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ENHANCEMENT OF EARTHQUAKE AND TSUNAMI DISASTER MITIGATION TECHNOLOGY IN PERU: A SATREPS PROJECT

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Abstract: This project aims to conduct a comprehensive research towards earthquake and tsunami disaster mitigation in Peru considering regional characteristics, under strong collaboration among researchers of Peru and Japan. Five main research activities are the followings: 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. After signing of the Record of Discussion (R/D) in January 2010 by the responsible organizations of the two nations, the project has just started and will continue for the five year period. This paper introduces the Japan-Peru earthquake and tsunami disaster mitigation research project.

1. INTRODUCTION

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 scheme of SATREPS is shown in **Figure 1**. Research proposals in the following three fields were invited to apply for the grant: 1) Environment and Energy, 2) Natural Disaster Prevention, and 3) Infectious Diseases Control. A proposal submitted by the present authors, "Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru," was selected as one of the projects in the field of natural disaster prevention in April 2009.

The project aims to conduct a comprehensive research towards earthquake and tsunami disaster mitigation in Peru considering regional characteristics, under strong collaboration among researchers of Peru and Japan. The first author (F. Yamazaki) is the principal investigator (PI) of the Japanese team and the second author (C. Zavala) is the PI of the Peruvian team. After the nomination of our project, the preparatory phase has started to plan the detail of the joint research, considering the needs of the developing country (Peru) and the promotion of science and technology on the global issue (disaster mitigation).

The Record of Discussion (R/D) was signed on 15 January 2010 by the responsible authorities of the two nations (JICA and National University of Engineering, Peru) in Lima, Peru. Then the project has formally started and will continue for the five year period (until March 2014). This paper describes the overall objectives and joint research plan of the project.

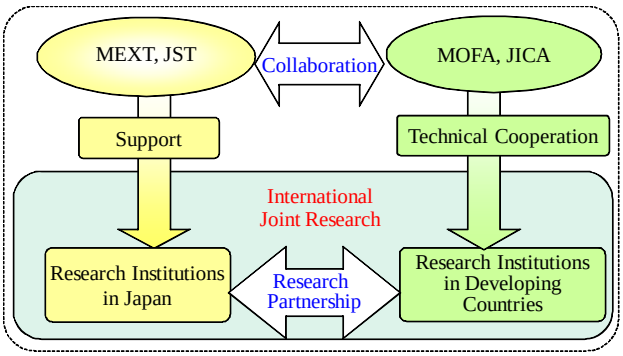

Figure 1 Scheme of Science and Technology Research Partnership for Sustainable Development (SATREPS) (http://www.jst.go.jp/global/english/about.html)

2. BACKGROUND AND OBJECTIVES OF THE PERU PROJECT

Natural disasters are one of the major threads for people in the world. Especially for the countries in the Asia-Pacific region, earthquakes and tsunamis are the major obstacles towards sustainable developments. In order to reduce disaster risks, understanding of natural hazards and upgrading of societal resilience are necessary. Since earthquakes and tsunamis are rare but devastating events, the data collection in a global scale is necessary and international collaboration is inevitable to reduce the losses due these events, as highlighted in Hyogo Framework of Action (International Strategy of Disaster Reduction (ISDR), 2005). In this sense, Japan is expected to serve a leading role in the promotion of international disaster mitigation because of its long history to cope with natural disasters.

Peru locates in the circum-Pacific seismic belt with high seismic and tsunami risks. **Figure 2** shows the tectonic settings and the epicenters of earthquakes in Peru and the surrounding region. It is seen that both Peru and Japan are located in a similar seismic environment, frequently hit by damaging earthquakes and tsunamis In this region, large plate-boundary earthquakes occurred recently in the offshore of Atico (M_w=8.4, 23 June 2001) and in the offshore of Pisco (M_w=8.0, 15 August 2007). A large number of buildings and infrastructures were destructed, hundreds of people were killed, and tsunamis were also generated by these events. Thus, earthquake and tsunami disaster mitigation draws considerable attentions in Peru.

Not just physical similarities of the two countries, Peru and Japan have a long term relationship since 1873, when the official relation has started. A large number of immigrants from Japan settled down in Peru in the early 20 century.

The relationship in the field of disaster mitigation technology also has some history. Japan-Peru Center for Earthquake Engineering and Disaster Mitigation (CISMID) was established within National University of Engineering (UNI) in 1987 by the support of Government of Japan. CISMID became the leading center of earthquake engineering research in South America. CISMID has been in collaboration with many Japanese research institutions, notably, Building Research Institute in Tsukuba, Japan.

Significance of this joint research between Peru and Japan can be summarized as the four points: 1) contribution of Japanese science and technology to disaster mitigation in Peru, 2) providing research fields to Japanese geoscience and earthquake engineering, 3) contribution to international tele-tsunami research for subduction-zone earthquakes, e.g. 1960 Chile earthquake, and 4) promotion of disaster mitigation and capacity building through sharing the knowledge from the international joint research.

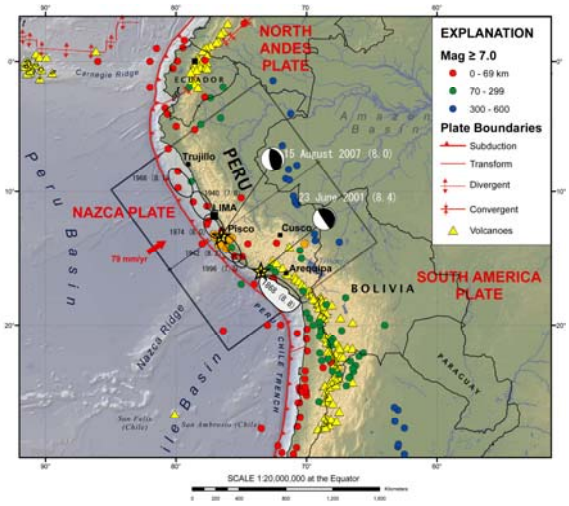

Figure 2 Tectonic setting and the epicenters of earthquakes in Peru and the surrounding region (modified from USGS (2007) and Chlieh et al. (2004))

3. OVERALL 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. **Figure 3** shows the organizational structure of this five year projects. 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.

Japanese reaserch team consists of five groups (G1 to G5 in Figure 3; the group leaders are the authors of this paper) corresponding to the five topics.

Peruvian research team consists of CISMID/UNI, National Institute of Civil Defense (INDECI), Geophysical Institute of Peru (IGP), Direction of Hydrology and Navigation (DHN), National Committee for Aerospace

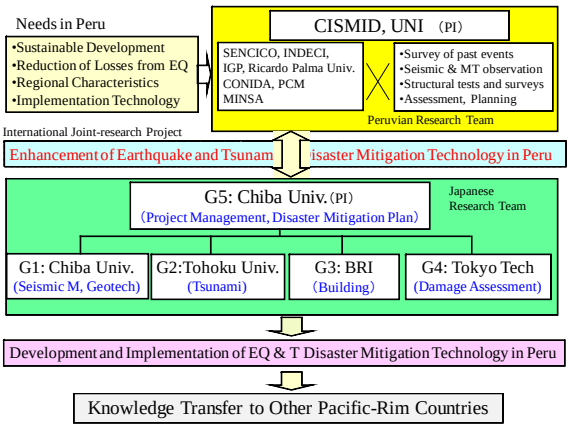

Figure 3 Organizational structure of the project

Research and Development (CONIDA), Disasters Prevention and Study Center (PREDES), National Institute of Culture (INC), Ministry of Housing, Construction, and Sanitation (MVCS), National Service of Training for the Construction Industry (SENCICO), Ricardo Palma University (URP), National Office of Electronic Government and Information (ONGEI-PCM), and Municipalities of the project study areas.

Figure 4 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 Lima including Callao has already selected as one of the study areas. The other two areas are still in discussion; currently, Chimbote in the north and Moquegua or Tacna in the south are possible candidates. Other than these areas, the affected areas due to the recent earthquakes, Pisco (the 2007 event) and Camana, Arequipa etc. (the 2001 event), will also be considered in developing hazard and damage assessment models.

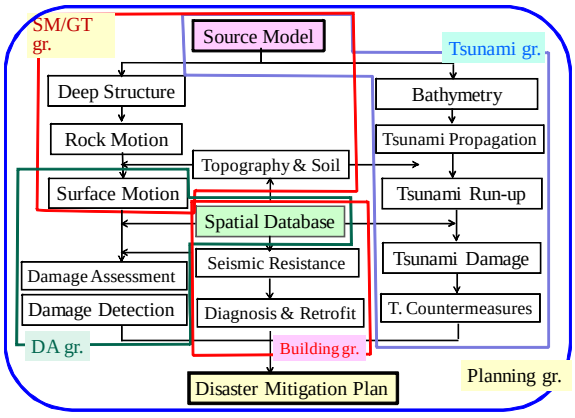

Figure 4 Research topics and items of the project and the groups in charge the items

4. IMPLEMENTATION AND PROSPECTED OUTPUTS OF THE PROJECT

The Japanese Detailed Planning Survey Team organized by JICA visited Peru from August 5 to 13, 2009, for the purpose of working out the details of the technical cooperation program concerning the project. During its stay in Peru, the team exchanged views and had a series of discussions with the Peruvian organizations concerned, led by CISMID/UNI. As a result, the team and the Peruvian organizations concerned agreed on the matters referred to in the document (JICA, 2009).

The objective of this project has agreed as "To develop technologies and measures for assessment and mitigation of earthquake/tsunami disasters caused by large-magnitude inter-plate earthquakes occurring off the coast of Peru." It is further envisaged that such technologies should be widely used in Peru, and also disseminated and applied to pacific-rim countries, especially to neighboring countries, facing the risks of large-magnitude inter-plate earthquakes and tsunamis. In addition, the project is expected to contribute to the enhancement of capacity as well as the advance of research for both Peruvian and Japanese research institutes involved in this project.

The following seven outputs are listed in the master plan agreed.

1. Scenarios of large-magnitude inter-plate earthquakes are identified which will cause the most significant losses in Peru (G1, G2).
2. Geographical information of the study areas is prepared (G4).
3. Tsunami disaster losses in study areas by scenario earthquakes are estimated, and mitigation technologies are developed (G2).
4. Strong motion and ground failure in study areas by scenario earthquakes are simulated (G1).
5. Earthquake disaster losses in study areas by scenario earthquakes are estimated, and mitigation technologies are developed (G4).
6. Technologies for evaluation of seismic-resistance and structural retrofit are developed, adapting to building characteristics of Peru (G3).
7. Earthquake/tsunami disaster mitigation is promoted in the study areas (G5).

Table 1 Schedule of the project

Research Items	Period (2009-2014) 1 st	2 nd	3 rd	4 th	5 th
Project Management 【Chiba U and CISMID/UNI】	WS▼	WS▼	WS▼	WS▼	WS▼
G1: Seismic motion & Geotechnical 【Chiba U and CISMID, IGP】	Source modeling	Simulation of SM			
1-1 Source modeling and seismic motion	EQ and MT observation, Geological survey			Microzonation	
1-2 Site response & Microzonation	Field survey, measurement		Seismic Response Analysis		Hazard map
1-3 Slope failure assessment					
G2: Tsunami 【Tohoku U and DHN, CISMID】	Tsunami simulation	Inundation and impact			
2-1 Tsunami propagation and impacts	Data collection	Damage assessment method		Tsunami damage analysis	
2-2 Tsunami hazard mapping	Historical tsunami data		Tsunami DM technology		
2-3 Tsunami DM technology					
G3: Buildings 【BRI and CISMID】	Literature Survey, Tests		Database development		
3-1 Seismic tests database	Develop diagnosis method		Retrofit technology, Validation tests		Guideline
3-2 Diagnosis and Retrofit	Survey, Risk assessment		Retrofit Technology		Guideline
3-3 Retrofit of historical buildings					
G4; Damage Assessment 【Tokyo Tech and CISMID, CONIDA】	Data collection	Geospatial data		Database development	
4-1 Geo-spatial database	Data collection	Methodology		Damage detection	
4-2 Damage detection using RS	Damage assessment method			Assessment, risk map	
4-3 Damage assessment for Scenario EQ					
G5; Disaster Mitigation Plan 【Chiba U and INDECI, CISMID】	Literature Survey		Planning	Dissemination, Education	

The schedule of the five-year project is shown in **Table 1**. To implement the project, JICA will provide the services of the JICA experts (Japanese research members), machinery, equipment and other materials necessary for the implementation of the project, and will receive the Peruvian personnel connected with the project for technical training in Japan. The actual joint research will be carried out by the five joint research groups in Table 1.

Other than group-based technical collaborations, the leading members of the project will meet annually either in Peru or Japan in the occasion of project workshops. The first project workshop will be held soon in Lima on March 15

and 16, 2010. About 25 researchers from Japan and scores of researchers/engineers/stakeholders from Peru will attend this workshop. Earthquake engineering researchers from the surrounding Latin American countries will also participated in the workshop.

The Joint Coordinating Committee (JCC) will be organized soon to oversight the project and meet at least once a year and whenever necessity arises, in order to fulfill the following functions (JICA, 2009):

(1) To approve the annual work plan of the project
(2) To review the progress of the annual work plan
(3) To review and exchange opinions on major issues that may arise during the implementation of the project
(4) To discuss any other issue(s) pertinent to the smooth implementation of the project

5. DETAILED RESEARCH PLANS AND ACTIVITIES

To obtain the expected outputs, the following research activities are planned for the five research groups.

5.1 Source, Seismic Motion and Geotechnical Issues

1-1 Surveying historical records of earthquakes, and grasping the characteristics of inter-plate earthquakes occurring off the coast of Peru
1-2 Developing earthquake source models that are suitable to the characteristics of inter-plate earthquakes occurring off the coast of Peru
1-3 Having preliminary estimation of earthquake/tsunami disaster losses using the source scenarios, and identifying the most devastating scenarios of inter-plate earthquakes
1-4 Observing microtremor in the study areas
1-5 Developing seismic observation networks in the study areas, and observing strong seismic motions
1-6 Collecting existing geological data of the study areas, and undertaking supplementary borehole surveys
1-7 Modeling deep and subsurface ground structures of the study areas
1-8 Simulating strong motions and ground failures in accordance with the inter-plate earthquake scenarios

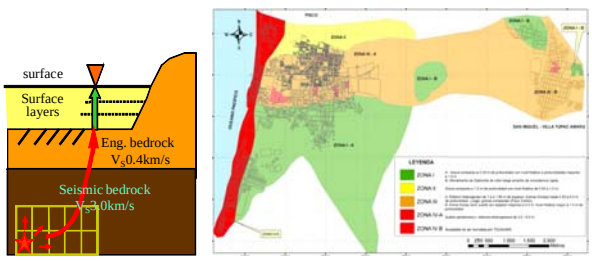

Figure 6 Scheme of simulation of seismic motion (left) and an example of seismic microzonation (right)

5.2 Tsunami Simulation and Damage Mitigation

2-1 Surveying historical records of tsunamis, and grasping the characteristics of tsunami propagation along the Pacific coast of Peru
2-2 Preparing merged bathymetry and topography data of the coastal zones of the study areas
2-3 Evaluating vulnerability of buildings and infrastructures in the study areas
2-4 Simulating tsunami propagation and run-up in accordance with the earthquake scenarios, and estimating tsunami disaster losses
2-5 Making tsunami hazard maps for the study areas
2-6 Making guidelines of designing emergency evacuation facilities

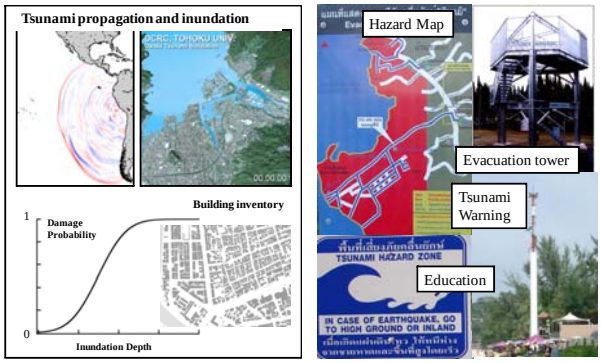

Figure 7 Scheme of tsunami simulation and damage assessment (left) and tsunami countermeasures (right)

5.3 Enhancement of Seismic Resistance of Buildings

3-1 Developing a database of structural test results and material test results for buildings
3-2 Developing technologies of seismic-diagnosis and retrofit for different types of buildings prevalent in Peru
3-3 Identifying historical buildings in the study areas that face significant earthquake disaster risks
3-4 Verifying the effects of structural retrofit technologies through structural tests and numerical analyses

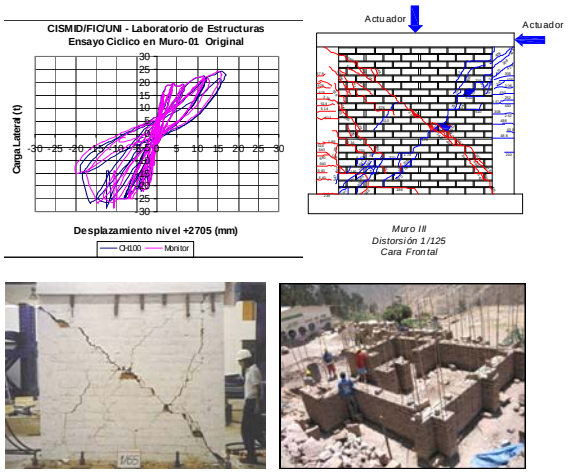

Figure 8 Scheme of structural testing (top) and photos of experiment and construction site (bottom)

5.4 Geo-spatial Database and Damage Assessment

4-1 Making digital surface models (DSMs) of the study areas using satellite images

4-2 Making land-use maps and building maps of the study areas using satellite images

4-3 Estimating earthquake disaster losses of the study areas in accordance with the inter-plate earthquake scenarios

4-4 Developing technology for rapid detection of earthquake/tsunami disaster losses using satellite images

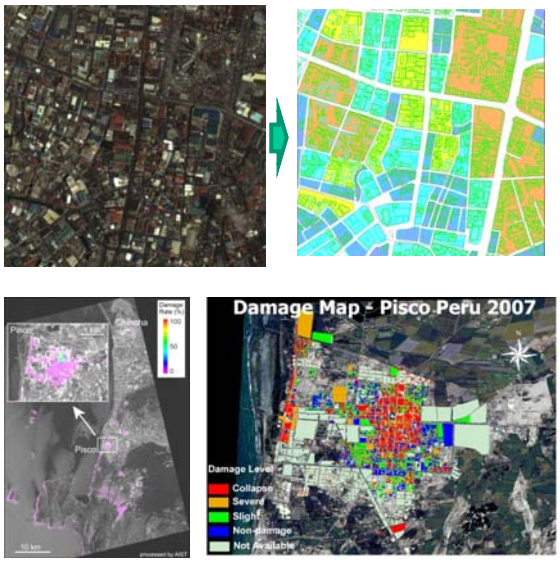

Figure 9 Scheme of developing building inventory (top) and damage assessment of the Pisco earthquake (bottom)

5.5 Development of Disaster Mitigation Plan

5-1 Developing land-use proposals for mitigation of earthquake/tsunami disasters

5-2 Developing local disaster mitigation plans for the study areas

5-3 Undertaking awareness raising and dissemination activities of earthquake/tsunami disaster mitigation for disaster management organizations and local communities

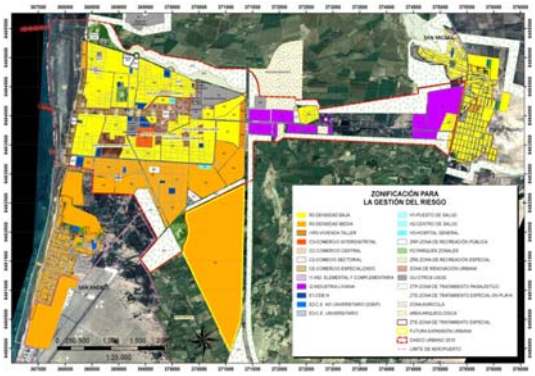

Figure 10 Land-use plan of Pisco city proposed by CISMID after the Pisco earthquake

6. CONCLUSIONS

Under the joint sponsorship of JST and JICA, a new international research program named "Science and Technology Research Partnership for Sustainable Development (SATREPS)" has started, and the proposal submitted by the present authors, "Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru," was accepted in the category of natural disaster prevention. In this paper, the background, objectives and research plan of the project were introduced. The project aims to conduct a comprehensive research towards earthquake and tsunami disaster mitigation in Peru considering regional characteristics, under strong collaboration among researchers of Peru and Japan. The progress of the project will be presented in the near future.

References:

Chlieh, M., de Chabalier, J. B., Ruegg, J. C., Armijo, R.; Dmowska, R., Campos, J., Feigl, K. L. (2004), "Crustal deformation and fault slip during the seismic cycle in the North Chile subduction zone, from GPS and InSAR observations," Geophys. J. Int., 158, 695-711.

ISDR (2005), "Hyogo Framework of Action for 2005-2015: Building the resilience of nations and communities to disasters," http://www.unisdr.org/eng/hfa/hfa.htm

Japan International Cooperation Agency (2009), "Minutes of meeting between JICA detailed planning survey team and the National University of Engineering."

USGS (2007), "Poster of the Ica, Peru Earthquake of 15 August 2007 -Magnitude 8.0, Earthquakes Hazard Program USGS," http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2007/20070815.php