

# Post-Earthquake Data Collection Workshop

## Executive Summary

Anchorage, Alaska

July 20-22, 2014

### Overview and Purpose

A workshop to discuss recent experiences and future needs related to post-earthquake data collection was held in Anchorage, Alaska from July 20 – 22, 2014 with participants from several different countries including New Zealand, Italy, Chile, Japan, Canada, and United States. Due to recent earthquakes in many of the represented countries, the workshop provided a unique opportunity to review data collected internationally, critically evaluate current data collection approaches, initiate collaborative international research efforts to maximize the knowledge gained from recent devastating events, and begin to develop international consensus on data collection protocols for future events.

To achieve a manageable scope, the workshop focused on building-related data. Lifelines such as roadways, power distribution systems, etc. are clearly essential for resilience but such data is generally collected in a systematic manner already since lifelines are typically managed by a single entity. Data collection for private buildings is considerably more challenging. Data of interest to this workshop include building performance, business interruptions, housing impacts and post-earthquake decisions.

Support and funding for this workshop was provided by the University of British Columbia, Ministry for Business Innovation and Employment (New Zealand), and the Earthquake Engineering Research Institute via its the National Science Foundation grant entitled "Seismic Observatory for Community Resilience - A Program to Learn from Earthquakes" (Award No: 1235573).



*Participants of Post-Earthquake Data Collection Workshop, Anchorage, Alaska, July 2014*

## **Workshop Procedure**

On Day 1 workshop participants from Italy, Japan, New Zealand, and Chile shared their experiences with data collection and data use after recent earthquakes. A few other presentations also were given to share lessons from recent efforts to measure resilience, summarize the key features and challenges of data collection tools developed by a variety of organizations, and hear perspectives from the insurance and risk modeling communities. These presentations prompted discussion and prepared participants for the next day of breakout discussions. The workshop purpose and agenda can be found in Appendix I and the Day 1 presentations can be found in Appendix II.

On Day 2, workshop participants broke into three groups for half-day discussions on data collection protocols for the following three topics areas: Physical Damage Data (led by Santiago Pujol), Impact Data (led by Mary Comerio), and Reconstruction and Recovery Data (led by Stephanie Chang). The groups were asked to consider and reach consensus on (1) “Why do we collect data?”, (2) “What do we collect?”, and (3) “How do we collect this data?” Summary presentations of these Day 2 breakout discussions can be found in Appendix III.

The final event of the workshop was a two-hour conclusion-generating discussion based upon the outcomes of the Day 2 breakouts. The resolutions and action items from this discussion are summarized below, after brief summaries of the breakout sessions.

### **Damage Data Breakout**

Building damage data is collected for several purposes following an event: guide immediate response and building management (e.g. placarding); identify knowledge gaps; collect damage statistics; assesses repair actions; insurance evaluation; and forensic studies. Data from the latter three purposes are not typically easily accessible due to privacy considerations. Different data will be collected depending on the purpose but common links between the data collected would serve to reduce duplication of effort. Discussants identified data fields to be collected under the following categories: Earthquake, Structure, and Consequences (Appendix AIII, pp. A431-A441). To avoid the restrictions of established checklists, damage descriptions can use narratives if standard terms and keywords are identified in advance.

The importance of having a representative sample, including both damaged and non-damaged buildings, was emphasized, particularly when using the data for damage statistics. This highlights the need for pre-earthquake data on buildings. In addition of helping with the selection of a representative sample, pre-earthquake data enables post-earthquake building management and improved assessment of building safety given better knowledge of structural system.

Research needs were identified for potential collaborative research proposals. In particular, it is critical to establish and validate methods for measuring the residual capacity of damaged building structures. Development of such a method will also inform the post-earthquake data collection needs.

### **Impact Data Breakout**

Impact data represents a holistic view of the impact on the social, economic and natural environments as a consequence of damages to the physical environment. The critical sectors include but are not limited to: Housing, Health, Education, Economy (Jobs), Environment, Communication, Lifeline operability, and the Safety of Civil Society. For each sector, it is important to define critical metrics and

recognize the need for baseline data of what existed before as well as after the event. The discussants recognized that there could be barriers to access for such data. However, the value of such information cannot be overstated. Impact data connects the physical damage with operational effectiveness—to define building functions by structure type and link loss/damage with disruption of service.

Minimum parameters for a baseline and post event data include: Population of the impacted area (make up by census); the percent Urbanized vs non-urbanized; the number of Dwelling Units (+ types), the number of Hospitals/beds (+types); the number of Schools (+types); the number of Government buildings; the number of Industrial/commercial buildings; economic Productivity of the impact area; Ground Surface Changes and Lifeline Status; to be linked with Structural and Non-Structural Damage.

Discussants were clear that data protocols would be critical and suggested existing examples such as the GEM consequence protocols, the World Health Organization reports, Sphere Standards, UNDAC and other existing models as a starting point. In addition the discussants made the case that the engineering community needs to take ownership of functionality requirements to improve Performance Based Design. See notes in Appendix AIII, pp. A442 - A446.

### Recovery Data Breakout

In addition to general research purposes, data collection during recovery is primarily intended to inform decision makers on “how recovery is proceeding”. The specific question to be addressed with the collected data depends on the phase of response and recovery as shown in figure below. Identification of data to be collected for each phase will assist in decision making after future events.

Type of Data	Social	<i>Basic services</i>	<i>Wellbeing, risk perception</i>	
	Physical	<i>Can the building be used?</i>	<i>What do you do with the building? (demolition decision)</i>	<i>Code changes</i>
	Hard			
		Emergency	Reconstruction	Recovery
	Time			

The following categories of data were identified by the discussants: Damage; Rebuilding; Functionality; Decisions; Economics; Behavior; Population; Perceptions. Types of data under each of these categories were identified and listed in Appendix AIII, pp. A447 - A453. Interviews with staff and general population will be an important data source for many of the categories identified.

Multiple sources and approaches to data collection are needed to achieve a complete picture of “how recovery is proceeding”. In particular, linking different data sources and types (e.g., buildings with owners/tenants; business actions/time/impact) is key to understanding cause and effect during recovery. The importance of making data public and available to all was emphasized during the breakout session.

## Resolutions

Empirical evidence from past earthquakes, documented through standardized collection of data, is essential to understanding and improving community resilience to earthquake disasters. The participants involved in this workshop are dedicated to reducing earthquake risk and increasing resilience of communities to future earthquakes by enhancing and improving the practice of pre- and post-earthquake data collection worldwide. To this end, the participants at this workshop resolve to:

1. Cooperate in future post-earthquake data collection and sharing efforts to the extent possible.
2. Promote a culture of open sharing of data in the field of earthquake engineering, similar to other scientific fields;
3. Work toward international agreements that will support standardization, interoperability, and sharing of data collected worldwide;
4. Collaborate in the development of a document identifying why post-earthquake data collection is critical to understanding and improving community resilience and use this document to promote the importance of standardized data collection with government agencies involved with post-earthquake recovery;
5. Establish lines of communication and relationships with data collectors and agencies that will be involved in future earthquake response and recovery in an attempt to initiate pre-earthquake data collection and coordinate data collection and sharing after future earthquakes;
6. Explore the creation of a standardized taxonomy that describes damage, impacts, and recovery;
7. Explore means of validating and assigning quality ratings to post-earthquake data;
8. Promote the development of inventories of existing infrastructure to benchmark existing conditions, train users in data collection tools, and be available immediately post-earthquake to improve data collection and damage assessments;
9. Promote the development of standardized damage descriptions for building structures to enable comparison of performance across an inventory of buildings and estimate building residual capacity;
10. Compile a list of common models used to quantify recovery/risk/vulnerabilities that would inform the types and amounts of data to be collected to calibrate the models.

Planning details of the above resolutions will be carried out based on further mutual agreement and through close consultation and exchange of information between the workshop participants.

## Action Items

Discussion led to the following action items to be implemented by the workshop participants.

1. Gather and translate data collection forms and protocols from each country in one place to allow others to review and study.
  - *EERI staff will lead this effort and host forms on an EERI website.*
2. Create working groups to consider how to attract funding to provide time and resources to act on the many ideas discussed in the meeting and included in the resolutions, considering but not limited to the following themes:
  - a. Standardization (for consistency and international interoperability of data)



- b. Defining value of data collection
  - c. Consideration of categorizing data under time and purpose
- 3. Create a working group (perhaps the meeting conveners) to develop a short opinion paper based upon notes and outcomes of this workshop.
- 4. Conduct a case study exercise to share existing data from recent earthquakes amongst workshop participants. This case study exercise could explore opportunities and challenges to sharing protocols, test data sharing platforms and approaches, and help inform the development of an international taxonomy or data framework to standardize data.

## Appendix

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# Appendix I

# **Post-Earthquake Data Collection Workshop**

Anchorage, Alaska

July 20-21, 2014

## **Background:**

The world has experienced unprecedented losses from earthquakes in recent years. For example, in Christchurch, New Zealand, the impacts of the February 2011 M6.3 earthquake include an estimated \$40 billion in losses (equivalent to 20% of New Zealand's GDP), demolition of ~70% of downtown buildings, including loss of more than 50% of heritage structures, expropriation of hundreds of homes in liquefied suburban regions, closure of the core business district for over 2 years, and outmigration of thousands of residents. Over the past five years, earthquakes have also impacted urban regions in Italy, Chile, and Japan, among many others. While devastating for the communities struck by the earthquakes, these events and their impacts present the international research and policy-development communities with unparalleled opportunities. This proposal aims to harness these opportunities through the development of an international workshop on post-earthquake data collection.

Empirical evidence from past earthquakes is essential to understanding and improving community resilience to earthquake disasters; however, we currently lack consensus on what data to collect, how to collect the data, and how to most effectively use it. Recent earthquakes around the world provide us with an opportunity to review data collected internationally, critically evaluate current data collection approaches, and initiate collaborative international research efforts to maximize the knowledge gained from recent devastating events and arrive at international consensus on data collection protocols for future events.

## **Workshop objectives:**

The objectives of the workshop are:

- To report on data collection practices from recent earthquakes: What data were collected? How were the data collected? What worked? What did not work? What data were lost?
- Initial development of consensus-based data collection protocols.

To achieve a manageable scope, this workshop will focus on building-related data. Lifelines such as roadways, power distribution systems, etc. are clearly essential for resilience but such data is generally collected in a systematic manner already since lifelines are typically managed by a single entity. Data collection for private buildings is considerably more challenging. Data of interest to this workshop include building performance, business interruptions, housing impacts and post-earthquake decisions (repair vs demolish).

It is also anticipated that the workshop may lead to the development of international collaborative projects using empirical data from recent earthquakes to assess and improve community resilience in the event of major earthquakes.

## **Participants:**

This unique multi-disciplinary workshop will include participants from six different countries: Canada, United States, New Zealand, Italy, Chile, and Japan. Notably, the latter four countries have all experienced devastating earthquakes in the past five years, thus the workshop will provide the

opportunity to share recent experiences and develop new partnership with international colleagues with common interests.

All international participants bring direct experience in data collection after recent earthquakes in their respective countries. Data have been collected by both government agencies and academic institutions, and hence both will be represented at the workshop. Notably, a representative from the insurance and reinsurance industry has been asked to contribute some remarks that will share the industry's perspective and assist in identifying potential sources of funding for collaborative research proposals from this important industry.

In order to keep the workshop effective, the number of participants will be limited to approximately 30, with the majority of participants bringing first-hand recent experience with data collection in Chile, Italy, Japan, and New Zealand.

### **Recent Earthquakes:**

A critical portion of the workshop will be reports from Italy, Chile, New Zealand, and Japan on data collection experiences after recent earthquakes. Each country's participants will work together to develop a 75 min presentation (followed by 15 minutes of questions) to be given on Day 1 of the workshop. This presentation should be coordinated by one representative from each country but can be delivered by multiple participants if this format is preferred. To provide consistency in the reporting and valuable information for the Day 2 breakouts, we ask that the country reports address the following questions:

1. **What forms of data were collected after the earthquake?** Data of interest to this workshop include building performance (physical damage), business interruptions, housing impacts, and post-earthquake decisions (repair vs demolish). We are interested in data at both the detailed building level as well as at the broader community level. What data were used to assess building residual capacity and how were these data used in reconstruction decisions? What should be implemented in data collection protocols to make the assessment of residual capacity more reliable?
2. **Have any relationships between the different forms of data been explored?** For example, what is the relationship between the physical damage and business interruption? Are there other factors influencing the socio-economic impacts, suggesting other forms of data that should be collected?
3. **What organizations were involved in collecting data and for what purpose?** Such organizations may include city government, insurance companies, university researchers, etc. Although the goal of data collection may be different for each organization, the data may be similar and synergistic efforts should be identified.
4. **What barriers are there to sharing data across different organizations?** What experience do you have in finding ways to share data across government and non-government entities?
5. **How were the data collected?** Were any advanced technologies used to collect data or were all data collected manually? What training was provided for data surveyors?
6. **What data were lost?** Were there specific data that were not collected, or not collected in a coordinated manner, such that the data may not be available for future research studies?

7. **Lessons from the data collection process.** What aspects of the data collection process seemed to work well? What could be improved upon?
8. **How are data stored after collection and what are access policies for this data?**
9. **Suggestions for the development of consensus-based data collection protocols?** One of the primary goals of the workshop is the initial development of consensus-based data collection protocols for application after future earthquakes around the world. What experiences from the events in your country could inform the development of these data collection protocols?

**Expected outcomes:**

The workshop is expected to provide the impetus for the development of two types of joint international research proposals: (1) focused on the development of consensus-based data collection protocols; and (2) focused on using empirical data from recent earthquakes to assess and improve community resilience.

For proposal type #1, funding will be sought from public-private partnerships between government agencies responsible for collecting data for the recovery process and the insurance industry interested in rich data to refine natural hazard risk models. This effort is urgently needed to ensure improved and consistent data collection protocols are available prior to the next major earthquake such that valuable data are not lost in the future. Application of the proposed procedures in future earthquakes will provide an excellent opportunity to continue collaborative efforts initiated at the workshop.

For proposal type #2, joint funding will be sought from several national research agencies. Such proposals will build on a US National Science Foundation grant held by the Earthquake Engineering Research Institute to create a Seismic Observatory for Community Resilience with the goal of documenting and understanding the factors influencing the ability of communities to recover after devastating earthquakes. Linkages with new proposals to other national research agencies will be explored to enable international workshop participants to contribute to future joint research projects.

**Timing and venue:**

The workshop will be held over 1.5 days immediately prior to the 10th US National Conference in Earthquake Engineering in Anchorage, Alaska, in July 2014. This international conference draws participants from around the globe, and hence provides the perfect opportunity to host the proposed workshop. Travel costs will be covered by the participants as it is expected that they will be attending the conference regardless of the workshop. The workshop will be held in the NCEE conference hotel, the Anchorage Hilton.

**Proposed Agenda:**

The first day will focus on experiences from recent earthquakes, while the second day will provide an opportunity to discuss the development of post-earthquake data collection protocols and future collaborative activities.

**Sunday, July 20, 2014**

8:00 am – 8:30 am	Breakfast
8:30 am – 8:50 am	Welcome and objectives of the workshop
8:50 am – 10:20 am	Italy experience (group organized presentation)
10:20 am – 10:40 pm	Break
10:40 am – 12:10 pm	Chile experience (group organized presentation)
12:10 pm – 1:00 pm	Lunch
1:00 pm – 2:30 pm	Japan experience (group organized presentation)
2:30 pm – 2:45 pm	Break
2:45 pm – 4:15 pm	New Zealand experience (group organized presentation)
4:15 pm – 4:35 pm	Resilience Observatory (Scott Miles)
4:35 pm – 4:50 pm	Break
4:50 pm – 5:10 pm	Data collection tools (EERI)
5:10 pm – 5:30 pm	Data collection and collaboration with (re)insurance industry (tentative)
5:30 pm – 6:00 pm	Discussion and plans for Day 2
6:00 pm – 7:00 pm	Reception

**Monday, July 21, 2014**

7:30 am – 8:00 am	Breakfast		
8:00 am – 9:30 am	Data Collection Protocols Discussion: (moderators)		
	Breakout 1: Physical Damage Data (Santiago Pujol )	Breakout 2: Impact Data (Mary Comerio)	Breakout 3: Reconstruction and Recovery Data (Stephanie Chang)
9:30 am – 9:50 pm	Break		
9:50 am - 11:30 am	Breakout 1 cont.	Breakout 2 cont.	Breakout 3 cont.
11:30 am – 12:00 pm	Box lunch and planning for evening meeting		

**Tuesday, July 22, Evening meeting:**

5:00 pm – 7:00 pm	Workshop resolutions and action items for collaborative proposals (with hors d'oeuvres)
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## Participant List:

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40	Erik McAdams	emcadams@eeri.org	US	EERI

# **Appendix II:**

## **Sunday July 20 Presentations**

# International Post- Earthquake Data Collection Workshop

Sponsored by

EERI

UBC

MBIE - NZ

# Thank you

- Co-Organizer, Stephanie Chang
- Marjorie Greene, Heidi Tremayne, Maggie Ortiz @ EERI
- Student and intern support
  - Panagiotis Galanis
  - Jenna Kim
  - Frederic Marquis
- **All of you!**

# Workshop motivation

- Empirical evidence from past earthquakes is essential to understanding and improving community resilience to earthquake disasters.
  - However, we currently lack consensus on what data to collect, how to collect the data, and how to most effectively use it.
- 10NCEE provides opportunity to consider lessons from recent earthquakes regarding post-earthquake data collection.
  - Italy, Chile, New Zealand, Japan

# Workshop objectives

- To report on data collection practices from recent earthquakes:
  - What data were collected?
  - How were the data collected?
  - What worked?
  - What did not work?
  - What data were lost?
- Initial development of **consensus-based data collection protocols** and strategizing about what data matters.
- Initiate discussions on joint international research proposals on related topics.

# Workshop scope

- Buildings
  - Lessons may come from lifeline data collection
- Data types:
  - building performance,
  - business interruptions,
  - housing impacts,
  - post-earthquake decisions (eg repair vs demolish)



# Workshop questions

- **What forms of data were collected after the earthquake?**
- **Have any relationships between the different forms of data been explored?**
- **What organizations were involved in collecting data and for what purpose?**
- **What barriers are there to sharing data across different organizations?**
- **How were the data collected?**
- **What data were lost?**
- **Lessons from the data collection process.**
- **How are data stored after collection and what are access policies for this data?**
- **Suggestions for the development of consensus-based data collection protocols?**

# Additional points to frame discussions

- What are the decisions that need to be made (on buildings) post-EQ and how will data help this decision making?
  - e.g. data for deciding fate of building (demolition), data for zoning?
- What data is needed for evaluating and adapting technical decisions?
- Need to identify two forms of links:
  - "links" that allow interoperability between data collected by different entities
  - "links" between physical damage, impact, and recovery data → to inform reconstruction policy.
- Bear in mind time frames
  - What is the minimum data to collect in the first weeks following, vs comprehensive collection later, vs data to assess residual capacity for decisions on demolitions.
- Recommendations coming out of this workshop could:
  - benefit decision-makers in earthquake-struck communities in the future, and
  - advance knowledge about earthquake disasters/recovery

# Sunday Agenda

8:00 am – 8:30 am	Breakfast	
8:30 am – 8:50 am	Welcome and objectives of the workshop	
8:50 am – 10:20 am	Italy experience (group organized presentation)	
10:20 am – 10:40 pm	Break	
10:40 am – 12:10 pm	Chile experience (group organized presentation)	
12:10 pm – 1:00 pm	Lunch (Bristol Bay Ballroom--Katmai room)	
1:00 pm – 2:30 pm	<i>New Zealand experience (group organized presentation)</i>	} Shuffled presentations!
2:30 pm – 2:50 pm	<i>Resilience Observatory (Scott Miles)</i>	
2:50 pm – 3:10 pm	<i>Break</i>	
3:10 pm – 3:30 pm	<i>Data collection tools (EERI)</i>	
3:30 pm – 5:00 pm	<i>Japan experience (group organized presentation)</i>	
5:00 pm – 5:15 pm	<i>Break</i>	
5:15 pm – 5:35 pm	Data collection and collaboration with (re)insurance industry (Paolo Bazzurro)	
5:35 pm – 6:00 pm	Discussion and plans for Day 2	
6:00 pm – 7:00 pm	Reception (Bristol Bay Ballroom--Katmai room)	

- Time will be made for discussion
- Keep notes for further discussion in breakouts tomorrow.

# Monday Agenda

Breakouts: Alaska Ballroom - Aleutian, 2fl; Lupine, 1fl; Chartroom, 15fl

7:30 am – 8:00 am	Breakfast		
8:00 am – 9:30 am	Data Collection Protocols Discussion: (moderators)		
	Breakout 1: Physical Damage Data (Santiago Pujol )	Breakout 2: Impact Data (Mary Comerio)	Breakout 3: Reconstruction and Recovery Data (Stephanie Chang)
9:30 am – 9:50 pm	Break		
9:50 am - 11:30 am	Breakout 1 cont.	Breakout 2 cont.	Breakout 3 cont.
11:30 am – 12:00 pm	Box lunch and planning for evening meeting		

- Please assist in an even distribution in the breakouts
- EQ Country participants: at least one person to each breakout please

# Tuesday evening

Boardroom, 2fl; **Dena'ina Convention Center**

5:00 pm – 7:00 pm	Workshop resolutions and action items for collaborative proposals (with hors d'oeuvres)
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Thank you!

# Sunday Agenda

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- Time will be made for discussion
- Keep notes for further discussion in breakouts tomorrow.

# Additional questions to frame discussions

- What are the decisions that need to be made (on buildings) post-EQ and how will data help this decision making?
  - e.g. data for deciding fate of building (demolition), data for zoning?
- What data is needed for evaluating and adapting technical decisions?
- Towns vs Cities - different data needed?
- Need to identify two forms of links:
  - "links" that allow interoperability between data collected by different entities
  - "links" between physical damage, impact, and recovery data → to inform reconstruction policy.
- Bear in mind time frames
  - What data is available (needed) at what times after event?
  - What is the minimum data to collect in the first weeks following, vs comprehensive collection later, vs data to assess residual capacity for decisions on demolitions.



## EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

### Post Earthquake Data Collection Workshop



## Italy Experience





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# ReLUIS – Competence Centre of Civil Protection Dept.

- **What is ReLUIS?**

Network of University Laboratories in  
Earthquake Engineering



## ORDINANCE OF THE PRIME MINISTER 3274/2003

ORDINANZA DEL PRESIDENTE DEL CONSIGLIO DEI MINISTRI  
20 marzo 2003.

Primi elementi in materia di criteri generali  
per la classificazione sismica del territorio nazionale  
e di normative tecniche per le costruzioni in  
zona sismica. (Ordinanza n. 3274).

- ART. 4
1. Al fine di assicurare la più agevole ed uniforme applicazione delle disposizioni di cui alla presente ordinanza, il Dipartimento della protezione civile è autorizzato a **promuovere la costituzione di un centro di formazione e ricerca nel campo dell'ingegneria sismica e di una rete dei laboratori universitari operanti nel medesimo settore.**

### Competence Centres



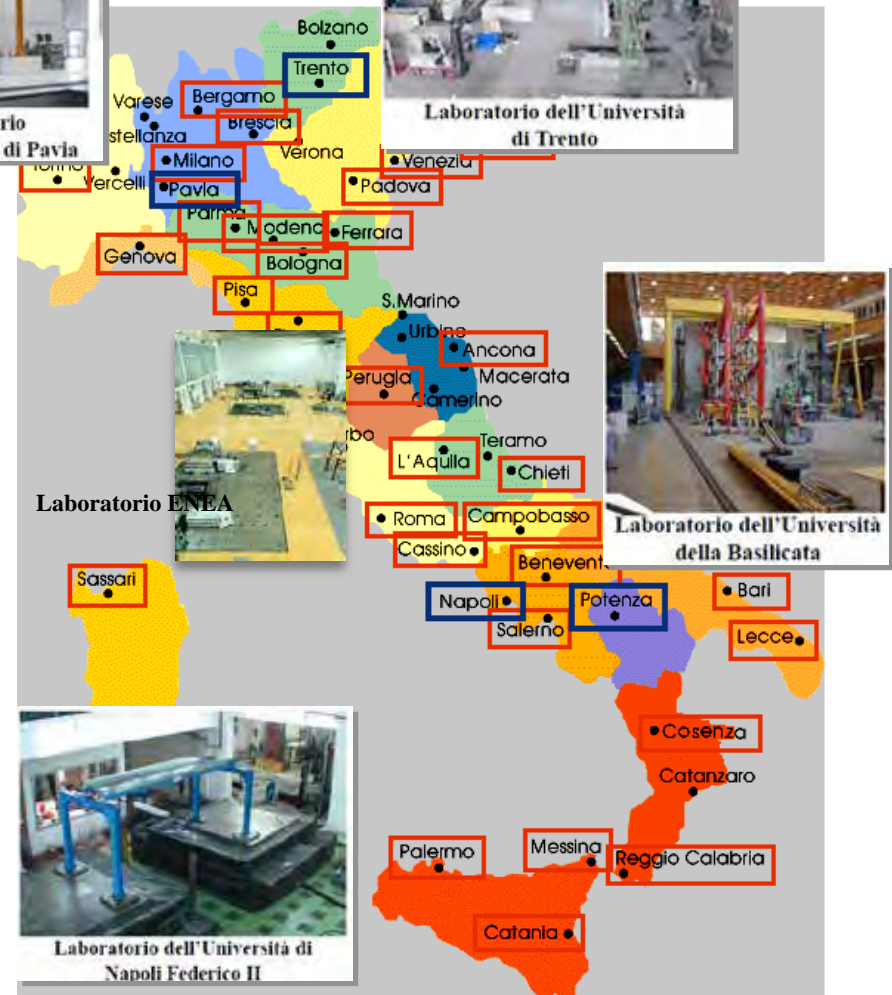
REte dei Laboratori Universitari di Ingegneria Sismica  
Charter members: Univ. Basilicata, Napoli, Pavia and Univ. di  
Trento) Collaboration with ENEA



# ReLUIIS – Competence Centre of Civil Protection Dept.

- **What is ReLUIIS?**

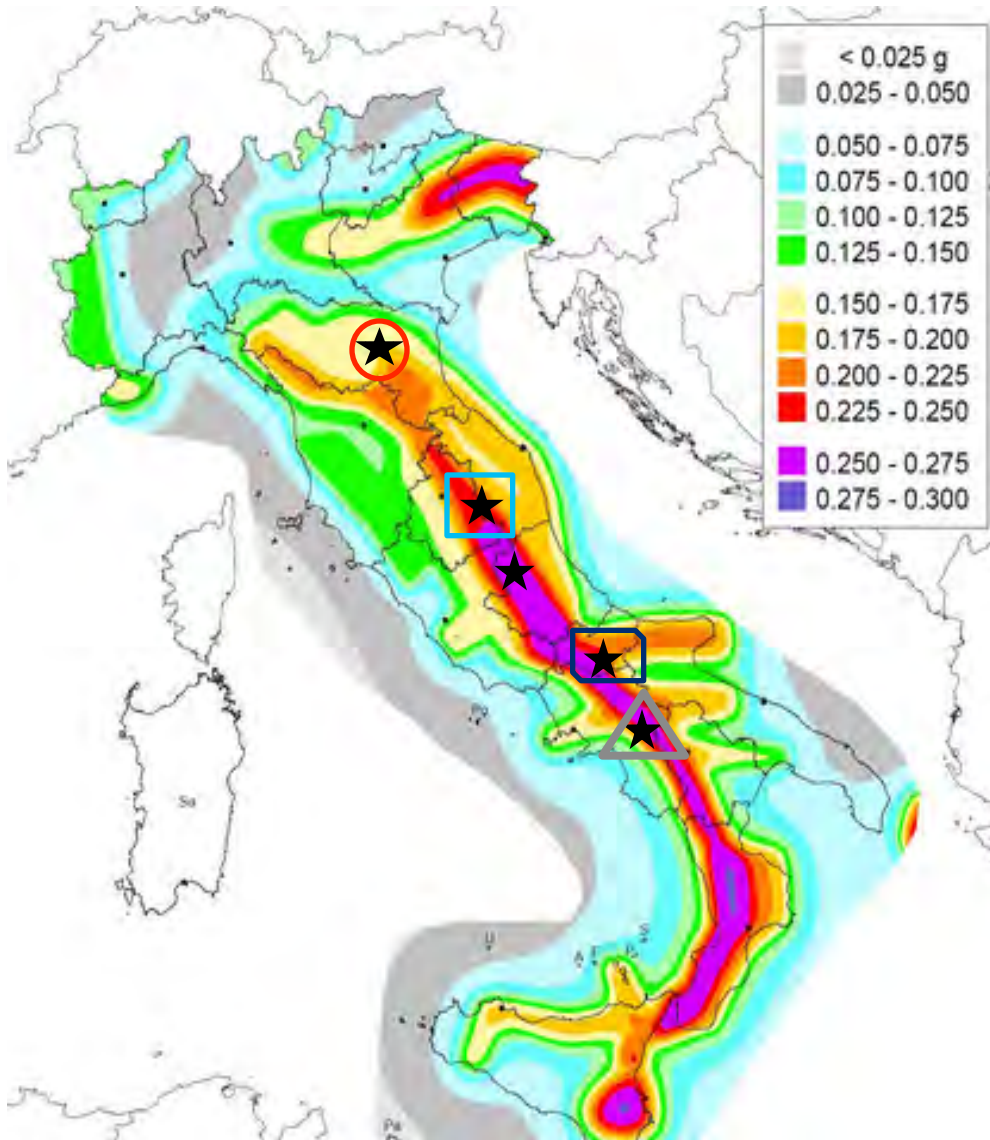
- The consortium ReLUIIS has many similarities with other earthquake engineering networks (i.e. Network for Earthquake Engineering Simulation – NEES and Asian Pacific Network for Center of Engineering Research - ANCER).



- ReLUIIS, is a interuniversity consortium with the purpose to coordinate the University Laboratories activity of seismic engineering, giving scientific, organizational, technical and financial supports to associated University



# Recent Earthquakes in Italy



△★ Southern Italy Earthquake  
23 November **1980** ( $M_s=6,9$ )

★ Umbria-Marche Earthquake  
26 September **1997** ( $M_s=5,5$ )

★ Molise Earthquake  
31 October **2002** ( $M_w=6,3$ )

★ L'Aquila Earthquake  
6 April **2009** ( $M_w=6,3$ )

★ Emilia-Romagna Earthquake in  
20-29 May **2012** ( $M_w=5,9;5,8$ )

# Recent Earthquakes in Italy

## ➤ Southern Italy Earthquake – 23 November 1980 (Ms=6,9)

The earthquake hit a vast area in Campania, Basilicata and, to a lesser extent, Puglia.

- 687 municipalities were seriously damaged;
- 2,914 deaths and more than 8,800 injured



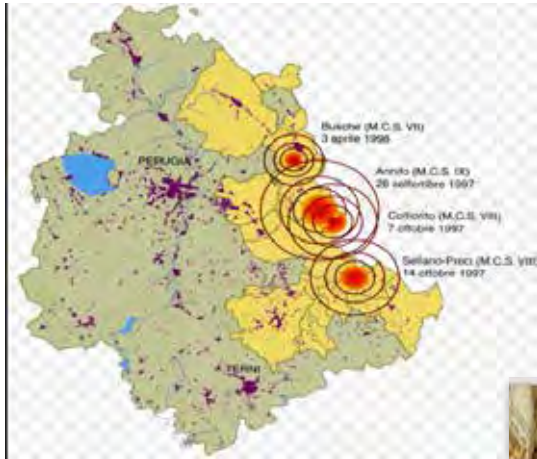
- February 1981 - Regulations for implementing the law of 1970 : instruction for the organization of a civil protection system;
- June 1981 – new Minister for Civil Protection (Zamberletti).



“HURRY to save those who are still alive,  
to help who no longer has anything”

# Recent Earthquakes in Italy

## ➤ Umbria-Marche Earthquake 26 September 1997 ( $M_s=5,5$ )



An initial earthquake tremor of magnitude 5.5 ( $M_s$ ) hit a vast area of central Italy. Then a seismic sequence continued for several months in Umbria and Marche, with thousands of tremors in a wide area, causing 11 deaths

Basilica of San Francesco d'Assisi



- For the first time the damage survey has been performed together with the usability survey (Aedes form)
- criteria for reconstruction phases: "light" and "heavy" reconstruction;
- Public funds (repair+ strengthening works) based on parametric costs assessed according to damages and vulnerability significant parameters;

## ➤ Molise Earthquake – 31 October 2002 ( $M_l=5,4$ )

- new seismic code (OPCM n. 3274/2003)
- Code provisions: seismic assessment of strategic buildings and infrastructures

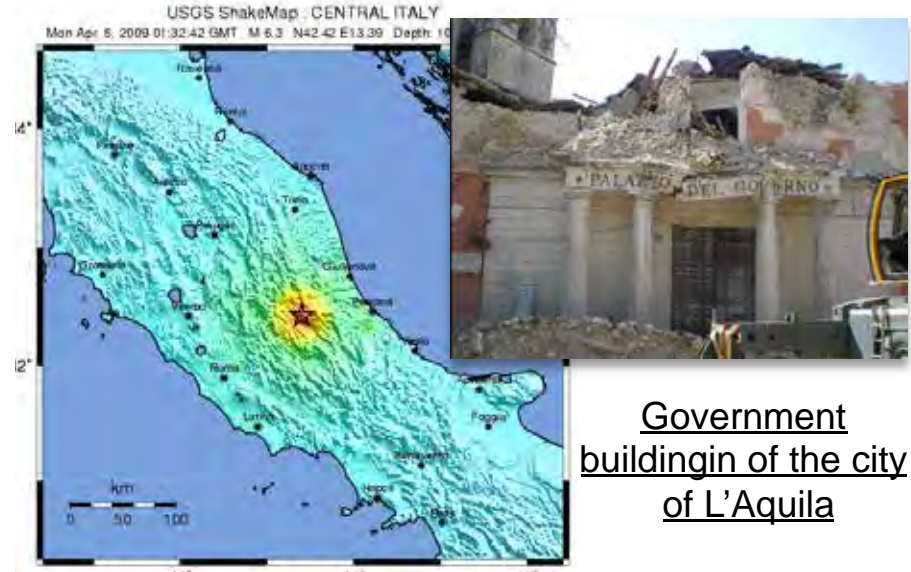




# Recent Earthquakes in Italy

## ➤ L'Aquila Earthquake – 6 April 2009 (Mw=6.3)

The main shock occurred at 03:32 on 6 April 2009, causing 309 deaths and over 1500 injured. Its epicenter was near L'Aquila, which together with surrounding villages suffered most damage.



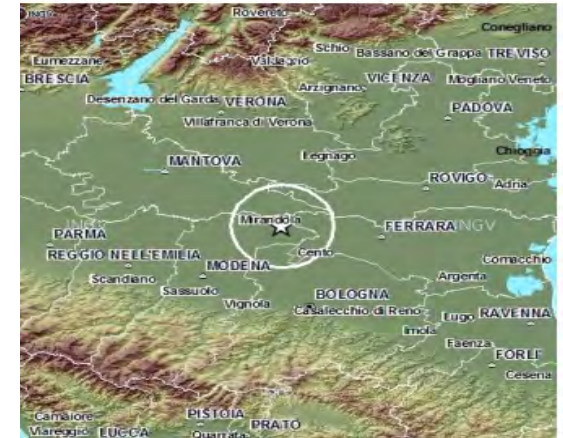
Government building of the city of L'Aquila

- damage and seismic usability assessment of each building through in situ inspections;
- The AeDES form was adopted as a rapid tool to evaluate the safety conditions of the buildings;
- The financial support to the reconstruction process was calibrated also depending on the building usability rate;
- Reconstruction process based on light and heavy reconstruction;
- For each building not only repair works but also local or global strengthening interventions (or demolition and reconstruction) were allowed; the retrofit design as well as their costs were designed and computed by practitioners.

# Recent Earthquakes in Italy

## ➤ Emilia-Romagna Earthquake – 20-29 May 2012 (Mw=5,9; 5,8)

In May 2012, two major earthquakes occurred in Northern Italy, causing 26 deaths and widespread damage.

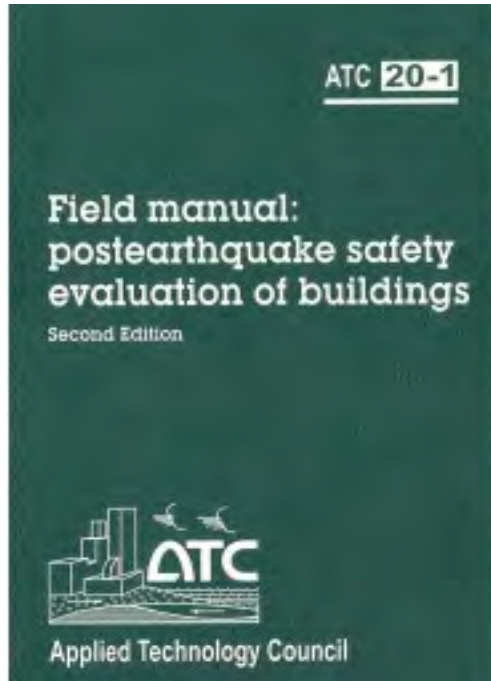


- Damages mainly on industrial buildings - Business interruption;
- additional damages provided by the earthquake of 29 may .
- Need to refine Usability form for precast buildings



# Post Earthquake Safety Evaluation of Buildings

## Damage and Safety assessment



### ➤ ATC-20

Following the San Fernando Earthquake in 1971 (South California), the Applied Technology Council (ATC) began developing Procedures for Postearthquake Safety Evaluations of Buildings (ATC-20) and a Field Manual: Postearthquake Safety Evaluations of Buildings (ATC-20-1).

### ➤ The Aedes form

The form and its manual derive from the experience gained in several earthquakes since earthquake in Umbria and Marche in 1997.

Updates were made after the earthquakes of Pollino 1998 and Molise in 2002.





# Post Earthquake Safety Evaluation of Buildings

## Data collected by Aedes Form

The usability evaluation is not a safety assessment, nor it substitutes it.

Buildings are intended as structural units - form takes into account only residential structure.

### ➤ Section 1 - Building identification

- localization;
- n° of the survey;
- date of the survey.

SECTION 1 Building identification

Building name: \_\_\_\_\_

Address: \_\_\_\_\_

Location: \_\_\_\_\_

Photograph of the structural unit with building indication

### ➤ Section 2 - Building description:

- metrical data;
- age ( period of construction);
- eventually renovation;
- type of use and exposure.

SECTION 2 Building description

Metrical data

Total number of units	Average story height [m]	Average story surface [m <sup>2</sup> ]	Construction and maintenance [year]	Use	No. of units	Utilization	No. of occupants
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# Post Earthquake Safety Evaluation of Buildings

## Data collected by Aedes Form

➤Section 4 - Damage to structural elements and existing short term countermeasures:

➤Section 5 - Damage to non-structural elements and existing short term countermeasures:

➤Section 6 - External risk induced by other construction and existing short term countermeasures

➤Section 7 - Soil and Foundation

➤Section 8 - Usability assessment

➤Section 9 - Note

### SECTION 4 Damage to structural elements and existing short term countermeasures

Damage level - extension	DAMAGE (1)										EXISTING SHORT TERM COUNTERMEASURES					
	D4-D5 Very Heavy			D2-D3 Medium-Severe			D1 Light				None	Removal	Ties	Propping	Shoring or passage protection	
	> 20	10-20	< 10	> 20	10-20	< 10	> 20	10-20	< 10							
Structural components	A	B	C	D	E	F	G	H	I	J	A	B	C	D	E	F
1 Vertical structures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 Floors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 Stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 Roof	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 Walls and partitions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6 Pre-existing damage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

(1) - The damage extension must be filled only if the corresponding damage level is present in the building.

### SECTION 5 Damage to non-structural elements and existing short term countermeasures

Damage	PRESENT	EXISTING SHORT TERM COUNTERMEASURES					
		None	Removal	Propping	Repair	No entry	Barrier or passage protection
1 Falling of plaster, coverings, false ceilings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 Falling of tiles, chimneys...	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 Falling of eaves, parapets...	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 Falling of other internal or external objects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 Damage to hydraulic or sewage systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6 Damage to electric or gas systems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### SECTION 8 Usability assessment

RISK EVALUATION				Building Classification	
RISK	STRUCTURAL (sect. 4)	NON-STRUCTURAL (sect. 5)	EXTERNAL (sect. 6)	GEOTECHNICAL (sect. 7)	
LOW	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	A USABLE building <input type="checkbox"/>
LOW WITH COUNTERMEASURES	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	B UNUSABLE building (totally or partially), but USABLE after short term countermeasures <input type="checkbox"/>
HIGH	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	C PARTIALLY UNUSABLE building (1) <input checked="" type="checkbox"/>
					D TEMPORARILY UNUSABLE building requiring a more detailed investigation <input type="checkbox"/>
					E UNUSABLE building <input type="checkbox"/>
					F UNUSABLE building due to external risk (1) <input type="checkbox"/>

(1) Restrictions on building use must be clearly reported in the notes when building is classified as B or C; causes of external risk when building is classified as F.

Survey accuracy: 1 ☐ Only from outside 4 ☐ Not surveyed because of: a ☐ Survey refused b ☐ Rains c ☐ Demolished  
2 ☐ Partial d ☐ Absent owner e ☐ Other \_\_\_\_\_  
3 ☐ Complete (> 2/3)

Suggested short term countermeasures, limited (\*) or extended (\*\*)

#	** Suggested short term countermeasures	#	** Suggested short term countermeasures
1 <input type="checkbox"/>	Tightening and application of strands	7 <input type="checkbox"/>	Removal of eaves, parapets, overhangs
2 <input type="checkbox"/>	Repair of light damages to infill panels and partition walls	8 <input type="checkbox"/>	Removal of other internal or external objects
3 <input type="checkbox"/>	Roof repair	9 <input type="checkbox"/>	Barriers and passage protection
4 <input type="checkbox"/>	Stairs propping	10 <input type="checkbox"/>	Repair of utility systems
5 <input type="checkbox"/>	Removal of plaster, coverings, false ceilings	11 <input type="checkbox"/>	
6 <input type="checkbox"/>	Removal of tiles, chimneys, parapets	12 <input type="checkbox"/>	

Unusable building units, families and people to be evacuated

Unusable building units  Families to be evacuated  People to be evacuated

# Post Earthquake Safety Evaluation of Buildings

## **Data collected by Aedes Form**

## ***Damage Level and extension***

D1 slight damage:

The damage not affect significantly the capacity of the structure; the damage is slight when the falling of objects can immediately be avoided.



D2-D3 medium-severe damage:

The damage changes significantly the capacity of the structure, without getting close to the limit of partial collapse of the main structural components.



D4-D5 very heavy damage:

The damage significantly modifies the capacity of the structure, bringing it close to the limit of partial or total collapse of the main structural components – including collapse



# Post Earthquake Safety Evaluation of Buildings

## Damage and Safety assessment

### ➤ ATC-20

Posting systems:

- **Inspected** - Appears safe for lawful occupancy
- **Limited Entry / Restricted Use** - Some restriction on use, controlled by building owner/manager
- **Unsafe** – Entry controlled by jurisdiction

The image shows three ATC-20 posting signs. The top sign is blue and white, labeled 'INSPECTED NO RESTRICTION ON USE OR OCCUPANCY'. It includes fields for 'Date', 'Time', 'Inspector', and 'Facility Name and Address'. The middle sign is yellow and white, labeled 'LIMITED ENTRY OFF LIMITS TO UNAUTHORIZED PERSONNEL'. It includes fields for 'Restrictions', 'Date', 'Time', 'Inspector', and 'Facility Name and Address'. The bottom sign is red and white, labeled 'UNSAFE DO NOT ENTER OR OCCUPY'. It includes fields for 'Date', 'Time', 'Inspector', and 'Facility Name and Address'. All signs have a header for 'APPLIED TECHNOLOGY COUNCIL CALIFORNIA' and a footer for 'ATC20 CARTELLONISTICA'.

### Usability Classification

A	USABLE building	
B	UNUSABLE building (totally or partially), but USABLE after short term countermeasures	
C	PARTIALLY UNUSABLE building (1)	
D	TEMPORARILY UNUSABLE building requiring a more detailed investigation	
E	UNUSABLE building	
F	UNUSABLE building due to external risk (1)	

### ➤ Aedes Form

Six usability rates:

- Usable
- Unusable but usable after short countermeasures
- Partially unusable
- Temporarily unusable
- Unusable
- Unusable due to external risk



# Technical management of seismic emergency – damage survey and safety evaluation

## Training

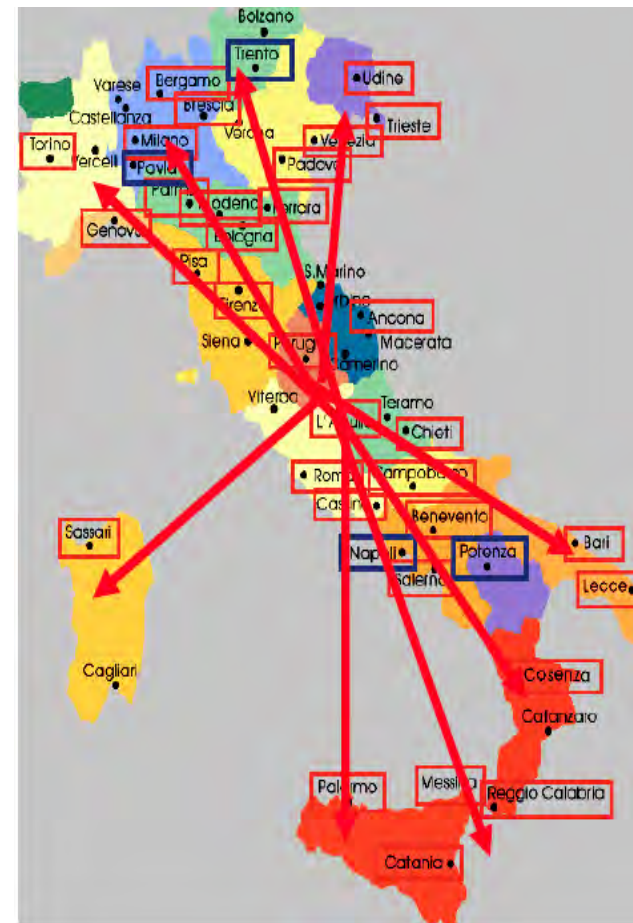
The training activities are carried out for:

- practitioners
- university professors and researchers



## Objectives

- share a unique approach at the national level in the technical management of seismic emergency
- promote common standards, procedures, languages and operating methods
- Homogeneous safety evaluations by experts from different fields and from different boards.





## **L'Aquila Earthquake**

- **Data collected - Aedes Form**
- **Housing impacts**

# Data collected after the earthquake

## Data collected - Aedes Form

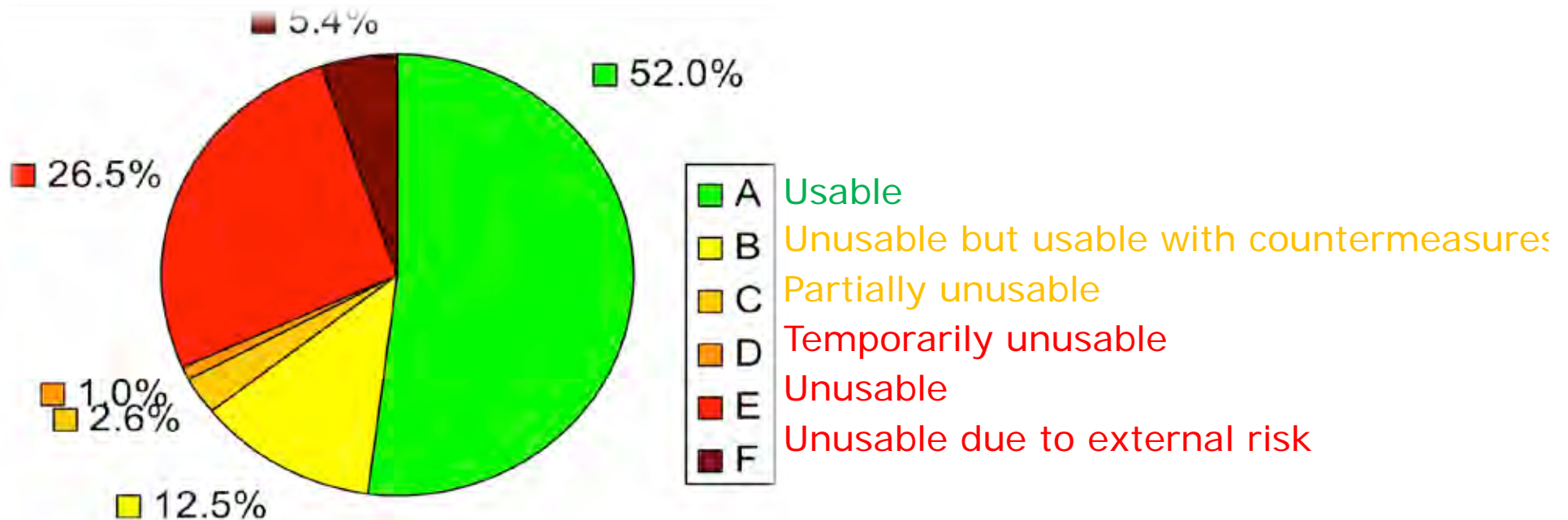
about **72,000** buildings  
inspected  
(more than 80,000 inspection)

7 April



# Data collected after the earthquake

## Data collected - Aedes Form

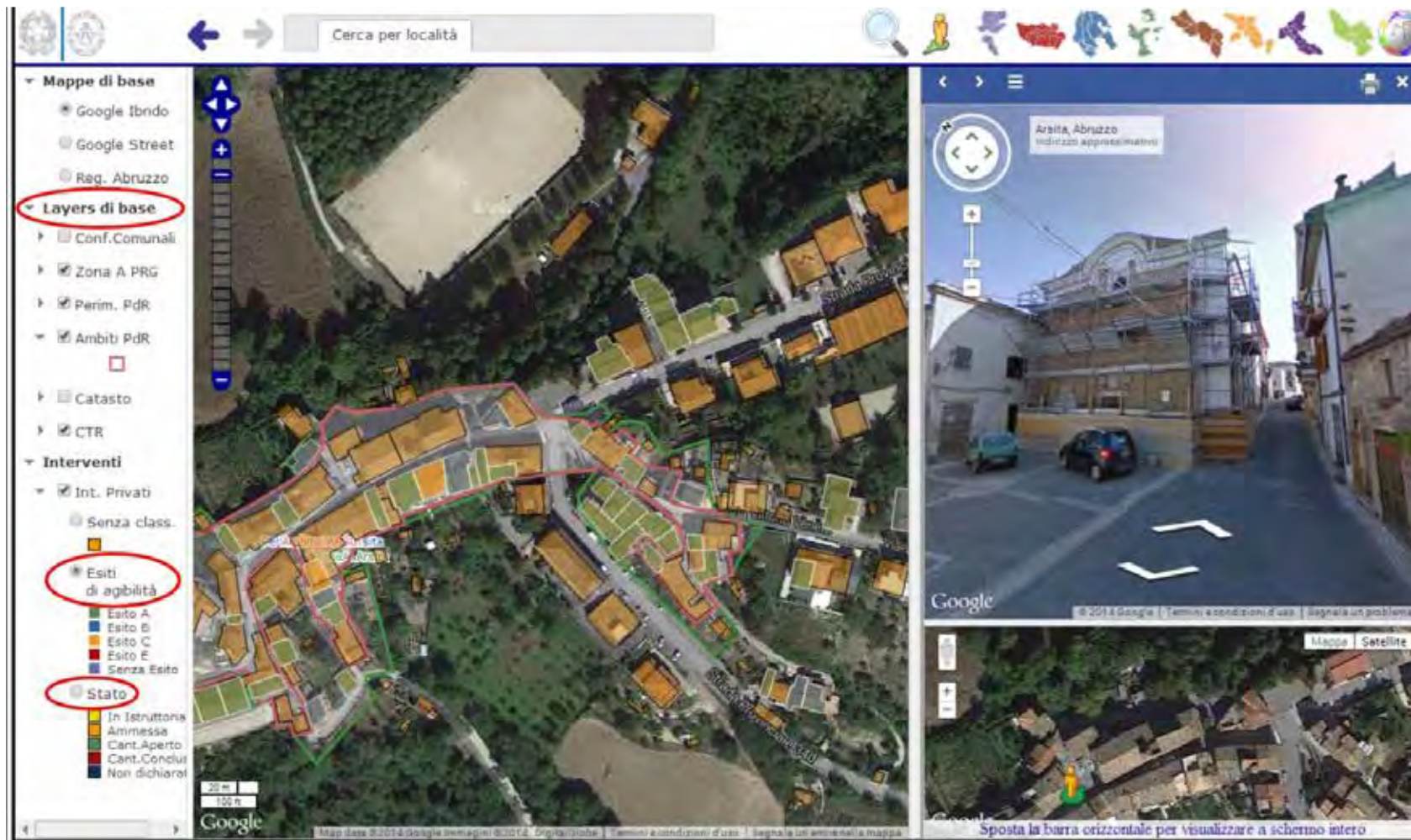


	A	B	C	D	E	F
Masonry	48.7%	10.7%	2.6%	1.2%	30.5%	6.3%
Mixed	62.9%	11.3%	3.0%	0.6%	17.1%	5.1%
RC	61.6%	19.4%	2.3%	1.1%	13.5%	2.1%
Total	52.0%	12.5%	2.6%	1.0%	26.5%	5.4%

# Data collected after the earthquake

## Data collected - GIS

GIS mapping of all damaged buildings



# Data collected after the earthquake

## Housing impacts



**Persons assisted:  
65.579**

***Last Update - 18.04.2009***



ACCOMMODATION IN TENTS					
	Camps	Tents	Persons assisted	Field kitchens	Advanced Medical Posts
COM1	36	1.512	13.876	13	15
COM2	24	869	5.475	16	14
COM3	40	946	6.562	10	3
COM4	19	906	4.518	17	3
COM5	10	868	4.206	9	6
COM6	14	247	1.850	4	0
COM7	18	609	3.123	0	0
COM8	not yet avail.	not yet avail.	not yet avail.	not yet avail.	not yet avail.
TOT	161	5.957	39.610	69	41

ACCOMMODATION IN HOTELS AND PRIVATE HOUSES	
Province	Persons
Teramo	18.468 persons: 13.458 in 194 hotels and 5.010 in 1.087 private houses
Pescara	3.875 persons: 3.872 in 65 hotels and 3 in 1 private house
Chieti	2.876 persons: 2.828 in 105 hotels and 48 in 6 private houses
Ascoli Piceno	750 persons in 9 hotels
<b>Total</b>	<b>25.969 persons</b>



# Data collected after the earthquake

## Housing impacts



Earthquake Umbria-Marche 1997 – Picture today

[www.protezionecivile.gov.it](http://www.protezionecivile.gov.it)

## ARE THEY TEMPORARY SOLUTIONS??



Village of containers  
(Valtopina) and/or of  
prefabricated houses  
in Umbria

Earthquake Umbria-Marche  
1997



# The C.A.S.E. Project



**Complessi (Complexes)**  
**Antisismici (Antiseismic)**  
**Sostenibili (Sustainable)**  
**Eco-compatibili (Eco-compatible)**

## OBJECTIVES

IMMEDIATELY  
tents

### USUAL STRATEGY

TEMPORARILY  
different modules  
(roulotte, containers, prefabricated)

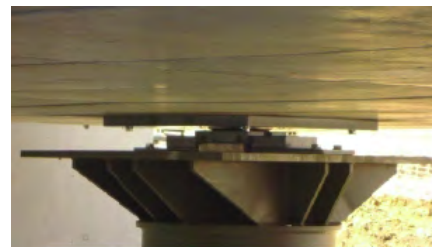
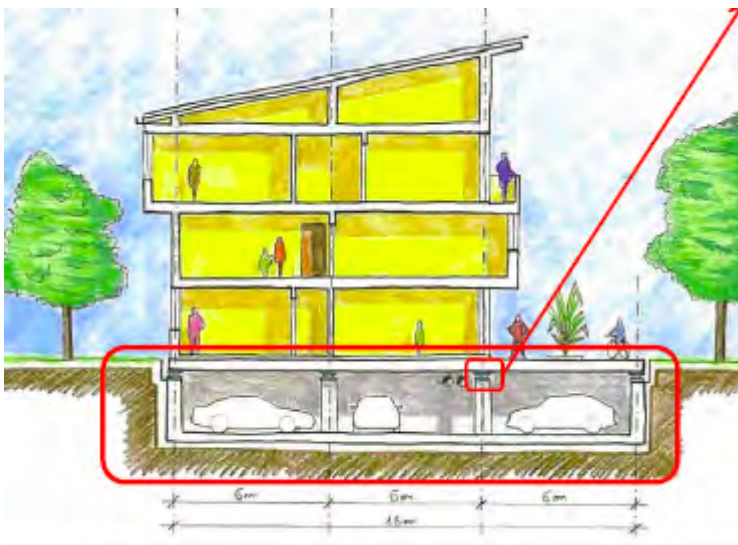
FINAL  
new or repaired original  
buildings

### C.A.S.E. STRATEGY

IMMEDIATELY  
tents

TEMPORARILY  
high standard  
dwelling buildings

FINAL  
new, or repaired and  
reinforced, original buildings



Seismic  
Isolators



**8,000** houses for **23,500 homeless** available in few months – **4449 apartments C.A.S.E. project**

## Typical solutions post-earthquake

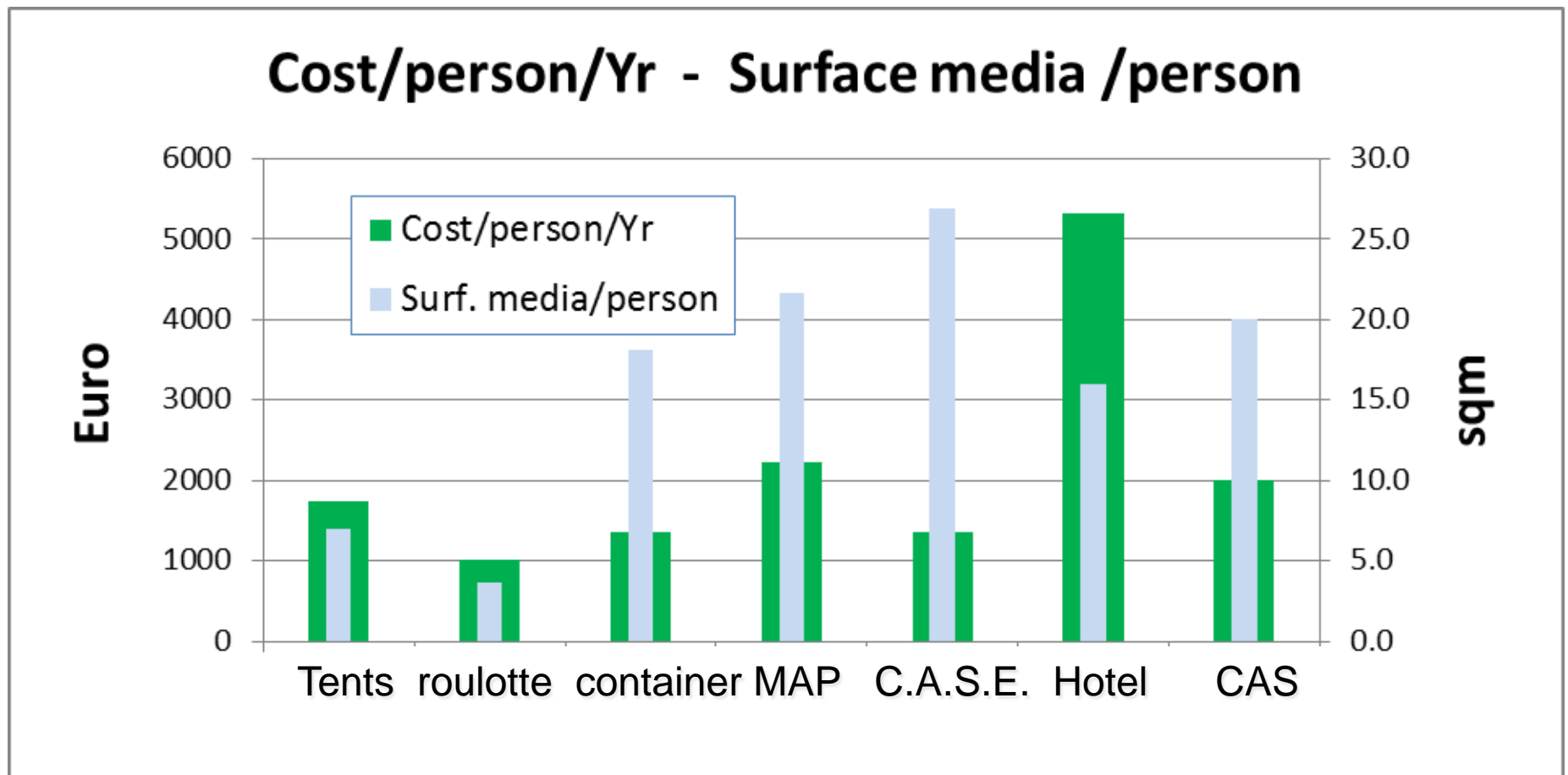
### Lodging with different levels of cost and, above all, of comfort

	Serviceable Useful life [year]	Surface/person about [mq]	Surface media [mq]	Cost /person [€/person]	Cost/Yr / person [€/person]
<b>Tents</b>	3	6,2 - 9,4	7,8	5243	<b>1748</b>
<b>Roulotte</b>	5	2,3 – 3,5	2,9	3125	<b>1005</b>
<b>Container</b>	8	5 - 7,5	6,2	10875	<b>1359</b>
<b>Wooden houses (MAP)</b>	15	17,8 – 25,4	21,6	33249	<b>2217</b>
<b>Project C.A.S.E</b>	30	22,1 – 31,6	26,9	40856	<b>1362</b>
<b>Hotel</b>	1	7-12	9,5	5323	<b>5323</b>
<b>CAS</b>	1	10-20	15	2000	<b>2000</b>



## Typical solutions post-earthquake

*Lodging with different levels of cost and, above all, of comfort*



## **L'Aquila Earthquake**

- **Data collected – Reconstruction process**
- **Organizations involved in collecting data**
- **Repair and strengthening works costs**
- **Demolition and reconstruction**

# The Ordinances

- Reconstruction policies**

**June 6, 2009 – OPCM 3778**



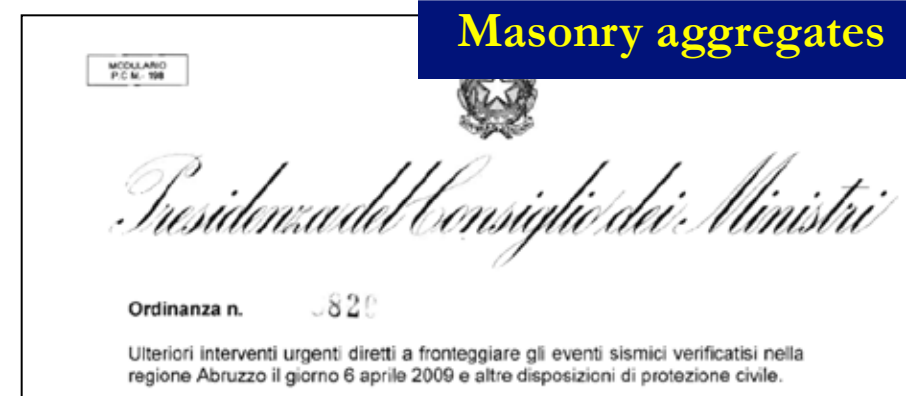
**June 6 2009 – OPCM 3779**



**July 9, 2009 – OPCM 3790**



**November 12 2009 – OPCM 3820**



(\*) With Annexes

# The Reconstruction Process of private buildings

- **Financial Support**

## **"LIGTH" RECONSTRUCTION**

### **Rate A: Usable buildings**

- ✓ Repair intervention with a maximum refund of **10.000 €** + 2.500 €/dwelling;



# The Reconstruction Process of private buildings

- **Financial Support**

## **"LIGTH" RECONSTRUCTION**

### **Rate A: Usable buildings**

- ✓ Repair intervention with a maximum refund of **10.000 €** + 2.500 €/dwelling;



### **Rate B: Building usable only after short term countermeasures**

### **Rate C: Partially usable building.**

- ✓ Total refund of repair intervention costs + local strengthening of structural or non-structural members up to **150 €/mq.**;

#### Local strengthening interventions:

- related to single structural members;
- no significant mass and stiffness change;
- only the local member capacity increase should be computed;
- the global analysis of the structure is not required.



# The approval process of funding requests

- **The “Filiera” activity**

✓The process consists of a series of checks by :

1. **FINTECNA: Finanziaria per i Settori Industriale e dei Servizi S.p.A.**



FINTECNA - Ministry of Economy and Finance, evaluates administrative check of application and documentation.

2. **ReLUIS: Laboratories University Network of seismic engineering**



Compliance between: i) repair intervention and damages; ii) local strengthening interventions and italian seismic code provisions (NTC 08 and Circ. 617/2009 as well as specific provisions for the Abruzzo Emergency (O.P.C.M. 3779, 3790 and Annexes by DPC). Technical check

3. **CINEAS: Interuniversity Consortium of Insurance Engineering**



Finacial check

# The approval process of funding requests

- **The “Filiara” activity**

LIBRO BIANCO SULLA RICOSTRUZIONE DEGLI  
EDIFICI PRIVATI FUORI DAL CENTRO STORICO  
DANNEGGIATI DAL SISMA DIL'AQUILA

Rete dei Laboratori Universitari di Ingegneria Sismica



Dipartimento di Protezione Civile



Consorzio Universitario Per L'Ingegneria Nelle Assicurazioni



BOZZA - Aprile 2014

WHITE BOOK ON THE RECONSTRUCTION  
OF PRIVATE BUILDINGS DAMAGED BY  
THE L'AQUILA EARTHQUAKE



# The approval process of funding requests

## • The “Filiere” activity

**19936 FUNDING REQUESTS**

- ✓ 19936 Funding requests related to L'Aquila city (outside the historical centre) and other municipalities have been analysed in the approval process



**U.I.I = Housing unit**

**P.C. = Communal areas**

**U.I.C. = Dwellings**



**L'Aquila**      **U.I.I = 2742**  
**2094**

**P.C. = 3033**  
**2761**

**U.I.C. = 13562**  
**13087**

**Other municipalities**      **698**

**272**

**475**

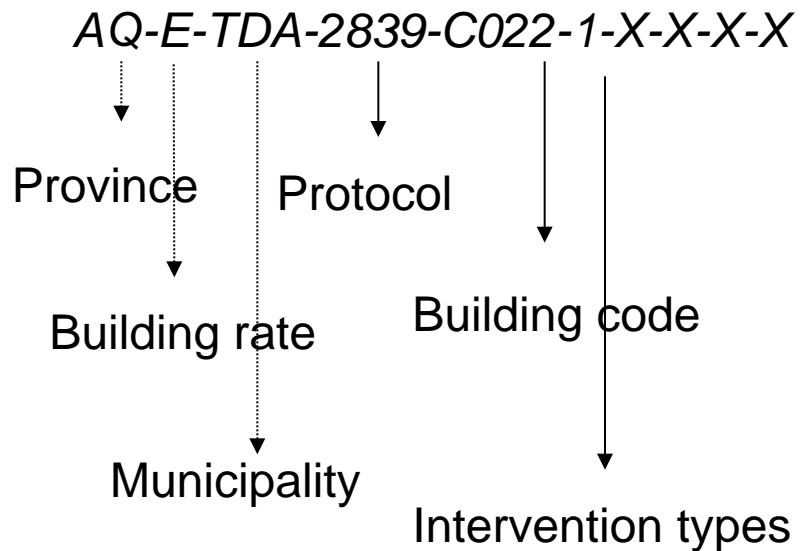


# The approval process of funding requests

- **Data Collection**

**19936 FUNDING REQUESTS**

**Application Digital documentatio**



# The approval process of funding requests

## • Data Collection

**QUERY** → Data

- Building address - Usability rate (B,C, or E);
- structural typology (RC, masonry, steel, etc.);
- number of stories;
- global surface;
- age of construction;
- number of dwellings;
- Approval process timing;
- repair and strenghtening interventions;
- risk indicator [ $\alpha$ ];
- dwellings repair costs;
- Structural repair costs, local strengthening interventions costs (B or C buildings);
- seismic capacity increase interventions costs (E buildings)
- Demolition and reconstruction

## Form to collect data

**DATI GENERALI**

Comune:

Indirizzo:

Foglio:  Particella:  Anno di Costruzione:

Agibilità:

**DATI PRATICA**

PROTOCOLLO:

U.I.C. correlate:

**DATI GEOMETRICI**

Altezza Totale (m):

Superficie Coperta (mq):

n° Piani Sopraelevati:

Altezza media Piani piano sottotetto (m):

n° Piani interrati:

**DATI AZIONE SISMICA**

LC:  Categoria Sottosuolo:  Categoria Topografica:

Regolarità in pianta:  Regolarità in elevazione:

**Dati dinamici**

T1:  T2:  T3:

MP1:  MP2:  MP3:

**CARATTERISTICHE MATERIALI E DETTAGLI COSTRUTTIVI**

**Calcestruzzo**

fcm (MPa):

**Acciaio**

fym (MPa):

Tipologia barre:

**Staffe**

Travi:  Pilastri:

Passo (cm):  Passo (cm):

**DATI INTERVENTO**

☐ Riparazione ☐ Intervento Locale ☐ Miglioramento

INTERVENTO 1:  ALTRO INTERVENTO:

INTERVENTO 2:

INTERVENTO 3:

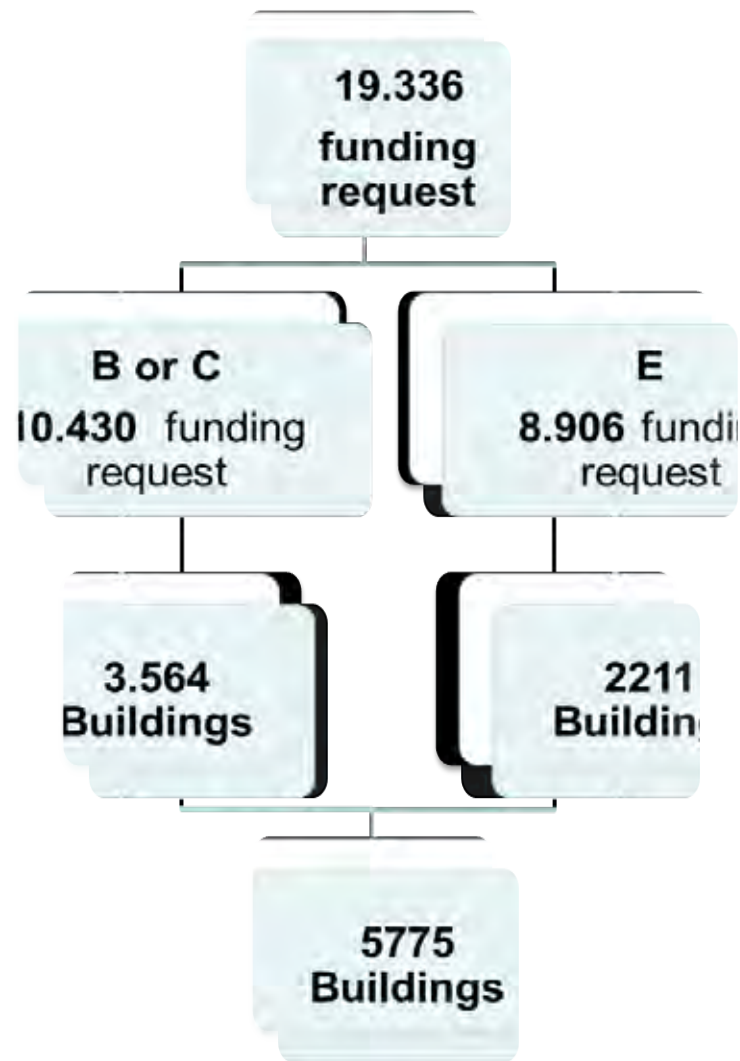
**Indicatori di rischio: rapporto tra capacità e domanda in termini di PGA**

alfa\_uv ANTE OPERAM:  alfa\_uv FONDAZIONE:

alfa\_uv POST OPERAM:

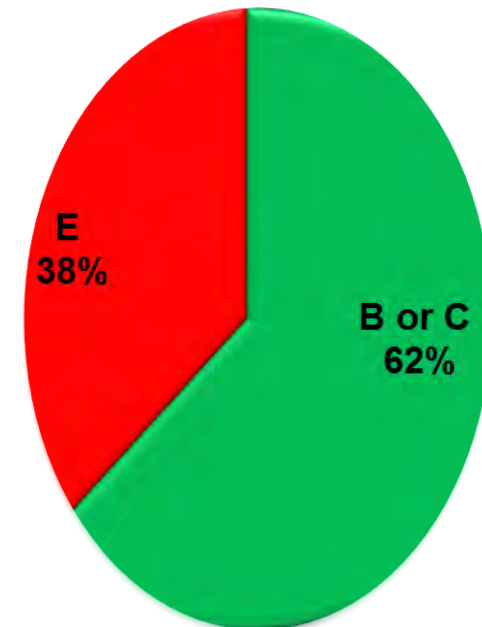
# The damaged building stock

- The “Filiara” activity***



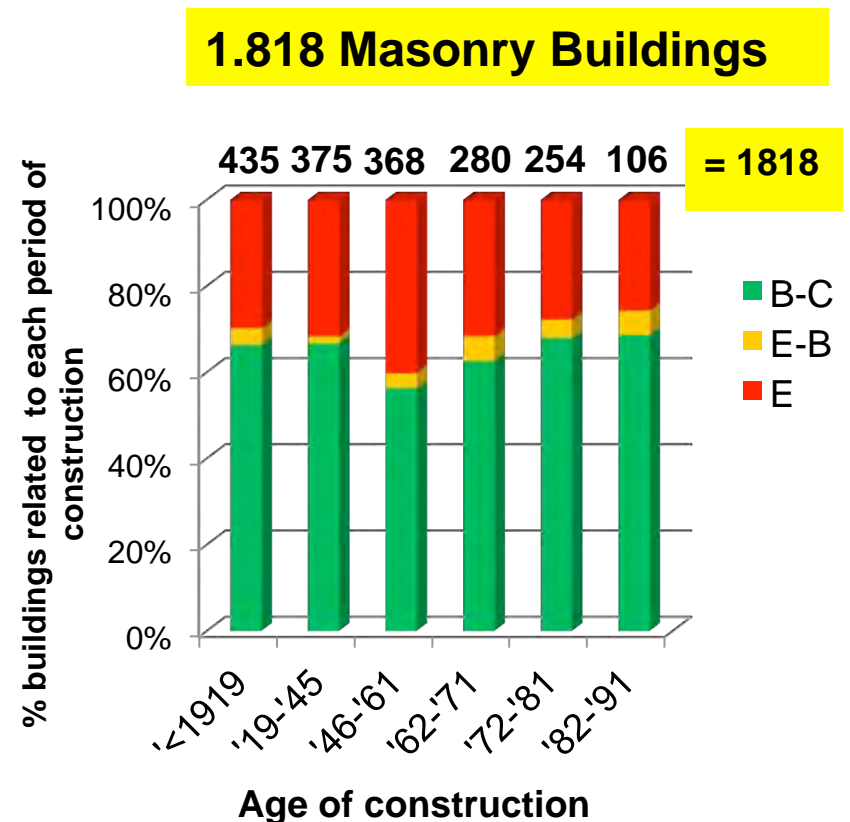
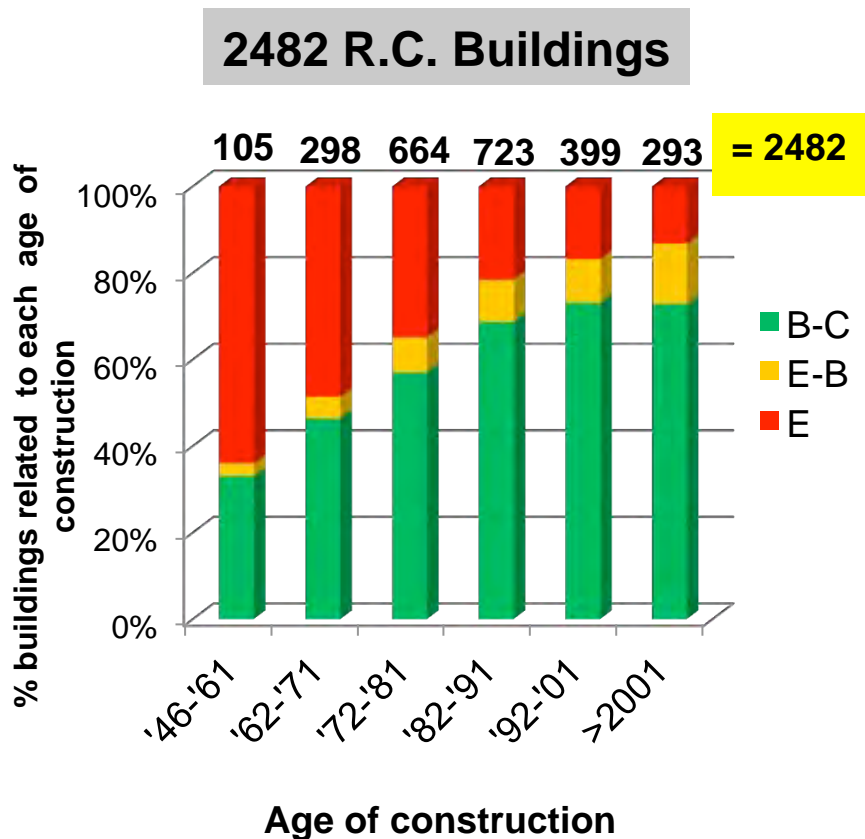
**5775 BUILDINGS**

5775 Buildings



# The damaged building stock

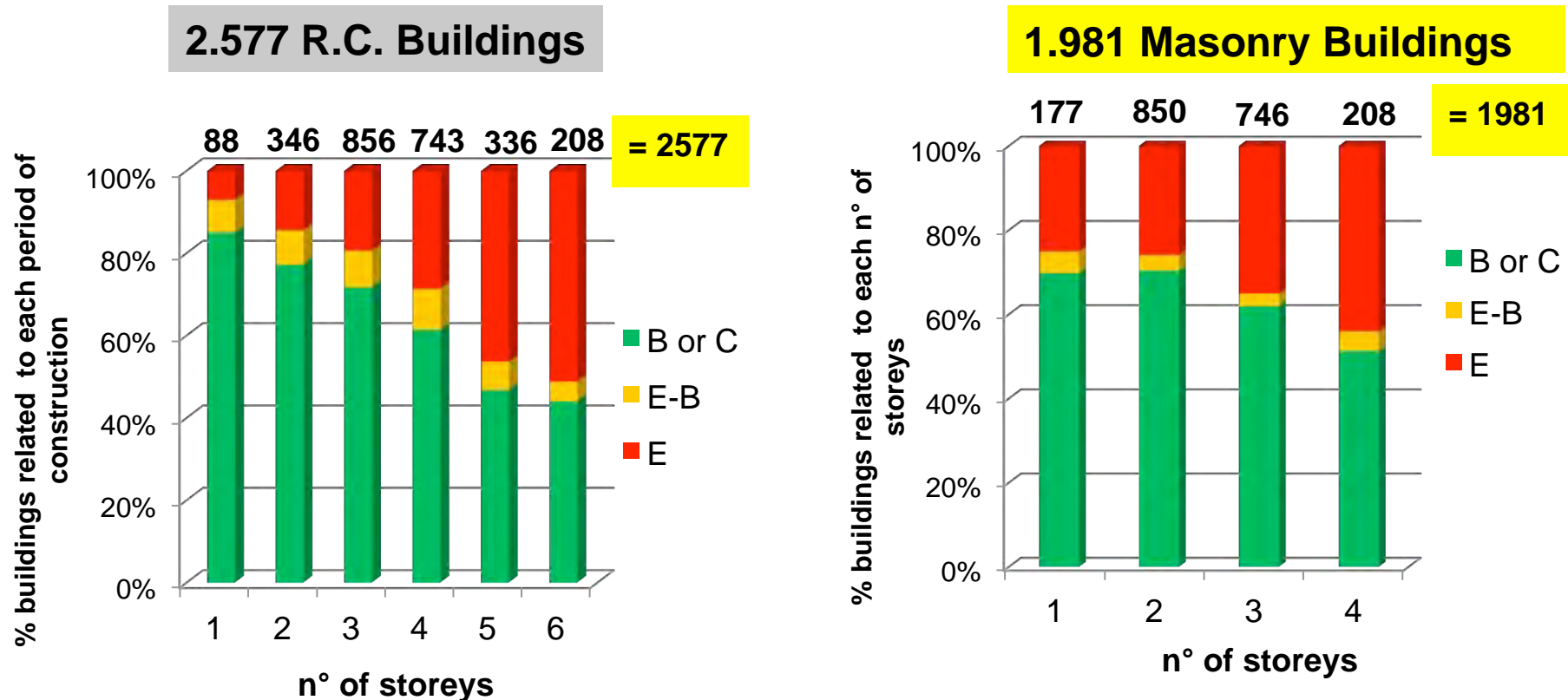
- Usability rate vs. structural type age of constr.**



- ✓ RC structures: E rate buildings decrease with recent age of construction (from about 60% to about 15%)
- ✓ Masonry structures: E rate buildings is almost constantly about 35%)

# The damaged building stock

- Usability rate vs. structural type *n° of stories***



- ✓ RC structures: E rate buildings increase with number of stories (from about 10% to about 50%)
- ✓ Masonry structures: E rate buildings increase with number of stories (from about 25% to about 45%)

# Light Reconstruction

June 6 2009 – OPCM 3779



2901 of L'aquila

**Rate A:** Usable buildings

**Rate B:** Building usable only after short term countermeasures

**Rate C:** Partially usable building.

# Light reconstruction – Buildings Usability rate

## THE “LIGTH” RECONSTRUCTION

- **Strong support to practioners**



## GUIDELINES AND CALCULATION EXAMPLES

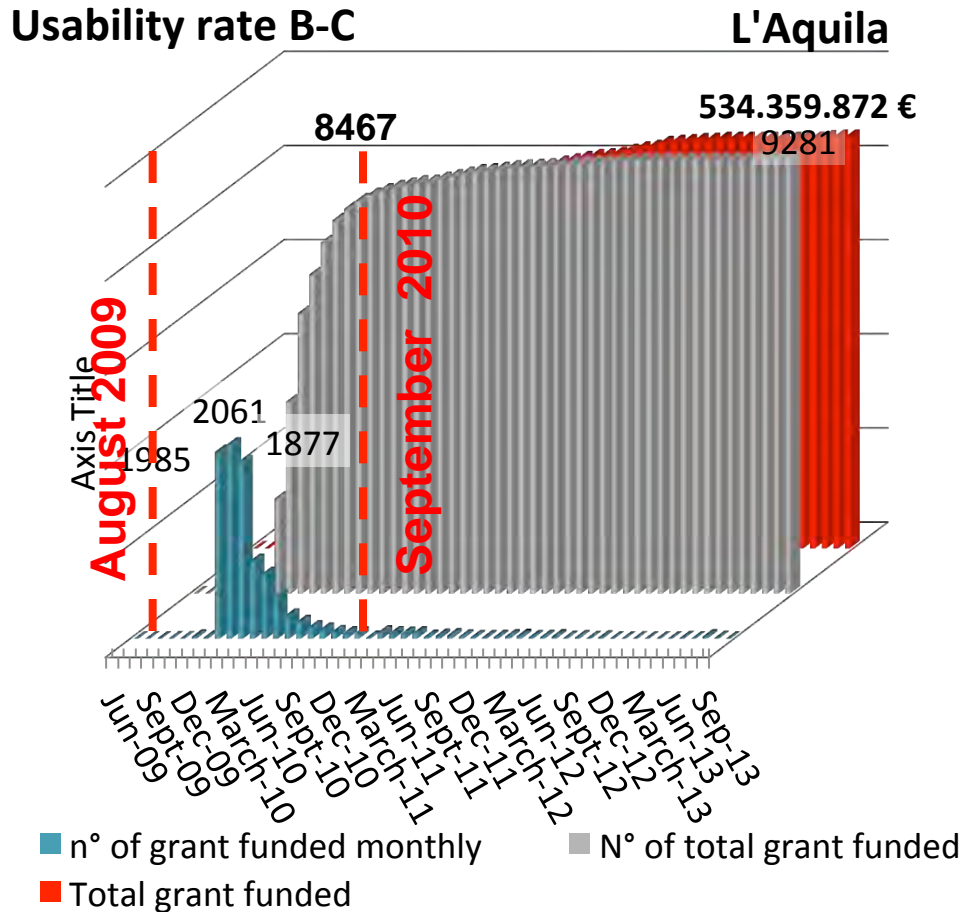
## REPAIR AND STRENGTHENING OF STRUCTURAL ELEMENTS, INFILLS, AND PARTITIONS

Freely downloadable at website  
**[www.reluis.it](http://www.reluis.it)**



# Light reconstruction - Approval process

- Funding requests grant (B or C buildings)**



Date	n° requests approved		Grant
	[-]	[%]	[€]
December 2009	34	0%	940.492,17
March 2010	5.957	63%	246.860.149,31
September 2010	8.467	90%	452.717.28,51
September 2011	9.048	96%	509.215.730,00
March 2013	9.247	98%	532.259.802,10
September 2013	9.281	98%	534.359.872,31

After 1 year 90% (8467 of 10439) financially approved by the municipality

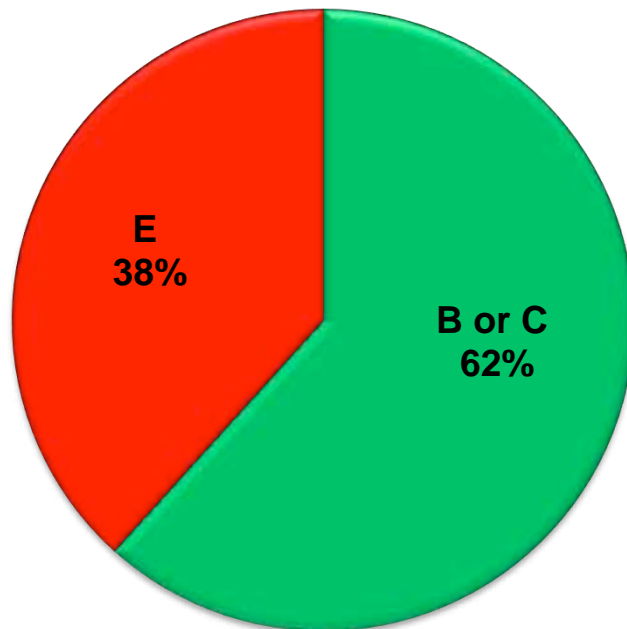
- ✓ Municipalities grant released: A grant of about 452 million of euro at September 2010, total "ligh" reconstruction costs of about € 534.000.000, 00



# Light reconstruction – Buildings Usability rate

- 3564 Private buildings**

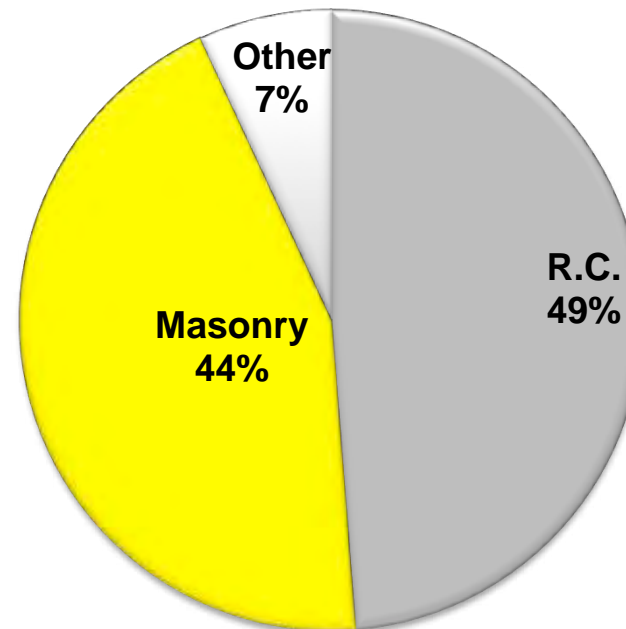
5775 Buildings



**3564** Usability rate B or C

**2211** Usability rate E

Usability rate B or C  
3564 Buildings



**1738** R.C. Buildings

**1580** Masonry Buildings

**246** Other typologies

**3318**

## Light reconstruction – Costs

- **Costs on 2501 Private buildings – L'Aquila**  
**Buildings B or C :**

The grant includes the costs for repair intervention + local strengthening of structural or no-structural members.



- **1.599 R.C. buildings - mean grant: 246 €/m<sup>2</sup>**



- **902 masonry buildings mean grant : 318 €/m<sup>2</sup>**

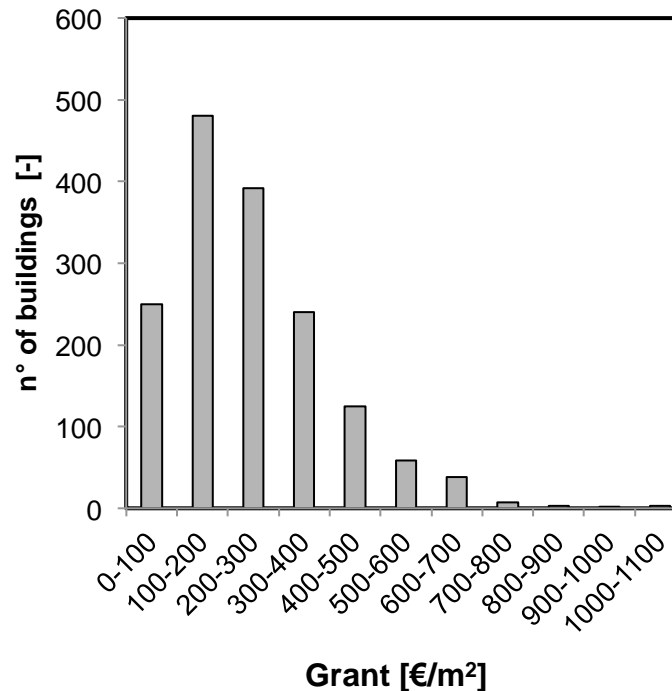
Costs include:  
practitioners technical fees and V.A.T.

# Light reconstruction – Costs

## • R.C. Private buildings

Buildings B or C :  
 - 1.500 reinforced concrete buildings - mean grant: 246 €/mq  
 - 1.000 masonry buildings - mean grant: 246 €/mq  
 - 900 masonry buildings - mean grant: 246 €/mq  
 - 1.000 masonry buildings - mean grant: 246 €/mq

n° of Buildings [-]	1599
<b>Mean [€/m²]</b>	<b>246,78</b>
Median [€/m²]	216,47
Minimum [€/m²]	41,03
Maximum [€/m²]	1.090,78
Range[€/mq]	1.049,75
16° Percentile	101,47
84° Percentile	390,74
Standard Dev.[€/m²]	154,57
CoV [%]	63
Asymmetry [-]	1
Kurtosis [-]	2
Total grant [€]	375.866.841,96
<b>Mean grant [€]</b>	<b>235.063,69</b>
<b>Mean Surface [m²]</b>	<b>898,28</b>



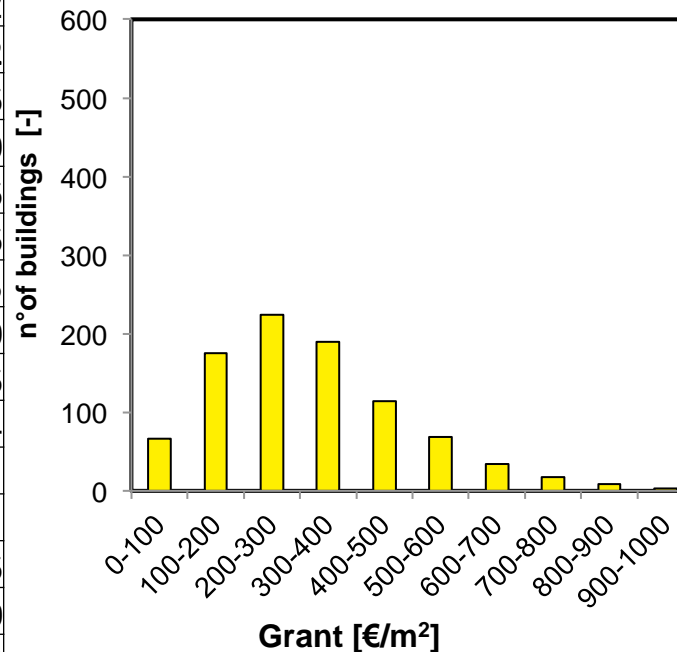
- ✓ Buildings grant: Mean value of 246 €/mq. , corresponding to a mean grant of about € 235.000, 00 for each building, mean surface of about 900 mq.

# Light reconstruction – Costs

## • Masonry Private buildings

Buildings B or C :  
 - 1.522 B-E buildings - mean grant: 246 €/m²  
 - 902 masonry buildings - mean grant: 318 €/m²  
 - 1.522 B-E buildings - mean grant: 246 €/m²  
 - 902 masonry buildings - mean grant: 318 €/m²  
 The average cost of light reconstruction of masonry buildings is 318 €/m². The total cost of light reconstruction of masonry buildings is 114.6543,00 €.

n° of Buildings [-]	902
<b>Mean [€/m²]</b>	<b>318,22</b>
Median [€/m²]	292,26
Minimum [€/m²]	32,20
Maximum [€/m²]	962,36
Range[€/mq]	930,16
16° Percentile	147,45
84° Percentile	488,10
Standard Dev.[€/m²]	172,16
CoV [%]	54
Asymmetry [-]	1
Kurtosis [-]	1
Total grant [€]	103.418.291,36
<b>Mean grant [€]</b>	<b>114.6543,0</b>
<b>Mean Surface [m²]</b>	<b>377, 35</b>



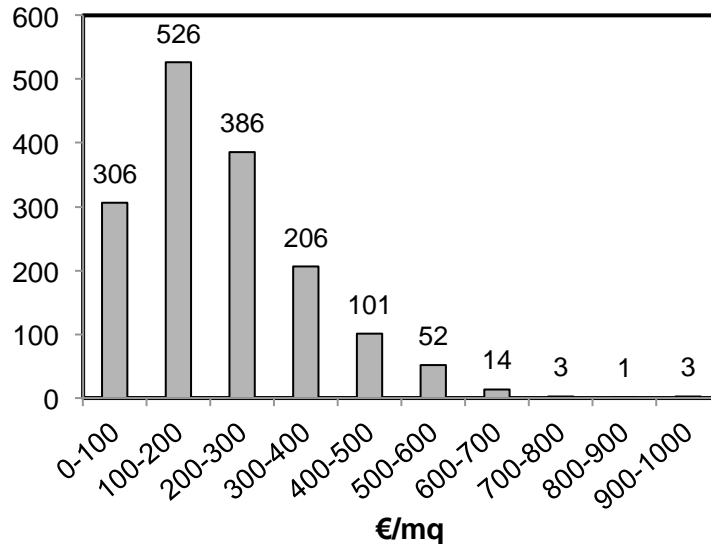
- ✓ Buildings grant: Mean value of 318 €/mq. , corresponding to a mean grant of about € 115.000, 00 for each building, mean surface of about 377 mq.

# Light reconstruction – Costs

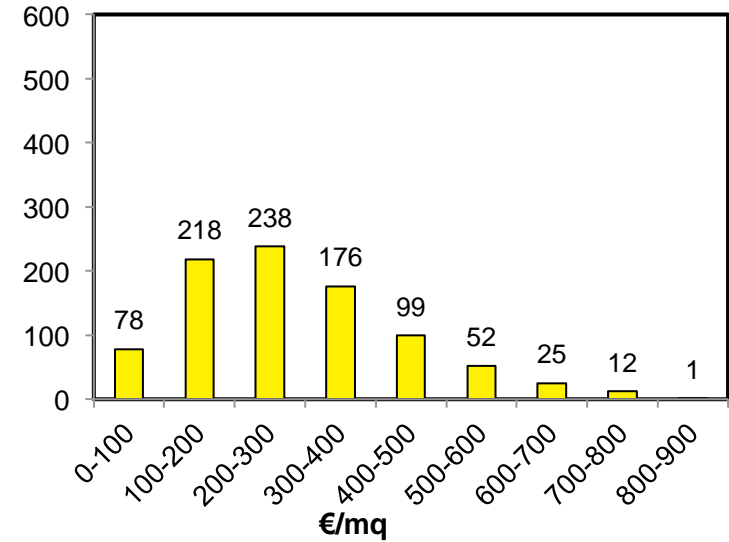
- Cost rates**

**R.C. Buildings: 1.599**

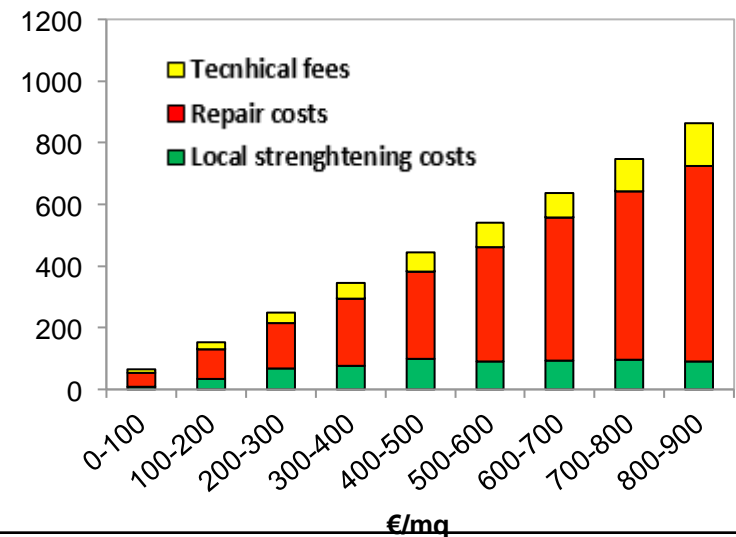
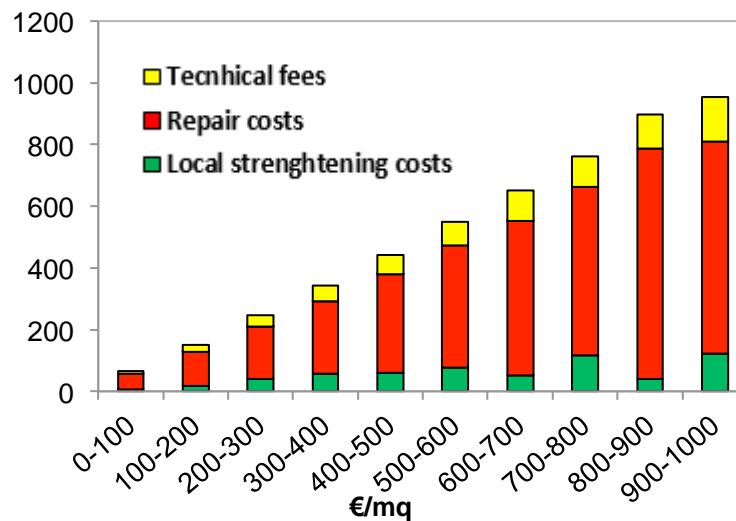
N° of buildings  
[-]



**Masonry Buildings: 902**



Mean costs  
[€/m²]



# Light reconstruction – Costs

- Private buildings

Building B or C :  
 - 1995-1999 buildings - mean grant: 246 €/m<sup>2</sup>  
 - 2000 masonry buildings - mean grant: 212 €/m<sup>2</sup>  
 The grant is 218 €/m<sup>2</sup> for repair intervention

- Repair cost rate due to dwellings: 115 €/m<sup>2</sup>

Note: Computed as the repair costs of dwellings (the ones for which the application was submitted) divided by the cover building total surface

Building B or C :  
 - 1995-1999 buildings - mean grant: 246 €/m<sup>2</sup>  
 - 2000 masonry buildings - mean grant: 212 €/m<sup>2</sup>  
 The grant is 218 €/m<sup>2</sup> for repair intervention

- On each building the repair cost rate due to dwellings is : 93 €/m<sup>2</sup>

- ✓ U.I.C. grant: Mean value of 218 €/mq., corresponding to a mean grant of about € 30.000 for each U.I.C.

Note: Computed as the repair costs of dwellings (the ones for which the application was submitted) divided by the cover building total surface

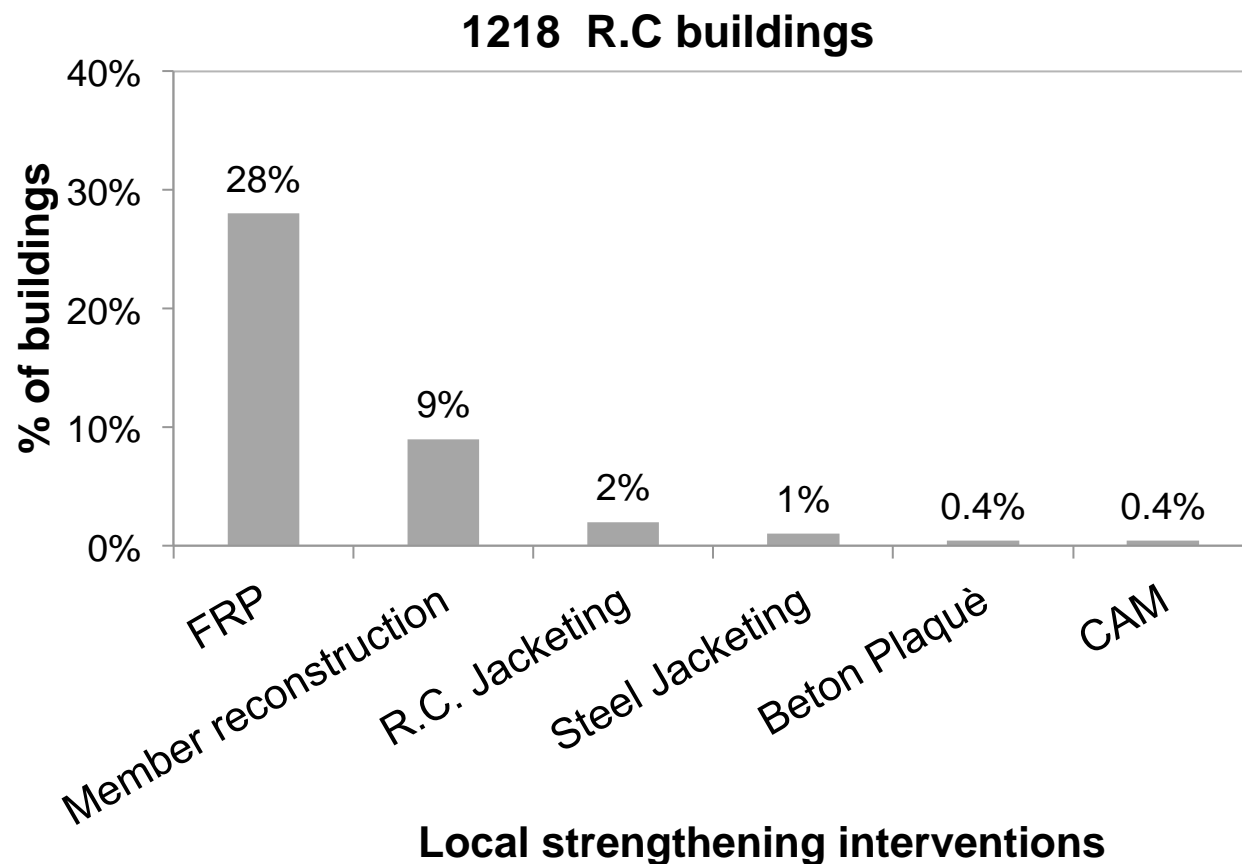




# Light reconstruction – Repair & Strength. Costs

- **R.C. Private buildings**

- **Repair mean costs: 208 €/m<sup>2</sup>**
- **Local Strengthening mean costs: 38 €/m<sup>2</sup>**



FRP



CAM

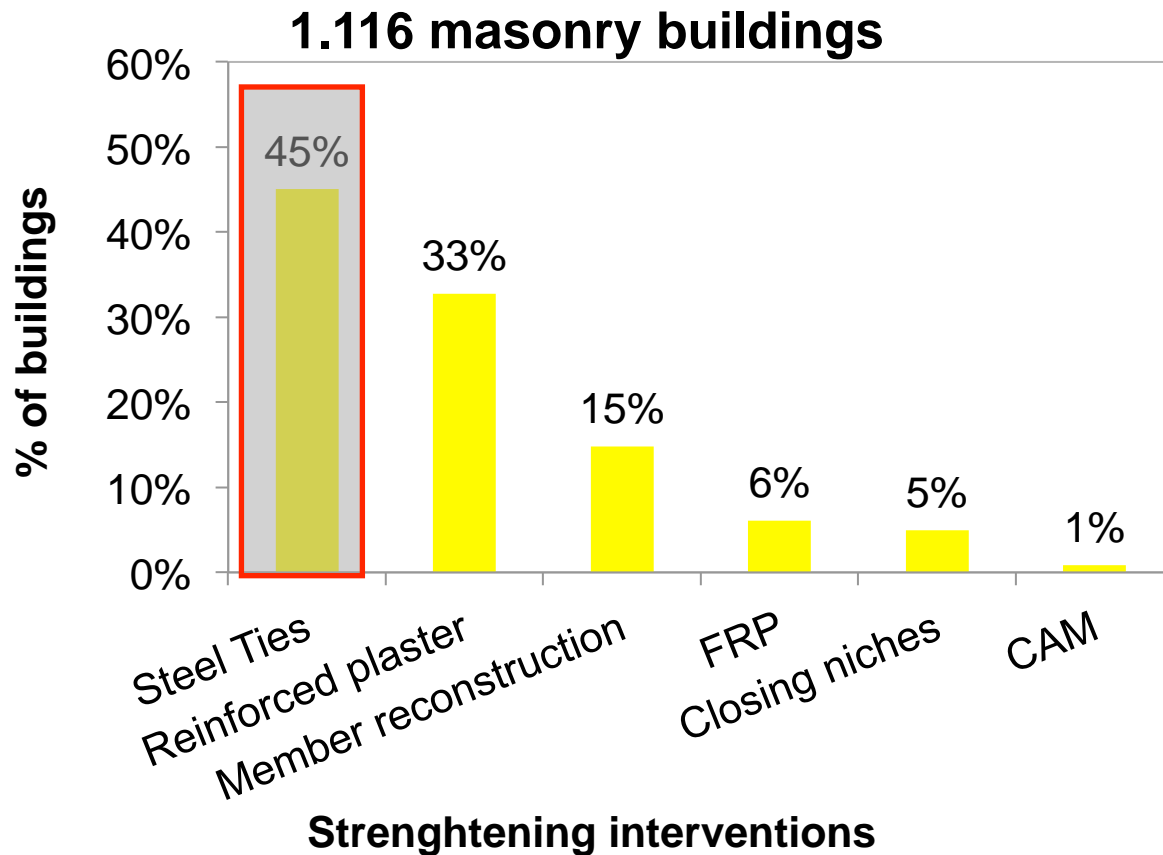


# Light reconstruction – Repair & Strength. Costs

- Masonry Private buildings**

- Repair mean costs: 242 €/m<sup>2</sup>**

- Local Strengthening mean costs: 76 €/m<sup>2</sup>**



**STEEL TIES**

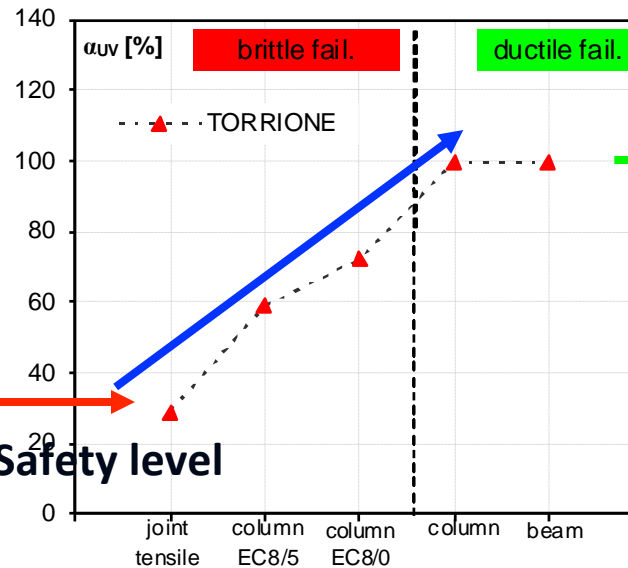
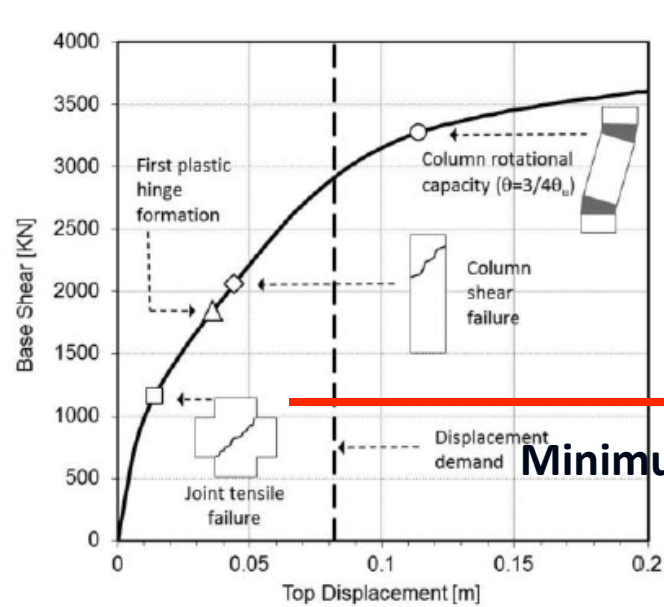


✓ Local strengthening costs: doubled with respect to RC buildings (in any case lower than maximum allowable **150 €/mq**)

# ReLUIS - Project on School Buildings

## SEISMIC SAFETY ASSESSMENT OF SCHOOL BUILDINGS IN L'AQUILA

### SAFETY INDEX INCREASE PROVIDED BY LOCL STRENGTHENING SOLUTIONS



Pushover

Rehabilitation



Removing brittle failure mechanisms

#### References

Frascadore R., Di Ludovico M., Prota A., Verderame G.M., Dolce M., and Cosenza E., "Local strengthening of RC structures as a strategy for seismic risk mitigation at regional scale" **Earthquake Spectra**, in press., online available.

Di Ludovico M., Balsamo A., Prota A., Verderame G.M., Dolce M., and Manfredi G., "Experimental Behavior of non-conforming full scale RC Beam-Column Joints Retrofitted with FRP" International Workshop Role of Research Infrastructures in Seismic Rehabilitation - **SERIES**, Istanbul, Turkey, February 8-9, 2012, paper ID SS2-5, pp. 21-22. (<http://web.itu.edu.tr/series>).



# " THE HEAVY" RECONSTRUCTION

July 9, 2009 – OPCM 3790



1951 of L'aquila

**Rate E: Unusable building.**

# The Reconstruction Process of private buildings

- **Financial Support**

## **"HEAVY" RECONSTRUCTION**

### **Rate E: Unusable building**

July 9, 2009 – OPCM 3790 Rate E



- ✓ Total refund of repair intervention costs + seismic strengthening up to **400-600 €/mq.** (minimum safety level 60% of current code request, up to 80%)
- ✓ In case of "E" buildings with a low level of structural damages, total refund of repair interventions and it is also possible to perform only the local strengthening of structural or non-structural members up to **250 €/mq.** (global analysis is not obligatory)

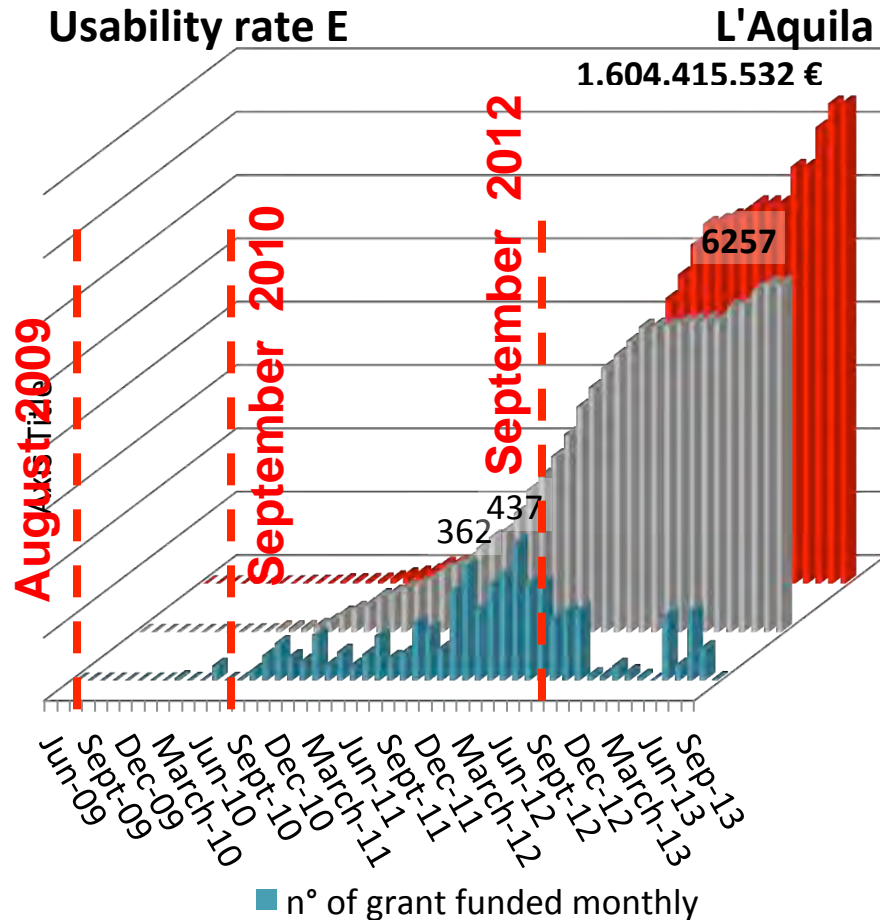
**The so called "E-B buildings" in the approval process**





# Heavy reconstruction - Approval process

- Funding requests submission (E buildings)**



Date	n° approval funding request		Grant
	[-]	[%]	[€]
March 2010	10	0%	2.520.526,28
September 2010	172	2%	16.189.933,57
September 2011	1.325	16%	231.255.611,15
September 2012	4.595	54%	901.860.304,41
September 2013	6.257	74%	1.604.415.532,45

After 3 years, 50% of requests (4585 out of 8906) financially approved by the municipalities

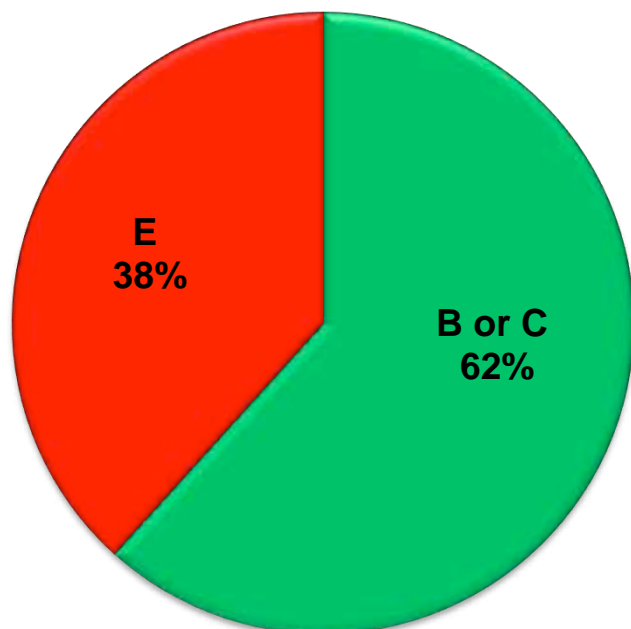
- ✓ Municipalities grant released: A grant of about 900 million of euro at September 2012, total "heavy" reconstruction costs of about € 1.600.000.000, 00



# Heavy reconstruction – Buildings Usability rate

- 2211 (1902 E+ 309 E-B) private buildings**

5775 Buildings

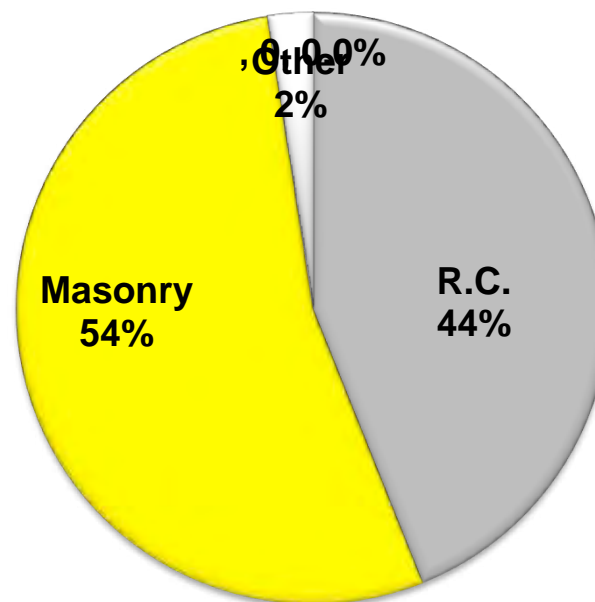


**3564** Usability rate B or C

**309** Usability rate E-B

**1902** Usability rate E

Usability Rate E - 1902 edifici



**836** R.C. Buildings

**1020** Masonry Buildings

**46** Other tipologies

# Heavy reconstruction – Buildings Usability rate

## Costs on 762 Private building – L'Aquila

### **Buildings E :**

The grant includes the costs for **repair intervention** + **seismic strengthening**. + **energy efficiency upgrade** + **structural and geotechnical tests**.



- **448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>**  
(about 4 times higher than in case o B or C buildings – 246 €/mq)



- **314 masonry buildings mean grant : 935 €/m<sup>2</sup>**  
(about 3 times higher than in case o B or C buildings – 318 €/mq)

**Costs include:**  
**practitioners technical fees and V.A.T.**

# Heavy reonstruction – Costs

- R.C. Private buildings**

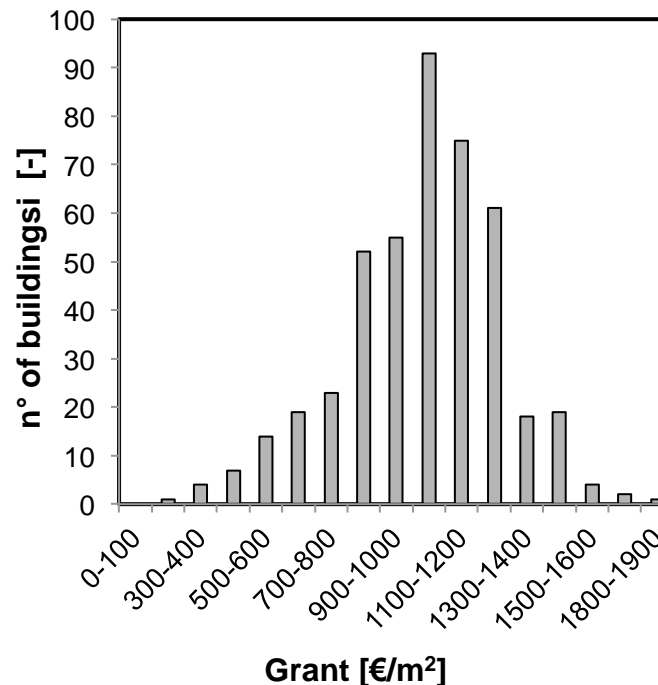
**Buildings E :**

- 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>

- 314 masonry buildings - mean grant : 935 €/m<sup>2</sup>

The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests

n° of Buildings [-]	448
<b>Mean [€/m<sup>2</sup>]</b>	<b>1.030,4</b>
Median [€/m <sup>2</sup> ]	1.057,4
Minimum [€/m <sup>2</sup> ]	168,0
Maximum [€/m <sup>2</sup> ]	1.826,96
Range[€/mq]	1.658,65
16° Percentile	806,41
84° Percentile	1.258,2
Standard Dev.[€/m <sup>2</sup> ]	240,68
CoV [%]	23
Asymmetry [-]	0
Kurtosis [-]	0
Total grant [€]	805.129.213,53
<b>Mean grant [€]</b>	<b>1.797.163,0</b>
<b>Mean Surface [m<sup>2</sup>]</b>	<b>1.733,8</b>



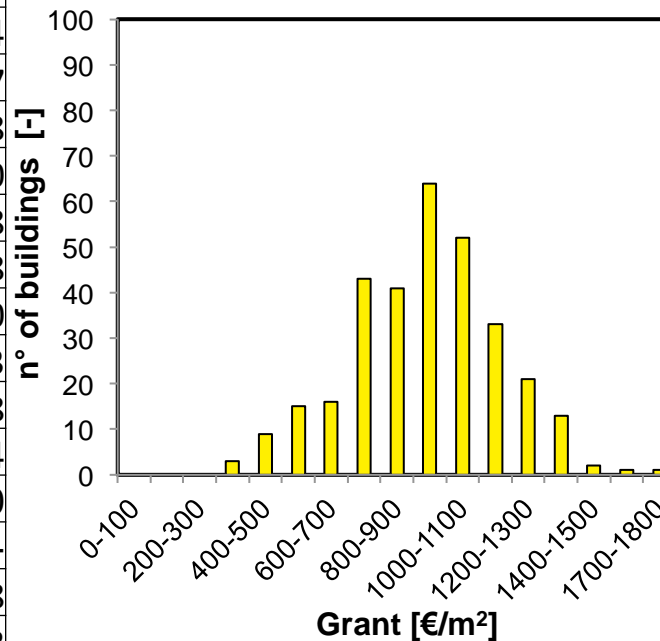
- ✓ Buildings grant: Mean value of 1.030 €/mq. , corresponding to a mean grant of about € 1.800.000, 00 for each building, mean surface of about 1.700 mq.

# Heavy reonstruction – Costs

## • Masonry Private buildings

Buildings E : - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>  
 - 314 masonry buildings - mean grant : 935 €/m<sup>2</sup>  
 The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests

n° of Buildings [-]	314
<b>Mean [€/m<sup>2</sup>]</b>	<b>934,97</b>
Median [€/m <sup>2</sup> ]	941,8
Minimum [€/m <sup>2</sup> ]	312,00
Maximum [€/m <sup>2</sup> ]	1.740,68
Range[€/mq]	1.428,58
16° Percentile	722,00
84° Percentile	1.148,63
Standard Dev.[€/m <sup>2</sup> ]	227,38
CoV [%]	24
Asymmetry [-]	0
Kurtosis [-]	-
Total grant [€]	180.718.716,58
<b>Mean grant [€]</b>	<b>575.537,3</b>
<b>Mean Surface [m<sup>2</sup>]</b>	<b>608,7</b>



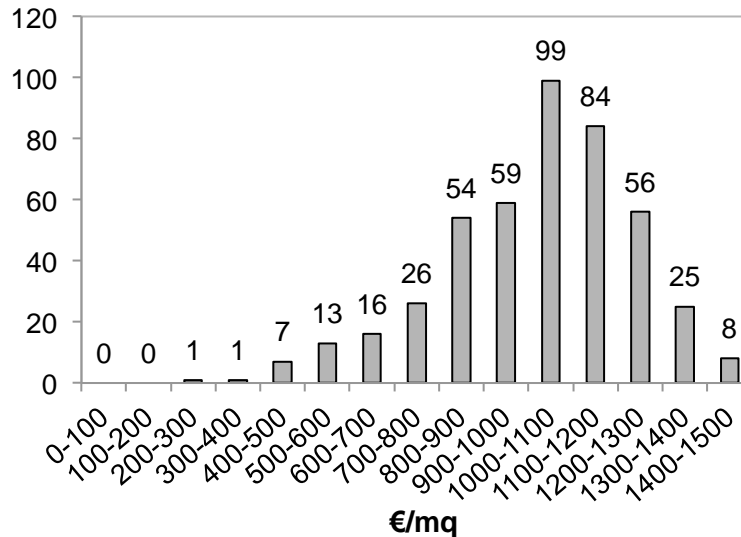
- ✓ Buildings grant: Mean value of 935 €/mq. , corresponding to a mean grant of about € 575.000, 00 for each building, mean surface of about 610 mq.

# Heavy reconstruction – Costs

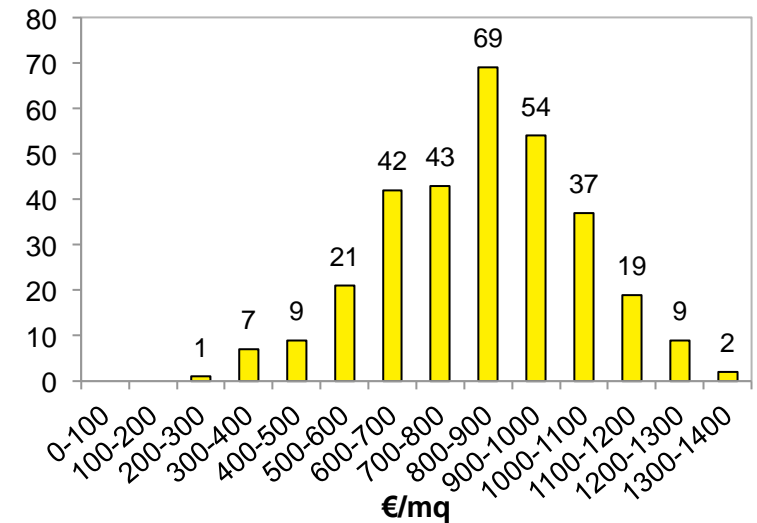
- Cost rates**

**R.C. Buildings: 448**

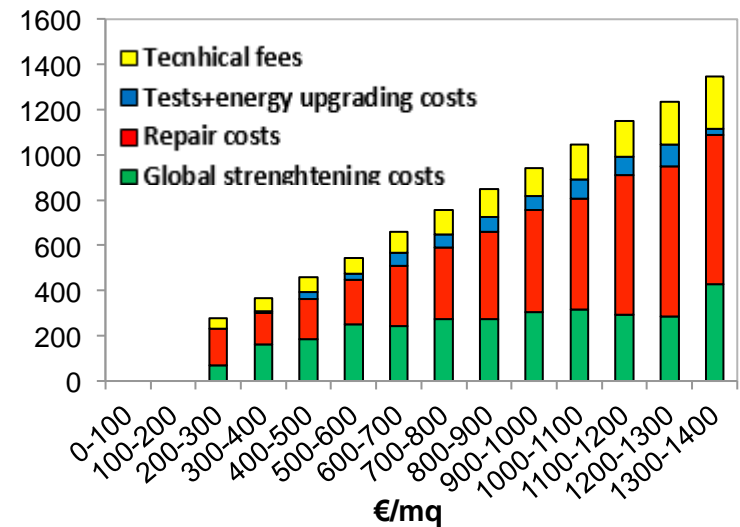
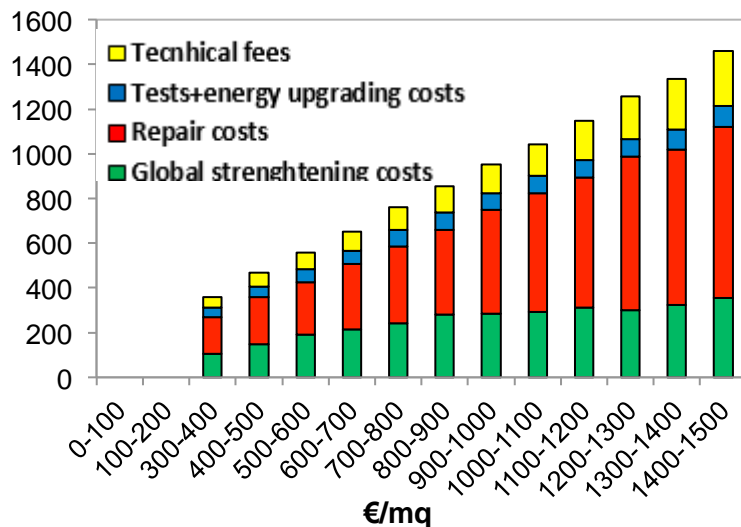
**N° of buildings  
[-]**



**Masonry Buildings: 314**



**Mean costs  
[€/m²]**



# Heavy reconstruction – Costs

- **Private buildings**

Buildings E : Buildings E :  
 - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup> - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>  
 - 314 masonry buildings - mean grant : 935 €/m<sup>2</sup> - 314 masonry buildings - mean grant : 935 €/m<sup>2</sup>  
 The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests. The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests.

- **Repair cost rate due to dwellings: 170 €/m<sup>2</sup>**

**Note: Computed as the repair costs of dwellings (the ones for which the application was submitted) divided by the cover building total surface**

Buildings E : Buildings E :  
 - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup> - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>  
 - 314 masonry buildings - mean grant : 935 €/m<sup>2</sup> - 314 masonry buildings - mean grant : 935 €/m<sup>2</sup>  
 The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests. The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests.

- **On each building the repair cost rate due to dwellings is : 116 €/m<sup>2</sup>**

- ✓ U.I.C. grant: Mean value of 287 €/mq., corresponding to a mean grant of about € 40.000 for each U.I.C.



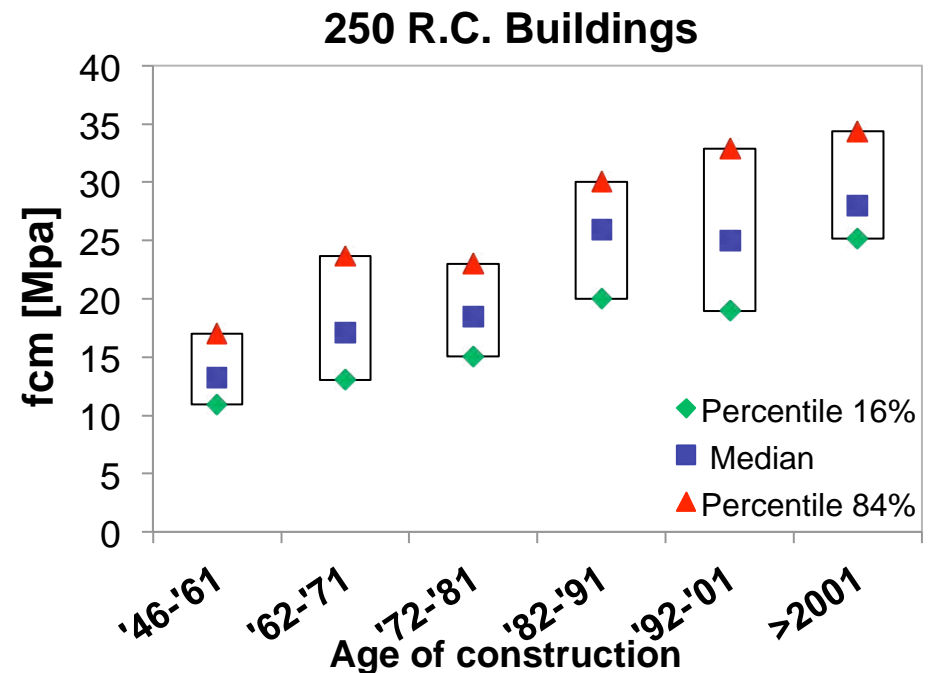
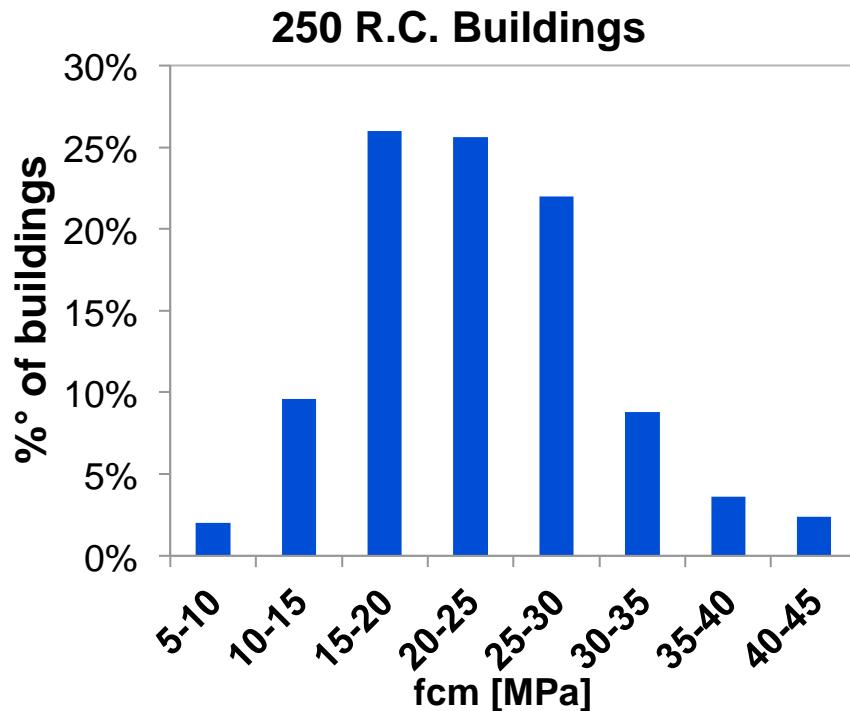


# Heavy reconstruction – Costs

## • R.C. Private buildings

Buildings R.C. - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>  
 Buildings Masonry - 314 masonry buildings - mean grant: 935 €/m<sup>2</sup>  
 The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural tests + geotechnical tests + adjustment of energy + seismic rehabilitation + adjustment of energy + structural and geotechnical tests

- Energy efficiency upgrade costs ( 394 build.): 96 €/mq.
- structural and geotechnical tests costs: 10 €/mq.



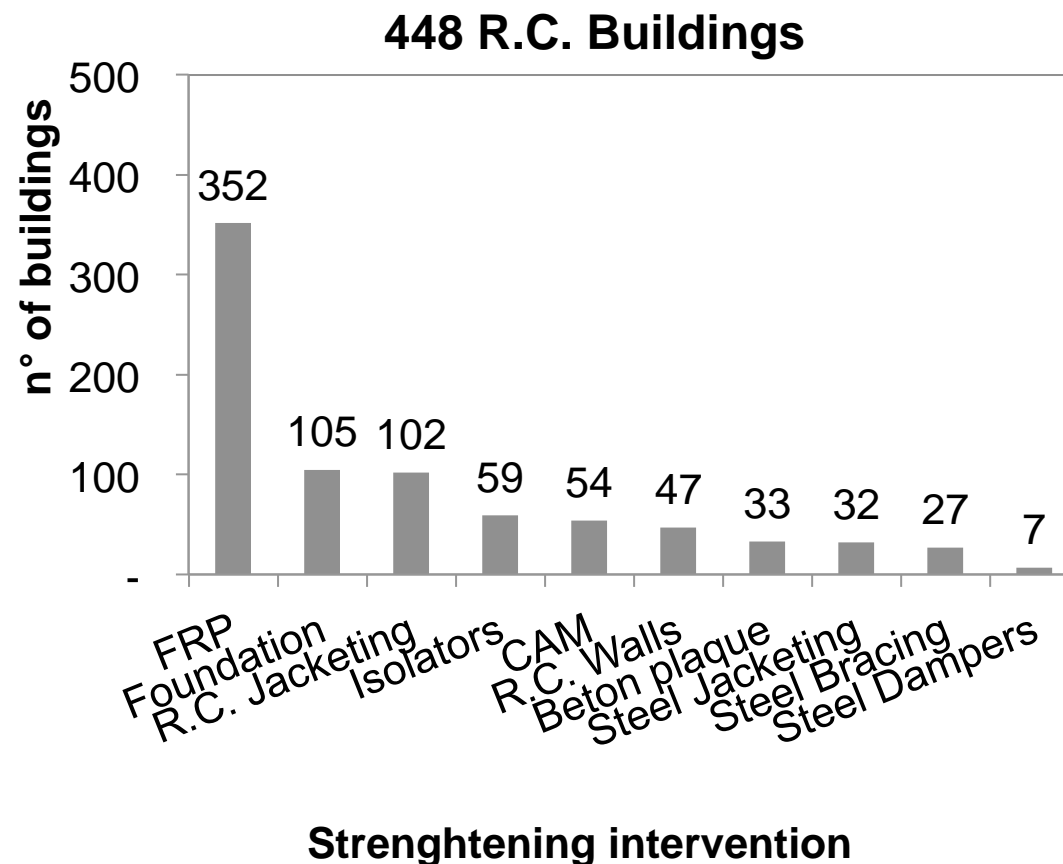
✓ Concrete average cylindrical compressive strength

# Heavy reconstruction – Repair & Strength. Costs

## • R.C. Private buildings

Buildings E  
 - 448 R.C. buildings - mean grant: 1030 €/m<sup>2</sup>  
 - 314 masonry buildings - mean grant: 935 €/m<sup>2</sup>  
 The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural tests and geotechnical tests

- Repair mean costs: 592 €/m<sup>2</sup>
- Seismic strengthening mean costs: 344 €/m<sup>2</sup>



Isolators

Steel dampers



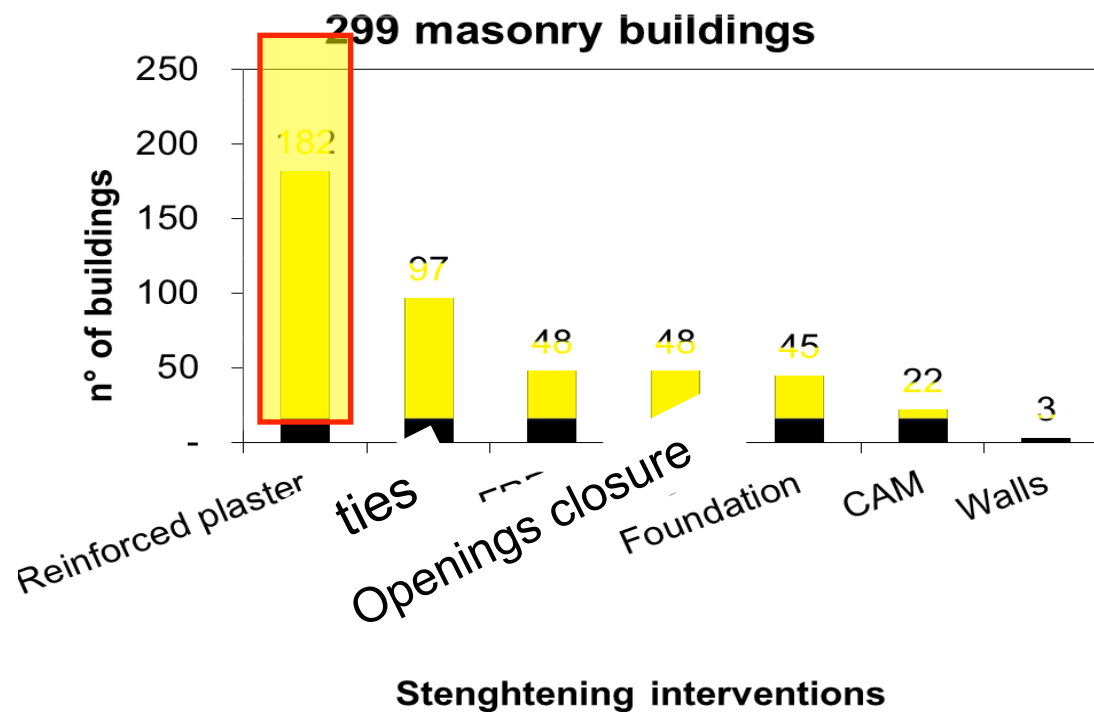
- ✓ Strong impetus for innovation
- ✓ Almost in every case two or more techniques have been used in combination

# Heavy reconstruction – Repair & Strength. Costs

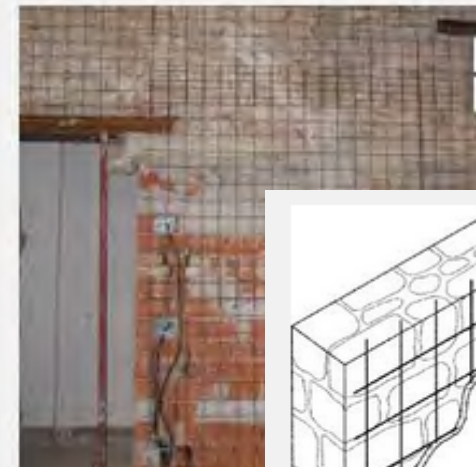
- Masonry Private buildings**

Buildings E  
= 448 R.C. buildings – mean grant: 1030 €/m<sup>2</sup>  
= 314 masonry buildings – mean grant: 935 €/m<sup>2</sup>  
The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests

- Repair mean costs: 499 €/m<sup>2</sup>**
- Seismic rehabilitation mean costs: 357 €/m<sup>2</sup>**



## Reinforced plaster



- Energy upgrade costs ( 394 buildings): 96 €/mq.**

# The Reconstruction Process of private buildings

- **Financial Support**

## **"HEAVY" RECONSTRUCTION**

### **Rate E: Unusable building**



- ✓ Demolition and Reconstruction or replacement in case of:
  - **Totally collapsed** buildings
  - **Masonry structures** partially collapsed (more than 25% in volume)
  - **Reinforced Concrete Structures**, average compressive cylindrical strength lower than 8 MPa
  - **Reinforced Concrete Structures**, more than 50% of storey's columns with a drift higher than 1.5%
  - **Demonstrating the economic convenience: demolitionn and reconstruction costs lower than repair and strengthening** (to be demonstreted)
- ✓ Specific Reccomendation for masonry aggregates

# The Reconstruction Process of private buildings

- Financial Support**

## **"HEAVY" RECONSTRUCTION**

### **Rate E: Unusable building**

#### demolition and reconstruction

Specific form to compute demolition and reconstruction costs

Cost range:

**1,200 - 1,700 €/mq.,**

depending on several building characteristics

Determinazione del limite di contributo ai sensi dell'art. 5, Co. 4 OPCM 3881/2010  
e del DCD n. 27 del 02-12-2010

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Inserire i dati nelle caselle grigie.  
Il presente documento, fornito a solo titolo esemplificativo, permette il calcolo del limite di contributo ammesso per la ricostruzione ai sensi dell'art. 5, comma 4 dell'OPCM 3881/2010 e del DCD n. 27/2010. La Struttura Tecnica di Missione non è responsabile per eventuali modifiche apportate al documento stesso.

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**identificazione dell'edificio**

Denominazione				
Comune		Indirizzo		Civico
n° aggregato		n° edificio		
Dati catastali:	Sezione	Foglio	particelle	Sub

---

**1) determinazione del limite di costo unitario**

**1a) costo base di realizzazione tecnica (C.B.N.)**

Costo base di realizzazione tecnica (C.B.N.)

				€ 808,00
a) Oneri aggiuntivi sicurezza lavori D.Lgs 81/2008 e s.m.i.	X	5%	€ 40,40	
b) Applicazione D.Lgs 192/2005, D.Lgs 311/2006 e s.m.i. in materia di rendimento energetico - INCREMENTO ART. 5, COMMA 4, ULTIMO CAPOVERSO	X	20%	€ 161,60	
c) rispetto nuova normativa sismica (DM 14-01-2008 e circolare 617 02-02-2009)	X	7%	€ 56,56	
<b>C.B.N. Risultante</b>				<b>€ 1.066,56</b>

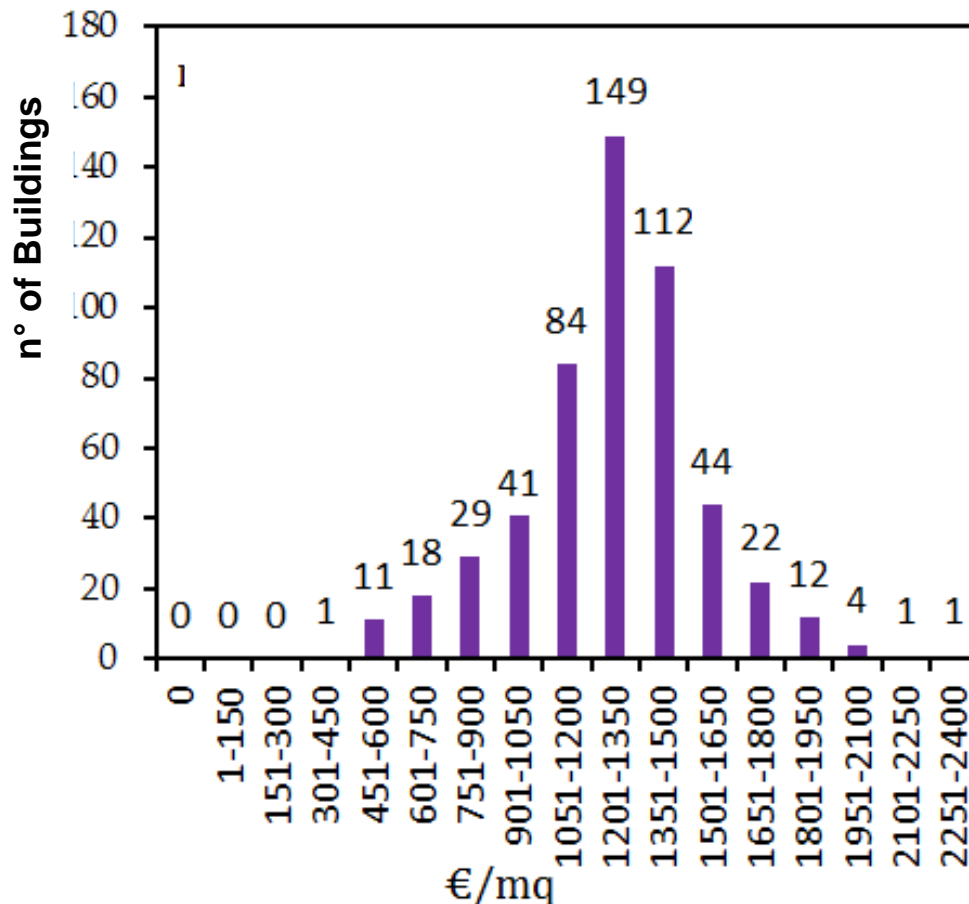
**1b) maggiorazioni sul differenziale di costo per particolari condizioni tecniche**

	SELEZIONE			
a) dotazione dell'intervento di polizze assicurative postume decennali a garanzia dei rischi di danni alla costruzione		0%	€ 0,00	
b) adozione di un piano di qualità relativo all'intervento e/o al programma di manutenzione	-			
c) miglioramento del comfort ambientale con riferimento agli aspetti acustici ed igrotermici - Incremento ART. 5, CO 4, ultimo capoverso OPCM 3881	X	5%	€ 40,40	
d) utilizzo di dispositivi antisismici		0%	€ 0,00	
e) particolari condizioni di localizzazione	X	3%	€ 24,24	
f) tipologie edilizie con numero di piani uguale o inferiore a quattro		0%	€ 0,00	
g) numero prevalente di alloggi con superficie utile non superiore a 65 mq		0%	€ 0,00	
h) produzione del fascicolo del fabbricato D.Lgs n. 81/2008	-			
<b>TOTALE MAGGIORAZIONI TECNICHE APPLICATE</b>				<b>€ 64,64</b>
<b>C.R.N. - Costo unitario a base d'appalto -</b>				<b>€ 1.131,20</b>
<b>LIMITE UNITARIO DI CONTRIBUTO SUL COSTO DI COSTRUZIONE (€/mq Sc)</b>				<b>€ 1.131,20</b>

# Heavy reconstruction – Demolition

- Demolition and reconstruction:**

**531 buildings (out of 1951) – 27% of the E building stock**



- 421 buildings:** repair and retrofit costs higher than demolition and reconstruction

**31 Buildings** forfai grant of 750 €/m<sup>2</sup>

**44 masonry buildings** partially collapsed (more than 25% in volume)

**1 R.C. building:** more than 50% of storey's columns with a drift higher than 1.5%;

**34 R.C. buildings:** average compressive cylindrical strength lower than 8 MPa

**-Demolition and reconstruction mean cost: 1261,04 €/m<sup>2</sup>**



# Robustness and resilience

- **L'Aquila: Collapsed R.C. Buildings**

15 collapsed R.C. buildings

135 victims

(43% of 309 victims of L'Aquila earthquake)

0.6% of R.C. damaged building stock



**Hotel Duca degli Abruzzi collapse,  
L'Aquila 2009.**



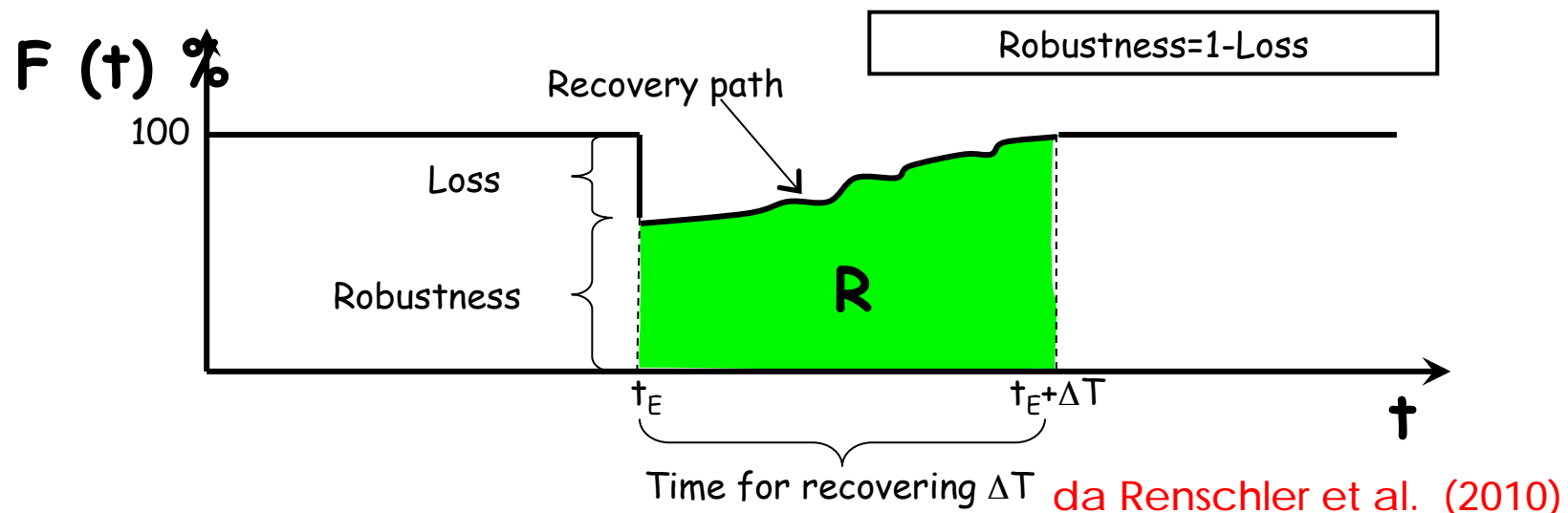
**Student's Home  
collapse, L'Aquila 2009.**

# Robustness and resilience – ReLUIS – DPC projects

✓ Within the 2014-2016 RELUIS-DPC research project, an activity is ongoing aimed at deriving a methodological approach to deal with structural robustness within the Italian national code:

✓ DPC-RELUIS Project – Task 3.2

«Development of methodologies to quantify structural robustness»;  
Prota, D. Asprone, G. Manfredi (University of Naples), D. Chiaia, A. Fantilli (Polytechnic of Turin)



**ROBUSTNESS** as a factor increasing **RESILIENCE**

# Robustness and resilience – ReLUIS – DPC projects

## **Initiative to improve community resilience**

Public information on risk

### **TERREMOTO PARLIAMONE INSIEME Earthquake: let's talk together**

Immediately after Emilia Earthquake

Series of events, started on 11 June 2012, sponsored by the Civil Protection Department, Emilia-Romagna Region and the National Institute of Geophysics and Vulcanology in collaboration with the Network of University Laboratories for Earthquake Engineering, the Regional Health Service of Emilia Romagna and voluntary organizations of civil protection

[www.protezionecivile.gov.it](http://www.protezionecivile.gov.it)



➤ **32 meetings on the Italian territory**



# Robustness and resilience – ReLUIS – DPC projects

## Initiative for seismic risk reduction

Public information on risk

**TERREMOTO IO NON RISCHIO** “Earthquake I don’t risk”

102 squares in 100 Municipalities in 2012

215 squares in 200 Municipalities in 2013

223 squares in 203 Municipalities in 2014 (June 15<sup>th</sup>-16<sup>th</sup>)



Campagna nazionale  
sulla riduzione  
del rischio sismico  
13-14 ottobre 2012



**Earthquake I don’t risk”**

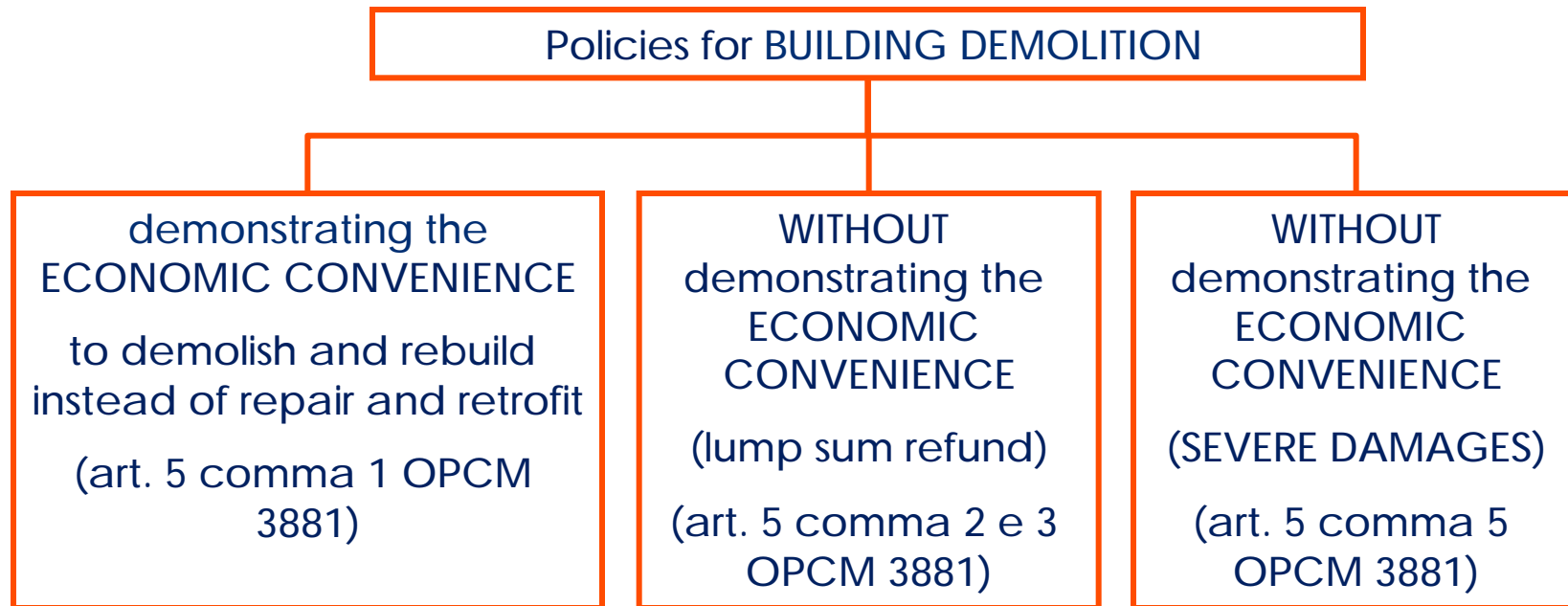
[www.iononrischio.it](http://www.iononrischio.it)

## Post-earthquake decisions

- What data were used to assess building RESIDUAL CAPACITY and how were these data used in reconstruction decisions?
- WHAT SHOULD BE IMPLEMENTED in data collection protocols to make assessment of residual capacity more reliable?

# Post-earthquake decisions

## Policies after L'Aquila earthquake

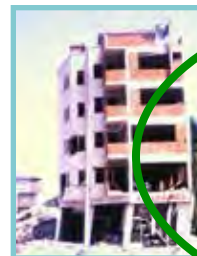


### For Masonry buildings



- ❖ partial failure of bearing walls for at least 25% of the building volume

### For R.C. buildings



- ❖ excessive residual deformations ( $\geq 1.5\%$  on more than 50% columns of a storey)
- ❖ weak concrete ( $f_c < 8$  Mpa)



# Post-earthquake decisions

## Residual drifts



Examples after  
L'Aquila 2009



# Post-earthquake decisions

## Residual drifts: measurements after L'Aquila 2009

Reluis has measured permanent drifts for two damaged buildings in L'Aquila confronting the efficacy of traditional and innovative techniques

plumb line



The simplest and more economic technique, may be applied only for accessible elements and is sensible to external interferences (e.g. wind)

total station



Traditional topographic technique, very precise (tolerance  $\pm 2\text{mm}$ ). Allows measuring discrete points, that have to be established a priori, on the element

laser-scanner 3D



Innovative technique, very precise (tolerance  $\pm 2\text{mm}$ ). Allows reconstructing the spatial coordinates of the surveyed object with a dense DEM. Specific points to be measured can be decided also a posteriori.

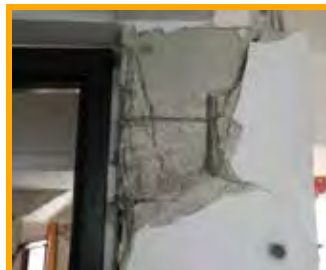
# Post-earthquake decisions

## Residual drifts: measurements after L'Aquila 2009

4 storey building in Pettino (AQ)



Building damage: a **soft storey** mechanism at the first level is activated.

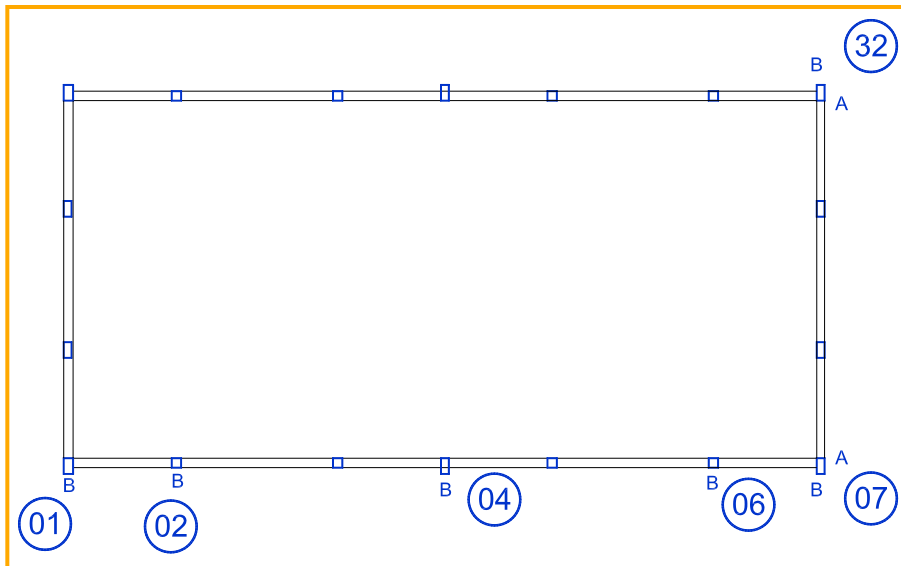


Example of damage on some of the columns at the first storey

# Post-earthquake decisions

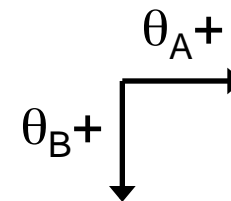
## Residual drifts: measurements after L'Aquila 2009

For security reasons, only accessible or visible columns on the perimeter, circled in the bottom figure, were measured



The measured columns

Sign convention



Pilastro	$\theta_B(\%)$	$\theta_A(\%)$
01	+0.74	/
02	+0.13	/
04	+0.96	/
06	+0.51	/
07	+2.52	+0.40
32	-0.93	+0.19

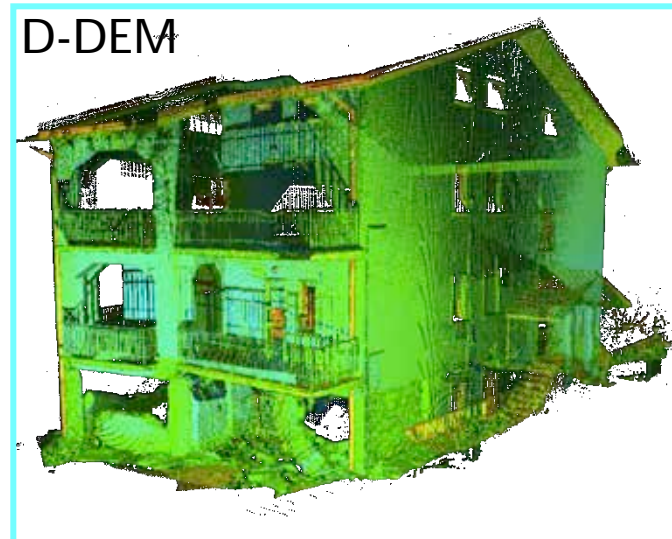
1<sup>st</sup> level permanent drifts  
(evaluation from D-DEM data)



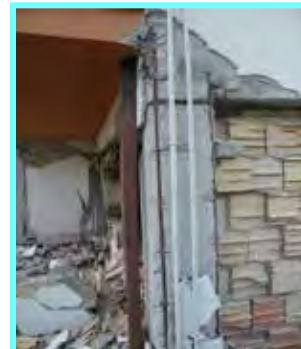
# Post-earthquake decisions

## Residual drifts: measurements after L'Aquila 2009

4 storey building in Pianola (AQ)



Building damage: a soft storey mechanism at the first level is activated.

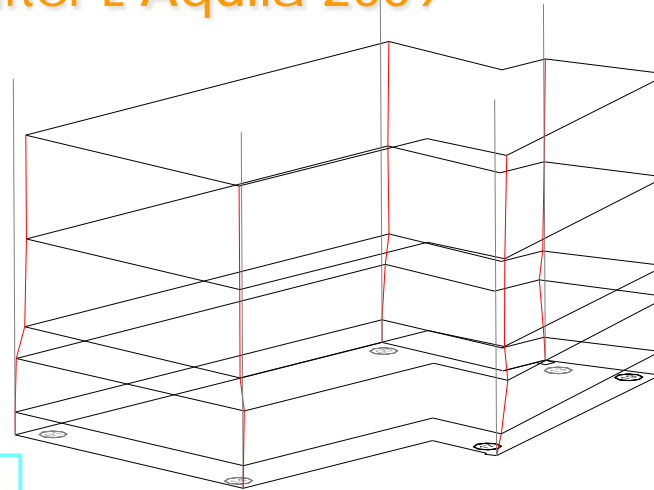


Example of damage on some of the columns at the first storey

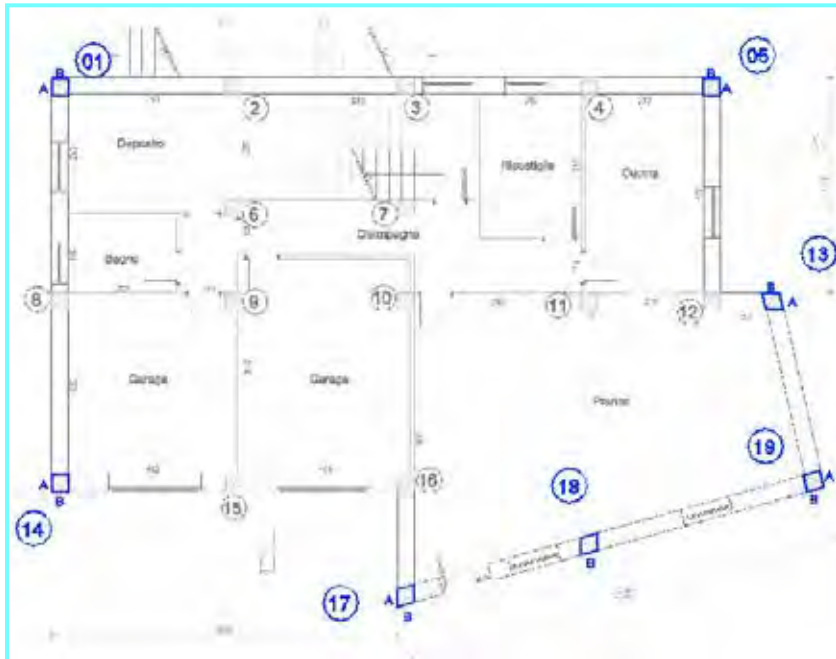
# Post-earthquake decisions

## Residual drifts: measurements after L'Aquila 2009

For security reasons, only accessible or visible columns on the perimeter, circled in the bottom figure, were measured

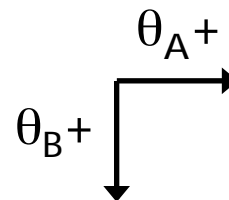


Permanent deformation of building in elevation  
(magnified displacements for representation purposes)



The measured columns

Pilastro	$\theta_B(\%)$	$\theta_A(\%)$
01	+1.04	-0.56
05	+0.25	+0.64
13	-1.79	+0.60
19	+0.77	+0.35
17	+1.89	-0.54
14	+0.29	0.00



1<sup>st</sup> level permanent drifts  
(evaluation from D-DEM data)



# What data were used to assess building residual capacity and how were these data used in reconstruction decisions?

➤ No direct evaluation of Residual Capacity

➤ Indirect evaluation through:

✓ **residual drifts** (difficult to measure; very few cases)  
→ usability of this criterion depends on the construction type

✓ **global damage level** (for very severe damage)

Direct  
decision  
on  
demolition

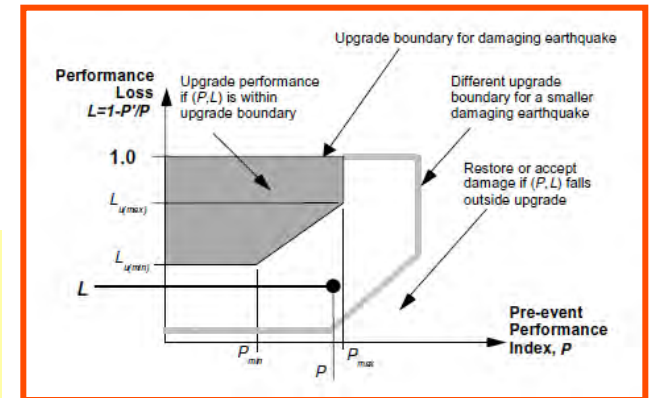
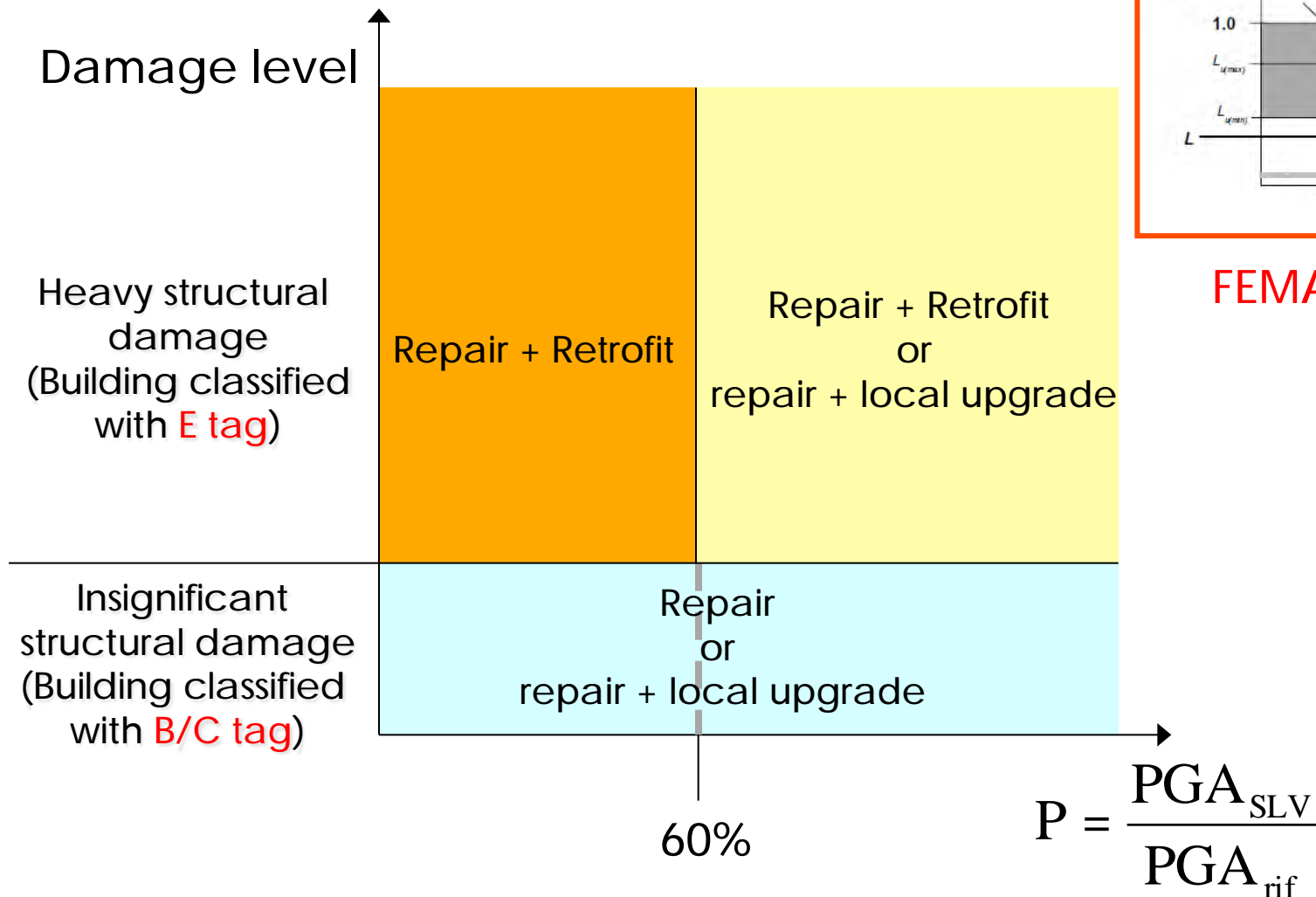
✓ **building tagging** (linked to damage) → influence on the applicable funding scheme

What should be implemented in data collection protocols to make assessment of residual capacity more reliable?

Residual Capacity as  
representative parameter for assessment of  
building reparability in a  
Performance Based Policy framework

# Reparability issues

## Repair/Retrofit criteria: Policies after L'Aquila earthquake



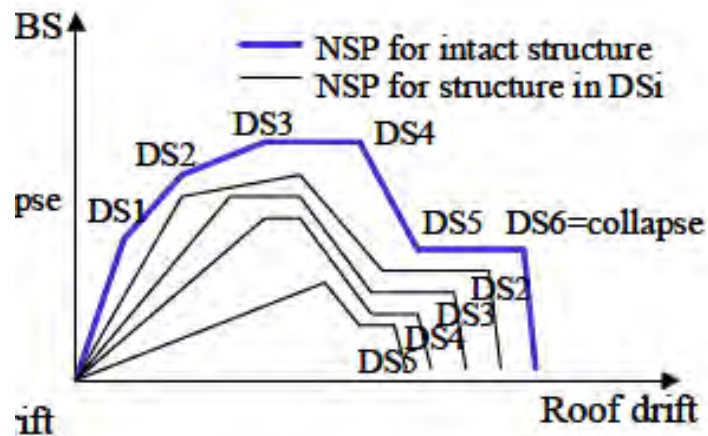
FEMA 308 (1998)

# Evaluation of REsidual Capacity (REC)

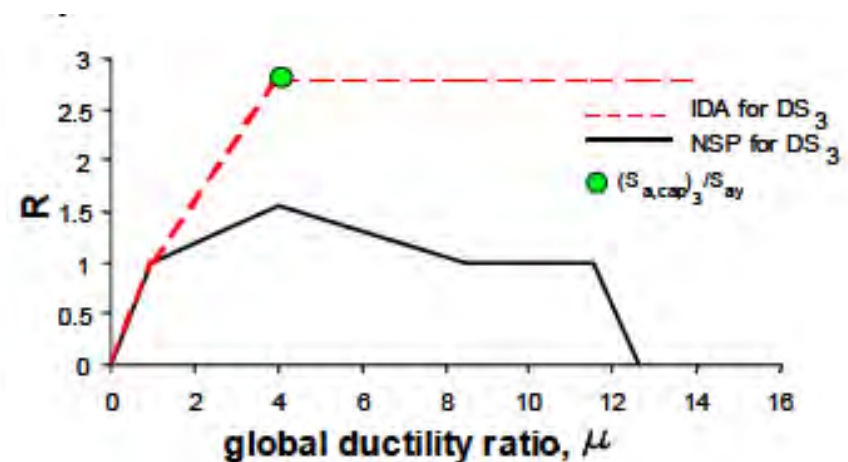
## Evaluation of Residual capacity (Bazzurro et al. 2004)

Residual Capacity as :

the minimum spectral acceleration (at elastic period  $T_1$  and with 5% damping) such as to determine local or global collapse during an aftershock



PUSHOVER CURVES for buildings  
at variable damage levels



+ SPO2IDA

# Evaluation of REsidual Capacity (REC)

Evaluation of Residual capacity (Bunno et al., 1999; Bunno and Maeda, 2001; Nakano et al. 2004)

$$R = \frac{I_{s,D}}{I_s} \cdot 100 (\%)$$

Residual Capacity Index (%)

$I_s$  seismic index;

$I_s \propto C \times F$  with  $C \propto$  base shear

Reduction Factor

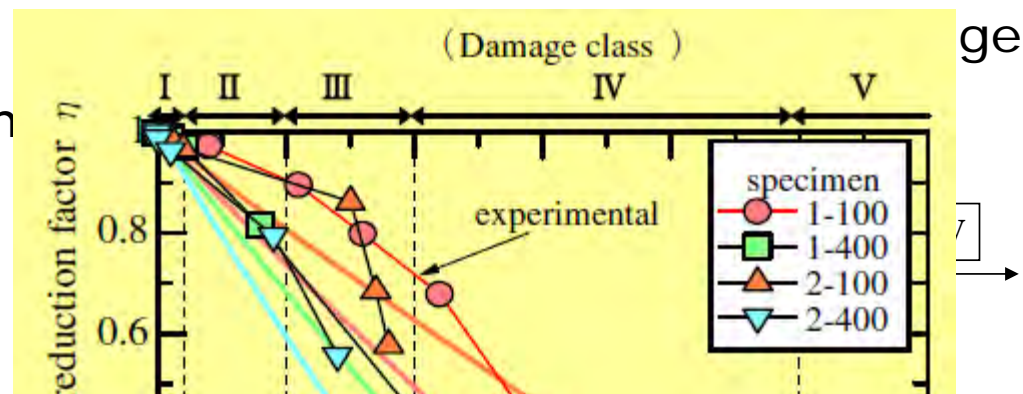


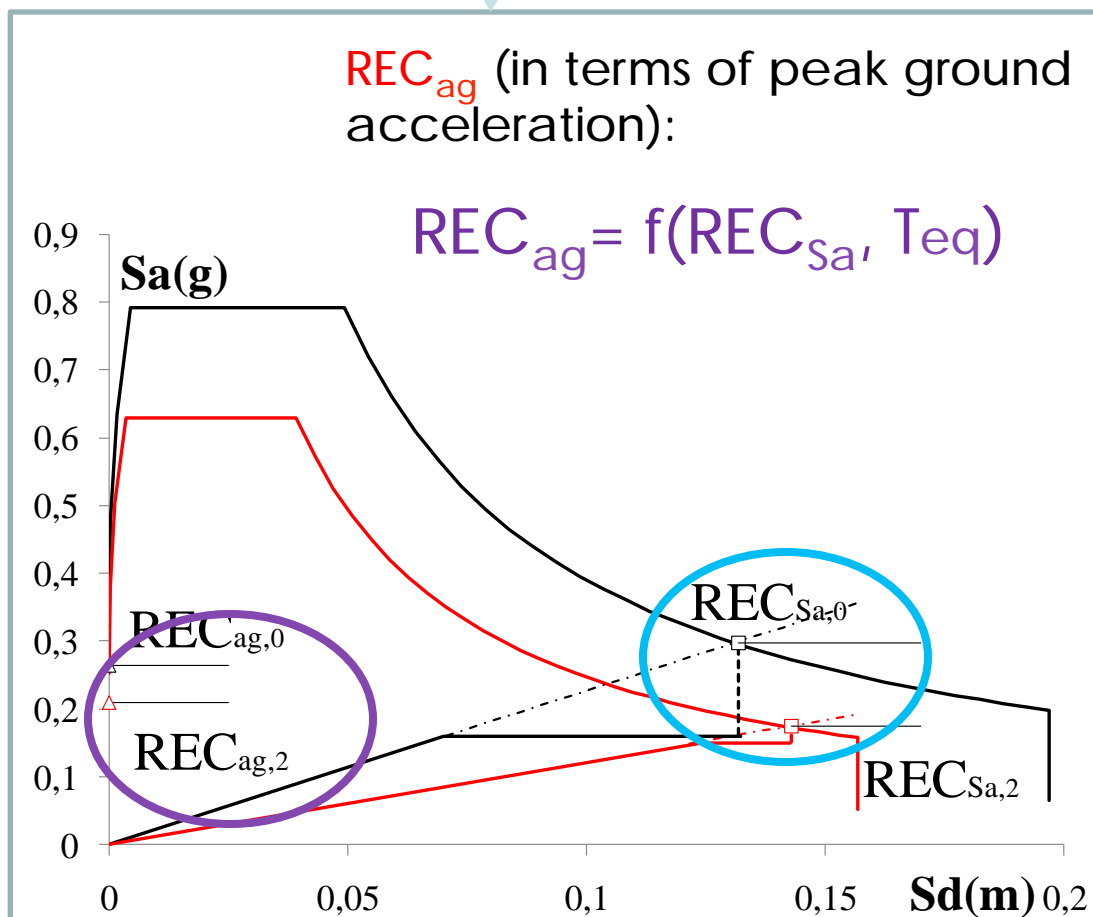
Table 3: Seismic Capacity Reduction Factor  $\eta$  (JBDPA [1])

Damage Class	Brittle Column*	Ductile Column*	Wall w/o Boundary Columns*	Column w/ Wing Wall(s)*	Wall w/ Boundary Columns*
I	0.95	0.95	0.95	0.95	0.95
II	0.60	0.75	0.60	0.60	0.60
III	0.30	0.50	0.30	0.30	0.30
IV	0	0.10	0	0	0
V	0	0	0	0	0

# Evaluation of RESidual Capacity (REC)

## ASSESSMENT OF RESIDUAL CAPACITY with SPECTRAL APPROACH

Residual Capacity  $REC_{Sa}$  spectral acceleration corresponding to collapse  
 $REC_{Sa}$  found applying IN2 method for intact or damaged building (Polese et al., 2013)



$$REC_{Sa} = C_b \cdot \mu_{cap}$$

for  $T_{eq} \geq T_c$

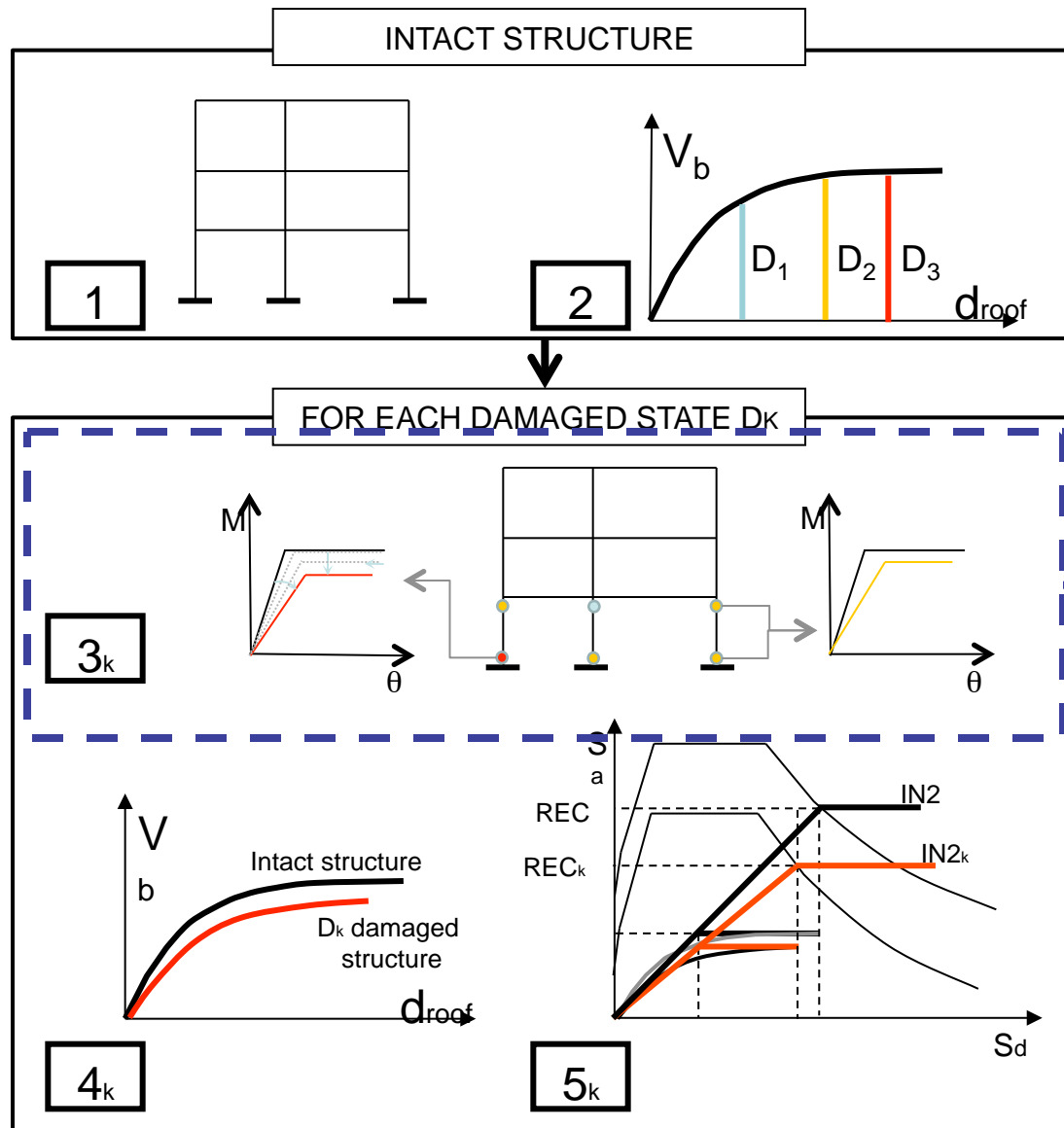
Note similarity with definition of  $I_s$  (and damaged  $I_{sD}$ ) by (Nakano et al. 2004)

$I_s$  seismic index;  $I_{sD}$  seismic index reduced due to damage;  $I_s \propto C \times F$  with  $C \propto$  base shear coeff. and  $F$  ductility factor



# Evaluation of RESidual Capacity (REC)

## Assessment OF RESIDUAL CAPACITY for Damaged buildings



Pushover based procedure to assess behavior of damaged buildings

(Polese et al. 2013, adapted after FEMA 306)

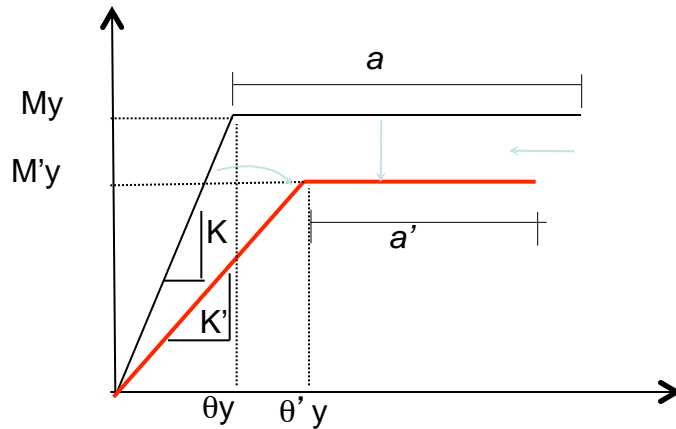
need for suitable calibration of plastic hinges modification factors for existing buildings (typically with non-conforming elements)

# Evaluation of REsidual Capacity (REC)

## PLASTIC HINGES MODIFICATION FACTORS

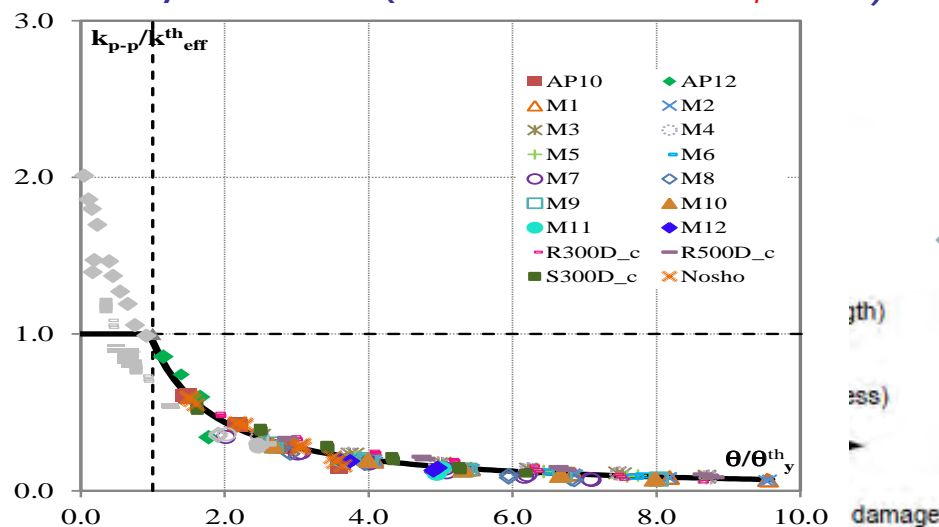
for NONCONFORMING columns

Definition of plastic hinges modification factors (after FEMA 306, 1998)

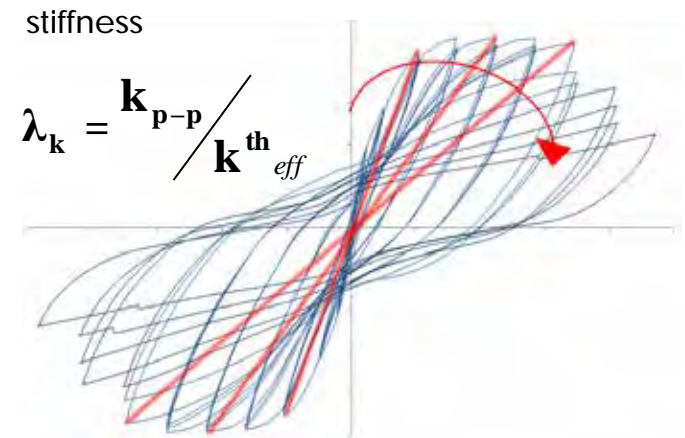


	stiffness	strength	Plastic rotation
intact	$K$	$My$	$a$
damaged	$K' = \lambda_K K$	$My' = \lambda_Q My$	$a' = a - \Delta a$

Modification factors as a function of local ductility demand (Di Ludovico et al., 2013)



Modification factors shall be derived via experimental calibration



# Evaluation of REsidual Capacity (REC)

A key aspect is the assessment of suitable **REDUCTION FACTORS** to determine residual capacity:

Based on damage level  
(post-earthquake  
assessment)

Based on ductility  
demand  
(modeling)

Need consistent values for:



- Different **damage-ductility intervals** (columns, walls, ....)
- Different types (proposed behavior of FEMA 307 & Japanese approach to be extended)  
....and more test-based calibration of **REDUCTION FACTORS**

# Damage Data (speed survey form)

The **DAMAGE DATA** collected in the Aedes survey form (speed form, for tagging purposes)

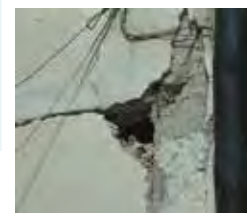
Definition of the damage levels for RC structural elements - beams and columns (in Aedes)

Damage level - extension  Structural component Pre-existing damage		DAMAGE <sup>(1)</sup>									
		D4-D5 Very Heavy			D2-D3 Medium-Severe			D1 Light			Null
		> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	
		A	B	C	D	E	F	G	H	I	
1	Vertical structures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
2	Floors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
3	Stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
4	Roof	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
5	Infills and partitions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
6	Pre-existing damage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>

(1) - The damage extension must be filled only if the corresponding damage level is present in the

Damage	Description
<b>D1</b>	Cracks up to <b>1 mm</b> in <b>beams</b> and up to <b>0.5 mm</b> in <b>columns or walls</b> , if not related to concrete crushing. Diagonal cracks in external walls up to 1 mm (up to 2 mm if at the frame interface)
<b>D2-D3</b>	Cracks up to <b>4-5 mm</b> in <b>beams</b> and up to <b>2-3 mm</b> in <b>columns</b> . Imperceptible leaning. <b>Incipient buckling</b> of reinforcing bars and concrete cover spalling. Diagonal cracks in external walls up to few mm.
<b>D4-D5</b>	Collapse or <b>inclination more than 1%</b> . Crack width is <b>more than 5 mm</b> in <b>beams</b> and <b>3 mm</b> in <b>columns</b> . Buckling of reinforcing bars.

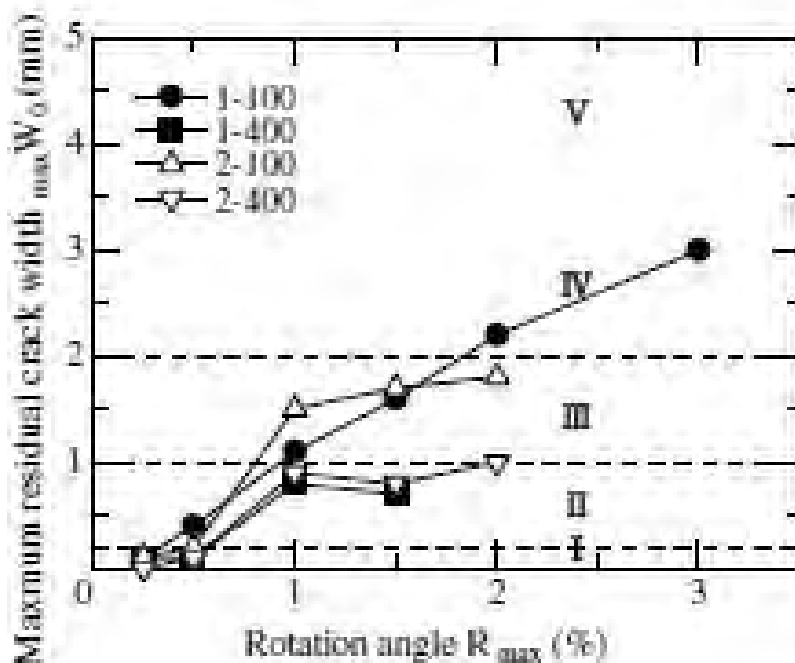
Examples from Manual



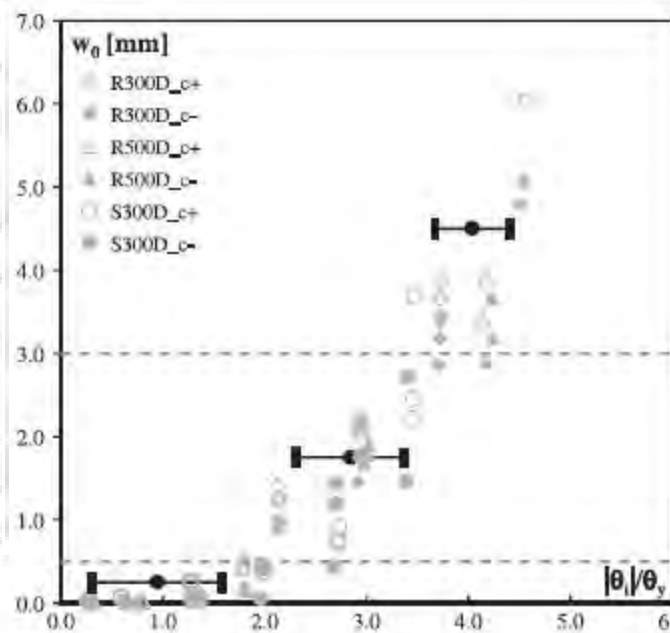
# Damage data vs residual capacity

How can we connect those damage definitions to local ductility demand and to the relative residual capacity variation?

Experimental assessment through residual cracks



Maeda et al., 2004



Di Ludovico et al., 2013

Need more calibration based on (new or existing) experimental tests:

- for various element types
- for various behavior modes

# Damage data vs residual capacity

## AFTER SPEED ASSESSMENT FOR ALL DAMAGED BUILDINGS

What **DAMAGE DATA** is collected in the Aedes survey form (speed form, for tagging purposes)

<div> <div>Damage level - extension</div> <div>Structural component</div> <div>Pre-existing damage</div> </div>		DAMAGE <sup>(1)</sup>									
		D4-D5 Very Heavy			D2-D3 Medium-Severe			D1 Light			Null
		> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	
		A	B	C	D	E	F	G	H	I	
1	Vertical structures	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
2	Floors	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
3	Stairs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
4	Roof	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
5	Infills and partitions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>
6	Pre-existing damage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="radio"/>

(1) - The damage extension must be filled only if the corresponding damage level is present in the

**DATA** available as **percentage** at the **building level**: difficult to use for lumped plasticity models, unless a mechanism type is assigned



## Damage data vs residual capacity

AFTER DETAILED ASSESSMENT AT SINGLE BUILDING LEVEL (lengthy, but necessary for decision)

What is available at the SINGLE BUILDING LEVEL (after detailed analysis by designer in orde

✓ DETAILED  
DAMAGE  
ASSESSMENT

✓ PHOTOS

## ✓ MATERIAL PROPERTIES CHARACTERIZATION



# What should be implemented in data collection protocols to make assessment of residual capacity more reliable?

## FOR SPEED SURVEY FORMS:

The need for speed is an imperative; data collection cannot be slowed by requests for detailed data evaluation

## Form to collect data

The form is titled 'Form to collect data' and is organized into several sections:

- DATI GENERALI**: Includes fields for 'Lavoro:', 'Inchiesta:', 'Regione:', 'Particolare:', 'Anno di Costruzione:', 'Regione:', 'Protocollo:', and 'U.S. Contatore:'.
- DATI GEOMETRICI**: Includes fields for 'Anno di Costruzione (m):', 'n° Piani Sotterranei (m):', 'n° Piani Sotterranei (m):', 'Superficie Coperta (m²):', 'Altezza media Piani (m):', and 'Altezza media Piani (m):'.
- DATI AZIONE SISMICA**: Includes fields for 'U.S.:', 'Categorie Sismiche:', 'Categorie Pagine:', 'Regione in piano:', and 'Regione in elevazione:'.
- CARATTERISTICHE MATERIALI E DETTAGLI COSTRUTTIVI**: Includes fields for 'Calcestruzzo', 'Acciaio', 'Dati dinamici', 'Tipologia Muro:', 'Travi', 'Piloni', and 'Piloni'.
- DATI INTERVENTO**: Includes fields for 'Intervento 1:', 'Intervento 2:', 'Intervento 3:', 'Intervento 4:', and 'Intervento 5:'.

## FOR DETAILED ASSESSMENT AT THE BUILDING LEVEL:

Request to categorize damage according to:

Element types;  
behavior modes;

Damage levels

Damage dis  
mechanism

Position



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# Post earthquake data collection workshop

Alaska, July 2014

## Chilean Experience



## **2010 CHILE EARTHQUAKE AND DATA COLLECTION METHODOLOGIES**

- Characteristics of the ground motion
- Emergency response system
- Information sources



## **BUILDING DATA**

- Immediate damage inspections
- Detailed visual inspection of damaged buildings
- Structural recovery or rehabilitation projects



## **GEOPHISICAL, EARTHQUAKE AND TSUNAMI INFORMATION**

- Instrumental data
- Geotechnical data
- Tsunami data



## **SOCIAL AND HUMAN IMPACT**

- Mental health
- Economic losses



## **LIVELINES AND CRITICAL INFRASTRUCTURE**

- Hospitals, schools, ports, road network
- Potable water, communications and electric power systems



## **LESSONS LEARNED**

- Conclusions





## POST-EARTHQUAKE DATA COLLECTION: THE 2010 MAULE EARTHQUAKE IN CHILE

De la Llera, J. C.<sup>1</sup>, Rivera F.<sup>1</sup>, Jünemann R.<sup>1</sup>, Mitrani-Reiser, J.<sup>2</sup>,  
Fortuño C.<sup>1</sup>, Hube M.<sup>1</sup>, Santa María H.<sup>1</sup>, Ríos M.<sup>1</sup>, Lagos R.<sup>3</sup>,  
Guendelman T.<sup>4</sup>, Candia G.<sup>1</sup>, Ledezma C.<sup>1</sup>, Cienfuegos R.<sup>1</sup>,  
Lindenberg, J.<sup>4</sup>.

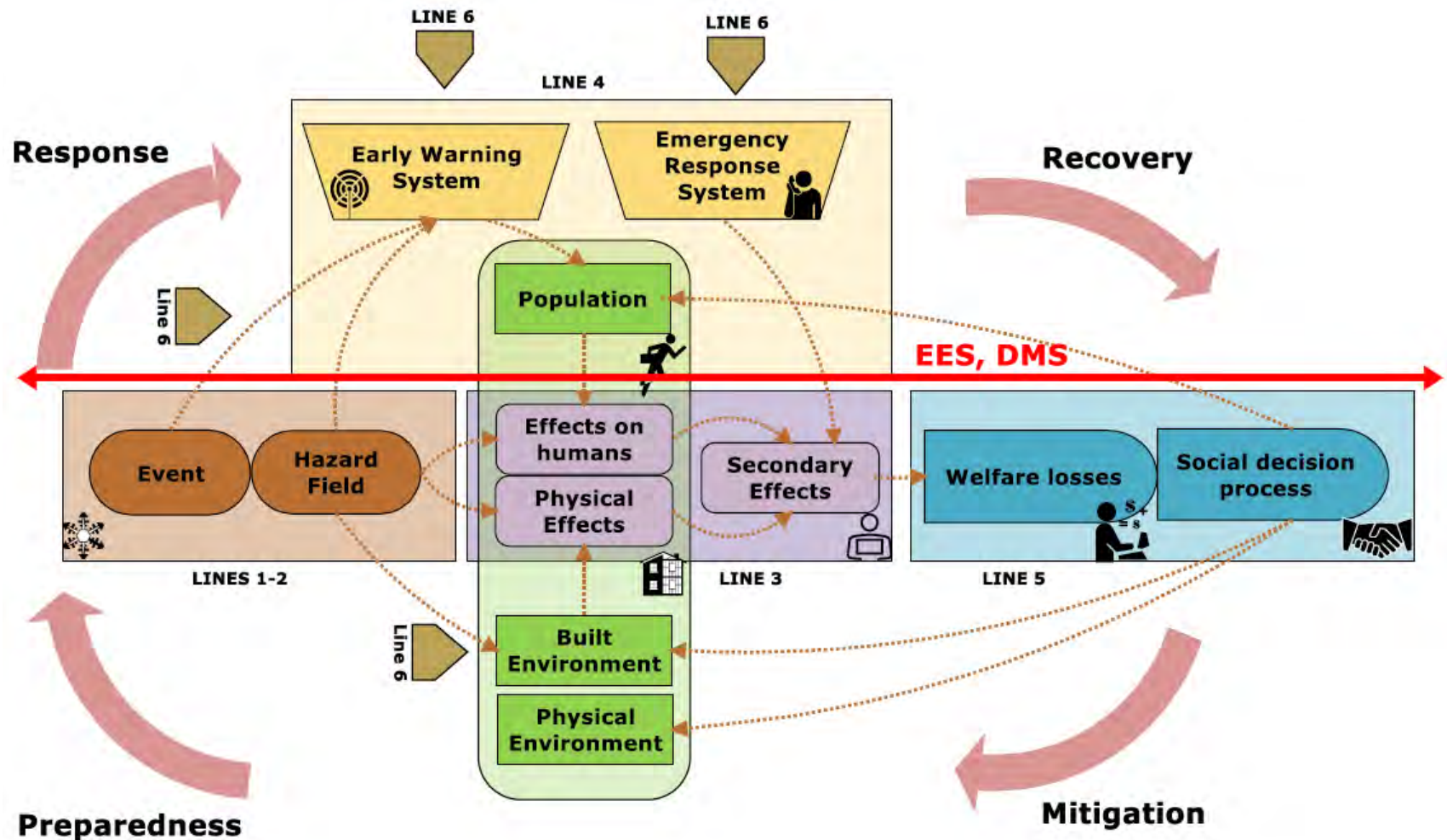
### ABSTRACT

This article presents an overview of the different processes of data recollection and the analysis done by different stakeholders during and after the emergency caused by the 2010 Maule earthquake in central-south Chile. The article is not an exhaustive recollection of all of the processes and methodologies used; it rather points out some of the critical processes that took place with special emphasis in the earthquake characterization and building data. Although there is strong similarities in all of the different processes for collecting data after the earthquake, the evidence shows that a rather disaggregate or atomized approach was used by the different stakeholders. Moreover, no common standards were implemented or used, and the resulting granularity and accuracy of the data was not comparable even for similar cases, which sometimes led to inadequate decisions. More centralized efforts were observed in resolving the emergency situations and getting the country back to normal in its operation, but the reconstruction process took different independent routes depending on several external factors and actions of individuals and communities. Several conclusions are presented that are lessons derived from this experience in dealing with a large amount of earthquake data. The most important being the true and immediate necessity of making all critical earthquake information available to anyone who seeks to study such data for a better understanding of the earthquake and its consequences. By looking at the information provided by all these data, we aim to finally improve seismic codes and engineering



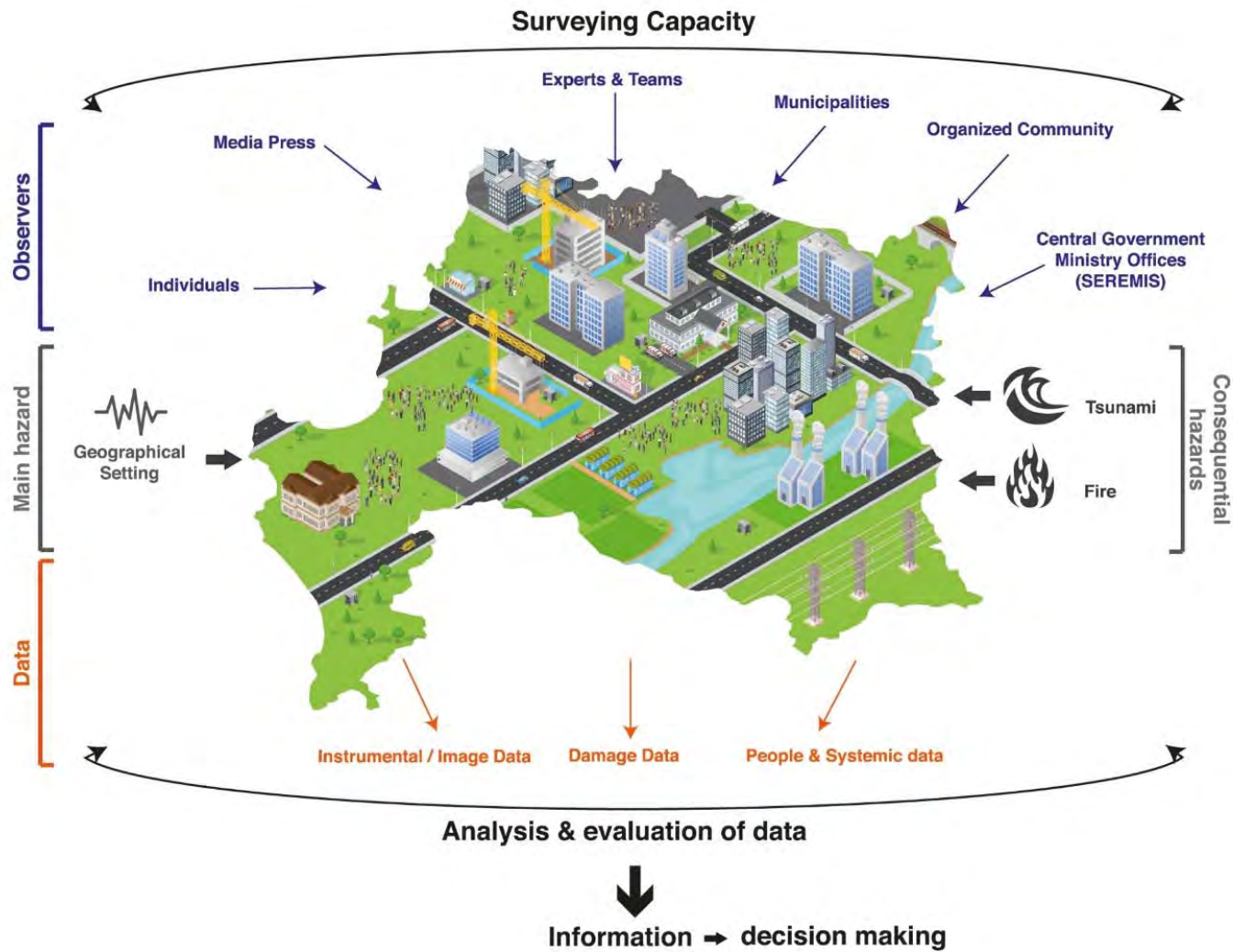


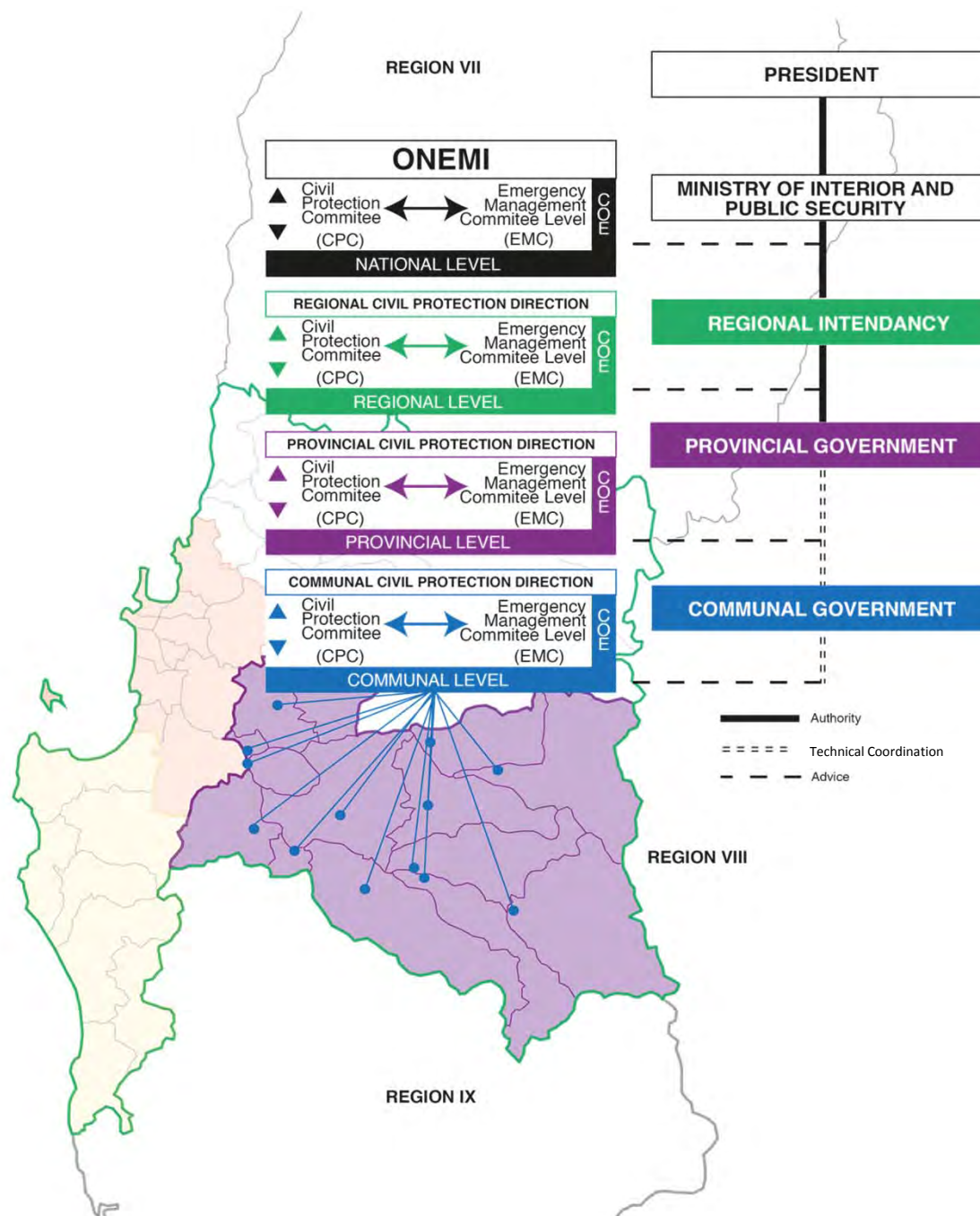
# National center for integrated disaster management, CIGIDEN





# Data collection Problem



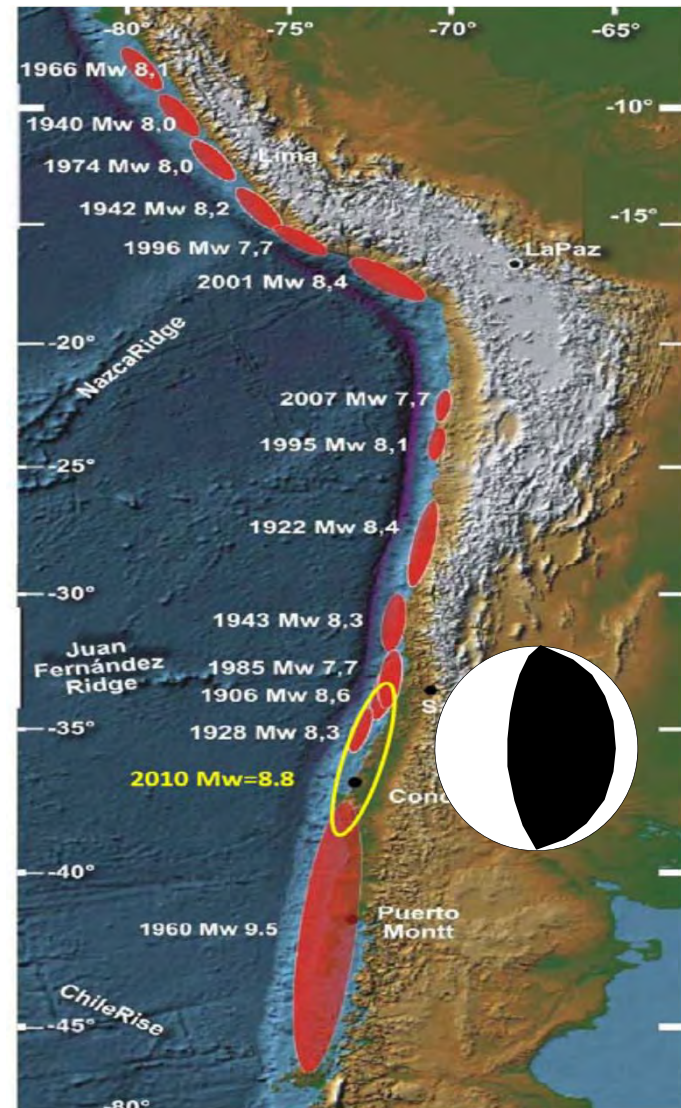
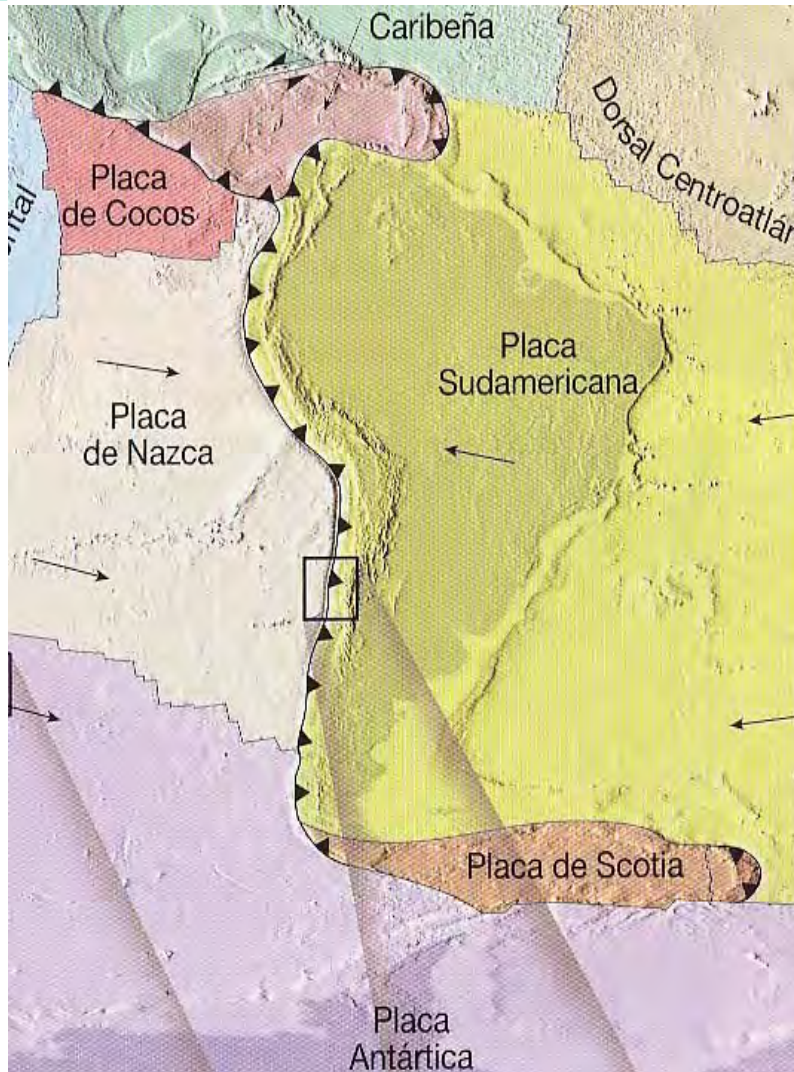




# **2010 CHILE EARTHQUAKE AND DATA COLLECTION METHODOLOGIES**



# Seismic Setting



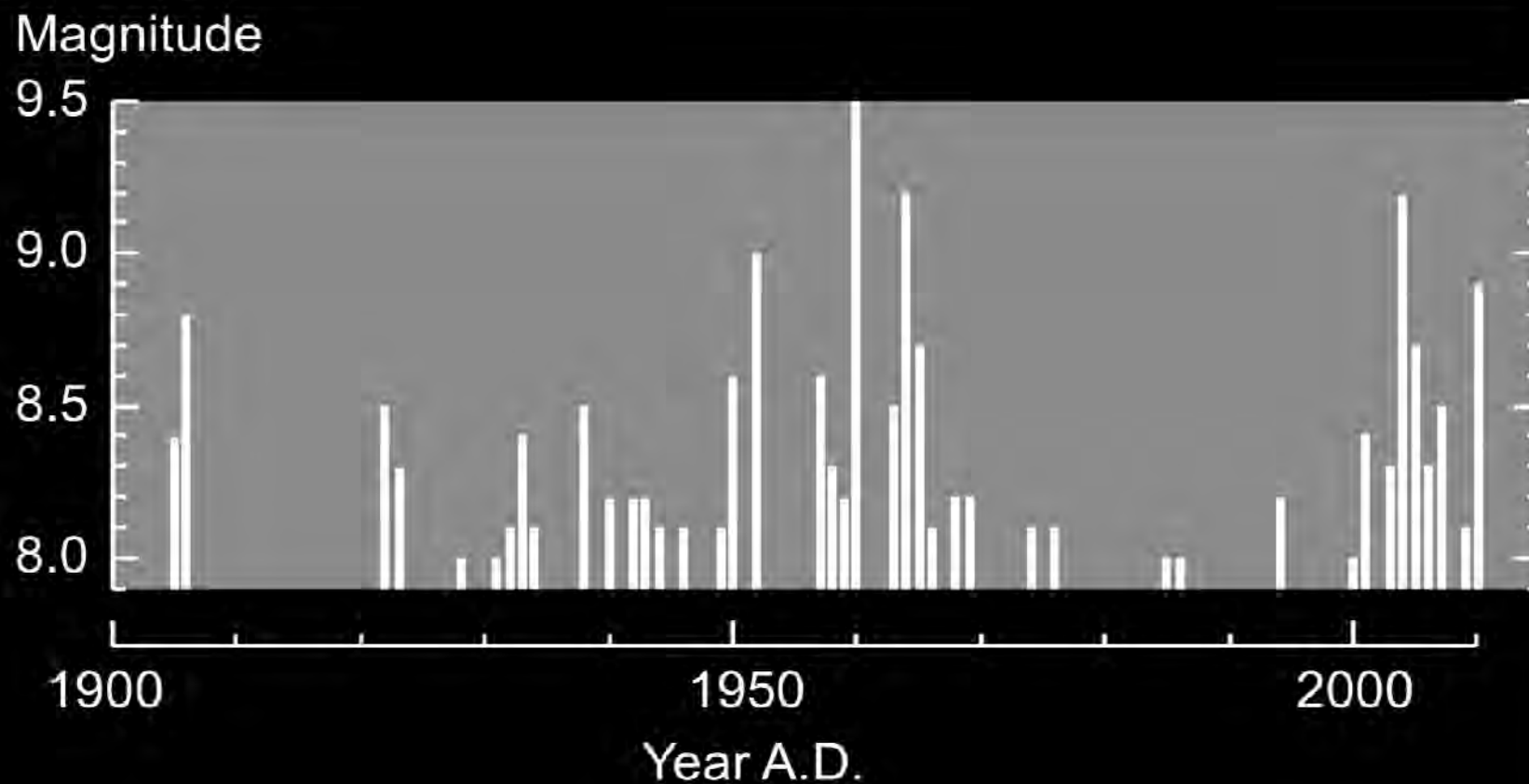


# Recent Earthquakes





# Big EQKs Since 1900



Kanamori (*J. Geophys. Res.* 82, 2981-2987, 1997)  
<http://earthquake.usgs.gov/earthquakes/eqarchives/year/>

Concepción, 2010



**Chile**  
**1000**  
**millions**  
\$USD/year



## Deaths

~ **580** in 2010

~ **1600** in 1960

~ **800** in 1922

Valdivia, 1960







Earthquake  
27/F





# Feb-27 Earthquake

**A**  
Residential Buildings



**C**  
Infra-structure



**B**  
Industrial Buildings



**D**  
Contents







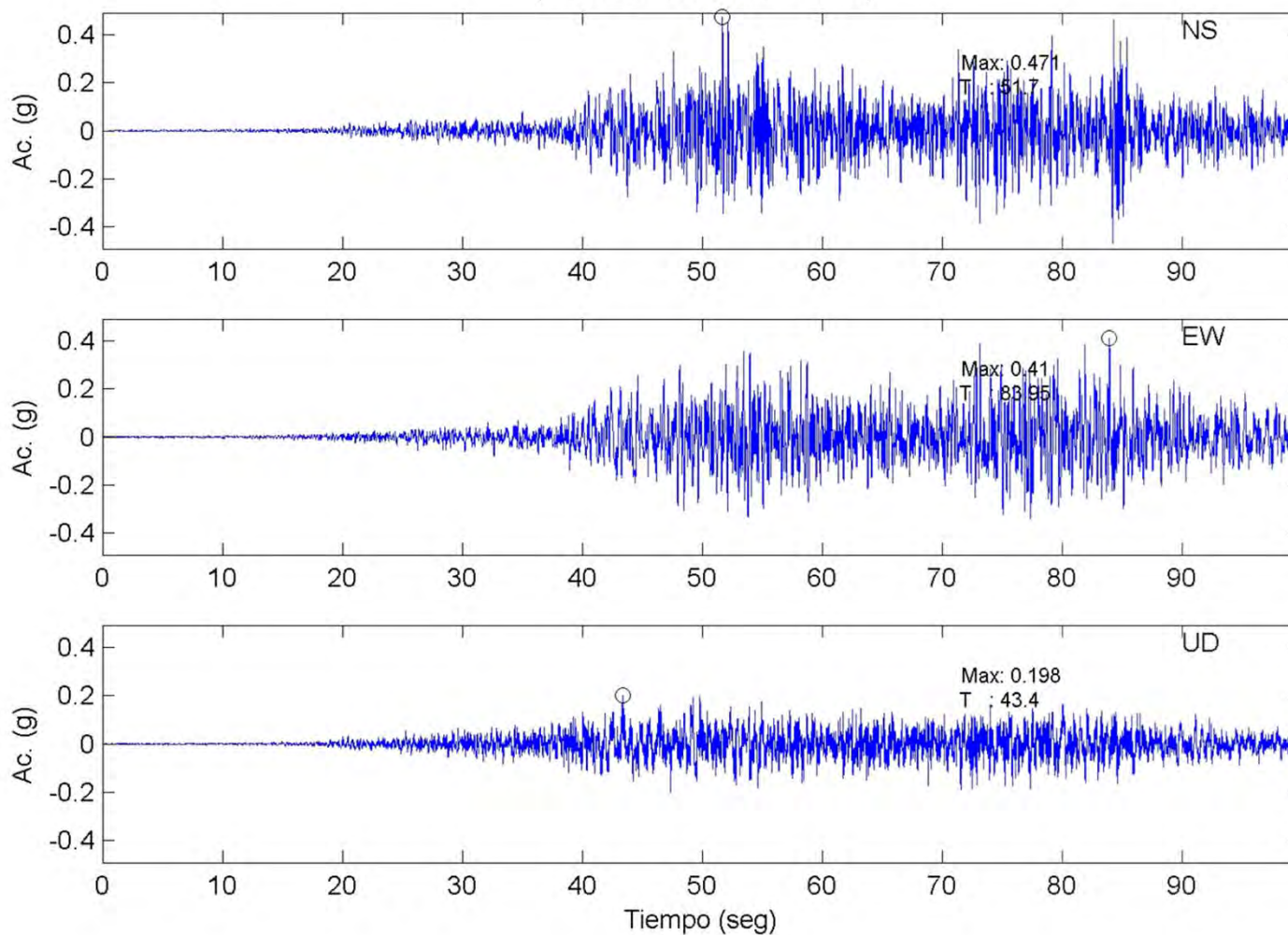
## **GEOPHISICAL, EARTHQUAKE AND TSUNAMI INFORMATION**

Data type	Source	Website
Acceleration records	Servicio sismológico Nacional (SSN) of Chile Renadic	<a href="http://www.sismologia.cl/">http://www.sismologia.cl/</a> <a href="http://terremotos.ing.uchile.cl/">http://terremotos.ing.uchile.cl/</a>
Waveform data	IRIS	<a href="http://www.iris.edu/wilber3/find_event">http://www.iris.edu/wilber3/find_event</a>
GPS	UNAVCO Data Archive	<a href="http://facility.unavco.org/data/dai2/app/dai2.html#">http://facility.unavco.org/data/dai2/app/dai2.html#</a>
	International GNSS Service	<a href="http://igsb.jpl.nasa.gov/">http://igsb.jpl.nasa.gov/</a>
	Argentinian cGPS network operated by Instituto Geografico Nacional (IGN) of Argentina	<a href="http://www.ign.gob.ar">http://www.ign.gob.ar</a>
	Brasilian cGPS network operated by Instituto Brasileiro de Geografia e estatistica	<a href="http://www.ibge.gov.br/">http://www.ibge.gov.br/</a>
	Chilo-German observatory of Concepcion operated by BKG-Frankfurt/U-Concepcion/IGM	<a href="http://www.tigo.cl">http://www.tigo.cl</a>
InSAR	Tong et al (2010)	<a href="http://supersites.earthobservations.org/chile.php#surface">http://supersites.earthobservations.org/chile.php#surface</a>
SAR images	JAXA, ALOS/PALSAR data	<a href="http://www.eorc.jaxa.jp/ALOS/en/">http://www.eorc.jaxa.jp/ALOS/en/</a>

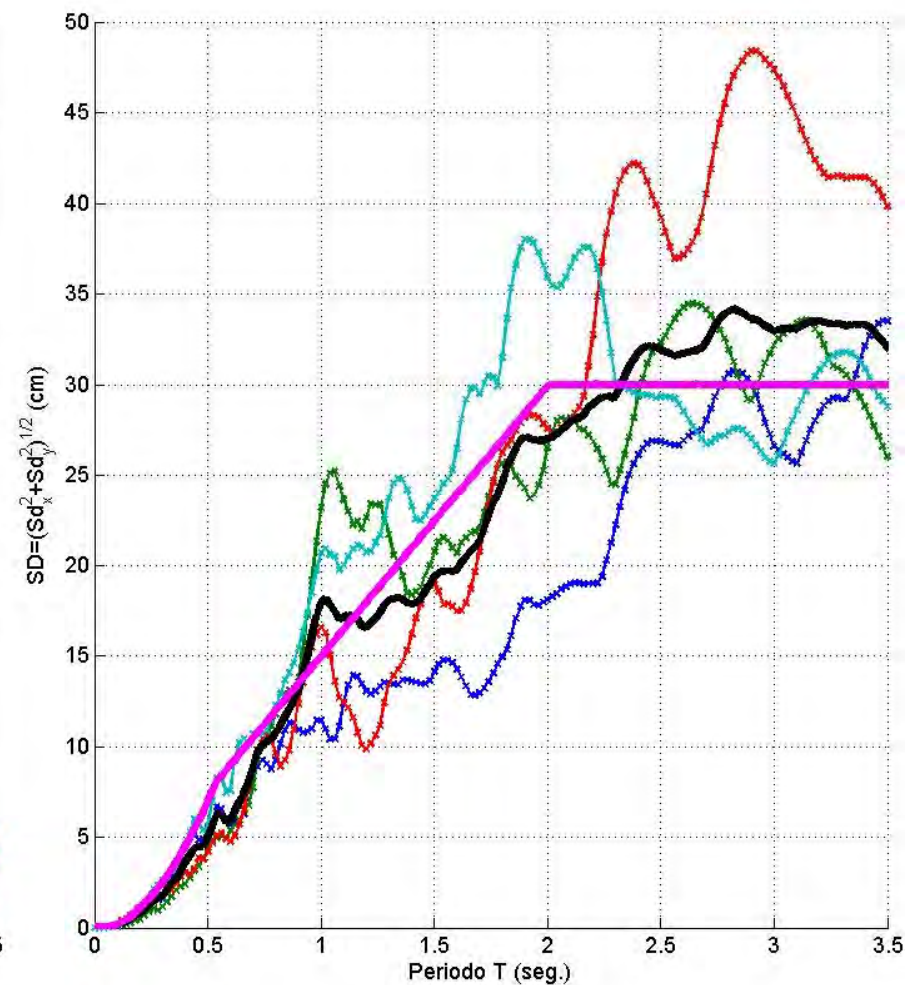
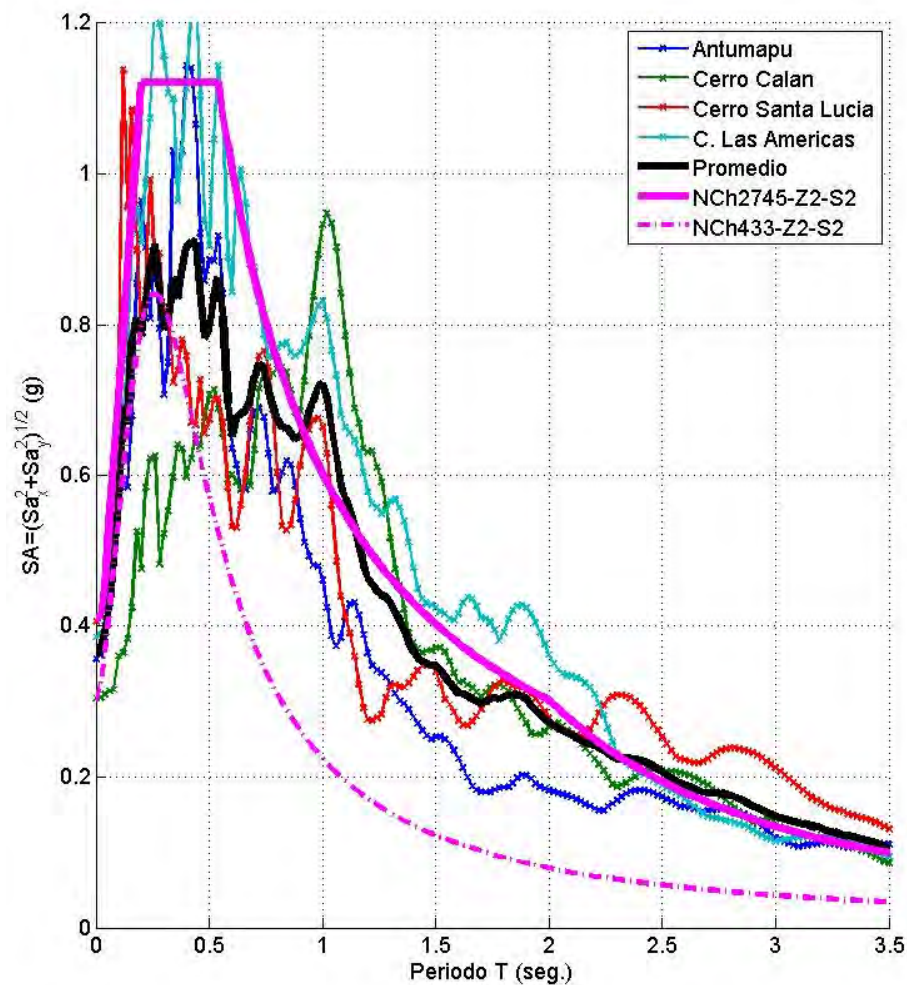


# Curico records

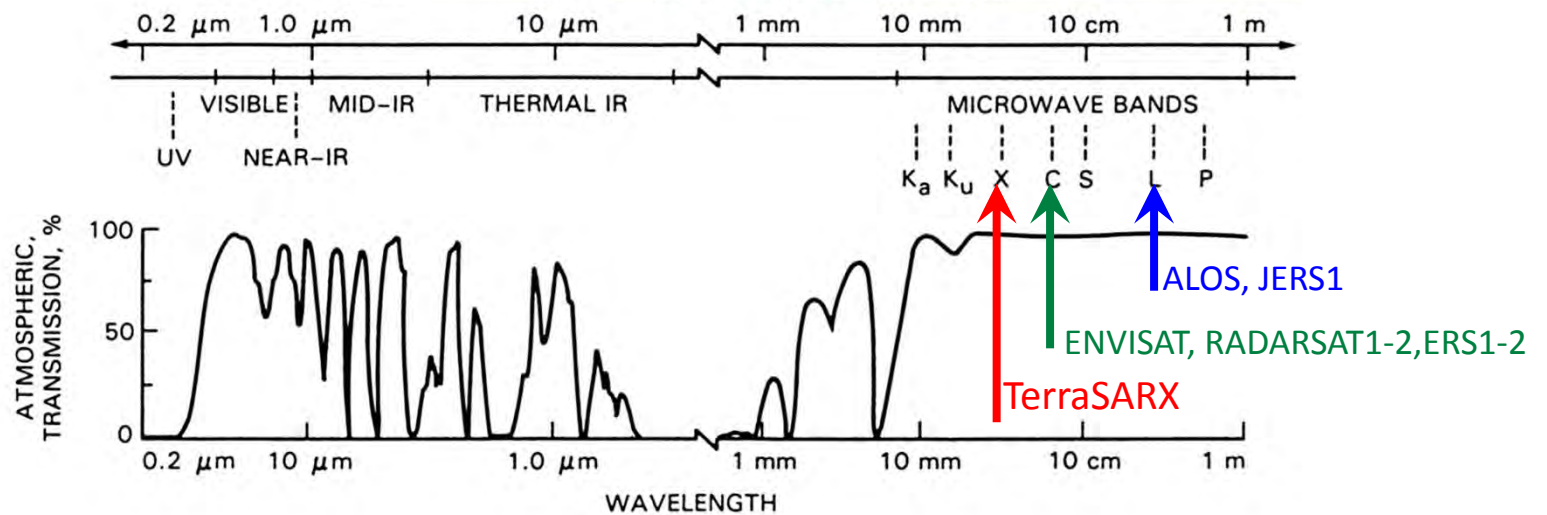
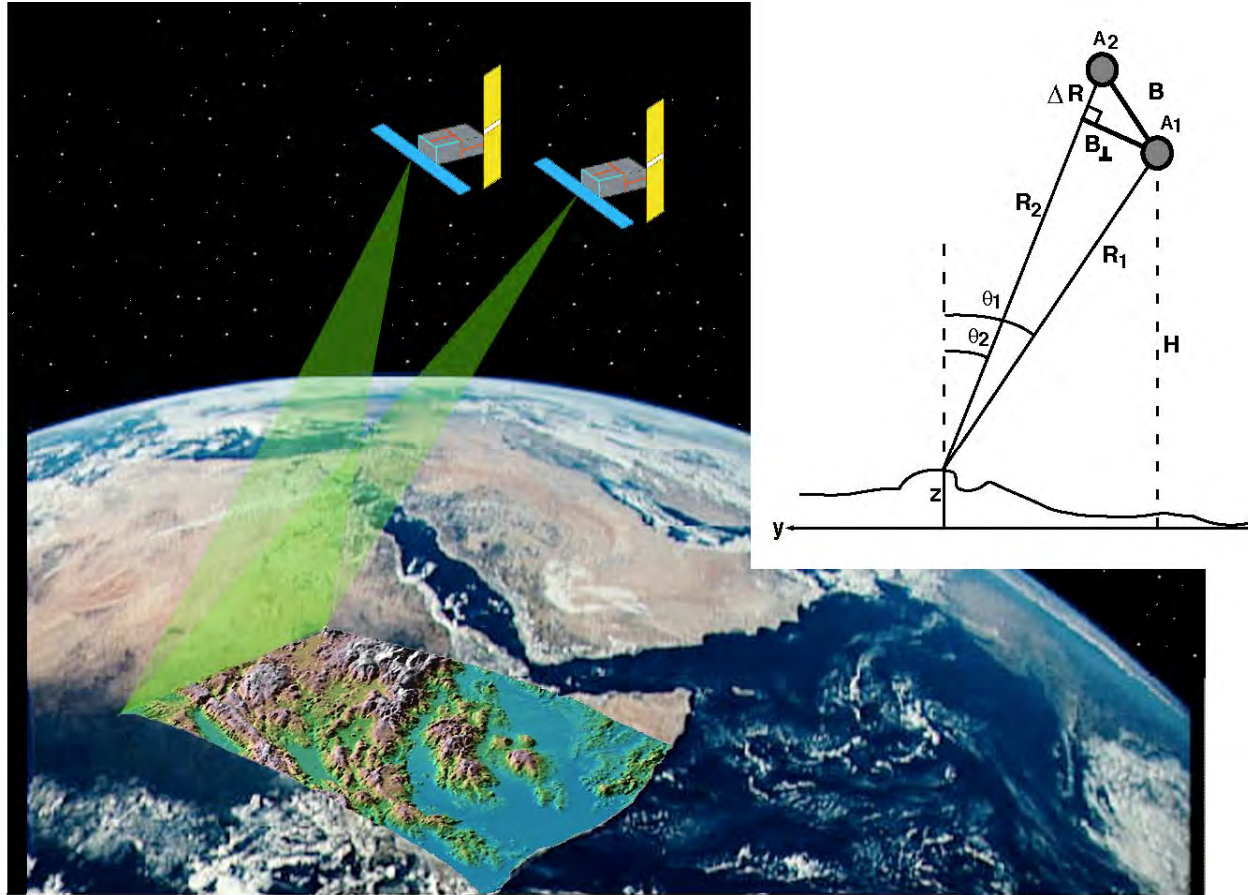
REGISTRO RENADIC: ESTACION: HOSP CURICO / P. SOTO R. BOROSCHEK  
UNIVERSIDAD DE CHILE RED NACIONAL DE ACELEROGRAFOS  
( Frec. Banda: 0.055 - 40 Hz)



# **Earthquake** **27/F 2010**

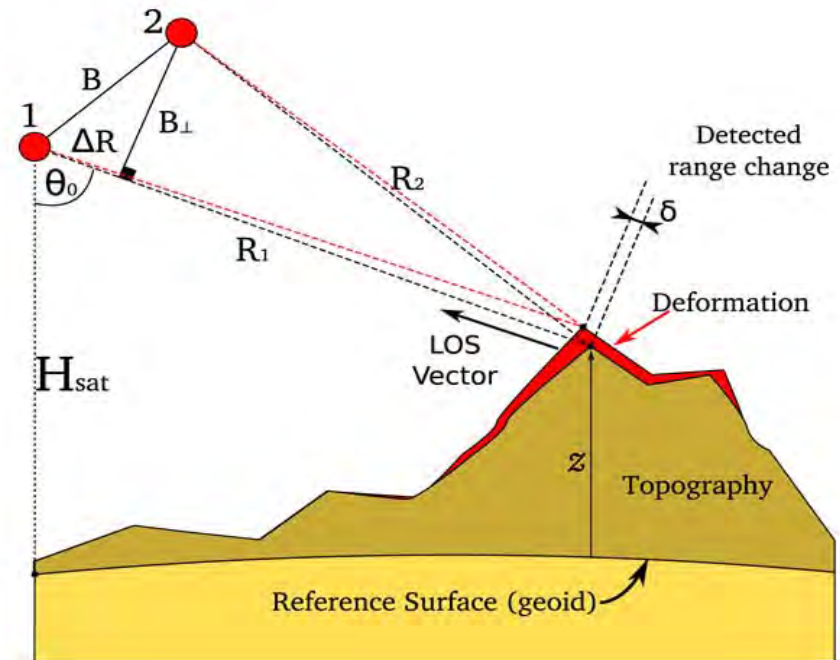






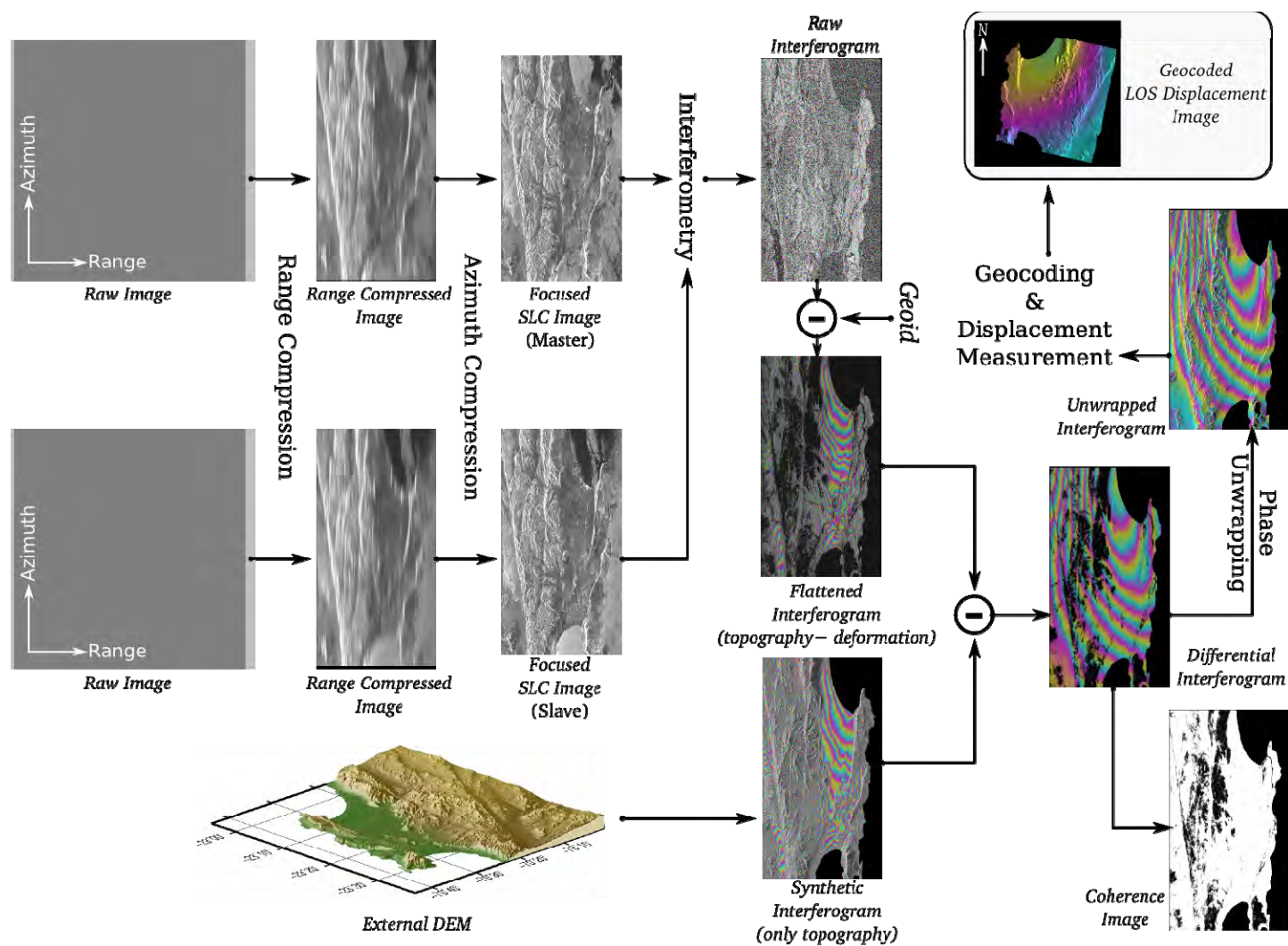


- The change in viewing geometry and surface changes is detected as a change in phase
- The range-change is related to various geometric sources

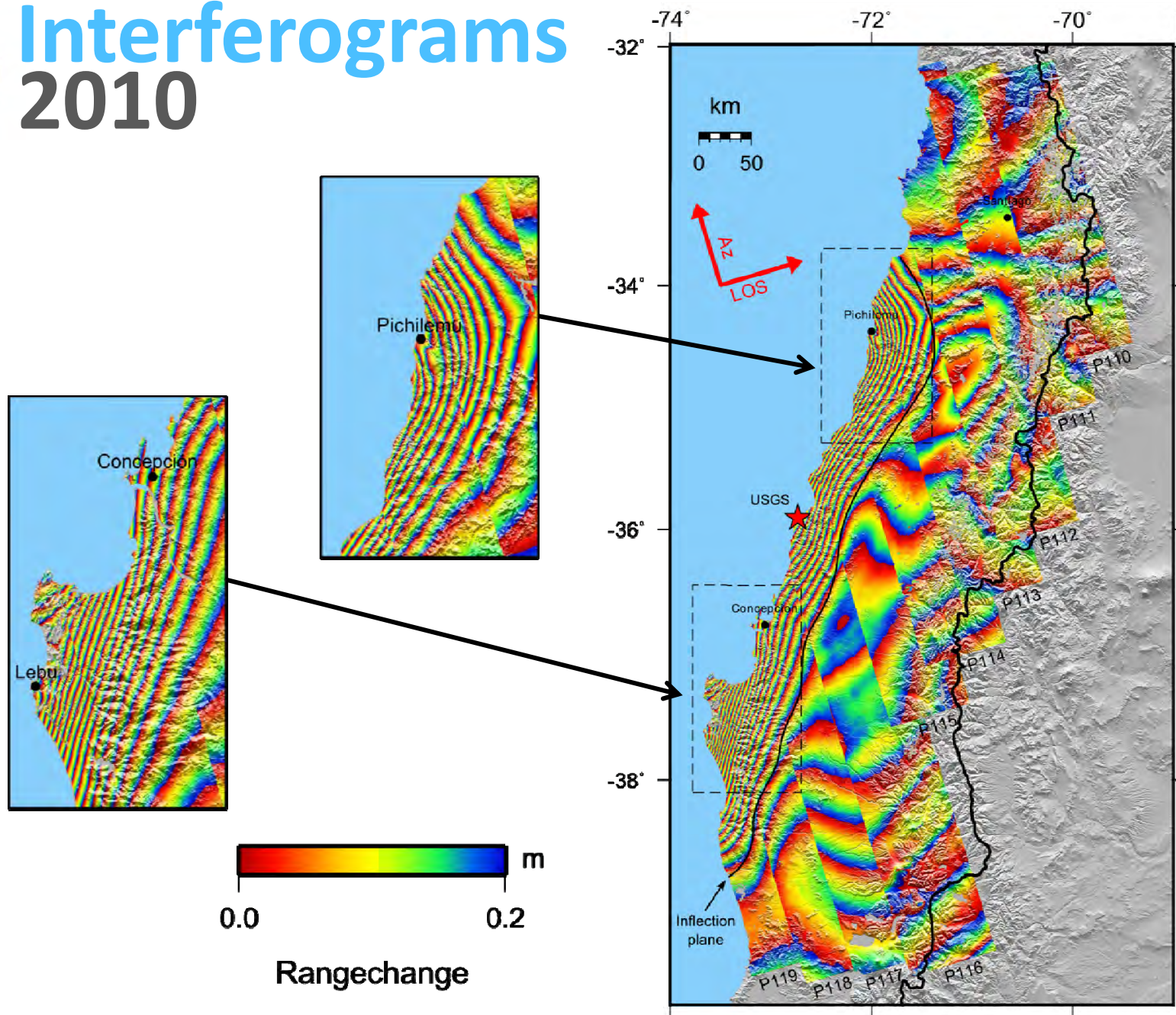


$$\Delta\phi_m = -\frac{4\pi}{\lambda} \left( \Delta R_{\text{datum}} - \frac{B_{\perp}}{R \sin \theta} z - \boxed{\delta} \right) + \phi_{\text{noise}} + n \cdot 2\pi$$

Deformation



# Interferograms 2010





# Interferograms 2010

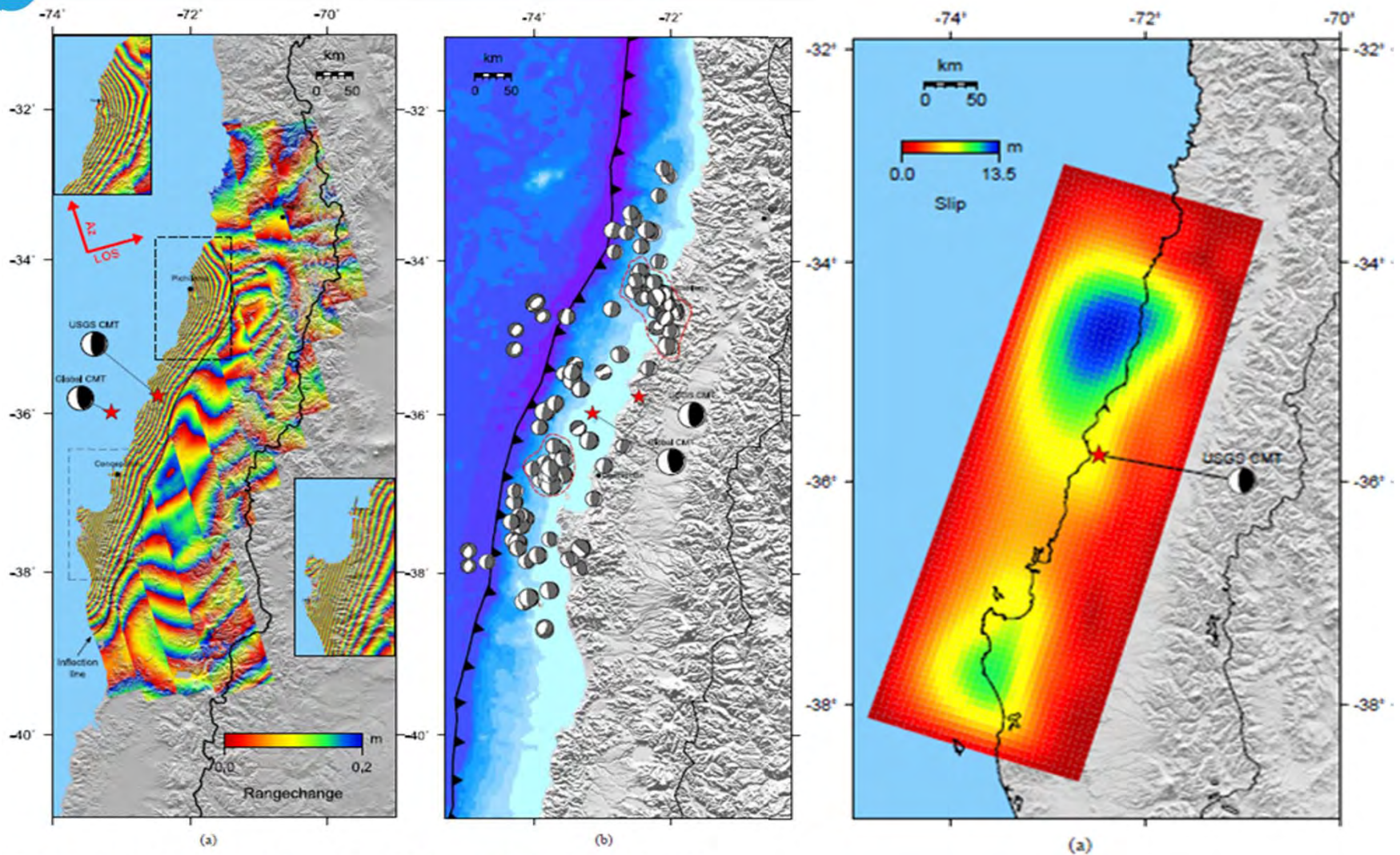
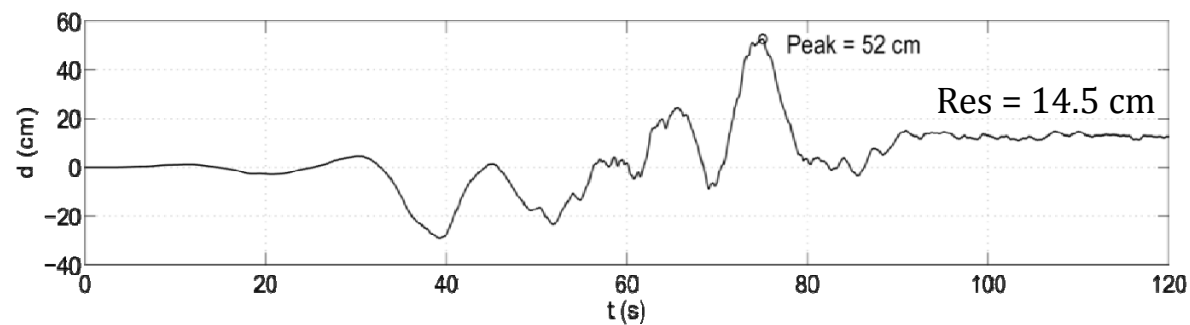
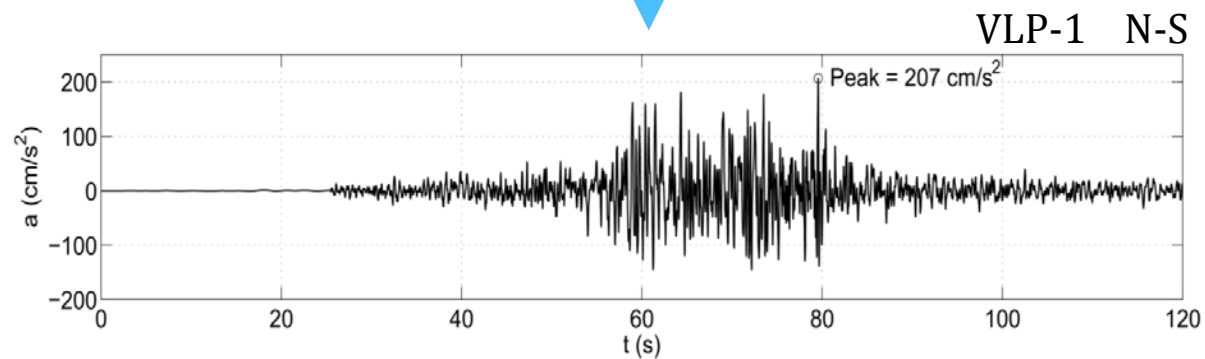
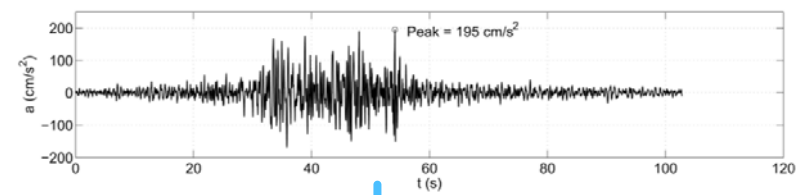
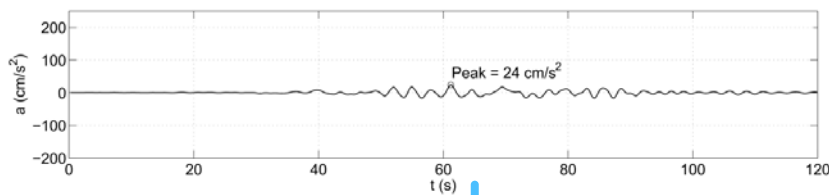


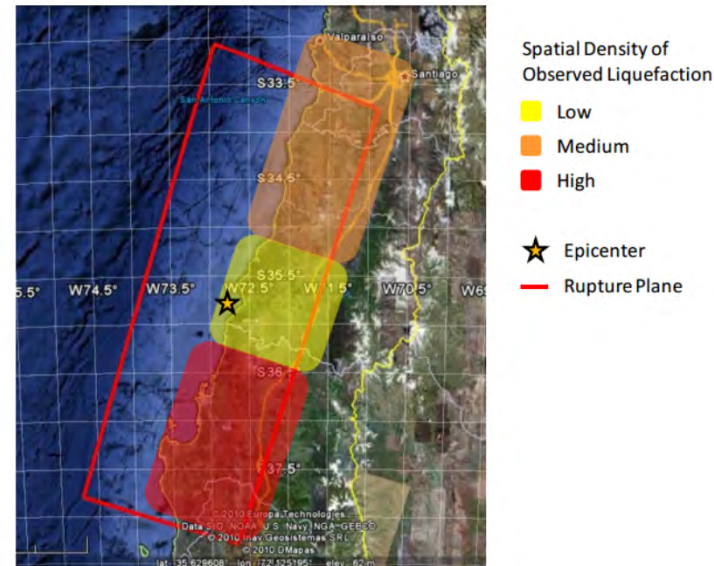
Figure 3: (a) Ascending unwrapped interferograms for Maule 2010 earthquake, (b) Aftershocks  $M_w \geq 5$  of Maule 2010 earthquake between Feb 27 and May 29 2010

**Synthetic (low-pass filter)**  $T_c = 3\text{ s}$  **Ground-motion filter**





# **Geotechnical Data**



Dam	Construction year	Type	Height (m)	Crest Length (m)	Distance to Epicenter (Km)
Llú Llú		Rockfill	20	530	340
Rapel	1968	Concrete arch	90	330	230
Colbun	1985	Earthfill	110	670	130
Pehuenche	1991	Earthfill	80	370	150
Cipreces	1955	Gravity pipes			175
Coihueco		Earthfill	20	500	180
El Toro	1973	Gravity pipes	540		120
Abanico	1952	Gravity pipes	150		195
Hueleheico					210
Pangue	1996	Concrete gravity	103	360	240
Ralco	2004	Concrete gravity	155	360	260

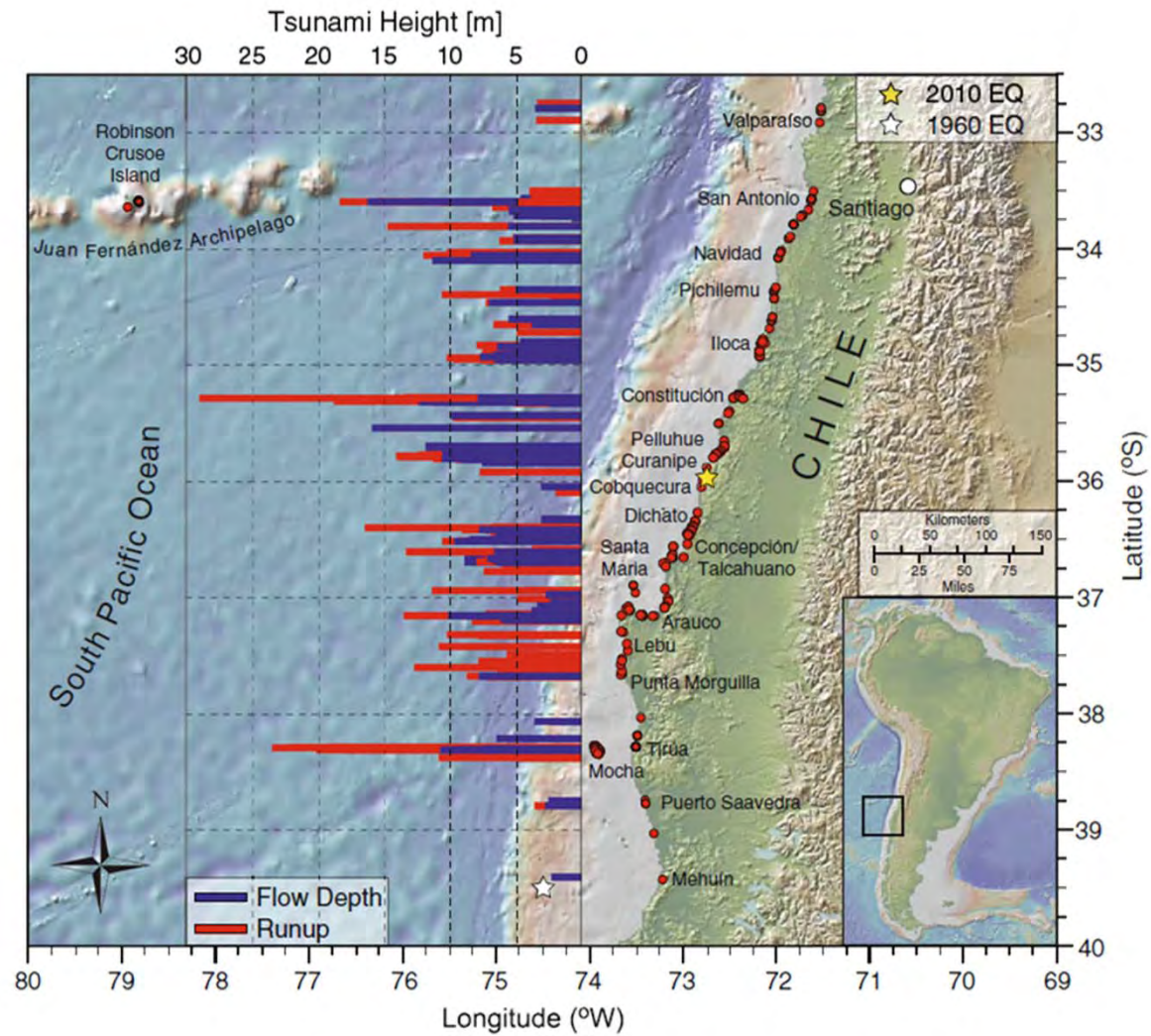
Source: GEER Report

# Tsunami

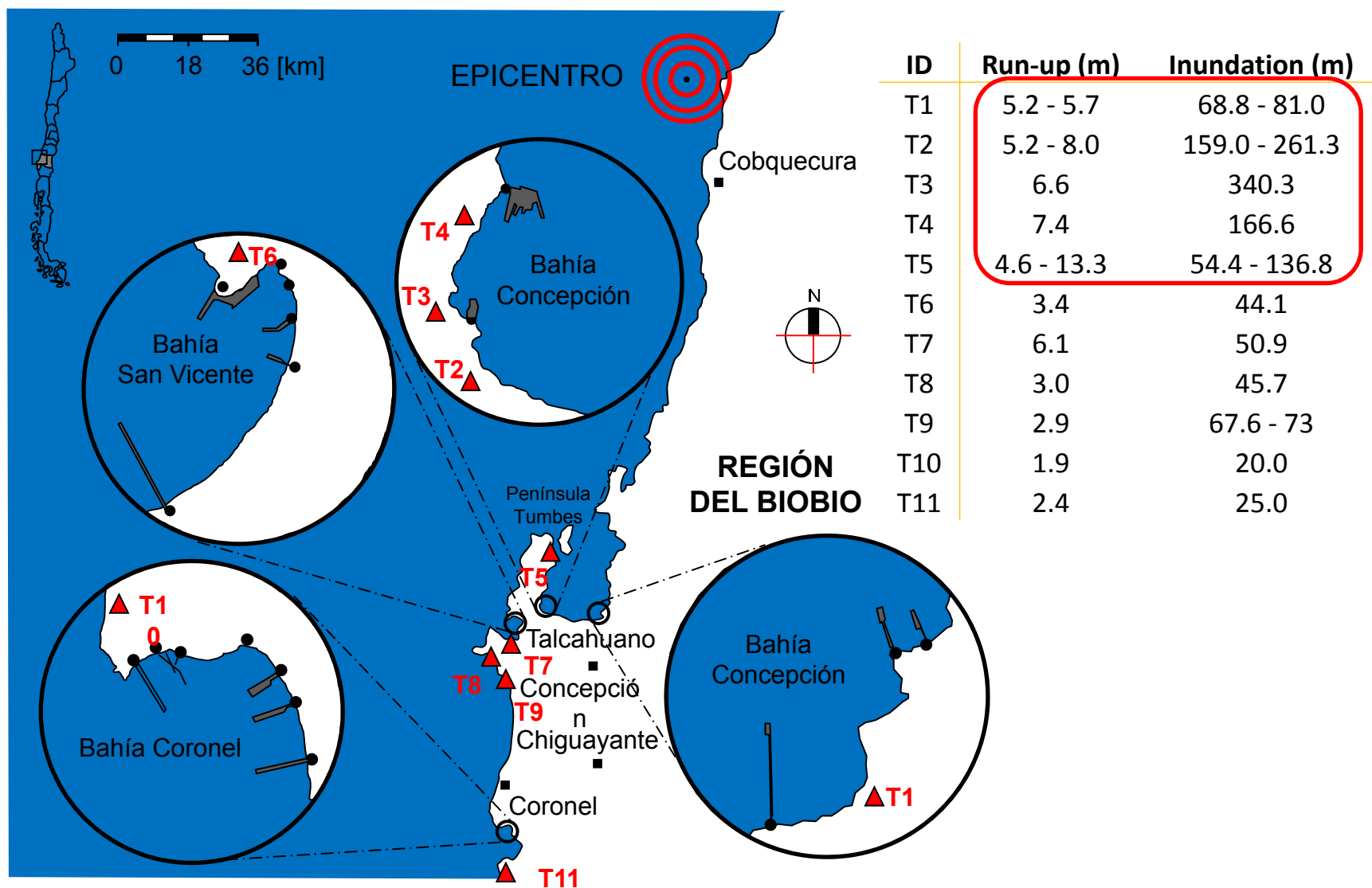




# Tsunami Data



# Tsunami Port area





## **LIFELINES AND CRITICAL INFRASTRUCTURE**



# International Teams



**US Teams: EERI (LFE); ASCE (TCLEE); USGS (GEER)**

**EERI focus on:** reinforced concrete, masonry, and steel buildings; bridges; healthcare facilities; non-structural building components; instrumentation; social sciences/planning/policy/recovery; and tsunami effects



# EERI Hospital

Reconnaissance Team



Talca Regional Public Hospital, Talca, Chile, March 19, 2010

## **Rick Bissell**

*Professor of Emergency Health Services,  
University of Maryland Baltimore County*

## **Francisco de la Masa**

*Chile Ministerio de Salud  
Santiago, Chile*

## **Judith Mitrani-Reiser**

*Assistant Prof of Civil Engineering,  
Johns Hopkins University*

## **Bill Holmes**

*Structural Engineer, Rutherford &  
Chekene, San Francisco, CA*

## **Thomas Kirsch**

*Associate Prof and Co-Director of the  
Center for refugee and Disaster  
Response, Johns Hopkins University*

## **Mike Mahoney**

*Senior Geophysicist at FEMA,  
Washington, DC*

## **Nicolas Santa Cruz Marin**

*Graduate Student of Civil Engineering,  
Pontificia Universidad Catolica, Chile*



# Goals of Hospital Team

- ▶ Assess physical damage:
  - structural
  - non-structural
  - utilities
  - equipment
- ▶ Identify vulnerabilities that can:
  - threaten patients
  - reduce the hospital's functional capacity (ability to provide medical care)
- ▶ Develop a protocol to collect detailed data measuring effectiveness and vulnerabilities of a single region medical system
- ▶ Assess the physical and medical similarity of Chilean Hospitals to the USA system



# Hospital Damage Overview

- ▶ No hospital suffered a complete structural failure
- ▶ Total number of hospitals in shaken region: 130
- ▶ Of the 79 damaged hospitals:
  - 4 uninhabitable
  - 12 had greater than 75% loss of function
  - 8 partially operating after main shock
  - 62% needed repairs or replacement
- ▶ Many had extensive loss of equipment
- ▶ **All lost power, external water supply, and communications**

(Source: [http://www.redsalud.gov.cl/noticias/noticias.php?id\\_n=761&show=3-2010](http://www.redsalud.gov.cl/noticias/noticias.php?id_n=761&show=3-2010)) 22 Mar 2010







# Bio-Bio Region

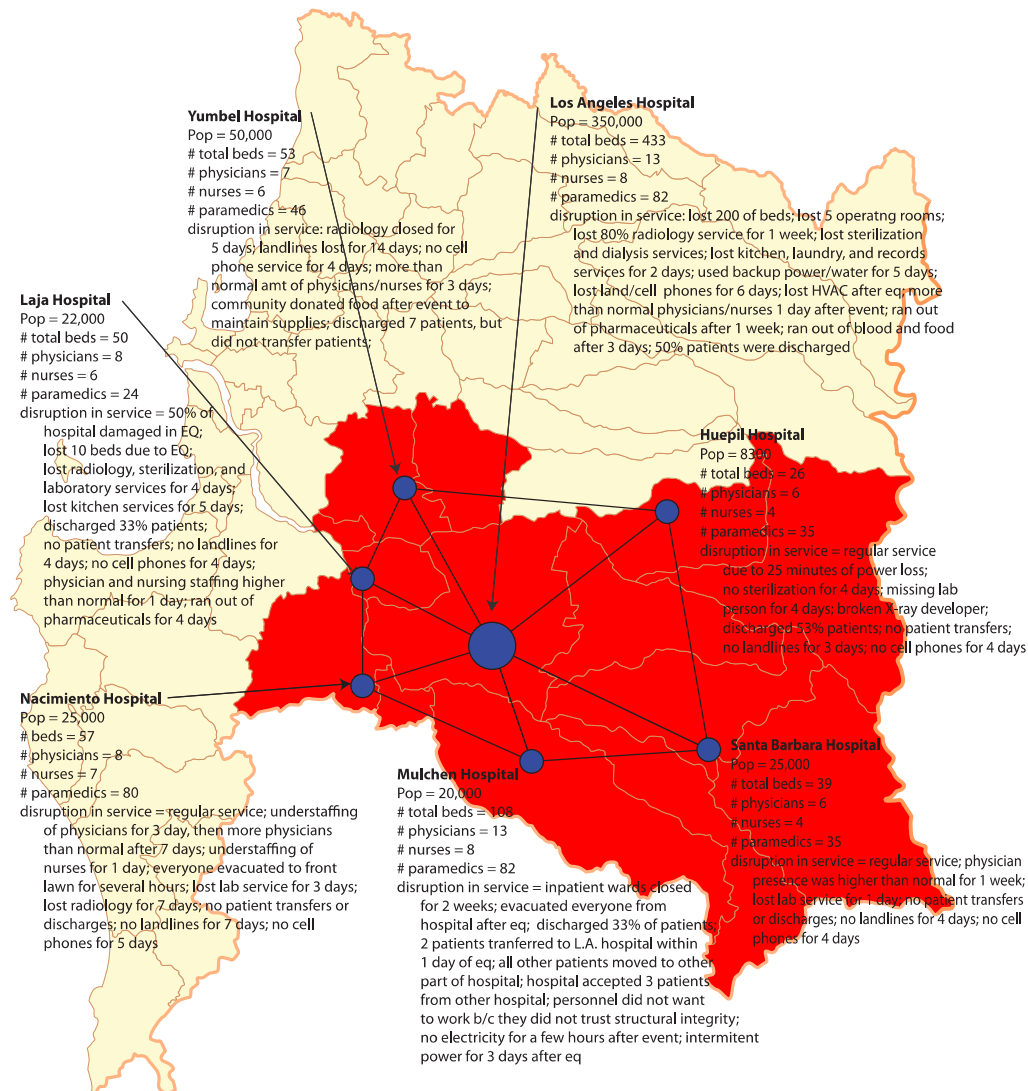
Hospitals studied in the Bio-Bio Province:

- Los Angeles Regional Hospital
- Hospital de Hupiel
- Hospital Laja
- Hospital Santa Barbara
- Hospital Nacimiento
- Hospital Yumbel
- Hospital Mulchen





# Hospitals





# Functional Damage

► Damage causing disruption and affecting patient safety:

- Loss of communication
- Loss of power
- Loss of water
- Elevator outage
- Water damage
- Damage to bulk oxygen tanks
- Ceiling failures
- Nonstructural masonry damage
- Disruption to special services such as paper medical records, pharmacies, and laboratories
- Damage to medical equipment
- Damage to MEP equipment
- Damage to MEP distribution systems



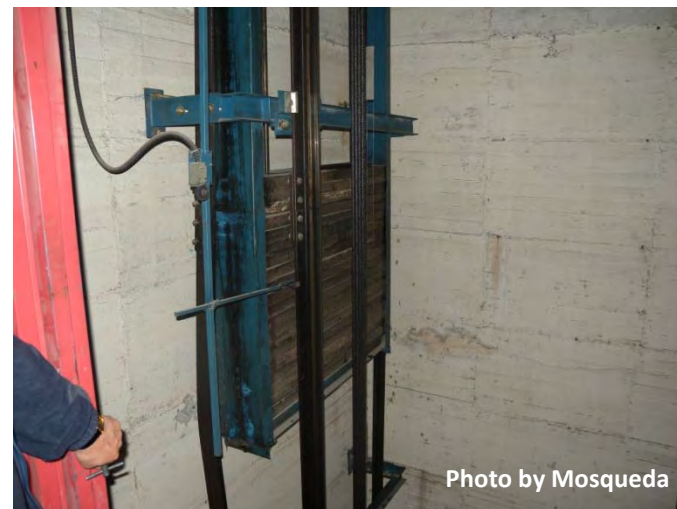
# Hospital Functions Disrupted:

## Patient Wards Evacuated

- ▶ The need to evacuate patients is a significant failure because it:
  - is extremely dangerous for patients
  - takes staff away from serving externally injured
  - creates demand for patient space, possibly off site
  
- ▶ Mutual aid
  - no patients were emergently transferred to other facilities (probably due to poor communications)
  - patients were temporarily housed on site
  - many were discharged to their homes
  - in a few cases, patients were transferred later

# Elevator Damage

- ▶ Significant failures; most due to derailed counterweights
- ▶ In every building evacuated, elevators were inoperable, requiring patients to be carried down stairs or ramps
- ▶ Elevator machine rooms and shafts are typically accessible only by elevator maintenance service or one person on site





# Communication Systems

- ▶ No plan for emergency communication in facility or between facilities, particularly to the centralized headquarters of the health system
  - lead to isolated hospital 'islands'
- ▶ Over-reliance on cell phones
  - widespread power outages
  - towers were down for days

**Most consistent issue  
identified by hospital  
administrators**



Community cell phone charging (EVARISTO SA, AFP)

# Power Damage

- ▶ All facilities lost outside power for various time periods (up to 3 days)
- ▶ All facilities have emergency generators and at least 3 days fuel supply.

However:

- Some generators did not automatically turn on and needed a manual start
- The generators were not always sufficient to power important medical equipment (e.g. radiology) or the entire facility



# Water Damage

- ▶ Most hospitals had on-site storage for 3 or more days of essential water (or wells)
  - *Unlike most hospitals in the USA*
- ▶ Water pressure from backup systems was often not sufficient for toilets and some medical equipment and the HVAC
- ▶ Some received priority water deliveries from municipal authorities
- ▶ Other water-related damage: damage to distilled water tanks, pipe failures and flooding



Photo by Mitrani

# Water storage tanks



Water storage tank at Concepcion.



New tank under construction at Talcahuano—not quite in time



# Water Damage

- ▶ Damage/disruption from water
  - not frequent
  - caused at least three buildings to be evacuated
  - shut down 3 of 6 ors in relatively new building





# Water Damage

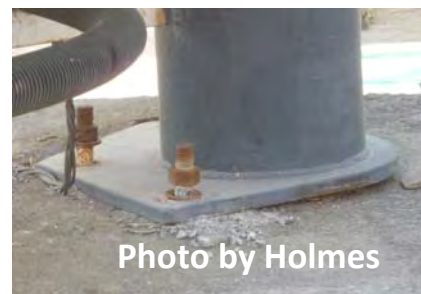
- ▶ 2005 building in Los Angeles Hospital: brick in-fill wall collapsed onto a water tank holding roughly 150 gallons of distilled water; water traveled through joints damaging hallway in front of surgical ward and shutting down 50% of the ward.



Photo by Holmes

# Oxygen Systems Hospital Functions

- ▶ Some hospitals lost internal systems
- ▶ Bulk oxygen storage tanks
  - Standard of practice is to anchor: **no overturning** reported.
  - Tensile yield failure of threaded fasteners.
  - Punching shear failure of tank leg.





# Non-Structural Damage

- ▶ **Suspended lay-in ceilings** - Generally without any seismic detailing.
  - Most consistent failure.
  - Often causes little real damage but great fear and disruption
  - Fallen light fixtures and air registers can be life safety issue
  - Older ceilings drop dust and other debris (in the US, often asbestos)

# Non-Structural Damage

- ▶ Los Angeles Hospital: fallen light fixtures and mechanical registers, in addition to ceiling panels



Photo by Holmes



# Non-Structural Damage

- ▶ Retrofit: clips used to stabilize ceiling tiles at Talca Hospital (new building)

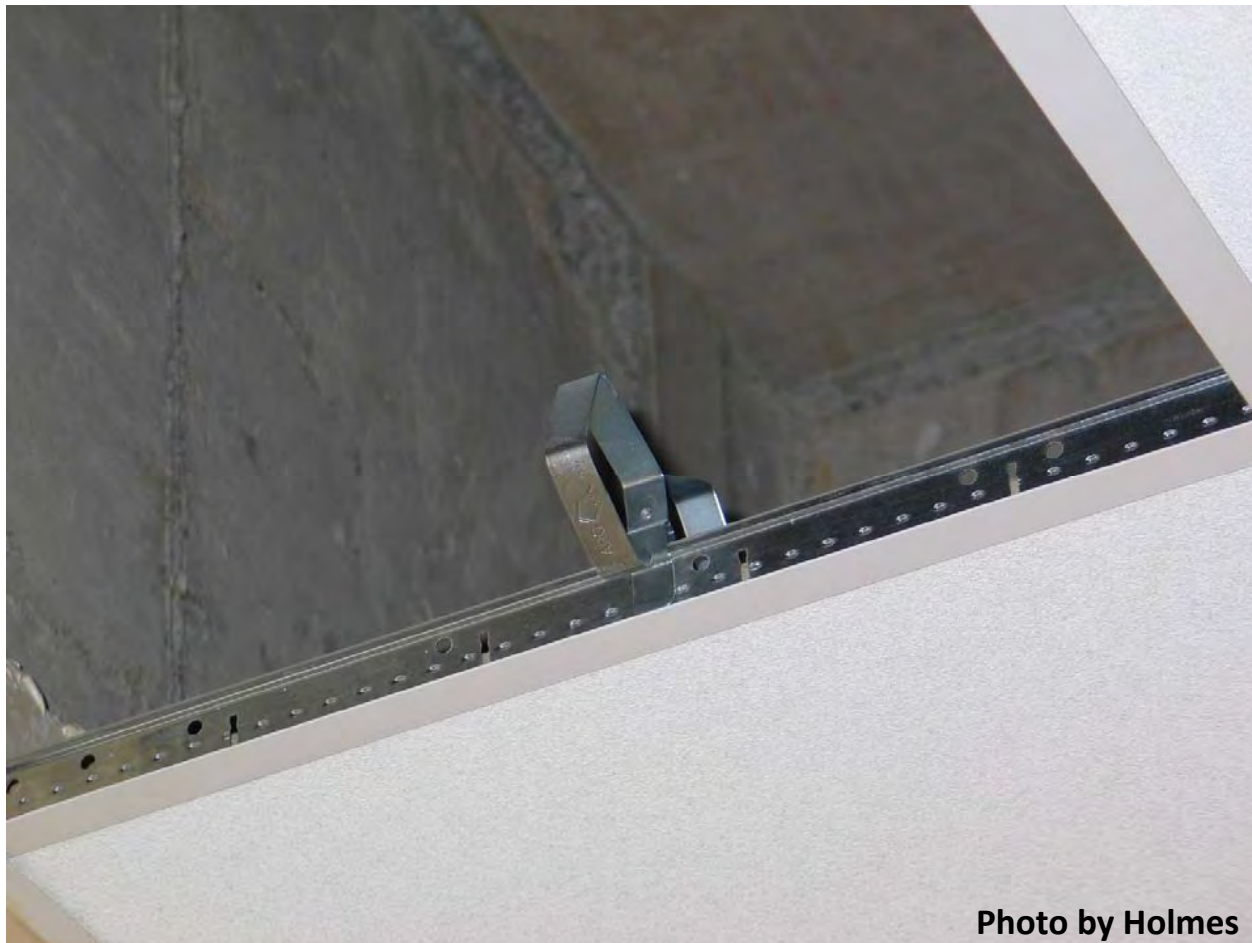


Photo by Holmes



# Non-Structural Damage

- ▶ Retrofit: packing tape used to keep dust out of ICU showed excellent seismic performance!



ICU, Talca Hospital (older building-evacuated)

Photo by Holmes

# Non-Structural Damage

- ▶ Infill masonry/heavy partition damage
  - Considered “nonstructural” but, like ceilings, causes fear, creates dust and occasionally risk of injury.



Cracked and spalled infill in patient room. Hospital Felix Bulnes (Santiago)

Photo by Holmes



# Non-Structural Damage

- ▶ Apparently vulnerable areas like **paper medical records, pharmacies, and laboratories**
  - Usually damaged only when building had other nonstructural damage
  
- ▶ **Medical Equipment**
  - Usually damaged only when building had other nonstructural damage
  - Damage to radiological equipment recorded

# Non-Structural Damage

- ▶ Essentially unstable medical record storage—undamaged. Nacimiento.





# Non-Structural Damage

- ▶ Still working on straightening out Talcahuano medical records after 3 weeks



Photo by Holmes





# Nonstructural

## Summary of Physical Damage:

- ▶ Loss of power, water, and communication
- ▶ Severe damage to suspended ceilings
- ▶ Mechanical equipment damage resulted in loss of hot water affecting kitchen, laundry, and sterilization services
- ▶ Medical equipment damage forced hospitals to sterilize off site, and disrupted diagnostic services
- ▶ Water damage forced hospitals to shut down buildings, dialysis treatment, and had severe sterilization implications (e.g., surgical ward)
- ▶ Stand-alone shelving damage, resulting in disorganization of medical records for few days to several weeks



# Hospital Physical Damage Impact

- ▶ Damage from even very small details can shut down a hospital.
  - Water damage from a small pipe break shut down operating rooms.
- ▶ Securing both mechanical and medical equipment can be critical to maintaining hospital operations.



# Hospital Preparedness

- ▶ All hospitals had backup systems for water and electricity, although they were not always sufficient to provide services
  - But none had backup for sewer
- ▶ Communications systems need redundancy.
  - Lead to complete isolation
  - One used ambulance radios for local communications.



# Summary

- ▶ Hospitals do not have to collapse to be rendered inoperable
- ▶ Functional losses are usually due to non-structural damage
- ▶ Communications systems are critical!
- ▶ Redundancy is necessary for water, power, and sewage systems
- ▶ Like Katrina- Hospitals must be prepared to be on their own for 2-3 days in a major event

# Seismic Performance of US Healthcare Facilities

- ▶ San Fernando Earthquake 1971 ( $M_w$  6.6; 6:01am PST) Olive View Medical Center



Photo by Karl Steinbrugge





# Seismic Performance of US Healthcare Facilities

- ▶ San Fernando Earthquake 1971 ( $M_w$  6.6; 6:01am PST) Olive View Medical Center



# Seismic Performance of US Healthcare Facilities

- ▶ Northridge Earthquake 1994 ( $M_w$  6.7; 4:31am PST) Kaiser Permanente Building



Photo by Gary Edstrom



# Acknowledgements

- ▶ This study was supported by the Earthquake Engineering Research Institute's Learning from Earthquakes (LFE) Program, the Johns Hopkins University's Office of Critical Event Preparedness and Response (CEPAR), and the Federal Emergency Management Agency (FEMA).
- ▶ We would also like to acknowledge the valuable input and support from Professors Juan Carlos de la Llera and Catterina Ferreccio at Pontificia Universidad Católica, Ministro de Salud Jaime Mañalich, Subsecretaria de Redes Asistenciales Giovanna Gutierrez, Rossana Fuentes, Jaime Vidal, and all the wonderful MINSAL employees who hosted us and patiently answered all of our questions.

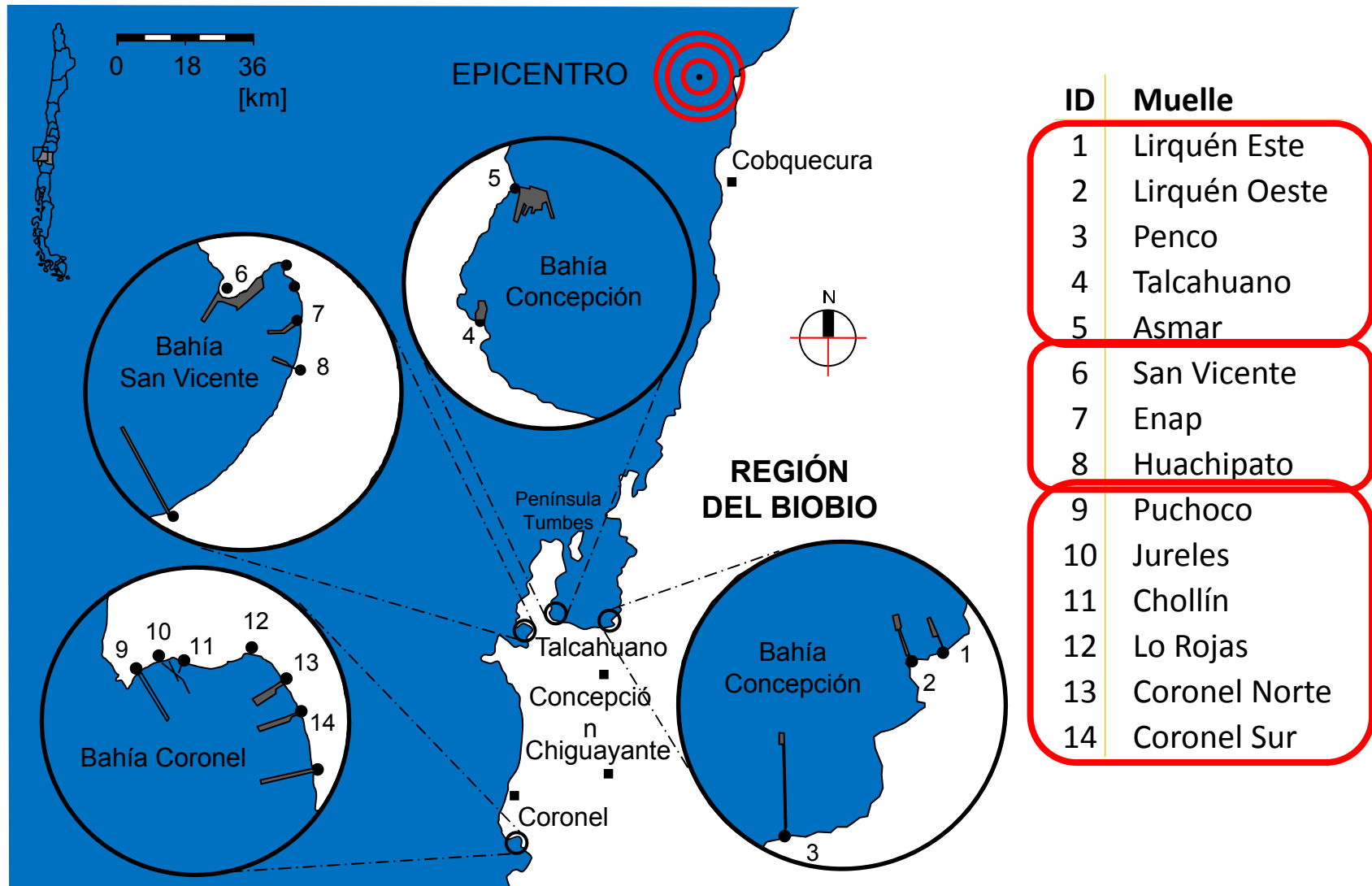


# Seismic response of Ports





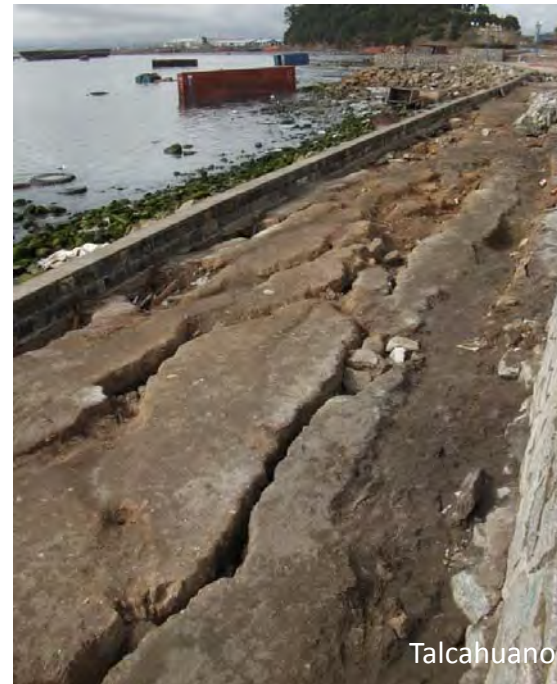
# Port Location



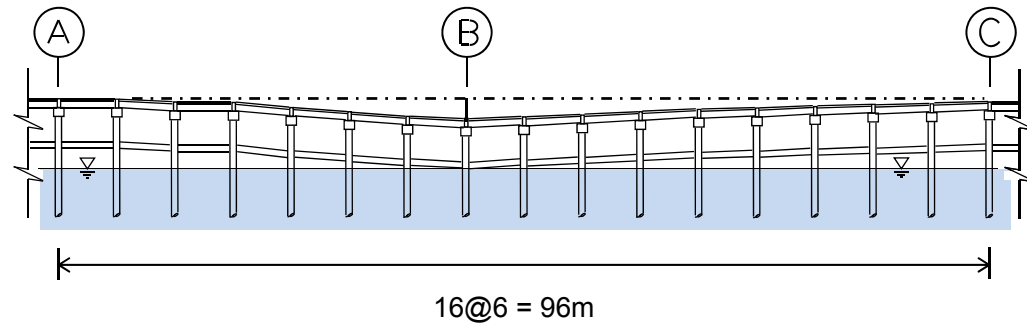
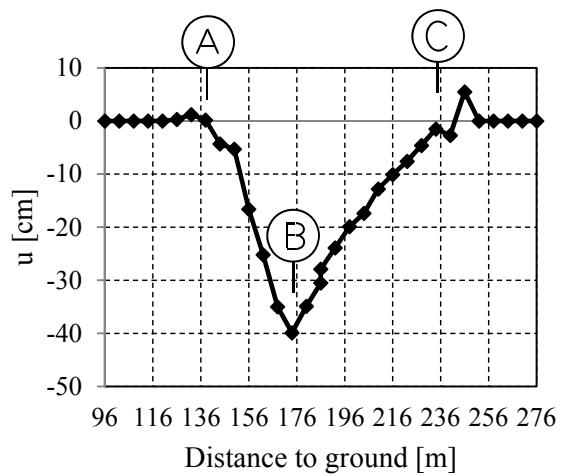
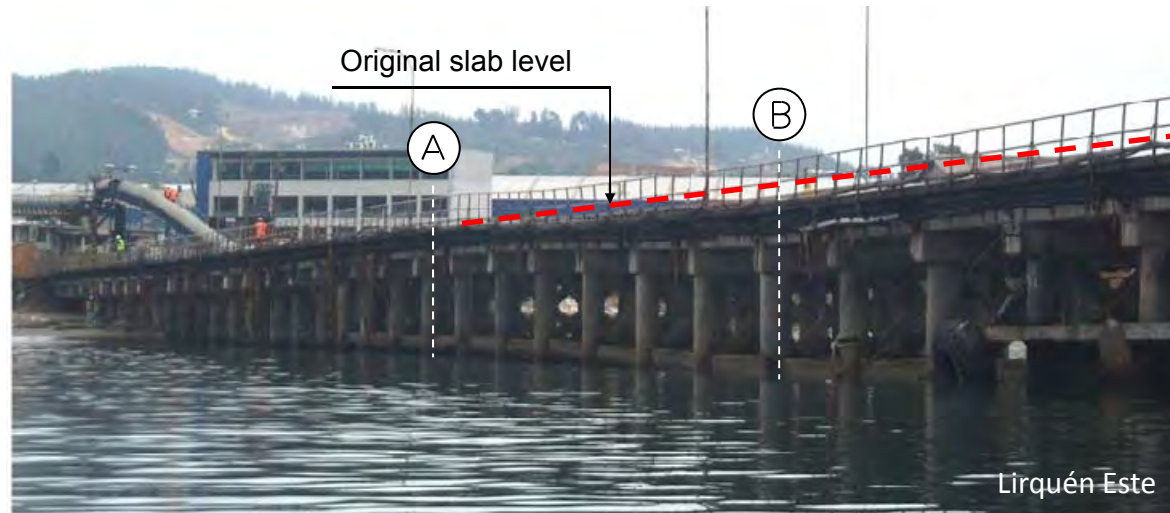
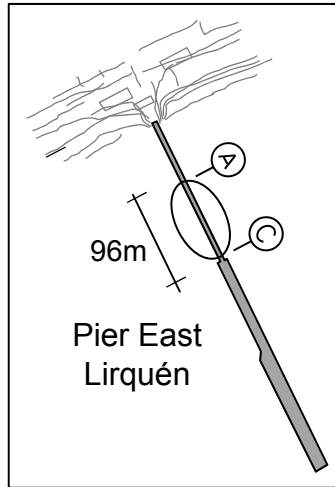


# Liquefaction

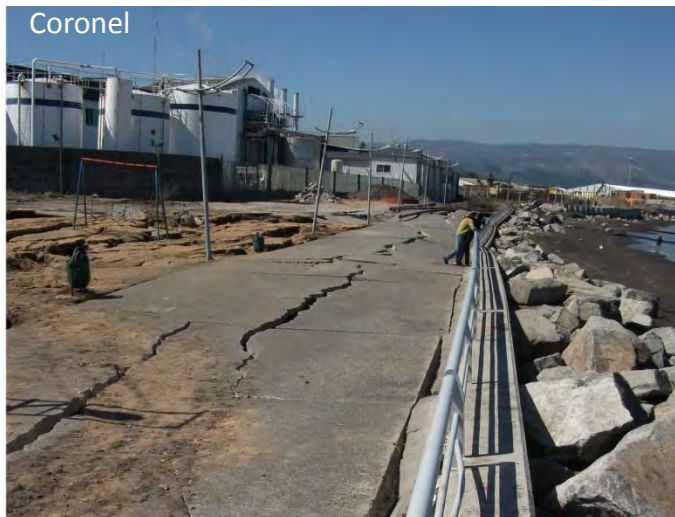
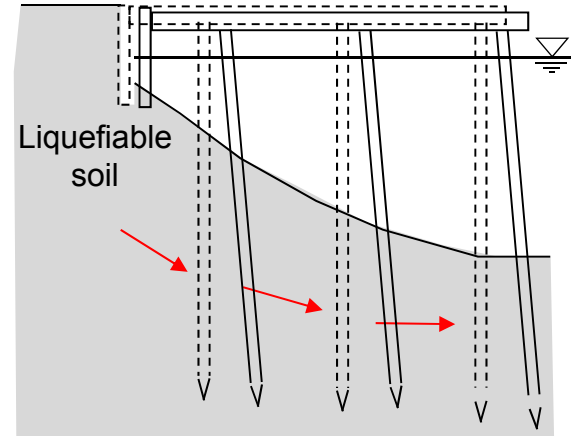
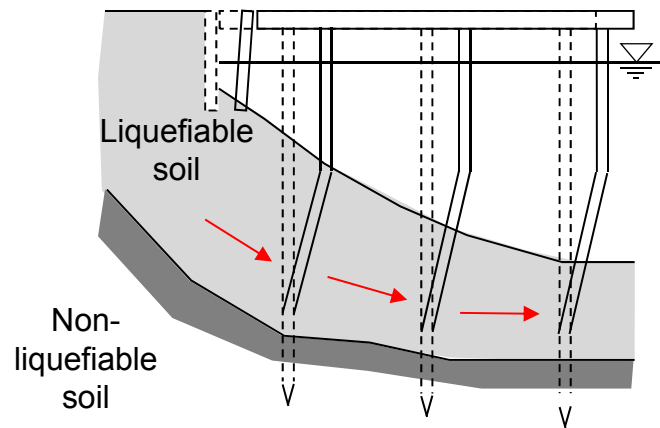
- Saturated and loose sands ( $\sigma_n = \sigma'_n + u_w$ )
- Consequences:
  - Temporary loss of support and stiffness



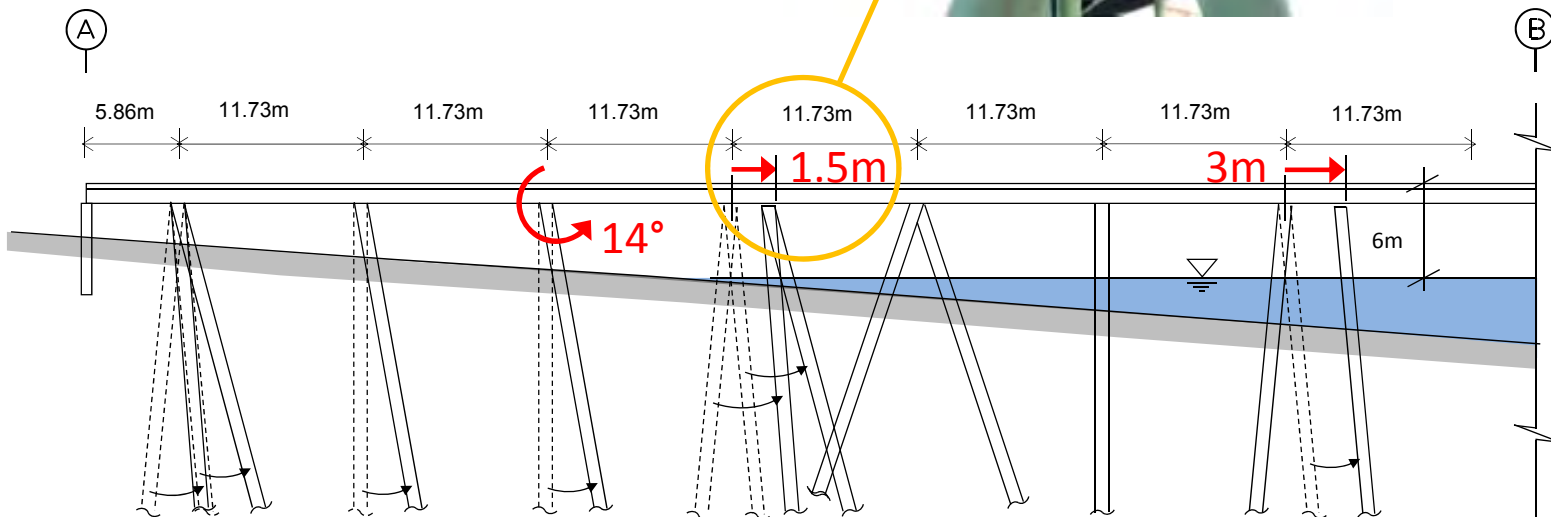
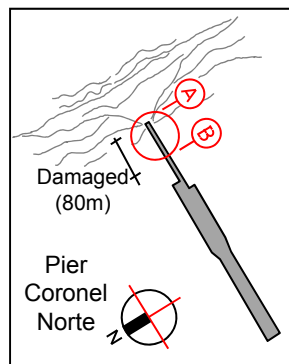
# Permanent settlements



# Lateral spreading



# Drag of foundation systems





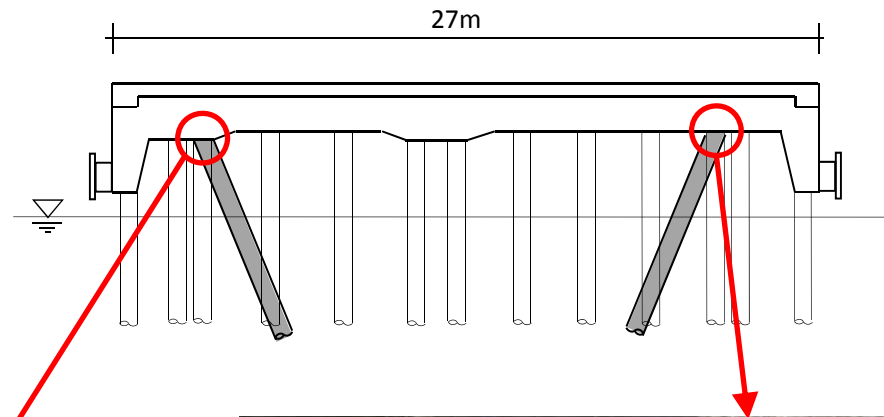
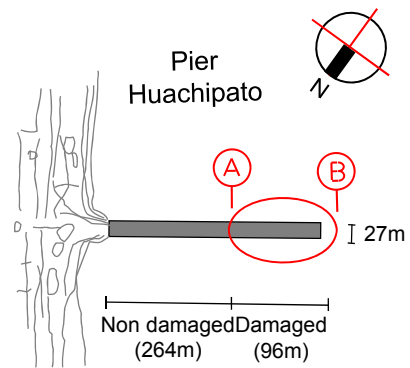
# Beam-pile connection

- Slanted piles are laterally very stiff



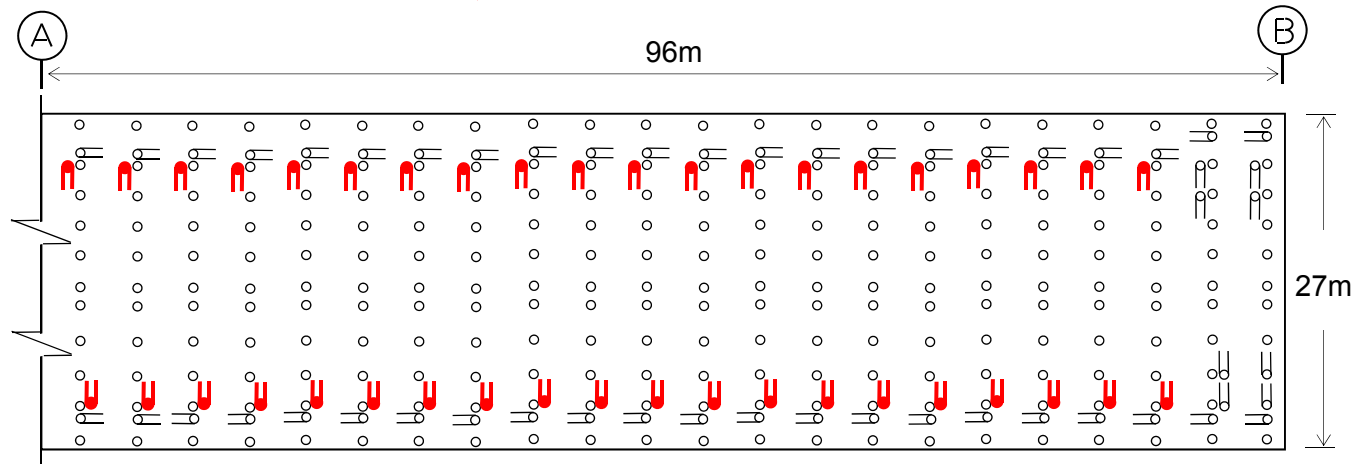
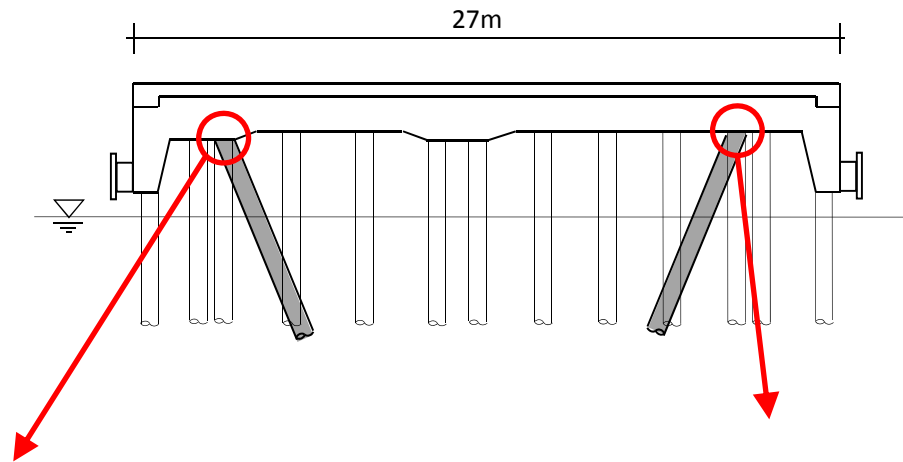
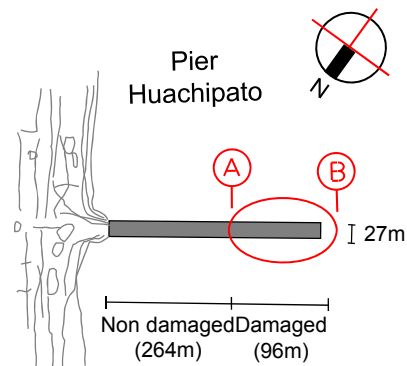


# Torsion





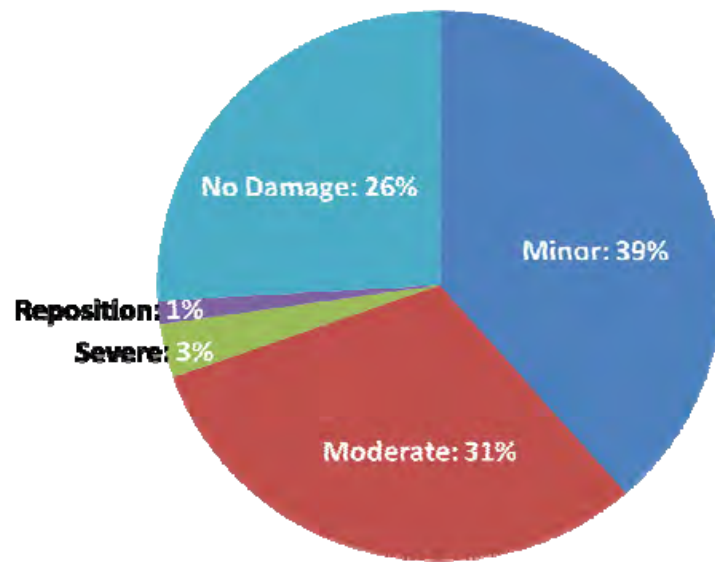
# Torsion





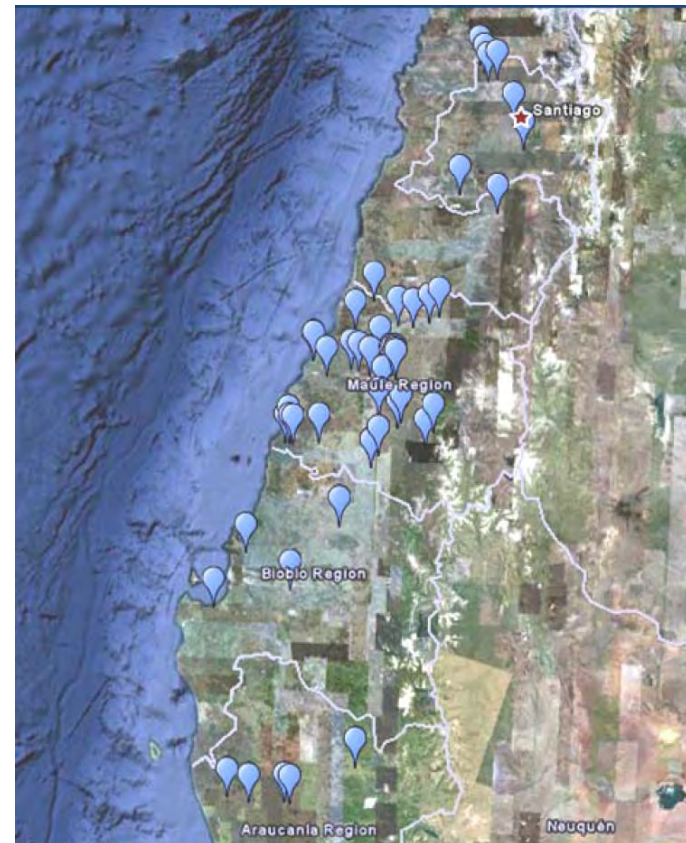
# K-12 Public Schools

## ► State of public schools after the earthquake



- 51 schools
- Structural assessment and retrofit projects

## ► Schools in RESCATE Project







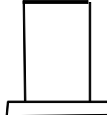
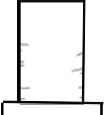

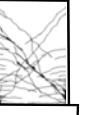

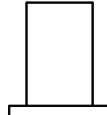

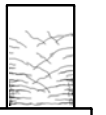


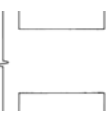
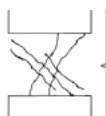
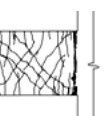
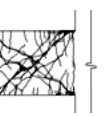

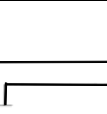
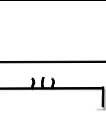
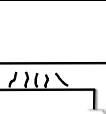
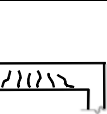
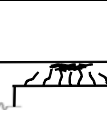
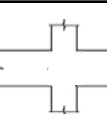
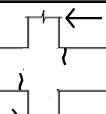
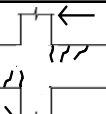
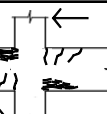

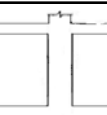
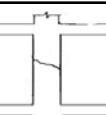
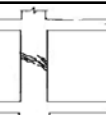
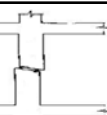

### ► Damage Level in RESCATE Schools

Escuela	Primaria (%)	Secundaria (%)	Terciaria (%)
TOTAL	43.4	38.9	19.7
ESCUELA LA VIRGENILLA	43.4	38.9	19.7
ESCUELA EUGENIO TABLA VALDES	43.4	38.9	19.7
ESCAPILLAN JOSE LUIS LOPEZ CARRASCO	43.4	38.9	19.7
ESCUELA EDUARDO NÚÑEZ FUENZALIDA	43.4	38.9	19.7
ESCUELA CORINTO	43.4	38.9	19.7
ESCUELA SAN ANTONIO	43.4	38.9	19.7
ESCUELA LAS POCILLAS	43.4	38.9	19.7
ESCUELA SAN ALFONSO CANIELLO	43.4	38.9	19.7
ESCUELA EL CULMEN	43.4	38.9	19.7
MAESTRA MAFRESA HORMAZABAL LEFELER	43.4	38.9	19.7
ESCUELA CERRO ALTO JOSE OPAZO DÍAZ	43.4	38.9	19.7
ESCUELA PIADOLETA DE POLPAICO	43.4	38.9	19.7
LICEO INDUSTRIAL A-22 DE SANTIAGO	43.4	38.9	19.7
LICEO HUERTOS FAMILIARES	43.4	38.9	19.7
LICEO MUNICIPAL SABA TRONCOSO TRONCOSO	43.4	38.9	19.7
LICEO TECNICO NERSE MARTI	43.4	38.9	19.7
ESCUELA BÁSICA PUERTAS NEGRAS	43.4	38.9	19.7
ESCUELA LOS LEONES	43.4	38.9	19.7
ESCUELA LA CAPILLA DE PILÉN ALTO	43.4	38.9	19.7
ESCUELA EL TRIGO	43.4	38.9	19.7
ESCUELA MANUEL MONITT	43.4	38.9	19.7
LICEO INDUSTRIAL DE CONCEPCIÓN	43.4	38.9	19.7
ESCUELA LOS BATROS	43.4	38.9	19.7
ESCUELA CHUPALLAR	43.4	38.9	19.7
ESCUELA JOSE MANUEL BALMACEDA	43.4	38.9	19.7
LICEO MARIA LUISA BOMBAL	43.4	38.9	19.7
ESCUELA TRUF-TRUF	43.4	38.9	19.7
ESCUELA PALMAS DE TOCONEY	43.4	38.9	19.7
ESCUELA DANILO SALAS DÍAZ	43.4	38.9	19.7
LICEO INDUSTRIAL PEDRO AGUIRRE CERDA	43.4	38.9	19.7
LICEO RURAL ENRIQUE MACIVER	43.4	38.9	19.7
LICEO TÉCNICO AMELIA COLIBRIS	43.4	38.9	19.7
LICEO POLivalente MANUEL BOGANGÜEZ	43.4	38.9	19.7
ESCUELA BAÑOS DE TAMBAGO	43.4	38.9	19.7
ESCUELA ORILLA DE NABARRO	43.4	38.9	19.7
ESCUELA NIDER OMESGO QUEVEDO	43.4	38.9	19.7
LICEO LUIS EDMUNDO CORREA ROJAS	43.4	38.9	19.7
LICEO INDUSTRIAL C-16 NUEVA IMPERIAL	43.4	38.9	19.7
ESCUELA SANTA RITA	43.4	38.9	19.7
LICEO INDUSTRIAL SUPERIOR	43.4	38.9	19.7
LICEO SAN FELIPE DE ARAUJO	43.4	38.9	19.7
LICEO CONSTITUCIÓN	43.4	38.9	19.7
LICEO POLitécnico C-12 CURACAUTÍN	43.4	38.9	19.7
INSTITUTO INDUSTRIAL SUPERIOR DE CHILLAN	43.4	38.9	19.7
ESCUELA OSVALDO HIRIART CORRALAN	43.4	38.9	19.7
LICEO POLitécnico PEDRO AGUIRRE CERDA	43.4	38.9	19.7
ESCUELA EL LLANO DE CALEU	43.4	38.9	19.7
ESCUELA EL EMBOQUE	43.4	38.9	19.7
ESCUELA BÁSICA	43.4	38.9	19.7
ESCUELA AULAS DE ESPERANZA	43.4	38.9	19.7

■ No damage/ repaired ■ Light/moderate damage ■ Severe damage/ collapse



### ► Structural damage by element

	Sin Daños ✓	Daño Leve ■	Daño Medio ■	Daño Severo ■	Colapso ✗
<b>Elementos Hormigón armado</b>	Fisuras menores a 0,2 mm	Fisuras menores a 0,8 mm	Fisuras menores a 2 mm. No cruzan cabeza de compresión. Desprendimiento recubrimiento	Armaduras a la vista Fisuras menores a 5 mm. Cruzan cabeza de compresión.	Armaduras deformadas Armaduras cortadas Pérdida de hormigón entre armaduras
Muro Hormigón armado Falla corte (Incluye columnas cortas)					
Muro Hormigón armado falla flexocompresión					
Viga Hormigón armado falla corte (vigas de acoplamiento)					
Viga Hormigón armado falla flexo-compresión en el vano (vigas largas)					
Viga Hormigón armado falla flexo-compresión en los apoyos (vigas largas)					
Columna Hormigón armado falla corte					



# Schools

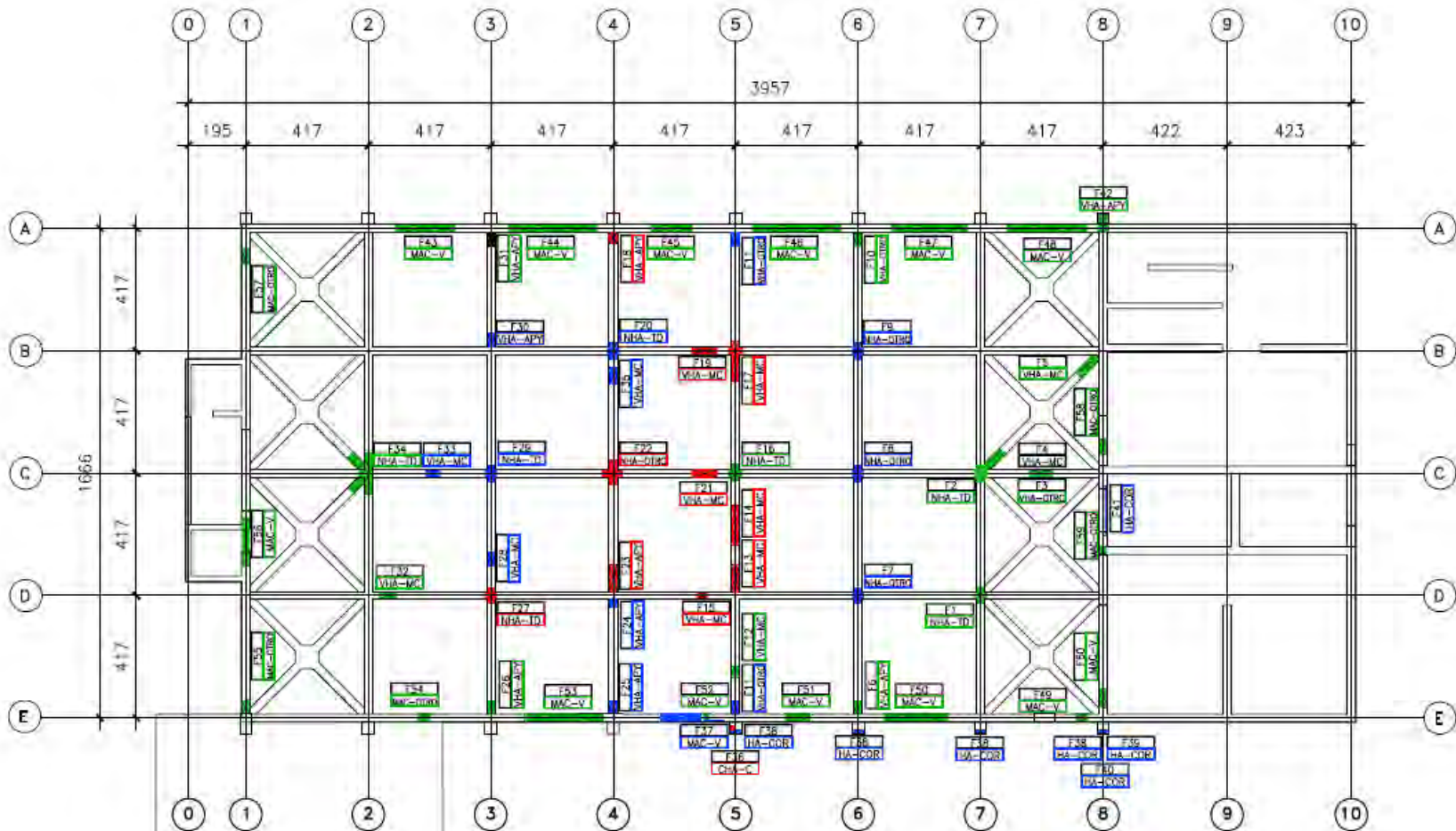
## Detailed inspection

### ► Structural damage by element

Columna Hormigón armado falla compresión					
Nudos Hormigón armado alla tracción diagonal					
Muro Albañilería confinada falla corte					
Muro Albañilería armada falla corte					
Muro Albañilería simple falla corte					
Elemento Hormigón armado falla corrosión					
Falla asentamiento					




### ► Structural damage by element




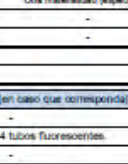


# Schools Detailed inspection

## ► Structural elements

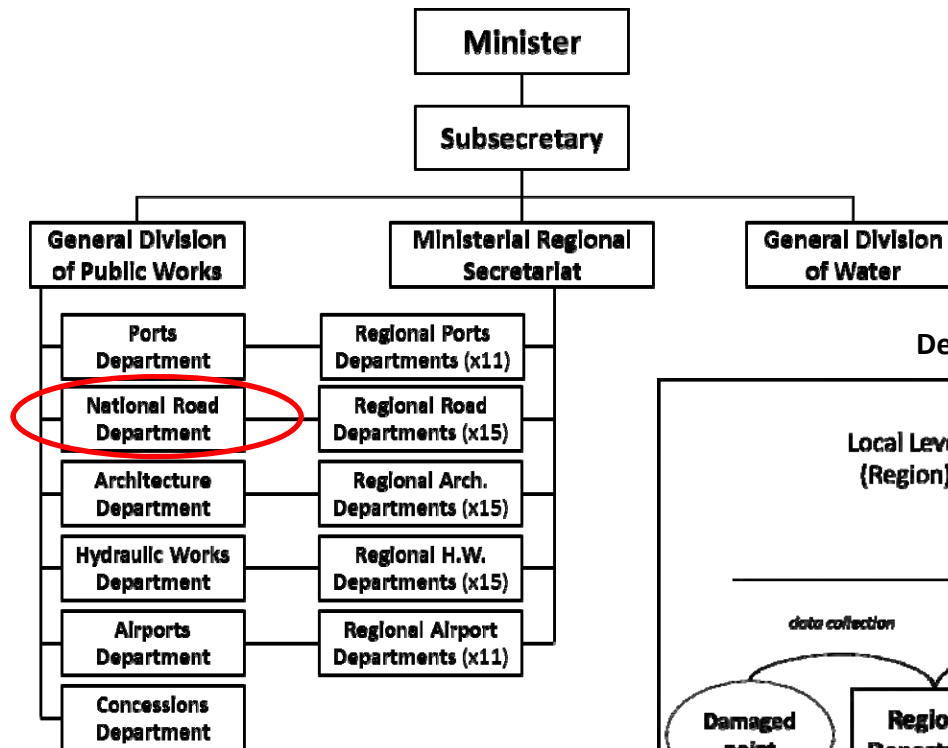
INGENIERÍA DICTUC		FICHA DE INSPECCIÓN ESTRUCTURAL DAÑADO					Cód. Establecimiento:
		3165					
INSPECCIONADO	Ingeniero Responsable	Fecha	Ficha N° / Total	Fotografías			
Nestor Aguirre	Hernán Santa María	21/01/11	5 / 57	6			
ELEMENTO ESTRUCTURAL - MATERIALIDAD - TIPO DE DAÑO	NIVEL DE DAÑO	1 Leve	2 Medio	3 Severo	4 Colapso	Información Adicional	
A Muro H.A. falla corte						¿Existe Fricción?	
B Muro H.A. falla flexocompresión						Ancho Promedio Fisuras:	
C Viga H.A. falla corte						1.2 - 1.7 [mm]	
D Viga H.A. falla flexocompresión						Observaciones Adicionales:	
E Viga H.A. falla flexocompresión en apoyos	X						
F Columna H.A. falla corte							
G Columna H.A. falla compresión							
H Nudo H.A. falla tracción diagonal							
I Losa H.A. falla flexión							
J Muro albañilería confinada falla corte							
K Muro albañilería armada falla corte							
L Muro albañilería simple falla corte							
M Elemento H.A. falla corrosión							
N Falla de asentamiento							
O Otro (especificar):							
	Fración rota en el apoyo	X					
DIMENSIONES Y UBICACIÓN DEL ELEMENTO	Sección L(m) x B(m) / Área losa al(m) x B(m)		Espesor(m)		Plao		
	-		-		Eje N-S		6
	-		-		Eje E-O		E
ARMADURAS DE REFUERZOS (sólo si son visibles):							
Muros		Columnas		Vigas			
Confinamiento Borde		Longitudinal		Longitudinal			
Doble Malla		Estribos		Estribos			
Recubrimiento [cm]		Recubrimiento [cm]		Recubrimiento [cm]			
Trabas		Losas					
Refuerzo Vertical (en A.A.)		Malla inferior		Malla Superior			
Escalerías		Recubrimiento [cm]		Recubrimiento [cm]			
FOTOGRAFÍAS ELEMENTO ESTRUCTURAL DAÑADO							
							
Fotografía 6							

## ► Non Structural elements

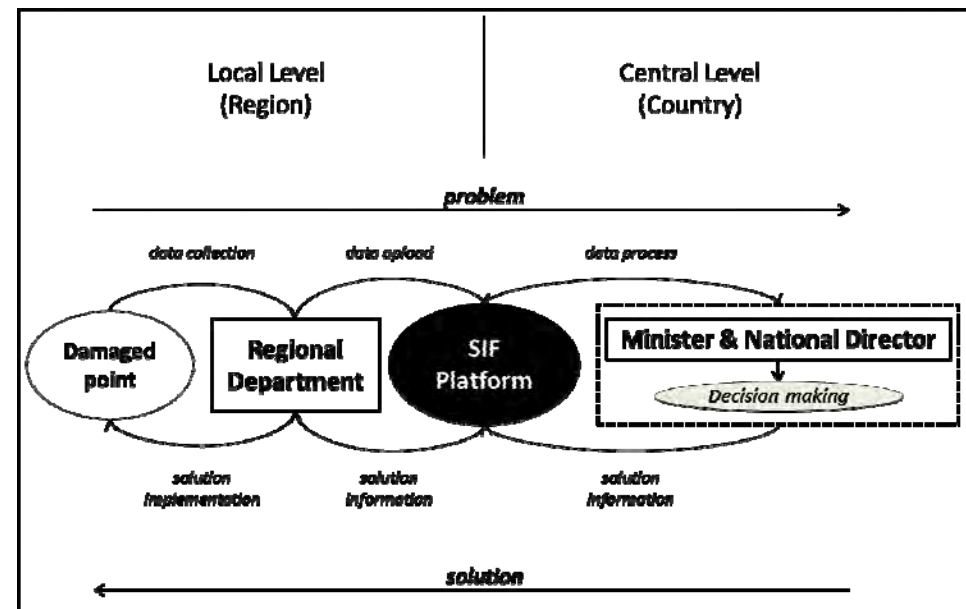
INGENIERÍA DICTUC		FICHA DE INSPECCIÓN POR RECINTO ELEMENTOS NO ESTRUCTURALES DAÑADOS					Cód. Establecimiento:	
		10432						
INSPECCIONADO	Ingeniero Responsable	Fecha	Ficha N°					
Pablo Fernández	Matías Hube	28/01/2011	2 / 36					
RECINTO	Piso	1	Otras indicaciones (si corresponde):					
Pabellón A - Sala 3	Ejes N-S	1.3 - 1.4						
	Ejes E-O	1.A - 1.B						
DAÑOS EN ELEMENTOS HORIZONTALES								
Descripción	Materialidad	Patología	Nivel de daño	Otra materialidad (especificar)		Fotografías		
Cielo	P.Y.C.	-	-	-		0300		
Pavimento	CER	-	-	-		0301		
DAÑOS EN ELEMENTOS VERTICALES (se toman fotografías generales y de detalles por cada cara del recinto). SE MUESTRA UNA FOTOGRAFÍA POR CADA CARA DEL RECINTO. Para mayor detalle consultar ficha digital.								
Descripción	Materialidad	Patología	Nivel de daño	Otra materialidad (especificar)				
Elemento vertical	H.A.	-	-	-				
Revestimiento	PN	-	-	-				
Altura revestimiento	3 [m]	N° puertas	0	Daño				
Fotografías:	0303 a 0304	N° vent.	0	Daño				
 								
 								
 								
Descripción	Materialidad	Patología	Nivel de daño	Otra materialidad (especificar)				
Elemento vertical	H.A.	-	-	-				
Revestimiento	PN	-	-	-				
Altura revestimiento	3 [m]	N° puertas	0	Daño				
Fotografías:	0307 a 0309	N° vent.	0	Daño				
INSTALACIONES								
¿En funcionamiento?	Descripción del daño (en caso que corresponda)						Fotografías	
Agua	-	-						-
Electricidad	Si	Enlucido 4 de 14 tubos fluorescentes						-
Gas	-	-						-
Alcantarillado	-	-						-



## Ministry of Public Work



## Decision making process







# Underpass damage infrastructure

## Damage Levels

- DL-1: No damage
- DL-2: Low damage that required minimum or no repair
- DL-3: Damage that required repair
- DL-4: Collapse

## Bridge Damage Level



## Girder Damage Level





# Road Network

## Public infrastructure

### ► Failure and solution process Llacolén Bridge, BíoBío Region





# Road Network

## Public-private partnership model

### ► Failure and solution process Claro River bridge

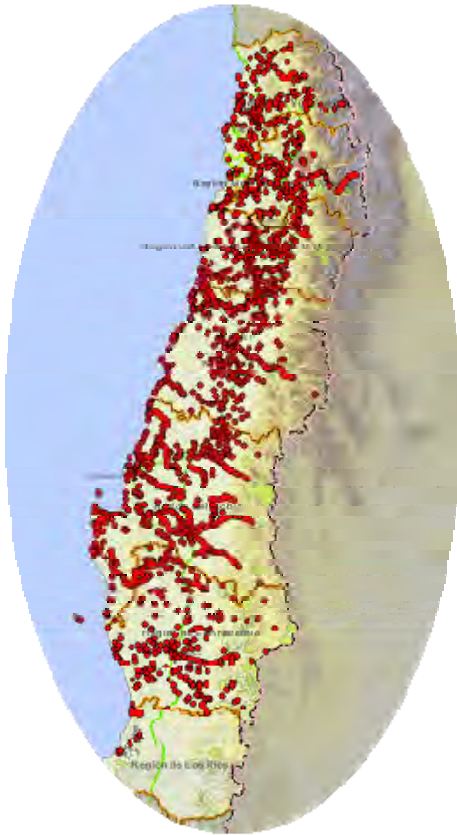




# Road Network

## Sif platform

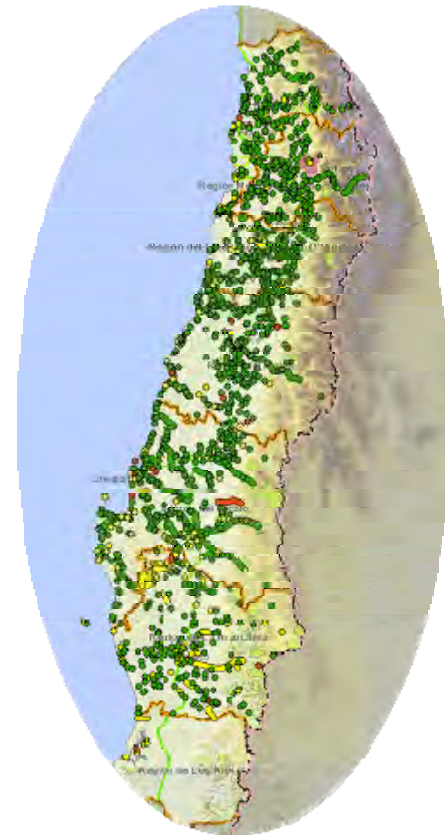
► February 2010



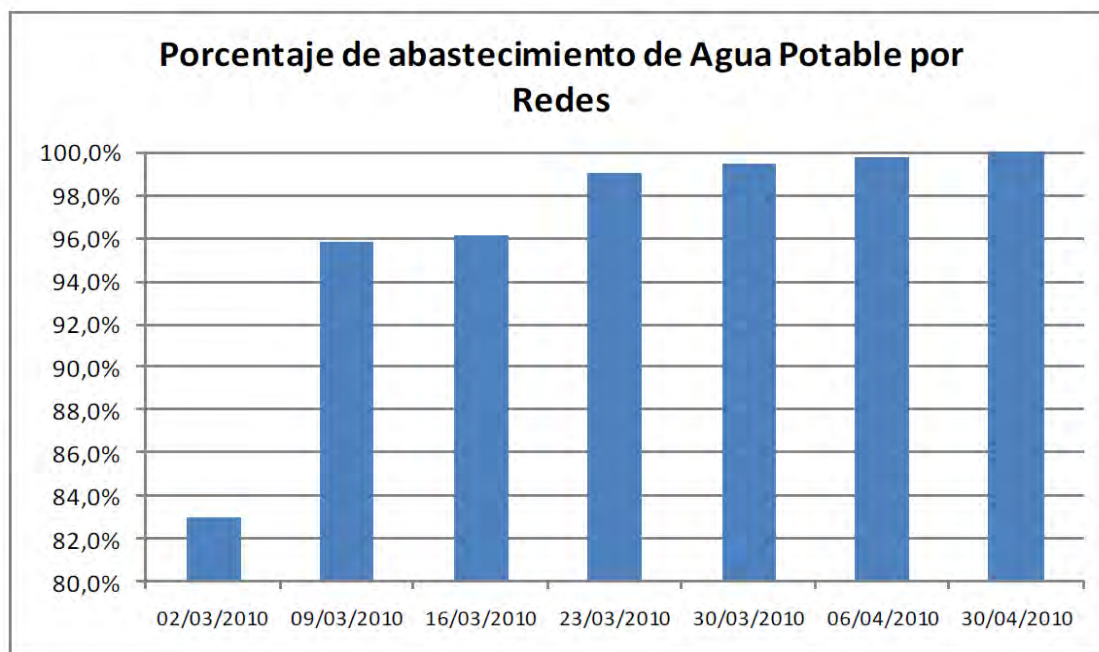
► March 2010



► August 2010



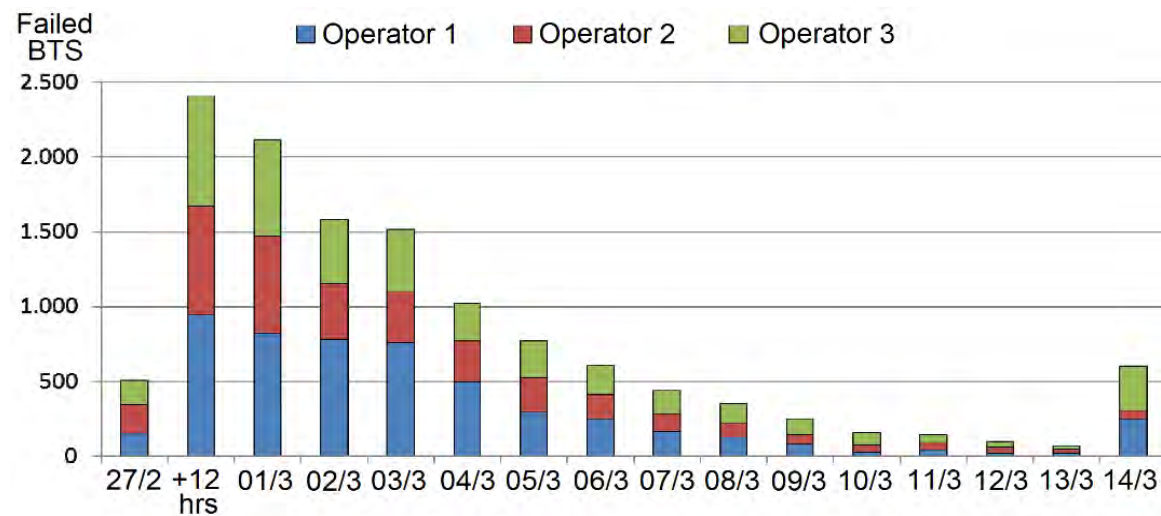
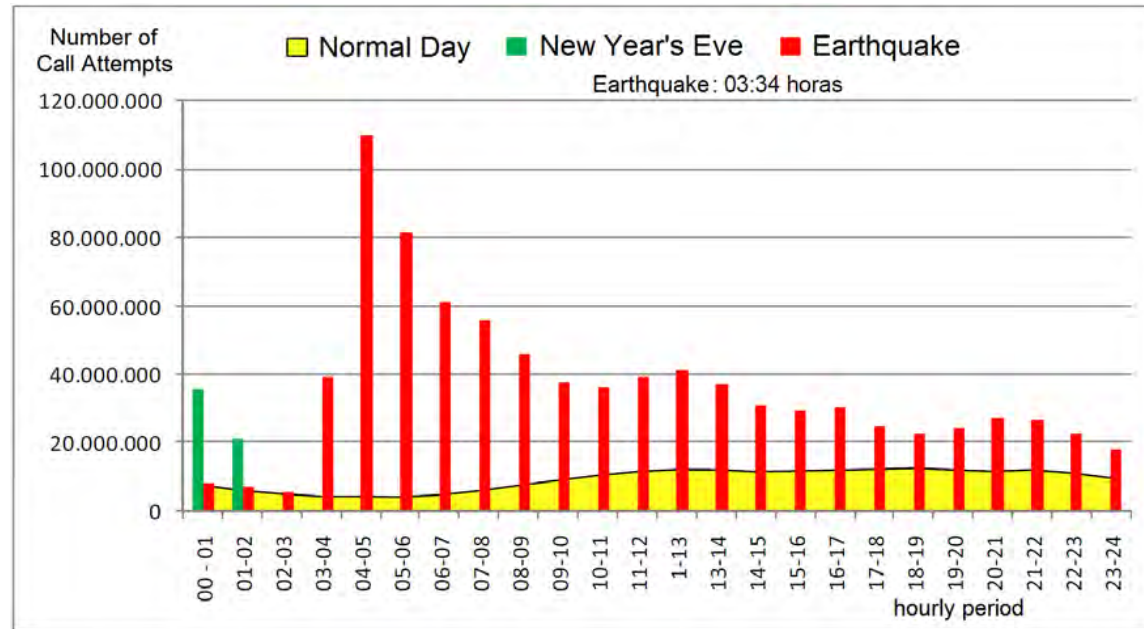


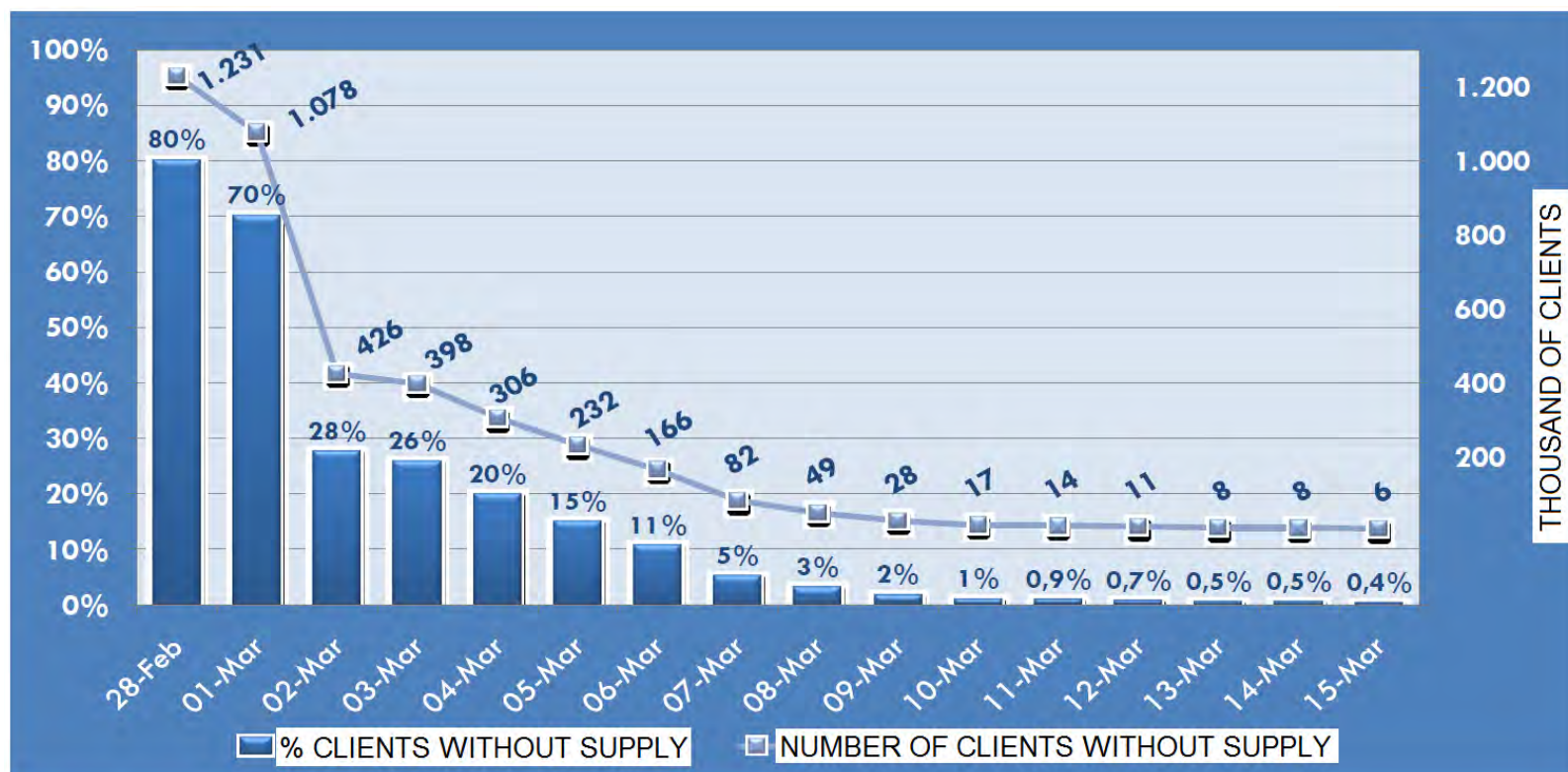


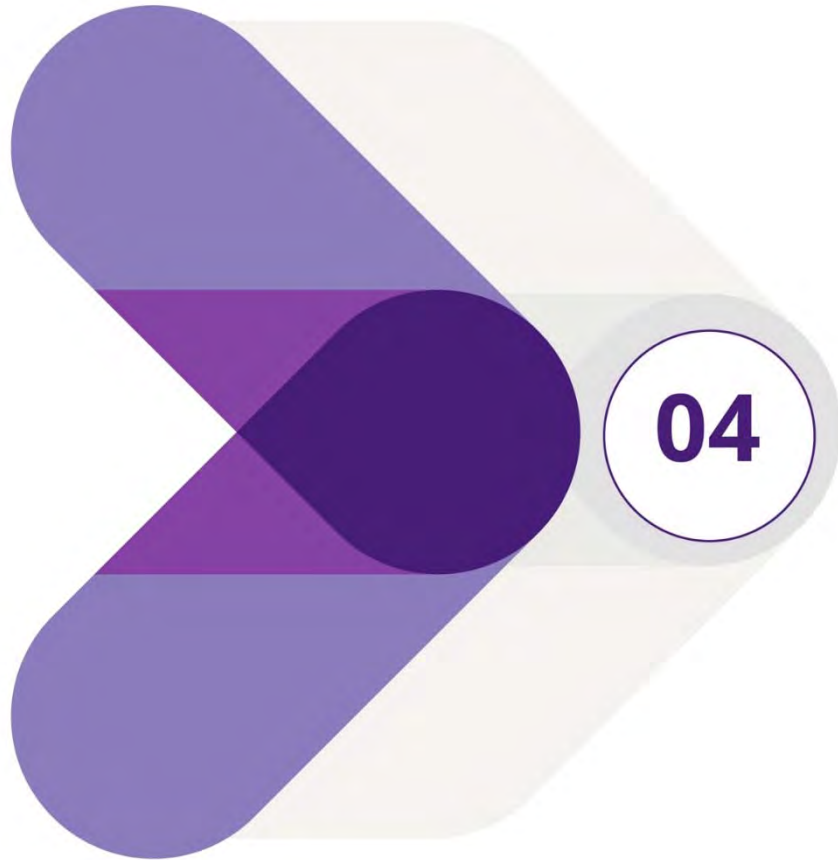




# Communication system



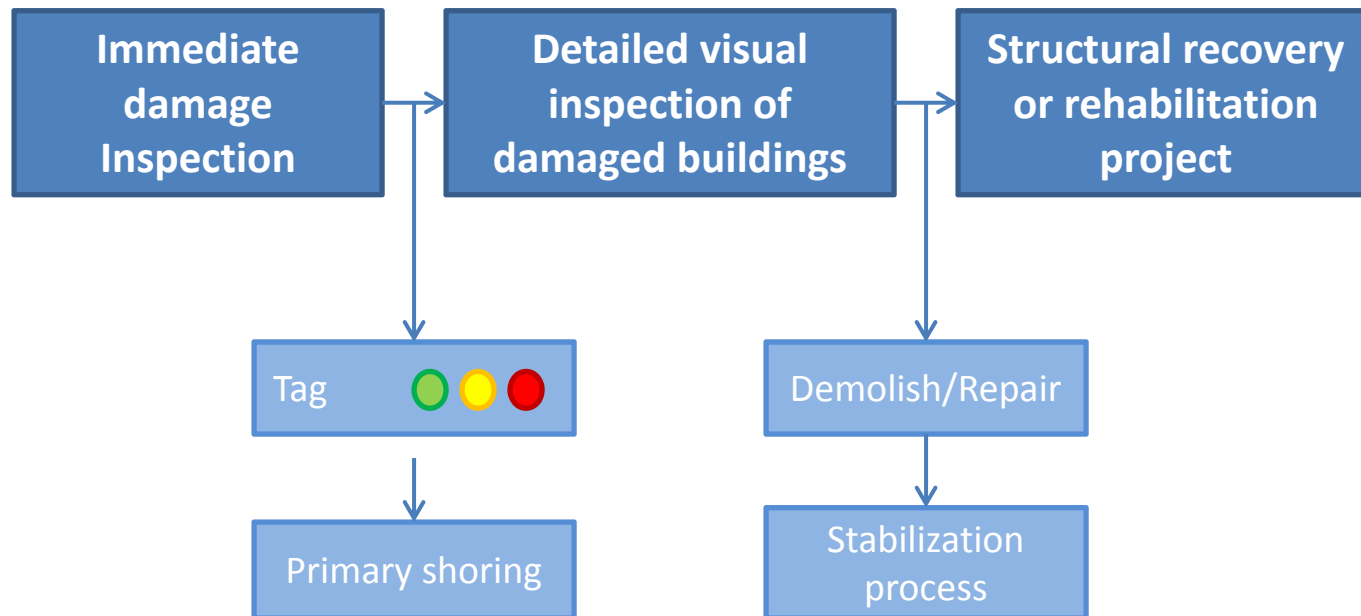




## **BUILDING DATA**



# Data Collection process





# Data

## Collection process

Type of Inspection	Immediate damage Inspection	Detailed visual inspection of damaged buildings	Structural recovery or rehabilitation project
<b>Stakeholder</b>	Community/owners/local government/constructors	Owners/constructors/local government	Owners/central government
<b>Objective</b>	Define basic security conditions of housing units: habitable/non-habitable/collapse risk	Analyze the current status of damaged buildings and decide repair or demolition	Feasibility study for repair or recovery of damaged buildings
<b>What?</b>	Global building situation/general building data/photographs	Building damage information/detailed building data (drawings, soil mechanic reports, etc.)	Detailed damage information by element/ laboratory tests
<b>Who?</b>	NGO's/volunteers/students/professionals	Professionals/academics	Professionals/academics
<b>How?</b>	Different damage inspection reports/non pre-established plan/ on site decisions	Inspection protocols for global damage survey/ internal strategies	Detailed survey of damaged elements/ instrumental measurements

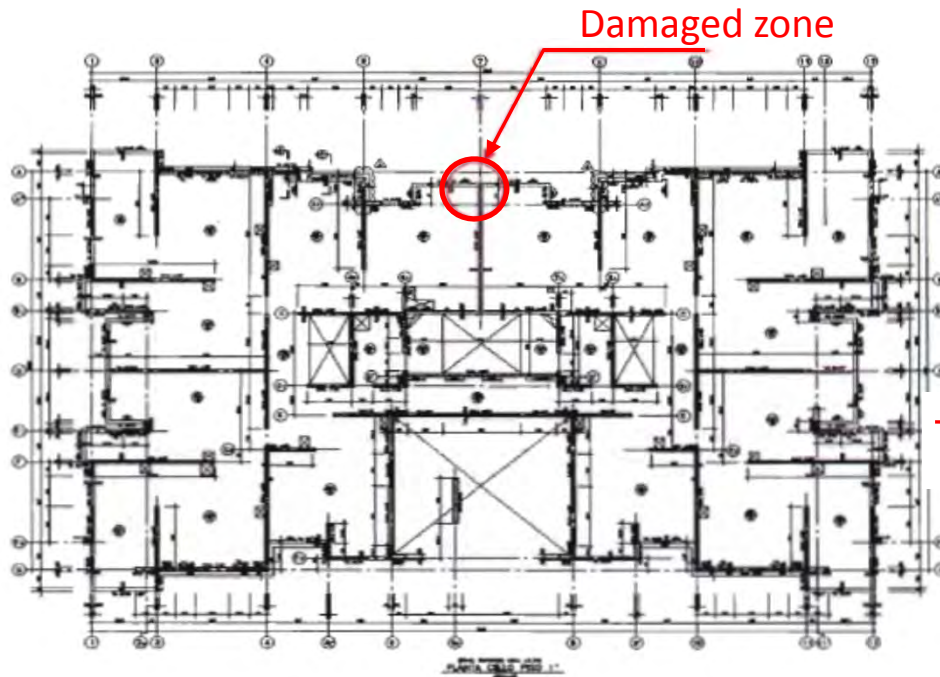




# Damage inspection in Santiago

## Local engineering offices

Type of information collected by local offices



Missing stirrups  
according to drawings



Horizontal steel  
mesh missing  
according to  
drawings





# Immediate damage inspections



FORMULARIO NÚMERO

División Ingeniería Estructural y Geotécnica

Área Ingeniería Estructural

Formulario de Evaluación de Intensidad de Daños -Rev. 0

## FORMULARIO DE EVALUACION DE INTENSIDAD DE DAÑOS ESTRUCTURALES TRAS SISMO.

### ► Damage Inspection form

<b>UBICACIÓN:</b> Dirección _____ Comuna _____ Ciudad _____		<b>FORMULARIO NÚMERO</b> _____ <b>Inspección de la Edificación</b> Exteriores e interiores <input type="checkbox"/> Solo exteriores <input type="checkbox"/> Solo interior <input type="checkbox"/> <b>CLASIFICACIÓN DE HABITABILIDAD</b> Verde <input type="checkbox"/> Amarillo <input type="checkbox"/> Naranja <input type="checkbox"/> Rojo <input type="checkbox"/>	
<b>IDENTIFICACIÓN DE LA EDIFICACIÓN</b> <b>NOMBRE EDIFICACIÓN</b> _____ <b>Uso predominante:</b> 1. Residencial 2. Comercial 3. Educativo 4. Salud 5. Hotelero 6. Institucional 7. Industrial 8. Oficinas 9. Bodegas 10. Estacionamientos 11. Otros <b>De la edificación</b> _____ <b>De la planta baja</b> _____ <b>Número de pisos:</b> Niveles sobre el terreno _____ <b>Total</b> _____ Subterráneos _____ <b>Dimensiones Aproximadas</b> <b>en Planta:</b> <b>Exteriores</b> Frente (m) _____ Fondo (m) _____ <b>Superestructura</b> Frente (m) _____ Fondo (m) _____		<b>DESCRIPCIÓN DE LA ESTRUCTURA</b> <b>Sistema estructural</b> Hormigón Armado Sistema de Muros <input type="checkbox"/> Prefabricados <input type="checkbox"/> Sistema de Vigas <input type="checkbox"/> Sistemas Mixtos <input type="checkbox"/> Alberilera Armada <input type="checkbox"/> Cerámica <input type="checkbox"/> Confinada <input type="checkbox"/> No armada <input type="checkbox"/> Falso <input type="checkbox"/> <b>Acero</b> Pórticos Armados <input type="checkbox"/> Pórticos no Armados <input type="checkbox"/> Mixto <input type="checkbox"/> Soldado <input type="checkbox"/> Apertado <input type="checkbox"/> <b>Madera</b> Pórticos y paneles en madera <input type="checkbox"/> Pórticos en madera y paneles en otro material <input type="checkbox"/> <b>Observaciones:</b> _____	
<b>ANTIQUEDAD DE LA ESTRUCTURA</b> <b>Año de recepción de la estructura (aprox.)</b> _____ <b>Reparaciones</b> Si <input type="checkbox"/> No <input type="checkbox"/> <b>Detalle:</b> _____ _____ _____ <b>El nivel de daño en comparación al terremoto de 1985 fue:</b> Menor <input type="checkbox"/> Igual <input type="checkbox"/> Mayor <input type="checkbox"/> N/A <input type="checkbox"/>		<b>Sistema de Piso</b> Hormigón Armado Losa <input type="checkbox"/> Maciza <input type="checkbox"/> Aligerada <input type="checkbox"/> Celular Modular <input type="checkbox"/> Vigas <input type="checkbox"/> <b>Acero</b> Placas <b>Calceolapatas</b> (Steel Deck) <input type="checkbox"/> Vigas de Sección Iera <input type="checkbox"/> Vigas Reticuladas <input type="checkbox"/> <b>Madera</b> Vigas <input type="checkbox"/> <b>Otro:</b> _____	
<b>ESTADO DE LA EDIFICACIÓN</b> <b>Estado general de la Edificación</b> Revisar la edificación en forma global y detallar las observaciones necesarias en la sección de comentarios. 1. Existe colapso 1. No 2. Parcial 3. Total 2. Desviación o inclinación de la edificación o de algún entrepiso 1. Si 2. No 3. No se pudo determinar 3. Faltas o asentamiento de la cimentación 1. Si 2. No 3. No se pudo determinar 4. Faltas en soporte o conservación de estribos 1. No 2. Parcial 3. Total 5. Faltas en cabezales de muros 1. No 2. Parcial 3. Total <b>Problemas Geotécnicos</b> 4. Faltas en talud o movimiento en masa 1. No 2. Puntos 3. General 5. Asentamiento circundante o licuación 1. No 2. Puntos 3. General		<b>Sistema de Techo</b> Losas de Hormigón Armado <input type="checkbox"/> Cerchas de Acero <input type="checkbox"/> Cerchas de Madera <input type="checkbox"/> Placa Fibrocemento <input type="checkbox"/> Tejado (cemento o cerámica) <input type="checkbox"/> Placa Zinc Alum <input type="checkbox"/> Placas de OBS <input type="checkbox"/> Entablado Artesanal <input type="checkbox"/> Placa estética <input type="checkbox"/> Otro: _____ <b>Sistema de Tabiquería</b> Placas de Fibrocemento <input type="checkbox"/> Placas de Yeso Cortón <input type="checkbox"/> Hormigón celular <input type="checkbox"/> Placas de OBS <input type="checkbox"/> Placas UDF <input type="checkbox"/> <b>Calceolapatas</b> <input type="checkbox"/> Hormigón con <b>calceolapatas</b> <input type="checkbox"/> Otro: _____ <b>Marcos Soportante de Madera</b> <input type="checkbox"/> <b>Marcos Soportante de Aluminio</b> <input type="checkbox"/> <b>Otro:</b> _____ <b>Revestimiento Exterior Adicional</b> Chapa ladrillo cerámica <input type="checkbox"/> Muro Cortina <input type="checkbox"/> Estuco (normal o arquitectónico) <input type="checkbox"/> Otro: _____ Membrante <input type="checkbox"/>	



# Damage inspections

## Engineering offices experience

### ► Damage inspection form

**PROTEGE**  
Red de asistencia técnica  
GUBERNACIÓN DEL EDO. A  
FOLIO 00000000000000000000

**FICHA TÉCNICA DE DAÑOS - HABITACIONAL**

**1.- IDENTIFICACIÓN PROPIEDAD.**

DIRECCIÓN:

COMUNA: FECHA:

**2.- TIPOLOGÍAS**

VIVIENDA: EDIFICIO: OTRO:

Nº PISOS: Nº PISOS: Nº PISOS:

TIPO AGRUPACIÓN:

ASLADO: PAREADO: CONTINUO:

TIPO VIVIENDA:

SERVIU: PRIVADO: OTRO:

AÑO EDIFICACIÓN APROXIMADO:

**3.- SISTEMA CONSTRUCTIVO**

ALBAÑILERÍA ARMADA: ALBAÑILERÍA REFORZADA: HORMIGÓN ARMADO: ADOBE: MADERA: OTROS:

**4.- DAÑOS APRECIADOS ESTRUCTURA PRINCIPAL Y TERMINACIONES**

ESTRUCTURAS	SI	NO	SI	NO	SI	NO
CIMENTOS/SOBRECIMENTOS			MURO MEDIANERO		LOSAS HORMIGÓN ARMADO	
RADIERES			MURO EXTERIOR/DESLINDES		ENTRAMADOS HORIZONTALES	
MURO ALBAÑILERÍA ARMADA			ANTEPECHOS		ESTRUCTURA TECHUMBRE	
MURO ALBAÑILERÍA REFORZADA			CADENAS/VIGAS		FRONTONES - ANTEPECHOS	
MURO HORMIGÓN ARMADO			PILARES		SUBTERRANEO ESTACIONAMIENTO	
TERMINACIONES	SI	NO	SI	NO	SI	NO
PAVIMENTOS INTERIORES			TERRAZA/BALCON/BARANDA		CIELOS	
TABICERÍAS INTERIORES			ESCALERAS INTERIORES		CANALES	
MARCOS Y PUERTAS EXTERIORES			ESCALERAS EXTERIORES		ASCENSORES	
MARCOS Y PUERTAS INTERIORES			CUBIERTA		COFA DE AGUA O ESTANQUE	
MARCOS Y VENTANAS			ALEROS			

SI = PRESENTA DAÑO VISIBLE; NO=NO PRESENTA DAÑO VISIBLE

**5.- DAÑOS APRECIADOS INSTALACIONES.**

INST. REDES	SI	NO	SI	NO	ARTEFACTOS	SI	NO	SI	NO
AGUA POTABLE			ELECTRICIDAD		SANITARIOS			CALEFON	
ALCANTARILL.			GAS		ELECTRICOS			NICHOS GAS	

**6.- HABITABILIDAD.**

HABITABLE: NO HABITABLE: COLAPSO PARCIAL: COLAPSO TOTAL:

**7.- OTRAS CONSIDERACIONES U OBSERVACIONES.**

NOMBRE REVISOR: NOMBRE PROPIETARIO:

FIRMA: FIRMA:

### ► Damage register symbol

**TIPO ELEM.:** MURO (M)  
VIGA (V)  
LOSA (L)  
PILAR (P)  
TABIQUE (T)

**GRADO:** SUPERFICIAL (1)  
(del daño) MEDIO (2)  
PROFUNDO (3)

**ORIGEN:** CORTE (S)  
FISURA FLEXIÓN (F)  
COMPRESIÓN (C)

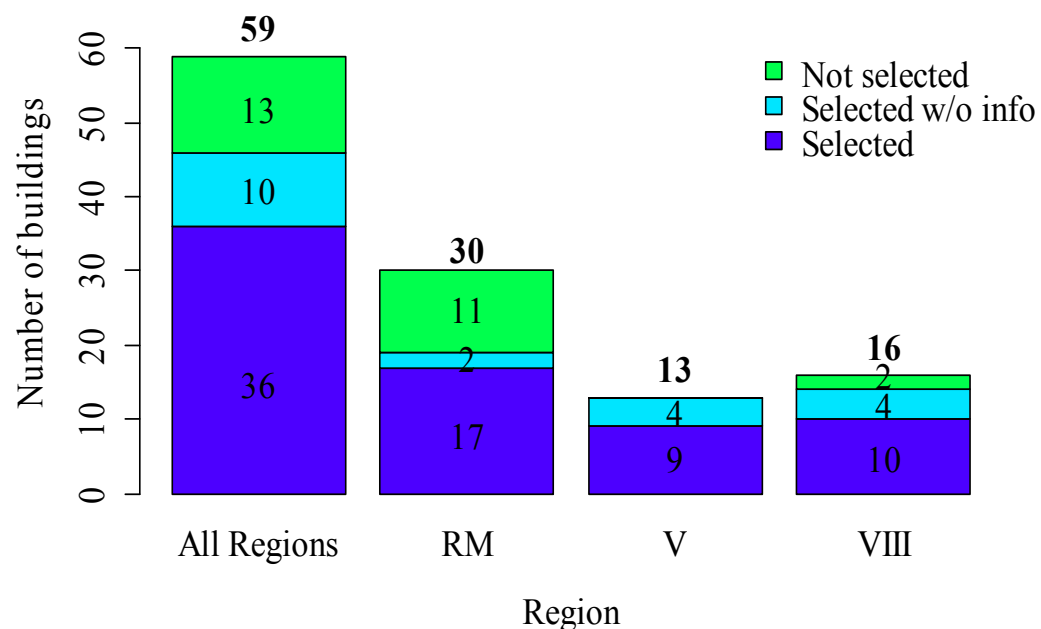
**DAÑO:** REVESTIMIENTO (R)  
DESPRENDIMIENTO (D)

**Nº:** NÚMERO CORRELATIVO

TIPO ELEM. | GRADO  
ORIGEN FISURA | DAÑO (Nº)



# Damaged building inventory



---

## General Information

---

1. Location
  2. Year of construction
  3. Number of stories
  4. Structural system
  5. Main occupancy
- 

## Damage information

---

1. Level of damage
  2. Damage report
  3. Photos
  4. Video
- 

## Documents and professionals

---

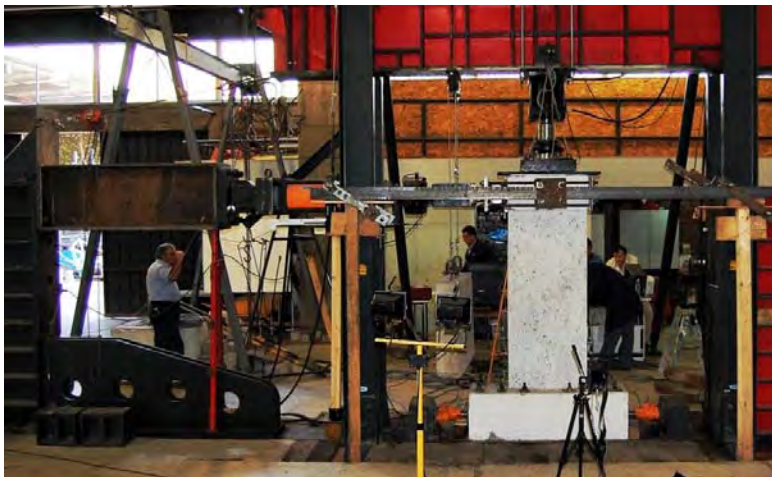
1. Documents
    - Soil mechanics
    - Structural drawings
    - Calculation report
    - Structural model
    - Architectural drawings
    - Construction documents
  2. Project Managers
    - Real Estate
    - Construction company
    - Engineering company
    - Architect
    - Structural reviewer
-



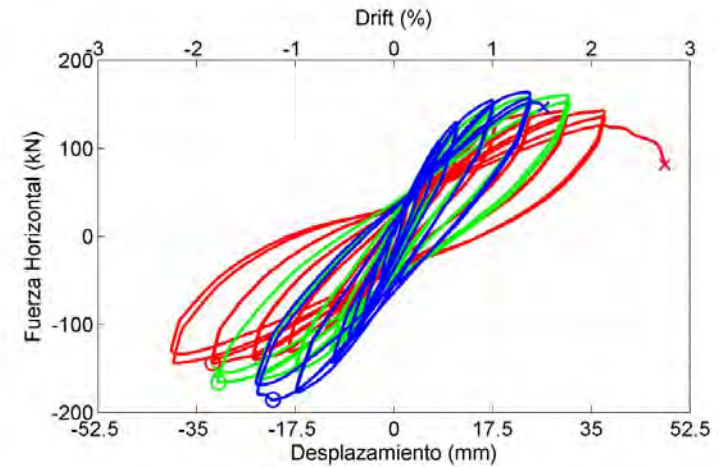


# Damaged RC walls

## Experimental and modeling



RC Wall Test



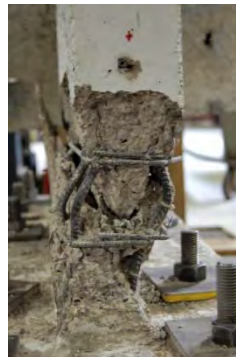
Force-Deformation relationship



W1



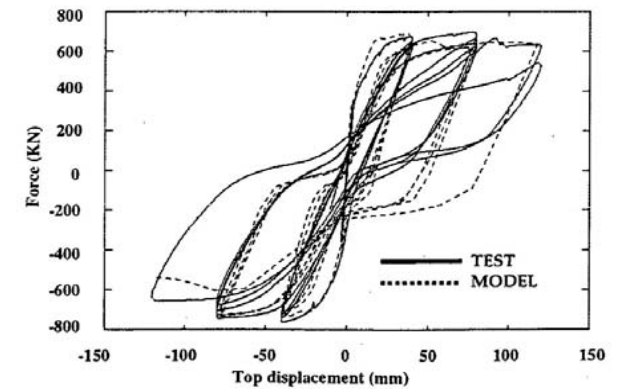
W2



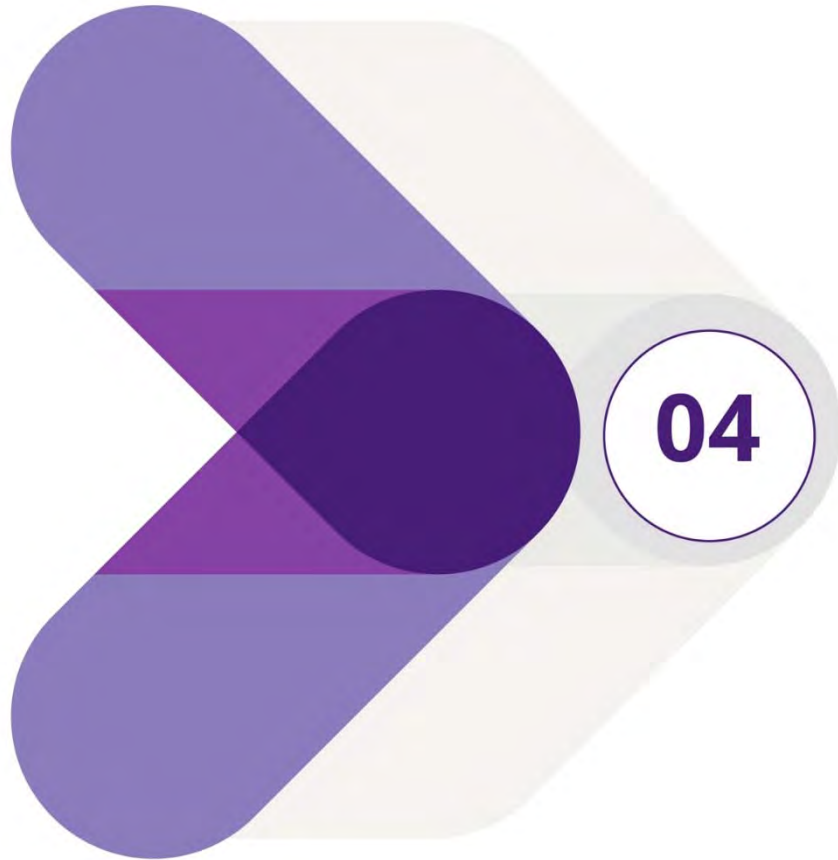
W3



2010 EQ



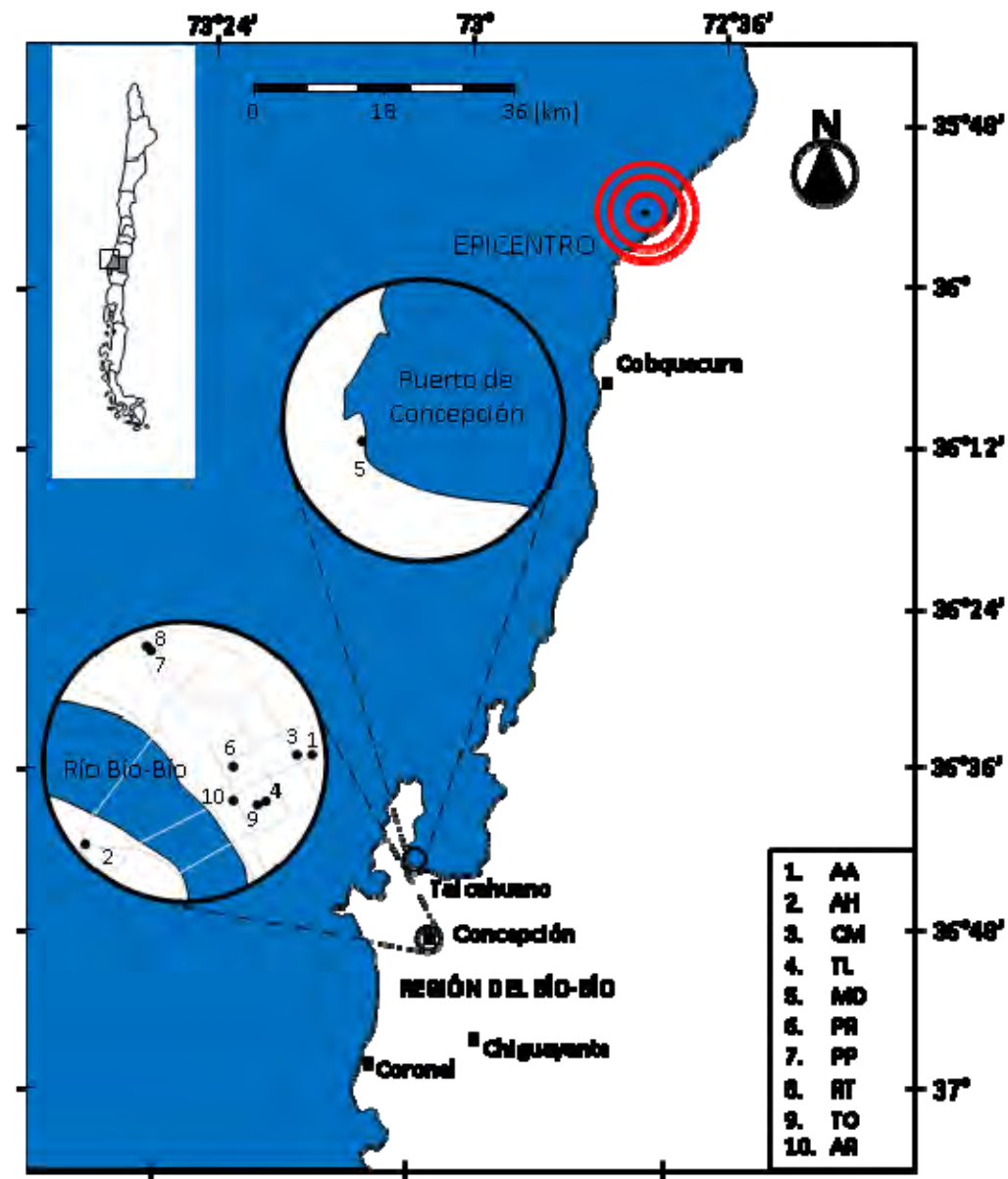




## **EXAMPLE: CONCEPCION**



# Concepcion buildings location





## **Trends in observed behavior**

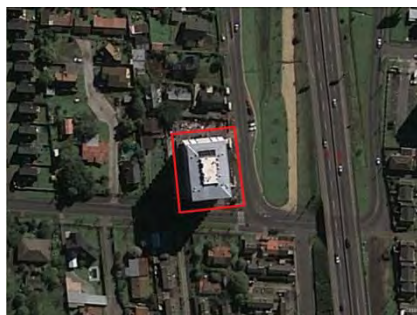
- **Orientation of buildings**
- **Plan and height irregularities**
- **Structural detailing and constructive errors**
- **Multi-story damage**
- **Sources of energy dissipation**



# Orientation of buildings



AA-1



AH-2



CM-3



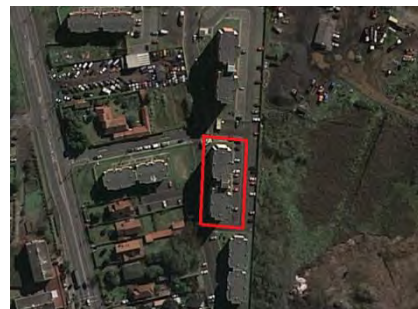
TL-4



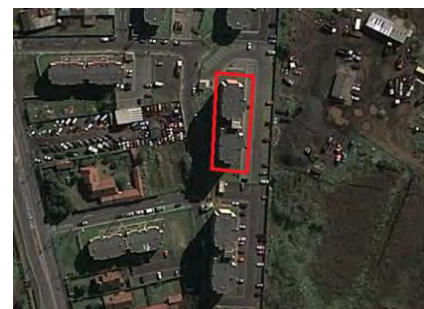
MD-5



PR-6



PP-7



RT-8



TO-9



AR (before)



AR (after)

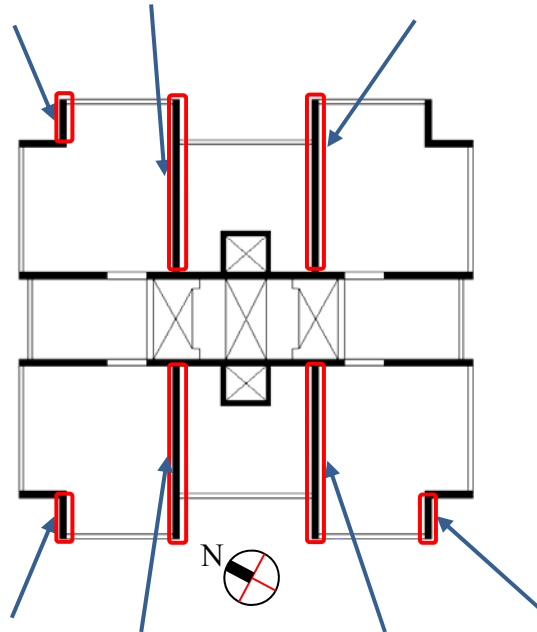




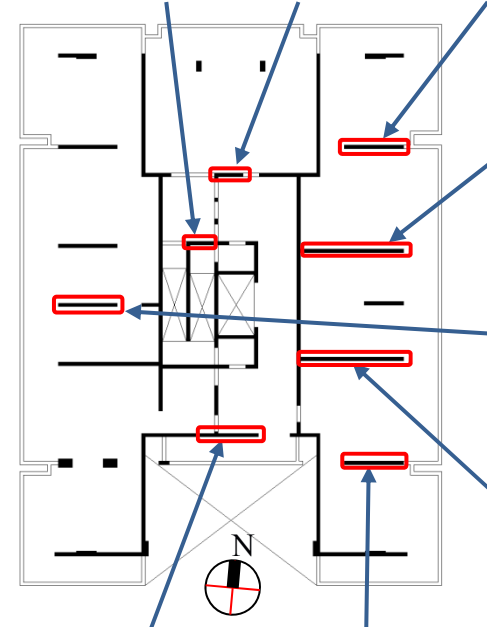


# Orientation of buildings

Main damage in the East-West direction and in the shortest axis of the structure

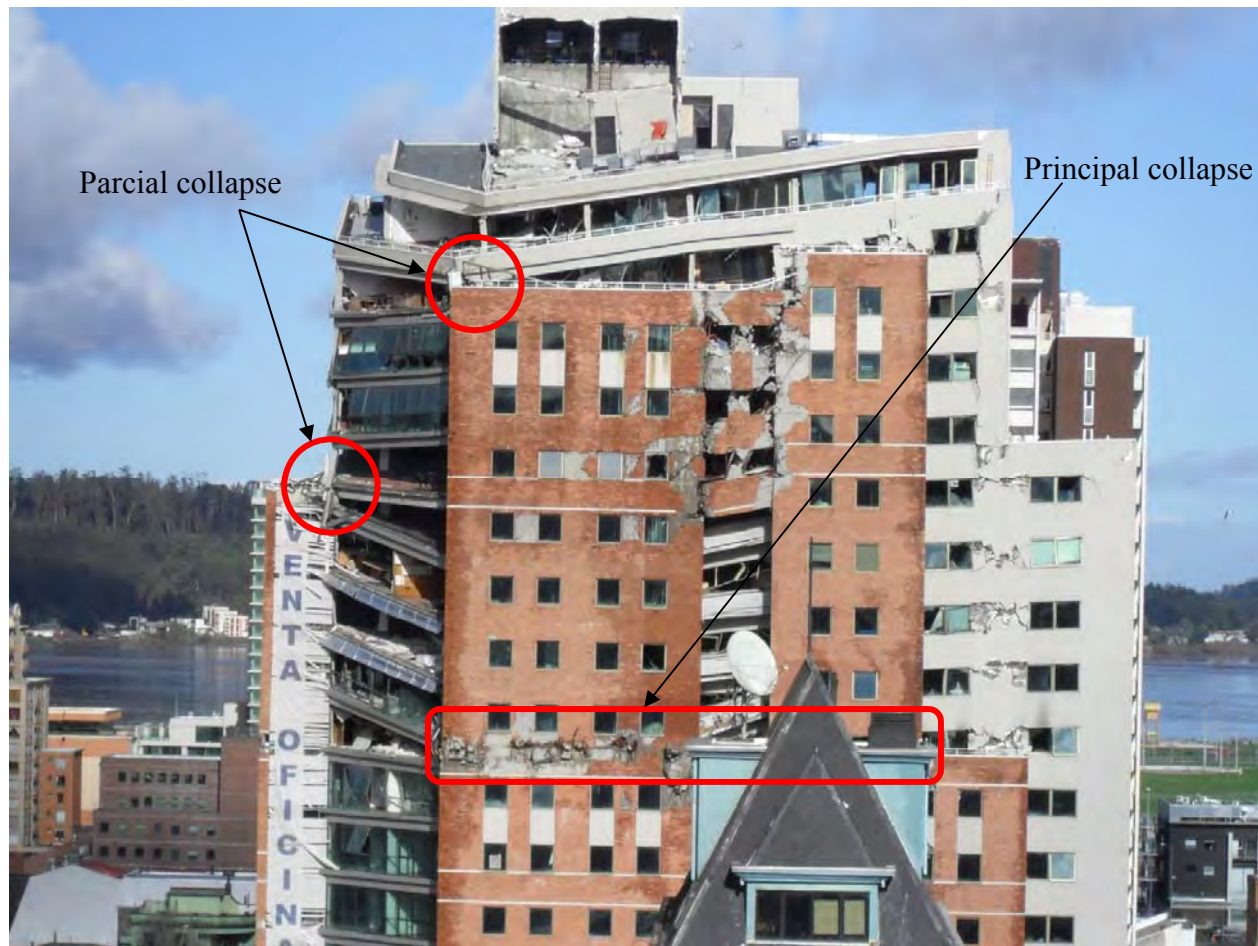


Severe damage in building TL



Severe damage in building AH



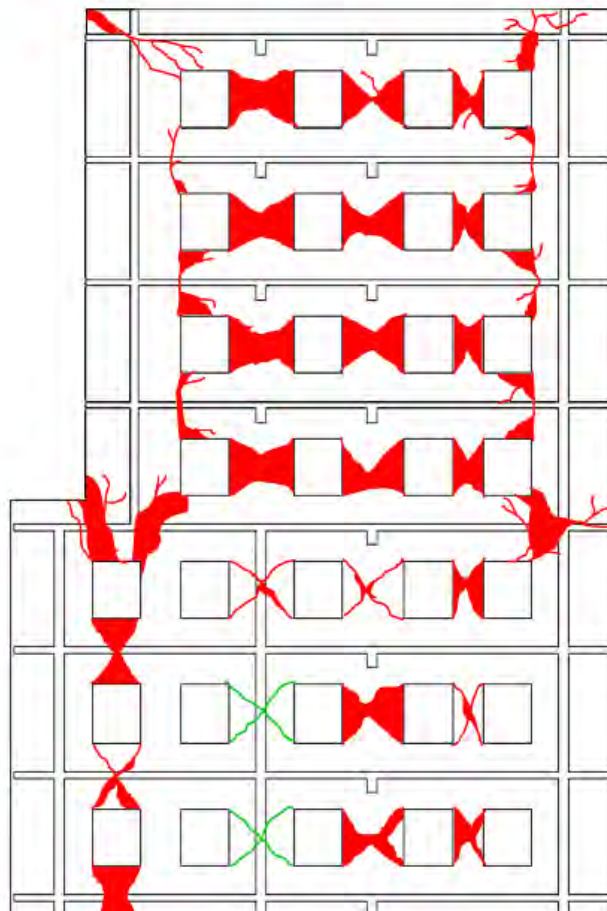


East elevation of TO



# Damage level representation

 Light damage     Moderate damage     Severe damage

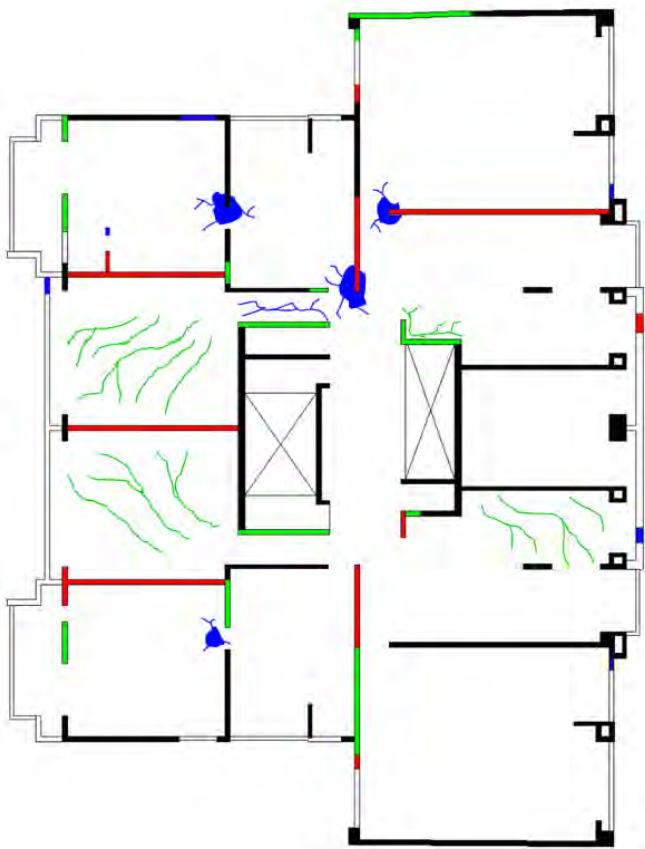


TO: Axis 1A

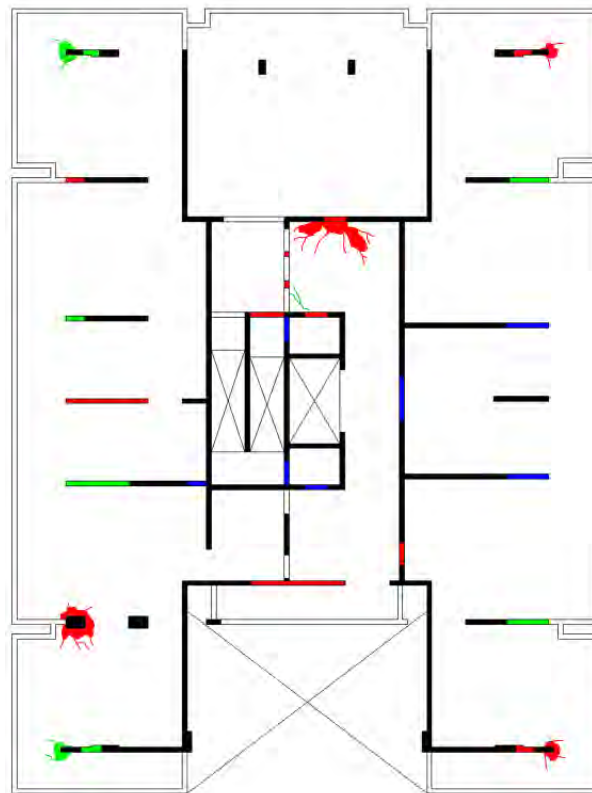


# Damage level representation

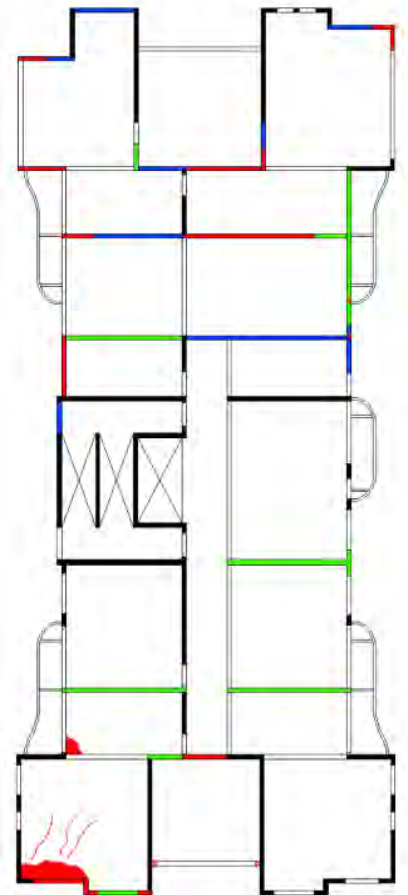
 Light damage     Moderate damage     Severe damage



AA: Story 2



AH: Story 1

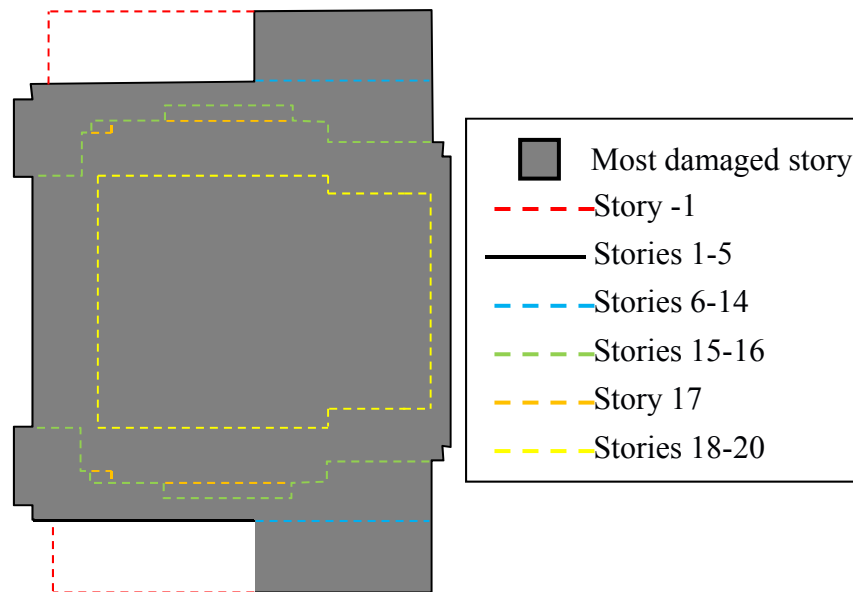


CM: Story 2

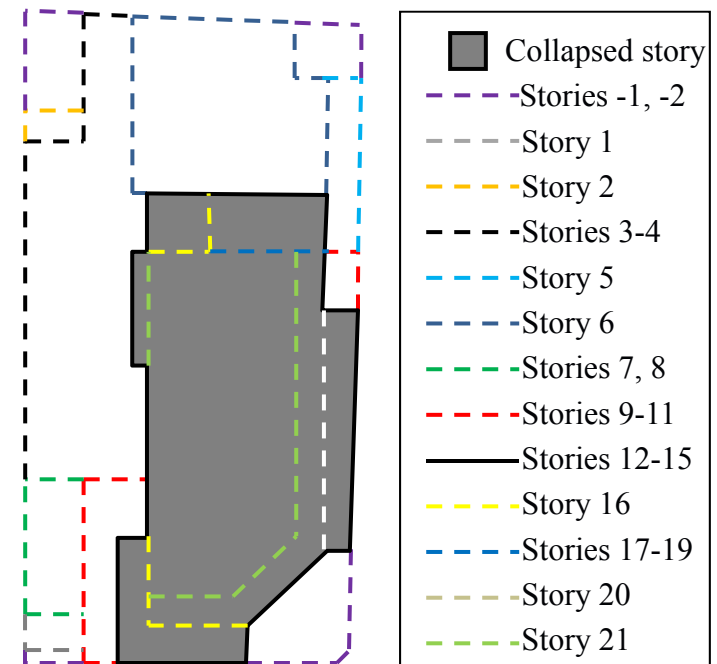
# Irregularities

Irregularities in plan and height had an important role in the observed damage

- The most irregular buildings (AA and TO) are the most damaged ones.



Schematic plan AA

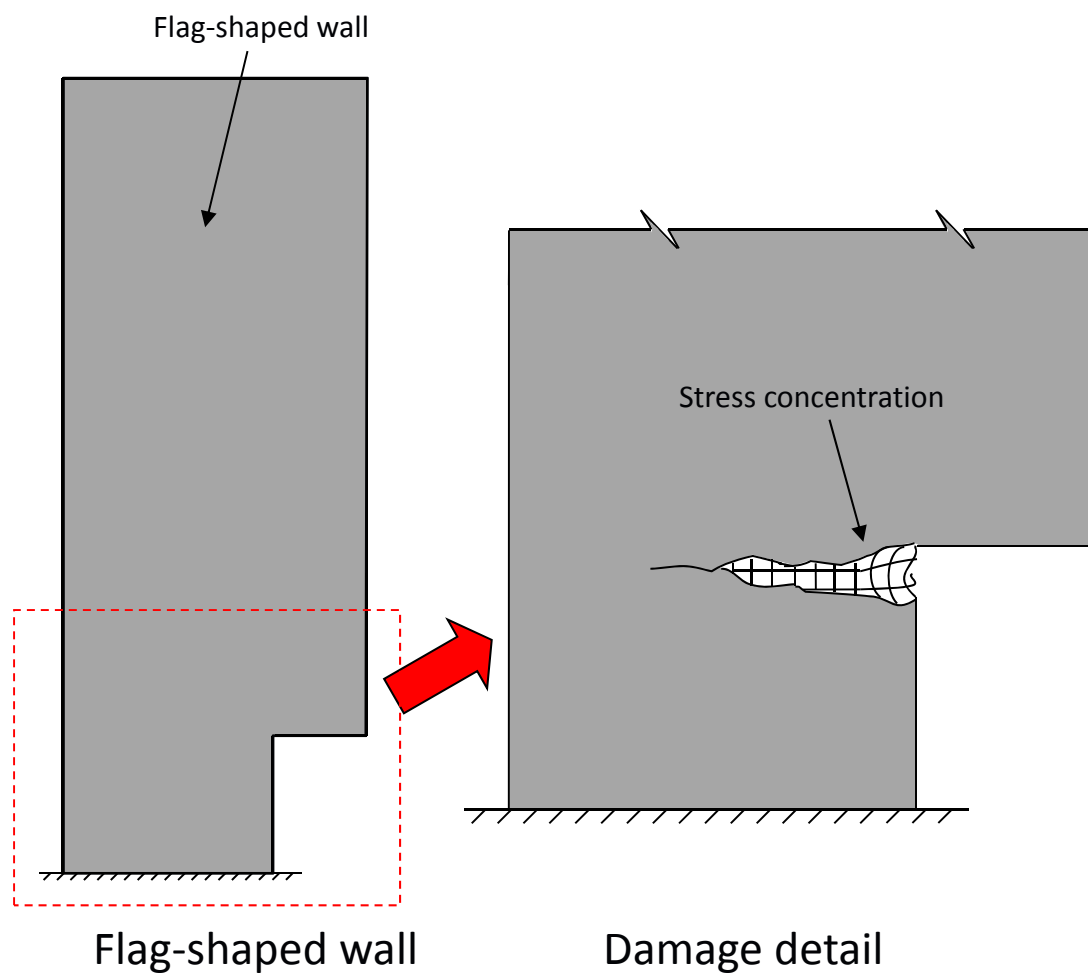


Schematic plan TO



# Irregularities

## “Flag-shaped” walls



AA Building



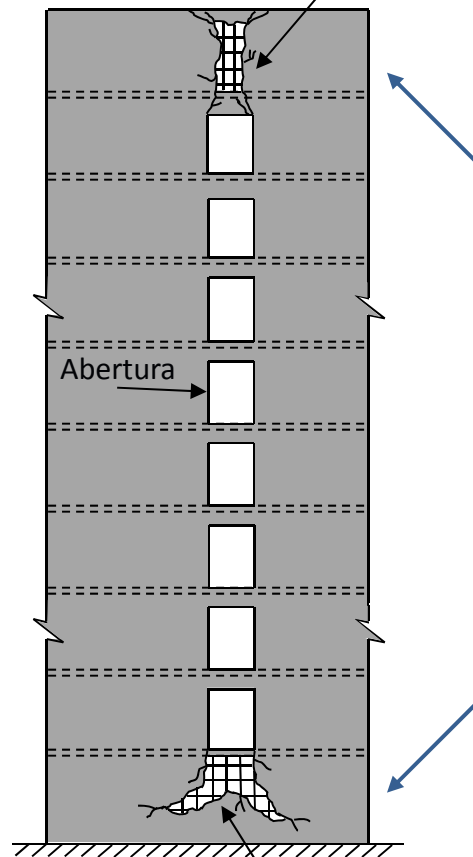
AH Building



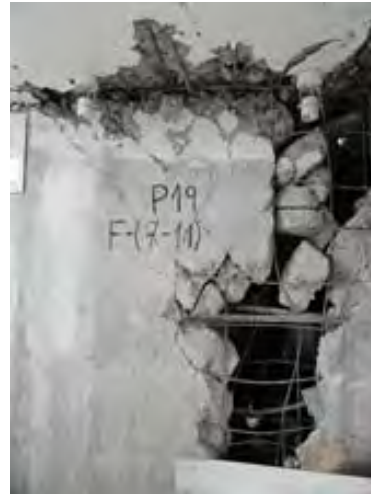


# Common Irregularities

Opening is formed in continuous wall on the upper stories



Opening is formed in continuous wall on the lower stories



AA



AH



CM



CM

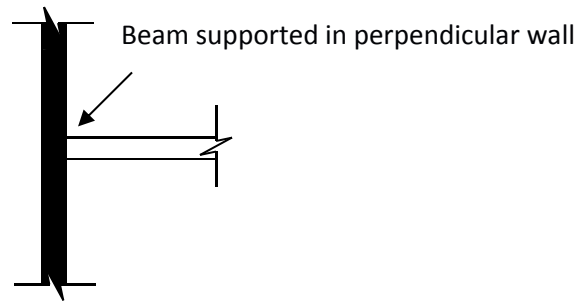


Chillán building

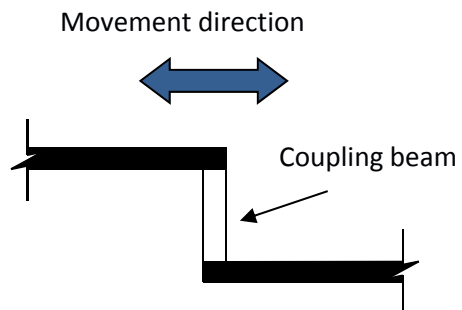


# Irregularities

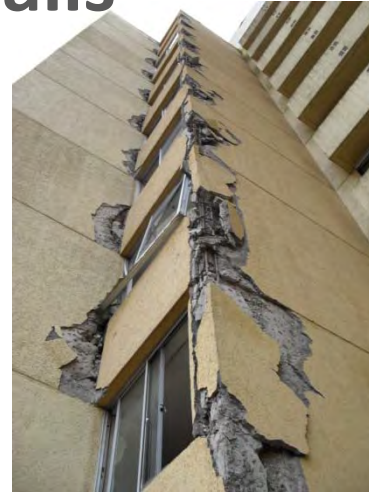
## Coupling beams in walls



Case A



Case B



PP



PP



RT



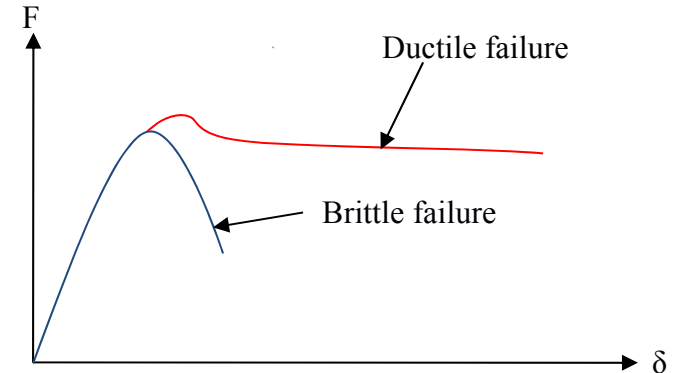
TO



# Detailing & brittleness

Thin walls with high axial load were unable to confine the concrete core

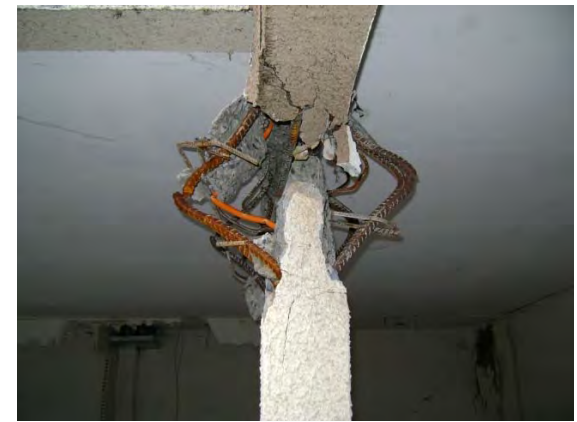
- Spalling of the concrete cover
- Buckling of longitudinal reinforcement
- Brittle collapse of the wall



AH



CM



PdR





# Structural & construction detailing

Serious detailing and construction issues are observed in the inspected buildings (specially in Torre O'Higgins)

- Bad anchor between beam-wall joints
- Cut stirrups and outside the confined area
- Absence of confinement in the wall boundaries



Lack of stirrups



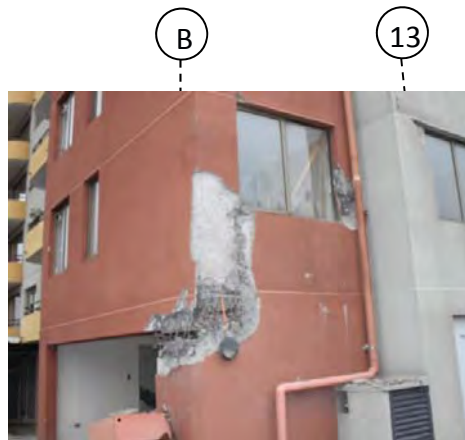
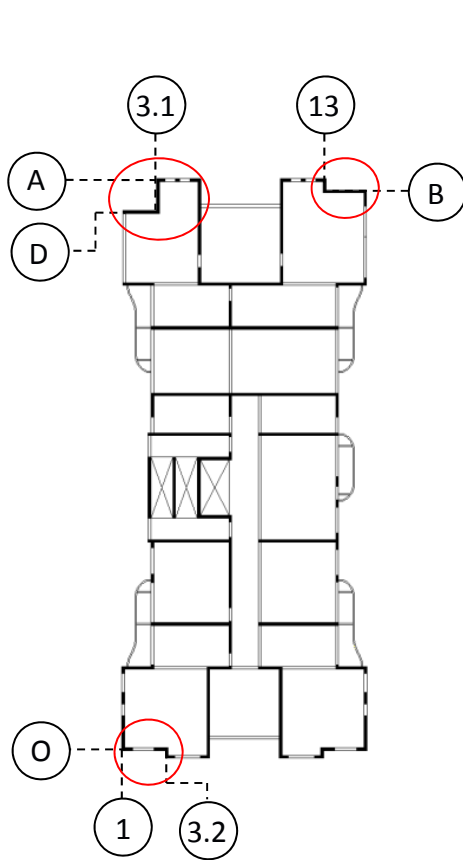
Reinforcement outside the confined area



Typical confinement detail

# Multistory damage

There is damage propagation between floors



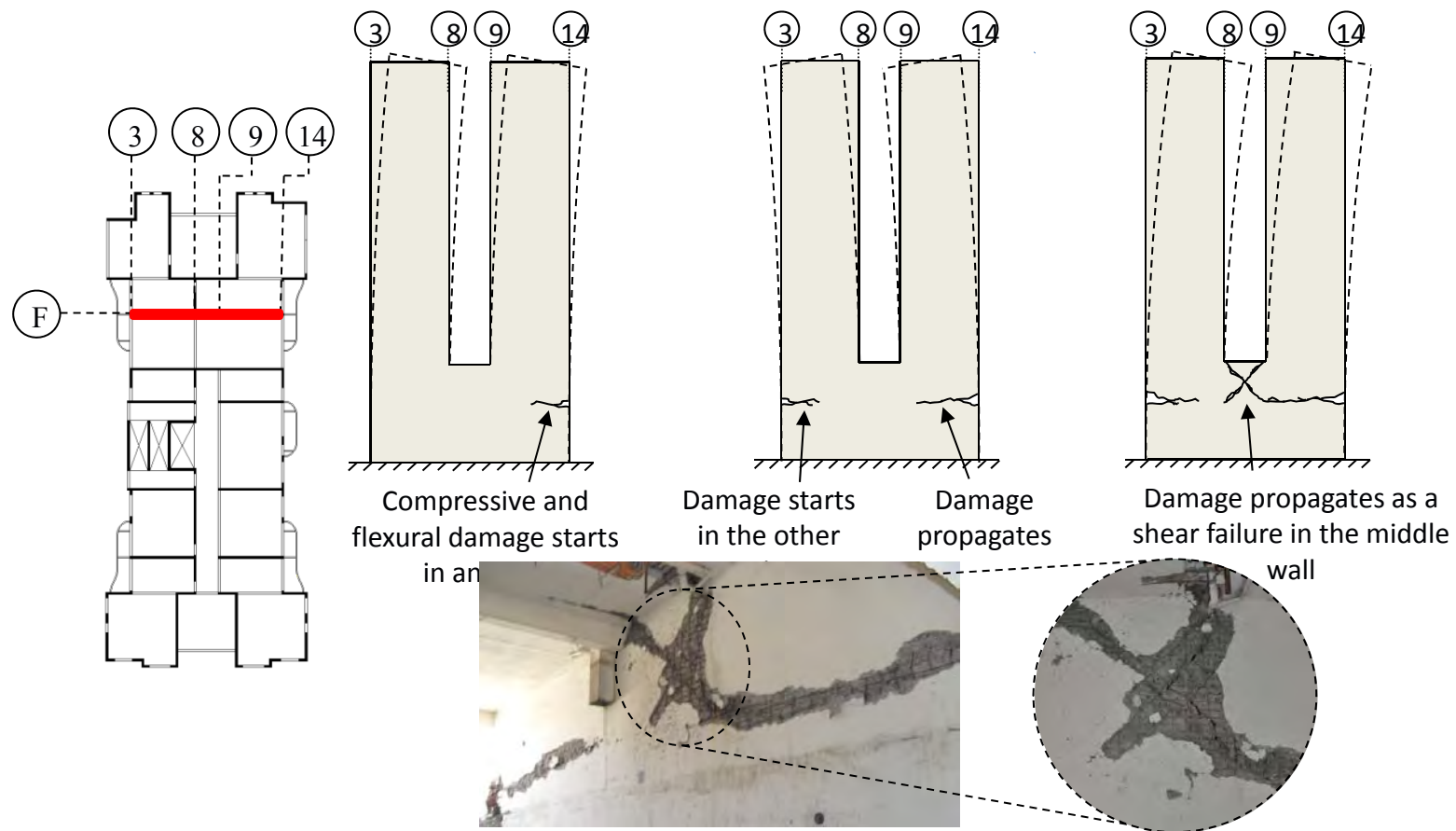
CM building: propagation of damage between stories





# Multistory damage

There is damage propagation between elements



CM: propagation of damage between elements

## Damage propagation between stories and elements



PdR building: damage propagation



# Energy dissipation elements

Since 1985 the buildings have changed continuously:

- Less wall thickness, less wall densities, bigger axial loads and elimination of lintels
- An important source of energy dissipation is eliminated —→ **Modify R factors!**



AA



AH



PP

PP



Non-structural elements totally damaged

RdT



Non-structural elements intact



# Building design

## review AA, CM, PdR, and TO

A design review was made (using chilean code NCh433) for the 4 most damaged buildings:

$$\text{Utilization factor} = FU = \frac{\text{Demand}}{\text{Strength}}$$

$$FU < 1$$



Satisfactory design

Walls:

- Shear
- Axial-flexural

$$1 < FU < 1.25$$



Slightly deficient elements

Beams:

- Shear
- Positive Moment
- Negative Moment

$$1.25 < FU < 1.5$$



Moderately deficient elements

Drifts y displacements:

- Drifts in CM < 2‰
- Maximum drifts < 1‰ drift CM

$$FU > 1.5$$

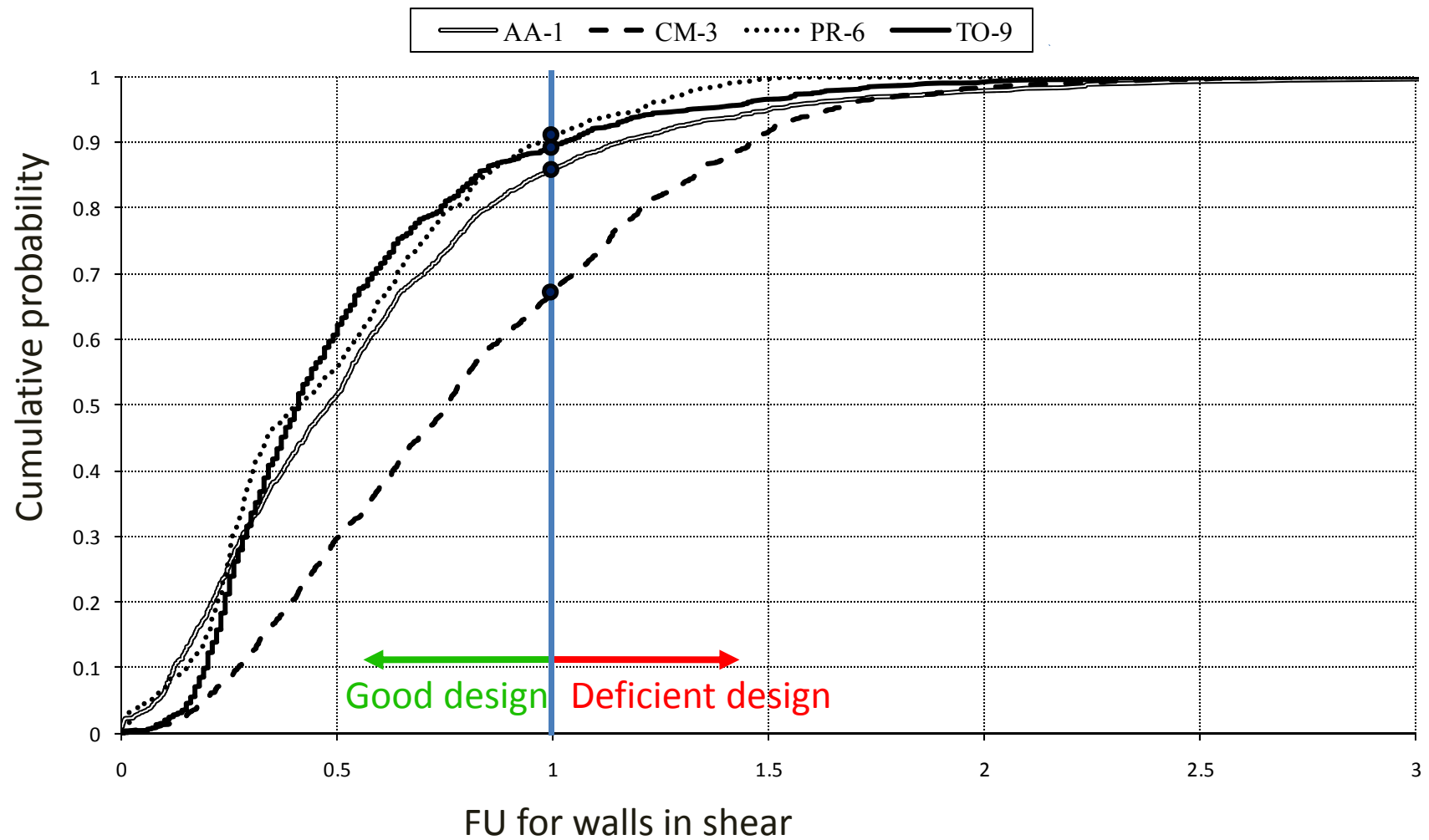


Severely deficient elements



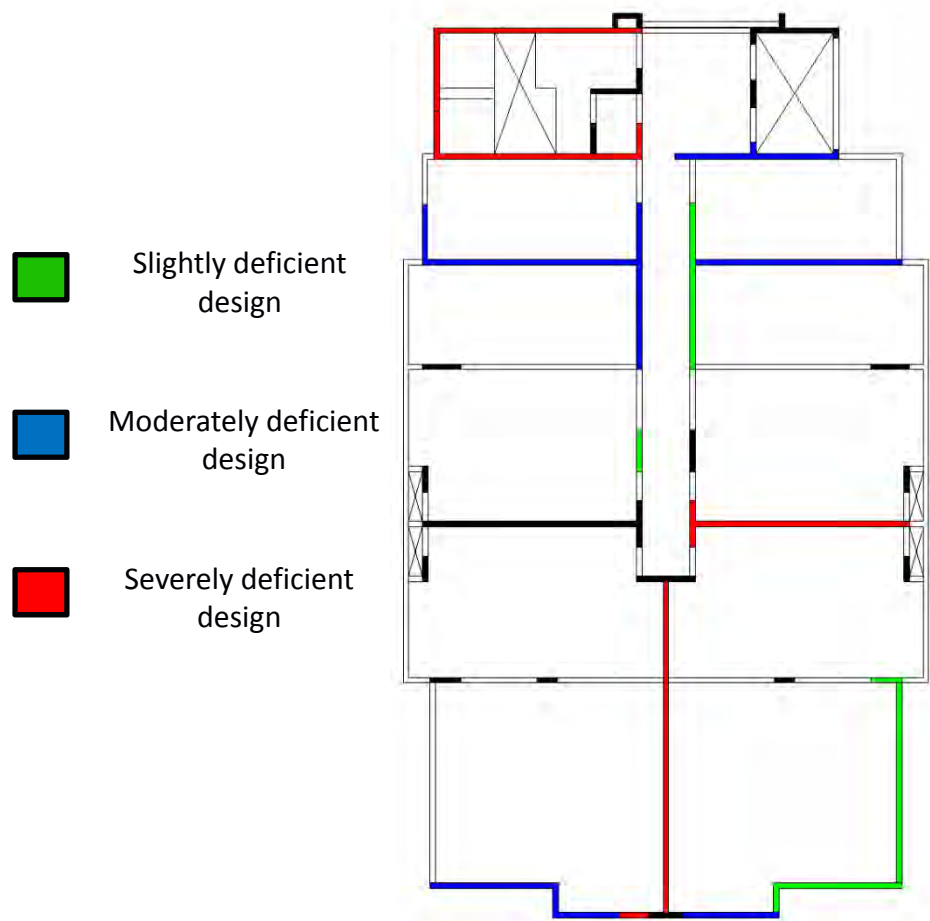
# Building design review

Walls in shear (~ 1000 elements per building)

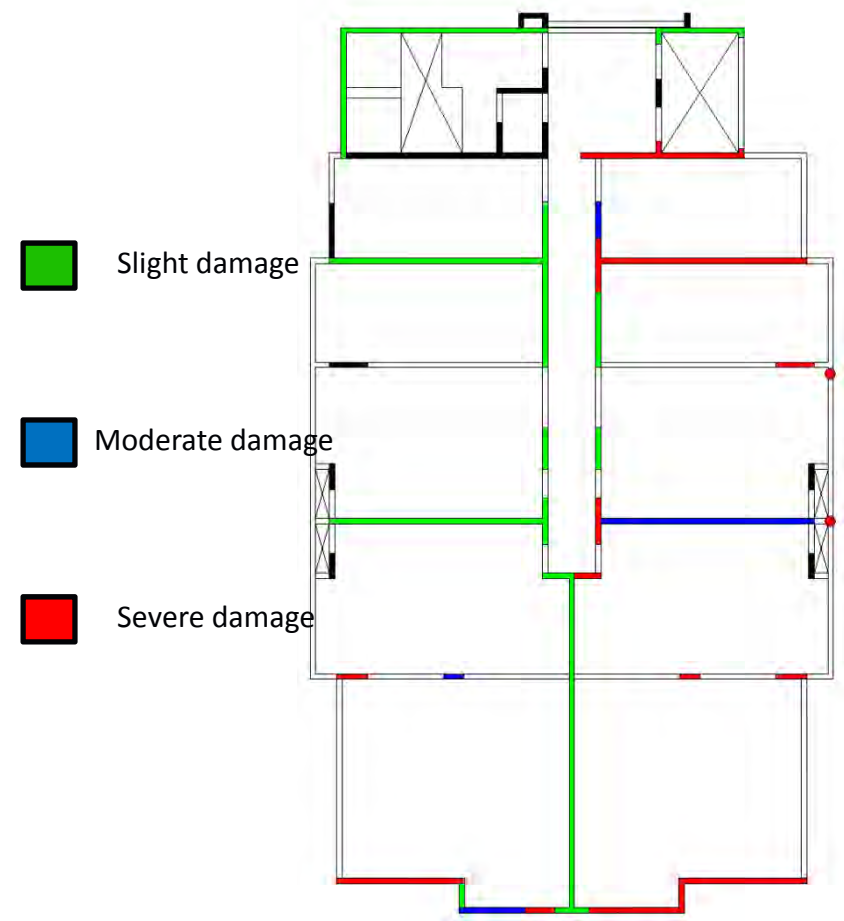




## Design review v/s observed damage:



Plaza del Río building: FU in 1st story

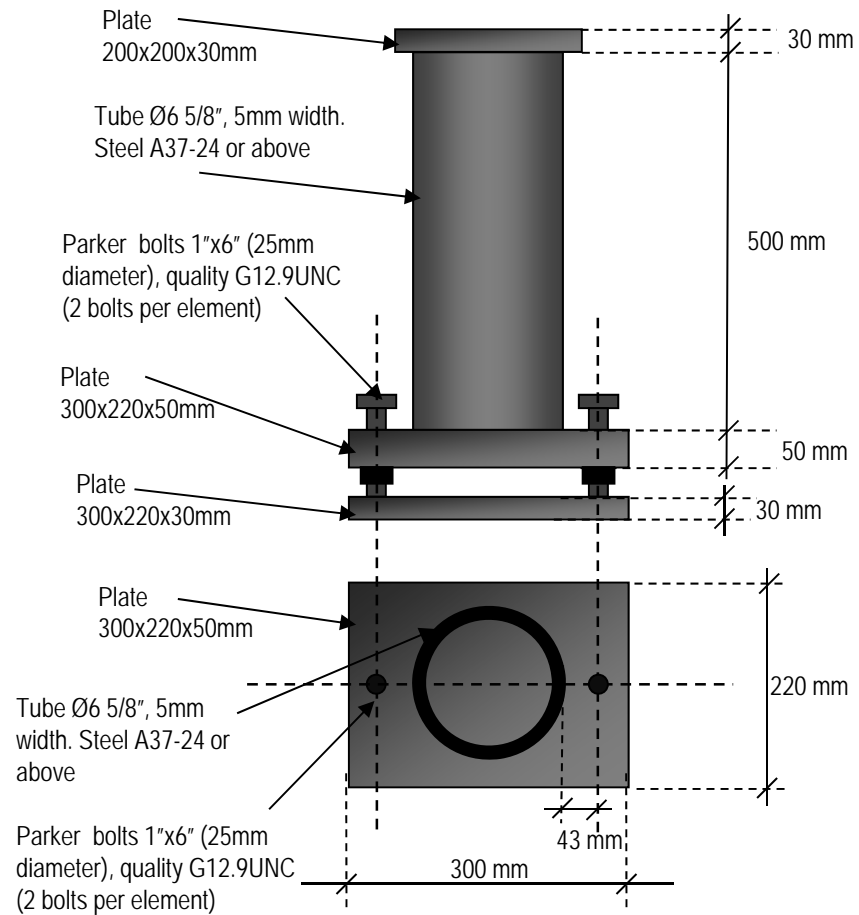


Plaza del Río building: Damage in 1st story



# Stabilization process

## EM Building





# Stabilization process

## EM Building

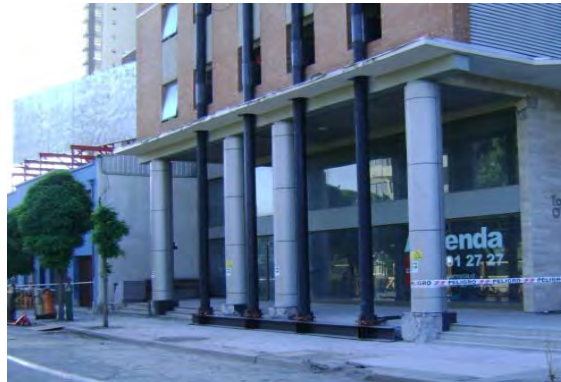
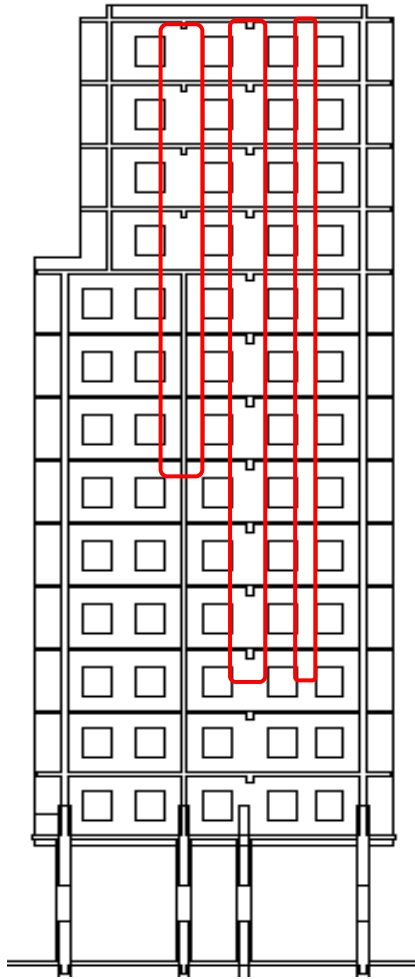






# Stabilization process

## TO Building





# Stabilization process

## TO Building





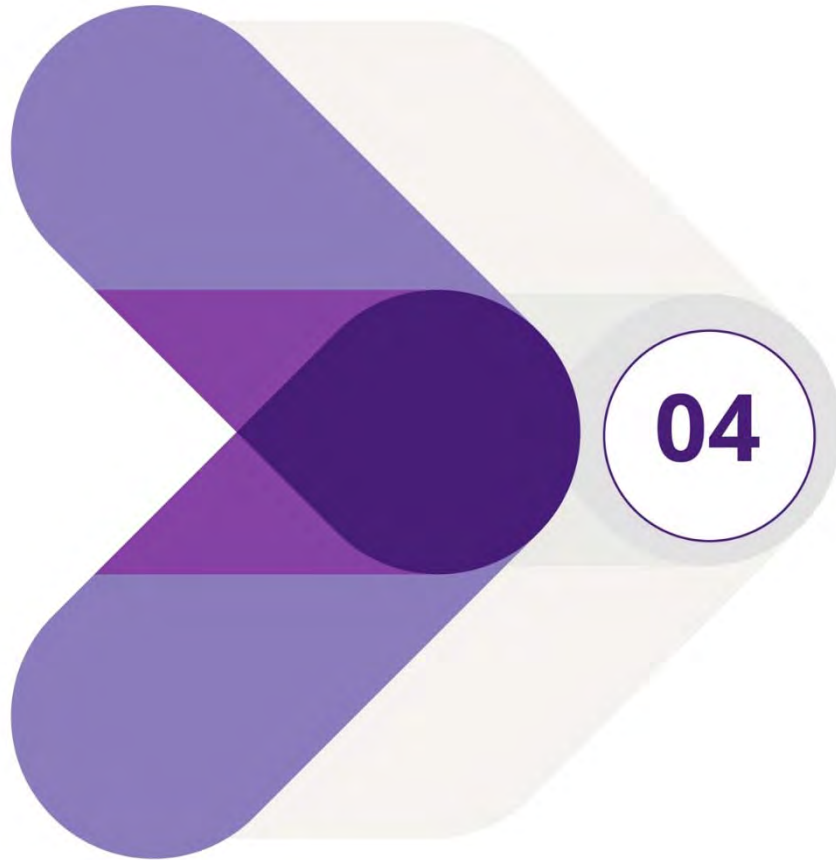


# Stabilization process

Repair, Stabilization and demolition of buildings



TO building: Temporary stabilization



## **EXAMPLE: PERFORMANCE OF SEISMICALLY PROTECTED BUILDINGS**



 **Military  
Hospital**





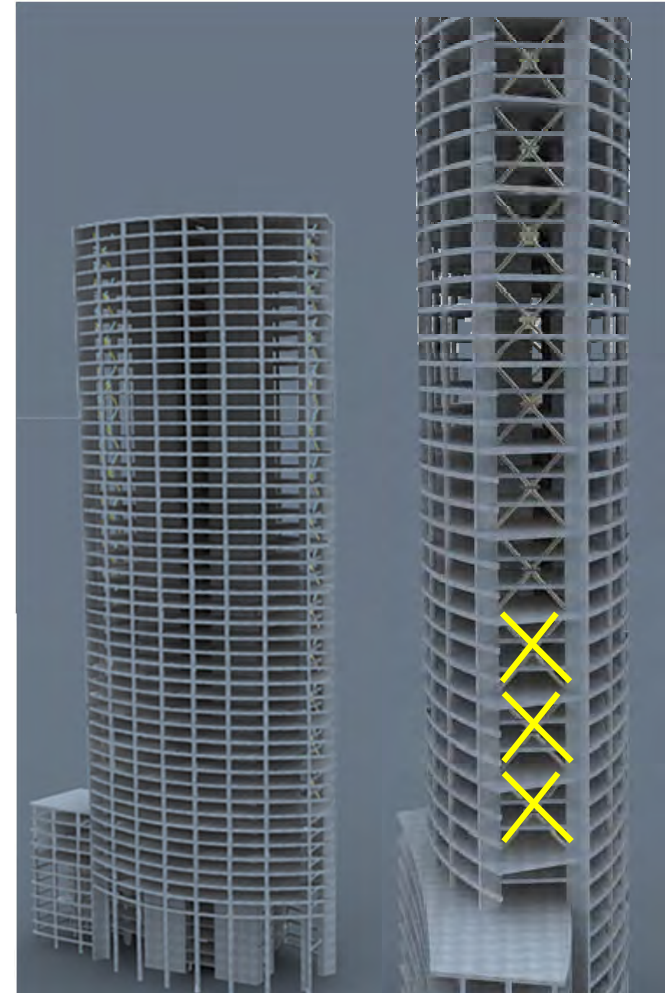
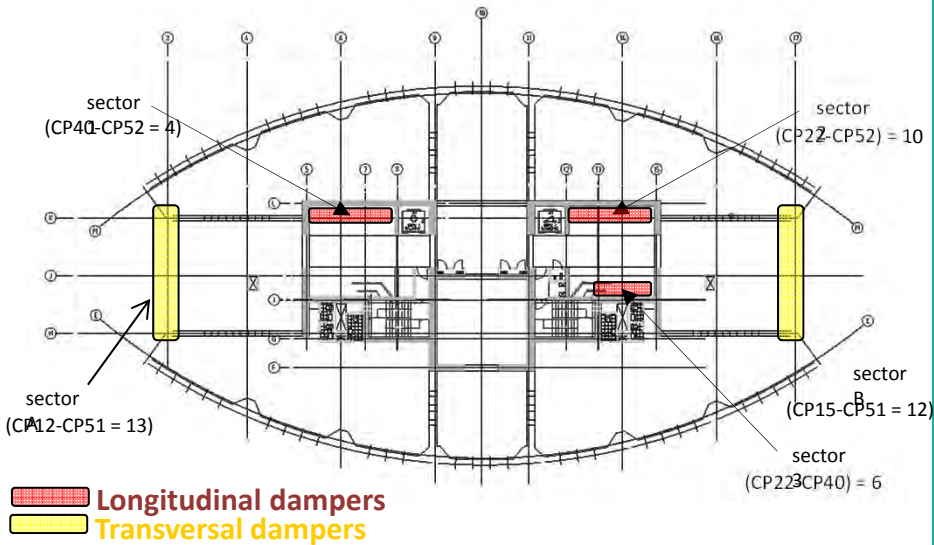
 **Coronel's**  
wharf





# Titanium tower

## Hysteretic damping





Base Sol





## **SOCIAL AND HUMAN IMPACT**

# Social behaviors







Survey of socioeconomic characterization added a mental health module and conducted a survey shortly after 27F

PTSD in caregivers of preschool children

**Módulo Impacto Psicosocial**

Personas de 18 años y más, presentes al momento de la encuesta, y que sean capaces de responder por sí solos la encuesta

Durante la última semana, a consecuencia del terremoto/tsunami, ¿Ud. ha experimentado alguno de los siguientes sucesos?

Indique la frecuencia y la intensidad (gravedad) según la tabla

Suceso	
1. Ha tenido alguna vez imágenes, recuerdos o pensamientos dolorosos del terremoto/tsunami.	10. Se ha sentido distante o alejado de la gente
2. Ha tenido alguna vez pesadillas sobre el terremoto/tsunami	11. Ha sido incapaz de tener sentimientos de tristeza o de afecto
3. Ha sentido que el terremoto/tsunami estaba ocurriendo de nuevo, como si lo estuviera reviviendo	12. Ha tenido dificultad para imaginar una vida larga y cumplir sus objetivos
4. Hay cosas que se lo han hecho recordar	13. Ha tenido dificultad para iniciar o mantener el sueño
5. Ha tenido sensaciones físicas por recuerdos del terremoto/tsunami (como transpiración, temblores, palpitaciones, mareos, náuseas o diarrea)	14. Ha estado irritable o ha tenido accesos de ira
6. Ha estado evitando pensamientos o sentimientos sobre el terremoto/tsunami	15. Ha tenido dificultades para concentrarse
7. Ha estado evitando hacer cosas o estar en situaciones que le recordaran el terremoto/tsunami	16. Se ha sentido nervioso, fácilmente distraído, o como "en guardia"
8. Ha sido incapaz de recordar partes importantes del terremoto/tsunami	17. Ha estado nervioso o se ha asustado fácilmente
9. Ha tenido dificultad para disfrutar de las cosas	

Frecuencia	Intensidad (Gravedad)
0 = nunca	0 = nada
1 = a veces	1 = leve
2 = 2-3 veces	2 = moderada
3 = 4-6 veces	3 = marcada
4 = a diario	4 = extrema

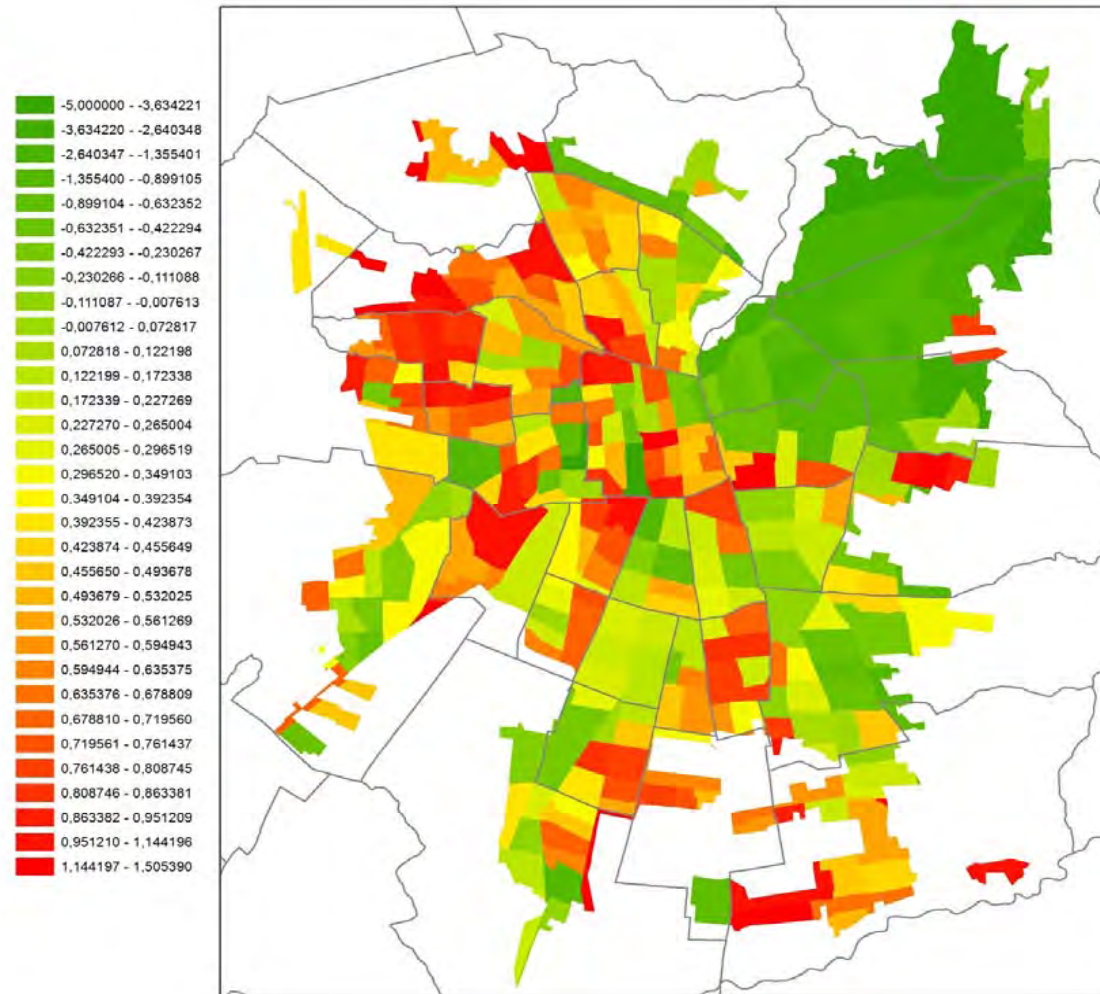
	1f	1g	2f	2g	3f	3g	4f	4g	5f	5g	6f	6g	7f	7g	8f	8g	9f	9g	10f	10g	11f	11g	12f	12g	13f	13g	14f	14g	15f	15g	16f	16g	17f	17g
1																																		
2																																		
3																																		
4																																		
5																																		
6																																		
7																																		
8																																		
9																																		
10																																		

Comuna	TEPT (%)
Antofagasta	2,6
Tocopilla	0,0
Montepatria	0,0
La Serena	3,7
Coquimbo	2,7
Los Andes	8,3
Valparaíso	7,4
Lampa	8,8
Quilicura	9,9
La Florida	3,1
Puente Alto	14,6
San Bernardo	16,5
Rengo	7,8
Collipulli	9,8
Vilcún	2,5
Río Bueno	5,1
Osorno	3,6
Puerto Montt	0,0
Total	7,3

Bedregal et al., 2013



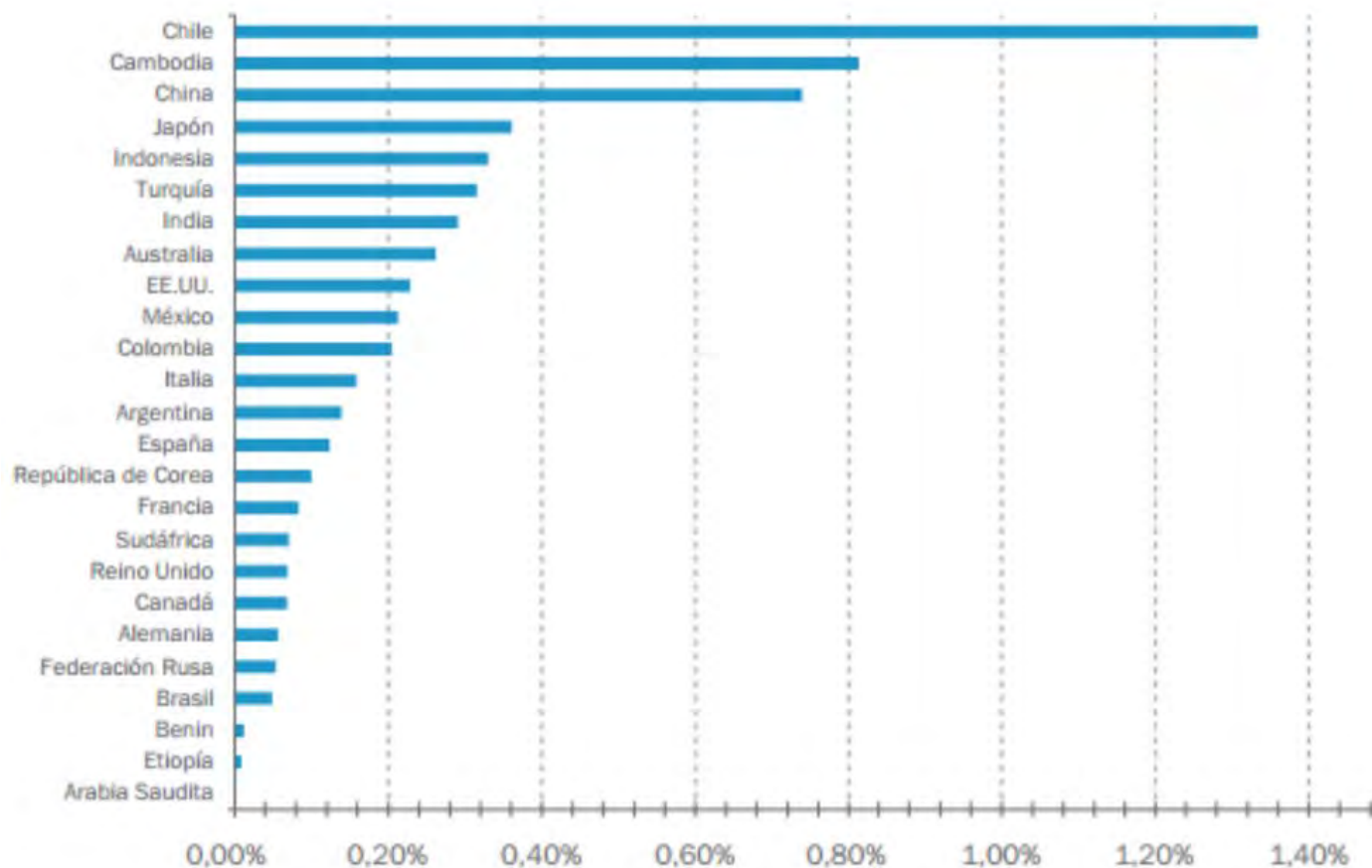
# Social Vulnerability index







# Economic Losses as %GDP





## **LESSONS LEARNED**



► **What forms of data were collected after the earthquake?**

Different data at different depths, from ground deformations and motion, tsunami effects, structural and non structural damage in structures, such as buildings, ports, schools, lifelines, etc., and social response

► **Have any relationships between the different forms of data been explored?**

- Building damage vs. soft soil conditions
- Types of building damage vs. focal distance
- Directivity and orientation in building response
- Loss of functionality vs. non-structural components
- Tsunami effect vs. fault-slip distribution
- Socio-economic status vs. earthquake resilience



► **What organizations were involved in collecting data and for what purpose?**

Ministry's, regional and communal governments, insurance, real-estate, construction and design companies, researchers, communities, individuals

► **What barriers are there to sharing data across different organizations?**

- Have possible personal and company liabilities
- Take scientific and professional advantage of seismic records and ground motion data in general
- Risk company and professional reputation
- Lose competitiveness relative to competition (e.g., ports)



### ► How were the data collected?

- Physical observations done by different agents on the physical environment: accelerometers, seismometers, GPS, InSAR, LiDAR, SASW, and DCPT
- Physical observations of the built environment: site visits and technical inspections
- Psycho-social observations of agents and communities: surveys on people and communities
- Operational observations of the integrated system: changes in ONEMI and new seismic codes (and decrees)

### ► What data were lost?

Earthquake data is almost always collected by someone, so the problem is more that of sharing the data and making it available for research purposes





- ▶ Lack of a standard instrument for inspections led to different assessments for the same structure
- ▶ Lack of planning resulted in duplication of efforts
- ▶ Large disparity in knowledge and technical criteria of the evaluators in building inspections
- ▶ Private companies could not disclose data to the public
- ▶ No consolidated information system, making it very difficult to share information among professionals and researchers
- ▶ Very few institutions were prepared with protocols and equipment to go out to inspect a large number of structures



# Suggestions for future development

- ▶ Scope of the post-earthquake inspection should be first clearly defined (emergency, operation recovery, or reconstruction)
- ▶ Data should be
  - Available for decision makers, authorities, and relevant stakeholders
  - Obtained by standardized procedures
  - Correct and unbiased for use in later research purposes to improve design standards and construction practices
  - Obtained only once to avoid unnecessary duplications and trouble to people
  - Mounted on a central platform that enables classifying and sharing it



# Suggestions for future development

- ▶ Define an “NDA” for data recollection and research purposes
- ▶ Use communication technologies exhaustively in collecting data
- ▶ Universities and research centers should develop and implement these protocols



# Post earthquake data collection workshop

July, 2014

## Chilean Experience



10NCEE Special Session, Anchorage, Alaska  
The Canterbury Earthquake Sequence: Lessons for Response and Recovery

July 23, 2014

# Canterbury Earthquakes Sequence Building Damage, Data Collection, & Access

Andrew King – GNS Science

Peter Wood – NZSEE

Mike Stannard – MBIE

Stefano Pampanin – University of Canterbury

John Hare – Holmes Consulting Group

David Johnston – GNS Science

New Zealand Post Earthquake Damage Data Collection Experience

# Introduction — *Andrew King GNS Science*

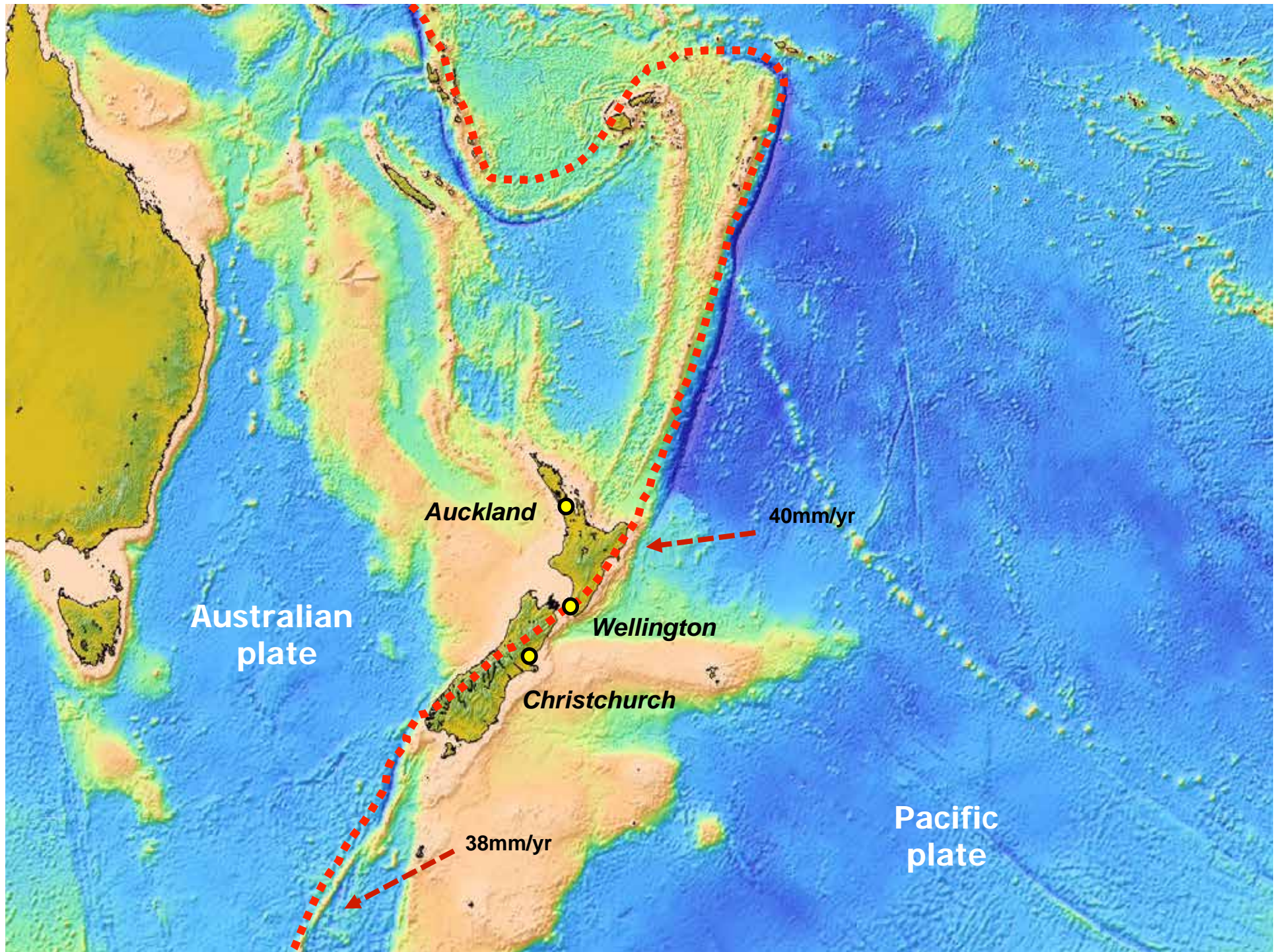
## Topic

- |   |                                 |
|---|---------------------------------|
| ➤ Scene setting – Regulation & Overview | Mike Stannard                   |
| ➤ Seismology & ground motions           | Andrew King                     |
| ➤ Ground deformations                   | Peter Wood                      |
| ➤ Building Safety Evaluations           | Mike & Andrew                   |
| ➤ Building Condition Evaluations        | John Hare &<br>Stefano Pampinin |
| ➤ Insurance and Losses                  | Andrew King                     |
| ➤ Socio-Economic Implications           | David Johnson                   |
| ➤ Discussion                            | Everyone                        |

# Regulatory and Overview

Mike Stannard, Chief Engineer, MBIE







# Canterbury Earthquake Sequence

4 Sept 2010, 22 Feb, 13 June, 23 Dec 2011

**Fatalities** – 185

**Cost** – Estimates up to \$NZ40 billion  $\approx$  20% GDP, (\$US35B)

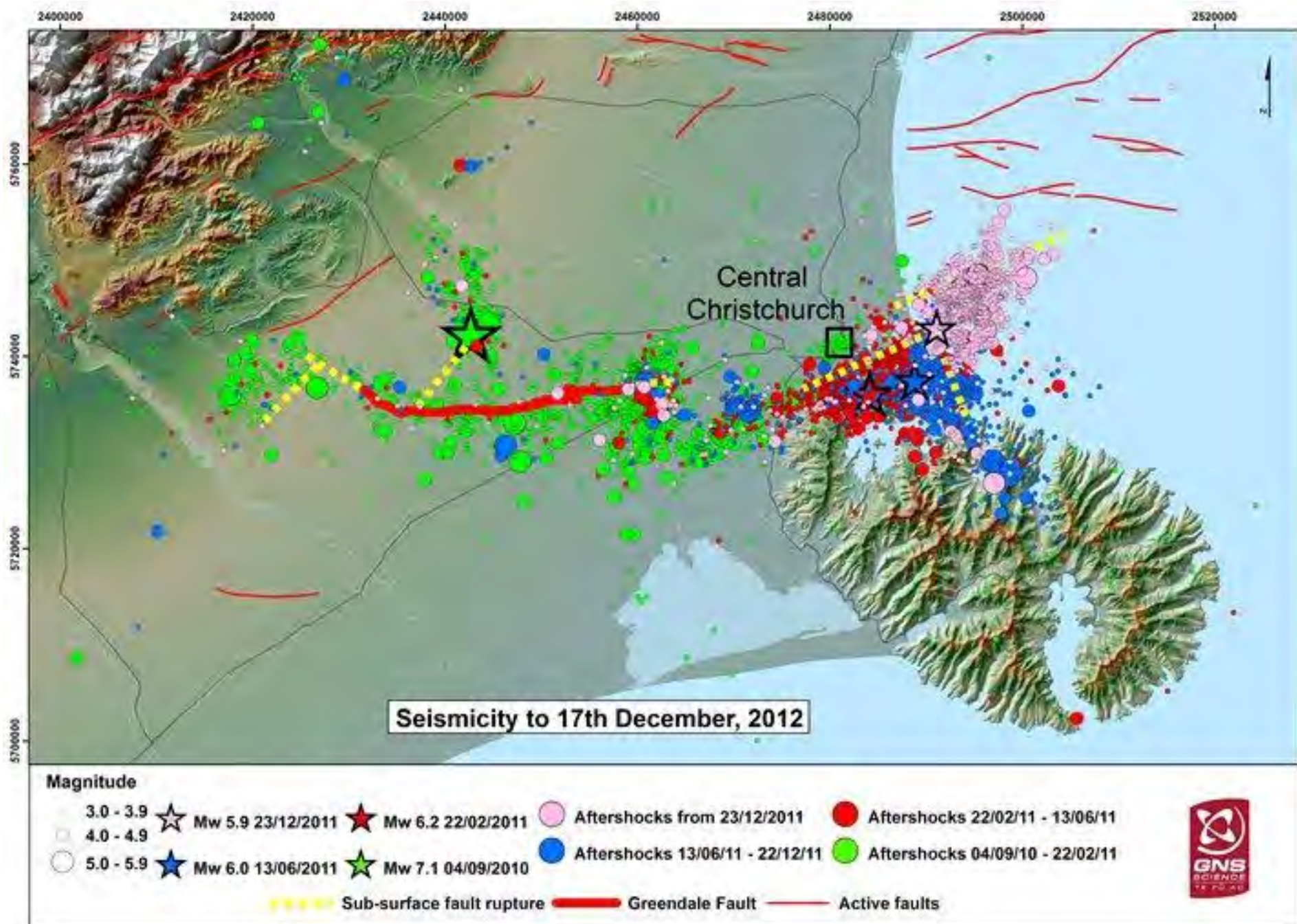
**Insurance** – one of biggest insurance claim events in world, > 450k residential claims for 170k houses

**Christchurch CBD** – 1700 commercial buildings demolished

**Government priority** – rebuild Christchurch, implement Canterbury Earthquakes Royal Commission recommendations.

**Events** – > 14,000 shakes, including M7.2 Sep 2010, M6.3 Feb 2011





New Zealand Post Earthquake Damage Data Collection Experience





30,000 tonnes ejecta  
removed September

300,000 tonnes removed  
February

## Liquefaction - Bexley

New Zealand Post Earthquake Damage Data Collection Experience

## Issues

Existing regulatory framework – Building Act/Code not addressing disaster response or recovery

- No legislative authorisation for building usability evaluation (safety)
- Repair after earthquake unclear

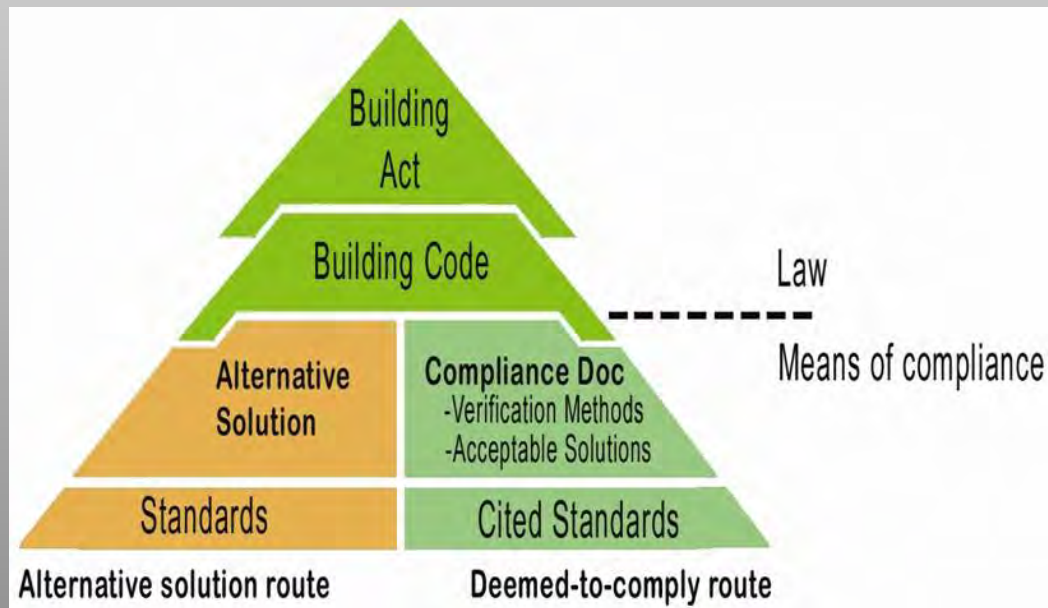
## Response

Legislation – Canterbury Earthquake Recovery Act

Short term changes to Building Act (dangerous buildings to include earthquake hazard)

- Proposed changes to Act to include rapid building usability assessment (tagging)
- Issue guidance

### National Building Act and Building Code

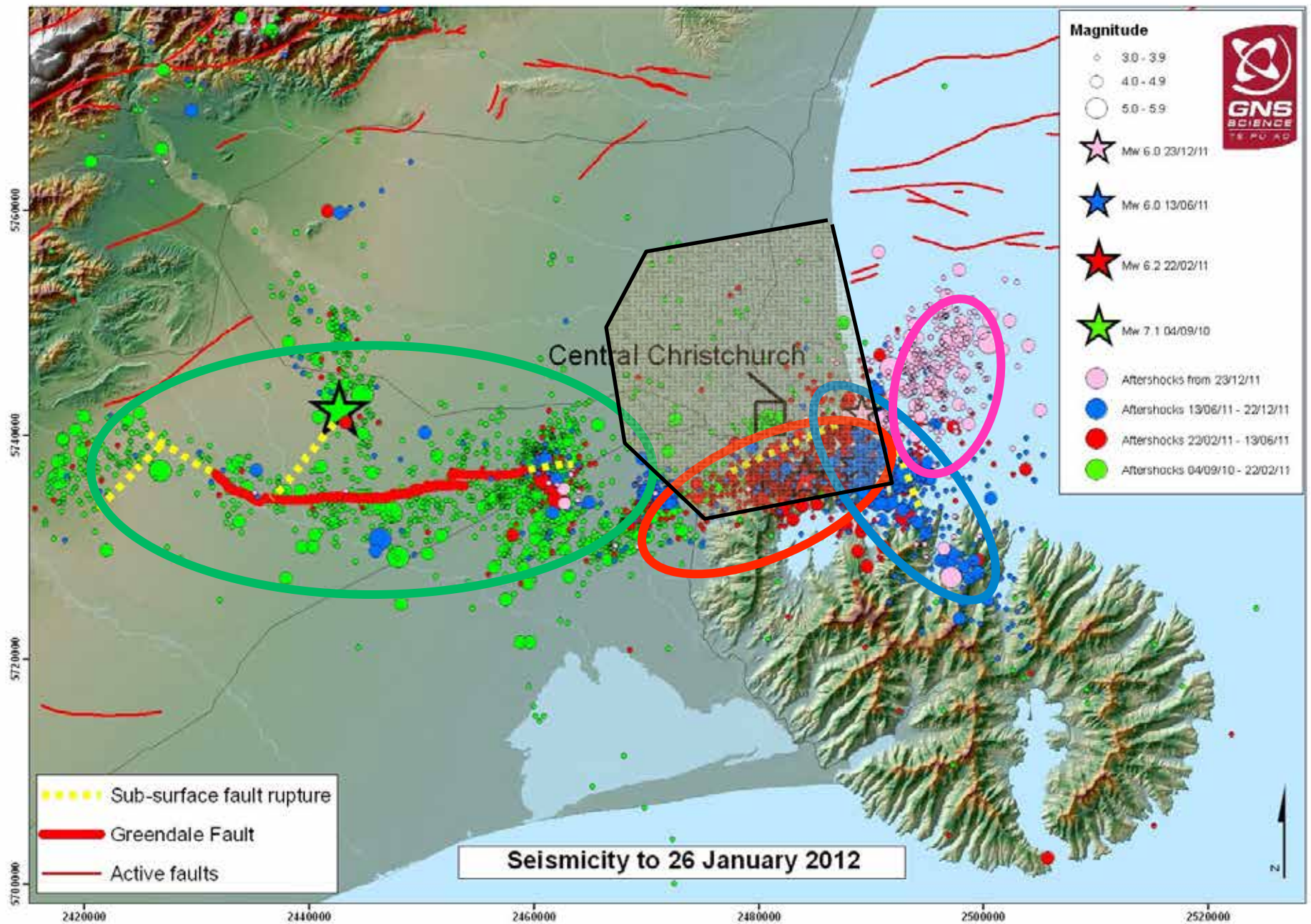




Issues	Response
Placards – damage evaluation, public perception buildings safe	Develop DEE process for residual capacity assessment
Seismic hazard changed as a result of earthquake	Engineers and seismologists working together to consider building performance and short and long term hazard – raise hazard factor 35%
Changed public perception of risk elsewhere	<p>Proposed amendment to earthquake-prone building legislation:</p> <ul style="list-style-type: none"> <li>-Balance cost and risk;</li> <li>-Different perceptions and preparedness to pay across NZ;</li> <li>-Affordability for rural towns, demolition;</li> <li>-Market/insurer drivers for strengthening.</li> </ul>
Clarity of objectives for building structural performance requirements	Proposals for review of Building Code to introduce tolerable impacts for various limit states

# Motion Records *Andrew King GNS Science*

- *Purpose:* Locate and quantify event signature (Mag, Depth, Rupture characteristics) for haz. evaluation & future seismicity projections; Evaluate within-event shaking characteristics
- *Collected using*
  - seismographs with backbone network (Sat-phone link)
  - supplemented by rapid-response instruments (aftershock) Cell-phone link + on-site storage
- *Collected by* Geonet (GNS) also U of Canterbury; later by some overseas research teams
- *Data Stored & accessible via* Geonet – Open Access
- *Missing:* – detailed instrumental site conditions
- *Improvements:* greater network density; forward predictive capacity; liquefaction trigger conditions



## Revised Forecast for Canterbury region (whole of Canterbury plains) starting July 1<sup>st</sup>, 2012

EQ Magnitude	5 years			20 years		
	Average Number	Range	Probability	Average Number	Range	Probability
5.0-5.4	4.6	1-9	99%	11.1	5-8	100%
5.5-5.9	1.4	0-4	75%	3.3	0-7	97%
6.0-6.4	0.4	0-2	<b>34%</b>	1.0	0-3	<b>64%</b>
6.5-6.9	0.1	0-1	11%	0.3	0-2	27%
7.0+	0.04	0-1	4%	0.1	0-1	13%

Source: GNS “50-year” Model revised following recent international expert peer review and using all data up to Jan 25<sup>th</sup>, 2012.



## 1 year hazard forecast for Canterbury region currently remains above Wellington region

<b>Magnitude</b>	<b>Canterbury</b> starting May 28 <sup>th</sup> 2012 (high rates now declining rapidly)	<b>Wellington</b> starting Dec 15 <sup>th</sup> 2011 (fairly stable numbers as no significant activity at present)
5.0-5.4	75%	40%
5.5-5.9	33%	13%
6.0-6.4	10%	3.6%
6.5-6.9	3% <sup>&lt;3% for city</sup>	1.0%
7.0+	1%	0.3%

Source: GNS “50-year” model revised following recent international expert peer review and using all data up to Jan 25<sup>th</sup>, 2012.

# Rapid Impact Assessments *Peter Wood NZSEE*

- ***Intended use:*** Response & Recovery planning; Future use (liquefaction; landslide & boulder roll risk projections); Foundation and infrastructure design requirements
- ***Collected using:*** Low-level Oblique imagery (NZDF, CDEM, GNS, Media), Satellite dInSAR, High Resolution vertical aerial imagery, LiDAR, Precise GPS and Precise levelling field survey of benchmarks
- ***Collected by and for:***
  - MCDEM - Response and recovery planning
  - EQC – Insurance claims settlement;
  - Consultants - building and utility repair strategy;
  - Universities - liquefaction mapping;
  - Researcher/Insurer - cause of damage

# Rapid Impact Assessments (2)

- **Data storage**, retrieval, and sharing policies – variable – still difficult! Private and confidential issues
- **Clearing Houses (NEHRP model)** –
  - shared rapid impact assessments: both physical and virtual;
  - The physical meetings continue, nearly four years after initiation.
- **Missing:**
  - Unique Building Identification;
  - Pre-event High-resolution digital elevation model (DEM);
  - Full appreciation of the relationships between ground, foundation, and structure.
- **Improvements:**
  - Common and standardised ways of describing buildings, building elements, foundations, ground, and then - damage.
  - Data management and sharing policies
  - Interoperability



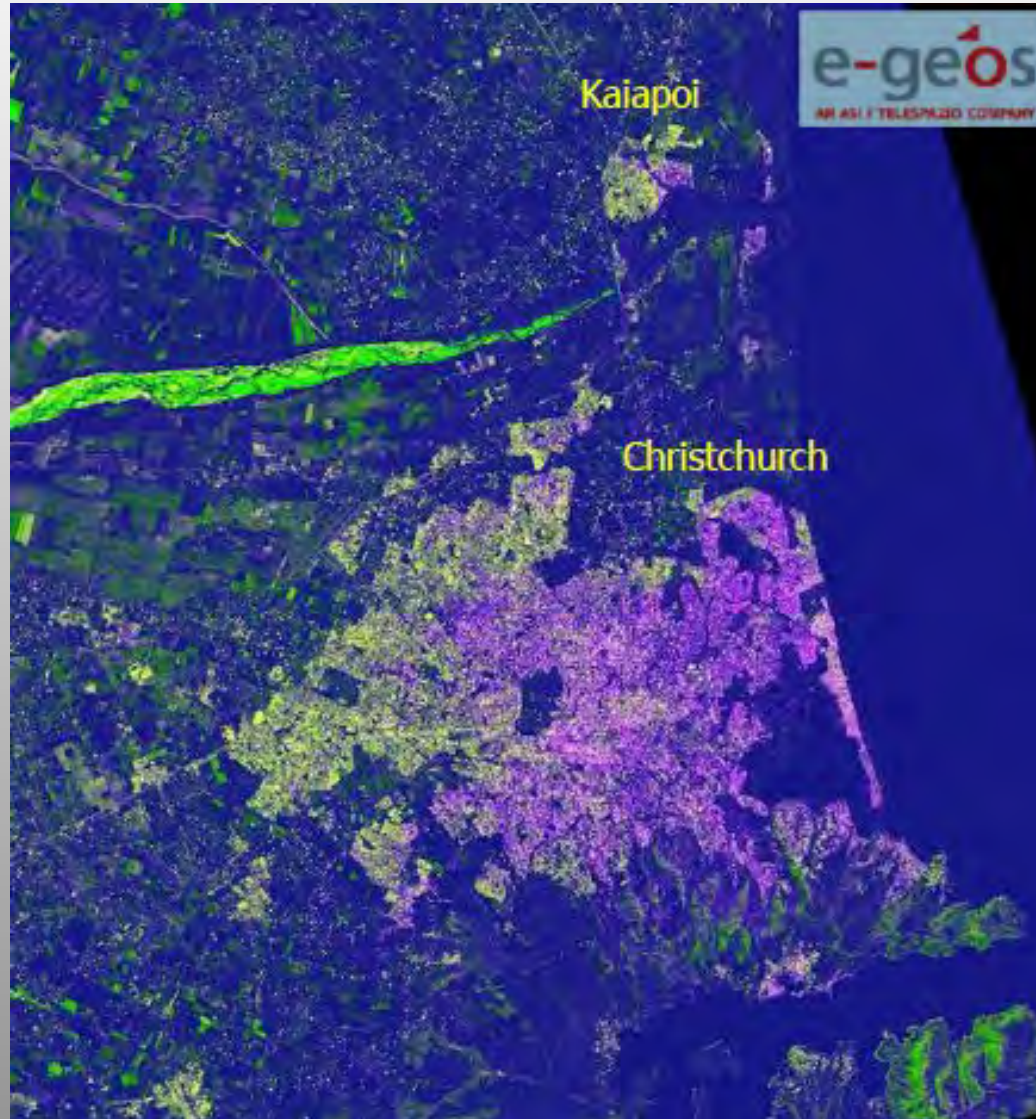


# Aerial photography - Liquefaction (NZAM)



New Zealand Post Earthquake Damage Data Collection Experience

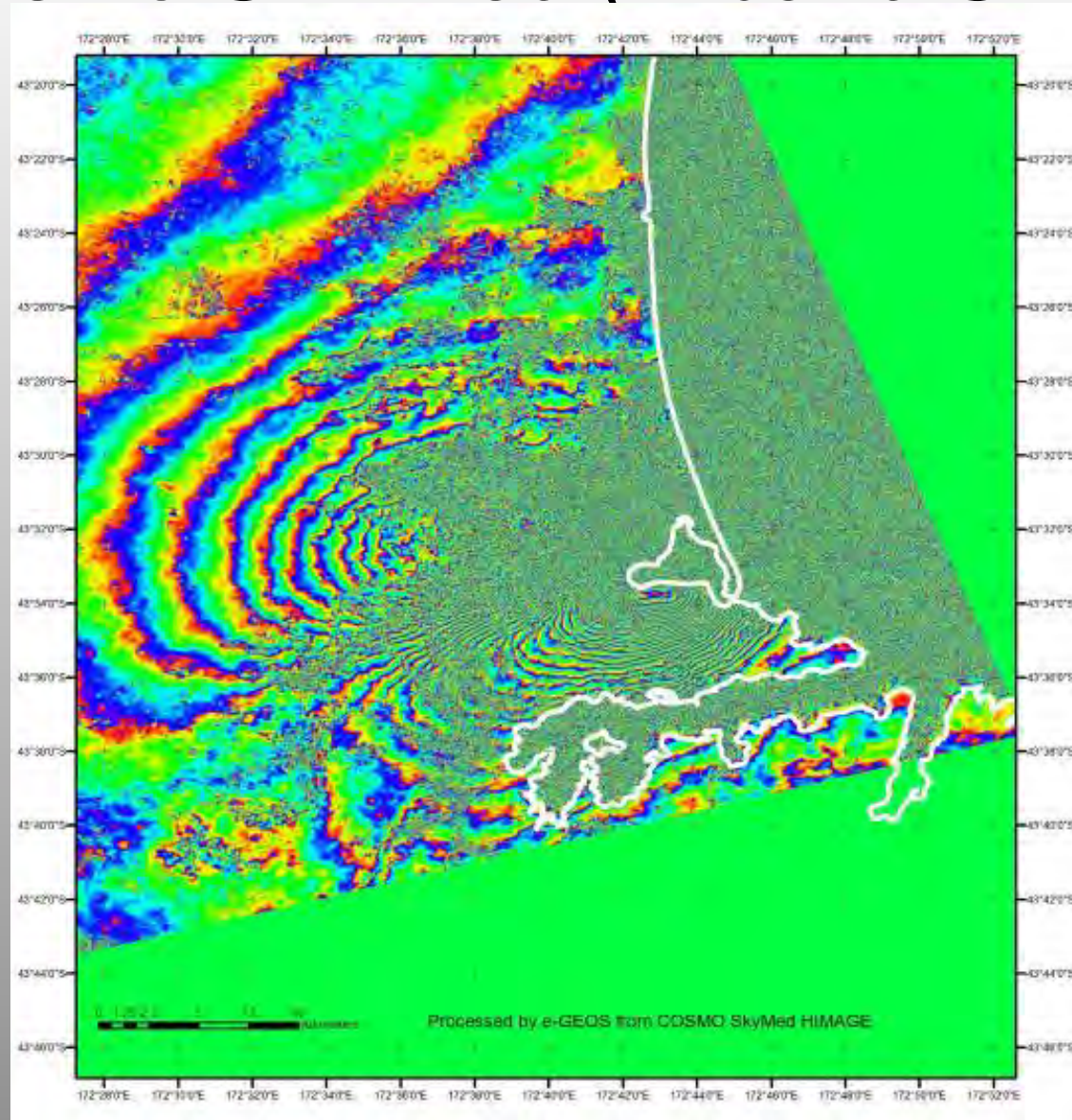
# Cosmo SKYMed coherence



New Zealand Post Earthquake Damage Data Collection Experience

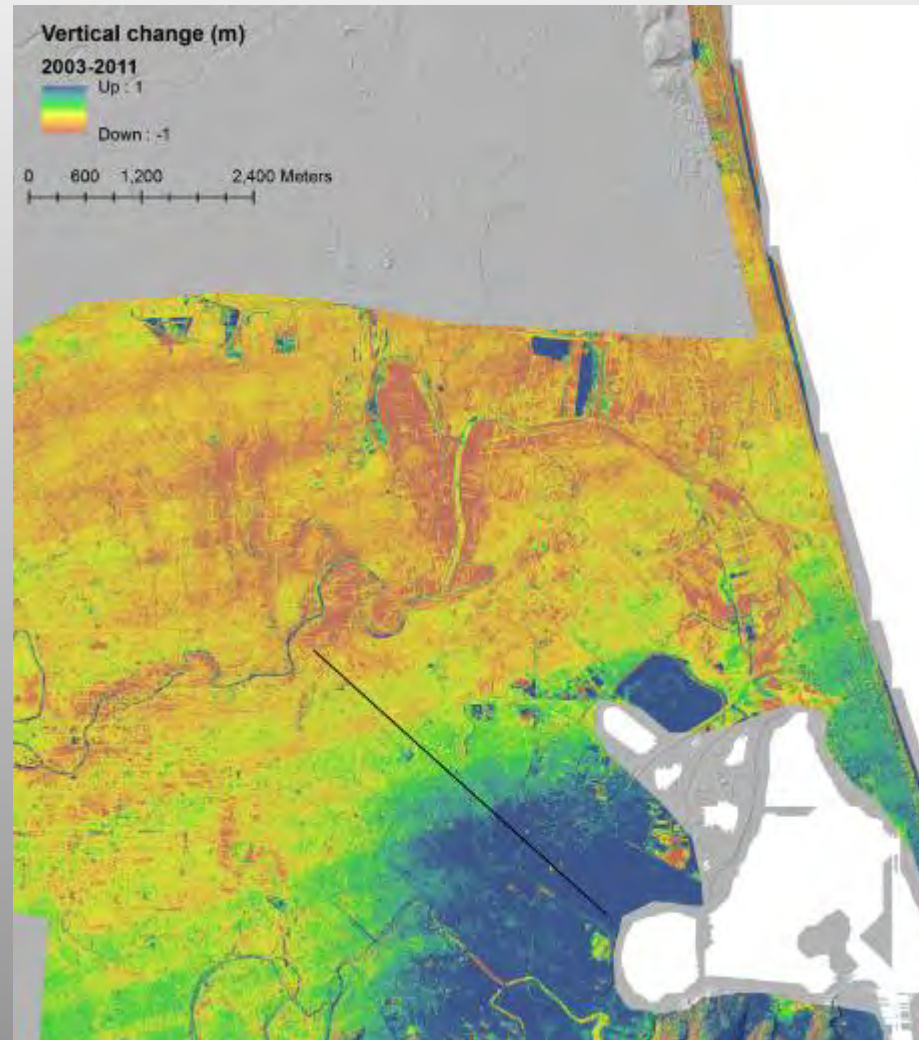


# Cosmo SKYMed (X-band SAR)



New Zealand Post Earthquake Damage Data Collection Experience

# Airborne LiDAR differencing (2003-2011)



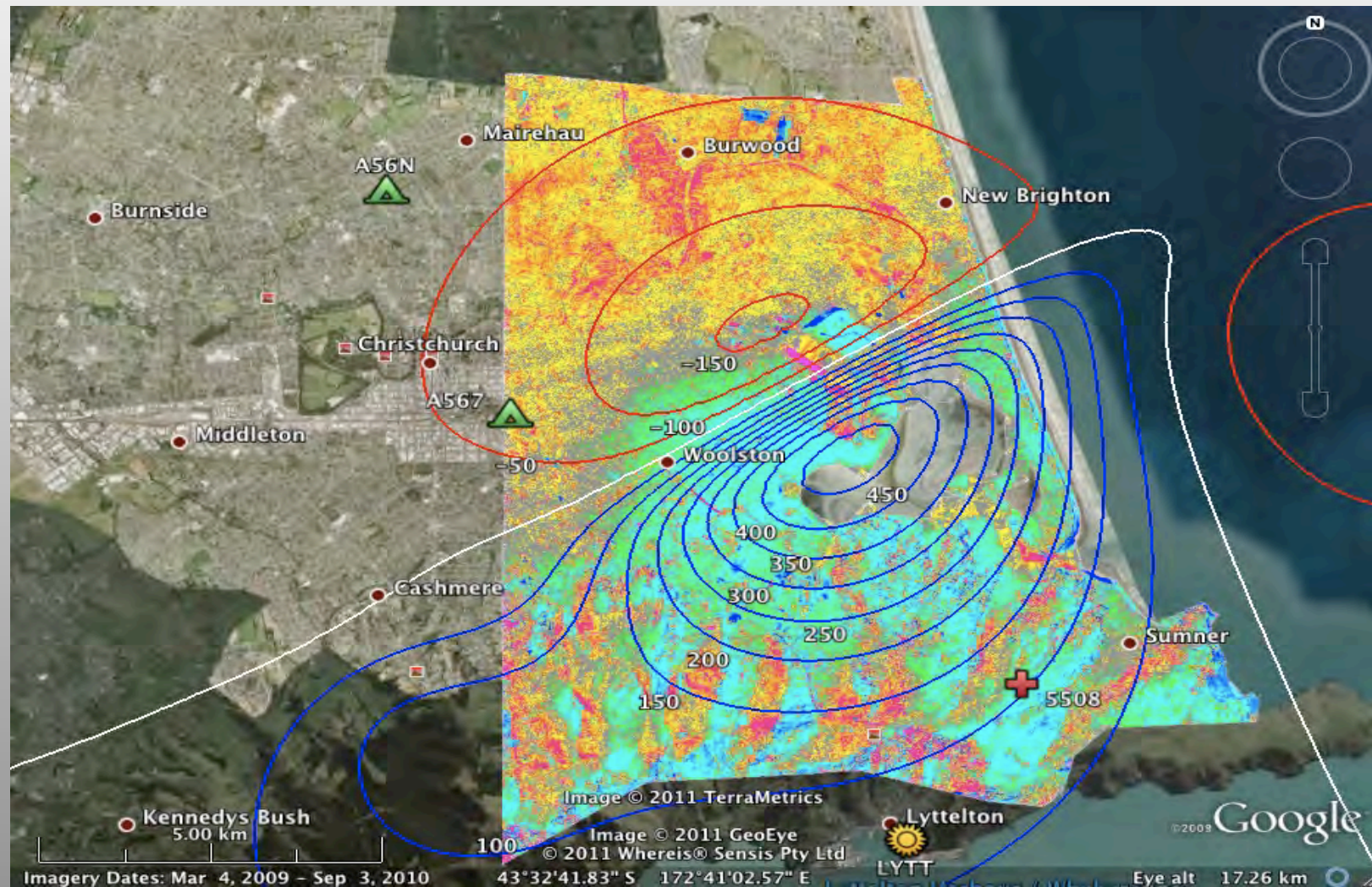
LiDAR data courtesy AAM (2003) and NZAM (2011)

New Zealand Post Earthquake Damage Data Collection Experience  
28-29 July 2011



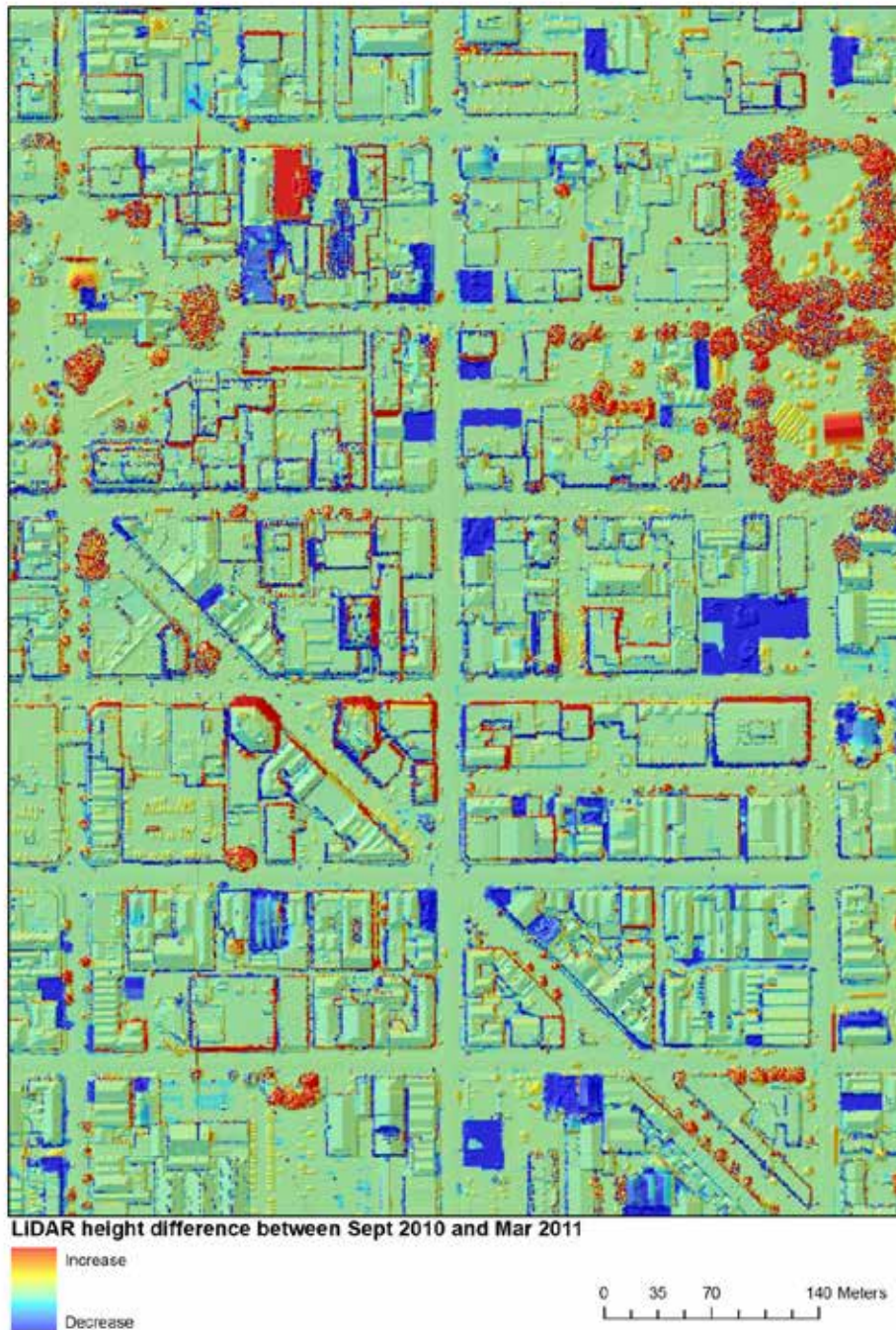
# Vertical displacement (mm)

modelled from GPS observations and 2003-2011 LiDAR



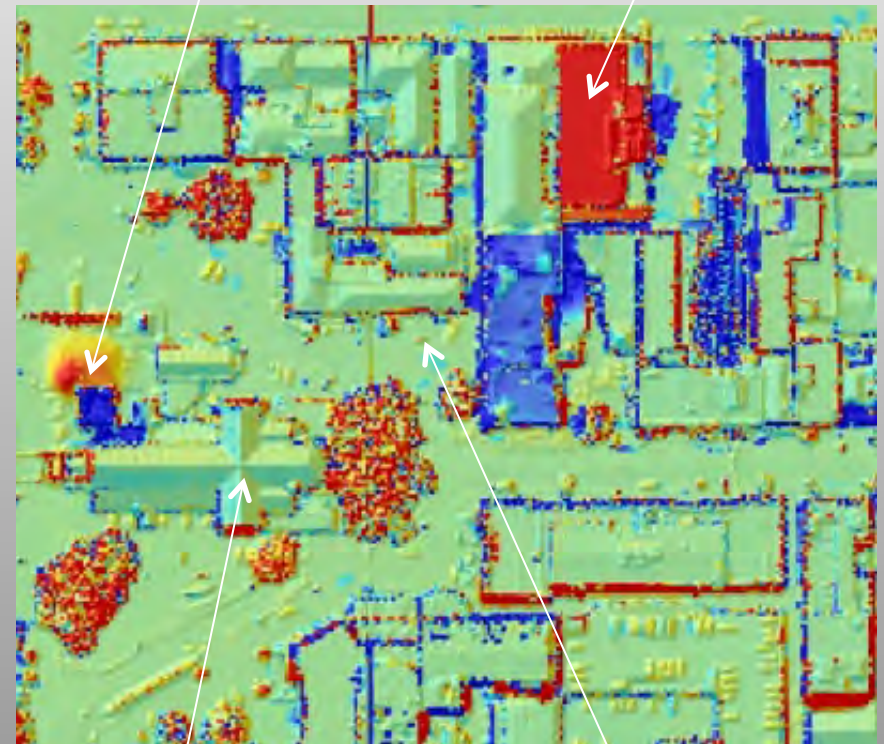


# LiDAR change detection



Collapsed spire  
and rubble

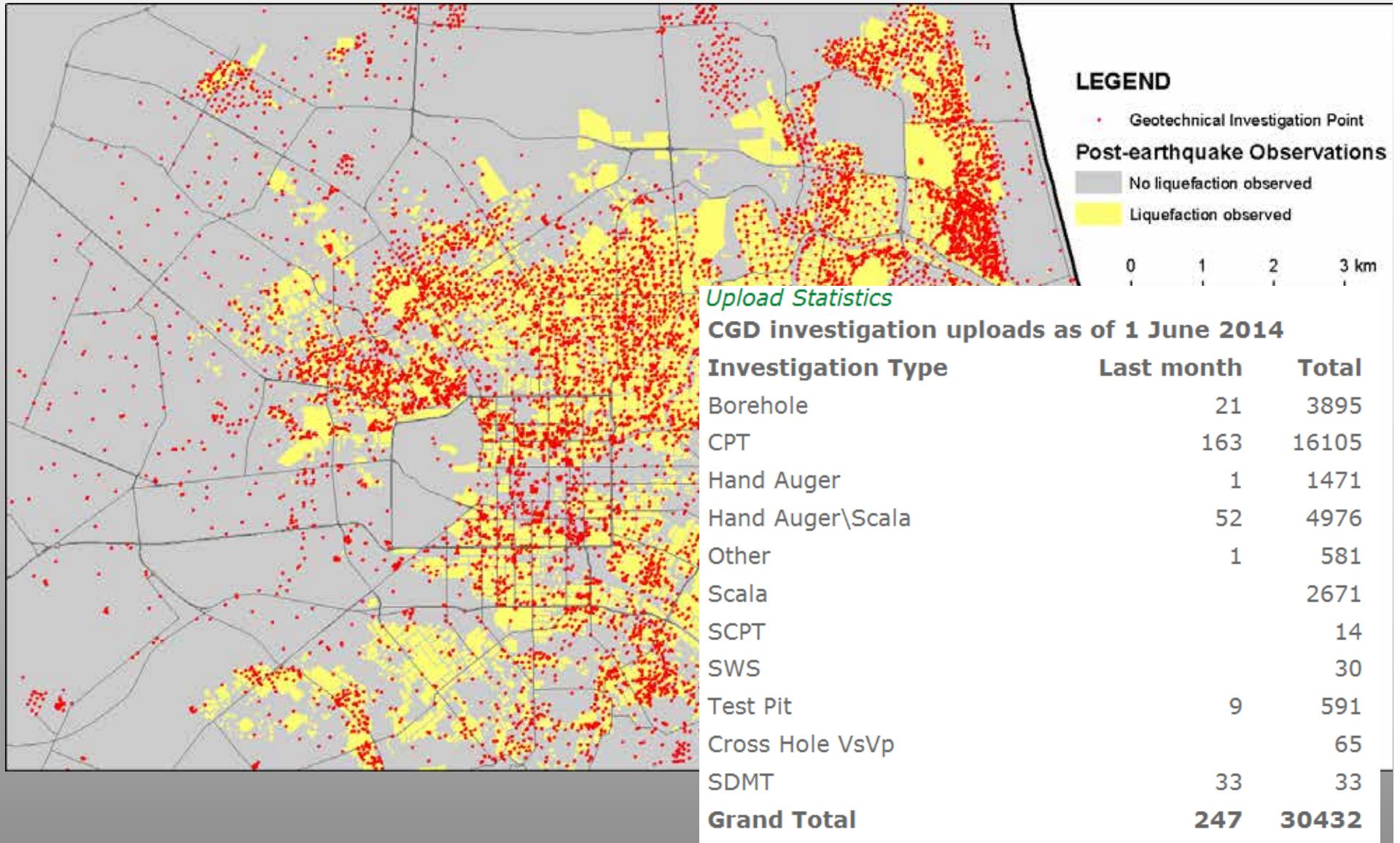
New construction



New Zealand Post Earthquake Damage Data Collection Experience



# Canterbury Geotechnical database



New Zealand Post Earthquake Damage Data Collection Experience



# Lateral displacement from LiDAR

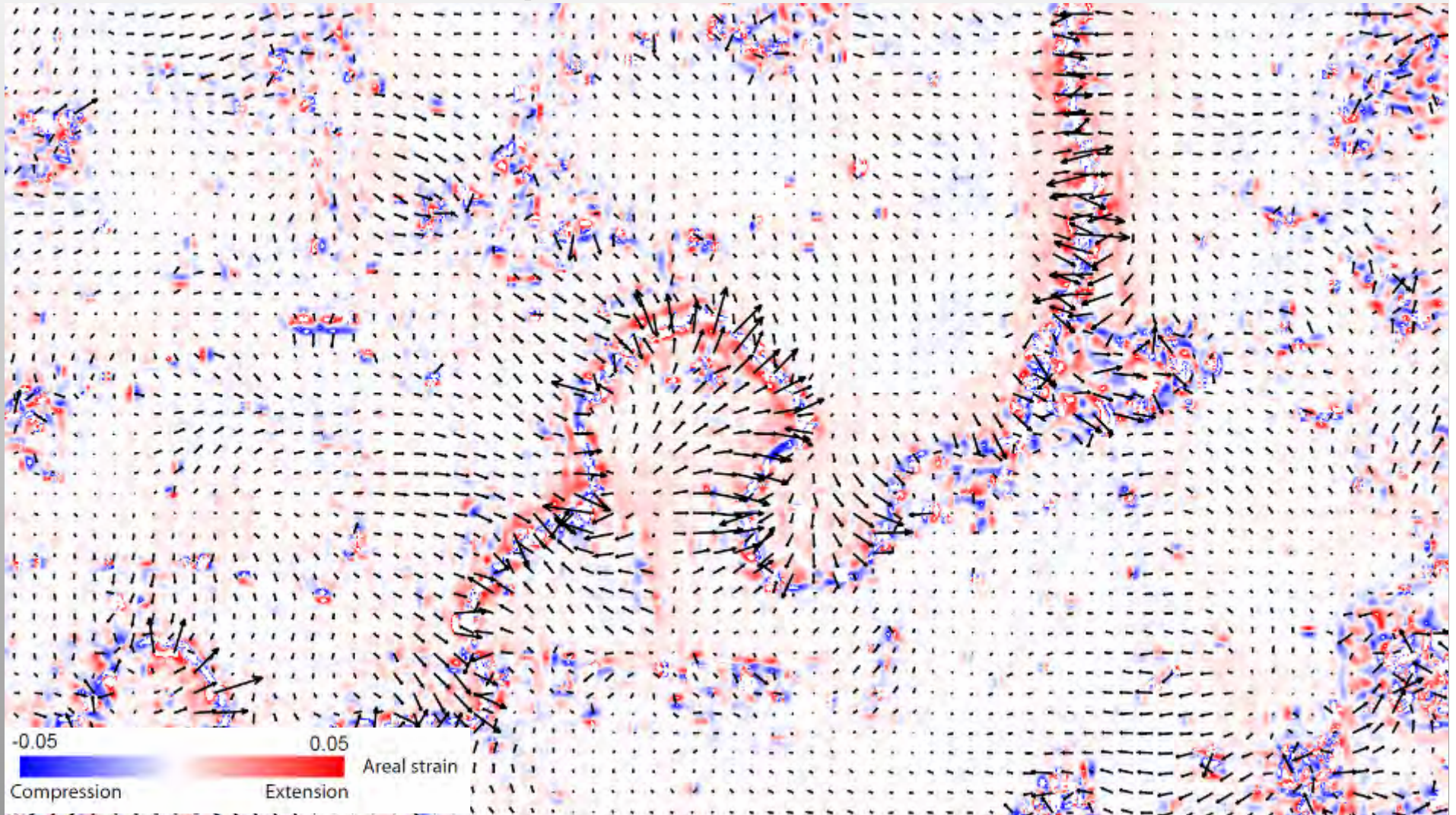


Image correlation processing by Sebastien Leprince, Caltech

New Zealand Post Earthquake Damage Data Collection Experience



http://tomnod.com/geocan/?group=3

Edit View Favorites Tools Help

Favorites 1840 DIA Intranet DIA ServiceDesk Gmail NZSEE DIA Secure LINZ CHC Imagery GeoNet CTC CERA CERA Login

tomnod Disaster Mapper | Christchurch GEOCAN

tomnod Disaster Mapper Christchurch GEOCAN

DISASTER MAPPER | INSTRUCTIONS | GEOCAN | CROWDSOURCING | CONTACT

login Tutorial 1 / 3

**tomnod** Disaster Mapper

Help map the damage.

On February 22, 2011, a 6.3 magnitude earthquake devastated Christchurch, New Zealand.

**START TUTORIAL**

**AFTER**

**BEFORE**

**NEXT MAP**

Internet 100%

# Building Safety Evaluation MS AK

- *Purpose:* Emergency phase screening of buildings that pose a unacceptable risk to occupants, the public or neighbouring properties
- *Conducted using:* Paper-based templates and 2009 guidance handbooks (Level 1 and Level 2) (based on ATC-20)
- *Conducted for:* Territorial Authority Building Control via the CDEM Controller – using co-opted Structural Engineers and Building Officials from around NZ.
- *Missing:*
  - Details of building history (prior to inspection) either as-built or since last inspection.
  - Adequate trained/qualified engineers to undertake evaluation (many problems with highly variable results)

# Building Safety Evaluation (2)

- Data storage: manually transferred data from paper to electronic database
  - procedure difficult and inaccurate particularly with multiple events requiring multiple inspections; didn't translate to timely map production
- Data retrieval: Council consider open – available on application as with building permit data; other departments are more restrictive (privacy issues!)
- Future improvements:
  - New guidance notes and training in preparation for ***Building Usability***, including replacing 'green' (implies safe) placard with '***white***' (implies inspected);
  - Legislative tools to transition back from emergency







# Building Damage Evaluation (JH SP)

- *Purpose:* To ensure that significant damage to buildings is identified and understood - to inform building repair and to inform ongoing occupancy of building.
- *Conducted using:* As-built plans and detailed on-site inspection (including invasive investigation if required)
- *Conducted for:* Building owners under direction from Government (CERA) by Consulting engineers (structural, material and Geotech)
- *Missing:* Detail as to:
  - cause or location of damage
  - basis upon which residual building capacity established
- *Issues:* Consistency of engineering evaluations, no uniformity of damage state and criticality

# Standardised Report Form

- Excel spreadsheet
  - Most common platform for engineers
- Used drop-down lists where thought possible and practical
- Limited free-field descriptions
- Included simple IEP capacity calculator – voluntary use
- *Next time:*
  - Add simple damage states
  - Even more drop-downs
  - Different platform?

[illegible]

# Building Damage Evaluation (2)

- *Data storage:* Electronic reports (pdf) and Detailed Engineering Evaluation (DEE) summary spreadsheets submitted to CERA; stored in CERA database until 'approved' by CERA then passed to Council Building Reports
- *Data retrieval:* Council considers their building records open to public as with building permit data; other departments are more restrictive (privacy issues!)
- *Future improvements:*
  - Pre-event assessment being undertaken as part of Earthquake Prone Building register evaluation
  - Data retrieval to hand-held inspection tablet now possible
  - Use of common fields for both inspection and loss projection

UC  
UNIVERSITY OF  
CANBERRA

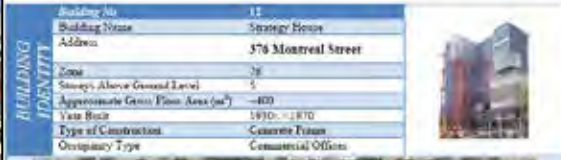
Draft Report on Pre-1970s Reinforced Concrete Buildings in Christchurch CBD  
Draft 10<sup>th</sup> March 2011 NOT FOR PUBLIC RELEASE

PRELIMINARY REPORT

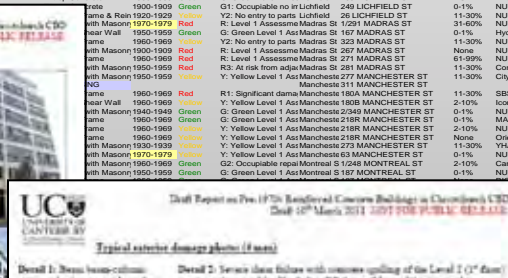
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**The Seismic Performance of Reinforced Concrete Buildings  
Built in 1930s-1970s in the Christchurch CBD**

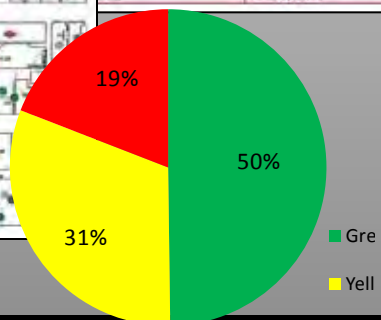
UC  Draft Report on Pre-1970: Reinforced Concrete Buildings in Chualar/CDO  
Draft 10th March 2018 -NOT FOR PUBLIC RELEASE-



*Contributing Authors:*  
 Uwe Albrecht  
 Wang Yuan Eme  
 Sahin Taşkınçlı  
 Patricia Quintana-Gallo



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Figure 10 consists of six sub-images labeled (a) through (f), showing various cracks in concrete beams and columns. (a) shows a vertical crack in a concrete beam. (b) shows a horizontal crack in a concrete beam. (c) shows a vertical crack in a concrete column. (d) shows a vertical crack in a concrete beam. (e) shows a horizontal crack in a concrete beam. (f) shows a vertical crack in a concrete column.



BUILDING IDENTITY	Building No	70s-XX
	Building Name	SBS Tower
	Address	128 Worcester St (180 Manchester St)
	Zone	8
	Storeys Above Ground Level	9
	Approximate Gross Floor Area (m <sup>2</sup> )	~900
	Year Built	1964-65
	Type of Construction	RC Coupled-Walls (EW/NS), Steel Frame (EW – north end)
	Occupancy Type	Commercial Office



North-West View



Map



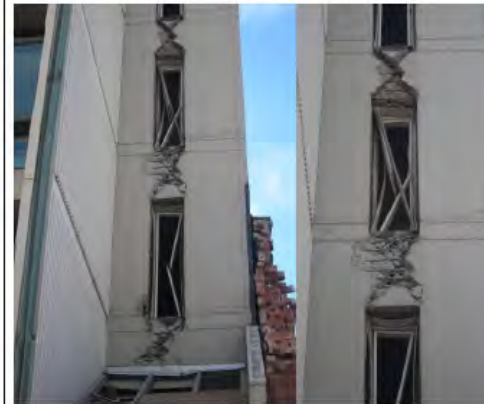
South-East View

Photos of SBS Building under construction in the 1960s.



Typical exterior damage photos (4 max)

Detail 1: Coupling beams damage at the West elevation.



Detail 2: Flexural-shear damage at the RC wall with opening at the East elevation.



Detail 3: Minimal damage at the facade precast panels (except for local crushing at the slab-window region).





In terior damage photos

**Detail 4:** Interior view of the damaged coupling beam at the West elevation walls. Diagonal and horizontal deformed reinforcements were observed. No confining vertical ties can be found in the spalled locations.



**Detail 5:** Interior view of the damaged shear walls in the East elevation.



**Detail 5:** 10-20mm cracking on the RC slab along the internal shear walls (E-W direction).



**Detail 7:** Damaged coupling beam at the internal coupled-walls (East-West direction).



**Detail 8:** Concrete spalling at the pin support at the bottom landing of the staircases. Damage was more severe at the upper levels.

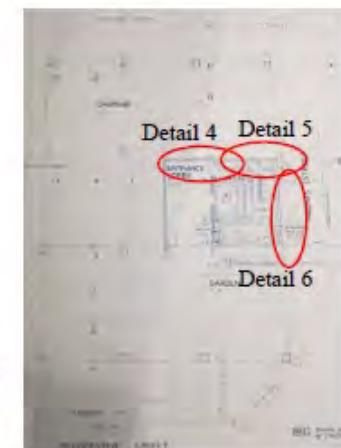
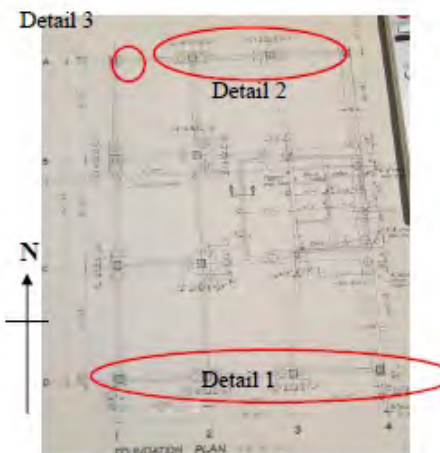


**Detail 9:** Movement at the top landing of the staircases. Gaps of 10-50mm were observed



BUILDING IDENTITY	
Building No	70s-302
Building Name	Securities House
Address	221 Gloucester
Zone	3a
Storeys Above Ground Level	8
Approximate Gross Floor Area (m <sup>2</sup> )	~330
Year Built	1970-1979
Type of Construction	Concrete Frames with Concrete Core walls
Occupancy Type	Commercial Office

Building Plans





### Foundation System

The foundation system is formed by isolated footings for columns and foundation (coarse) beams for walls, attached to the ground using piles (size and depth not specified in available drawings). Footings are attached to each other using slender foundation beams. Wider beams were used on axis 4, whereas thin beams were used to attach the outer ends of the C-shaped wall to the west side columns.

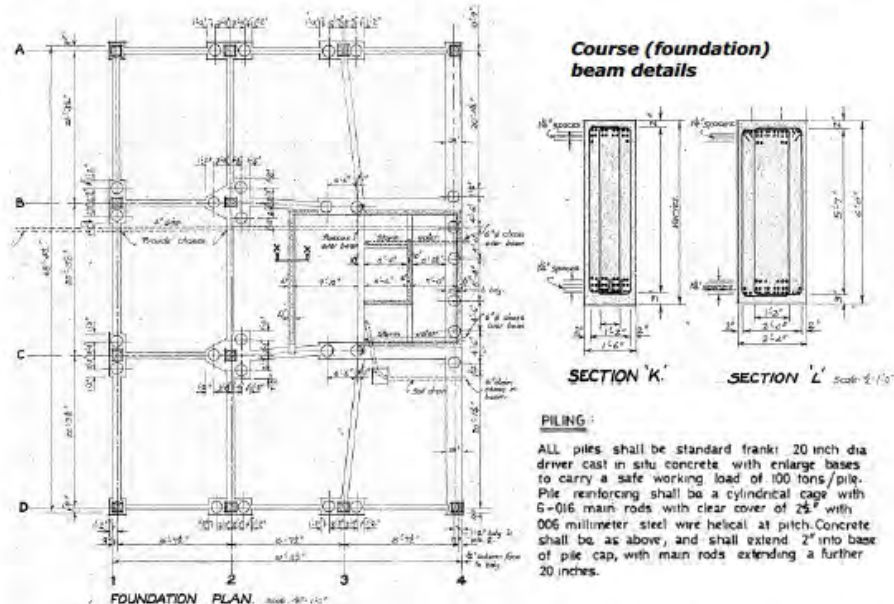


Figure 2: Foundation system. Left: foundation pan view; right: course beam details and piling information

### Structural System

The structural earthquake resistant system is conformed by perimeter RC frames and RC structural core C-shaped and L-shaped walls. Gravity loads in the central area are resisted by columns with capitals jointed continuously to the cast in situ floor slab. The C-shaped wall is used as support for stairs together with the L-shaped thin wall, as shown in details. Note the interior RC L-shaped wall has got a single mesh inside, as shown in details. Stairs are jointed at each floor level to the structural walls using cast in situ floor slabs. Floor system consists in cast in situ RC slabs 5 in. thick (130mm).

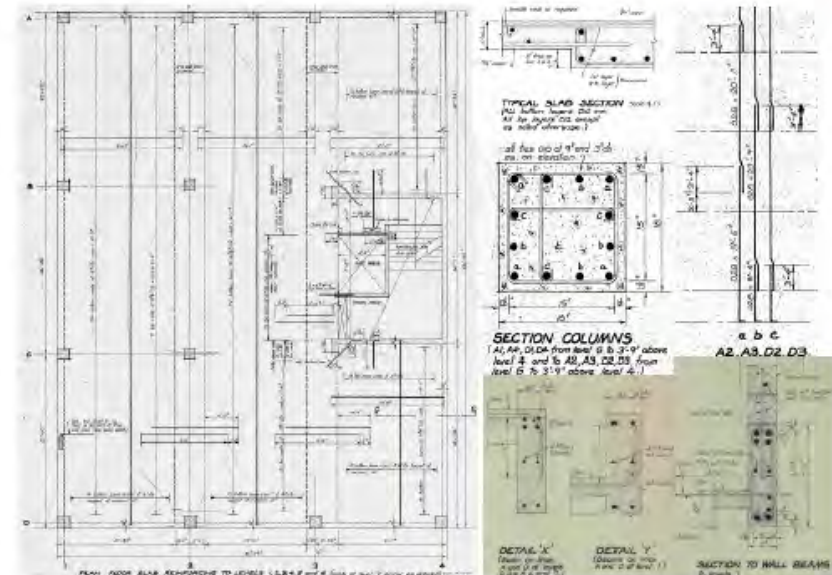


Figure 3: Structural System. Left: typical plan view; right: Column, beam and slab details

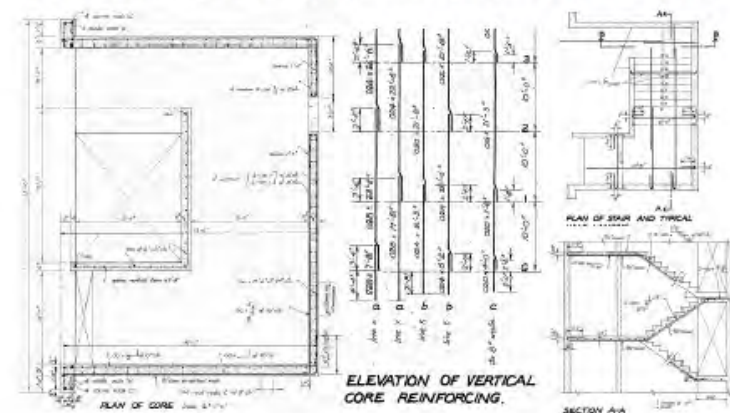
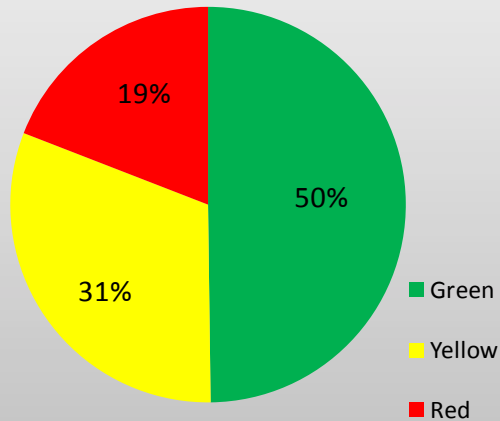


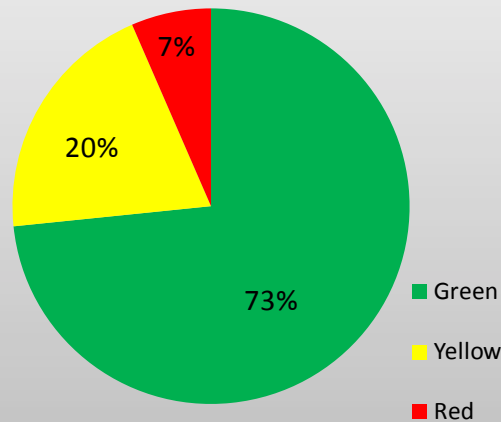
Figure 4: Structural System. Left: C-shaped wall details; right: stairs connection details

# Damaged buildings (22 Feb 2011)

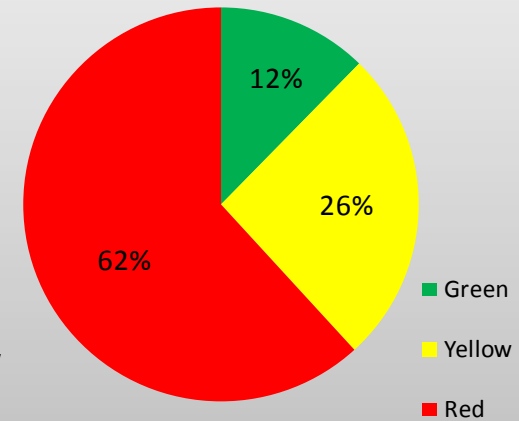
Reinforced Concrete



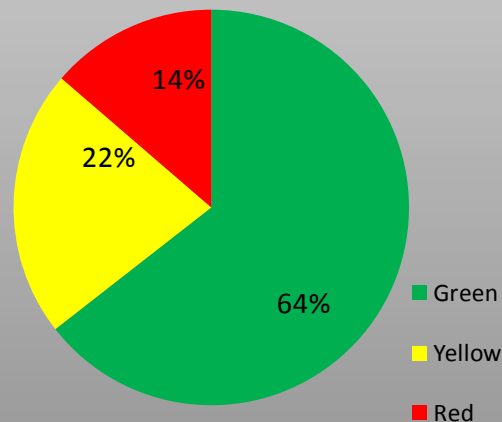
Steel



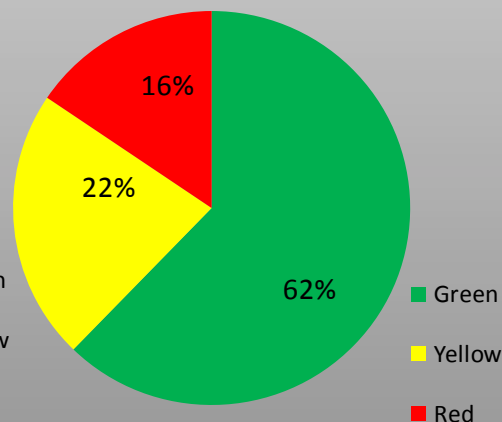
Unreinforced Masonry



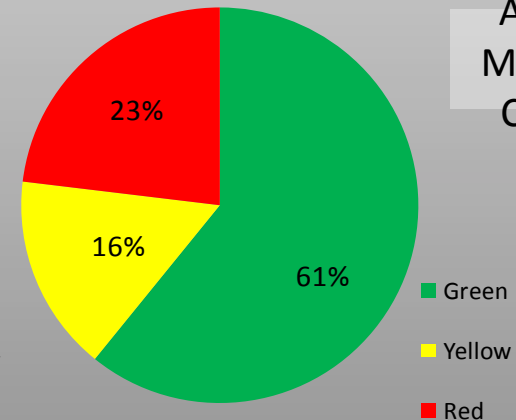
Timber



Reinforced Masonry

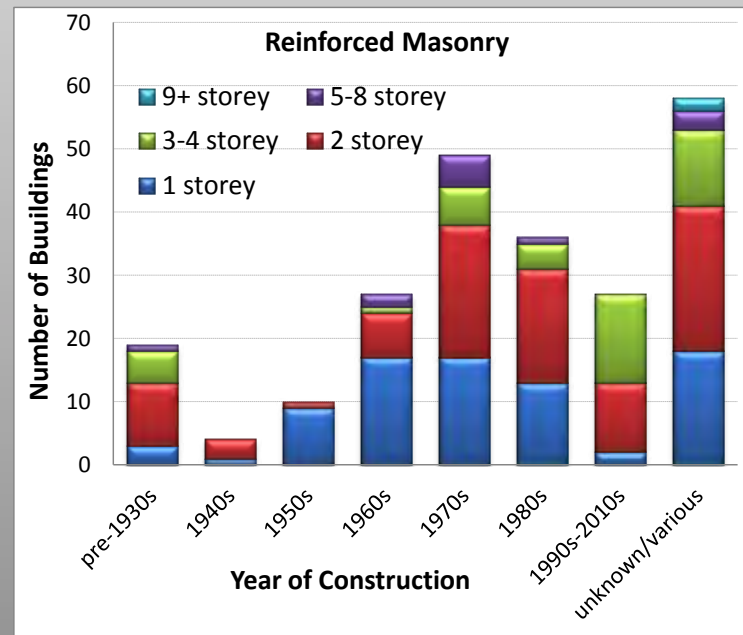
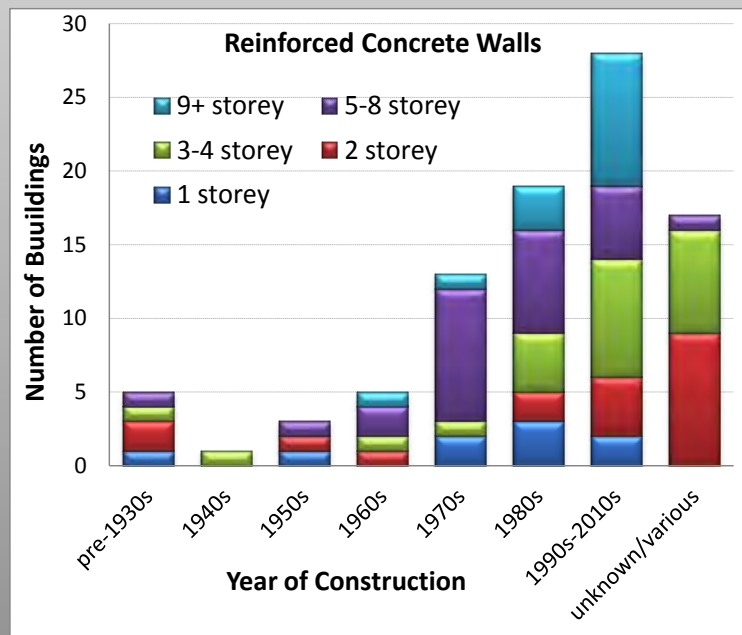
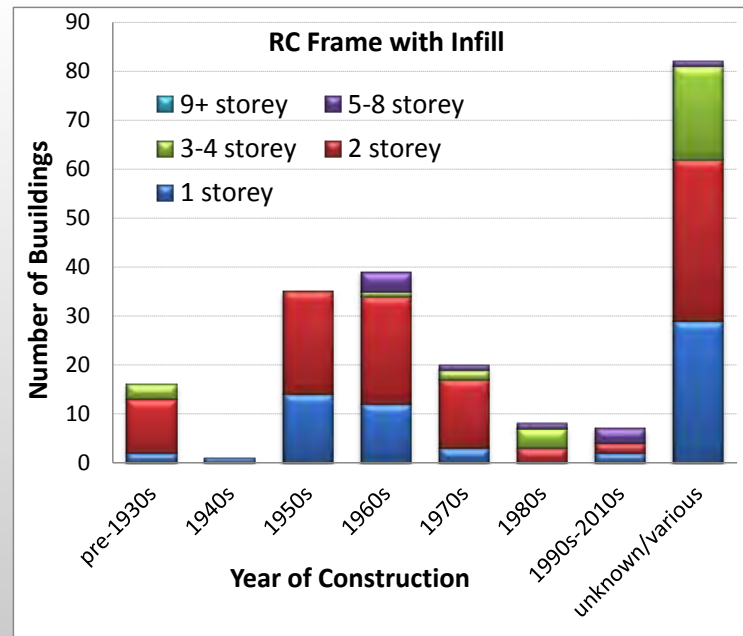
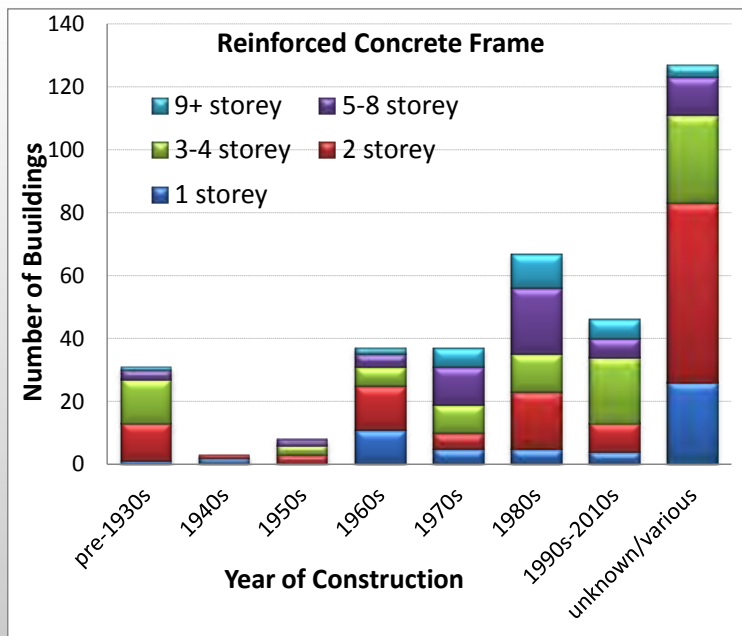


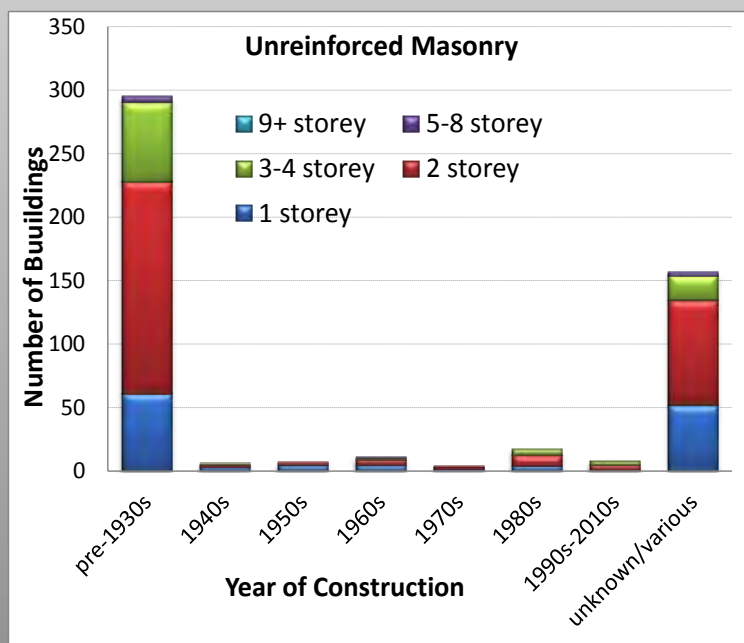
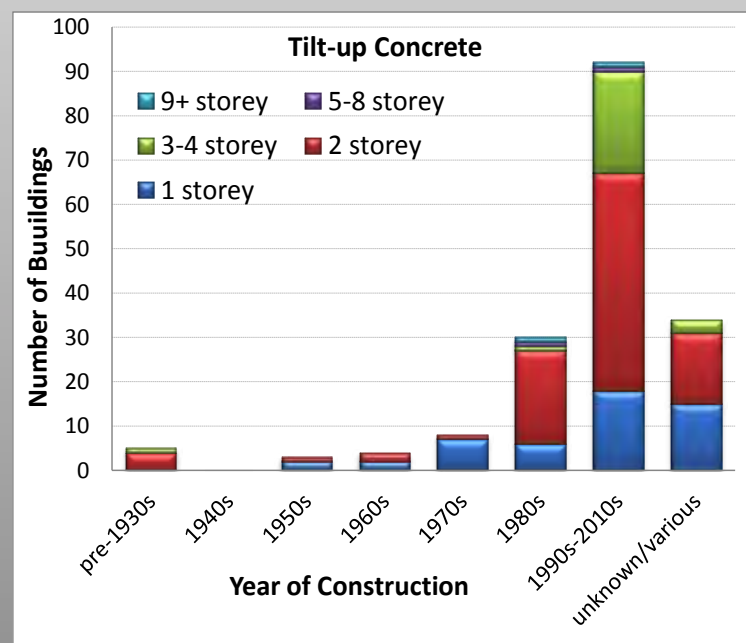
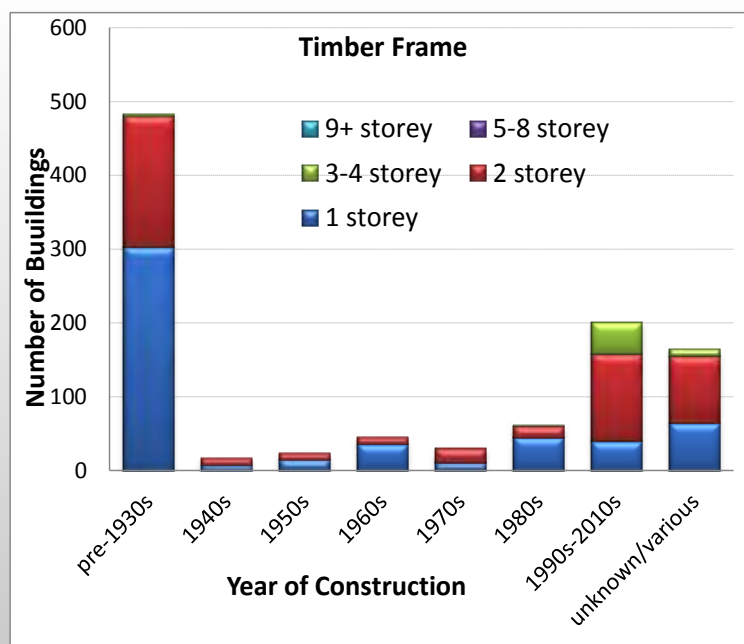
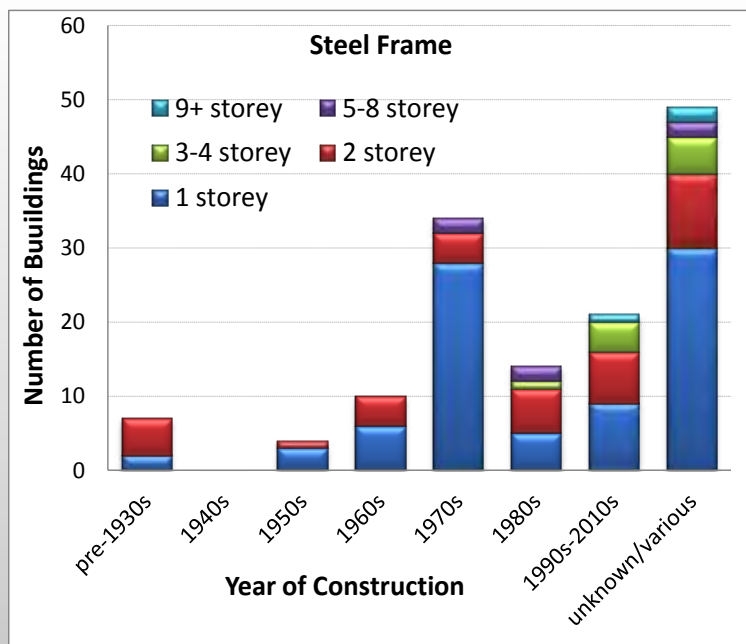
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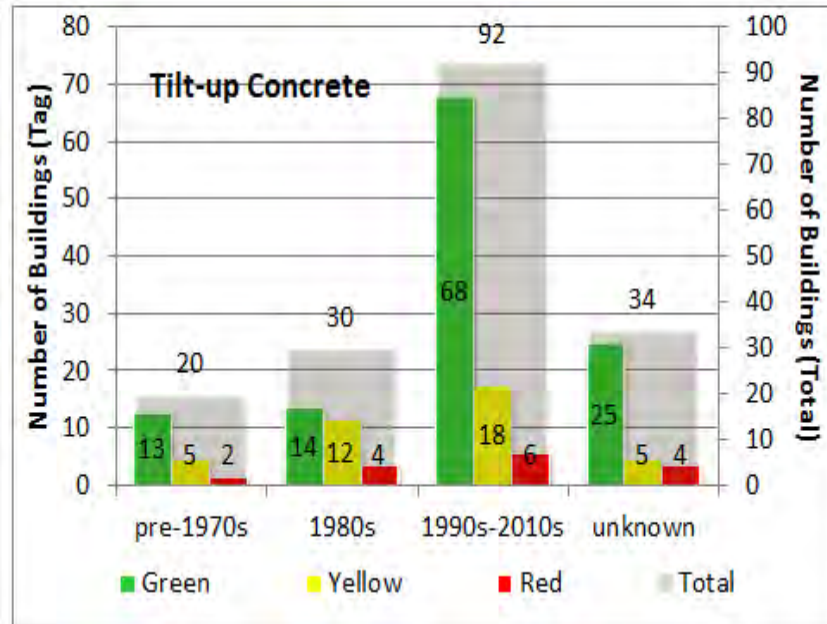
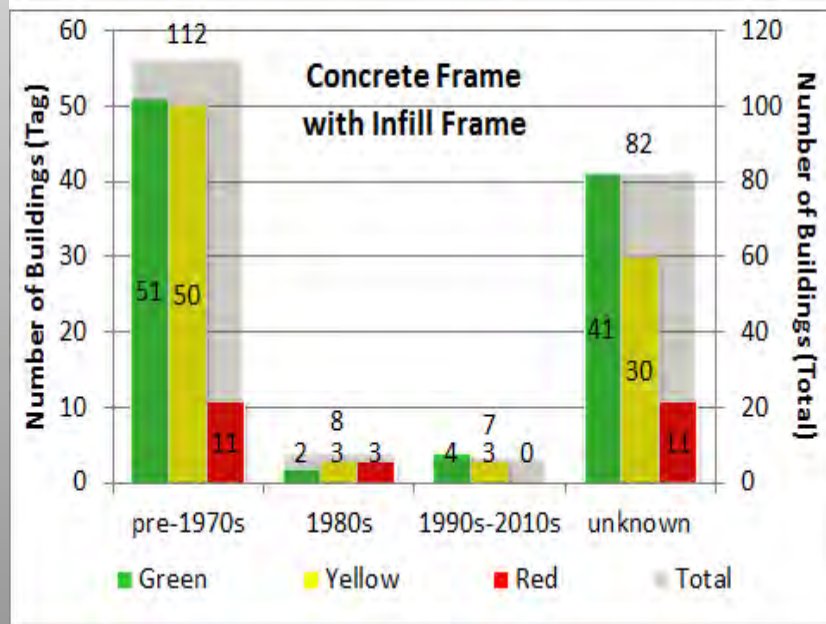
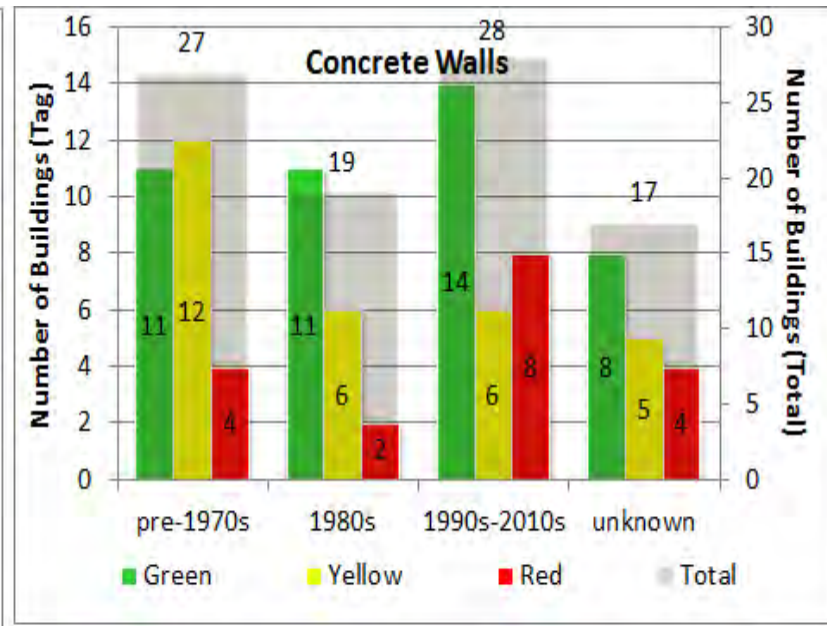
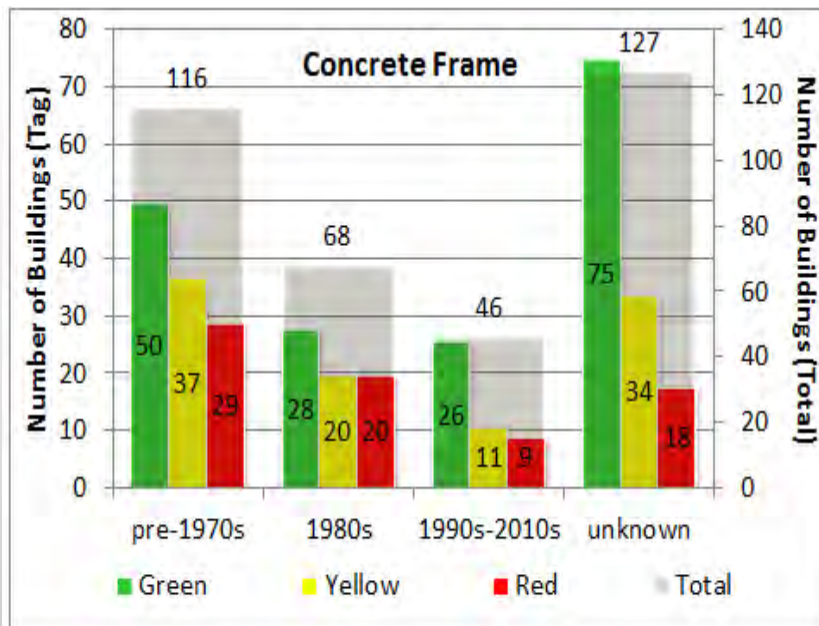


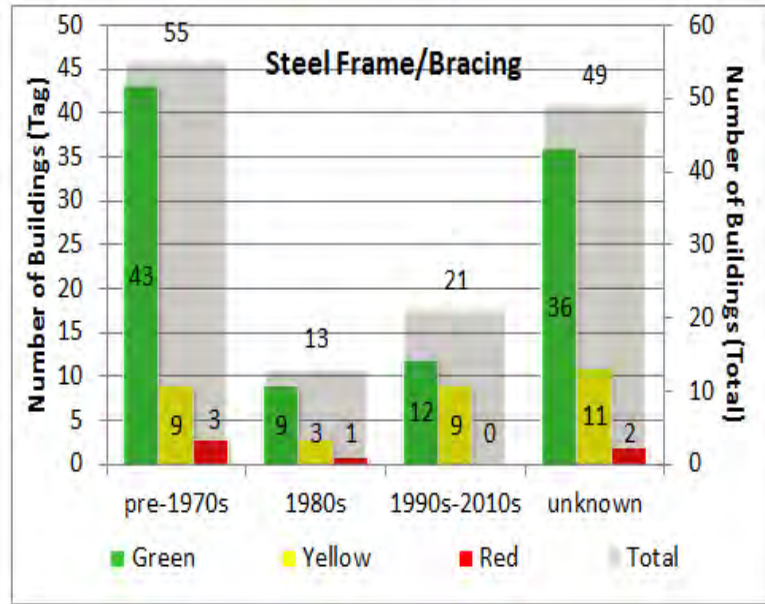
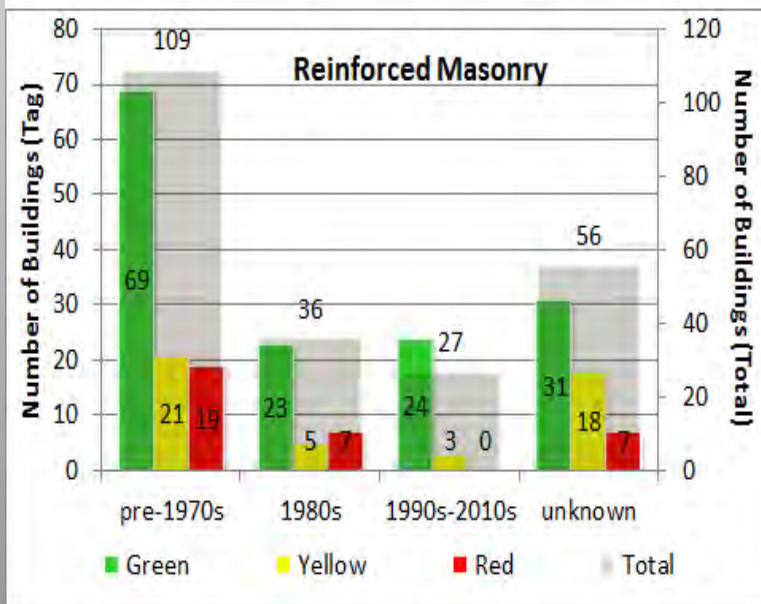
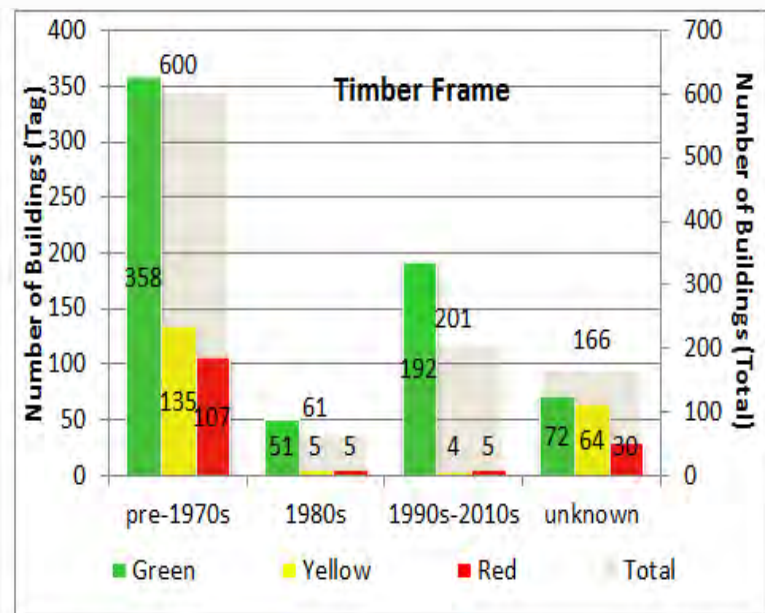
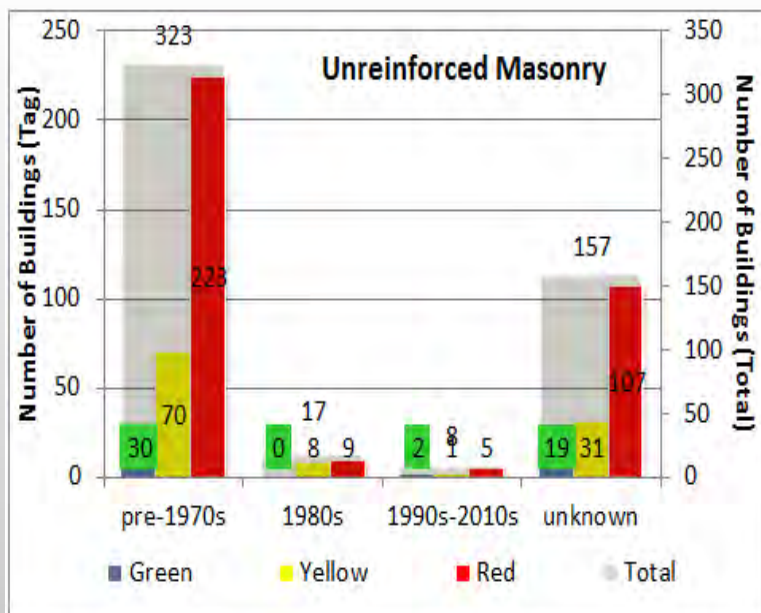
As per 18  
Mar 2011 –  
CCC Data



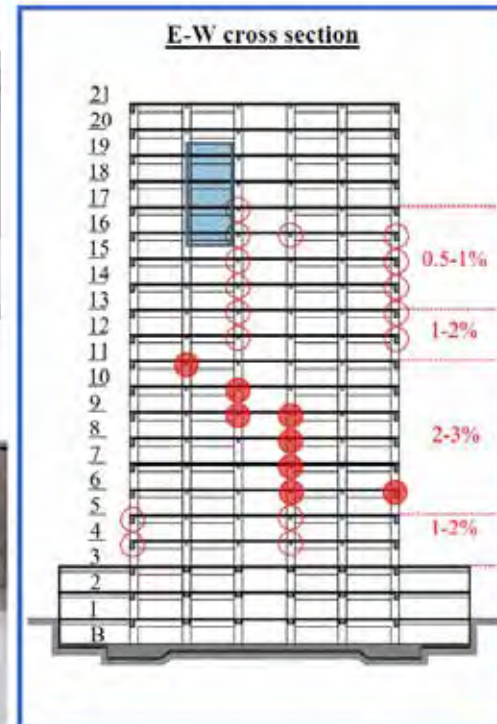




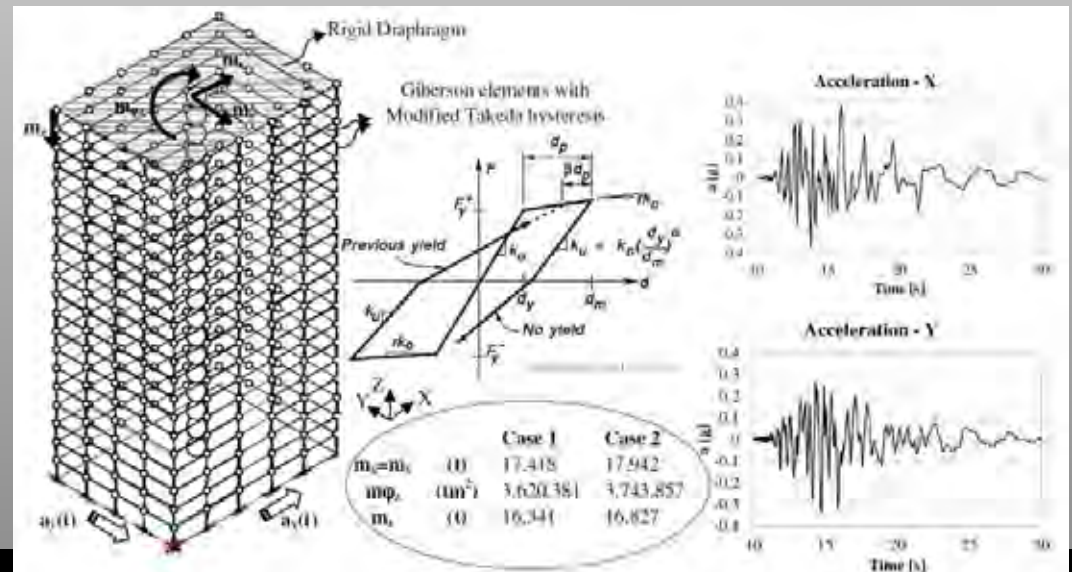








Key points:



New Zealand Post Earthquake Damage Data Collection Experience

# Building Loss – Consequences (AK SP)

- *Purpose:* determination of a settlement claim consistent with the specific insurance policy.
- *Collected using:* Electronic tablet and data collection tools; paper forms.
- *Collected By:* Insurance loss adjusters and their technical advisors
- *Data Storage:* within each the respective private insurers, usually in electronic form
- *Data access policy:* Privacy prevents any (or nearly any) disclosure; Special arrangements are required and possible in some cases where trust and security can be assured.

# Residential assessments - EQC

- Globally unique EQC role in providing cover for land damage – EQC claims settlement not just about buildings but also the associated land;
- Understanding land changes and likely future ground performance critical input to recovery – transparency of this information essential for international confidence and community engagement;
- Importance of geotechnical information for the recovery drove new approaches to information management and private-public sharing

# Residential assessments – EQC <sub>2</sub>

The Canterbury Earthquake Sequence (CES) necessitated multiple recollection of all data (including aerial photography & LiDAR) after each significant event.

Some complexities:

- Overlapping interests in building safety and loss/damage evaluations, particularly for multi-unit dwellings;
- The nature of the CES and the legislation generated multiple claims for the same dwelling – necessitated multiple assessments for a single building, over 750,000 assessments undertaken by EQC in association with the CES.

Loss information is currently being shared (under NDAs) with reinsurers, researchers, and loss modellers.



# Building Loss – Consequences (2)

## ➤ *Missing:*

- Description of damage (and in many cases of the building since the focus is on the remedy)
- Descriptions of the cause (shaking or deformation)

## ➤ *Data retrieval:* possible (with 'special arrangements' but complicated (particularly for large claims with multiple insurance layers

## ➤ *Future improvements:*

- Access to loss data – by regulation if necessary.
- More consistent (standardised) insurance policies that appropriately assign risk.

# Social Impact and Injuries (DJ)

- *Purpose:* to gain an appreciation of the factors that influence social response and community resilience
- *Collected using:* Surveys, direct discussion and census
- *Collected for:* Stats NZ, ACC; MSD; CERA; Councils, DHBs
- *Missing:* Community wellbeing, transient populations, linking meta-data
- *Data Storage:* within many organizations
- *Data Retrieval:* Stats NZ Portal, data sharing protocols
- *Future Improvements:* data sharing protocols between agencies

## The 2010/2011 Canterbury earthquakes: context and cause of injury

David Johnston · Sarah Standring · Kevin Ronan · Michael Lindell · Thomas Wilson · Jim Cousins · Emma Aldridge · Michael Warne Ardagh · Joanne Margaret Deedy · Steven Jensen · Thomas Kirsch · Richard Bissell

Received: 10 September 2013 / Accepted: 13 February 2014  
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**Abstract** The aim of this study was to investigate causes of injury during the 2010/2011 Canterbury earthquakes. Data on patients injured during the Darfield (4 September 2010) and Christchurch (22 February 2011) earthquakes were sourced from the New Zealand Accident Compensation Corporation. The total injury burden was analyzed for demography, context of injury, causes of injury, and injury type. Injury context was classified as direct (shaking of the primary earthquake or aftershocks causing unavoidable injuries), action (movement of person during the primary earthquake or aftershocks causing potentially avoidable injuries), and secondary (cause of injury after shaking ceased). Nine categories of injury cause were identified. Three times as many people were injured in the Christchurch earthquake as in the Darfield earthquake (7,171 vs. 2,256). The primary

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University of Canterbury, Christchurch, New Zealand

J. Cousins  
GNS Science, Wellington, New Zealand

Published online: 27 February 2014

 Springer

## Relative risk by gender and age

	Christchurch	Darfield			Christchurch		
	Population	Total Injuries (n)	Injuries per 10,000	Risk	Total injuries (n)	Injuries per 10,000	Risk
<b>Gender</b>							
<b>Male</b>	168,423	803	47.7	1.0	2525	149.9	1.0
<b>Female</b>	180,012	1453	80.7	1.7	4646	258.1	1.7





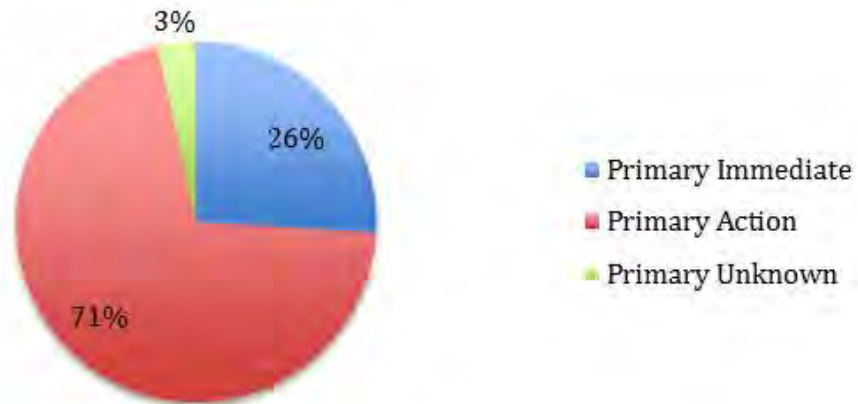
## Relative risk by gender and age

	Christchurch			Darfield		Christchurch	
	Population	Total Injuries n	Injuries per 10,000	Relative risk	Total injuries n	Injuries per 10,000	Relative risk
<b>Under 5</b>	21,477	15	7	1	66	30.7	1
<b>5-9</b>	21,396	12	5.6	0.8	41	19.2	0.6
<b>10-14</b>	22,797	31	13.6	1.9	86	37.7	1.2
<b>15-19</b>	25,875	62	24	3.4	241	93.1	3
<b>20-24</b>	27,597	68	24.6	3.5	359	130.1	4.2
<b>25-29</b>	22,506	81	36	5.2	371	164.8	5.4
<b>30-34</b>	24,858	145	58.3	8.4	433	174.2	5.7
<b>35-39</b>	26,310	224	85.1	12.2	636	241.7	7.9
<b>40-44</b>	26,091	240	92	13.2	674	258.3	8.4
<b>45-49</b>	25,008	304	121.6	17.4	784	313.5	10.2
<b>50-54</b>	21,927	274	125	17.9	821	374.4	12.2
<b>55-59</b>	20,313	197	97	13.9	644	317	10.3
<b>60-64</b>	15,084	175	116	16.6	554	367.3	12
<b>65+</b>	47,196	428	90.7	13	1461	309.6	10.1

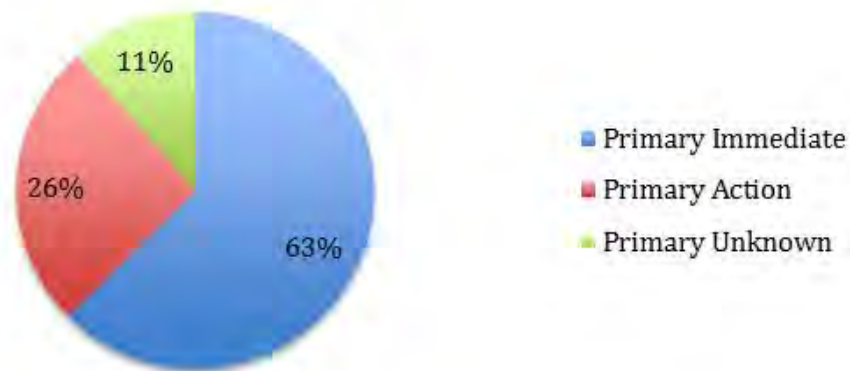
## Context of injury

	Darfield	Christchurch
	n (%)	n (%)
<b>Primary Immediate</b>	377 (16.7)	3129 (43.6)
<b>Primary Action</b>	1025 (45.4)	1293 (18.0)
<b>Primary Unknown</b>	50 (2.2)	574 (8.0)
<b>Secondary</b> (including clean-up)	499 (22.1)	1881 (26.2)
<b>Aftershock Immediate</b>	165 (7.3)	172 (2.4)
<b>Aftershock Action</b>	134 (5.9)	103 (1.4)
<b>Aftershock Unknown</b>	6 (0.3)	19 (0.3)

## Primary Injuries - 4th September 2010



## Primary Injuries - 22nd February 2011



**Christchurch quake- first 24 hours**  
**Accident location and external cause of injury**

	<b>Total injuries</b>	<b>Male</b>	<b>Female</b>	<b>Ratio</b>
	<b>n</b>	<b>n (%)</b>	<b>n (%)</b>	<b>F:M</b>
<b>Accident Scene</b>				
<b>Home</b>	3392	1002 (30%)	2390 (70%)	2.39
<b>Commercial/Service Location</b>	1549	444 (29%)	1105 (71%)	2.49
<b>Road/Street</b>	399	143 (36%)	256 (64%)	1.79
<b>Industrial Place</b>	228	112 (49%)	116 (51%)	1.03
<b>School</b>	140	34 (24%)	106 (76%)	3.12
<b>Place of Recreation or Sport</b>	80	21 (26%)	59 (74%)	2.81
<b>Place of Medical Treatment</b>	45	8 (18%)	37 (82%)	4.63
<b>Other/Not Obtainable</b>	826	268 (32%)	558 (68%)	2.08



- Gender differences were significant and causes are varied. Further work is need to explain them.
- In general, improved building codes, strengthening buildings and securing fittings will reduce future earthquake deaths and injuries.
- However, the high rate of action injuries earthquake suggests that further education is needed to promote appropriate actions during and after earthquakes.



## 9. Suggest possible data collection protocols?

- Seek consensus and standards for describing earthquake damage to ground and to buildings, to aid interoperability;
- Clarify what data can be shared and what is restricted because of privacy and confidentiality reasons – support with relevant data structures;
- Seek arrangements that encourage ***Collaboration*** versus ***Competition***

10NCEE Special Session, Anchorage, Alaska  
The Canterbury Earthquake Sequence: Lessons for Response and Recovery

July 23, 2014



# Canterbury Earthquakes Sequence Building Damage, Data Collection, & Access

Andrew King – GNS Science

Peter Wood – NZSEE

Mike Stannard – MBIE

Stefano Pampanin – University of Canterbury

John Hare – Holmes Consulting Group

David Johnston – GNS Science

New Zealand Post Earthquake Damage Data Collection Experience



**Post-Earthquake Data Collection Workshop**  
**Anchorage, July 20-21, 2014**

**Japan session**  
**July 20, 15:30 – 17:00**

**Toshimi Kabeyasawa, University of Tokyo**  
**Masaki Maeda, Tohoku University**  
**Koichi Kusunoki, University of Tokyo**  
**Toshikazu Kabeyasawa, National Institute for  
Land and Infrastructure Management**  
**Tomohisa Mukai, Building Research Institute**  
**Satoshi Tanaka, Tokoha University**  
**Susumu Kono, Tokyo Institute of Technology**





**Post-Earthquake Data Collection Workshop**  
**Anchorage, July 20-21, 2014**

**Japan experience**  
**Focused on damages to reinforced buildings**

**Presentations (70min)**

**Toshimi Kabeyasawa, AIJ disaster committee and damage survey**

**Masaki Maeda, Damage level evaluation and 3.11 Tohoku experience**

**Koichi Kusunoki, Non-structural damages, Survey organizations**

**Toshikazu Kabeyasawa, Tsunami disaster**

**Tomohisa Mukai, Functional use of buildings**

**Satoshi Tanaka, Insurances and housing impacts**

**Susumu Kono, Possible future improvement and discussions**

**Discussions and questions (20min)**

**Post-Earthquake Data Collection Workshop**  
**Anchorage, July 20-21, 2014**

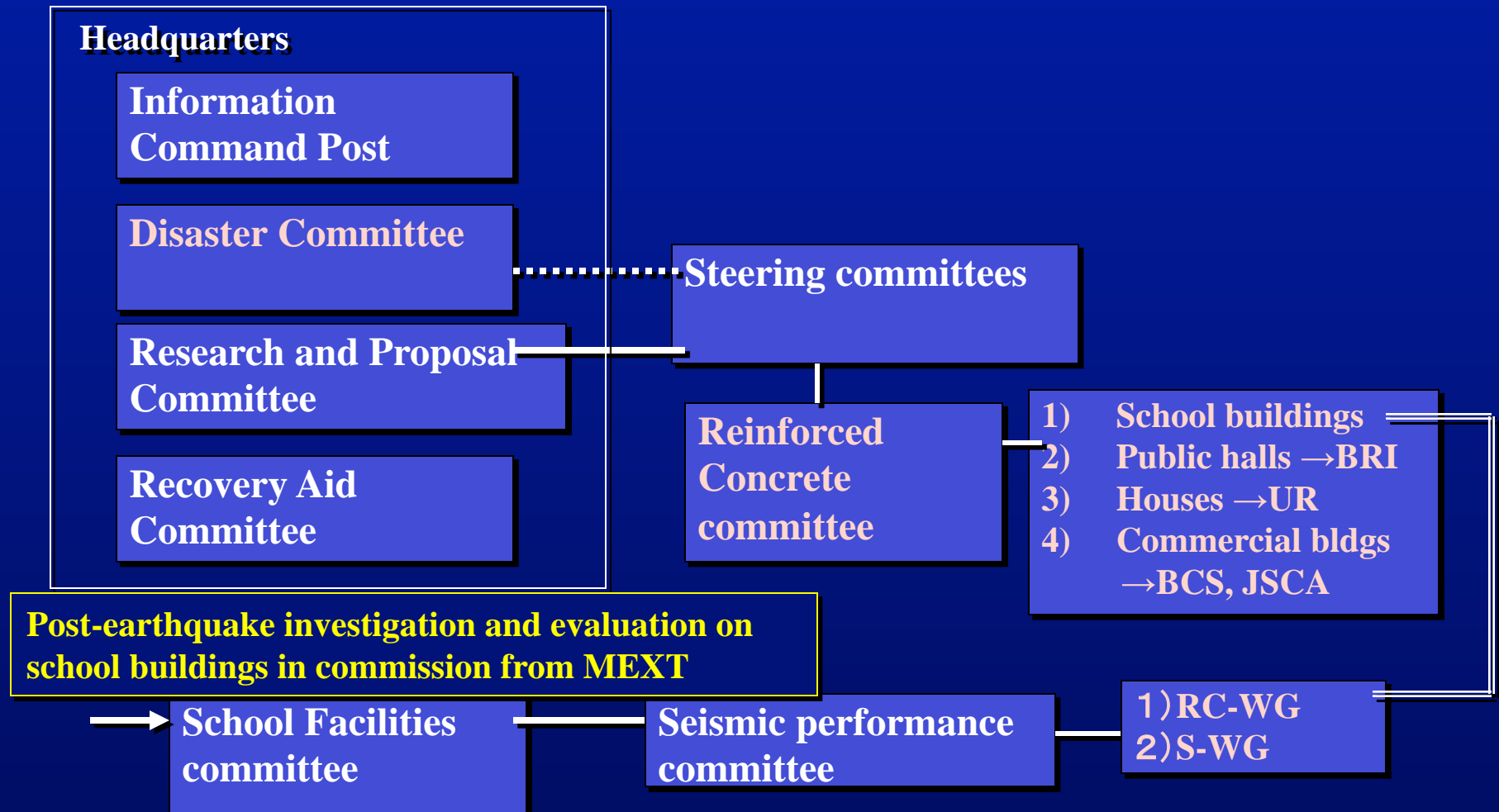
**AIJ Disaster Committee and**  
**Post-Earthquake Organized Survey**

- 1. AIJ disaster committee and survey on damage to buildings**
- 2. Collected and lost data on the damages to school buildings in Fukushima by the East-Japan Earthquake, Mar 11, 2011**

**Toshimi Kabeyasawa**  
**壁谷澤 寿海**  
**Earthquake Research Institute**  
**The University of Tokyo**



# Reconnaissance framework in Architectural Institute of Japan



**780 school buildings were surveyed in detail: 400 RC, 200 S, 180 other educational facilities: e.g. 46 requests and 9 severely damaged from 890 high-school buildings in Fukushima prefecture**

## Collected and lost data

### Collected data:

**Damage evaluation:** 780 damaged school buildings were inspected by AIJ, Damage levels were evaluated for above requested from local governments to AIJ through MEXT

**Recovery:** The damage levels are to be used for recovery procedure

**Seismic evaluation:** The seismic indices(Is) had been evaluated for most of the old school buildings (before 1981)

**Retrofit:** Some of the old buildings had been retrofitted

**Ground motions:** Free field earthquake motions were recorded at 2000 K-net stations in 20km mesh and 2000 others

### Lost data:

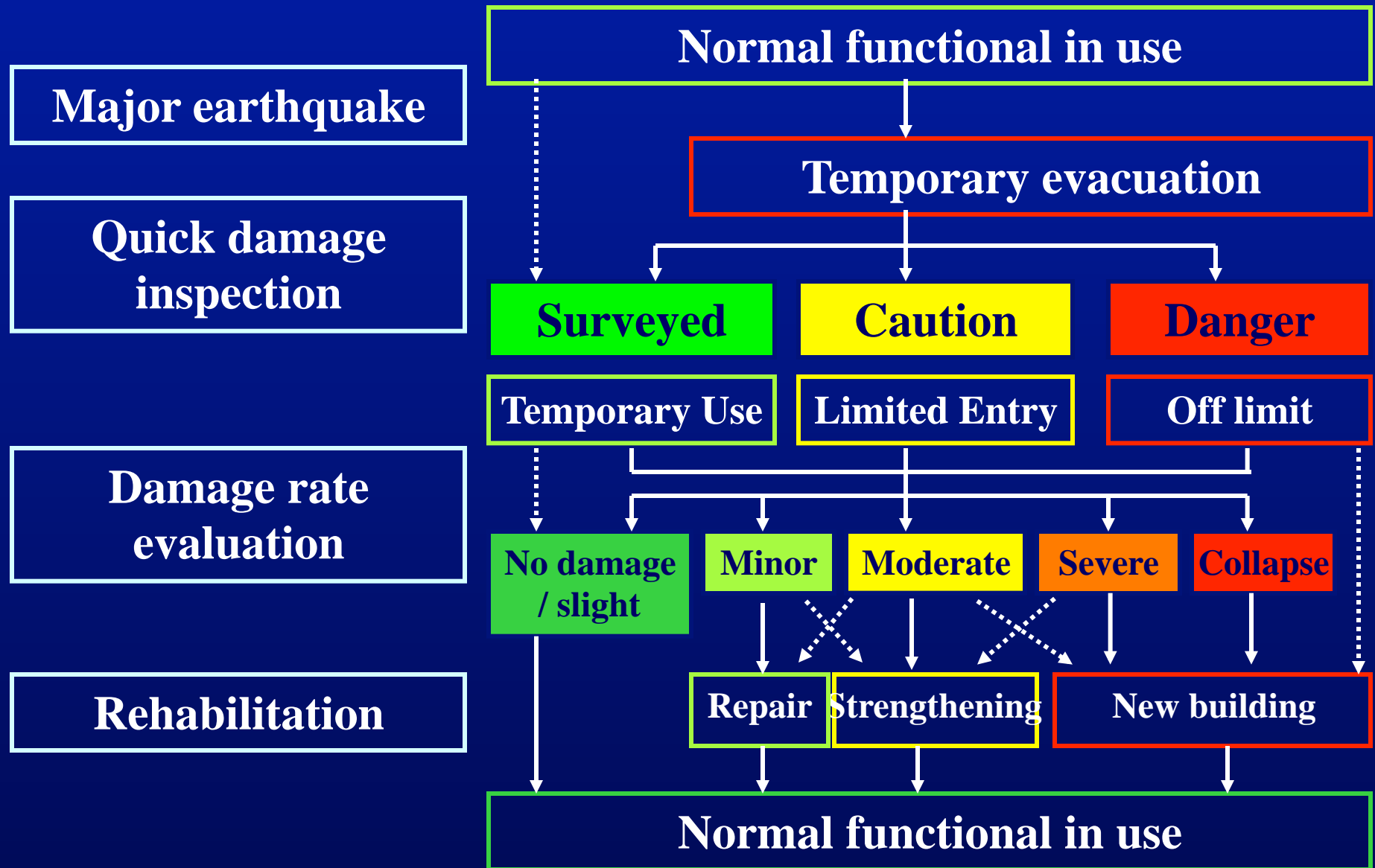
**Damage statistics:** Inventory data including minor/no damages and complete damage rate statistics are insufficient

**Private Info Protection Law:** Damage survey on private buildings became basically difficult after 2006

**Input motions to buildings:** Inputs and responses were recorded at some buildings, but very few in cases with severe damages



# Post-earthquake response to damages of buildings

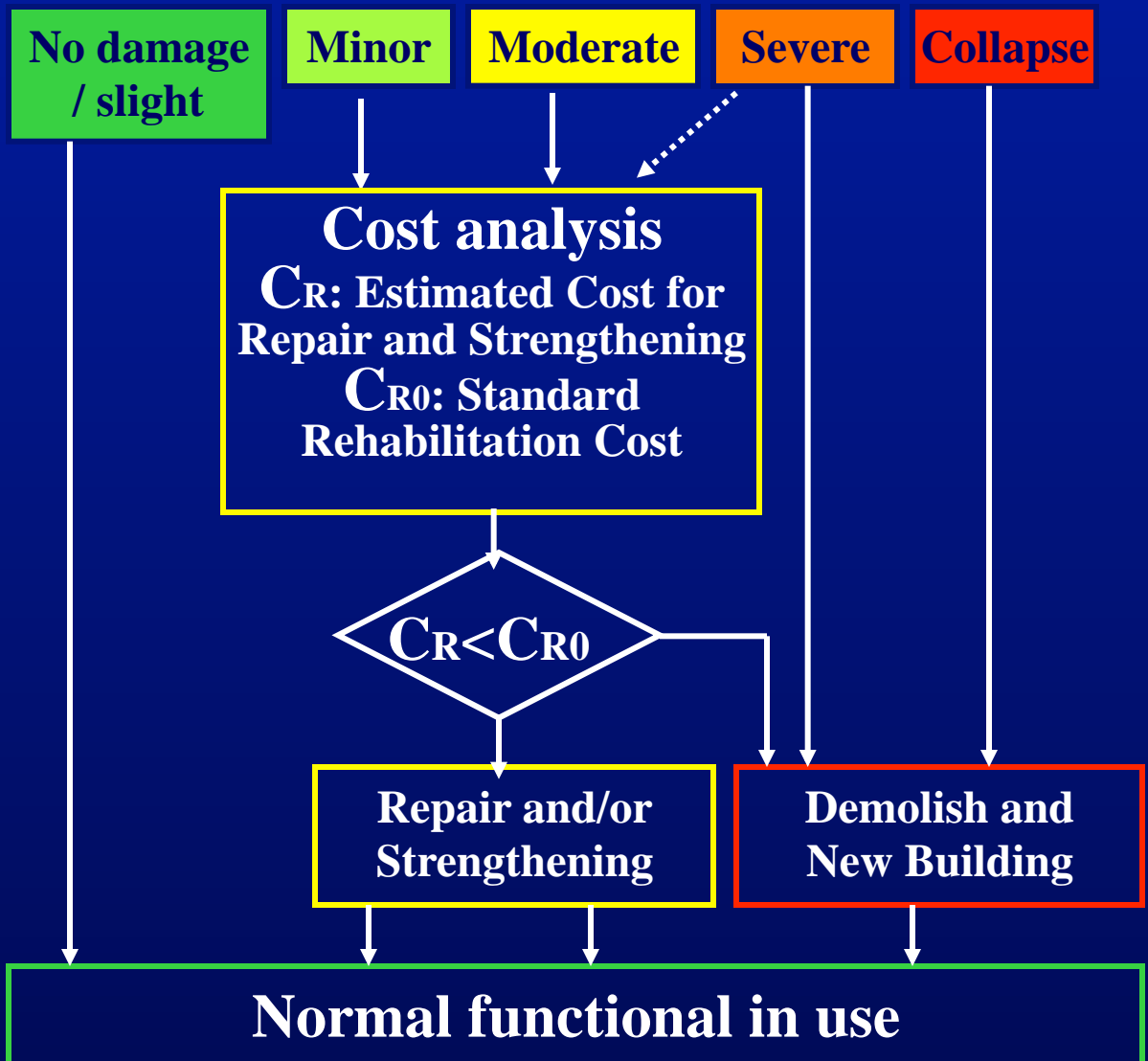


# Rehabilitation procedure for RC school buildings

Damage Rate  
Evaluation

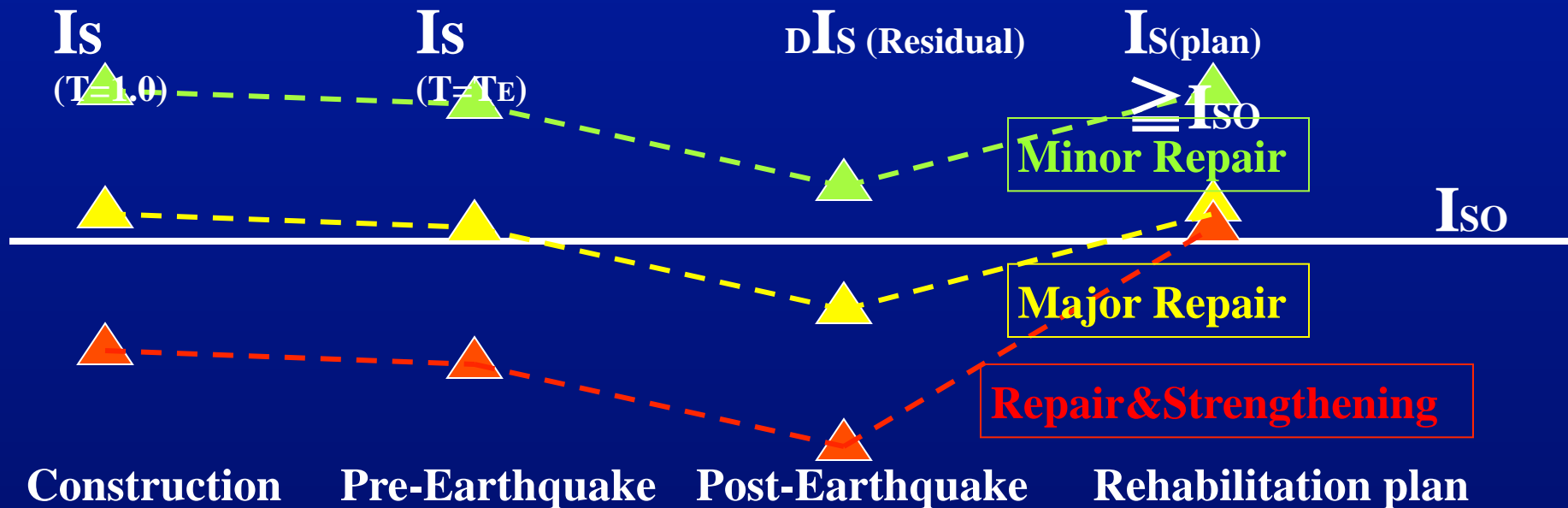
Rehabilitation Plan  
and Cost Estimation

Rehabilitation



# Rehabilitation procedure for RC school buildings

Target performance for with **moderate/minor** damage



Seismic Index after rehabilitation shall be planned as:

$$I_{s(plan)} = D I_s + \Delta I_s \geq I_{so}$$

$I_{s(plan)}$  =: Seismic Index for the planned structure

$D I_s$ : Residual Seismic Index for damaged structure

$\Delta I_s$ : Incremental Seismic Index with repair and strengthening

$I_{so}$ : Seismic Index required for school ( $\geq 0.7$  or  $0.75$ )

# 3.11 2011 East Japan Earthquake

- ✓ **Tsunami**
- ✓ **Nuclear Power Plant**
- ✓ **Wide affected area due to high magnitude**

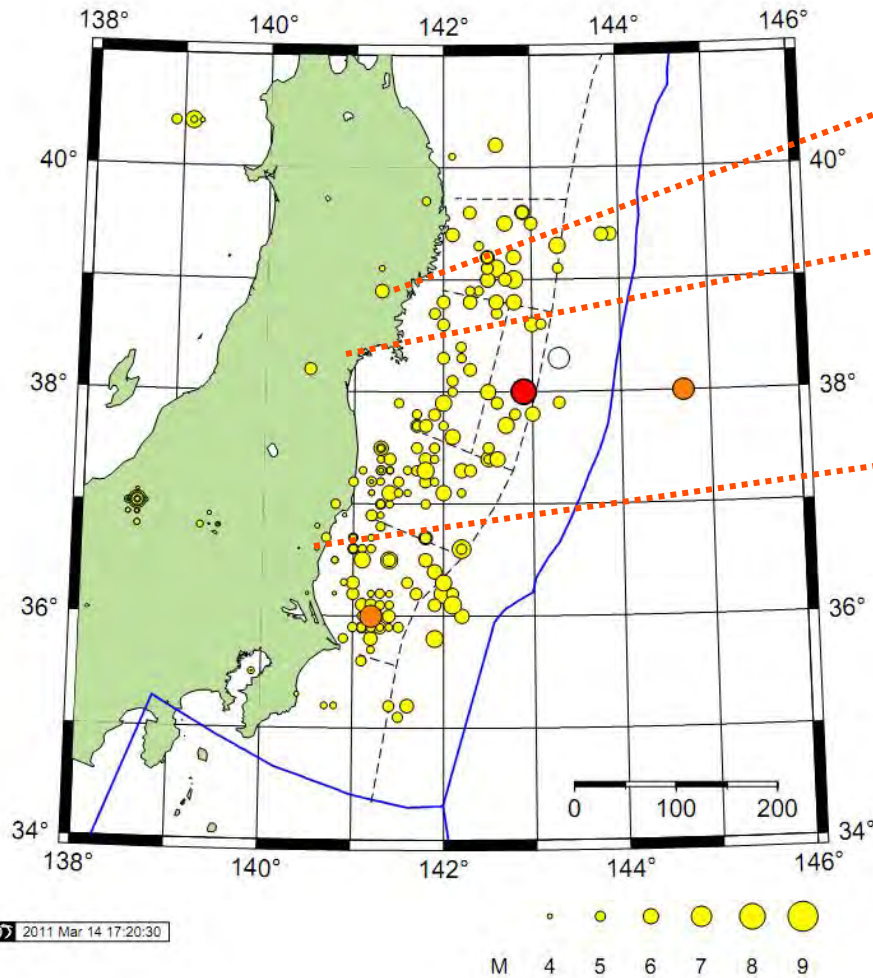


- ✧ **Difficulty in reconnaissance**
- ✧ **Delayed and long-term recovery**

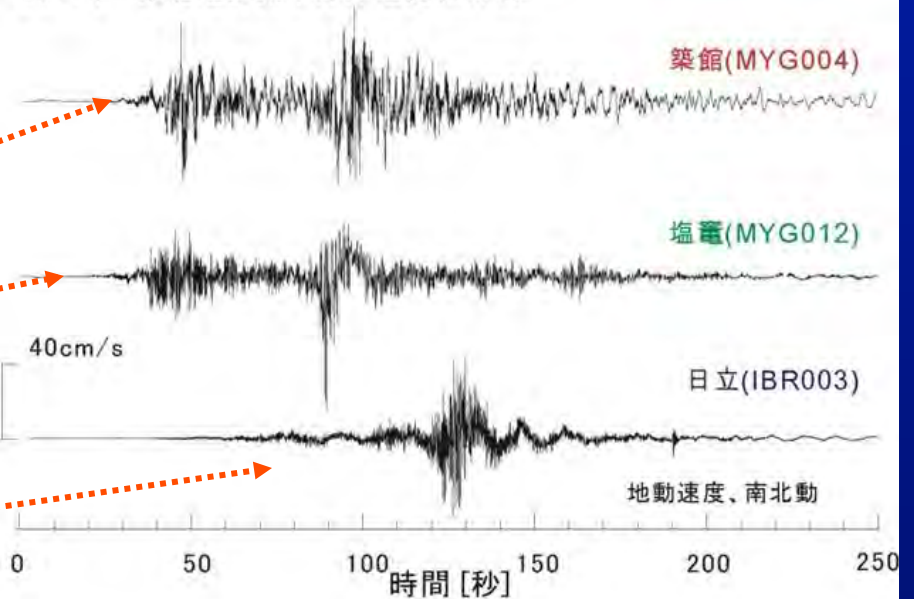


# Observed strong motions in 2011 East Japan EQ

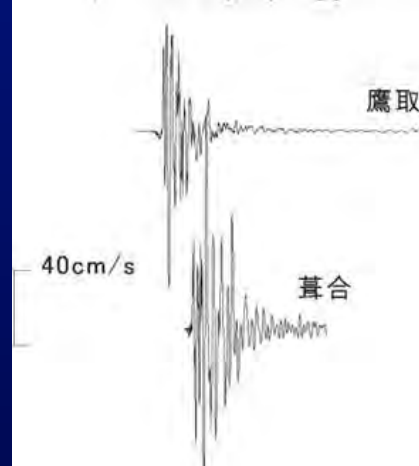
Aftershock Distribution (JMA)



2011年 東北地方太平洋沖地震(M9.0)

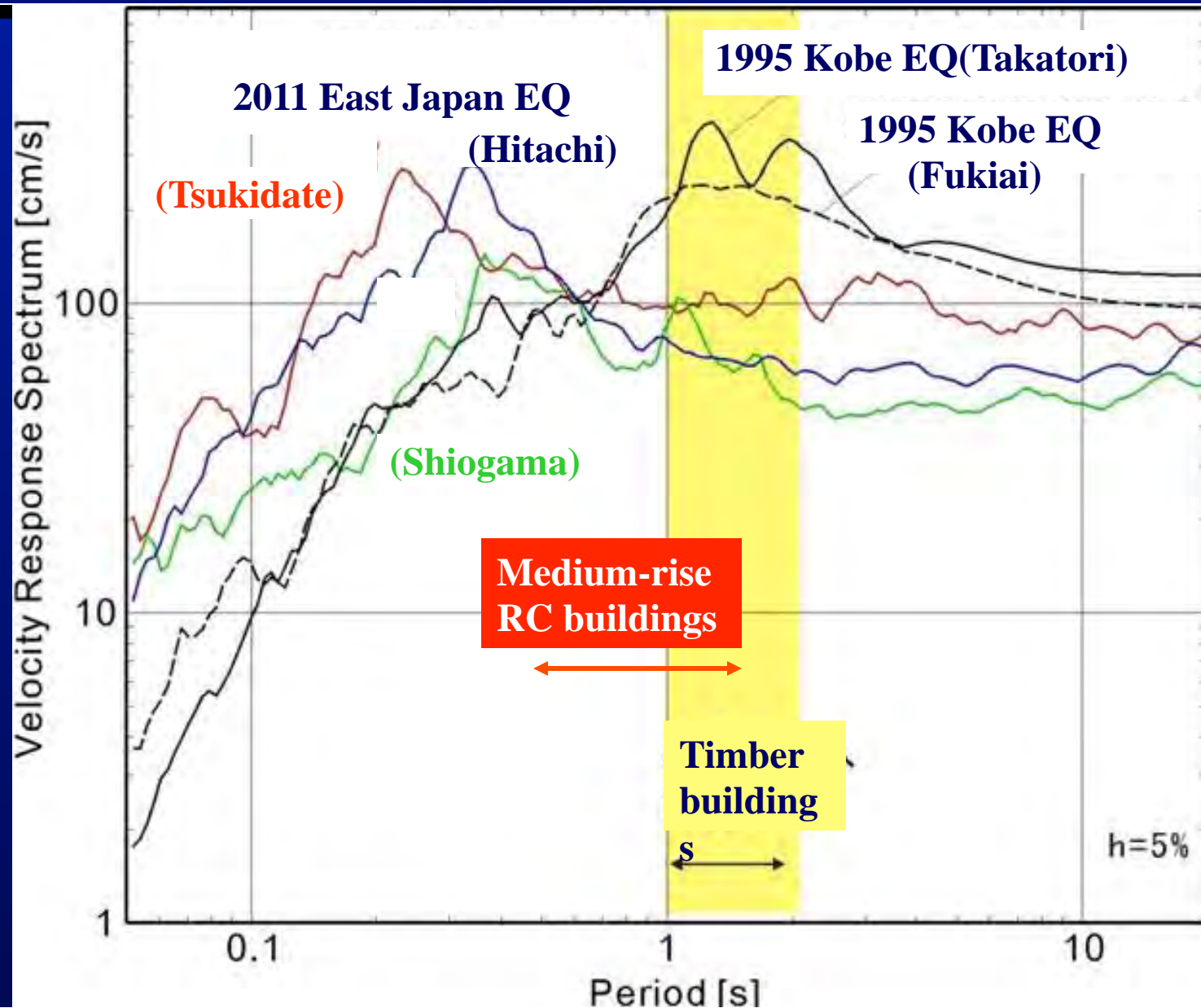


1995年 兵庫県南部地震(M7.3)



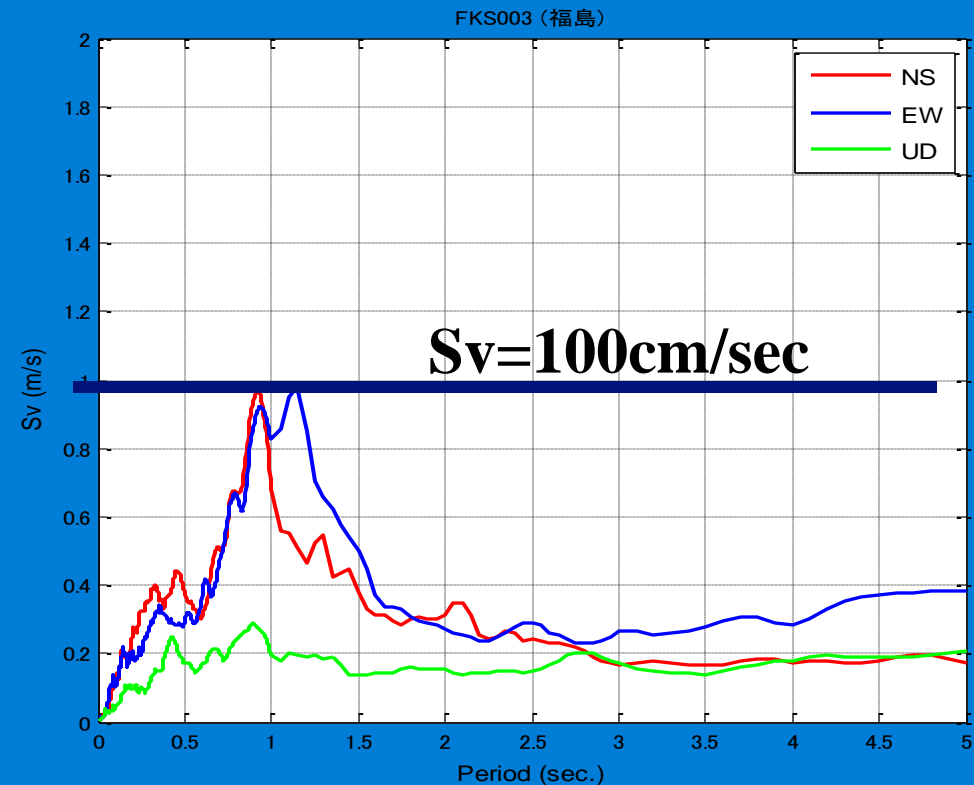
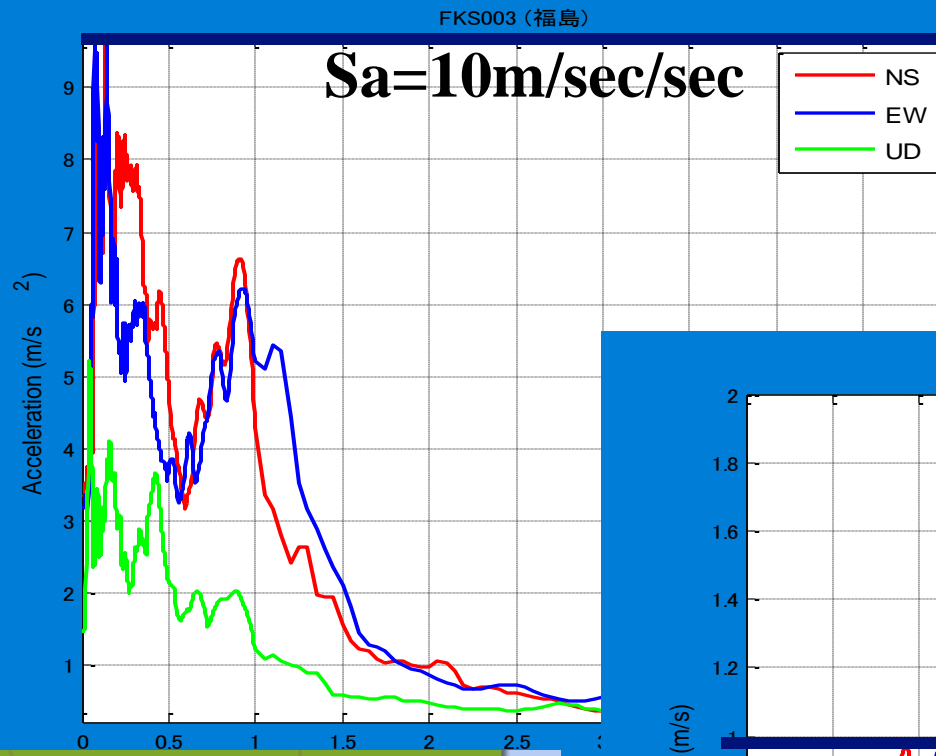
**1995 Kobe**

# Frequency components of far/near field motions (2011 East Japan/1995 Kobe)



# Acceleration and Velocity Spectra (Fukushima, FKS003)

**K-net**  
**Fukushima city**





# Pancake crush of a building in private college in Fukushima



Kabeyasawa, ERI



**Reconstruction on 2012.6.23**



**In case of private schools, recovery is relatively fast,  
and demolish and reconstruction was completed until  
15 months after.**

# No. 4 Building of Public F-High School ( F-cities, RC3, 1961-1963)



2011/5/9, Kabeyasawa



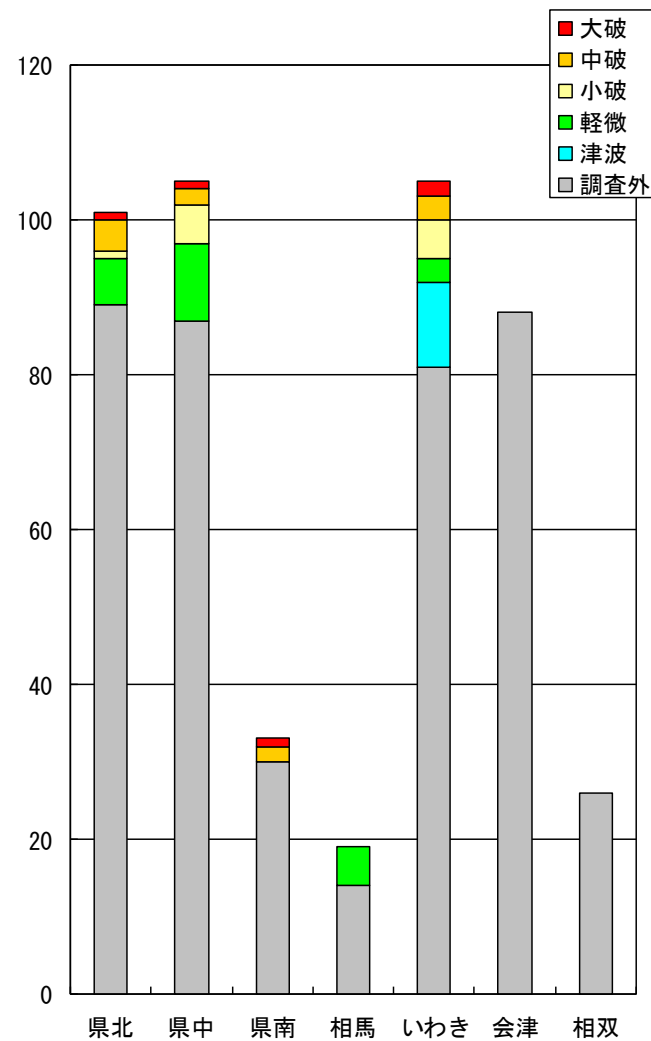
## Reconstruction and temporary school building ( April 23, 2014 )



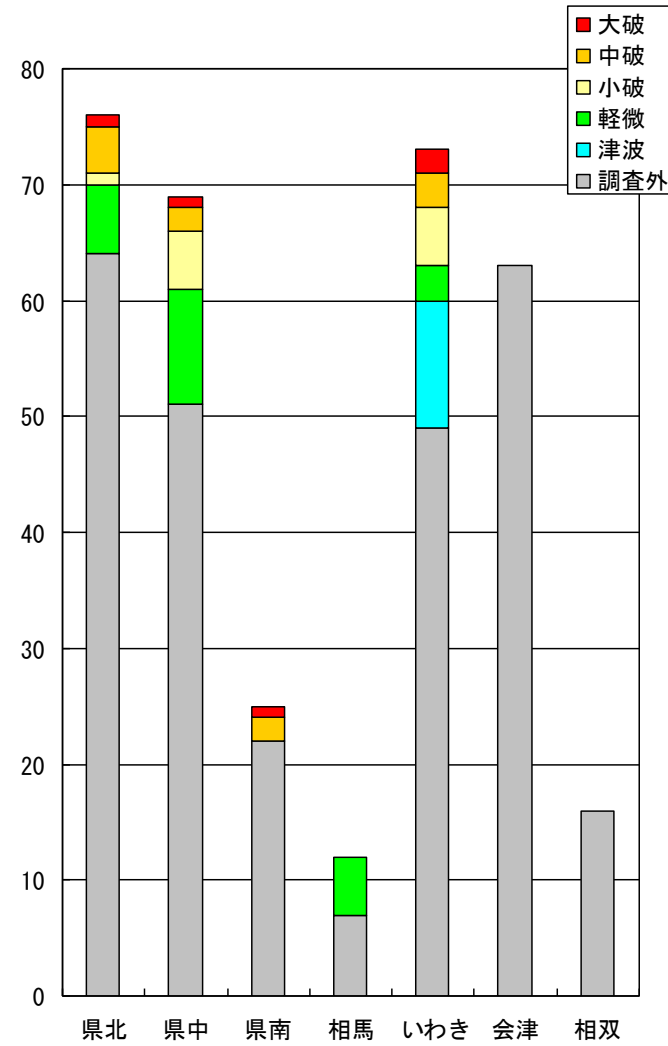
**The reconstruction is still under procedure after three years in case of this public high school, my old school in Fukushima.**

# Damage statistics for RC bldgs of public high-schools in Fukushima

県立高校RC全数



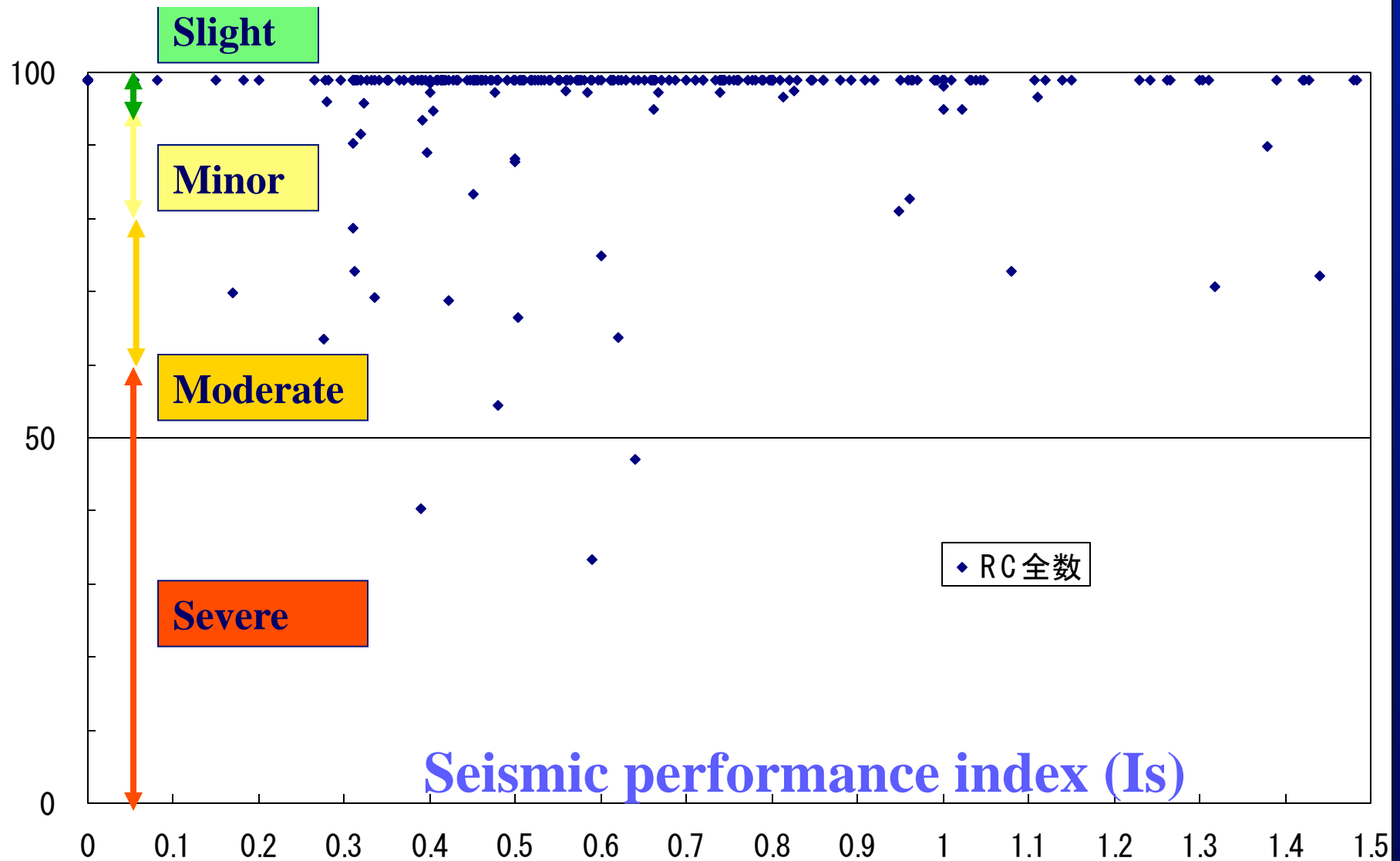
県立高校RC (1981以前)全数





# Relations between seismic performance indices $I_s$ and residual seismic capacity $R$

Damage rates ( $R$ ) in terms of residual capacity

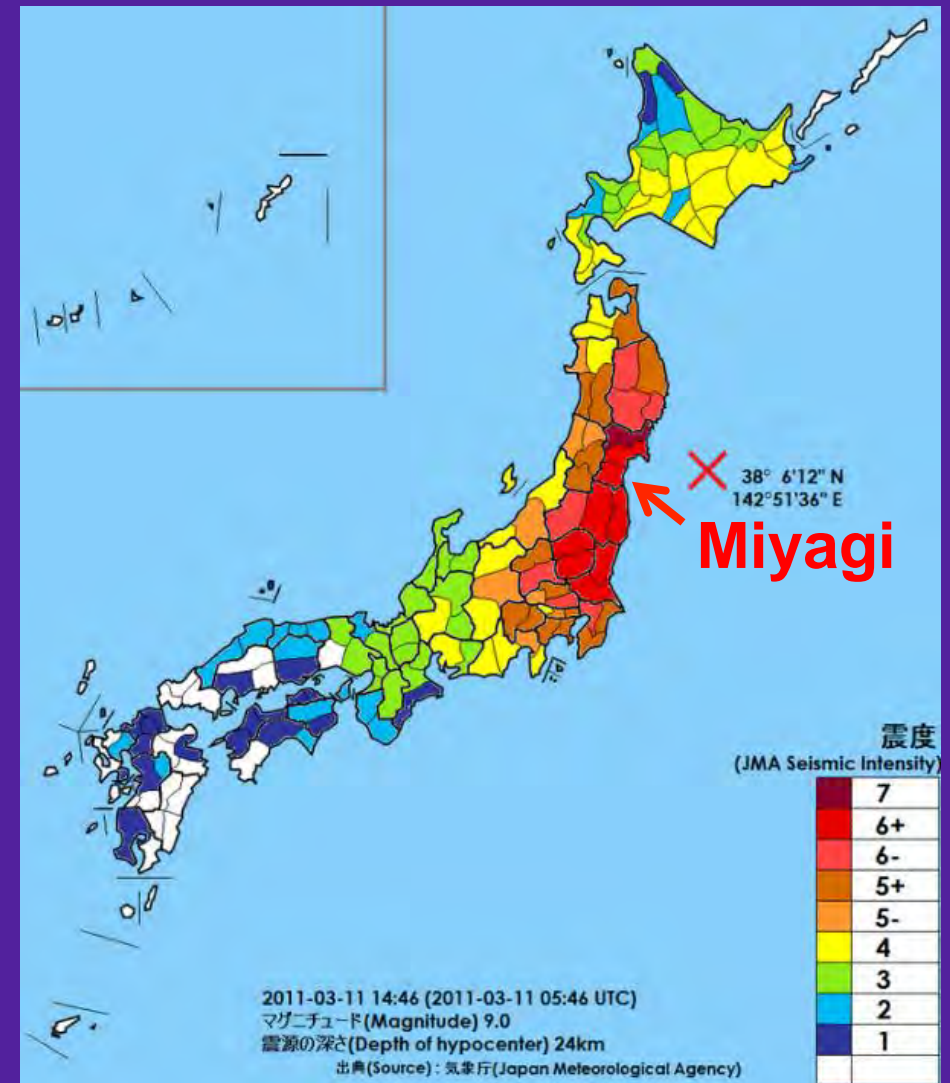
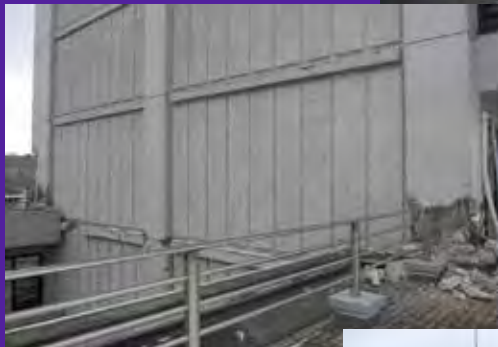


# ***Report from Japan Damage level evaluation and 3.11 Tohoku experience***

Masaki MAEDA  
Tohoku University

# Miyagi prefecture and 3.11 EQ

2011/03/11 14:46(JST)



## Q1: What forms of data were collected after the earthquake?

- Seismic capacity evaluation
- Damage level and residual capacity

## Q5: How were the data collected?

- Manually with specific forms: damage
- Instruments: seismic motions



# *Post-EQ inspection and rehabilitation*

Occurrence of EQ



Quick inspection

Conducted by local government

Inspector = structural engineers & architects



Damage evaluation and rehabilitation

Conducted by owner

Inspector = structural engineers, researchers

# Quick inspection

- Conducted by local government
  - Lecture and training in all the prefectures after 1995 Kobe EQ.
  - Over 100,000 inspectors in Japan, 2000 in Miyagi pref.

The image displays three vertical Japanese inspection forms, each with a distinct color and header. The first form is green and titled '調査済' (Inspected) with the English word 'INSPECTED' below it. The second form is yellow and titled '要注意' (Limited Entry) with the English words 'LIMITED ENTRY' below it. The third form is red and titled '危険' (Dangerous) with the English word 'DANGEROUS' below it. Each form contains several lines of Japanese text, including instructions and fields for recording information. The forms are arranged side-by-side, showing the progression of inspection results from 'Inspected' to 'Limited Entry' to 'Dangerous'.

# Check sheet for quick inspection

- Summary of the building
- ✓ Name, Address, Usage
- ✓ Structural type/system
- ✓ No. of story
- Hazard on structure (Rank A, B, C)
- ✓ Most severe damage to columns
- ✓ Ground, base and surroundings
- Hazard on falling objects
- ✓ Window glass
- ✓ Exterior finishing board
- ✓ Signboard, etc



TOHOKU  
UNIVERSITY

2014/7/20

Post-EQ Data

## 鉄筋及び鉄骨鉄筋コンクリート造建築物等の応急危険度判定調査表

整理番号 〇〇-〇〇〇 調査日時 / 月 25 日 午前・午後 〇 時 調査回数 / 回 1  
調査者氏名 (都道府県/No) 〇〇〇〇 (H4 / 〇〇-〇123)

建築物概要 1.1 建築物番号 A A A 2.1 住宅地図整理番号 A A A

3 建築物用途 1.戸建て専用住宅 2.長屋住宅 3.共同住宅 4.併用住宅 5.店舗 6.事務所  
7.旅館・ホテル 8.庁舎等公共施設 9.病院・診療所 10.保育所 11.工場  
12.倉庫 13.学校 14.体育館 15.劇場、演劇場等 16.その他 ( )

4 構造種別 1.鉄筋コンクリート造 2.プレキャストコンクリート造 3.ブロック造  
4.鉄骨鉄筋コンクリート造 5.混合構造 (SRC) と (RC)

5 階数 地上 10 階 地下 1 階  
6 建築物規模 1階寸法 約 40 m x 25 m

調査 調査方法: ( ) 外観調査のみ実施 ( ) 内観調査も併せて実施  
1 一見して危険と判定される。 (該当する場合は ( ) を付け危険と判定し調査を終了し総合判定へ)

1.建築物全体又は一部の崩壊・落離	2.基礎の著しい破壊、上部構造との著しいずれ
3.建築物全体又は一部の著しい傾斜	4.その他 ( )

### 2 隣接建築物・周辺地盤等及び構造躯体に関する危険度

	Aランク	Bランク	Cランク
① 調査項目上の調査部位の有無	1.無し	2.あり	3.危険あり
② 隣接建築物・周辺地盤の破壊による危険	1.危険無し	2.不明確	3.危険あり
③ 地盤破壊による建築物全体の沈下	1.0.2m以下	2.0.2m~1.0m	3.1.0m超
④ 不同沈下による建築物全体の傾斜	1.1/60以下	2.1/60~1/30	3.1/30超
柱の調査 (トコ⑤⑥の調査指 (被害最大の場合) 2 階) (破壊の場合は柱を壁の長さに読みかえる)			
⑤ 調査項目の柱本数/調査柱本数	1.1%以下	2.1%~10%	3.10%超
⑥ 調査項目の柱本数/調査柱本数	1.10%以下	2.10%~30%	3.30%超
判定②	1.調査済 全部Aランクの場合	2.要注意 Bランクが1の場合	3.危険 Cランクが1以上又はBランクが2以上
危険度の判定	1.調査済み (要内観調査)	2.要注意	3.危険

### 3 落下危険物・転倒危険物に関する危険度

	Aランク	Bランク	Cランク
① 窓枠・窓ガラス	1.ほとんど無被害	2.歪み、ひび割れ	3.落下の危険あり
② 外壁材 (モルタル・タイル・石貼り等)	1.ほとんど無被害	2.部分的なひび割れ、剥離	3.顕著なひび割れ、剥離
③ 外壁材 (ALC板・PC板・金属・ブロック等)	1.目地の亀裂程度	2.板に亀裂が見られる	3.顕著なひび割れ、破損
④ 屋根・屋根材	1.被害無し	2.わずかな傾斜	3.落下の危険あり
⑤ 屋外階段	1.傾斜無し	2.わずかな傾斜	3.顕著な傾斜
⑥ その他 (落し物等)	1.安全	2.要注意	3.危険
危険度の判定	1.調査済み 全部Aランクの場合	2.要注意 Bランクが1以上ある場合	3.危険 Cランクが1以上ある場合

総合判定 (調査の1で危険と判定された場合は危険、それ以外は調査の2と3の大きい方の危険度で判定する。)

1. 調査済 (緑) 2. 要注意 (黄) 3. 危険 (赤)

コメント (構造躯体等が危険か、落下物等が危険かなどを記入する。)

2階以下3階の柱に被害大、危険。  
屋外階段は土下り材のぼろ、落下の可能性あり、危険。

コメントは判定ステッカーの注記と同じとする。

集計値は数字で記入

RC

整理番号 〇〇-〇〇〇

建築物番号 A A A

住宅地図整理番号 A A A

建築物用途 3

構造種別 5

階数 10 階

地下 1 階

建築物規模 40 m

25 m

調査方法 2

1 -

判定① 2

判定② 1

判定③ 1

判定④ 1

判定⑤ 3

判定⑥ 1

判定⑦ 3

判定⑧ 3

判定⑨ 3

判定⑩ 3

判定⑪ 3

判定⑫ 3

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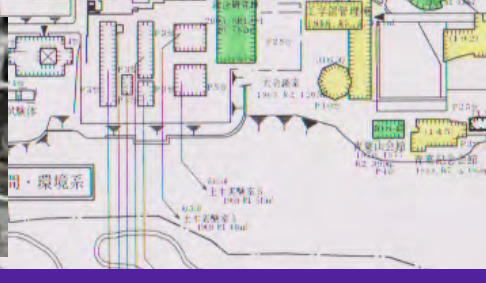
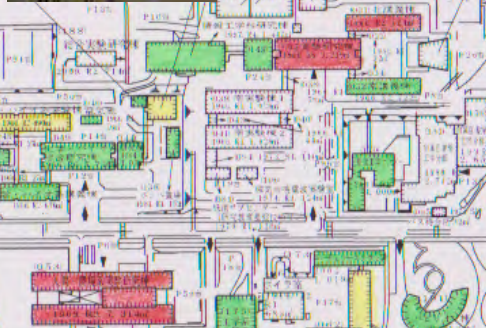
判定 3

判定 3

判定 3



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# *Post-EQ inspection and rehabilitation*

Occurrence of EQ



Quick inspection

Conducted by local government

Inspector = structural engineers & architects



Damage evaluation and rehabilitation

Conducted by owner

Inspector = structural engineers, researchers

# Post-EQ Damage Evaluation

## ■ Japanese Guideline (JBDRA, 1990)

- Residual seismic capacity,  $R$ , is evaluated by damage class (I, II, III, IV, V) of structural members



	<i><math>R</math> – index (%)</i>	<i>Limit state</i>
[Slight]	95 - 100	Serviceability
[Minor]	80 - 95	
[Moderate]	60 - 80	Reparability
[Severe]	- 60	
[Collapse]	$\doteq 0$	Safety

# Basic concept of Damage level evaluation

## Residual Seismic Capacity Ratio $R$

$$R = \frac{Dl_s}{I_s}$$

← residual capacity

← original capacity

$I_s$ : seismic performance index in Seismic Evaluation Standard(1977)

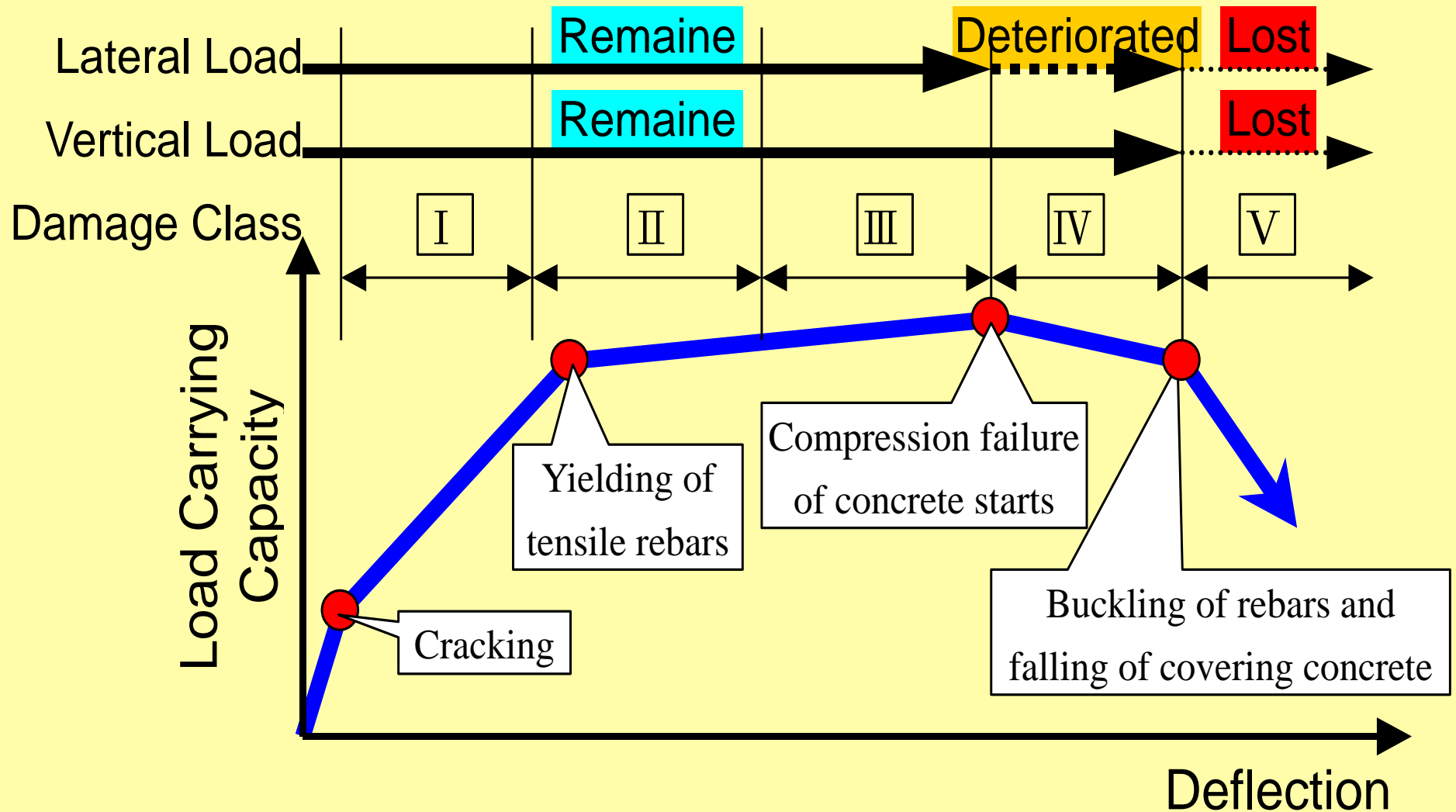
$$I_s = E_0 \times S_D \times T$$

$E_0 = C \times F$  : Basic Structural Index

$C$  : Strength Index,  $F$  : Ductility Index

$S_D$  : Shape Factor (0.4-1.0),  $T$  : Age Factor (0.5-1.0)

# Load Carrying Cap. vs. Damage Class





# ***Damage class of structural member***

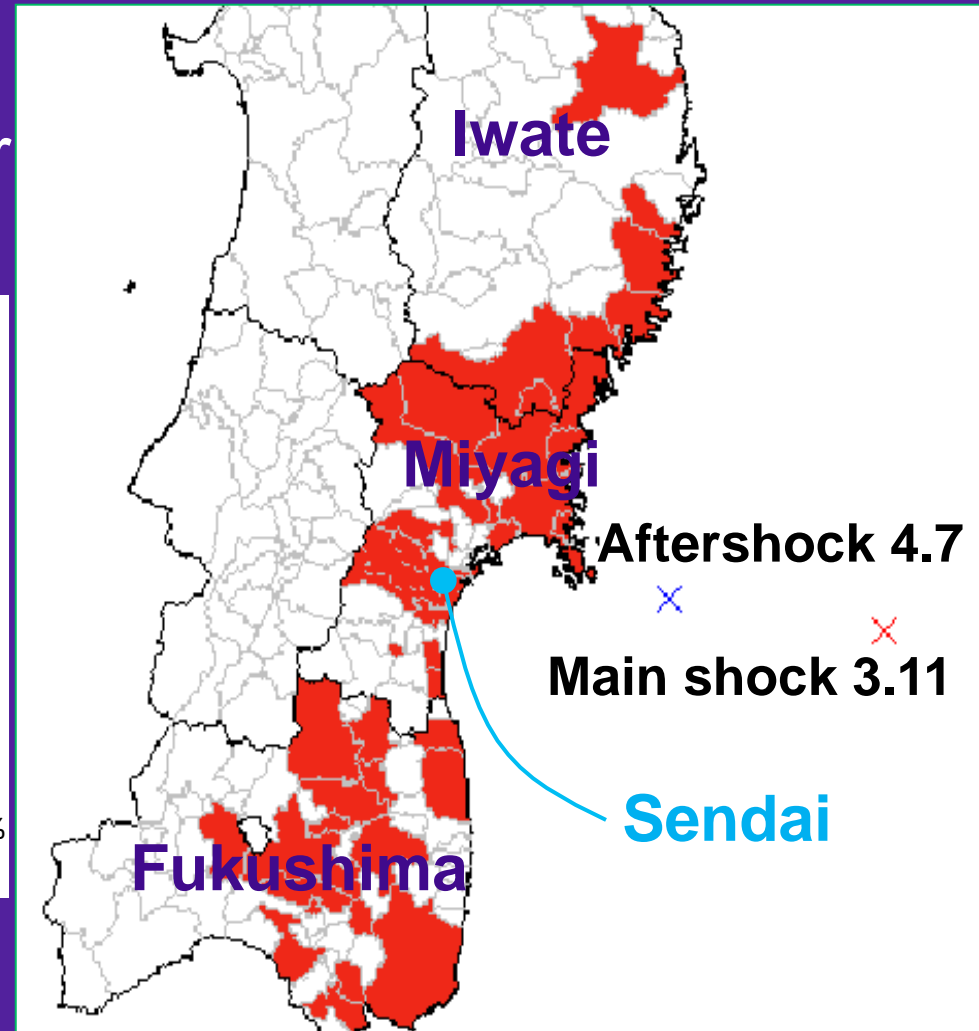
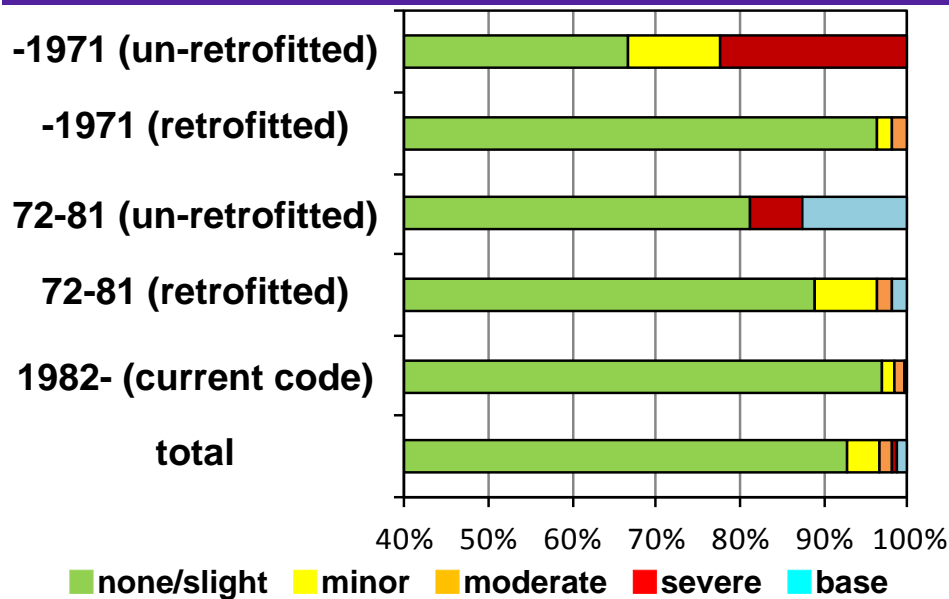
## Damage Level Classification Standard (1991)

Damage Class	Observed Damage to Structural Members
I	Some cracks are found. Crack width is narrower than <b>0.2 mm</b> .
II	Cracks of <b>0.2 - 1 mm</b> wide are found.
III	Heavy cracks of <b>1 - 2 mm</b> wide are found. Some spalling of concrete is observed.
IV	Many heavy cracks are found. Crack width is <b>2 mm or wider</b> . Reinforcing bars are exposed due to spalling of covering concrete.
V	Buckling of reinforcement, crushing of concrete and vertical deformation of columns and/or shear walls are found. Side-sway, subsidence of upper floors, and/or fracture of reinforcing bars are observed in some cases.



# Damage survey for school buildings

546 RC school bldgs. were investigated by AIJ reconnaissance team (over 20 professors)



# Check sheet for damage level evaluation

## 2.3 上部構造の耐震性能残存率 $R$ による判定

- ① 被害の最も激しい階と方向 1 階 方向：☒短辺方向 ☐長辺方向
- ② ゾーニングの要否：☒不要（建物全体で判定する）  
☐必要（ゾーニングした区画を平面図などで明示し、区画ごとに判定する）
- ③ 構造部材の損傷度調査結果 ※（ ）内にそれぞれの柱本数や壁枚数を記入し合計を計算する。

Damage class I to V

	Shear col.	Flexural col.	Column	Wall	合計	
総部材数	( 25 )	( )	( )	( 4 )	( 2 )	( 31 )
調査部材数	( 25 ) <sup>①</sup>	( ) <sup>②</sup>	( ) <sup>③</sup>	( 4 ) <sup>④</sup>	( 2 ) <sup>⑤</sup>	( 31 )
	①× 1	②× 1	③× 1	④× 2	⑤× 6	( 45 ) = $A_{org}$
損傷度 0	( 1 )	( )	( )	( )× 2	( 1 )× 6	( 7 ) = $A_0$
損傷度 I	( 3 )× 0.95	( )× 0.95	( )× 0.95	( )× 1.9	( )× 5.7	( 2.85 ) = $A_1$
損傷度 II	( 11 )× 0.6	( )× 0.75	( )× 0.6	( 2 )× 1.2	( )× 3.6	( 9 ) = $A_2$
損傷度 III	( 4 )× 0.3	( )× 0.5	( )× 0.3	( 1 )× 0.6	( 1 )× 1.8	( 3.6 ) = $A_3$
損傷度 IV	( 2 )× 0	( )× 0.1	( )× 0	( )× 0	( )× 0	( 0 ) = $A_4$
損傷度 V	( 4 )× 0	( )× 0	( )× 0	( 1 )× 0	( )× 0	0 = $A_5$
$\sum A_j = A_0 + A_1 + A_2 + A_3 + A_4 + A_5 = ( 22.5 )$						

### ④ 耐震性能残存率 $R$

$$R = \frac{\sum A_j}{A_{org}} \times 100 = \frac{(22.5)}{(45)} \times 100 = ( 50 )$$

上部構造の耐震性能残存率  $R$  による被災度区分

- ☐無被害（ $R=100$ ）      ☐軽微（ $95 \leq R < 100$ ）      ☐小破（ $80 \leq R < 95$ ）  
☐中破（ $60 \leq R < 80$ ）      ☒大破（ $R < 60$ ）      ☐倒壊（崩壊・落階等によりほぼ  $R \approx 0$  とみなせる）

# Pictures and comments

文科省学校調査 写真集	
学校名：鶴谷東小学校 住所：仙台市宮城野区鶴ヶ谷六丁目2 建物名（台帳番号）：西校舎（①-2～7） RC造3階建（3,708m <sup>2</sup> ） 昭和49年建築 担当者：東北大学（前田匡樹、松川、青木、三浦、高橋、前田美里、松尾） 調査日時：4月22日（金）AM9:00～12:00 応急危険度：危険 被災度：中破	
	校舎全景。写真右が西校舎、左が東校舎。通り廊下を通して連絡され、Exp.Jが、通り廊下の西校舎側の位置に設けられている。東校舎は耐震補強されているが、西校舎は耐震診断の結果、補強不要と判断されている。
	北側の周囲地盤で、20cm程度の沈下が見られた。損傷がほとんどない柱位置で傾斜を計測したところ、傾斜はほとんど0であった。
	建物自体には、目立った傾斜や沈下は確認されなかったが、床には多数のひび割れが見られ、1cm程度の段差が生じている。また、これらのひび割れは、校庭に生じた亀裂と同じ位置に生じ、上階のスラブまでひび割れが生じている。

写真1

写真2

写真3

文科省学校調査 写真集	
	西面南側1階の柱。短柱となったことでせん断破壊し、損傷度V程度まで進行していた。この他に損傷度Vの短柱が1本、損傷度IVの短柱が5本、損傷度IIIの短柱が5本確認された。桁行は20スパンあり、北側の柱は同様に短柱となっていたものの、南側に比べて被害は小さかった（損傷度I～II程度）。また東面の柱は、西面とは異なり短柱となっておらず、概ね損傷度I～II程度であった。
	西面南側1階の柱型付壁。開口の部分でせん断破壊が生じ、ひび割れが内部まで貫通しており、地震力を負担できない状態であると思われる（損傷度V）。
	2階西面南側の柱（損傷度II）。短柱となっている場所でも、損傷度は最大II程度であり、1階と比較すると被害は軽微であった。3階についても、ほぼ同程度の被害であった。

写真4

写真5

写真6



# Database of RC school buildings

## In addition to quick inspection

- Summary of the building
- ✓ Const. year
- ✓ Ground, base, pile
- ✓ Seismic intensity
- Damage to structure
- ✓ Damage class for all structural members
- ✓ Settlement, inclination

- ✓ Residual capacity ratio  $R$
- ✓ Damage level (slight – collapse)
- ✓ Damage by tsunami
- ✓ Comments
- Seismic capacity
- ✓ /s-indeces
- ✓ Strengthening & retrofit

[illegible]

## Q6: What data were lost (not yet collected)?

- Damage to non-structural elements, impact to building function,
- Decision and procedure of rehabilitation
- Costs for repair and strengthening

# Summary

## Data Collection in Miyagi pref.

### ■ Collected (approx. 500 school buildings)

Configuration of structure, material ...

Seismic capacity (Is-index)

Damage class of structural members, residual capacity R

Photo ...

### ■ Lost (or not yet collected)

Damage to non-structural elements, functionality, social impact ...

Decision making procedure for rehabilitation



# *Reconstruction almost completed*






# Report from Japan on Q2, Q3, and Q8

KOICHI KUSUNOKI  
FROM EARTHQUAKE RESEARCH INSTITUTE,  
THE UNIVERSITY OF TOKYO





Q2: Have any relationships  
between the different forms  
of data been explored?

# Data Collection of damages to non-structural elements

- ▶ Fortunately, the number of the severely damaged building due to Tohoku E.Q. is not so much.
- ▶ The damage to non-structural elements are focused, since it is also harmful to the people around them.



Ceiling system




Concrete block wall

# Data Collection of damages to non-structural elements

- ▶ Non-structural damage of the buildings administrated by MEXT are investigated.
- ▶ In order to get fund for the repairmen, reports on the level of the non-structural damages including photos, written estimates, and the building identification number were submitted to MEXT.
- ▶ There is a database in MEXT on building information such as structural type, design year, constructed year, number of stories, and etc.
- ▶ We got permission to see the reports and database.





Q3:What organizations were involved in collecting data and for what purpose?

# Post earthquake survey organizations in Japan (Q3)

- ▶ Governments and national research institutes
  - ▶ Local governments
    - ▶ To grasp the damage of the area

## Quick Inspection

To reduce additional damages due to aftershocks

To reduce the number of refugees from seismically OK Buildings

To figure out what area and what type buildings were damaged.

Inspection is based on Visual Investigation.

地震発生後注意喚起  
**要注意**  
LIMITED ENTRY  
本区域は地震発生後、建物や道路の被害が予想されるため、入域を制限しております。  
入域の際は、必ずこの注意喚起の表示を確認してください。  
入域許可証  
氏名：  
住所：  
電話番号：  
入域日時 月 日 年 時 分 場所  
入域許可証 発行

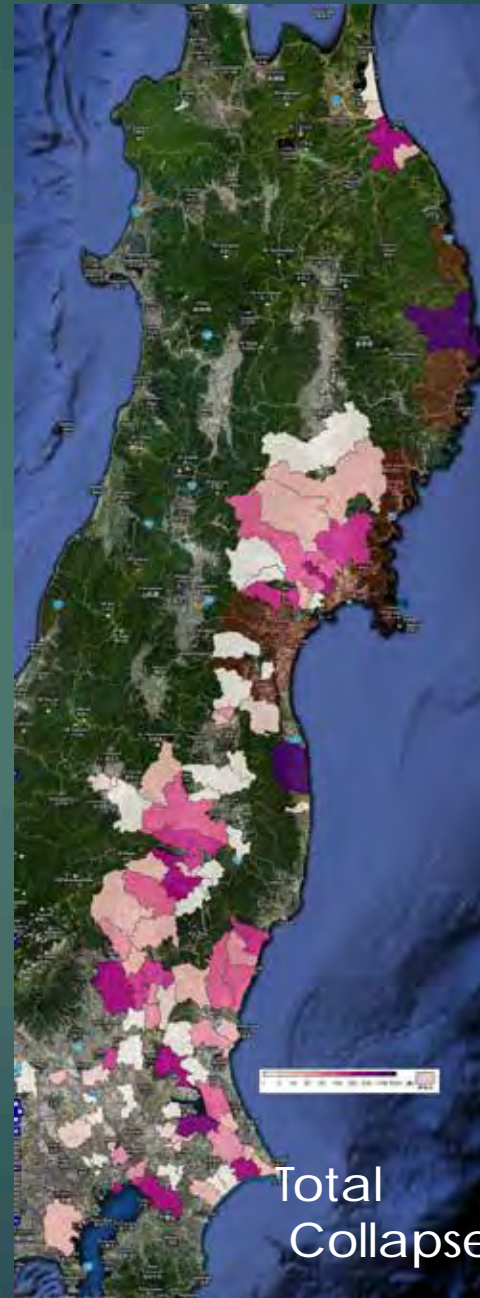
# Post earthquake survey organizations in Japan (Q3)

- ▶ Governments and national research institutes
  - ▶ Ministry of Land, Infrastructure, and transportation
    - ▶ To check the Building code and building administrations
    - ▶ Building Research Institute(BRI)
    - ▶ National Institute for Land and Infrastructure Management (NILIM)
  - ▶ Ministry of Education, Culture, Sports, Science and technology
    - ▶ From the scientific point of view
    - ▶ National Research Institute for Earth Science and Disaster Prevention (NIED)
    - ▶ Institutes and Laboratories of Universities
      - ▶ Earthquake Research Institute, the University of Tokyo
      - ▶ Disaster Prevention Research Institute, Kyoto University





Partially  
Collapse



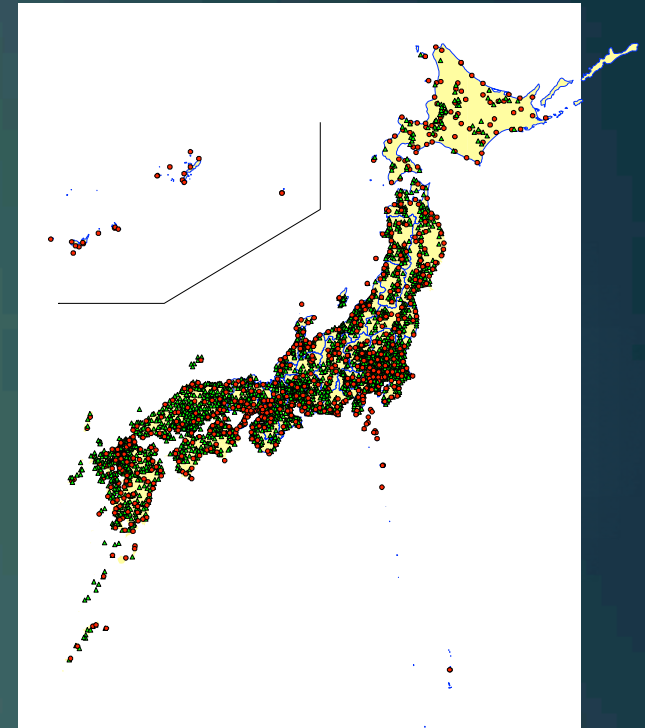
Total  
Collapse

Cabinet Office





- ▶ K-Net by NIED
- ▶ Strong motion observation network.
- ▶ Open to everybody
- ▶ Data is available soon after the earthquake



# Post earthquake survey organizations in Japan (Q3)

- ▶ Academic associations and branches
  - ▶ To record the earthquake and damages
  - ▶ Disaster Management Committee, AIJ
  - ▶ Tohoku Branch of AIJ
  - ▶ Japan Association of Earthquake Engineering
  - ▶ Data Sharing between JAEE, JSCE, JGS, SSJ, and JSME
    - ▶ Societies decided to control the field investigation under the name of societies
      - ▶ Not to disturb the rescue activities and local government works
      - ▶ Due to nuclear power plant accident
- ▶ Research institutes and associations of construction, design, insurance, real estate, homebuilding companies such as BCS/JSCA, UR,
  - ▶ To check their buildings



Q8:How are data stored after collection and what are access policies for this data?

# The data list format to the AIJ report (Q8)

- ▶ The data of the damaged buildings were collected in a formatted list and shared within the research group. The data list is to be published as the appendices of the research report.

## Data list of AIJ report

- Building name
- Location
- Structural type
- Number of stories
- Damage to the structure
- Damage to the ground
- Year of construction
- Seismic intensity
- Quick inspection result
- Seismic screening result(If available)
- Damage classification result
- Residual seismic capacity ratio(If available)
- Tsunami damage
- Memo
- Etc.



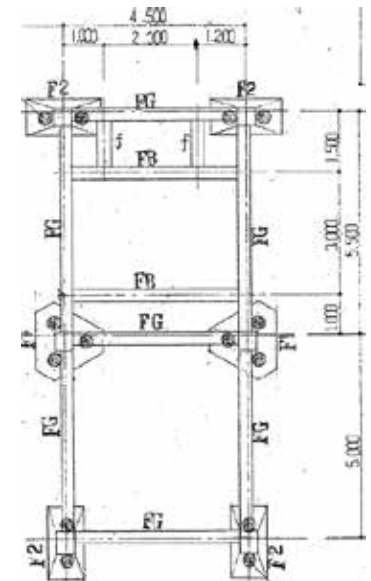
# Collected and lost data, difficulties in the BRI survey on Tsunami damages(Japan Experience)

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National Institute of Land and Infrastructure Management  
Toshikazu Kabeyasawa

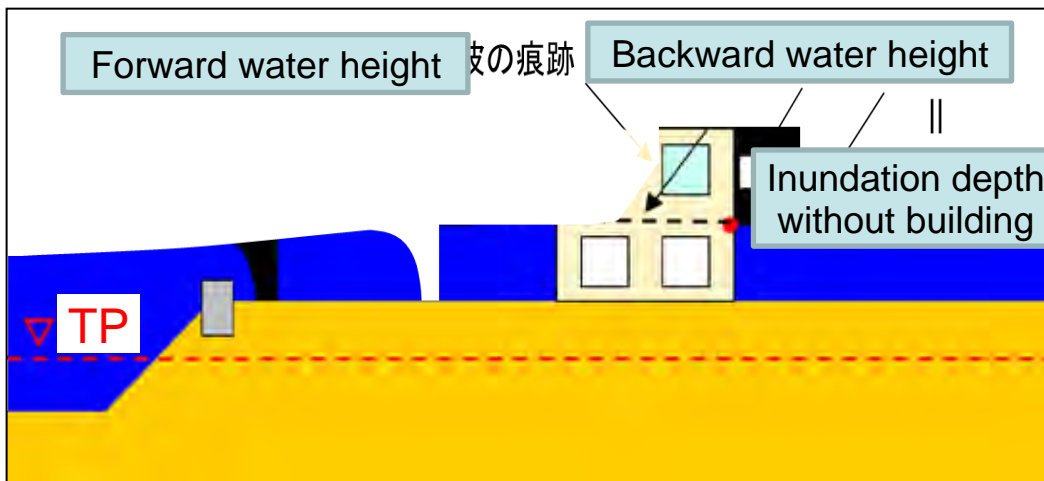
# What forms of data were collected ?

- ① Inundation depth of the building
- ② Onsite investigation of damaged building
  - (1) State (Location, Damage)
  - (2) Dimension (Plan, Height, Openings)
  - (3) Detail (Member, Material)
- ③ Collecting drawings of Public buildings



# How were the data collected?

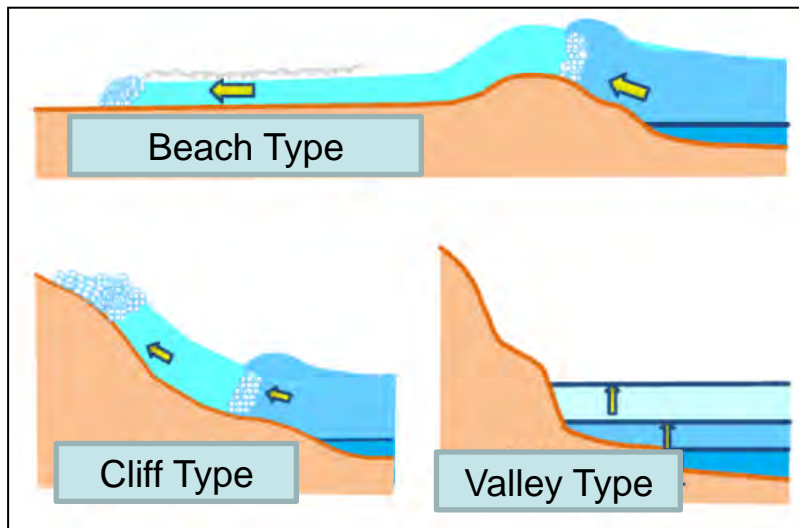
- ① Water mark of forward and backward of survived building
- ② Measure building and member dimension manually  
(focused on small-scale buildings)
- ③ Data usage permission for official purpose from local government



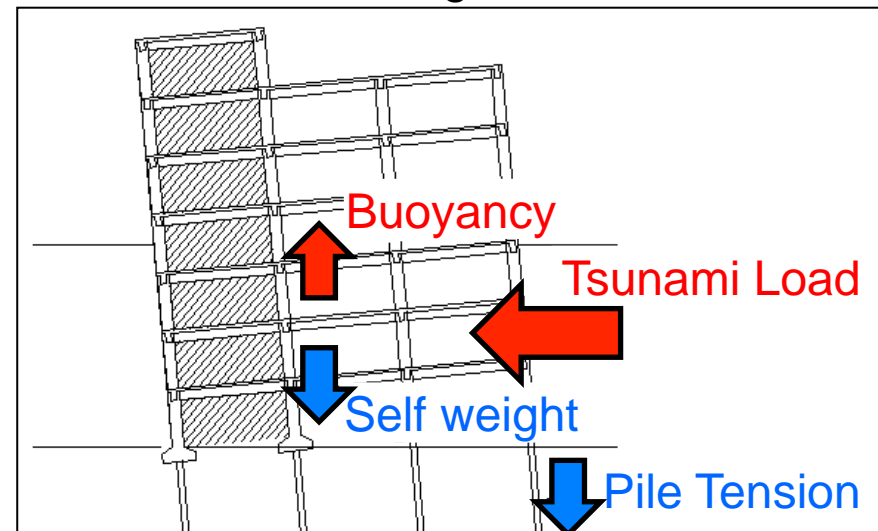
# Difficulty in collecting data

- ① Water traces disappears one month after earthquake by rain  
Tsunami flow characteristic is affected by topography
- ② Damage process or mechanism is not clarified  
Effect of Buoyancy, Debris Impact or Damming
- ③ Most of drawings and buildings are washed out

Tsunami Flow Characteristic



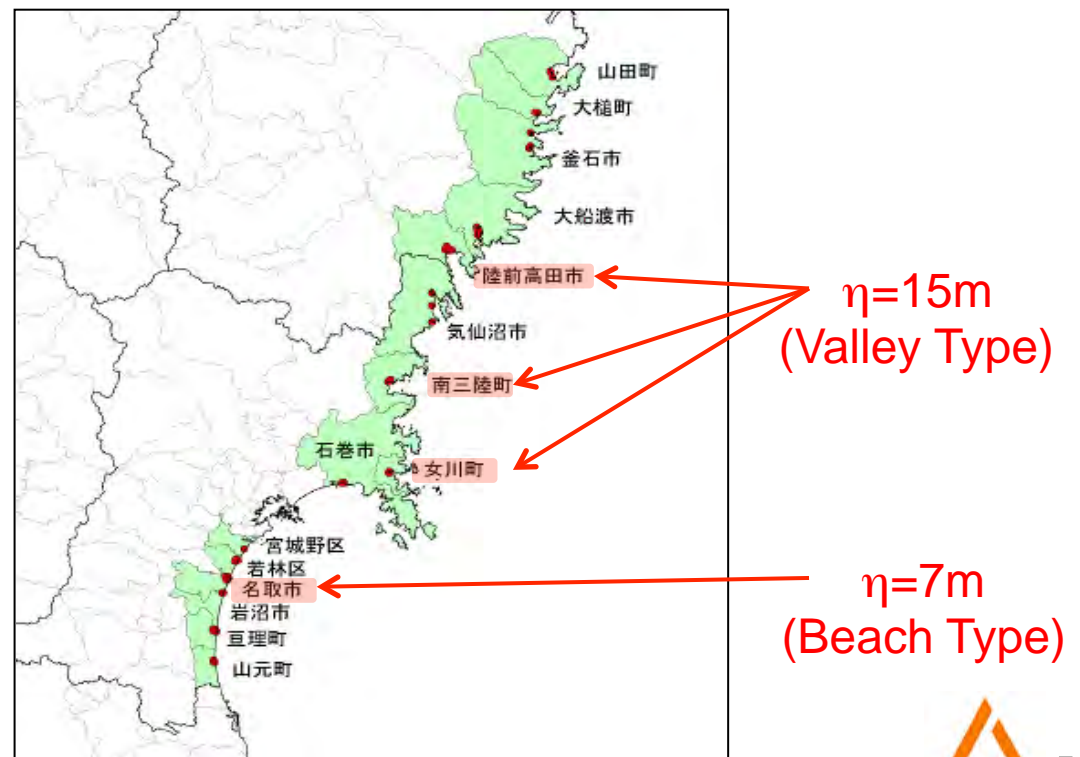
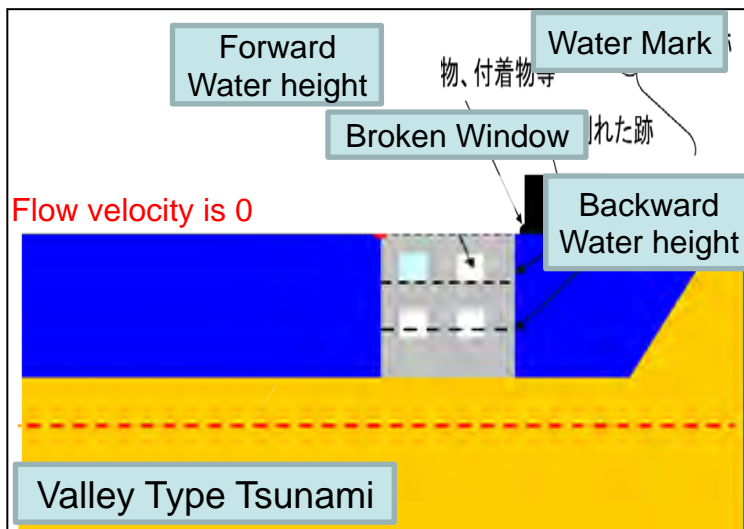
Overturning Mechanism





# What data were missed?

- ① Difference of water height disappears in valley type tsunami  
Minimum tsunami height for reconstruction decisions
- ② Investigation concentrates on severely damaged area  
Survived buildings with direct foundation (effect of buoyancy)



# How are data stored after collection?

## Prompt Investigation Database (BRI/NILIM Report)

建物番号	OG-11	調査日	2011年4月9日
名称			
所在地	女川町女川浜女川	建設年	不明
用途	商業施設・店舗	津波避難ビル	指定なし
構造種別	RC造 (耐力壁付ラーメン構造)		
建物規模	階数	2階 (地下 階)	高さ: 7.2 m
	平面寸法	11.3 m × 9.4 m	
建物位置	海岸からの距離	約100 m	標高 15 m (GPS)
	立地条件	女川街道沿い	
最大浸水深		14 m	周辺建物側面に痕跡
津波後の状況	建物の状態	原位置に残存	1×2スパン、非構造物のみ被害が見られた
	躯体の被害	被害なし	
	非構造物材の被害	被害あり	窓ガラス・天井材の脱落
備考			

- ・女川沿岸部に立地し残存していたRC2階建て
- ・津波の作用方向(梁間方向)に開口付き耐力壁を有し、桁行構面には大きな開口を有している
- ・内部には梁せり下まで浸水の痕跡が見られる
- ・柱断面は800×500mm、壁厚は180mmであった



写真1 建物外観(1)



写真2 建物外観(2)



写真3 建物1階の浸水痕



写真4 建物1階の浸水痕

## Analysis of buildings based on drawings (BRI/NILIM Report)

### 6.2.6 建築物Eの被害

#### (1) 被災建築物の概要

本建築物は1970年に建設された壁式プレキャストRC造(リブ付中型コンクリートパネル造)2階建ての公営集合住宅である。本団地は1棟あたり3〜5戸からなる住棟6棟から構成されており、海岸線に近い側の4戸1住棟2棟について検討を行う。1階平面は図6.2.6-1に示す通り、長辺は4スパン(スパン長さ3.81m)、短辺は1スパン(スパン長さ5.16m)で共通である。本建築物では屋上に漂流物が確認されたことから、浸水深は建築物高さ(=5.85m)以上と推定され、近隣のRC造3階建て集合住宅の前面における津波浸水深は7.5mであった。本建築物の被害状況としては、周辺地盤の洗掘による傾斜(写真6.2.6-1)や、漂流物の衝突によるとみられる2階表壁の損傷(写真6.2.6-2)が現れたものの、1階には構造的な大きな損傷は確認されなかった。なお、海岸線から本建築物までの距離は約800mであった。



写真6.2.6-1 周辺地盤の洗掘による傾斜



写真6.2.6-2 2階表壁の損傷

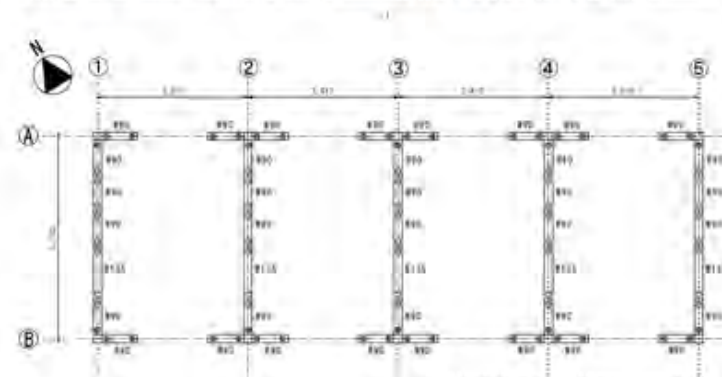


図6.2.6-1 耐力壁割付図

# Statistical Damage Survey

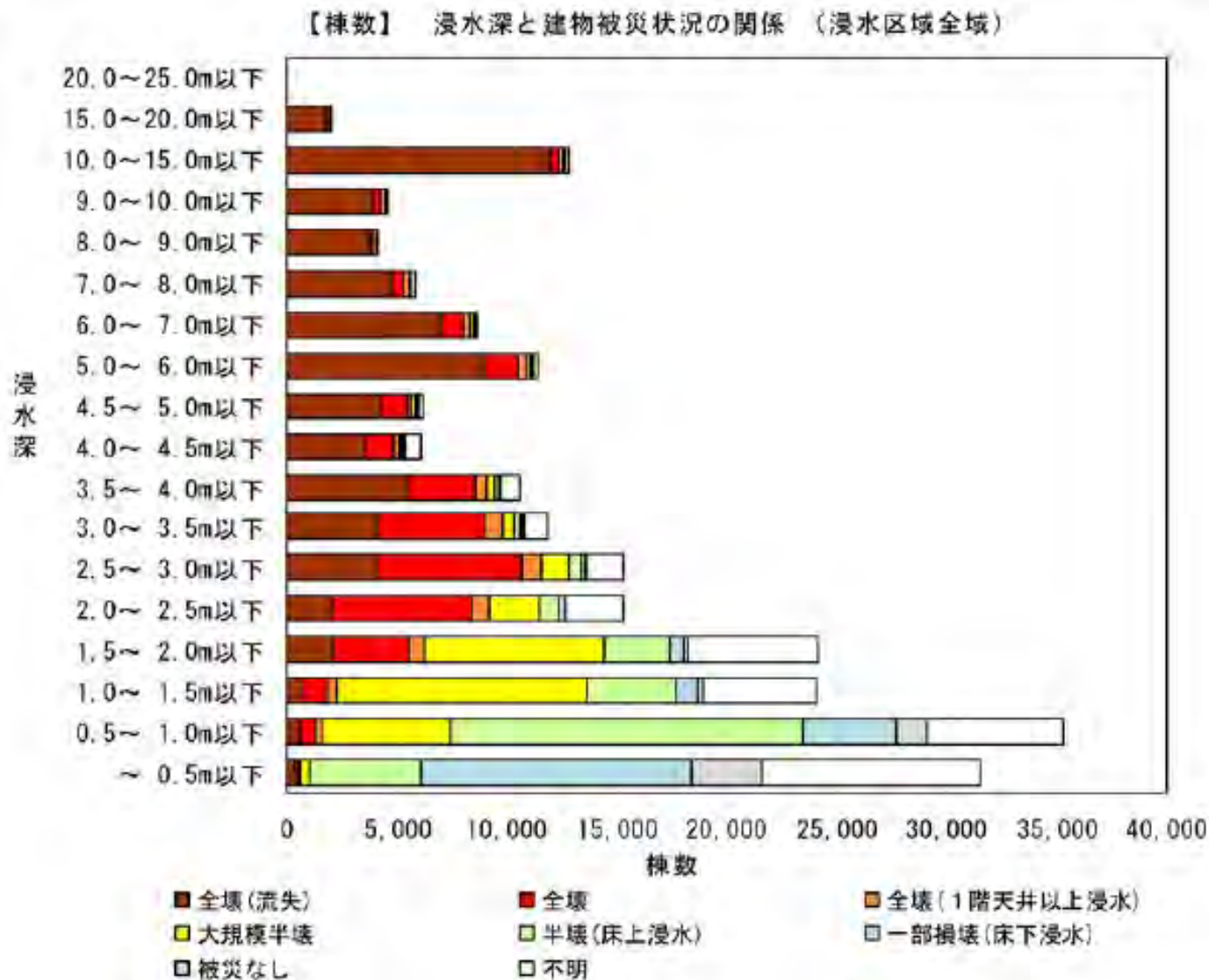
区分	全壊 (流失)	全壊	全壊 (1階天井以上浸水)	
主な建物 状況	基礎だけ残して、建物が完全に 流されている	主要構造が損壊しており補修に より元通りに再使用することが困 難	1階天井以上浸水しており、大規 模修繕等による再使用も可能	
サンプル 写真				
棟数※	約 78,000	約 34,000	約 8,000	
区分	大規模半壊	半壊 (床上浸水)	建物被災状況 (イメージ) 	
主な建物 状況	床からおおむね1m以上(天井未 満)浸水している	床から概ね1m未満の床上浸水 (一部補修により再利用可能)		
サンプル 写真				
棟数※	約 36,000	約 40,000		
区分	一部損壊 (床下浸水)	棟数合計		
主な建物 状況	床下の泥を取り除けば再利用可 能	被災建物総計      うち全壊		
サンプル 写真				
棟数※	約 23,000	約 219,000	約 120,000	

被災建物 棟数割合



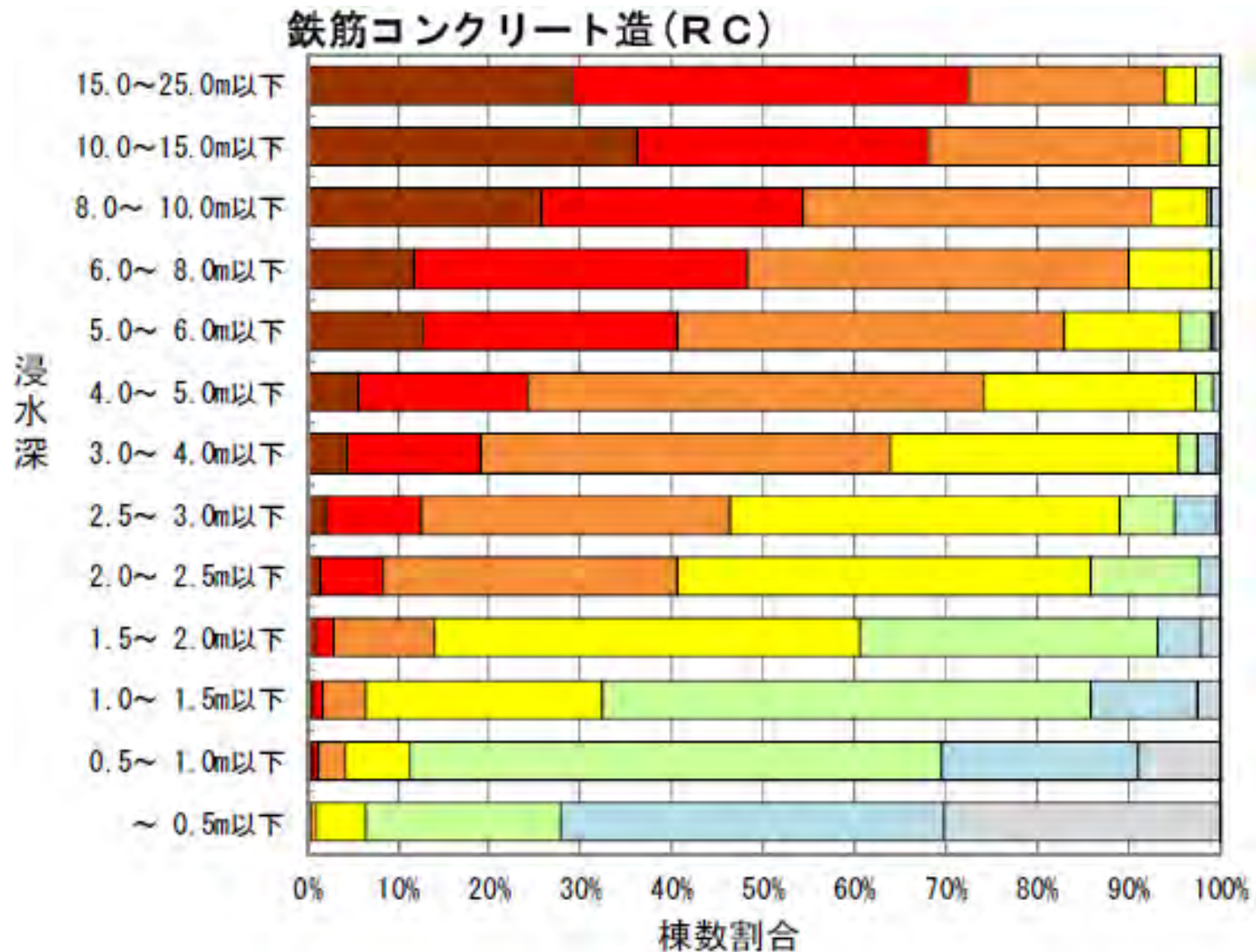


# Statistical Damage Survey



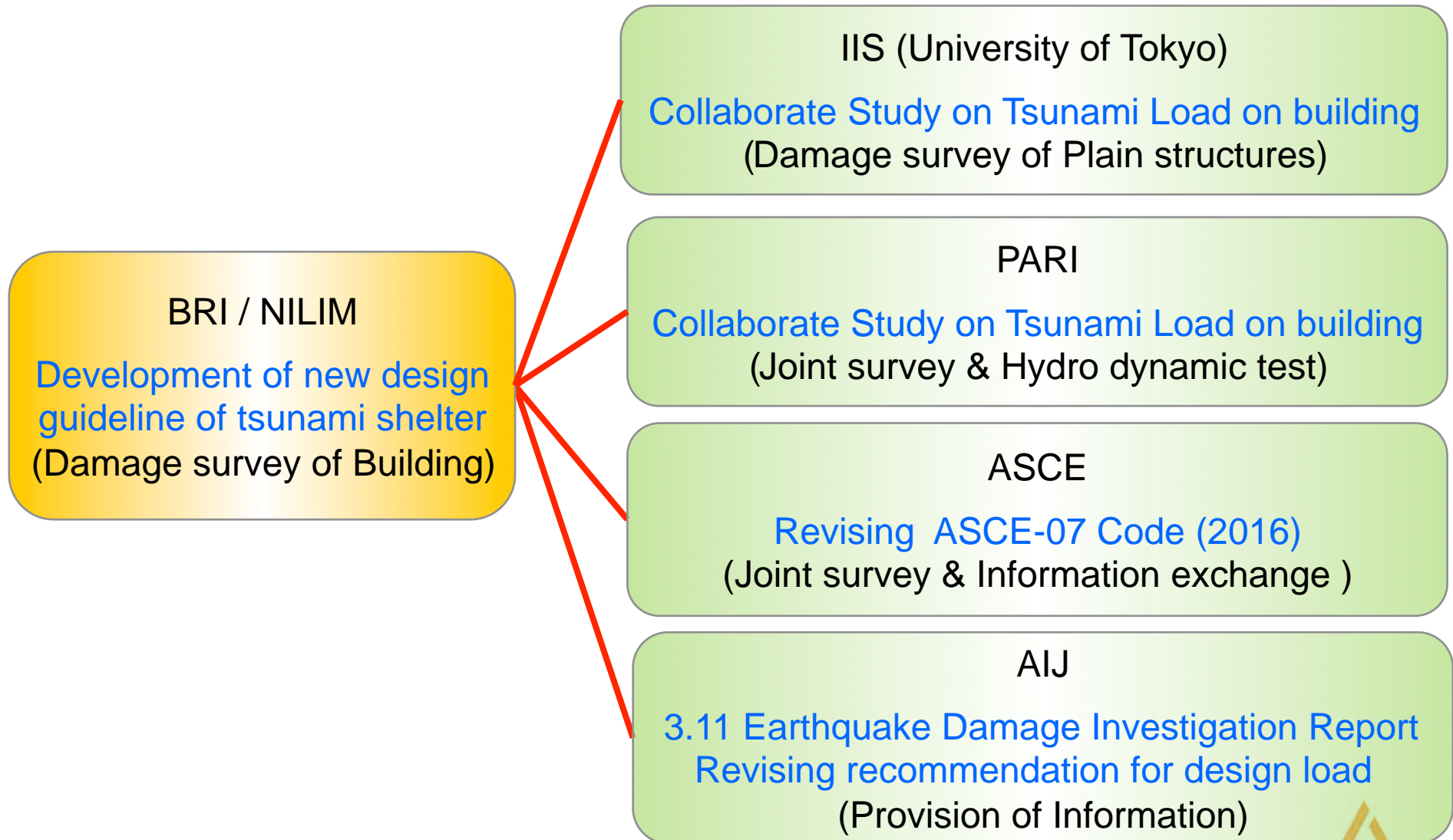


# Statistical Damage Survey



# Sharing data across different organization

Official study purpose is important for sharing data



# **Report from Japan**

## **Survey on the post-earthquake functional use of public buildings by BRI**

**Building Research Institute, Japan  
Tomohisa MUKAI**



# Background

## Damage Examples of Government Buildings

Even damage level was minor, those government buildings had no functional use after EQ.

No.	Area	Const. Year	Seismic Evaluation	Continuous Use	Seismic Intensity	Damage Level
A	Tohoku	1963	(NG)	NG	5 Upper	Severe
B	Kanto	1961	No	NG	6 Lower	Minor
B'		1961	No	—	6 Lower	Moderate
C		1970	(NG)	NG	6 Upper	Severe
D	Kanto	1968	(NG)	NG	6 Upper	Minor
E		1967	(NG)	NG	5 Upper	Minor
F		1960	(NG)	NG	6 Lower	Severe
G	Kanto	1958	No	NG	6 Upper	Moderate
H		1966	No	NG	6 Upper	Moderate
I		1964	No	NG	6 Upper	Severe
J		1969	(OK)	NG	6 Upper	Moderate

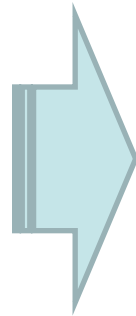




# Objectives

Obtaining and analyzing data on situations of post-earthquake functional use for public buildings

Collect data on post-EQ situation



Analyze the situations on post-EQ functional use



# Collecting post-EQ data

## -> Factor Analysis of barriers on post-EQ functionality

① Collecting data of post-EQ situation for RC government buildings, RC gymnasias, RC public housings (Collected Number is 41 cases) :

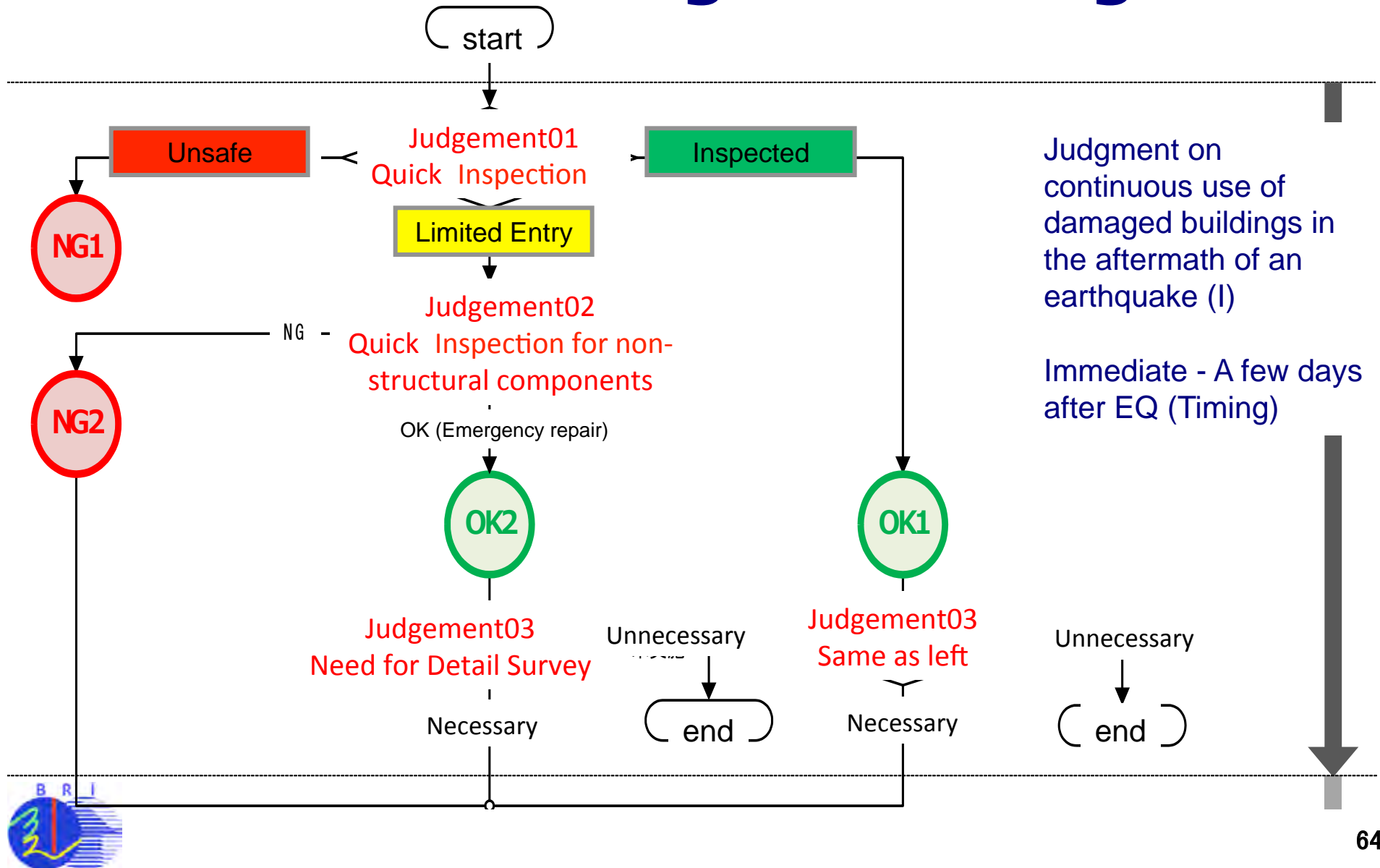
→ drawings, structural documents, information on situation of post-EQ continuous use

② Factor Analysis of situations on post-EQ functionality :

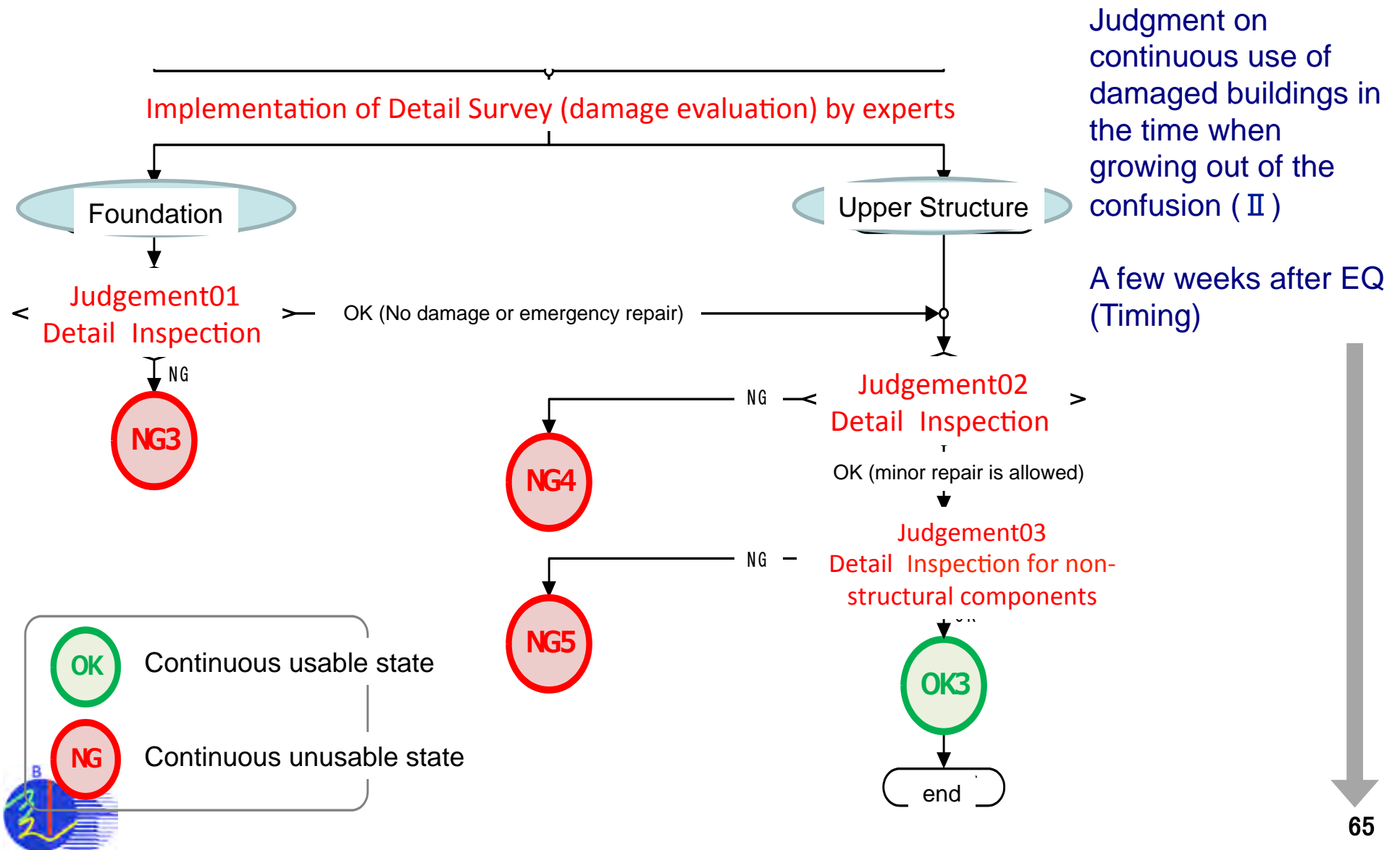
→ Making the **Flowchart** which can explain the situation of post EQ continuous use for damaged buildings considering the collected data



# Flowchart for post-EQ continuous use of damaged buildings



# Flowchart for post EQ continuous use of damaged buildings





# Conclusions

## ① Objectives • Methodology of data collection :

In order to understand the post-EQ functional use for government buildings and evacuation facilities, **hearing surveys** were done by BRI.

## ② Analysis Result of collecting data :

We showed the flow-chart which explain how the administrators took **actions** and make **decisions on post-EQ functional use** for damaged public buildings.



# **Appendices;**

## **Answers to Ken-san's 8 questions In the case of BRI**



# Question01

## **What forms of data were collected after the earthquake?**

Data of interest to this workshop include building performance (physical damage), business interruptions, housing impacts, and post-earthquake decisions (repair vs demolish). We are interested in data at both the detailed building level as well as at the broader community level. What data were used to assess building residual capacity and how were these data used in reconstruction decisions? What should be implemented in data collection protocols to make the assessment of residual capacity more reliable?

## **Answer01;**

**BRI collected the data on post-earthquake functional use for public buildings to analyze the barrier of post-EQ functional use for public buildings.**



# Question02

**Have any relationships between the different forms of data been explored?** For example, what is the relationship between the physical damage and business interruption? Are there other factors influencing the socio-economic impacts, suggesting other forms of data that should be collected?

**Answer02;**  
**No relevant items.**





# Question03

**What organizations were involved in collecting data and for what purpose?** Such organizations may include city government, insurance companies, university researchers, etc. Although the goal of data collection may be different for each organization, the data may be similar and synergistic efforts should be identified.

**Answer03 (same as A01);**  
**BRI collected the data on post-earthquake functional use for public buildings to analyze the barrier of post-EQ functional use for public buildings.**



# Question04

**What barriers are there to sharing data across different organizations?** What experience do you have in finding ways to share data across government and non-government entities?

## Answer04;

Regarding public buildings, sharing data depends on the objectives. Basically we need permission to the administrator of public buildings in advance.



# Question05

**How were the data collected?** Were any advanced technologies used to collect data or were all data collected manually? What training was provided for data surveyors?

## Answer05;

**BRI collected all the data manually.**



# Question06

**What data were lost?** Were there specific data that were not collected, or not collected in a coordinated manner, such that the data may not be available for future research studies?

**Answer06;**

**Not at all.**





# Question07

**Lessons from the data collection process.** What aspects of the data collection process seemed to work well? What could be improved upon?

## Answer07;

First of all, intimate personal and organizational relationships seems to be effective to collect the data after earthquake. Secondary, the system to judge the post-EQ functional use before earthquake occurs may enable us to collect the detail data of buildings.



# Question08

How are data stored after collection and what are access policies for this data?

## Answer08;

**The data of the damaged buildings were collected in a formatted list and shared within the BRI.**

**Items in the formatted list:**

- 1.Surveyed building information (usage, structural type, foundation system, geological formation)**
- 2.Damage information (measured seismic intensity(JMA), information on judgments for post-EQ continuous use of the damaged building and on the components which became barrier for post-EQ continuous use, repair method & process, classification of building's importance after EQ)**
- 3.Relevant data (structural documents, drawings, damage survey reports)**



# Question09

**Suggestions for the development of consensus-based data collection protocols?**

One of the primary goals of the workshop is the initial development of consensus-based data collection protocols for application after future earthquakes around the world. What experiences from the events in your country could inform the development of these data collection protocols?

## Answer09;

After big earthquake occurs, it is very difficult to collect the data immediately. The system to collect the building's data is needed before occurrence of earthquake.



# Post Earthquake Data Collection by Local Government

Satoshi TANAKA

Tokoha University



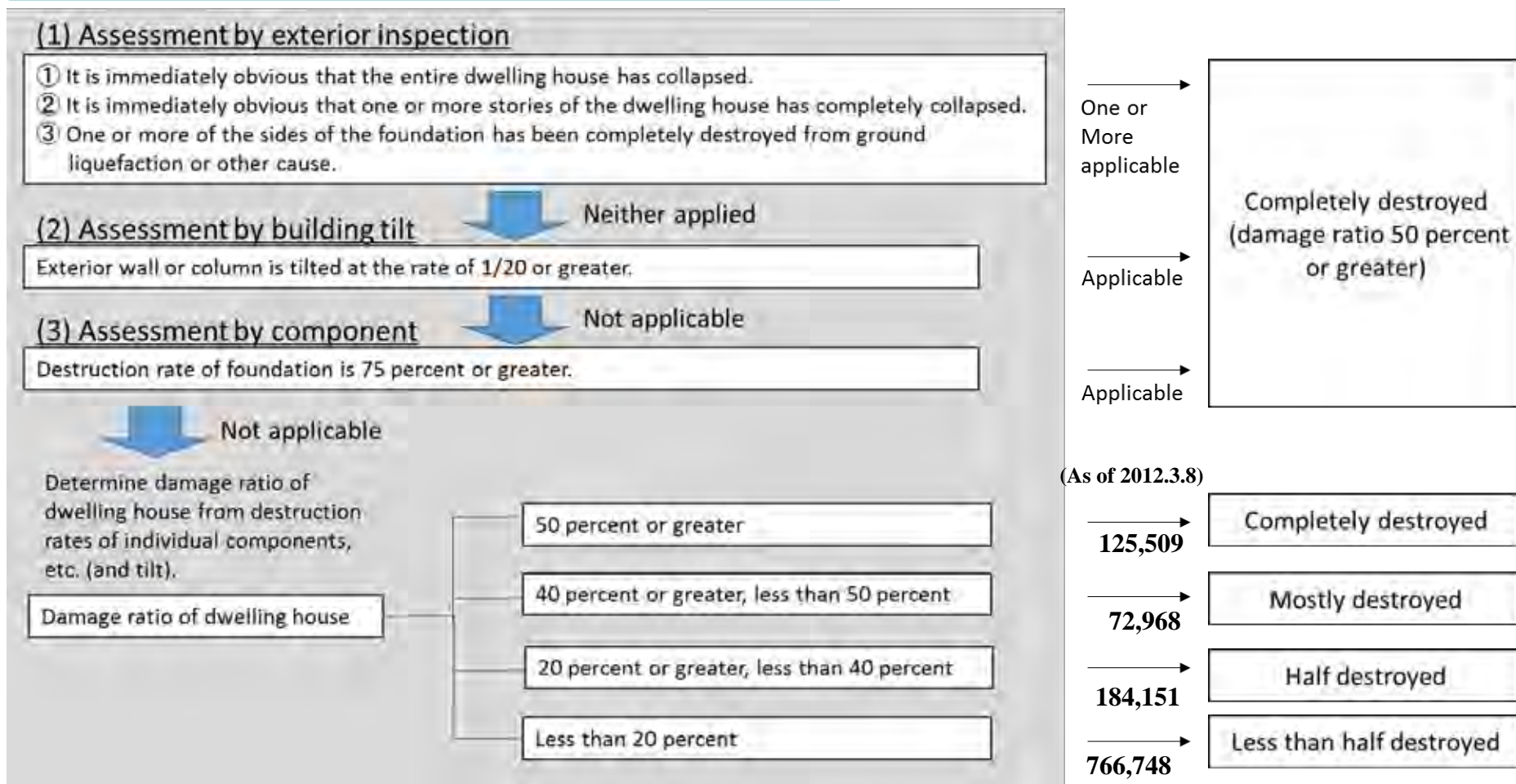
# Summary of the Inspection

- Local Gov. officials inspect the building damage
- Most of the victim support programs require the result of this inspection
- It covers all the disaster areas
- Collect the building damage data for both structural and non-structural components
- All the buildings (Wood, RC, and Steel) for all hazards (Earthquake, Flood, and Wind)
- Evaluate the damage from economical view point

# What forms of data were collected after the earthquake?

## Damage Assessment by Local Government

Damage ratio =  
Economic Damage / Entire Value



Operational Guideline for Damage Assessment of Residential Houses in Disaster (Cabinet Office)

**Untrained local government officials (not engineers) inspect and collect the data.**

**Visual inspection of the exterior and interior of building with check sheets.**

**Data is recorded on papers and stored them at the local government.**

**Access to the original data is very limited though the summary of the data is in GIS**

**Primary inspection is carried out by the visual inspection of the exterior**

[illegible]

# Tsunami

[illegible]

# Earthquake

# Secondary inspection is the visual inspection of both exterior and interior

Record damaged parts on building floor plan

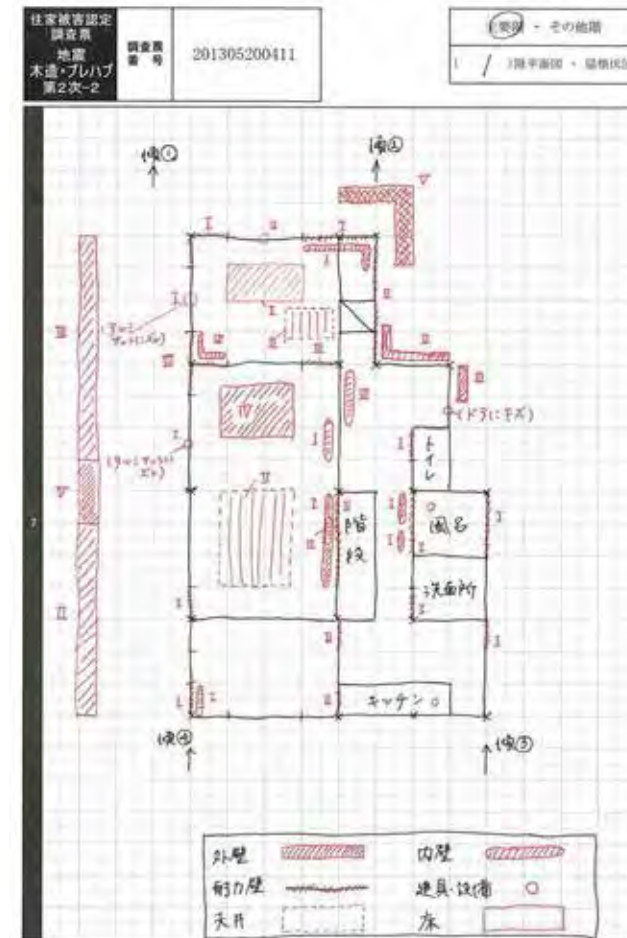
Evaluate the rank and extent of damage of each building component.

Inspection sheet for evaluation of damage of dwelling house		Inspection sheet no.		Main floor		Other floor		Total	
Wood and prefabricated house				1)		2)		1.0	
				3)		4)		1.0	
9	Exterior wall	No damage	0	0	0	0	0	0	0
		Rank I	0	0	0	1	1	1	1
		Rank II	0	1	1	2	2	3	3
		Rank III	1	1	2	3	4	5	5
		Rank IV	1	2	3	5	6	8	8
		Rank V	1	2	4	6	8	10	10
Total				Total × 0					
10	Interior wall	No damage	0	0	0	0	0	0	0
		Rank I	0	0	1	1	1	2	2
		Rank II	0	1	2	2	3	4	4
		Rank III	1	2	3	5	6	8	8
		Rank IV	1	2	5	7	9	11	11
		Rank V	2	3	6	9	12	15	15
Total				Total × 0					
11	Floor (excludes exterior wall)	No damage	0	0	0	0	0	0	0
		Rank I	0	0	0	1	1	1	1
		Rank II	0	1	1	2	2	3	3
		Rank III	1	1	2	3	4	5	5
		Rank IV	1	2	3	5	6	8	8
		Rank V	1	2	4	6	8	10	10
Total				Total × 0					
12	Ceiling (excluding ceiling wall)	No damage	0	0	0	0	0	0	0
		Rank I	0	0	1	1	1	2	2
		Rank II	0	1	2	2	3	4	4
		Rank III	1	2	3	5	6	8	8
		Rank IV	1	2	5	7	9	11	11
		Rank V	2	3	6	9	12	15	15
Total				Total × 0					
13	Roof	No damage	0	0	0	0	0	0	0
		Rank I	0	0	1	1	1	2	2
		Rank II	0	1	2	2	3	4	4
		Rank III	1	2	3	5	6	8	8
		Rank IV	1	2	5	7	9	11	11
		Rank V	2	3	6	9	12	15	15
Total				Total × 0					
14	Ceiling	No damage	0	0	0	0	0	0	0
		Rank I	0	0	0	0	0	1	1
		Rank II	0	0	1	1	1	1	1
		Rank III	0	1	1	2	2	3	3
		Rank IV	0	1	2	2	3	4	4
		Rank V	1	1	2	3	4	5	5
Total				Total × 0					
15	Interior fixtures	No damage	0	0	0	0	0	0	0
		Rank I	0	0	0	1	1	1	1
		Rank II	0	1	1	2	2	3	3
		Rank III	1	1	2	3	4	5	5
		Rank IV	1	2	3	5	6	8	8
		Rank V	1	2	4	6	8	10	10
Total				Total × 0					
16	Facilities	No damage	0	0	0	0	0	0	0
		Rank I	0	0	0	0	0	0	0
		Rank II	0	0	0	0	0	0	0
		Rank III	0	0	0	0	0	0	0
		Rank IV	0	0	0	0	0	0	0
		Rank V	0	0	0	0	0	0	0
Total				Total × 0					

Exterior wall		Floor area ratio		~10%		~20%		~40%		~60%		~80%		~100%		Total	
No damage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Rank I	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1		
Rank II	0	0	1	1	2	2	3	4	5	5	5	5	5	5	5		
Rank III	1	1	2	3	5	6	8	10	10	10	10	10	10	10	10		
Rank IV	1	2	3	5	6	8	10	10	10	10	10	10	10	10	10		
Rank V	1	2	4	6	8	10	10	10	10	10	10	10	10	10	10		
Total		Total × 0															

Inspection form



Floor plan with results of damage inspection noted



# Damage Rank of Column for wooden house

木造・プレハブ [地震による被害]・部位による判定

第2次調査

柱 (又は耐力壁)・・・ア.柱の損傷

＝ p1-26 2-2 ア.柱の損傷

## ● 程度Ⅰ



柱と梁の仕口になずれが生じている。



柱間コンクリートのひび割れが見られる。

## ● 程度Ⅱ



柱、梁が若干たわんでいる。



アンカーボルトの伸びが見られる。

## ● 程度Ⅲ



柱と梁の仕口になずれが生じている。



柱、梁に割れが見られる。

## ● 程度Ⅳ



柱、梁に大きな割れが見られる。



柱、梁の仕口になずれが見られる。

## ● 程度Ⅴ



柱、梁の割れ、断面欠損が著しい。



柱、梁に著しい損傷が生じており、交換が必要である。

## ● 損傷の判定 <表 柱 損傷比20%>

程度	損 傷 の 例 示		損傷程度
	既築工法]	鉄骨系プレハブ]	
Ⅰ	柱と梁の仕口になずれが生じている。	柱間コンクリートのひび割れが見られる。	10%
Ⅱ	一部の柱と梁の仕口にあみ等損傷が見られる。 柱、梁が若干たわんでいる。	アンカーボルトの伸びが見られる。 耐力ボルトのすべりが見られる。	25%
Ⅲ	柱と梁の仕口になずれが生じている。 柱、梁に割れが見られる。	柱頭座屈による小さな変形が柱に生じている。 梁接合部の変形が見られる。	50%
Ⅳ	柱、梁に大きな割れが見られる。 柱、梁に断面欠損が見られる。 柱、梁に折損が見られる。 柱、梁の仕口になずれが見られる。	柱頭座屈による中程度の変形が柱に生じている。 梁接合部の亀裂、ボルトの一部破断が見られる。	75%
Ⅴ	柱、梁の割れ、断面欠損が著しい。 柱、梁に著しい折損が生じており、交換が必要である。	柱頭座屈による大きな変形が柱に生じている。 梁接合部に破断が見られる。	100%

災害に係る住家の被害調査標準手順書(参考資料(損傷程度の例示))

# Damage Rank of Columns for Steel and RC

非木造 [地震・水害・風害による被害] ● 部位による判定

## 柱(又は耐力壁)A. 鉄骨造 ア. 柱

○地震 p1-51 1-1 ア. 柱(又は壁)の損傷  
○地震 p1-66 2-1 A. ア柱の損傷  
○水害 p2-47 1-1 A. ア柱の損傷  
○風害 p3-45 1-1 A. ア柱の損傷

### ●程度Ⅰ



柱脚コンクリートのひび割れが見られる。

8101

### ●程度Ⅳ



局部座屈による中ぐらゐの変形が柱に見られる。

8104

### ●程度Ⅱ



アンカーボルトの伸びが見られる。

8102

### ●程度Ⅴ



接合部の破断が見られる。

8106

### ●程度Ⅲ



局部座屈による小さな変形が柱に見られる。

8103

### ●損傷の判定

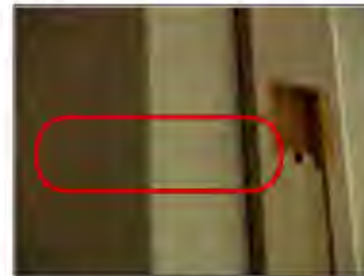
<表 柱(地震1次調査):損成比60%  
／柱(地震2次調査・水害・風害):損成比50%>

程度	損傷の例示	損傷程度
I	・柱脚コンクリートのひび割れが見られる。	10%
II	・アンカーボルトの伸びが見られる。 ・高力ボルトのすべりが見られる。	25%
III	・局部座屈による小さな変形が柱に見られる。	50%
IV	・局部座屈による中ぐらゐの変形が柱に見られる。	75%
V	・局部座屈による大きな変形が柱に見られる。 ・接合部の破断が見られる。	100%

## 柱(又は耐力壁)B. 鉄筋コンクリート造 ア. 柱

○地震 p1-51 1-1 ア. 柱(又は壁)の損傷  
○地震 p1-69 2-1 B. ア柱の損傷  
○水害 p2-50 1-1 B. ア柱の損傷  
○風害 p3-48 1-1 B. ア柱の損傷

### ●程度Ⅰ



遠くからと見えにくい程度のひび割れ(幅約0.2mm以下)が生じている。

8201

### ●程度Ⅳ



大きなひび割れ(2mmを超える)が多数生じ、コンクリートの剥落も激しい。鉄筋が露出しているが、鉄筋の変形は見られない。

8204

### ●程度Ⅱ



肉眼ではっきりと見える程度のひび割れ(幅約0.2mm～1mm)が生じているが、コンクリートの剥落は生じていない。

110025

### ●程度Ⅴ



鉄筋が大きく露出しており、鉄筋の曲がり・破断が見られる。内部のコンクリートも剥れ落ち、柱の高さ方向の変形が生じている。

8206

### ●程度Ⅲ



比較的大きなひび割れ(幅約1mm～2mm)が生じているが、コンクリートの剥落は増えずで、鉄筋は露出していない。

110026

### ●損傷の判定

<表 柱(地震1次調査):損成比60%  
／柱(地震2次調査・水害・風害):損成比50%>

程度	損傷の例示	損傷程度
I	・遠くからと見えにくい程度のひび割れ(幅約0.2mm以下)が生じている。	10%
II	・肉眼ではっきりと見える程度のひび割れ(幅約0.2mm～1mm)が生じているが、コンクリートの剥落は生じていない。	25%
III	・比較的大きなひび割れ(幅約1mm～2mm)が生じているが、コンクリートの剥落は増えずで、鉄筋は露出していない。	50%
IV	・大きなひび割れ(2mmを超える)が多数生じ、コンクリートの剥落も激しい。鉄筋が露出しているが、鉄筋の変形は見られない。	75%
V	・鉄筋が大きく露出しており、鉄筋の曲がり・破断が見られる。内部のコンクリートも剥れ落ち、柱の高さ方向の変形が生じている。	100%



# Damage Rank of Non-Structural Components

非木造 [地震・水害・風害による被害] ● 部位による判定

## 外部仕上・雑壁・屋根

○地震 p1-58 1-2 雑壁・仕上等  
○地震 p1-76 2-3 外部仕上・雑壁・屋根  
○水害 p2-60 1-3 外部仕上・雑壁・屋根  
○風害 p3-59 1-3 外部仕上・雑壁・屋根

### ● 程度 I



【外部仕上】  
仕上材のわずかな割れ、目地のずれが見られる。 9301



【雑壁】  
一部にひび割れ(幅約0.2mm～1mm)やはがれが生じている。 9302

### ● 程度 II



【外部仕上】  
仕上やタイルの目地にはっきりとしたひび割れが見られる。仕上材が部分的に剥離している。 9303



【雑壁】  
各部にひび割れ(幅約0.2mm～1mm)やはがれが生じている。 9304

### ● 程度 III



【外部仕上】  
大きなひび割れ又は仕上の剥離が見られる。 9305



【雑壁】  
全体にひび割れ(幅約0.2mm～1mm)やはがれが生じている。 9306

### ● 程度 IV

#### 《仕上材》



【外部仕上】  
仕上材の破壊、脱落が一部見られる。 9401

#### 《雑壁》



【雑壁】  
全体にひび割れ(幅約1mm～5mm)やはがれが生じている。 9402

### ● 程度 V



【外部仕上】  
全面にわたる大きな亀裂が見られ、面外への大きなはらみ出し、大きな剥離が見られる。 9403

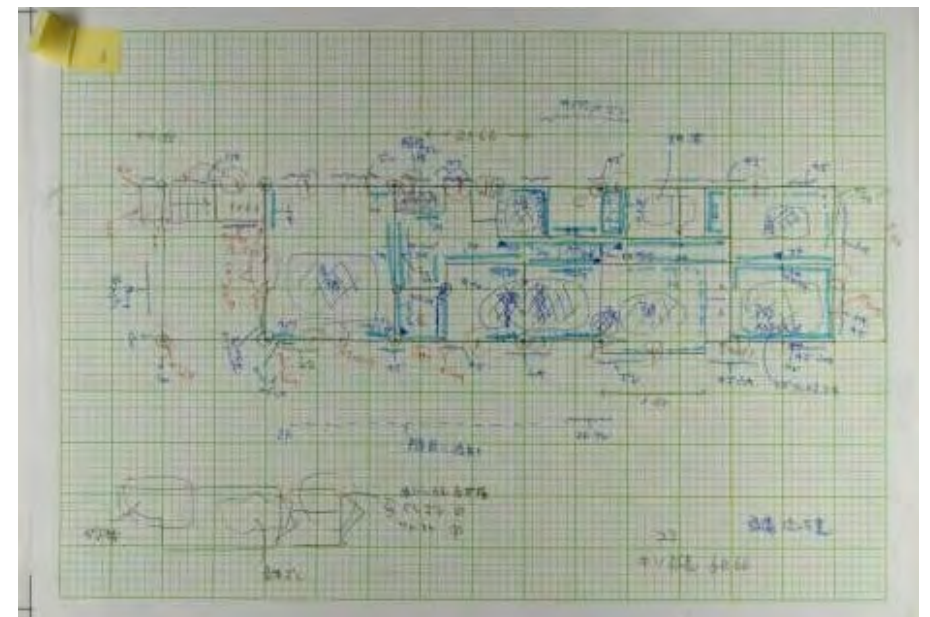
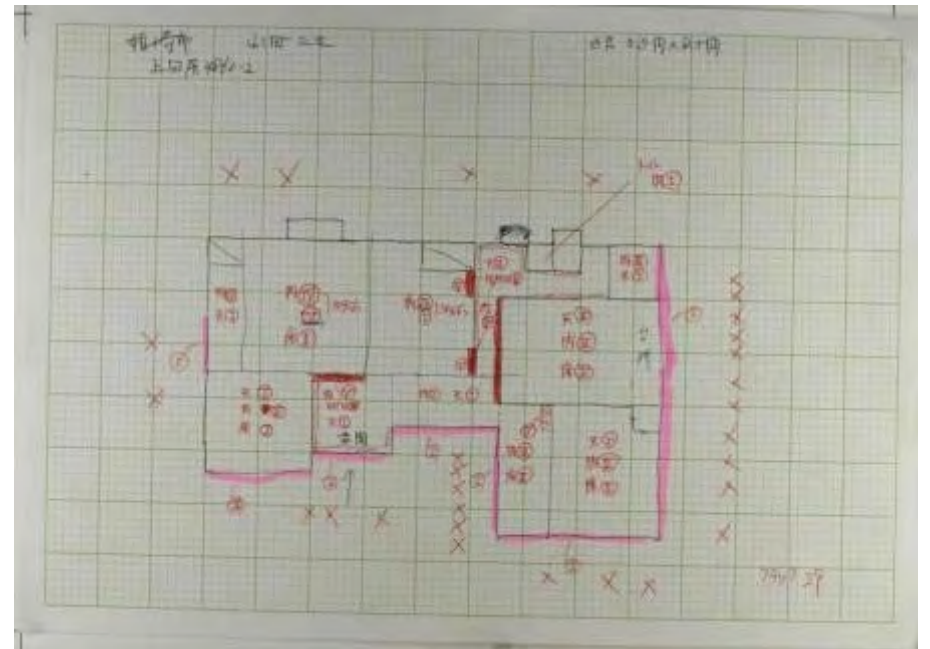


【雑壁】  
全体が変形し、仕上の大部分が剥離している。 9404

### ● 損傷の判定

＜表 雑壁・仕上等(地震1次調査):構成比25%  
／外部仕上・雑壁・屋根(地震2次調査・水害・風害):構成比10%＞

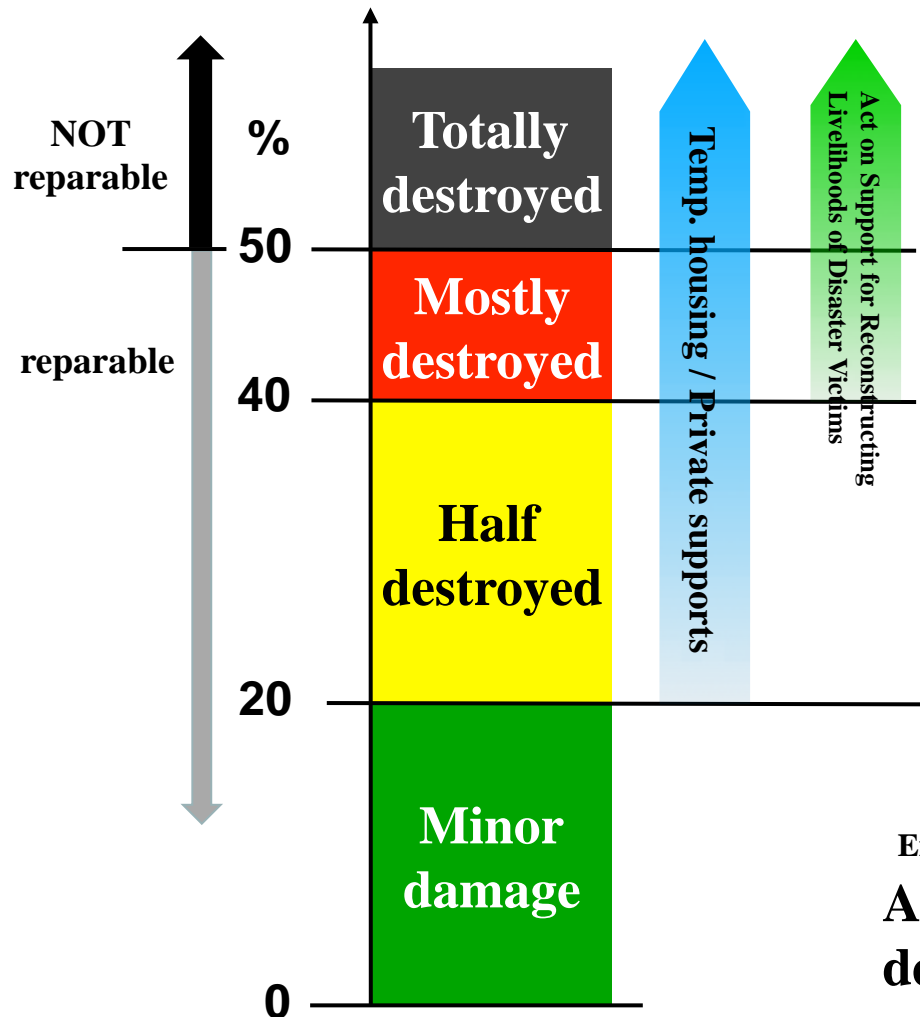
程度	損傷の例	損傷程度
	【外部仕上】	【雑壁・雑壁】
I	・仕上や仕上材の目地にわずかなひび割れ(幅約0.2mm)が見られる。 ・仕上材の隅角部にわずかな亀裂が生じている。 ・仕上材のわずかな剥離、目地のずれが見られる。	・一部にひび割れ(幅約0.2mm～1mm)やはがれが生じている。
II	・仕上やタイルの目地にはっきりとしたひび割れが見られる。 ・仕上材の目地にずれが見られる。 ・仕上材が部分的に剥離している。 ・一部に飛来物による軽微な衝突がある。	・各部にひび割れ(幅約0.2mm～1mm)やはがれが生じている。 ・一部に飛来物による軽微な衝突がある。
III	・大きなひび割れ又は仕上の剥離が見られる。 ・仕上材が部分的に剥離・剥離している。 ・一部に飛来物による突き刺さり、貫通がある。	・全体にひび割れ(幅約0.2mm～1mm)やはがれが生じている。 ・一部に飛来物による突き刺さり、貫通がある。
IV	・仕上の面外へのはらみ出し、又は剥離が見られる。 ・仕上材の破壊、脱落が一部見られる。 ・大半にわたって飛来物による衝突、突き刺さり、貫通がある。	・全体にひび割れ(幅約1mm～5mm)やはがれが生じている。 ・大半にわたって飛来物による衝突、突き刺さり、貫通がある。
V	・全面にわたる大きな亀裂が見られ、面外への大きなはらみ出し、大きな剥離が見られる。 ・全面にわたって飛来物による衝突、突き刺さり、貫通がある。	・全体が変形し、仕上の大部分が剥離している。 ・全面にわたって飛来物による衝突、突き刺さり、貫通がある。





# Have any relationships between the different forms of data been explored?

Victim support programs are applied based on the inspection result



➡ **Speed and fairness are essential to the inspection**

1. Act on Support for Reconstructing Livelihoods of Disaster Victims
2. Donation Money by many organizations
3. Tax exemption
4. Low interest loan
5. Tuition exemption
6. Temporary housing

Ex. 3.11 Tohoku EQ, Miyagi Pref. case

A victim whose house was totally destroyed will receive about \$50,000 by 1 and 2 support programs.

# Post-earthquake decisions (demolish or repair)

- Inspection result does not relate to the residual capacity
- Cost (repair vs new construction) is the key factor to the decision
- Supporting programs
  - Demolishing cost
  - Reconstruction cost (ex. \$20000 + )
- Changes in Family structure

# Issues need to concern for data collection

- Since the inspectors are not well trained, they could record the damage but could not evaluate the damage properly.
- Difficult to know the structural component from the non-structural one.
- Just a visual inspection, which does not remove the covers of the structure.

# **What barriers are there to sharing data across different organizations?**

- Act on the Protection of Personal Information
  - Damage data is regarded as personal information
- Original data is recorded on papers, not digitalized
- No standardized protocol for transferring and accumulating the data
- Data = damage description+ damage evaluation
  - Damage description, such as location, type and extent of damage, photos, can be sharing
  - Damage evaluation depends on objectives of inspection
  - Need to separate the damage description from damage evaluation



International Post-Earthquake Data Collection Workshop  
Anchorage Alaska, July 20-21, 2014,

# Japanese Experience

~~1:00 pm – 2:30 pm~~

3:30 pm – 4:00 pm, July 20

# Seven Participants

1. Toshimi Kabeyasawa, University of Tokyo (Q1, Q6)
2. Masaki Maeda, Tohoku University (Q1, Q5, Q6)
3. Koichi Kusunoki, University of Tokyo (Q2, Q3, Q8)
4. Toshikazu Kabeyasawa, MLIT (Q6)
5. Tomohisa Mukai, Building Research Institute (Q1)
6. Satoshi Tanaka, Fuji-Tokoha University (Q1, Q2, Q4)
7. Sam Kono, Tokyo Institute of Technology (Q7, Q9)

# Reconnaissance report on Tohoku EQ (29 volumes)

- Summary

1. Seismology
2. Tsunami
3. Soil failure

- JSCE

1. Damage and recovery①
2. Damage and recovery②
3. Lifelines
4. Traffic facilities
5. Nuclear
6. Immediate reactions
7. Economic influence
8. Recovery

- AIJ

1. RC
2. PS/SRC/Wall/Masonry
3. Steel
4. Timber
5. Foundations
6. Non-structural
7. Fire
8. Equipment
9. Socio-economic
10. Planning
11. Standards and laws

- JGS (Geotech)
- JSME (Mechanical)
- City Planning Inst.
- JEES

# 東日本大震災合同調査報告 刊行予定一覧

刊行予定書	刊行予定
<b>■共通編 (3編)</b>	
共通編1 地震・地震動 (幹事学会：日本地震工学会)	2014年3月刊行
共通編2 津波の特性と被害 (幹事学会：土木学会)	2014年春
共通編3 地盤災害 (幹事学会：地盤工学会)	2014年春
<b>■土木学会編 (8編) (幹事学会：土木学会)</b>	
土木編1 土木構造物の地震被害と復旧	2014年～2016年
土木編2 土木構造物の津波被害と復旧	
土木編3 ライフライン施設の被害と復旧	
土木編4 交通施設の被害と復旧	
土木編5 原子力施設の被害とその影響	
土木編6 緊急・応急期の対応	
土木編7 社会経済的影響の分析	
土木編8 復興	
<b>■日本建築学会編 (11編) (幹事学会：日本建築学会)</b>	
建築編1 鉄筋コンクリート造建築物	2014年～2016年
建築編2 プレストレストコンクリート造建築物／鉄骨鉄筋コンクリート造建築物 ／壁式構造・組積造	
建築編3 鉄骨造建築物／シェル・空間構造	
建築編4 木造建築物／歴史的建造物の被害	
建築編5 建築基礎構造／津波の特性と被害	
建築編6 非構造部材／材料施工	
建築編7 火災／情報システム技術	
建築編8 建築設備・建築環境	
建築編9 建築社会システムと震災／集落計画	
建築編10 建築計画	
建築編11 建築法制／都市計画	
<b>■地盤工学会編 (3編) (幹事学会：地盤工学会)</b>	
地盤編1 地盤構造物の被害、原因検討、復旧	2014年
地盤編2 被災調査の記録	
地盤編3 地盤に関連する施設や地域の復興	
<b>■日本機械学会編 (1編) (幹事学会：日本機械学会)</b>	
機械編	2013年8月刊行
<b>■日本都市計画学会編 (1編) (幹事学会：日本都市計画学会)</b>	
都市計画編	2014年
<b>■日本地震工学会編 (1編) (幹事学会：日本地震工学会)</b>	
原子力編	2014年
<b>■総集編 (1編)</b>	
総集編・資料編 (幹事学会：日本建築学会)	2017年





# Report from Japan on Q7 and Q9

+Heidi's question (online collection of  
case studies)

Sam KONO  
Tokyo Institute of Technology

# Q7:Lessons from the data collection process.

## Good points

- EQ's are good wake-up calls. (People, engineers, government, researchers, ect.)
- EQ's keep proof-testing current codes/standards and education. (Lessons from previous EQ's are reflected in codes/standards. The updates are tested repeatedly.)
- People prepare for EQ's in a good sense. (Market is aware of EQ's. People are aware of Tsunami after EQ's.)
- Large amount of knowledge can be obtained for professional engineers and young engineers.
- Reconnaissance report 29 volumes  
(Summary3+Civil8+Building11+Soil3+Mechanical1+CityPlanning1+NPP1+Appendix1)

# Q7:Lessons from the data collection process.

## Bad points

- Individuals, government, private companies, academic societies have different ways of collecting data and usage. (Market value may go down by sharing data. Private Information Protection Law )
- Hard to control inter-organization corporation/format for the first action. (Many organizations and individuals swarm to the damaged structures.)
- Interdisciplinary collaborations are far away. (except individual levels)
- Data collections are not easy task at all and there is not good momentum to share data with others. (Some collaboration system is required.)
- Data sharing policies are all different.



# Q9:Consensus-based data collection protocols

- Specific goals are necessary to balance labor/time and outcome.
- Most data are voluntarily collected. It is not easy to pass them to unknown people since it is hard to tell how the database is used. (Commercial use will cause a problem.)

# Heidi's question: Can Japan contribute to online collection of case studies?

- Each researcher is happy to contribute his/her data.
  - For very limited number of cases for public buildings (municipal building and schools).
- It is not easy to share data on private buildings.



# **EERI Seismic Observatory for Community Resilience: Canterbury Case Study**

National Science Foundation  
Award #1235573









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- Healthy Christchurch
- Holmes Consulting Group
- Human Rights Commission
- Lincoln University

The aim of the case study is to observe and understand how stakeholders in New Zealand are measuring, monitoring, and acting upon data-driven indicators of recovery after the Canterbury earthquakes. A goal is to help EERI decide what type of role, assistance, and infrastructure it can provide or facilitate in future earthquakes with respect to measuring and monitoring recovery. The Canterbury earthquakes provide an excellent case study for this, being perhaps the most data-rich disaster in history.



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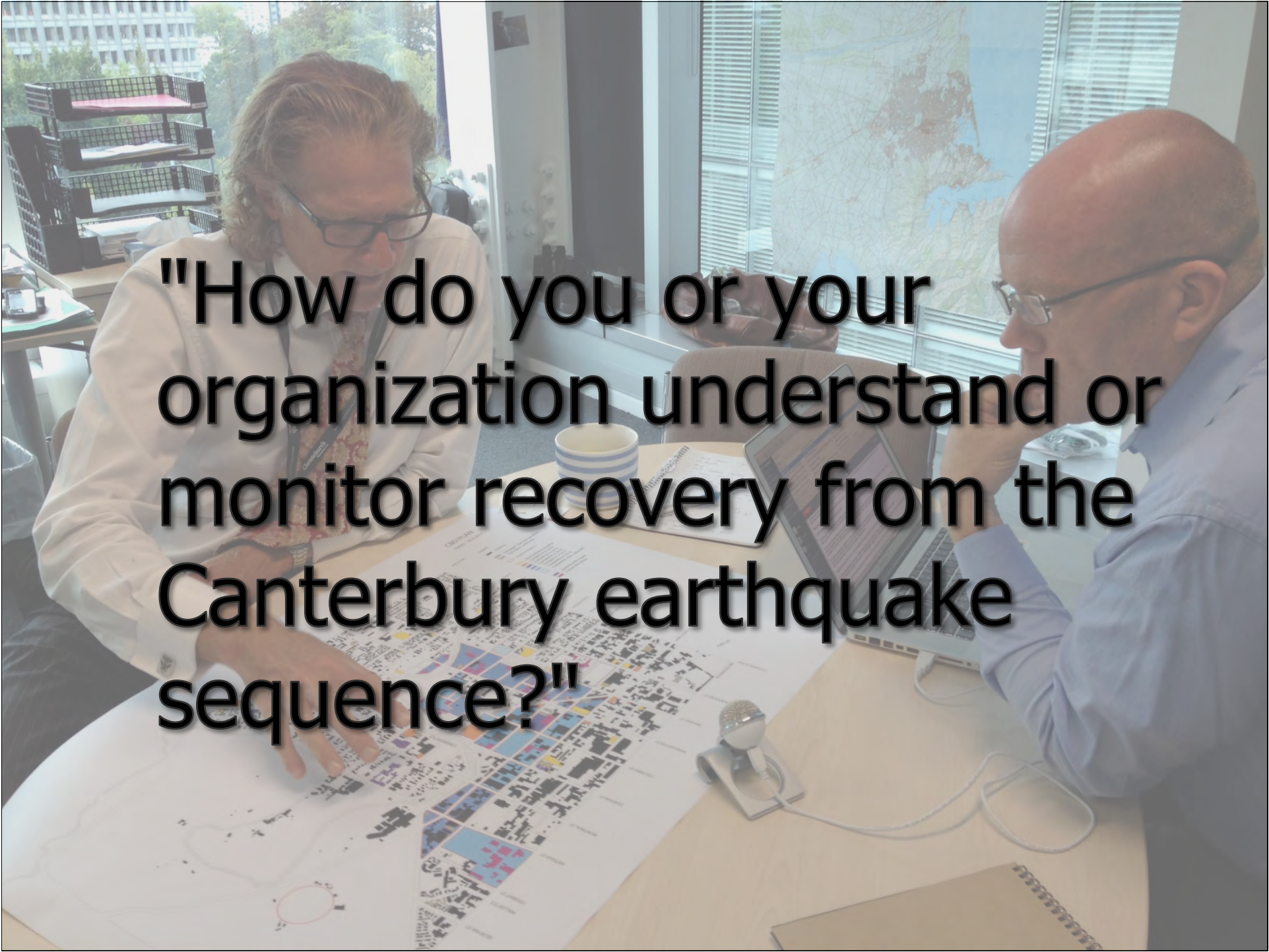
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# 45 Meetings

- 13 meetings = built environment
- 11 = social capital
- 8 = economic recovery
- 8 = human well-being
- Remaining = multiple roles



A photograph of two men in an office setting. The man on the left, with long hair and glasses, is pointing at a large map on the table. The man on the right, bald with glasses, is looking at a laptop. The map shows a city grid with various colored areas. A laptop is open on the table, and a microphone is visible. The background shows a window with a view of a city and a large map on the wall.

**"How do you or your organization understand or monitor recovery from the Canterbury earthquake sequence?"**



# Themes

- Data Collection, Analysis, and Communication
- Use of Data in Decision Making
- Coordination and Sharing of Data
- Role of EERI and Outside Experts

# Data Collection Tools

Heidi Tremayne

with Marjorie Greene and Maggie Ortiz

*Earthquake Engineering Research Institute*

with Sean Wilkinson, *Newcastle University & EEFIT*

# Data collection and visualization tools for Eqk Reconnaissance

- Hardware
  - Phones, tablets, laptops, GPS, cameras, video
- Software
  - OS (fleeting), GIS, custom form or browser based solutions, databases
- Data
  - Taxonomy/metadata, GIS, before/after satellite data, imagery, notes, drawings, form data, etc.
- Visualization and Web Dissemination
  - Upload, Mapping, Photo Gallery, Search, archive



# Post-Eq Data Collection History

- EERI has been conducting organized post-earthquake reconnaissance and data collection since the 1960s
- Traditional approach of EERI (as well as other organizations) has been hand written notes and photo documentation
- Since 2000 many organizations have tried to develop tools utilizing modern technologies





# Challenges to Data Collection Tools



# Challenge: Technology Outdated Quickly

- IT and technology advances quickly making tools obsolete, even mid-development.
- Example: Rover with Windows Mobile



Note: Rover is still in use, but now uses web interface

# Challenge: Level of Data Detail

## Systematic data? What level of detail & quality?

- Limited time in field often leads to quick collection
- Slow, unwieldy tools can hamper use of detailed collection forms
  - Example: Accela (Palm & PC)
- Many researchers want to visit areas with most damage
- Few researchers want to document limited or no damage
- Many people with different levels or experience/expertise collect data. If data to be entered requires interpretation, the resulting data/interpretation may be inconsistent

The screenshot shows a software window titled 'New Investigation' with a menu bar (File, Investigation, Tools, Help) and a toolbar. The 'Investigation' tab is active. The form is divided into two main sections: 'Event Information' and 'Investigation Information'. In the 'Event Information' section, there are radio buttons for 'Pick from list' (selected) and 'Enter number manually:'. Below these are dropdown menus for '<SELECT>' and 'GIS Area: <SELECT>'. The 'Investigation Information' section has radio buttons for 'Pick from list' (selected), 'Enter number manually:', and 'Create New:'. Below 'Create New:' is a dropdown menu for '<SELECT>' and a text field for 'Parcel Number:'. There is a 'Contact:' dropdown menu for '<SELECT>' and a form for 'First Name', 'M.', and 'Last Name'. A 'Camera File Prefix/Desc:' text area is also present. At the bottom, there is a 'Standard Comments' button, a checkbox for 'Create new copy after submit', and 'Submit', 'Save', and 'Cancel' buttons. A status bar at the very bottom reads '0 Outgoing, 0 Returned successfully, 0 Failed.'

# Challenge: Data Ownership

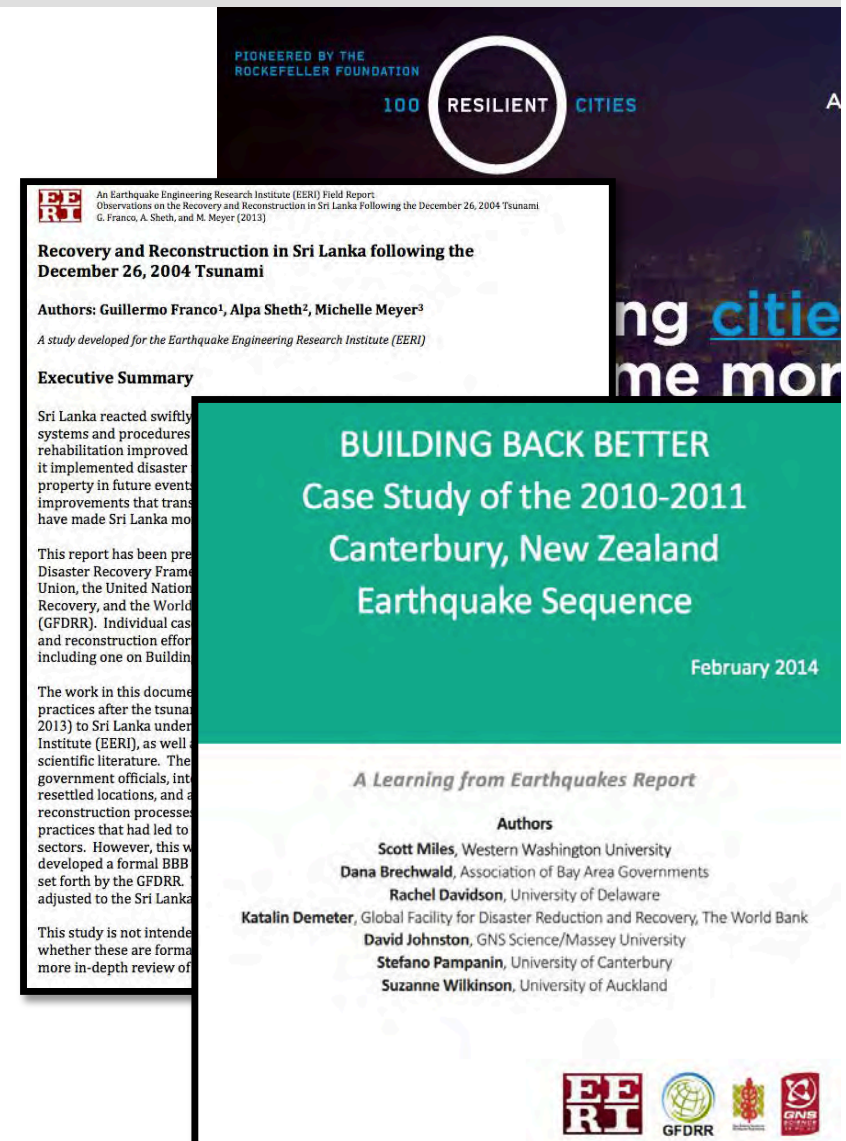
- Many organizations, governments and government agencies involved in response and recovery hesitate to share data due to privacy, liability, etc. concerns.
- Each organization in the field wants to collect their own data, in their own way.
- Resistance to using other tools, when have developed in-house tools, would need training, or are comfortable with status-quo.





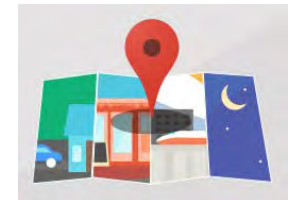
# Challenge: Extended Timeline

- Reconnaissance Timeline:
  - Immediate Post-Eq
  - Intermediate Resilience
  - Long-term Recovery
- Data collection consistency?
- Identifying key data to collect?



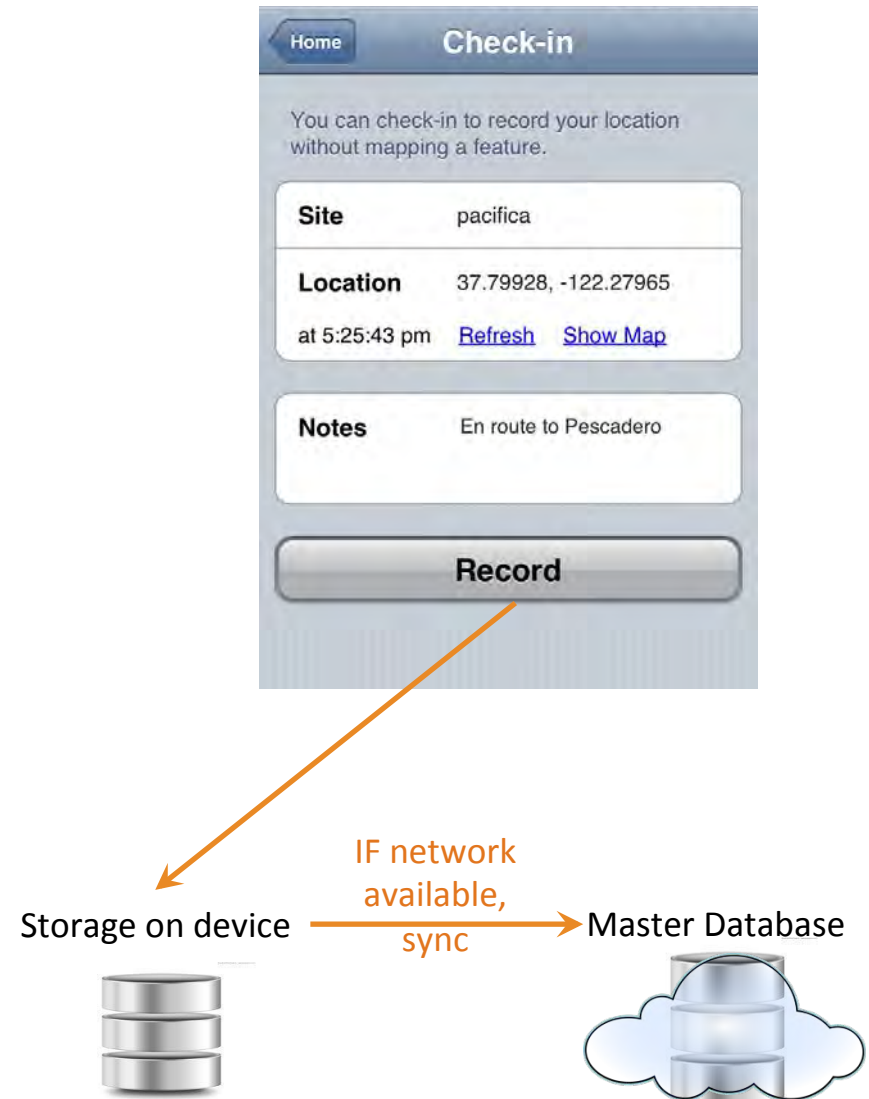
# Challenge: Large Number of Tools

- Many organizations have independently developed tools for data collection
- Data sharing can be difficult with different forms, metadata, and data frameworks
- Visualization of multiple data sets can be complicated



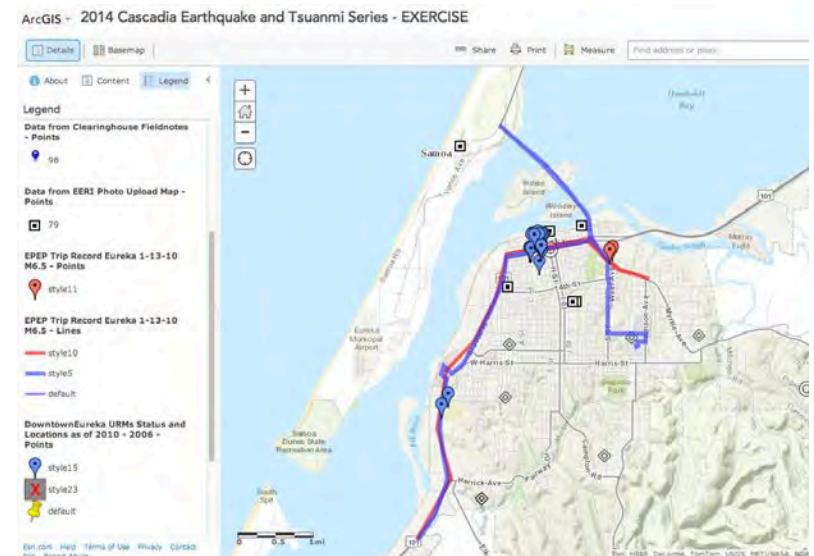
# Challenge: Connectivity

- Change to constant internet connectivity in modern life leads to expectations of near-immediate data collection, sharing, and visualization
- With limited cellular or internet access many tools may not be operable
- Example: USGS html5 web-app tool has some functionality off line (but limited)



# Challenge: Visualization

- Geo-located data is becoming easier to collect, thus map interfaces are becoming more common
- KMZ & KML map data layers exports are becoming easier and allow overlayment with other data
- With many levels of data and meta-data, other visualization may be needed beyond mapping
  - Search & Filter by metadata
  - Database
  - Image Galleries





# Trends & Opportunities in Data Collection



# Trend: Systematic Data Collection

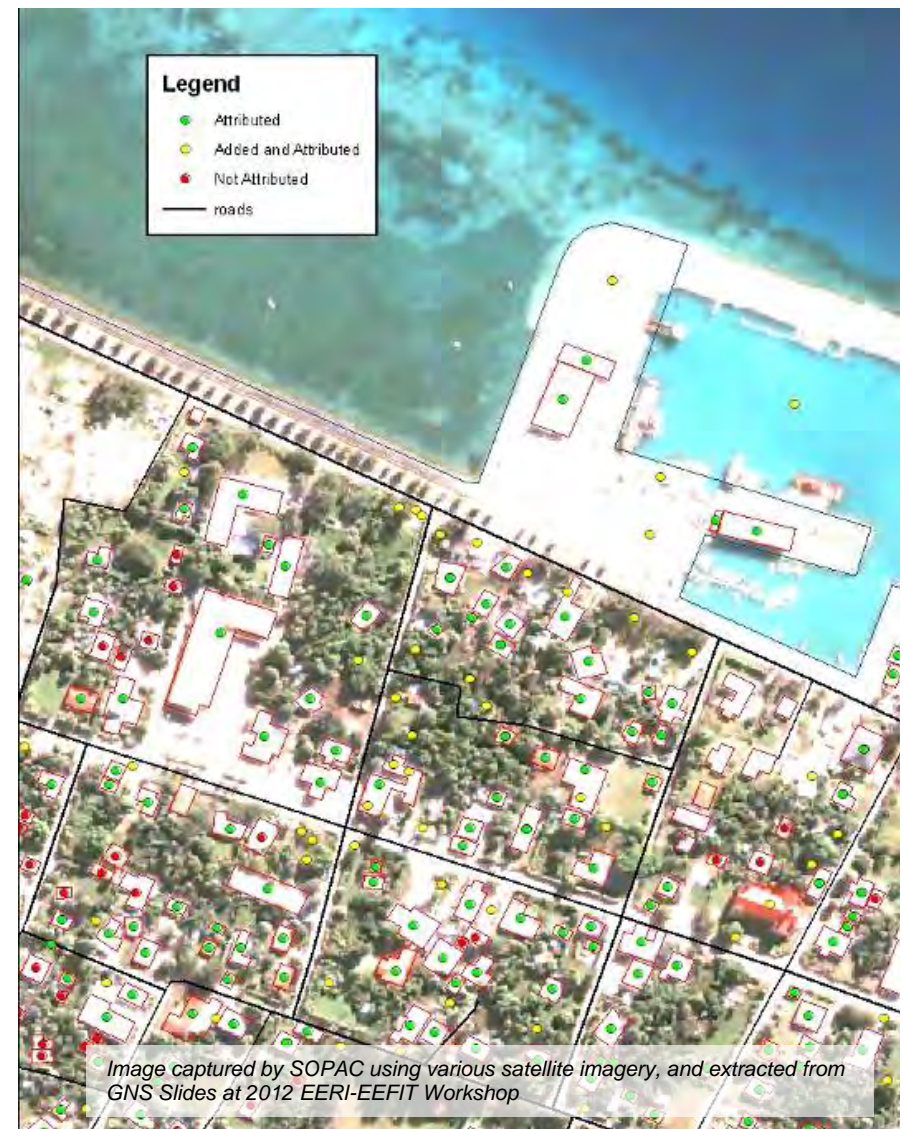
- Researchers have an increasing need for detailed data to:
  - Measure resilience
  - Calibrate engineering models and analytical tools
  - Validate performance-based earthquake engineering approaches
  - Improve risk & loss modeling
- Will researchers be willing to gather this detailed data in the field?
- Example: GEM & PEER tools

Gem Direct Observation Tools – DO capture form 2.0 April 2013

GEM GLOBAL EARTHQUAKE MODELING Working Together to Save Lives		Project		Date		Page 1 of 2	
Completed by				Time			
Phone: (intl) no	Email:	Struct. Eng.	Architect	Building Official	Civil Eng.		
Basic Building Metadata		Build No.	GPS	Longitude (X)	Latitude (Y)		
Address (building location)		City:		State:		Zip/PCode	
		No. stories above grade:		between		Exact	Circle
		No. stories below grade:		between		Exact	Circle
		Ground Floor Height: m.		between		Exact	Circle
		Year Built/Modified:		between		Exact	Circle
Direction of main facade		Unknown	Perpendicular to street	Parallel to street	Slope	deg	
Occupancy Type		Unknown	Mixed Use	Residential	Comm./Public	Industrial	Agricultural
Position within block		Detached Building	Adjoining building(s) on one side	Adjoining building(s) on two sides	Adjoining building(s) on three sides		
Structural Irregularity Primary		Unknown	Regular	Irregular	Soft story	Crinkle wall	Short column
Structural Irregularity Secondary		Unknown	Regular	Irregular	Soft story	Crinkle wall	Short column
Plan Shape		Unknown	B-shape	Curved, solid (circular, elliptical, oval)	Triangular, solid	Triangular, opening	Irregular shape
Roof Shape		Unknown	Pitched with gable ends	Pitched with hipped	Pitched with domers	Monosiph	Sawtooth
Roof Cover material		Unknown	Concrete (only)	Clay/concrete tile	Fiberglass/metal tile	Membrane roofing	Slate
Roof System material		Unknown	Masonry	Metal	Wood	Concrete	Other
Roof Connection		Unknown	Connection not present	Connection present	Tie-down - unknown	Tie-down not present	Tie-down present
Floor Type		Unknown	Masonry	Concrete	Wood	Other	
Floor Connection		Unknown	Connection not present	Connection present	Deep WITH lateral capacity	Deep NO lateral capacity	Other
Foundation System		Unknown	Shallow WITH lateral capacity	Shallow NO lateral capacity	Deep WITH lateral capacity	Deep NO lateral capacity	Other

# Trend: Remote Sensing

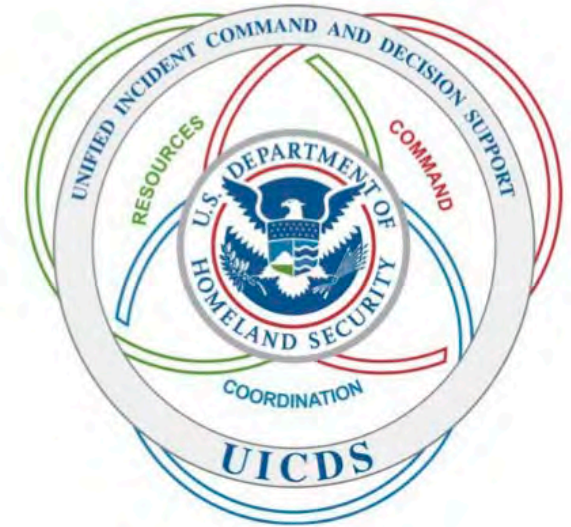
- Data can be obtained remotely e.g. lidar, satellite imagery, Other satellite imagery e.g. DTMs, soil properties
- “Big data” can now be collected, stored and analysed relatively easily.
- This can feed directly into decision support



# Trend: Data Visualization Framework

- California Clearinghouse approach utilizing UICDS

- middleware developed by the U.S. Dept of Homeland Security to allow diverse datasets/organizations to share data without common platform or software



- Allows:

- data collection and ownership to remain with partner
- partner to set what data is visible to others
- Rapid sharing

- Approach = popular; implementation = challenging

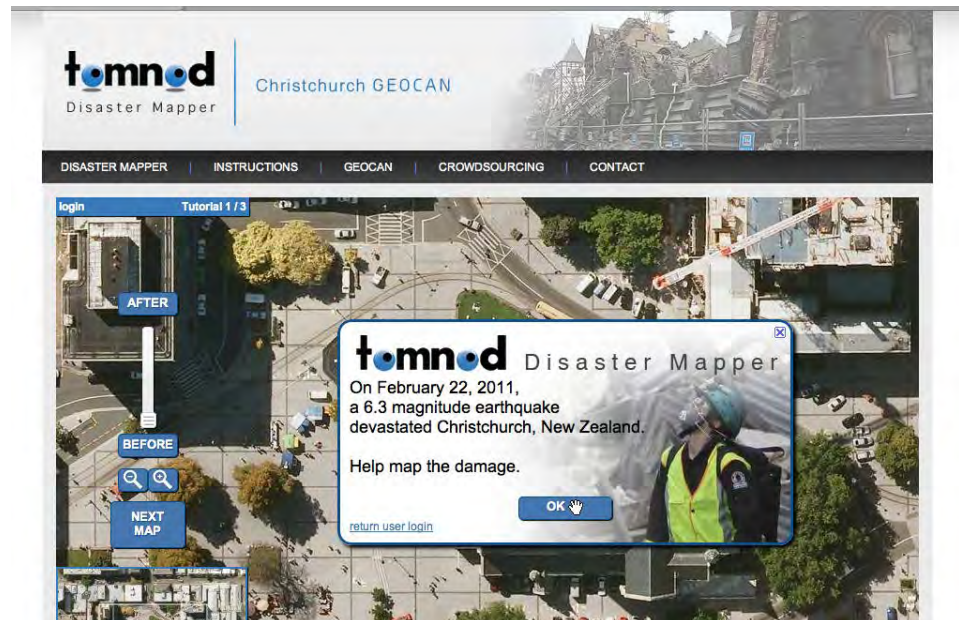
- Requires metadata adaptor to the Incident Command Data Framework





# Trend: Social Media & Remote Data

- Utilizing data from social media:
  - Paper by Mahalia Miller (at 10NCEE)
- Remote participation by experts or public:
  - Gleaning data from media reports, etc.
  - Example of crowdsourcing through GEOCAN after Haiti, NZ earthquakes
- This can feed directly into decision support



# Trend: Increasing # of Field Teams

- As US reconnaissance funding models change, smaller and more numerous teams are participating in reconnaissance
  - EERI, TCLEE, GEER, PEER, ATC, ASCE, universities, professional societies, firms, etc.
- Broadening international collaboration and participation is also yielding additional researchers, data, tools, complexity, and opportunity.
- Reconnaissance teams for other disaster types are developing, can we learn from them?



# Recommendations

- Data collection & visualization tools need to be:
  - Flexible and adaptable as IT functionality rapidly evolves
  - Platform and operating system independent
  - Functional with and without internet connectivity
  - Metadata and framework to facilitate sharing across disciplines, organizations and countries
- For systematic data collection to be possible, tools need to be flexible, able to accommodate detailed collection quickly, and widely adopted by the research community.

## Damage/Loss data needed and collected by Insurance industry

1. What is damage/loss data?
  2. For which perils do damage/loss data exist?
  3. Who collects the damage/loss data?
  4. Issues with DATA collected in the insurance industry
  5. Accessibility of data
- **For which perils do damage/loss data exist?** In general data for weather related perils is much more plentiful than data from earthquakes.
  - **Who collects the damage/loss data?** Data is collected by primary insurance companies and by risk modeling companies for different business reasons
    - Primary insurance companies: claim settlement purposes (insurance companies) done by loss adjustors.
    - Risk modeling companies:
      - for improving vulnerability functions for loss assessment
      - marketing purposes (risk modelers)
  - **Issues with DATA collected in the insurance industry are:**
    - DATA collected by insurance companies:
      - Usually good quality data, although the quality varies wildly from company to company.
      - sometimes biased by the strategy used for settling claims. Data usually not shared outside of the industry.
      - interest restricted to certain types of structures (insurable buildings in their books);
      - their interest is not holistic but often capped by the insurance limit (they might not care for losses beyond the limit they are responsible for);
      - Censored data: in many occasions, especially if claims are low, they might not conduct investigation but pay directly.
      - Detailed data about the damage that generate the loss is shared very rarely
    - DATA collected by risk modeling companies:
      - Lack of time and support to conduct resource-intensive structured data collection
      - data is not standardized
      - Data is not collected in a systematic way. Biased towards more damaged buildings
      - Sometimes biased low because of lack of accessibility to structures



- **Accessibility of data:** In general data is held proprietary mostly for liability reasons (insurance companies) or to prevent accessibility by competitors (risk modelers). Circulation of insurance data within the industry does exist though:
  - From particular insurance companies TO consulting companies (for analysis and insight)
  - From (re)insurance companies TO (re)insurance companies (to gain trust, reinsurance)
  - From (re)insurance companies TO broking companies (reinsurance placement, consulting)
- When data is shared externally it is only done at an aggregate level (minimal information about building type and no detailed information about exact location), which then loses significant potential for scientific and numerical analysis

**Appendix III:**  
**Monday July 21 Discussion**  
**Summary Presentations & Notes**

# International Post-Earthquake Data Collection Workshop: Wrap-up

## Agenda

- Breakout summaries (<45 min with discussion)
  - Five slides each breakout
  - Discussion after all three have been presented
- Next Steps (<1 hour)
  - Resolutions
  - Action items

# Damage

PHYSICAL



# WHY

- Identify Knowledge Gaps
- Conduct Forensic Studies
- Produce Damage Statistics
- Guide Response

# WHAT

CATEGORY	DATA	DEFINITION

# EARTHQUAKE

CATEGORY	DATA	DEFINITION
Earthquake	Name	
	<b>Date</b>	
	Ground Record(s)	
	Response Record(s)	

# STRUCTURE

CATEGORY	DATA	DEFINITION
Structure	ID	
	<b>Coordinates</b>	
	<b>Address</b>	
	<b>Number of Stories</b>	
	Occupancy	
	Number of Occupants	
	Number of Housing Units	
	Force-Resisting System(s)	
	Seismic Isolation	
	Mechanical Protection Device	
	Strengthening	
	<b>Nonstructural Elements</b>	



# STRUCTURE

CATEGORY	DATA	DEFINITION
Structure	ID	
	<b>Coordinates</b>	
	<b>Address</b>	
	<b>Number of Stories</b>	
	<b>Nonstructural Elements</b>	

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# CONSEQUENCES

CATEGORY	DATA	DEFINITION
Consequences	Survey Date	
	Tag	
	In Use or Not in Use	
	Damage Level	
	Damage Description	
	Cause of Damage	
	Tsunami Run-up Height	
	Crack / Damage Maps	
	Site / Soil Damage	
	Photos, Video, Media	

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# HOW

- Representative samples
- Narratives with standard terms or keywords instead of or in addition to pull-down menus and check boxes?
- Explicit references to standards and ranking systems

# Research Needs

- Define an index to quantify residual capacity
- Produce better simulation tools and models
- Identify factors contributing to resilience
- Develop better methods to estimate regional vulnerability

# Summary of Impact Data Breakout Discussion

Mary Comerio, Moderator

With help from Judith Mitrani-Reiser

# What are Critical Impact Sectors

- Housing
- Health
- Education
- Economy (Jobs)
- Environment
- Communication
- Lifeline operability
- Safety of Civil Society

↑ All are interconnected ↓

Holistic Overview:  
Social  
Economic  
Natural Environment



# What are Minimum Parameters for Baseline and Post-Event

Population impacted area (make up by census)

Urbanized vs non-urbanized

# Dwelling Units (+ types)

# Hospitals/beds (+types)

# Schools (+types)

# Government buildings

# Industrial/commercial buildings

Productivity

Ground Surface Changes

Lifeline Status

Non-Structural Damage

# Data Collection Procedures and Use of International Protocols

- Data Protocols are critical
  - GEM consequence protocols, WHO reports, Sphere Standards, UNDAC other existing models
- Link Damage Survey to operational effectiveness –to define building functions by structure type and link loss/damage with disruption of service
- Engineering community needs to take ownership of functionality requirements to improve Performance Based Design

# Value of Data

## Time Sensitivity of Data

- Overcome barriers to sharing by demonstrating community benefits
  - Examples NZ Geotech/ACC data, Hur. Sandy NYC hospitals shared beds avail daily
- Base Line (pre-event) AND Change in event
- Timeframe for data vary by sector
- Note what is perishable. Because of relation to functioning vs recovery

# Recovery and Reconstruction

## Participants

David Johnston (NZ)  
Mike Stannard (NZ)  
Marco Di Ludovico (IT)  
Juan Carlos de la Llera (CHILE)  
Tomohisa Mukai (JP)  
Scott Miles (US)  
Vesna Terzic (US)  
Ayhan Irfanoglu (US)  
Ken Elwood (U. Auckland)

## Moderator


Stephanie Chang

## Student/recorder

Frederic Marquis

## Why collect data? (value)

\* “How is the recovery going?” (informing decision-makers)

Type of Data	Social	Basic services	Wellbeing, risk perception	
	Physical	Can the building be used?	What do you do with the building? (demolition decision)	Code changes
	Hard			
		Emergency	Reconstruction - Recovery	
Time 				



# What minimum types of data are required?

## Categories

1. Damage
2. Rebuilding
3. Functionality
4. Decisions
5. Economics
6. Behavior
7. Population
8. Perceptions

## 2. Rebuilding

- % buildings... (by type, loc., T)
  - Assessed
  - Permitted
  - Repaired
  - Retrofitted
  - Demolished
  - Rebuilt
  - Occupied
- Trends (multiple/proxy/simplified)
- Community changes

# How to Collect and Share Data (principles, ideas)

- Balance data for informing decision-makers with data for research
- Interviews with staff (as well as population)
- Multiple sources, triangulation (e.g., rebuilding)
- Build in links (e.g., buildings with owners/tenants; business actions/time/impact)
- Data has to be made public and available

## **Breakout Session – Recovery and Reconstruction (Theme #3)**

Post-Earthquake Data Collection Workshop

Anchorage, Alaska

July 20-21, 2014

**Moderator:** Stephanie Chang (UBC)

**Student:** Frederic Marquis (UBC)

**Participants:** David Johnston (NZ), Mike Stannard (NZ), Marco Di Ludovico(IT), Juan Carlos de la Liera (CHILE), Scott Miles (US), Vesna Terzic (US), Tomohisa Mukai (JP), Ayhan Irfanoglu (US), Ken Elwood (U. Auckland)

## **What minimum types of data are required?**

### **Categories**

#### **1. Damage**

- a. Detailed building geometry, materials, soils properties and damage data to fill gaps of building performance with the level of shaking experienced by the building.
- b. Amount of damage for members and damaged building by experimental tests
- c. Repair costs (structural members, non-structural members, damage location in the building) (individual building or community)
- d. Effectiveness of mitigation

#### **2. Rebuilding**

- a. % buildings
  - i. Assessed
  - ii. Permitted
  - iii. Repaired
  - iv. Retrofitted
  - v. Demolished
  - vi. Rebuilt
  - vii. Occupied
- b. Trends (multiple indicators, proxy indicators, simplified information)
- c. Community changes (e.g. spatial differences)

#### **3. Functionality**

- a. Post-EQ functionality not to shut down after EQ
- b. Occupancy of public buildings (e.g. hospitals)
- c. Lifelines recovery (different indices) and lifeline interdependencies. How the system works (lifelines, healthcare system, etc.)

#### **4. Decisions**

- a. Government (Policies, Legislation, Recovery Authority, Building Codes, Coding System, Communication to Population)
- b. Building Owners
- c. Impacts (including code changes and retrofits)

## **5. Economics**

- a. Business database: type of business, downtime, timeline of inspection, type of data collected, time to initiate repair, time to repair, sequence of actions and their durations prior to repair of the buildings, tags, business interruption losses.
- b. Data to link types of businesses to dependency on their buildings to inform the need for relative reconstruction speed versus alternative work arrangements
- c. Data to link tenants to buildings to building owners and then track during recovery
- d. Businesses by place and time (number, open/close, % functional, \$/% output, jobs)
- e. Total jobs (new, lost)

## **6. Behavior**

- a. CCTV footage inside buildings during earthquakes and along sidewalks/streets

## **7. Population**

- a. Population by place and time (and movements)
- b. School enrolment

## **8. Perceptions**

- a. Detailed data on the response of people at different levels (individuals, communities, etc.) and their risk perception and how it has evolved in time.
- b. Psycho-social data of people's perception of loss and reconstruction of their built environment (e.g. "How much change is too much?")
- c. Comfort level, wellbeing, acceptable damage level and comprehension of risks at the community level.
- d. Effectiveness of mitigation

## Value of the data

- How's the recovery going? (informing decision-makers)
- Matrix

Social	<i>Basic services</i>	<i>Wellbeing, risk perception</i>	
Physical	<i>Can the building be used?</i>	<i>What do you do with the building? (demolition decision)</i>	<i>Code changes</i>
Hard			
	Emergency	Reconstruction -	Recovery

- Balance between research and decision-making needs
- Decision-making in future events

## How to collect and share data

- Interviews with local staff, returnees, etc.
- Data has to be public and available
- Multiple sources, triangulation (e.g. rebuilding)



## Summary Notes from Tuesday Comments & Participant Observations

- We need to start speaking to data analysis experts because approaches are now often more schema-less. Data searching through meta-data, searched and filtered by modern and novel tools at the cutting edge of data.
- All of the groups have different outcomes and thus the hard data commonalities seem to be the location and time of collection and occupancy type.
  - Maybe that there are more commonalities but need to study further?
- The commonality may be the aim of having all teams on recon missions are collecting a matrix of data that has a similar framework. Is this the main outcome of this exercise? An agreement to a collaborative approach and procedure?
- Need to align each data to its purpose. Could this be the unifier that all data is linked by purpose for its use?
- Time is correlated to the purpose. Questions change over time. By segmenting in time, there may be a way to look at frameworks that change by time? (Many at workshop agreed with this statement.)
- Countries will act in their own ways, but it would be nice to validate this data in a common way. Protocols could ensure that data is valuable.
- Could we use Christchurch as an after the fact case study to better understand gaps in data when it was gathered by fragmented and various groups?
- What data is available before the event? This should be considered as the fundamental data in advance that we measure how it changes after the earthquake. A study of recent 2010 and 2011 earthquakes could be done in this regard???
- Its all about the deltas? Standards may help if we were working together and combining recon with the importance of data for local community response and recovery
- Self assigned quality score for data collection? Using cross checks? Duplicate data collection by multiple researchers for redundancy? A variety of solutions could be devised to validate field data and add error bar to damage ratings or values. Multiple teams should meet to calibrate and benchmark collection before they go into the field. This could help to achieve data consistency.
- Common themes could also be occupancy type. See above.
- Questions about how quick to gather data. Don't want to be in the way of responders but perhaps some quick observations can be made to make a quick assessment, then a later group can get more data if suitable. This does go against having quick teams add functionality questions to avoid needing to do interviews
- Consider use of GIS and geospatial data.
  - What is location? Need to be clear on these items. (coordinates of building or where recording data, etc) Also standards on other meta data to be clear on accurate location.
- Time and Purpose should be more important from perishable data.
- Structural damage is only tip of iceberg. More work is needed on nonstructural, networks, function, etc. Model calibration for risk, function, interconnection, network models, not just structural models.
- Need common tools that are easy to collect by many, not just a select few. This could also include crowd-sourced data from the public.
- Phases matter. The recovery phase is arguably more important than the first response phase. We need to add data from others, not just what we can gather. Must think

bigger beyond engineers. The focus of our efforts and discussion should be around standardizing process to get good data when others gather it, not what should be collected.

- Work needs to be done to come to consensus on damage levels (standardization).
- This group needs to focus on realistic resolutions on what we (internally) can do as a group, instead of beyond to major other stakeholders.
- It is important to move away from data as a currency, how it is used matters. Our creativity in its use should be the power, not the raw data. This can be seen in the life sciences arena where data sharing is commonplace and required. This needs to be a culture shift.
- Legal issues conflict in Japan and many other countries.
- Concepts of data collection and sharing is overwhelming and time consuming. A clearer, more definite outcome would help scale and clarify the scope of what we are doing. Countries and engineers in countries after earthquakes are so busy that it is hard to share, even several years after the event, while they are still trying to gather and understand data in their own country for their own purposes.
- How do we share the legacy of what we learned for researchers in the future? Can we create a document, activity or other items that can do this collectivity between our countries? Can we capture common best practices from all these countries who have recently been impacted?