Progress of JST-JICA Project on Earthquake and Tsunami Disaster Mitigation in Peru

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SUMMARY:
This project conducts a comprehensive research towards earthquake and tsunami disaster mitigation in Peru under the framework of "Science and Technology Research Partnership for Sustainable Development (SATREPS)", sponsored by Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA). The project focuses on five research fields such as seismic motion and geotechnical issues, tsunami, buildings, spatial information database and damage assessment, and disaster mitigation plan. Two and half years have passed since the project started after signing on the Record of Discussion (R/D) in January 2010, now in the middle of the five-year contract. In this project, researchers from Peru and Japan coordinate the schedule and collaborate together to achieve the overall objectives. This paper describes the scope of the work and the progress of the SATREPS Project on Earthquake and Tsunami Disaster Mitigation in Peru.

Keywords: Disaster Mitigation, International Project, Peru, Earthquake, Tsunami

1. INTRODUCTION

A project of “Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru” started in January 2010 to conduct a comprehensive research towards earthquake and tsunami disaster mitigation in Peru. This project is performed under the strong collaboration among Peruvian and Japanese researchers with the framework of “Science and Technology Research Partnership for Sustainable Development (SATREPS)”. Fig. 1.1 shows the project system between research institutes in Japan and Peru and two funding agencies. Headquarters of research institutes are Chiba University in Japan and National University of Engineering (UNI) in Peru. Fumio Yamazaki and Carlos Zavala are leading the research teams as the principal investigators of this project. Japan Science and Technology Agency (JST) support the Japanese institutes for the joint research, such as technological development and data collection of the global earthquake and tsunami disasters. Japan International Cooperation Agency (JICA) supports the project for Peruvian institutes by sending the Japanese experts, machinery, and inviting the Peruvian trainees to Japan. This joint sponsorship is unique and specially developed for the SATREPS projects. Under this framework, the project is ongoing for the earthquake and tsunami disaster mitigation in Peru.

2. BACKGROUND AND OBJECTIVES

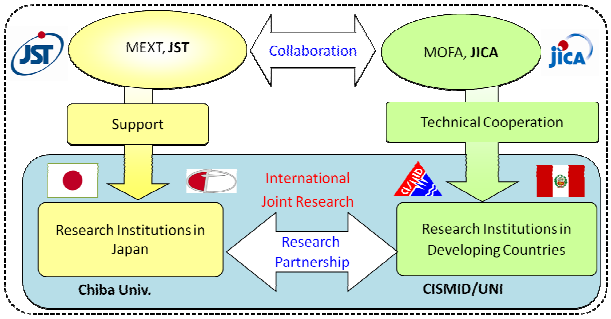

Figure 1.1. Scheme of Science and Technology Research Partnership for Sustainable Development (SATREPS)

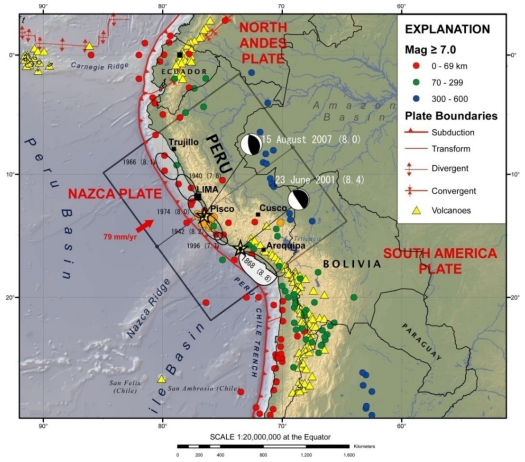

Figure 2.1. Tectonic settings and epicenters of earthquakes in Peru (modified from USGS, 2007)

Earthquakes and tsunamis are major concerns in the Asia-Pacific region towards sustainable developments for these countries. Understanding natural hazards and upgrading societal resilience are necessary to reduce disaster risks. Since earthquakes and tsunamis are rare events, the data collection is important in a global scale. Therefore, the international collaboration is a key among these countries by sharing their experiences. Currently, Japan is one of the leading societies in the field of international disaster mitigations because of its long history for fighting against earthquake and tsunami disasters. Peru also has a long history for challenging the earthquake and tsunami disasters with the similar seismic environment to Japan. Fig. 2.2 shows the tectonic settings for this region. Large plate-boundary earthquakes occurred recently in the offshore of Atico (M_w 8.4, June 23rd, 2001) and in the offshore of Pisco (M_w 8.0, August 15th, 2007). Seismic shakings and tsunami caused hundreds of fatalities with a large number of building failures and infrastructure damages. Therefore, there is a major concern for earthquakes and tsunamis in Peruvian society too.

Peru and Japan have a long-term relationship which started in 1873 with the conclusion of diplomatic relation. A large number of immigrants from Japan settled down in Peru in the early 20th century. In 1987, Japan-Peru Centre for Earthquake Engineering and Disaster Mitigation (CISMID) was established in UNI with the support by Japanese government. CISMID became a leading centre of earthquake engineering in South America by collaborating with many Japanese research institutions such as Building Research Institute in Tsukuba, Japan.

On the basis of these backgrounds, the objectives of this joint research project are described into four points. The first objective is the contribution of Japanese science and technology to disaster mitigation in Peru. The second one is that the project will provide research fields to Japanese geoscience and earthquake engineering in a global scale. The third one is that the project contributes to international tsunami research for subduction-zone earthquakes which affects many countries around the Pacific Ocean. The last one is the promotion of disaster mitigation and capacity building by sharing the knowledge between the two countries. According to these objectives, the Japanese and Peruvian researchers promote the joint research to fulfil the objectives of the project.

3. RESEARCH ORGANIZATION AND TOPICS

Research organizations and topics for this project are shown in Fig. 3.1. The project primary comprises five main research topics such as strong motion prediction and development of seismic microzonation (Group 1), development of tsunami effects based on numerical simulations (Group 2), enhancement of seismic resistance of buildings based on structural experiments and field investigation (Group 3), development of spatial information database using remote sensing technology and earthquake damage assessment for scenario earthquakes (Group 4), and development of earthquake and tsunami disaster mitigation plan and its implementation to the society (Group 5). Each group has

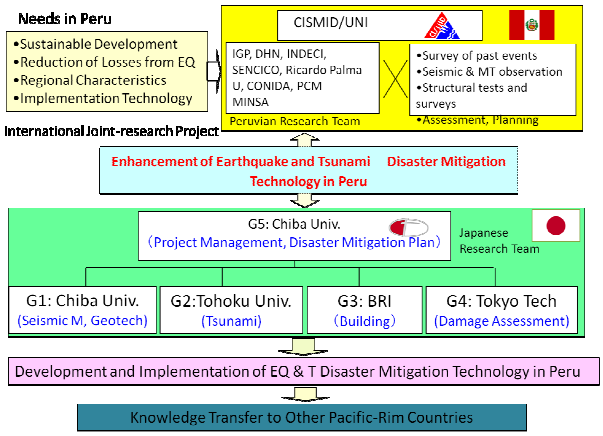

Figure 3.1. Organization of the SATREPS-Peru project

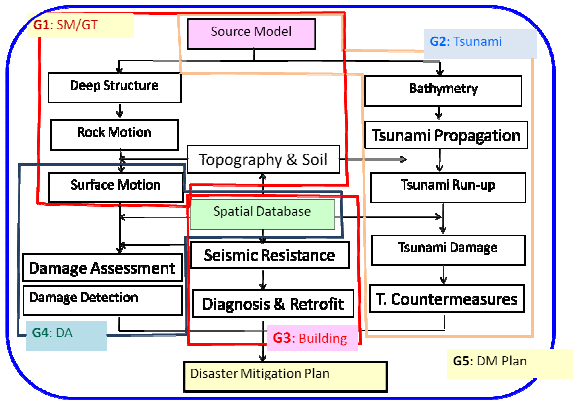

Figure 3.2. Research topics and items of the project with the arrangement of the groups

collaboration institutes in Japan and Peru. The researchers in Chiba University study seismic motions and geotechnical issue (G1), working with the researchers in Geophysical Institute of Peru (IGP). Similarly, the researchers in Tohoku University collaborate with Direction of Hydrology and Navigation (DHN) in evaluating the tsunami hazard in Peru (G2). Building Research Institute and CISMID collaborate together to evaluate the building vulnerability against strong ground motions in Peru (G3). Tokyo Institute of Technology and CISMID perform the damage assessment together against the earthquakes in Peru (G4). Finally, these works are summarized and implemented into disaster mitigation plans in Peru (G5) by collaborating with Chiba University and National Institute of Civil Defence (INDECI). Fig. 3.2 shows the research topics and items for each group in the project. Each group has a few topics these outcomes are shared with other groups. By integrating these outcomes from Group 1 to Group 4, Group 5 proposes disaster mitigation plans for earthquake and tsunami and implements these to Peruvian societies. A part of Metropolitan Lima including Callao is selected as one of the study areas. The city of Tanca is also selected as a study area, which locates near the border between Peru and Chile. Pisco, Camana, and Arequipa are also considered in developing hazard and damage assessment models because these cities were damaged by the recent large earthquakes and tsunamis.

4. SCOPE OF WORK

JICA sent a study team to Peru from August 5th to 13th in 2009 to investigate the details of the technical cooperation in the project. The team and the Peruvian organizations came to an agreement on the matters listed in the document (JICA, 2009). The scope was agreed 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. This will meet the demands in Peruvian and

Table 4.1. Scope of Work in the Agreement between Peru and Japan

Item No.	Descriptions
1	Scenarios of large-magnitude inter-plate earthquakes are identified to cause the most significant losses in Peru.
2	Geographical information of study areas is prepared.
3	Tsunami disaster losses in study areas by scenario earthquakes are estimated, and mitigation technologies are developed.
4	Strong motions and ground failures in study areas by scenario earthquakes are simulated.
5	Earthquake disaster losses are estimated against scenario earthquakes, and mitigation technologies are developed.
6	Technologies are developed for evaluating the structural seismic resistances and these retrofits, which are applicable to regional buildings in Peru.
7	Earthquake and tsunami disaster mitigation is promoted in study areas.

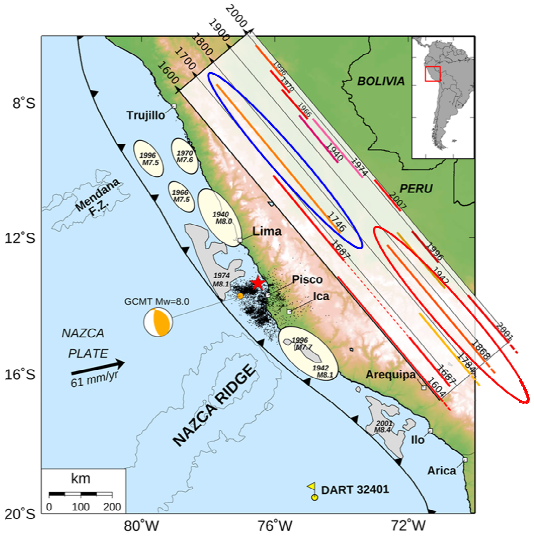

Figure 5.1. Two scenario earthquakes in Peru

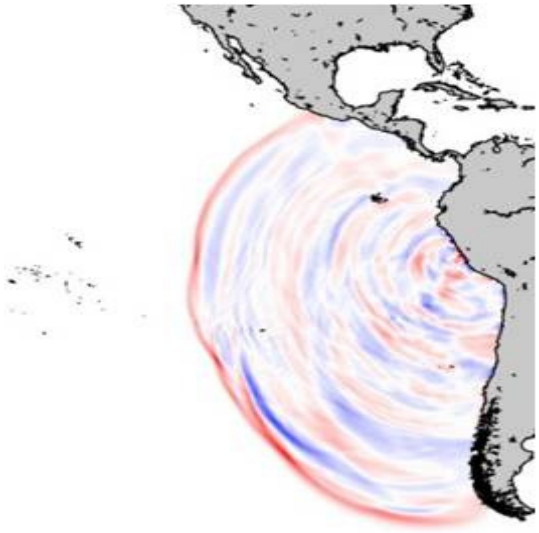

Figure 5.2. Example of tsunami simulation

Figure 5.3. Laboratory experiment at CISMID

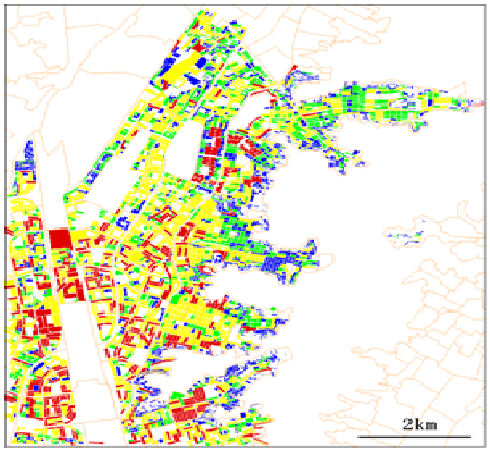

Figure 5.4. Developed building inventory in Lima

Japanese societies, and these outcomes will be applied to other pacific-rim countries, especially to neighbouring countries facing to the risks of large-magnitude inter-plate earthquakes and tsunamis. Table 4.1 shows the seven outputs listed in the master plan developed by JICA. The members of the project team meet annually either in Peru or Japan at the project workshop. A meeting of the Joint Coordinating Committee (JCC) is held annually in order to approve the annual work plan by reviewing the progress, exchange opinions and discuss details of the project for the implementation into Peruvian society.

5. RESEACH ACTIVITIES

Each group performs the research on the basis of the master plan. Group 1 studies the seismic motions and geotechnical aspects in Peru. Fig. 5.1 shows the selected earthquake scenarios based on the work by Peruvian and Japanese researchers. The scenarios come from two major historical earthquakes. One is the 1746 great earthquake (M_w 8.6) that destroyed the City of Lima completely, and the other is the 1868 great earthquake (M_w 8.8) which caused the significant tsunami damages in Peru. Group 1 also performs the site investigation to measure ground responses and shear wave velocity profiles in Lima and Tacna by array mictrotremor observations. These results are available at more than 200 sites in Peru to provide microzonation and hazard maps. Carderon et al. (2012) used these results and calculated the amplification factors for the Fourier Spectra. They compared the results to the

Figure 6.1. The 2010 Chile Earthquake reconnaissance survey (a) Team 1, (b) Team 2, (c) Team 3

Figure 7.1. Japanese experts' activities in Peru (a) lecture at Peruvian Congress, (b) tsunami simulation seminar, (c) field survey of historical buildings

acceleration recordings, and showed a good agreement between them. This result indicates the capability to provide the hazard maps with this methodology. Group 2 studies tsunami simulation and damage mitigation. Adriano et al. (2012) calculated the tsunami inundation areas for the 2001 Atico Earthquake, and compared the computed tsunami run-up heights with actual observations. The study shows a good agreement between these, which validates the application of numerical simulation to tsunami hazard evaluation in Peru. Fig. 5.2 shows an example of tsunami propagation simulation for the 1746 great earthquake, performed by Tohoku University and CISMID (Koshimura, 2012). These results are currently utilized to obtain inundation maps in Lima and referenced for the evacuation plan at La Punta district in the metropolitan Lima.

Group 3 studies seismic resistance of and retrofit of buildings in Peru. Cuadra et al. (2011) performed a field survey to present the vibration characteristics of regional adobe-quincha buildings in Lima. Zavala et al. (2012) calculated structural damages in Lima by earthquake shaking and translated these damages into loss estimations in terms of retrofitting costs. Laboratory experiments were also performed at CISMID and Yokohama National University. Fig. 5.3 shows a concrete wall experiment at CISMID. These experiments create a database to find the effective retrofit methods for regional buildings in Peru by combining with field survey results.

Group 4 performs the damage assessment in Peru. Fig. 5.4 shows an example of building inventory in Lima obtained by the census data, satellite images, land-use maps and elevation maps (Miura et al., 2012). On the basis of these building inventories, earthquake damages will be evaluated against the scenario earthquakes provided by Group 1

6. FIELD SURVEY FOR THE 2010 MAULE EARTHQUAKE IN CHILE

A magnitude M_w 8.8 earthquake occurred off the Pacific coast of Maule, Chile on February 27th, 2010. The epicentre was located at 35.909^{o}S and 72.733^{o}W with a depth of 35 km. The event took place at the convergent boundary where the Nazca plate moves below the South American plate. Tsunamis were generated by the earthquake to hit the coastline of Chile, and propagated through the Pacific Ocean to Pacific Islands and even to Japan. Although the project's interest is large-magnitude inter-plate earthquakes in the offshore of Peru, this event in Chile was considered to be good a

Figure 7.2. Activities by Peruvian researchers and trainees in Japan (a) technical tour at Port and Airport Research Institute (PARI), (b) tsunami damage survey at Onagawa, (c) training for seismograph data at Chiba University

Figure 7.3. The 3rd Japan-Peru Workshop on Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru at Campus Innovation Center, Tokyo in March, 2012

reference for the project study. After the occurrence of the earthquake, joint field survey teams by Japanese and Peruvian researchers were planned with the collaboration by Chilean researchers. JST provided the financial support to send the three survey teams to Chile. Fig. 6.1 shows the team members of each group. Team 1 collected the ground truth data using handheld GPSs with satellite images. Team 2 surveyed tsunami run-up water-depth measurements and damages. Team 3 investigated the detailed building damages from the view point of seismic motion and geotechnical aspects. On the basis of these surveys, Pulido et al. (2011) perform an inversion analysis and explained the rupture process in the Maule Earthquake. The reconnaissance report was also written and posted at the project website (JST-JICA SATREPS Peru Project Chile Earthquake Field Investigation Team, 2010). These studies are efficiently used in this project to understand the earthquake and tsunami disasters in Peru.

7. PROJECT MANAGEMENT AND OUTCOMES

Since SATREPS are funded by two agencies, the both have the different objectives throughout the project. JICA, an agency under Ministry of Foreign Affairs (MOFA), supports the project as a part of Official Development Assistance (ODA), which requires the development of practical technologies to Peruvian societies. On the other hand, JST, an agency under Ministry of Education, Culture, Sports, Science and Technology (MEXT), expects scientific achievements by developing novel theories and

Figure 7.4. Sendai International Symposium (a) panel discussion by representatives from different projects, (b) field trip at Onagawa town hospital

new technologies. Therefore, the project provides equipment such as seismometers, structural testing devices, and geospatial data, but also develops technologies related to image analyses, tsunami simulations, and survey technologies. Large portion of the budget was spent to provide structural testing equipment and seismometers and microtremor devices based on the communication between Peruvian and Japanese researchers. The equipment was mainly purchased in Japan by Chiba University and shipped to Peru by JICA. The shipping process is relatively complicated and very new for Japanese researchers including the petition of tax exemption and installation in sites. Therefore, the progress was slow in the start-up period, but is accelerating more each year.

The other focus of the project is the technical support by sending the Japanese experts to Peru and inviting Peruvian researchers to Japan. The most of Japanese researchers, especially young researchers, had good experiences by working with Peruvian researchers in laboratory tests and field surveys. Fig. 7.1 shows Japanese researchers' activities in Peru. Fig 7.1a shows the seminar at Peruvian Congress about Japanese technology related to earthquake and tsunami disaster mitigation. Fig 7.1b shows a lecture at CISMID on tsunami propagation simulation. Fig. 7.1c shows a joint field survey of historical buildings in Peru. The project also invites Peruvian researchers for capacity building of human resources. Five short-term trainees have already been invited to study in Japan at Chiba University, Tohoku University, and Building Research Institute with the support by JICA. Two doctoral students are studying at Chiba University and Yokohama National University with the support by MEXT. Fig. 7.2a shows a technical tour to tsunami facility at PARI after the 2011 project workshop. Fig. 7.2b shows the field survey of tsunami damaged areas after the 2011 Tohoku earthquake and tsunami by Mr. Jimenez, who was a short-term trainee at Tohoku University. Fig. 7.2c shows seismometer data collections by Mr. Gonzales and Ms. Uriarte, both were short-term trainees at Chiba University.

Project workshops were organized in 2011 and 2012 in Japan by inviting more than 15 researchers from Peru and Latin American countries for each year. Fig. 7.3 shows a picture at the workshop in 2012, for which more than 70 people attended. We discussed the progress of the project and the annual schedule for the coming fiscal year. We also joined the International Symposium on Earthquake and Tsunami Reduction in Sendai city from March 14th to 16th, 2012 organized by JICA, JST, and National Research Institute for Earth Science and Disaster Prevention (NIED), which is a one-year memorial of the 2011 Tohoku earthquake. Fig. 7.4a shows the panel discussion by principal investigators from Peru, Indonesia, Philippine, and Chile for earthquake and tsunami disaster mitigation programs (SATREPS). We shared the knowledge and technologies developed through the projects at the symposium to reduce earthquake and tsunami disaster risks among these countries. Fig. 7.4b shows a group photo at Onagawa town hospital during the field trip for tsunami damages by the 2011 Tohoku earthquake. The experiences in Japan by the earthquake were shared with Peruvian researchers to raise awareness and preparedness for large earthquakes in Peru in the future.

8. CONCLUSIONS

An international research program named "Science and Technology Research Partnership for Sustainable Development (SATREPS)" has started under the joint sponsorship by JST and JICA. This paper describes the project of “Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru” with its background, objectives and research activities for the past two years. Five research groups consist of the project, and their activities and progresses are described in details as a result by strong collaboration between Peruvian and Japanese researches. The field survey for the 2010 Maule, Chile earthquake was performed by coordinating Peruvian and Japanese researchers with the support by Chilean researches. Seven young Peruvian researchers have been invited to Japan as a short-term trainee and doctoral student. Project workshops were organized annually by inviting more than 15 Peruvian and Latin American researchers each year. This project will continue to conduct a comprehensive research towards earthquake and tsunami disaster mitigation in Peru for coming three years. Seismic and tsunami losses are integrated and these mitigation technologies are studied regarding the regional characteristics in Peruvian societies. The project also contributes to the capacity building of human resources by providing the educational opportunities for younger Peruvian researchers.

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