SEARCHING TSUNAMI AFFECTED AREA BY INTEGRATING NUMERICAL MODELING AND REMOTE SENSING

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1. INTRODUCTION

The 2004 Indian Ocean tsunami, which caused more than 237,000 fatalities, propagated entire Indian Ocean and caused extensive damage to 12 countries. Because of the devastating damage on infrastructure and local/regional/international communication network and the failure of the disaster response activities, the tsunami-affected areas and overall damage could not be addressed for months. As one of the lessons from this event, the importance of developing technologies to search tsunami-affected area has been raised. However, the extensive scale of catastrophic tsunami makes it difficult to search the impacted area in the aftermath of the event.

A project is under way to search tsunami-affected area using recent advances of remote sensing technologies combined with a numerical modeling of tsunami propagation/inundation. In the present study, the authors propose a framework in developing a method to search and detect the impact of tsunami disaster by integrating numerical modeling, remote sensing, and GIS. Part of the method is implemented to recent tsunami events including the 2009 tsunami in American Samoa and the 2010 Chilean earthquake tsunami to search the tsunami-affected area and detect the structural damage, using the numerical modeling and the analysis of high-resolution optical satellite images.

2. METHODS

The structure of our method consists of several damage mapping efforts. The first phase is the regional hazard mapping. Mapping the potential tsunami hazard in regional scale is based on the numerical modeling of tsunami propagation and bathymetry/topography database. The numerical model for regional scale is based on the finite difference method of shallow-water theories in spherical or cartesian co-ordinate systems[1].

In the second phase, to identify the potential tsunami impact along the coast, the authors incorporate PTE (the Potential Tsunami Exposure)[2] as the number of population exposed against the potential tsunami hazard. PTE is obtained by the GIS analysis integrating the numerical model results and the world population database, such as LandScan[3].

In the third phase, after the potential tsunami-affected areas are estimated, the analysis gets focused and moves on to the “ detection ” phase using remote sensing. Recent advances of remote sensing technologies expand capabilities of detecting spatial extent of tsunami affected area and structural damage. To detect the impacted area in regional and local scales, the authors use the capability of SAR (Synthetic Aperture Radar) image analysis[4] and interpretation of high-resolution optical satellite images, such as QuickBird and IKONOS.

This research was supported, in part, by Industrial Technology Research Grant Program in 2008 (Project ID : 08E52010a) from New Energy and Industrial Technology Development Organization (NEDO). The tsunami survey shown in the figure is obtained by International Tsunami Survey Team[5].

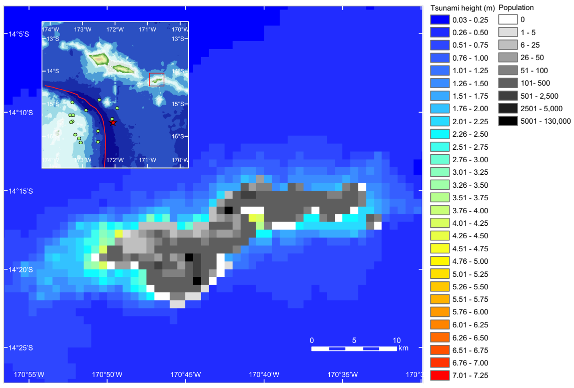

Fig. 1. The estimated tsunami height of the 2009 tsunami in American Samoa and distribution of exposed population.

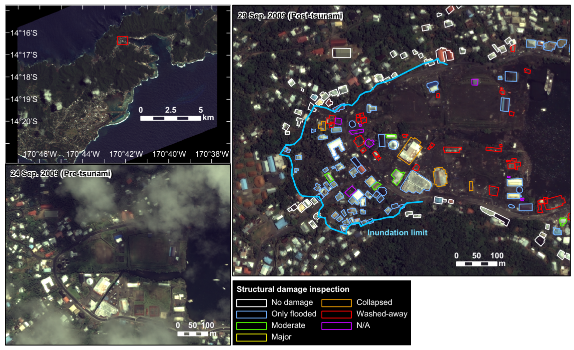

Fig. 2. Interpretation of structural damage in Pago Pago, American Samoa.

3. PRELIMINARY RESULTS

The method has been implemented and verified in recent tsunami events. Here, an example is shown from the most recent tsunami, which was generated by an earthquake of magnitude 8.0 on 29 September 2009 (UTC) in Samoa. The tsunami caused more than 120 fatalities in Samoa, Am. Samoa and Tonga[5]. Fig.1 is the result of our analysis searching the potential tsunami-affected area of the 2009 tsunami in American Samoa. The result indicates the possibilities that the tsunami attacked densely populated areas along the central and western coasts of Tutuila island, American Samoa. This estimation suggests that the disaster response should focus on these areas to investigate its impact using emergency satellite observation.

Fortunately in this event, Digital Globe Inc. succeeded to take the image in the central Tutuila island by QuickBird satellite. Fig. 2 is the result of visual interpretation and field inspection of pre and post-tsunami QuickBird images, which were acquired on 24 and 29 September 2009 (UTC) in Tutuila island, American Samoa. Especially, the post-tsunami image was acquired approximately four hours after the earthquake occurred. As estimated in the tsunami numerical modeling with population data, Pago Pago which locates at the central coast of the island was severely affected.

4. REFERENCES

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[5] S. Koshimura, Y. Nishimura, Y. Nakamura, Y. Namegaya, G. J Fryer, A. Akapo, L. S. Kong, D. Vargo, "Field Survey of the 2009 Tsunami in American Samoa," *Eos*, vol. 90, no. 52, Fall Meet. Suppl., Abstract, 29 December 2009.

Preparedness System against Damage Earthquakes in Korea

June 4, 2010

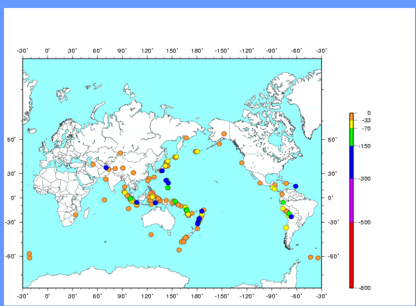
Kang, Ik Bum

Korea Society of Hazard Mitigation

Contents

- Seismic Activities
- Tsunami by Earthquake
- Prepared System

Seismic Activities in the World(>7.0)



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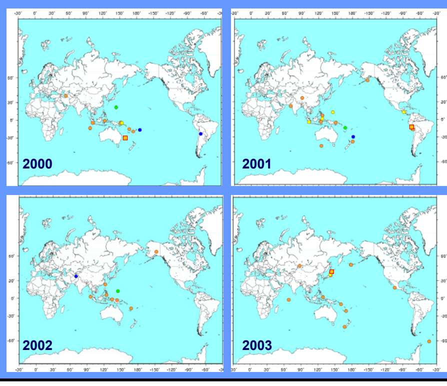
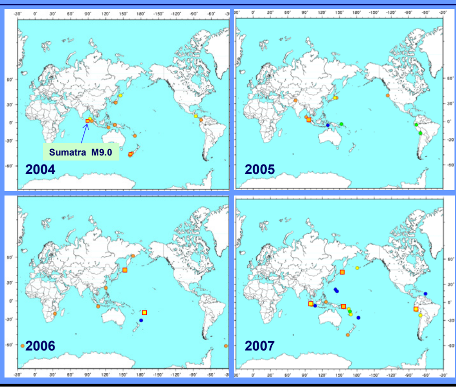


Seismic Activities in the World(>7.0)



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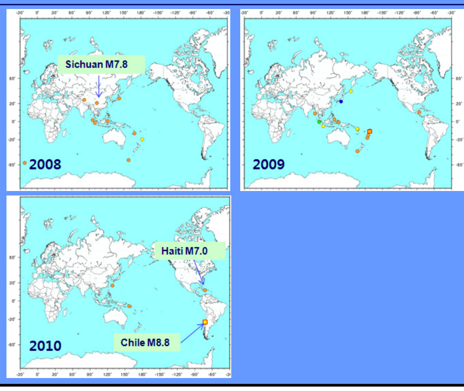


Sumatra Earthquake in 2004

- Occurred : December 26, 2004

  in northern offshore of Sumatra, Indonesia
- Magnitude : 9.0
- Casualties : More than 200,000 peoples

  mostly caused by Tsunami

Sumatra Earthquake in 2004

Sichuan Earthquake in 2008

- Occurred : May 12, 2008

  in Sichuan Province, China
- Magnitude : 7.8
- Casualties : About 100,000 peoples dead/missed

Sichuan Earthquake in 2008

Haiti Earthquake in 2010

- Occurred : January 12, 2010

  at 15km southwestward from Port-au-Prince, Haiti
- Magnitude : 7.0
- Casualties : About 350,000 peoples dead/missed

Haiti Earthquake in 2010

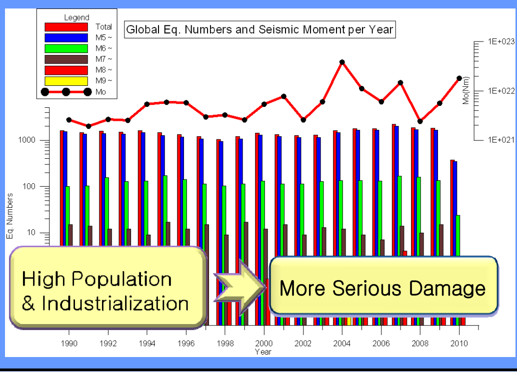
Chile Earthquake in 2010

- Occurred : February 27, 2010

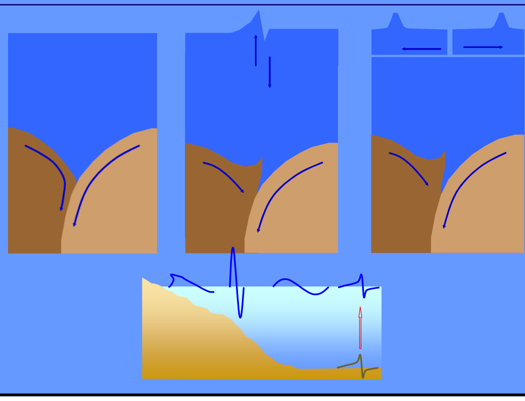
  Offshore Maule, Chile
- Magnitude : 8.8
- Casualties : Several Hundred Peoples

Chile Earthquake in 2010

Seismic Activities in the World



Occurrence of Tsunami by Earthquake



Sumatra Earthquake

Origin time	2004/12/26 07:58(local)
Magnitude	9.0
Location	Offshore West Sumatra Island, Indonesia
Dead	153,200
Missing	27,000

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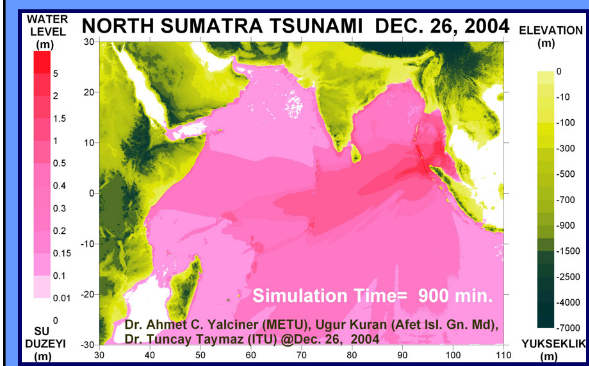
Sumatra Earthquake



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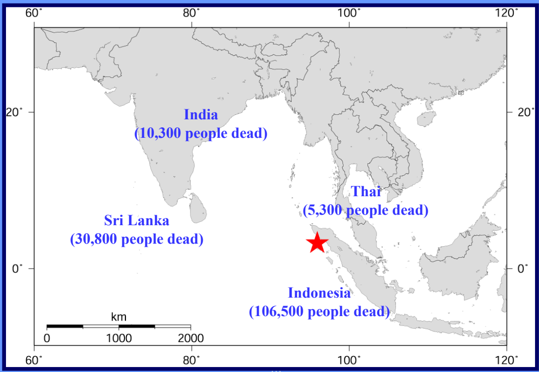
Sumatra Earthquake



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Lesson from Sumatra Earthquake

- Considerable power of Natural Earthquake of Magnitude 9.0
- International Cooperation against great Earthquake
- Counter-Measure against Tsunami or Powerful Earthquake

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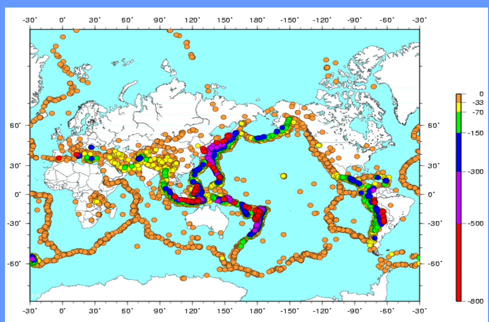
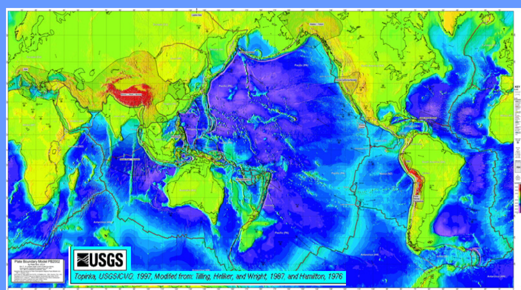
Seismic Activities in the World(>5.0)

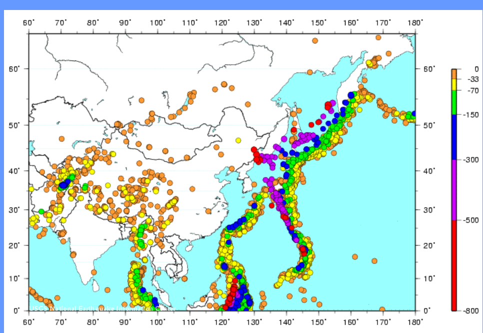


Seismic Activities with Plate Tectonics

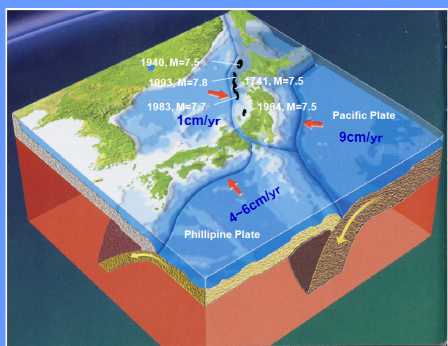


Seismic Activities around Korea(>5.0)

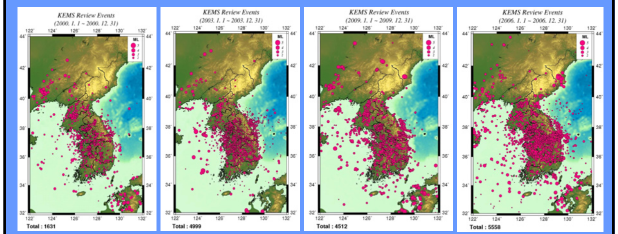
(2000. 1.1 ~ 2010. 4. 15)



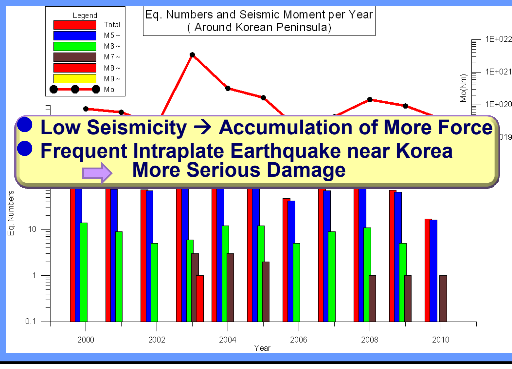
Seismic Activities around Korea With Plate Tectonics



Seismic Activities in Korea (Mag>2) Since 2000



Seismic Activities in Korea



Historical Earthquake Lists in Korea

- 779 in Shilla Dynasty
- Kyungju in South East Korea
- M=6.8
- 100 People Died

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Hongsung Earthquake

- Origin Time : 1978/Oct./7 18:19(local)
- Magnitude : 5.0
- Damage
  - Injury : 2 people
  - Buildings(partially destroyed/cracks) : about 1000
  - No communication & Cracks in road
  - 30 M US$ in loss

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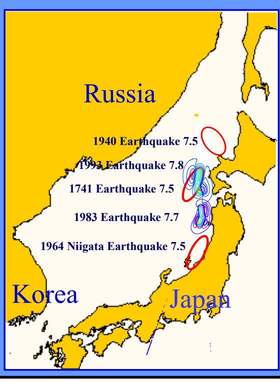
Tsunami caused by Earthquakes in Korea



Tsunami in Imwon in East Coast of Korea in 1983

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Tsunami in Imwon in East Coast of Korea in 1983

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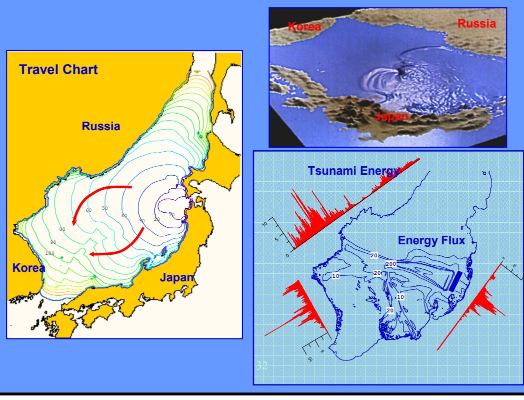
Path of Tsunami to Korea



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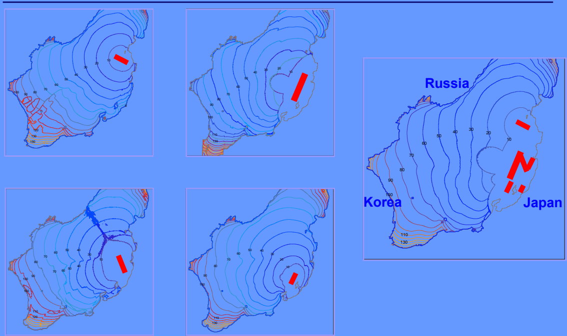
Modeling on Arrival Time of Tsunami



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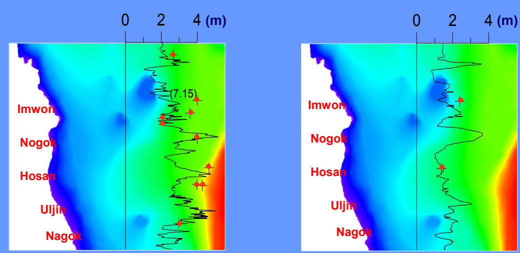
Comparison of Two Tsunami in 1983 & 1993



1983 1993

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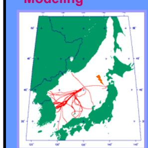
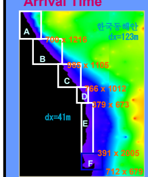
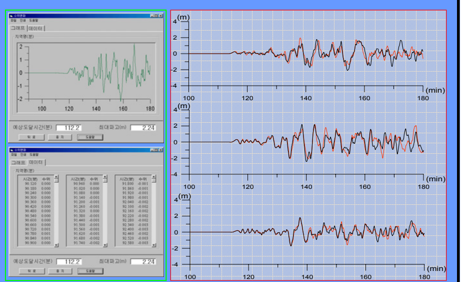
Forecasting System against Tsunami in Korea

Modeling



Arrival Time





Quick Forecasting through D/B

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Counter-Measure against Tsunami by Earthquake

Structural Measure	▪ Re-organization of Coastal Structure : economically infeasible
Nonstructural Measure	▪ Analysis of historical tsunami : Evaluation of tsunami potential ▪ Tsunami Numerical Investigation : Evaluation of tsunami risk ▪ Life safety : Education, escape and safety function ▪ Tsunami forecasting system ▪ Local coastal disaster mitigation plan

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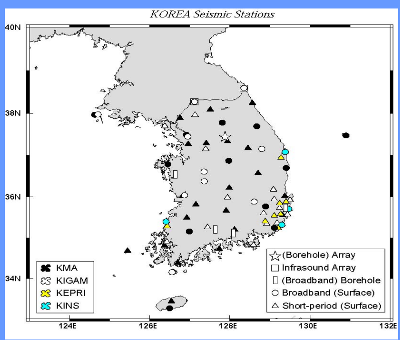
Establishment of Coastal Disaster Mitigation

Data Collection
↓
Numerical Simulation
↓
Risk Evaluation
↓
Response

Local Coastal Disaster Mitigation Plan

Elementary Survey
↓
Risk Evaluation for Target Area
↓
Establishment of Local Coastal Disaster Mitigation

Seismic Stations in Korea



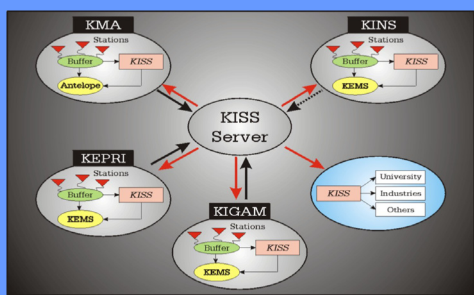
Seismic Stations in Korea

- Owned by
  - **KMA**(Korea Meteorological Agency) making public to People
  - **KEPRI**(Korea Electrical Power Research Institute), **KINS**(Korea Institute for Nuclear Safety) monitoring safety of Nuclear Power Plant
  - **KIGAM** (Korea Institute of Geoscience and Mineral Resources) making Bulletin and Discrimination
  - **Universities**

Seismic Stations in Korea

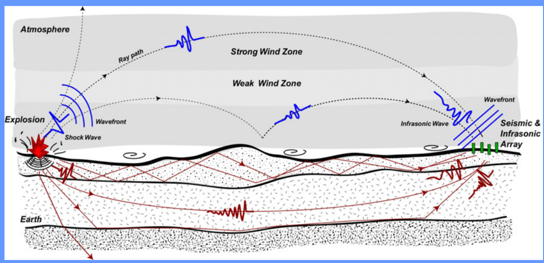
- **KMA**
  Short-Period, Broad-Band 3-C Velocity Sensors
  3-C Acceleration Sensors
- **KEPRI, KINS**
  3-C Acceleration Sensors
- **KIGAM**
  Borehole Array including 3-C Short-Period & Broad-Band Velocity, Infrasound, 3-C Acceleration Sensors
- **Universities**
  3-C Short-Period Velocity Sensors

Korea Integrated Seismic System (KISS)



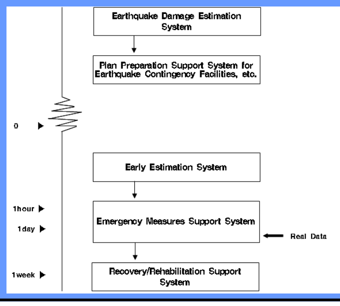
Korea Institute of Geoscience and Mineral Resources (KIGAM)
Korea Meteorological Administration (KMA)
Korea Institute of Nuclear Safety (KINS)
Korea Electric Power Research Institute (KEPRI)

Basic Principle of Infrasound Technology



Preparedness System(Japan)

- DIS/Earthquake under Ministry of Land & Transport



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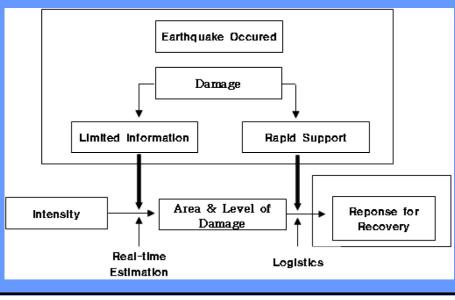
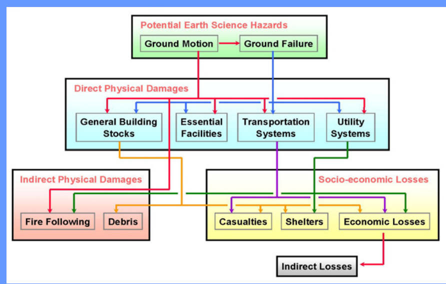


Preparedness System(USA)

- HAZUS Program under FEMA



Preparedness System(USA)

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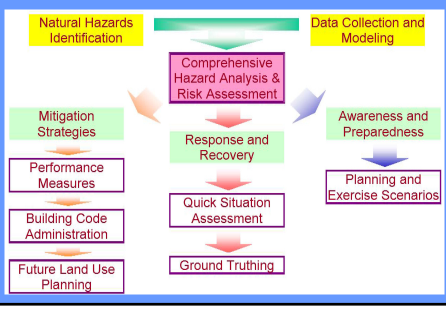

Preparedness System(Korea)

- Application of HAZUS to Korean Peninsula under KIGAM

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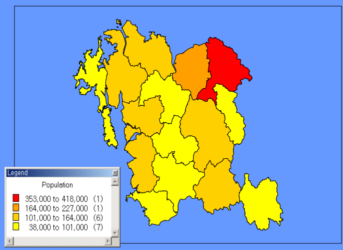

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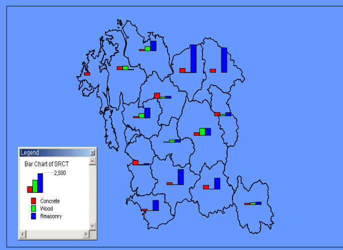

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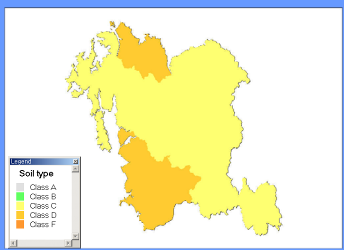

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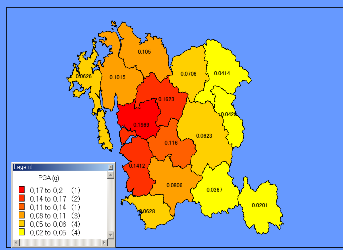

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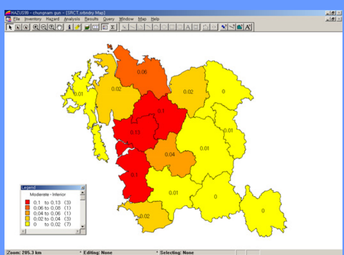

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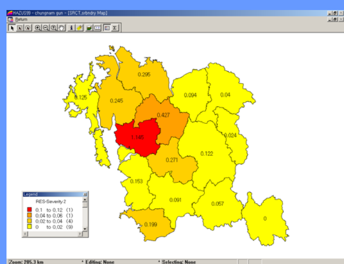

Summary

- High population & industrialization cause more serious damage by big Earthquakes.
- In Korea low seismicity relative to surrounding countries occurred but low seismicity may accumulate more force and more seismic sensor monitor more seismic events.
- Korea experienced several tsunamis through numerical modeling on arrival time & tide heights of tsunami and Korea establish counter-measure against tsunami.
- Among prepared system against damage earthquake adopted by other countries Korea is applying the HAZUS program to Korean peninsula.

Long term recovery from the 2004 Indian Ocean Tsunami

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Faculty of Human Life and Environment, Nara Women's University, Japan
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1. Introduction

It becomes five years from the devastating damage of the 2004 Indian Ocean Earthquake and Tsunami Disaster. Banda Aceh in Indonesia is the nearest region from the epicenter, where around 126,000 were killed from the event. Especially children who are vulnerable to tsunami because of short height were killed for tsunami.

Due to international support from all over the world, recovery of infrastructures and housing has almost completed within four years and BRR, which is in charge about coordinating recovery works, ended their business in April of 2009. And those who lost their spouse are having new family, and post-tsunami born kids are playing in the field. One remaining big recovery project is the recovery of road network between Banda Aceh and Calang. And now is the real kick off of long term recovery in Banda Aceh by local people.

This paper shares long-term recovery process in Banda Aceh from the annual field survey in Banda Aceh region, and discusses about remaining issues for long term recovery.

2. Housing Recovery

2.1 Issues on housing recovery

Housing recovery is the largest project in the recovery project. Almost 50 % of recovery budget was used for housing recovery (RAN database). At first, the government decided to distribute housing to those who owned and lost their housing. Unit size of the housing is 36m2 and cost is around USD3, 000. But within the impacted area, there were no housing stock and renters cannot leave from the interim housing, barrack. And government extended targets for housing support to renters.

2.2 Structure of Housing Recovery

There are two axes about housing recovery after disaster. One is on site or moving out from the impacted place, the other is making decision individually or by community (Fig.2). In case of housing recovery in Banda Aceh, on site – individual reconstruction is basic way. But one neighborhood community, Desa Lambung, successfully completed land use readjustment. And, there exits three types of housing recovery with relocation such as 1) housing for renters, l2) and use regulation, and 3) losing land for land subsidence. Housing complexes for renters which locate suburban of Banda Aceh will have serious problem after all the recovery projects.

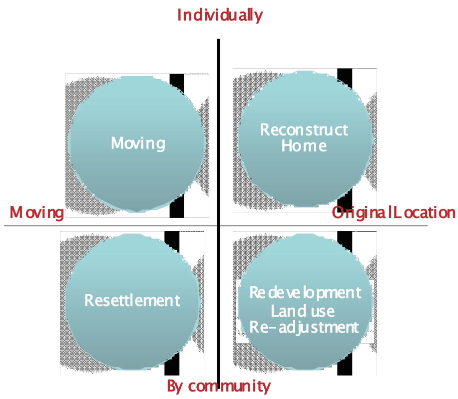

Fig.2 Structure of Housing Recovery after Disaster

3. Remaining issues on long-term recovery

It takes at least ten years to complete a long term recovery from devastating disaster. Continuous monitoring on recovery process is necessary. Following are comments from five years monitoring and evaluation about a long term recovery process of Banda Aceh.

3.1 Recovery in Submersed Village

Because of subsidence of ground for plate movement with earthquake, in eastern cost of Aceh State, many villages were sunken under water. For the recovery of villages, they have moved to new location near from their villages formally their farming lot etc. We don't have lessons about recovery process from sunken villages, and it is important to learn from their experiences.

3.2 Housing Supports for Low Income People

Those who moved to suburban resettlement complex for renters are mainly works for informal sectors such as temporary construction workers, cab drivers etc. And they don't afford to pay for transportation fees to commute to working place in urban area. It is likely that they sell their houses at suburban area and move to urban area in Banda Aceh or move out to large cities in Banda Aceh after all the construction works for recovery have completed, because they cannot find their job in Aceh area.

Housing support policy keeping them to interim housing until housing stock in urban area even though they should stay shanty barrack for longer time could be considered.

3.3 Strategic Timeline Management of Housing Recovery

Reconstructed housings should be used as permanent housing. In the very early stage of housing reconstruction, low quality housing were supplied to complete housing recovery as fast as possible. However, it needs almost five years to complete housing recovery for devastating disaster. Housing recovery with good quality houses with five years strategic timeline should be considered.

3.4 Sustainable Long Term Recovery

2004 Indian Ocean Earthquake and Tsunami Disaster occurred in Christmas season, and killed many foreign tourists. Because of that, unexperinced huge donation was collected, and unpresidnted scale of recovery support was conducted.

Support from all over the world overwhelmed management capacity of supporting agencies. For example, Medical Sun Frontier refused to receive donation after some period because they cannot responsible for quality of support. And huge recovery support also caused "support addiction" at impacted communities. India refused international support for this event because it was internally manageable scale of disaster. Both refusals of supports were explained as good examples in Disaster Report 2005 of Red Cross and Red Crescent because it makes sustainable response and recovery possible. It is important to consider the support scheme which can keep self reliance of impacted community even after devastating disaster.

3.5 Telling Lessons from Disaster

In Band Aceh, Tsunami Museum building was completed but preparation of exhibition is still on the way. In Japan, the importance of sharing lessons inter generation and area is commonly understood, but not in the other countries. Sharing lessons of disaster are essential to make disaster resilient society. Importance to maintain and sharing live lessons of disaster should be shared in all over the world.

Fig.2 Tsunami Museum in Banda Aceh

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Tsunami Hazard Map at Imwon, Korea

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Abstract

The East Sea surrounded by Korea, Japan and Russia is one of the most vulnerable places to tsunami attacks in the world. A number of tsunamis have been occurred during last decades in the region. In special, the middle areas of the eastern coast of the Korean Peninsula have been damaged due to the Central East Sea Tsunami occurred in 1983. Thus, tsunami hazard mitigation becomes an important issue at those coastal communities. The countermeasures against unexpected tsunami attacks are not sufficient because the government policy of Korea generally focused on not preventing but recovering. In this study, a hazard map based on the field survey and tsunami evacuation plan is developed to mitigate tsunami damage at Imwon port, which was severely damaged during the 1983 Central East Sea Tsunami.

Keywords: *Tsunami, Hazard map, Field survey, Evacuation*

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1. Introduction

Tsunamis are long-period oceanic waves generated by underwater earthquakes, submarine or subaerial landslides or volcanic eruptions. They are among the most huge nature disasters which have become the biggest killer for communities in coastal areas in the last decade. It is important to prepare a plan for preventing damage of unexpected tsunami. The most representative plan for tsunami hazard mitigation is a hazard map. Hazard map describes the initial responsibilities and action to be taken to protect all human in the event of real natural disaster(Cho, 1995).

The Eastern Coast of Korea is very vulnerable to tsunami attacks because of the large amount of tsunami energy concentration caused by the topographic condition of the region(Lee et al., 1997). The historical tsunami events show that the Imwon port is the most susceptible area from tsunami attacks generated at the Western Coast of Japan. The Central East Sea Tsunami occurred on May 26, 1983 caused a damage at Imwon port(Casualty - death 3, injury 2, Structure damage - destruction 23, inundation 21). Thus, tsunami hazard mitigation becomes an important issue at those coastal communities.

In this study, a tsunami hazard map is developed for more effective and economic countermeasures against unexpected tsunami attacks based on the field survey and tsunami evacuation plan.

2. Field Survey

The Central East Sea Tsunami occurred on May 26, 1983 caused a huge damage at Imwon port. Fig. 1 shows the location of Imwon port, Korea. A series of tsunamis with height of 3-4m attacked at Imwon port on May 26, 1983. Three people were killed and two inhabitants were injured. When the tsunami attacked Imwon port, oil tank which diameter is 7m and capacity is 8 ton was shattered entirely and moved toward village(Kim et al., 2007). Approximately, 22 houses were destroyed and 7 houses were inundated. In special, several houses near the Imwon River were destroyed drastically because sea water ran over the bank located about 700m upstream from the Imwon port. A boat was jumped about 3.5m and bumped into the building’s roof.

The survey team interviewed inhabitants to investigate run-up heights, inundation area and damages from tsunami attacks by using voice recorder. The 6 locations were selected and historical maximum run-up heights are estimated.

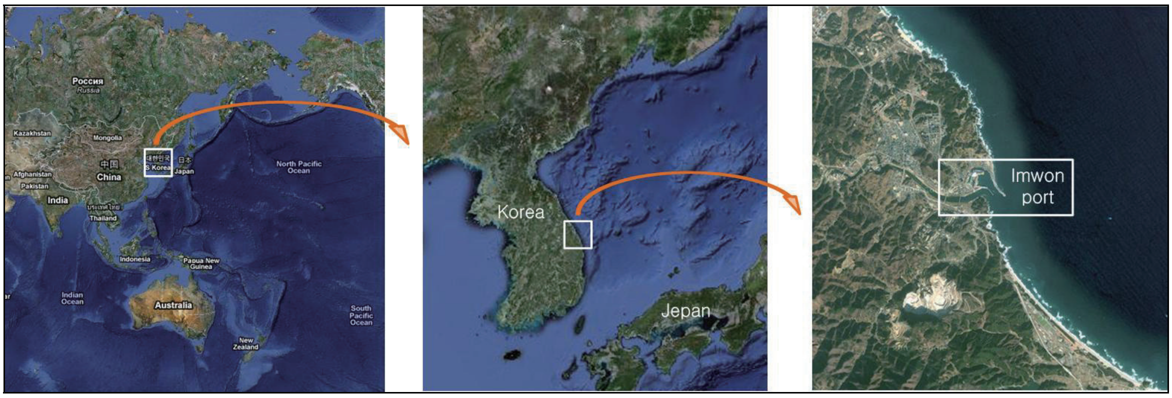

Fig. 1 Location of Imwon port, Korea

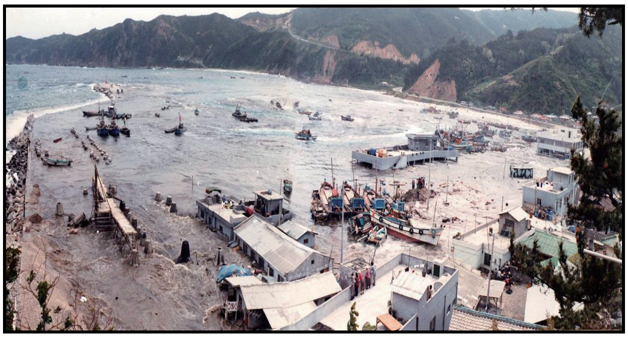

Fig. 2 Tsunami damage at Imwon port, Korea(1983 Central East Sea Tsunami)

Fig. 3 shows inundated areas at Imwon port during the tsunami. The field survey data can be used to verify the tsunami inundation model and also has an important role to set up the tsunami evacuation plan. Fig. 4 shows position and name of suitable buildings for temporary and designated shelters and evacuation routes at Imwon port.

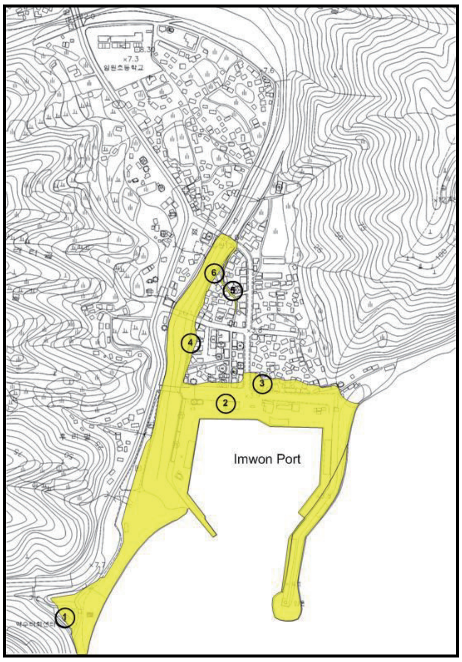

Fig. 3 An inundated areas at Imwon port during the Central East Sea Tsunami

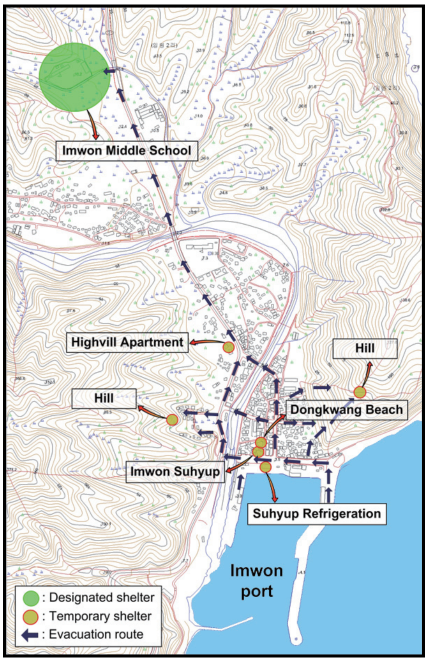

Fig. 4 Evacuation plan at Imwon port, Korea

3. Generation of Tsunami Hazard Map

A tsunami hazard map consists of the information which contains location of shelter, evacuation routes and the maximum inundated areas caused by a tsunami. In an addition to that, it contains satellite photograph of the target area, emergency contact lists, main construction nearby and other information of evacuation. Fig. 5 is the tsunami hazard map at Imwon port.

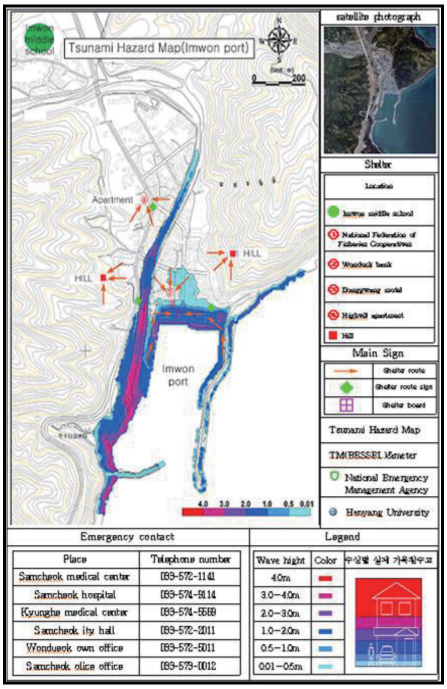

Fig. 5 Tsunami hazard map at Imwon port, Korea

4. Conclusion Remarks

A well-established hazard map may play an important role in prevention of the damage occurred by disasters such as tsunami high tide and storm surge. In this study, a tsunami hazard map at Imwon port where is the most susceptible area from tsunami attacks generated at the Western Coast of Japan is developed for more effective and economic countermeasures against unexpected tsunami attacks. It can contribute to real evacuation plan which is element of tsunami hazard mitigation plan as a reference material.

Acknowledgements

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