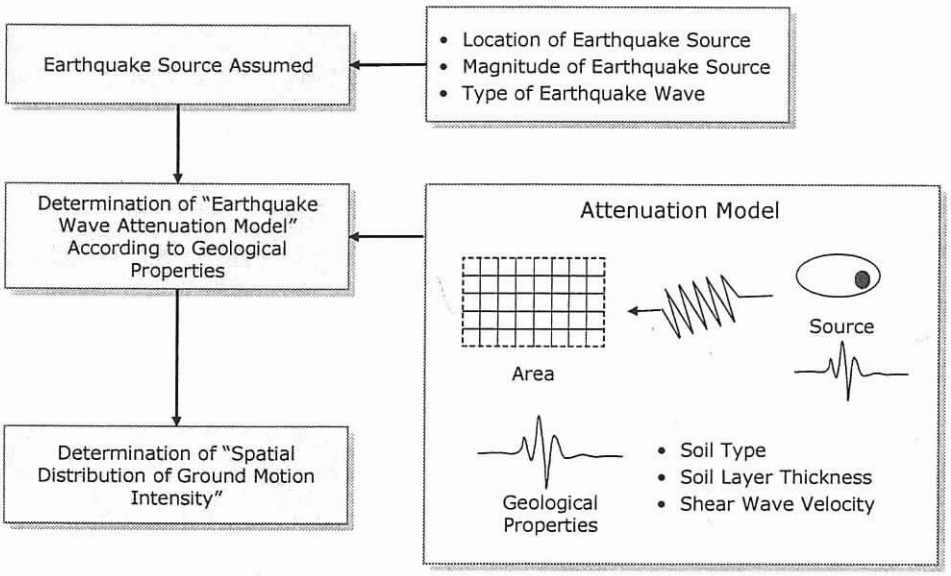


Figure 5.6 Ground Motion Analysis Procedure by Virtual Earthquake Source

5.4 Damage Assessment for Scenario Earthquake in Model District of Seoul [8]

The model district representing the residential environment of Seoul, the Side Areas of Gangnam Mainroad in Seoul (1km^2 District), is selected for the earthquake damage assessment. The damage assessment is conducted as the following procedure; Collection and Classification of Inventory Data, Investigation of Geological Properties, Distribution of Ground Motion Intensity by Scenario Earthquake, Distribution of Damage Probability, Preparation and Illustration of GIS Database.

6. Research Activities on Earthquake Engineering in Korea [2,5]

6.1 Research Institutions in Korea

There are various research institutions related to disaster mitigation, earthquake science and engineering sponsored by the government and funding agencies such as ; Korea Earthquake Engineering Research Center (KEERC), Earthquake Engineering Society of Korea (EESK), National Institute for Disaster Prevention (NIDP), Korea Meteorological Administration (KMA), Korea Institute of Geoscience and Mineral Resources (KIGAM) and Smart Infra-Structure Technology Center (SISTeC).

The mission of NIDP is for reduction of loss of human lives and protection from all types of natural disasters. KEERC has played key roles in research and development activities in earthquake engineering, which include developing new seismic design concept, updating the seismic design codes for various types of civil structures and also developing the retrofit techniques.

6.2 Research Vision of KEERC

The Korea Earthquake Engineering Research Center headquartered at Seoul National University was founded to help establish earthquake resilient communities throughout Korea with the grant from KOSEF.

The primary goal of KEERC is to contribute to the mitigation of earthquake hazards through researches in the area of seismic hazard evaluation, seismic analysis and design technology and social preparedness. The eventual goal of KEERC is to protect the people and the social and economic system from the seismic hazards, and contribute to the development of national economy.

The KEERC vision is to be a national center for research, education, and industrial interaction in the field of earthquake engineering. To implement this vision, we have continuously examined and refined the strategic research plan developed in 1997. First period, from 1997 to 1999, we emphasized the fundamental and multi-disciplinary research. Second period, from 2000 to 2002 we are devoted to the applied research. Third period, from 2003 to 2005, we will make our research outcomes practical for industry and public.

6.3 Organization of Research Projects

Under the framework of moderate seismic design and retrofit techniques, the researchers in KEERC have made numerous achievements in the 4 research divisions: Ground Motion and Geotechnical Engineering, Seismic Design and Analysis, Seismic Assessment and Upgrading, and Seismic Risk,

Reliability, and Economics as shown Figure 6.1.

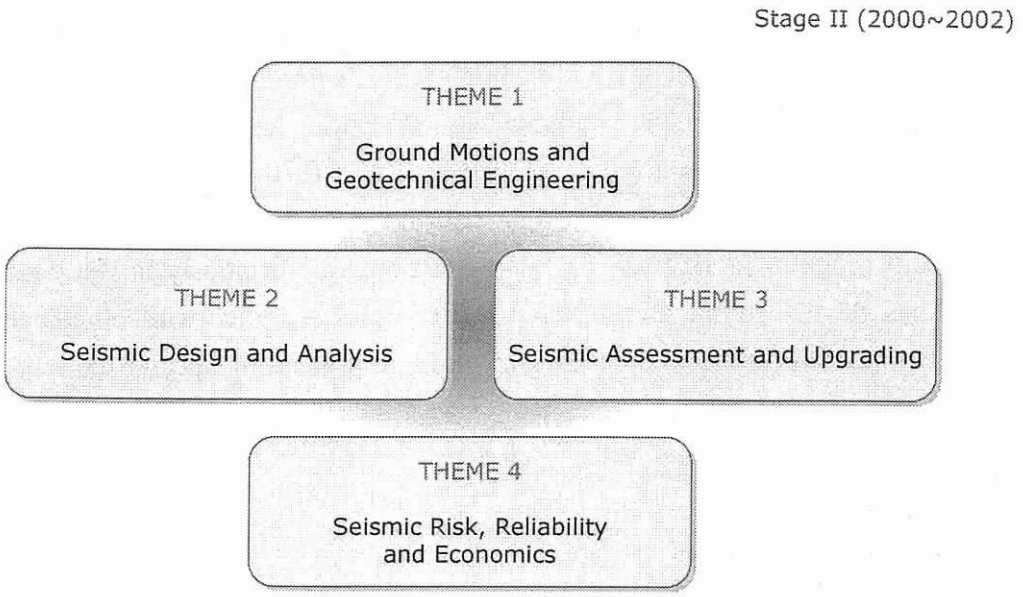


Figure 6.1 Ongoing Research Program of KEERC

The objective of the 3rd stage of research program, from 2003 to 2005 is to make the integrated research accomplishment of KEERC applicable, practical and useful for industry and public. So the following 3 research divisions are adopted: Systematization of Moderate Seismic Region Technique, Innovative Seismic Technology and Earthquake Damage Assessment System of National Infrastructures.

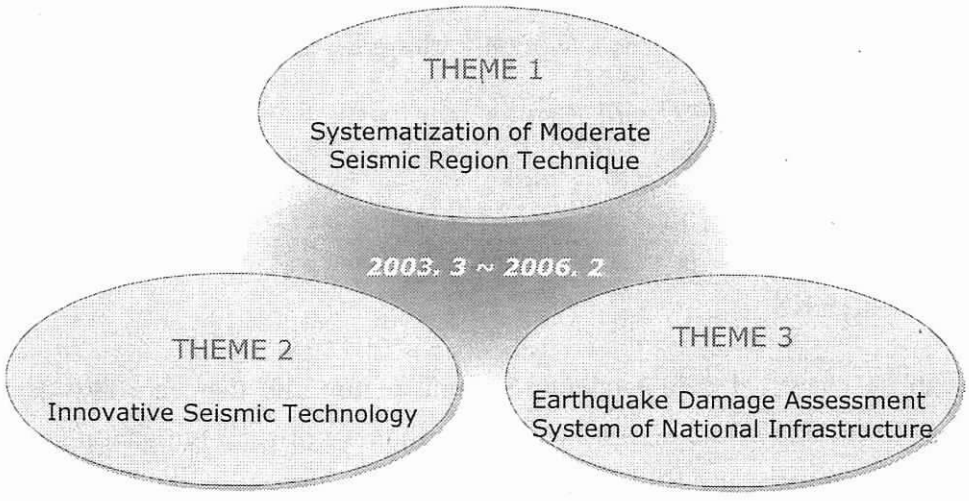


Figure 6.2 Research Plan for Stage III

6.4 Cooperation with Industry

KEERC has established Korea Consortium of Seismic Design (KCSD) to activate its outreach

program. The education and propagation of seismic design technology and the seismic hazard mitigation are the important tasks of KEERC for public benefit. KEERC has done great contribution for the enlargement of manpower in earthquake engineering field through a number of research projects. In addition, technology workshop, information service and technology explanatory meeting are offered for the purpose of education and propagation. For the industrialization of seismic design technology developed by KEERC, the technology transfer has been conducted through seismic design technology consulting and working-level technology transfer. The partnership program in KEERC has also contributed enormously to the transfer of technology. KEERC has developed number of new technologies together with companies and helped them to have competitiveness in related industry through possessing specialized techniques and the patent rights.

6.5 International Cooperation Activities

Recently, KEERC has actively performed international activities such as symposiums, workshops, and seminars.

After the 4th international symposium on earthquake engineering for the moderate seismicity regions, which was held on February in 2001, an Asian-Pacific Network of Centers for Earthquake Engineering (ANCER) was established with the founding members of Korea Earthquake Engineering Center, Institute of Engineering Mechanics of China Seismological Bureau, Multidisciplinary Center for Earthquake Engineering Research of USA, Mid-America Earthquake Center of USA, Pacific Earthquake Engineering Research Center of USA, Disaster Prevention Research Institute of Japan, and Center for Research on Earthquake Engineering of Chinese Taipei.

Through the ANCER activities, KEERC will perform more actively its international cooperative research works.

7. CONCLUDING REMARKS

Korean peninsula can be classified as a moderate seismic region and there are few destructive earthquakes in 20th century. That is the reason, why the earthquake disaster mitigation measures in Korea have not well been prepared until recently. However, Korean government realized the social and economic consequences of the earthquake disaster after Hyogoken Nambu earthquake in Japan.

The first step which the Korean Government adopted for the mitigation of the earthquake disaster is the promulgation of the "Law on the Natural Disaster Countermeasures" including the earthquake disaster countermeasures in 1995.

During last 7 years, the Ministry of Government Administration and Home Affairs has being

initiated the development of the earthquake response system through the official organization of National Institute for Disaster Prevention (NIDP), and the Ministry of Construction and Transportation (MOCT) developed the new seismic design codes for buildings and infrastructures, which are appropriate to the moderate seismic region, through the Earthquake Engineering Society of Korea (EESK) and Korea Earthquake Engineering Research Center (KEERC). MOCT established also the Infrastructure Safety and Technology Corporation for the evaluation and improvement of the seismic performance of the existing structures.

To complete the comprehensive earthquake risk management system in Korea, the development of the Earthquake Forecast System and Earthquake Early Warning System including the mitigation of Urban Disasters are the next urgent research topics in near future, which are not developed sufficiently until now.

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