United Nations
Educational, Scientific and
Cultural Organization

PROTECTING STRUCTURES, SAVING LIVES

UNESCO-IPRED-PUC INTERNATIONAL WORKSHOP
SANTIAGO DE CHILE, CHILE, 26-28 JULY 2011

Pontificia Universidad Católica de Chile
Departamento de Ingeniería Estructural y Geotécnica
Santiago de Chile, Chile

INTERNATIONAL PLATFORM FOR REDUCING EARTHQUAKE DISASTERS (IPRED)

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Cover photo: View from the Medical Center of Onagawa about one year after the Great East Japan Earthquake and Tsunami of 11 March 2011. Onagawa Town, Tohoku.

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FOREWORD

The UNESCO-IPRED-PUC International Workshop on “Protecting Structures, Saving Lives” hosted by the Pontificia Universidad Católica de Chile, Departamento de Ingeniería Estructural y Geotécnica, and supported by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the Japan International Cooperation Agency (JICA) provided an opportunity to advance international cooperation in the evaluation, prevention and mitigation of earthquake disasters. The meeting took place against a backdrop of an appalling loss of human lives and wholesale destruction of communities and infrastructure as a result of a major earthquakes and tsunamis.

Human losses, suffering and damage caused by disasters across several countries have tragically reminded the world of our vulnerability to natural hazards. Disaster resilience is a human development priority. We must recognize the tight link between safety and disaster risk reduction and build on this as a central component of our work for overall sustainable development. Natural disasters, including earthquakes and tsunamis, do not recognize geographical borders. The recent major devastating earthquakes and tsunamis came as a tragic reminder of the urgent need for nations to make optimum use of knowledge and technology in order to reduce the risk of disasters. Efforts must be pursued so that all realistic measures are taken to ensure more resilient communities.

In July 2008, UNESCO launched the International Platform for Reducing Earthquake Disaster (IPRED) programme to identify gaps and priorities through the sharing of scientific knowledge and experience in the field of seismology and earthquake engineering, and to support the development of political will and public awareness, to ensure better earthquake preparedness and build a culture of safety for people around the world. Earthquakes are one of the major expected disasters, especially in the metropolitan areas located in seismic zones all over the world. UNESCO’s IPRED programme is intended to advance partnership and networking and to help draw lessons from earthquake disasters.

The workshop, which aimed in particular to examine essentially the outcomes of recent major earthquakes and tsunamis: Indonesia 2009, Haiti and Chile 2010, and New Zealand and Japan 2011, was very successful, providing important exchange of knowledge, experience and ideas concerning topics of particular interest including the safety issues of communities, public structures and housing safety (building codes). It also considered the presentation of new technologies and techniques which would contribute to the reduction of earthquake losses, and therefore to the health and safety of millions of people worldwide.

UNESCO wishes to express its gratitude to all those who have contributed to the success of the workshop. UNESCO thanks the Pontificia Universidad Católica de Chile, Departamento de Ingeniería Estructural y Geotécnica and JICA for their cooperation in implementating the workshop and producing this book. The commitment and hospitality of Pontificia Universidad Católica de Chile made the meeting a success. UNESCO extends its gratitude to the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan, whose generous financial and technical support has enabled the platform to become a reality. Special thanks also are due to the Building Research Institute (BRI) of Japan, and its International Institute of Seismology and Earthquake Engineering (IISEE), which serves as a centre of excellence for this platform.

Badaoui Rouhban
Director
Unit for Natural Disasters
UNESCO, Paris

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UNESCO'S IPRED PROGRAMME AND RELEVANT ACTIVITIES FOR DISASTER RISK REDUCTION

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ABSTRACT

Risk of disasters is increasingly caused by human behaviour and attitude, including urbanization in developing countries which adds extra pressure on building construction. Whereas hazards may be inevitable, disasters are not. We can break the link by proper prevention and disaster preparedness. UNESCO is engaged in the study and mitigation of natural hazards since 1960s. Its scope of work concerns promoting knowledge and education aimed at enhancing disaster prevention and preparedness. The mission of the UNESCO's IPRED programme is to identify gaps and priorities through the sharing of scientific knowledge and experience in the field of seismology and earthquake engineering, and to support the development of political will and public awareness, for the purpose of ensuring the better preparation against earthquakes and building a culture of safety for the people in the world. UNESCO intends to contribute to the creation of safer built environment, through its network including the IPRED, by advocating important issues on building codes and promoting education for disaster risk reduction as well as school safety.

KEYWORDS

UNESCO, IPRED, disaster risk reduction, earthquake, building codes, education, school safety

INTRODUCTION

The risk of natural disasters is on the rise. The risk is ever increasing as urbanization in developing countries adds extra pressure on building construction. Earthquakes are not directly related to the climate change, but the risk is increasing because of population increase, growing urbanisation, continuous unregulated construction of buildings. However, more importantly, we still have many existing buildings which may not withstand the future earthquakes.

Over the past months and years images of death and destruction caused by various natural disasters worldwide are still with us. The tragedies caused by the Tohoku earthquake in Japan in March 2011, the Canterbury earthquake in February 2011, earthquakes in Chile in February 2010 and in Haiti in January 2010 are a dramatic reminder.

We have also witnessed how fires or floods can disturb a nation like Australia, Thailand, and so on. According to the EM-DAT, it seems clear that the number of natural disasters has increased dramatically since the beginning of the last century. And more clearly, since 1950, and in particular during the last 20 years, the rate of disaster increase is very high as shown from the steep incline in this curve (Figure 1).

It may be no exaggeration to say that major disasters are not behind us and clearly, today, natural disasters are becoming increasingly a global issue: because of increasing vulnerability and exposure, because of population increase, growing urbanisation, continuous unregulated construction of buildings which often are not resilient to natural disasters, environmental degradation and poorly planned development, and also because of the implication of global climate change which may be behind further extreme climatic events.

According to the EM-DAT again, the estimated damages by natural disasters in the past 20 years was large in Asian and American continents. Especially, Asia has been suffered from earthquake disasters the most. When we see the proportion of damages in each continent, Africa also has been suffered from earthquakes quite a lot (Figure 2).

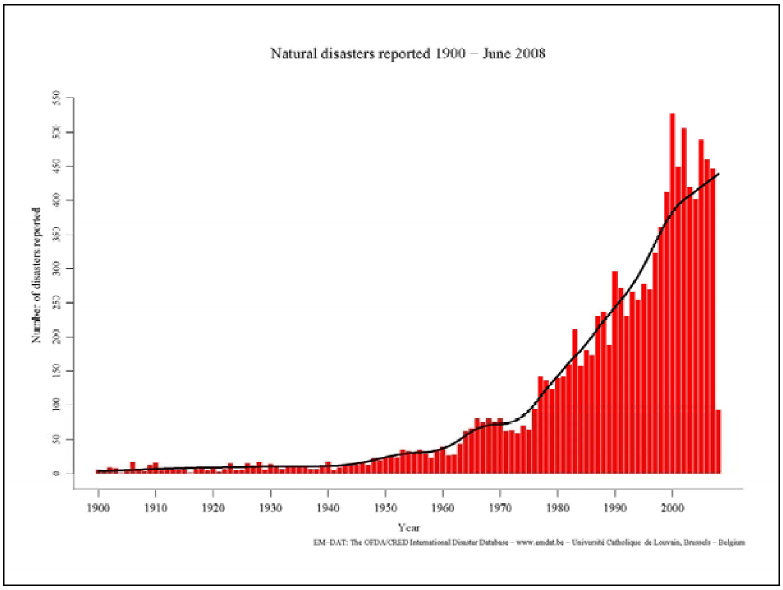


Figure 1. Natural disasters reported (EM-DAT)

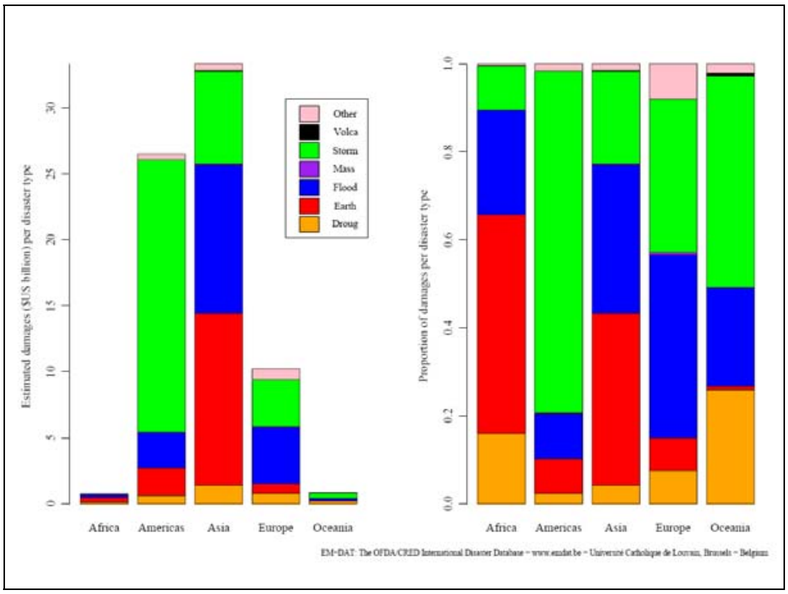


Figure 2. Estimated damages per disaster type by regions (EM-DAT)

Ms. Irina Bokova, Director-General of UNESCO has pointed out, "UNESCO should become the leader and mobilizer of governments, specialized agencies and the scientific community in the field of science, innovation and new technologies, including green technologies, under the slogan 'Science and Technology serving Humanity." Indeed, UNESCO is the only United Nations specialized agency with "SCIENCE" inscribed in its name and with a specific mandate to promote science. The bulk of UNESCO's activities regarding natural hazards are performed in the UNESCO's Natural Sciences Sector (Figure 3). However, activities on Disaster Risk Reduction (DRR) also involve other programme sectors including the Education Sector, the Culture Sector and the Communication and Information Sector of UNESCO. The contribution is also handled by units both in Headquarters and in Field Offices. Altogether, UNESCO advocates a shift in emphasis from "relief and emergency response" to "prevention and increased preparedness and education of potentially affected populations" (Figure 4).

Figure 3. UNESCO as the only United Nations specialized agency with "Science" in its name

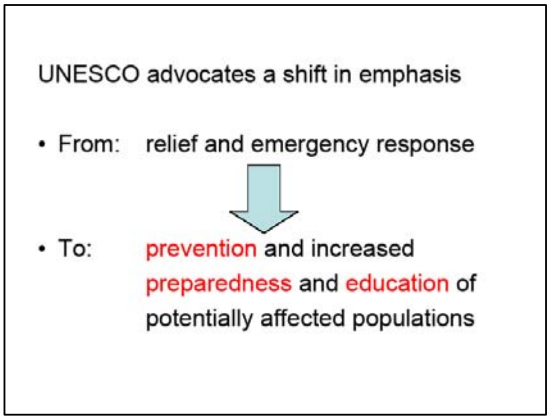


Figure 4. UNESCO advocates a shift from relief to prevention efforts

UNESCO has been engaged in the study and mitigation of natural hazards since 1960s. Its scope of work concerns promoting knowledge and education aimed at enhancing disaster prevention and preparedness. The purposes of the Organization are to promote a better understanding of earthquakes and other hazards, and to enhance preparedness and public awareness through education and training. UNESCO is an active partner in the International Strategy for Disaster Reduction (ISDR) system.

UNESCO's long-term goals of DRR include the promotion of better understanding of earthquakes and other hazards, the enhancement of public awareness through education and communication, the promotion of disaster-resistant building codes and safer construction, the support development of hazard risk mapping, the observation and early warning networks of natural hazards, the integration of DRR into education, and the protection of cultural monuments and sites (Figure 5). UNESCO's DRR efforts are not only in the field of earthquakes; it is also tackling all other natural hazards not to turn into disasters (Figure 6).

Figure 5. UNESCO's Long-term Goals of DRR

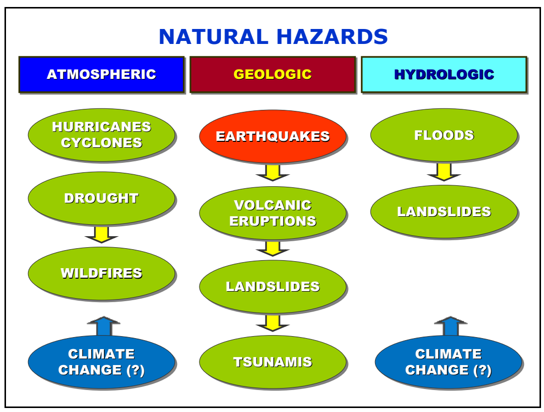
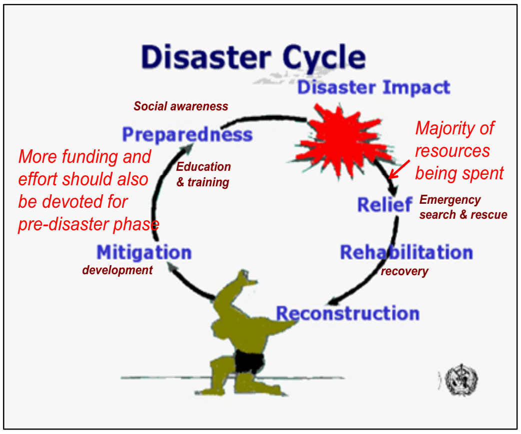


Figure 6. Natural hazards UNESCO is tackling

Generally speaking, when we look at the disaster cycle, we unfortunately observe that the majority of resources for disaster-related activities are spent at the occurrence of disasters and for the emergency response phase and relief operations (Figure 7). Much less funding and effort are devoted to investing in the other phases of the cycle, namely the mitigation, the disaster preparedness or more generally the pre-disaster phase. This trend must be reversed in order to reduce losses in a true sense.

Disasters are increasingly caused, or aggravated, by human behaviour and attitude. Whereas hazards may be inevitable, disasters are not (Figure 8). Because disasters could have been prevented or mitigated, Ms. Margareta Wahlström, Assistant Secretary-General of UN/ISDR, once mentioned that all disasters are man-made, which are caused by hazards. We can break the link by proper prevention and disaster preparedness. As for earthquakes, the earthquake hazard itself does not kill people, but buildings and other infrastructure kill them and turn into a disaster. We must, and we can, prevent disasters by making safer environment.



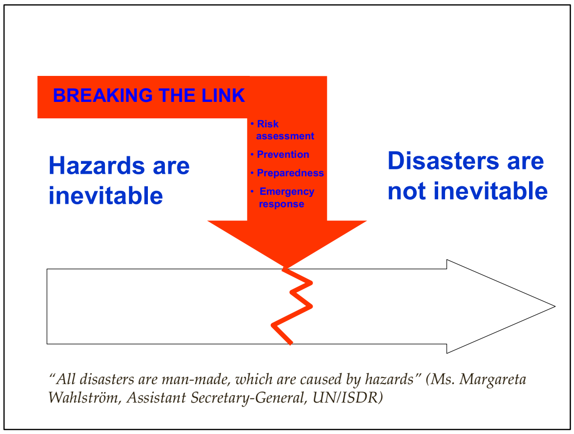
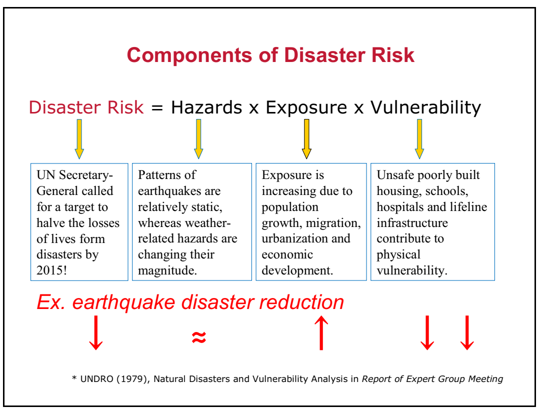


Figure 7. Disaster Cycle

Figure 8. Hazards vs Disasters

Disaster risk can be expressed as a combination of hazards, exposure and vulnerability (Figure 9). Regarding hazards, patterns of earthquakes are relatively static, whereas weather-related hazards may be changing their magnitude due to global climate change. Exposure is increasing due to population growth, migration, urbanization and economic development (Figure 10). Unsafe poorly built housing, schools, hospitals and lifeline infrastructure contribute to physical vulnerability.

On the other hand, the UN Secretary-General, Mr. Ban Ki-moon, called for a target to halve the losses of lives form disasters by 2015, the ending year of the Hyogo Framework for Action (HFA). Because the exposure is increasing, in order to seriously reduce the disaster risk, we need to make greater efforts in reducing vulnerability, physically as well as socially.



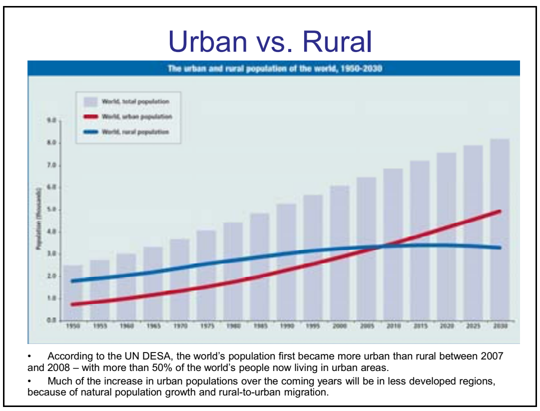


Figure 9. Components of Disaster Risk UNDRO (1979)

Figure 10. The urban and rural population of the world, 1950-2030

IPRED – UNESCO'S PROGRAMME FOR EARTHQUAKE DISASTER REDUCTION

As regards research and expertise on earthquake risk, UNESCO established the International Platform for Reducing Earthquake Disasters (IPRED) in 2008, with the support of the Government of Japan. It aims at setting up an international network for collaborative research, training, and education regarding seismology and earthquake engineering, including the establishment of a system for post-earthquake field investigation. The International Institute of Seismology and Earthquake Engineering (IISEE) of Japan acts as the "Centre of Excellence" of this Platform.

In addition, UNESCO has been jointly carrying out workshops devoted to promote programmes for reducing earthquake losses, in cooperation with the U.S. Geological Survey (USGS) and earthquake science organizations in the Mediterranean and in South Asia Region, etc. They are called the Programme on Reducing Earthquake Losses in the Enlarged Mediterranean Region (RELEMR) and the Programme on Reducing Earthquake Losses in the South Asia Region (RELSAR). UNESCO has also established a similar programme in the Northeast Asia Region. These workshops offer a forum for scientists and engineers from countries presenting a diversity of political contexts to work together under UNESCO's umbrella and discuss regional approaches to improve collaboration in earthquake data exchange and analysis.

BACKGROUND OF THE IPRED

Buildings, especially housing, should protect human beings from natural disasters. When buildings are themselves damaged by earthquakes, the impact on the lives of the occupants is enormous. Damage to buildings caused by disasters can also seriously hinder relief and repairing efforts. For example, major hospitals and other facilities may become unable to function, roads may be blocked by wreckage, and there may be massive refugee flows.

In January 2005, the United Nations World Conference on Disaster Reduction (WCDR) was held in Kobe, Japan and the WCDR adopted the Hyogo Framework for Action (HFA) 2005-2015: Building the resilience of nations and communities to disasters. At one of the Conference sessions, it was discussed that it is important to improve the safety of buildings and housing as a basic and vital priority for the world's disaster reduction efforts. It was then proposed that the "Building Disaster Reduction Network" should be established.

Such a network is especially needed in the field of earthquakes in order to activate and share data of invaluable experience of each country, as it is difficult for a single country to experience and verify the effects of measures. As Japan has experienced many large earthquakes since ancient times, earthquake disaster reduction has been researched and studied quite extensively. UNESCO has recognized and supported these Japanese efforts and expertise concerning earthquake risk reduction.
In 1960, the Government of Japan launched international training courses on seismology and earthquake engineering. In 1962, UNESCO participated in a joint venture with the Building Research Institute (BRI) of Japan when the Government of Japan established the IISEE. Since then, the IISEE has conducted international training courses on seismology and earthquake engineering for researchers and engineers from foreign countries. UNESCO provided financial support to the training courses from 1963 to 1972.

Since 2005, the curricula of the training courses are conducted as the Master Program on Earthquake Disaster Mitigation at the National Graduate Institute for Policy Studies (GRIPS) of Japan, and in 2006, UNESCO provided funds in support of it. Today, supported by the Japan International Cooperation Agency (JICA), more than 1,400 researchers and engineers (a total number since 1960) from almost 100 countries have graduated from the training courses (Figure 11).

ESTABLISHMENT OF THE IPRED

Against the above-mentioned background, and in order to address policy-relevant issues related to earthquake risk reduction and better prepare for the future earthquakes in the world, UNESCO and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan, in cooperation with the BRI of Japan, agreed to promote and expand an international platform regarding earthquakes, including a research and training platform for earthquake disaster reduction based on seismology and earthquake engineering.

The kickoff meeting of this initiative was held in June 2007 in Japan jointly organized by UNESCO, MLIT and BRI, and supported by Japanese National Commission for UNESCO, the Ministry of Foreign Affairs of Japan and other related organizations. The meeting was attended by representatives of the UNESCO Headquarters, nine countries (Chile, Egypt, Indonesia, Japan, Kazakhstan, Mexico, Peru, Romania, and Turkey) with experiences of JICA projects regarding earthquake disaster reduction in the past and related organizations (Figure 12).

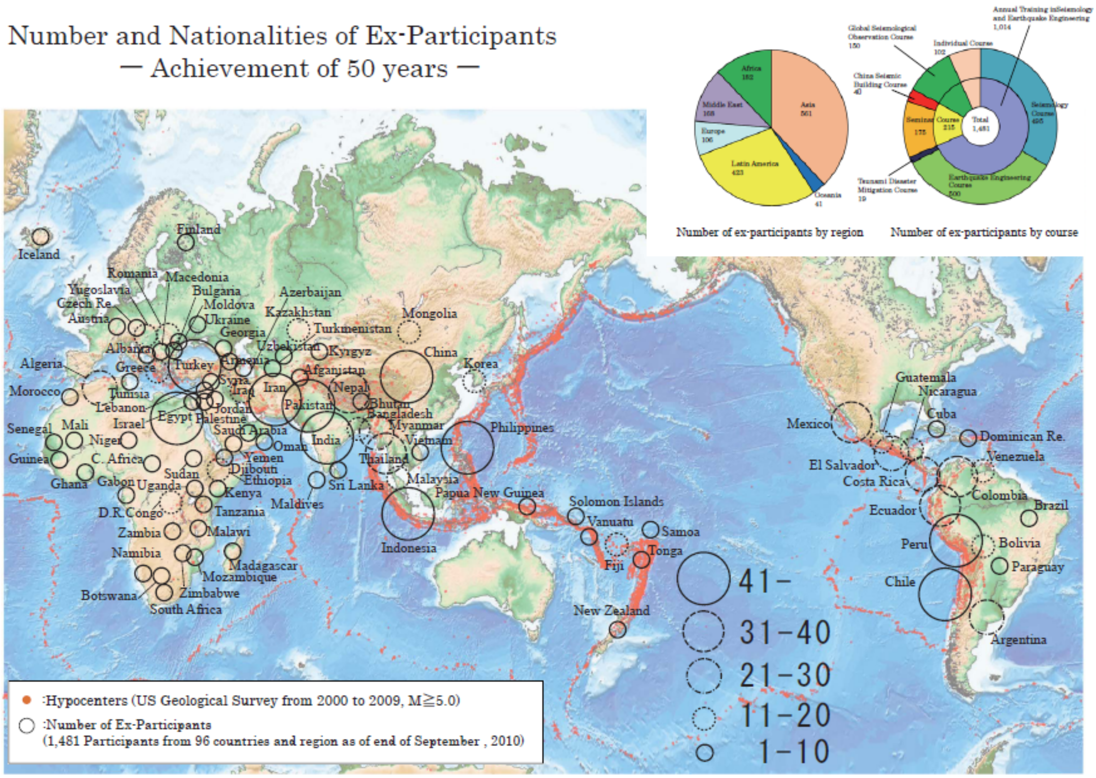


Figure 11. Worldwide ex-participants of UNESCO-supported IISEE Training Courses

Figure 12. Kickoff meeting (Tokyo, June 2007)

At the end of the kickoff meeting, the participated members adopted the resolutions including the establishment of an international platform to promote earthquake risk reduction of buildings, and the formal name of this initiative was later agreed as the "International Platform for Reducing Earthquake Disasters (IPRED)" (Figure 13).

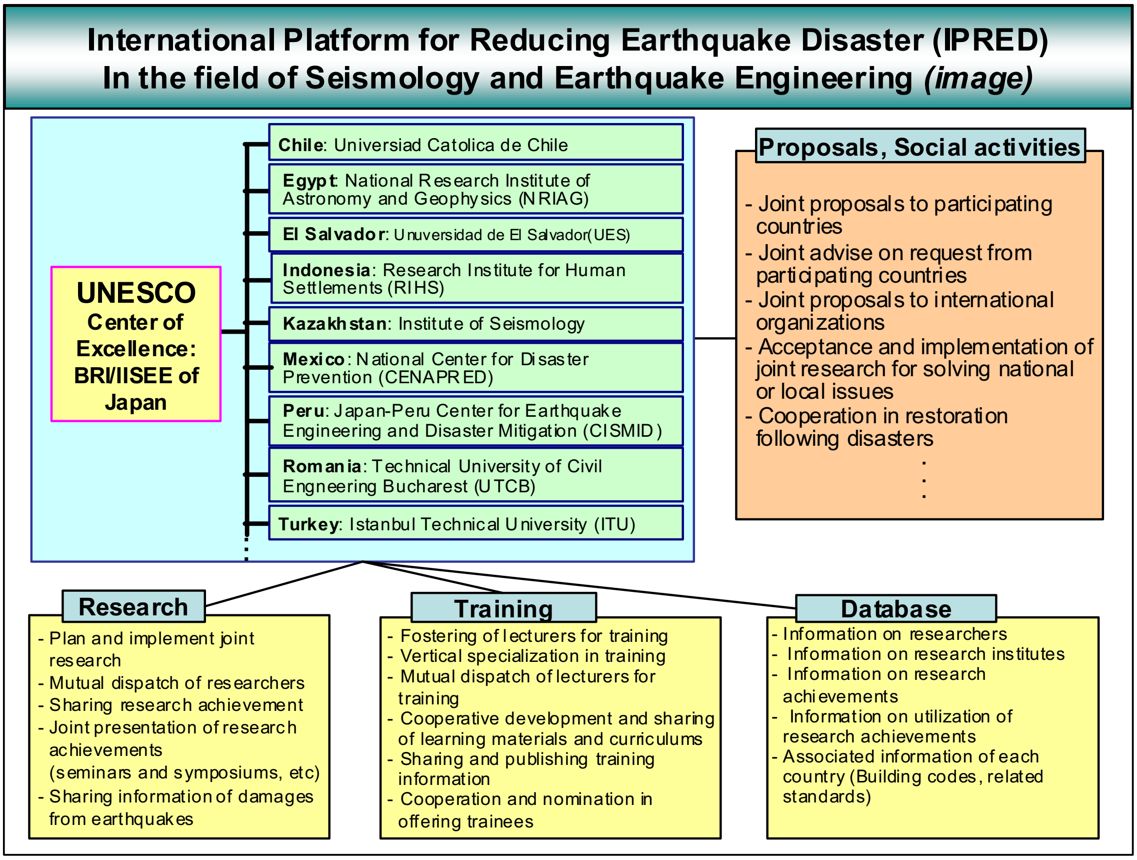


Figure 13. Activities of the IPRED

Figure 14. The first session of the IPRED (Pairs, July 2008)

Figure 15. The second session of the IPRED (Istanbul, July 2009)

The first IPRED meeting was held in July 2008 at the UNESCO Headquarters in Paris. The meeting was attended by representatives of nine earthquake-prone countries (Chile, Egypt, Indonesia, Japan, Kazakhstan, Mexico, Peru, Romania, and Turkey) as well as a guest expert from a Chinese university and the several observers from the Permanent Delegations to UNESCO. At the meeting, quick reports and lessons learned from recent devastating earthquake disasters were shared, and the Action Plan (see below) was discussed. The second Session of the IPRED was held in Istanbul in July 2009, the third Session of the IPRED was held in Padang in July 2010, and the fourth Session of the IPRED was held in Santiago de Chile in July 2011 at which El Salvador newly joined the IPRED (Figures 14 through 17).

THE MISSION AND OBJECTIVES OF THE IPRED

The mission of the IPRED is to identify gaps and priorities through the sharing of scientific knowledge and experience in the field of seismology and earthquake engineering, and to support the development of political will and public awareness, for the purpose of ensuring the better preparation against earthquakes and building a culture of safety for the people in the world.

The principal objectives of the IPRED are as follows:

a. To exchange information and propose plans on collaborative research, training, and education regarding seismology and earthquake engineering in order to reduce earthquake disasters, especially on buildings and housing;
b. To address policy-relevant issues related to the reduction of earthquake disaster risks and implementation of the Hyogo Framework for Action, including making recommendations on priorities in the International Strategy for Disaster Reduction (ISDR) system;
c. To establish a system to dispatch experts to an earthquake stricken country in order to carry out post-earthquake field investigations and draw lessons for future risk reduction, by utilizing the worldwide network of ex-participants of IISEE international training courses;
d. To support and cooperate with the IISEE in its activities including implementation of international training courses on seismology and earthquake engineering aiming at earthquake disaster reduction;
e. To propose and organize specific enquiries regarding seismology and earthquake engineering in order to investigate and address priority matters to the governments and regional or international communities;
f. To advise the IPRED members on scientific and technical issues regarding seismology and earthquake engineering; and
g. To assist and coordinate scientific and technical activities within the ISDR system, including the initiatives of the ISDR Global Task Force on Building Codes coordinated by UNESCO.

THE IPRED ACTION PLAN

- ***Action 1***: *Development of database to contribute to field investigations (database related to anti-seismic performance, etc.) (http://www.ipred-iisee.org/database/)*
- ***Action 2***: *Establishment of a system for post-earthquake field investigations*
- ***Action 3***: *Development of educational materials database (for the e-learning system, etc.)*
- ***Action 4***: *Promotion of international joint research programmes*
- ***Action 5***: *Promotion of international cooperation with universities*
- ***Action 6***: *Promotion of sharing engineering data on structural testing, soil properties, etc.*
- ***Action 7***: *Promotion of ground motion observation network and the data sharing*
- ***Action 8***: *Training of trainers through the IISEE follow-up trainings, follow-up workshops, etc.*
- ***Action 9***: *Development of the portal website (http://www.ipred-iisee.org/)*
- ***Action 10***: *Establishment of the "IISEE-UNESCO Lecture Notes Series" (http://iisee.kenken.go.jp/lna/)*
- ***Action 11***: *Development of the microtremor array exploration techniques*
- ***Action 12***: *Dissemination of activities through International and/or regional events related to seismology or earthquake engineering*

- ***Action 13***: *Planning of international workshops to raise IPRED's awareness*
- ***Action 14***: *Information dissemination by distribution of printed materials*
- ***Action 15***: *Translation of building codes into other languages*

Figure 16. The third session of the IPRED (Padang, July 2010)

Figure 17. The fourth session of the IPRED (Santiago de Chile, July 2011)

THE IPRED POST-EARTHQUAKEE FIELD INVESTIGATION

One of the important objectives of the IPRED is to establish a system for post-earthquake field investigation. It is recommended that, before the occurrence of major earthquakes, UNESCO and the IISEE as the Centre of Excellence of the IPRED prepare the register of names and email addresses of members who may be able to cooperate with and/or participate in the post-earthquake field investigations. In principal, at the initial stage, it would be a good idea to utilize the worldwide network of ex-participants of IISEE international training courses (Figure 18).

Based on the IPRED Action Plan, UNESCO and the IISEE have developed the database to contribute to post-earthquake field investigations regarding building codes, materials and guidelines, etc. and it is being upgraded. (http://www.ipred-iisee.org/database/)

If and when a major earthquake occurs, UNESCO and the IISEE are supposed to gather information on its scale and damages, and dispatch the information to the registered members via the Internet and/or emails. If the post-earthquake field investigation is judged as necessary, UNESCO and the IISEE will promptly establish the field investigation team in cooperation with the registered members.

Some principal criteria of the judgment of the necessity of the field investigation would include the following:

i. Severe Damages have occurred to many engineered buildings, or characteristic damages have occurred to non-engineered buildings;
ii. Lessens on seismology and/or earthquake engineering regarding plans, designs and construction works can be obtained;
iii. There are no major difficulties in the situation of public safety in order to carry out the field investigation.

It would be important to synthetically take into account widely distributed construction methods, languages, customs and livelihood in the earthquake-stricken area as well as any difficulties in carrying out the field investigation including humanitarian issues. In order to carry out the field investigation as effectively and efficiently as possible, and not to cause annoyance to the victims or rescue teams in the earthquake-stricken area, the field investigation team shall be arranged not to overlap too much with other field investigations dispatched by other organizations.

In order to take effective actions, it would also be necessary to develop some manuals regarding how to proceed with field investigations. The primary aim of field investigations would be to grasp the overall situation of damages to buildings and to record such information for academic/scientific purposes. Therefore, it would be difficult to offer detailed examinations and/or advices on seismic retrofitting, etc. for a specific building during such field investigations. However, it would also be possible to contribute to the earthquake-stricken area later on, by reporting to local governments on results of the field investigation, advising a future reconstruction plan, introducing the state-of-the-art knowledge/technology, etc.

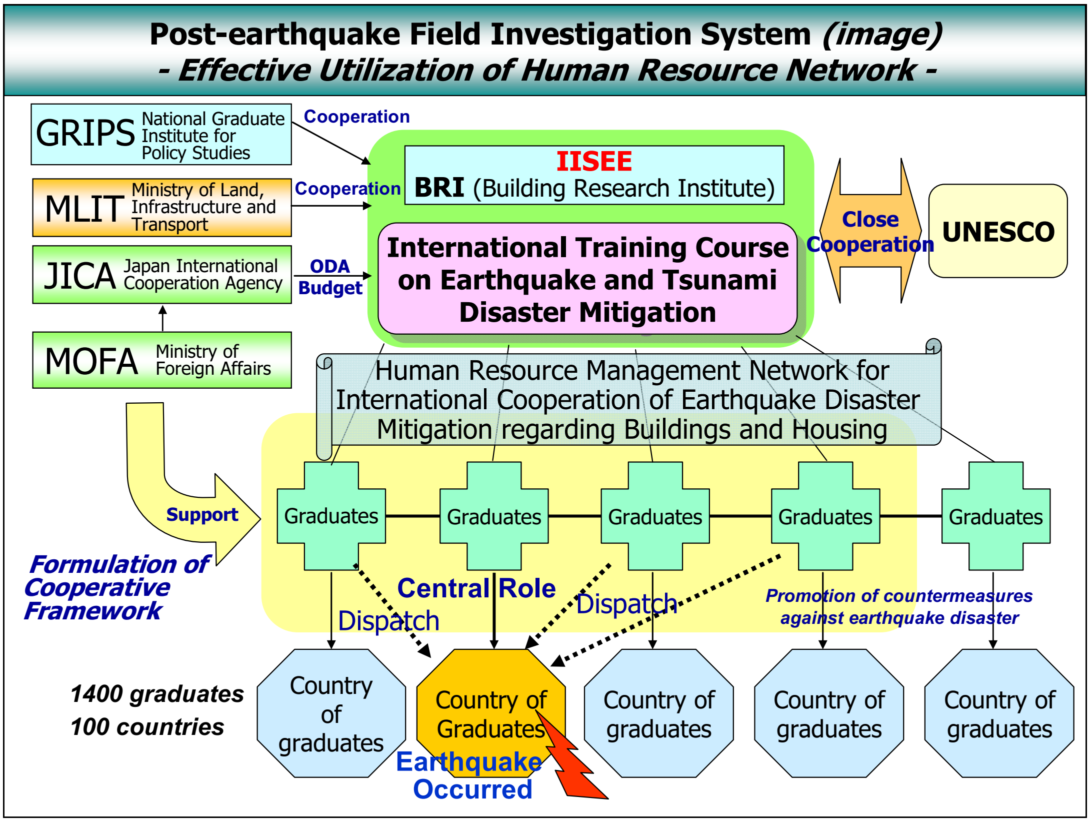


Figure 18. Image of IPRED post-earthquake field investigation system

After field investigations, UNESCO shall upload the quick report on its website. As occasion demands, UNESCO may make plans for a meeting on the quick report, publication of the field investigation results, etc.

In principle, each individual member of the field investigation team shall bear the traveling expenses of the investigations. However, UNESCO will facilitate the funding of this mechanism through its own programme and budget or by mobilizing extrabudgetary resources, provided such resources are available. At any rate, at the request of the field investigation team, UNESCO will consider the support of all or part of the expenses within the limits of its budget according to the situation. UNESCO may also offer convenience to the member, including the request of prompt grant of a visa to the affected county and other arrangement with the relevant organization in the affected country.

When a foreign government dispatches a field investigation team to the country affected by a major earthquake, it is the ordinary procedure that the government of the affected country first makes an official request to the foreign government on this matter through the diplomatic establishments in the said affected country. However, it may not be easy for the government to make such a request smoothly under the confusion in the wake of the earthquake.

On the other hand, when a foreign nongovernmental organization such as an academic society dispatches a field investigation team to the country affected by a major earthquake, there may be no such ordinary, formal procedure. However, it may not be easy for them to obtain a visa to the affected county.

Therefore, UNESCO as a United Nations organ proposes to make prior arrangements with related governments and organizations to facilitate post-earthquake field investigations.

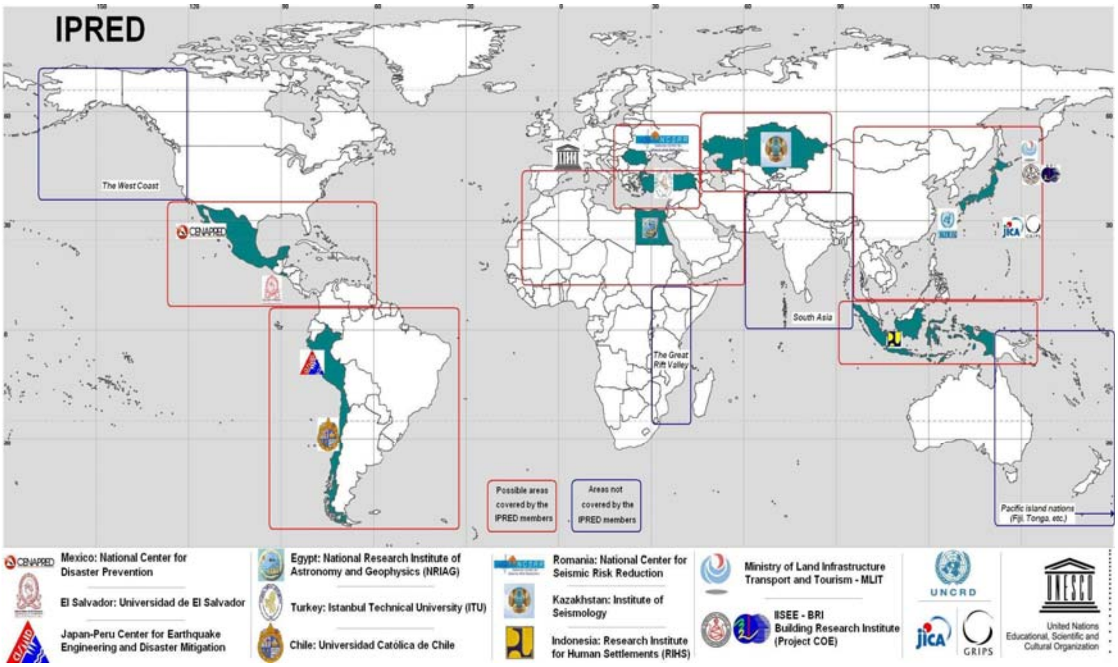


Figure 19. Possible regional network under the IPRED programme

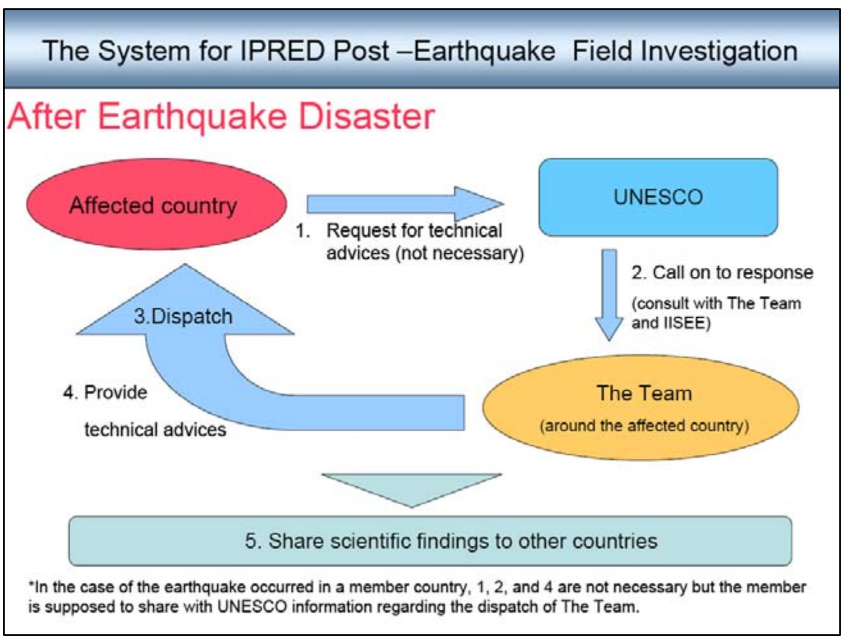


Figure 20. The Image of the IPRED Post – Earthquake Field Investigation

Figure 21. The Letter of Intent signed between RIHS and UNESCO in cooperation with IISEE (Padang, July 2010)

Figure 22. The Letter of Intent signed between PUC and UNESCO in cooperation with IISEE (Santiago de Chile, July 2011)

During the third session of the IPRED in Padang, Indonesia in July 2010, the Letter of Intent (LoI) between the Research Institute for Human Settlements (RIHS) and UNESCO in cooperation with the IISEE concerning cooperation for reducing earthquake disaster risks and post-earthquake field investigations was signed during the Closing Ceremony of the Workshop. It was a great first step for the cooperation on the post-earthquake field investigation, and the similar agreement was signed between the Pontifical Catholic University of Chile (PUC) and UNESCO in cooperation with the IISEE in Santiago de Chile in July 2011. The similar agreements should be signed between UNESCO and each key IPRED member institute or university in cooperation with the IISEE as well (Figures 19 through 22).

EDUCATION FOR DRR & SUSTAINABLE DEVELOPMENT (INCLUDING SCHOOL SAFETY)

The dramatic increase in human and economic losses from disasters in recent years is alarming. In particular, natural disasters continue to often strike hardest at some of the world's poorest communities, which are the least well placed to defend themselves or to recover afterwards. While natural hazards are not a new phenomenon, sadly, they tend only to attract attention when they manifest themselves as disasters. Despite the ample available body of knowledge and know-how on the assessment of natural hazards and the attenuation of their consequences, reducing and mitigating disaster risks is still not high on many governments' agenda.

We need to make a major conceptual shift from a focus on disaster response, to an emphasis on disaster prevention. The implementation of the Hyogo Framework for Action is, more than ever, an imperative in pursuing the substantial reduction of disaster losses. Operating as it does at the interface between education, the sciences, the social science, culture and communication, UNESCO is committed to play a vital role in contributing to constructing a global culture of disaster resilience.

For decades, the Organization has been actively engaged in the study of natural hazards and in building capacities to mitigate their effects. As an active partner in the International Strategy for Disaster Reduction (ISDR), UNESCO promotes international and regional networks of systems and expertise for the monitoring, exchange and analysis of hazards data, in particular data related to earthquakes, tsunamis, floods, droughts and landslides.

As a United Nations specialized agency with "EDUCATION" inscribed in its name, UNESCO is also concerned with the integration of education and disaster risk reduction as well as with the protection of educational buildings and cultural monuments and sites in hazard-prone areas. It is an intrinsic element of the UNESCO-led United Nations Decade of Education for Sustainable Development (UN DESD). The decade proposes a vision of education handling the issues of environment, democracy, economy, human rights, culture, parity, etc., in a transdisciplinary approach.

The decade will promote:

- An education empowering people to commit themselves to sustainability, transforming people in responsible citizens with creative and critical thinking and others skills: oral and written communication, collaboration and cooperation, conflict management, decision-making, problem-solving and planning using appropriate ICTs;
- An education that fosters responsible citizens and promotes democracy by allowing individuals and communities to enjoy their rights and fulfill their responsibilities, to learn to live together in peace and tolerance;
- An education at all levels of education systems and in all social contexts (family, school, workplace and community)

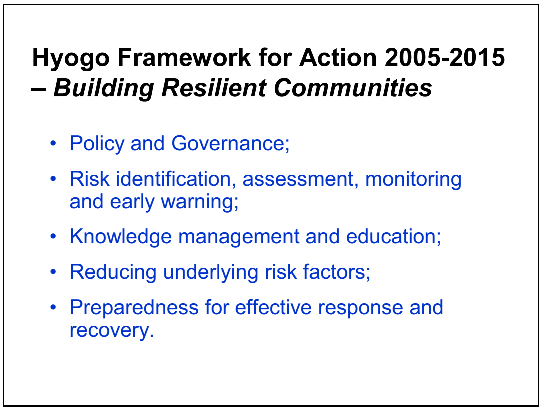


Figure 23. HFA Priority of Action

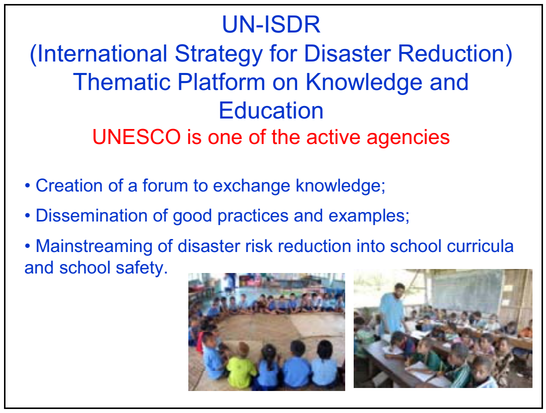


Figure 24. UN-ISDR Thematic Platform on Knowledge and Education (TPK&E)

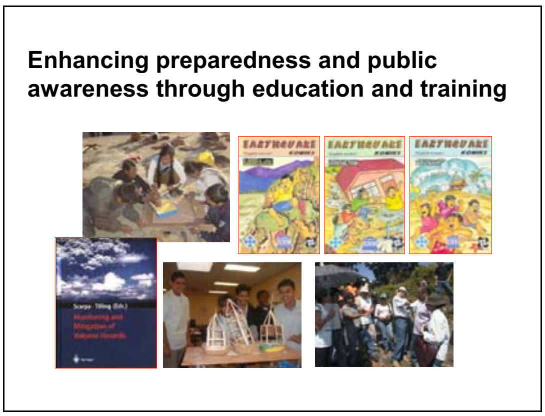


Figure 25. Promotion of education and training

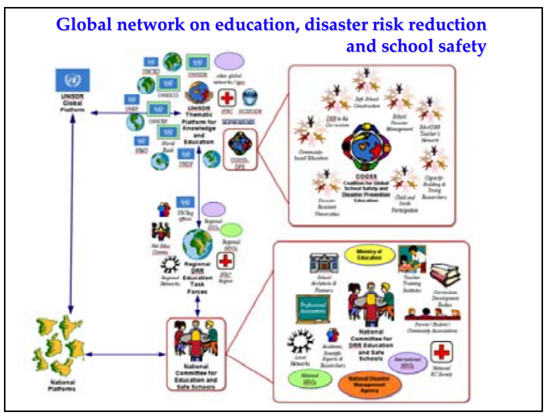


Figure 26. Global network on DRR education and school safety (http://cogssdpe.ning.com/)

Of course UNESCO does not and cannot do this alone and it has to form part of a network of UN agencies, inter-governmental groups, and non-governmental or civil society organizations that are teamed together as part of the ISDR. In this sense, UNESCO serves as the "convener" of the UN multi-stakeholder platform concerned with the knowledge and education for disaster reduction (Figures 23 through 26).

GLOBAL TASK FORCE ON BUILDING CODES (GTFBC)

Background of the GTFBC

Building codes are considered as the most effective tools to safeguard the lives and property against major disasters like earthquakes and hurricanes. They are already in place in many of the disaster prone countries. However, the large scale of deaths and property loss in recent disasters has been largely attributed to the non-compliance of building codes. Many people are being killed by buildings and housing.

The implementation of building codes requires involvement of different stakeholders. It is essential to take an inter-disciplinary, all-encompassing approach to include political science and engineering, and to involve community stakeholders.

The establish of the GTFBC

On the occasion of the First Session of the ISDR Global Platform for Disaster Risk Reduction (GP/DRR) held in Geneva in June 2007, UNESCO co-organized the side event on building codes. During the side event, it was proposed to set up a Taskforce Group on Building Codes, and UNESCO volunteered to serve as the secretariat for this Taskforce Group (Figure 27).

The Taskforce Group was called "Global Task Force on Building Codes (GTFBC)" and was initially formed by participants of the session on building codes during the ISDR GP/DRR in Geneva in June 2007. The list of the GTFBC members has grown through a number of events on building codes including IDRC Davos 2008, ISDR GP 2009, etc. The GTFBC consists of worldwide experts in the field of building codes and practices: UN agencies (UN-ISDR, UN-OCHA, World Bank, UNDP, UN-HABITAT, UNESCO, UNICEF, UNCRD, UNU, etc.), international organizations and NGOs (IFRC, IAEE, IAWE, IG-WRDRR, ICC, ADPC, ADRC, EERI, Build Action, RICS, DWF, EMI, Plan, INEE, COGSS-DPE, Risk Red, etc.), national governments and institutions, universities, building officials, architects, engineers, seismologists, etc.

Figure 27. Side event during the GP in 2007

The Special event at ISDR GP/DRR 2009

During the Second Session of the GP/DRR, UNESCO organized a special event on "Safer Building Codes and Construction: A Strategy for Enforcement, Implementation and Dissemination" on Tuesday, 16 June 2009 in cooperation with the United Nations Centre for Regional Development (UNCRD) and other relevant organizations as part of the initiatives of the Taskforce Group to discuss how we could realize safer building codes and the actual constructions that conform to those building codes (Figure 28, Figure 29).

The Taskforce Group considered new and further steps to promote the subject area, including through extending its members and calling out to other participants in GP/DRR for sharing up-to-date information with an integral and trans-disciplinary approach. The participants reviewed the current state of implementation of building codes and discussed gaps and opportunities. The primary goal of this special session was to sensitize stakeholders, especially national and local governments, on the building codes.

Figure 28. The Second Session of GP

Figure 29. Special event during the GP in 2009

The Special events at ISDR GP/DRR 2011

At the Third Session of the GP/DRR, UNESCO, in cooperation with Coalition for Global School Safety and Disaster Prevention Education (COGSS-DPE) and RICS Disaster Management Commission, organized the workshop of GTFBC on 9 May 2011 and the GTFBC side event “Making Building Codes Work for the Vulnerable: Improving Compliance and Retrofitting” on 12 May 2011 (Figure 30).

Chaired by Garry de Pomerai from COGSS-DPE, over 20 core member of GTFBC participated in the workshop and discussed the 2011-2013 action plan of the GTFBC intensively following the presentations of international experts (Figure 31).

Figure 30. Workshop at the GP in 2011

Figure 31. Special event during the GP in 2011

At the side event, more than 70 participants including the experts from the World Bank Global Facility for Disaster Reduction and Recovery (GRFRR) shared some experiences of earthquake reconstruction and lessons learned from those experiences; found gaps; and discussed strategies for development, dissemination and implementation of early standards/guidelines for transitional construction and retrofitting as well as strategies to improve compliance for the vulnerable majority. The session also developed a 2011-2015 strategic action plan for the Taskforce group in order to address critical activities for future risk reduction. The Taskforce will continue the effort to achieve the action plan (Figure 32).

The followings are key outcomes and recommendations of the side event:

1. Simplify language highlighting the reasons for the importance of building codes to non-technical people and communities; including energy efficiency standards.
2. Imperative to collaborate between different groups working on strategies for building codes, safer schools, safer hospitals, shelter and land tenure, etc. There is a need to develop mechanisms to address link between temporary and permanent shelter.
3. Greater investment is required to better quantify the problems of non-compliance and find effective solutions for retrofitting.
4. Building codes and standards for retrofits are a critical risk reduction issue, which must be tackled by everyone, in creating the early conditions for the development of compliance and of setting standards.

<u>GTFBC Action Plan for 2011-13 (Outline)</u>

GTFBC Implied Mandate - Hyogo Framework for Action Priority 4: Apply building codes and retrofit buildings to 'substantially reduce disaster losses

Overall (GTFBC) Objective - Promote participative development and implementation of building codes and retrofitting by communities and governments

Specific Objectives and Activities

1. Review the current state of adoption and implementation of building code, and find the gaps and opportunities
   - 1.1 To collate and map current building codes(structural safety), with comment about their validity and compliance
   - 1.2 To collate and map current retrofitting projects and standards, with comments about their validity and compliance
   - 1.3 To collate the current standards/guidelines for transitional shelters
   - 1.4 To promote action to address any identified gaps - through advocacy or direct project implementation by GTFBC or its members

2. Compile case studies of government and community actions in building code development and application, and disseminate good practice models
   - 2.1 To identify best practices for development, adoption, promotion and compliance of building codes in different contexts
   - 2.2 To identify best practices for successful retrofitting projects and standards in different contexts
   - 2.3 To identify a group of strategies that allow GTFBC to disseminate effectively the outcomes found in the execution of objectives 1 and 2

3. Promote adoption of policy framework for building codes/retrofitting for DRR by governments, and mutual support of related work with other campaigns
   - 3.1 Develop basic guidelines for development of a policy framework for building codes and retrofitting
   - 3.2 Generate greater support for building codes/retrofitting and also urban/land use planning through increased collaboration with governments, donors and other related campaigns
4. Monitor and report progress in line with these objectives and overall HFA objectives

Figure 32. GTFBC Action Plan for 2011-13 (Outline)

As a group of experts on seismology and earthquake engineering, with its expertise in the field of buildings and housing, the IPRED has greatly contributed to the GTFBC discussions. Indeed, after the Haiti earthquake in January 2010, the IPRED members contributed to the GTFBC in gathering a number of useful materials, guidelines, etc. which could be utilized for the reconstruction of safer buildings and houses in Haiti, and it supported efforts made by the Shelter Cluster in Haiti (Figure 33).

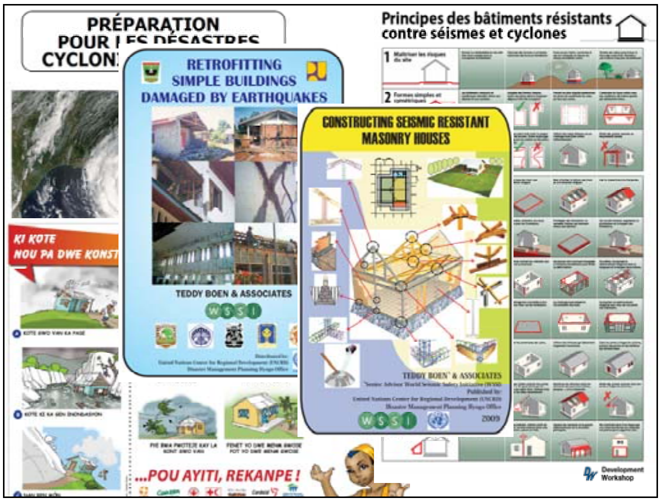


Figure 33. Materials, etc. gathered after the Haiti earthquake

In his article titled “Don't just wait for disaster” in March 2010, the UN Secretary General, Mr. Ban Ki-moon mentioned that no country can afford to ignore the lessons of the earthquakes in Chile and Haiti. However, in Chile, because stringent earthquake building codes were enforced, much worse casualties were prevented. On the other hand, Haiti had nonexistent or unenforced building codes, and very poor preparedness. In flood and earthquake-prone areas, the solution is to enact and enforce building regulations. The Chile and Haiti earthquakes showed us once again why action before disasters makes all the difference. To prevent natural hazards turning into disasters, we must all act sooner and act smarter (Figure 34).

Don't just wait for disaster

By Ban Ki-moon (24 March, 2010)

- No country can afford to ignore the lessons of the earthquakes in Chile and Haiti.
- (Chile) Because stringent earthquake building codes were enforced, much worse casualties were prevented.
- (Haiti) Had nonexistent or unenforced building codes, and very poor preparedness.
- In flood and earthquake-prone areas, the solution is to enact and enforce building regulations.
- The Chile and Haiti earthquakes showed us once again why action before disasters makes all the difference. To prevent natural hazards turning into disasters, we must all act sooner and act smarter.

Figure 34. “Don’t just wait for disaster” by the UN Secretary General

CONCLUDING REMARKS

The UNESCO's IPRED programme, as a group of experts on seismology and earthquake engineering with its expertise in the field of buildings and housing, has a mission and a great potential of contribution by promoting the following objectives among others:

a. To exchange information and propose plans on collaborative research, training, and education regarding seismology and earthquake engineering in order to reduce earthquake disasters, especially on buildings and housing;
b. To address policy-relevant issues related to the reduction of earthquake disaster risks and implementation of the Hyogo Framework for Action, including making recommendations on priorities in the International Strategy for Disaster Reduction (ISDR) system; and
c. To establish a system to dispatch experts to an earthquake stricken country in order to carry out post-earthquake field investigations and draw lessons for future risk reduction, by utilizing the worldwide network of ex-participants of IISEE international training courses.

Building codes already exist in most of disaster-prone countries, but the biggest challenge would be how to enforce, implement and disseminate building codes. Building codes are not the enemy; they should be respected and complied. They can save lives. It is not only the technical matters, but the more important point is how to translate our scientific knowledge to be understood by policy-makers and non-scientific communities.

ACKNOWLEDGEMENT

Regarding the IPRED workshop held in Santiago de Chile in July 2011, I wish to extend my heartfelt gratitude to all the participants of the workshop, meeting and field trip, especially to colleagues at the Pontifical Catholic University of Chile (PUC) for their great efforts in organizing this successful event. I would also like to thank the IISEE, BRI and MLIT of Japan for their support to this project.

And I wish to thank Mr Takashi Imamura, my predecessor and best friend, for kindly permitting to use some of his figures for this paper.

CHANGES TO CHILEAN SEISMIC DESIGN CODES AFTER MW = 8.8 EARTHQUAKE IN CHILE FEBRUARY 27, 2010

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ABSTRACT

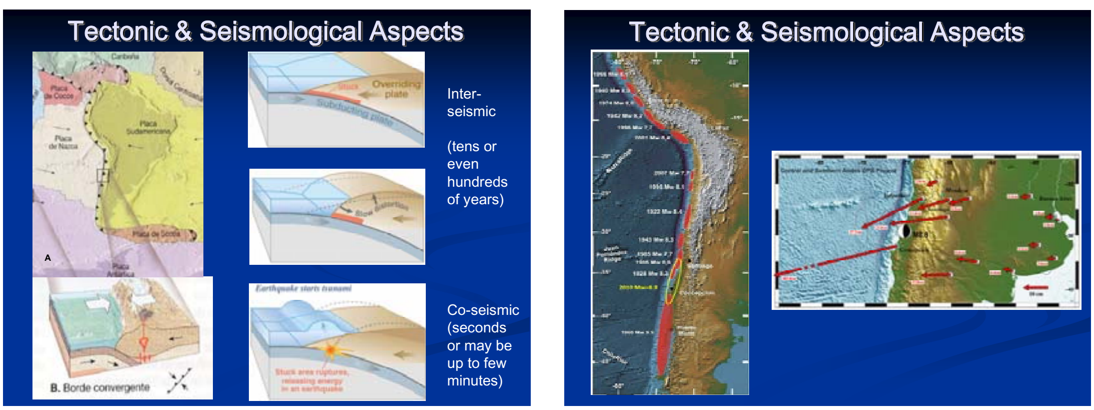
On February 27th, 2010 in Chile was stroked with one of the largest earthquakes that humanity has recorded. While the vast majority of the buildings presented a good seismic performance, many cities were destroyed by the quake and subsequent tsunami that ravaged coasts. The following paper presents the Chilean experience during this major earthquake, focusing in the damage observed in high and low rise buildings, and the code changes introduced to the Chilean seismic design codes due to the lessons learned from analyzing the different types of damage observed.

KEYWORDS

Chile, earthquake, tectonic plates, structural damages, non-structural damages, soil mechanics, Chilean seismic codes.

INTRODUCTION

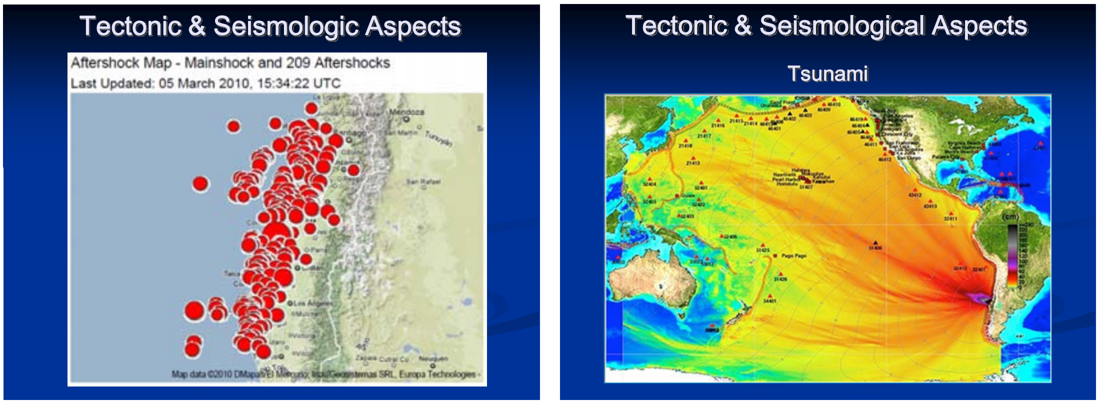
On February 27th, 2010, Chile was stroked by one of the biggest telluric movements recorded in human history. The earthquake stroked at 3:34 AM local time (6:34 UTC) and had a moment magnitude of Mw = 8.8, with a duration greater than 120 seconds. The earthquake was caused by the subduction of the Nazca plate beneath the South American Plate (where Chilean mainland lies over, see Figure 1 (a)), causing a rupture zone of 600 km long on the plate interface. The earthquake affected more than 70% of the country's population, producing severe damages to fields, cities, ports, airports, industries, governmental buildings, etc. A large amount of these damages were due to the post-earthquake tsunami that hit the Chilean south-central waterfront area. The land displacement due to the South American Plate recovery affected even remote areas on the other side of the continent, see Figure 1 (b).



(a) (b)

Figure 1. (a) Dynamic of tectonics plates, (b) geographical gap and land displacement

A week after de earthquake, there had been registered over 200 aftershocks in the affected area, some of these of magnitude around Mw = 7 (Figure 2 (a)). The post-earthquake tsunami hit hard the Chilean south-central coast, and its effect could be seen in almost the entire Pacific Ocean. (Figure 2 (b))



(a) (b)

Figure 2. (a) Aftershock map, (b) tsunami effect in the Pacific Ocean.

OBSERVED DAMAGES

In spite of the strong earthquake, the country's major cities, highly built with medium and high rise buildings, (Figure 3 (a)) remained without widespread damage. Nevertheless, one of the most affected cities was Concepción, the closest large city to the earthquake epicenter. A panoramic view of the city is shown in Figure 3 (b)

(a) (b)

Figure 3. (a) General view of the largest cities in Chile, (b) Panoramic view of Concepción city

Damages in high rise buildings

A typical damage observed in tall buildings, where one can observe the presence of soft stories, with high stiffness change in both the first level as in intermediate levels.

Figure 4 (a) shows the only tall structure with total collapse due to earthquake. This building had a double height soft first story, very common in Chilean construction. Figure 4 (b) shows an intermediate soft story collapsed, without a total collapse of building. Both buildings are in Concepción city.

(a) (b)

Figure 4. (a) Collapsed building with soft first story, (b) Building with partially collapsed soft intermediate story.

Another typical damage was concrete crushing and vertical steel reinforcement buckling in the edges of shear walls, as shown in Figure 5. This damage is due to the poor confinement of the shear wall boundary element, which was not required by the Chilean code before 2008.

Figure 5. Typical observed failures due to the poor confinement in shear wall boundary elements.

Damages in low rise buildings

The damages in low rise buildings were not very different from those already mentioned in high rise buildings. In addition, development or splice length failures were observed, especially for large diameter reinforcing bars in very thin shear walls (Figure 6).

Figure 6. Typical observed failures: poor confinement in shear wall boundary element, vertical reinforcing steel buckling, and development or splice length failures in thin shear walls.

Damages in non-structural elements

The most common damage observed in buildings was in non-structural elements. Many buildings had brittle partition walls, composed mainly of gypsum board. These partition walls did not have proper seismic anchoring and seismic separation from the structural walls and slabs.

Ceilings and air conditioning units with poor seismic anchorage presented severe damages and in many cases theirs fall, injuring people crossing under the affected areas, as shown in Figure 7.

Lessons learned: code changes

Damages allowed in the seismic code

Chilean code of seismic design (NCh433.Of1996 – Seismic design of buildings) is oriented to achieve structures that: a) support without damage earthquakes of moderate intensity, b) limit the damage in nonstructural elements during earthquakes of medium intensity, c) but, if damages occur, avoid collapse during exceptionally severe intensity earthquakes. See Figure 8. These three levels of seismic intensity are defined generically by the Chilean code, without establishing more specific performance levels.

Moreover, Chilean code specifies reduction factors, applicable to the elastic design spectrum, that demand a great ductility to the buildings, and therefore, a higher expected damage under severe intensity earthquakes. However, in many buildings, the observed damage was occurred due to brittle failure of the shear walls, without reaching the levels of ductility implicit in the code and their design.

The damages observed during the earthquake of February 27th, 2010, and their causes were analyzed and discussed by committees of experts that generated consensus in the need to introduce changes to pre-earthquake Chilean codes. Consequently, changes to seismic design Chilean codes were introduced, in particular to the standard NCh433.Of1996 - Seismic design of buildings, and NCh430.Of2008 - Reinforced concrete - Design and calculation requirements.

Figure 7. Typical damages in non-structural elements.

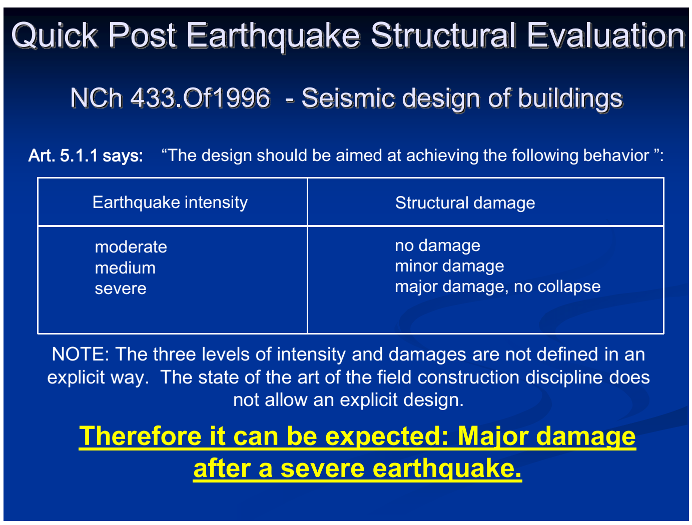


Figure 8. Expected seismic performance.

Changes to the NCh433.Of1996 – Seismic Design of Buildings

Modifications to the standard NCh433.Of1996 have been introduced through the promulgation of Supreme Decree No. 61 of Ministry of Housing and Urban Development, hereafter DS61. The main changes are related with the establishment of new requirements for soil classification and a better estimate of the seismic demand on the buildings.

Soil Classification:

The DS61 defines six soil types (A, B, C, D, E and F) that are determinated with the more representative soil parameter. This parameter corresponds to the stiffness at low deformations of the upper strata corresponding to the average of the shear wave velocity for the 30 meters above the ground, Vs30.

The soils classification varies from the soil with the higher shear wave velocity (Rock: Soil Type A) to the one smallest shear wave velocity (soil type E: soil with medium compactness or with medium consistency), see Figure 9.

In addition, the soil Type F requires special geotechnical studies of amplification of seismic wave to characterize the seismic action. This soil type includes potentially liquefiable soils, soils susceptible to densification by vibration, collapsible soils, fine soils saturated, peat, and lands with irregular topography where the local amplification phenomena could occur.

The definition of soil types associated with Seismic Soil Classification

Type Soil		Vs_{30} (m/s)	RQD	q_u (MPa)	N_1 (blows/fit)	S_u (MPa)
A	rock, cemented soil	≥ 900	≥ 50%	≥ 10 ($\varepsilon qu \leq 2\%$)		
B	soft or fractured rock,	≥ 500		≥ 0.40 ($\varepsilon qu \leq 2\%$)	≥ 50	
C	very dense or strong soil	≥ 350		≥ 0.30 ($\varepsilon qu \leq 2\%$)	≥ 40	
D	medium dense or strong soil	≥ 180			≥ 30	≥ 0.05
E	medium compact or consistency soil	< 180			≥ 20	< 0.05
F	special soils	*	*	*	*	*

Figure 9. Table of Seismic Soil Classification according to requirements of DS61 MINVU 2011.

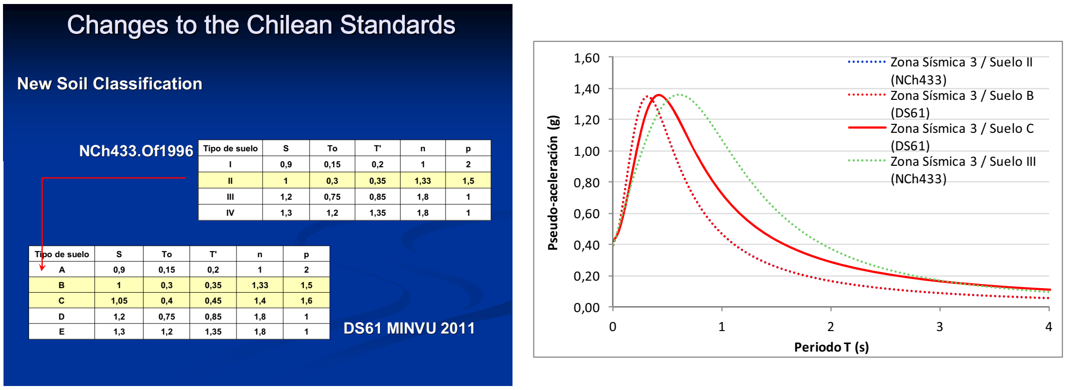
These new six seismic soil types have similarities with the ones defined in NCh433.Of1996 (soil type I, II, III and IV). The soil type A is similar to those on type I, the type B to those on type II, the type D to those on type III and the type E to those on type IV, as shown in Figure 10 (a). Additionally, the DS61 defines the soil type C which corresponds to an intermediate soil type between the soil Type II and the soil Type III, as shown in Figure 10 (a) and (b).

Despite the similarity between the two standards, the DS61 prescribes more stringent requirements for soil classification, particularly for soil type B. This means that many soils that classify as soil type II under the requirements of the standard NCh433.Of1196, under the new requirements of DS61, will be classified as type D (equivalent to soil type III) resulting in a higher seismic demand.

Seismic design spectrum:

Regarding with the design spectrum of pseudo-acceleration, the DS61 introduces a new parameter S that depends on the soil type and amplifies the spectral function, see Figure 11 (a).

The parameter S values varies from 0.9 for soil type A to 1.30 for soil type E as shown above in Figure 10 (a), therefore, the seismic action is amplified significantly for soft soils, as shown in Figure 11 (b).

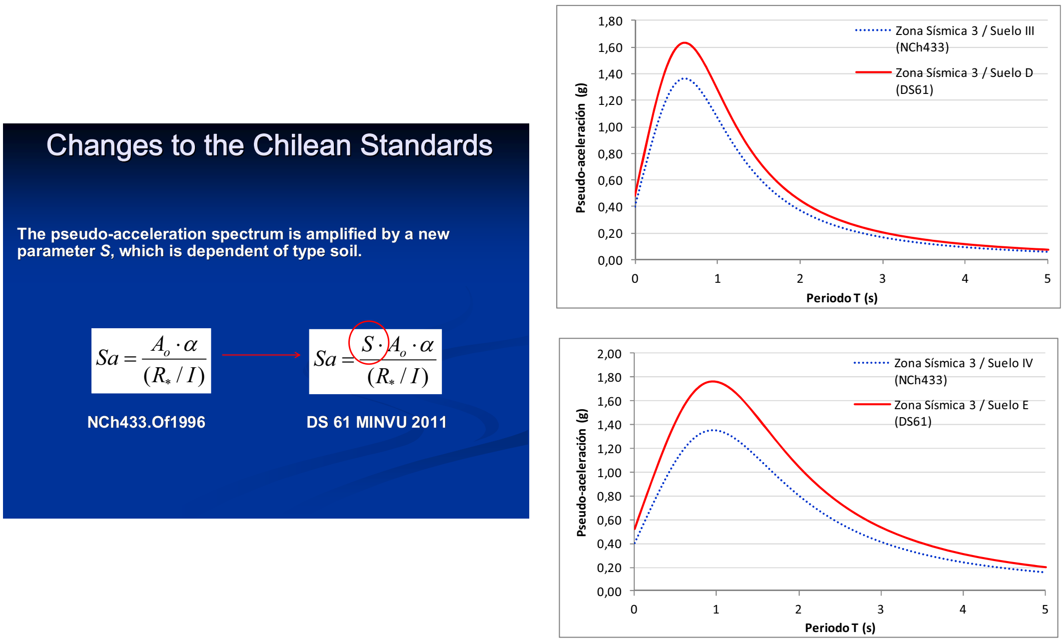


Tipo de suelo	S	To	T'	n	p
I	0,9	0,15	0,2	1	2
II	1	0,3	0,35	1,33	1,5
III	1,2	0,75	0,85	1,8	1
IV	1,3	1,2	1,35	1,8	1

Tipo de suelo	S	To	T'	n	p
A	0,9	0,15	0,2	1	2
B	1	0,3	0,35	1,33	1,5
C	1,05	0,4	0,45	1,4	1,6
D	1,2	0,75	0,85	1,8	1
E	1,3	1,2	1,35	1,8	1

(a) (b)

Figure 10. (a) Table of parameters which depend on the soil type, (b) elastic pseudo-acceleration spectrum (comparison between NCh433.Of1996 and DS61 MINVU 2011).



(a) (b)

Figure 11. (a) Definition of seismic design spectrum, (b) elastic spectrum of pseudo-acceleration for soft soils (comparison between NCh433.Of1996 and DS61 MINVU 2011).

Additionally, the DS61 introduces the definition of an elastic displacement spectrum, due to the spectrum of the NCh433.Of1996 significantly underestimates the displacement demand on the structure for the long periods. The elastic displacement spectrum defined in DS61 is shown in Figure 12.

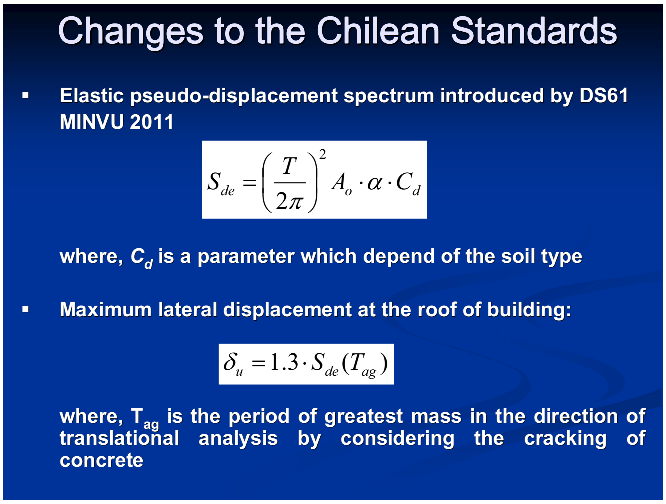


Figure 12. Definition of elastic pseudo-displacement spectrum by DS61 MINVU 2011 and maximum lateral displacement at top of the building.

The elastic spectrum has the Cd factor which depends on the type of soil. The values for this parameter were defined by equations corresponding to an analytical adjustment of the spectral values obtained of the seismic records of February 27th, 2010.

For soils classified as Type E (special soils), DS61 requires a special study to define the elastic displacement spectrum.

In the particular case of the structures of reinforcement concrete, the maximum lateral roof displacement at top of the building can be considered equal to the ordinate of the elastic displacement spectrum to 5% of the critical damping, for the fundamental translational period in the direction of analysis, considering the cracking of the concrete, multiplied by a factor of 1.3, as shown in Figure 12.

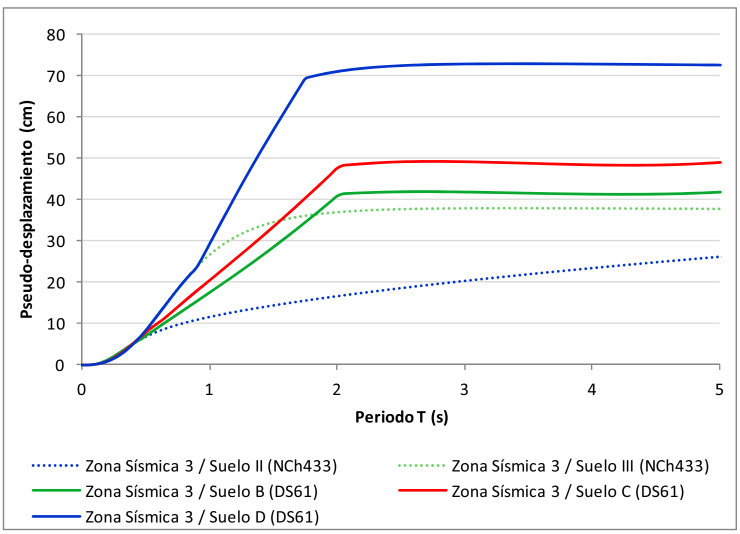


Figure 13. Elastic pseudo-displacement spectrum
(Comparison between NCh433. of 1996 and DS61 MINVU 2011)

Changes to the NCh430.Of2008 - Reinforced concrete - Design and calculation requirements

Modifications to the standard NCh430.Of2008 have been introduced through the promulgation of Supreme Decree No. 60 of Ministry of Housing and Urban Development, hereafter DS60. The main changes to the standard are mentioned below.

Wall critical section:

The DS61 introduces the concept of critical section, which is defined as the zone of a wall in where the inelastic behavior is expected. However, the location of this critical section in a building is open to the structural engineer judgment; this has generated extensive discussion in the engineering community due to the absence of a unified approach among the Structural Engineering companies.

In order to avoid a brittle behavior in the critical section, the DS61 requires verify that the capacity of curvature is greater than the demand of curvature, so that the strain on the compression fiber of the critical section of the wall does not exceed 0008.

Shear wall boundary element:

As shown in Figure 14, the DS 61 introduces the calculation of the special boundary element length as function of seismic displacement demand of the building, no considering a value of 1.5% for the story drift that is implicit in the expressions of ACI318 Code.

Additional requirements to the detailing of the special boundary elements were defined to prevent excessive concrete crushing.

The horizontal spacing between crossties or legs of overlapping hoops shall not be more than the minimum between 20 cm and the half of the thickness of boundary element. A minimum thickness of 30 cm for the confined section of the wall is required.

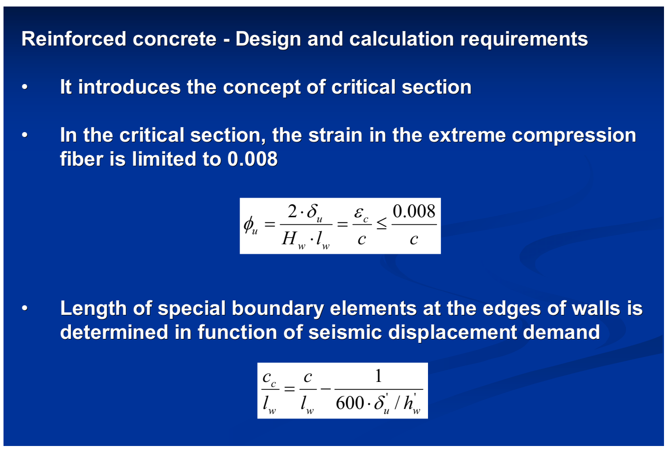


Figure 14. The main changes introduced by DS60 MINVU 2011.

To prevent the buckling of the vertical reinforcement in the boundary elements, the spacing of the transversal reinforcement must not exceed 6 times the diameter of the reinforcement, and must have a diameter more than one third the diameter of the holding bar.

To avoid steel reinforcement congestion, the diameter of the vertical bars at the boundary element was limited to be less than or equal to one-ninth of the smallest dimension of the boundary element.

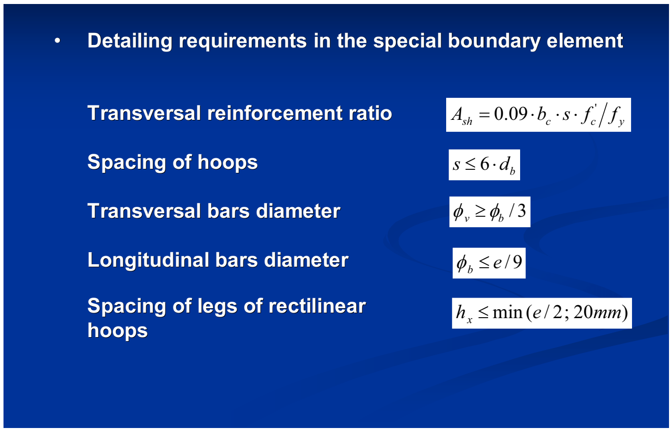


Figure 15. Detailing requirements for the special boundary element per DS60 MINVU 2011.

Compressive strength:

In order to prevent brittle failure of the shear walls, the provisions of DS61 introduce the limit of 0.35 times the cylinder strength of the concrete for the axial compressive load on the elements.

While this limit gives a good approximation for the behavior of the sections for a first stage in the sizing of the elements, it may be insufficient to analyze the behavior of composite sections as required by the provisions of DS61, especially in asymmetric sections such as T, L, C or others. In these cases, further analysis is required to satisfy the DS61 provisions to ensure a proper behavior.

Requirements for design of non-structural elements

Before the earthquake of February 27th, 2010, the design of nonstructural elements subject to seismic forces was regulated by the provisions of Chapter 8 of the Standard NCh433.Of1996, which will be replace for the MINVU Technical Standard NTM 001-2010 that currently is in process to become an official standard. The committee responsible for the study of this standard was constituted with organizations and individuals related to the structural and construction engineering field.

The Technical Standard NTM 001-2010 defines the minimum seismic design loads and special requirements for the design to the anchorage of nonstructural components to the seismic-resistant structure. Also, it specifies special design requirements to the architectural components and their supports and joints, mechanical and electrical components, ceilings, interior partitions walls, glasses in curtain walls, among others.

In Addition, in its Addendum, it provides guidelines to estimate the seismic demand using time history analysis.

CONCLUSIONS

There are many aspects to be learned from this event, not only by Chile, but by the international earthquake engineering community as well.

In general, structures designed with good engineering practices presented a well seismic performance. There were few exceptions that presented a poor performance. In these cases, the characterization of soils, stiffness change in height, and poor confinement in shear wall boundary elements were the main cause of the severe damage on buildings.

The earthquake made apparent that some of the requirements of codes and regulations pre-earthquake were not adequate to assure an appropriate seismic behavior, and therefore, some changes in the codes were introduced to these codes.

These changes addressed the main observed damage to the buildings during the earthquake, however, there are still some aspects to be studied and discussed, such as the definition of response reduction factors, which in the current Chilean regulations are defined based on building materials, leaving aside aspects like horizontal and vertical building irregularities.

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The material contribution from professors and students of the Engineering School of the Pontificia Universidad Católica de Chile, specially Prof. E. Cruz, Prof. J.L. Almazán, Prof. C. Ledezma, Prof. H. Santa María, Prof. G. Thenoux, and other professors of the Structural and Geotechnical Engineering Department, and from the Japanese Building Research Institute (BRI), in allowing the authors to participate in the UNESCO-IPRED initiative is gratefully acknowledged.

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LESSONS LEARNT FROM THE RECENT OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE IN JAPAN

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ABSTRACT

The Great East Japan Earthquake, the magnitude (Mw) 9.0 undersea mega thrust earthquake off the coast of NE Japan, occurred at 14:46 JST (5:46 UTC), 11th March 2011. This magnitude ranked fourth among the earthquakes in the world since 1900. The earthquake caused extremely destructive tsunami waves. In addition to loss of lives and destruction of buildings, the tsunami induced nuclear serious accidents in Fukushima Daiichi Nuclear Power Plant, where the response activity is still in process. Deaths and missing by the earthquake and tsunami are15,547 and 5,344, respectively, and total and partial collapses of buildings are 107,758 and 116,817, respectively, as of July 10, 2011.

The Building Research Institute (BRI) and the National Institute for Land and Infrastructure Management (NILIM), the Ministry of Land, Infrastructure, Transport and Tourism, are carrying out following research activities and field surveys to understand mechanisms of damages and to learn lessons from the Tohoku earthquake:

1. Strong motion observations
2. Research activities (relocation of earthquakes, duration magnitude, tsunami simulation)
3. Field Surveys of damage to buildings
    1) Damage to buildings caused by seismic motion
    2) Damage to buildings caused by tsunami
    3) Damage to buildings caused by fire

The BRI and NILIM dispatched more than100 experts to the survey areas.
Damages to buildings caused by seismic motion are as follows:

1. It was observed that damage to buildings is not so severe whereas the seismic intensities were high and the disaster areas were extended to extremely large.
2. *Timber Structure*：Typical seismic damage was observed.
3. *RC Structure*：Significant difference appears between before and after the new seismic design codes (1981). Typical seismic damage was observed.
4. *Steel Structure*：Damage to vertical / horizontal braces and joints was observed.
5. *Non-structural Elements*：The fall of exterior walls, the fall of suspended ceilings in large-scale spaces, and the fall of interior materials were observed.
6. Damage occurred in some grounds of residential area development or sloping area.
7. The severe liquefaction damage occurred in wide areas, especially Tokyo Bay area.

Damage to buildings caused by Tsunami:

1. BRI and NILIM have jointly carried out damage surveys several times to understand the general status of damage to buildings.
2. Data related to water depth and dimension in damaged buildings were also extensively collected. They are supposed to be much informative for the estimation of the effect of tsunami loads and also for the verification of the current design guidelines.

We have started collaborative research with private companies in the development and promotion project of building standards for technical supporting to the Ministry of Land, Infrastructure, Transport and Tourism. Subjects are as follows: 1) Consideration of contributing to the development of building standards in the tsunami hazard areas. 2) Consideration of contributing to the development of Non-structural elements standard based on earthquake damage. 3) Consideration of the effect of long-period seismic motion on super high-rise buildings.

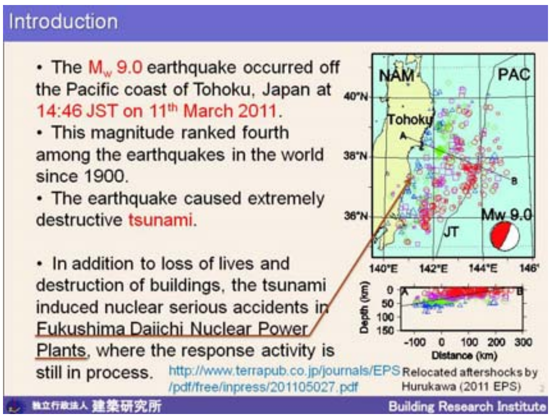
KEYWORDS

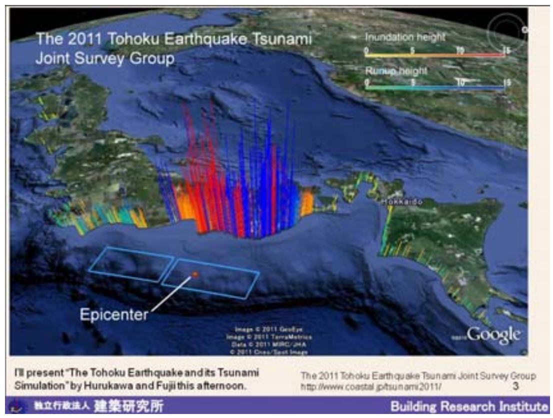
2011 off the Pacific coast of Tohoku earthquake, Great East Japan Earthquake, Tsunami. Strong motion, Building, Damage

INTRODUCTION

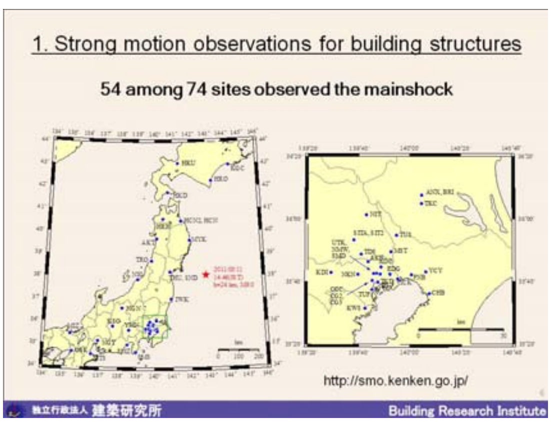
National Institute for Land and Infrastructure Management (NILIM) and Building Research Institute (BRI) have jointly carried out damage surveys to understand the general status of damage to buildings caused by seismic motion, tsunami, and fire. The quick report of the field survey and research on "The 2011 off the Pacific coast of Tohoku Earthquake" (the Great East Japan Earthquake) was already published in Japanese (NILIM and BRI, 2011a). Its English summary was also available on BRI's website (NILIM and BRI, 2011b). This report is a brief summary of the above research works.

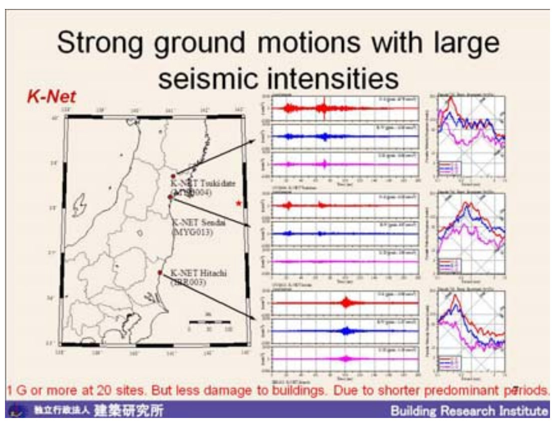
Furthermore research activities on relocation of earthquakes, duration magnitude, and tsunami simulation were done by staff members of BRI (Hurukawa, 2011; Hara, 2011; Fujii *et al*., 2011).

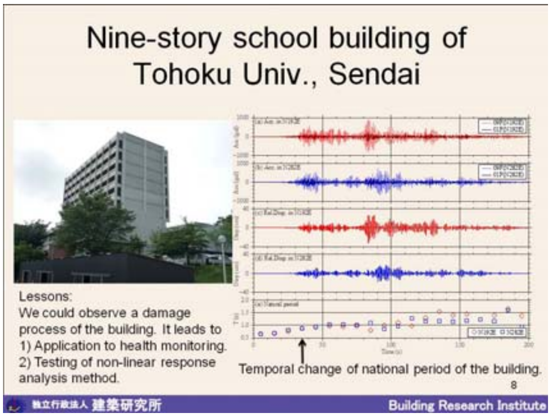


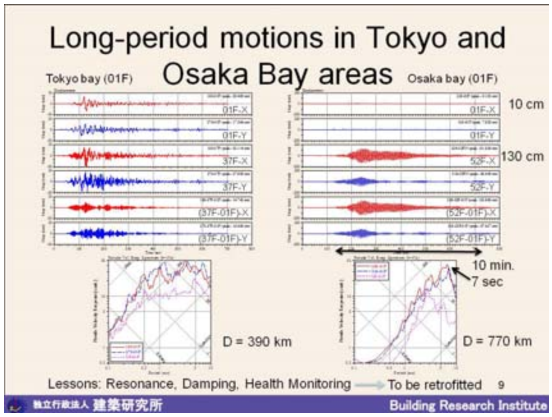


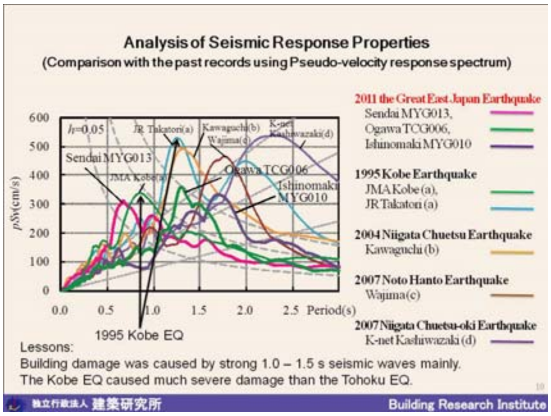
1. **Strong motion observations for building structures**



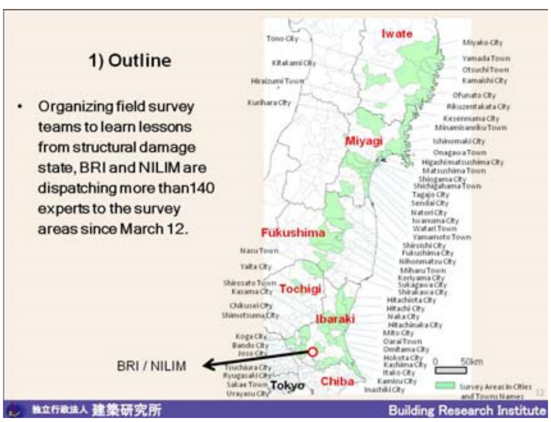








2. **Field surveys of damage to buildings**
   1) Outline
   2) Damage to buildings caused by Seismic motion
      - Timber Structure
      - Reinforced Concrete Structure
      - Steel Structure, Non-Structural Elements
      - Housing-Site Ground, Foundations
   3) Damage to buildings caused by Tsunami
   4) Damage to buildings caused by Fire

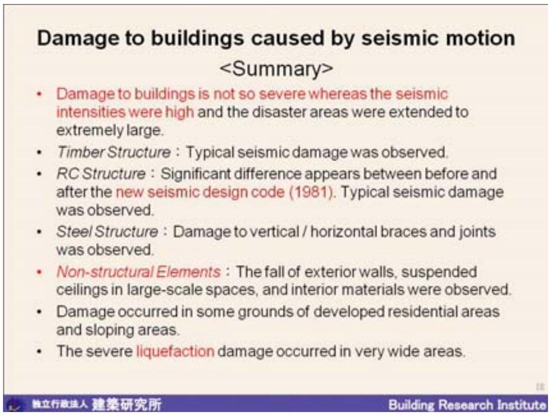


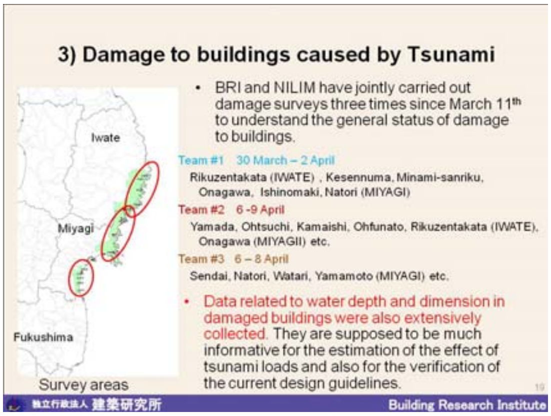

• Damage to RC Structure
• Cracks in columns and exterior walls
• Shear failure of non-structural wall next to entrance
Building Research Institute


• Damage to RC Structure
• 1st story of 3 storied RC building was collapsed. Front side is frame structure and back side is frame with wall structure.
• Shear failure in columns on 1st story of 4 storied RC building which shows 180 degree hooks of main bars.
Building Research Institute

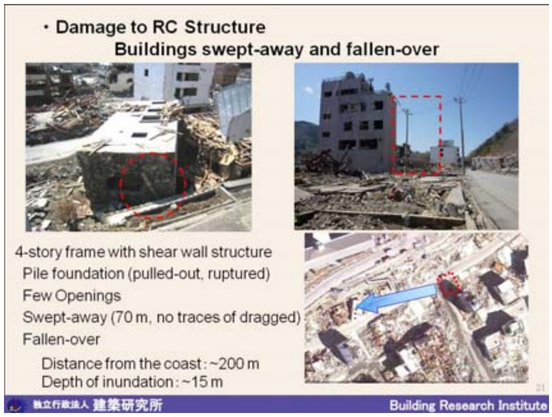

• Damage to Steel Structure and Non-Structural Elements
Building Research Institute

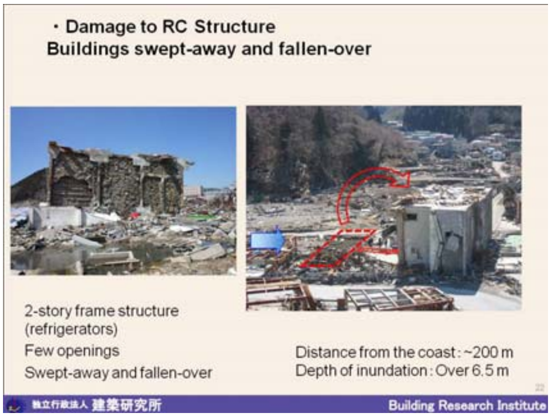

• Damage to Housing-Site Ground and Foundations
Building Research Institute

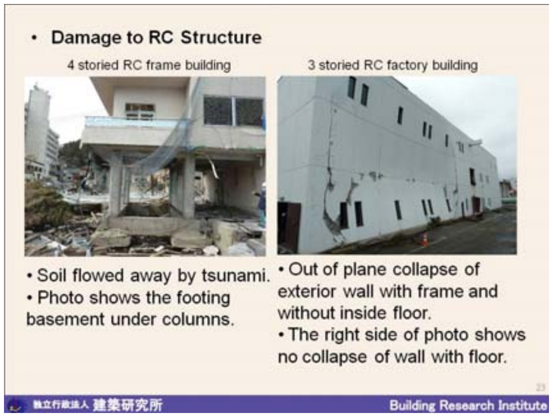

Damage to buildings caused by seismic motion
<Summary>
• Damage to buildings is not so severe whereas the seismic intensities were high and the disaster areas were extended to extremely large.
• Timber Structure : Typical seismic damage was observed.
• RC Structure : Significant difference appears between before and after the new seismic design code (1981). Typical seismic damage was observed.
• Steel Structure : Damage to vertical / horizontal braces and joints was observed.
• Non-structural Elements : The fall of exterior walls, suspended ceilings in large-scale spaces, and interior materials were observed.
• Damage occurred in some grounds of developed residential areas and sloping areas.
• The severe liquefaction damage occurred in very wide areas.
Building Research Institute


3) Damage to buildings caused by Tsunami
• BRI and NILIM have jointly carried out damage surveys three times since March 11th to understand the general status of damage to buildings.
Iwate
Miyagi
Fukushima
Survey areas
Team #1 30 March – 2 April
Rikuzentakata (IWATE) , Kesennuma, Minami-sanriku, Onagawa, Ishinomaki, Natori (MIYAGI)
Team #2 6 -9 April
Yamada, Ohtsuchi, Kamaishi, Ohfunato, Rikuzentakata (IWATE), Onagawa (MIYAGII) etc.
Team #3 6 – 8 April
Sendai, Natori, Watari, Yamamoto (MIYAGI) etc.
• Data related to water depth and dimension in damaged buildings were also extensively collected. They are supposed to be much informative for the estimation of the effect of tsunami loads and also for the verification of the current design guidelines.
Building Research Institute


• Damage to RC Structure
• Collapse of 1st story of 2 storied RC frame building with concrete brick wall. The 2nd story was supported by 4 RC columns.
• Falling over of 4 storied RC frame building with shear wall. This building was flowed 70 meters.
•Photo shows the undersurface and a façade.
独立行政法人 建築研究所
Building Research Institute

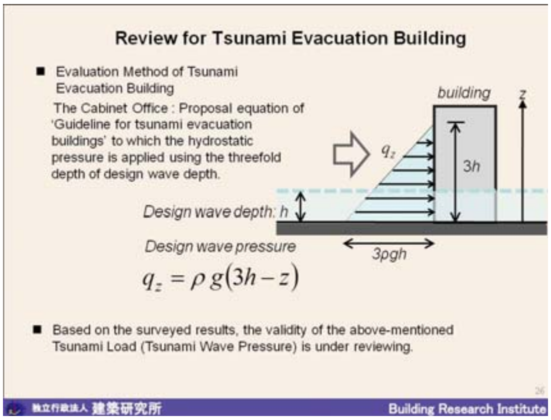

・Damage to RC Structure
Buildings swept-away and fallen-over
4-story frame with shear wall structure
Pile foundation (pulled-out, ruptured)
Few Openings
Swept-away (70 m, no traces of dragged)
Fallen-over
Distance from the coast : ~200 m
Depth of inundation : ~15 m
独立行政法人 建築研究所
Building Research Institute


・Damage to RC Structure
Buildings swept-away and fallen-over
2-story frame structure
(refrigerators)
Few openings
Swept-away and fallen-over
Distance from the coast : ~200 m
Depth of inundation : Over 6.5 m
独立行政法人 建築研究所
Building Research Institute


• Damage to RC Structure
4 storied RC frame building
3 storied RC factory building
• Soil flowed away by tsunami.
• Photo shows the footing basement under columns.
• Out of plane collapse of exterior wall with frame and without inside floor.
• The right side of photo shows no collapse of wall with floor.
独立行政法人 建築研究所
Building Research Institute


• Damage to Steel Structure
独立行政法人 建築研究所
Building Research Institute

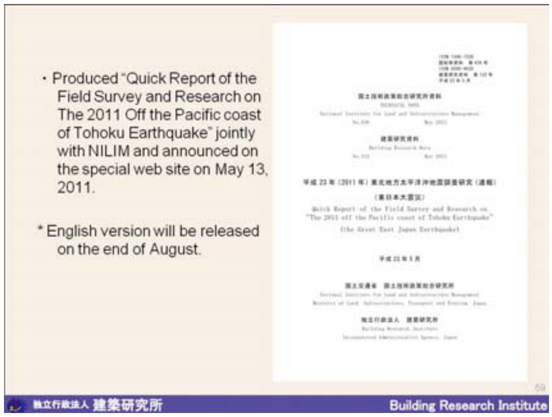

• Damage to Timber Structure
独立行政法人 建築研究所
Building Research Institute



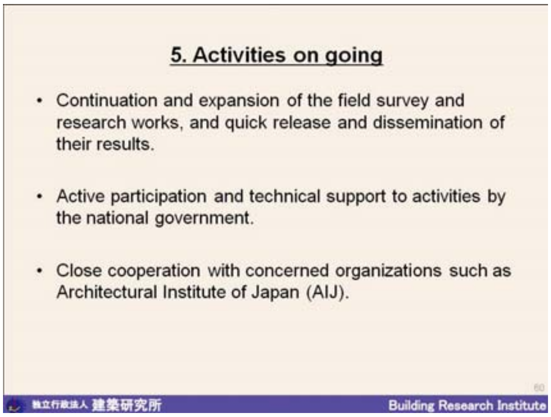
Damage to break water

3. Technical support to the Ministry of Land, Infrastructure, Transport and Tourism

4. **Information uploads**



5. **Activities on going**



ACKNOWLEDGEMENTS

Many research activities and field survey were carried out jointly by National Institute for Land and Infrastructure Management (NILIM) and Building Research Institute (BRI). I appreciate staff members of NILIM and BRI who carried out these research activities and field survey.

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TOWARDS RECONSTRUCTION FROM THE GREAT EAST JAPAN EARTHQUAKE 2011

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ABSTRACT

Immediately after the occurrence of the Great East Japan Earthquake on 11 March 2011, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan has made tremendous efforts towards recovery and reconstruction. In the field of buildings and housing, the MLIT has carried out post-earthquake quick inspections of damaged buildings for the purpose of protecting people from secondary disasters. The MLIT also requested to housing industry to provide more than 50,000 units of temporary housing. Measures related to building codes have been considered, including establishment of tsunami evacuation buildings, establishment of building codes for non-structural elements such as ceilings, consideration of the effect of long-period seismic motions, etc. These efforts are still under way.

KEYWORDS

MLIT, earthquake, tsunami, temporary housing, building codes

MLIT RECOVERY AND RECONSTRUCTION MEASURES FOLLOWING THE GREAT EAST JAPAN EARTHQUAKE 2011

Immediately after the occurrence of the Great East Japan Earthquake on 11 March 2011, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan has made tremendous efforts towards recovery and reconstruction.

I would like to introduce measures taken by the MLIT for recovery and reconstruction from the Great East Japan Earthquake. Damage caused by earthquake and tsunami varied by types of regions (Figure 1 and Figure 2). Some municipalities like Rikuzentakata city were completely devastated by tsunami, whereas some municipalities at high elevations like Kesennuma city were unaffected. Municipalities like Natori city suffered from damage mainly incurred in farmland, costal area and rural villages. Some inland areas suffered from damage to structures atop man-made or augmented embankments.

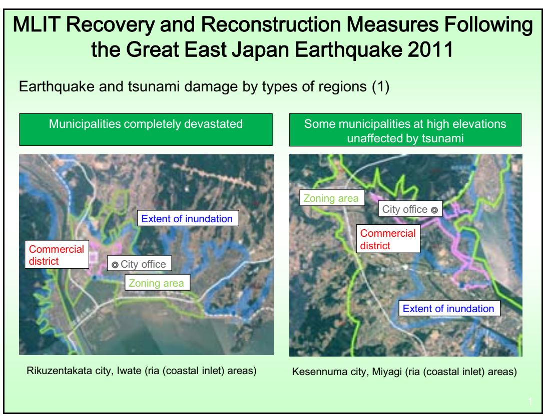


Figure 1. Earthquake and tsunami damage by types of regions (Rikuzentakata and Kesennuma)

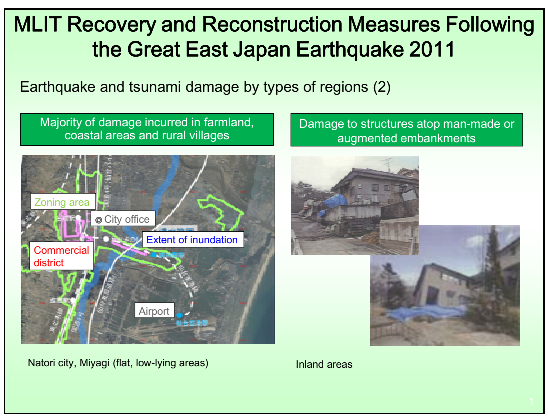


Figure 2. Earthquake and tsunami damage by types of regions (Natori, etc.)

In general, the Government of Japan's measures to be taken immediately after major natural disasters are 1) collecting information on the extent of damages, 2) providing information to the public, 3) rescuing and firefighting, 4) opening up routes for emergency transportation, 5) delivering relief supplies, and 6) taking emergency measures in cooperation with local governments (Figure 3).

Among the roles of the MLIT are:

- Collecting information on the status of infrastructure and transportation
- Securing emergency transportation
- Collecting information on damage of buildings and housing
- Prevention of second disasters
- Securing housing

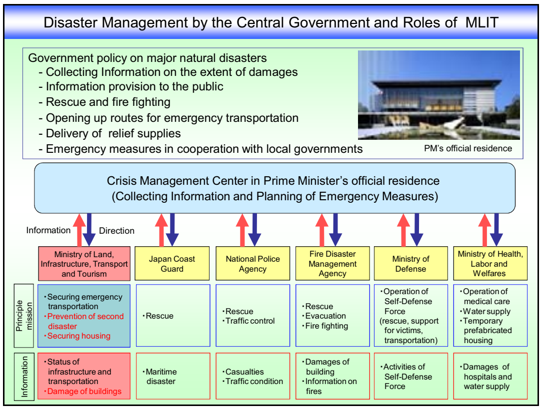


Figure 3. Disaster management by the central government and roles of MLIT

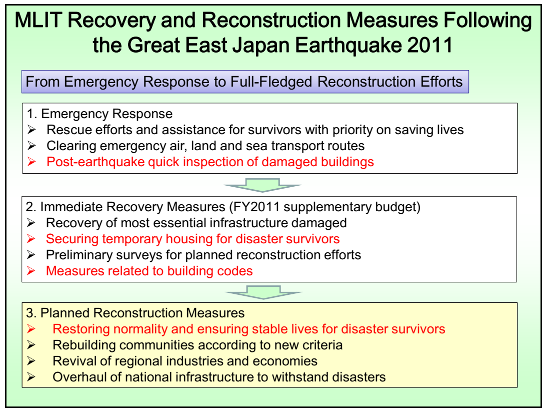


Figure 4. MLIT recovery and reconstruction measures following the 2011 earthquake

Immediately after the 2011 earthquake, the MLIT took such emergency responses as rescue efforts and assistance for survivors with priority on saving lives, clearing emergency air, land and sea transport routes, and post-earthquake quick inspection of damaged buildings (Figure 4).

Then, immediate recovery measures were taken by FY2011 supplementary budget, including recovery of most essential infrastructure damaged, securing temporary housing for disaster survivors, preliminary surveys for planned reconstruction efforts, and measures related to building codes.

In the long run, planned reconstruction measures will be taken for the purpose of restoring normality and ensuring stable lives for disaster survivors, rebuilding communities according to new criteria, revival of regional industries and economies, and overhaul of national infrastructure to withstand disasters.

In the field of buildings and housing, the MLIT has carried out post-earthquake quick inspections of damaged buildings for the purpose of protecting people from secondary disasters due to aftershocks or damage from the first strike, by posting colored stickers on those buildings (Figure 5). After the Great East Japan Earthquake, 95,381 buildings were inspected by 8,541 inspectors, of which 11,699 buildings were judged unsafe (Figure 6).

After the emergency response phase, various measures were required to restore social activities and life to normal conditions, and to rehabilitate damaged buildings and destroyed urban areas. In the field of buildings and housing, the following activities were required in this phase (Figure 7).

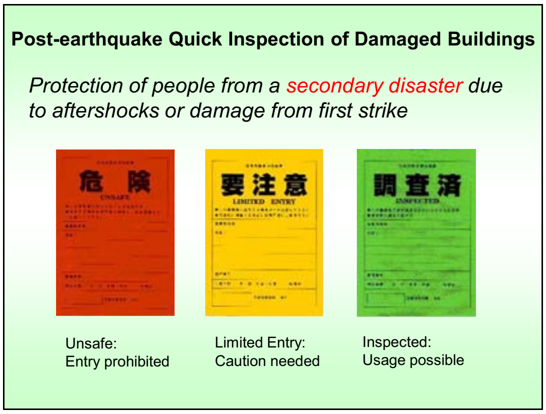
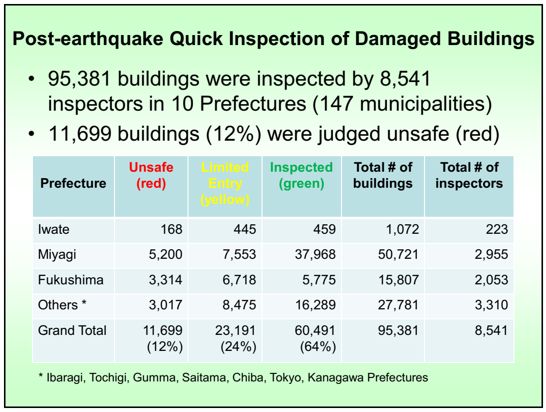


Figure 5. Post-earthquake quick inspection of Damaged buildings



Prefecture	Unsafe (red)	Limited Entry (yellow)	Inspected (green)	Total # of buildings	Total # of inspectors
Iwate	168	445	459	1,072	223
Miyagi	5,200	7,553	37,968	50,721	2,955
Fukushima	3,314	6,718	5,775	15,807	2,053
Others *	3,017	8,475	16,289	27,781	3,310
Grand Total	11,699 (12%)	23,191 (24%)	60,491 (64%)	95,381	8,541

Figure 6. Result of the quick inspection after the 2011 earthquake

- ➢ Enable refugees to leave emergency shelters and move to safe accommodations (Supply temporary prefabricated housing; accommodate refugees in vacant public housing units, etc.)
- ➢ Remove collapsed buildings which obstruct other activities
- ➢ Temporary repair of lightly damaged housing
- ➢ Restriction on new building construction within designated areas (Article 84 of the Building Standard Law (BSL) of Japan)

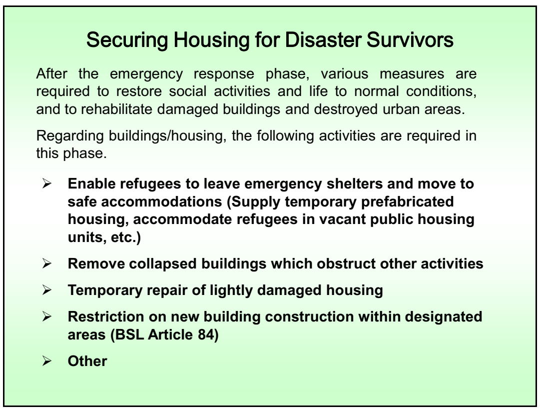
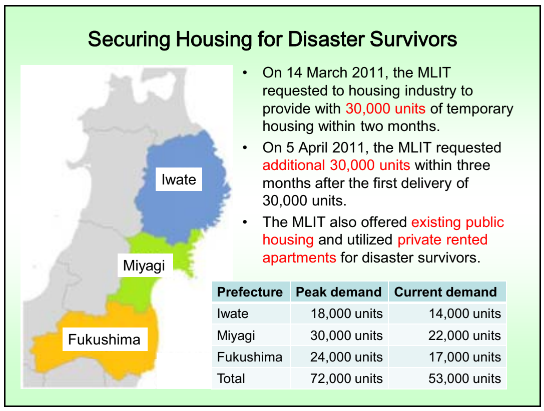


Figure 7. Securing housing for disaster survivors



Prefecture	Peak demand	Current demand
Iwate	18,000 units	14,000 units
Miyagi	30,000 units	22,000 units
Fukushima	24,000 units	17,000 units
Total	72,000 units	53,000 units

Figure 8. Situation after the 2011 earthquake

CONSTRUCTION OF TEMPORARY HOUSING

On the occasion of the Great East Japan Earthquake, on 14 March 2011, the MLIT requested to housing industry to provide with 30,000 units of temporary housing within two months. On 5 April 2011, the MLIT requested additional 30,000 units within three months after the first delivery of 30,000 units. The Ministry also offered existing public housing and utilized private rented apartments for disaster survivors. The peak demand from three affected prefectures was 72,000 units. However, the demand dropped down to some 53,000 units, which caused problems in the housing industry as they had been already preparing the requested 60,000 units. This decrease of demand also limited the necessity of temporary housing imported from overseas (Figure 8).

At first, temporary housing was scheduled to be completed before mid-August 2011, but it was delayed due to the lack of suitable construction sites. However, as of 11 March 2012, one year after the earthquake and tsunami, 99 % of demanded number of units has been completed, and the rest are being or about to be constructed (Figure 9). Figure 10 shows some photos of the temporary housing in Kesennuma city taken in June 2011.

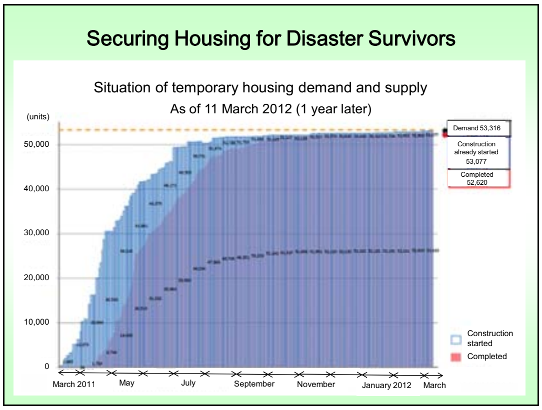


Figure 9. Situation of temporary housing demand and supply (1 year later)

Figure 10. Temporary housing in Kesennuma city, Miyagi (2011 ©T. Imamura)

Figure 11. Temporary housing in Ootama Village, Fukushima (2011 ©T. Imamura)

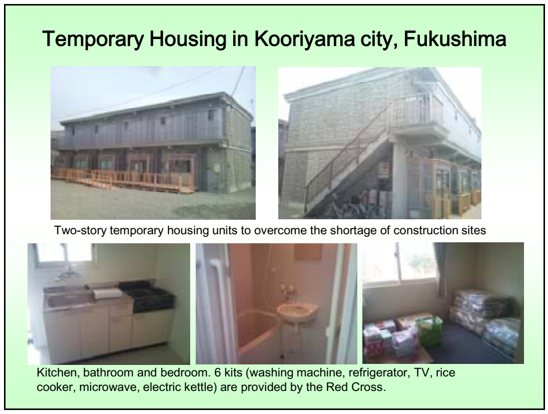


Figure 12. Temporary housing in Kooriyama city, Fukushima (2011 ©T. Imamura)

Figure 13. Other examples of temporary housing (2011 ©T. Imamura)

Figure 14. Temporary housing imported from overseas (2011 ©T. Imamura)

Figure 11 through Figure 14 show some photos of the temporary housing in disaster-affected area which were taken by the author in June 2011.

MEASURES RELATED TO BUILDING CODES

The report titled "Summary of the Field Survey and Research on the 2011 off the Pacific coast of Tohoku Earthquake" (the Great East Japan Earthquake) was finalized in September 2011. Post-earthquake field investigation and technical study carried out by the MLIT National Institute for Land and Infrastructure Management (NILIM) summarized the building damage as follows (Figure 15):

- Structural damage to buildings was not so significant as a whole even in the areas where strong seismic intensity was recorded.
- The current seismic design in the Building Standard Law (BSL) of Japan is generally appropriate for the seismic-related damage mitigation.
- Most of RC buildings that suffered from seismic damage were designed before 1981 with the old seismic design method.
- Damages to ceilings in steel gymnasiums, etc. were observed.
- The earthquake caused liquefaction of soil more extensively than the recent earthquake.
- Typical types of tsunami-induced damage to buildings such as turn-over and swept-away of entire structures were observed.

Based on the above findings, measures related to building codes were considered (Figure 16). Such measures included 1) restriction on building construction work, 2) establishment of tsunami evacuation buildings, 3) establishment of building codes for non-structural elements such as ceilings, 4) consideration of the effect of long-period seismic motions, and 5) subsidy for existing elevator safety, etc.

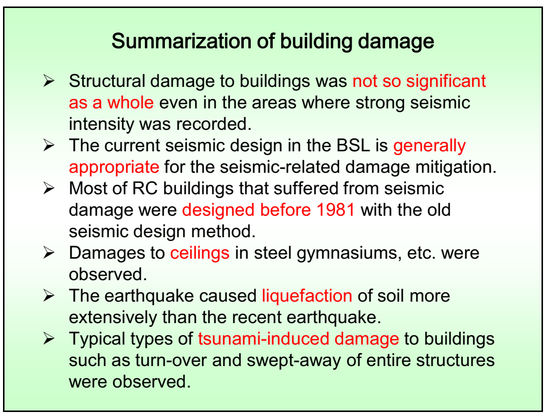


Figure 15. Summarization of building damage

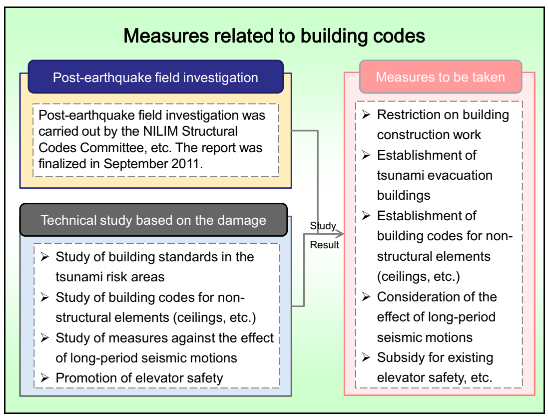


Figure 16. Measures related to building codes

With regard to the restriction on building construction work, on 8 April 2011, in order to secure well-planned reconstruction process, Miyagi Prefecture designated some disaster-affected areas in which the construction of buildings was not allowed for two months after the disaster (Article 84 of the BSL). Then, the MLIT proposed a new Law so that the restriction on building construction could be extended up to eight months, which passed the Diet and was enacted (Figure 17).

Building restriction in disaster-affected areas

- On 8 April 2011, in order to secure well-planned reconstruction process, Miyagi Prefecture designated some disaster-affected areas in which the construction of buildings was not allowed for two months after the disaster (Article 84 of the BSL).
- The MLIT proposed a new Law so that the restriction on building construction could be extended up to eight months, which passed the Diet and was enacted.

Figure 17. Building restriction in disaster-affected areas

Establishment of tsunami evacuation buildings

- Consideration of the tsunami effect on buildings is not stipulated in the Japanese building codes.
- Cabinet office released an official guideline on the structural design of buildings for vertical evacuation from tsunamis in 2005.
- The guideline provides a simplified method to calculate wave pressure affecting buildings by using design water depth.
- The guideline was reviewed reflecting the NILIM/BRI field damage survey.

Figure 18. Establishment of tsunami evacuation buildings

ESTABLISHMENT OF TSUNAMI EVACUATION BUILDINGS

As for the establishment of tsunami evacuation buildings, consideration of the tsunami effect on buildings is not stipulated in the current Japanese building codes; the Cabinet office of Japan has released an official guideline on the structural design of buildings for vertical evacuation from tsunamis in 2005. This guideline provided a simplified method to calculate wave pressure affecting buildings by using design water depth. After the 2011 earthquake, the guideline was reviewed by reflecting the NILIM/BRI field damage survey (Figure 18).

Figure 19 through Figure 24 show some photos of damaged buildings in tsunami-affected area which were taken by the author in June 2011. The third floor of 4-storied RC construction apartments was completely flooded by the tsunami. There remained some 3-storied steel construction buildings, but only the framework. No wooden construction buildings survived, except for their RC foundation.

In Minamisanrku town, Miyagi, the 3-storied steel construction Disaster Management Center also remained only with its framework. At the right next to this building, there was a sign “2.4m tsunami occurred due to Chilean earthquake on 24 May 1960,” which was completely destructed.

Although most of wooden houses were washed away, some remained standing. Wooden houses attacked by tsunami waves of less than 2m did not suffer much. Only 15% of those attacked by tsunami waves of 2-4m was heavily damaged. Most of those attacked by tsunami waves of more than 4m were totally destroyed or washed away.

Tsunami-induced damage in Oofunato city, Iwate

Figure 19. Tsunami-induced damage in Oofunato city, Iwate (2011 ©T. Imamura)

Tsunami-induced damage in Rikuzentakata city, Iwate

Figure 20. Tsunami-induced damage in Rikuzentakata city, Iwate (2011 ©T. Imamura)

Figure 21. Tsunami-induced damage in Kesennuma city, Miyagi (2011 ©T. Imamura)

Figure 22. Tsunami-induced damage in Minamisanriku town, Miyagi (2011 ©T. Imamura)

Figure 23. Tsunami-induced damage in Onagawa town, Miyagi (2011 ©T. Imamura)

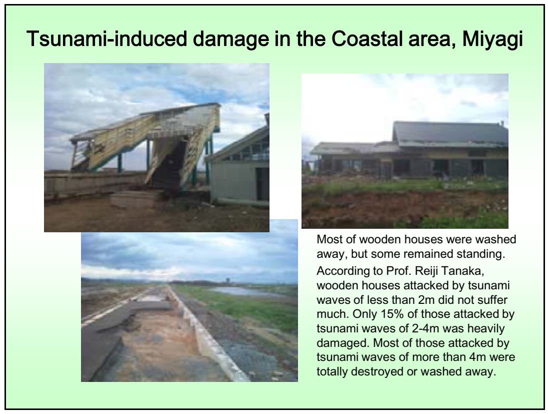


Figure 24. Tsunami-induced damage in the coastal area, Miyagi (2011 ©T. Imamura)

As of March 2010, one year earlier than the 2011 earthquake, 1,790 tsunami evacuation buildings had been designated, but only 21% of municipalities in the coastal area had designated them. Structural requirements in the guideline included the conformity with the current seismic code 1981, and that the buildings should be RC or SRC construction with the necessary stories according to the expected water depth. Additional consideration was to be taken such as easy access to and unlocking of the buildings, emergency power source, emergency warehouse, and to utilize the buildings as local gathering place ordinarily (Figure 25). Figure 26 through Figure 30 show some concepts stipulated in the guideline of tsunami evacuation buildings.

After the 2011 earthquake, some survey findings of tsunami-induced damage to RC buildings include the following (Figure 31):

- Collapse of the first floor (observed for buildings with one or two stories)
- Turn-over (observed for buildings with four stories or less, some connected with piles)
- Tilt by scouring (corner of buildings excavated by water stream)
- Out-of-plane destruction of exterior walls (smaller openings for exiting water)
- Collision of driftage (non-structural members damaged by driftwood, etc.)

Establishment of tsunami evacuation buildings

- Currently 1,790 tsunami evacuation buildings are designated, but only 21% of municipalities in the coastal area have designated them. (As of March 2010)
- Structural requirements in the guideline:
  - ✓ Conformity with the current seismic code 1981
  - ✓ RC or SRC construction with the following stories:

Water depth	Estimated # of stories
1m or less	2 stories or more
1-2 m	3 stories or more
2-3 m	4 stories or more

- Other consideration:
  - ✓ Easy access and unlocking
  - ✓ Emergency power source, emergency warehouse
  - ✓ Utilization as local gathering place ordinarily

Figure 25. Structural requirement in the tsunami guideline

Establishment of tsunami evacuation buildings

- L1 = P1 * (T-t1-t2)
  - L1: Distance possible for evacuation (m)
  - P1: Walking speed (m/s)
  - T: Time before tsunami arrival (s)
  - t1: Time before evacuation starts after earthquake (s)
  - t2: Time necessary to climb up to safer places (s) (=Maximum water depth H (m) / climbing speed P2 (m/s)

- Distance possible for accommodation L2 (m)
  = sqrt [{# of people accommodated (persons) / population density (persons/m2) } * A / 3.14]
  A : 2 in case the evacuation area is a half circle,
  4 in case the evacuation area is a quarter circle, etc.

Figure 26. Equations concerning tsunami evacuation buildings

Establishment of tsunami evacuation buildings

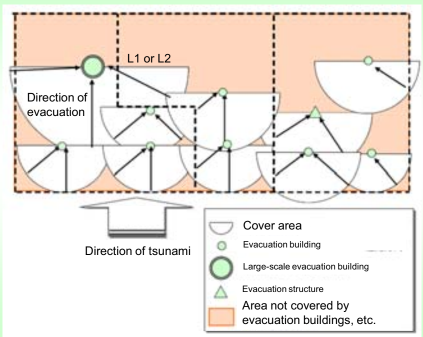


Figure 27. Areas covered by tsunami evacuation Buildings

Establishment of tsunami evacuation buildings (Signs related to tsunami evacuation)

Caution for tsunami:	Tsunami evacuation place:	Tsunami evacuation buildings:
Area possibly attacked by tsunami at the time of earthquakes	Place for evacuation to avoid tsunami	Buildings safe from tsunami

Figure 28. Signs related to tsunami evacuation

Establishment of tsunami evacuation buildings

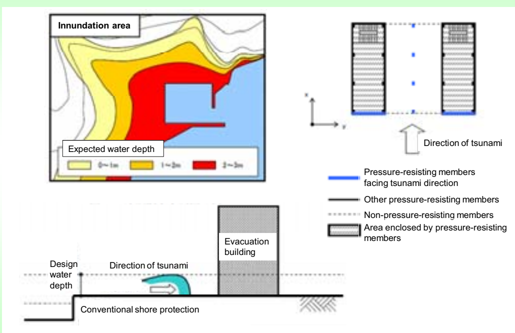


Figure 29. Concept of structural calculation of tsunami evacuation buildings

Establishment of tsunami evacuation buildings (Tsunami pressure equation)

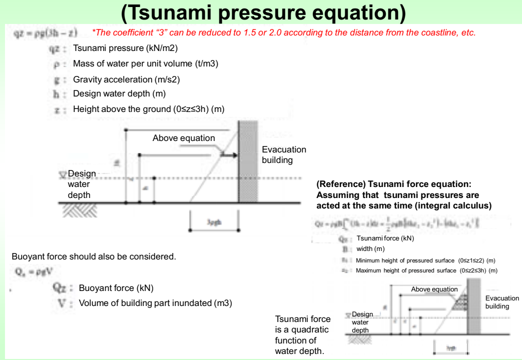


Figure 30. Structural calculation of tsunami evacuation buildings

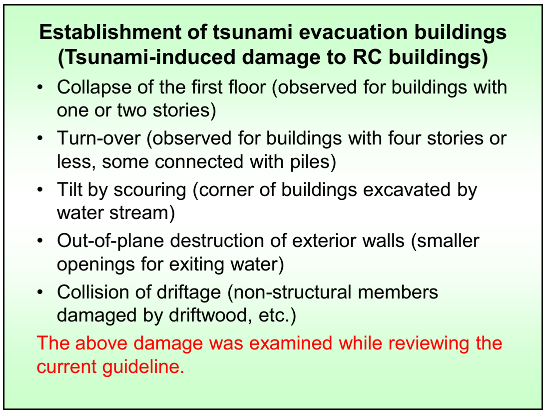


Figure 31. Tsunami-induced damage to RC buildings

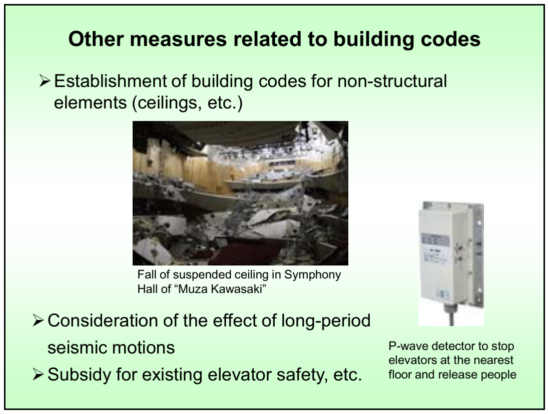


Figure 32. Other measures related to building codes

OTHER MEASURES RELATED TO BUILDING CODES

Other measures related to building codes include the establishment of building codes for non-structural elements such as ceilings, consideration of the effect of long-period seismic motions, and subsidy for existing elevator to install safety devices such as the P-wave detector which stops elevators at the nearest floor and release people (Figure 32).

In addition, some escalators (4 escalators at 3 shopping centers) were found to be fallen down due to the 2011 earthquake. The MLIT is considering the establishment of a new seismic regulation for escalators.

Figure 33. An escalator fallen down at the Sendai-Saiwaicho shopping center (Sendai city)

Figure 34. Escalators stuck together at the Izumi-osawa shopping center (Sendai city)

REFERENCE1: OUTLINE OF THE MLIT RECOVERY AND RECONSTRUCTION MEASURES

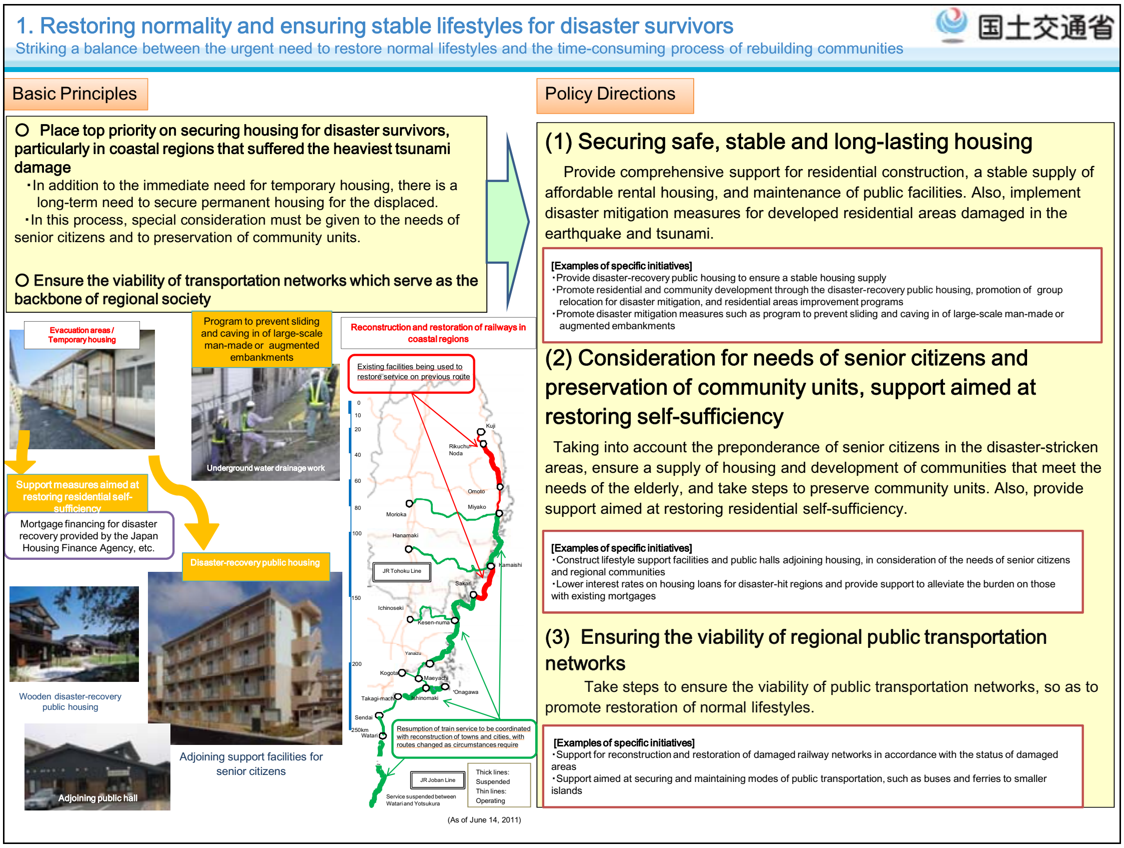


Figure 35. Restoring normality and ensuring stable lifestyles for disaster survivors

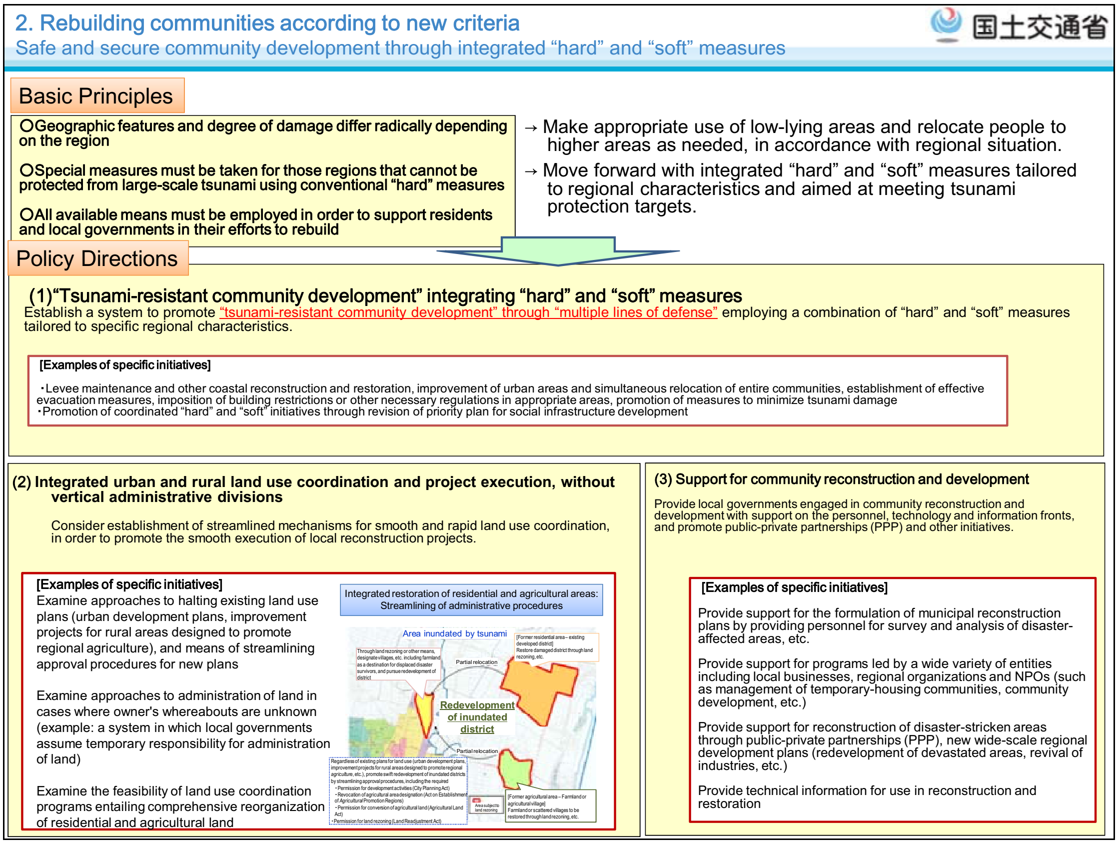


Figure 36. Rebuilding communities according to new criteria

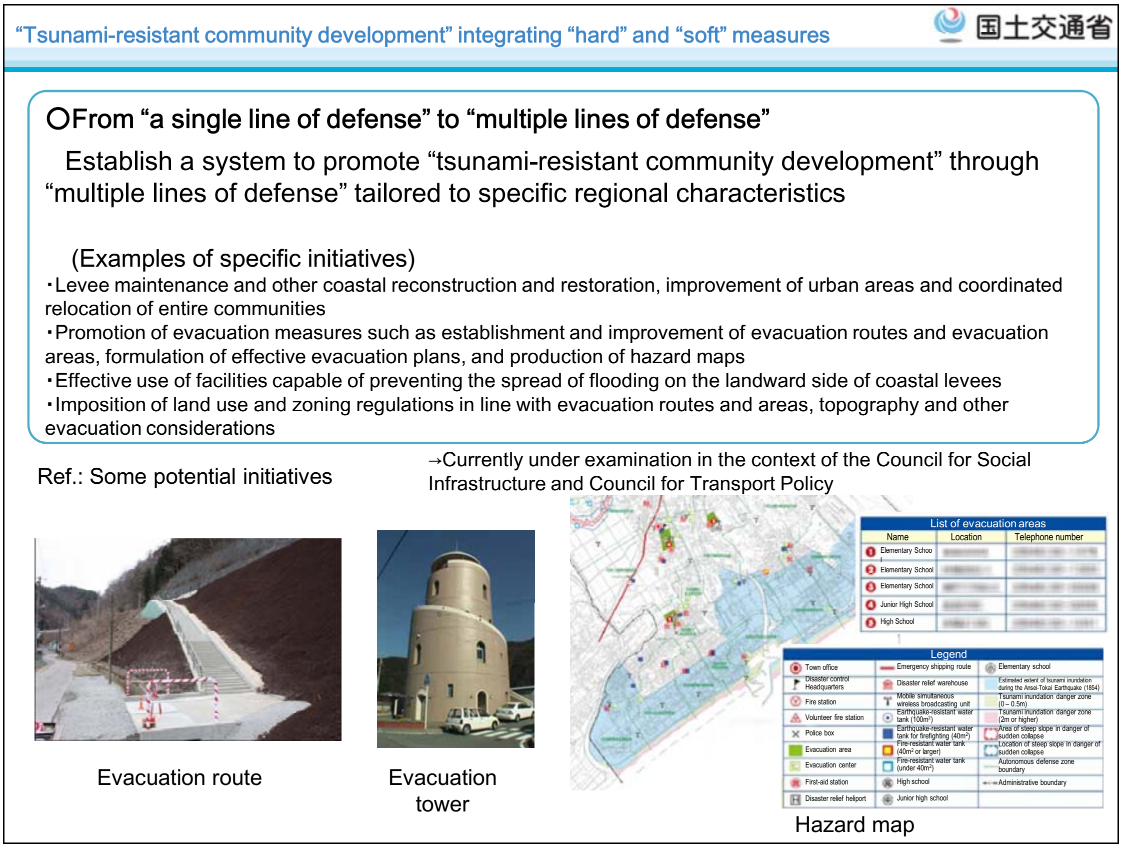


Figure 37. Tsunami-resistant community development integrating "hard" and "soft" measures

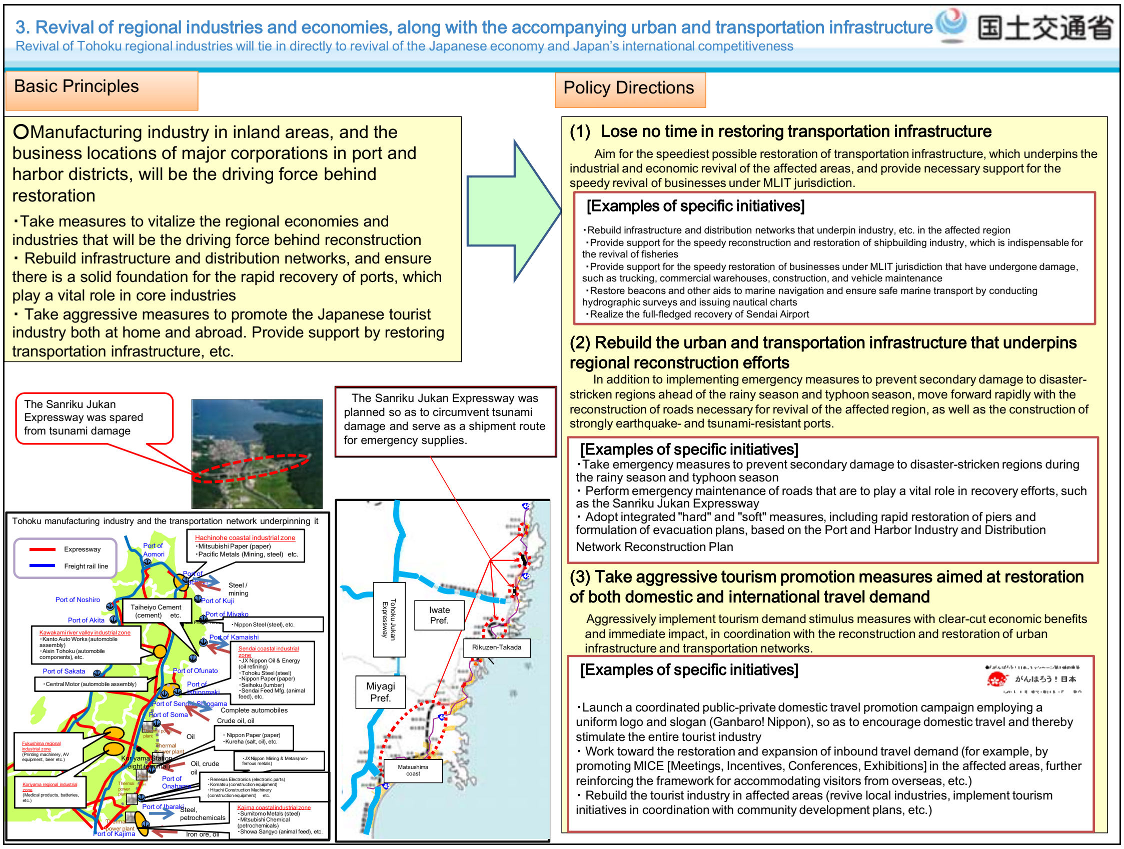


Figure 38. Revival of regional industries and economies, along with the accompanying urban and transportation infrastructure

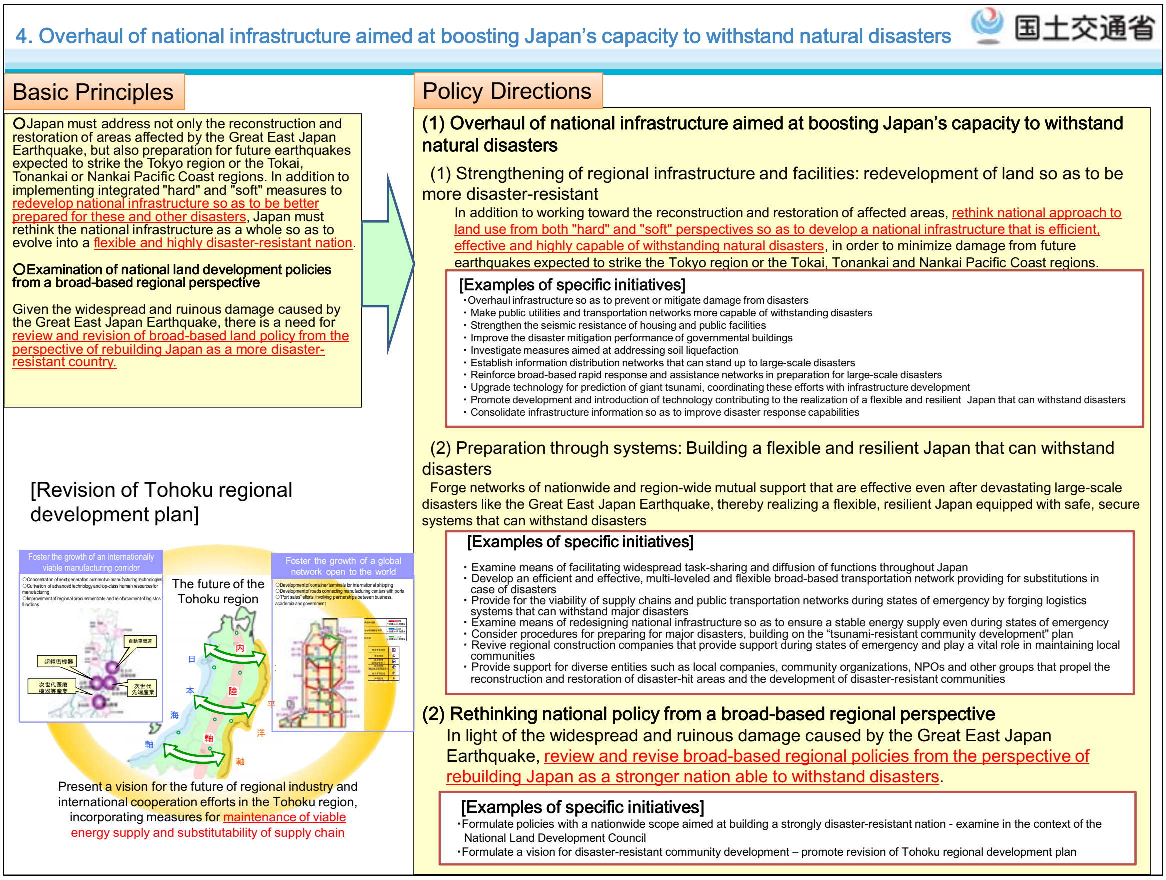


Figure 39. Overhaul of national infrastructure aimed at boosting Japan's capacity to withstand natural disasters

REFERENCE2: REPORT TO THE PRIME MINISTER OF THE RECONSTRUCTION DESIGN COUNCIL (25 JUNE 2011)

Seven principles for the reconstruction framework included in the report to the Prime Minister are as follows:

- **Principle One**: For us, the surviving, there is no other starting point for the path to recovery than to remember and honor the many lives that have been lost. Accordingly, we shall record the disaster for eternity, including through the creation of memorial forests and monuments, and we shall have the disaster scientifically analyzed by a broad range of scholars to draw lessons that will be shared with the world and passed down to posterity.

- **Principle Two**: Given the vastness and diversity of the disaster region, we shall make community-focused reconstruction the foundation of efforts towards recovery. The national government shall support that reconstruction through general guidelines and institutional design.

- **Principle Three**: In order to revive disaster-afflicted Tohoku, we shall pursue forms of recovery and reconstruction that tap into the region's latent strengths and lead to technological innovation. We shall strive to develop this region's socioeconomic potential to lead Japan in the future.

- **Principle Four**: While preserving the strong bonds of local residents, we shall construct disaster resilient safe and secure communities and natural energy-powered region.

- **Principle Five**: Japan's economy cannot be restored unless the disaster areas are rebuilt. The disaster areas cannot be truly rebuilt unless Japan's economy is restored. Recognizing these facts, we shall simultaneously pursue reconstruction of the afflicted areas and revitalization of the nation.

- **Principle Six**: We shall seek an early resolution of the nuclear accidents, and shall devote closer attention to support and recovery efforts for the areas affected by the accidents.

- **Principle Seven**: All of us living now shall view the disaster as affecting our own lives, and shall pursue reconstruction with a spirit of solidarity and mutual understanding that permeates the entire nation.

Figure 40 through Figure 44 show some concepts included in the report to the Prime Minister.

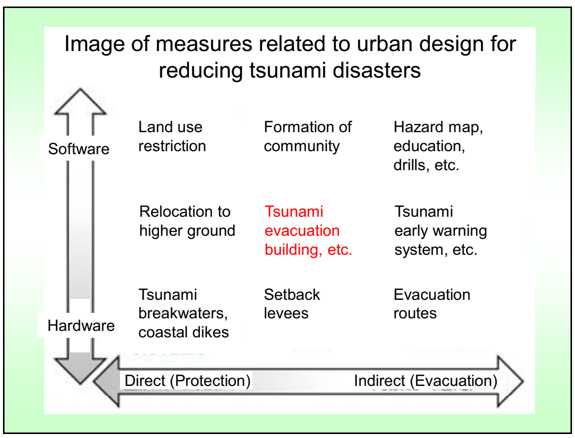


Figure 40. Image of measures related to urban design for reducing tsunami disasters

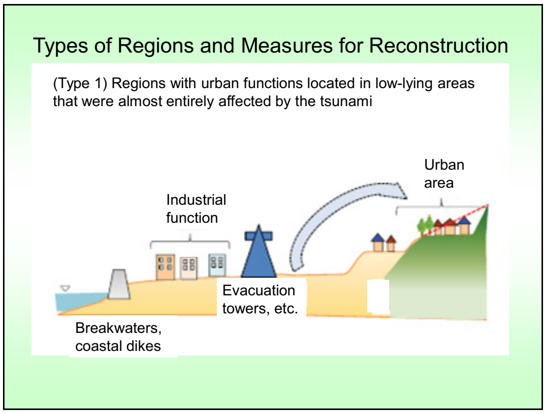


Figure 41. Types of regions and measures for reconstruction (Type 1)

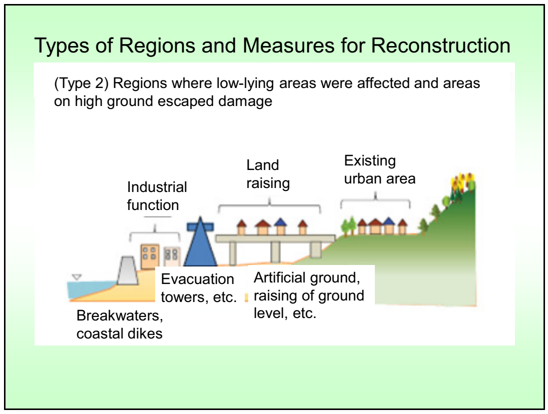


Figure 42. Types of regions and measures for reconstruction (Type 2)

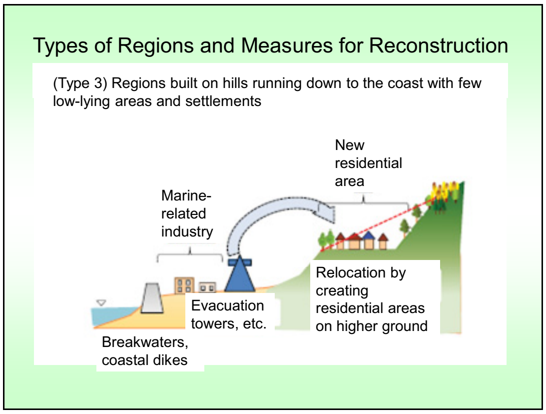


Figure 43. Types of regions and measures for reconstruction (Type 3)

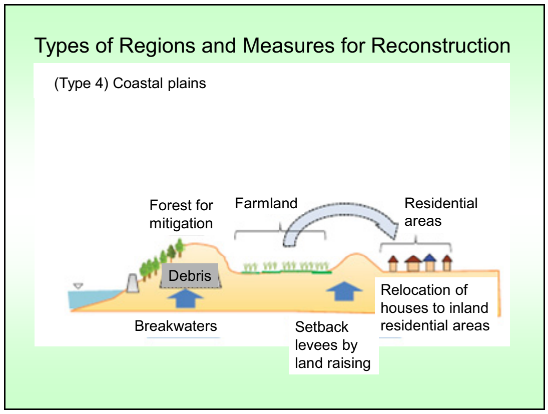


Figure 44. Types of regions and measures for reconstruction (Type 4)

CONCLUSION

So far, after the 2011 earthquake, the MLIT of Japan carried out post-earthquake quick inspections of damaged buildings, provided sufficient temporary housing, considered measures related to building codes including establishment of tsunami evacuation buildings, establishment of building codes for non-structural elements, consideration of the effect of long-period seismic motions, etc. These efforts are still under way.

Now, after one year from the earthquake, we are already in the reconstruction phase. We need to continue efforts for restoring normality and ensuring stable lives for disaster survivors by providing permanent public housing, etc. We need to rebuild communities. We need to revive regional industries and economies. We need to overhaul national infrastructure to withstand disasters.

After the 2011 earthquake, we were given great kindness and support from all over the world, and we shall never forget it. We still have many things to do from now on, but we will never give up!

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the colleagues at the Pontifical Catholic University of Chile for their great efforts in organizing this successful workshop, and I wish to convey my sincere thanks to all the IPRED members for their valuable information.

As a participant from Japan, I would like to thank my Japanese colleagues who traveled together all the way from the other side of the earth. I also would like to thank the Japan International Cooperation Agency (JICA) for their support in Santiago de Chile.

Finally, I would like to extend my heartfelt gratitude to UNESCO colleagues, especially Mr. Badaoui Rouhban, Mr. Yasuo Katsumi, Mr. Jair Torres, Ms. Kristine Tovmasyan, Ms. Aïssatou Gakou and Ms. Brigitte Sartre, for their warmhearted guidance and advice for the IPRED programme.

HOUSING RECONSTRUCTION STATISTIC AND THEIR SOLUTIONS CHILEAN RECONSTRUCTION PLAN

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ABSTRACT

Chile has been able to overcome the February 27th 2010 Earthquake as a united country facing todays the reconstruction process. Within the active leadership of all regional and national authorities, active participation of private sector, strong and vital social organization participation, and an outstanding work of NGOs. In order to repair and rebuild the damage cause by the earthquake and later tsunami, the Chilean Government developed an holistic plan, where the Ministry of Housing and Urban Planning (MINVU) was in charge of the reconstruction for: housing, neighborhood, and damage in territory and cities.

In order to do so, MINVU launched the Reconstruction Plan: “United Reconstructing a better Chile” with a budget of 2.5 billion dollars for the reconstruction of housing and neighborhood, with a total of 220,000 houses to be repair of rebuild. Because of different zones and types of damage, in each case a different solution was applied in order to give and integrate solutions. The damages registered by the register of people affected, which contain information of type, locations and other miscellaneous of homeless families, shows patrons in type of the damage and reveal a large dispersion. This information was used to create specifics strategies for reconstruction. Three special cases are included in this study case.

First, the correlation of social housing buildings made of masonry with the damage levels suggest to the Reconstruction Team to creates a specific strategy those buildings. Second, the difficulties to reconstruct in the central zone because the large number of heritage houses that were destroyed was developed a special subside for heritage damaged buildings. And finally, the challenge to rebuild houses in pre-owned sites with the laws difficulties that can carry old land properties needs a special approach and opportunity to develop middle density project was taken.

KEYWORDS

IPRED, earthquake, tsunami, building codes, housing, public policy, reconstruction plan.

INTRODUCTION

Chile has been able to overcome the February 27th 2010 Earthquake as a united country facing todays the reconstruction process. Within the active leadership of all regional and national authorities, active participation of private sector, strong and vital social organization participation, and an out of standard work of NGOs.

The Earthquake and later tsunami was characterized by the dispersion and different types of damage that they cause. In order to repair and reconstructed this damage the Chilean Government develop a holistic plan. In this plan the Ministry of Housing and Urban Planning (MINVU) is in charge of the reconstruction of: housing, low and middle social economics families whose lost their homes; neighborhood, such as socials housing project and displaced families by the tsunami; and damage in territory and cities, such as zoning plans to include risk, heritage recovery, and the development of plans that guide the reconstruction process.

In order to do so MINVU develop the Reconstruction Plan: “United Reconstructing a better Chile”, and create the Reconstruction Department. This new department is an interdisciplinary professional team responsible of manage the MINVU Reconstruction plan. The principal objective of the Plan are: reconstruct considering existing need of local developments, guarantied decision that respond to a holistic view of reconstruction and developments, base the plan in realistic expectations and providing transparency in the process, and finally, return to normal conditions as soon as possible.

The Plan has three main areas: Housing, Neighborhood, and Territory and Cities. In the context of the Housing area, the government invests 2.5 billion dollars for the reconstruction of housing and neighborhood, with a total of 220,000 houses to be repair of rebuild. Because of the different zones and types of damage, different solutions were applied in order to give and integrated solutions.

DIMENSIONING THE DAMAGE

The damage caused by the January 2010 Earthquake and later Tsunami was one of the largest hazard event in Chilean History and may be the largest since the 1960 Earthquake and tsunami of Valdivia. The affected population was more than 12.8 million people, the 75% of total population of Chile. Furthermore, 500 fatal victims and missing persons and 800,000 peoples were affected, by losing their jobs, house or were injured. In an economic aspect, near to 30 billions of dollars can be estimated lost caused by the earthquake. Particularly for the public sector the lost was 8.5 billion dollars. For example: in education sector, 157 schools were destroyed or with several damages; and in health sector, 1,082 hospitals have middle damage. Concerning to housing damage, 103,543 housed were destroyed and 105,039 homes were several damaged. This damage can be compared with the investment of Chilean government in the last 4 years by their housing policy, resulting in 4 years of back steps.

ESPECIFIC SOLUTIONS FOR SPECIFIC PROBLEMS

The damages registered by the register of people affected, which was used to collect type, locations and other miscellaneous information, shows patron in the type and reveal a large dispersion of the damage in the central southern region of Chile. Three topic concerning to housing reconstruction are highlighted. First, the correlation of social housing buildings made of masonry with the damage levels suggest to the Reconstruction Team to creates a specific strategy those buildings. Second, the difficulties to reconstruct in the central zone because the large number of heritage houses that were destroyed was developed a special subside for heritage damaged buildings. And finally, the challenge to rebuild houses in pre-owned sites with the law difficulties that can carry an old land properties.

Masonry constructions and Social Housing

Masonry buildings are distributed uniformly in the country as well as the damage in buildings constructed with this material. Most of the masonry buildings with 3 or more stories have some level of damage. At the same time 90% of the social housing projects constructed or subcontracted by regional services of housing and urbanism (SERVIU) that presents damages caused by the earthquake are constructed with masonry. Most of them constructed during 1990, where a policy of building large project was applied with a repetitive design.

A total of 26 SERVIU’s projects need to be demolished. In a total of 8,327 houses or apartment, 6,514 were demolished. The same failure was present in 50% of the building and all of them have in common the layout design.

Even though, a fast reconstruction was need, the opportunity of apply new technologies was present and used. In these context, the Paniahue condominium, one of the SERVIU’s old projects destroyed by the earthquake, is been reconstructed using seismic insulations.

Heritage reconstruction

A large number of the damage of wood houses in the VIII region and adobe houses in the VI and VII region are heritage houses. A special strategy was needed to rebuild the same architectural image using contemporary construction material. In order to satisfy this requirement and extra subsidies was applied to this type of building in order to finance the extra cost of design and construction. Some examples of these subsidies are presented in the attachment.

Reconstruction in the pre owner site

The largest damage was presented in one unit type houses. Specially in VI and VII region where 76% of the houses damage were made of adobe. The large number of buildings located in the principal cities of both regions such as: Talca, Curicó, Cauquenes, Linares y Constitución. Instead to build all new houses in the periphery of each city, the effort was focused in reconstruct in the same owned site of the homeless family. In order to do this, a special subsidy was applied to this cases, and a special program for middle density project are been developed in site where a large houses were destroyed. Doing these, homeless families were not forces to go outside the cities where they live, in addition, new families can now live near to the center of the city where are located all the amenities.

Advances

In order to measure the advance of the Reconstruction Plan, the number of subsidies assigned, projects started, projects finished and other miscellaneous information are collected each month. At the time of this report, 158,583 subsidies have been assigned to a homeless family, 102,897 projects have been started, and 50,241 finished. And it has a constant increment in the rate each index. At the same time, a general view is represented by the number of building permits per month. Where, permits of most damaged regions are 5 times more than the national average.

CONCLUSIONS

In general, the January 2010 Earthquake generates a large damage in the central southern zone of Chile. The earthquake and later tsunami affect to 75% of Chilean total population. In order to repair all the damage caused by the earthquake the Chilean government develop a holistic plan where the Ministry of Housing and Urban Planning was in charge of the reconstruction of Housing, Neighborhood, and cities.

Concerning to the housing reconstruction, based in the estimation of the ministry 220,000 houses were destroyed or need to be repair. The Plan “United Reconstructing a better Chile” with a budget of 2.5 billion dollars, was launched in responded of the citizens’ needs. The register of people affected was created with the objective of have a data base with the information of locations, type of material, type of damage, and other miscellanies information. Based in an analysis of the register information three special strategy were developed.

First, social housing projects constructed or subcontracted by SERVIUs that have important damage. A special program was created in order to supervise the demolishing and reconstruction process. In this context should be highlighted the opportunity taken by usage of new technologies such, seismic insulation in the reconstruction of this type of buildings.

Second, even though a large part of the heritage building damaged were constructed using *adobe*, a material which have a low structural share capacity and could not be repair using the same material, the architectural image of the building was saved. By applying a special programme that includes more resources in order to finance the extra cost of design and construction.

Third, a policy of reconstruction in the owned site rather than move all the homeless families to the periphery of the city was applied, even though this approach is more difficult. However a better condition of life for families in the future is achieved.

Finally, the data of starting and finishing of number of solutions shows that the plan is working with a constant rate. With this information may be concluded that the plan “United Reconstructing a better Chile” is working as it was planned.

In a hazard context challenge can be turned as opportunities of solutions, and each case should be studied in detail in order to found improvement or new public policies in building field. In this particular case, the reconstruction of the February 2010 earthquake, more special strategies are been applied, such as auto-construction and material bank, and should be studied.

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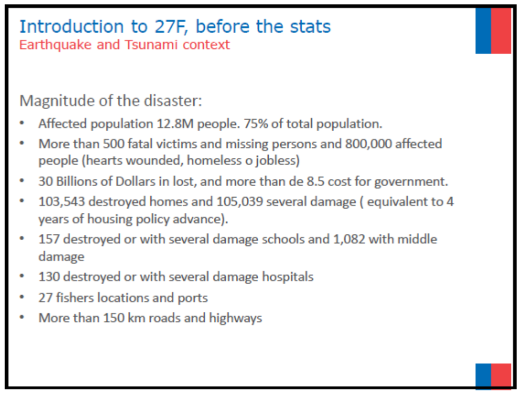
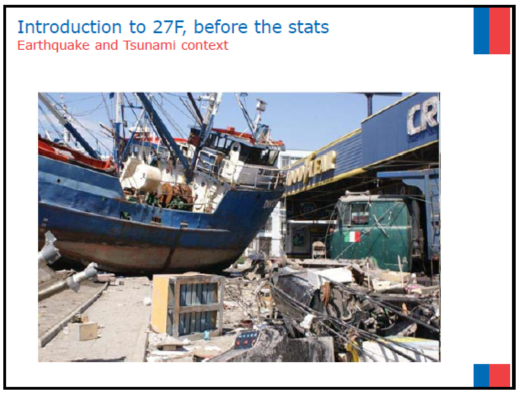
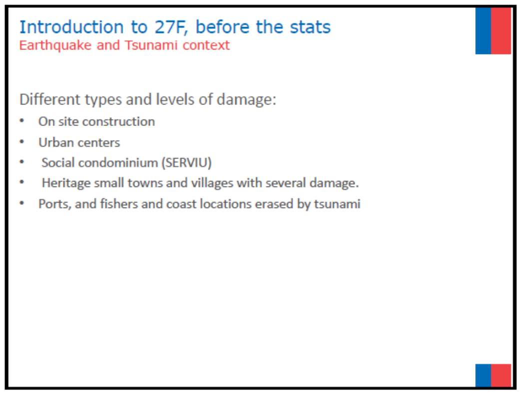
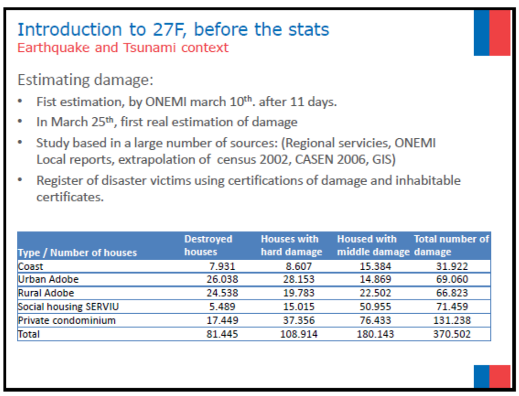
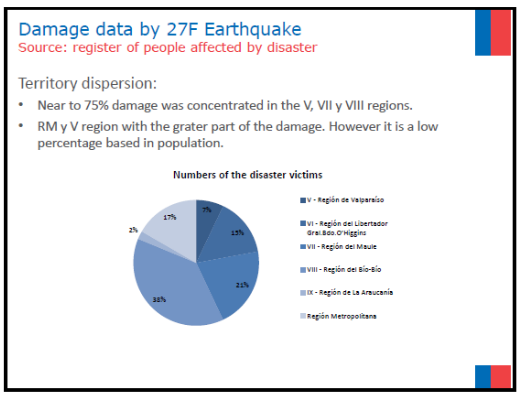








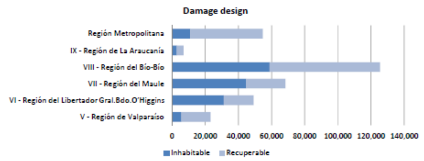
Type / Number of houses	Destroyed houses	Houses with hard damage	Housed with middle damage	Total number of damage
Coast	7.931	8.607	15.384	31.922
Urban Adobe	26.038	28.153	14.869	69.060
Rural Adobe	24.538	19.783	22.502	66.823
Social housing SERVIU	5.489	15.015	50.955	71.459
Private condominium	17.449	37.356	76.433	131.238
Total	81.445	108.914	180.143	370.502



Damage data by 27F Earthquake
Source: register of people affected by disaster

Type of damage by region:

- 50% damage are categorized as inhabitable.
- In zones were was common "Adobe" constructions, have a low percentage of reparable damage. (Note: adobe is an old construction material, homemade, made by clay mud. Very large weight and low share resistance)
- Regions with the biggest cities have large percentage of repair damage.



Damage data by 27F Earthquake
Source: register of people affected by disaster

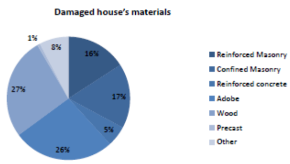
Type of damage by region:

- High scale damage at coast cities, towns, and villages.
- Correct solution: hold the location of cities instead translocate them.
- Solutions must support tsunamis without a total collaps
- 90% of tsunami damage is concentrated in 5 location. (Tome, Talcahuano, Arauco, Pelluhue y Constitución)

Damage data by 27F Earthquake
Source: register of people affected by disaster

Damaged house's materials:

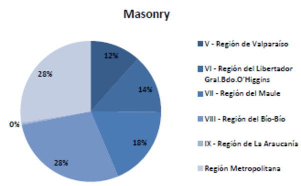
- House damages in traditional materials
- Adobe and masonry most common typologies
- Strong relation between material and geographic locations



Damage data by 27F Earthquake
Source: register of people affected by disaster

Damaged house's materials:

- Masonry structures with damage were uniformed distributed within the affected location.
- Most of old structures (old design criteria) with damage.
- Large damage in masonry structures of midle high (4 stories)



Damage data by 27F Earthquake
Source: register of people affected by disaster

Reconstruction of Social Housing Project SERVIU

- Social housing project built by or subcontracted by SERVIU (Housing and Urban Planning Service in Spanish) under social housing policies in the last 30 years.
- Based in studies, the demolitions, partial or total, of 26 of this projects was decided.
- This 26 project sum 8,327 houses or apartments, where 6,514 were or will be demolished.
- 90% of reinforced masonry (concrete and clay blocks) and 50% of them have the same layout.

Damage data by 27F Earthquake
Source: register of people affected by disaster

Reconstruction of Social Housing Project SERVIU

- Social housing of social housing policy of 1990.

Damage data by 27F Earthquake
Source: register of people affected by disaster

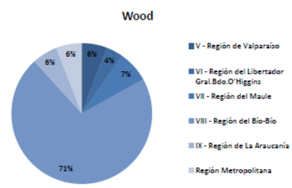
Reconstruction of Social Housing Project SERVIU

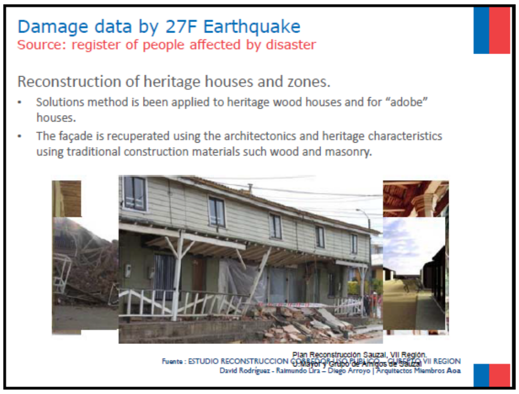
- Today, all projects are in their reconstruction phase.
- Opportunities of new seismic technologies applied. (Seismic Insulation system in "Santa Cruz" Project)

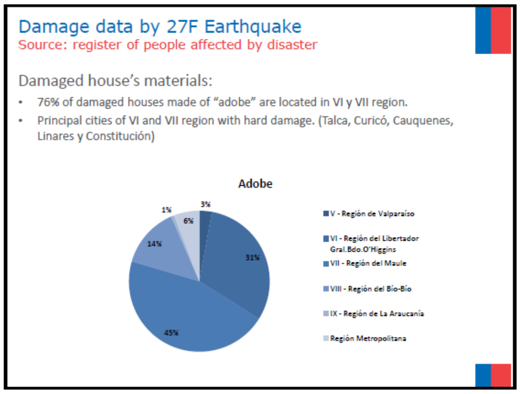
Damage data by 27F Earthquake
Source: register of people affected by disaster

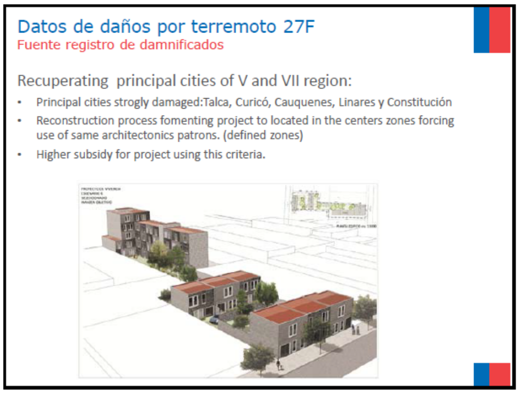
Damaged house's materials:

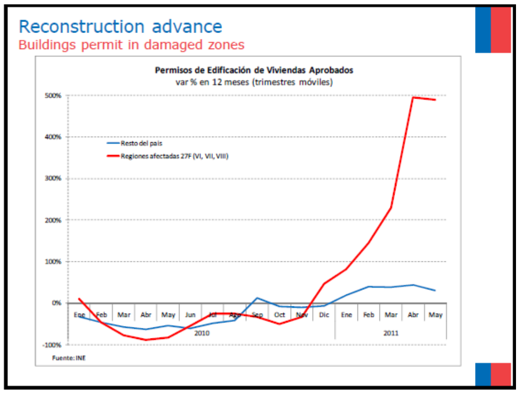
- 70% og damage of wood houses are located in the VIII region
- Of this 70%, 30% are in only 6 locations: Talcahuano, Coronel, Curanilahue, Chillán, Lota y Arauco. Equal to 18M housed.
- 4,000 are heritage housed and 10,000 were afected by slopes failed.

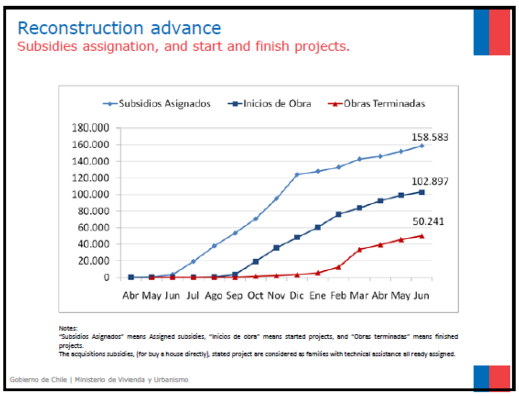



Damage data by 27F Earthquake
Source: register of people affected by disaster
Reconstruction of heritage houses and zones.
• Solutions method is been applied to heritage wood houses and for "adobe" houses.
• The façade is recuperated using the architectonics and heritage characteristics using traditional construction materials such wood and masonry.


Damage data by 27F Earthquake
Source: register of people affected by disaster
Damaged house's materials:
• 76% of damaged houses made of "adobe" are located in VI y VII region.
• Principal cities of VI and VII region with hard damage. (Talca, Curicó, Cauquenes, Linares y Constitución)
Adobe
3%
6%
1%
14%
31%
45%
V - Región de Valparaíso
VI - Región del Libertador Gral.Bdo.O'Higgins
VII - Región del Maule
VIII - Región del Bío-Bío
IX - Región de La Araucanía
Región Metropolitana


Datos de daños por terremoto 27F
Fuente registro de damnificados
Recuperating principal cities of V and VII region:
• Principal cities strogly damaged:Talca, Curicó, Cauquenes, Linares y Constitución
• Reconstruction process fomenting project to located in the centers zones forcing use of same architectonics patrons. (defined zones)
• Higher subsidy for project using this criteria.


Reconstruction advance
Buildings permit in damaged zones
Permisos de Edificación de Viviendas Aprobados
var % en 12 meses (trimestres móviles)
500%
400%
300%
200%
100%
0%
-100%
Resto del país
Regiones afectadas 27F (VI, VII, VIII)
Ene Feb Mar Abr May Jun Jul Ago Sep Oct Nov Dic Ene Feb Mar Abr May
2010
2011
Fuente: INE


Reconstruction advance
Subsidies assignation, and start and finish projects.
Subsidios Asignados
Inicios de Obra
Obras Terminadas
180.000
160.000
140.000
120.000
100.000
80.000
60.000
40.000
20.000
0
158.583
102.897
50.241
Abr May Jun Jul Ago Sep Oct Nov Dic Ene Feb Mar Abr May Jun
Notes:
"Subsidios Asignados" means Assigned subsidies, "Inicios de obra" means started projects, and "Obras terminadas" means finished projects.
The acquisitions subsidies, (for buy a house directly), stated project are considered as families with technical assistance all ready assigned.
Gobierno de Chile | Ministerio de Vivienda y Urbanismo


Thanks
Gracias
Ministerio de Vivienda y Urbanismo
Gobierno de Chile

THE TOHOKU EARTHQUAKE AND ITS TSUNAMI SIMULATION

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ABSTRACT

An *Mw* 9.0 earthquake occurred off the Pacific coast of Tohoku on March 11, 2011 and caused severe damage in the Tohoku and Kanto districts of the northeastern part of Japan. This was a thrust earthquake occurring at the boundary between the North American and Pacific plates and is the largest earthquake ever recorded instrumentally in Japan. An *Mw* 7.5 foreshock preceded the mainshock on March 9 and many large aftershocks including three *Mw* 7-class aftershocks followed the mainshock. The size of the one-day aftershock area is ~450 km in the northerly direction and ~400 km in the easterly direction.

Tsunami waveform inversion for the Tohoku earthquake indicates that source of the largest tsunami was located near the axis of the Japan Trench. Ocean bottom pressure and GPS wave gauges recorded two-step tsunami waveforms, gradual increase of water level (~2 m) followed by an impulsive tsunami wave (3 to 5 m). The slip distribution estimated from coastal tide gauges, offshore GPS wave gauges and ocean bottom pressure gauges show that the large slip, more than 40 m, was located along the trench axis. This offshore slip is responsible to the recorded large impulsive peak. Large slip on the plate interface at southern Sanriku-oki (~30 m) and Miyagi-oki (~17 m) around the epicenter is responsible to the initial water rise and presumably large tsunami inundation in Sendai plain. The total seismic moment is estimated as 3.8×10^{22} Nm (*Mw* = 9.0).

KEYWORDS

Pacific coast of Tohoku, earthquake, Tsunami.

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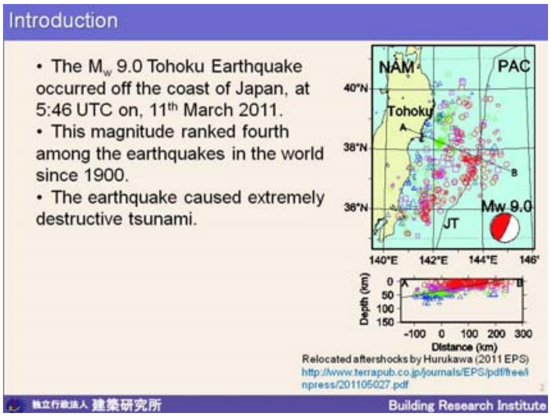
Introduction
• The Mw 9.0 Tohoku Earthquake occurred off the coast of Japan, at 5:46 UTC on, 11th March 2011.
• This magnitude ranked fourth among the earthquakes in the world since 1900.
• The earthquake caused extremely destructive tsunami.
NAM
PAC
Tohoku
Mw 9.0
JT
Depth (km)
Distance (km)
Relocated aftershocks by Hurukawa (2011 EPS)
http://www.terrapub.co.jp/journals/EPS/pdf/free/inpress/201105027.pdf
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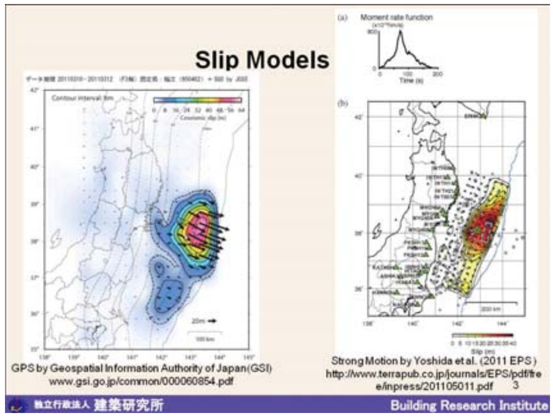
Building Research Institute


Slip Models
Moment rate function
GPS by Geospatial Information Authority of Japan(GSI)
www.gsi.go.jp/common/000060854.pdf
Strong Motion by Yoshida et al. (2011 EPS)
http://www.terrapub.co.jp/journals/EPS/pdf/free/inpress/201105011.pdf
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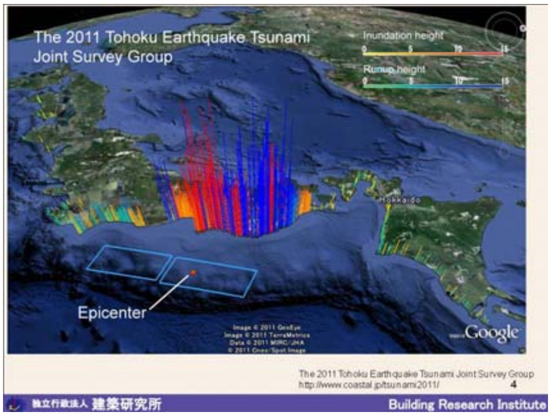
The 2011 Tohoku Earthquake Tsunami Joint Survey Group
Inundation height
Runup height
Hokkaido
Epicenter
Google
The 2011 Tohoku Earthquake Tsunami Joint Survey Group
http://www.coastal.jp/tsunami2011/
4
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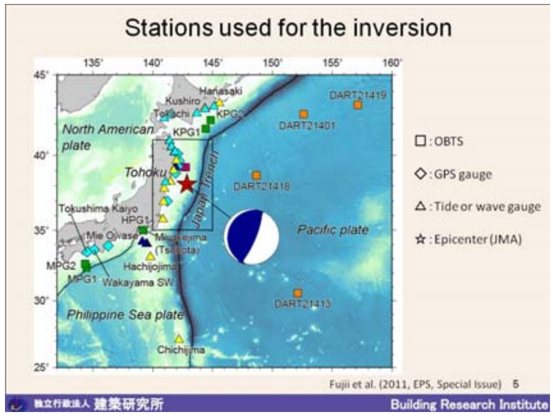
Stations used for the inversion
North American plate
Tohoku
Pacific plate
Philippine Sea plate
Japan Trench
□ : OBTS
◇ : GPS gauge
△ : Tide or wave gauge
☆ : Epicenter (JMA)
Fujii et al. (2011, EPS, Special Issue) 5
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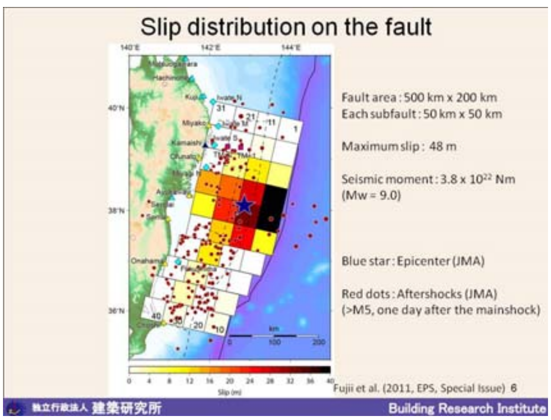
Slip distribution on the fault
Fault area : 500 km x 200 km
Each subfault : 50 km x 50 km
Maximum slip : 48 m
Seismic moment : 3.8 x 10^22 Nm
(Mw = 9.0)
Blue star : Epicenter (JMA)
Red dots : Aftershocks (JMA)
(>M5, one day after the mainshock)
Slip (m)
Fujii et al. (2011, EPS, Special Issue) 6
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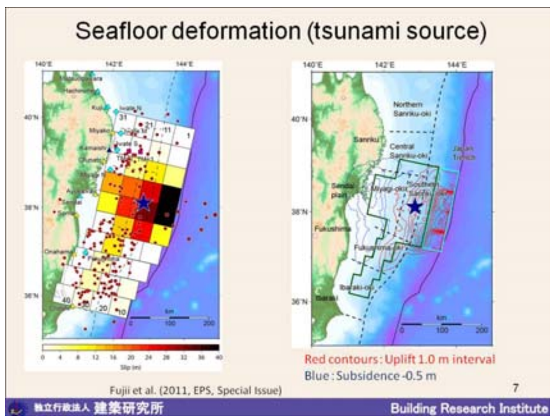
Seafloor deformation (tsunami source)
Red contours : Uplift 1.0 m interval
Blue : Subsidence -0.5 m
Fujii et al. (2011, EPS, Special Issue)
7
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SEISMIC RESISTANT BUILDING RESEARCH AND PROJECTS FOR EARTHQUAKE AND TSUNAMI RISK MITIGATION

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olb@cenapred.unam.mx[2]

ABSTRACT

Taking into account the effects produced by recent earthquakes, e.g. Haiti, Chile and Mexico (2010) and Japan (2011),) the Mexican Government has started a master plan for preparation, response and recovery, known as Plan Sismo, which includes the participation of all the government sectors into a single strategy, collecting the experiences obtained during the last 25 years of the National System for Civil Protection (SINAPROC), promote research activities and improving procedures for effective response.

For the said purpose the recent experiences obtained by personnel from the National Center for Disaster Prevention (CENAPRED) during field inspections in earthquake affected countries, research lines have been reviewed in order to improve experiments and to provide better elements for updating national building codes. This is related with the fact that private companies and civil engineers associations have shown strong interest (mainly derived from the effects mentioned above) to test their models and materials in the CENAPRED Large Scale Structures Laboratory.

Also a brief description is presented to synthesize the actions taken, as part of the master plan mentioned above, towards the integration of the National Seismic Network and the National Tsunami Warning System, promoted by the Mexican Government, supported by the National Autonomous University and other institutions.

KEYWORDS

Structural resistant experiment, damage inspection, national seismic network, tsunami early warning

INTRODUCTION

After the great magnitude earthquakes occurred in 2010 in Haiti (January 12, M 7.0), Mexicali, (April 4, M 7.2), Chile (February 27, M 8.8) and 2011 in Japan (March 11, M 9.0), researchers in civil engineering, in charge of structural testing at the Large Scale Structures Laboratory (LSL) at CENAPRED, participated in field inspections in the above mentioned countries, as part of international cooperation teams. In each case technical help was provided in accordance to local authorities requirements in previously selected areas. Besides, the presence of CENAPRED researchers was an opportunity to be in contact with local researchers and to improve knowledge about structural behaviour during strong seismic motion.

OBSERVATIONS IN HAITI

Field inspection in the epicentral area

On January 12, a M 7.0 earthquake occurred with an epicenter located about 25 km southwest of the capital city of Port-au-Prince, with depth of 13 km and producing a maximum intensity, according to the USGS evaluation, of IX. At least 6 aftershocks with magnitudes between 4.5 y 5.9 were recorded during the first 2 hours. During the first 9 hours 26 aftershocks with magnitude greater than 4.2, 12 of them with magnitude greater than 5.

On January 14 a Mexican relief team was dispatched to Haiti, including the participation of the Ministries of the Interior (SEGOB), Foreign Affairs, Navy, Mexico City Civil Protection and the United Nations Developing Program among others.

The capital city was divided into 22 sectors; Sector 8 was assigned to the Mexican team; 3117 houses were evaluated, finding that 856 had structural damage and 740 collapsed, the rest had moderate to minimum damage. Ten government buildings, including the National Palace, 25 schools, 7 hospitals and 7 churches collapsed. This represents that about 62% of construction in Sector 8 had damage to some degree.

The behavior problems in the buildings and dwelling can be summarized as follows:

A high vulnerability characterizes constructions in the metropolitan area, mainly due to low density of walls and vertical elements with respect to medium-high level of seismicity, also the properties and distribution of confining concrete elements in masonry structures were also inadequate; the solutions of bearing wall–slab, beam –columns and slab–columns joints in reinforced concrete buildings were inadequate. In some cases the lightweight (waffle) slabs using sand-cement blocks do not present steel mesh on the upper part of the slabs (Fig. 1). Also the foundation solutions were found to be inappropriate to withstand modified and unstable slopes exposed to seismic demands.

The generalized use of poor materials like plain steel bars and concrete with highly porous materials contributed to a high degree of vulnerability.

Figure 1. Lightweight elements used in floor systems without reinforcement. In the right side photo it is clear the lack of reinforcement in the wall – slab joint, these procedure do not allow the coupling of vertical elements to withstand seismic demands

Figure 2. The reinforcement detail in the Haitian Construction Code is not adequate for medium to severe seismic demands

Assistance programme

Few months after the visit of the research team, the National Center for Disaster Prevention proposed a technical assistance programme for Haiti, taking into account the success achieved with El Salvador, through the trilateral project *Improvement of Technology for Building and Dissemination of Seismic Resistance Popular Dwelling*, commonly known as Taishin Programme, developed under the scheme South-South Cooperation sponsored by the Japan International Cooperation Agency (JICA).

In this case the proposal, named *Human Resources Formation in Civil Protection and Seismic Resistant Building*, included as main goals: 1) technology transference, in which basic knowledge about structural behaviour and experiences will be provided through specialized courses by CENAPRED. Also, evaluation of slope stability is taken into account as a major issue in seismic safety. In this case, special training will be provided using field testing instruments; and 2) technical assistance, whose main purpose is to support the development of earthquake resistant building codes based on the necessities and capabilities of Haitian engineers.

Figure 3. The chaotic urban development in Port-au-Prince has led to increased vulnerability of slope stability under seismic demand, as well as under gravitational load (Photo by Eduardo Miranda, 2010)

OBSERVATIONS IN CHILE

After the February 27, M 8.8 earthquake occurred at the coast of Chile, and attending the call of the Chilean government to the international community, a technical assistance team, including nine structures specialists, was dispatched on March 4. The coordination with the Chilean government was through the Ministry of Public Works (Ministerio de Obras Públicas) which emphasized the importance of school safety assessment. On that basis ten scholar buildings were inspected in order to determine an overall damage degree and to recommend basic measures.

Most of the inspected structures were old buildings, two of them with one and two hundred years of existence, respectively, in which only minor to moderate structural damage was observed, in spite of having being exposed to several strong earthquakes during those periods.

Also, two housing complexes were inspected at the municipality of Ñuñoa; these were Villa Olímpica and Villa Canada. Before the 2010 earthquake these two complexes were exposed to strong earthquakes in 1965, 1971 and 1985. After inspection it was found that, in the first case, minor to severe damage occurred, however the structure remains stable. In the second case, although the damage was diagnosed as moderate to severe, it is feasible to be repaired.

As a result of this earthquake, there are some questions about the expected behavior of reinforced concrete walls as main structural elements for tall buildings. Also, it was observed that reinforced concrete robust walls do not necessarily show shear failure, concrete crushing occurred at the ends of the walls due to flexural bending product of the seismic lateral forces.

OBSERVATIONS IN MEXICALI

On April 4, 2010, an earthquake occurred with magnitude 7.2, depth of 10 km, along the Laguna Salada fault, which epicenter was 60 km distant from Mexicali city, in the northern part of Baja California peninsula. Although the epicenter was very close to the city and accelerations were measured between 0.284g and 0.027g in stations at 60 and 190 km away, the number of casualties was 2 and 230 injured. The number of damaged buildings did not exceed 3200 (CENAPRED, 2010). The structural damaged was concentrated in the Municipality of Mexicali (CENAPRED, 2010).

This earthquake presented the opportunity to verify the performance of several kinds of structures in an area under the influence of near source events and settled on sandy soil.

From the field inspection made in the affected area several problems were identified. One of them was the inconsistency of local building regulations with respect to a regional hazard assessment which assigns the highest hazard level. Also several evidences of insufficient supervision were found mainly in low cost and moderate to high level dwelling (Figure 4). Figure 4 shows an inadequate attempt to combine the normativity for reinforced concrete and masonry, something absolutely inadmissible by the difference in reliability and safety factors involved in the theoretical approaches. Several buildings collapsed with what is considered a serviceability earthquake.

a) b) c)

Figure 4. a) Popular dwelling (absolute lack of reinforcement and confined elements in masonry), b) Middle class dwelling, with an estimated cost of 150,000 USD. In both cases the lack of application of building code is evident (see detail of front in c, corresponding to middle class dwelling)

Another main issue with respect to structural behaviour of critical facilities is that a general hospital in the area of Mexicali presented damage in non-structural elements. Under that condition the responsible authorities made the decision of closing it temporarily, which appears unacceptable.

Figure 5. Hospital temporarily closed due to non-structural damage

SEISMIC RESISTANT EXPERIMENTS AT CENAPRED

The experiences collected, mainly at Haiti and Mexicali, during recent field inspections, as has been described, have been useful to review the experimental research program at CENAPRED, or to improve some testing procedures. As a summary of deficiencies observed, the following appear remarkable:

- The building codes are commonly inadequate or not taken into account
- The quality of materials is low, the design concepts are inadequate and the building practice is poor
- The lack of supervision is very common by authorities, during construction stage.

The details observed in different kinds of constructions, mainly in Haiti, provide important information about the contributing factors for vulnerability.

The information and conclusions were used for the preparation of experiments about the behaviour of partially prefabricated slabs under seismic load pattern (Figure 6) and experimental studies on the behaviour of confined ceramic masonry walls with different types of retrofitting methods (Figure 7). Particularly in the case of the partially prefabricated slabs the purpose was to verify the rigidity in the floor system (rigid diaphragm), and once it is damaged by lateral forces the remaining capacity is studied under vertical load.

Figure 6. Experimental research on the behaviour of partially prefabricated slabs under seismic type loads and vertical live loads

During the last 8 years the number of housing builders that look for advice from CENAPRED with the purpose of assessing the quality of materials being used and building procedures has increased. Recently, mainly due to last earthquakes, the interest in laboratory tests has grown. Two of the biggest building companies in the country have shown interest in testing their products before applying them for low and medium cost housing, an example of those researches is shown in Figure 8.

(a) (b)

Figure 7. Confined ceramic masonry walls with different type of retrofitting procedures: A) Mortar with steel fiber; B) Mortar with wire mesh as examples of current experiments

Figure 8. Reinforced concrete precast panel construction system for low cost housing has been tested at LSL of CENAPRED during the last year

RECENT INFORMATION ABOUT THE MAXIMUM POSSIBLE MAGNITUDE FOR AN EARTHQUAKE AT THE MEXICAN WESTERN COAST

It is well known that at the Mexican Pacific coast, particularly at Guerrero state, a great magnitude earthquake is likely to occur, within a segment where no great magnitude earthquakes have occurred since 1911. The activity in this region is related to the Cocos plate subduction beneath the North American plate. The maximum expected magnitude for a single event has been estimated in 8.2, although it is possible that several events with magnitudes between 8 and 7.8 occur along a period of some years.

In Figure 9 a collection of rupture areas is shown on a map developed by the National Seismological Service (SSN). They correspond to subduction events occurred during 20th Century. Along with Guerrero gap appears a gap in the Tehuantepec area. For a long time the discussion has been if Tehuantepec area is an aseismic region or has a very long return period in comparison with other regions in the Mexican Pacific coast.

After the M 9.0 Tohoku earthquake occurred in March 11, 2011, the question if such a magnitude could be observed along the Mexican subduction zone took relevance.

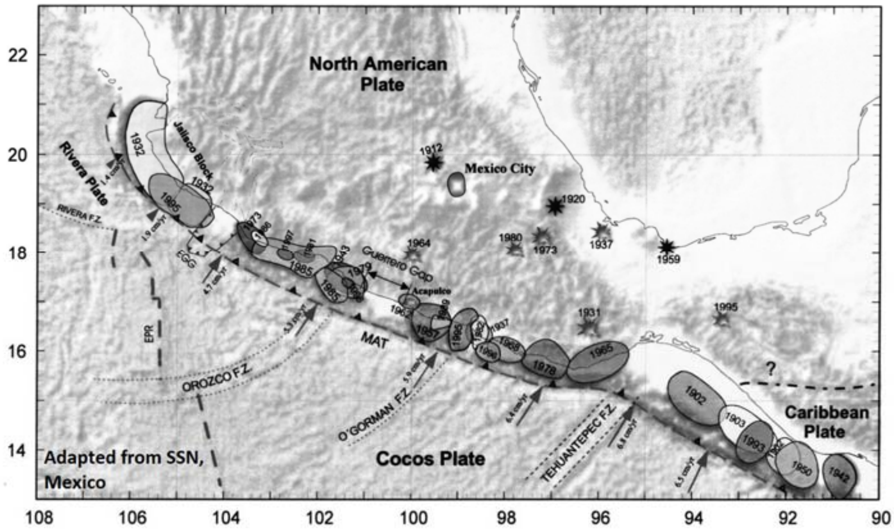

Figure 9. Location of Guerrero seismic gap together with several rupture areas from recent past earthquakes. Also a gap at Tehuantepec area is shown (Adapted from SSN)

In that sense, it has to be mentioned that derived from recent research based on MMI intensities from historical information it has been estimated a magnitude of 8.6 for an earthquake in March 28, 1787, which rupture area is located mainly at the coastal region of the state of Oaxaca. An outstanding characteristic of this event is a great tsunami that reached an estimated distance of 6 km inland as a maximum.

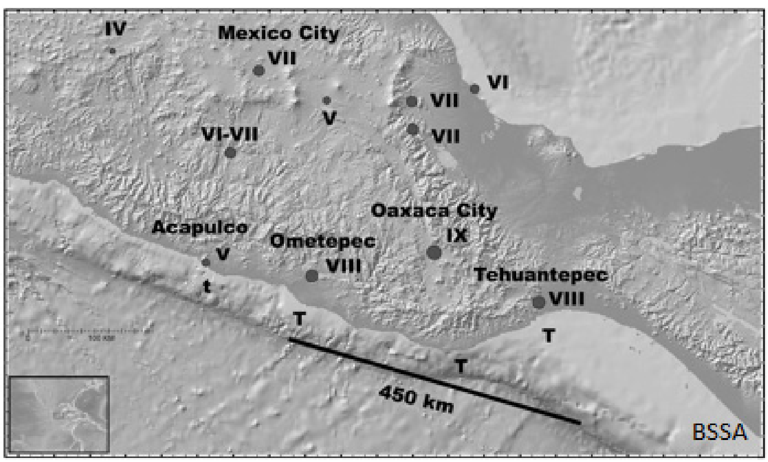

Figure 10. Length of rupture area for an earthquake with estimated magnitude of 8.6, occurred on March 28, 1787 (Suárez and Albini; BSSA, 2009)

Although, on the basis of the tectonic configuration along the Mexican subduction zone a M9.0 is not likely to occur, the estimation of a M8.6 has to be considered in order to update building codes in coastal states and also in far cities where site effect has been observed and those where this phenomenon could be expected.

PROJECTS FOR EARTHQUAKE AND TSUNAMI RISK MITIGATION

Mexican Seismic Network

With the main purpose of providing timely and accurate information about earthquakes and tsunamis for decision making and risk management, CENAPRED and the National Autonomous University (UNAM) are heading a national project to integrate all the seismographic networks, many of them covering specific regions or states.

The main objectives of this project are:

- To increase the number of seismic stations, particularly in those states where no sensors are currently operating,
- to install at least one broad band station and one strong motion station in 22 cities with more than 300,000 inhabitants
- To integrate the available information throughout the country into a single data base to improve seismic risk assessment and management
- To disseminate timely and homogeneously the information for people and authorities
- To produce shake maps for major cities and regions affected by a great magnitude earthquake in order to efficiently distribute the assistance and rescue efforts. This will provide valuable elements for decision makers in the civil protection level.
- To identify seismogenic earthquakes along the western coast

An investment of 45 million US dollars has been approved by the federal government to develop this project.

NATIONAL TSUNAMI EARLY WARNING SYSTEM

Mexican western coast has been affected repeatedly by tsunamis with distant origin but mainly by those due to local subduction earthquakes. It has been documented through a catalog that includes events since the 18th Century. The waves produced by some of the biggest tsunamis produced by local earthquakes have reached 10 and 11 m, one of them penetrating 1 km in June 1932,in Cuyutlán at Colima state.

As a complement of the Mexican Seismic Network project a National Tsunami Early Warning System was proposed to the federal authorities by a group of institutions headed by CENAPRED.

The project includes the participation of UNAM, mainly through its Seismological Service and Mareographic Service, the Mexican Transport Institute and the Center for Scientific Research and Higher Education of Ensenada, Baja California (CICESE), CENAPRED and the Secretariat of the Navy (SEMAR). SEMAR is in charge of permanently monitor the seismic and oceanographic activity, and in coordination with the Seismological Service, determine seismogenic events to timely disseminate a warning signal for coastal areas. This system has been recently implemented and is subject to permanent improvement.

CONCLUSIONS

After 1985 the National System for Civil Protection took off in Mexico. Since then, gradually the population and authorities have been involved in the construction of the civil protection culture within a co-responsibility scheme for prevention and response. In that process CENAPRED, UNAM and research centers have played a central role including domestic and international issues. Among the latter Mexico has participated in international reconnaissance groups in earthquake affected countries during recovery stages; the observations derived from the inspections are taken into account to review and improve domestic projects with impact throughout the country.

Within the National System for Civil Protection master plan for preparation, response and recovery, *Plan Sismo*, Mexican institutions are working to develop a single platform to produce, organize and disseminate seismic information looking for the maximum benefit in terms of assessing and diminishing the seismic risk for about 30 % of the population exposed to a significant seismic risk level, to achieve a better response in case of great damage, and to implement a tsunami early warning system. Although many lessons still have to be included in these tasks and projects, they can be considered as significant steps in prevention and risk mitigation.

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LESSONS LEARNED FROM BIG EARTHQUAKES IN EGYPT WITH SPECIAL EMPHASIS ON CAIRO EARTHQUAKE

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ABSTRACT

It has been estimated that, during historical many people have lost their lives in earthquakes during ground shaking, such as soil amplification and/or liquefaction, landslides and tsunamis or its immediate aftereffects, as fires. An earthquake may be large but not destructive; on the other hand, an earthquake may be destructive but not large. Egypt is suffered a numerous of destructive earthquakes. The seismicity especially at the zones of high activity is investigated in details in order to obtain the active source zones not only by the Egyptian National Seismic Network (ENSN) but also by the local seismic networks at, Aswan, Hurghada, Aqaba, Abu Dabbab and Dabbaa. On the other hand the soil condition, soil amplification, soil structure interaction, liquefaction and seismic hazard are carried out in particular the urbanized areas and the region near the source zones. All these parameters are integrated to obtain the Egyptian building code which is valid to construct buildings resist damages and consequently mitigate the earthquake disasters. Since the year of 1994 till now, the geodetic observations by means of Global Positioning System (GPS) were applied instead of the terrestrial ones to cover some other regions of the country. These regions include Sinai, Gulf of Suez, Greater Cairo, Aswan and the Middle part on the River Nile.

KEYWORDS

Tectonics, Earthquakes, GPS, Crustal deformation**.**

INTRODUCTION

Nowadays and during the history many people have lost their lives in earthquakes during ground shaking or due to its immediate aftereffects (Ambraseys et al 1994). An earthquake may consider as large but not destructive; on the other hand, an earthquake may be destructive but not large. The absence of correlation is due to the fact that, great number of other factors entering into consideration: first of all, the location of the earthquake in relation to populated areas, also soil conditions and building constructions. Soil liquefaction has been identified as the underlying phenomenon for many ground failures, settlements and lateral spreads, which are a major cause of damage to soil structures and building foundations in many events (El-Shahat 2010).

Egypt is suffered a numerous of destructive earthquakes as well as Kalabsha earthquake (1981, Mag 5.4) near Aswan city and the High dam, Dahshour earthquake (1992, Mag 5.9) near Cairo city and Aqaba earthquake (1995, Mag 7.2). The seismicity especially at the zones of high activity is investigated in details in order to obtain the active source zones not only by the Egyptian National Seismic Network (ENSN) but also by the local seismic networks at, Aswan, Hurghada, Aqaba, Abu Dabbab in the eastern desert near the Red Sea Coast and Dabbaa near the Mediterranean Coast (ENSN Bulletin 2005, Maamoun et al 1984).

The experiences from the earthquakes show that there is a need for an earthquake action plan which will provide the necessary guidelines for facing the many problems which arise after such a catastrophe. The residential buildings, whose construction has not been given the adequate attention, has been most vulnerable to earthquake damage and has been the greatest problem in the post earthquake recovery of respective regions. Seismic hazards are carried out in particular the urbanized areas and in the region near the source zones (Abuo El-Ela et al 2000). Global Positioning System (GPS) were applied instead of the terrestrial ones to cover some other regions of Egypt. These regions include Sinai, Gulf of Suez, Greater Cairo, Aswan and the Middle part on the River Nile. The GPS system allows scientists to record, with high precision, the minute movements of the Earth associated with earthquakes. The buildup of strain is directly tied to the earthquake potential. Tracking it will help scientists to assess earthquake hazards (Mahmoud 2003; Saleh, M. 2010; Rayan et al 2010)).

SUMMARY

- The experiences from the earthquakes show that there is a need for an earthquake action plan which will provide the necessary guidelines for facing the many problems which arise after such a catastrophe.
- The ground liquefaction and slope failures involving retaining walls and embankments of various kinds.
- The soft subsoil in the heavily populated region amplifies shaking and therefore damage.
- In case of s strong earthquake, substantial liquefaction may be expected.
- Due to fractures and injuries only the first aid and orthopedics medical help is required.
- Mobilization of local potential rather than dependence on external assistance is more effective approach.
- The uneven distribution of basic social needs and the wider gap between the rich and poor make the process of recovery slower in the developing societies.
- South west Cairo zone (Dahshour area), is characterized by high seismic activity.
- A cluster of seismic activity comes clearly from the central part of Gulf of Suez, which indicates that the entire Gulf is active.
- High seismic activity is also related to the Gulf of Aqaba and its extension towards the north.
- A new cluster of seismic activity in E-W direction is recorded along the southern part of Aswan Lake.
- The network recorded a scattered activity from the western desert to the west of Minya and Sohag cities.
- Microzonztion studies should be carried out in detail around the highly populated areas
- A new seismic zone extends from Abu-Dabaab area along the Red Sea coast to the western Direction until the Nile River.
- GPS observations in Egypt were applied for the first time since 1994 till now to cover different regional networks (e.g. Sinai, Aswan, Greater Cairo and Middle Part of Egypt).
- Adjustment and analysis of the repeated GPS campaigns from the different networks prevailed significant motions.
- Deformation zones may correlate closely with mapped, active faults and historical seismicity.

LESSONS

- The seismicity of the region of Cairo is generally underestimated.
- According to past experience and length of faults in the region near Cairo, a substantially larger earthquake than that of 1992 is possible.

- The soft subsoil in the heavily populated region amplifies shaking and therefore damage.
- In case of a strong earthquake, substantial liquefaction may be expected.
- Many valuable elements at risk are exposed to shaking from strong distant earthquakes.
- There appear to be a number of seismic gaps in the general region which means that the risk during the coming decades is higher than that represented by long-term average return periods of earthquakes.
- There is a risk that Egypt will experience above-average seismicity when global seismicity switches to an exceptionally active phase which is bound to be far more seismic than most of the present century.
- The earthquake of 12 October 1992 had a surface wave magnitude of only about Ms 5.3 which is near the lower bound of potentially damaging earthquakes.

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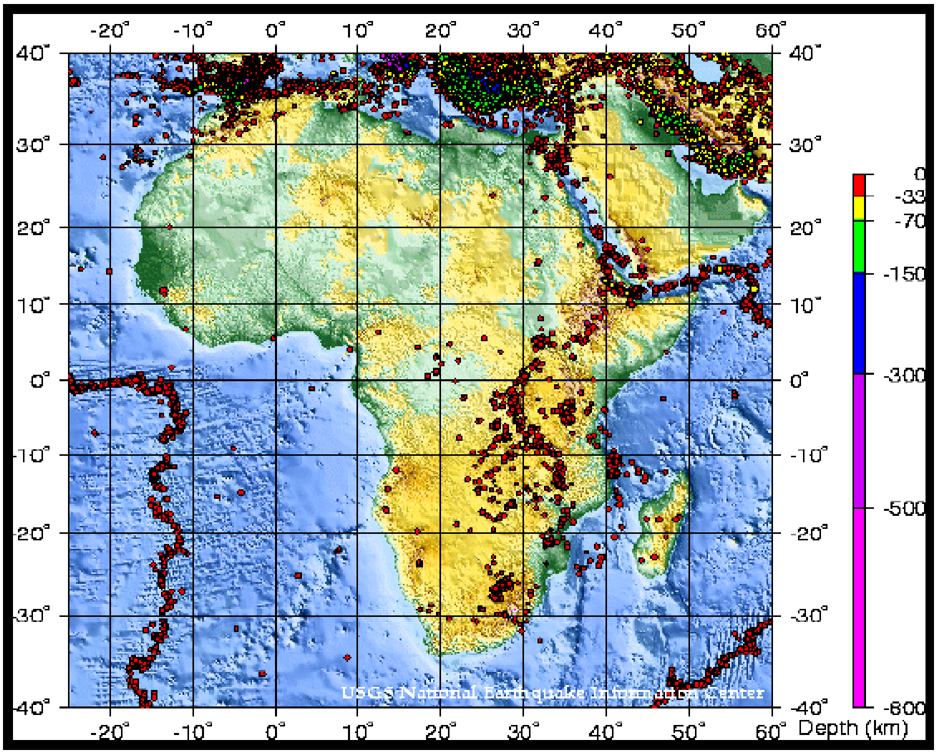


Figure 1. Earthquakes 1977-2008

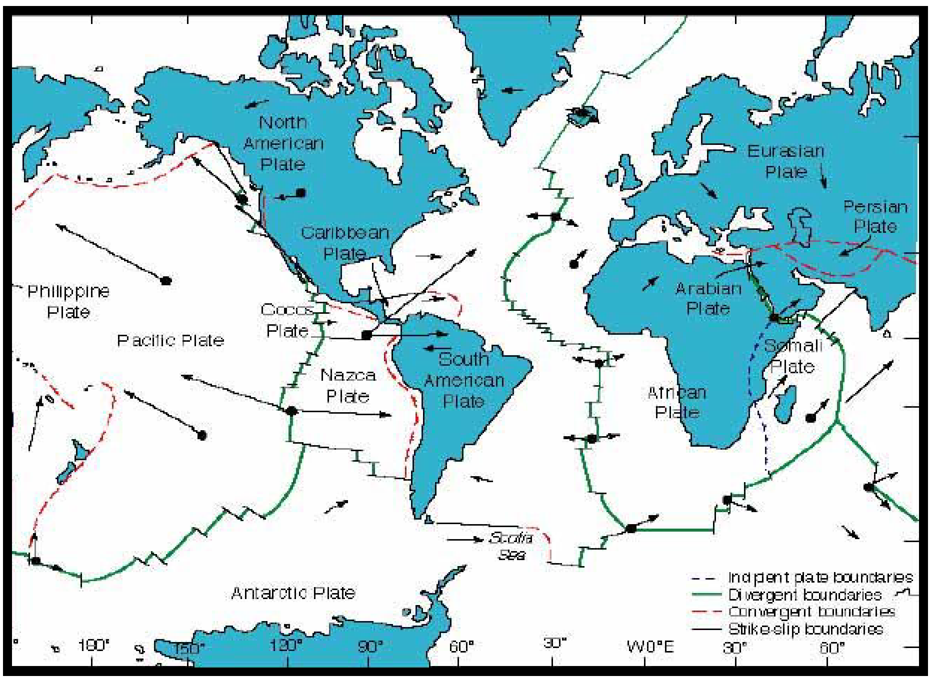


Figure 2. Tectonics & Global Plate motions

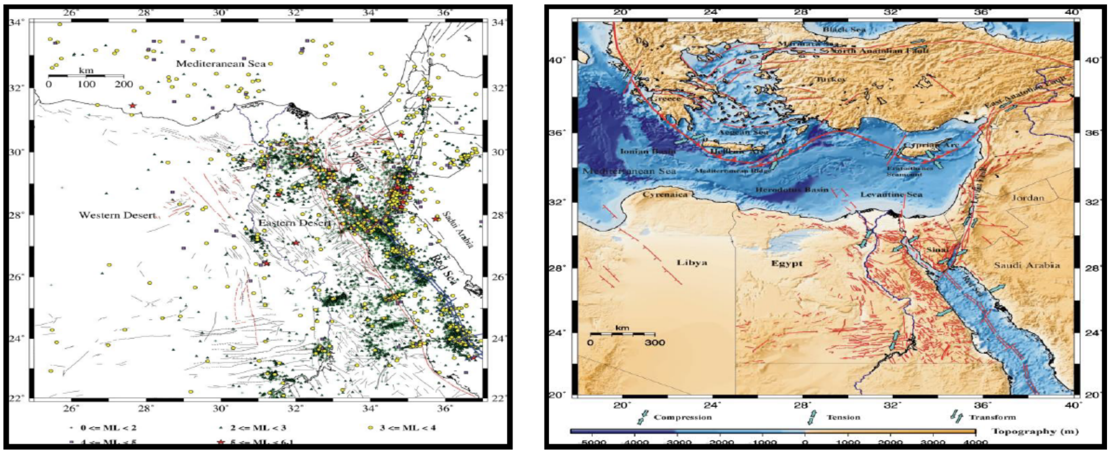


Figure 3. Regional tectonic setting of Egypt

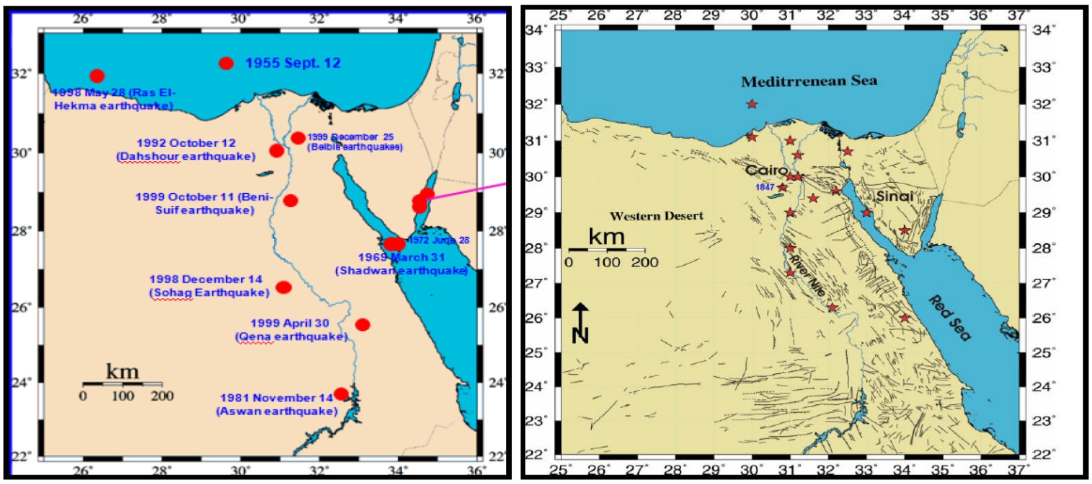


Figure 4. Recent significant earthquakes in Egypt (left), and,
Historical seismicity event of 1847 located at the same site of Dahshour 1992 earthquake (right).

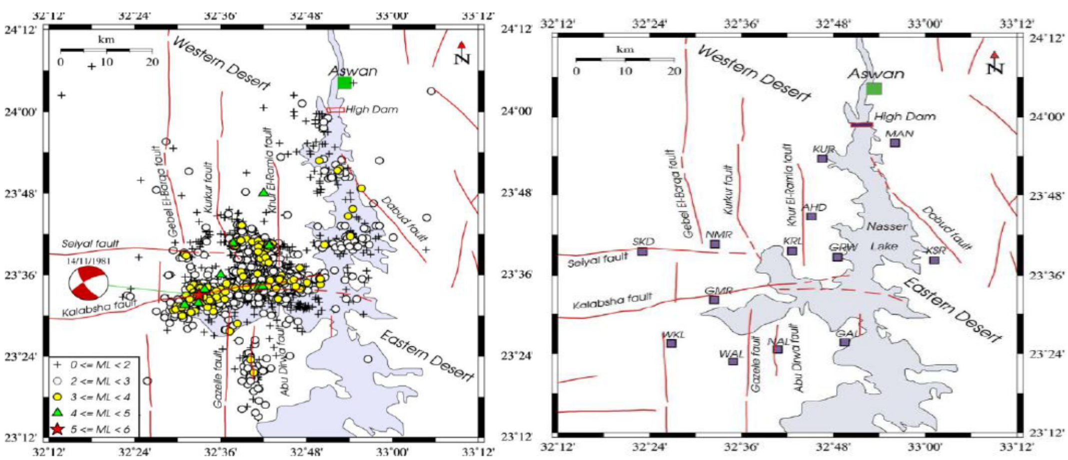
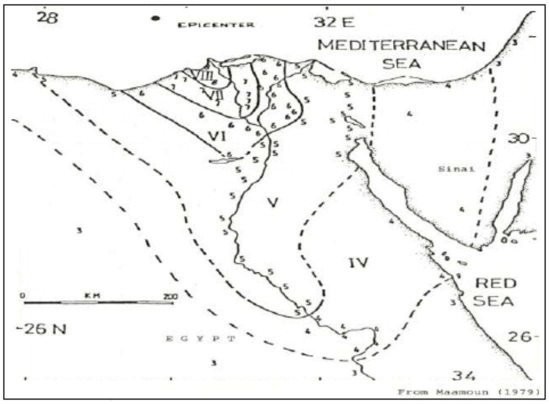


Figure 5. Aswan earthquake of 1981 with magnitude 5.4 (left), and,
Aswan local network and faults of potential (right)



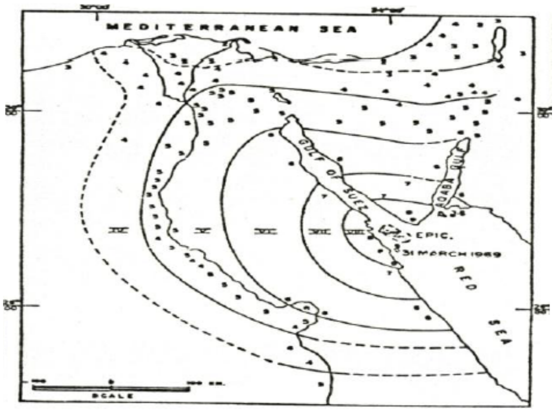
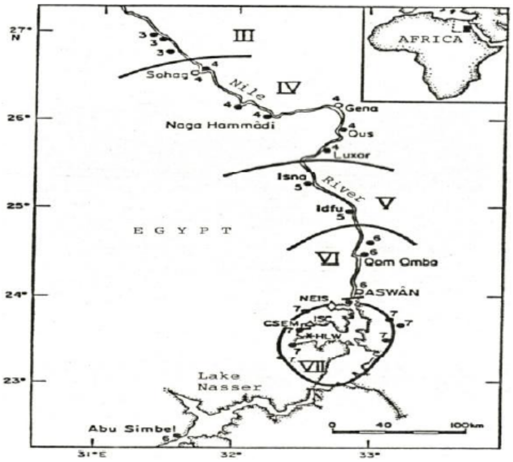


Figure 6. 1955 Alexandria Earthquake

Figure 7. 1969 Shedwan earthquake



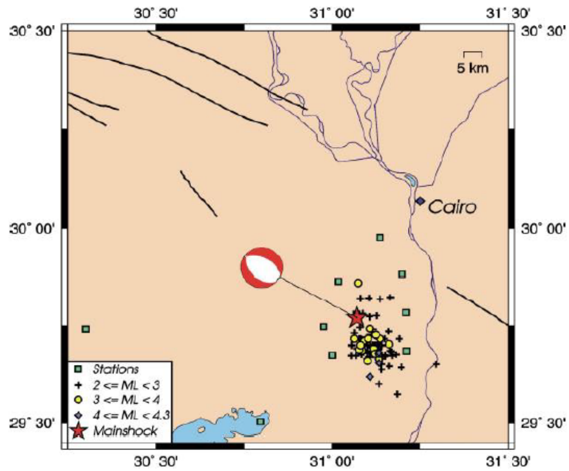


Figure 8.1981 Aswan Earthquake

Figure 9.Cairo earthquake of 1992 with Magnitude 5.9

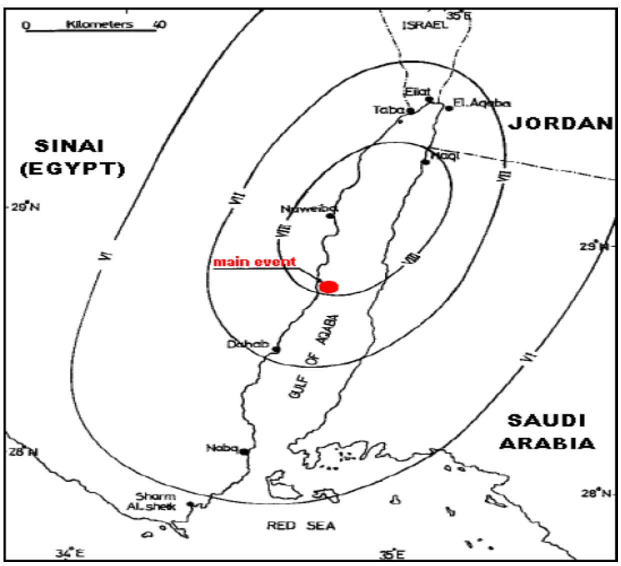


Figure 10. November 22, 1995 Gulf of Aqaba Earthquake Magnitude Mw = 7.2

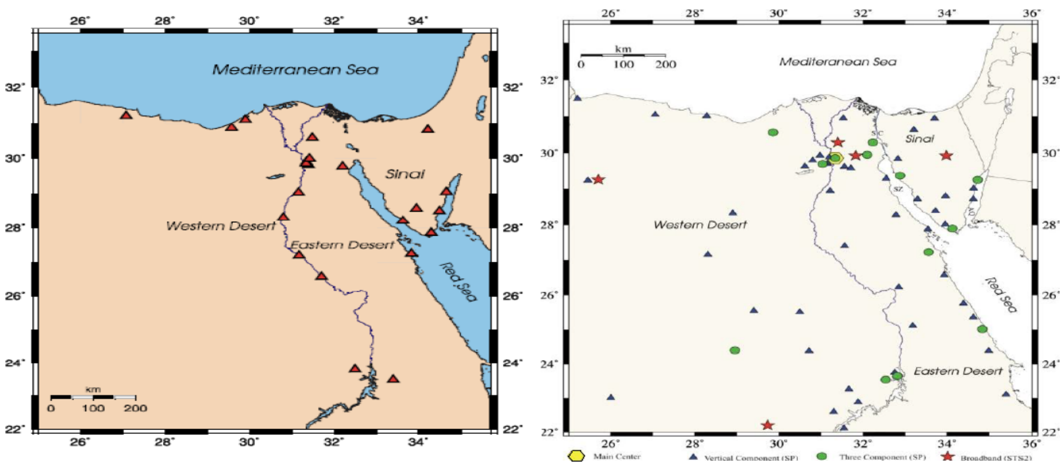


Figure 10. The Egyptian National Seismic Network (ENSN)

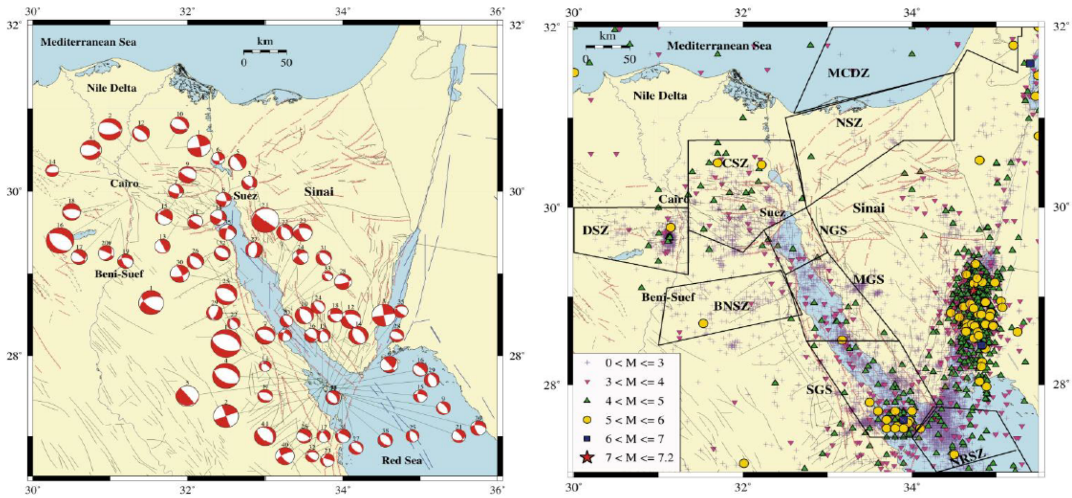


Figure 11. Earthquake source zones around Cairo area

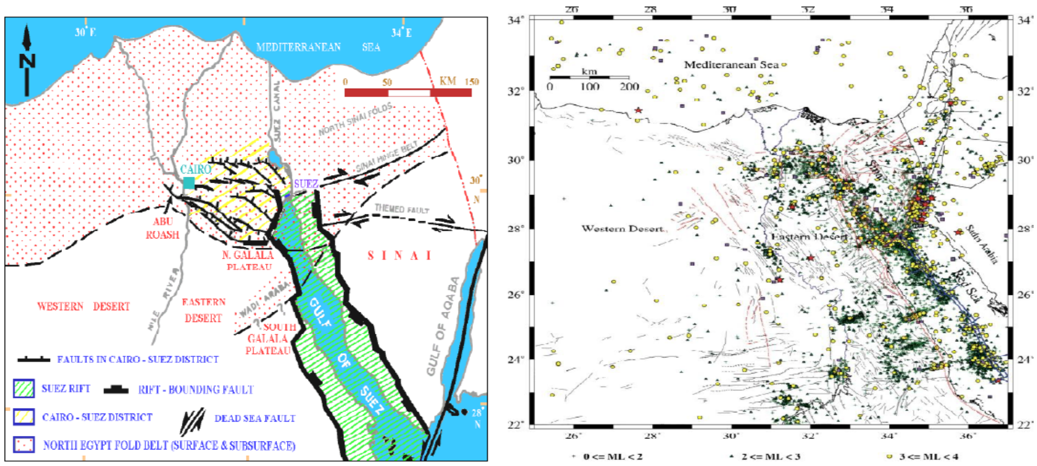
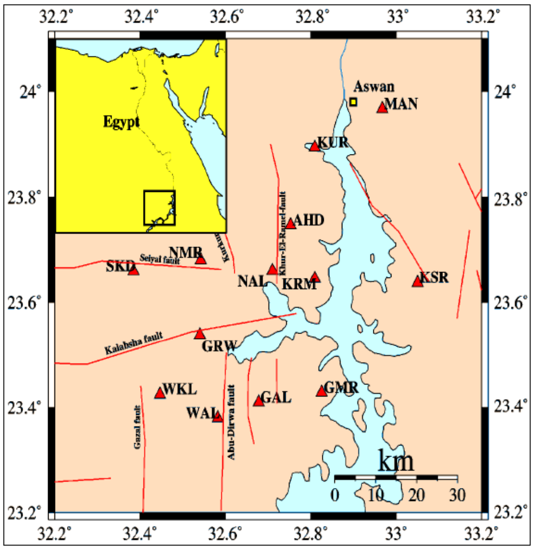


Figure 12. Seismtectonics of Egypt

Local Seismic Networks



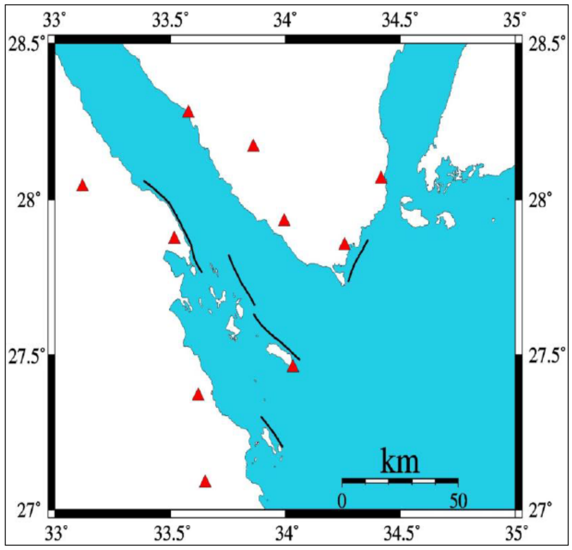


Figure 13. Aswan local seismic network (13 stations)

Figure 14. Hurghada local seismic network (1994) as Cooperation with Japan (JICA, IISEE)

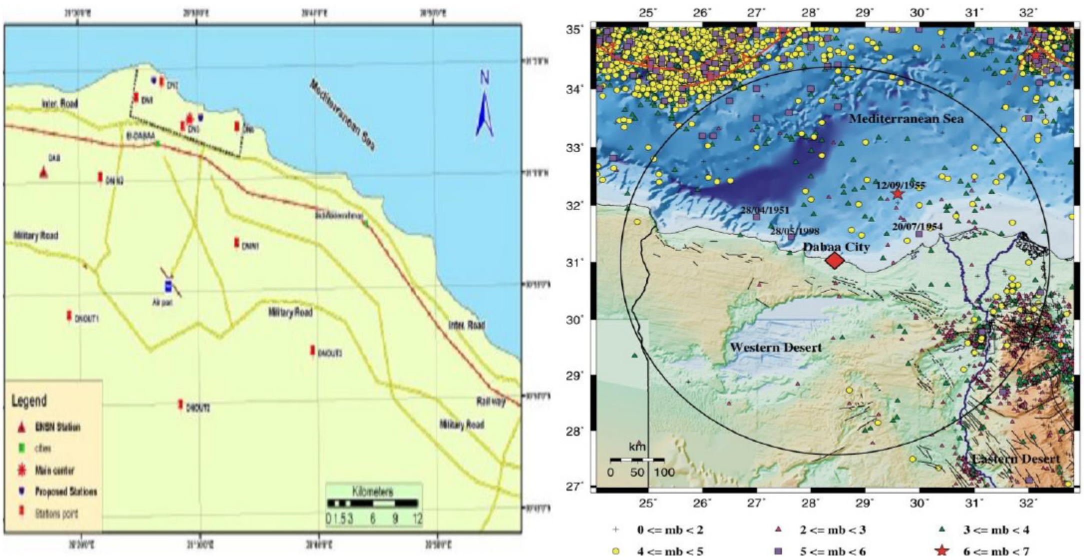


Figure 15. Dabbaa local seismic network (2006) for monitoring seismic activity around the proposed site of the nuclear power plant

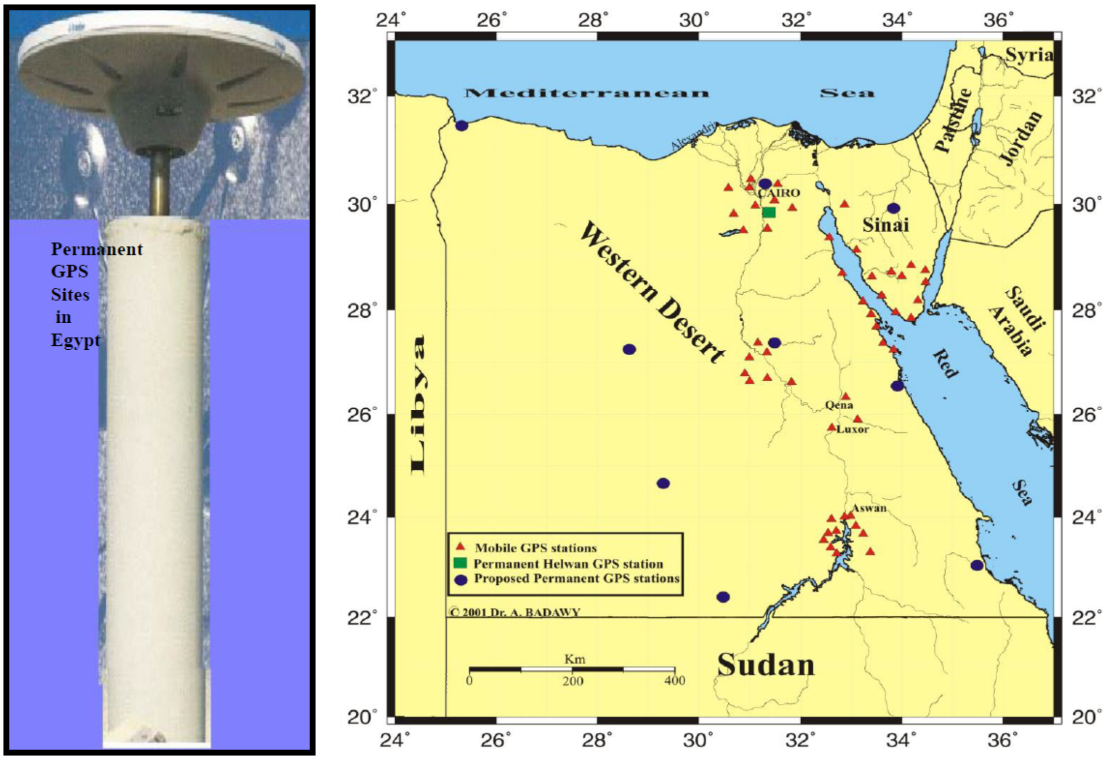
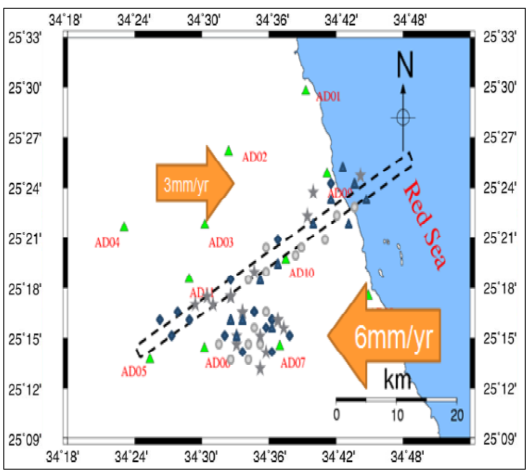


Figure 16. GPS Networks



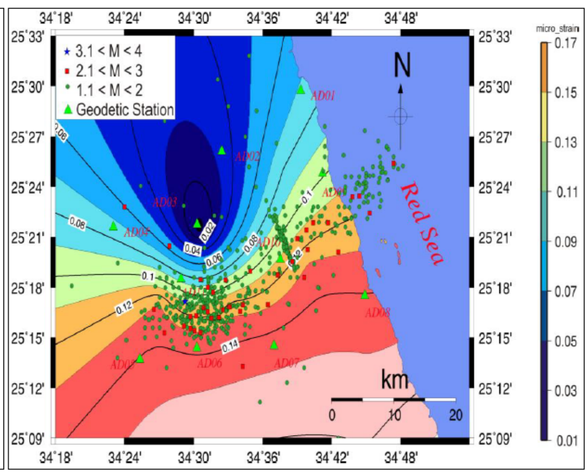
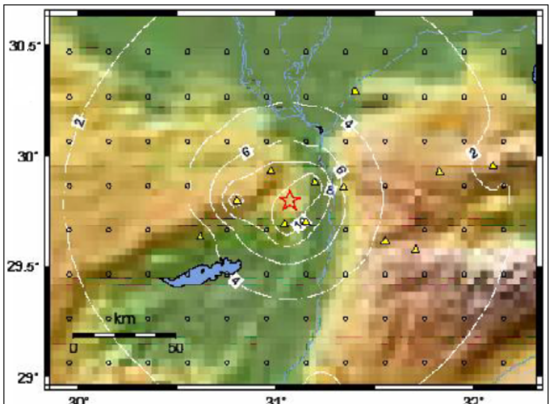


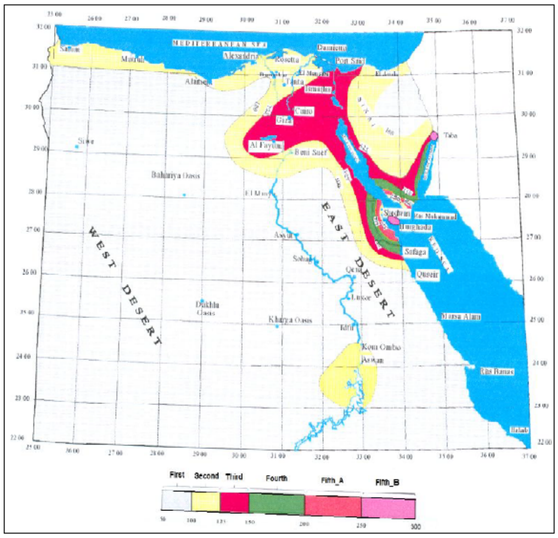
Figure 17. Primarily result

Figure 18. Maximum Shear Strain



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

(a)



(b)

Figure 19. Seismic Hazard.

(a) Shakemap has installed successfully at NRIAG Tested for 1992 Cairo Earthquake for: Macroseismic Intensity, and, PGA & PGV. PGA distribution map for 1992 Cairo earthquake. (PGA unit is in %g);

(b) the deduced Peak Ground Acceleration (PGA) distribution map of Egypt used for constructing the Egyptian building code. (PGA values ranges between 10-300 cm/sec^2 (gal))

REINFORCED CONCRETE BUILDINGS BEHAVIOUR DURING THE FEBRUARY 27TH, 2010 EARTHQUAKE

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ABSTRACT

The February 27, 2010 earthquake, Mw = 8.8, hit a very densely populated region of the country with a very important number of reinforced concrete buildings up to 50 floors high. Most of them survived the earthquake with minor damage, less to that should have been expected according to the criteria of the Chilean seismic design codes that are not much different from the criteria used in highly developed seismic countries as the United States, Japan and New Zealand.

Some buildings (less than 2% of the inventory) showed damage. Some were failures that are typically observed as a result of all major earthquakes worldwide: undersized elements failures, failure of short columns, lintels failures and faults for construction defects. However, as was the case with all strong earthquakes that occurred during the past 30 years in the world, the February 27 earthquake produced some surprises that could have been avoided with some additional research and a greater number of representative tests.

After the earthquake of 1985, which hit the central part of Chile, many lessons of the quake were incorporated to the seismic design standards. These new standards were based on the behavior exhibited by buildings built before 1985. But the buildings that were built later, especially during the last 10 years, underwent major changes. The height of the buildings was growing up but the density of the wall area in plant was maintained. The thickness of the walls was decreasing. Irregularities in plant and height also became increasingly frequent. As a result, the structural behavior of several buildings, that were designed with effective seismic reduction factors grater then 4, was elastic-brittle and suffered major damage during the February 27, 2010, earthquake.

This presentation details the behavior of such buildings and outlines the measures taken to avoid recurrence in the future. It also shows other cases with local defects in design and construction that are interesting to keep in mind.

KEYWORDS

Earthquakes, building codes, R.C. buildings, structural behavior.

INTRODUCTION

The great majority of the buildings that were affected by the March 03, 1985 earthquake (Ms 7.8) that struck central Chile, behaved extremely well. Only a few suffered minor damage. About 400 reinforced concrete shear wall buildings, up to 15 storey high, with a wall density (wall area/plan area) of about 3% in each of the main directions of the building, have been compromised. Back then, in the opinion of foreign experts, the Chilean reinforced concrete shear wall buildings would be non-collapsible.

Consequently, the Chilean seismic code NCh433.Of 1996, which required design the reinforced concrete shear wall buildings according to the ACI 318-95 code, excluded the special confinement requirements that the ACI code requires use for certain cases. These requirements were restored in the 2008 version of the NCh 433 standard.

From 1985 the height of reinforced concrete buildings grew up to 50 stories, maintaining the plant density of the walls virtually unchanged. As a result the axial stress on the walls was increased strongly without imposing special conditions of confinement until 2008, which reestablished the special confinement requirements of ACI-318-08 code. During the period 1996-2008 the thickness of the walls were reduced from more than 25cm, normal prior to 1985, to values of 15 to 20cm. Coupling beams, who are appropriate to dissipate energy in case of strong earthquakes, was stopped using due to the difficulty of designing them to meet the capacity design criteria. A number of irregularities, such as changes in the walls section, were accepted, leading to an elastic-brittle behavior of the buildings. They also began to build tall buildings in soft soils. As a result, the February 27, 2010 (Ms 8.8) earthquake, that affected the central-south region of the country, caused considerable damage at about 2% of the 2000 buildings over 9 floors that were built between 1985 and 2010. Even a total collapse, the Alto Río building in Conception, was recorded.

This paper illustrates and discusses the major damages that occurred as a result of this major earthquake that struck the most densely populated part of the country.

CHARACTERISTICS OF THE FEBRUARY 27, 2010 EARTHQUAKE

The February 27, 2010 earthquake was of great magnitude (Ms 8.8, the 6th largest of the earthquakes in the world) and had very special characteristics. Was due to a dislocation between the Nazca and South American plate at the height of Copquecura (about 100km north of Concepción), followed by a second event of importance to the height of Rancagua (Figure 1). This fact gave rise to an earthquake whose effective ground accelerations, A0, were similar to those that indicate the NCh433 versions of standards that were in effect between 1996 and 2010, but whose strong movement lasted more than one minute (Figure 2) and whose response spectra associated to many places in the area, significantly exceeded the standard design NCh433 (Figure 3), which were mainly based on the records of the 1985 earthquake.

Figure 1. Epicenter and other major dislocations of the February 27, 2010 earthquake

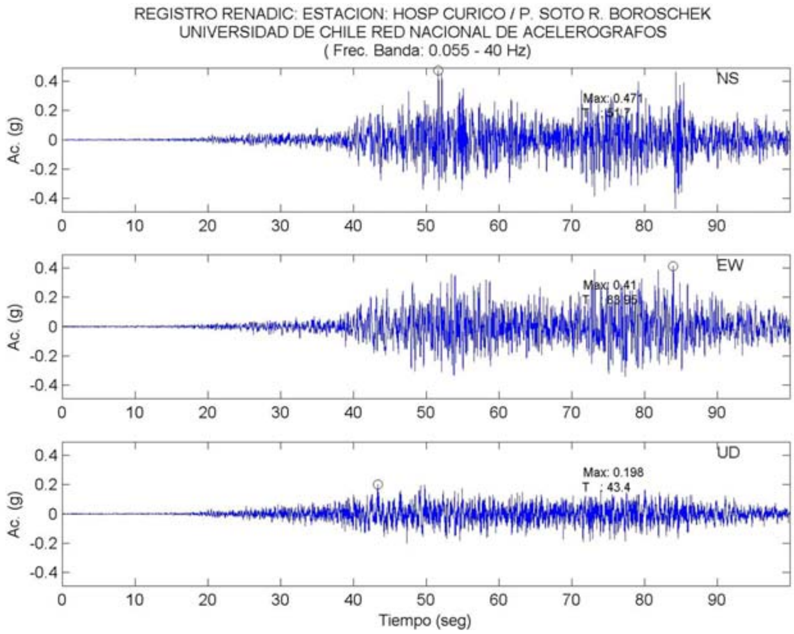

Figure 2. Record of the February 27, 2010 earthquake in Curicó

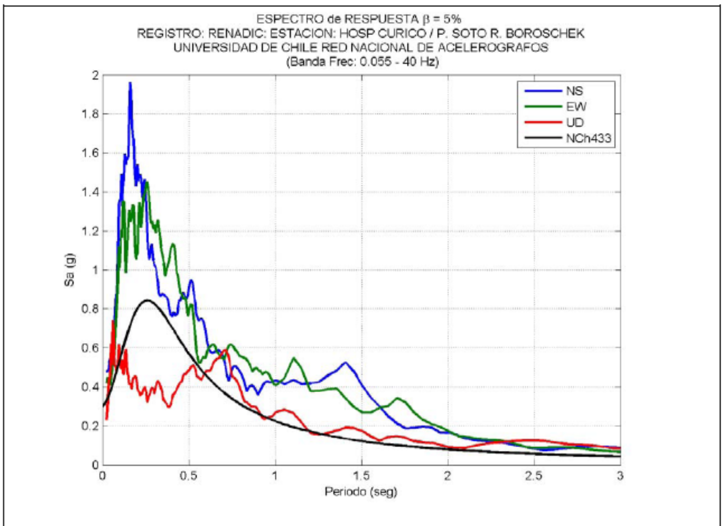

Figura 18 **Comparación Espectro de Diseño Norma Chilena NCh433 – Estación Hospital Curico.**

Figure 3. Acceleration spectrum of the February 27, 2010, earthquake in Curicó

CHARACTERISTICS OF REINFORCED CONCRETE BUILDINGS IN CHILE

The reinforced concrete buildings that were built in Chile before 1985 (about 400) were less than 15 stories high and were structured on the basis of more than 25cm thick shear walls. These buildings are relatively rigid (T ≈ number of floors / 20) with a wall density (wall area/plan area) of about 3% in each of the main directions of the building. The layout of the walls was generally symmetrical and the cross section of the walls throughout the height of the buildings was uniform.

The excellent performance of these buildings during the earthquake of 1985 encouraged the construction of reinforced concrete buildings in height, reaching up to 50 stories high. On the other hand, the thickness of the walls began to decrease, reaching only 15cm in many buildings up to 25 stories high. Despite the increase in buildings height, the density of the plan section of the walls remained approximately constant, thus raising the flexo-compression stresses on them, without changing the confinement of the walls in order to accept the maximum deformation that could be reached. They began to build tall buildings in relatively poor soils. In many cases the section of the walls was reduced in the underground to allow the flow of cars and they can be used for parking. In many cases the coupling beams between walls were eliminated due to the difficulty of designing them appropriately to resist the high shear stresses that are generated in them. The availability of better programs and analysis tools gave the designers the confidence to set and accept architectural oddities. As a result of the above, the behavior of the buildings were elastic-brittle, but they were designed with seismic reduction factors shown to be suitable for buildings that were designed prior to 1985.

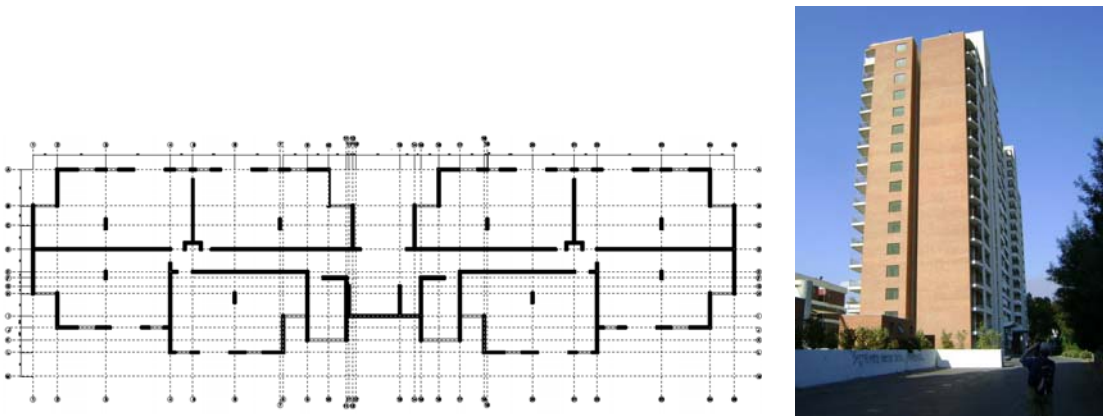

Figure 4. Typical plan and overview of modern residential building

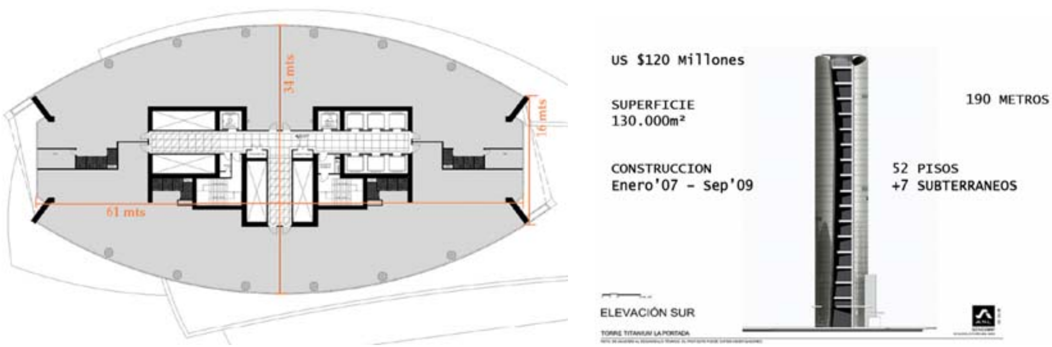

Figure 5. Typical plan and elevation of a modern office building

RESPONSE OF REINFORCED CONCRETE BUILDINGS DURING THE 27/02/10 EARTHQUAKE

The February 27, 2010 earthquake was very large (Ms 8.8) and affected a region with more than 10,000 over five stories high concrete buildings. Overall their behavior was very good. Less than 0.5% of them had significant damage and only one of them collapsed (Rio Alto building in Concepción) although the spectral ordinates of the earthquake exceeded in several locations in more than 200% the values of current design codes (Figure 3).

Most of the buildings of reinforced concrete that had major damage during the earthquake of February 27, 2010 were recorded in buildings between 15 and 25 stories high that were built after 1990 in relatively poor soils. The failures were mainly in compression of thin walls (15 - 20cm thick) heavily loaded ($N / A_c > 0.5 f_c'$).

Damage due to defective design

Following the February 27, 2010 earthquake three main types of damage due to defective design were observed.

The first type of damage attributable to a defective design was the classic failure of short columns and coupling beams that normally occur at all earthquakes in the world. These are damages that have been declining over the time, but still appear commonly.

Figure 6. Typical failure of short columns and coupling beams

The second type of damage due to design defects corresponds to singularities which were not analyzed and detailed conveniently. These particular cases are generally not captured directly by the common analysis programs and are not analyzed in detail by the designers. This local damages does not dissipate a lot of energy, but can lead to a partial collapse of the structure and even lead to a major in chain failure.

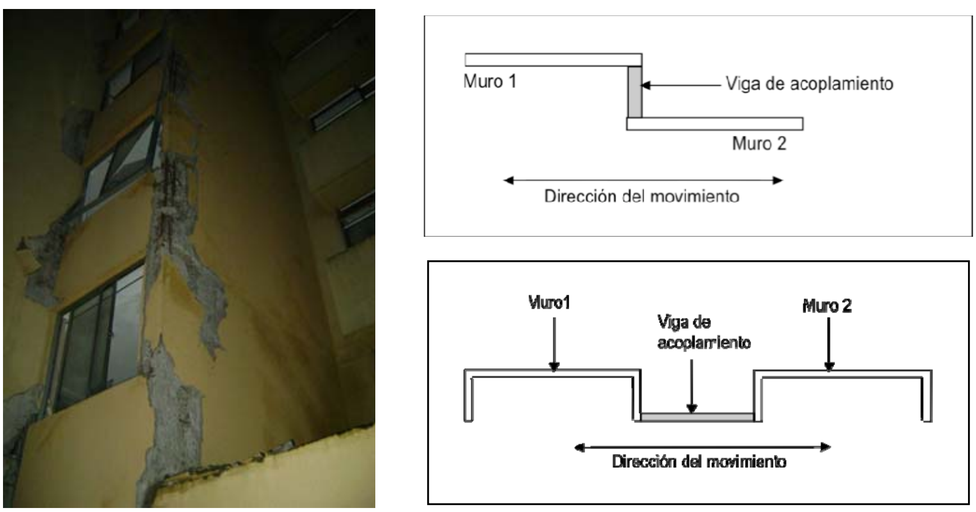

Figure 7. Failure due to poor detailing of the anchor of coupling beams.

Figure 8. Failure due to bad modeled singularities

The third type of damage due to design defects corresponds to the failure in compression of thin walls (15 - 20cm) heavily loaded. This was the most serious and recurrent type of failure that occurred during the February 27, 2010 earthquake in buildings that were built after 1990. It was a surprising failure, no one expected after the good behavior of reinforced concrete buildings during the 1985 earthquake. But it was a type of damage that seems perfectly logical and predictable after analyzing what happened during the 2010 earthquake.

Figure 9. Typical compression failure of heavily loaded thin walls

Figure 10. Typical compression failure of heavily loaded thin walls

Figure 11. Typical compression failure of heavily loaded thin walls

It is easy to show that thin walls (less than 30cm thick) practically cannot be confined. These walls are not able to accept axial deformations exceeding 0.4%, which severely limits its ability to deform if subjected to high axial loads. The supplementary provisions to the rules of NCh430 and NCh433, which were issued as supreme decrees 60 and 61 in January 2012, give background of the conditions of confinement that must meet the walls of reinforced concrete buildings to achieve the maximum horizontal displacement that may able to accept, according to the characteristics of the building, the seismic zone that is the building and type of foundation soil. Unfortunately the maximum displacement imposed by the Decree 61 does not depend on the energy dissipation capacity of the structure, but exclusively the material of construction, in our case, reinforced concrete. It is a deficiency that should be improved in the future.

Damage due to construction defects

Strong earthquakes always expose construction defects, especially defects of concrete (stone nests and defective concrete joints) and defects in the placement of the reinforcement (inadequate detailing). The February 27, 2010 earthquake was not an exception.

However, it is interesting to note that many construction failures were the result of a design that virtually could not be built properly. Among the cases that occurred more frequently during this earthquake are heavily armed thin beams that are embedded in thin walls with, as shown in Figure 12.

Another very common case is the anchor beams, reinforced with large diameter bars, in thin (15 – 20cm) orthogonal walls. This type of anchorage is very difficult to realize in an appropriate manner. Generally it is a poor anchor as shown in the in Figure 12.

Figure 12. Poor anchorage of beam reinforcement in thin walls

CONCLUSIONS

The reinforced concrete buildings had a very good performance during the February 27, 2010 earthquake (Ms 8.8) whose effects in many locations of the affected area were much higher than considered in the current design codes.

The major damage occurred in buildings of 15 to 25 stories height built after 1990, with thin reinforced concrete walls subjected to high axial loads (N / Ac > 0.5 ht') and built on poor soils. These buildings were unable to accept the maximum strain imposed upon them by the quake.

The damages occurred allowed to recognize that thin walls (<30cm) in practice cannot be confined to be able to accept axial deformations higher than 0.4%. This was a surprise that could be avoided with a greater amount of theoretical and experimental studies.

The lessons of the February, 27, 2010 earthquake were collected by the supreme decrees 60 and 61 which were issued in January 2012. Such decrees supplement the analysis and design standards and NCh433 and NCh430, to overcome the main shortcomings presented.

What is still lacking, and it is urgent to improve, is the estimate of the maximum deformations that buildings should be able to accept according to their ability to dissipate energy. Currently this is done without considering details of the structure of the building, but only on the basis of the material of the resistant structure of the building, in our case, reinforced concrete.

ACKNOWLEDGEMENTS

I need to thank all the engineers with whom I have had the opportunity to interact during the inspection of the buildings that were affected by the earthquakes of 1985 and 2010 and during workshops and seminars held after both earthquakes.

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RESPONSE OF BRIDGES DURING THE EARTHQUAKE OF FEBRUARY 27TH, 2010

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ABSTRACT

Of the about 12000 bridges in Chile, 10150 are public bridges and 1850 are concession bridges. Most of the concession bridges have been built in the last 15 years. After the 1985 earthquake several bridge design practices were introduced, and later included in the *Manual de Carreteras*, for seismic design of bridges. Some of them are the use of diaphragms and vertical anchors (hold downs) at supports, use of shear keys or stoppers, the definition of the seat width, based on AASHTO (1996) recommendations. Construction of concession highways introduced modifications to the design requirements of the *Manual de Carreteras* (MOP, 2002), resulting in three different configurations used in the connection between superstructure and piers or abutments.

The seismic response of highway bridges, mainly overpasses, is presented. The observed damage in overpass bridges located in Santiago, Concepción and along the highway between Santiago and Concepción is described, and the performance of the three configurations used is discussed. Some responses observed are: the seat width used was too short in skewed bridges; the steel shear keys used failed for large horizontal displacements, resulting in some cases in unseating of girders or the collapse of the superstructure; presetressed concrete girders without end diaphragm were damaged; skewed bridges with small seat width also collapsed. The design based in the requirements of the Manual de Carreteras (MOP, 2002), mainly the use of end diaphragm and strong concrete shear keys, had the best performance.

KEYWORDS

Bridge engineering, earthquake, bridge codes, bridge failure.

INTRODUCTION

In the previous 15 years a large increase in the number of new highways has occurred due to a system of concessions. Within this system, private companies build highways, including the bridges and overpasses, and then can charge a toll to recuperate de investment. About 1850 bridges have been built in this time period. Damage in many overpasses occurred after the earthquake, in some cases leading to the collapse of the superstructure.

The three typical typologies of overpasses in existence at the time of the earthquake are described, emphasizing the differences among them and the consequences in the observed damage of each type of structure. The damage produced in those overpasses is described.

At the end, the current seismic design provisions in Chile are explained in the context of the damage and failures shown before. The effectiveness of the new design provisions have to be studied.

TYPICAL STRUCTURES

Three typical configurations of the structural solution at the support of overpasses have been in use in the last 20 years in Chile. Two of them were defined in the last 10 to 15 years, being them modifications of the configuration used previously. The modifications were introduced to improve the speed and easiness of construction. The three configurations are described in the following section.

Type 1: Traditional design

Previous to the year 2000, most of the bridges had a similar structure, defined in the Manual de Carreteras (MOP, 2002), being the main components as described in the following and shown in Figure 1:

i) Precast, prestressed concrete beams.
ii) Concrete slab.
iii) Concrete diaphragms between main prestressed beams, located at least at the supports of the beams, over the abutments or piers.
iv) Steel bars anchored to the abutment or the piers and to the slab, at the location of the end diaphragm, to hold down the bridge. The bars were not prestressed.
v) Large concrete shear keys at the abutments and piers, located at the sides of the two lateral prestressed beams.

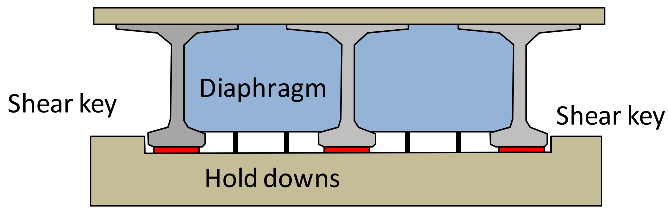

Figure 1. Schematic of the Type 1 configuration: Traditional design

Type 2: Post 2000 design

After 2000, construction companies, mostly from Spain, proposed to eliminate the diaphragm and replace it by reinforcement within the web of the beams as a mean to increase the speed of construction. The additional reinforcement was designed to provide transversal strength to the beams. The Chilean Ministry of Public Works (MOP) accepted the change in design, resulting in a structure with the following typical components, as shown in Figure 2:

i) Precast, prestressed concrete beams.
ii) Concrete slab.
iii) No end concrete diaphragms between main beams.
iv) Steel bars anchored to the abutment or the piers and to the slab, at the location of the end diaphragm, to hold down the bridge. The bars were not prestressed.
v) Concrete shear keys at the abutments and piers, located at the sides of the two lateral beams. The shear keys could be large, as in older designs, or a thin wall, as shown in Figure 2.

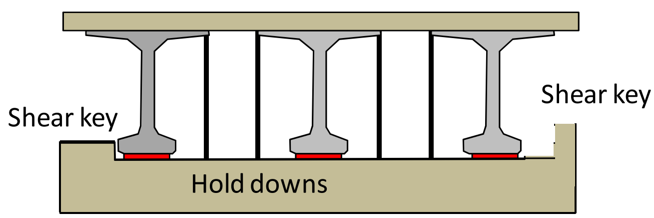

Figure 2. Schematic of the Type 2: Post 2000 design

Type 3: Post 2000 design

At some time a modification of the Type 2 design was allowed. The modification consisted in eliminating the hold down bars and the concrete shear keys, and adding steel shapes, bolted to the abutments or the pier caps, at both sides of the bottom flange of each main beam. The following are the components of the structure and the schematic of the structure is shown in Figure 3.

i) Precast, prestressed concrete beams.
ii) Concrete slab.
iii) No end concrete diaphragms between main beams.
iv) No concrete shear keys.
v) Steel shapes to provide lateral support and hold down the main beams.

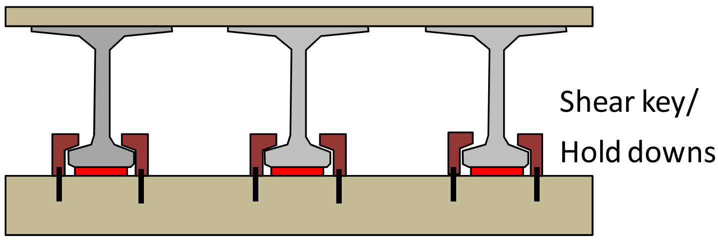

Figure 3. Schematic of the Type 3: Post 2000 design

OBSERVED DAMAGE IN OVERPASSES

In the following sections the observed damage of each type of structure is described.

Type 1: Traditional design

In Figure 4 are shown the typical damage observed in bridges Type 1: important damage of the strong shear key, as shown in the photographs of Figure 4, at the left end of the piers. It can be seen that the shear keys were large, and, even though they failed, they were able to restrict the lateral displacement of the superstructure, avoiding collapse. These overpasses and bridges were open for traffic a short time after the earthquake. Notice in Figure 4(a) that the north bridge in Americo Vespucio Norte, over Idependencia Avenue, only suffered limited lateral displacement and damage to a shear key.

(a) (b) (c)

Figure 4. Damage of Shear keys at (a) north bridge in Americo Vespucio Norte over Idependencia Avenue, (b) overpass in Costanera Norte, (c) Río Claro bridge

Type 2: Post 2000 design

This type of structure suffered large amount of damage. The damage is shown in Figures 5 through 8. In Figure 5 are shown three cases of large lateral displacement. Notice in Figure 5(a) the very thin wall used as a shear key. Also, in Figure 5(c) one main beam is barely supported vertically. In all the cases shown traffic had to be stopped until safety was insured.

(a) (b) (c)

Figure 5. Large lateral displacement at (a) a central pier, (b) an abutment, (c) an abutment. All photographs were taken at Ruta 5 Highway

Another type of damage was failure of the thin shear keys, as shown in Figure 6. Some shear keys resisted and did not collapse, holding in place the superstructure, but allowing large lateral displacements. In those cases the web of the beams bent about its weak axis, producing the failure of the web of the beams at the supports, as shown in Figure 6(a), 6(c) and Figure 7. In some cases, as in Figure 7(a), even the bottom flange of the beam failed due to bending. In all these cases traffic was stopped for a long time, until the superstructure was stabilized or the beams repaired.

(a) (b) (c)

Figure 6. Damage at shear keys and web of beams (a) wall shear key at abutment, (b) tall shear key at central pier, (c) short shear key at abutment. All photographs were taken at Ruta 5 Highway

(a) (b)

Figure 7. Damage at prestressed beams (a) failure of bottom flange and web of beam, (b) failure of beam. All photographs were taken at Ruta 5 Highway

Partial collapse of the superstructure occurred in a number of cases, with one or two beams falling over the slope in front of the abutment (see Figure 8(a)). In one case total collapse occurred, falling both spans of the bridge to the ground due to large rotations of the superstructure and the low strength of the shear keys, see Figure 8(b).

(a) (b)

Figure 8. (a) Partial collapse of the superstructure, (b) total collapse of the superstructure. All photographs were taken at Ruta 5 Highway

Type 3: Post 2000 design

This type of structure suffered large amount of damage. The damage is shown in Figures 9 through 12. In Figure 9 is shown the south bridge in Americo Vespucio Norte, over Independencia Avenue. It can be seen in Figure 9(a) that the south bridge is very close to the north bridge (about 27 m center-to-center), which suffered limited lateral displacement of the superstructure (see Figure 4(a) above). On the other hand, Figure 9(b) shows the large lateral displacement that occurred in the south bridge, which can be noticed within a white circle. Figure 9(c) shows that beams were close to lose vertical support. Steel hold-downs were not able to limit the displacement, and were destroyed by the beams. Figure 9(b) confirms that those hold downs just fell to the floor. This bridge was closed to traffic for a long time period.

(a)

(b) (c)

Figure 9. South bridge in Americo Vespucio Norte over Independencia Avenue: (a) relative location of the south and north bridges (Source: Google Earth); large lateral displacement at a central pier: (b) front view, (c) detail

Two overpasses suffered total collapse of at least one span, as seen in Figure 10. In both cases the bridges were skewed. Collapse occurred at spans supported by abutments in one end or by intermediate piers at both ends. Most probably local site effects produced amplification of the lateral displacement demands, because bridges with the same structural type located at Vespucio Sur, less than 20 km south of Vespucio Norte, did not show residual lateral displacement. On the other hand, a bridge with Type 1 structure suffered much smaller lateral displacements than a bridge with Type 3 structure located less than 30 m from the first one. This suggests that Type 3 structure was not a safe structural solution to the support of the bridges.

(a) (b)

Figure 10. Collapsed bridges in Americo Vespucio Norte highway: (a) at Lo Echevers, (b) at Miraflores

SKEWED BRIDGES – SEAT WIDTH

As discussed before, many of the bridges that collapsed in overpasses were skewed. The same was observed in bridges at other locations, like the one shown in Figure 11. In Figure 11(a) it is shown a skewed bridge, with steel beams, that collapsed at one abutment. The seat width, which was calculated in Chile using the same expressions as in AASHTO (1996), was very short, as can be seen in Figure 11(b). The bridge had also thin concrete walls as shear keys.

In the Nebuco Bridge, shown in Figure 12, which is a skewed bridge, one span collapsed. In Figure 12(b) is shown the seat width at the support of the collapsed span, which is very short.

(a) (b)

Figure 11. Bridge in Matta Av.: (a) collapsed span, (b) support at the abutment

(a) (b)

Figure 12. Nebuco Bridge: (a) collapsed span, (b) support of collapsed span

NEW SEISMIC DESIGN CRITERIA

After a survey of the damage that occurred in bridges due to the earthquake MOP published in July 2010 a set of new seismic design criteria (MOP 2010) that has to be followed when designing a new bridge. These were composed of short term provisions, to be applied to new bridges, and proposals that have to be studied and implemented in the medium and long term. Some of the new proposals to be applied immediately are described as follows.

Seat Width

The minimum length of the seat width, that was calculated using AASHTO 1996 provisions, was changed to the provisions from the Japanese Specification for Highway Bridges (JRA, 2002). These take into account the skew angle of the bridge. If the minimum calculated seat width is too long, longitudinal and lateral stoppers can be used for unseating prevention of the superstructure.

Skewed bridges

Bridges with large skew angle have to be avoided. If it cannot be avoided, the minimum value of the width to span length ratio of the superstructure, as a function of the sew angle, has to be limited in such a way that excessive lateral displacements don't occur during an earthquake. If excessive lateral displacements are expected then stoppers between all girders would be needed. These limits were taken from Fig. C-16.5.4 of The Japanese Specification for Highway Bridges (JRA , 2002).

Transverse diaphragm

All bridges, irrespective of neither their location nor the structural material used, have to have transverse diaphragms at least at the supports and at the centre. The interaction between the diaphragm and the lateral stoppers has to be calculated using acceleration equal to the maximum ground acceleration A_o.

Lateral stoppers

Lateral stoppers have to be provided at the lateral ends of the superstructure, but also at intermediate positions. The intermediate lateral stoppers have to respond as shear keys of the diaphragms, so the main beams are not damaged if the superstructure impacts the stoppers.

Some proposed provisions to be applied in the medium and long term are:

- Define new seismic design spectra and perform microzonification to avoid damage due to amplification of the seismic response because of local soil effects.

- To instrument several bridges along the country to better understand the seismic response of bridges.

- To increase the use of seismic isolation devices and dampers in structures that have irregular geometry, that are too tall, or have long spans.

- To improve the design of the vertical anchor rods (hold downs) currently used, studying the anchoring system, the quality of the steel to be used, and the posttensioning force to be applied.

CONCLUSIONS

Three types of configuration of the structure of the bridges were used in the highways built in Chile within the last 15 years. One is the configuration typically used in bridges built after 1985. The other two configurations have modifications introduced mostly after 2000. Some of those bridges collapsed and many others suffered extensive damage. It was found a pattern of damage that leads to conclude that the two configurations used after 2000 were not effective in preventing damage in bridge. En diaphragms are necessary to avoid damage of the main beams. Also, if lateral stoppers and hold downs are weak, large lateral displacements and even collapse of a span can occur. It was also observed that skewed bridges were designed and built with seat widths too short to avoid unseating of the main beams.

New seismic provisions, mostly based in the Japanese experience, were introduced shortly after the earthquake, especially to improve the deficiencies described in the previous paragraph, and are currently being enforced in projects of new bridges. The effectiveness of these design criteria have yet to be evaluated.

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SEISMIC AND WIND RESPONSE CONTROL OF BUILDINGS WITH SUPPLEMENTAL ENERGY DISSIPATION DEVICES. CASE STUDIES IN BUCHAREST

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ABSTRACT

Bucharest, one of the earthquake prone largest cities in Europe, has a large building stock fragile to earthquakes and in need of seismic rehabilitation. Also, the new high-rise buildings have to overcome large seismic and wind demands in terms of forces and displacements/accelerations. This paper presents three case studies regarding the seismic/wind protection of buildings by response control. The first case study refers to an existing reinforced concrete soft and weak groundfloor building seismically rehabilitated by response control strategy using fluid viscous dampers in the groundfloor. The second case study refers to an existing flexible reinforced concrete frame building seismically rehabilitated by using of fluid viscous dampers in the frames' openings strengthened with SRC frames on the height of the building. The third case study refers to a new high-rise steel moment-resisting frame building with very high seismic and wind demands. Especially the comfort criteria for wind induced response are very severe and cannot be accommodated efficiently without response control devices.

KEYWORDS

Earthquake, wind, control, energy, dissipation, damper.

INTRODUCTION

Romania is one of the earthquake prone countries in Europe. The first generation of enforced Romanian seismic design code was issued in 1963, as P13-63 followed by a revision in 1970 known as P13-70. The March 4 1977 Vrancea subcrustal earthquake was the milestone for completely changing the seismic design code such as to include the lessons painfully learnt at that time. The seismic design code issued after 1977 was known as P100-78 and it was revised in 1981 as P100-1981. Since then other revisions were made: P100-1990, P100-1992, P100-1/2006, the latter one being in line with the provisions of EN 1998-1. The buildings build before the first issue of the seismic design code and also the buildings designed before 1978, when P100-78 earthquake resistant design code, based on the knowledge acquired after March 4, 1977, was issued and enforced, shall be seismically evaluated and most of them retrofitted in order to comply with the current code provisions.

SEISMIC DEMAND FOR BUCHAREST ACCORDING TO P100-1/2006 BUILDING DESIGN CODE

The seismic demand for Bucharest according to P100-1/2006 Earthquake Resistant Design Code is characterized by a pair of values: (i) the design value of peak ground acceleration with 100 years mean recurrence interval, a_g=0.24g (g - acceleration of gravity), and (ii) the control/corner period of absolute acceleration response spectrum, T_c=1.6s. The large value of the control/corner period imposes high seismic demands for buildings and structures in terms of spectral velocities and spectral displacements. The elastic response spectrum of absolute accelerations for 5% damping ratio, S_e is obtained by multiplying the design value of peak ground acceleration with the normalized elastic response spectrum (with a maximum dynamic amplification factor of horizontal peak ground acceleration of 2.75). For damping ratios different of the default value of ξ=5%, the spectral ordinates are modified by a correction factor depending on the actual damping ratio used in the analysis. The elastic response spectra used in Bucharest for different damping ratios are presented in Figure 1. The design spectrum is obtained by modifying the elastic response spectrum of absolute accelerations by a structural behaviour factor depending on the type of the structural system as well as on its ability to dissipate seismic energy.

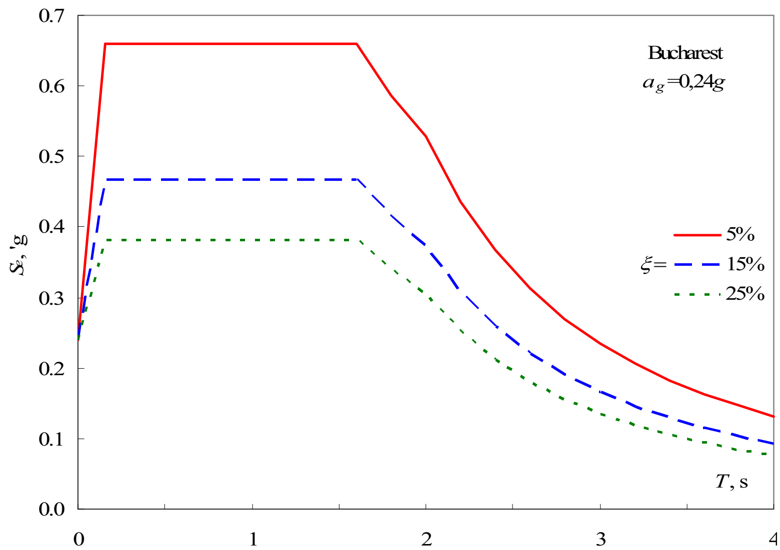


Figure 1. Elastic response spectra of absolute accelerations used in Bucharest for different damping ratios according to P100-1/2006

CASE STUDY 1 – SEISMIC REHABILITATION OF A SOFT AND WEAK GROUNDFLOOR BUILDING

The building to be seismically rehabilitated is located in the city of Bucharest, Figure 2. It was erected in 1960's, it has 11 storeys (B+GF+10S) and its main destination is residential in the upper stories and commercial in the ground floor, Figure 3. The structural system consists of reinforced concrete frames in the groundfloor, Figure 4 and RC structural walls in the upper stories, Figure 5. The ground floor is a soft and weak story, with no structural walls. The building consists of 3 parts (A, B and C). In what concerns the seismic evaluation and retrofitting, part A is under discussion hereinafter. The building A has a rectangular base of 11.42 x 32.85 m. A staircase connects the buildings "A" and "B". Amongst all 3 buildings there are joints of 3 cm. The ground floor height is 4.80m while the height of the rest of the floors is 2.73m. The soil underneath the building is made of layers of sand with gravel fractions in the medium compacted state, with a 3 daN/cm^2 conventional pressure. The building's footprint area is 380 m^2.

The RC beams sections vary from 15x55 cm up to 37.5x60 cm. The RC columns sections vary from 40x55 cm to 80x50 cm; there are also two elongated columns of 170x50cm transversally placed in the axes 9 and 10. The concrete used is B250 (equivalent to C16/20) and the reinforcing steel used is OB37 and TOR47. The structural wall thickness varies from 15 to 20 cm. The slabs are made of reinforced concrete of 8 to 11 cm in thickness. The infrastructure system consists of a rigid box in the basement with continuous foundations under all the structural elements.

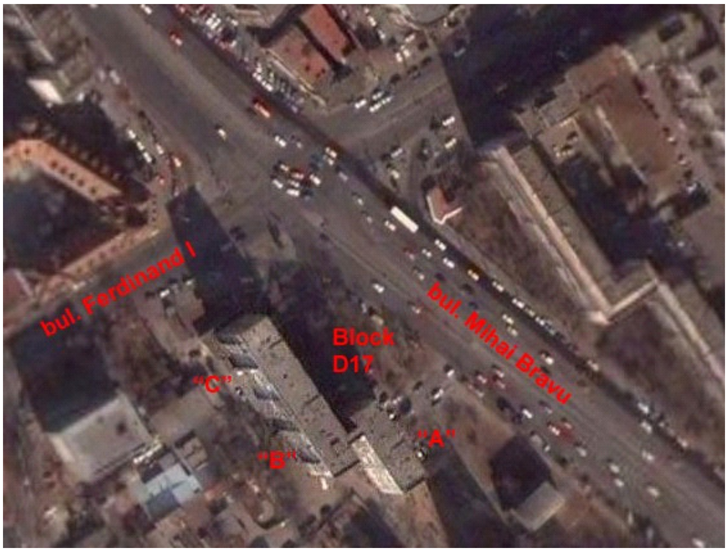


Figure 2. Satellite view of the building site (www.earth.google.com)

Figure 3. Main façade of the building A

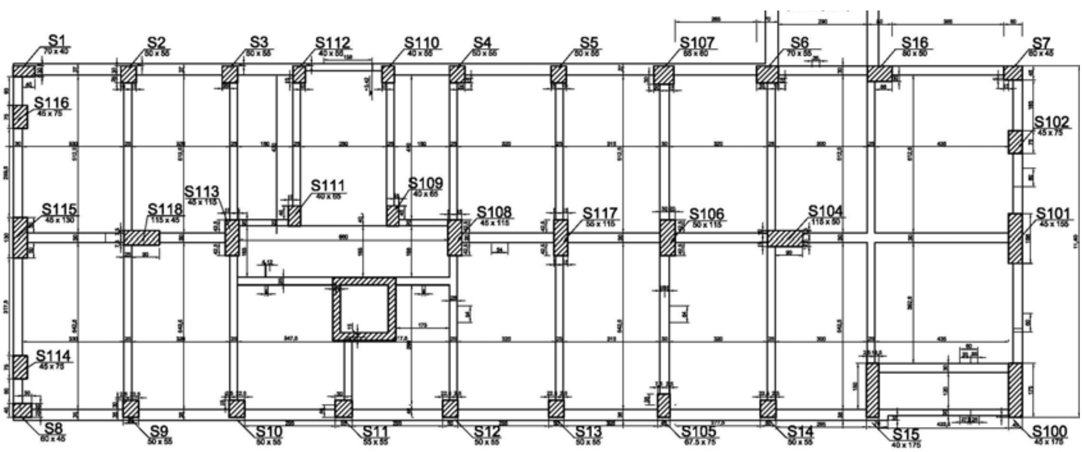


Figure 4. Groundfloor plan view

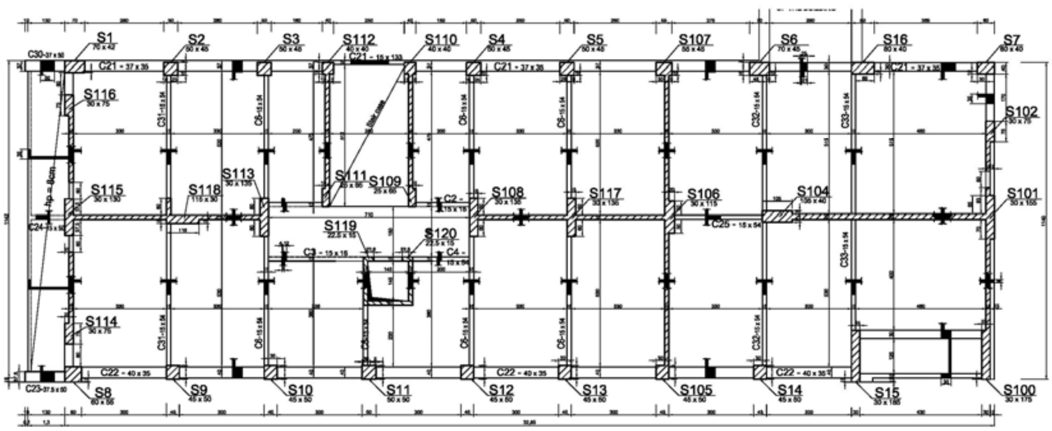
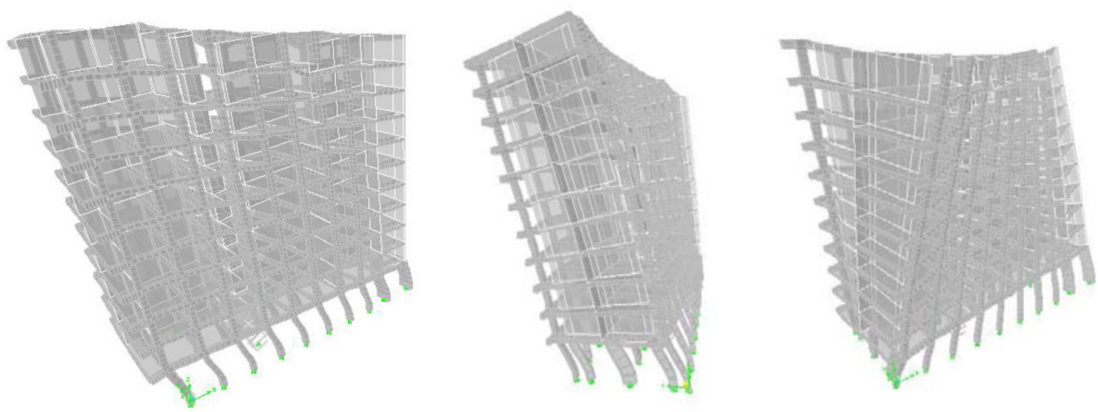


Figure 5. Plan view of current floor

Two levels of seismic evaluation were applied for the building. The first level, quantitative evaluation, revealed the weak issues of the structural system. First of all, the building typology itself is very vulnerable to earthquakes because of the soft and weak groundfloor. The transversal cross sections of the columns are generally smaller than they should be according to the current design practices for a ten-story building. The longitudinal reinforcing ratios of the columns are between 1.3 % and 1.5%, larger than the minimum recommended ratios by the structural design codes in force in Romania. However the distance between the stirrups is not reduced at the ends of the columns and not all the longitudinal bars are tied to a corner of a stirrup. The beams present an obvious reinforcing deficit in the support regions, in some cases reaching a reinforcement ratio of 0.2%; the anchors of the longitudinal bars are shorter than 40 – 50d. The shear reinforcement of the structural walls does not comply with the current structural design regulations in force in Romania. Figure 6 presents the first three eigenvalues and the eigenshapes of the building.



T_1=0.68s T_2=0.56s T_3=0.45s

Figure 6. Modal shapes and eigenvalues of the building

The second level of seismic evaluation consists in applying structural nonlinear static procedures of analysis. For the evaluation of the seismic capacity of the building several nonlinear pushover analyses were performed for each direction of the building using ETABS^{TM} computer software and SNAP computer software. Expected seismic response of the building for the design earthquake obtained using Capacity Spectrum Method is given by: spectral acceleration of 0.26g and spectral displacement of 4.5 cm. The nominal degree of seismic safety expressed in terms of displacement is 0.28 (while 1 is the value for a building designed according to the earthquake resistant design regulations in force in Romania). Details on the seismic evaluation can be found elsewhere (Vacareanu et.al., 2007, Chesca et.al., 2007).

The seismic rehabilitation solution adopted for building "A" consists of introducing fluid viscous dampers in the groundfloor, steel jacketing of the columns in the groundfloor and steel jacketing of the structural walls in the upper stories. Once the retrofitting strategy and solution was established, a detailed linear dynamic analysis of the structure equipped with linear and nonlinear fluid viscous dampers was performed using ETABS^{TM} computer software. Meanwhile, a nonlinear dynamic analysis was performed employing SNAP software.

Both for linear and nonlinear analyses of rehabilitated building, the input ground motions consist of five artificial accelerograms compatible with the elastic acceleration response spectrum from the earthquake resistant design code P100-1/2006. Figure 7 presents one artificial accelerogram and Figure 8 presents the elastic acceleration response spectra for the five artificial accelerograms, mean acceleration response spectrum for the five samples and elastic acceleration response spectrum of P100-1/2006. One may notice that for each and every period, the mean value of the spectral accelerations of the five generated accelerograms is no more than 10% less than the design acceleration value.

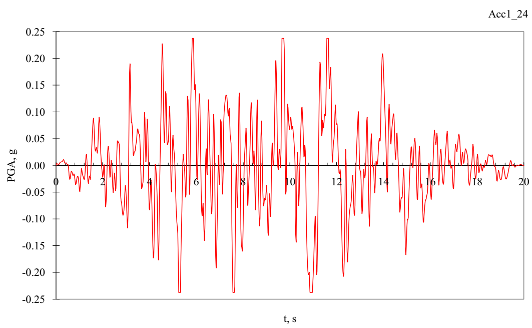


Figure 7. P100-1/2006 elastic response spectrum compatible artificial accelerogram

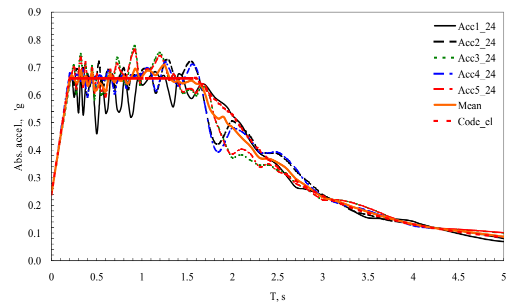


Figure 8. Response spectra of artificial accelerograms, mean response spectrum and code elastic response spectrum of absolute accelerations

The fluid viscous dampers layout was chosen taking into account the position of the upper stories structural walls. One or two dampers are placed under each structural wall. The reason for this layout is the proper transfer of the shear force between the dampers and the structural walls atop them. The dampers are placed in the openings beneath the upper structural walls. In order to avoid any supplemental forces added to the groundfloor columns, the final dampers configuration was a chevron one, with dampers placed in horizontal position, at the upper part of the groundfloor. The layout of the dampers in the ground floor is presented in Figure 9.

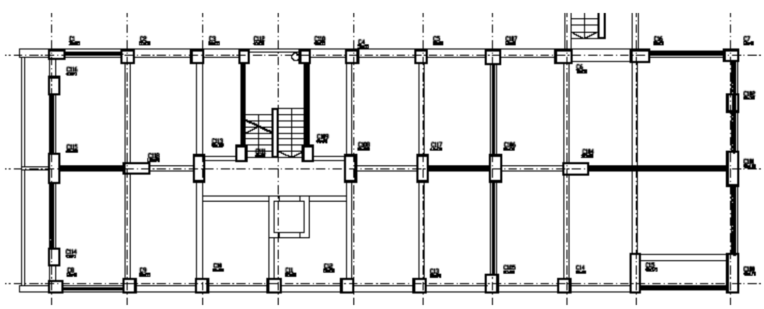


Figure 9. Damper layout in the groundfloor (solid lines)

The possible range of the damping constant is investigated according to the prescriptions of FEMA 356. Given the range previously established, linear dynamic analyses are performed and the damping constant was chosen to be *C*=20 kN*s/mm. The possibility of using nonlinear fluid viscous dampers was investigated. The nonlinear damper parameters, in term of damping constant and velocity exponent are: *C*= 250 kN*(s/mm)^0.3 and α=0.3.

Figure 10 represents the time-history of the ground floor top displacement for the building equipped with linear fluid viscous dampers and for the existing building. One may notice a 50% reduction in the maximum displacement demand as well as the reduction of the number of cycles at high amplitudes. For confirming the damper characteristics, several nonlinear dynamic analyses were performed using SNAP[TM] computer software and one of the artificial accelerograms. The analyses were performed for the existing building, for the building rehabilitated with linear dampers and for the building rehabilitated with nonlinear dampers. Figure 11 and Figure 12 presents the base shear force versus the ground floor relative horizontal displacement of the existing building and of the rehabilitated building.

Figure 13 presents the dampers connection details beneath a structural wall. Several horizontal damper connections in the same frame were analysed. The optimal solution is to connect the dampers to the middle RC column in order to avoid the connection of the dampers to tension weakened corner columns.

The other retrofitting measures consisted in steel jacketing of the ground floor RC columns and steel jacketing of the first 3 stories RC structural walls. Details on the seismic rehabilitation as well as on the evaluation of expected seismic losses for the building can be found elsewhere (Vacareanu et.al., 2007, Chesca et.al., 2007). The concept and detailed design of the seismic rehabilitation was performed within the *JICA Technical Cooperation Project on Reduction of Seismic Risk for Buildings and Structures in Romania*.

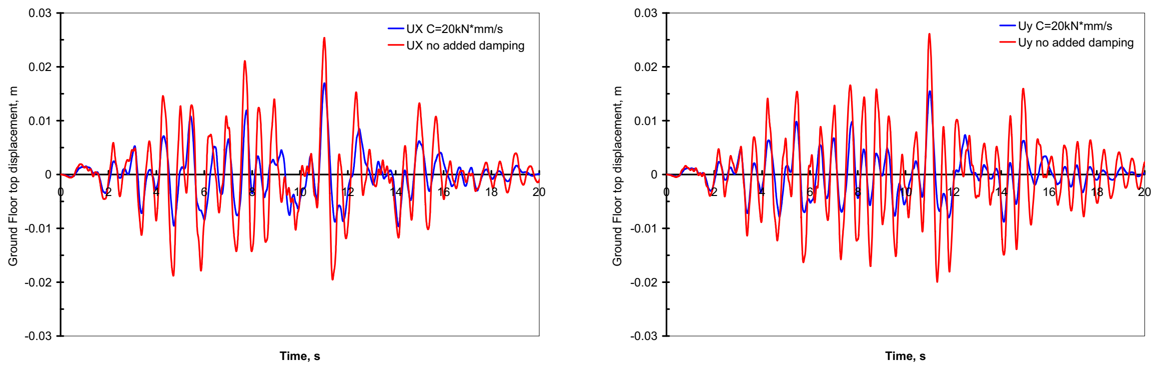


Figure 10. Groundfloor top displacement time-history for the building equipped with fluid viscous dampers and for the existing building

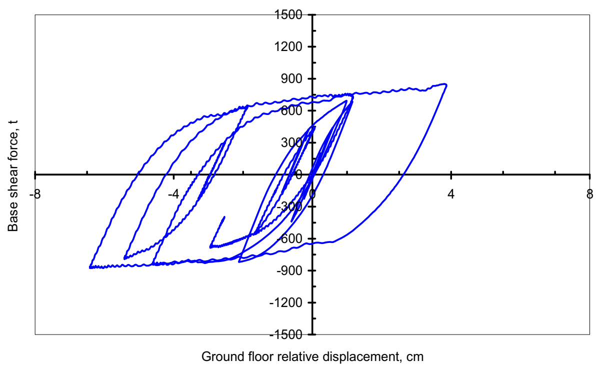


Figure 11. Base shear force versus groundfloor relative displacement -longitudinal direction of the existing building

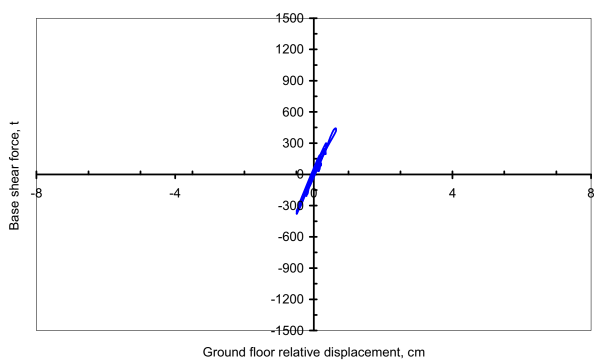


Figure 12. Base shear force versus groundfloor relative displacement on longitudinal direction for the building equipped with nonlinear dampers

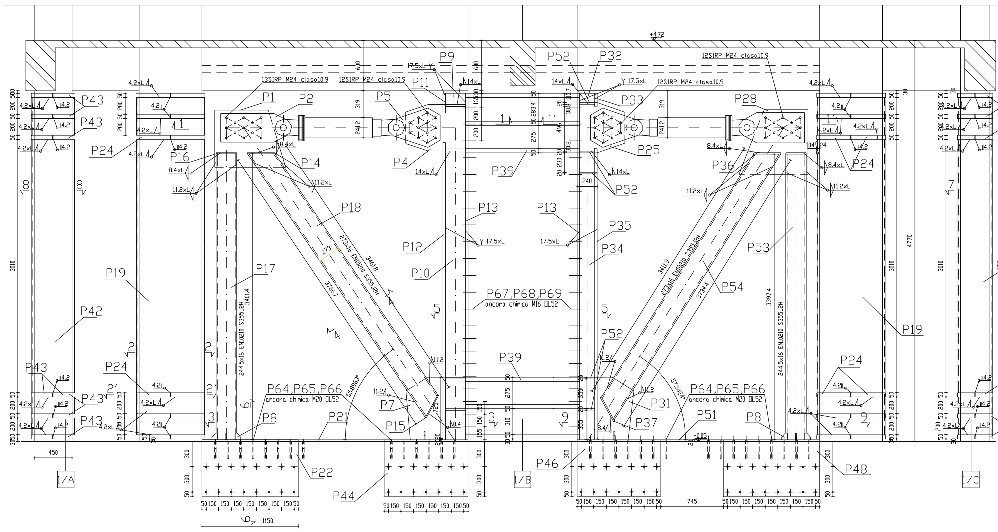


Figure 13. Damper connection detail

CASE STUDY 2 – SEISMIC REHABILITATION OF A RC FRAME BUILDING

The building to be seismically rehabilitated is located in the city of Bucharest. It was erected in 1968, it has 8 storeys (B+GF+7S) and its main destination is office building. The structural system consists of reinforced concrete frames. The building consists of 3 parts (A, B and C), parts A and C being identical, located symmetrically with respect to part B. The groundfloor height is 4.80m while the height of the rest of the stories is 2.73m. The building's footprint area is 1008 m^2. The weight of part A is 3633 t, while the weight of part B is 2809 t. The class of the concrete is C10/12.5 and the design yield strength of the steel is 210 MPa and 300 MPa.

The structural model of the existing building is presented in Figure 14. The seismic evaluation consists in applying nonlinear static procedures of analysis of structural response. For the evaluation of the seismic capacity of the building several nonlinear pushover analyses were performed for each direction of the building using ETABS^{TM} computer software. The expected seismic response of the buildings A and C for the design earthquake obtained in ETABS^{TM} is given by: yielding seismic force of 1850 kN in the transversal direction and 2360 kN in the longitudinal direction; yield displacement of 5 cm in the transversal direction and 4 cm in the longitudinal direction. The nominal degree of seismic safety is 0.26 in the transversal direction and 0.34 in the longitudinal direction (while 1 is the value for a building designed according to the earthquake resistant design regulations in force in Romania). The nominal degree of seismic safety for building B is similar.

The seismic rehabilitation solution adopted for the building consists in:

- tying together the three buildings by extending the existing RC slabs with four gusset-like RC slabs at each floor of the building and RC jacketing the adjacent columns such as to create a single column made of two existing columns; this decision is necessary because of the insufficient joints of 2 cm between the adjacent buildings and the possible pounding effects during a major earthquake;
- adding RC frames (green lines) and SRC frames (blue lines) on the perimeter of the building, Figure 15 in order to increase the stiffness and the ductility of the structural system;
- increasing the dimensions of the perimeter foundations is order to resist the seismic demands imposed by the newly added RC and SRC frames;
- steel jacketing of the existing RC columns form basement up to the fourth floor in order to increase the shear capacity of the elements;
- introducing fluid viscous dampers in the openings of the SRC frames; for buildings A and C 92 fluid viscous dampers of 750 kN with ±100mm stroke are used; for building B 64 fluid viscous dampers of 1000 kN with ±100mm stroke are used;
- jacketing of existing partition walls using carbon fibre sheets applied on both sides of the walls.

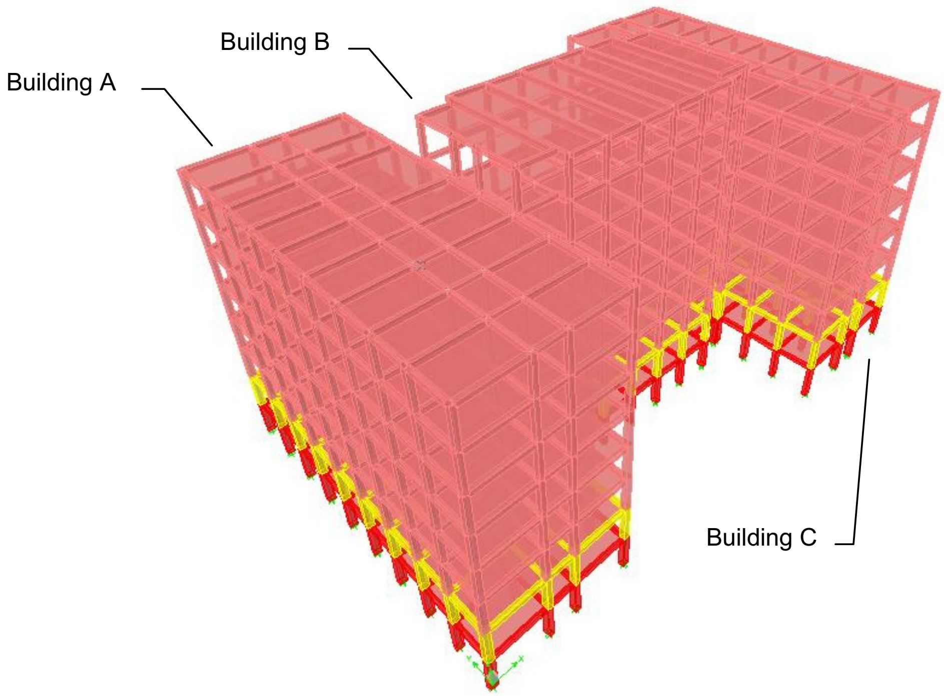


Figure 14. Computer model of the existing structural system

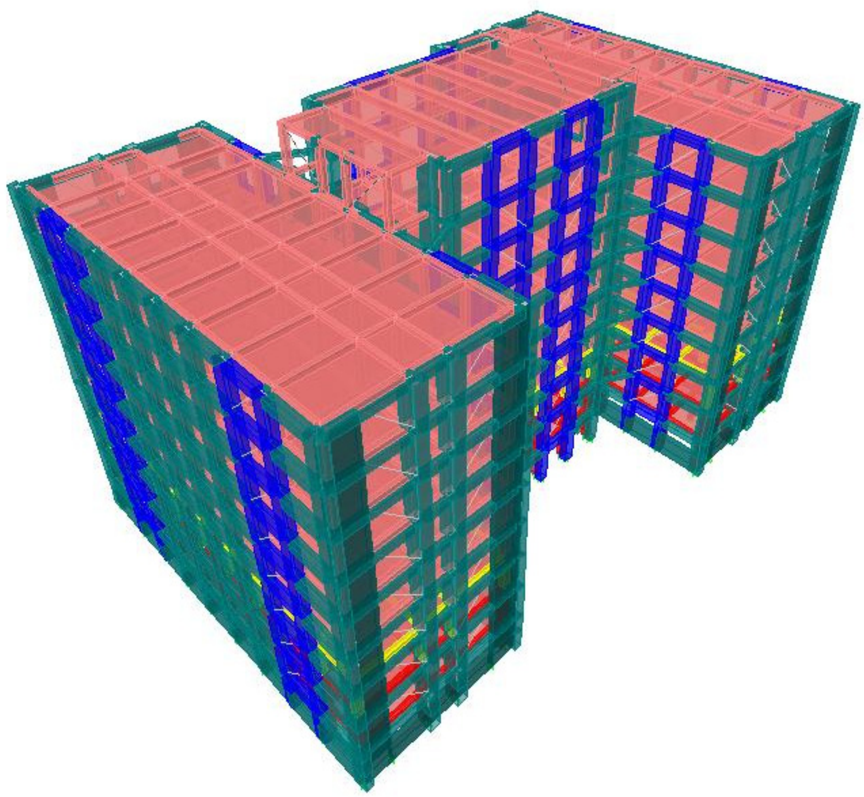


Figure 15. Computer model of the seismically rehabilitated structural system

Once the retrofitting strategy and solution is established, a detailed linear dynamic analysis of the structure equipped with linear fluid viscous dampers is performed using ETABS^{TM} computer software. For the linear dynamic analyses of rehabilitated building the input ground motions consist of seven artificial accelerograms compatible with the elastic response spectrum of absolute accelerations given in earthquake resistant design code P100-1/2006, Figure 16. A sample accelerogram with peak ground acceleration of 0.24*g* (design peak ground acceleration for Bucharest) is given in Figure 17. The ordinates of the artificial accelerograms are multiplied with the earthquake importance and exposure factor of 1.4 imposed by P100-1/2006 earthquake resistant design code for Category I (most important) buildings. The seismic response analysis is conducted using a behaviour factor of 4.

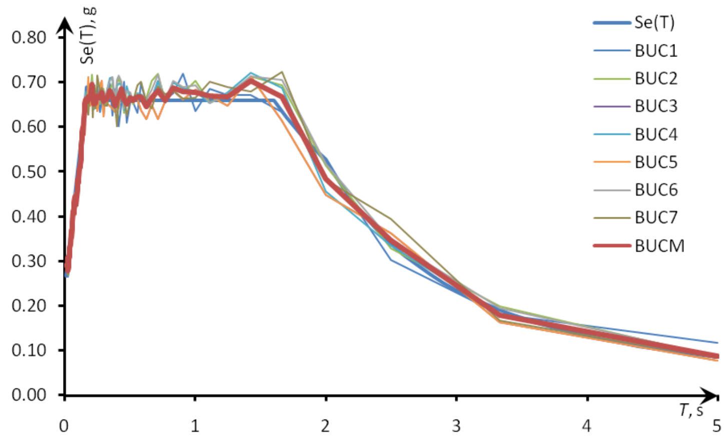


Figure 16. Target elastic acceleration response spectrum $S_e(T)$, elastic acceleration response spectra of the artificial accelerograms *BUC*1...7 and average elastic acceleration response spectrum *BUCM*

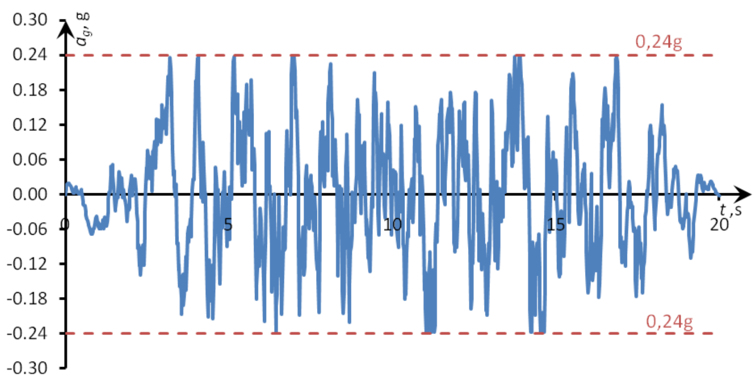


Figure 17. P100-1/2006 elastic response spectrum compatible sample accelerogram

An overall supplemental damping ratio of 25% is considered for enabling a proper expected seismic response of the building. The fine tuning and optimisation of the damping constants revealed that nonlinear viscous dampers with the velocity exponent of 0.5 are the most appropriate for achieving the target performance objective for the buildings. The damping constants are in the range 1800-5000 [kN*(s/m)$^{0.5}$].

The main results of the linear dynamic analyses of building A are given in Figures 18-21. One may notice the reduction of the displacement demand by more than 50% for the seismic rehabilitated building and the very limited post-yield incursions of the rehabilitated structural system. Improvements of the expected seismic response are also obtained for building B.

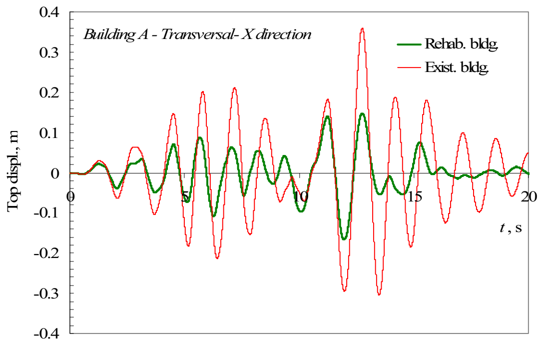


Figure 18. Top displacement time-history – transversal direction

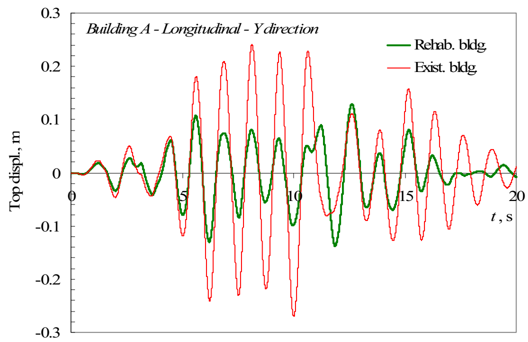


Figure 19. Top displacement time-history – longitudinal direction

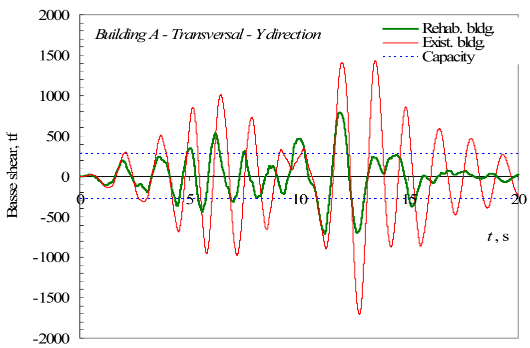


Figure 20. Base shear force time-history – transversal direction

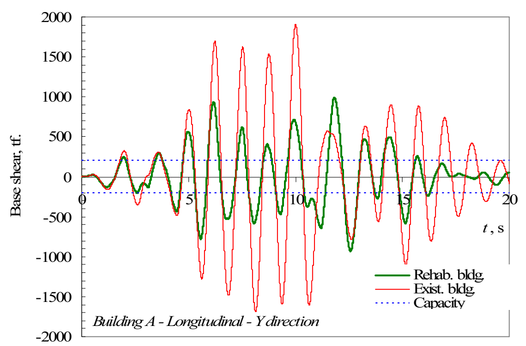


Figure 21. Base shear force time-history – longitudinal direction

Due to seismic rehabilitation of the buildings the nominal degree of seismic safety increases at 0.75 in the transversal direction and 0.73 in the longitudinal direction for building A and at 0.77 in the transversal direction and 0.78 in the longitudinal direction for building B. The minimum nominal degree of seismic safety permitted by the seismic rehabilitation design code P100-3/2008 after seismic rehabilitation is 2/3.

CASE STUDY 3 – RESPONSE CONTROL OF A HIGH-RISE STEEL BUILDING

The moment-resisting frame steel building is 37 stories in height over the terrain (one ground floor, seven mezzanine floors, 28 typical stories and one top floor). The typical floor height is 3.55m; the groundfloor and top floor are 3.85 m and 6.6 m in height, respectively (Figure 22 and Figure 23). The occupancy of the building is mainly for offices.

The columns are made of double I steel section (Malta cross section) with 1000 mm section height and different web and flange thickness. The beams are made of HEA and HEB steel section. Stories 9&10 and 25&26 are conceived as rigid stories with stiff steel trusses. The slabs are made of reinforced concrete supported on secondary steel beams and steel decks.

Due to the height of the building, very severe seismic and wind demands are imposed to the building. The seismic response as well as the wind-induced response of the building revealed violation of the criteria for the ultimate limit state in case of earthquake and for the serviceability limit state in case of wind action. Because of the very tough functional and occupancy conditions and because of land use limitations, no further refinements of the shape of the building in the vertical and horizontal directions were allowed. Furthermore, the cross-sections of the columns could not be increased because of the limitations of the available sections. Hence, the adopted strategy is to control the response of the building by energy dissipation devices added to the structural system of the building. The option of the designer is to use fluid viscous dampers with nonlinear behaviour, because of the better performance in case when both seismic response and wind-induced response are in need of control/mitigation. The solution for introducing the supplemental energy dissipation devices is to replace some steel braces with viscous dampers in the transversal direction and to insert two new brace lines in the longitudinal direction. The characteristics of the viscous fluid dampers are: 2000 kN capacity, velocity exponent α=0.3, stroke = ± 100mm. Overall, 64 dampers of 2000 kN are to be used in the structural system of the building.

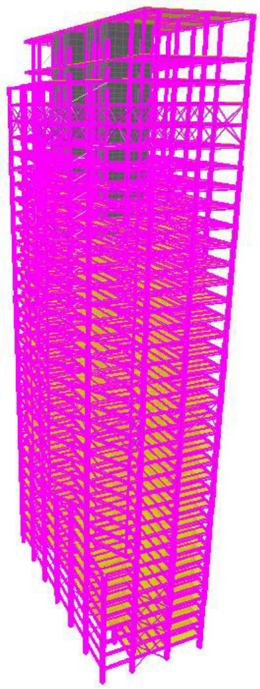


Figure 22. 3D view of the building model

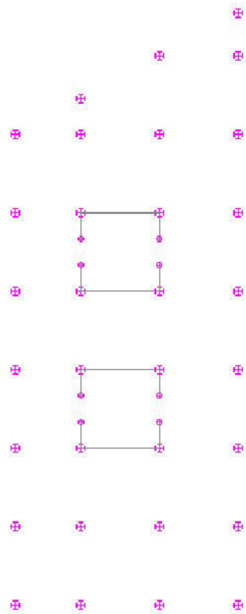


Figure 23. 2D view of the building model

The characteristics of the fluid viscous dampers are obtained through linear dynamic analysis of the seismic response of the building using artificial accelerograms and increasing overall damping ratios. The input is the suite of 5 artificial accelerograms described previously for case study #1, increased by the earthquake importance and exposure factor of 1.2 (Category II building) because of the very high occupancy of the building in terms of number of occupants. The seismic response analysis is conducted using a behaviour factor of 1.5, thus considering that the building behaves rather elastically and the seismic energy dissipation takes place within the system of fluid viscous dampers. The overall drift ratio of the building for the ultimate limit state is 0.8%-0.9% and the maximum story drift ratio is 1.2%-1.3%, thus complying with the criteria set forth in P100-1/2006 Earthquake Resistant Design Code.

Once the criteria for ultimate and serviceability limit states are fulfilled for the seismic response of the building, the solution is further refined for complying with the comfort criteria in the case of wind action. The wind conditions for Bucharest are described in the Romanian Code NP082-2004. According to the regulations in force, the reference wind velocity at 10 m above the open terrain averaged on 10 minutes and with 50 years mean recurrence interval for Bucharest is 29.4 m/s and the reference wind velocity pressure is 0.5 kPa. The roughness of the terrain around the building corresponds to category III (EN 1991-1-4). The total height of the building is 135 m and the reference height of the building is 81 m. The first eigenperiod of the building is 3.11 s. The mean wind velocity at the reference height is 36.2 m/s and the fluctuating wind velocity at the same height is 21.3 m/s. In order to check the efficiency of the dampers in mitigating the wind-induced response, linear dynamic analyses of the behaviour of the building in turbulent along-wind direction are performed. The dynamic input for the analysis is represented by three samples of total wind force time-history applied at the reference height of the building. Time history samples of fluctuating wind velocity of 600 s duration are generated such as to fit the power spectral density function of along-wind gustiness adopted in EN 1991-1-4 and NP082-2004, Figure 24. Examples of time histories of fluctuating wind velocity, total wind velocity, total wind-velocity pressure and along-wind force at the reference height of the building in X and Y direction are presented in Figures 25-29. The aerodynamic force coefficient used in the analysis is 1.3. In order to check the comfort criteria, the wind action is scaled down from a mean wind velocity with 50 years mean recurrence interval to a mean wind velocity with 10 years mean recurrence interval. The scaling is performed considering the Gumbel distribution for maxima of the maximum annual wind velocity and the scaling factor is 0.75.

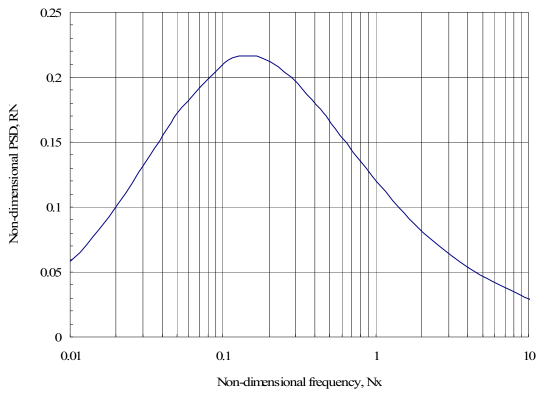


Figure 24. Power spectral density function

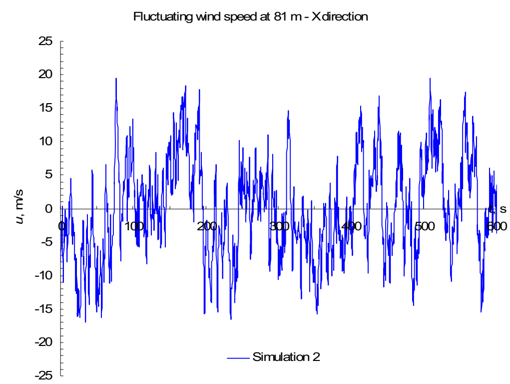


Figure 25. Fluctuating wind velocity at 81 m

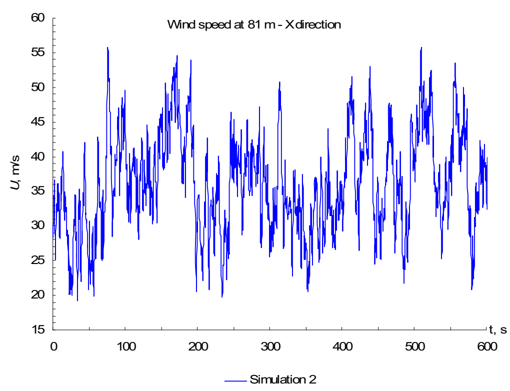


Figure 26. Total wind velocity at 81 m

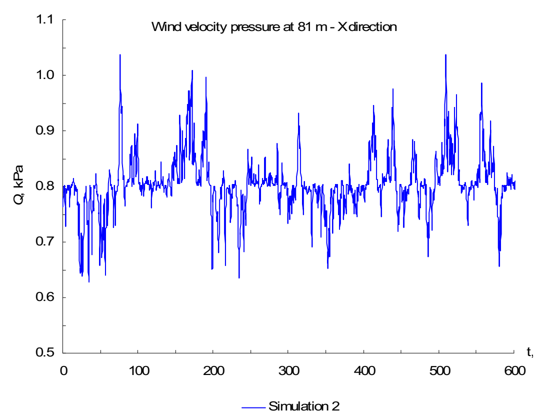


Figure 27. Total wind velocity pressure at 81 m

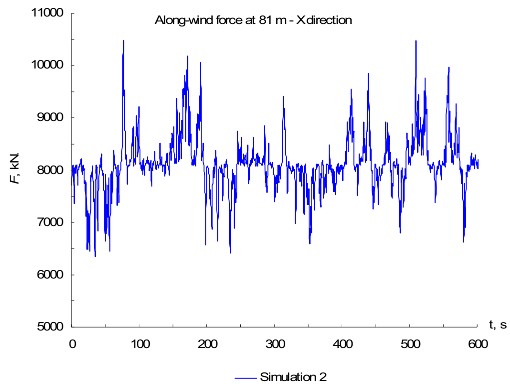


Figure 28. Along-wind force at 81 m – X direction

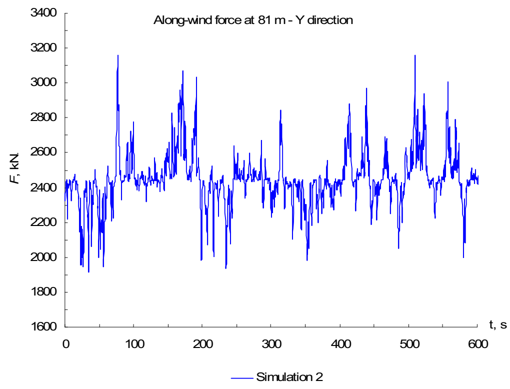


Figure 29. Along-wind force at 81 m – Y direction

The maximum values of response parameters obtained through linear dynamic analyses for both wind and seismic actions are presented in Table 1.

Table 1. Maximum values of response parameters for seismic action and wind action

Parameter	Structure with nonlinear dampers		Reduction factor damped/ undammed	
	X	Y	X	Y
Top floor seismic displacement, *MRI*=100 years [m]	0.80	0.69	0.90	0.95
Top floor seismic acceleration, *MRI*=100 years [m/s^2]	5.77	4.98	0.90	0.70
Seismic base shear force, *MRI*=100 years [kN]	65040	58673	0.67	0.70
Top floor wind displacement, *MRI*=50 years [m]	0.23	0.08	0.91	0.75
Top floor wind acceleration, *MRI*=50 years [m/s^2]	0.26	0.10	0.79	0.60
Top floor wind displacement, *MRI*=10 years [m]	0.13	0.05	0.91	0.75
Top floor wind acceleration, *MRI*=10 years [m/s^2]	0.15	0.06	0.79	0.60
Wind base shear force, *MRI*=50 years [kN]	24830	7621	0.87	0.81

The wind-induced response analysis is checked against comfort criteria for the serviceability limit state given a wind velocity with 10 years mean recurrence interval. The comfort criteria considered are set forth within the [*CNR-DT 207/2008 - Istruzioni per la valutazione delle azioni e degli effetti del vento sulle costruzioni*]. According to the previously mentioned document, the limit of accepted horizontal acceleration is:

$$a_{lim} = \begin{cases} \dfrac{a_0}{n_{1,x}^{0,56}} & \text{if } n_{1,x} < 1\text{Hz} \\ a_0 & \text{if } 1\,\text{Hz} \le n_{1,x} \le 2\text{Hz} \\ 0{,}5 \cdot a_0 \cdot n_{1,x} & \text{if } n_{1,x} \ge 2\text{Hz} \end{cases} \tag{1}$$

where:

a_0 = 6 cm/s^2 for office buildings;
a_0 = 4 cm/s^2 for residential buildings;
$n_{1,x}$ is the first eigenfrequency of the building in the along-wind direction.

The comfort limit of the horizontal acceleration based on Eq. 1 is 0.12 m/s^2. The maximum value of top floor wind acceleration in X direction of 0.15 m/s^2 exceeds the comfort limit but it is obtained under the assumption of perfect correlation of peak values of the wind velocity pressure on the facade of the building. The uncorrelated gusts on the very large facade will produce a 15-20% drop in the overall response permitting the fulfillment of the comfort criteria for the serviceability limit state.

CONCLUSIONS

The seismic rehabilitation solutions presented in this paper provides good results for the seismic rehabilitation of existing soft and weak ground floor buildings and flexible buildings in Bucharest. The merit of the solutions consists in fewer disturbances for the occupants of the buildings and less intervention in the structural system of the buildings. The employment of the fluid viscous dampers in the buildings provides supplemental energy dissipation. Usually, viscous dampers for seismic rehabilitation of moment resisting frames requires special attention to be paid to their contribution to the columns' axial forces, but for this buildings, the solution is to use steel jackets for the columns adjacent to the fluid viscous dampers. The damper configuration is chosen in such a way as to use as much as possible the interstory velocity and to minimize the supplemental axial force to be induced in the columns. The employment of the supplemental energy dissipation device proved to be efficient also for the wind & earthquake response control of a high-rise moment-resistant steel building.

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TAISHIN PROJECT IN EL SALVADOR

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ABSTRACT

El Salvador is a prone earthquake country. The most recent seismic disaster occurred on 2001, when two earthquakes (January 13th and February 13th) caused the collapse of many houses throughout the country. In order to reduce the seismic risk of the country promoting earthquake-resistant construction technologies for housing, the government of El Salvador requested technical cooperation to the government of Japan. TAISHIN project started in 2003 with the collaboration of the Japanese International Cooperation Agency (JICA), the technical collaboration of Building Research Institute (BRI) and National Center for Disaster Prevention of Mexico (CENAPRED). In El Salvador, the project is under the coordination of the Vice-Ministry of Housing and Urban Development (VMVDU) with the participation of the Salvadorian Foundation for Development and Minimum Housing (FUNDASAL), Universidad de El Salvador (UES), Universidad Centroamericana Jose Simeón Cañas (UCA) and the Salvadorian Institute of Construction (ISC). Two main facilities have been built in El Salvador: one laboratory to conduct tests on natural-scale walls (in plane behavior of walls) and one tilting table to evaluate the out-of-plane behavior of houses (especially for earthen constructions or brittle materials). The main objective of this project is to develop and disseminate enhanced materials and construction methods to improve the earthquake-resistant capabilities of low-cost popular housing in El Salvador. Results are expected to improve the current guideline provisions for housing. The technical information will be disseminated trough the guidelines and manuals of construction for workers.

KEYWORDS

TAISHIN project, low-rise masonry constructions, house construction guidelines, institutional strengthening.

INTRODUCTION

El Salvador is the smallest (21,040 km^2) and at same time the most densely populated country (293/km^2) of the Spanish speaking countries in the American Continent (***Figure 1***).

Figure 1. Location of El Salvador (Google Earth)

The country is affected by two main sources of seismicity. Parallel to the coastal area is the region where the Caribbean plate subducts the Cocos Plate. During the twentieth century, the strongest earthquake generated in front of El Salvador coastal area occurred on 1917, with a magnitude Ms of 7.8 and a focal depth between 45 and 60 km. In 1982, at the same region, an earthquake with magnitude Ms of 7.3 caused landslides and widespread damage in adobe and bahareque houses. Similar characteristics occurred during the earthquakes occurred in 2001, however, a larger number of casualties were reported compared with the casualties registered in 1982.

The second seismic source is related to the volcanic region which extends along the country. Due to their shallow hypocenters and their epicenters located close to the populated areas, these earthquakes have caused more destruction than larger magnitude earthquakes in the subduction area. San Salvador the capital city has been affected by many of these local earthquakes. The most recent occurred in 1986, when a local earthquake with magnitude Ms 5.4 caused the collapse of many buildings in the capital.

Besides the amount of casualties by the seismic activity, the main impact after earthquakes is the significant proportion of population which becomes homeless or continues living in damaged houses.
This paper describes the current situation of house constructions in El Salvador and the efforts to improve the constructive practices traditionally used in the country.

MASONRY CONSTRUCTIONS IN EL SALVADOR

As most of the Latin American countries, masonry constructions are widely spread along the country, especially for housing. However, codes did not include guidelines for this type of constructions until 1994. Officially, since 1966 (after an earthquake in 1965 destroyed the capital city) El Salvador adopted the Construction Regulations used in Acapulco, Mexico. However, the seismic design code was rarely applied. After the 1986' earthquake in San Salvador, a new modification was conducted to improve the technical regulations, including technical requirements for house construction, specifically for one and two floor buildings, which are the most common typical configuration for housing in the country. The technical information has not been properly disseminated to local governments or to the people in general, and their contents of the guideline are oriented for engineers. Besides, the application of guidelines is not enforced by local governments and its implementation depends on the area of construction of the house.

Type of house constructions

As mentioned before, housing in El Salvador are typically one or two story buildings. At the roof level, the use of flexible diaphragms is the most common constructive practice. Except for urbanizations, individual constructions are carried out by local workers specialized in constructions. Only for very exceptional cases, the house construction is carried out with the design or supervision of civil engineers or architects. The most common type of constructions used by workers can be summarized as follows:

Earthen construction (adobe and bahareque)

Soil always has been used as construction material. Some evidences of the construction techniques before the European colonization in America (1492) have been found during excavations in archeological sites in El Salvador. ***Figure 2*** shows the type of constructions founded under layers of volcanic ash in Joya de Cerén (UNESCO World Heritage since 1993). The constructive system is known as bahareque and consists of a mesh constructed with cane which was casted with mud (***Figure 2***).

This type of construction has been modified through the years, especially on the internal reinforcement configuration which includes the use of wooden trusses filled with soil or clay bricks. Unfortunately it is difficult and expensive to find good quality wood in the country and lifespan of houses is limited.

One of the main NGO (Non-Governmental Organization) in the country, the Salvadorian Foundation for Development and Minimum Housing (FUNDASAL) has been promoting the construction of the original system, named as Bahareque Cerén.

Figure 2. Archeological site Joya de Cerén.

After the European colonization in Latin America, adobe construction was widely implemented. Adobe construction consists of sun dried bricks joined with mortar, both fabricated with a mixture of soil and water. In a traditional adobe construction no reinforcement is included.

Based on the census conducted on 2007, these earthen constructions represent almost 20% of the total number of houses in El Salvador. Most of the earthen constructions are concentrated on the rural areas, being more common the adobe constructions (15% of the total percentage).

As FUNDASAL, some NGO have tried to implement the installation of reinforcement and additional geometrical features for adobe constructions. Except for some older constructions (as churches and houses in the urban areas), the common practice for adobe and bahareque is limited only for one-story dwellings.

Fired clay brick confined masonry

Besides earthen construction, confined masonry using fired clay bricks is one of the most typical constructions used in the rural areas. However this type of constructions can be found spread throughout urban areas.

Due to environmental issues, the production of fire clay bricks is being promoted to disappear. As a common practice, artisan ovens are used to fire the bricks during three or four days, requiring big amounts of wood and polluting the air with considerable amounts of smog. As an option, the use of sun dried bricks constructed with soil stabilized with small amounts of cement will be promoted.

The common practice used by laborers for confined masonry is not reflected in the current guidelines. In El Salvador, the common practice for single floor houses is to add an extra horizontal concrete element at the center of the walls (***Figure 3***). This element is known as "*solera intermedia*" (intermediate beam) which is prolonged from the bottom of the windows openings as a continuous element on the walls.

Figure 3. Intermediate beam used in confined masonry in El Salvador

Hollow concrete block.

For multiple house projects, concrete block construction is the widely used by construction companies, due to the low time required for construction. Hollow concrete blocks follow the specifications described by the ASTM, although low quality blocks can be found, due to the existence of small local companies which produce blocks. Depending on the experience of workers, the construction of concrete block houses is similar to the construction of confined masonry, using intermediate concrete elements to confine the concrete blocks (***Figure 4***). Besides the hollow concrete block quality, one of the main problems for this type of constructions is how to keep uniform the grout and joint mortar quality.

Figure 4. Intermediate beam used in hollow concrete block construction in El Salvador

RESEARCH ACTIVITY

Technical researches about these types of constructions have been basically conducted by Universities through the development of graduation thesis. Most of the theses related to masonry construction developed by Universities are related to constructive details, as mortar or brick quality using local materials. Some other researches about quality control during constructions or development of alternative construction techniques have been undertaken by some NGO and private companies. The seismic behavior of the constructive systems had not been studied before 2004 due to the lack of facilities in the Universities. As an example, before that time, the equipment to conduct tests at the School of Civil Engineering (since 1954) at the national university, Universidad de El Salvador (founded on 1841) consisted on a universal testing machine used to evaluate mechanical properties of materials. Most of the equipped laboratories were related to soil analysis and quality of materials.

Considering the damages occurred in dwellings during the 2001 earthquakes, El Salvador asked for technical assistance to Japanese Central Government through JICA. Considering the experiences accumulated by Mexico through CENAPRED (National Center for Disaster Prevention), Japanese Central Government decided to start a project in order to improve the quality of the constructive systems traditionally used by the population. The project is known as TAISHIN and its main goal is the dissemination of constructive practices which increase the seismic resistance of dwellings.

Taishin project

The Project “Enhancement of technology for the construction and dissemination of popular earthquake-resistant housing” (known as TAISHIN project) is a trilateral technical cooperation project jointly undertaken by the governments of Japan, Mexico and El Salvador in accordance with an exchange of agreements signed in November and December, 2003. The main objective of this project is to develop and disseminate enhanced materials and construction methods for the strengthening of the seismic-resistant capabilities of low-cost popular housing in El Salvador. Japanese Central Government through the Japanese International Cooperation Agency (JICA) contributed with equipment and training of Salvadorian professionals in Japan for the implementation of the project. Mexican experts visited frequently El Salvador to share experiences on structural testing.

Two main facilities have been constructed in El Salvador: one laboratory to conduct in-plane tests on walls (a reaction system to evaluate in-plane behavior of walls) and one tilting table to evaluate the out of plane behavior of houses (especially for earthen constructions or brittle behavior materials). The improvement of laboratories in Universities allows establishing a permanent research on these types of constructions and the improvement on the educational background of students.

The project has been divided in two phases. The initial phase started in 2004 and finished at 2008. A new extension of the project was approved by JICA starting in 2010, planned to finish at the end of 2013. The construction of the reaction system was conducted during the first year of the project (***Figure 5***). The construction of the tilting table (***Figure 6***) was finished in 2006 during the research of adobe constructions.

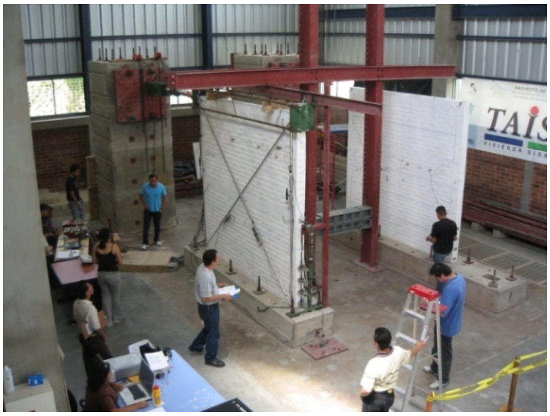

Figure 5. Reaction system donated by JICA.

Figure 6. Tilting table system constructed in UES.

During the first stage of the project, the main constructive systems previously detailed were investigated. The main points evaluated in each system are described as follows:

Adobe constructions

In order to improve the behavior of adobe constructions, a new constructive technique for new houses is being studied. The modification includes the use of internal reinforcement and buttresses to improve the out of plane behavior of adobe walls. In order to evaluate the improvement of internally reinforced adobe constructions a series of experiments were conducted. The comparison was conducted by testing unreinforced and reinforced specimens against lateral loads on a tilting table (***Figure 7***).

Figure 7. Test on adobe houses

Confined masonry

The current practice used in the country for this type of construction involves the manufacturing of fired clay bricks, which produce pollution and deforestation. During this research, the use of bricks constructed with soil and cement as substitute of traditional bricks was studied. At same time, because the guideline does not specify the use of the intermediate beam in walls (as used by workers), the evaluation of the improvement of the in-plane behavior of walls when the intermediate beam is included was studied (***Figure 8***).

Figure 8. Test on confined masonry wall

Reinforced concrete hollow block construction

Because the materials used in this constructive system are mostly industrialized, concrete block construction becomes the easiest system to replicate, especially for multiple housing projects. The parameters described in the guideline for this kind of constructions were evaluated, as the distribution of internal reinforcement (horizontal and vertical). The experimental proposal consisted to evaluate the recommended separation of vertical reinforcement, which could diminish the cost of constructions (***Figure 9***).

Figure 9. Test on hollow concrete block wall

FUTURE WORKS

The second phase of TAISHIN project is under execution until December 2012. Main objective of the second phase is aimed to check and improve the provisions described on the special guidelines for house construction. The goal is to provide to the population with simplified procedures to construct one-story houses less than 50 square meters. To fulfill this purpose, a new guideline for confined masonry and hollow concrete block is under development. At same time, the current provisions for adobe constructions are being revised, implementing the results obtained in the phase 1.

Adobe constructions guideline existed in El Salvador since 1946 as a presidential decree. However, the provisions were oriented to unreinforced adobe masonry. One of the purposes for adobe constructions is the enforcement for new constructions to include vertical and horizontal reinforcement, besides the use of buttresses at the center and intersection of walls.

The technical information of confined, hollow concrete block and reinforced adobe masonry will be disseminated trough the guideline and manuals of construction for workers.

DISSEMINATION OF RESULTS

Different institutions from El Salvador are participating actively in TAISHIN project. The national university (Universidad de El Salvador) and the main private university (Universidad Centro Americana "Jose Simeon Canas") are providing the personnel (civil engineers and architects) for technical research of the project. FUNDASAL, the most experienced NGO provides the experience in the development of local projects through the self-construction modality, allowing the population to construct the houses in communities. The Vice Ministry of Housing and Urban Development (VMVDU) represents the legal and official counterpart of the project. Through this organism, the dissemination of the technical information will be conducted through practical manuals to workers and municipalities. Municipalities and regional offices will be trained to offer technical support to the population.

The material developed during the first stage of TAISHIN has been distributed in some of the municipalities (***Figure 10***). The material describes, based on the technical results obtained by the researchers, good practices of construction for the studied systems.

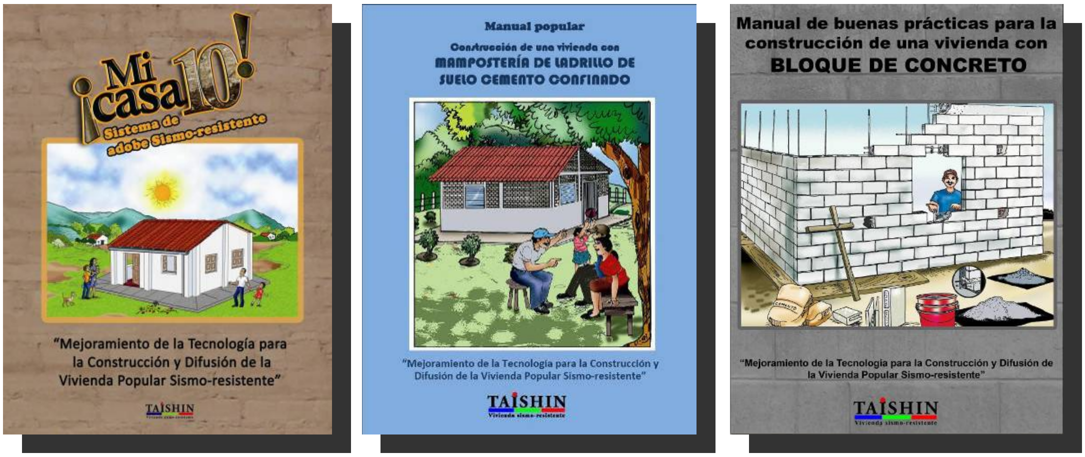

Figure 10. Material distributed to the population

As mentioned before, one of the key points to disseminate and enforce the provisions described in the guidelines is the strengthening of the governmental institutions, responsible for the legality of the constructions in the country. Compared with phase 1, TAISHIN project in phase 2 is including the institutional strengthening component, to increase the technical skills of the officers.

CONCLUSIONS

The current efforts to improve the situation of housing in El Salvador allow the development of safe constructive techniques for housing. The main results can be summarized as follows:

1. Before 2004, the investigations about seismic behavior of structures in El Salvador depended on bibliographical investigation made in other countries. With the construction of laboratories and throughout the training and experiences exchange with Japanese and Mexican experts, El Salvador can contribute to enhance their own construction systems.

2. The support of JICA has included the exchange of experiences with Mexican and Peruvian experts, which allows in the future sharing and comparing the technical results, considering that Latin America uses similar constructive systems.

3. In Central America, El Salvador becomes the main reference for this type of researches. In 2012, through a new JICA project, El Salvador will support technically to Nicaragua, offering technical training for civil engineers and students.

4. Through the use of laboratories in universities and with the support of government and/or private companies, a plan for permanent research can be developed through the incorporation of students who are developing research or thesis.

5. The training of engineers or specialists involved in the project has been developed through JICA courses in different institutions in Mexico, Peru and Japan. Building Research Institute (BRI) has provided the training for the engineers in the seismic engineering area. The participants are involved as professors at the Universities, which improves the quality of the education in seismic engineering issues.

ACKNOWLEDGMENTS

The TAISHIN project would not have been possible without the kind support of JICA in El Salvador and all the technical collaboration of the experts from Building Research Institute (BRI) of Japan and Centro Nacional de Prevención de Desastres (CENAPRED) of Mexico. All the technical and empirical support of researchers, experts, workmanship and collaborators involved during TAISHIN project is gratefully acknowledged.

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IMPROVING DISASTER MITIGATION TECHNOLOGIES IN PERU

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ABSTRACT

In the last 10 years, after 2001 Atico Quake, improving disaster mitigation technologies in Peru has been develop through several initiatives in the country explaining for the decision maker and authorities the importance of the knowledge of the seismic risk prior an event. This paper introduces the Japan-Peru earthquake and tsunami disaster mitigation research project sponsored by JICA and JST. This project has been developed under the join cooperation program between The University of Chiba of Japan and The National University of Engineering of Peru. This cooperation has been supported by JST trough JICA. The project consider develop of research activities by five groups joined by research activities: G1) Strong motion and seismic microzonation; G2) Tsunami simulation and countermeasures; G3) Seismic resistance of buildings; G4) Spatial information database and earthquake damage assessment; G5) Earthquake and tsunami disaster mitigation plan. Each of the groups are integrated by Japanese and Peruvians researchers from prestigious Universities from both countries. Among the members of the groups researchers from IISEE-BRI and CISMID are working together in the experimental field of structure evaluation. The presentation will consider some of the advances in the project developed by the Peruvian side.

INTRODUCTION

At 3.33 p.m. on Saturday June 23rd 2001 an earthquake of magnitude 8.4 Mw with intensity VII MM shock the cities of Arequipa, Moquegua, Tacna and Ayacucho. The earthquake shakes cities on Puno, Cuzco and north part of Chile and Highland Bolivia. According with Peru's Geophysical Institute (IGP), the epicenter was reported between the coast of Arequipa and Moquegua, in latitude –16.08 degrees and longitude –73.77 degrees with a depth of 33 Km., near Atico city. Civil Defense organization (INDECI) reports causalities and damage in the three main affected zones in Table 1.

Table 1: Damage and causalities on Atico quake

	Arequipa	Moquegua	Tacna
Deaths	37	24	14
Illness	1997	307	363
Homeless	87345	57497	74795
Collapse Housing	9112	10004	5396

As consequence of this quake, research organizations such IGP, INDECI, Ministry of Housing, Ministry of Culture, CISMID and others, consider the study of the risk in main coastal cities because seismic gap in some zones of the country. The worried is the probable occurrence of severe quake in Lima (the main city of Peru) and Tacna (city in the border with Chile). Historically the larger severe quake in Tacna occurs in 1868, and since that time non-destructive quake has been register. Also Lima experience the largest quake occurs in 1746 and a big Tsunami that destroy Callao, since that time big quakes like 1940, 1966 and 1974 generate destruction in Lima. According with the seismic catalog of IGP, a probability of occurrence is high on Lima and Tacna.

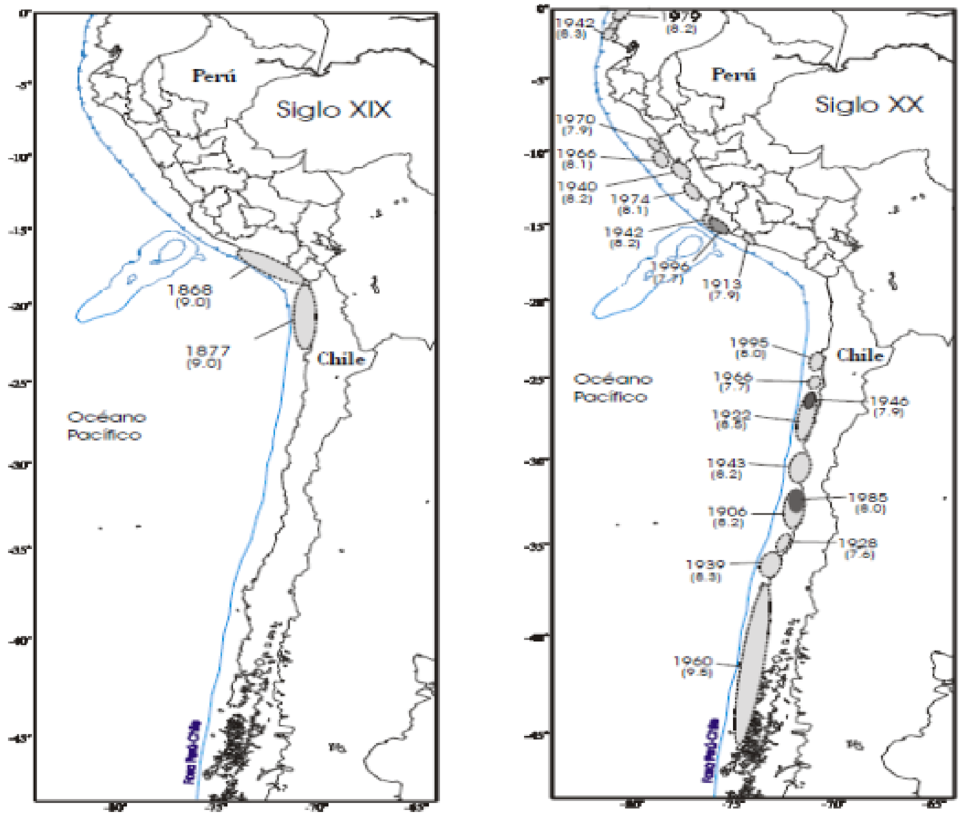

Figure 1: Seismic Gap in central and southern Peru (IGP)

Therefore many initiatives has been generated such PNUD, INDECI, PREDES, Ministry of Housing, Prime Ministry Secretarial and CISMID, in order to generate a diagnosis of the seismic risk for Lima city. CISMID has been working under three schemes of projects:

- The APESEG project: Developed in 2003-2005 to develop a probable maximum losses (PML) sponsor by the Association of Insurance Companies (APESEG) that produces a diagnosis for the insurance clients only.
- The PGT project: Developed in 2010-2011 to generate the seismic risk diagnosis for 6 districts of Lima city.
- The JST-JICA project: On run project to generate the seismic risk diagnosis for 3 districts in Lima and Tacna city diagnosis.
-

In this report the JST-JICA project scheme will be presented and also the first outputs of the project, to illustrate a research initiative by join cooperation between Peru and Japan.

SCHEME OF JOIN COOPERATION RESEARCH JST-JICA PROJECT

A new international research program named “Science and Technology Research Partnership for Sustainable Development (SATREPS)” has started since 2008 under the joint sponsorship of Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA). The proposal “Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru” (Presented by The University of Chiba and its partner National University of Engineering UNI– CISMID) was selected as one of the projects in the field of natural disaster prevention in April 2009. The Record of Discussion (R/D) was signed on 15 January 2010 by JICA and National University of Engineering (UNI) in Lima, Peru. Then the project has formally started and will continue for the five year period.

RESEARCH PLAN AND ORGANIZATIONAL STRUCTURE

In this research project, a comprehensive research towards earthquake and tsunami disaster mitigation in Peru will be carried out under strong collaboration among researchers of Peru and Japan. The joint research will be carried out in five main research topics: 1) Strong motion prediction and development of seismic microzonation; 2) Development of tsunami countermeasures based on numerical simulations; 3) Enhancement of seismic resistance of buildings based on structural experiments and field investigation; 4) Development of spatial information database using remote sensing technology and earthquake damage assessment for scenario earthquakes; 5) Development of earthquake and tsunami disaster mitigation plan and its implementation to the society.

Figure 2 shows the research topics and items of the project and the groups in charge the items. Based on the research outputs from the four groups (G1-G4), the disaster mitigation plan group (G5) will propose and implement earthquake and tsunami disaster mitigation plans to case study areas in Peru. Three case study areas will be decided soon after preliminary surveys. A part of Metropolitan has already selected as one of the study areas. The other area is Tacna city in the southern Peru.
Under the above scheme, counterparts from both countries are develop the research that includes field survey of the area, geotechnical survey, monitoring of dynamic characteristic of the soil, evaluation of building vulnerability, and estimation of the seismic risk.

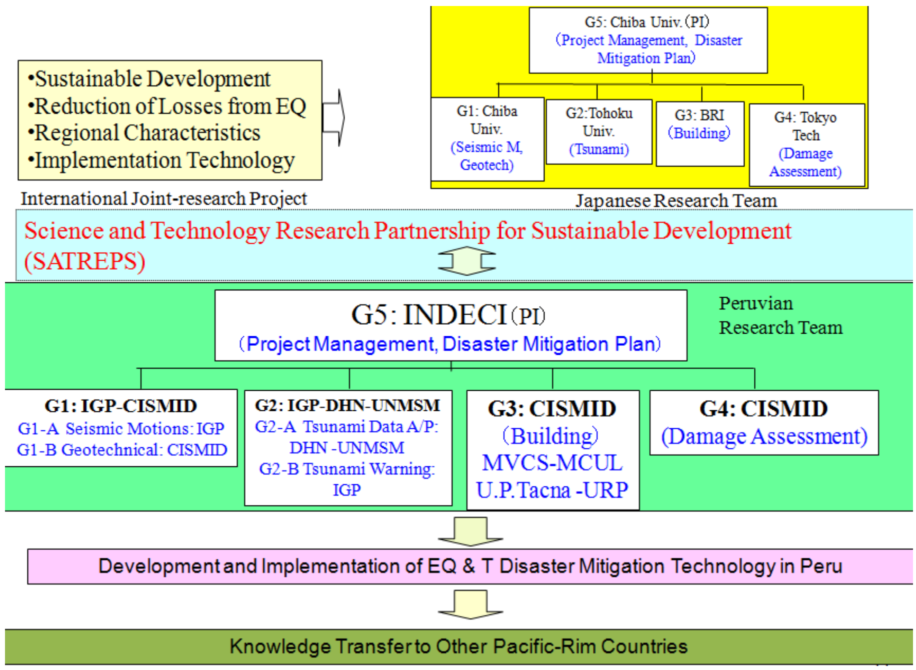

Figure 2: Peruvian working group and the interaction with Japanese counterpart

On Figure 2 it is possible to understand the multidisciplinary groups' scheme of the five working groups, where each group has a partner in the Japanese research team. We must mention that for Seismology and Geotechnical G1, the Geophysical Institute of Peru (IGP) is the leader on seismic motions and CISMID is working the geotechnical issues of the group 1. The tsunami group G2, is under the leadership of Direction of Hydrographic and Navigation of the Peruvian Navy (DHN) working together with San Marcos National University and receive the seismic alert form IGP.

The building group (G3) is leading by CISMID, who works together with the Ministry of Hosing and Sanitation, Ministry of Culture, Tacna Private University and Ricardo Palma University. Since this group should generate a data base for earthquake response of the structures, it must use the results from G1 and G2. Also, CISMID is the leader of damage assessment group (G4), who will produce risk diagnosis using the data base of G3, the source model from G1, and the information of the G2.

Finally the project management and the group that generate the disaster mitigation plan will be G5. This group will use the results from the others groups in order to generate or improve disaster management and mitigation plan, providing possibilities for the decision makers and authorities to reduce the disaster effects in the study areas.

OUTLOOK OF THE PROJECT: LA MOLINA DISTRICT SEISMIC RISK CASE

One of the first outputs of the project has been the estimation of the seismic risk in La Molina district in Lima, where historically has been partially destroyed in two opportunities 1966 and 1974 Lima quakes.

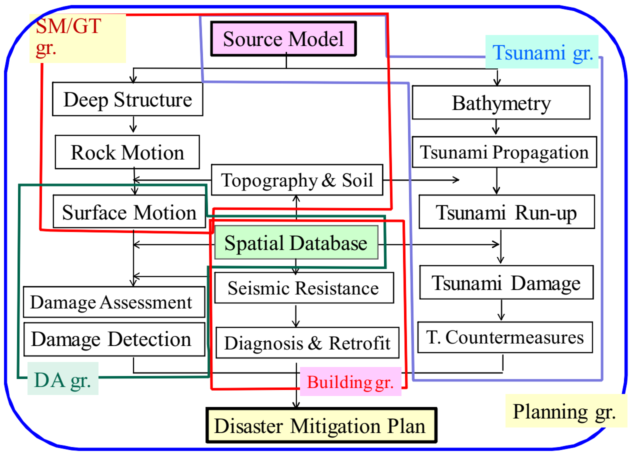

Figure 3: Research topics and items of the project and the groups in charge the items

During past earthquakes La Molina experience a high level of soil accelerations due to the local conditions of the soil. This originates a high seismic intensity caused by the effect of refraction of the seismic waves on the hills and towards the deposits of soil. This phenomenon causes an amplification of the spectral component of acceleration that in accordance with the studies developed by Aguilar [1] comes to values bigger than 5 on spectral components. Therefore waves differ from zone to zone and there exists in some of them a significant amplification that can damage some types of structural system more than others due to high frequencies. Figure 4 presents the update seismic microzonification map of La Molina district.

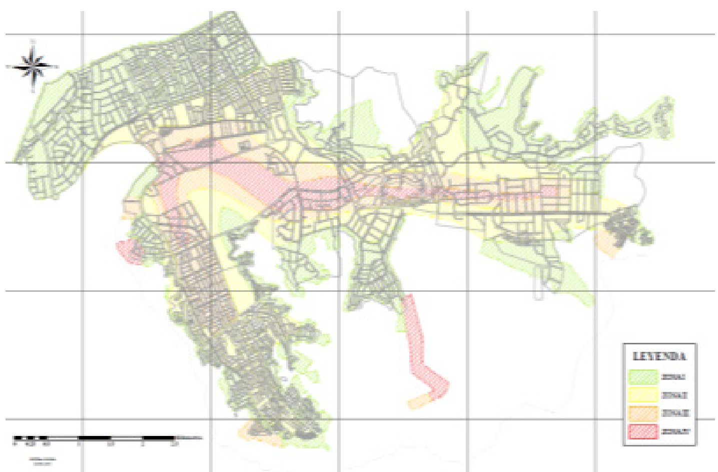

Figure 4: Seismic Microzonification in La Molina district

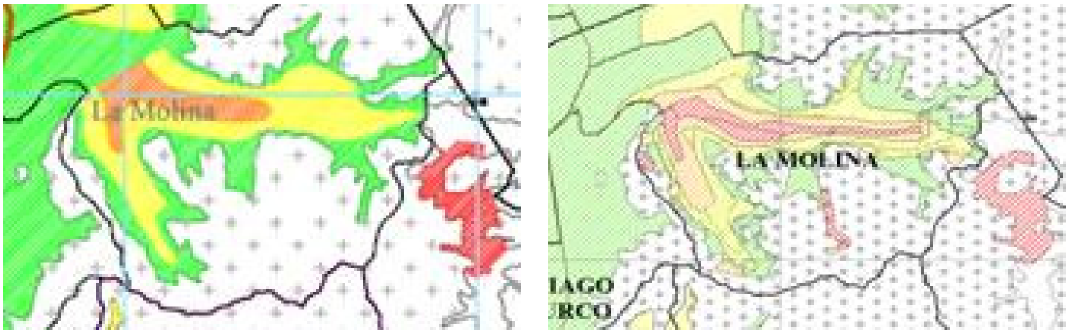

Figure 5: Microzoning Study 2003 and Microzoning Study 2011

A review of the results and updated was consider in this project, performing new Microtremor measuring, field survey of samples of soil, geophysical arrangements, producing an update microzoning map. Here the comparison of the 2003 and 2011 studies, where the last map shows the increment of resolution on the results due to the use of a set of refined data base of soil survey profiles.

Using the evaluated Microzonification of La Molina district, a field survey considers a representative house for a block was performed. A data base was created with the identification of key variables such number of stories, structural system, state of conservation, age of construction, etc. Using this data the evaluation of the vulnerability of the survey´s sample is presented on Figure 6, where the red zones shows high vulnerability housing, the yellow zones present medium vulnerability buildings and the green areas presents low vulnerability blocks.

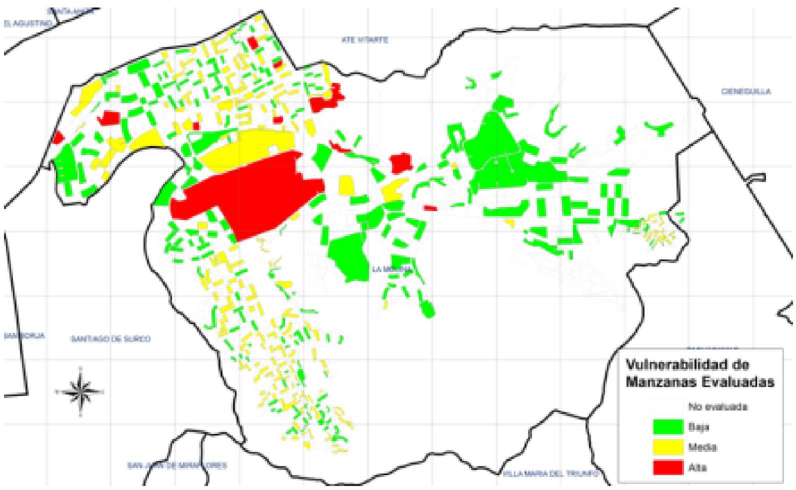

Figure 6: Housing vulnerability of La Molina district

For the evaluation of the seismic risk, a seismic response simulator with damage level estimation (Simulador Respuesta Sísmica y Nivel de Daño SRSND in Spanish) to evaluate the seismic response of buildings using survey data and approximation parameters is used [2]. The simulator performs an approximate methodology based on a SDOF system that used the predominant period of the building to compute the seismic response and damage level. Using the field survey data, the simulator SRSND performed the risk analysis results in terms of reconstruction cost using the damage matrix. Figure 7 presents the diagnosis developed for La Molina district in terms of the percentage of the reposition cost of the building. Here green zones will need less than 15% of the reposition cost to be in operation after a sever quake. Housing located on zones in light green will need 15% to 30% of the reposition cost to be safe again. Zones in yellow will need 30% to 60% to recover its function. However zones in orange and red expect collapse of housing, and they should be demolish and replace.

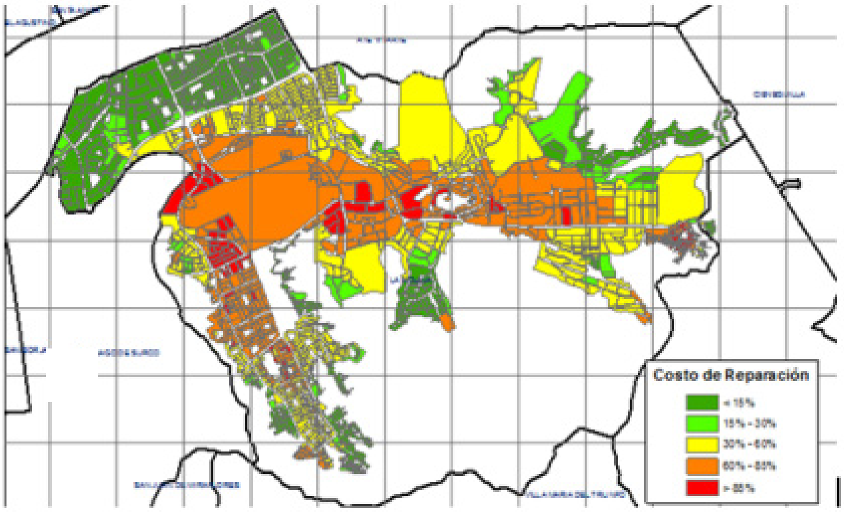

Figure 7: Seismic Risk in Terms of Reconstruction Cost

SOME OUTPUTS OF THE PROJECT

In the project the donation of equipment, improvement of the capacities of young researchers, dispatch of Japanese experts and transportation has been considered. Therefore each group received support with new equipment in order to collect data for the project.

GROUP -1 and GROUP 2
In order to exchange of knowledge on evaluation of seismic sources, seismic hazard and tsunami evaluation, a training course on evaluation technologies for Seismology (G1) and Tsunamis (G2) was developed at CISMID with the participation of IGP, DHN, UNMSM and UNI.

Figure 8: Training course of G1 and G2 at CISMID

G1 receive a LAN sensor network and also Microtremor GEODAS--10, where results can be joint to produce study of the soil dynamic, by the application of geophysical arrangements of the sensors, as is presented in Figure 9, where measuring were performed in the campus of the National University of Agriculture in La Molina district.

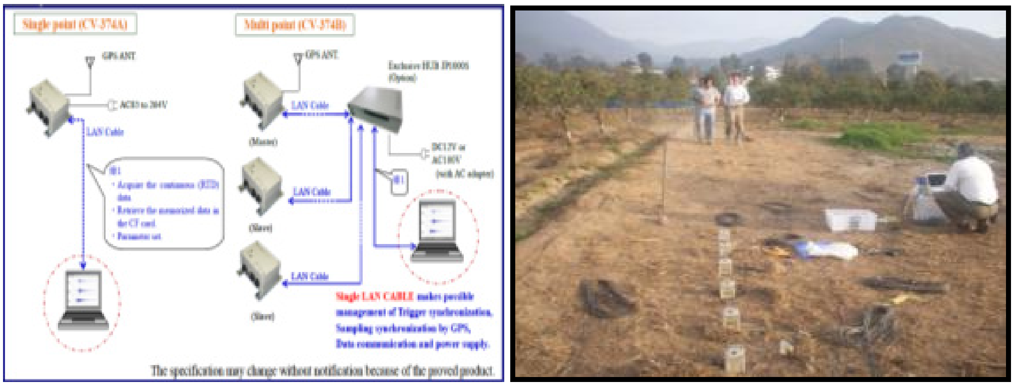

Figure 9: LAN Sensor network and integration with GEODAS-10

GROUP 3

One of the kick off activities for this group was the visit of the Japanese mission from Building Research Institute of Japan (BRI), in order to survey Lima city and identify the more likely used construction systems and material. Also a visit the valuable historical buildings was performed. This group organize a symposium on the Private University of Tacna where governmental authorities, academic researchers, students and practitioners, were quiet interested in the visit of the Japanese mission from BRI of Professor Shunsuke Sugano, Dr. Taiki Saito and Dr. Tomohisa Mukai., as is presented on Figure 10.

Figure 10: Japanese mission in Lima and Tacna Symposium

Figure 11: Lecture of Professor Sugano at CISMID

Also among the activities of this group the creation of a data base for masonry structures, collecting test data around the world from masonry wall test and concrete wall test, and the implementation of this models in the earthquake response and simulation of seismic behavior is considered. Therefore to understand the behavior of concrete elements, Professor Shunsuke Sugano gave lectures of behavior of concrete elements at CISMID, as is presented on Figure 11.

GROUP 4

One of the investigations generated by G4 was the use of satellite images to develop a diagnosis of the social class of the residents and then infer the quality of housing. The satellite information contains not only image but spectral information that can be processed. Therefore, spectral information can be used to solve this issue.

Figure 12: Two different of land use in La Molina district

On Figure 12, the left side present the image of a very high social class on La Molina district [3]. Here it is possible to identify the pools inside the houses. However of the right side of the figure we can identify another land use, typically of low income social class. Using the spectrometer donated by JICA in order to identify the spectral characteristic of pools in the area, it is possible to generate an automatic process for the identification of the number of pools in the district. Here the diagnosis is presented on Figure 13, where the non-existence of a pool is identify in red color, following by orange color that means 1 pool, 2 to 5 pools in yellow color and continue. This prove that in the case of town attack by a quake, the application of this technique will be used generating the identification of debris instead of pools.

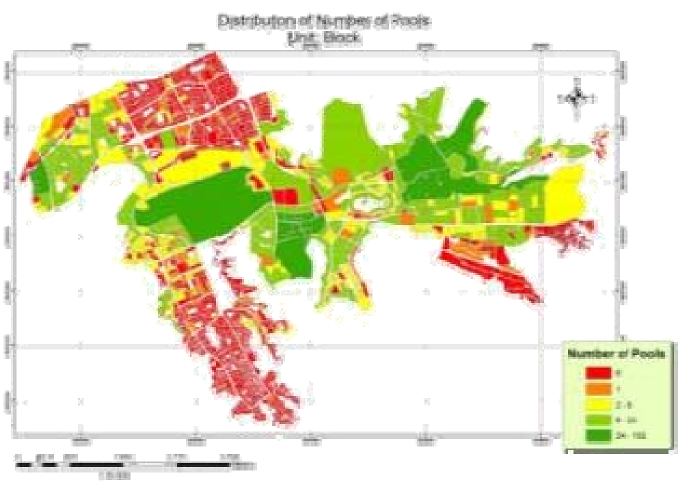

Figure 13: Diagnosis of the number of pools

GROUP 5

This group should promote the application of earthquake and tsunami technologies by the decision makers. The group makes a presentation of the project under the Natural Disaster Committee of the Peruvian Congress. Also the group organize international symposium, and working group sessions has been performed individually and in a plenary, in order to exchange knowledge and proposal from the groups to be used by G5.

Figure 14: Presentation of the project on Congress and Workshop in Lima - CISMID

CONCLUSIONS

- The initiatives for improve the technologies for study quakes has been presented. Among the initiatives the JST-JICA project presents an integrated scheme for join cooperation.
- The JST-JICA project considers five components in the diagnosis of the seismic risk. Researchers of both countries will consider the application of similar technologies and the transfer or improve of them with through the technical cooperation.
- As one of the initial outputs results of the seismic risk estimation is presented using the SRSND simulator. The diagnosis is presented in terms of reposition cost of the building. This tool will be used by the Peruvian side to be developed.

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REVISION OF IAEE GUIDELINES FOR EARTHQUAKE RESISTANT NON-ENGINEERED CONSTRUCTION

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ABSTRACT

A large majority of houses and buildings in the world can be classified as non-engineered construction. Some of them are (1) un-reinforced masonry (stone, brick or concrete block masonry), (2) wooden construction, (3) earthen construction (adobe or tapial), (4) confined masonry, etc. And most of the loss of life in past earthquakes has occurred due to the collapse of these houses and buildings. Because of the continued use of such construction in the world, it is essential to introduce earthquake resistant features in their construction. The International Association for Earthquake Engineering (IAEE) published the "Guidelines for Earthquake Resistant Non-Engineered Construction" in 1986. More than twenty years have passed since the publication and also the guidelines are still used in many parts in the world, the possible revision of the guidelines was discussed among three of the committee members for the 1986 edition. The revision is going to be completed with the supports of UNESCO and the International Institute of Seismology and Earthquake Engineering (IISEE), JAPAN.

KEYWORDS
non-engineered construction, un-reinforced masonry, confined masonry, wooden construction, earthen construction, earthquake.

INTRODUCTION
A large majority of houses and buildings in the world can be classified as non-engineered construction. And most of the loss of life in past earthquakes has occurred due to the collapse of these houses and buildings. Because of the continued use of such construction in the world, the International Association for Earthquake Engineering (IAEE) published the "Guidelines for Earthquake Resistant Non-Engineered Construction" in 1986 (see Fig.1). More than twenty years have passed since the 1986 edition and also the guidelines are still used in many parts in the world, the revision of the guidelines will be helpful to minimize the damage and loss of lives caused by earthquakes. The revised draft with a number of pictures (see Figs. 2--8) can be downloaded at the web site (http://iisee.kenken.go.jp).

NON-ENGINEERED CONSTRUCTION
Many buildings are spontaneously and informally constructed in various countries in the traditional manner without any or little intervention by qualified architects and/or engineers. Some types of the non-engineered construction are (1) un-reinforced masonry (stone, brick or concrete block masonry) (see Figs.3 and 5), (2) confined masonry (see Fig.4), (3) wooden construction (see Fig.6), (4) earthen construction (adobe or tapial, i.e. rammed earth) (see Fig.7), etc.

IAEE GUIDELINES IN 1986
The "Guidelines for Earthquake Resistant Non-Engineered Construction" was published by the International Association for Earthquake Engineering (IAEE) in 1986 (see Fig.1). It is a revised and amplified version of "Basic Concepts of Seismic Codes, Vol.1, Part II, Non-Engineered Construction", published also by IAEE in 1980. The revision resulted from the work of an ad-hoc Committee, integrated by Anand S. Arya, Chairman (India), Teddy Boen (Indonesia), Yuji Ishiyama (Japan), A. I. Martemianov (USSR), Roberto Meli (Mexico), Charles Scawthorn (USA), Julio N. Vargas (Peru) and Ye Yaoxian (China).

The guidelines start with the presentation of the basic concepts that determine the performance of constructions when subjected to high intensity earthquakes, as well as with the sensitivity of that performance to the basic geometrical and mechanical properties of the systems affected. This information is later applied to the formulation of simplified design rules and to the presentation of practical construction procedures, both intended to prevent system collapse and to control the level of damage produced by seismic excitations. Emphasis is placed on basic principles and simple solutions that can be applied to different types of structural systems, representative of those ordinarily used in low-cost housing construction in different regions and countries in the world.

The guidelines consist of nine chapters, i.e. 1) The Problem, Objective and Scope, 2) Structural Performance during Earthquakes, 3) General Concept of Earthquake Resistant Design, 4) Buildings in Fired-Brick and Other Masonry Units, 5) Stone Buildings, 6) Wooden Buildings, 7) Earthen Buildings, 8) Non-Engineered Reinforced Concrete Buildings, 9) Repair, Restoration and Strengthening of Buildings, and Appendices.

REVISION OF THE GUIDELINES

Three members of the committee for the 1986 edition, i.e. Dr. Anand S. Arya, Ir. Teddy Boen and Dr. Yuji Ishiyama met in Tokyo, Japan during “The International Symposium 2008 on Earthquake Safe Housing”, which was held on November 28 and 29 in 2008. Since more than twenty years had passed after the publication and also the guidelines are still used in many parts in the world, they discussed the possible revision of the guidelines and agreed to make a working group in IAEE including the original members who are willing to participate in it and some new members who are also willing to join it. Since there is no special fund allocated to the working group in IAEE, the revision is mainly done through e-mail communications. The activities on the revision have been supported in parts by UNESCO and the International Institute of Seismology and Earthquake Engineering (IISEE), JAPAN. The three members met in Delhi, India in April, 2010 and in Singapore in March 2011. The draft for the IAEE Guidelines can be downloaded at the website of IISEE (http://iisee.kenken.go.jp). The revision is going to be soon completed and to be reported at the next World Conference on Earthquake Engineering (WCEE) in Portugal in 2012.

This revised edition essentially retains the Guidelines in the original form except for some minor editorial changes and modifications. Some building damage photographs from recent earthquakes have been included for illustration (see Figs.2, 3, 5, 6 and 7) so that the concept of the guidelines will be easily understood. A major addition is Confined Masonry in Chapter 4 (see Fig.4) and Appendices in Chapter 10 giving the MSK Intensity Scale as related to buildings, a table for assessment of seismic safety of a masonry building, and examples of posters (see Fig. 8)on brick and wooden buildings.

CONCLUDING REMARKS

The revision of the IAEE Guidelines for Earthquake Resistant Non-Engineered Construction is going to be completed soon. Those who have interests for the revision are recommended to send their comments on the draft to: Anand S. Arya (India): asarun3155@gmail.com, Teddy Boen (Indonesia): tedboen@cbn.net.id, or Yuji Ishiyama (Japan): to-yuji@nifty.com.

ACKNOWLEDGMENTS

The meetings and activities for the revision of the guidelines have been supported in parts by UNESCO, IISEE (International Institute of Seismology and Earthquake Engineering) in Japan, etc. Their assistance is gratefully acknowledged.

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GUIDELINES FOR EARTHQUAKE RESISTANT NON-ENGINEERED CONSTRUCTION

Revised Edition of "Basic Concepts of Seismic Codes" Vol. I, Part 2, 1980

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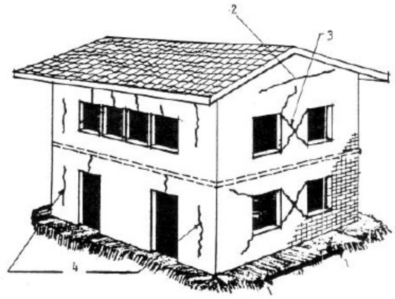
October 1986

(a) Title page of IAEE Guidelines (1986)



1-1 Earthquake motion, 2-Horizontal crack in gables, 3-Diagonal cracks due to shear, 4-Cracks due to bending of wall.

FIG.4.1 CRACKING IN BEARING WALL BUILDING DUE TO BENDING AND SHEAR.

ii) A wall can fail as a bending member loaded by seismic inertia forces on the mass of the wall itself in a direction, transverse to the plane of the wall. Tension cracks occur vertically at the centre, ends or corners of walls. Longer the wall and longer the openings more prominent is the damage (Fig.4.1.). Since earthquake effects occur along both axes of a building simultaneously, bending and shearing effects occur often together and the two modes of failure are often combined. Failure in the piers occurs due to combined action of flexure and shear.

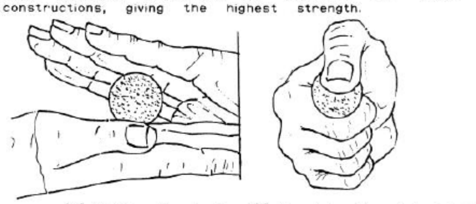
iii) Unreinforced gable end masonry walls are very unstable and the strutting action of purlins imposes additional force to cause their failure. Horizontal bending tension cracks are caused in the gables.

iv) The deep beam between two openings one above the other is a weak point of the wall under lateral in-plane forces. Cracking in this zone occurs before diagonal cracking of piers (Fig.4.2.). In order to prevent it and to enable the full distribution of shear among all piers, either a rigid slab or r.c. band must exist between them.

(b) Easy to read with illustrations

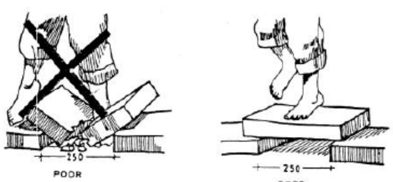
b. **Fissuring Control Test**

At least eight sandwich units are manufactured with mortars made with mixtures in different proportions of soil and coarse sand. It is recommended that the proportion of soil to coarse sand vary between 1:0 and 1:3 in volume. The sandwich having the least content of coarse sand which, when opened after 48 hours, does not show visible fissures in the mortar, will indicate the most adequate proportion of soil/sand for adobe constructions, giving the highest strength.



(i) Making the ball (ii) Crushing the dried ball

(a). DRY-BALL STRENGTH TEST FOR SOIL.



(b). TESTING OF ADOBE STRENGTH.

FIG.7.3 FIELD TESTING OF STRENGTH OF SOIL AND ADOBE.

Strength Test of Adobe

The strength of adobe can be qualitatively ascertained as follows: After 4 weeks of sundrying the adobe it should be strong enough to support in bending the weight of a man (Fig.7.3.b). If it breaks, more clay and fibrous material is to be added. Quantitatively, the compressure strength may be determined by testing 10cm cubes of clay after completely drying them. A minimum value of $1.2 N/mm^2$ will be desirable.

(c) Applicable at construction site

7.8. **SUMMARY OF DESIRABLE FEATURES**

The desirable features for earthquake resistance of earthen houses are briefly illustrated in Fig.7.14.

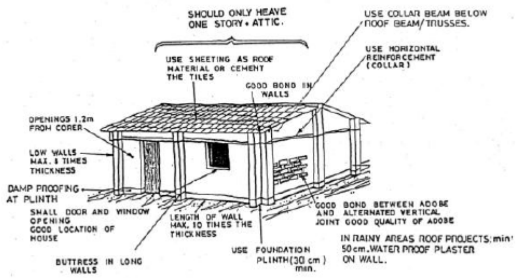


FIG.7.14. GOOD FEATURES OF EARTHQUAKE RESISTANT CONSTRUCTION.

7.9. **WORKING STRESSES**

7.9.1. **Unit Compressive Strength**

The compressive strength of the unit is an index of its quality and not of the masonry.

It will be determined by testing cubes of approximately 100mm. The compressive strength (fo) is the value exceeded by 80% of the number of specimens tested.

The minimum number of specimens is six (6) and they should be completely dry at the time of testing.
The minimum value of (fo) is $1.2 N/mm^2$.

(d) Desirable features of earthen construction

Figure 1. IAEE Guidelines for Earthquake Resistant Non-Engineered construction (1986)

(a) 1992 Flores Earthquake

(b) 2004 Ache Earthquake

Figure 2. Damage caused by tsunami (Indonesia)

(a) 1994 Liwa Earthquake

(b) 2006 Central Java Earthquake

Figure 3. Out-of-plane failure of brick masonry wall (Indonesia)

(a) Single storey house (Ache)

(b) Two storey house under construction (Jawa)

Figure 4. Construction of confined masonry (Indonesia)

(a) Unreinforced stone masonry (b) Damage to the stone masonry wall

Figure 5. Damage to stone masonry (2005 Northern Pakistan Earthquake)

(a) Damage concentrated to the first storey (b) Detail of the damaged wooden house

Figure 6. Damage to wooden houses (1995 Kobe Earthquake, Japan)

(a) Damaged adobe (2007 Pisco Earthquake) (b) Damaged tapial (1990 Rioja Earthquake)

Figure 7. Damage to earthen buildings (Peru)

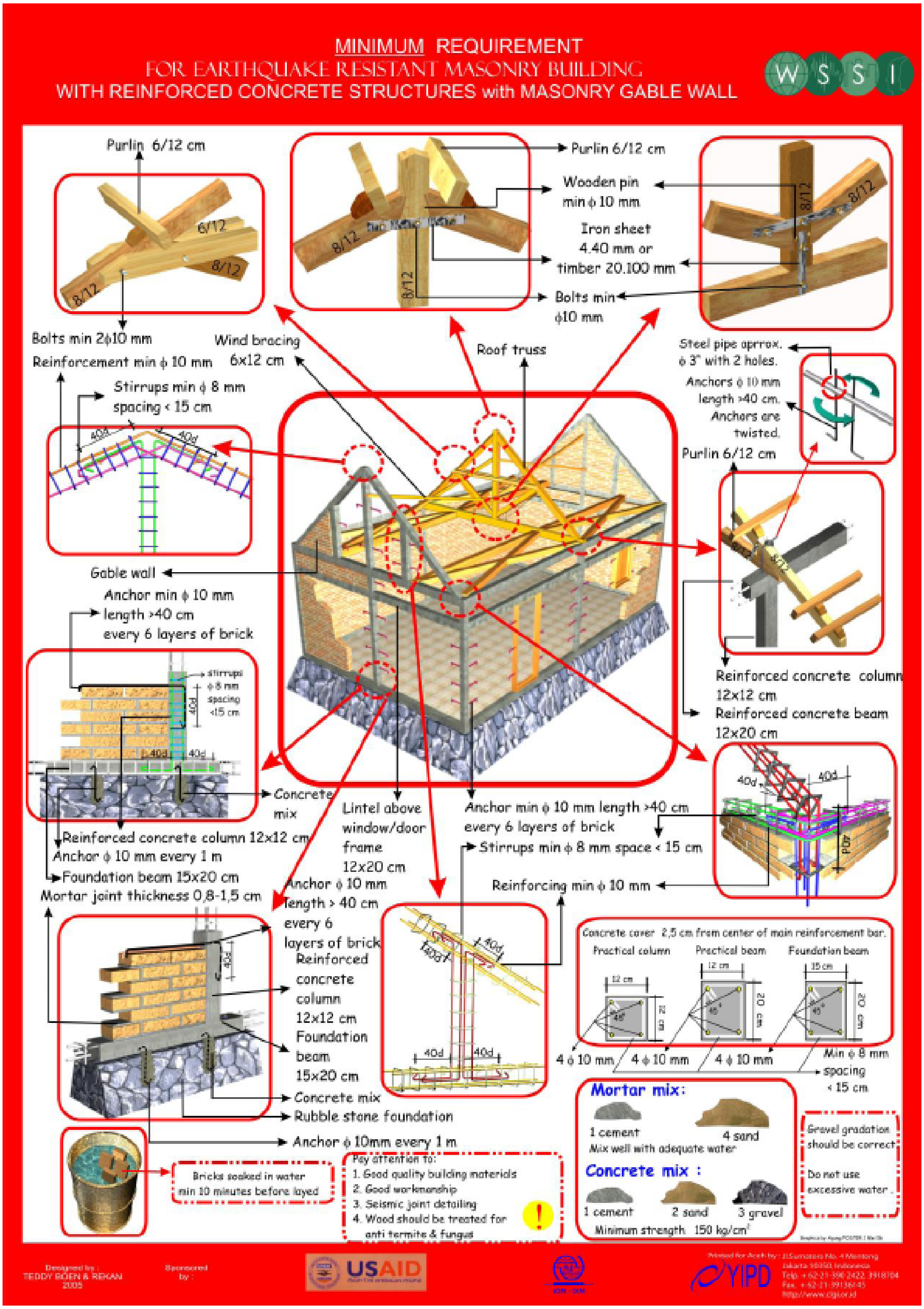


Figure 8. Poster for half brick confined masonry

THE GREAT EAST JAPAN DISASTER AND METROPOLITAN PLANNING

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ABSTRACT

This report has summarized the role of public officials, citizens, and corporations in the reconstruction activities following from the natural (earthquakes, tsunamis) and man-made (Nuclear Power Plant Exposition) catastrophes of the Great East Japan Disaster. When considering the reconstruction plans of Iwate and Miyagi Prefectures, the specifics of the plans are quite different. In Iwate the incorporation of people connected to the fisheries has led to “reconstructionism”. However, in Miyagi, the governor has advocated for modernization of agriculture and fisheries and a new reconstruction-planning model (excluding one area of cooperatives and associations that has demanded a reconstruction plan developed by local people). Both prefectures have established 10-year reconstruction plans and these plans can be expected to meet with much success. In contrast, the reconstruction plan in Fukushima is expected to take at least 30 years to implement. While Fukushima was heavily damaged by the earthquake and tsunami, the Nuclear Power Plant in Onagawa Nuclear Plant in Miyagi prefecture happened to be shut down at the time of Tsunami and only experienced a short in the high voltage supply board and did not get significant damage. Officials must examine the cause.

Nuclear power plants are created by research and technology of human intellect. When emergencies occur, the most important question is how determinate how the worst scenario could be prevented. For this reason the nuclear issue has been cast as a global problem for all of humanity. For large metropolitan areas such as Tokyo, smaller cities such as Hiroshima and Nigata, and even in towns and villages scattered around these cities, detailed scientific review and reformulation of disaster prevention policies based on historical studies and present considerations is imperative. Even large-scale national planning strategies are formed from the accumulation of countless smaller scale plans. If local and larger scale plans are well integrated, various localities can join together and a sustainable national land strategy will emerge.

KEYWORDS

Great East Japan Disaster, Reconstruction Planning, Fukushima Nuclear Power Plant Disaster, Metropolitan Planning

INTRODUCTION

The Great East Japan Earthquake and Tsunami of March 11, 2011 demonstrates that our plans for housing, construction, cities, communities and national planning have not been effectively prepared us for catastrophic events. From now on, we must consider how to deal with natural events that occurs only once every 30 or even 100 years, and also deal immediately with the air, soil and water pollution caused by radioactive emissions from the damage to the Fukushima Nuclear Reactors.

Under such situation, it is imperative for the Prime Minister to take the lead by setting the recovery and reconstruction policy agenda and mobilizing the necessary budgetary means and resources. However, embroiled in political turmoil, the central government has yet to establish the basic recovery plan (in Mid-August of 2012). For professionals in the planning field, the current stage, when the recovery plan and budget is being set, is the critical and decisive period. Indeed, when the execution phase arrives, the planning game is to a considerable extent already over.

Immediately after the Great Kantou Earthquake of 1923, the disaster that resulted in over 105,000 dead and missing persons, Goto Shinpei, the head of the Home Ministry and the Capital Reconstruction Commission, proposed a three point reconstruction plan: 1) no Capital relocation, 2) a reconstruction budget of 40,000,000 yen (or 3 times the central government budget of the time) and 3) large-scale land readjustment, parks, green spaces and infrastructure (i.e. trunk roads). To implement these plans, and based on the instructions of Dr. Charles Beard, a leading expert in urban planning from the United States, the extensive use of eminent domain was considered. However, land expropriation was strongly resisted by the powerful landlords headed by the privy councilor, Itsuki. Moreover, only 10% of the proposed 40,000,000-yen reconstruction budget was allocated and the grand plans for reconstruction were thus severely constrained. Today, the 44m wide Showa Avenue connecting the downtown and Shinbashi represents one of the realized plans.

Within decades of the Great Kanto Earthquake disaster, disaster struck Tokyo another again, this time in the form of air raids by U.S. military forces near the end of World War II resulting in a comparably massive urban disaster. In total, 215 cities and 164,599ha of urban lands in Japan were flattened and burned by incendiary bombing. In 1947, two years after the end of the War, the author (Sazanami) graduated from University of Tokyo and began to work on the construction of public housing, in the Housing Division of the Reconstruction Bureau, National Reconstruction Corporation. This work was the prototype for the Public Housing Act of 1951. This “commoner housing” consisted of two types corresponding to residents’ income levels, including a 10.5m^2 flat for middle-income households and a 7.5m^2 flat for lower income households, both of wooden construction. On one hand, the “commoner housing” was a continuation of a wartime housing policy conducted by the Ministry of Health and Welfare. However, with the involvement of well-respected architects such as Dr. Uzou Nishiyama of Kyoto University and the well-known architect Ken Ichiura, it can also be seen as a successor of the Dojunkai, a special Official Housing Corporation set up by the Government’s Funds with Emperor’s Donation, to the groundbreaking initiatives established in the wake of the Great Kanto Earthquake public housing authorities.

The author (Sazanami) was involved in establishing public housing standards and projects for 15 years in total (1947-1962). By 1955 basic government organization policies related to public housing were established and, over the span of 30 years, the tremendous shortage of housing in the postwar period had been dealt with.

Following the lean years immediately after the war, Japan quickly recovered through the “Income-Doubling Plan” of the Ikeda Cabinet and the “Reconstruction of the Japanese Archipelago Plan” of the Tanaka Cabinet. By the 1980s, Japan had emerged as an economic superpower on par with the world’s leading economy in the United States. When the national housing shortage had been eliminated, housing policy shifted from public sector towards role by the private sector, a feature that continues today.

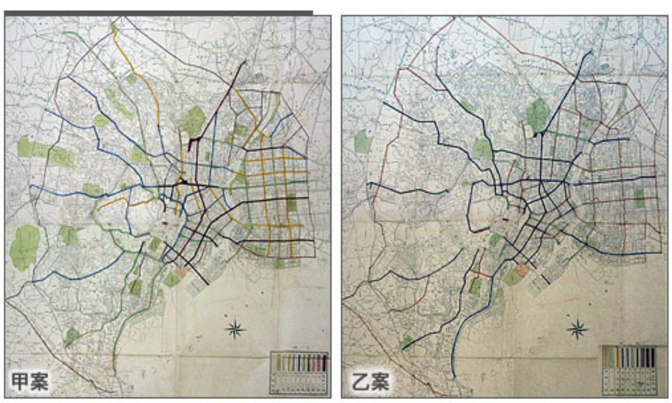

Figure 1. Recovery program proposal (Few green tracts were adopted (right side))

While a large number of housing units have been destroyed in the recent Great East Japan Disaster, 12% of all public housing units throughout the country were vacant at that time. These could have been leased to Great East Japan Disaster's victims free of charge for a certain period (e.g. two years). This could have been an economically efficient policy that saves on the extraneous costs of constructing temporary housing. However, housing policies after the most recent disasters were, like the Hanshin Earthquake in 1995, also limited by the principle of providing temporary housing within the immediate administrative districts. However, the United States, which frequently suffers from natural disasters, has substituted temporary housing construction with a system of relief vouchers and coupons that allows disaster victims to select from available housing apartments in vicinity.

Figure 2. Showa Street

Temporary housing is plagued by a number of issues, including weak communal ties, and a lack of housing for the elderly and the handicapped. After the Hanshin Earthquake, private sector construction companies of various sizes were the main implementers of reconstruction and they managed largely to return the area to its pre-disaster state. However, in the case of the Great East Japan Earthquake, it is not clear whether such a reliance on the private sector will provide the facilities necessary for the affected communities to recover. Without places to live and work, and suitable schools, hospitals, supermarkets, it is possible that families could be broken up as companies transfer and businesses succumb to a weakened economic environment.

It was reported that the central government and the three most severely affected prefectures (i.e. Iwate, Miyagi, and Fukushima) aimed to finalize reconstruction plans by August, 2011. At this stage, the relevant agencies conducted discussions with influential leaders from academia, businesses and labor unions worked to release interim reports.

While the reconstruction effort after the Hanshin Earthquake was characterized by active participation by local residents, and public officials and municipal officers proposed reconstruction plans for local districts based on debate and discussion, the development of reconstruction planning at the local level and participation of local communities has not been as considerable in Tohoku. In addition, clearance of debris from the affected areas is progressing slowly and the recovery of agricultural and fishery activities have yet to begin.

DRAFT PROPOSAL FOR A RECONSTRUCTION PLAN

In the prefectures most drastically affected by Great East Japan Disaster, reconstruction plans are advancing, as demonstrated in the following brief summaries.

Reconstruction plans in Iwate

The "Iwate Prefecture Great East Japan Earthquake and Tsunami Reconstruction Plan" was released on June 9, 2011. The plan emphasizes the importance of connections between people and communities to the reconstruction process and establishes three guiding principles: 1) “ensuring safety”, 2) “rebuilding everyday lives” and 3) “regenerating industries”.

Table 1. Contents and the period of a plan

1st term	2nd term	3rd term
-2013	2013-2016	2016-2018
Basis rehabilitation period	A formal rehabilitation period	The connection period to the further deployment

Under the heading of tsunami policy through community planning, the plan for “developing safe living environments” calls for strengthening and relocating housing and residential areas to higher ground through a process of consultation with local residents. The plan for “land use planning in consideration of tsunamis” calls for tsunami simulation study in affected districts to identify areas appropriate for controlling construction. It also calls for relocating public facilities such as municipal offices, schools, hospitals and other facilities essential to disaster response efforts to higher ground. In addition, the “public facilities and disaster prevention” plan calls for reducing evacuation time through the construction of breakwater defense and evacuation towers, evacuation parks and roads, and land use planning for tsunamis. In addition, main roads, railways and other transportation links will be reviewed by public officials and private sector consultants and be strengthened in accordance with their suitability for evacuation routes and disaster recovery.

Other components of the plan include centralizing and unifying residential and commercial areas based on the principle of “developing compact cities”, establishing efficient residential and commercial areas to “regenerate industries” and an overall grand design for community development that emphasizes “harmony with the environment” through low impact urban development and renewable energy.

Reconstruction plans in Miyagi

The “Draft Proposal for Disaster Reconstruction Policy” proposed by the Miyagi Prefectural government consists of four guiding principles: 1) individual citizens as the main agents of reconstruction, 2) building better rather than simply rebuilding, 3) model community building in response to current social challenges and 4) model development for post-catastrophe reconstruction.
The planning period is set for a total of 10 years and divided into three phases, including; 1) “Reconstruction” (2011-13), 2) “Revitalization” (2014-2017) and 3) “Expansion” (2018-2020).

Urgent priorities are identified as: 1) securing necessities and a resource base for refugees (temporary and rental housing for 30,000 households), 2) immediate reconstruction of public works facilities and vital lifelines, 3) recovering administrative functions of affected municipalities, 4) removal of debris from the polluted area to a primary area (first year) and to secondary facility within three years, 5) restoration of educational facilities, 6) restoration of health, medical and welfare facilities, 7) restoration of employment and income, 8) restoration of agriculture, forest and fisheries industry, 9) restoration of commerce and production and 10) reconstruction of healthy and safe local societies.

Miyagi Prefecture has a total of 35 municipalities and each has been affected by the disaster. Particularly affected are the 8 cities and 7 towns along the Pacific Coast that experienced catastrophic damage from the tsunami, including Kesenuma, Minami-Sanriku, Ishinomaki, Onagawa, Higashi-Matsushima, Matsushima, Rifu, Shiogama, Tagajou, Shichirigahama, Sendai, Natori, Iwanuma, Watari and Yamamoto. In these municipalities complete restoration of prior conditions is simply not an option. Key foci of reconstruction plans are technical support personnel, introduction of special zones, consideration of rights related to land adjustment measures, which must be implemented to curb speculative land transactions and unregulated construction activity.

Reconstruction plan in Fukushima Prefecture

Immediately after the earthquake and tsunami, the explosion at the Fukushima Daiichi Nuclear Power Station that emitted radiation into the air, soil and water devastated Fukushima Prefecture. Moreover, pollution from the plant is still not under control. Accordingly, rather than national or prefectural level planning, disaster planning in Fukushima has centered firstly on emergency response measures by officials in the nuclear power field. At the prefectural level, the issues of nuclear radiation cleanup and policies for supporting the lives and livelihoods of refugees are of urgent importance.

Faced with these adverse circumstances, the Fukushima Prefectural Government produced a “Reconstruction Vision” in July 2011 and is aiming to formulate a concrete “First Phase Reconstruction Plan” late in 2012. The reconstruction vision committee is composed of 12 members from research and industry. Without prospect of resolving the nuclear accident, the future of the economically crucial nuclear industry in question, and uncertainty over the decommissioning of nuclear power, disaster recovery in Fukushima has exceeded the provincial level and become a national and indeed international issue. At the international level, the difficulty of moving away from nuclear energy is evidenced by Germany’s decision to abolish nuclear power and its continued reliance on nuclear derived energy from France. For these reasons, the Fukushima nuclear issue has attracted a great deal of international attention. Nuclear radiation control activities at the plant have received critical technical support from American and French experts, and the International Atomic Energy Agency provided international and logistical support that remains critical.

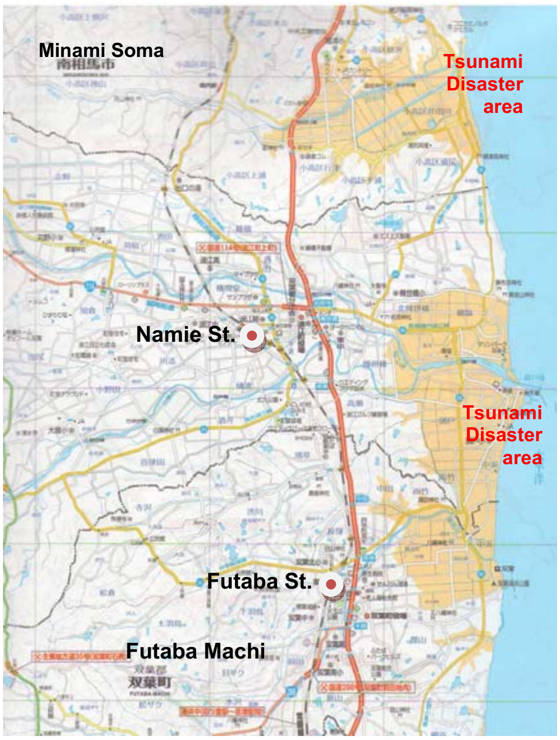

Figure 3. The Tsunami disaster situation of Fukushima Prefecture

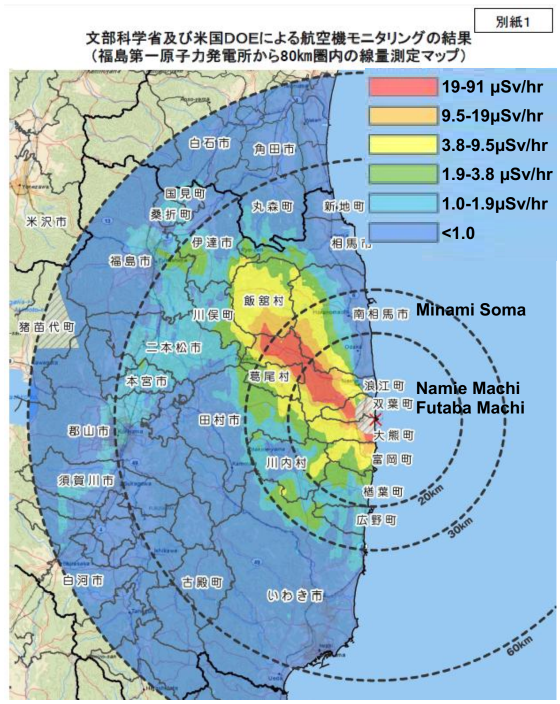

Figure 4. Radioactive contamination map （June 5, 2011）

While more than a year has passed since the explosions at the Fukushima Nuclear Power Plant, significant progress on the restoration and cleanup of the site has not yet been achieved and many sources suggest that this process could take 30 years to adequately complete. Radioactive contamination spread over a vast area will long persist in the air, ground, and water of the region, and currently a work in progress for the removal of contaminated soil remains.

In Namie, a town in Fukushima Prefecture and well within the affected area, contaminated soil was first removed from the grounds of the elementary and junior high schools. However, it remains to be seen whether the families with elementary and junior high school students who have been living in rented quarters elsewhere will return to the area.

Through repeated and close consultations with various groups, including residents, corporations, educators, professionals, prefectural officials, and other civil servants as well as non-profit organizations and central government officials, the mayors of Minamisoma, Okuma and Futaba are aiming to construct a blueprint for the future.

These goals are estimated to take 30 years to implement, but could conceivably represent targets of closer to 50 to 100 years.

To note an example with some parallels, during the Taisho Era (1912-26), many Japanese immigrated to Hawaii, the U.S. mainland and to Brazil, primarily from Hiroshima Prefecture, to work as farm laborers. Today, 100 years later, the Japanese immigrants and their descendants in Sao Paulo, for example, have moved out of agriculture to engage in commercial and industrial activities and the Japanese population has evolved into an important part of the local society.

Currently, a national project is being advanced that aims to develop a large wind farm as part of an effort to develop renewable energy sources as a means of reconstruction in Fukushima. Towards this end, the government has already projected 12.5 billion yen in the third supplementary budget.

More specifically, the plan calls for a “floating offshore wind power farm” to be developed 30 ~ 40km off the coast of Fukushima Prefecture in an area with water depths between 100 ~ 200m.

In the scenarios developed by by Fukushima Prefecture’s “Coordinating Committee for the Promotion of Renewable Energy", the term “industrial clusters” appears with great frequency. The model for this scenario is the German port town of Bremerhaven in the state of Bremen. Following the end of the Cold War, the German government took the initiative in industrial development, including the devlopment of the windmill industry in Bremerhaven. The offshore wind turbines have blades over 100 meters in length and, due to the large scale of the site, only manufacturing and shipping can be pursued in the harbor. Thus, it is considered to be a viable revitalization strategy for the seaport.

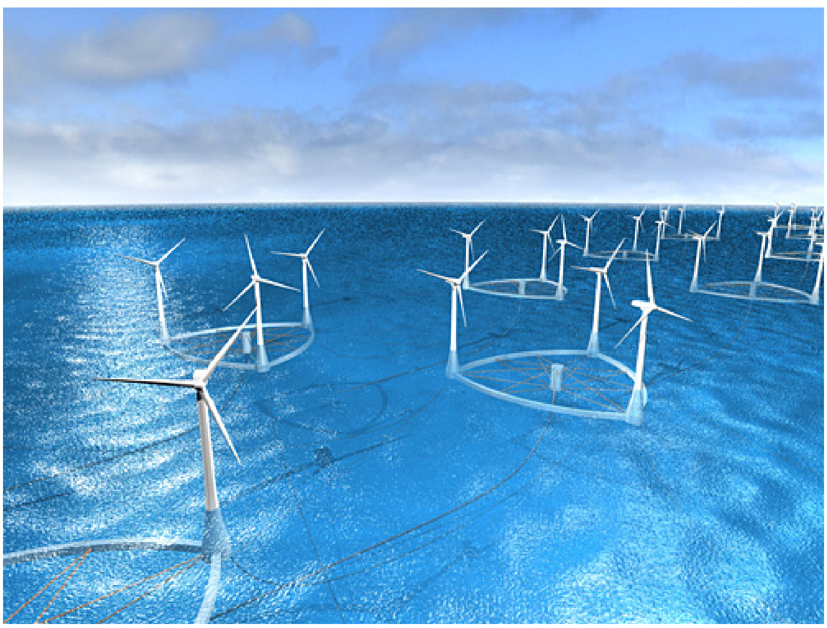

Figure 5. Float type wind power on the ocean, offing of Fukushima (by The Univ. of Tokyo)

GREAT KANTO EARTHQUAKE AND FUKUSHIMA

As is discussed earlier, Shinpei Goto's Capital Reconstruction Plan after the Great Kanto Earthquake of September 10, 1923 met with strong opposition from local landowners and was only realized in limited examples, such as Showa Avenue. Later, under the control of military warlords, our country plunged into the Second World War, culminating in the unconditional surrender of 1945. The recent Tohoku disaster was exacerbated by the unprecedented explosion at the Fukushima Nuclear Power Plant, caused by Tokyo Electric Power Company's failure to take sufficient precautionary measures. This nuclear disaster has shattered the myth of assumed safety, and exposed that such assumptions can be highly lethal.

In the Great East Japan disaster, the government mobilized the Self-Defense Forces for lifesaving and emergency rescue measures, and then to handle the large amounts of rubble and debris from destroyed housing and infrastructure. However, there still remains much work to be done and I believe that the primary restoration work would take around 30 years.

A regional reconstruction plan for the prefectures of Iwate, Miyagi, Fukushima is being pursued. The principles of the regional framework are the following: 1) attract large manufacturing plants, 2) attract corporate research departments, 3) support smaller local enterprises contracting with the Industry Support Centers in each local municipality, 4) promotion of agriculture, 5) connected with national spatial planning, the recent disaster has shown that previous policies related to infrastructure development, land readjustment and zoning, and embankment construction need to be reformed in line with examination of active faults.

Although the budget for emergency construction has been provided, without significant changes, it is questionable whether; 30 years from now, this budget will have been utilized well.

From the beginning of 2012 Japanese, corporates' relocation to Asian countries, including China and India, is becoming more pronounced, even for medium and smaller sized companies, and the Japanese government is considering what policies to adopt in response. Negotiations over TPP, an agreement promoting tariff eliminations, are nearing completion. Since agricultural officials and many with a stake in the Japanese agricultural industry in general are absolutely opposed to joining, the Noda cabinet is faced with difficult decisions.

THE TOKYO QUESTION

The Great East Japan Disaster, and particularly the nuclear accident at Fukushima Daiichi Power Plant, has come as a major political, economic, and social setback for Japan. Yet in terms of international economic activity, former production levels have largely been maintained. The fact that the industrial base of Tohoku was largely restored and back on line within 3 months without large-scale economic loss can be seen as highly fortunate for this scale of disaster. However, if such a powerful earthquake had occurred directly under the Tokyo Metropolitan Area, it would undoubtedly have had a much larger impact on the global economy. While the overall population in Japan is expected to decrease from today's 120 million to 90 million by 2050, it is imperative to develop a strategy to improve the overconcentration of people and institutions in the Tokyo metropolis.

In the 1950s, the National Capital Development Corporation used Prof. Patrick Abercrombie's Greater London Plan as a model and attempted to establish a green belt 5km in width in an area 30-40km from the Tokyo's main city center as vital part of the first National Capital Plan. However, the cooperation of many local authorities and influential local leaders in these areas could not be obtained and, after many violations of the policy orders, the green belt was eventually deregulated. Moreover, agricultural lands confiscated for urban planning during the war were also returned in the process of agricultural land reform and urban sprawl.

With an ageing population and serious energy provisioning issues looming, how to foster economic growth is the most serious question facing our cities. Energy issues and carbon dioxide emissions are the grave problems that we are facing when we think about how to reconstruct the world city of Tokyo.
In the wake of the Great east Japan Disaster, we are awakened again to the imperative of planning for disasters that would strike Tokyo at any time. Regional evacuation centers, and urgent development of

critical facilities and infrastructure requirements, such as the International Medical Center, are required. As a concrete example, rivers, roadside areas, and sport centers should be developed as evacuation areas through the protection and establishment of large open spaces.

THE OSAKA METROPOLIS

The eight measures of Osaka Mayor Hashimoto have attracted the interest of local residents throughout the Osaka Metropolitan Area. The concept was originally proposed for the Metropolitan Area, but has expanded as powerful leaders and voters from the around country have put their support behind it.

Today, the Democratic Party and Liberal Democratic Parties are in a critical situation, and civic instruction is at a low. Moreover, the Noda Cabinet is unwilling to hold General Elections as a means of potentially resolving the current political impasse. Can we expect Mayor Hashimto to use the Satchmo coalition strategy employed by Sakamoto Ryoma in the Meiji period to overcome this situation?

The idea of the “Metropolis” was proposed by former French geographer Jean Gottmann and is the product of the information age. After the Fukushima Nuclear Power Plant Disaster, we are questioning what kind of city can be hoped to provide the basic living conditions for human settlement.

THE JAPANESE POLITICAL AND FINANCIAL SYSTEM

Surveying the political and financial system of the major countries of Europe and North America, presidents or prime ministers are selected through popular elections and their terms last for a single period of around 5 years or a two term period of around 10 years. A political system where elected officials are changed annually, but the same party continues to hold power for extended periods, can only be found in Japan. In addition, although we have placed great emphasis on large and medium sized export industries, the appreciation of the yen challenges this strategy.

BRICS

In the twenty-first century, serious attention is being paid to the economic development of the five BRICS, including in Asia the economic giants of China and India which are increasingly being recognized internationally as superpowers. In this competitive situation, we are questioning the wisdom of relying on various minerals and resources, similar to that of relying solely on oil and natural gas from Middle East. For many years, JICA (Japan International Cooperation Agency) has made significant contributions to infrastructural development in developing countries. In particular, through cooperation with various government agencies with strong international agendas (i.e. Ministry of Foreign Affairs and the Ministry of International Trade and Industry, and Ministry of Land, Infrastructure and Transport) and JICA, the coastal area of Dubai and its monorail was built nicely. This project has been an important achievement and met with the great satisfaction of local people.

UNEP CO2 REDUCTION, KYOTO PROTOCOL

On the issue of nature conservation and global warming, however, there was criticism of the Kyoto Protocol that country delegates negotiated in Kyoto in 2002 and the Kyoto Protocol was formulated, the United States and Canada didn’t participate in this international agreement. Japan is actively endeavoring to promote the resolution of this matter, and to avoid a breakdown of negotiations.

Environmental issues are a much discussed topic, particularly this year, since 2012 is the fortieth anniversary of the establishment of UNEP (United Nations Environment Programme) and the ten year festival of the 2002 conference on sustainability, plus in June 2012, the UN Conference on Sustainability will be held in Rio de Janerio to mark its twentieth anniversary, or ‘Rio + 20’.

AFGHANISTAN PAKISTAN PROBLEM

In 1956, I traveled for three months around countries and large cities of the Middle East Iran, Pakistan and India. After travelling to Athens, Istanbul, Beirut, Alexandria, Cairo, Port Said, Damascus, Baghdad, Tehran, Masher and Qom, Islamabad and Lahore, I entered into India and into New Delhi. From Port Said to the southeast Iranian province of Qom, I travelled by bus, and then from Qom onto Lahore on the Pakistan Railway. Although I did not enter Afghanistan, I spent a good deal of time in the border regions between Afghanistan and Pakistan, the Haidela Pass region in particular, where a number of tents had been built, and local families were kindly by the women, elderly and children of the area accommodated. They were at that time fighting against the Soviet Army and would return from time to time to their tents. Now is not the time to simply wait and wonder when peace will come to Central Asia and the Middle East, but rather the time to actively cooperate to restore peace and order. This cannot be about simple bonds, but about a determined effort to resolve the situation.

If you examine the emergence, growth and decline of the cities of Japan, you will discover that these transformations are always contingent changes in governance structures. According to the oldest Government's Official Record, Emperor Jimmu moved the capital from Takachiho through Kii to Yamato, while Emperor Kammu transferred the capital from Nara to Kyoto, and, in the Meiji period, the capital was again moved from Kyoto to Tokyo. Regardless of its physical location, however, the capital has always represented the country. Will the metropolis initiative of Mr. Hashimoto be realized as a result of the information age? This should be decided during the next 30 years. As for the basic time periods of ethnic culture and civilization theory, during my 30, 50, and 100 years period, the ruins of Western European countries has been closely examined.

From the civilizations of Egypt, Persia, Greece and Rome to the Baroque, Otto Wagner to Bristol and Functionality, and onto Bauhaus and Corubusier, Frank Lloyd Wright, Walter Gropius, and Mies van der Rohe, the principle of functionality has been formed. The CIAM Athens Charter shows the fruition of their thoughts. However, it was dissolved in the face of Team 10, and those well-formed and focused groups are not formulated today.

CONCLUSIONS

In terms of advanced defense issues, these plans are carried out from Kadena Air Base in Okinawa Prefecture. Despite opposition from local residents over many years, the government is going ahead with construction of Air Base. Today, the Obama administration is contemplating making significant reductions to the defense budget that would reduce the cost of the Marine Corps Base in Okinawa. This is a great opportunity for Japan to properly reconsider the financial resources necessary to defense capabilities and related issues in response to this U.S. military base. In addition, in order to prepare for an earthquake in the Tokyo Metropolitan area, the U.S. base in Tachikawa is also of great strategic value. To protect the people and citizens of the country, the dangers of war and natural disaster must be properly dealt with.

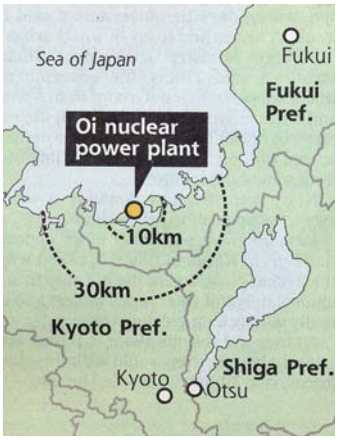

Figure 6. Fukui Prefecture, Oi nuclear power plant

The Prime Minister Y. Noda accompanied by Y. Edano, Minister of Economy, Trade and Industry and O. Fujimura, Chief Cabinet Secretary attended the Meeting for restarting Oi Reactors in Fukui Prefecture.

The Government of Fukui, Kyoto and Shiga also attended the meeting to discuss the survey report for issues and proposals of Oi reactor made by the Special research and Survey Committee.
Mr. Noda has strong will to restart reactors. A lot of observers at the meeting were against of restarting reactors. Furthermore, Mr. Noda is surrounded by opposition members of Democratic Party on the issues related the rate of sale tax from present 5 percent to 10 percent in 2015.
These 2 big political issues may not be solved by the General Parliamental election in coming June.
It is essential to revise the government system to strengthen cabinet secretary functions through there reforms, the Prime Minister can control each minis only and other national organizations.

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LESSONS FROM THE 2010 MAULE EARTHQUAKE A GEOTECHNICAL ENGINEERING PERSPECTIVE

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ABSTRACT

Some of the key lessons drawn from the seismic behavior of geotechnical structures during the M8.8 2010 Maule, Chile earthquake are summarized. Localized damage patterns indicate that site effects could have played an important role in this earthquake. On the other hand, soil liquefaction occurred at many sites, and often led to ground failure and lateral spreading. Also, the damage to some sections of Ruta 5, the primary North-South highway in Chile, was pervasive, which disrupted the flow of supplies and traffic following the event. Most dams, levees, and mine tailings dams performed well. However, several key earth structures experienced some distress, and in one case an abandoned tailings dam failed because of liquefaction-induced flow slide. Most earth retention systems, such as retaining walls and basement walls, proved to be inherently robust. Landsliding was not pervasive, which appears to have resulted from native slopes that are generally composed of competent earth materials and the relatively low groundwater levels present at the date of the event.

INTRODUCTION

From a geotechnical engineering point of view, the key lessons that can be drawn from the Mw8.8 February 27, 2010 Maule Earthquake, are related to three main aspects: effects of liquefaction to the built environment, roads' earth fill behavior, and site effects.

LIQUEFACTION EFFECTS

Liquefaction is defined as the "transformation of a granular material from a solid to a liquefied state as a consequence of increased pore-pressure and reduced effective stress" (Marcuson, 1978). When soils liquefy, their strength and stiffness gets drastically reduced, which can be the cause of great damage to the structures that interact with these soils. In the case of the 2010 Maule Earthquake, and among several effects, liquefaction caused excessive vertical settlement of buildings, the collapse of an abandoned tailings dam which killed a family of four, and it induced lateral spreading at some bridge abutments. Probably, the most relevant lesson in this sense is that our seismic codes should incorporate recommendations regarding liquefaction triggering, liquefaction effects' evaluation, and liquefaction mitigation.

EARTH FILL BEHAVIOR

Chile's main highway, Route 5, which runs in the north-south direction along most part of the country, was severely affected by the collapse or partial collapse of portions of the earth fills that support the road. In most cases, failure was not caused by inadequate performance of the earth fill itself, but because the underlining foundation soil's resistance got reduced by the seismic motion. The key lessons in this sense were that (i) soil conditions have an important effect on the seismic response of earth fills, and (ii) as earth fills thicknesses get higher, and especially in critical lifeline roads, more detailed geotechnical analyses should be enforced.

SITE EFFECTS

It is known that surface movements are affected by local soil conditions. Soil properties may affect amplitude, frequency content, and duration of ground motions, and, in this sense, key parameters of the soil layers are: soil type, layer thickness, and stiffness. In Santiago, for instance, damage got concentrated in some well-defined areas, which has led us to think that site effects could have played a role on the seismic response of these sites. Some of the lessons in this aspect were that (i) site's seismic classification should be based on a single or limited number of relevant, yet practical parameters, (ii) design response spectra should be more closely related to site classification, and (iii) we should work on a unified design spectra which is independent of the type of structure that will be built on the site.