# 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**

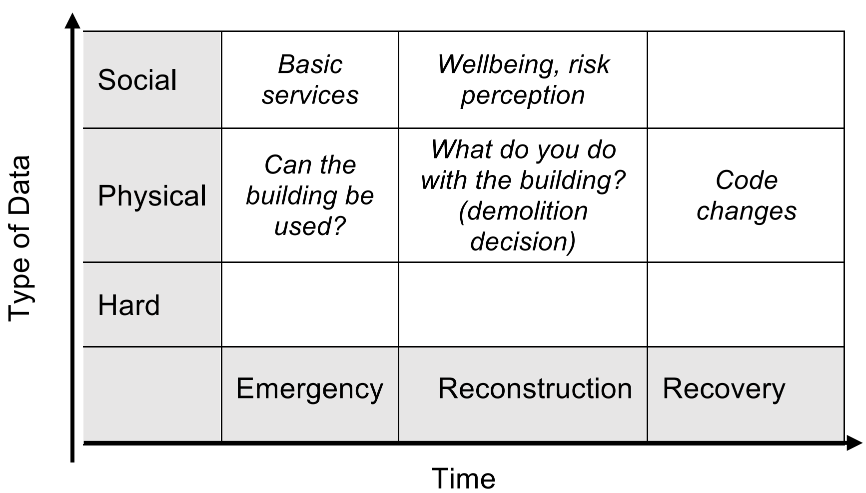
Impact data represents a holistic view of the impact on the social, economic and natural environments as a consequence of damages to the physical environment. The critical sectors include but are not limited to: Housing, Health, Education, Economy (Jobs), Environment, Communication, Lifeline operability, 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.




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**

# 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 counties 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:<br>Physical Damage Data<br>(Santiago Pujol ) | Breakout 2:<br>Impact Data<br>(Mary Comerio) | Breakout 3:<br>Reconstruction and Recovery Data<br>(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) |

**Participant List:**

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# 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,<br>*vs* comprehensive collection later,<br>*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** | *New Zealand experience (group organized presentation)* |
| **2:30 pm – 2:50 pm** | *Resilience Observatory (Scott Miles)* |
| **2:50 pm – 3:10 pm** | *Break* |
| **3:10 pm – 3:30 pm** | *Data collection tools (EERI)* |
| **3:30 pm – 5:00 pm** | *Japan experience (group organized presentation)* |
| **5:00 pm – 5:15 pm** | *Break* |
| **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) |

**Shuffled presentations!** (1:00 pm – 5:15 pm)

- 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:<br>Physical Damage Data<br>(Santiago Pujol ) | Breakout 2:<br>Impact Data<br>(Mary Comerio) | Breakout 3:<br>Reconstruction and Recovery Data<br>(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<br>(with hors d'oeuvres) |

# Thank you!

# Sunday Agenda

| | |
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**Shuffled presentations!**

- 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,<br>*vs* comprehensive collection later,<br>*vs* data to assess residual capacity for decisions on demolitions.

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

Post Earthquake Data Collection Workshop

# Italy Experience

reluis


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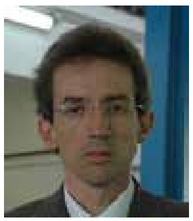


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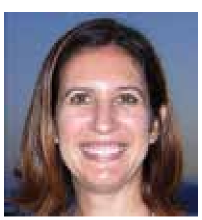


## Maria Polese
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**Network of University Laboratories in Earthquake Engineering**
**RE**te dei **L**aboratori **U**niversitari di **I**ngegneria **S**ismica

# ReLUIS – Competence Centre of Civil Protection Dept.

- ***What is ReLUIS?***

**Network of University Laboratories in Earthquake Engineering**

*Supplemento ordinario alla "Gazzetta Ufficiale" n. 105 dell'8 maggio 2003 - Serie generale*

Spediz. abb. post. 45% - art. 2, comma 20/b
Legge 23-12-1996, n. 662 - Filiale di Roma

GAZZETTA UFFICIALE
DELLA REPUBBLICA ITALIANA

PARTE PRIMA — Roma - Giovedì, 8 maggio 2003

N. 72

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).

COPIA TRATTA DA GURITEL — GAZZETTA UFFICIALE ON-LINE

## ORDINANCE OF THE PRIME MINISTER 3274/2003

**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**

EUCENTRE
Centro Europeo di Formazione e Ricerca in Ingegneria Sismica

reluis

**RE**te dei **L**aboratori **U**niversitari di **I**ngegneria **S**ismica
Charter members: Univ. Basilicata, Napoli, Pavia and Univ. di Trento) Collaboration with ENEA

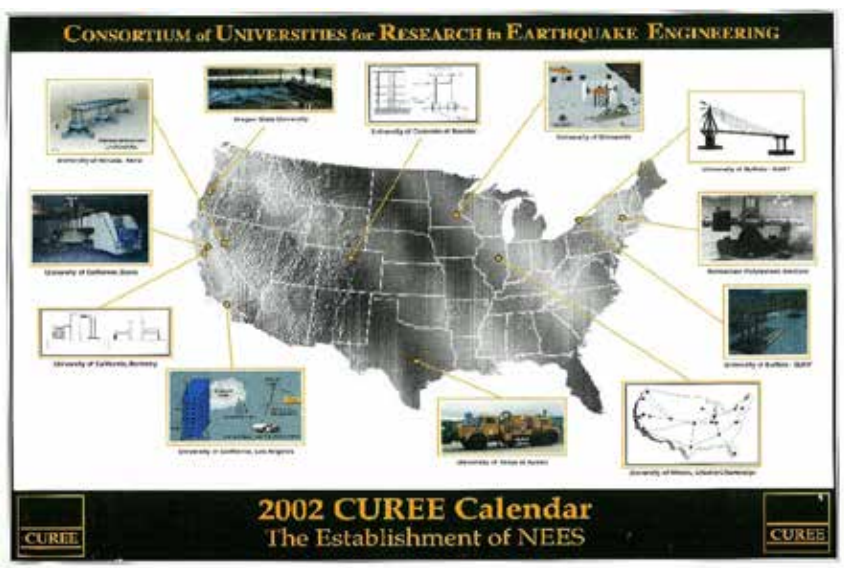
PROTEZIONE CIVILE NAZIONALE

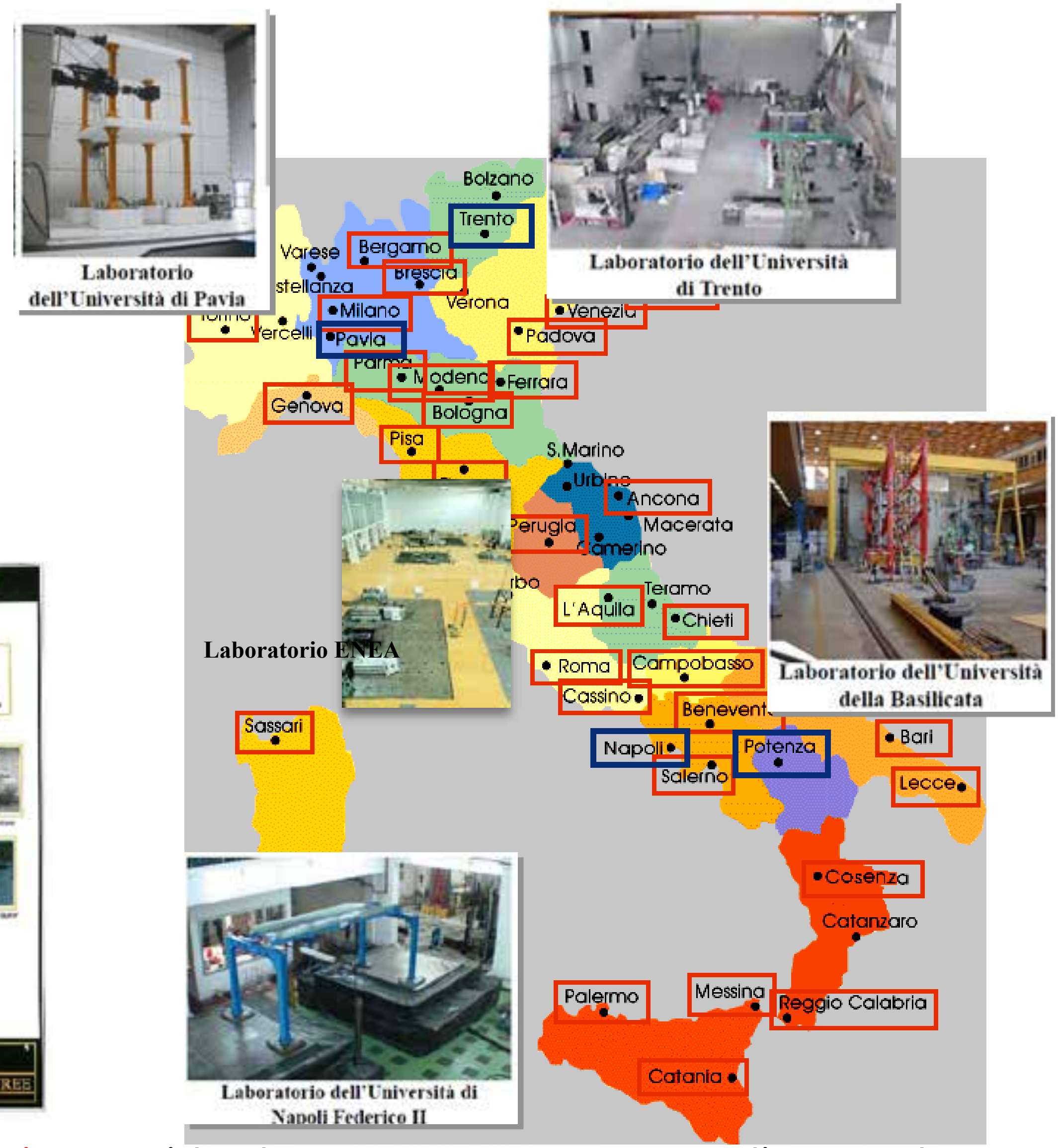
ENEA
ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE

# ReLUIS – Competence Centre of Civil Protection Dept.

- ***What is ReLUIS?***

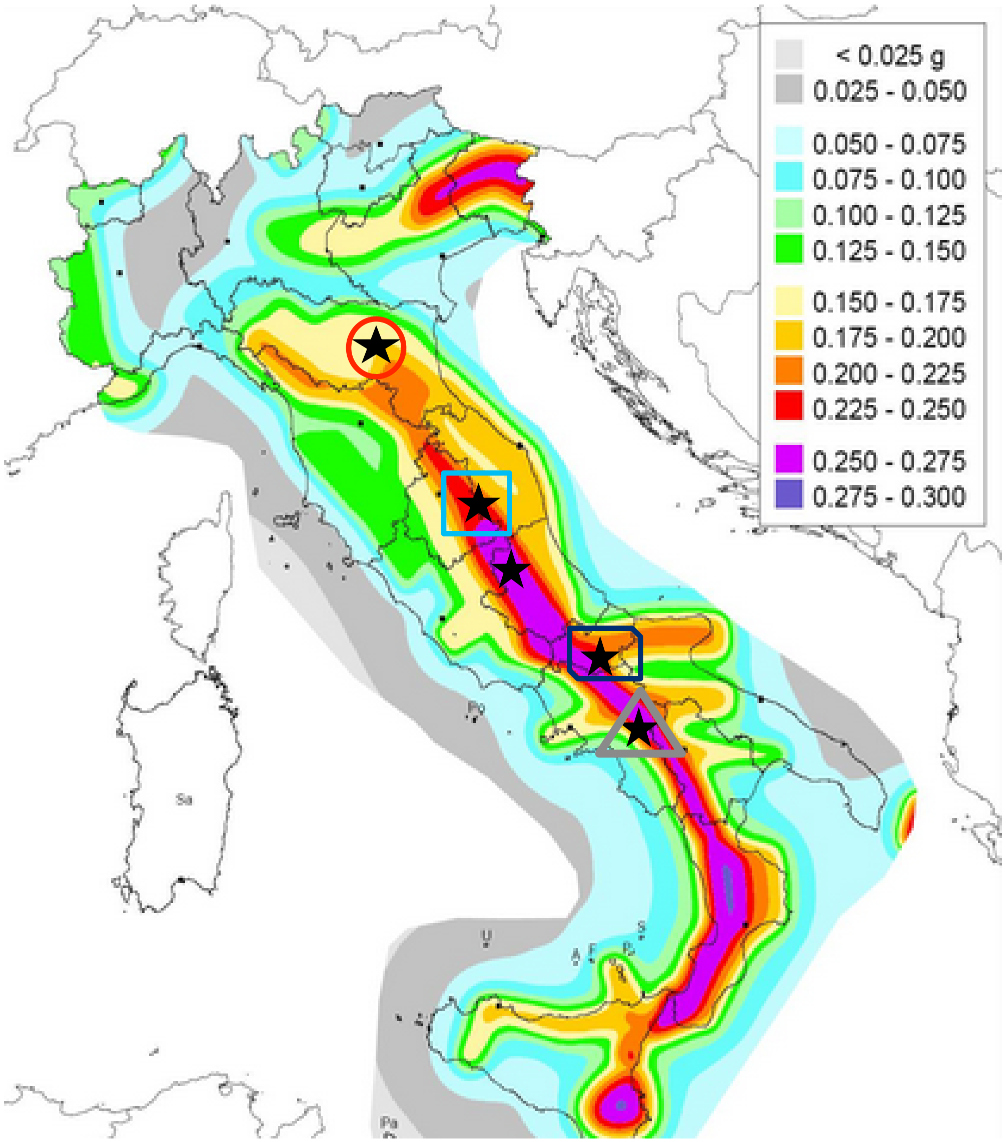
•The consortium ReLUIS has many similarities with other earthquake engineering networks (i.e. *Network for Earthquake Engineering Simulation* **– *NEES*** *and* Asian Pacfic Network for Center of Engineering Reasearch **- *ANCER***).




•ReLUIS, 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 (Ms=6,9)**

**Umbria-Marche Earthquake**
**26 September 1997 (Ms=5,5)**

**Molise Earthquake**
**31 October 2002 (Mw=6,3)**

**L' Aquila Earthquake**
**6 April 2009 (Mw=6,3)**

**Emilia-Romagna Earthquake in**
**20-29 may 2012 (Mw=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).

IL MATTINO

CRESCE IN MANIERA CATASTROFICA IL NUMERO DEI MORTI (SONO 10.000?) E DEI RIMASTI SENZA TETTO (250.000?)

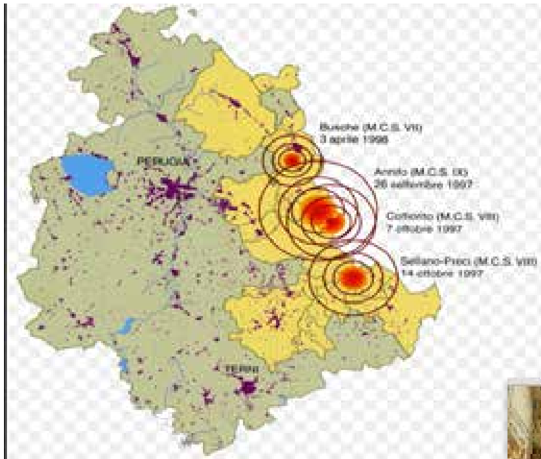
FATE PRESTO

*per salvare chi è ancora vivo*
*per aiutare chi non ha più nulla*

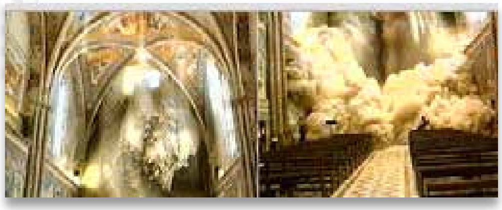
"HURRY to save those who are still alive, to help who no longer has anything"

# Recent Earthquakes in Italy

## ➢ Umbria-Marche Earthquake 26 September 1997 (Ms=5,5)




An initial earthquake tremor of magnitude 5.5 (Ms) 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;

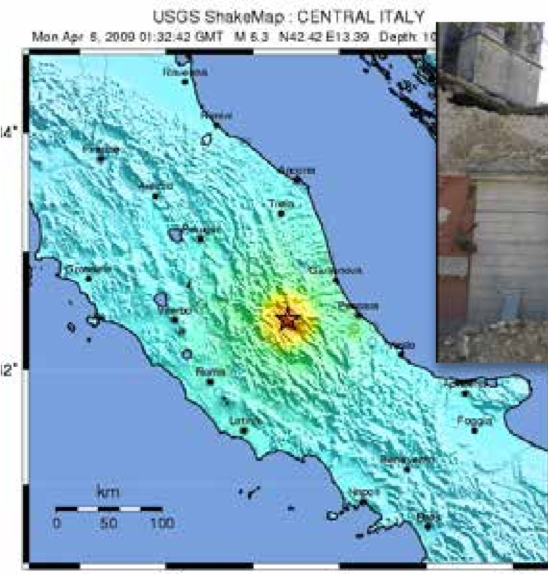
## ➢ Molise Earthquake – 31 October 2002 (Ml=5,4)

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



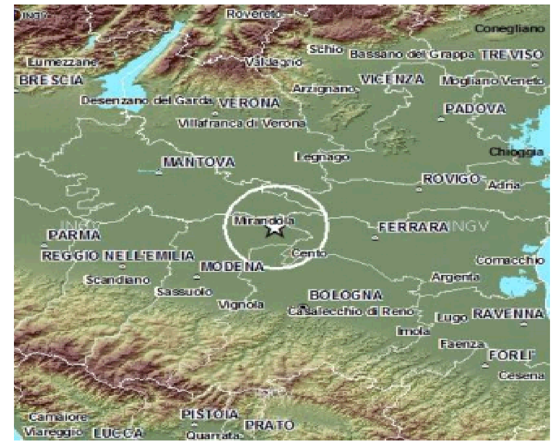

Government buildingin of the city of L'Aquila

- 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)

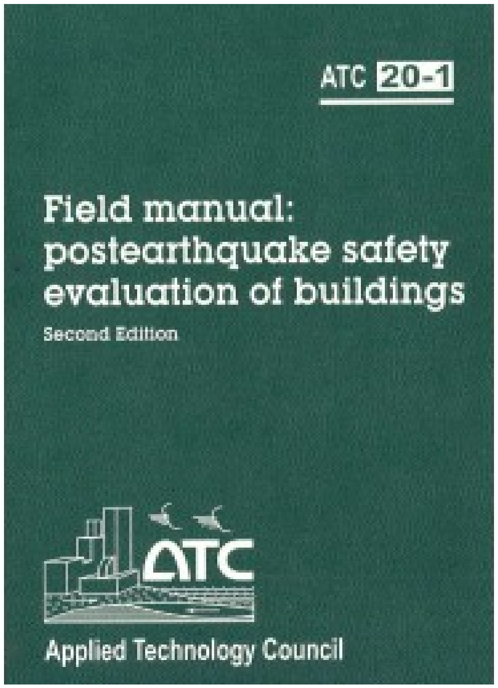
In May 2012, two major earthquakes occurred in Northen Italy, causing 26 deaths and widespread damage.




- 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

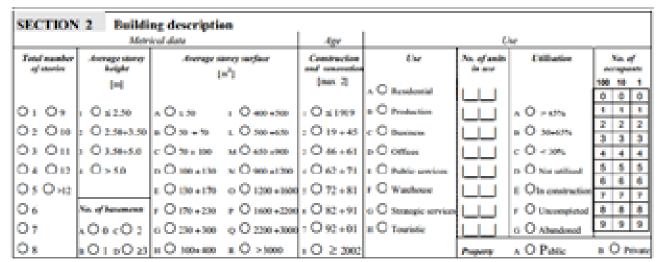
- localization;
- n° of the survey;
- date of the survey.


SECTION 1 Building identification

1.1. BUILDING IDENTIFICATION

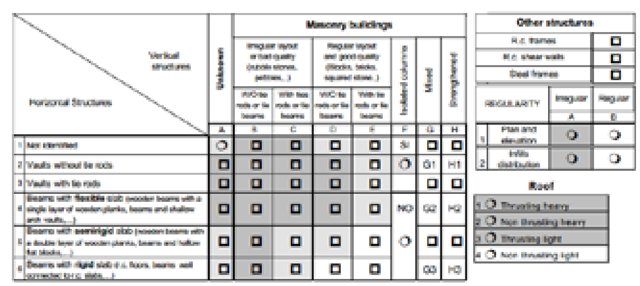
### ➢Section 2 - Building description:

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


SECTION 2 Building description

### ➢Section 3 - Building typology

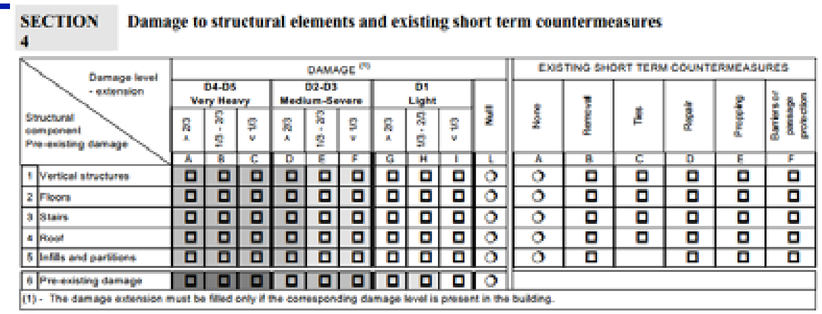
- <u>structural typology;</u>
- <u>main elements of vulnerability.</u>



# Post Earthquake Safety Evaluation of Buildings

## Data collected by Aedes Form

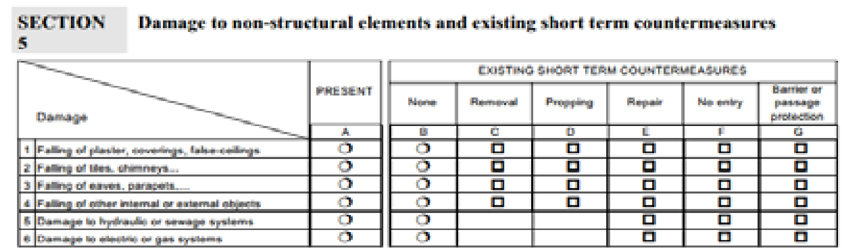
- ➢Section 4 - Damage to structural elements and existing short term countermeasures:
- ➢Section 5 - Damage to no structural elements and existing short term countermeasures:
- ➢Section 6 - External risk induced by other construction and and existing short term countermeasures
- ➢Section 7 - Soil and Foundation
- ➢Section 8 - Usability assessment
- ➢Section 9 - Note



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

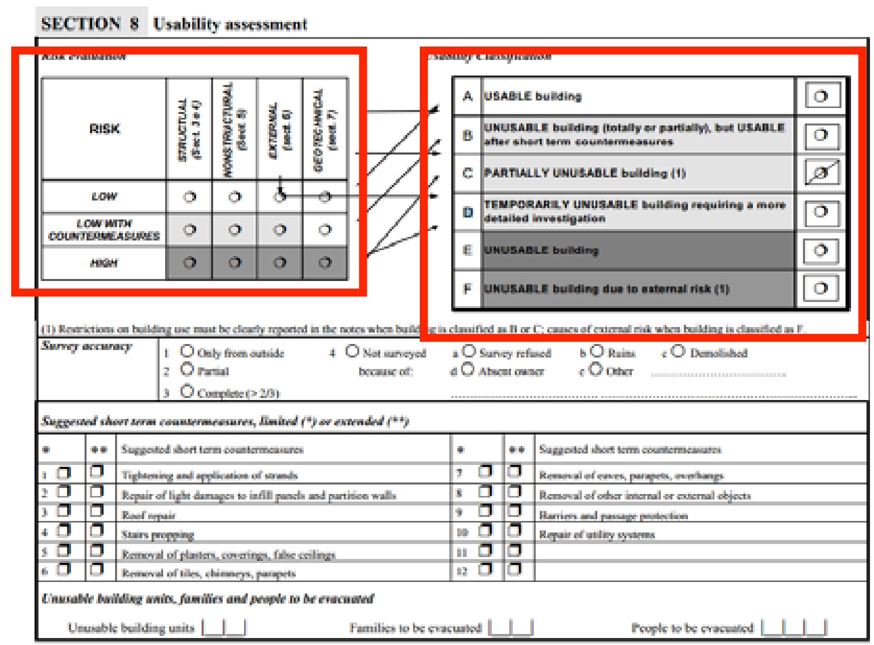
| Damage level - extension / Structural component / Pre-existing damage | DAMAGE (1) D4-D5 Very Heavy > 2/3 | D4-D5 1/3 - 2/3 | D4-D5 < 1/3 | D2-D3 Medium-Severe > 2/3 | D2-D3 1/3 - 2/3 | D2-D3 < 1/3 | D1 Light > 2/3 | D1 1/3 - 2/3 | D1 < 1/3 | Null | EXISTING SHORT TERM COUNTERMEASURES None | Removal | Ties | Repair | Propping | Barriers or passage protection |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | H | I | L | A | B | C | D | E | F |
| 1 Vertical structures | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2 Floors | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3 Stairs | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4 Roof | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5 Infills and partitions | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ | ○ | ☐ | | ☐ | ☐ | ☐ |
| 6 Pre-existing damage | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ | | | | | | |

(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 |
|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G |
| 1 Falling of plaster, coverings, false-ceilings | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 2 Falling of tiles, chimneys... | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 3 Falling of eaves, parapets,... | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 4 Falling of other internal or external objects | ○ | ○ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 5 Damage to hydraulic or sewage systems | ○ | ○ | | | ☐ | ☐ | ☐ |
| 6 Damage to electric or gas systems | ○ | ○ | | | ☐ | ☐ | ☐ |



**SECTION 8** Usability assessment

| RISK | STRUCTURAL (Sect. 3 e 4) | NONSTRUCTURAL (Sect. 5) | EXTERNAL (sect. 6) | GEOTECHNICAL (sect. 7) |
|---|---|---|---|---|
| LOW | ○ | ○ | ○ | ○ |
| LOW WITH COUNTERMEASURES | ○ | ○ | ○ | ○ |
| HIGH | ○ | ○ | ○ | ○ |

| | | |
|---|---|---|
| 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) | ○ |

(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 2 ○ Partial 3 ○ Complete (> 2/3) 4 ○ Not surveyed because of: a ○ Survey refused b ○ Ruins c ○ Demolished d ○ Absent owner e ○ Other

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

| * | ** | Suggested short term countermeasures | * | ** | Suggested short term countermeasures |
|---|---|---|---|---|---|
| 1 ☐ | ☐ | Tightening and application of strands | 7 ☐ | ☐ | Removal of eaves, parapets, overhangs |
| 2 ☐ | ☐ | Repair of light damages to infill panels and partition walls | 8 ☐ | ☐ | Removal of other internal or external objects |
| 3 ☐ | ☐ | Roof repair | 9 ☐ | ☐ | Barriers and passage protection |
| 4 ☐ | ☐ | Stairs propping | 10 ☐ | ☐ | Repair of utility systems |
| 5 ☐ | ☐ | Removal of plasters, coverings, false ceilings | 11 ☐ | ☐ | |
| 6 ☐ | ☐ | Removal of tiles, chimneys, parapets | 12 ☐ | ☐ | |

*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


*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) | |

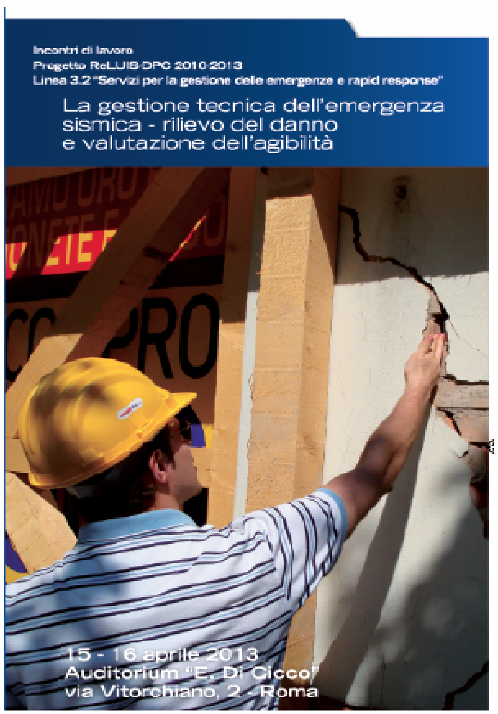
### ➢ Aedes Form

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

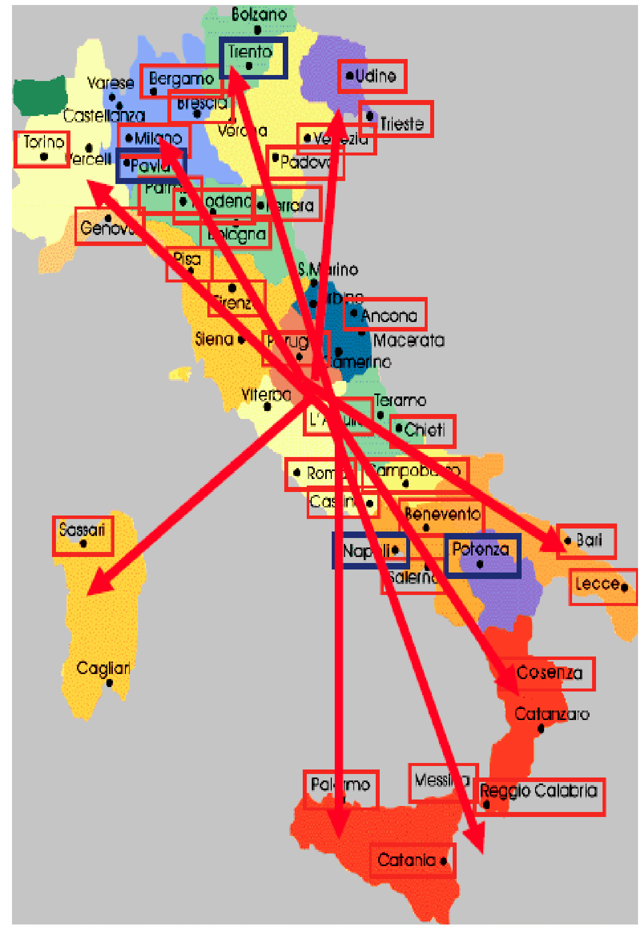



PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

reluis

## 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.



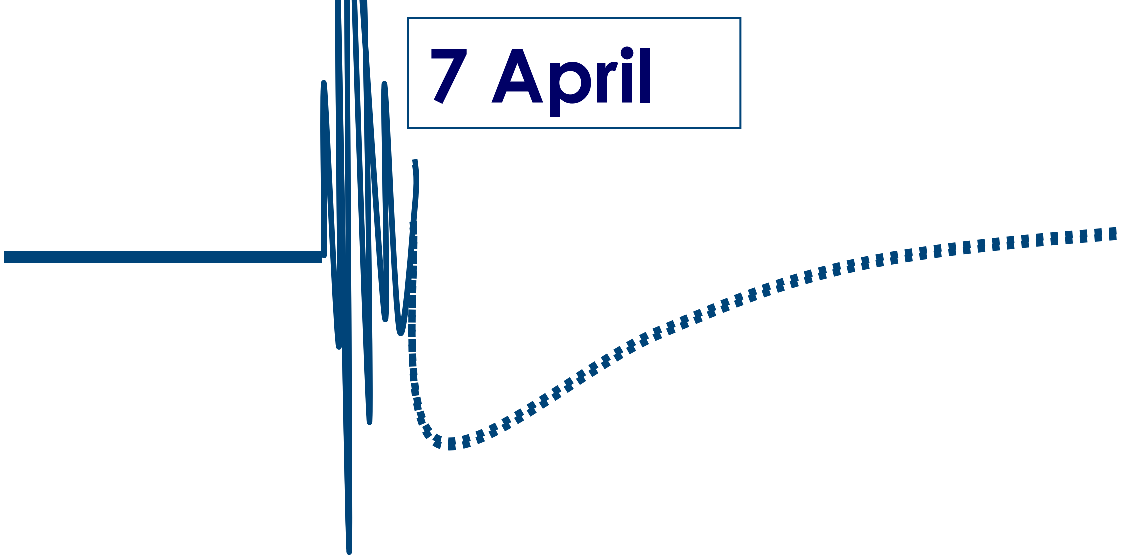
# L'Aquila Earthquake

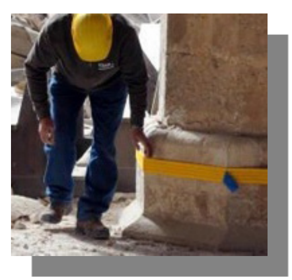
- Data collected - Aedes Form
- Housing impacts

# Data collected after the earthquake

***Data collected - Aedes Form***

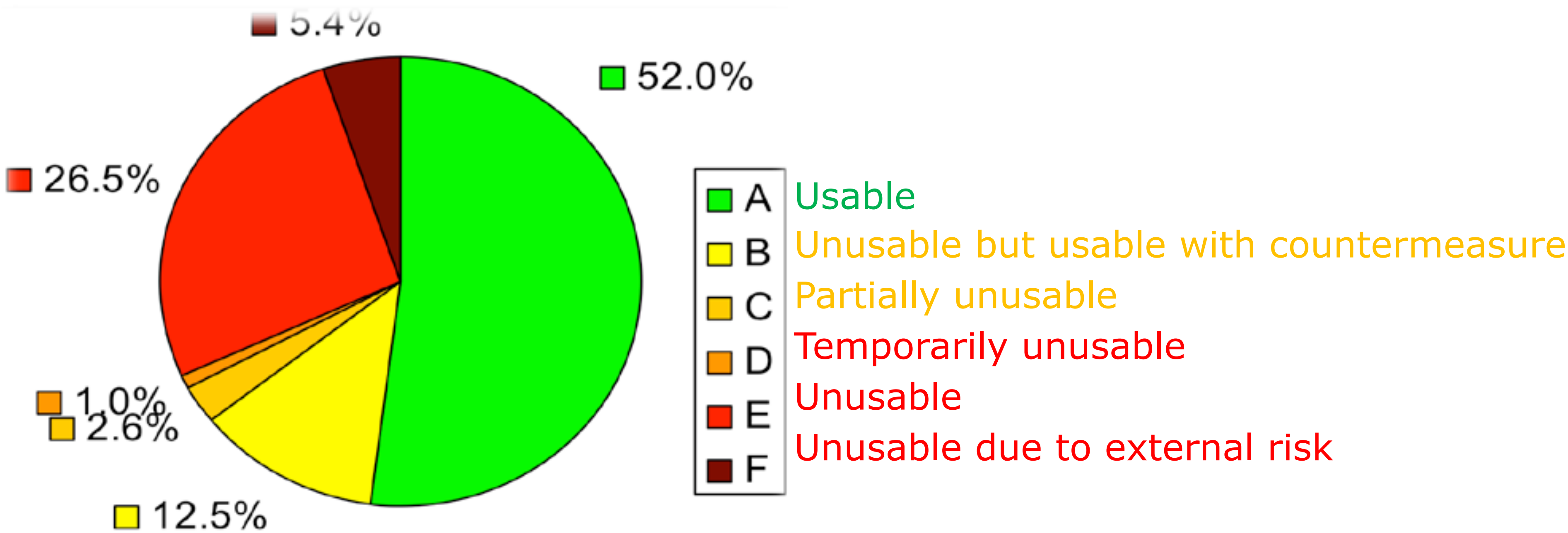
about 72,000 buildings inspected
(more than 80,000 inspection)



# Data collected after the earthquake

## ***Data collected - Aedes Form***

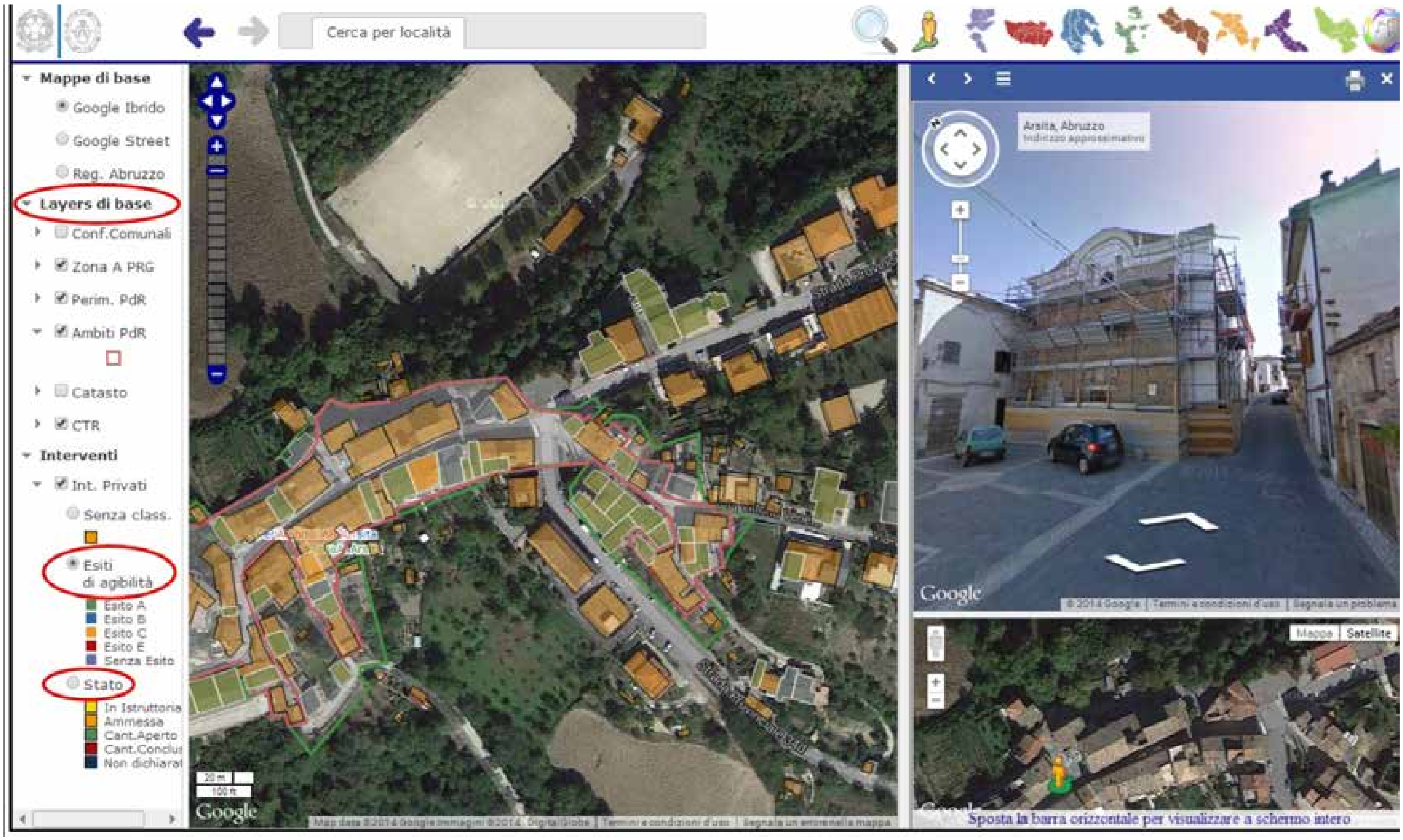



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Masonry | 48.7% | 10.7% | 2.6% | 1.2% | 30.5% | 6.3% |
| Mixed | 62.9% | 11.3% | 3.0% | 0.6% | 17.1% | 5.1% |
| RC | 61.6% | 19.4% | 2.3% | 1.1% | 13.5% | 2.1% |
| Total | 52.0% | 12.5% | 2.6% | 1.0% | 26.5% | 5.4% |

# 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 |
| **Total** | **25.969 persons** |

# Data collected after the earthquake

## ***Housing impacts***

# The C.A.S.E. Project

complessi antisismici sostenibili ed ecocompatibili
c.a.s.e.

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

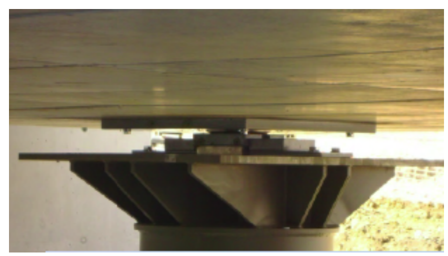
## OBJECTIVES

**USUAL STRATEGY**

IMMEDIATELY tents → 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**

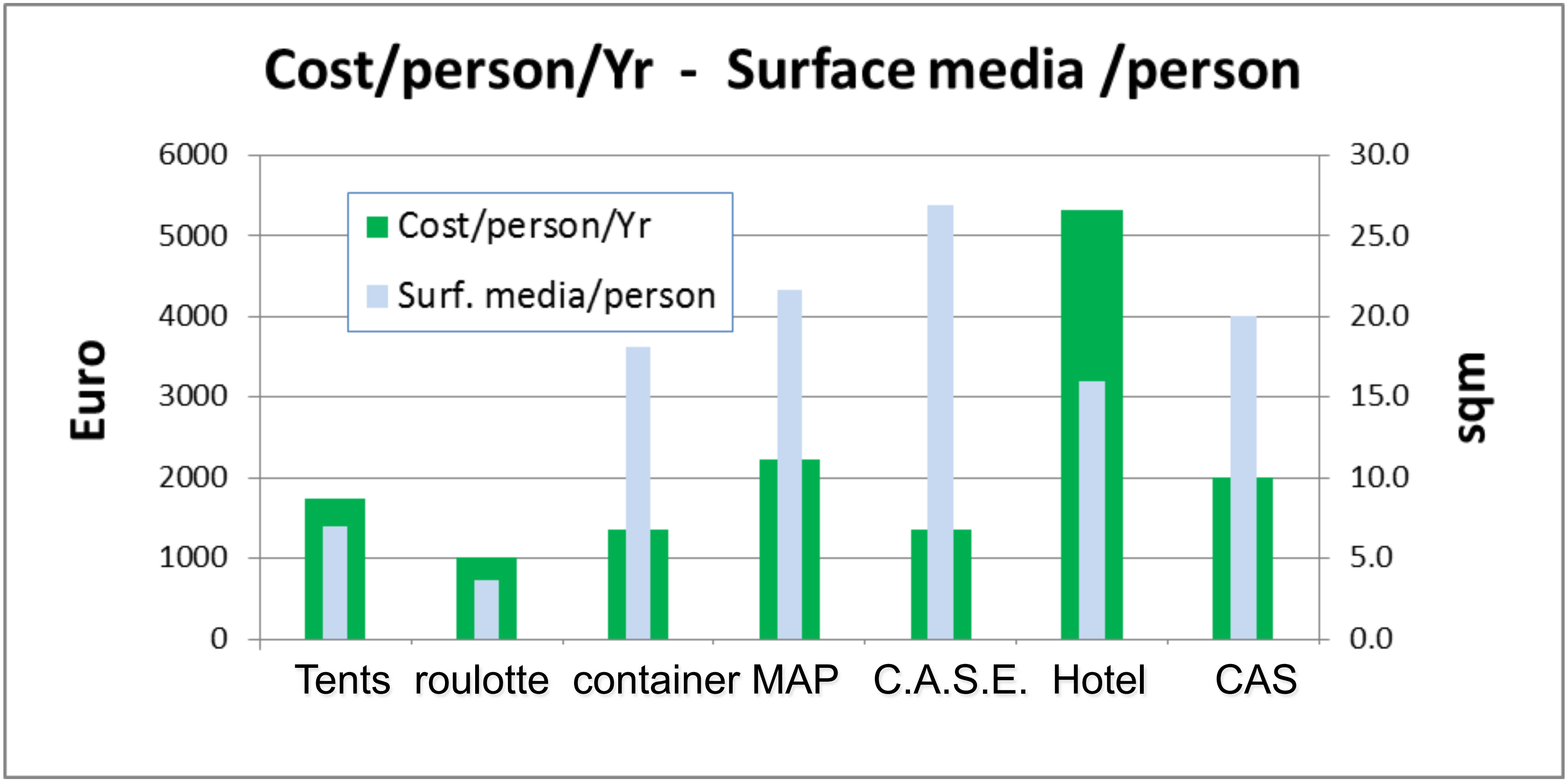
# Typical solutions post-earthquake

## ***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] |
|---|---|---|---|---|---|
| **Tents** | 3 | 6,2 - 9,4 | 7,8 | 5243 | **1748** |
| **Roulotte** | 5 | 2,3 – 3,5 | 2,9 | 3125 | **1005** |
| **Container** | 8 | 5 - 7,5 | 6,2 | 10875 | **1359** |
| **Wooden houses (MAP)** | 15 | 17,8 – 25,4 | 21,6 | 33249 | **2217** |
| **Project C.A.S.E** | 30 | 22,1 – 31,6 | 26,9 | 40856 | **1362** |
| | | | | | |
| **Hotel** | 1 | 7-12 | 9,5 | 5323 | **5323** |
| **CAS** | 1 | 10-20 | 15 | 2000 | **2000** |

# 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**

**Rate A**

MODULARIO P.C.M. - 198

*Presidenza del Consiglio dei Ministri*

Ordinanza n. 3778

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni urgenti di protezione civile.

**June 6 2009 – OPCM 3779**

**Rate B or C**

*Presidenza del Consiglio dei Ministri*

Ordinanza n. 3779

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni urgenti di protezione civile. (*)

**July 9, 2009 – OPCM 3790**

**Rate E**

MODULARIO P.C.M. - 198

*Presidenza del Consiglio dei Ministri*

Ordinanza n. 3790

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni urgenti di protezione civile. (*)

**November 12 2009 – OPCM 3820**

**Masonry aggregates**

MODULARIO P.C.M. - 198

*Presidenza del Consiglio dei Ministri*

Ordinanza n. 3820

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni di protezione civile.

(*) 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 "Filiera" activity***

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

BOZZA

Rete dei Laboratori Universitari di Ingegneria Sismica

reluis

Dipartimento di Protezione Civile

Consorzio Universitario Per L'Ingegneria Nelle Assicurazioni

CINEAS

BOZZA – Aprile 2014

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

# The approval process of funding requests

- ***The "Filiera" activity***

**19936 FUNDING REQUESTS**


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

| U.I.I = Housing unit | P.C. = Communal areas | U.I.C. = Dwellings |
|---|---|---|

| | U.I.I = 2742 | P.C. = 3033 | U.I.C. = 13562 |
|---|---|---|---|
| L'Aquila | 2094 | 2761 | 13087 |
| Other municipalities | 698 | 272 | 475 |

# The approval process of funding requests

- ***Data Collection***

**19936 FUNDING REQUESTS**

*AQ-E-TDA-2839-C022-1-X-X-X-X*

Province

Protocol

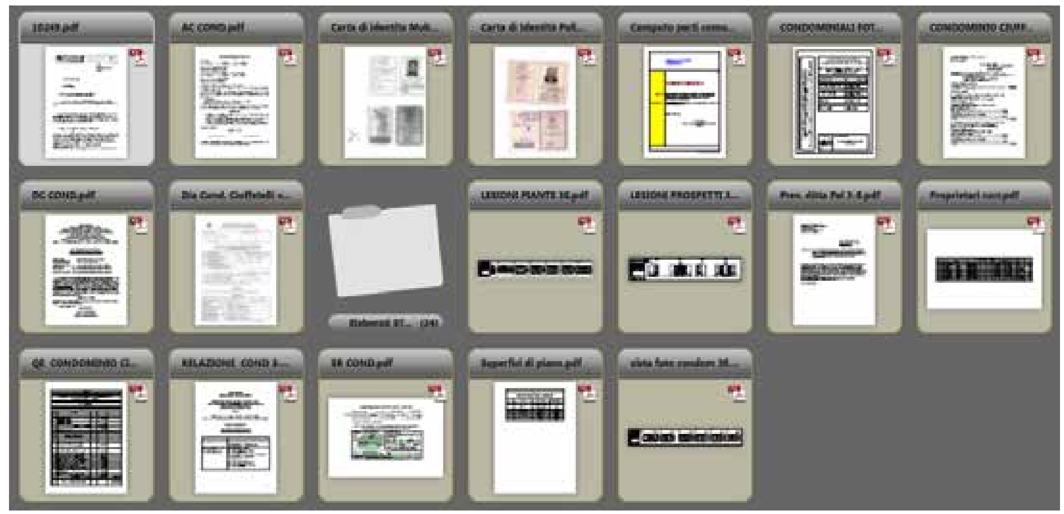
Building rate

Building code

Municipality

Intervention types

**Application Digital documentatio**



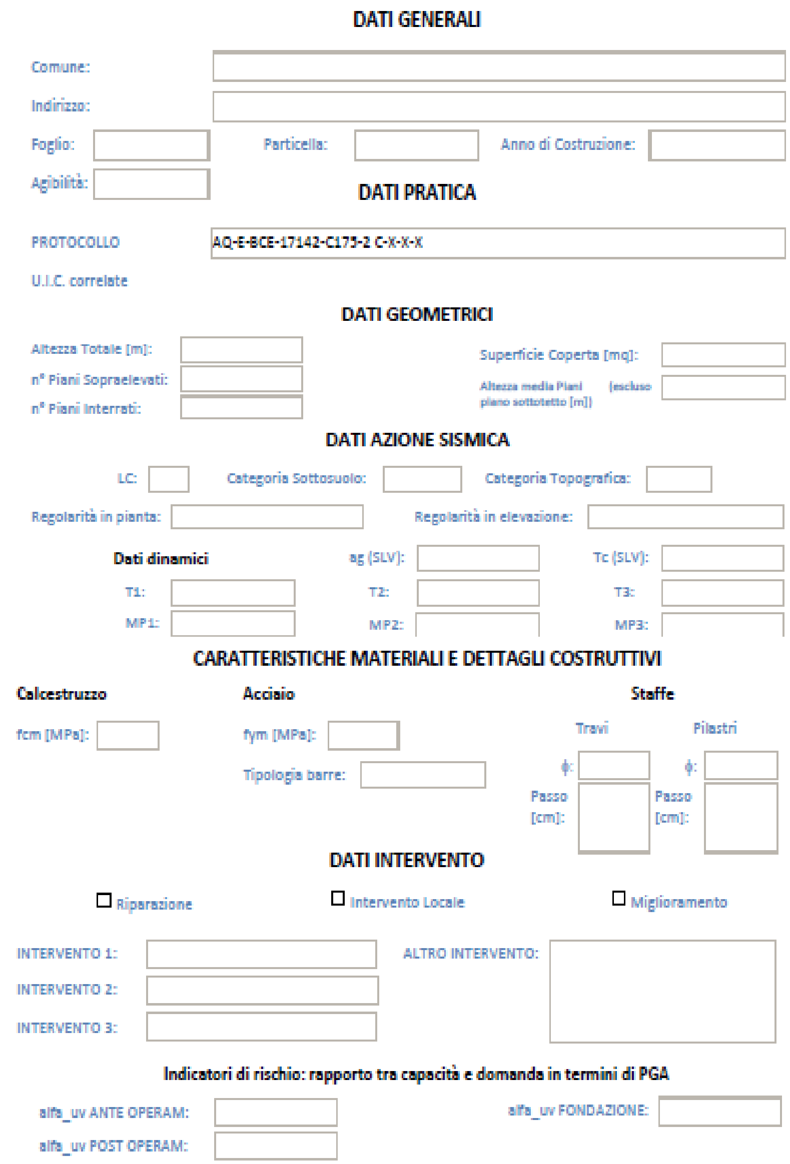
# The approval process of funding requests

- ***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 [α];
- 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 AQ-E-BCE-17142-C175-2 C-X-X-X

U.I.C. correlate

DATI GEOMETRICI

Altezza Totale [m]:

n° Piani Sopraelevati:

n° Piani Interrati:

Superficie Coperta [mq]:

Altezza media Piani (escluso piano sottotetto [m])

DATI AZIONE SISMICA

LC: Categoria Sottosuolo: Categoria Topografica:

Regolarità in pianta: Regolarità in elevazione:

Dati dinamici ag (SLV): Tc (SLV):

T1: T2: T3:

MP1: MP2: MP3:

CARATTERISTICHE MATERIALI E DETTAGLI COSTRUTTIVI

Calcestruzzo

fcm [MPa]:

Acciaio

fym [MPa]:

Tipologia barre:

Staffe

Travi: ϕ: Passo [cm]:

Pilastri: ϕ: Passo [cm]:

DATI INTERVENTO

☐ Riparazione ☐ Intervento Locale ☐ Miglioramento

INTERVENTO 1:

INTERVENTO 2:

INTERVENTO 3:

ALTRO INTERVENTO:

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

alfa_uv ANTE OPERAM:

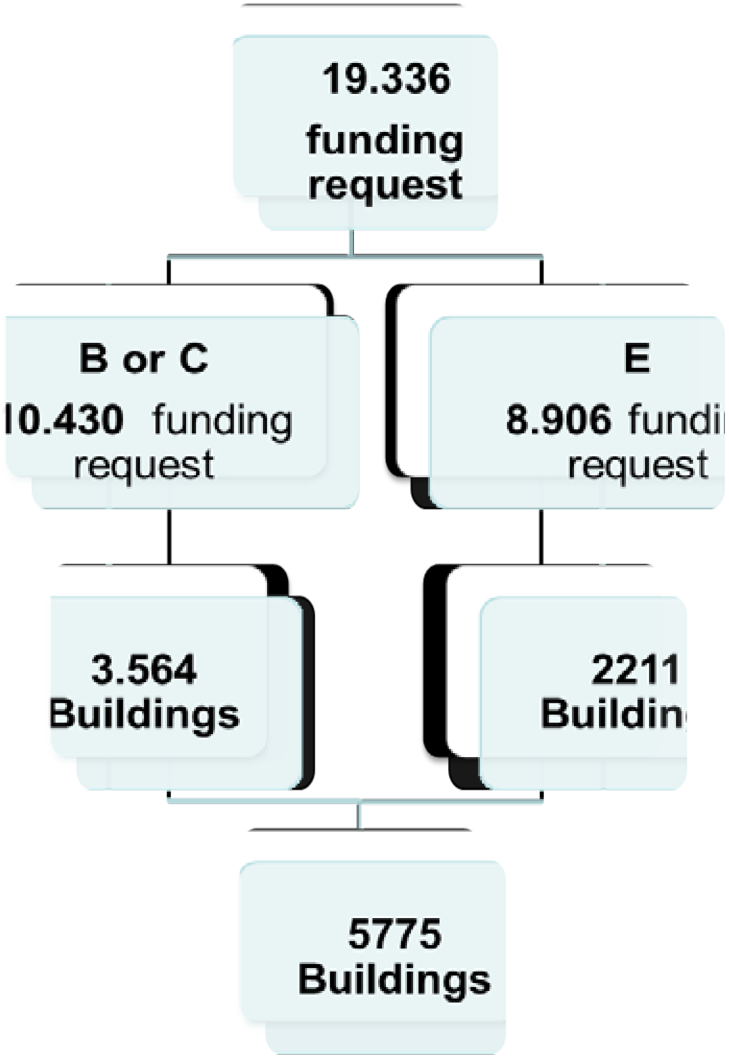
alfa_uv POST OPERAM:

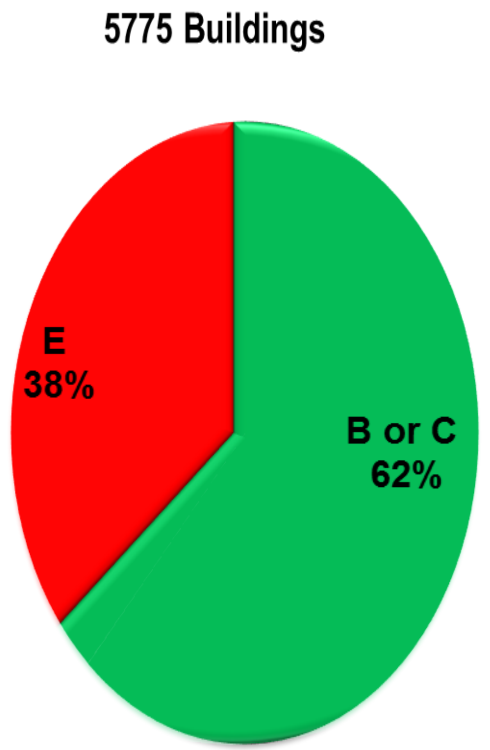
alfa_uv FONDAZIONE:

# The damaged building stock

- ***The "Filiera" activity***

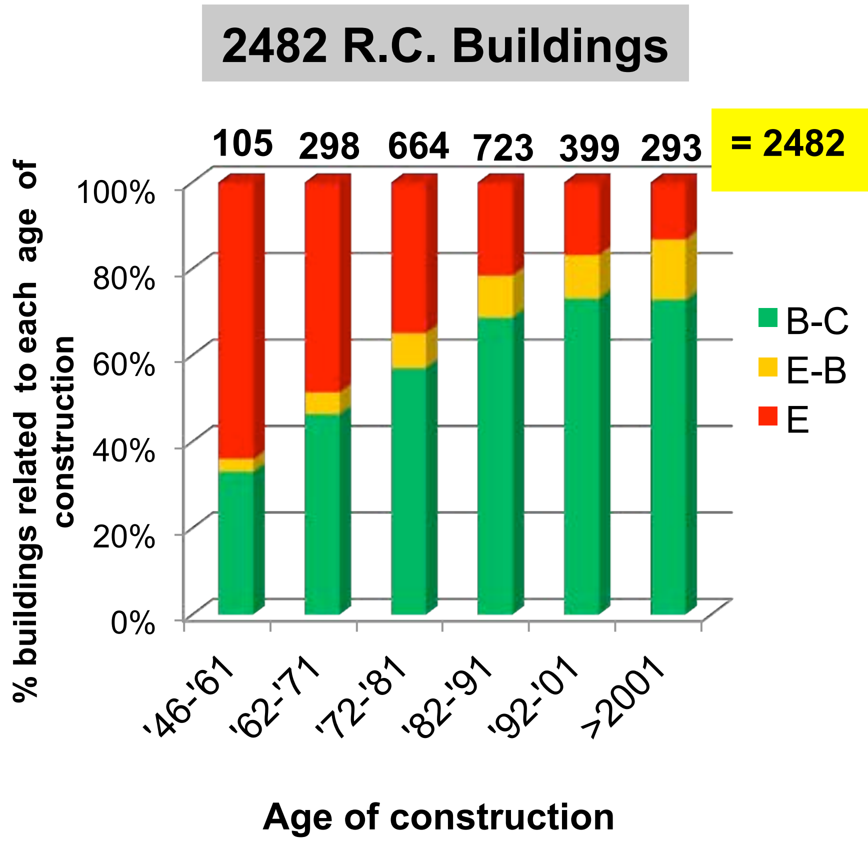
**5775 BUILDINGS**

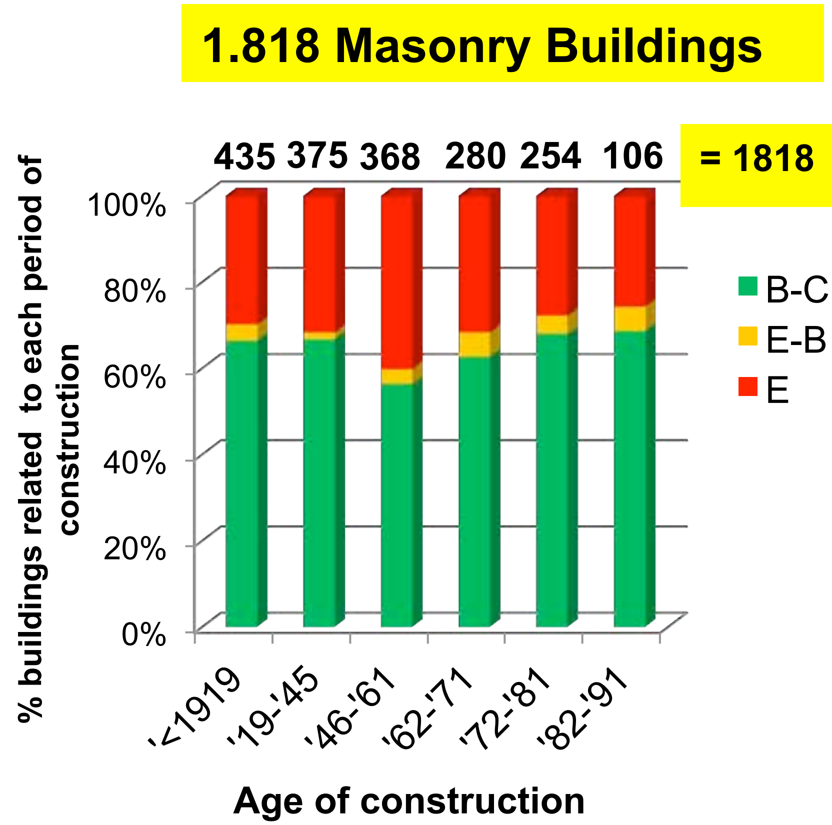


# The damaged building stock

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

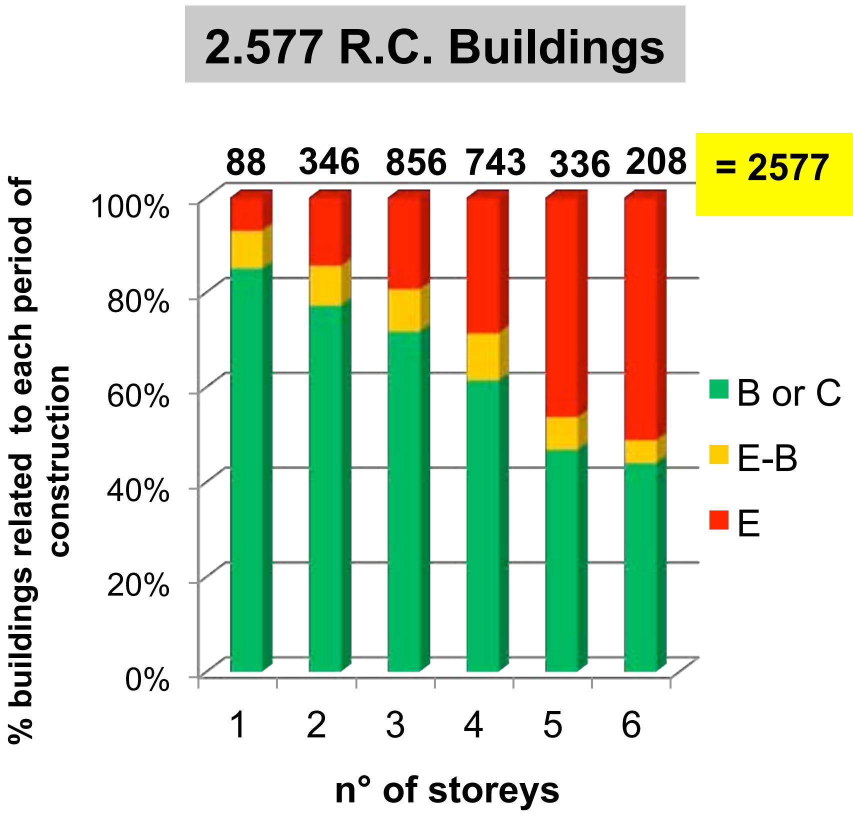


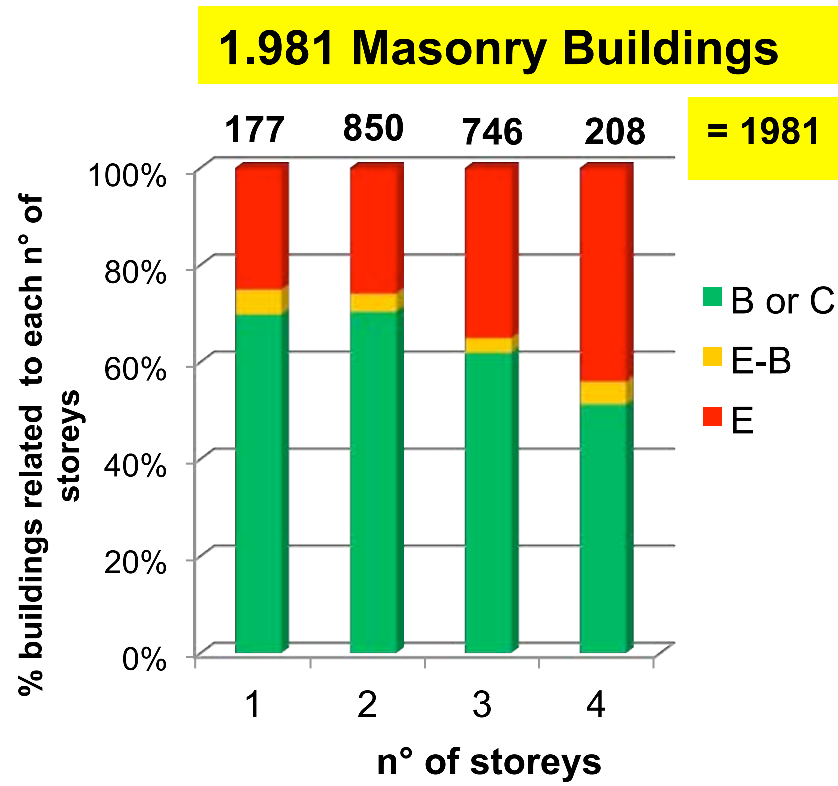




- ✓ **RC structures:** E rate buildings decrease with recent age of construction (from about 60% to about 15%)
- ✓ **Masonry structures:** E rate buildings is almost constantly about 35%)

# The damaged building stock

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




✓ **RC structures:** E rate buildings increase with number of stories (from about <u>10%</u> to about <u>50%</u>**)**

✓ **Masonry structures:** E rate buildings increase with number of stories (from about <u>25%</u> to about <u>45%</u>)

# *Light Reconstruction*

**June 6 2009 – OPCM 3779**

Presidenza del Consiglio dei Ministri

Ordinanza n. 3779

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni urgenti di protezione civile.

Rate B or C

(*)

B or C
10.430 funding request

3.564 Buildings

2901 of L'aquila

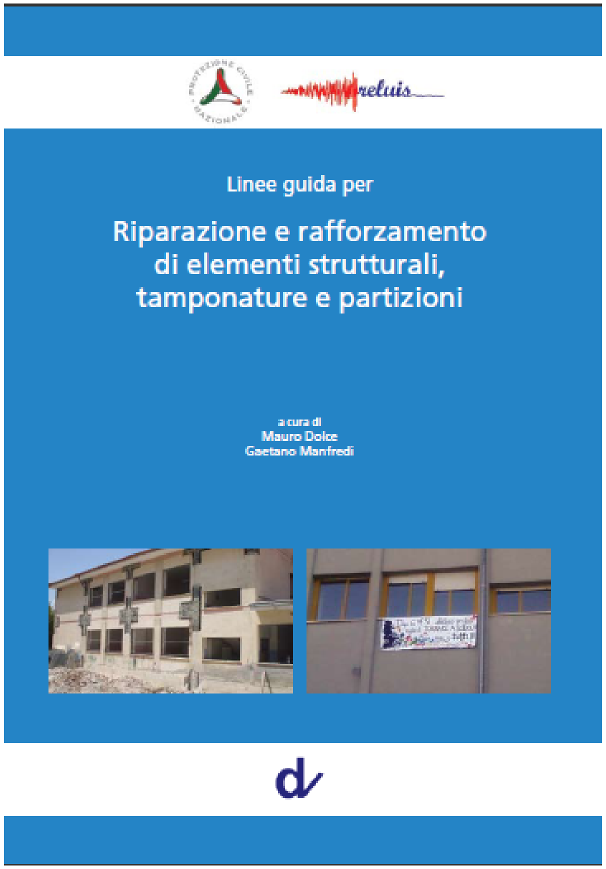
**Rate A:** **Usable buildings**

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

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

# THE "LIGTH" RECONSTRUCTION

- ***Strong support to practioners***



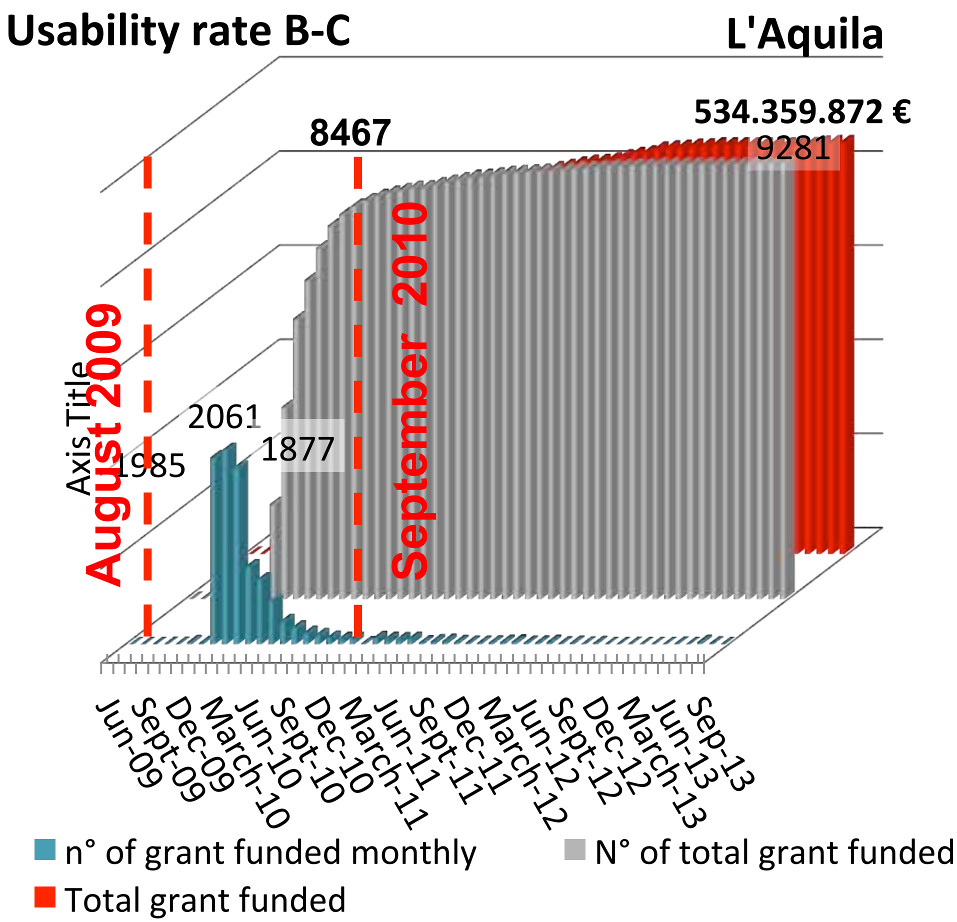

## GUIDELINES AND CALCULATION EXAMPLES

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

Freely downloadable at website
***www.reluis.it***

# Light reconstruction - Approval process

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



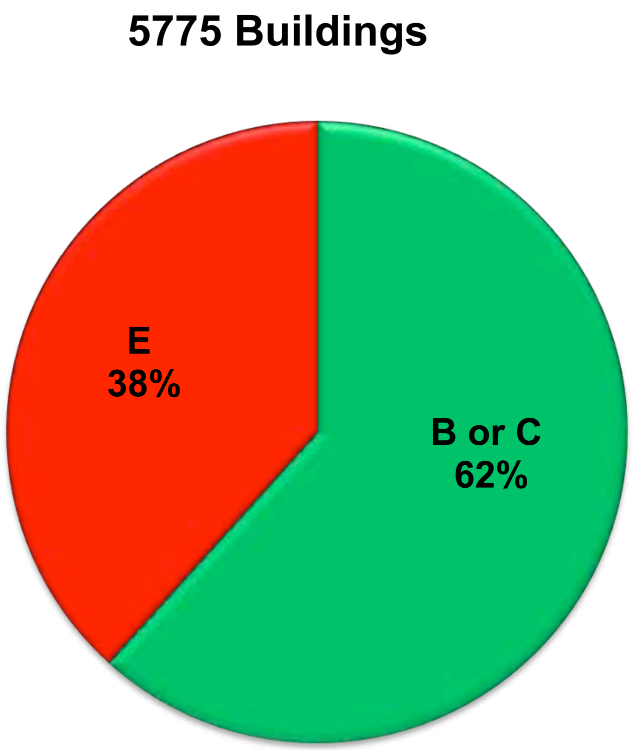

| Date | n° requests approved | | Grant |
|---|---|---|---|
| [-] | [-] | [%] | [€] |
| December 2009 | 34 | 0% | 940.492,17 |
| March 2010 | 5.957 | 63% | 246.860.149,31 |
| September 2010 | 8.467 | 90% | 452.717.28,51 |
| September 2011 | 9.048 | 96% | 509.215.730,00 |
| March 2013 | 9.247 | 98% |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

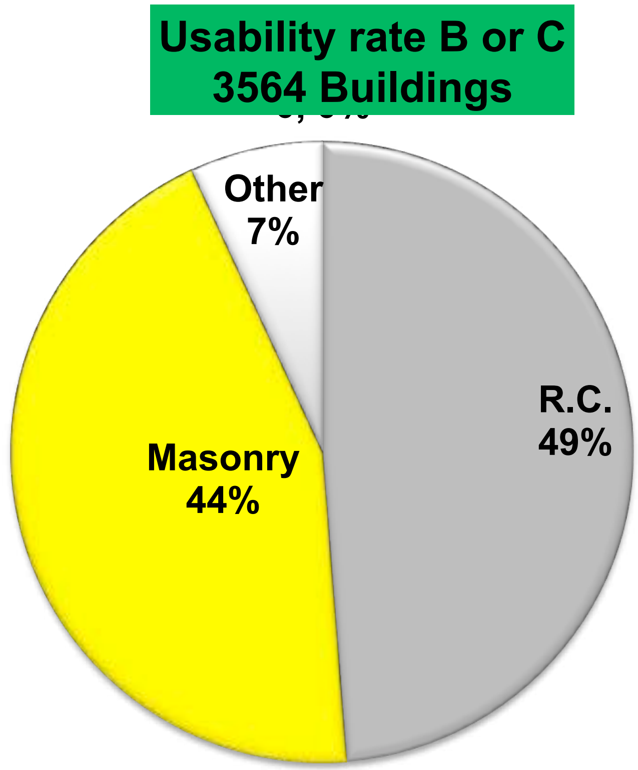
After 1 year 90% (8467 of 10439) financially approved by the municipality

✓ **Municipalities grant released:** A grant of about 452 million of euro at September 2010, total "ligth" reconstruction costs of about <u>€ 534.000.000, 00</u>

# Light reconstruction – Buildings Usability rate

- ***3564 Private buildings***




**3564** Usability rate B or C

**2211** Usability rate E

**1738** R.C. Buildings

**1580** Masonry Buildings

**3318**

**246** Other tipologies

# 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$^2$**

- **902 masonry buildings mean grant : 318 €/m$^2$**

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

•

# Light reconstruction – Costs

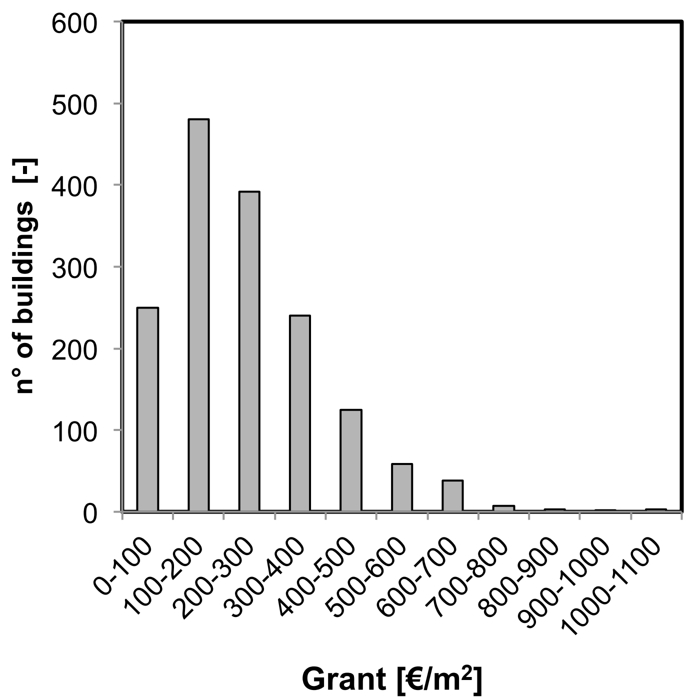
- ***R.C. Private buildings***

Buildings B or C :

- 1.599 R.C. buildings – mean grant: 246 €/m²
- 902 masonry buildings mean grant : 318 €/m²

The grant includes the costs for the repair intervention [illegible] local strengthening of structural members.

| | |
|---|---|
| n° of Buildings [-] | 1599 |
| **Mean [€/m²]** | **246,78** |
| 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 |
| **Mean grant [€]** | **235.063,69** |
| **Mean Surface [m²]** | **898,28** |




✓ **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***

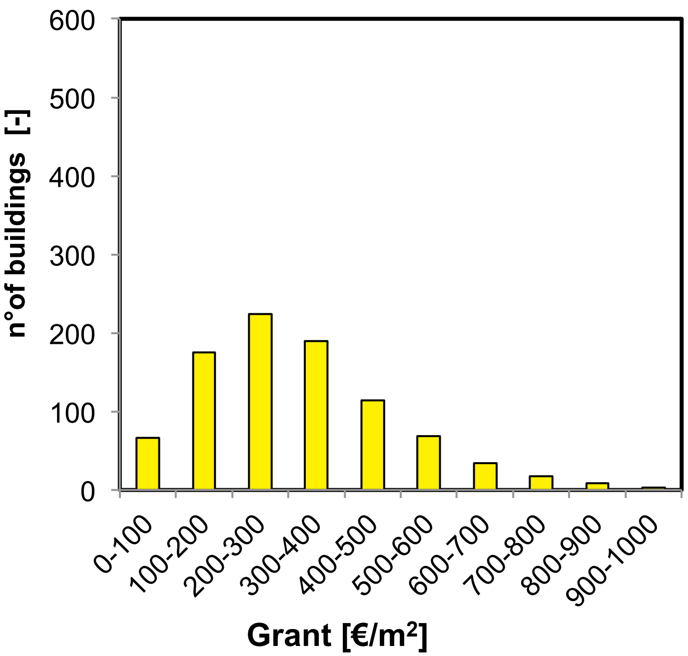
Buildings B or C :

- 1.599 R.C. buildings – mean grant: 246 €/m²
- 902 masonry buildings mean grant : 318 €/m²

The grant includes the costs for repair intervention + local strengthening of structural or not-structural members.

Buildings B or C :
- 1.599 R.C. buildings – mean grant: 246 €/m²
- 902 masonry buildings mean grant : 318 €/m²
The grant includes the costs for repair intervention + local strengthening of structural or not-structural members.

| | |
|---|---|
| n° of Buildings [-] | 902 |
| **Mean [€/m²]** | **318,22** |
| 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 |
| **Mean grant [€]** | **114.6543,0** |
| **Mean Surface [m²]** | **377, 35** |

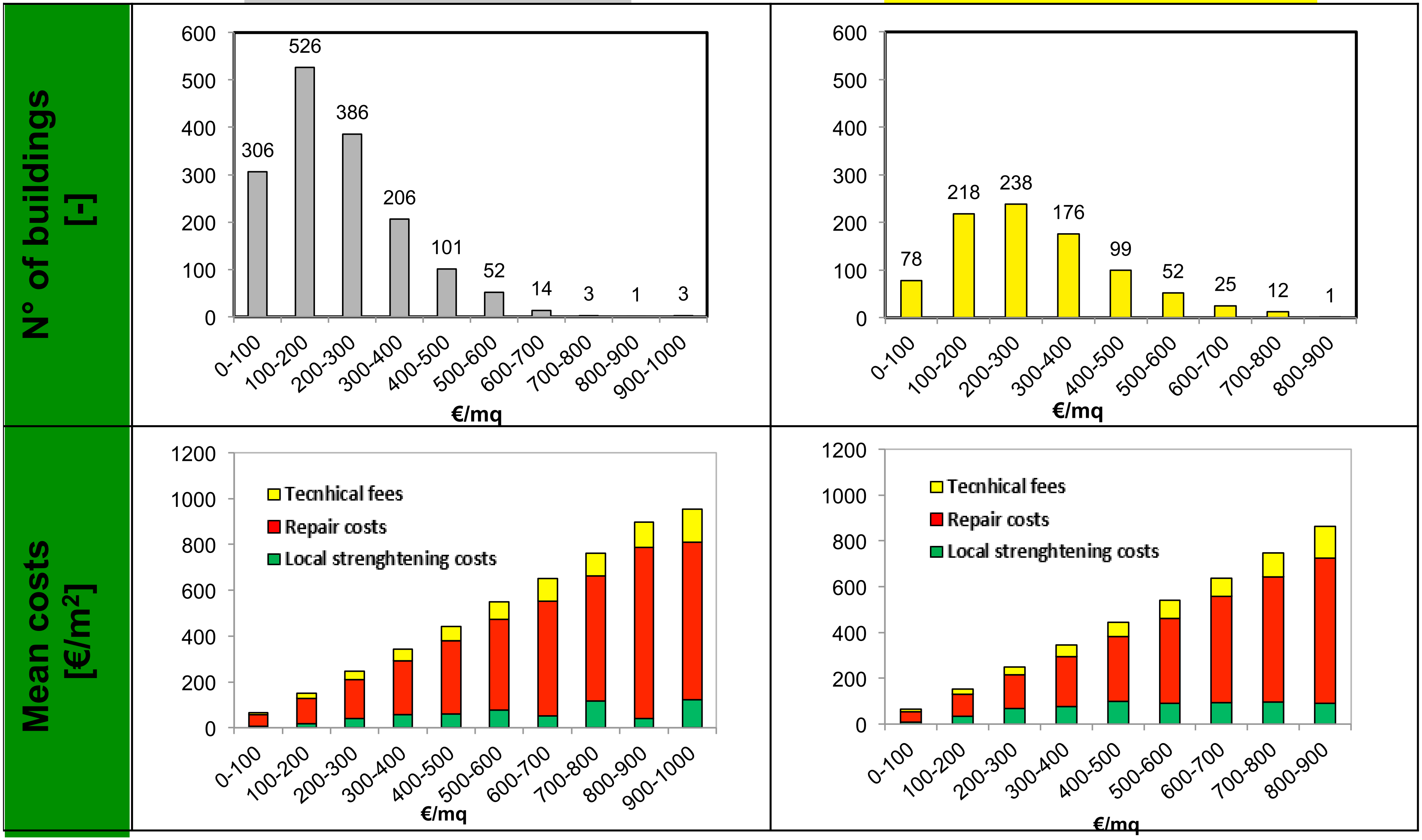



✓ **Buildings grant:** Mean value of 318 €/mq. , corresponding to a mean grant of about € 115.000, 00 for each building, mean surface of about 377 mq.

# Light reconstruction – Costs

- ***Cost rates***

**R.C. Buildings: 1.599** | **Masonry Buildings: 902**



# Light reconstruction – Costs

- ***Private buildings***

- ***Repair cost rate due to dwellings: 115 €/m²***

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

- ***On each building the repair cost rate due to dwellings is : 93 €/m²***

✓ **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**

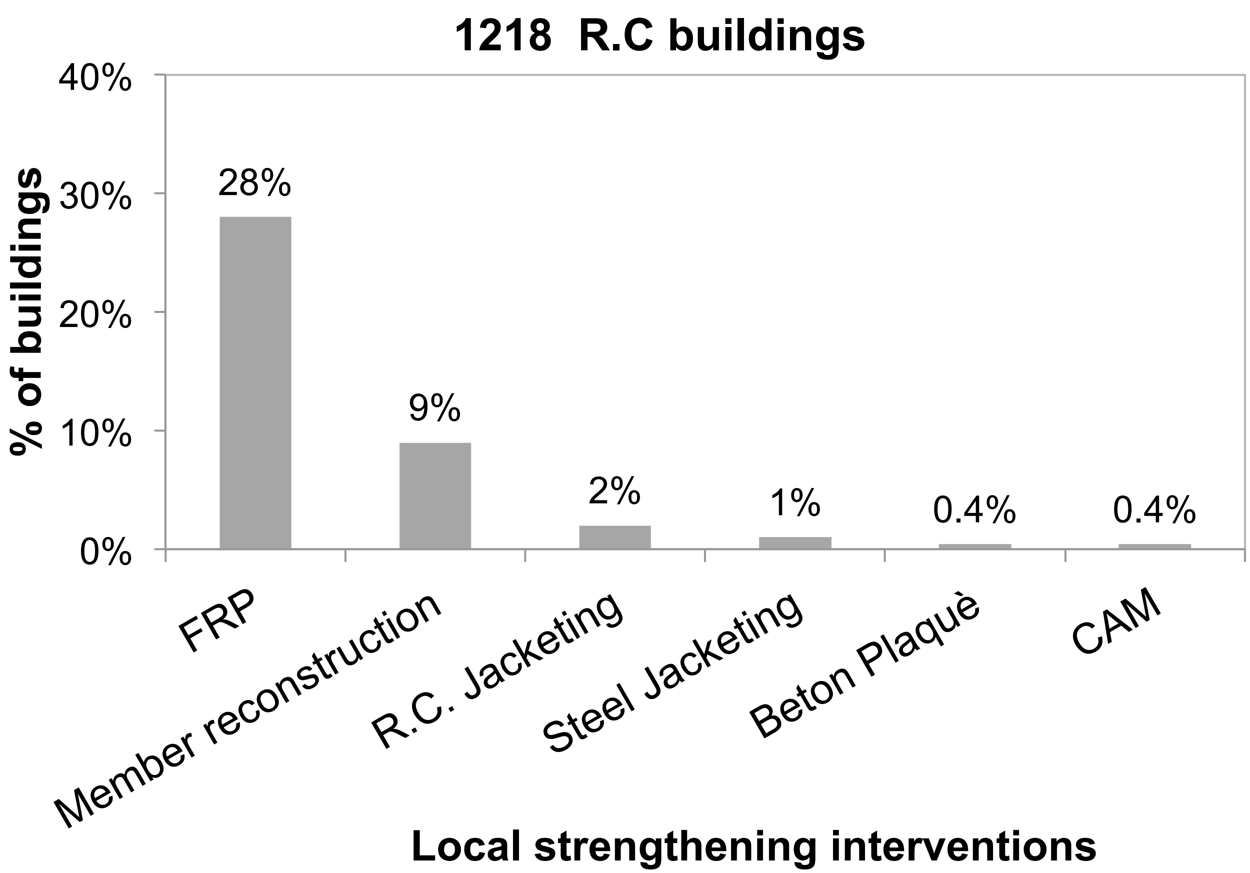
# Light reconstruction – Repair & Strength. Costs

- ***R.C. Private buildings***

Buildings B or C :

- 1.599 R.C. buildings – mean grant: 246 €/m²

- ***Repair mean costs: 208 €/m²***
- ***Local Strengthening mean costs: 38 €/m²***

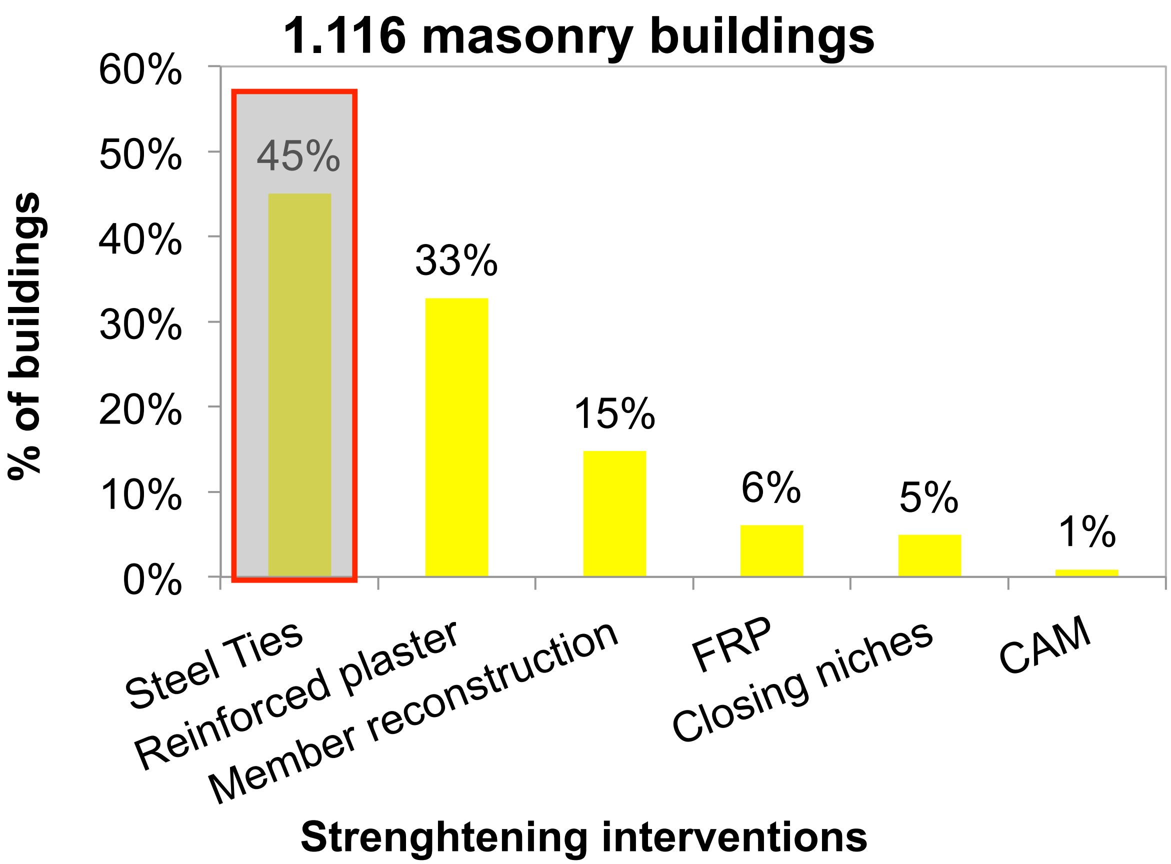



**FRP**

**CAM**

# Light reconstruction – Repair & Strength. Costs

- ***Masonry Private buildings***
  - ***Repair mean costs: 242 €/m²***
  - ***Local Strengthening mean costs: 76 €/m²***




STEEL TIES

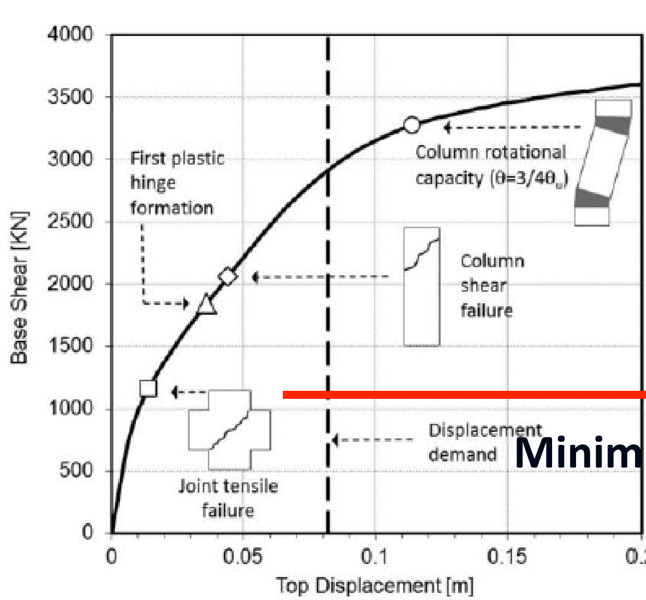
✓ **Local strengthening costs:** doubed with respect to RC buildings (in any case lower than maximum allowable 150 €/mq)

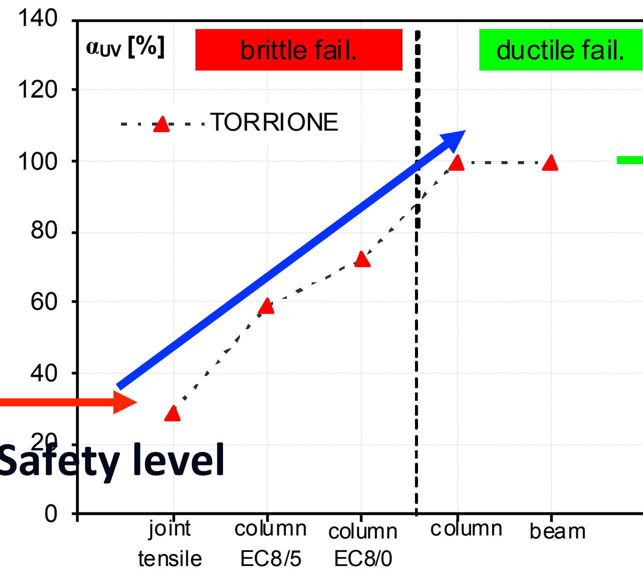
# ReLUIS - Project on School Buildings

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

### SAFETY INDEX INCREASE PROVIDED BY LOCL STRENGTHENING SOLUTIONS

**Pushover**




Minimum Safety level

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**

**Rate E**

MODULARIO P.C.M. 198

*Presidenza del Consiglio dei Ministri*

**Ordinanza n.** 3790

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni urgenti di protezione civile. (*)

**E**
**8.906 funding request**

**2211 Buildings**

1951 of L'aquila

**Rate E: Unusable building.**

# The Reconstruction Process of private buildings

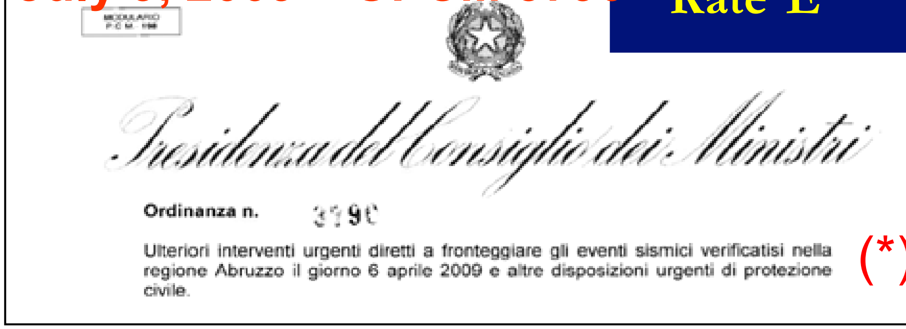
- ***Financial Support***

***"HEAVY" RECONSTRUCTION***

**Rate E: Unusable building**

**July 9, 2009 – OPCM 3790**

**Rate E**


Presidenza del Consiglio dei Ministri

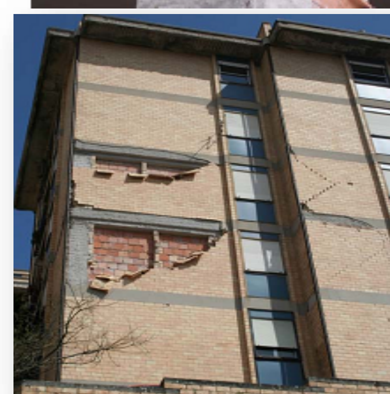
Ordinanza n. 3790

Ulteriori interventi urgenti diretti a fronteggiare gli eventi sismici verificatisi nella regione Abruzzo il giorno 6 aprile 2009 e altre disposizioni urgenti di protezione civile.

(*)

- ✓ Total refund of repair intervention costs + **seismic strengthening** up to **400-600 €/mq**. (minimum safety level 60% of current code request, up to 80%)

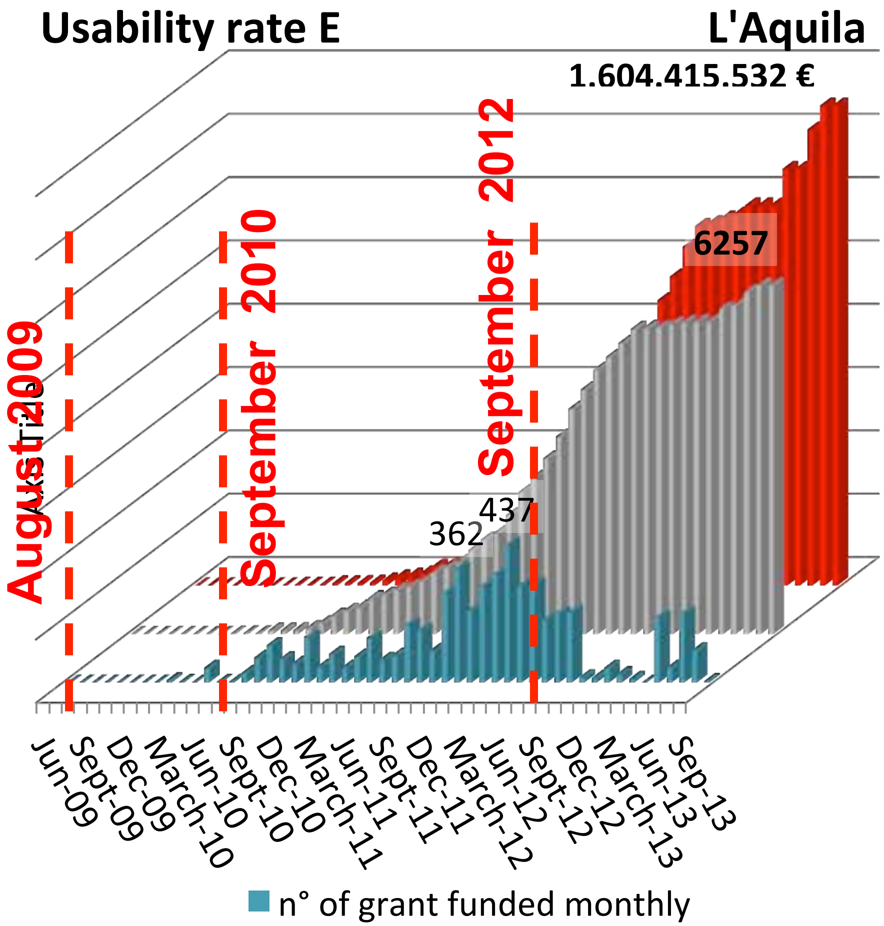
- ✓ In case of "E" buildings with a low level of structural dameges, total refund of repair interventions and it is also possible to perform only the **local strengthening** of structural or non-structural members up to **250 €/mq**. (global analysis is not obligatory)



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

# Heavy reconstruction - Approval process

- ***Funding requests submission (E buildings)***



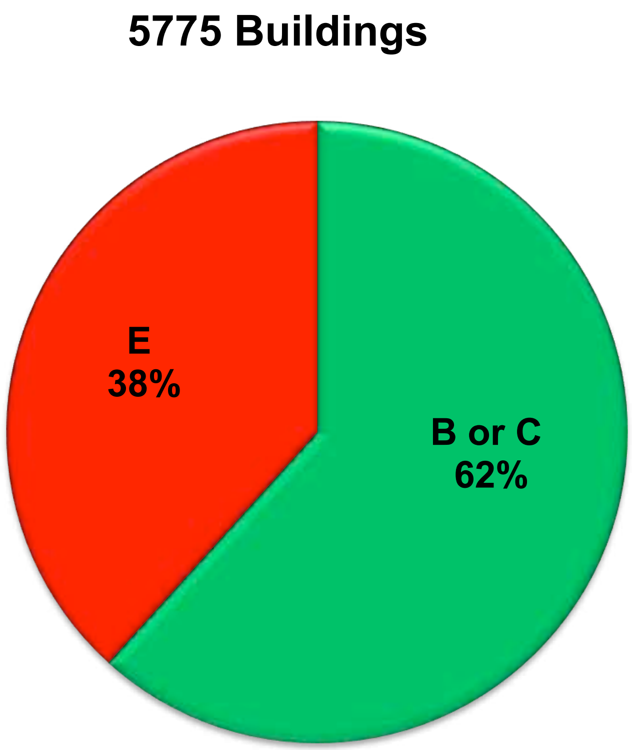

| Date | n° approval funding request | | Grant |
|---|---|---|---|
| [-] | [-] | [%] | [€] |
| **March 2010** | 10 | 0% | 2.520.526,28 |
| **September 2010** | 172 | 2% | 16.189.933,57 |
| **September 2011** | 1.325 | 16% | 231.255.611,15 |
| **September 2012** | 4.595 | 54% | 901.860.304,41 |
| **September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

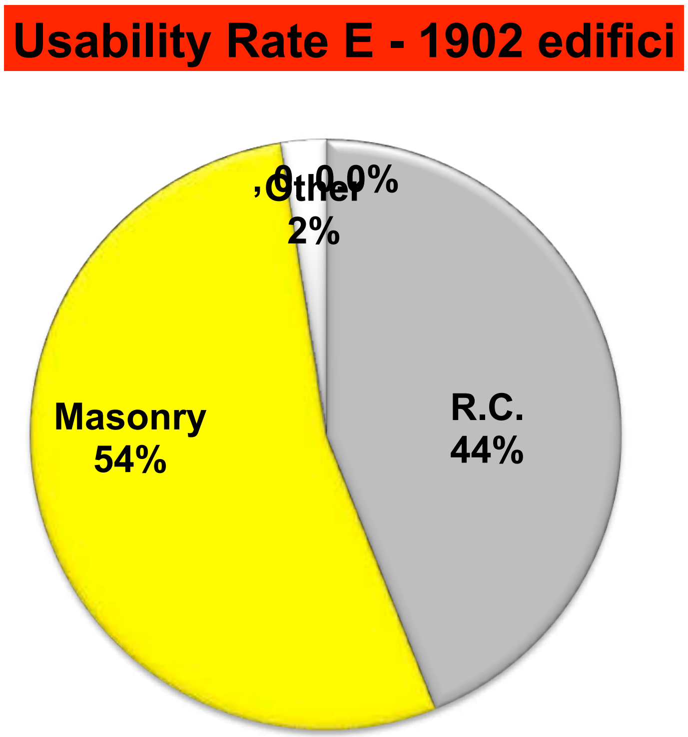
After 3 years, 50% of requests (4585 out of 8906) financially approved by the municipalities

✓ **Municipalities grant released:** A grant of about 900 million of euro at September 2012, total "heavy" reconstruction costs of about <u>€ 1.600.000.000, 00</u>

# Heavy reconstruction – Buildings Usability rate

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




**3564** Usability rate B or C

**309** Usability rate E-B

**1902** Usability rate E

**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 geothecnical tests**.

- **448 R.C. buildings - mean grant: 1030 €/m$^2$**

(about 4 times higher than in case o B or C buildings – 246 €/mq)

- **314 masonry buildings mean grant : 935 €/m$^2$**

(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 €/m²
- 314 masonry buildings mean grant : 935 €/m²

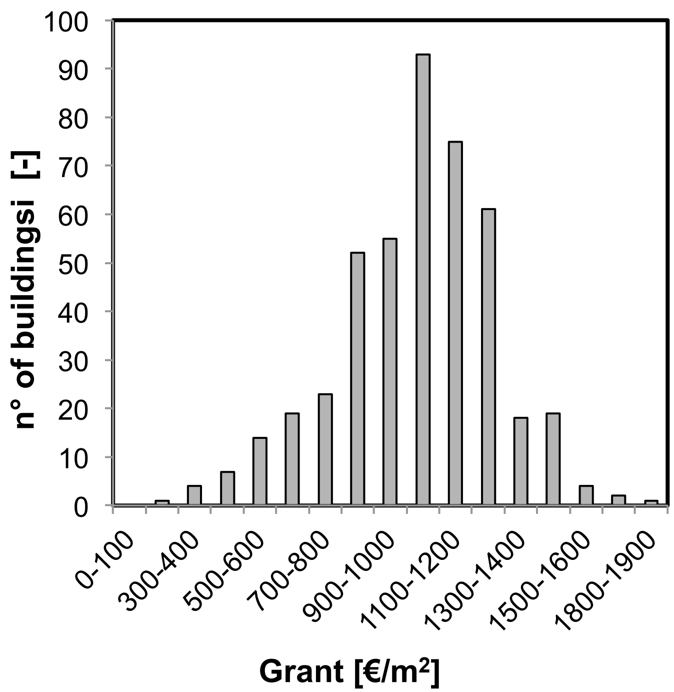
The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geothecnical tests

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

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

| | |
|---|---|
| n° of Buildings [-] | 448 |
| **Mean [€/m²]** | **1.030,4** |
| Median [€/m²] | 1.057,4 |
| Minimum [€/m²] | 168,0 |
| Maximum [€/m²] | 1.826,96 |
| Range[€/mq] | 1.658,65 |
| 16° Percentile | 806,41 |
| 84° Percentile | 1.258,2 |
| Standard Dev.[€/m²] | 240,68 |
| CoV [%] | 23 |
| Asymmetry [-] | 0 |
| Kurtosis [-] | 0 |
| Total grant [€] | 805.129.213,53 |
| **Mean grant [€]** | **1.797.163,0** |
| **Mean Surface [m²]** | **1.733,8** |




✓ **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 €/m²
- 314 masonry buildings mean grant : 935 €/m²

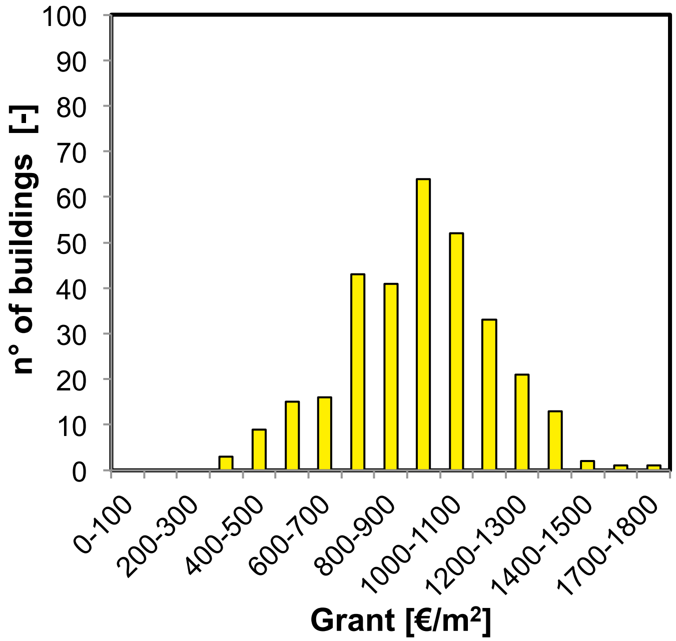
The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geothecnical tests


Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

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


| | |
|---|---|
| n° of Buildings [-] | 314 |
| **Mean [€/m²]** | **934,97** |
| Median [€/m²] | 941,8 |
| Minimum [€/m²] | 312,00 |
| Maximum [€/m²] | 1.740,68 |
| Range[€/mq] | 1.428,58 |
| 16° Percentile | 722,00 |
| 84° Percentile | 1.148,63 |
| Standard Dev.[€/m²] | 227,38 |
| CoV [%] | 24 |
| Asymmetry [-] | 0 |
| Kurtosis [-] | - |
| Total grant [€] | 180.718.716,58 |
| **Mean grant [€]** | **575.537,3** |
| **Mean Surface [m²]** | **608, 7** |

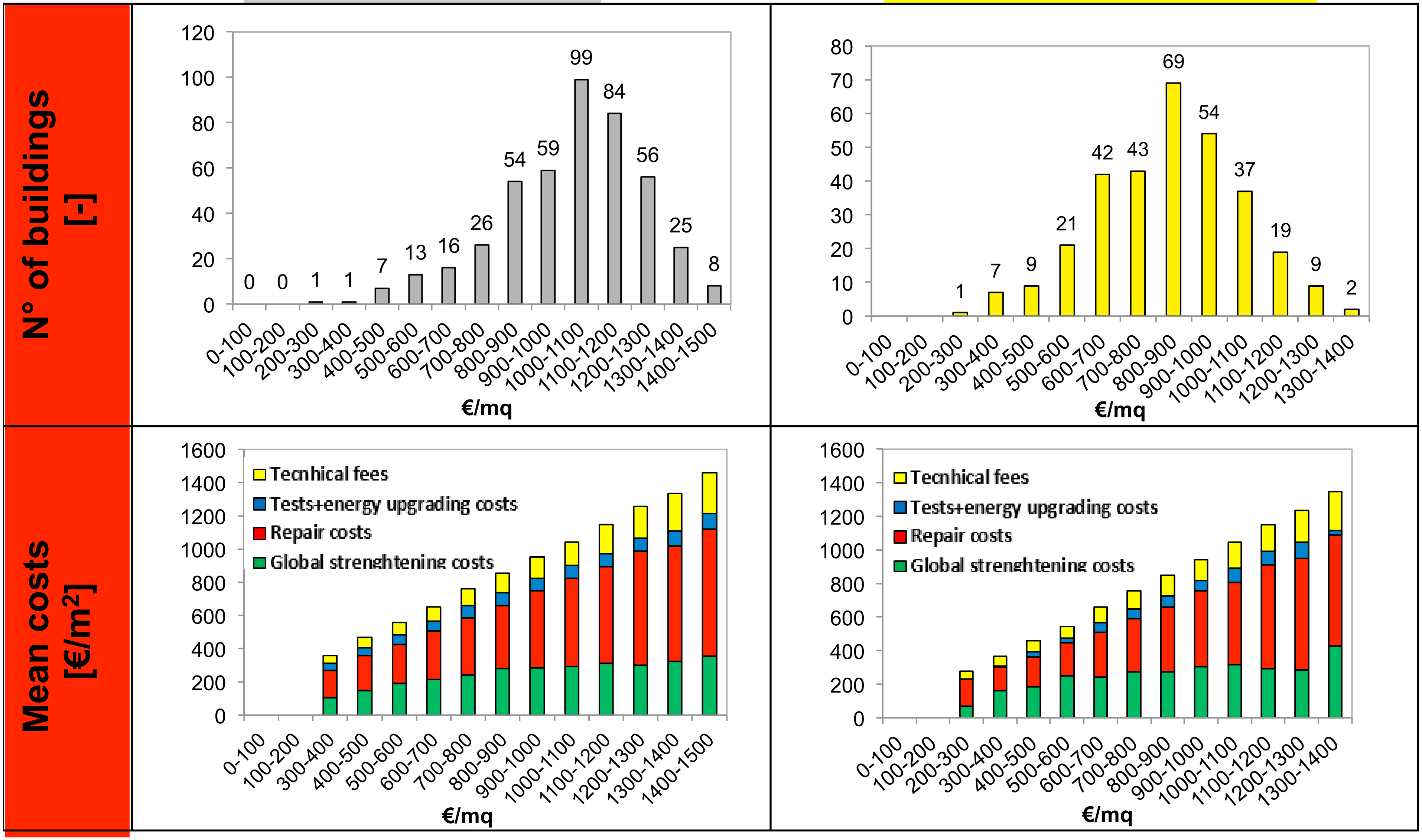



✓ **Buildings grant:** Mean value of 935 €/mq. , corresponding to a mean grant of about € 575.000, 00 for each building, mean surface of about 610 mq.

# Heavy reconstruction – Costs

- ***Cost rates***

**R.C. Buildings: 448** | **Masonry Buildings: 314**



# Heavy reconstruction – Costs

- ***Private buildings***

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings  mean grant : 935 €/m²

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

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings  mean grant : 935 €/m²

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

- ***Repair cost rate due to dwellings: 170 €/m²***

**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 :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings  mean grant : 935 €/m²

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

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings  mean grant : 935 €/m²

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

- ***On each building the repair cost rate due to dwellings is : 116 €/m²***

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

# Heavy reconstruction – Costs

- ***R.C. Private buildings***

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

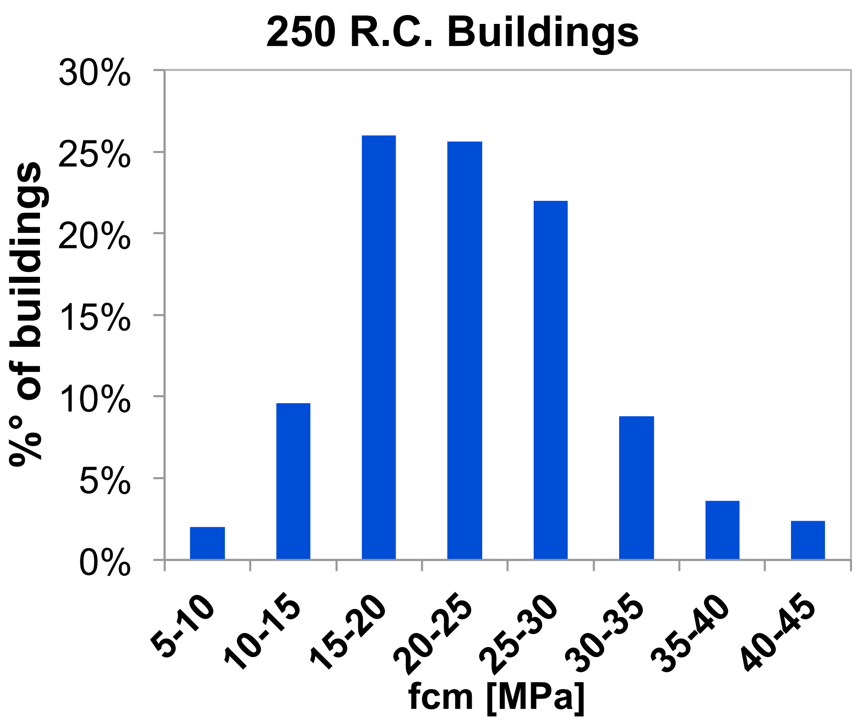
The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotechnical tests

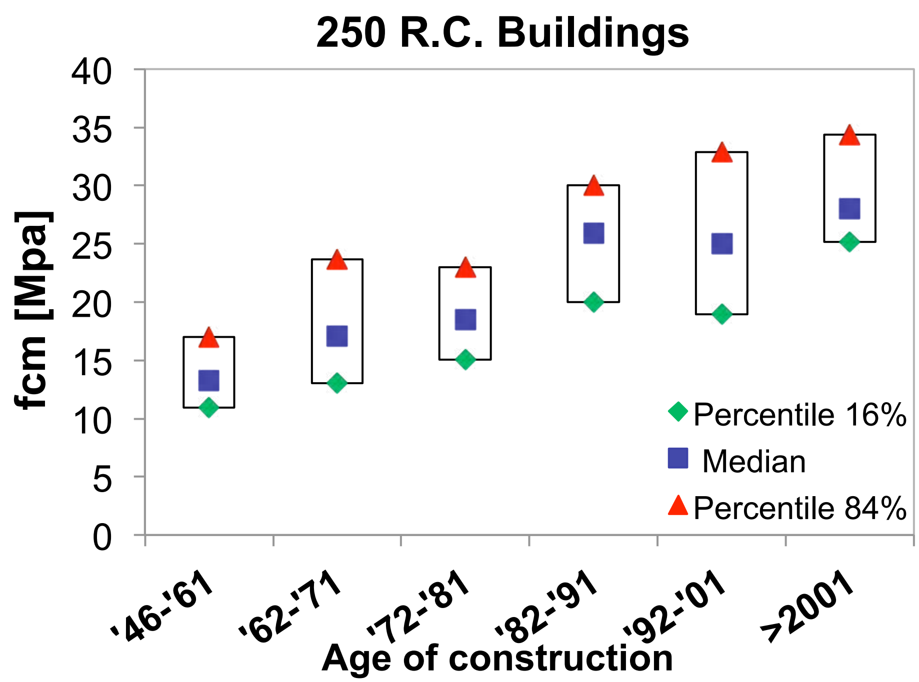
Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

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

- ***Energy efficiency upgrade costs ( 394 build.): 96 €/mq.***
- ***structural and geothecnical 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 €/m²
- 314 masonry buildings mean grant : 935 €/m²

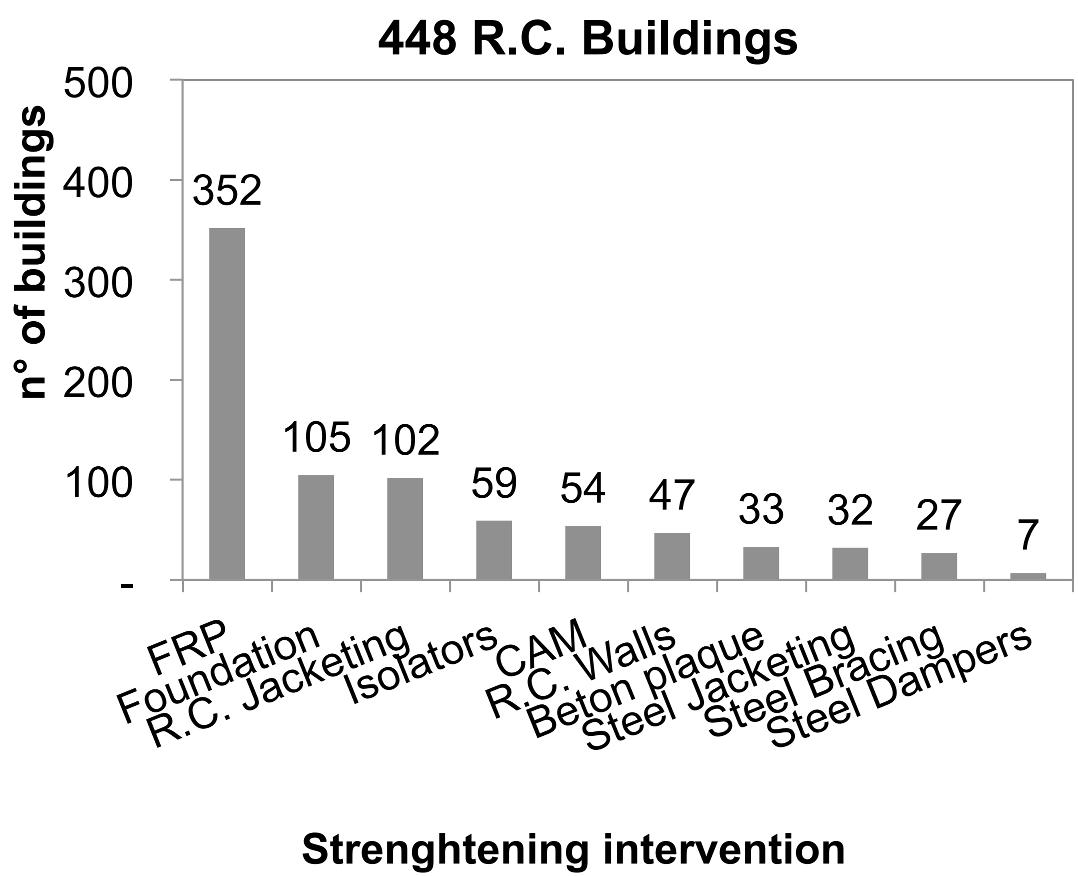
The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geotheecnical tests

Buildings E :

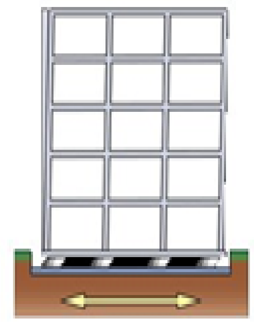
- 448 R.C. buildings - mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

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

- ***Repair mean costs: 592 €/m²***
- ***Seismic strengthening mean costs: 344 €/m²***




Isolators



Steel dampers

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

# Heavy reconstruction – Repair & Strength. Costs

- ***Masonry Private buildings***

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

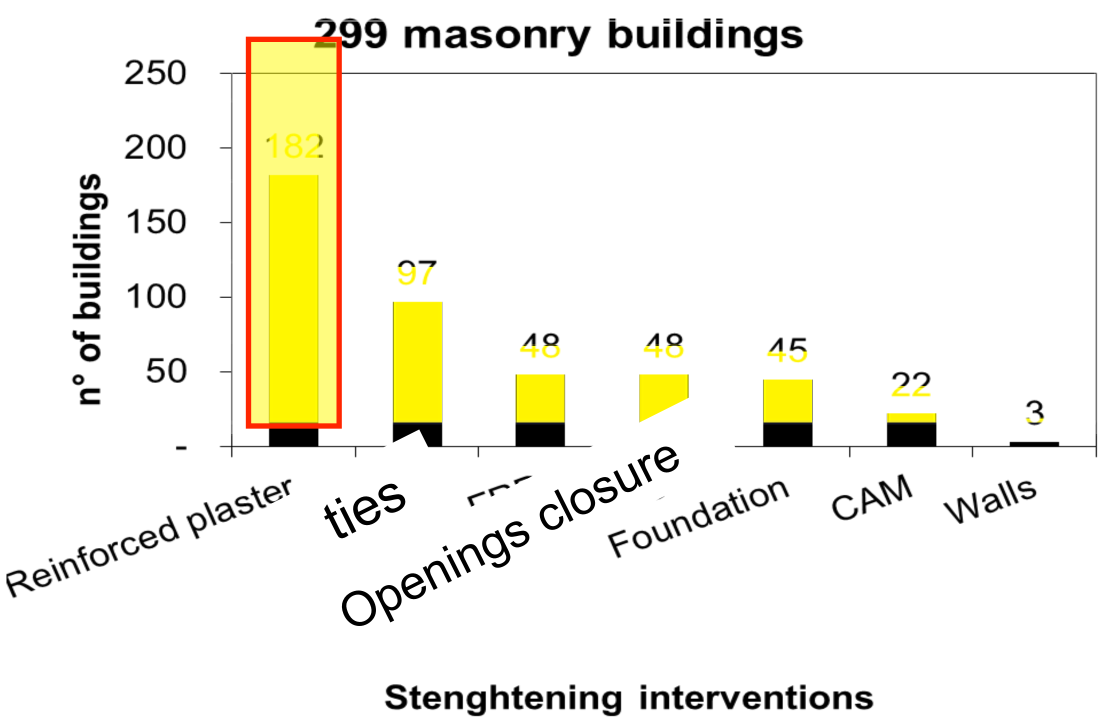
The grant includes the costs for repair intervention + seismic rehabilitation + adjustment of energy + structural and geothecnical tests

Buildings E :

- 448 R.C. buildings – mean grant: 1030 €/m²
- 314 masonry buildings mean grant : 935 €/m²

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

- ***Repair mean costs: 499 €/m²***
- ***Seismic rehabilitation mean costs: 357 €/m²***





- ***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%
- Demostrating 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

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 eventua modifiche apportate al documento stesso.

**dentificazione dell'edificio**

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

**) 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 |
| **C.B.N. Risultante** | | | **€ 1.066,56** |

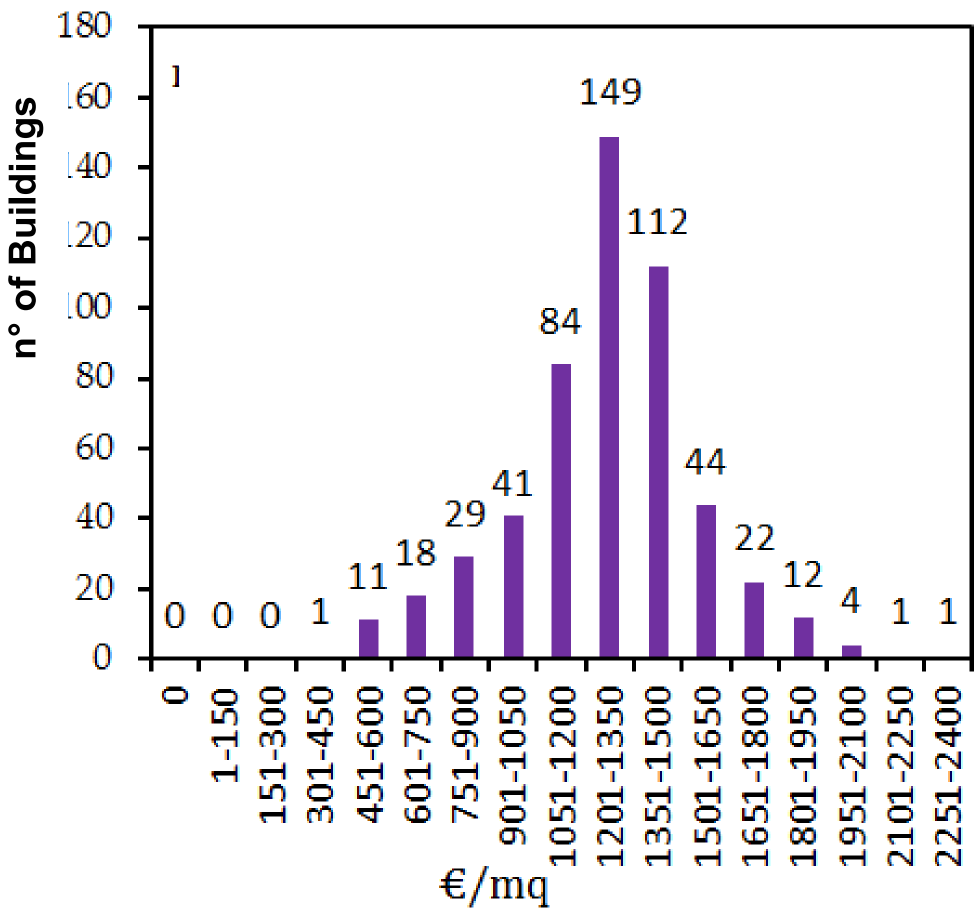
Pagina 1

| 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 | - | | |
| TOTALE MAGGIORAZIONI TECNICHE APPLICATE | | | € 64,64 |
| **C.R.N. - Costo unitario a base d'appalto - LIMITE UNITARIO DI CONTRIBUTO SUL COSTO DI COSTRUZIONE (€/mq Sc)** | | | **€ 1.131,20** |

# 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 Buldings** forfait grant of 750 €/m²

**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 €/m²**

# 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**

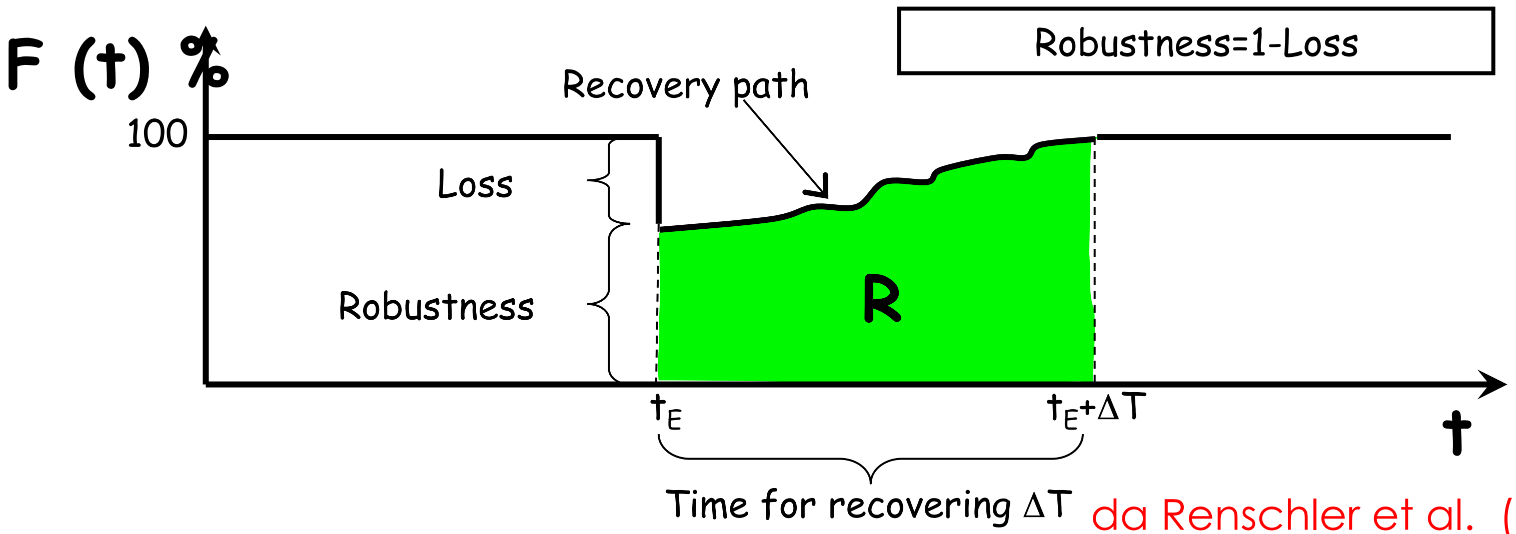
Hotel Duca degli Abruzzi collapse, L'Aquila 2009.

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)




da Renschler et al. (2010)

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**

**ww.protezionecivile.gov.it**

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

- **32 meetings on the Italian territory**

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile
INGV
reluis
ANPAS
RegioneEmilia-Romagna

# 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 15th-16th)***

TERREMOTO IO NON RISCHIO

Campagna nazionale sulla riduzione del rischio sismico

13-14 ottobre 2012

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

INGV

ANPAS

reluis

**Earthquake I don’t risk”**

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

Policies for **BUILDING DEMOLITION**

**demonstrating the ECONOMIC CONVENIENCE**

to demolish and rebuild instead of repair and retrofit

(art. 5 comma 1 OPCM 3881)

**WITHOUT demonstrating the ECONOMIC CONVENIENCE**

(lump sum refund)

(art. 5 comma 2 e 3 OPCM 3881)

**WITHOUT demonstrating the ECONOMIC CONVENIENCE**

(**SEVERE DAMAGES**)

(art. 5 comma 5 OPCM 3881)

For Masonry buildings

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

For R.C. buildings

- excessive residual deformations

  (≥1.5% on more than 50% columns of a storey)

- weak concrete (fc <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 ± 2mm). Allows measuring discrete points, that have to established a priori, on the element

### laser-scanner 3D

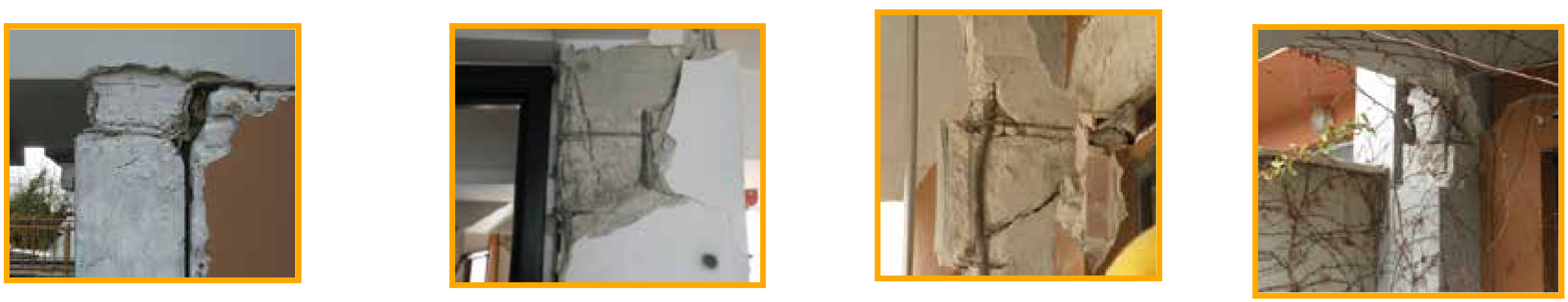
Innovative technique, very precise (tolerance ± 2mm). Allows reconstructing the spatial coordinates of the surveyed object with a dense DEM. Specific points to be measured can be decided also a posteriori.

# 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.



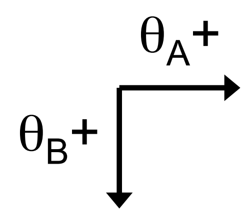
Example of damage on some of the columns at the first storey

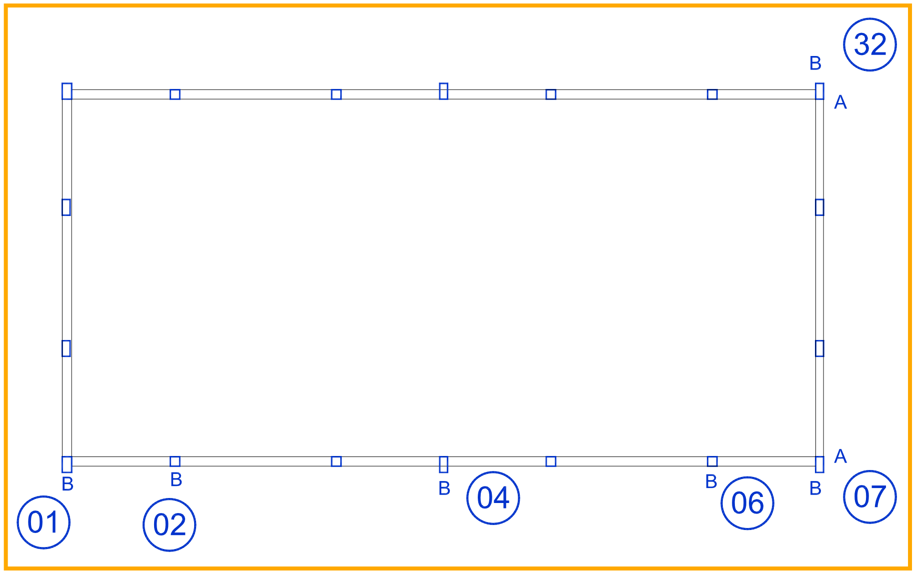
# Post-earthquake decisions

## 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

Sign convention




The measured columns

| 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 |

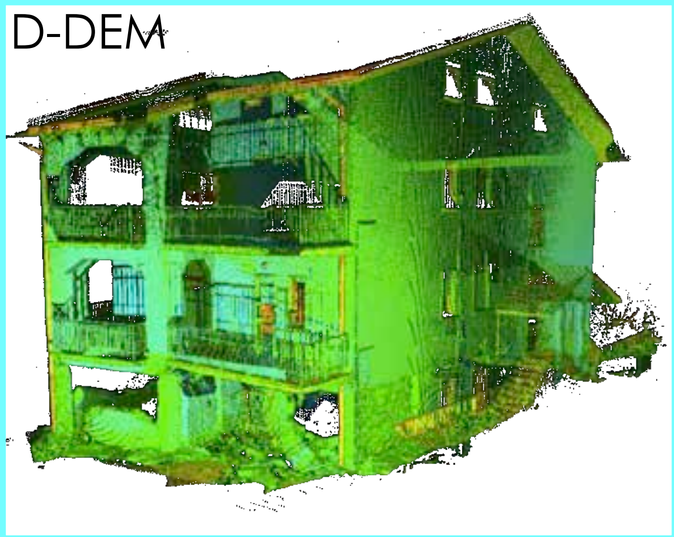
1st level permanent drifts (evaluation from D-DEM data)

# 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.

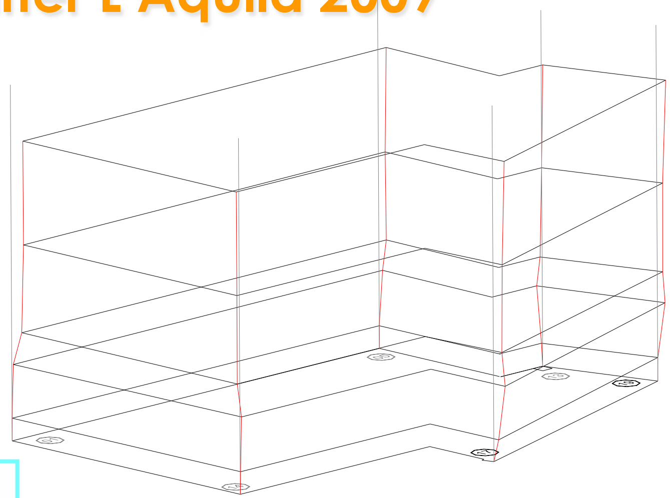



Example of damage on some of the columns at the first storey

# Post-earthquake decisions

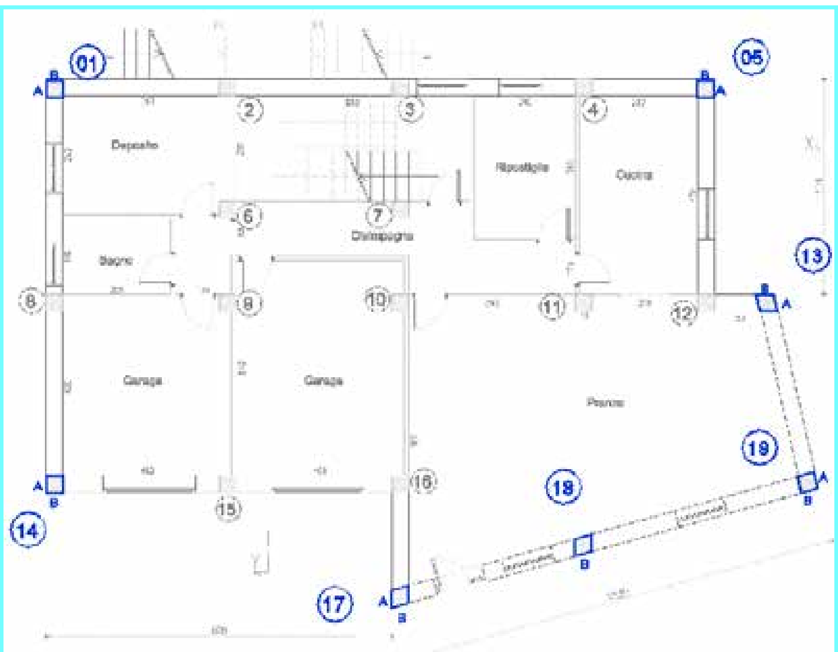
## Residual drifts: measurements after L'Aquila 2009

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

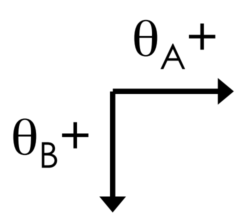


Permanent deformation of building in elevation

(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 |

1st 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* (applies to the two criteria above)

  - ✓ **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

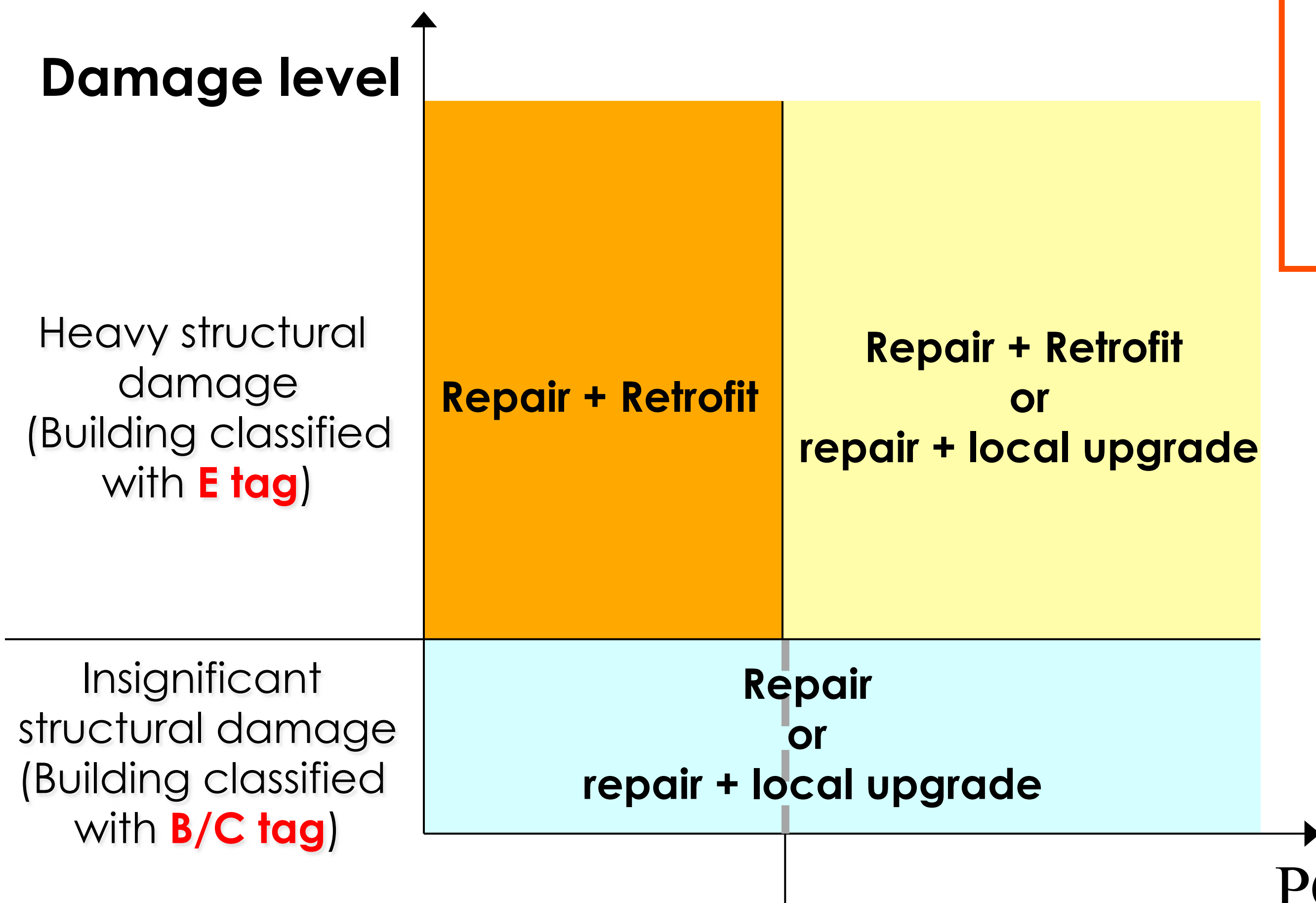
representative parameter for assessment of

**building reparability** in a

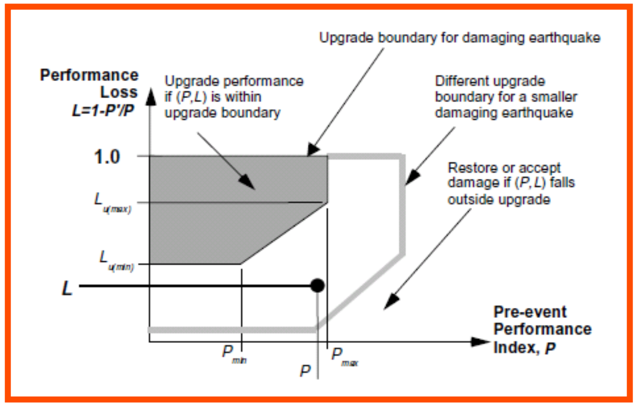
Performance Based Policy framework

# Reparability issues

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




$$P = \frac{PGA_{SLV}}{PGA_{rif}}$$



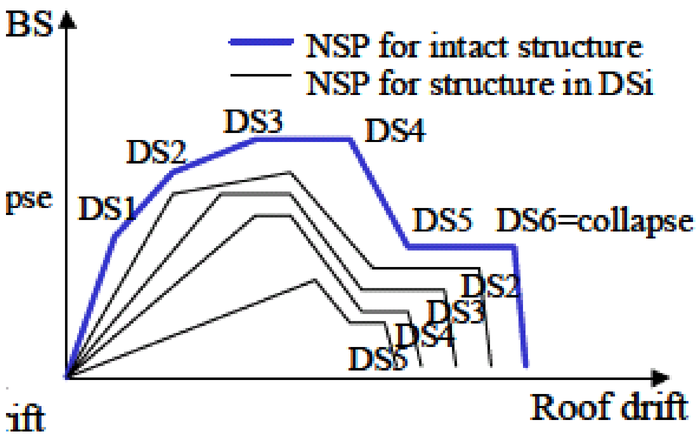

FEMA 308 (1998)

# Evaluation of REsidual Capacity (REC)

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

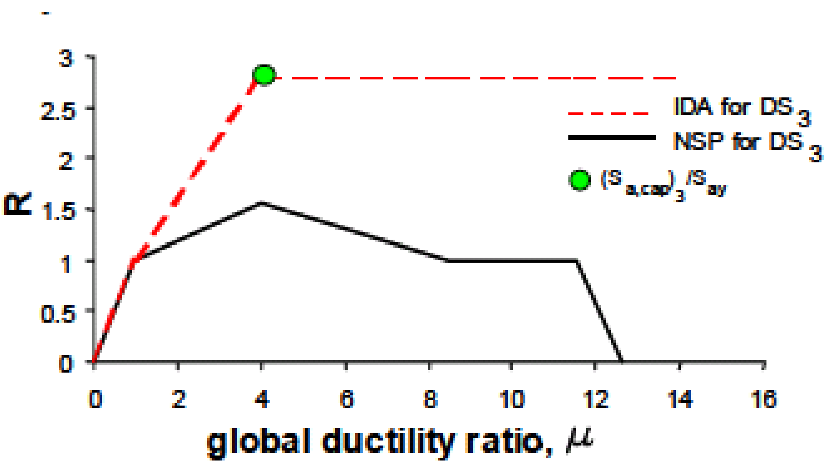
**Residual Capacity as :**

the minimum spectral acceleration (at elastic period T1 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 (%)**

**Is** seismic index; ge

Is ∝ **CxF** with **C** ∝ base sh

Reduction Factor

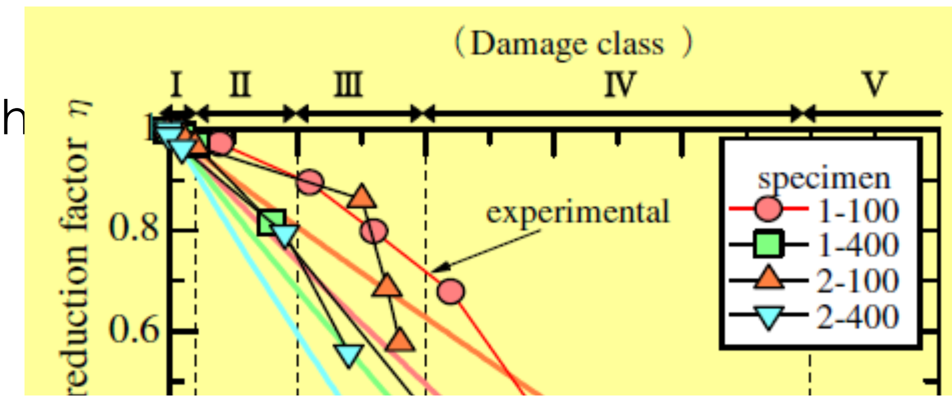



**Table 3: Seismic Capacity Reduction Factor $\eta$ (JBDPA [1])**

| 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)

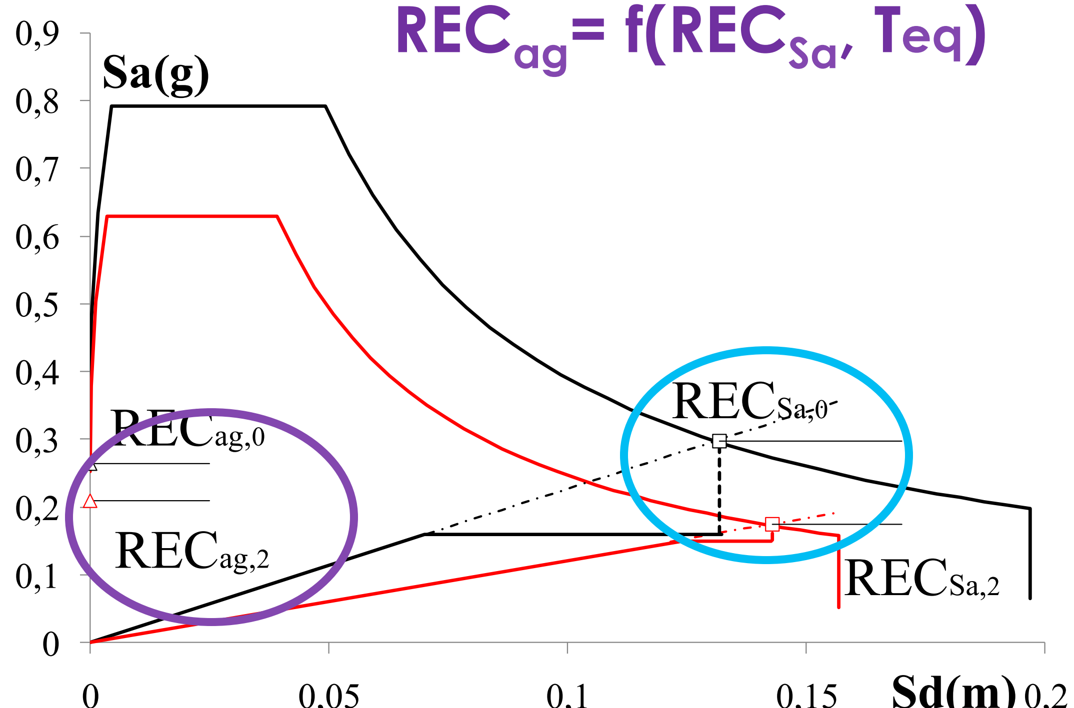
**ASSESSMENT OF RESIDUAL CAPACITY with SPECTRAL APPROACH**

**Residual Capacity $REC_{Sa}$: spectral acceleration** corresponding to collapse

**$REC_{Sa}$** found applying IN2 method for intact or damaged building (Polese et al., 2013)

$REC_{ag}$ (in terms of peak ground acceleration):

$$REC_{ag} = f(REC_{Sa}, T_{eq})$$




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

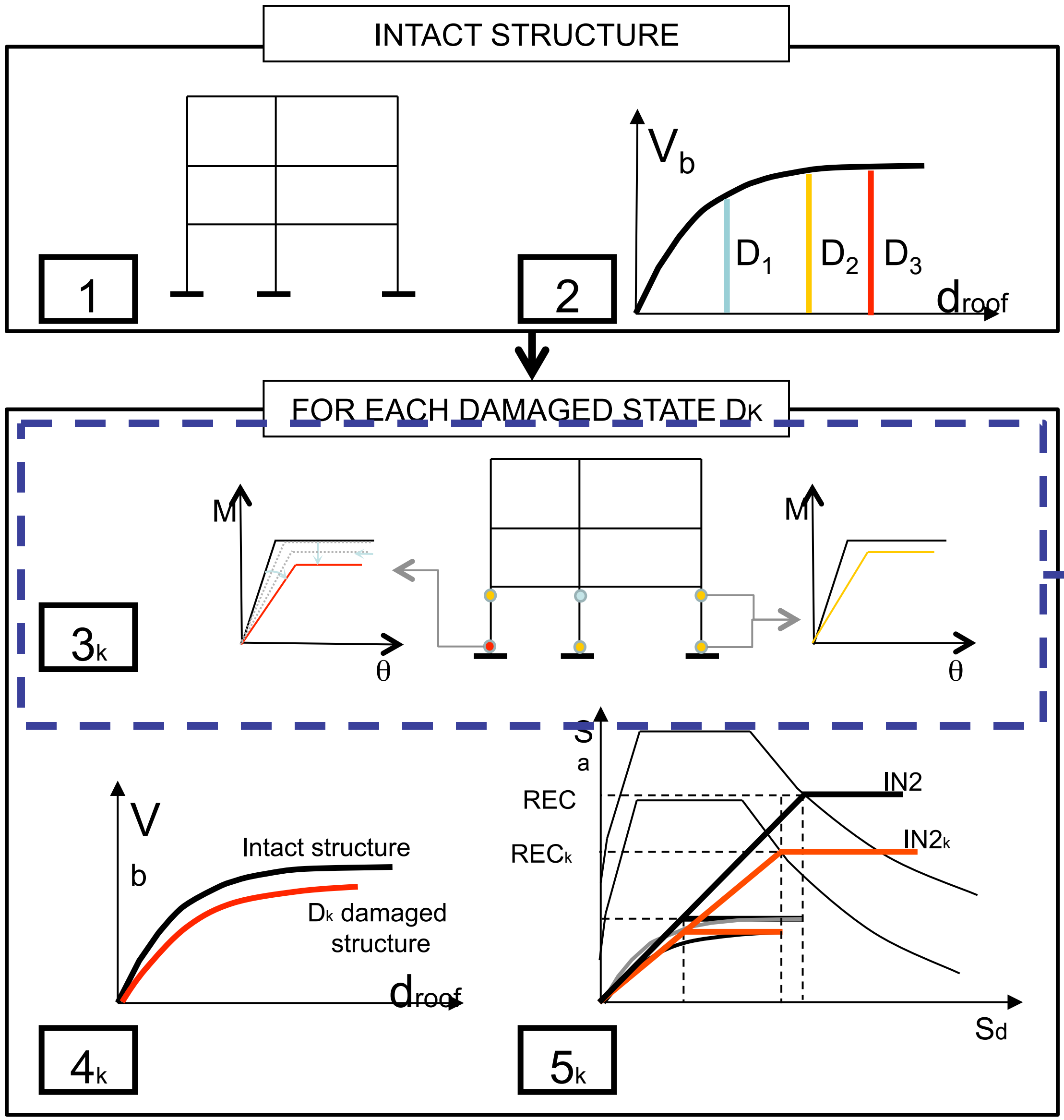
$$\text{for } T_{eq} \geq T_c$$

**Note similarity with definition of Is (and damaged Isd ) by (Nakano et al. 2004)**

**Is** seismic index; **Is,D** seismic index reduced due to damage; Is ∝ **CxF** with **C** ∝ 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)

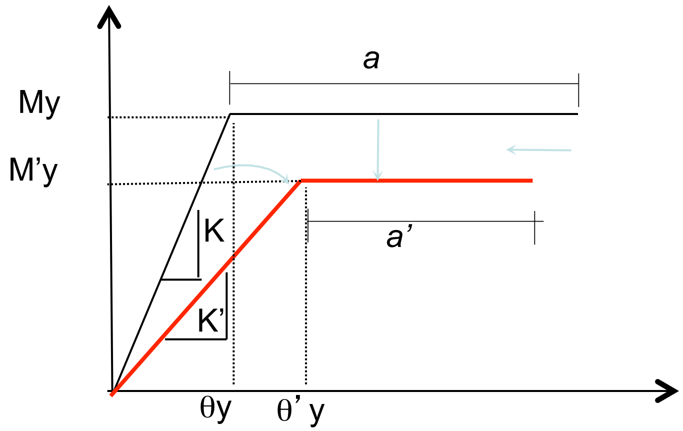
**need** for **suitable calibration of plastic hinges modification factors** for existing buildings (typically with **non-conforming elements**)

# Evaluation of REsidual Capacity (REC)

## PLASTIC HINGES MODIFICATION FACTORS

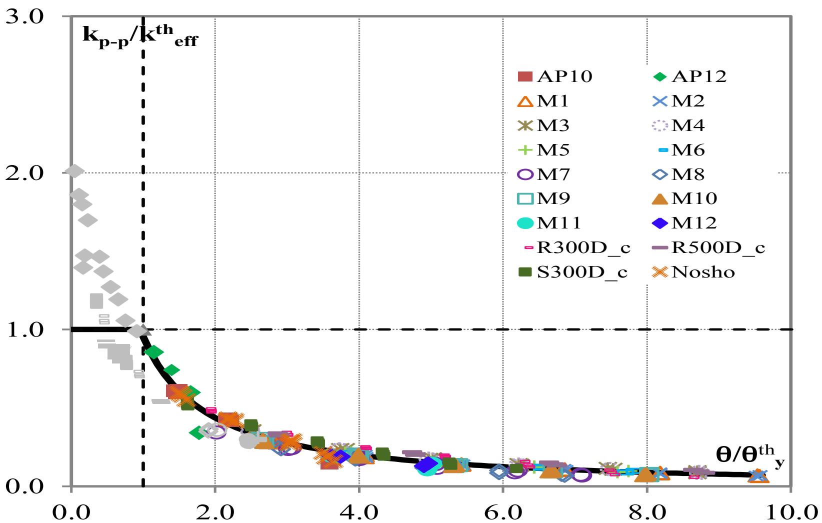
## for NONCONFORMING columns

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



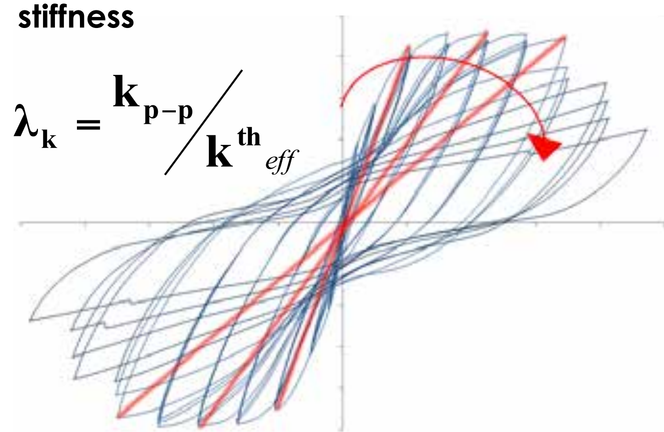

| | stiffness | strength | Plastic rotation |
|---|---|---|---|
| intact | K | My | a |
| damaged | $K' = \lambda_K K$ | $My' = \lambda_Q My$ | a'=a-ad |

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




### Modification factors shall be derived via experimental calibration

stiffness



# 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:**

**Need consistent values for:**

- **Different element types (beams, columns, walls, ….)**
- **Definition of damage-ductility intervals**
- **for different elements and behavior types**
- Preliminary (proposals exist in FEMA 307 & Japanise 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)

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

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

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

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

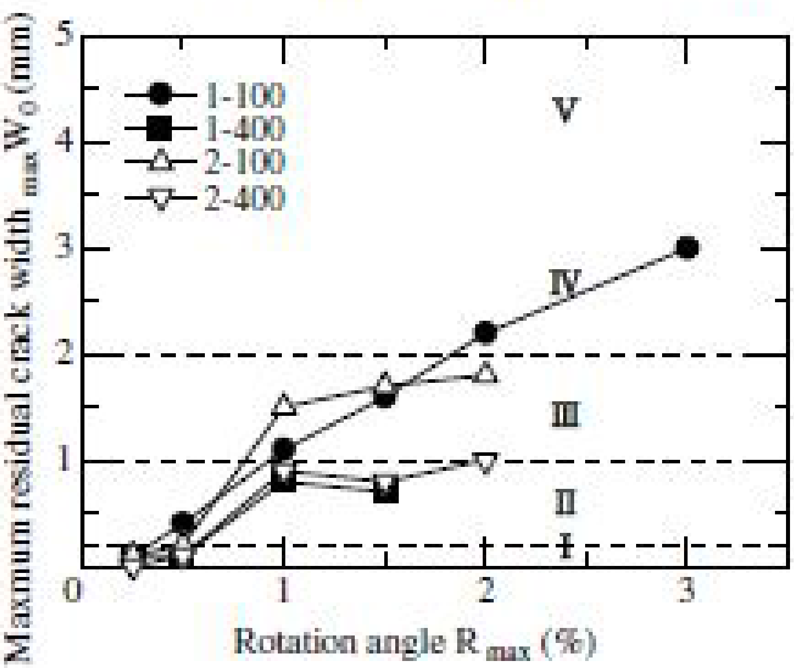
Examples from Manual

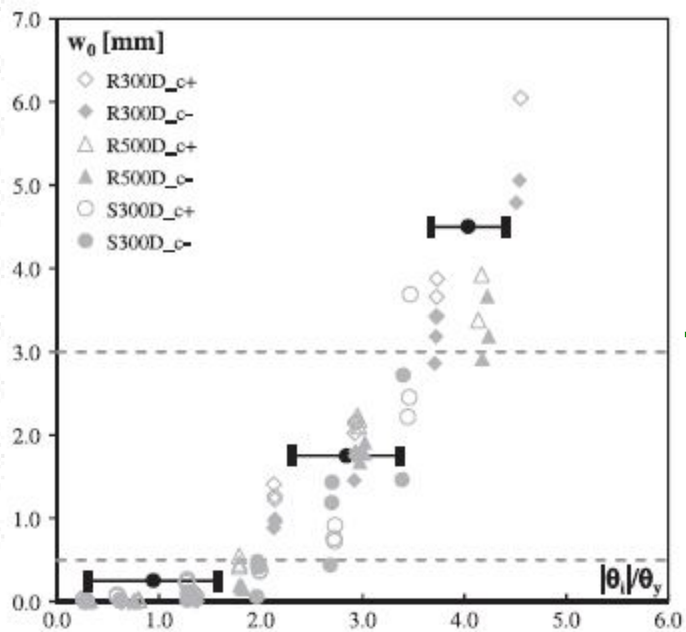
A104

# 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**




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

- **for various element types**
- **for various behavior modes**

**Maeda et al., 2004** **Di Ludovico et al., 2013**

# 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)

| Damage level - extension / Structural component Pre-existing damage | | DAMAGE (1) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 | L |
| 1 | Vertical structures | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ |
| 2 | Floors | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ |
| 3 | Stairs | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ |
| 4 | Roof | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ |
| 5 | Infills and partitions | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ |
| 6 | Pre-existing damage | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ○ |

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

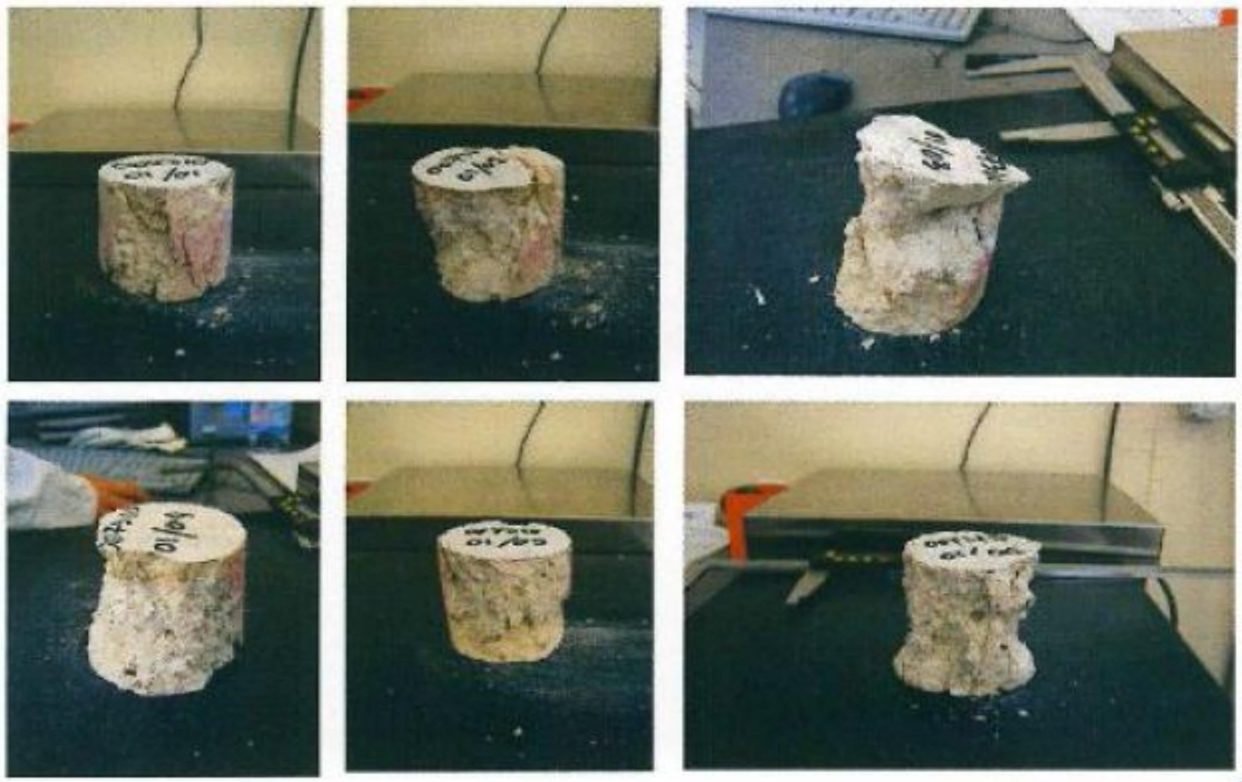
**DATA** available as **percentage** at the **building level**: difficult to use for lumped plasticity models, unless a mechanism type is assigned

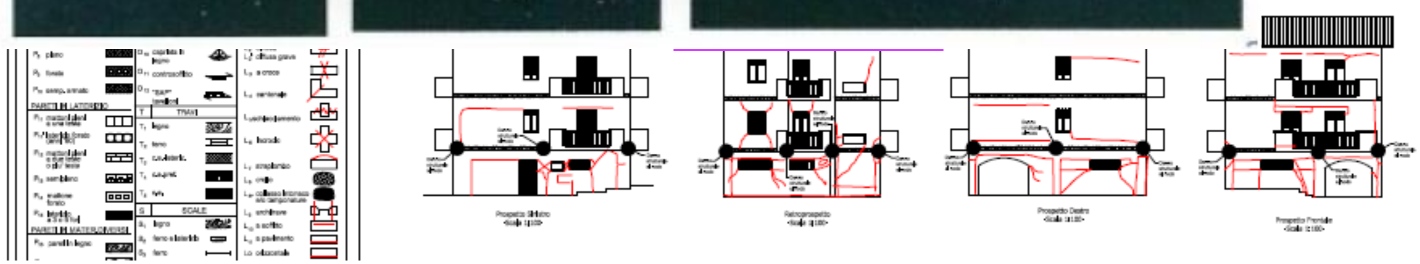
# Damage data vs residual capacity

**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

## FOR DETAILED ASSESSMENT AT THE BUILDING LEVEL:

Request to categorize damage according to:

Element types;

behavior modes;

Damage levels

Damage di
mechanism

Position

Form to collect data


DATI GENERALI

Comune:

Indirizzo:

Foglio:

Particella:

Anno di Costruzione:

Agibilità:

DATI PRATICA

PROTOCOLLO:

DATI GEOMETRICI

DATI AZIONE SISMICA

CARATTERISTICHE MATERIALI E DETTAGLI COSTRUTTIVI

Calcestruzzo

Acciaio

Staffe

DATI INTERVENTO

INTERVENTO 1:

INTERVENTO 2:

INTERVENTO 3:

ALTRO INTERVENTO:

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

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*Civil Protection Department*
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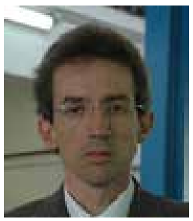

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## Andrea Prota
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# thank you!


## Marco Di Ludovico
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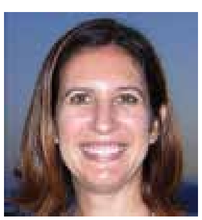
*Email:* ***diludovi@unina.it***



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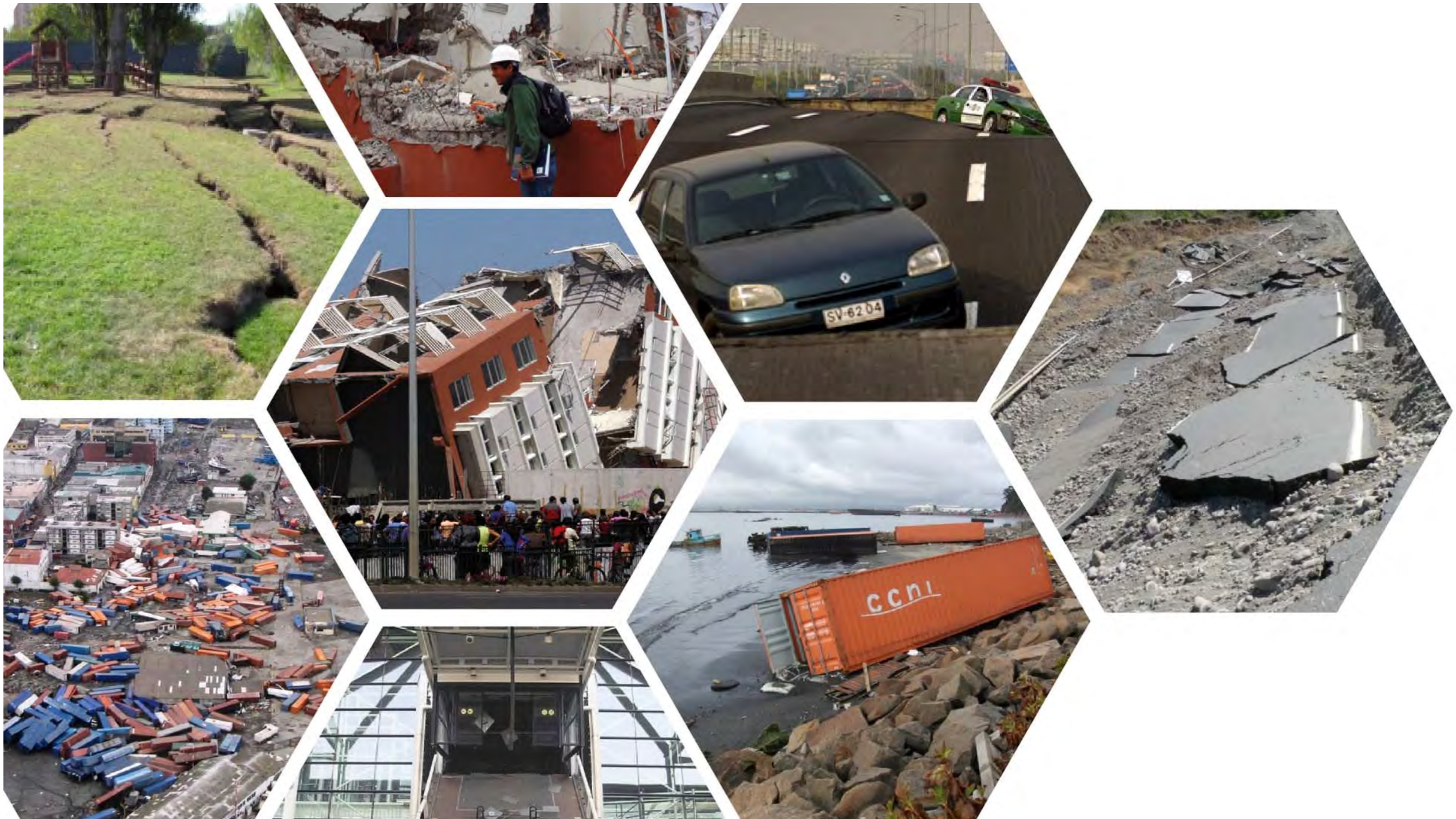
**Network of University Laboratories in Earthquake Engineering**
**RE**te dei **L**aboratori **U**niversitari di **I**ngegneria **S**ismica




# Post earthquake data collection workshop

# Chilean Experience

Alaska, July 2014

## 01 2010 CHILE EARTHQUAKE AND DATA COLLECTION METHODOLOGIES

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

## 02 GEOPHISICAL, EARTHQUAKE AND TSUNAMI INFORMATION

- Instrumental data
- Geotechnical data
- Tsunami data

## 03 LIVELINES AND CRITICAL INFRASTRUCTURE

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

## 04 BUILDING DATA

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

## 05 SOCIAL AND HUMAN IMPACT

- Mental health
- Economic losses

## 06 LESSONS LEARNED

- Conclusions

# Data Collection

Tenth U.S. National Conference on Earthquake Engineering
Frontiers of Earthquake Engineering
July 21-25, 2014
Anchorage, Alaska

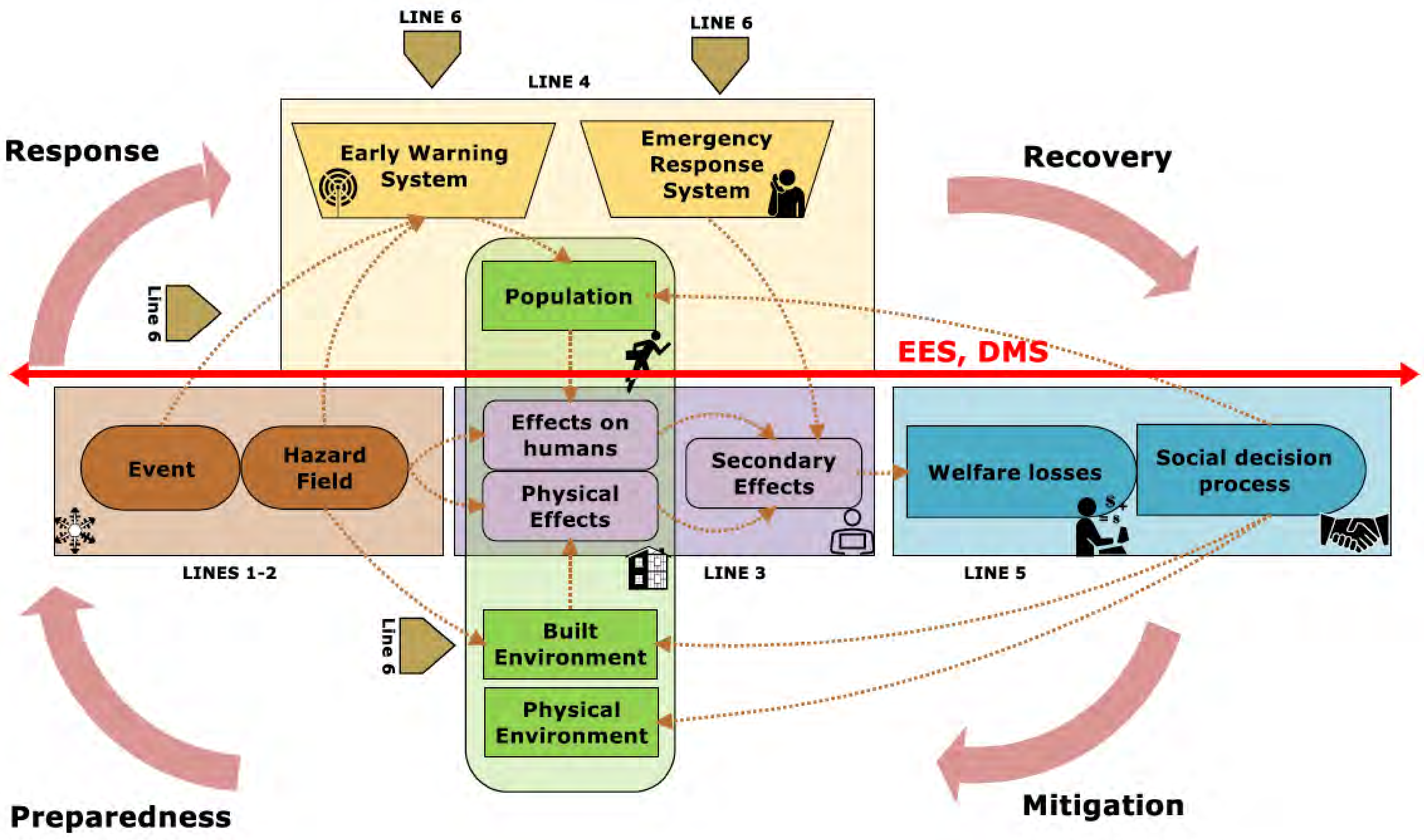
## POST-EARTHQUAKE DATA COLLECTION: THE 2010 MAULE EARTHQUAKE IN CHILE

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

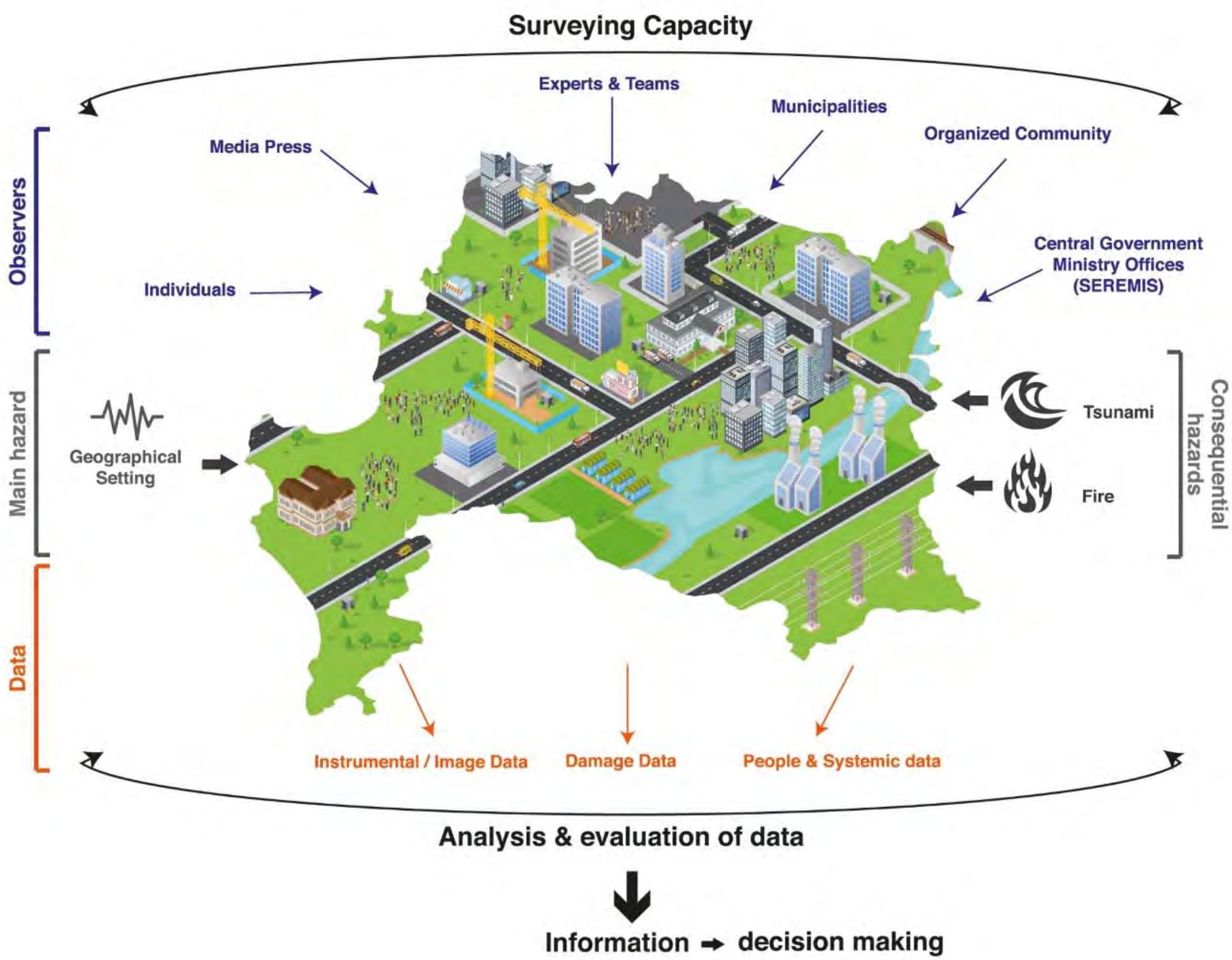
**ABSTRACT**

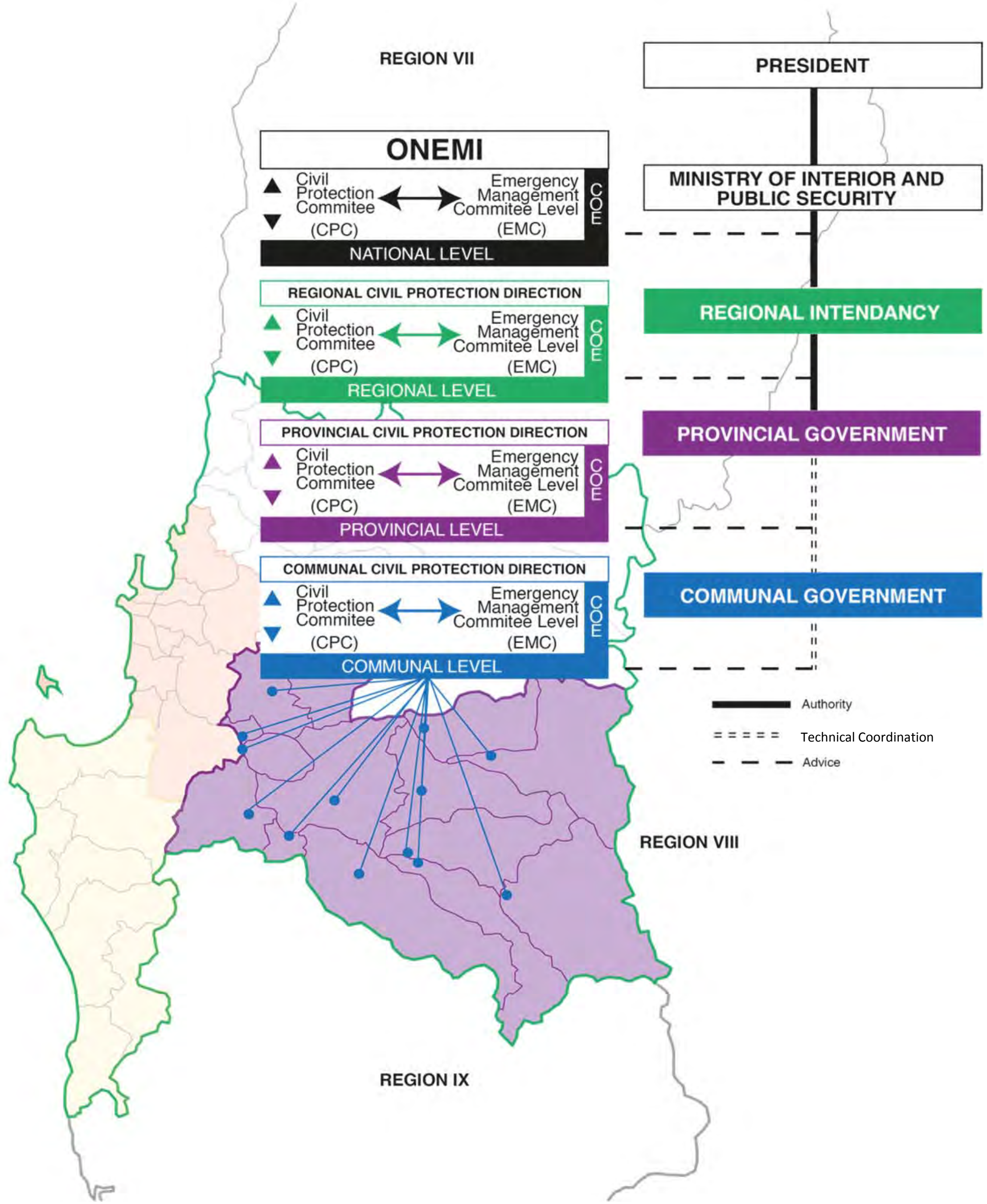
This article presents an overview of the different processes of data recollection and the analysis done by different stakeholders during and after the emergency caused by the 2010 Maule earthquake in central-south Chile. The article is not an exhaustive recollection of all of the processes and methodologies 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

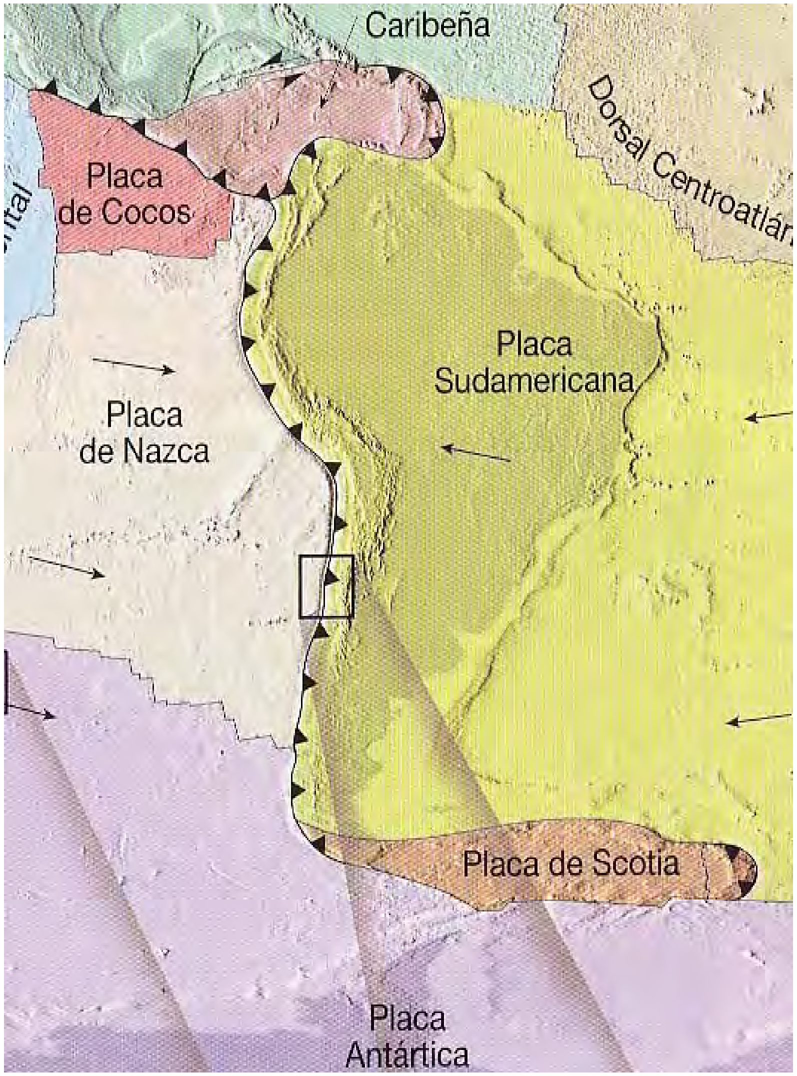


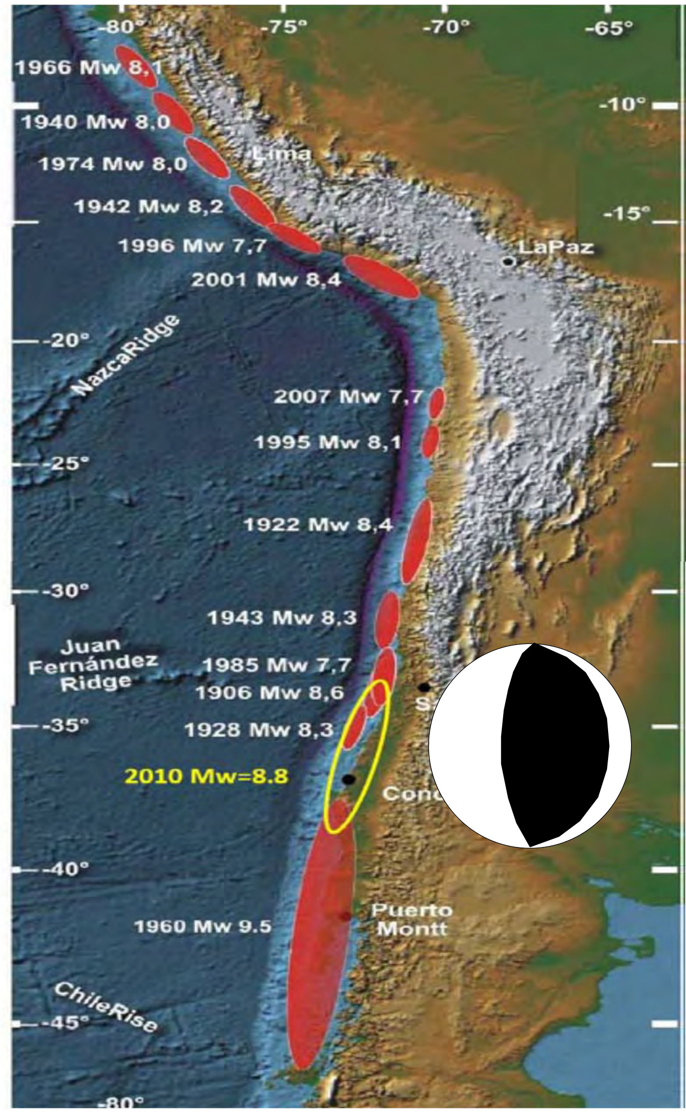

REGION VII
PRESIDENT
ONEMI
Civil Protection Commitee (CPC)
Emergency Management Commitee Level (EMC)
COE
NATIONAL LEVEL
MINISTRY OF INTERIOR AND PUBLIC SECURITY
REGIONAL CIVIL PROTECTION DIRECTION
Civil Protection Commitee (CPC)
Emergency Management Commitee Level (EMC)
COE
REGIONAL LEVEL
REGIONAL INTENDANCY
PROVINCIAL CIVIL PROTECTION DIRECTION
Civil Protection Commitee (CPC)
Emergency Management Commitee Level (EMC)
COE
PROVINCIAL LEVEL
PROVINCIAL GOVERNMENT
COMMUNAL CIVIL PROTECTION DIRECTION
Civil Protection Commitee (CPC)
Emergency Management Commitee Level (EMC)
COE
COMMUNAL LEVEL
COMMUNAL GOVERNMENT
Authority
Technical Coordination
Advice
REGION VIII
REGION IX

01

# 2010 CHILE EARTHQUAKE AND DATA COLLECTION METHODOLOGIES

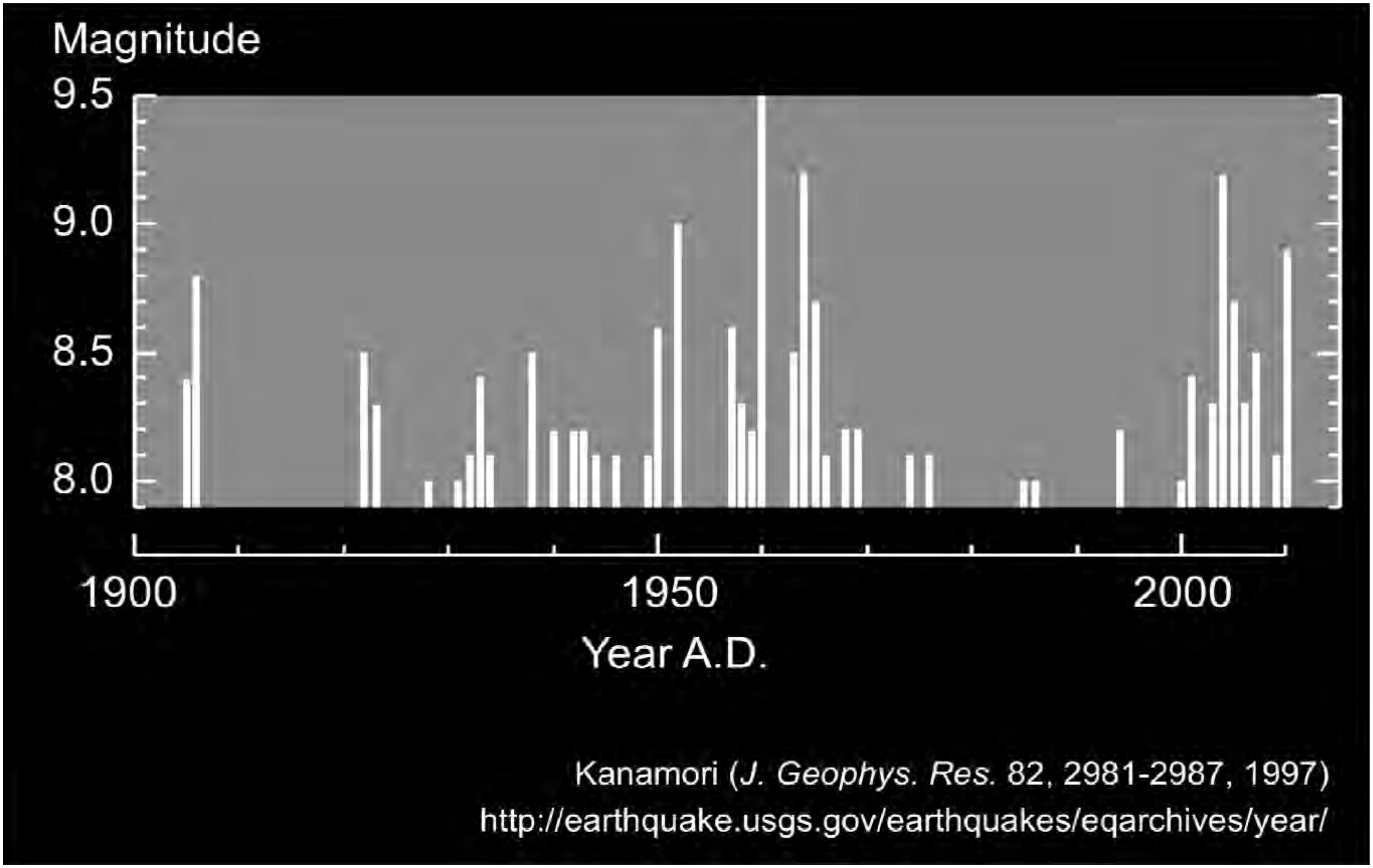
# Seismic
## Setting



# Recent
## Earthquakes

# Big EQKs
## Since 1900




Concepción, 2010

# Chile
# 1000
## millions
### $USD/year


Valdivia, 1960

# Deaths

~ **580** in 2010

~ **1600** in 1960

~ **800** in 1922


Earthquake
27/F


Earthquake
27/F

# Feb-27 Earthquake

**A**
**Residential Buildings**

**B**
**Industrial Buildings**

**C**
**Infra-structure**

**D**
**Contents**

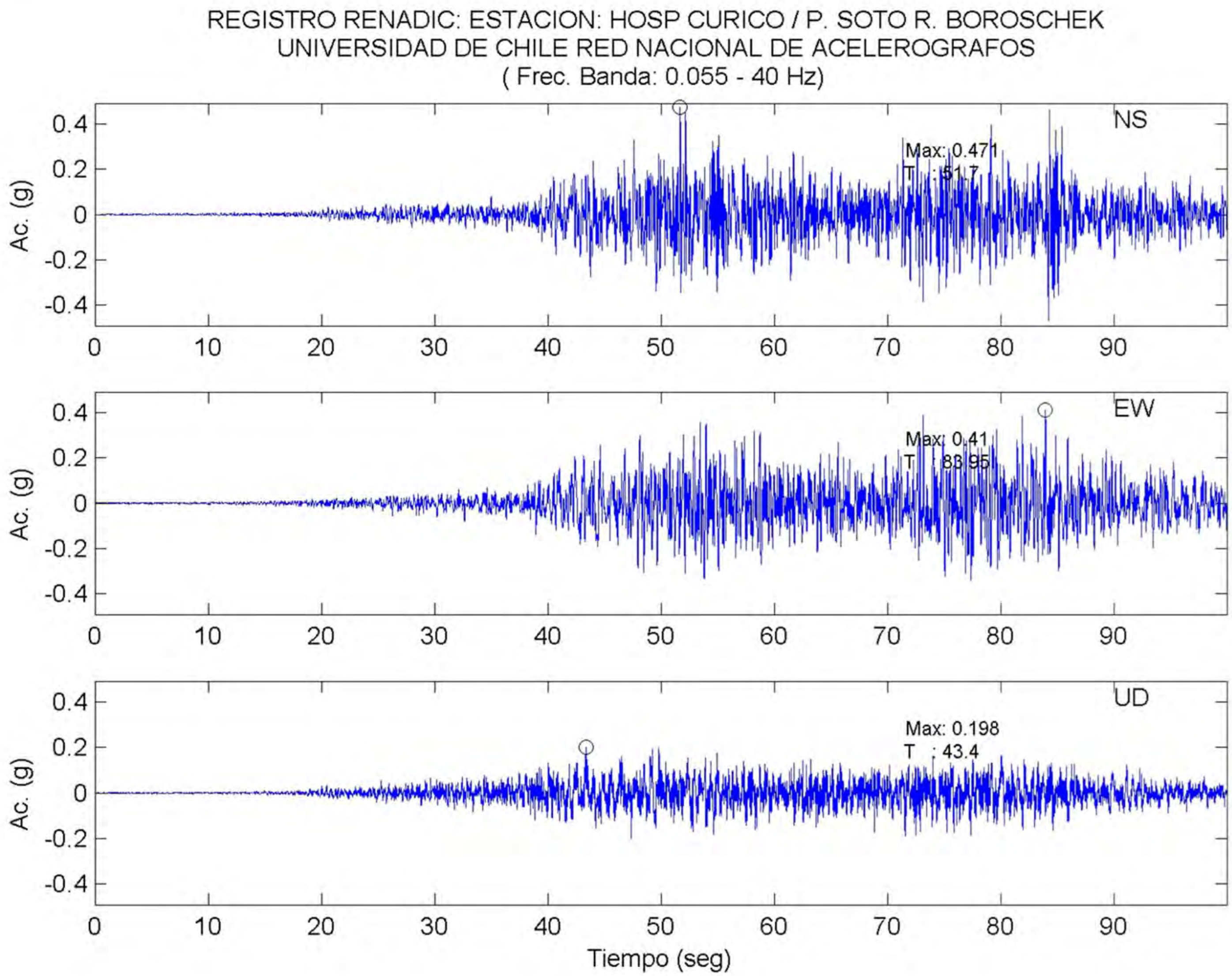
02

# GEOPHISICAL, EARTHQUAKE AND TSUNAMI INFORMATION

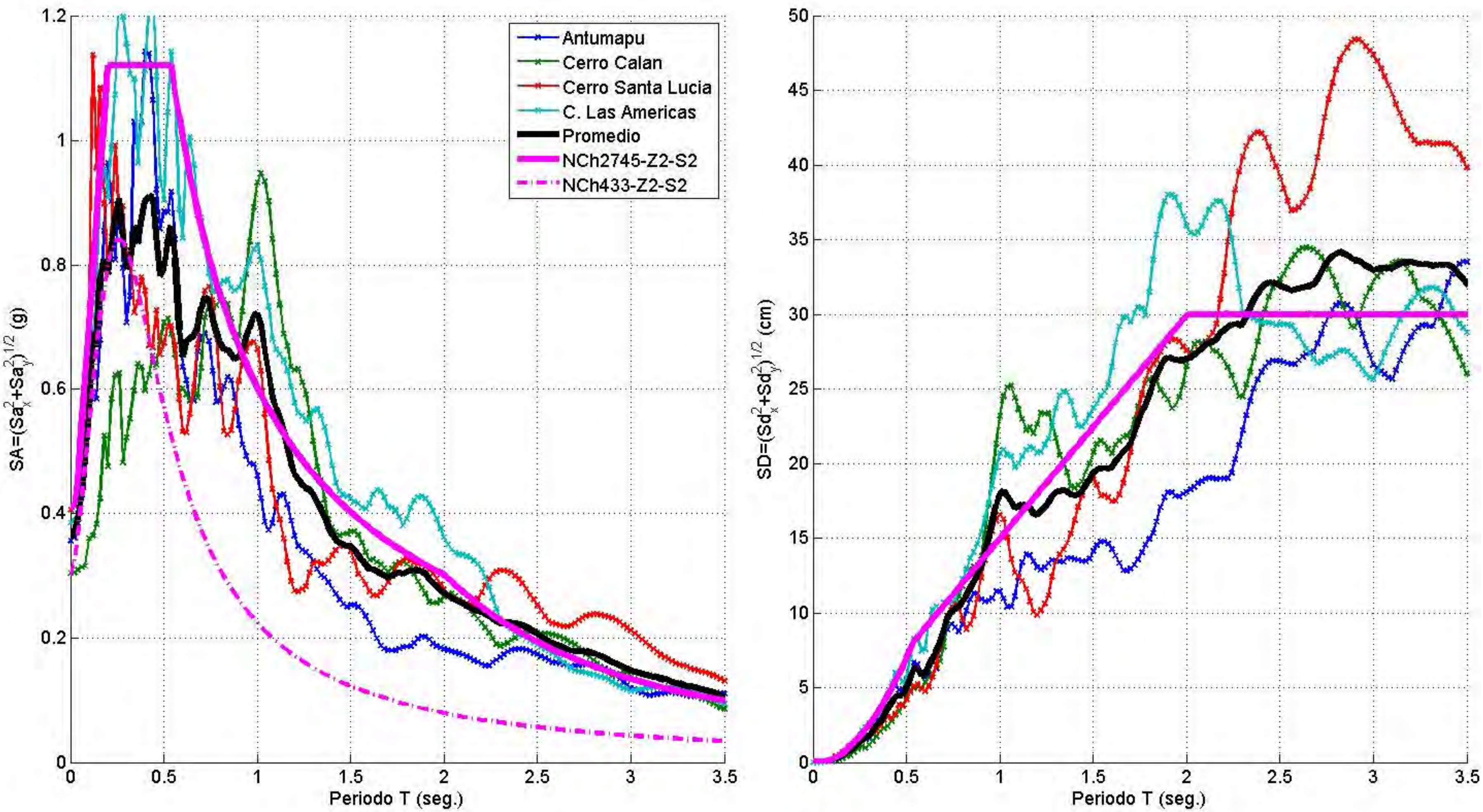
# Instrumental Data

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

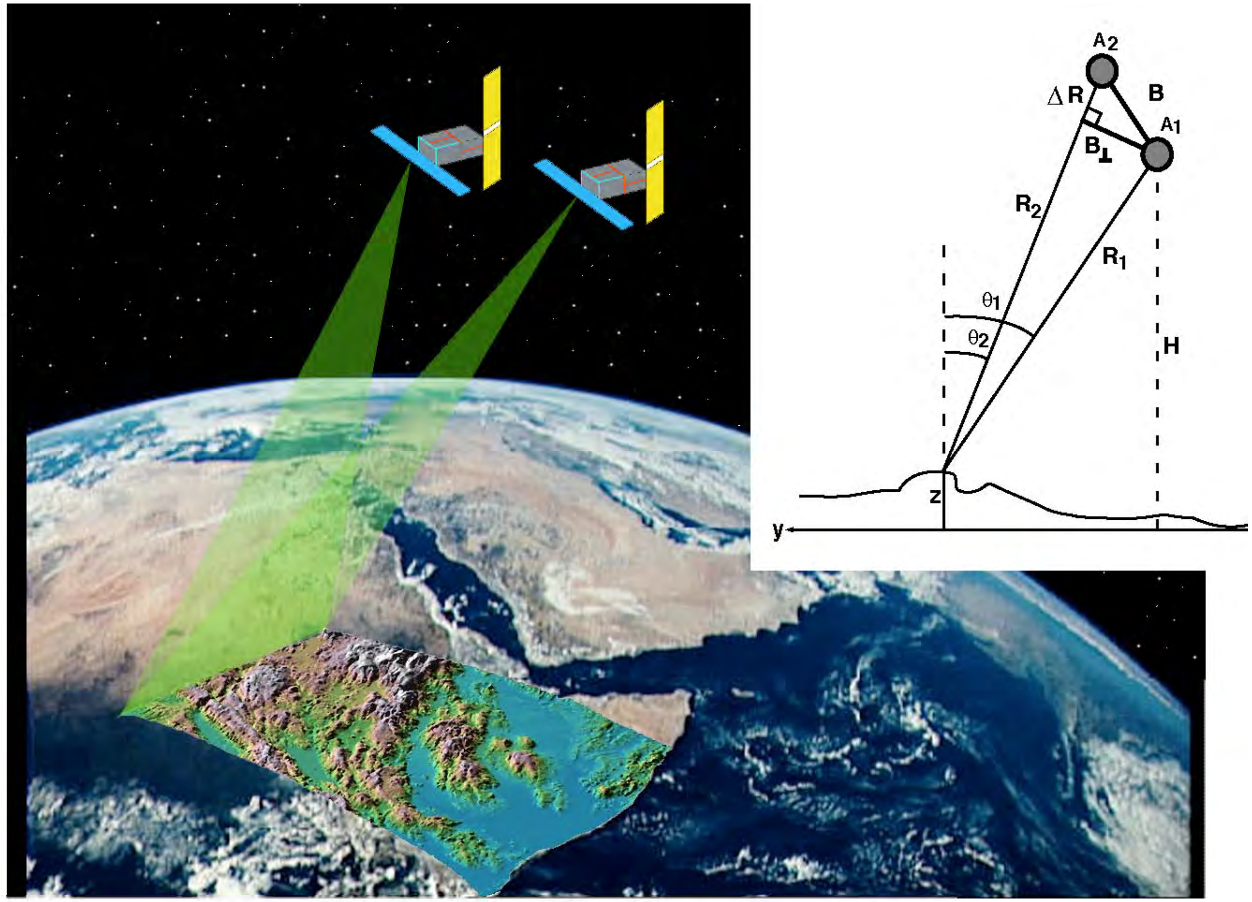
# Curico records



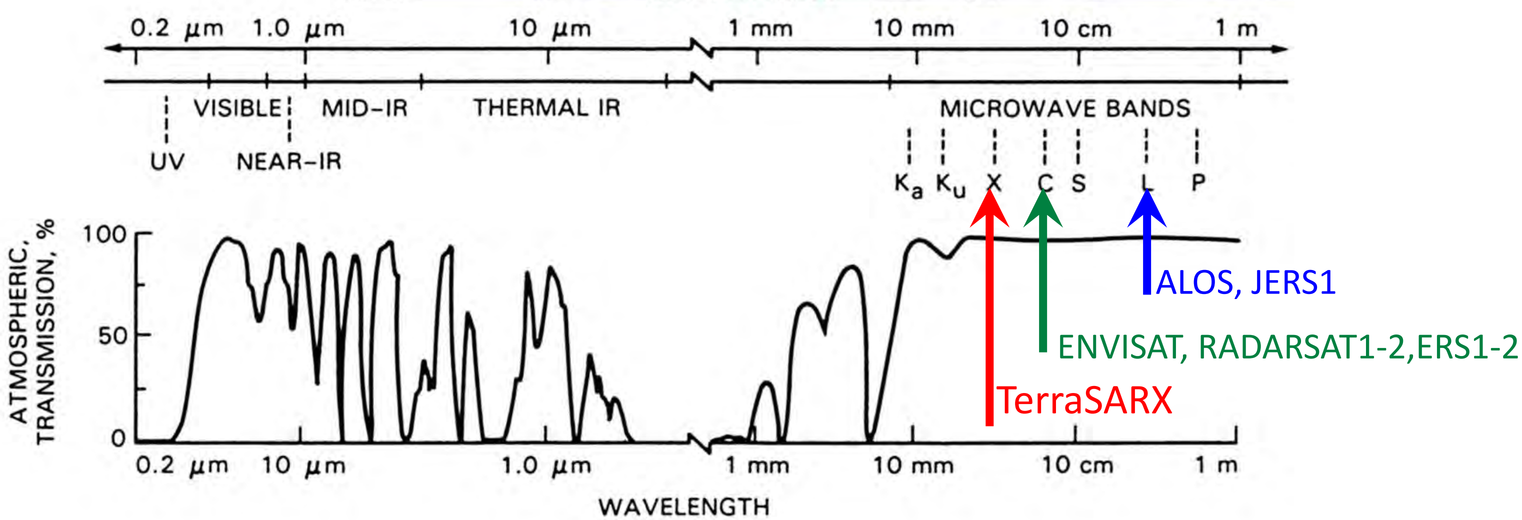
# Earthquake 27/F 2010



# InSAR



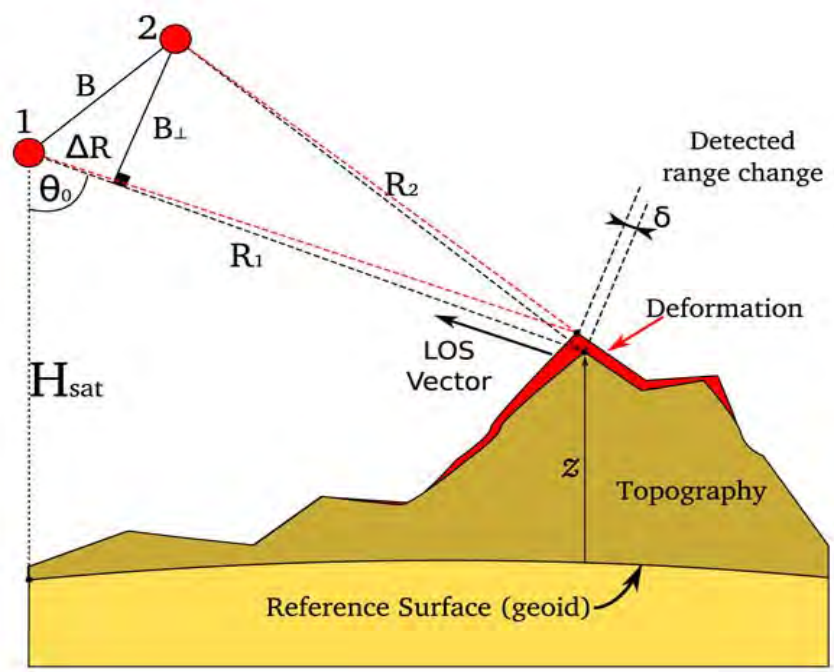
A2
ΔR
B
A1
B⊥
R2
R1
θ1
θ2
H
z
y

0.2 μm
1.0 μm
10 μm
1 mm
10 mm
10 cm
1 m
UV
VISIBLE
NEAR-IR
MID-IR
THERMAL IR
MICROWAVE BANDS
Ka
Ku
X
C
S
L
P
ATMOSPHERIC, TRANSMISSION, %
100
50
0
WAVELENGTH
ALOS, JERS1
ENVISAT, RADARSAT1-2,ERS1-2
TerraSARX

# InSAR
## Geometry

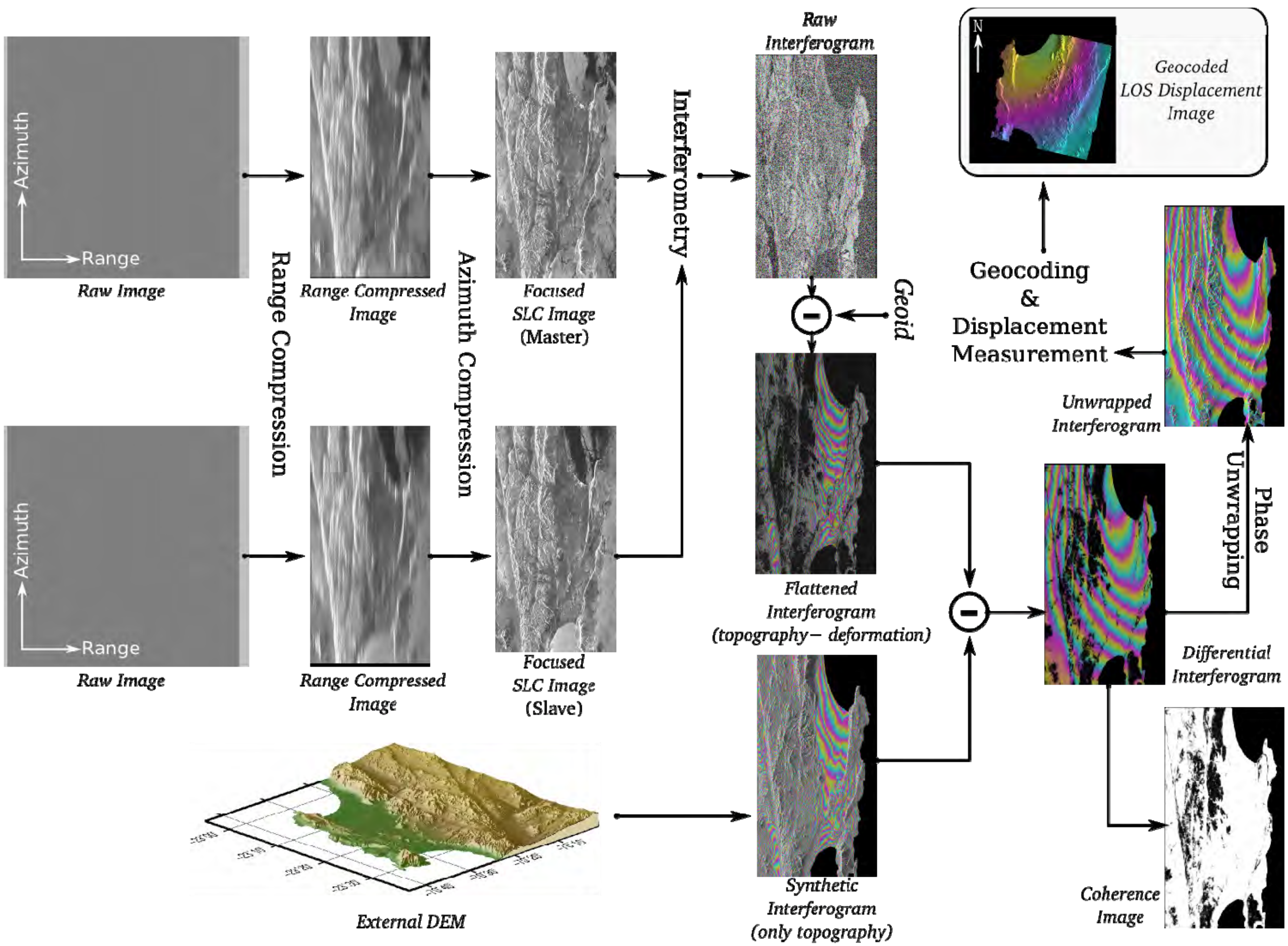
- The change in viewing geometry and surface changes is dectected as a change in phase
- The range-change is related to various geometric sources



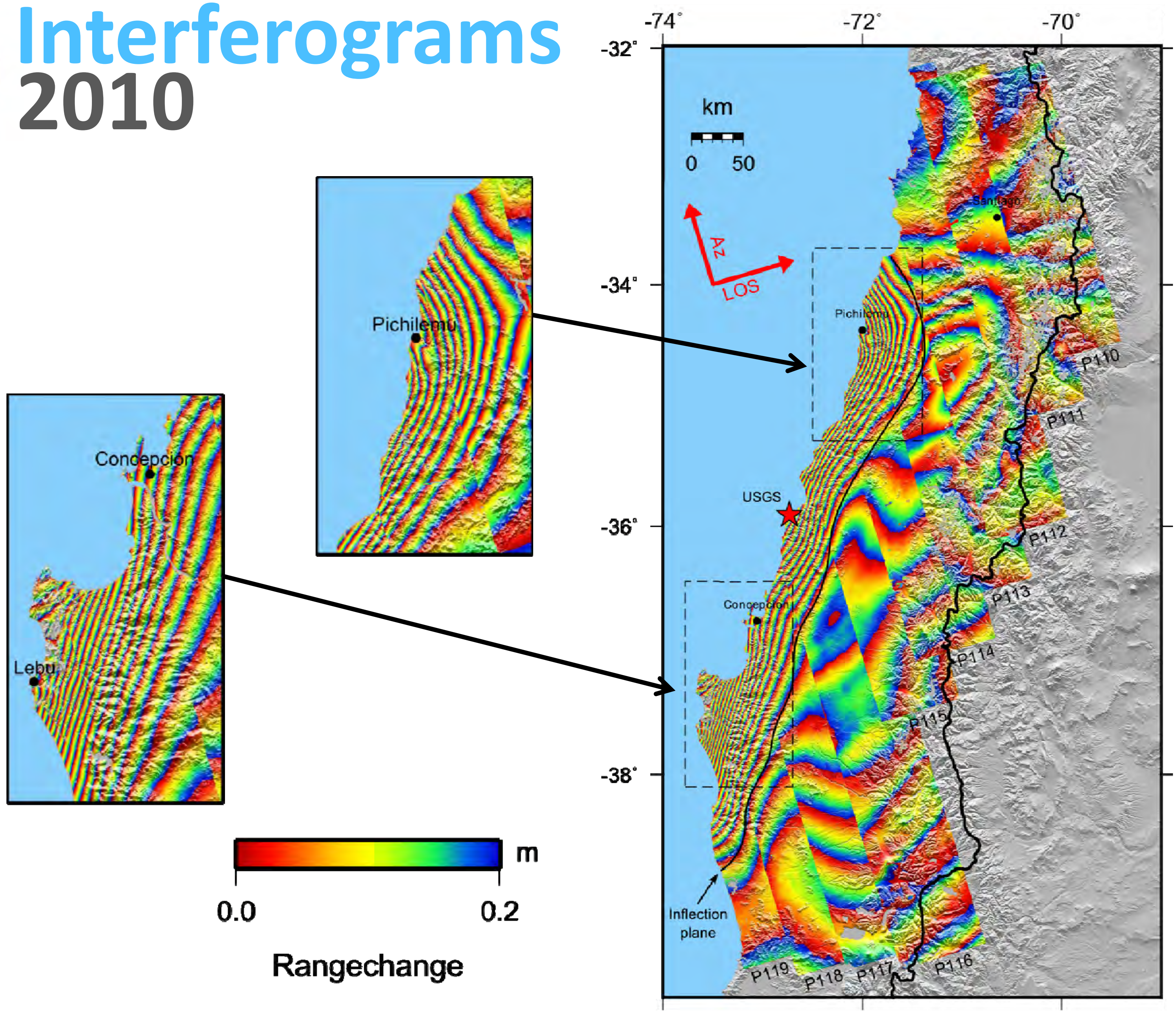

$$\Delta\phi_m = -\frac{4\pi}{\lambda}\left(\Delta R_{\text{datum}} - \frac{B_\perp}{R\sin\theta}z - \delta\right) + \phi_{\text{noise}} + n \cdot 2\pi$$

Deformation

# InSAR
## Processing



# Interferograms 2010



# Interferograms 2010

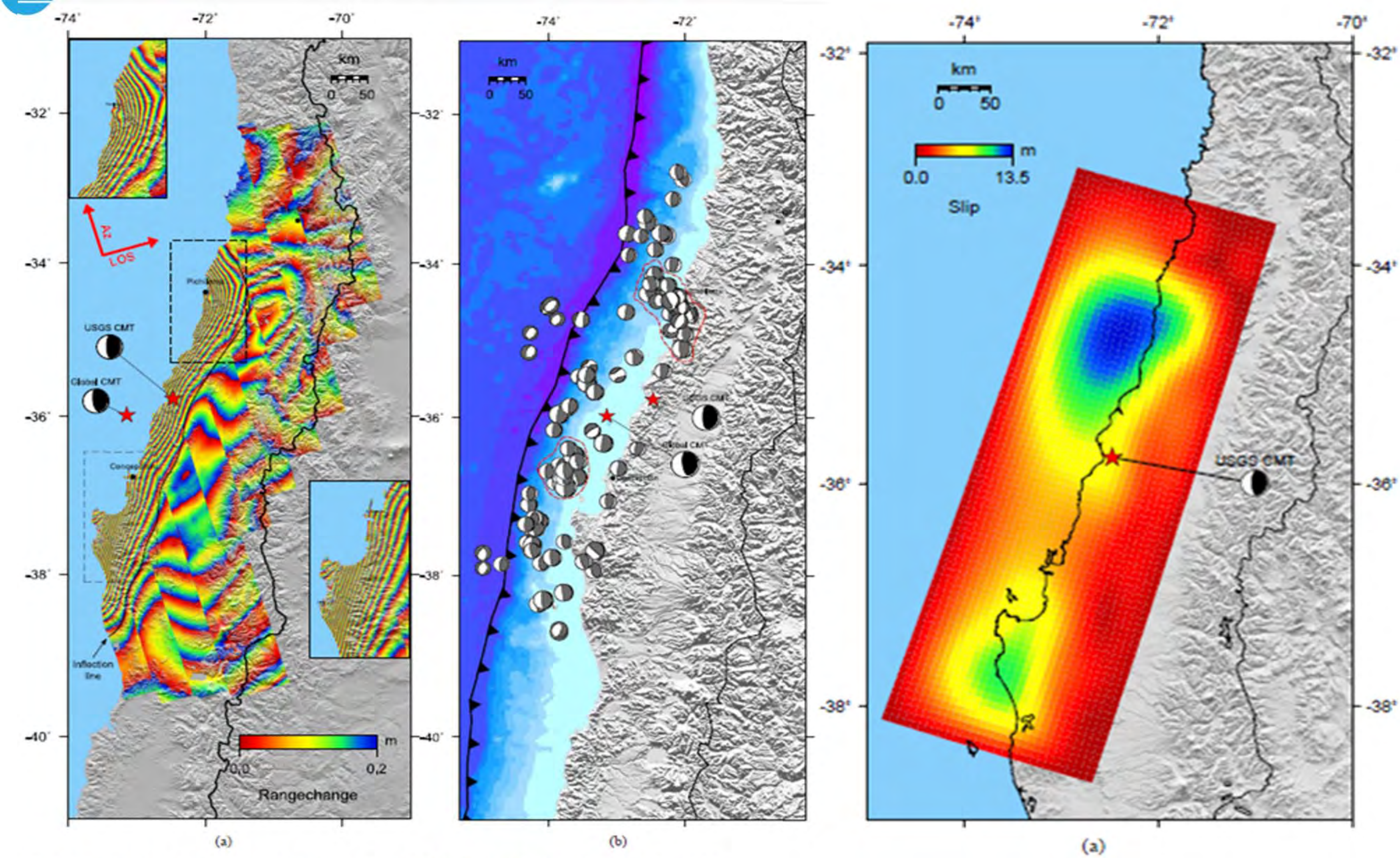
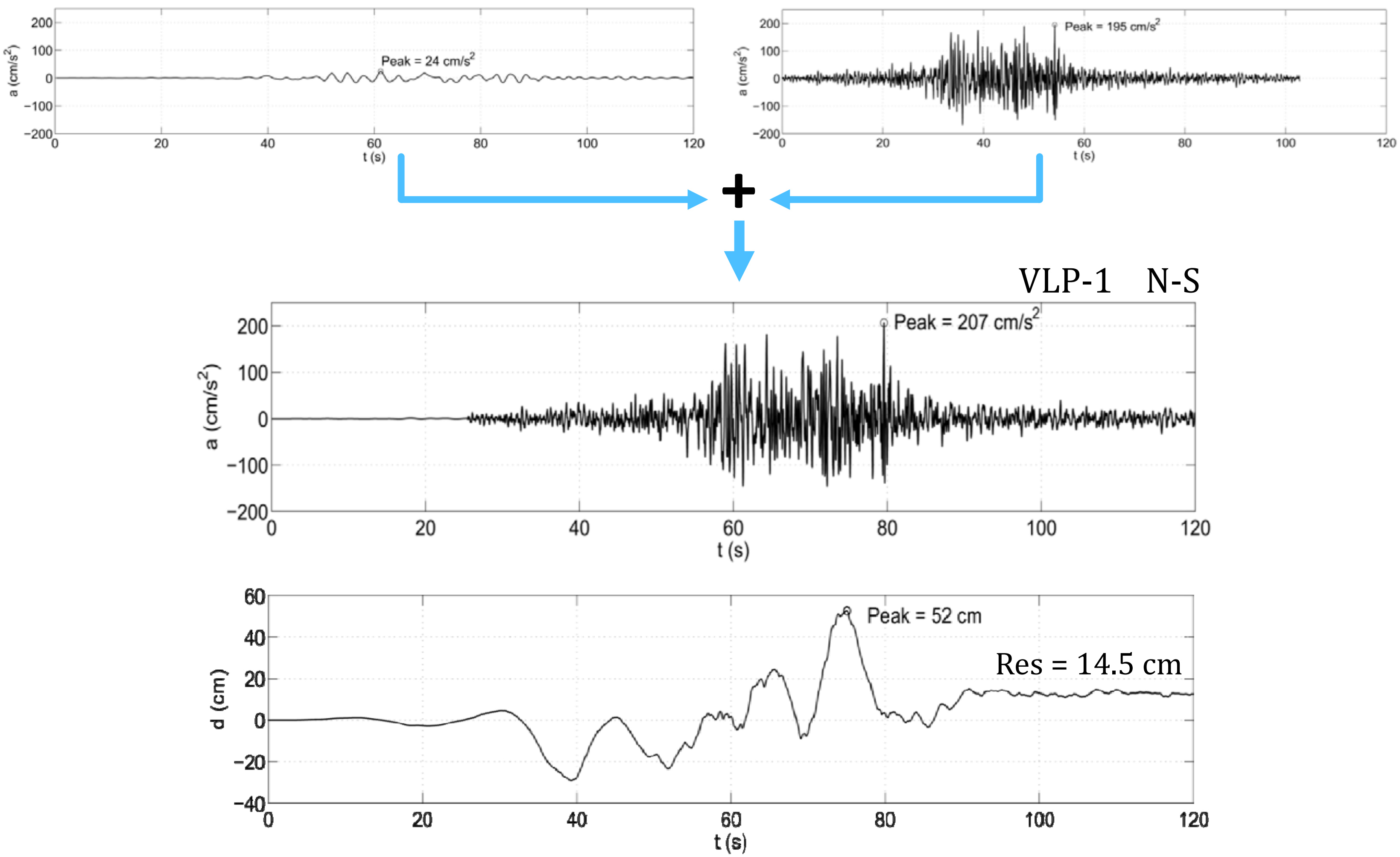


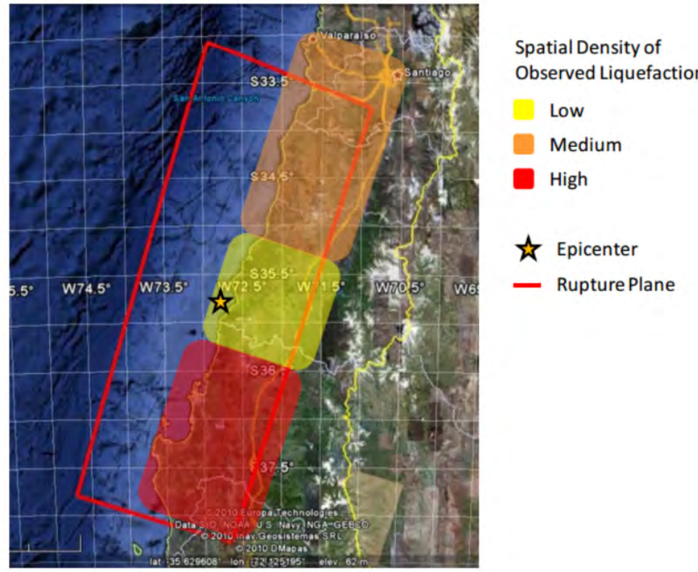

Figure 3: (a) Ascending unwrapped interferograms for Maule 2010 earthquake, (b) Aftershocks $M_w \geq 5$ of Maule 2010 earthquake between Feb 27 and May 29 2010

# Synthetic
## Valparaiso record

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



# Geothecnical Data

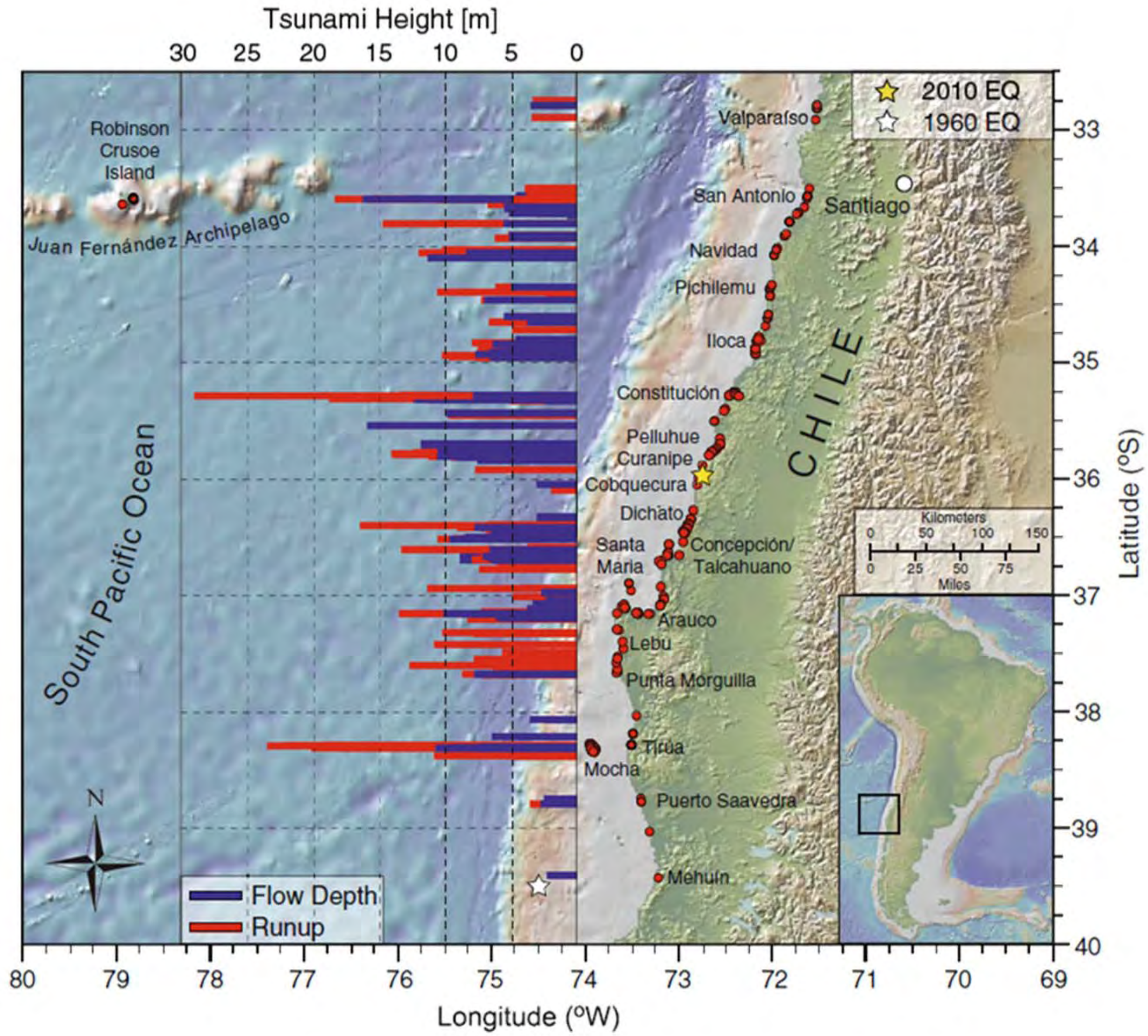



| Dam | Construction year | Type | Height (m) | Crest Length (m) | Distance to Epicenter (Km) |
|---|---|---|---|---|---|
| Lliu Lliu | | Rockfill | 20 | 530 | 340 |
| Rapel | 1968 | Concrete arch | 90 | 330 | 230 |
| Colbun | 1985 | Earthfill | 110 | 670 | 130 |
| Pehuenche | 1991 | Earthfill | 80 | 370 | 150 |
| Cipreces | 1955 | Gravity pipes | | | 175 |
| Cioihueco | | 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 |

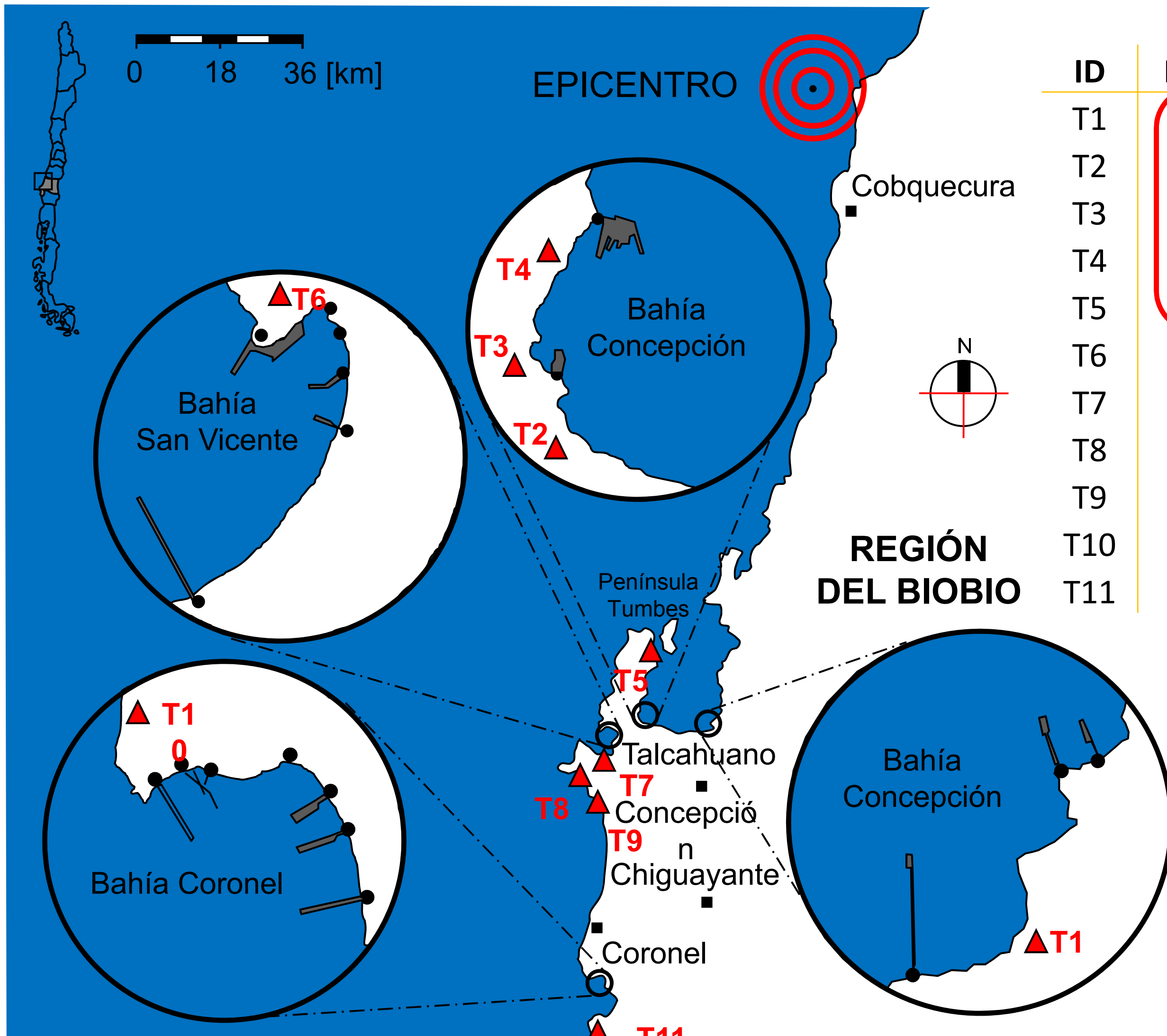
*Source: GEER Report*

# Tsunami


Tsunami Data



# Tsunami
## Port area




| ID | Run-up (m) | Inundation (m) |
|---|---|---|
| T1 | 5.2 - 5.7 | 68.8 - 81.0 |
| T2 | 5.2 - 8.0 | 159.0 - 261.3 |
| T3 | 6.6 | 340.3 |
| T4 | 7.4 | 166.6 |
| T5 | 4.6 - 13.3 | 54.4 - 136.8 |
| T6 | 3.4 | 44.1 |
| T7 | 6.1 | 50.9 |
| T8 | 3.0 | 45.7 |
| T9 | 2.9 | 67.6 - 73 |
| T10 | 1.9 | 20.0 |
| T11 | 2.4 | 25.0 |

03

# 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) 22 Mar 2010

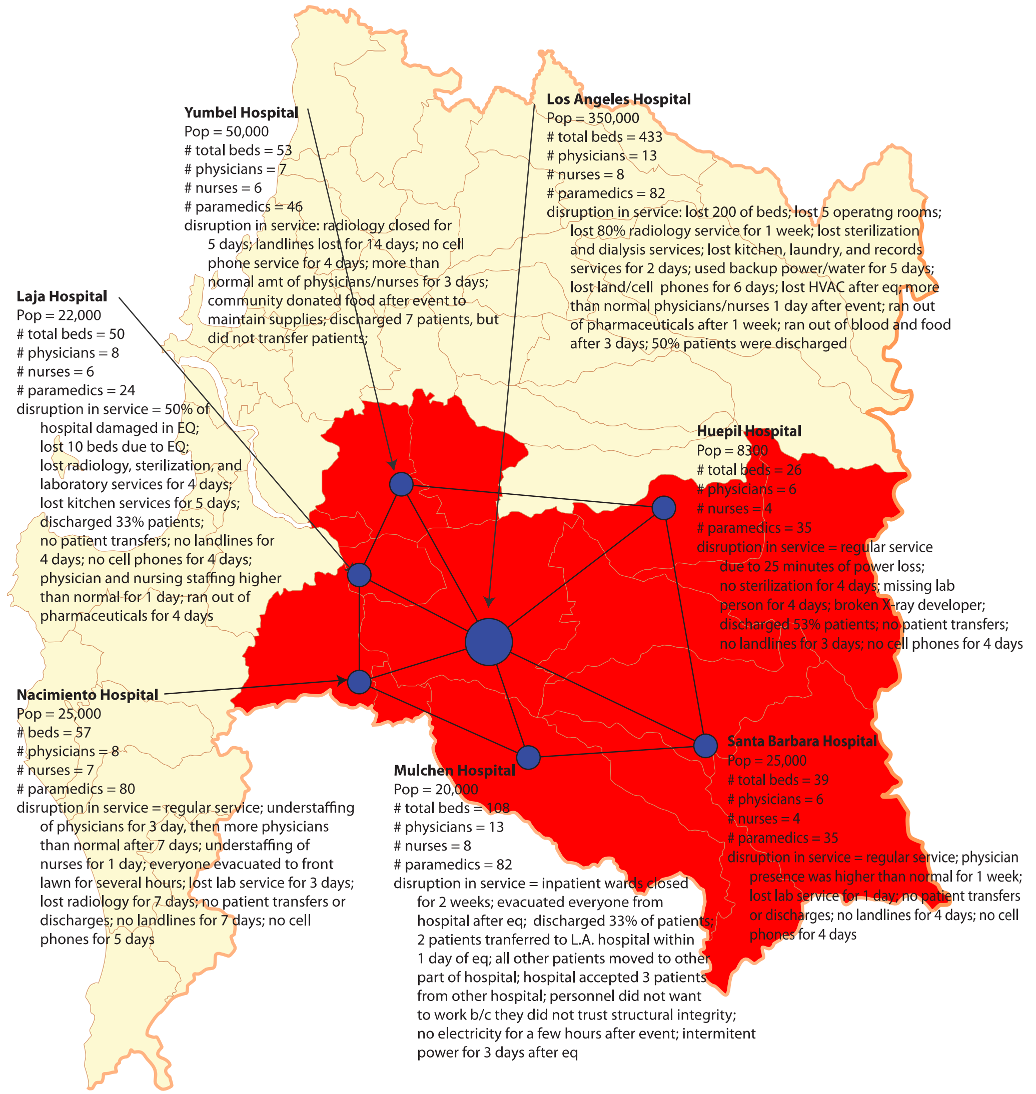
# Findings

# 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



Yumbel Hospital
Pop = 50,000
# total beds = 53
# physicians = 7
# nurses = 6
# paramedics = 46
disruption in service: radiology closed for 5 days; landlines lost for 14 days; no cell phone service for 4 days; more than normal amt of physicians/nurses for 3 days; community donated food after event to maintain supplies; discharged 7 patients, but did not transfer patients;
Los Angeles Hospital
Pop = 350,000
# total beds = 433
# physicians = 13
# nurses = 8
# paramedics = 82
disruption in service: lost 200 of beds; lost 5 operatng rooms; lost 80% radiology service for 1 week; lost sterilization and dialysis services; lost kitchen, laundry, and records services for 2 days; used backup power/water for 5 days; lost land/cell phones for 6 days; lost HVAC after eq; more than normal physicians/nurses 1 day after event; ran out of pharmaceuticals after 1 week; ran out of blood and food after 3 days; 50% patients were discharged
Laja Hospital
Pop = 22,000
# total beds = 50
# physicians = 8
# nurses = 6
# paramedics = 24
disruption in service = 50% of hospital damaged in EQ; lost 10 beds due to EQ; lost radiology, sterilization, and laboratory services for 4 days; lost kitchen services for 5 days; discharged 33% patients; no patient transfers; no landlines for 4 days; no cell phones for 4 days; physician and nursing staffing higher than normal for 1 day; ran out of pharmaceuticals for 4 days
Huepil Hospital
Pop = 8300
# total beds = 26
# physicians = 6
# nurses = 4
# paramedics = 35
disruption in service = regular service due to 25 minutes of power loss; no sterilization for 4 days; missing lab person for 4 days; broken X-ray developer; discharged 53% patients; no patient transfers; no landlines for 3 days; no cell phones for 4 days
Nacimiento Hospital
Pop = 25,000
# beds = 57
# physicians = 8
# nurses = 7
# paramedics = 80
disruption in service = regular service; understaffing of physicians for 3 day, then more physicians than normal after 7 days; understaffing of nurses for 1 day; everyone evacuated to front lawn for several hours; lost lab service for 3 days; lost radiology for 7 days; no patient transfers or discharges; no landlines for 7 days; no cell phones for 5 days
Mulchen Hospital
Pop = 20,000
# total beds = 108
# physicians = 13
# nurses = 8
# paramedics = 82
disruption in service = inpatient wards closed for 2 weeks; evacuated everyone from hospital after eq; discharged 33% of patients; 2 patients tranferred to L.A. hospital within 1 day of eq; all other patients moved to other part of hospital; hospital accepted 3 patients from other hospital; personnel did not want to work b/c they did not trust structural integrity; no electricity for a few hours after event; intermitent power for 3 days after eq
Santa Barbara Hospital
Pop = 25,000
# total beds = 39
# physicians = 6
# nurses = 4
# paramedics = 35
disruption in service = regular service; physician presence was higher than normal for 1 week; lost lab service for 1 day; no patient transfers or discharges; no landlines for 4 days; no cell phones for 4 days

# 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

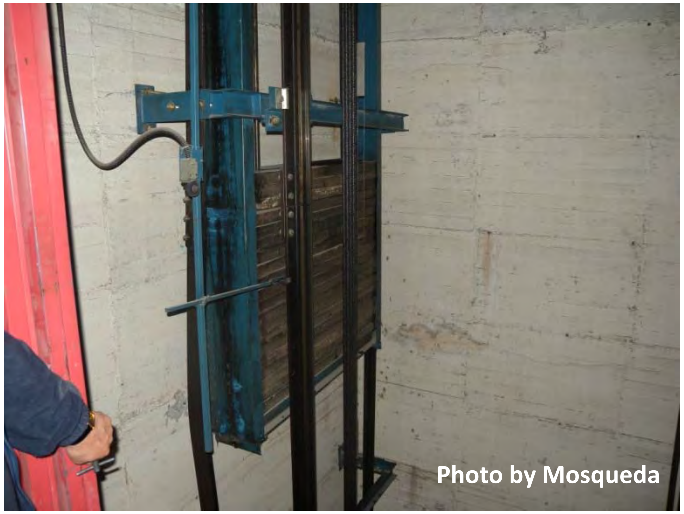
# Hospital Functions Disrupted:
## Patient Wards Evacuated

- 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

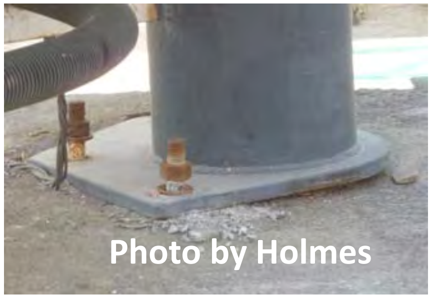
# Water Damage

- 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

# Non-Structural Damage

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

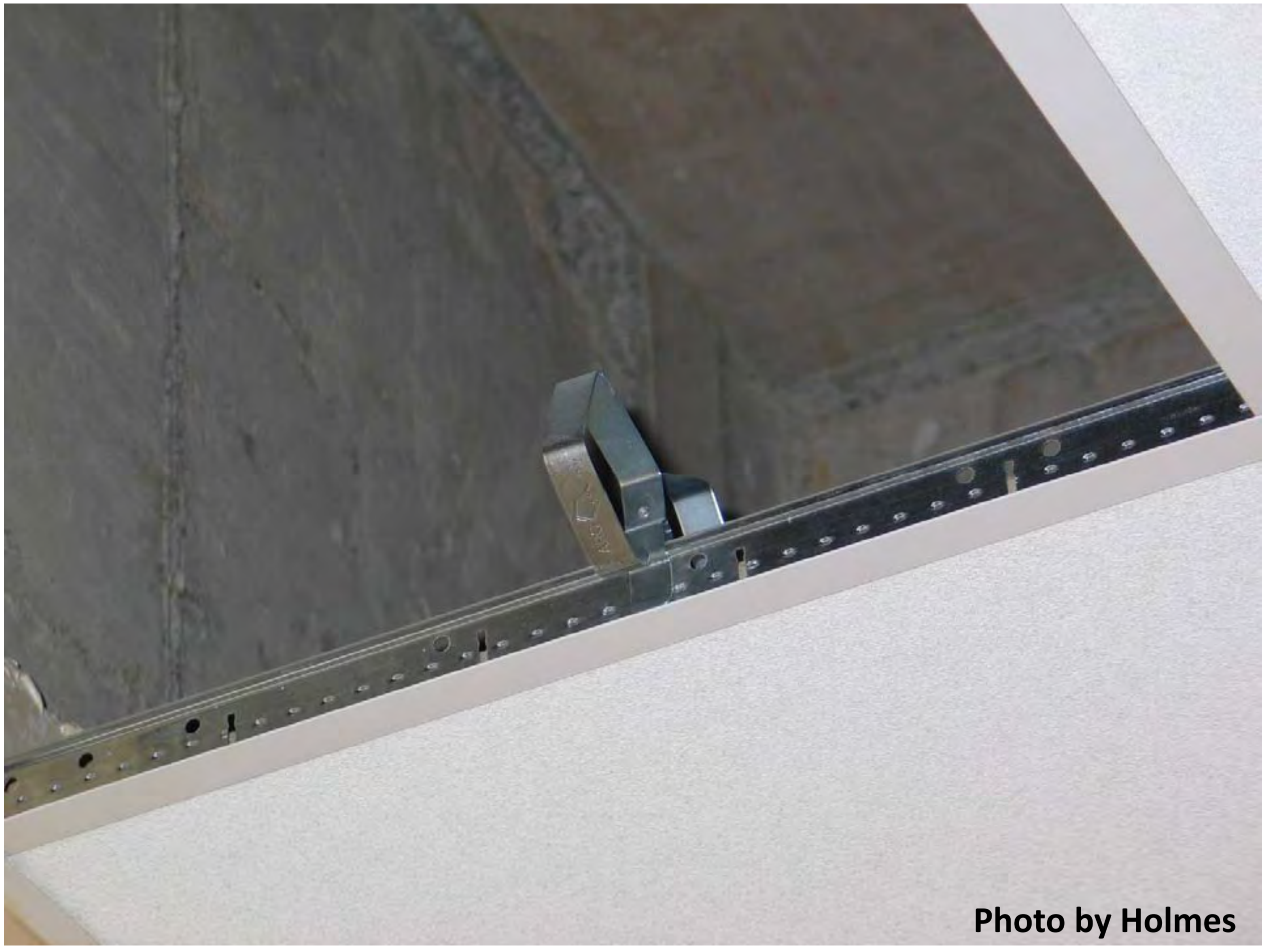


Photo by Holmes

# Non-Structural Damage

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

# 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)

# Non-Structural Damage

- Apparently vulnerable areas like **paper medical records, pharmacies, and laboratories**
    - Usually damaged only when building had other nonstructural damage

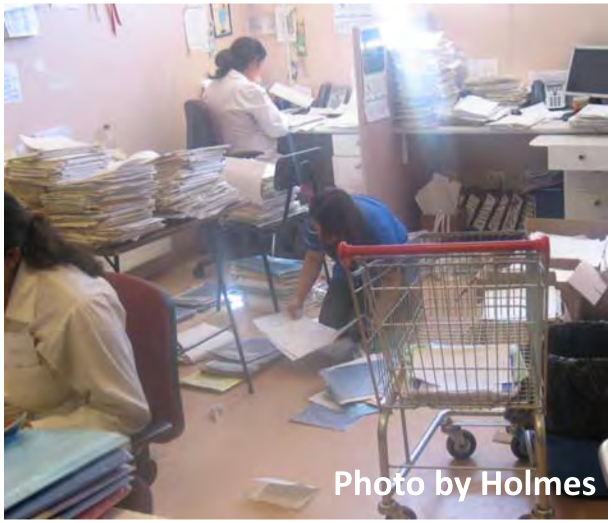
- **Medical Equipment**
    - Usually damaged only when building had other nonstructural damage
    - Damage to radiological equipment recorded

# Non-Structural Damage

- Essentially unstable medical record storage—undamaged. Nacimiento.

# Non-Structural Damage

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



# 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

# 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

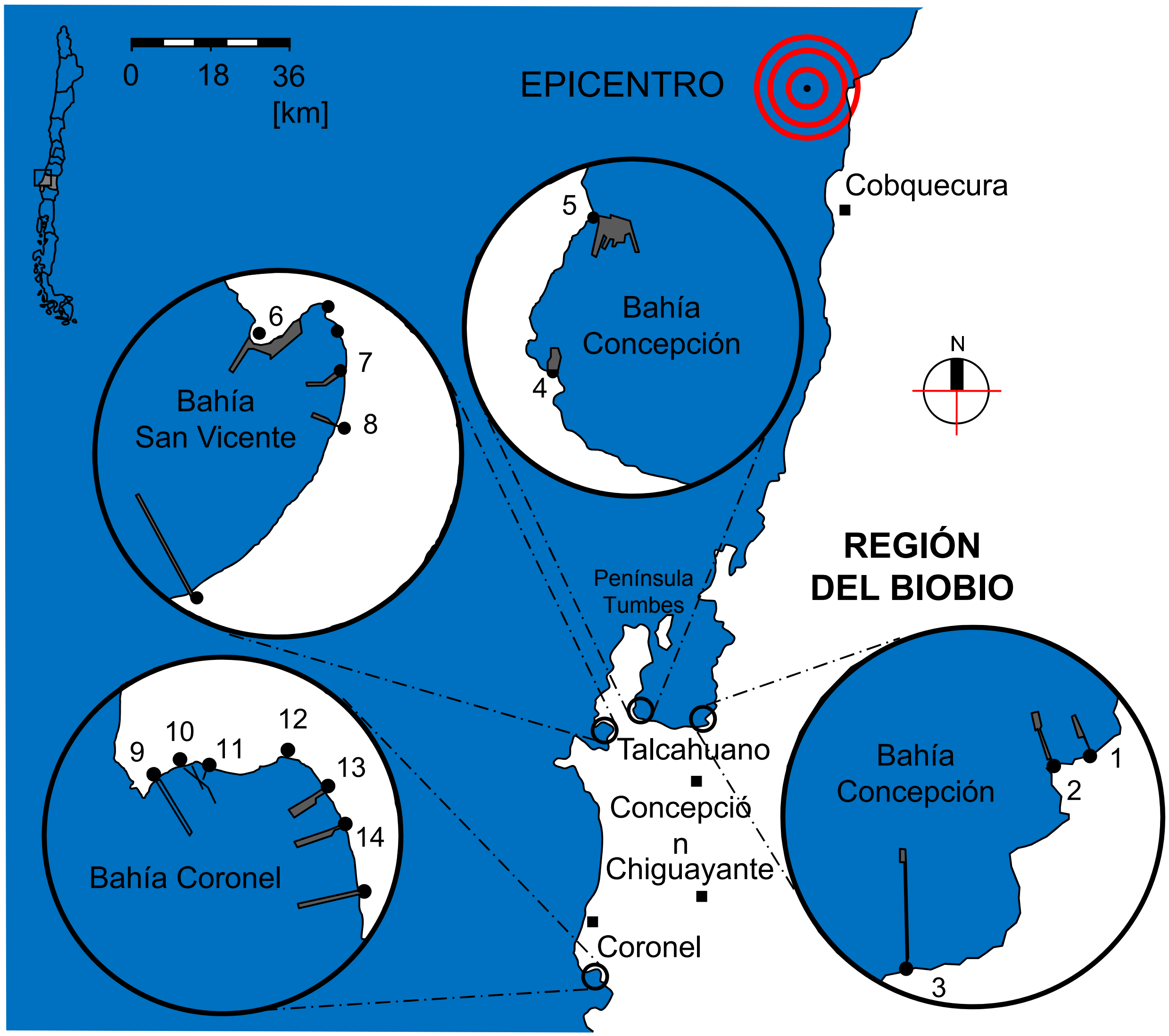
# Acknowledgements


- 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

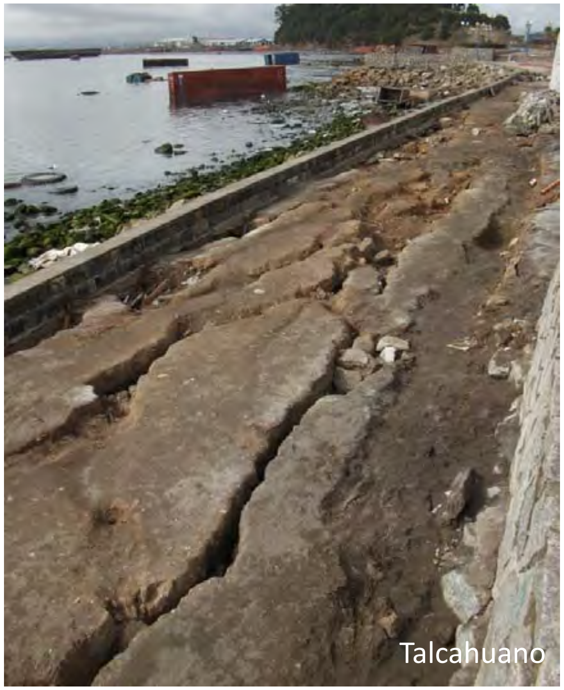
# Port Location



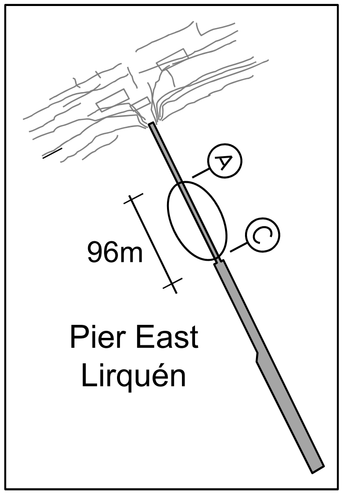

| ID | Muelle |
|---|---|
| 1 | Lirquén Este |
| 2 | Lirquén Oeste |
| 3 | Penco |
| 4 | Talcahuano |
| 5 | Asmar |
| 6 | San Vicente |
| 7 | Enap |
| 8 | Huachipato |
| 9 | Puchoco |
| 10 | Jureles |
| 11 | Chollín |
| 12 | Lo Rojas |
| 13 | Coronel Norte |
| 14 | Coronel Sur |

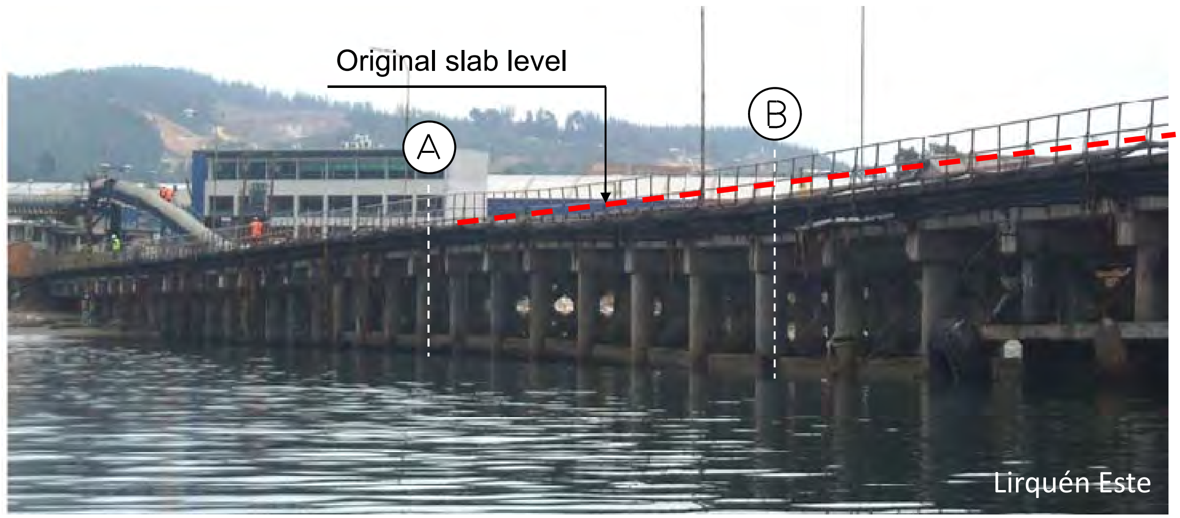
# Liquefaction

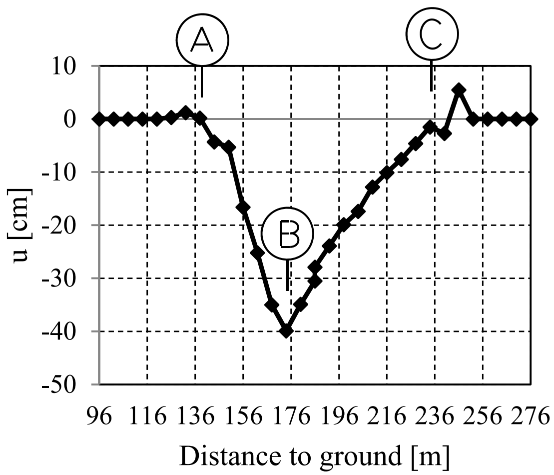
- Saturated and loose sands $(\sigma_n = \sigma_n^{'} + u_w)$
- Consequences:
  - Temporary loss of support and stiffness

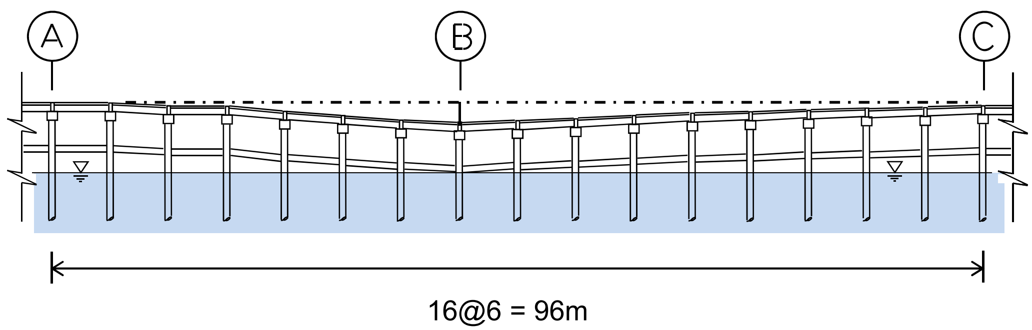



# Permanent settelments

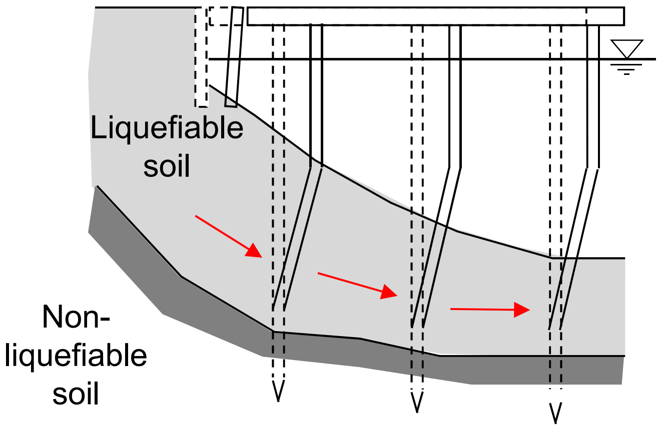


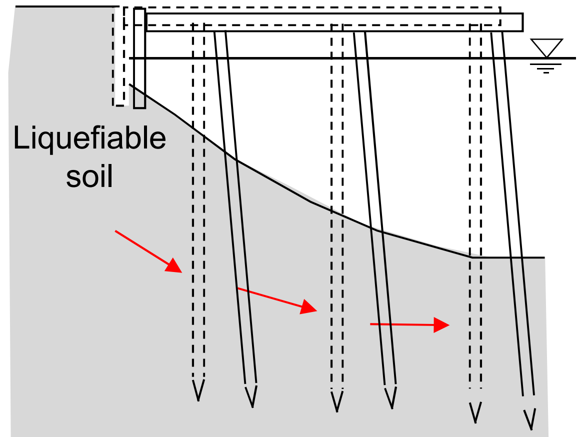



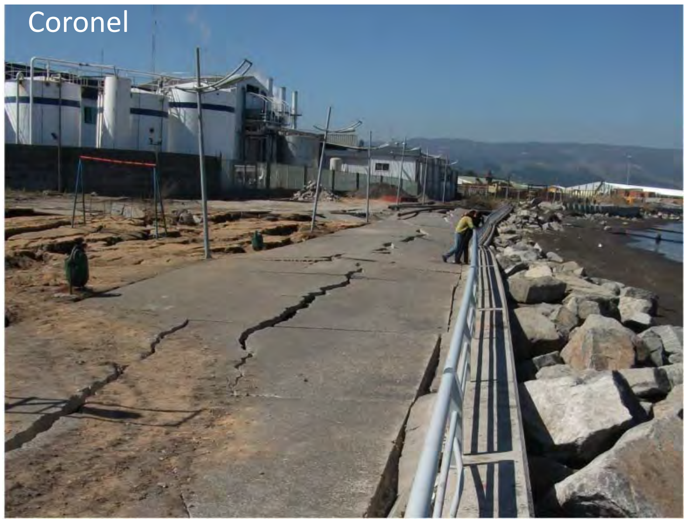



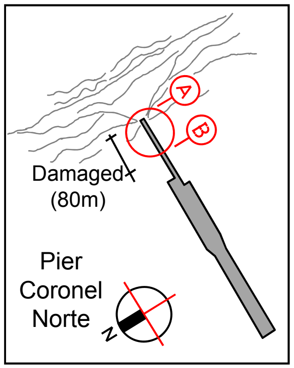
# Lateral spreading



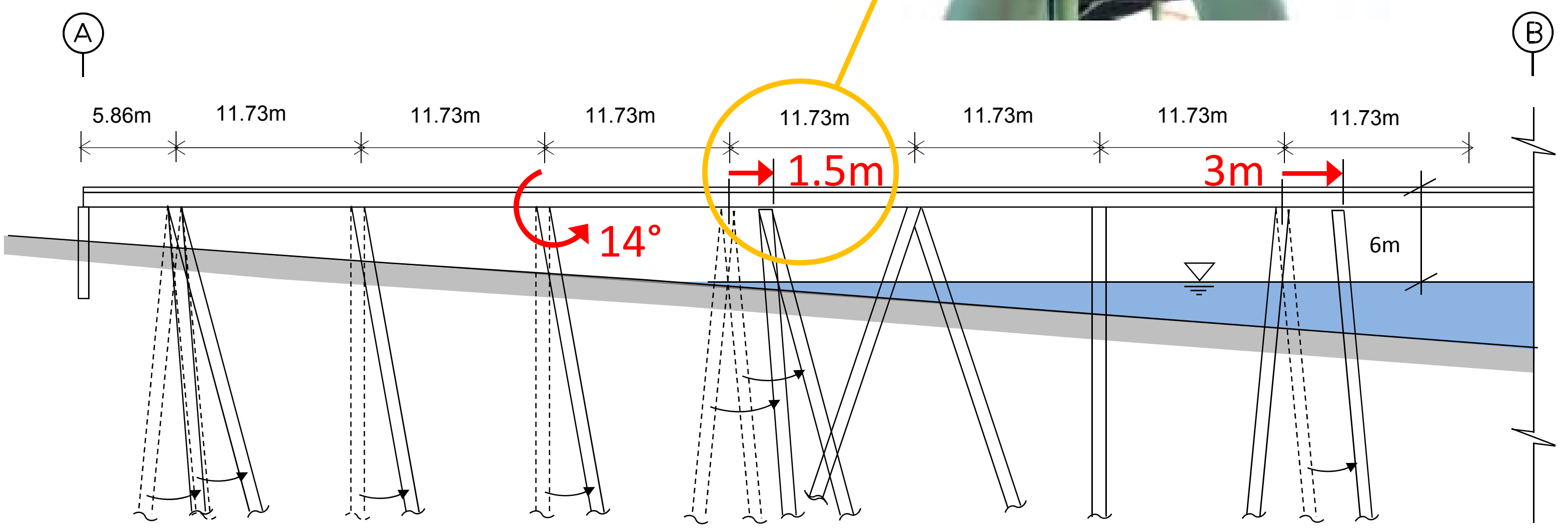




# Drag of foundation systems



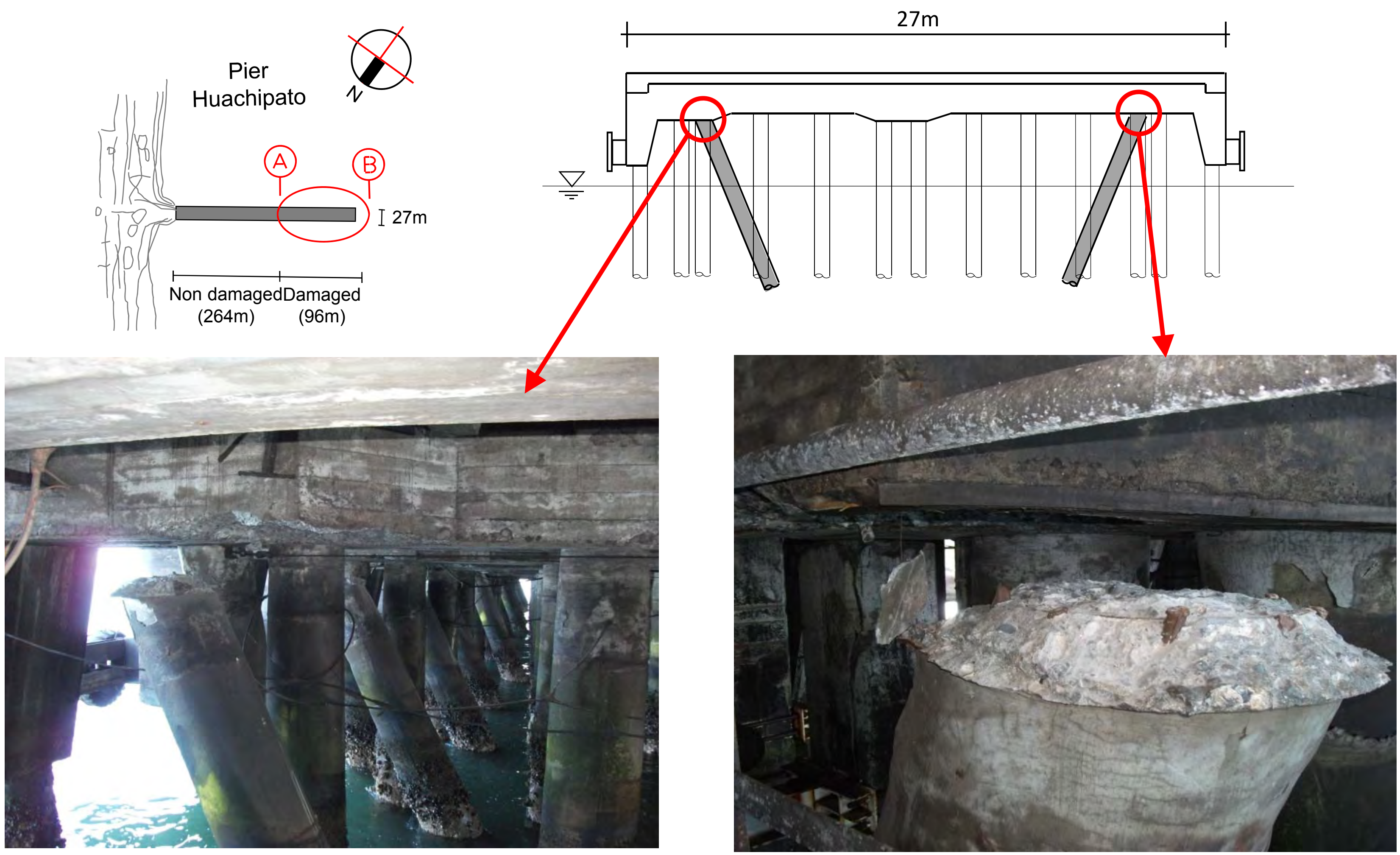




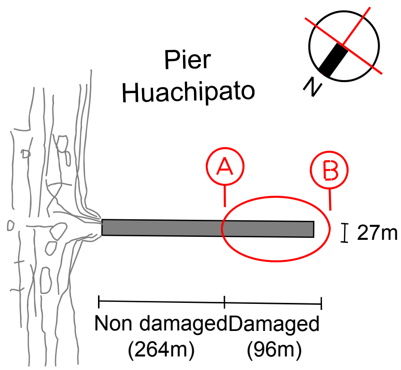
# Beam-pile connection

- Slanted piles are laterally very stiff

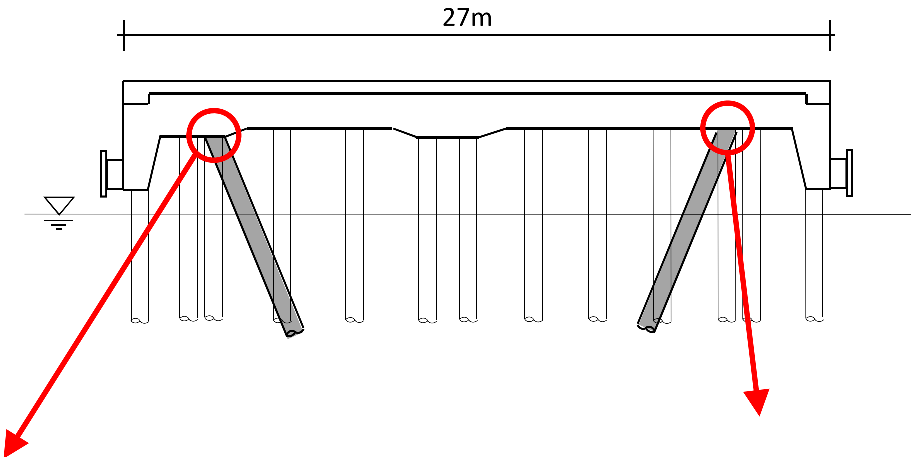

# Torsion



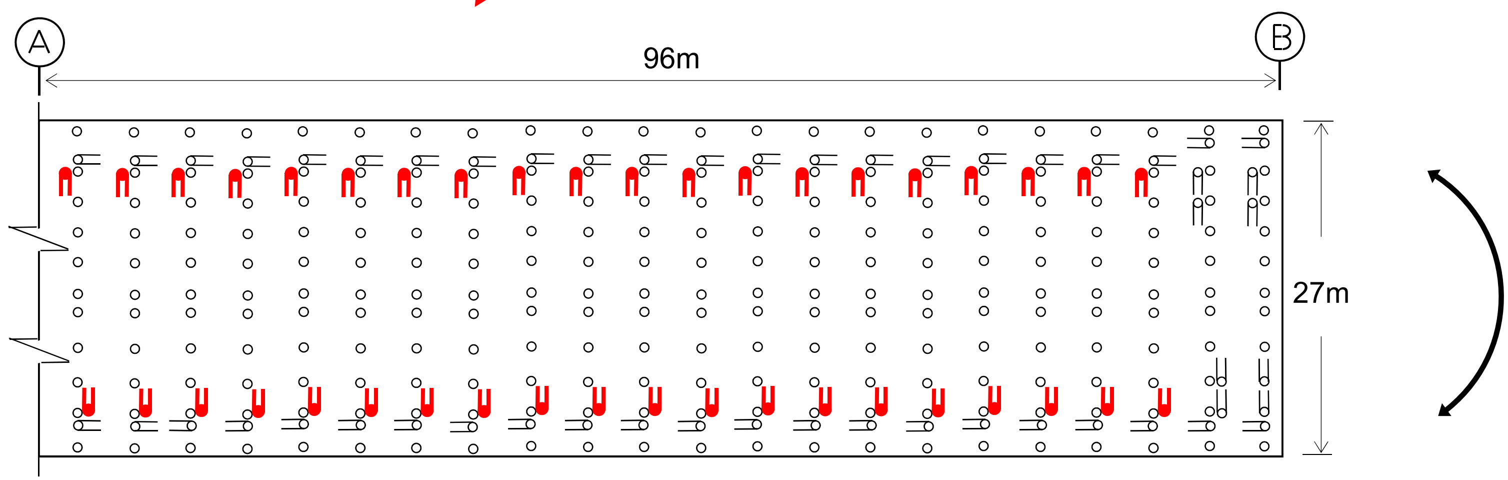
# Torsion



Pier
Huachipato
N
A
B
27m
Non damaged
(264m)
Damaged
(96m)

27m

A
B
96m
27m

# Access joints

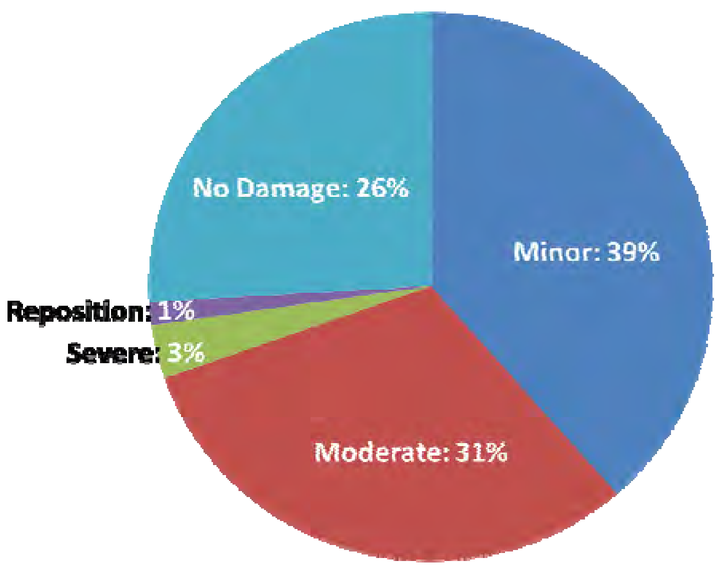

Lo Rojas


Jureles


Coronel Sur

# K-12 Public Schools

▶ State of public schools after the earthquake




▶ Schools in RESCATE Project


- 51 schools
- Structural assessment and retrofit projects

# Schools
## Preliminary inspection

▶ **Rapid inspection and damage assessment**

INGENIERÍA DICTUC

PROYECTO RESCATE
FICHA GENERAL POR ESTABLECIMIENTO

Cód. Establecimiento: 3387

| ESTABLECIMIENTO | FECHA INICIO | FICHA Nº |
|---|---|---|
| LICEO FEDERICO HEISE MARTI - CUERPO 1 - EDIFICIO ACCESO | 28/01/2011 | 1 / 4 |

| DIRECCIÓN | COMUNA | REGIÓN | ÁREA GEO. |
|---|---|---|---|
| URRUTIA S/N | PARRAL | 7 | URBANA |

| NOMBRE CONTACTO | CARGO | TELÉFONO | MAIL |
|---|---|---|---|
| Marcela Guzmán | Arquitecta SECPLAN | 73-637710 | mguzmanarquitecto@gmail.com |

**INFORMACIÓN GENERAL DE ANTECEDENTES**

| ¿Existían planos? | ¿Consistencia con terreno? | Año recepción | Otros antecedentes: |
|---|---|---|---|
| Sí | No | - | |

**INFORMACIÓN GENERAL DE LA ESTRUCTURA**

| Niveles sobre terreno | 3 | ¿Estructura rectangular? | Sí | Área en planta [m²] | 3474 |
|---|---|---|---|---|---|

| Materialidad | | Sistema de piso | | Sistema de tabiquería | |
|---|---|---|---|---|---|
| Hormigón Armado (H.A.) | | Losas de H.A. | X | Placas de yeso cartón | X |
| Albañilería Armada (A.A.) | | Losas aligeradas | | Placas de fibrocemento | |
| Albañilería Confinada (A.C.) | X | Vigas de madera | | Placas de OSB | |
| Albañilería Simple (A.S.) | | Vigas de acero | | Ladrillo pandereta | |
| Otro: | | Otro: | | Otro: | |

**Observaciones adicionales:**
Daños importantes en albañilería confinada y columnas de hormigón armado de segundo y tercer piso.

**RESUMEN GENERAL VISITA A TERRENO**

| Nº días de inspección | 2 | Fotografías | 8769, 8771 a 8775 | Ingeniero responsable inspección |
|---|---|---|---|---|
| Nº personas inspección | 3 | Video | 8540 | Carl Lüders |

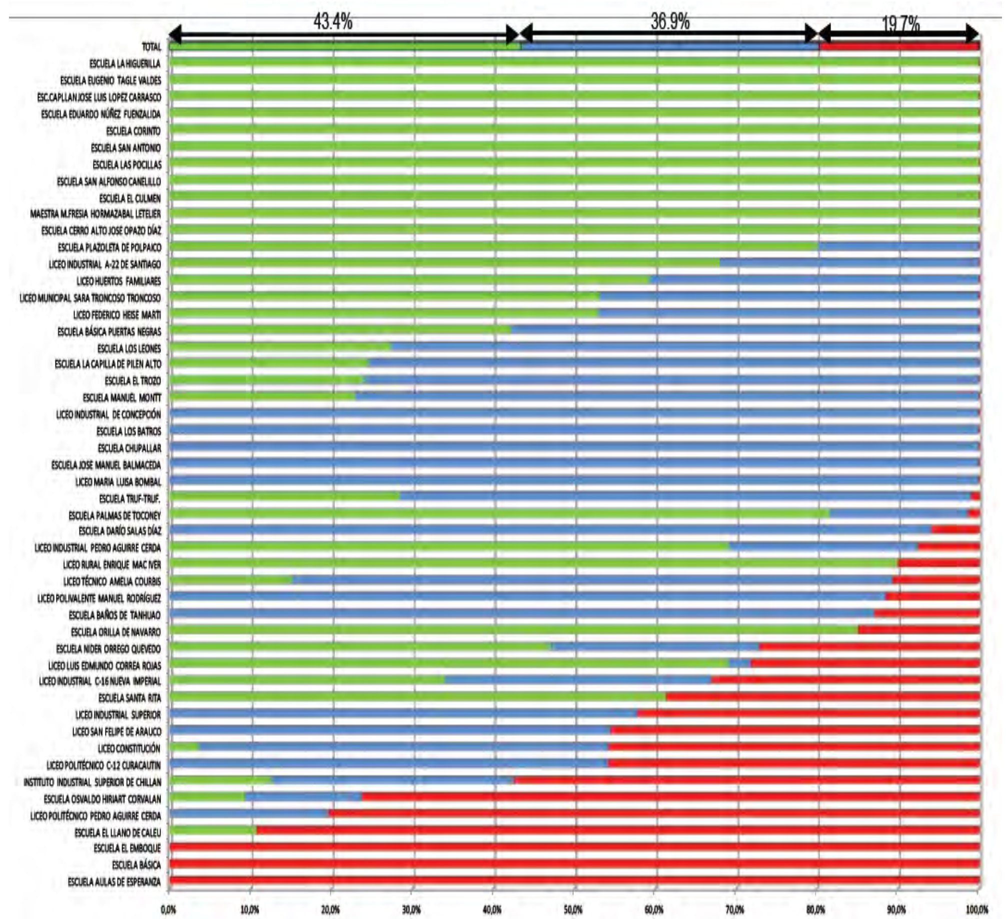
**ESTADO GENERAL DE LA ESTRUCTURA**

| | | | | |
|---|---|---|---|---|
| Sin daño | | Daño Severo | X | Comentarios: El edificio tiene daño moderado a severo, concentrado en determinados puntos de la estructura. Sin embargo, existe la factibilidad de recuperación. De acuerdo a esto, se recomienda desarrollar un proyecto detallado de reparación y refuerzo. |
| Daño leve | | Colapso | | |
| Daño moderado | | | | |

**MAPA Y/O FOTOGRAFÍA DEL ESTABLECIMIENTO**



▶ **Damage Level in RESCATE Schools**

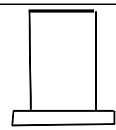
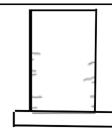
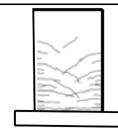
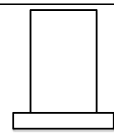
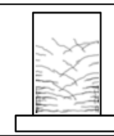
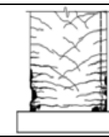
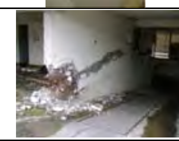
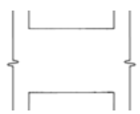
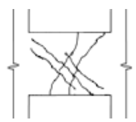
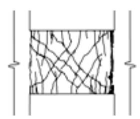
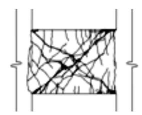
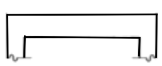
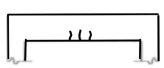
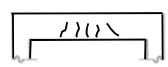
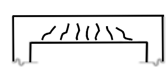
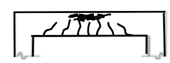
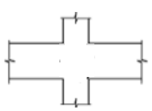
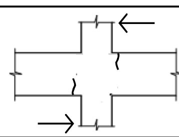
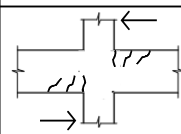
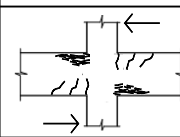
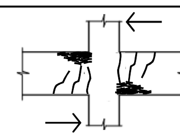
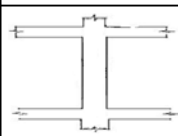
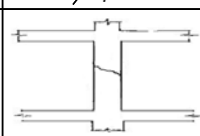
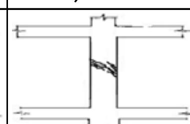
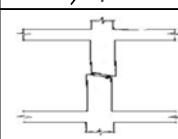




No damage/ repaired | Light/moderate damage | Severe damage/ collapse

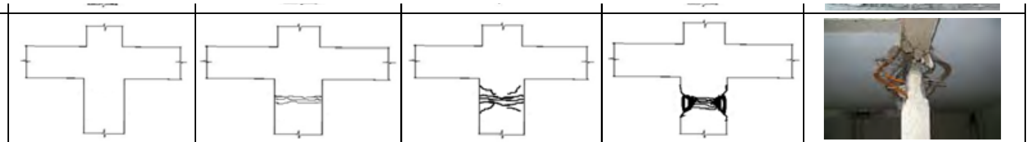
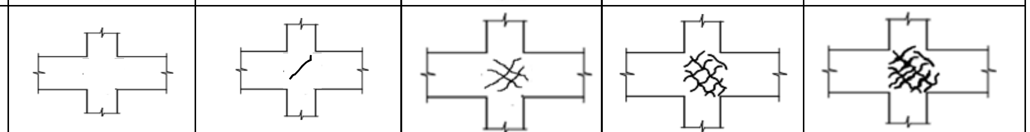
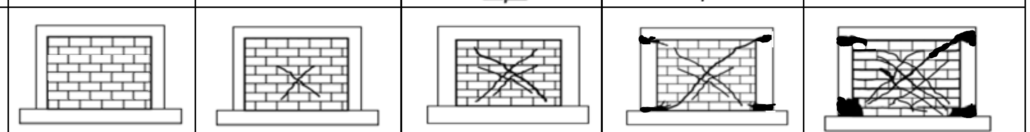
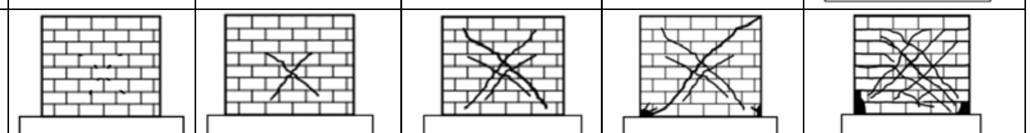
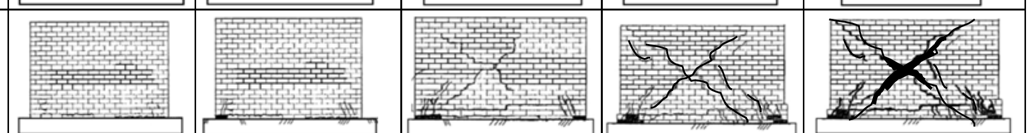
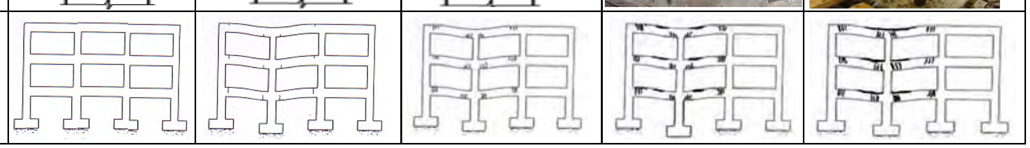
# Schools
## Detailed inspection

### ▶ Structural damage by element

| | Sin Daños ✔ | Daño Leve | Daño Medio | Daño Severo | Colapso ✖ |
|---|---|---|---|---|---|
| **Elementos Hormigón armado** | 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 |  |  |  |  |  |

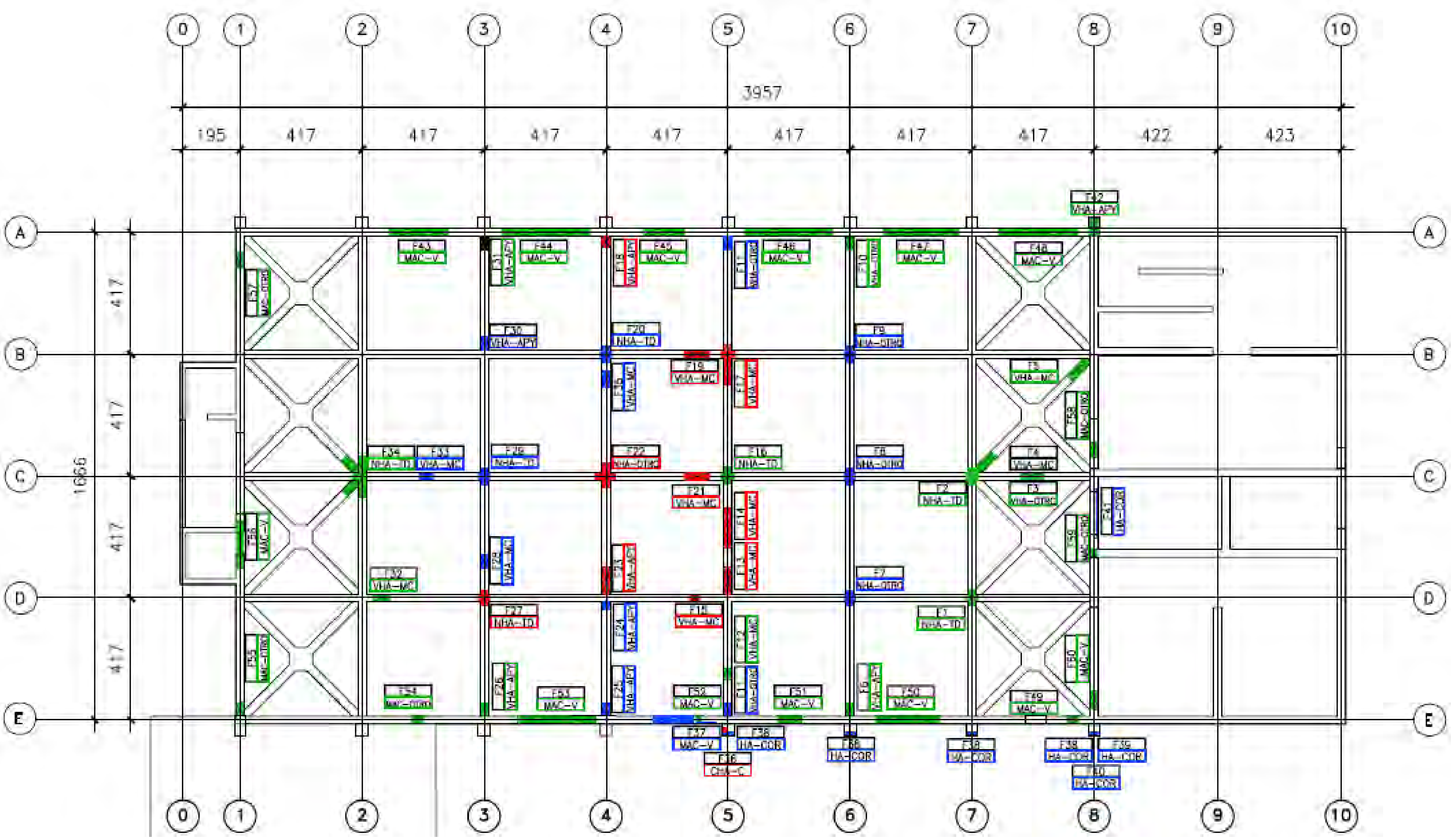
# Schools
## Detailed inspection

### 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 |  |

# Schools
## Detailed inspection

**Structural damage by element**



# Schools
## Detailed inspection

### ▶ Structural elements

**INGENIERÍA DICTUC** — FICHA DE INSPECCIÓN — ELEMENTO ESTRUCTURAL DAÑADO — Cód. Establecimiento: **3165**

| INSPECCIONÓ | Ingeniero Responsable | Fecha | Ficha N° | Total | Fotografías |
|---|---|---|---|---|---|
| Nestor Aguirre | Hernán Santa María | 21/01/11 | 6 | 67 | 6 |

| | ELEMENTO ESTRUCTURAL - MATERIALIDAD - TIPO DE DAÑO | 1 Leve | 2 Medio | 3 Severo | 4 Colapso |
|---|---|---|---|---|---|
| A | Muro H.A. falla corte | | | | |
| B | Muro H.A. falla flexocompresión | | | | |
| C | Viga H.A. falla corte | | | | |
| D | Viga H.A. falla flexocompresión | | | | |
| 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): Formación rótula en el apoyo. | X | | | |

Información Adicional
¿Existe Fisuración? SI
Ancho Promedio Fisuras: 1,2 - 1,7 [mm]
Observaciones Adicionales:

| DIMENSIONES Y UBICACIÓN DEL ELEMENTO | Sección L[cm]xh[cm] / Área losas a[cm]xb[cm] | Espesor[cm] | | |
|---|---|---|---|---|
| | - x - | - | Piso | - |
| | | | Ejes N-S | 6 |
| | | | Ejes 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 | |
| Escalerillas | | 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**

| INSPECCIONÓ | Ingeniero Responsable | Fecha | Ficha N° |
|---|---|---|---|
| Pablo Fernández | Matías Hube | 28/01/2011 | 2 / 36 |

| RECINTO | | | Otras indicaciones (si corresponde): |
|---|---|---|---|
| Pabellón A- Sala 3 | Piso | 1 | - |
| | 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. | - | - | - | 0302 |
| 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.

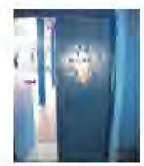
| Descripción | Materialidad | Patología | Nivel daño | Otra materialidad (especificar) |
|---|---|---|---|---|
| Elemento vertical | H.A. | - | - | - |
| Revestimiento | PIN | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| Altura revestimiento: | 3 [m] | N° puertas: | 0 | Daño: | - |
| Fotografías: | 0303 a 0304 | N° vent.: | 0 | Daño: | - |

| Descripción | Materialidad | Patología | Nivel daño | Otra materialidad (especificar) |
|---|---|---|---|---|
| Elemento vertical | H.A. | DESC | Leve | - |
| Revestimiento | PIN | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| Altura revestimiento: | 3 [m] | N° puertas: | 0 | Daño: | - |
| Fotografías: | 0310 | N° vent.: | 12 | Daño: | - |

Fotografía 0304



Fotografía 0306

Fotografía 0310

Fotografía 0309

| Descripción | Materialidad | Patología | Nivel daño | Otra materialidad (especificar) |
|---|---|---|---|---|
| Elemento vertical | H.A. | - | - | - |
| Revestimiento | PIN | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| Altura revestimiento: | 3 [m] | N° puertas: | 2 | Daño: | DPU |
| Fotografías: | 0305 a 0306 | N° vent.: | 13 | Daño: | - |

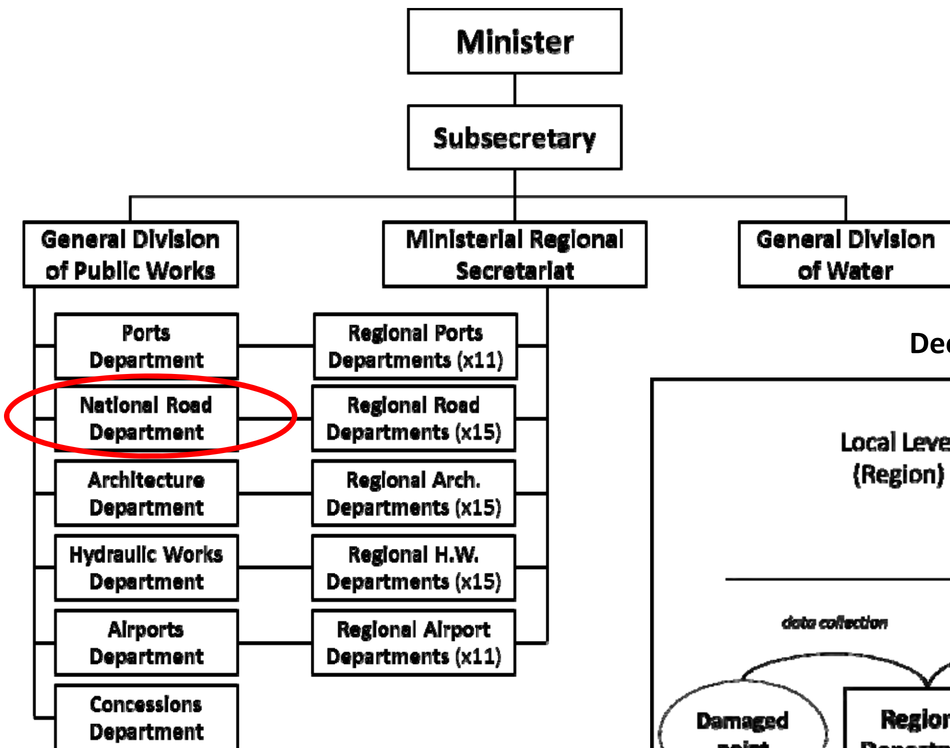
| Descripción | Materialidad | Patología | Nivel daño | Otra materialidad (especificar) |
|---|---|---|---|---|
| Elemento vertical | H.A. | - | - | - |
| Revestimiento | PIN | - | - | - |

| | | | | | |
|---|---|---|---|---|---|
| Altura revestimiento: | 3 [m] | N° puertas: | 0 | Daño: | - |
| Fotografías: | 0307 a 0309 | N° vent.: | 0 | Daño: | - |

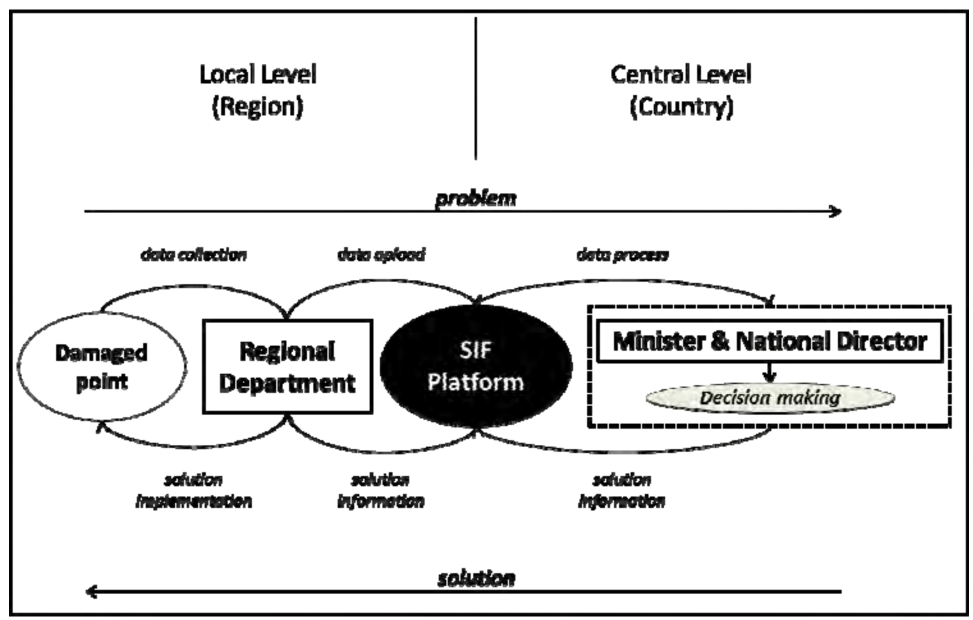
| INSTALACIONES | ¿En funcionamiento? | Descripción del daño (en caso que corresponda) | Fotografías |
|---|---|---|---|
| Agua | - | - | - |
| Electricidad | Sí | Encienden 4 de 14 tubos fluorescentes. | - |
| Gas | - | - | - |
| Alcantarillado | - | - | - |

Road Network

## 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

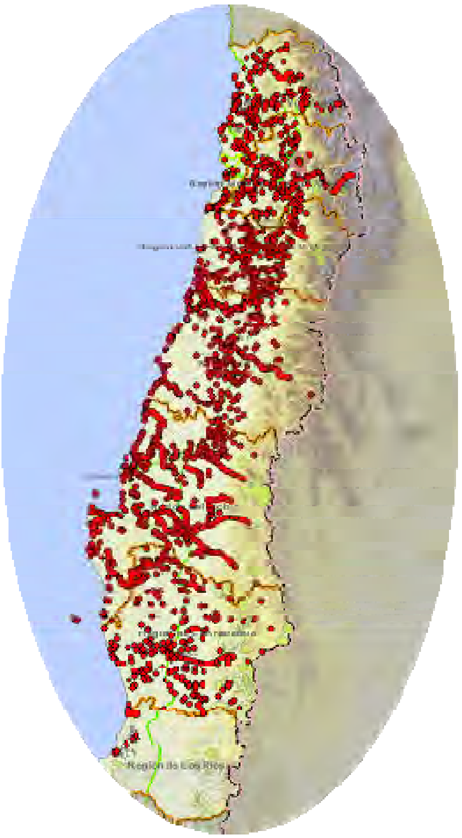
**Failure and solution process Llacolén Bridge, Bíobío Region**

# Road Network
## Public-private partnership model

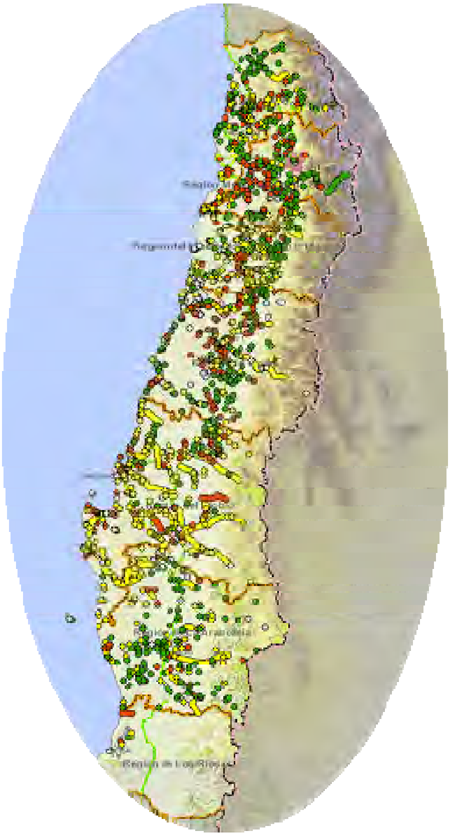
- **Failure and solution process Claro River bridge**

# Road Network
## Sif platform

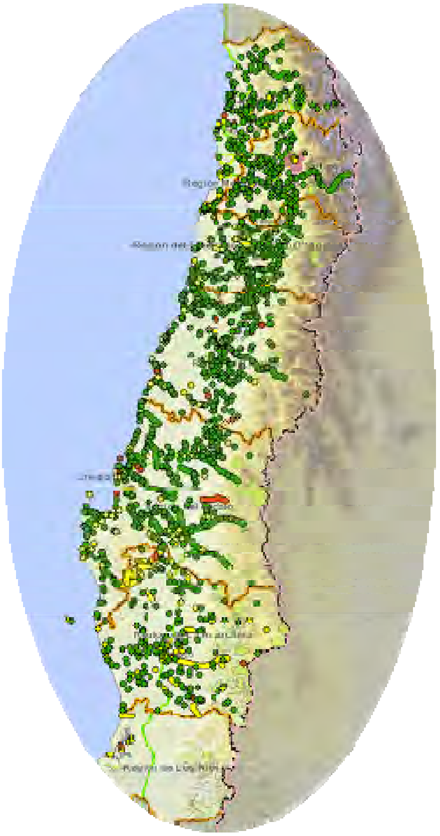
▶ **February 2010**

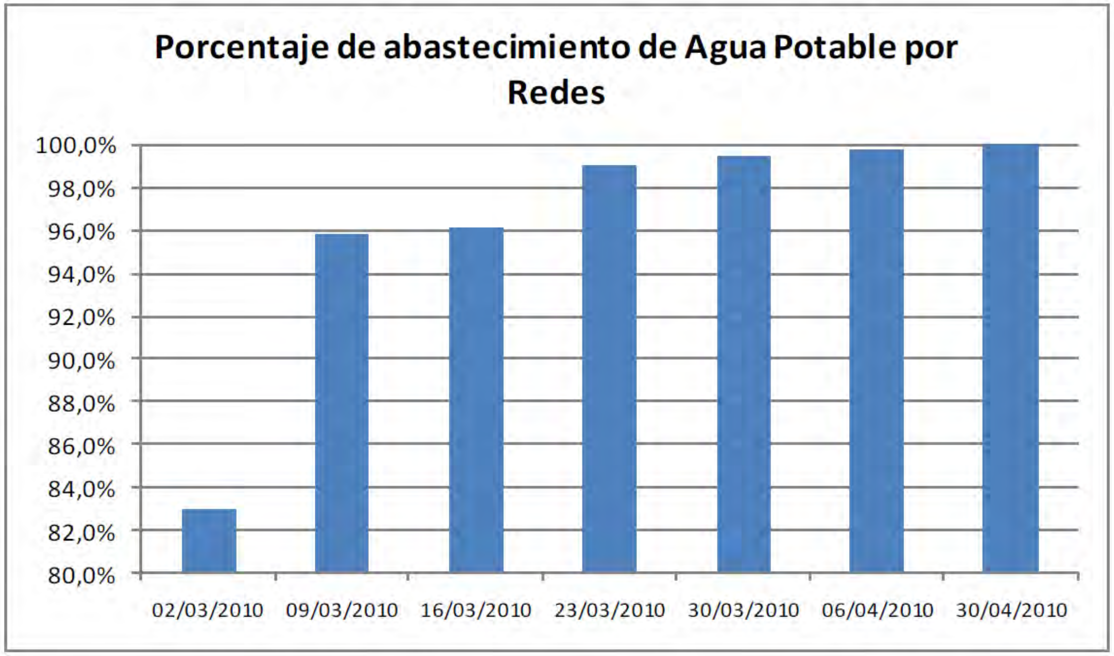


▶ **March 2010**



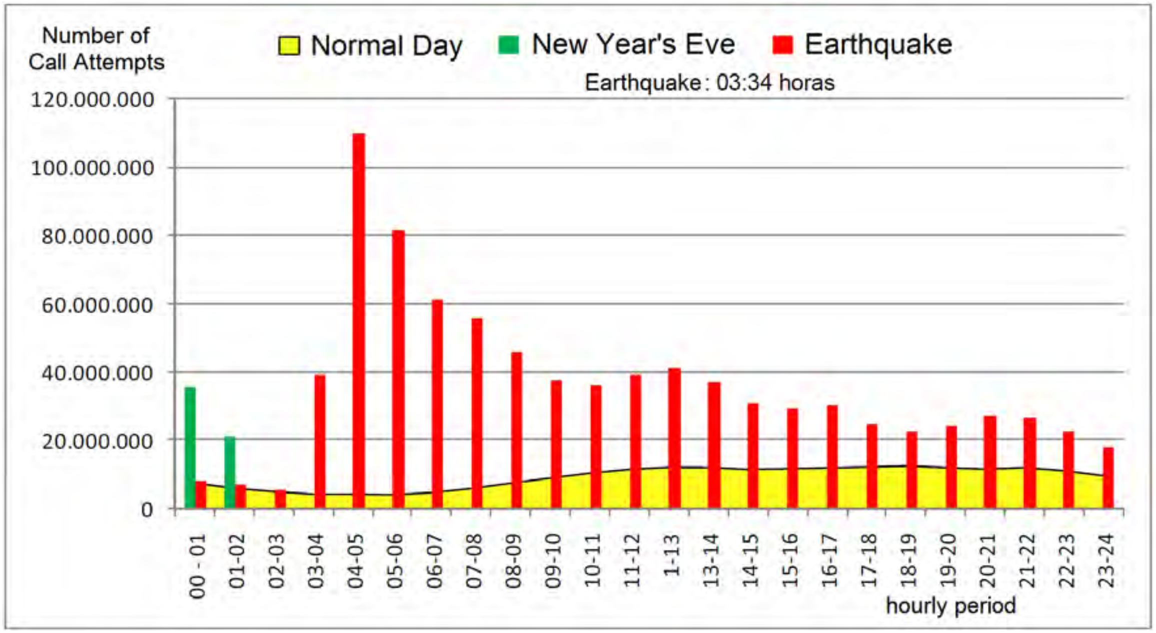
▶ **August 2010**

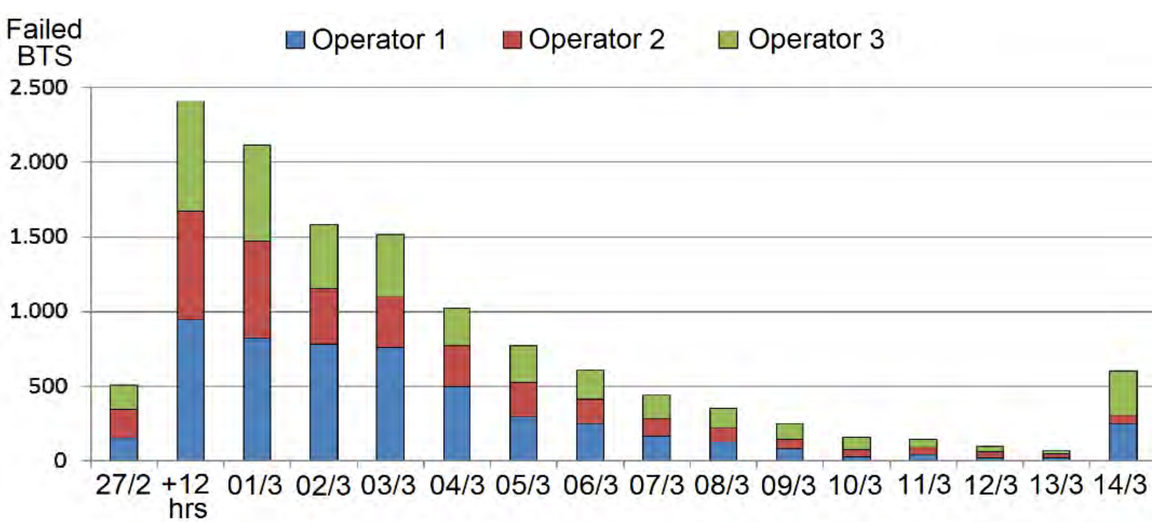




Porcentaje de abastecimiento de Agua Potable por Redes
100,0%
98,0%
96,0%
94,0%
92,0%
90,0%
88,0%
86,0%
84,0%
82,0%
80,0%
02/03/2010
09/03/2010
16/03/2010
23/03/2010
30/03/2010
06/04/2010
30/04/2010


# Communication system

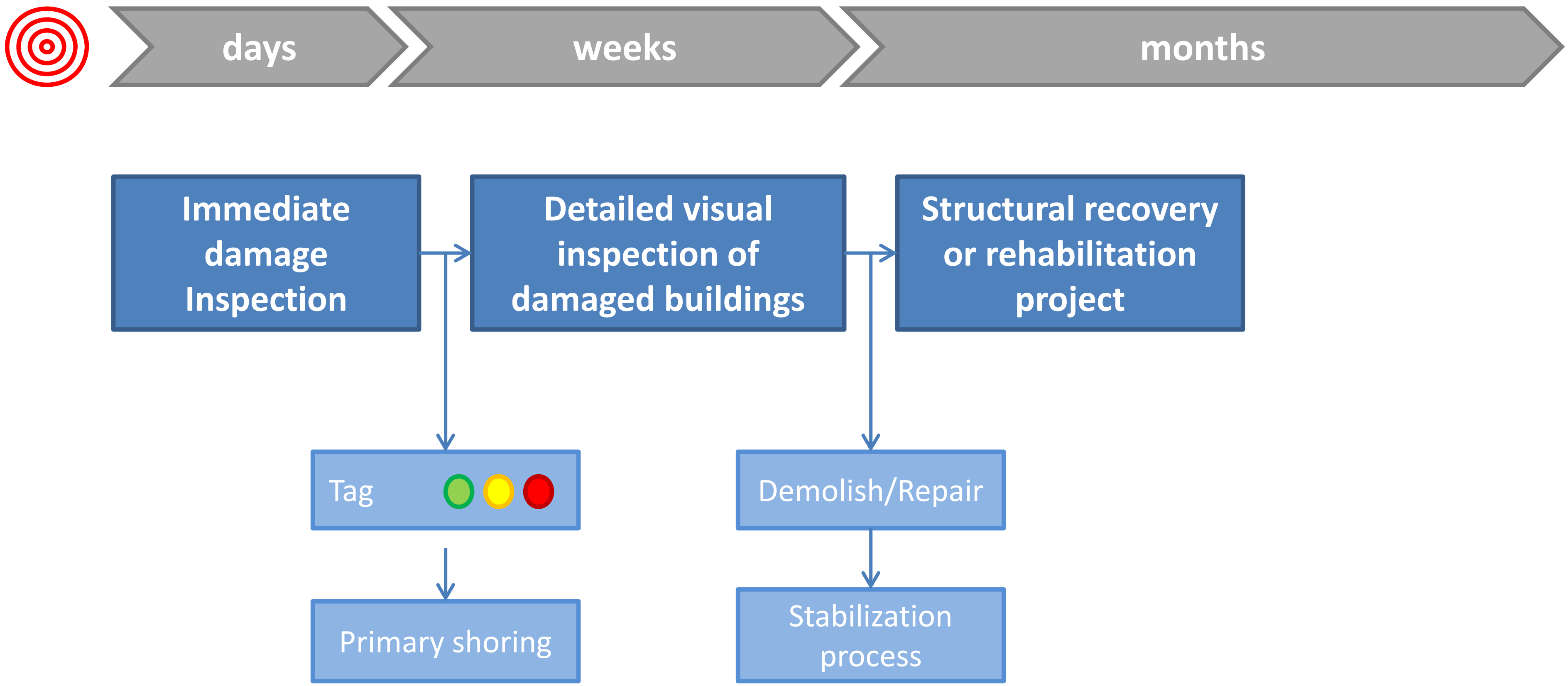


Electric
Power system

# 04 BUILDING DATA

# Data
## Collection process

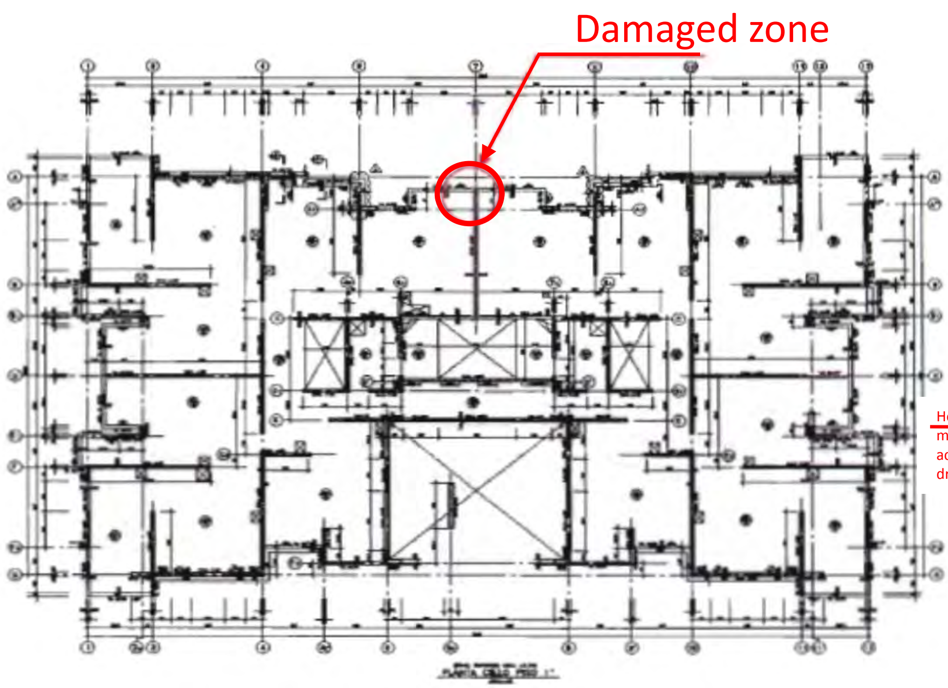


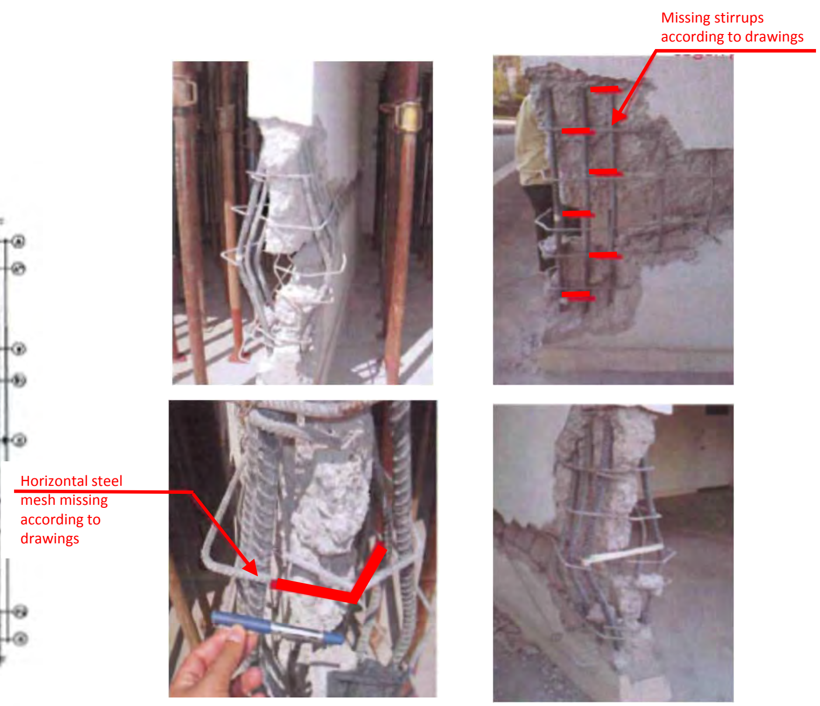
# Data
## Collection process

| Type of Inspection | Immediate damage Inspection | Detailed visual inspection of damaged buildings | Structural recovery or rehabilitation project |
|---|---|---|---|
| **Stakeholder** | Community/owners/local government/constructors | Owners/constructors/local government | Owners/central government |
| **Objective** | 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 |
| **What?** | Global building situation/general building dagta/photographs | Buiding damage information/detalied building data (drawings, soil mechanic reports, etc.) | Detailed damage information by element/ laboratory tests |
| **Who?** | NGO's/volunteers/students/ professionals | Professionals/academics | Professionals/academics |
| **How?** | Different damage inspection reports/non pre-established plan/ on site decisions | Inspection protocols for global damage survey/ internal strategies | Detailed survery of damged elements/ instrumental measaurements |

# Damage inspection in Santiago
## Local engineering offices

**Type of information collected by local offices**



# Immediate damage inspections

- Damage Inspection form

INGENIERÍA DICTUC

FORMULARIO NUMERO

División Ingeniería Estructural y Geotécnica
Área Ingeniería Estructural
Formulario de Evaluación de Intensidad de Daños -Rev. 0

**FORMULARIO DE EVALUACION DE INTESIDAD DE DAÑOS ESTRUCTURALES TRAS SISMO.**

UBICACIÓN: Dirección ____ Comuna ____ Ciudad ____

FORMULARIO NUMERO

Inspección de la Edificación
Exteriores e interiores ◯ Solo exterior ◯ Solo Interior ◯

CLASIFICACIÓN DE HABITABILIDAD
Verde ◯ Amarillo ◯ Naranja ◯ Rojo ◯

**IDENTIFICACION DE LA EDIFICACION**

NOMBRE EDIFICACION

Uso predominante:
1. Residencial 2. Comercial 3. Educacional 4. Salud
5. Hotelero 6. Institucional 7. Industrial 8. Oficinas
9. Bodegas 10. Estacionamientos 11. Otros

De la edificación ____ De la planta baja ____

Número de pisos: Niveles sobre el terreno ____ Subterráneos ____ Total ____

Dimensiones Aproximadas en Planta: Subterráneo Frente (m) Fondo (m); Superestructura Frente (m) Fondo (m)

**ANTIGUEDAD DE LA ESTRUCTURA**

Año de recepción de la estructura (aprox.) ____
Reparaciones Sí ◯ No ◯
Detalle: ____

El nivel de daño en comparación al terremoto de 1985 fue:
Menor ◯ Igual ◯ Mayor ◯ N/A ◯

**ESTADO DE LA EDIFICACION**

Estado general de la Edificación
Revisar la edificación en forma global y detallar las consideraciones 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. Sí 2. No 3. No se pudo determinar
3. Falla o asentamiento de la cimentación
1. Sí 2. No 3. No se pudo determinar
4. Falla en soporte o conservación de estanques
1. No 2. Parcial 3. Total
5. Fallas en cabezales de muros.
1. No 2. Parcial 3. Total

Problemas Geotécnicos
4. Falla en talud o movimiento en masa
1. No 2. Puntual 3. General
5. Asentamiento circundante o licuefacción
1. No 2. Puntual 3. General

**DESCRIPCION DE LA ESTRUCTURA**

Sistema estructural
Hormigón Armado: Sistema de Marcos ◯ Sistema de Muros ◯ Sistemas Mixtos ◯ Prefabricados ◯
Albañilería: Armada ◯ Confinada ◯ No armada ◯ Cerámica ◯ Fiscal ◯
Acero: Pórticos Arriostrados ◯ Pórticos no Arriostrados ◯ Soldado ◯ Apernado ◯ Mixto ◯
Madera: Pórticos y paneles en madera ◯ Pórticos en madera y paneles en otro material ◯
Observaciones: ____

Sistema de Piso
Hormigón Armado: Losa → Maciza ◯ Celular Modular ◯ Alivianada ◯ Vigas ◯
Acero: Placas Colaborantes (Steel Deck) ◯ Vigas de Sección llena ◯ Vigas Reticuladas ◯
Madera: Vigas ◯
Otro ____

Sistema de Techo
Losas de Hormigón Armado ◯ Cerchas de Madera ◯ Tejado (cemento o cerámico) ◯ Placas de OBS ◯ Placa asfáltica ◯
Cerchas de Acero ◯ Placa Fibrocemento ◯ Placa Zinc Alum ◯ Entablado Artesanal ◯ Otro ____

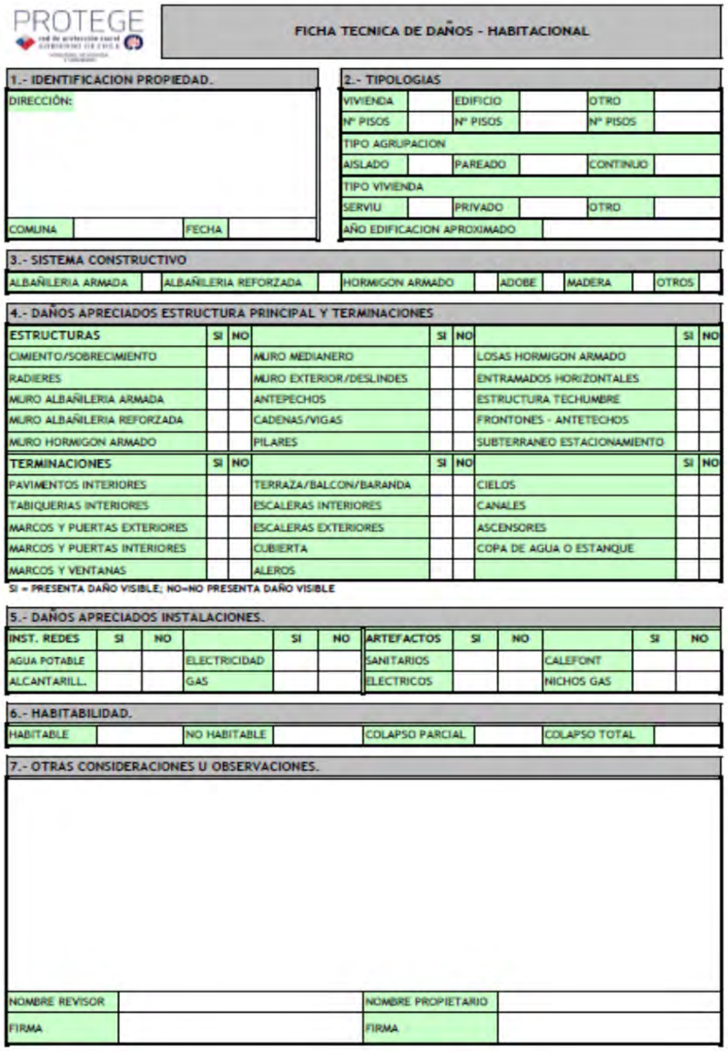
Sistema de Tabiquería
Placas de Fibrocemento ◯ Hormigón celular ◯ Placas MDF ◯ Hormigón con poliestireno ◯
Placas de Yeso Cartón ◯ Placas de OSB ◯ Lapour ◯ Otro ____
Marcos Soportante de Madera ◯ Marcos Soportante de Aluminio ◯ Otro ____

Revestimiento Exterior Adicional
Chapa ladrillo cerámico ◯ Estuco (normal o arquitectónico) ◯ Mampostería ◯
Muro Cortina ◯ Otro ____

# Damage inspections

## Engineering offices experience

### ▶ Damage inspection form



PROTEGE

**FICHA TECNICA DE DAÑOS - HABITACIONAL**

**1.- IDENTIFICACION PROPIEDAD.**

| | | | |
|---|---|---|---|
| DIRECCIÓN: | | | |
| COMUNA | | FECHA | |

**2.- TIPOLOGIAS**

| | | | | | |
|---|---|---|---|---|---|
| VIVIENDA | | EDIFICIO | | OTRO | |
| Nº PISOS | | Nº PISOS | | Nº PISOS | |
| TIPO AGRUPACION | | | | | |
| AISLADO | | PAREADO | | CONTINUO | |
| TIPO VIVIENDA | | | | | |
| SERVIU | | PRIVADO | | OTRO | |
| AÑO EDIFICACION APROXIMADO | | | | | |

**3.- SISTEMA CONSTRUCTIVO**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ALBAÑILERIA ARMADA | | ALBAÑILERIA REFORZADA | | HORMIGON ARMADO | | ADOBE | | MADERA | | OTROS | |

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

| ESTRUCTURAS | SI | NO | | SI | NO | | SI | NO |
|---|---|---|---|---|---|---|---|---|
| CIMIENTO/SOBRECIMIENTO | | | MURO MEDIANERO | | | LOSAS HORMIGON ARMADO | | |
| RADIERES | | | MURO EXTERIOR/DESLINDES | | | ENTRAMADOS HORIZONTALES | | |
| MURO ALBAÑILERIA ARMADA | | | ANTEPECHOS | | | ESTRUCTURA TECHUMBRE | | |
| MURO ALBAÑILERIA REFORZADA | | | CADENAS/VIGAS | | | FRONTONES - ANTETECHOS | | |
| MURO HORMIGON ARMADO | | | PILARES | | | SUBTERRANEO ESTACIONAMIENTO | | |
| **TERMINACIONES** | **SI** | **NO** | | **SI** | **NO** | | **SI** | **NO** |
| PAVIMENTOS INTERIORES | | | TERRAZA/BALCON/BARANDA | | | CIELOS | | |
| TABIQUERIAS INTERIORES | | | ESCALERAS INTERIORES | | | CANALES | | |
| MARCOS Y PUERTAS EXTERIORES | | | ESCALERAS EXTERIORES | | | ASCENSORES | | |
| MARCOS Y PUERTAS INTERIORES | | | CUBIERTA | | | COPA 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 | | | CALEFONT | | |
| ALCANTARILL. | | | GAS | | | ELECTRICOS | | | NICHOS GAS | | |

**6.- HABITABILIDAD.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HABITABLE | | NO HABITABLE | | COLAPSO PARCIAL | | COLAPSO TOTAL | |

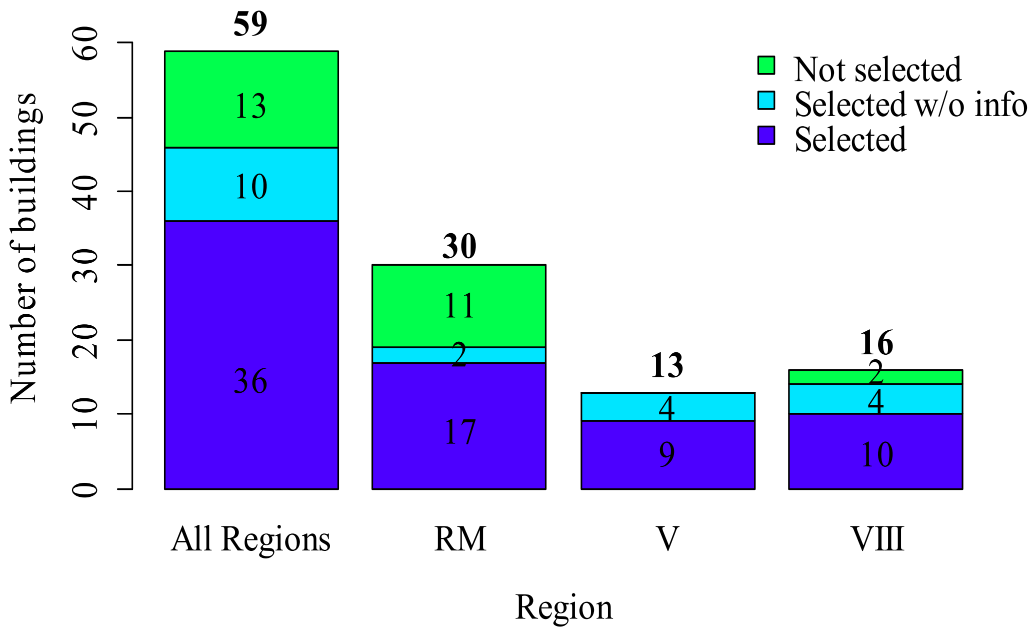
**7.- OTRAS CONSIDERACIONES U OBSERVACIONES.**

| | | | |
|---|---|---|---|
| NOMBRE REVISOR | | NOMBRE PROPIETARIO | |
| FIRMA | | FIRMA | |

### ▶ Damage register symbol

| | | |
|---|---|---|
| TIPO ELEM.: | MURO | (M) |
| | VIGA | (V) |
| | LOSA | (L) |
| | PILAR | (P) |
| | TABIQUE | (T) |
| GRADO: (del daño) | SUPERFICIAL | (1) |
| | MEDIO | (2) |
| | PROFUNDO | (3) |
| ORIGEN: FISURA | CORTE | (S) |
| | FLEXIÓN | (F) |
| | COMPRESIÓN | (C) |
| DAÑO: | REVESTIMIENTO (R) | |
| | DESPRENDIMIENTO (D) | |
| N°: | NÚMERO CORRELATIVO | |

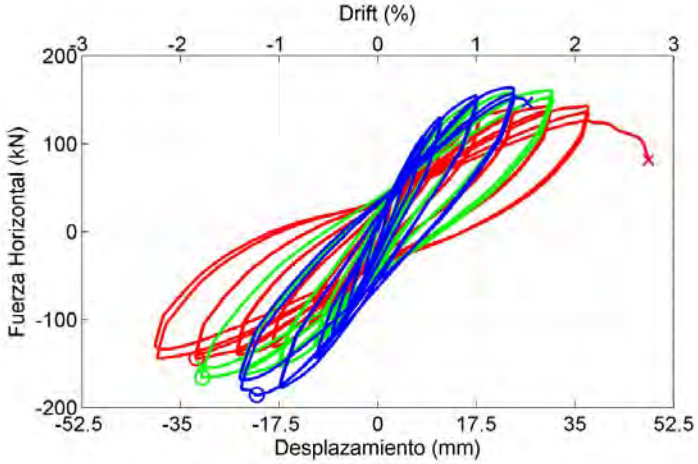
# Damaged building
## inventory




| 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

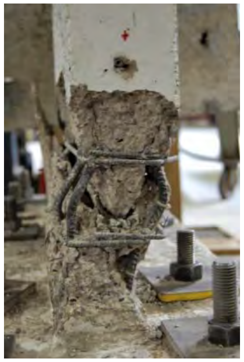
RC Wall Test




Force-Deformation relationship

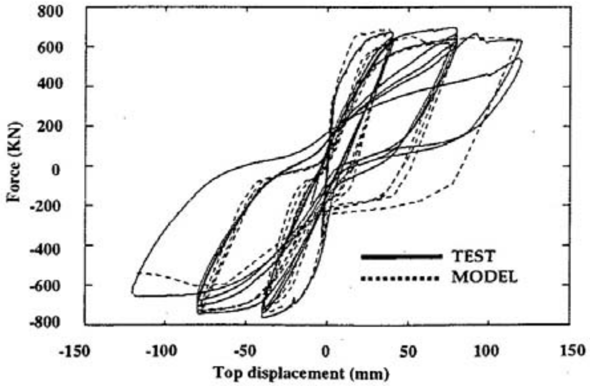
W1

W2



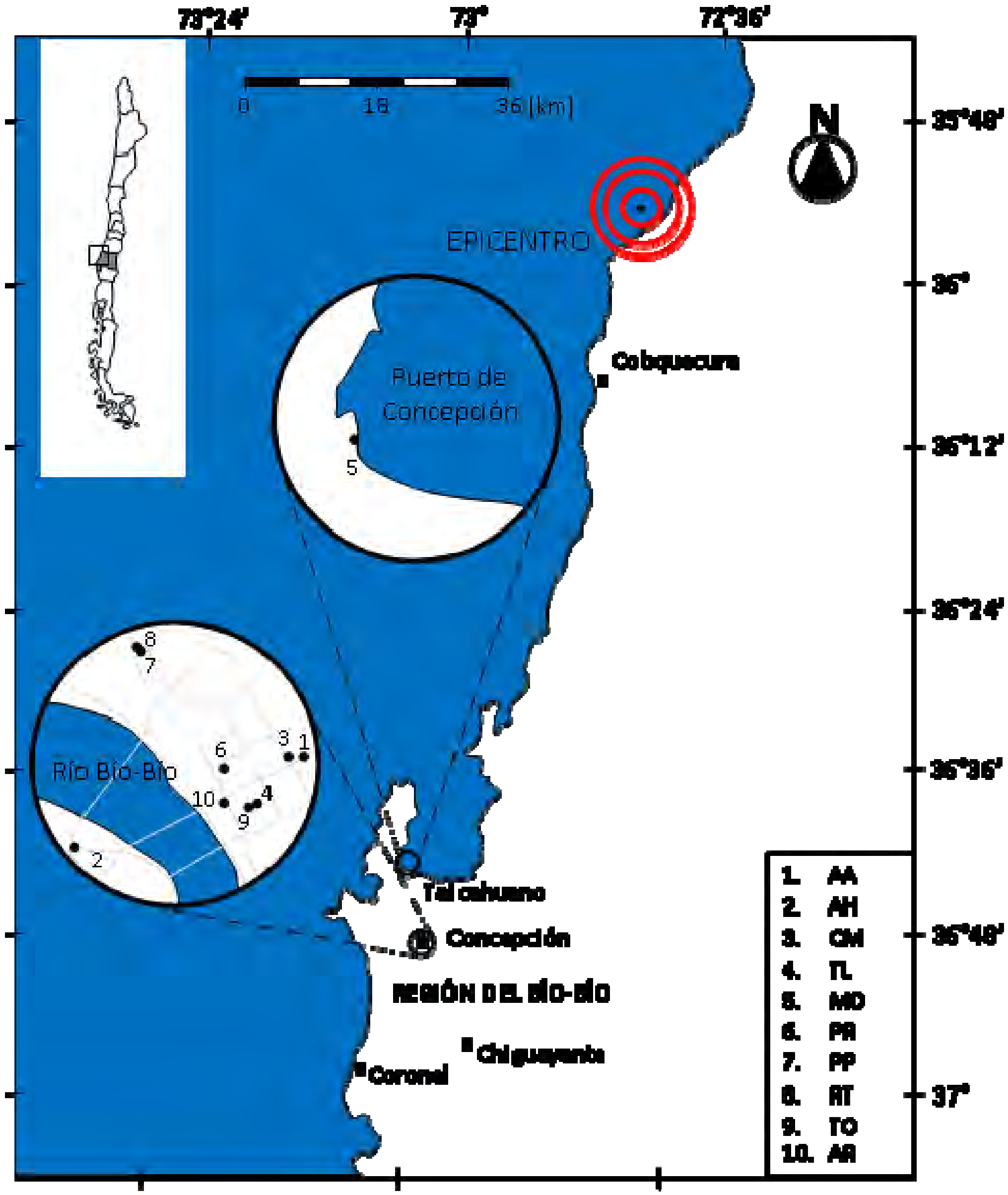
W3

2010 EQ



# 04 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

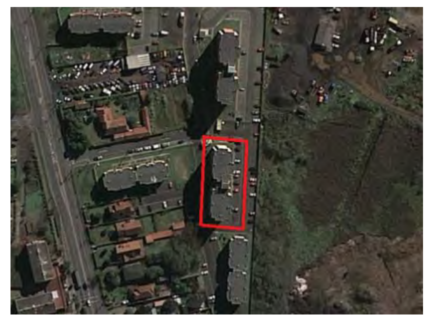
AH-2

CM-3

TL-4

MD-5

PR-6



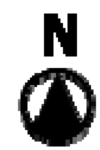
PP-7

RT-8

TO-9

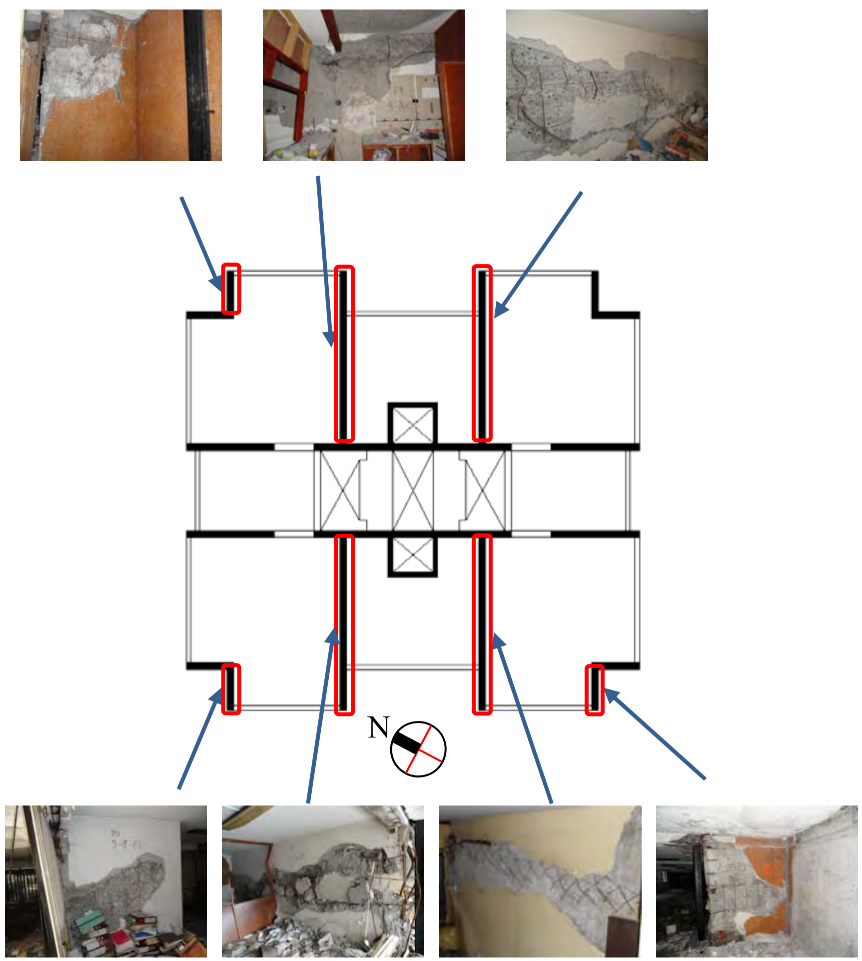
AR (before)

AR (after)

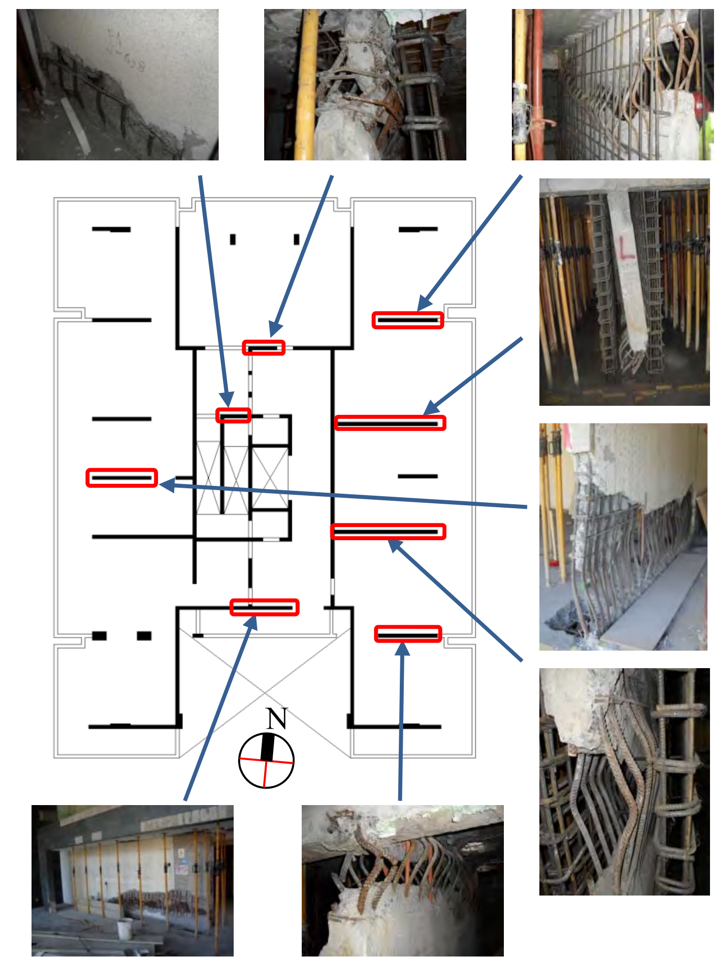


# Orientation
## of buildings

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

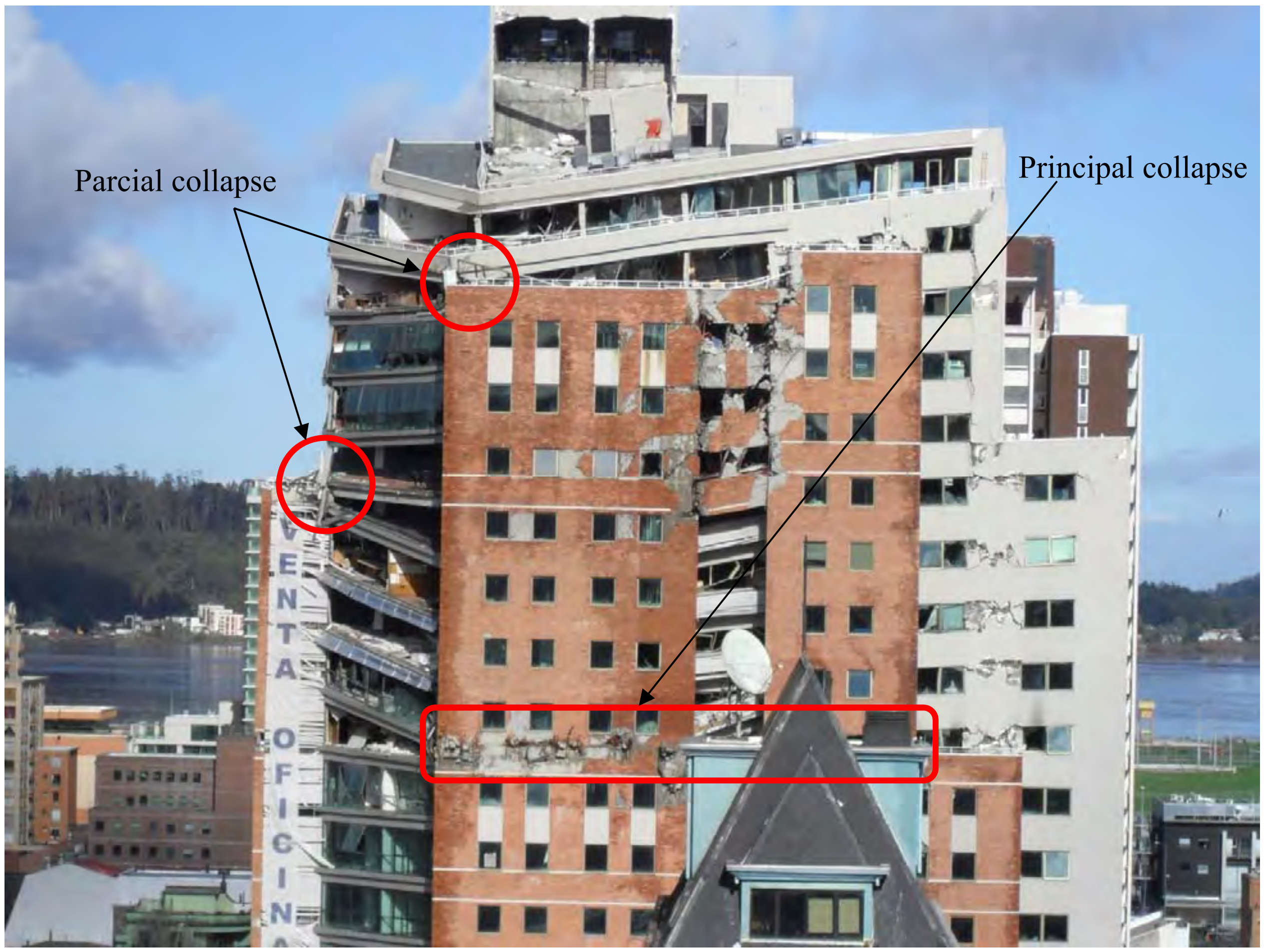



Severe damage in building TL




Severe damage in building AH

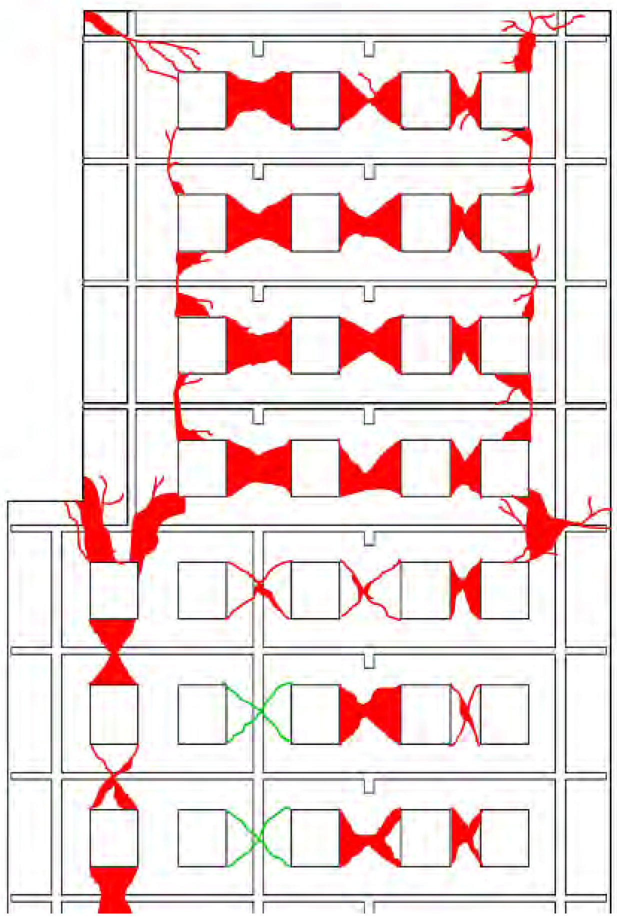
# Building damage




East elevation of TO

# Damage level
## representation

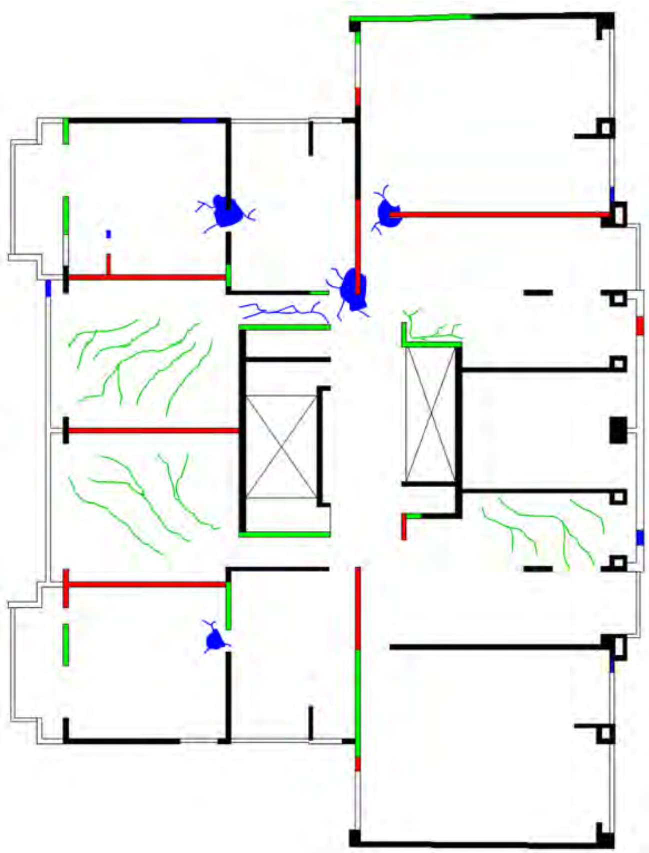
Light damage · Moderate damage · Severe damage



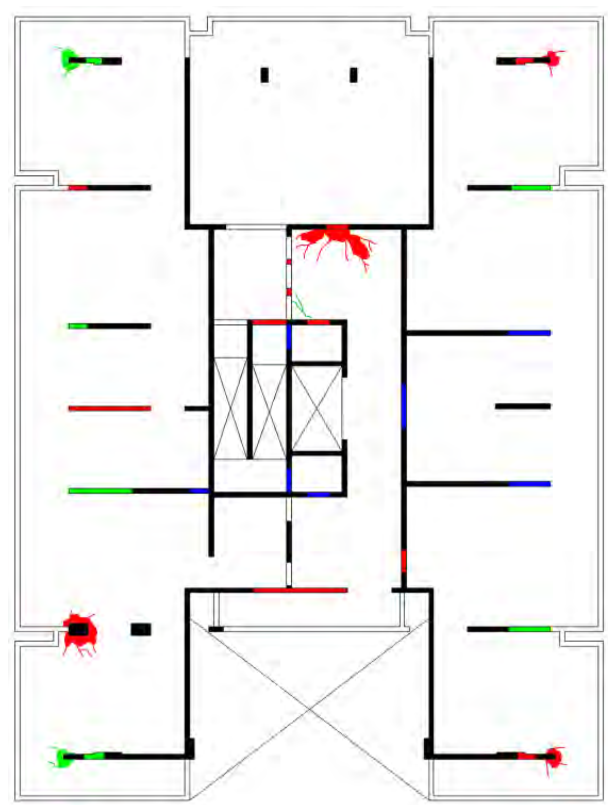
TO: Axis 1A

# Damage level
## representation

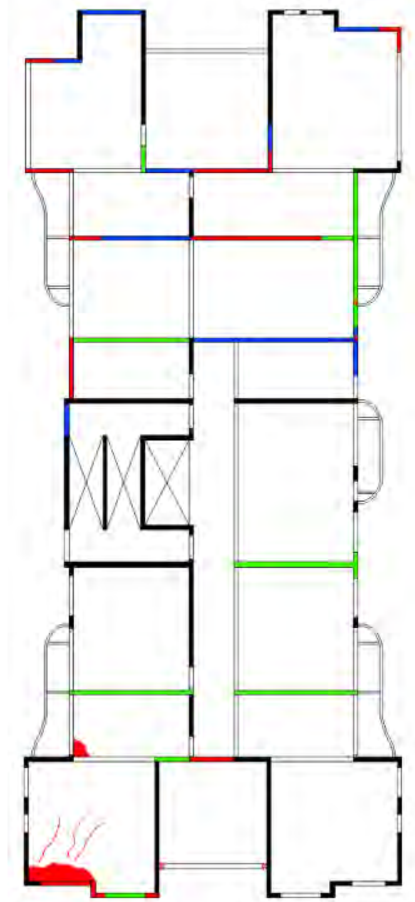
Light damage | Moderate damage | Severe damage



AA: Story 2



AH: Story 1

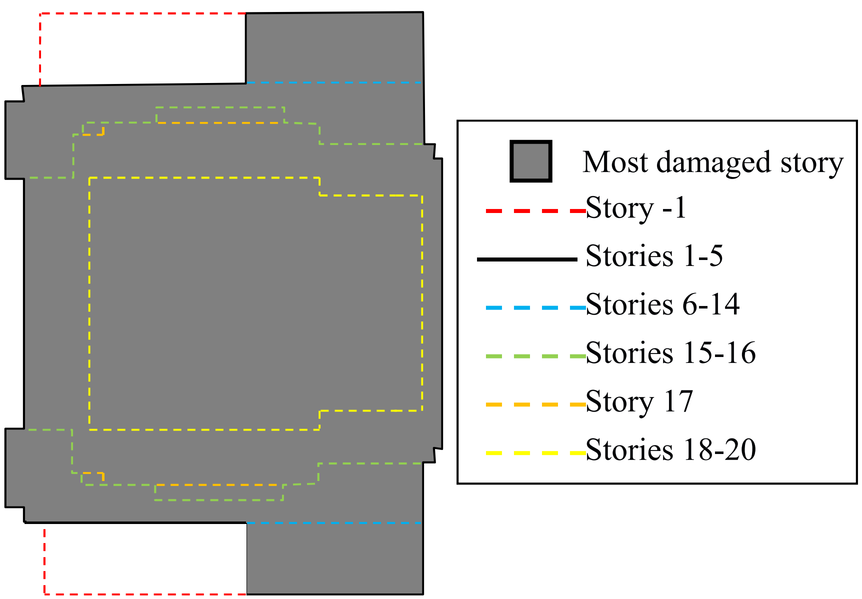


CM: Story 2

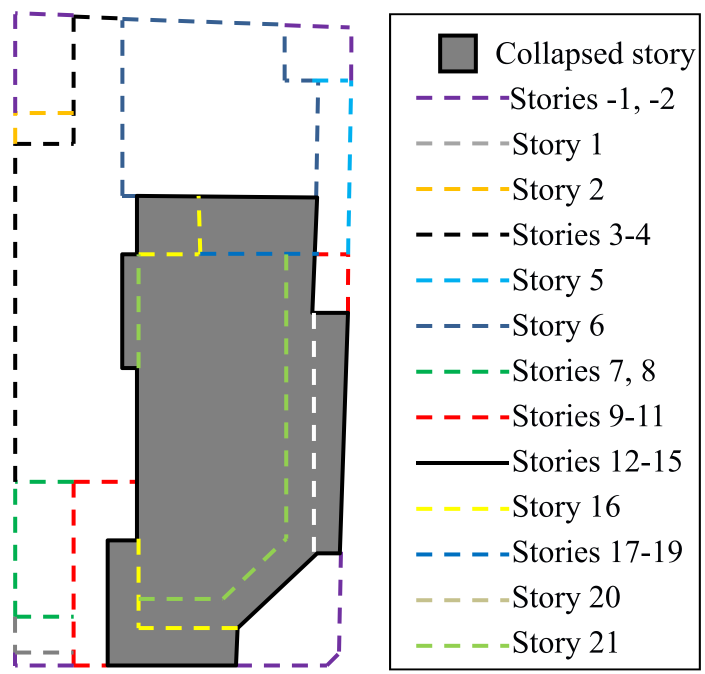
# Irregularities

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.

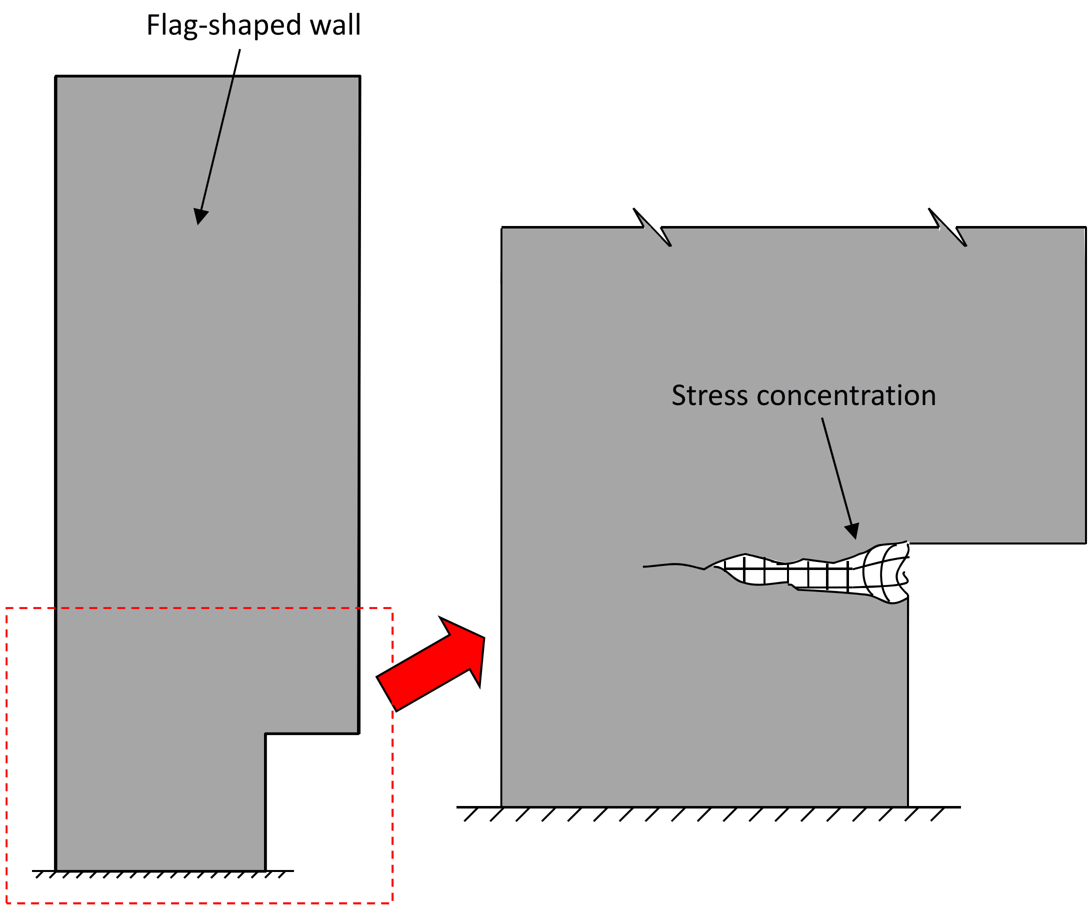



Schematic plan AA




Schematic plan TO

# Irregularities
## "Flag-shaped" walls



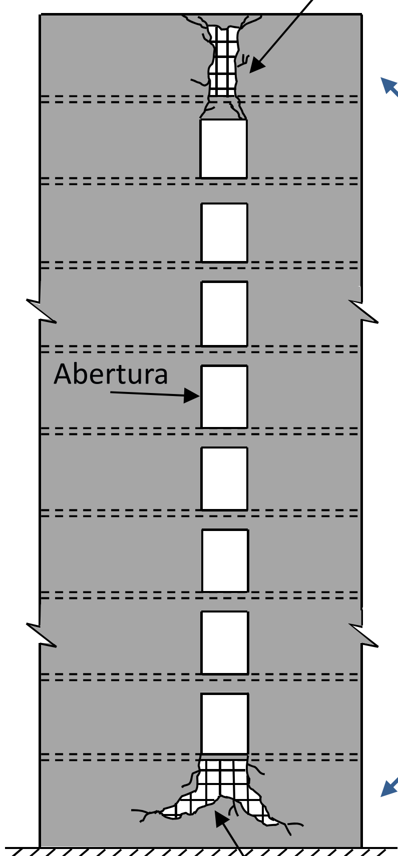

Flag-shaped wall Damage detail

AA Building

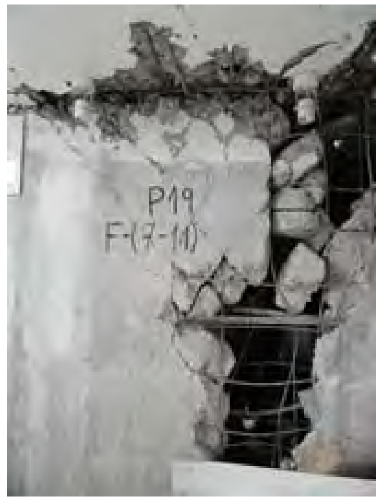
AH Building

# Common Irregularities

Opening is formed in continuous wall on the upper stories




Opening is formed in continuous wall on the lower stories



AA

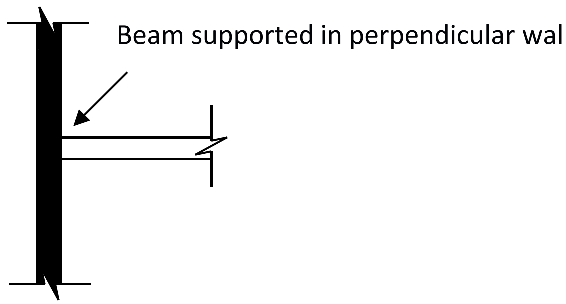
AH

CM

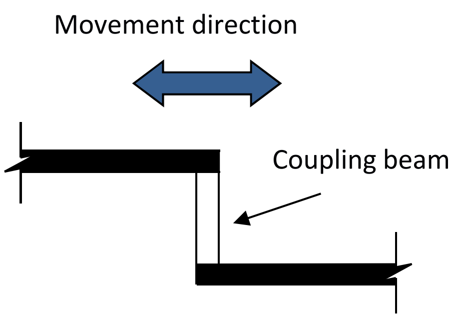
CM

Chillán building

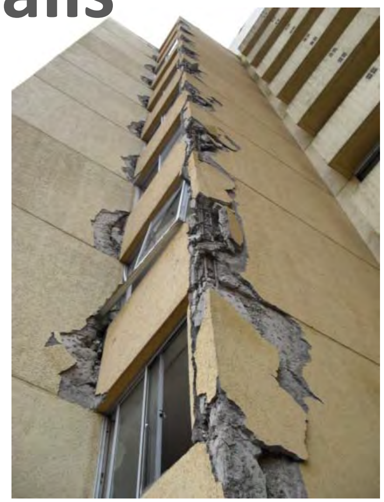
# Irregularities
## Coupling beams in walls




Case A

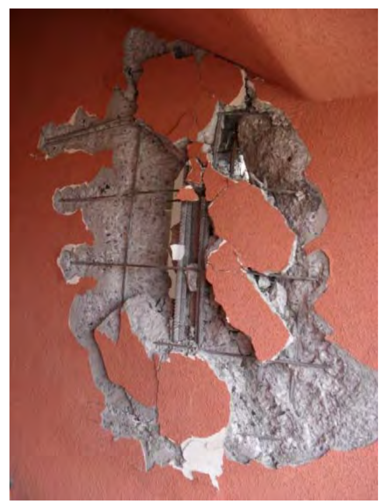



Case B



PP

PP



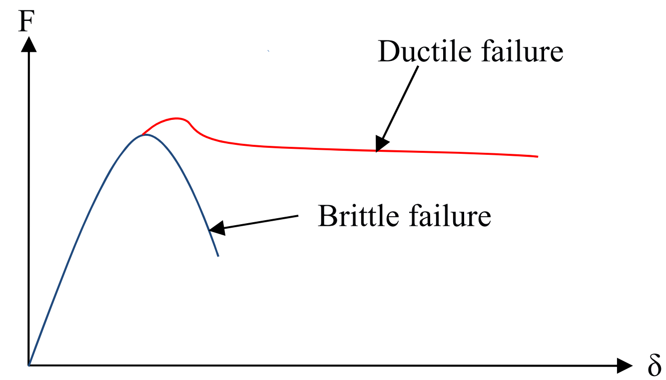
RT

TO

# Detailing & brittleness

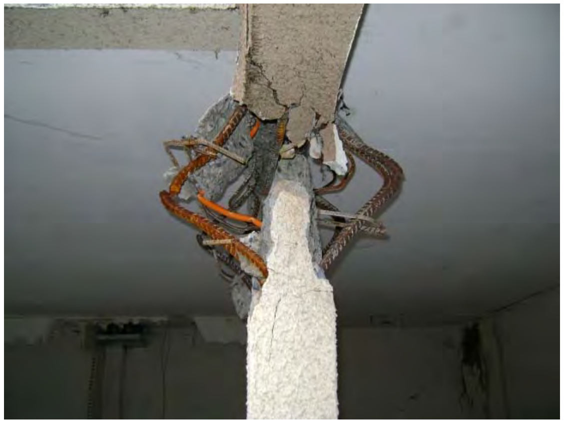
Thin walls with high axial load were unable to confine the concrete core

- 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

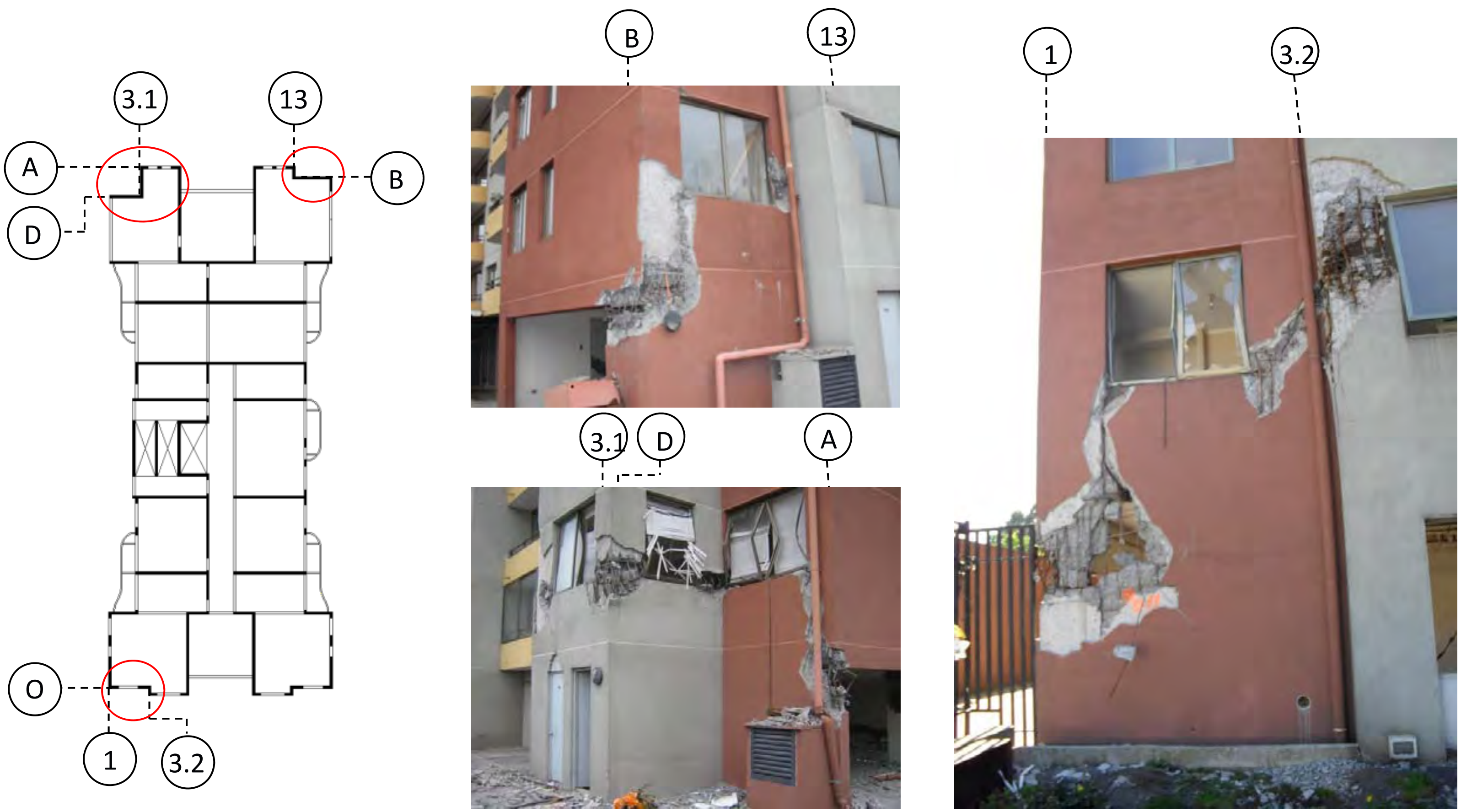
Lack of stirrups

Reinforcement outside the confined area

Typical confinement detail

# Multistory
## damage

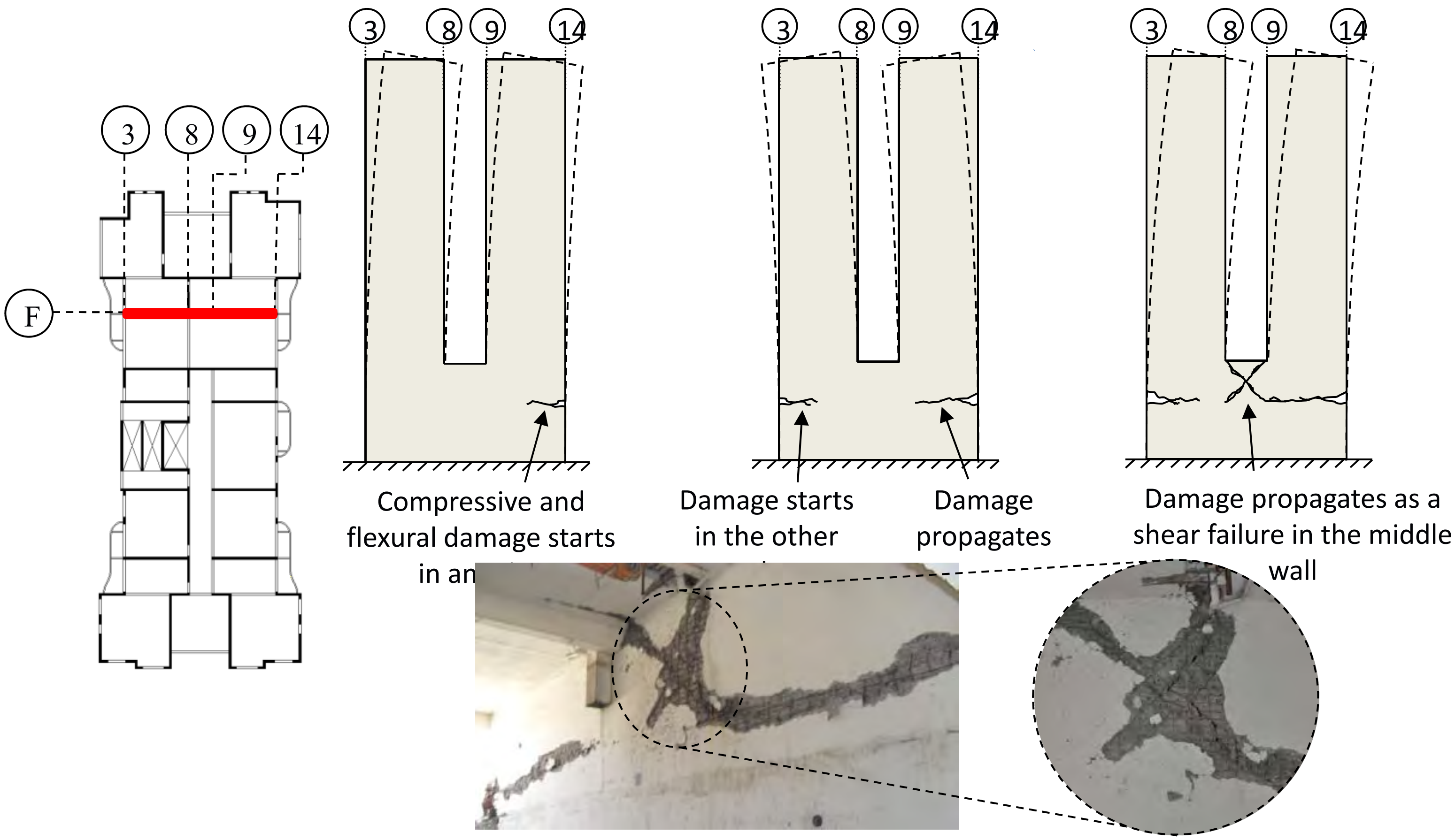
There is damage propagation between floors




CM building: propagation of damage between stories

# Multistory damage

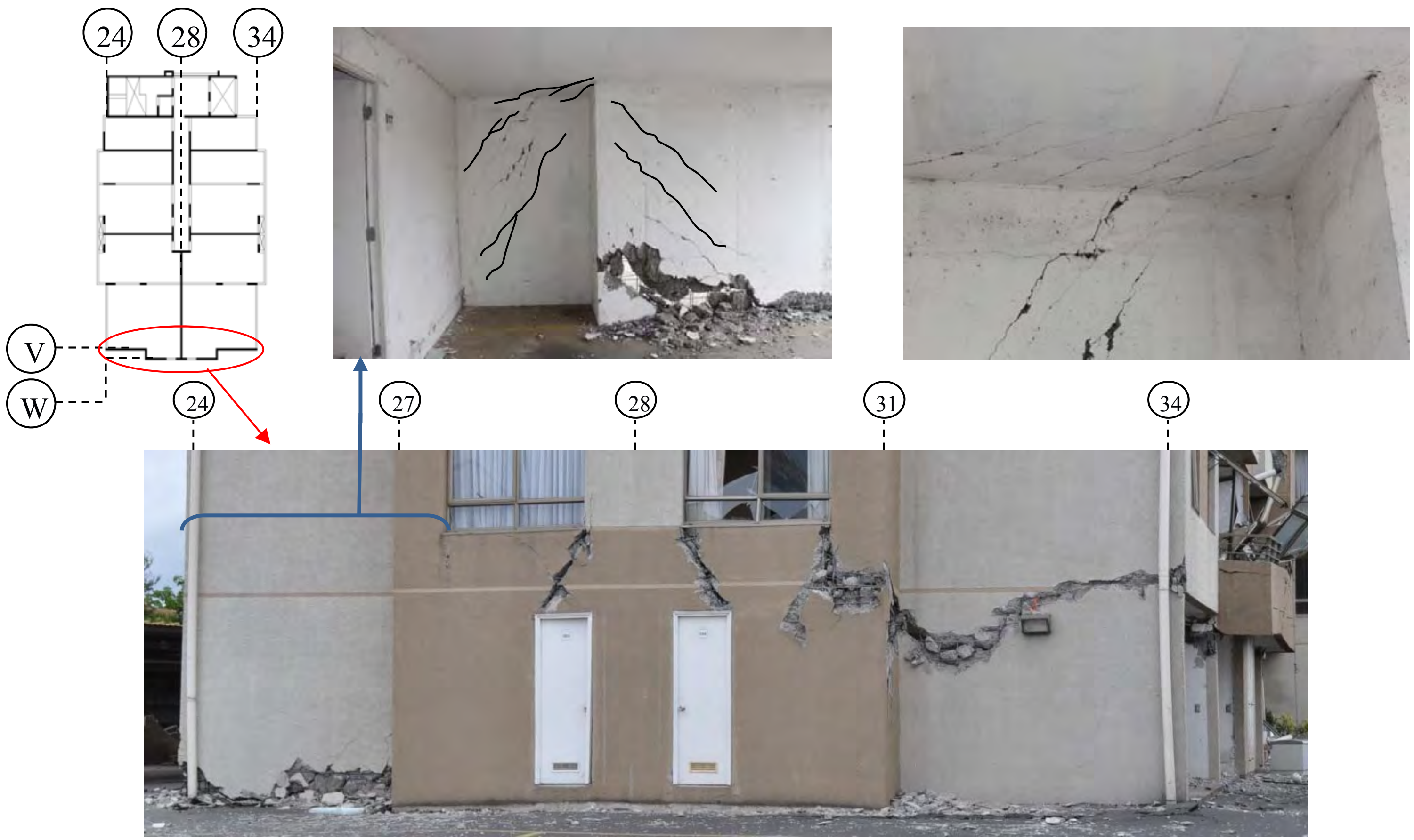
There is damage propagation between elements




CM: propagation of damage between elements

# Multistory
## damage

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

$1 < FU < 1.25$ → Slightly deficient elements

$1.25 < FU < 1.5$ → Moderately deficient elements

$FU > 1.5$ → Severely deficient elements

Walls:

- Shear
- Axial-flexural

Beams:

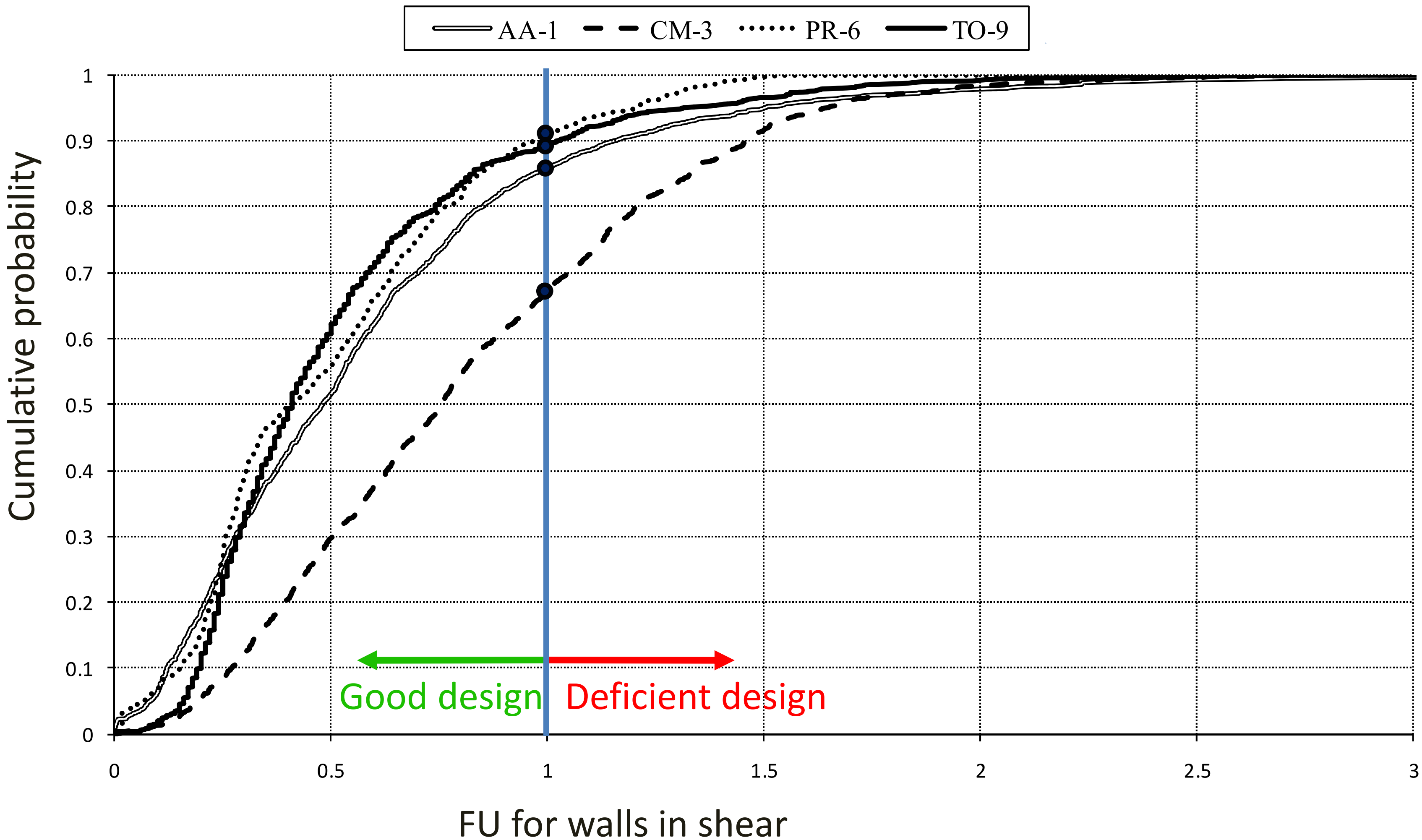
- Shear
- Positive Moment
- Negative Moment

Drifts y displacements:

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

# Building design
## review

Walls in shear (~ 1000 elements per building)

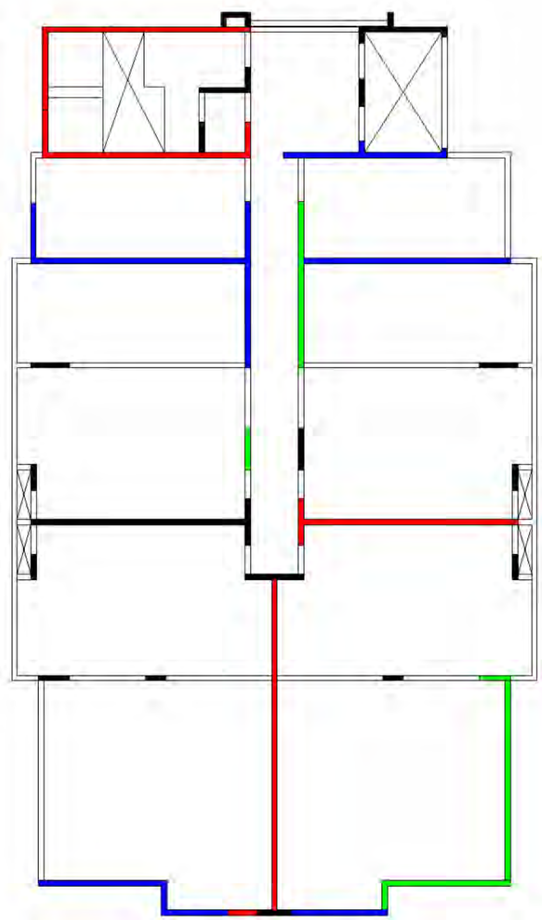



A223

Design review

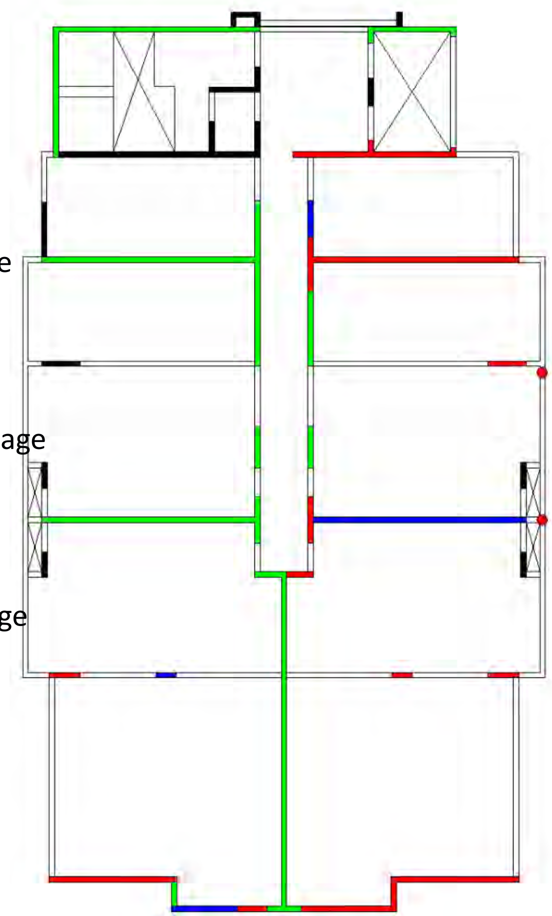
# Design review v/s observed damage:

- Slightly deficient design
- Moderately deficient design
- Severely deficient design



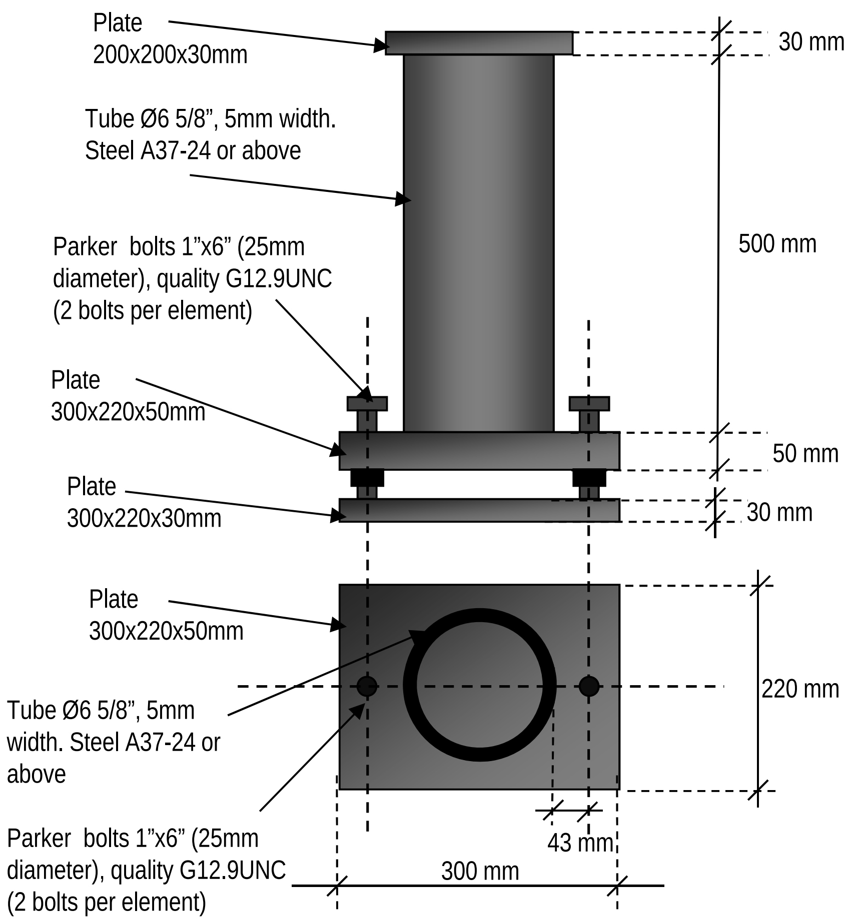
Plaza del Río building: FU in 1st story

- Slight damage
- Moderate damage
- Severe damage



Plaza del Río building: Damage in 1st story

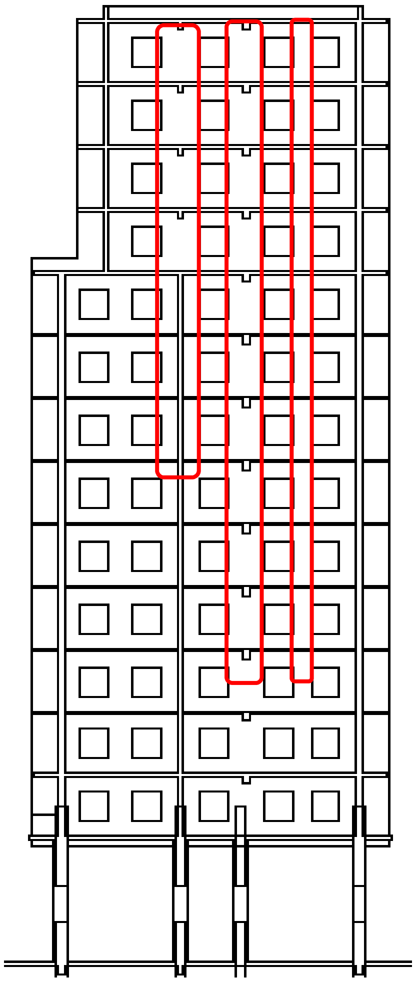
# Stabilization process
## EM Building

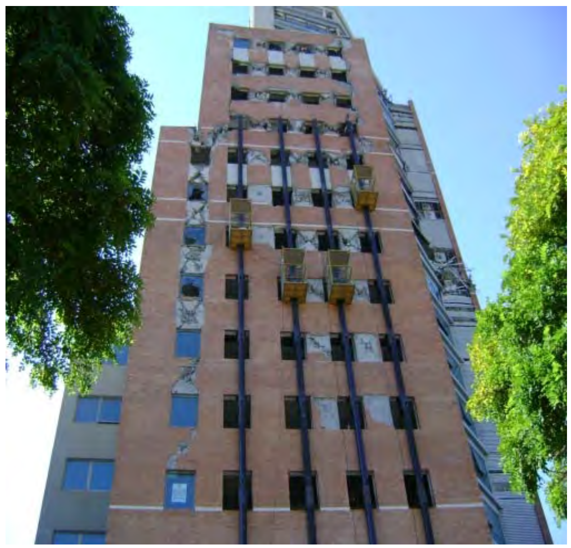


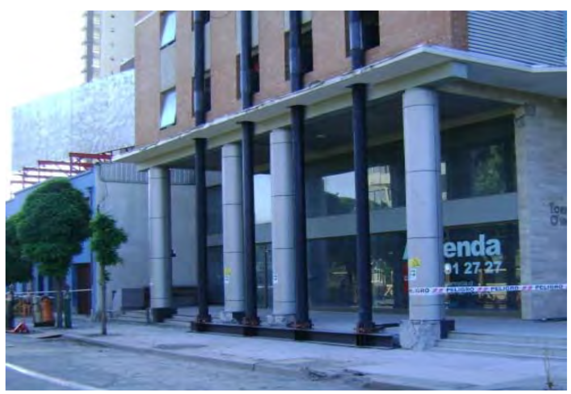

# Stabilization process
## EM Building

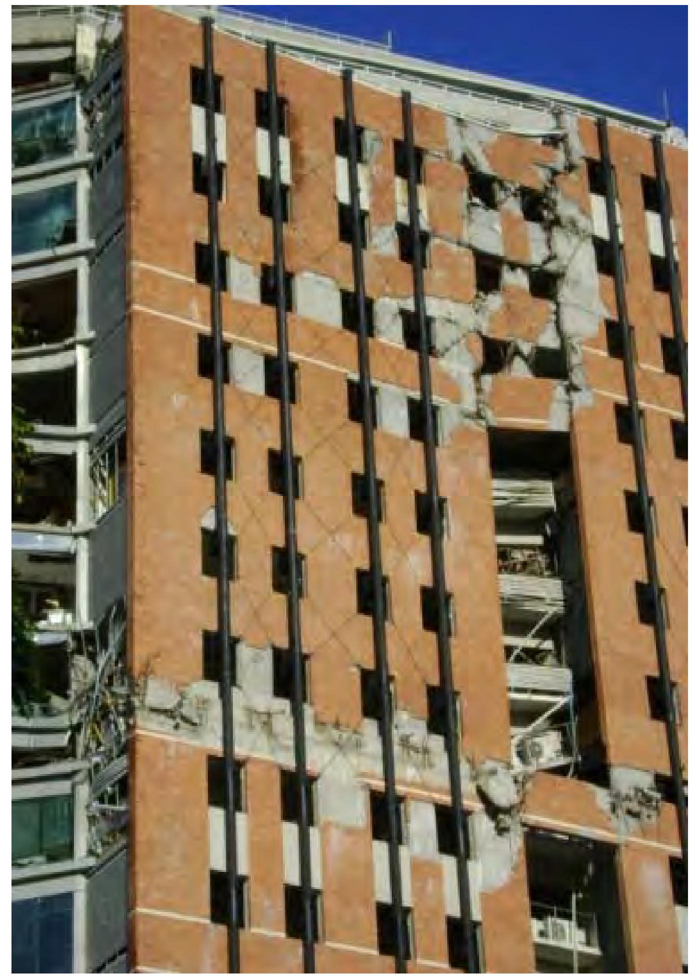



# Stabilization process
## TO Building





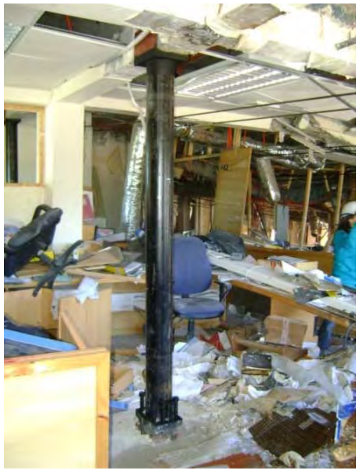




# Stabilization process
## TO Building





# Stabilization process

Repair, Stabilization and demolition of buildings

TO building: Temporary stabilization

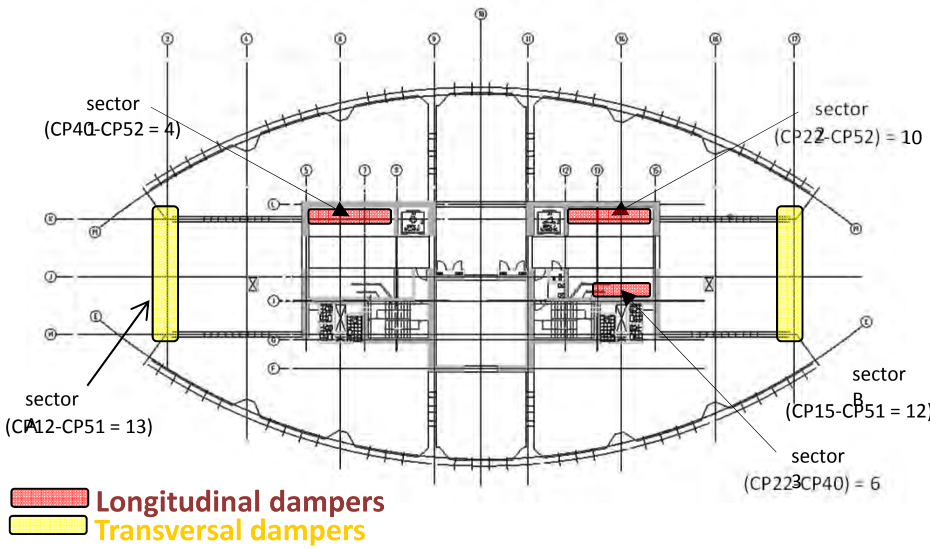
04

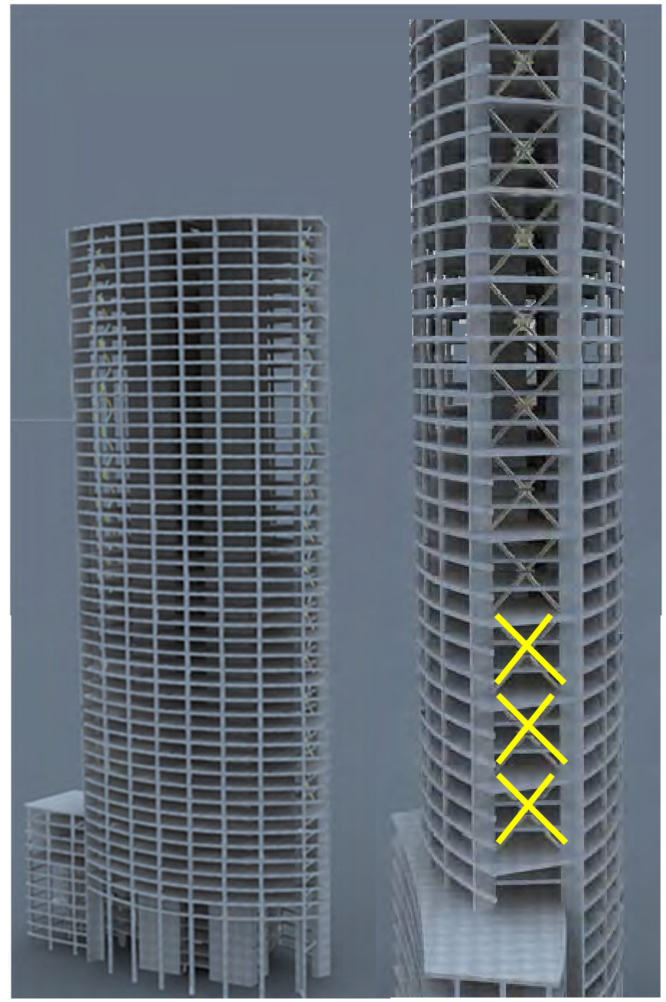
# EXAMPLE: PERFORMANCE OF SEISMICALLY PROTECTED BUILDINGS

# Military Hospital


# Coronel's wharf

# Titanium tower
## Hysteretic damping




Fixed Base

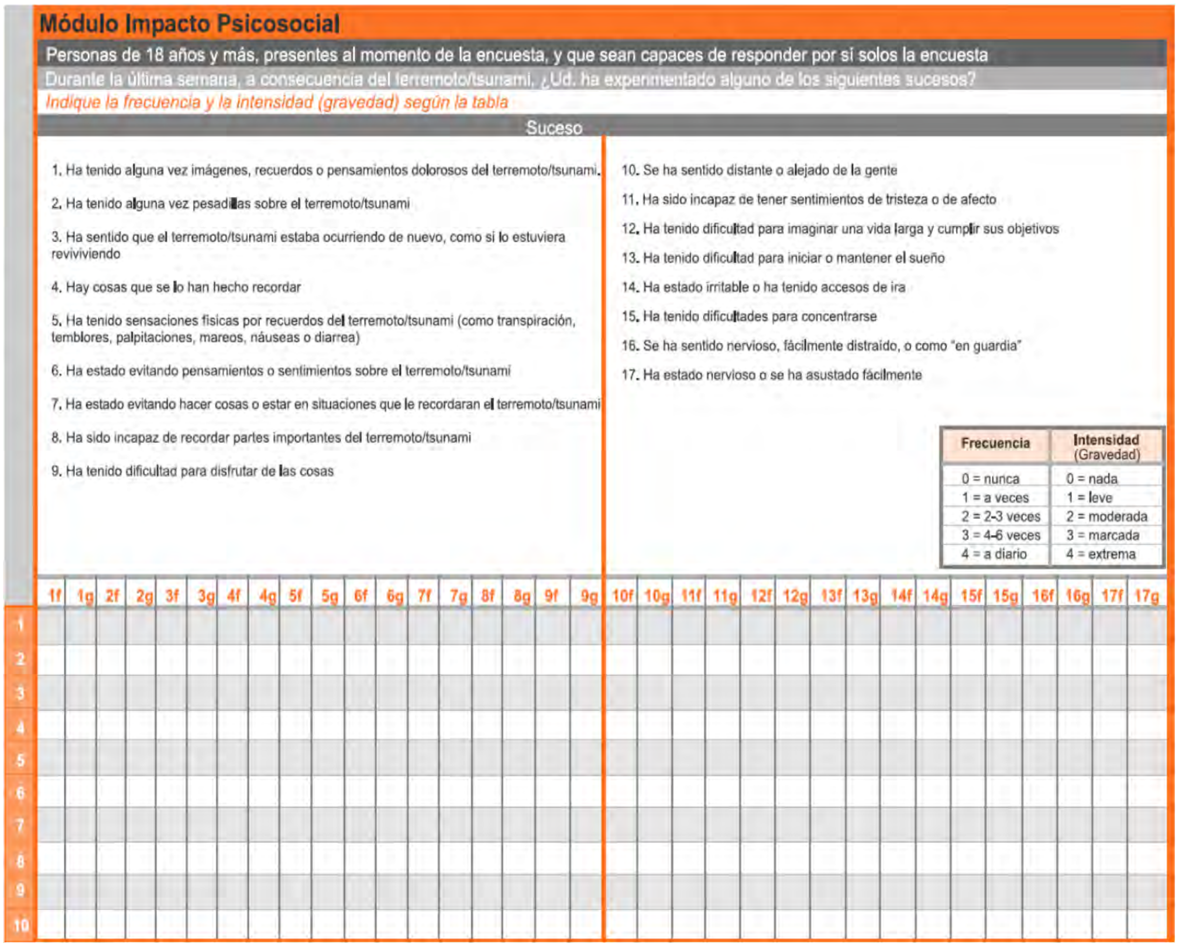
05

# SOCIAL AND HUMAN IMPACT

# Social behaviors

Mental health

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


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

| 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

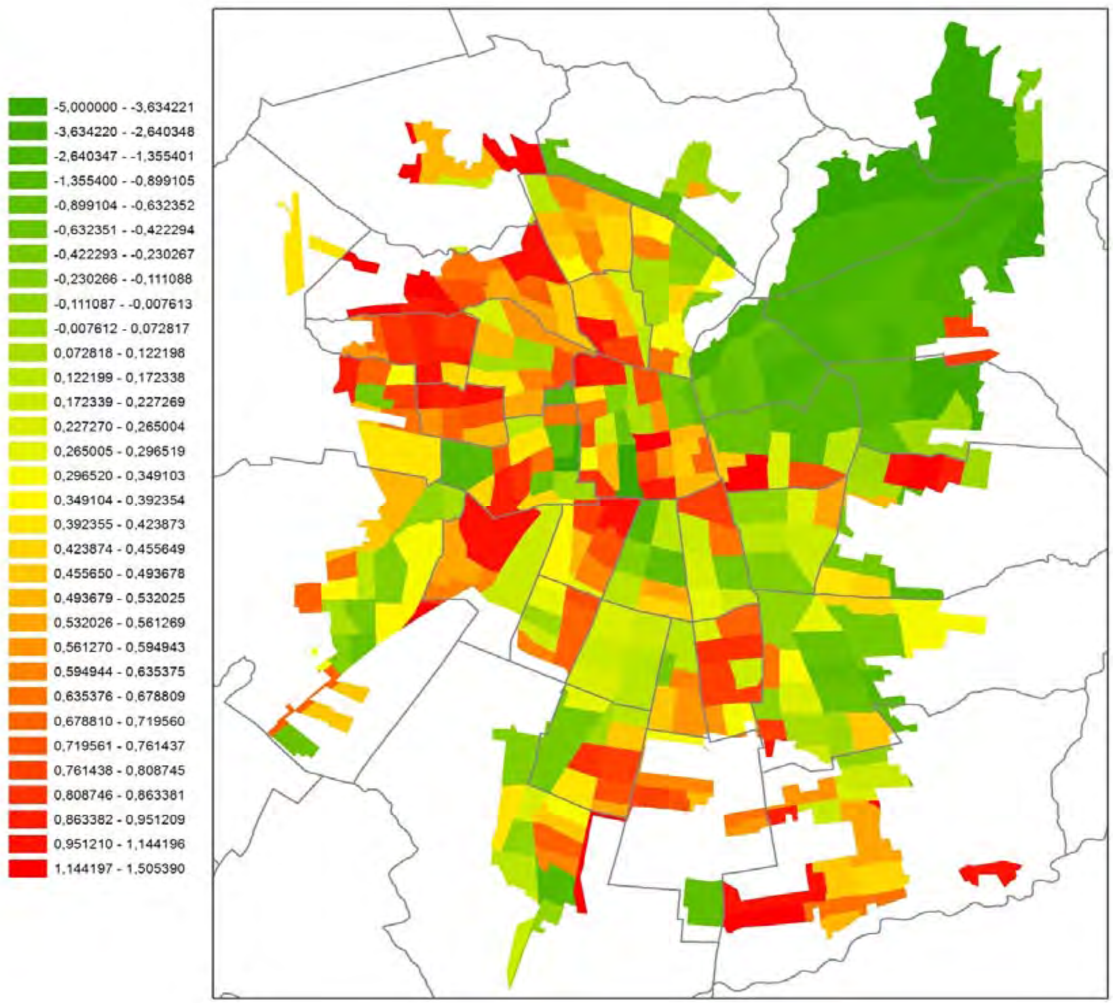
1 2 3 4 5 6 7 8 9 10

PTSD in caregivers of preschool children

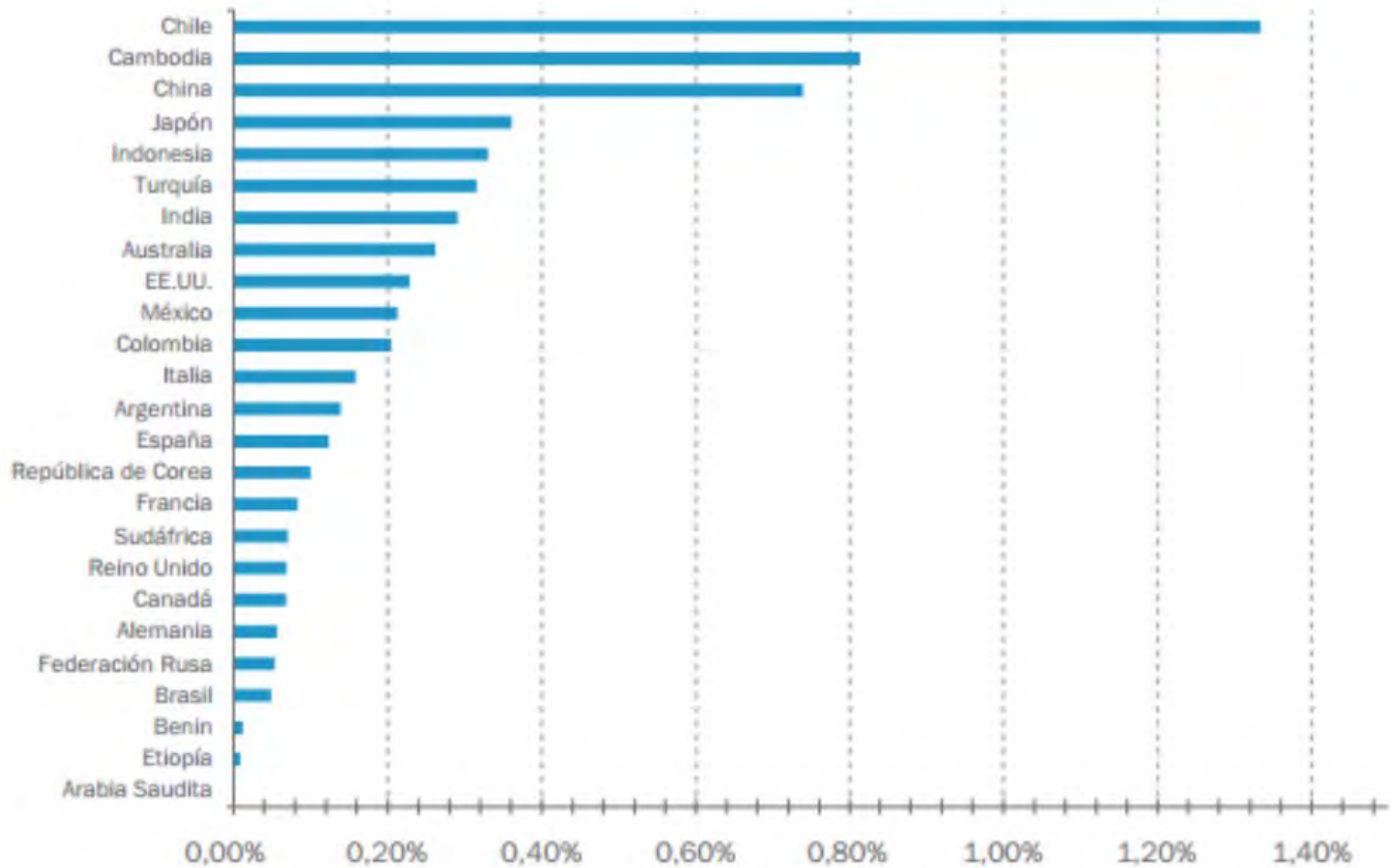
| Comuna | TEPT (%) |
|---|---|
| Antofagasta | 2,6 |
| Tocopilla | 0,0 |
| Montepatria | 0,0 |
| La Serena | 3,7 |
| Coquimbo | 2,7 |
| Los Andes | 8,3 |
| Valparaíso | 7,4 |
| Lampa | 8,8 |
| Quilicura | 9,9 |
| La Florida | 3,1 |
| Puente Alto | 14,6 |
| San Bernardo | 16,5 |
| Rengo | 7,8 |
| Collipulli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



# 06 LESSONS LEARNED

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

# Lessons learned

▶ **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)

Lessons learned

## 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

# Lessons learned

- 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

# Chilean Experience

July, 2014

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

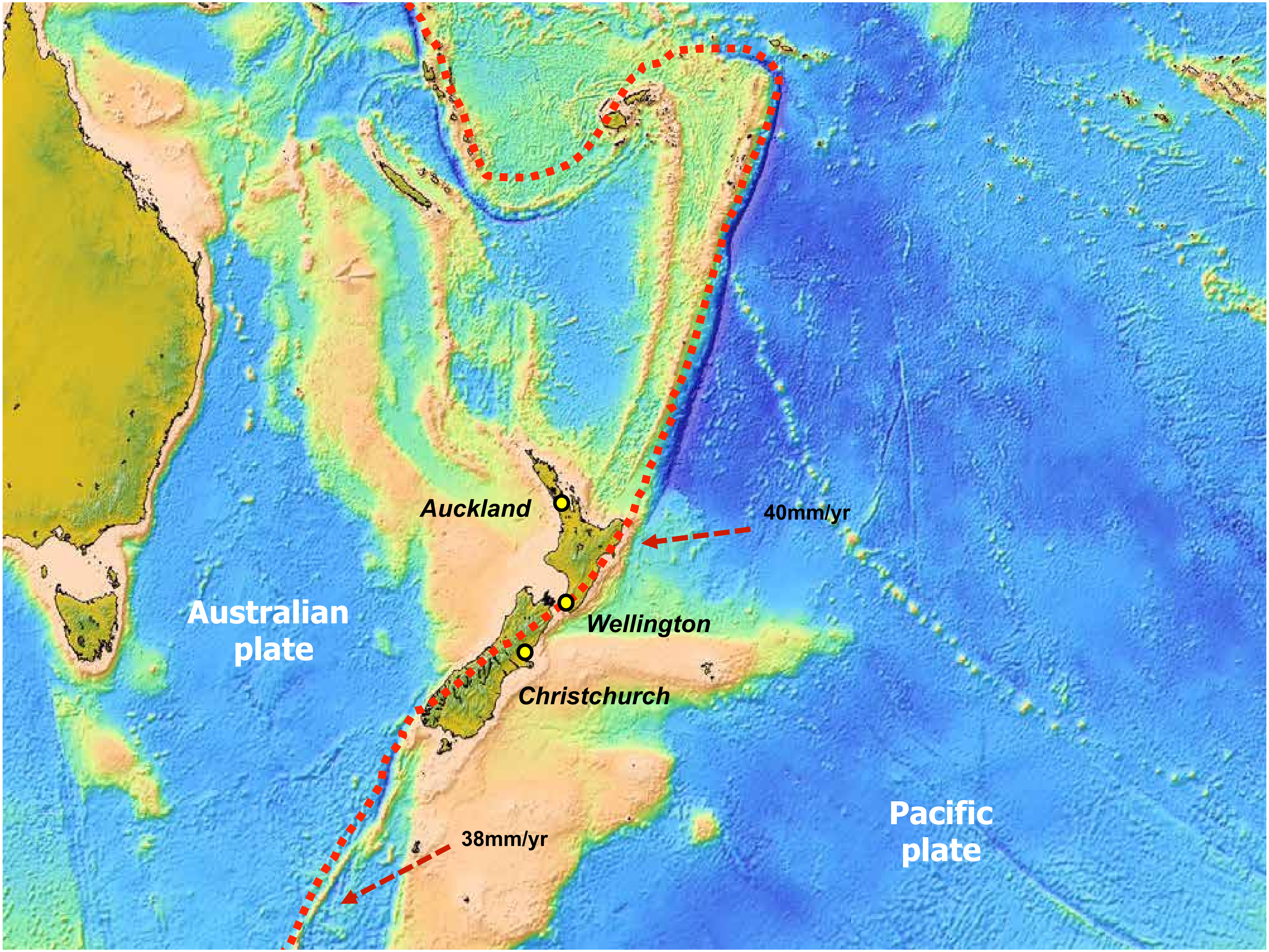
David Johnston – GNS Science

# 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 & Stefano Pampinin |
| ➢ Insurance and Losses | Andrew King |
| ➢ Socio-Economic Implications | David Johnson |
| ➢ Discussion | Everyone |

# Regulatory and Overview

Mike Stannard, Chief Engineer, MBIE



Auckland
40mm/yr
Australian plate
Wellington
Christchurch
Pacific plate
38mm/yr


A251

# Canterbury Earthquake Sequence

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

**Fatalities** – 185

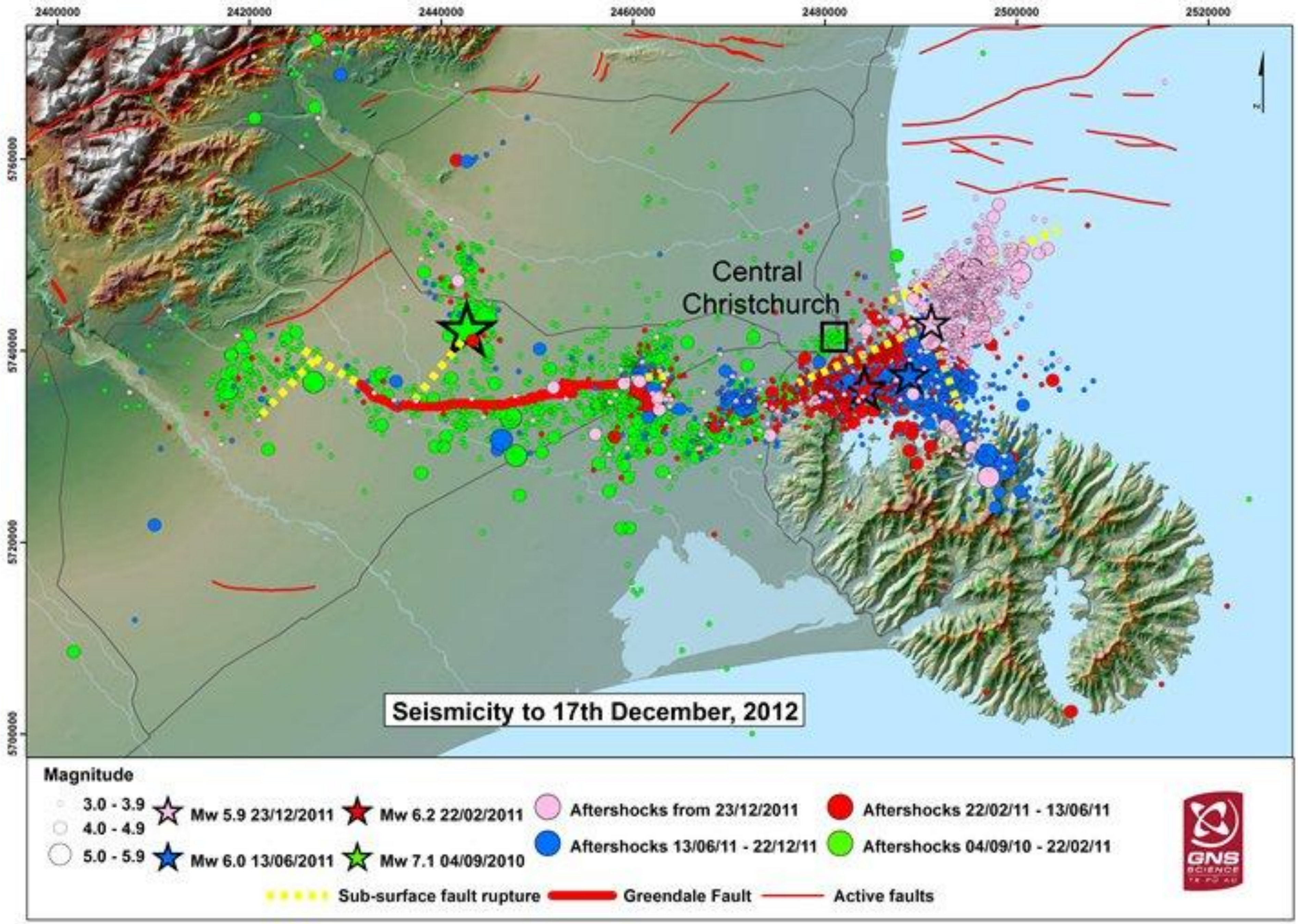
**Cost** – Estimates up to $NZ40 billion ≈ 20% GDP, ($US35B)

**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


2400000
2420000
2440000
2460000
2480000
2500000
2520000
5760000
5740000
5720000
5700000
Central Christchurch
Seismicity to 17th December, 2012
Magnitude
3.0 - 3.9
4.0 - 4.9
5.0 - 5.9
Mw 5.9 23/12/2011
Mw 6.0 13/06/2011
Mw 6.2 22/02/2011
Mw 7.1 04/09/2010
Aftershocks from 23/12/2011
Aftershocks 13/06/11 - 22/12/11
Aftershocks 22/02/11 - 13/06/11
Aftershocks 04/09/10 - 22/02/11
Sub-surface fault rupture
Greendale Fault
Active faults
GNS SCIENCE

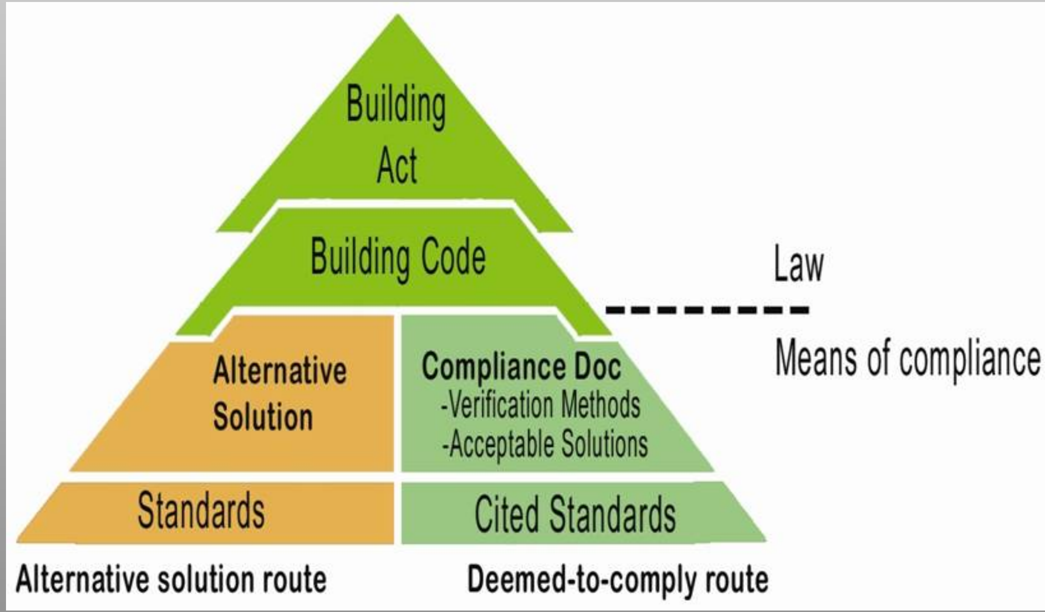
30,000 tonnes ejecta removed September

300,000 tonnes removed February

# Liquefaction - Bexley

| Issues | Response |
| --- | --- |
| Existing regulatory framework – Building Act/Code not addressing disaster response or recovery<br><br>-No legislative authorisation for building usability evaluation (safety)<br>-Repair after earthquake unclear | Legislation – Canterbury Earthquake Recovery Act<br>Short term changes to Building Act (dangerous buildings to include earthquake hazard)<br>-Proposed changes to Act to include rapid building usability assessment (tagging)<br>-Issue guidance |

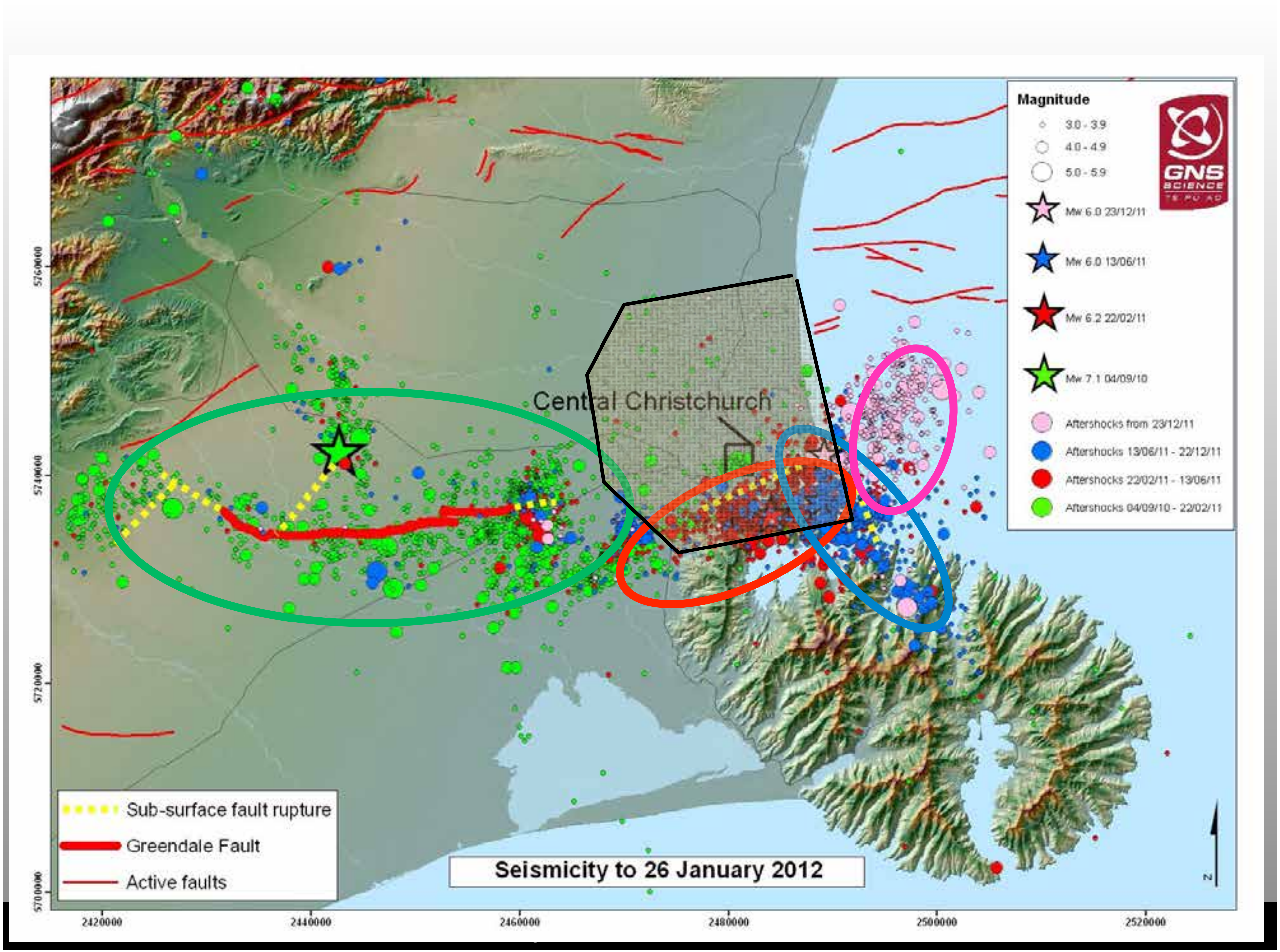
**National Building Act and Building Code**



| 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 | Proposed amendment to earthquake-prone building legislation:<br>-Balance cost and risk;<br>-Different perceptions and preparedness to pay across NZ;<br>-Affordability for rural towns, demolition;<br>-Market/insurer drivers for strengthening. |
| 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


Magnitude
3.0 - 3.9
4.0 - 4.9
5.0 - 5.9
Mw 6.0 23/12/11
Mw 6.0 13/06/11
Mw 6.2 22/02/11
Mw 7.1 04/09/10
Aftershocks from 23/12/11
Aftershocks 13/06/11 - 22/12/11
Aftershocks 22/02/11 - 13/06/11
Aftershocks 04/09/10 - 22/02/11
GNS SCIENCE
Central Christchurch
Sub-surface fault rupture
Greendale Fault
Active faults
Seismicity to 26 January 2012
5760000
5740000
5720000
5700000
2420000
2440000
2460000
2480000
2500000
2520000
N

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

| | 5 years | | | 20 years | | |
|---|---|---|---|---|---|---|
| EQ Magnitude | 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 | **34%** | 1.0 | 0-3 | **64%** |
| 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 25th, 2012.

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

| **Magnitude** | **Canterbury** starting May 28th 2012 (high rates now declining rapidly) | **Wellington** starting Dec 15th 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% **<3% for city** | 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 25th, 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

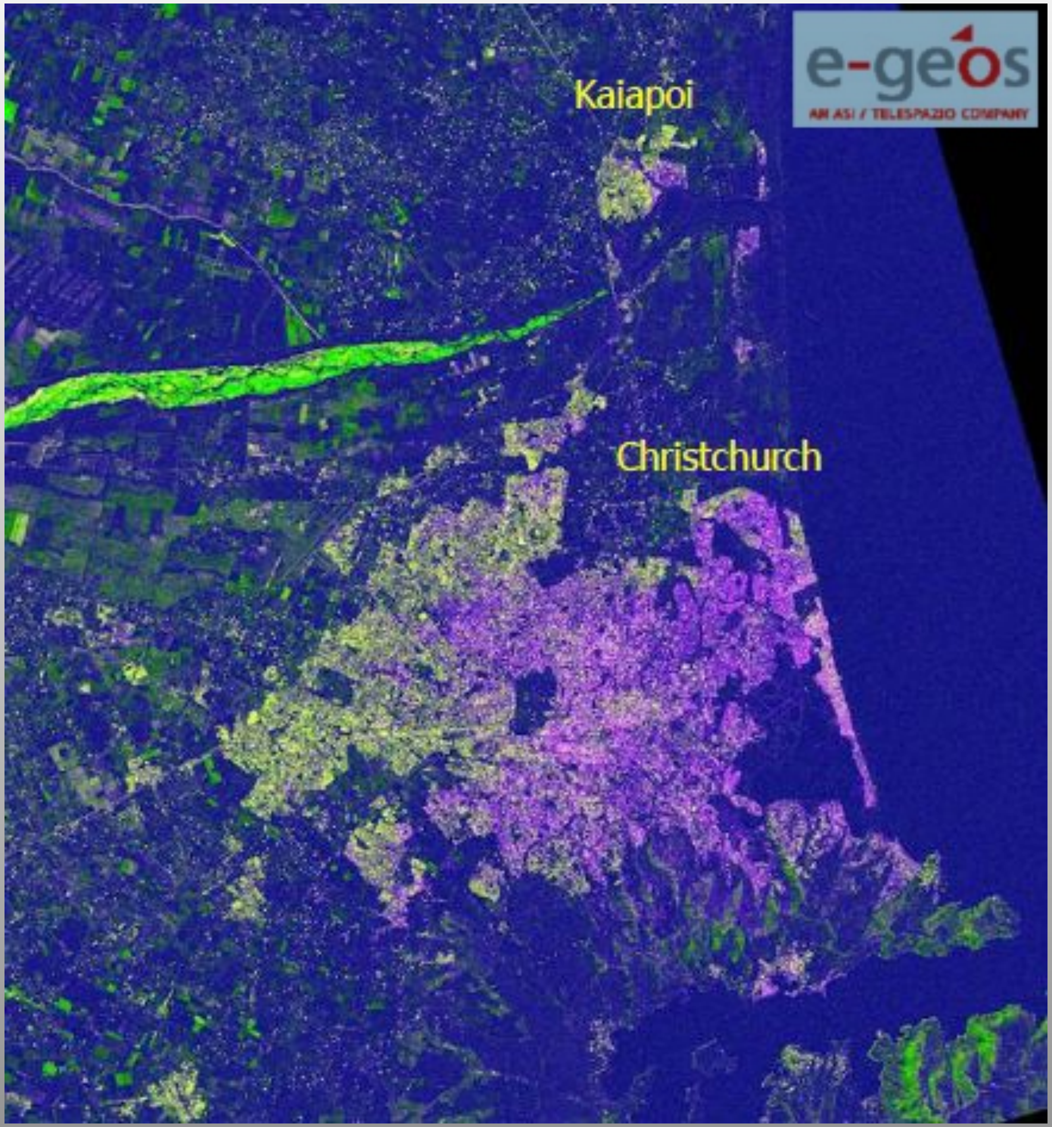
# Rapid Impact Assessments (2)

- ***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 meetingscontinue, 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

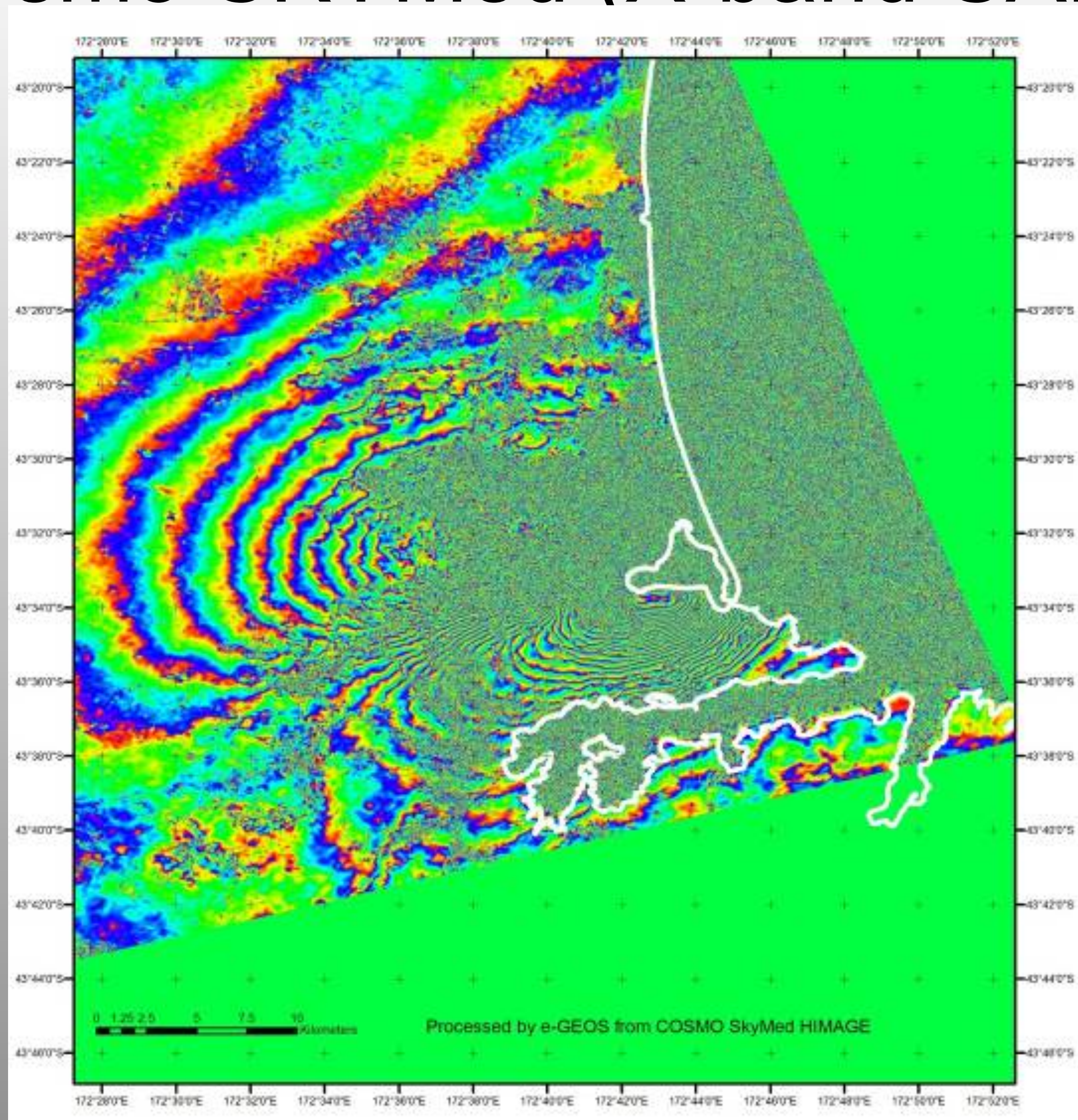
A263

# Aerial photography - Liquefaction (NZAM)

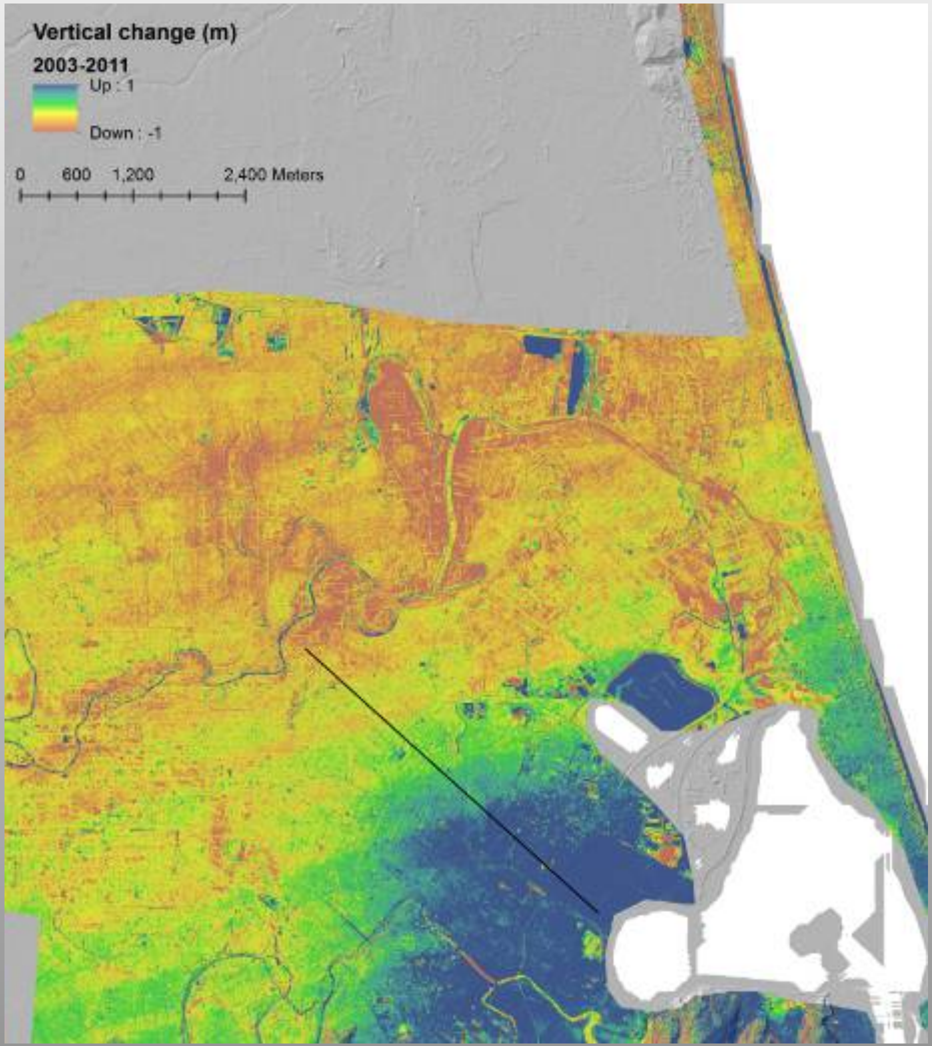
# Cosmo SKYMed coherence



# Cosmo SKYMed (X-band SAR)



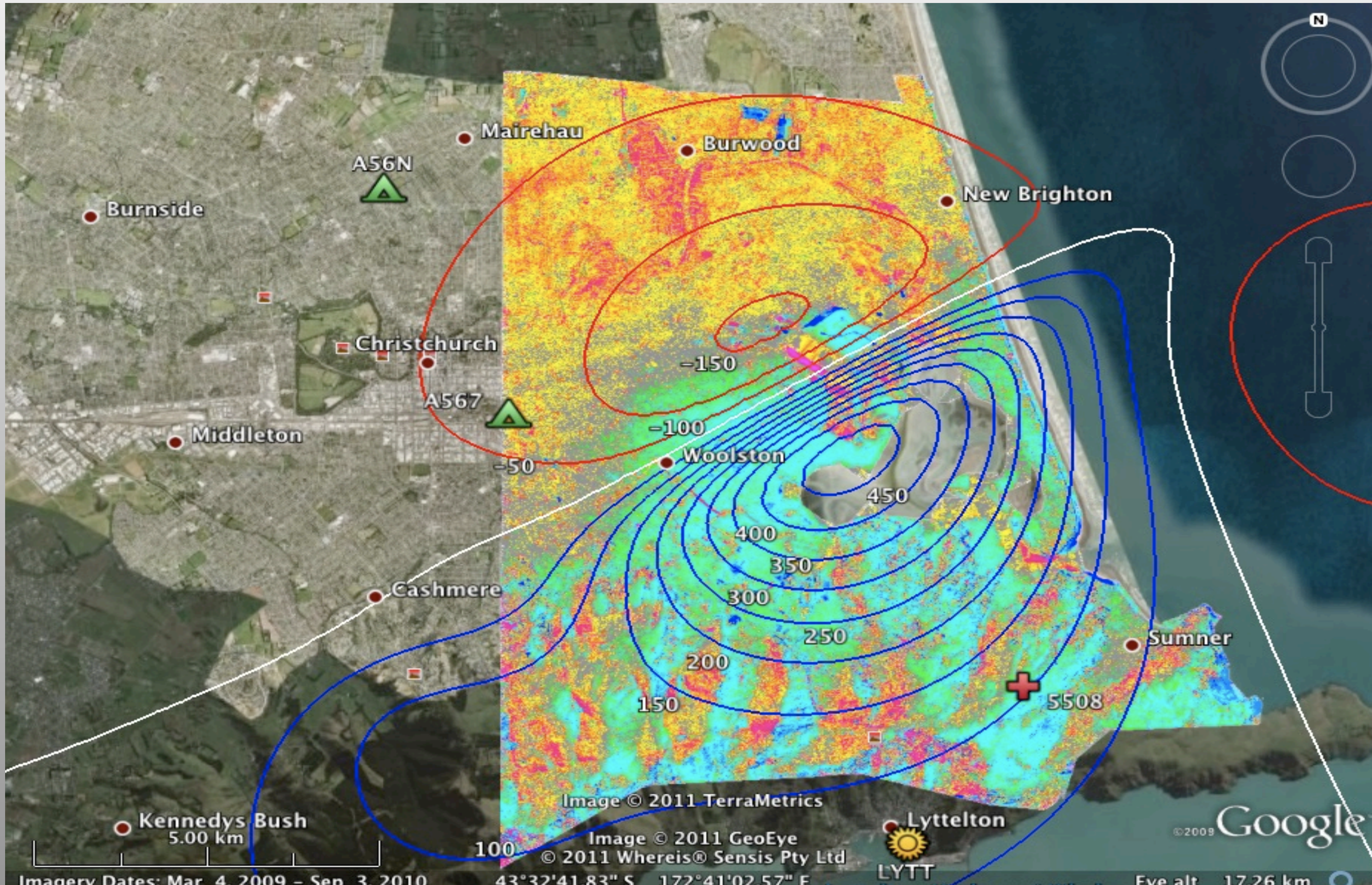
# Airborne LiDAR differencing (2003-2011)




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

# Vertical displacement (mm)

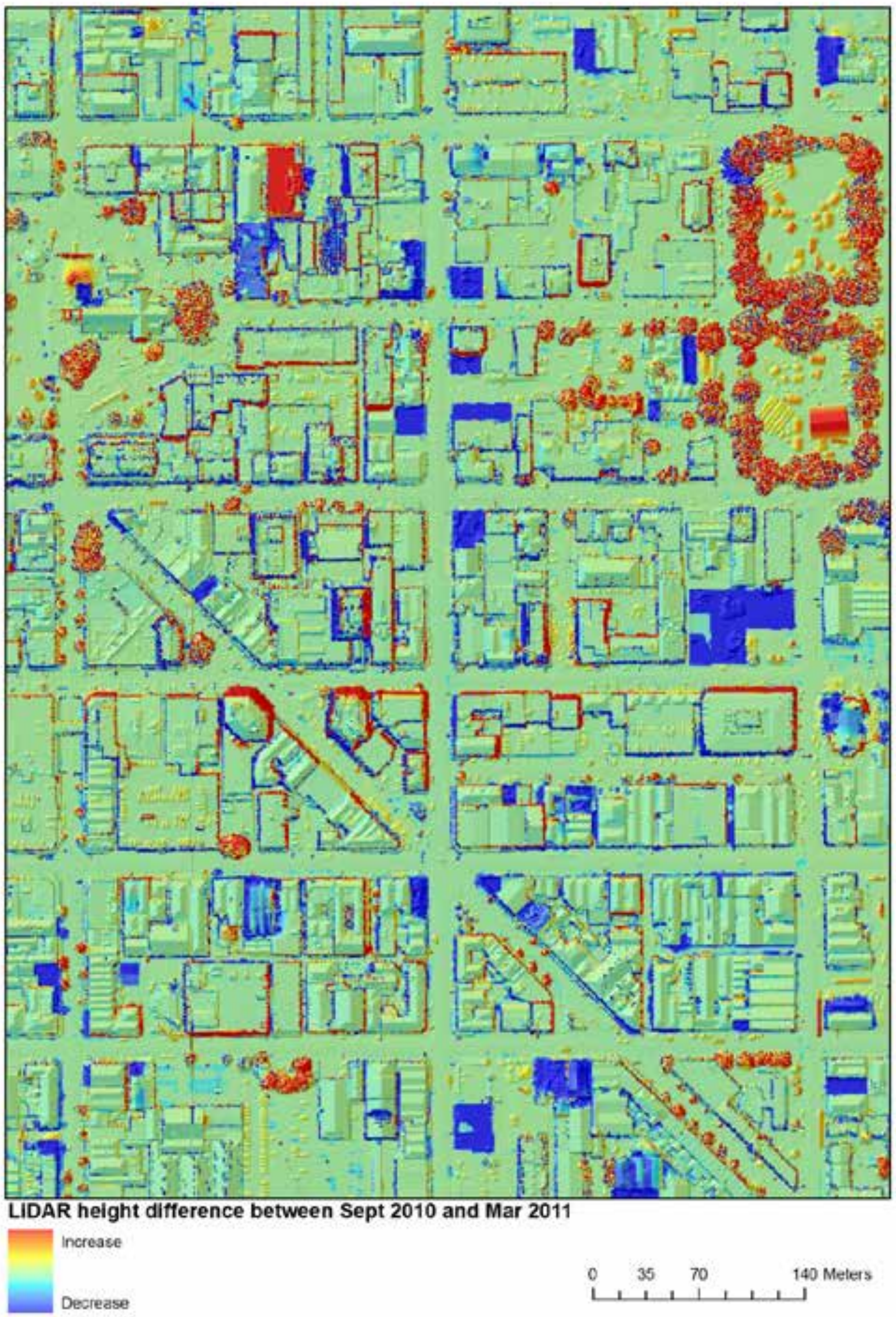
## modelled from GPS observations and 2003-2011 LiDAR

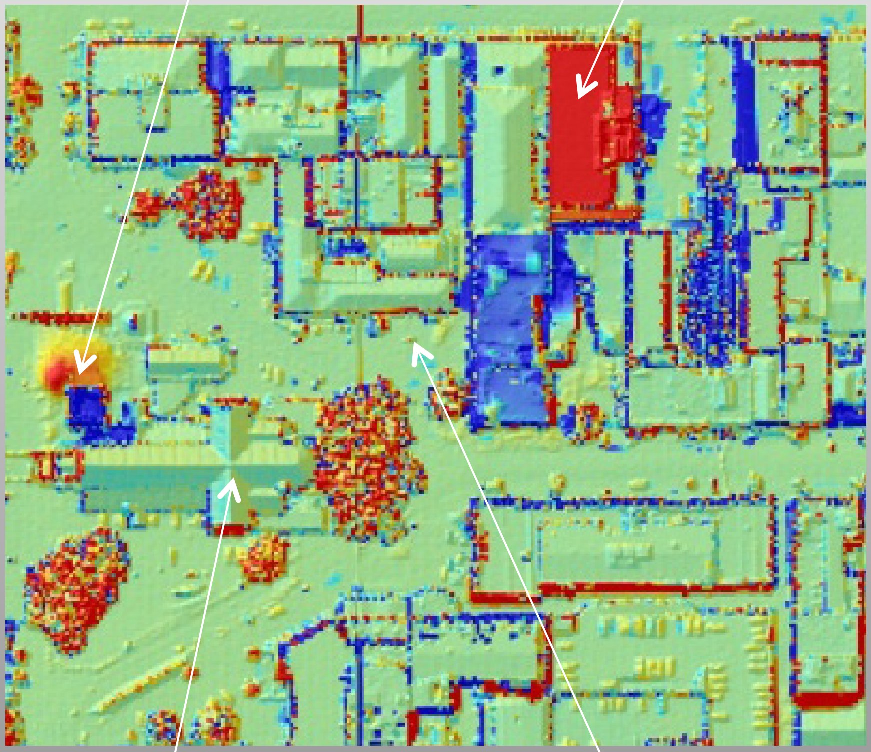



Blue= up, Yellow/Red = down

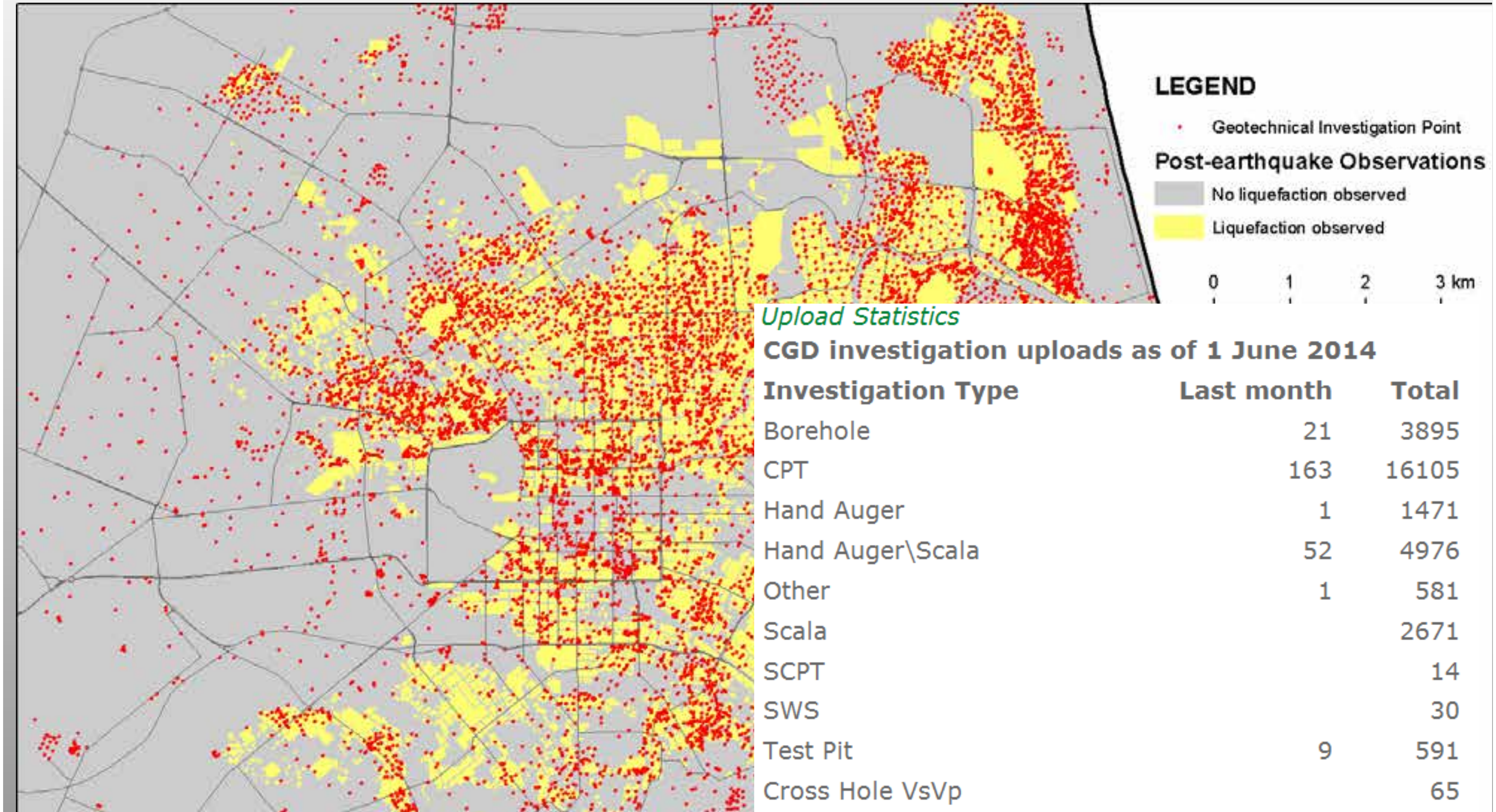
Source: J. Beavan, GNS Science

# LiDAR change detection



# Canterbury Geotechnical database




*Upload Statistics*

**CGD investigation uploads as of 1 June 2014**

| Investigation Type | Last month | Total |
|---|---|---|
| Borehole | 21 | 3895 |
| CPT | 163 | 16105 |
| Hand Auger | 1 | 1471 |
| Hand Auger\Scala | 52 | 4976 |
| Other | 1 | 581 |
| Scala | | 2671 |
| SCPT | | 14 |
| SWS | | 30 |
| Test Pit | 9 | 591 |
| Cross Hole VsVp | | 65 |
| SDMT | 33 | 33 |
| **Grand Total** | **247** | **30432** |

# Lateral displacement from LiDAR

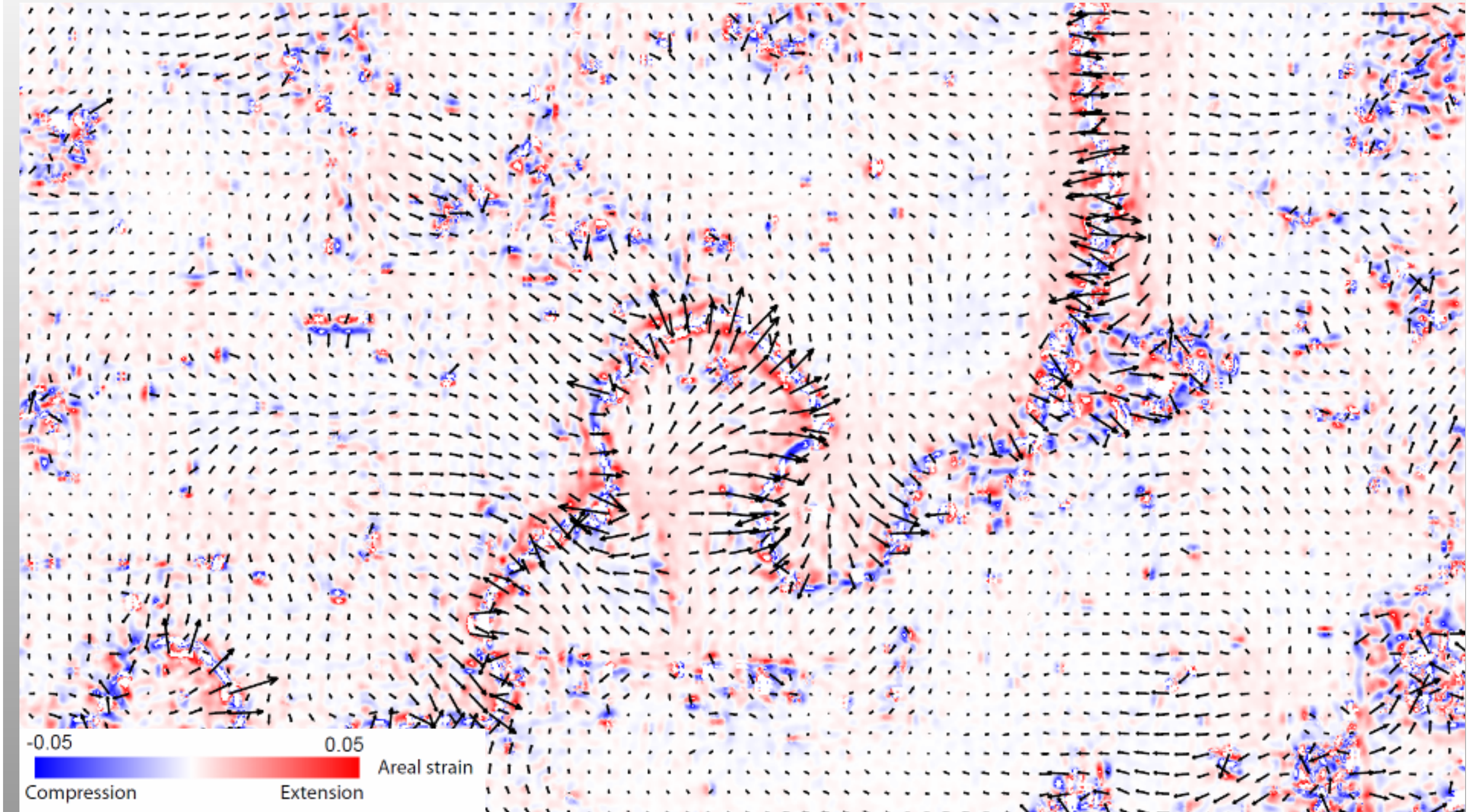
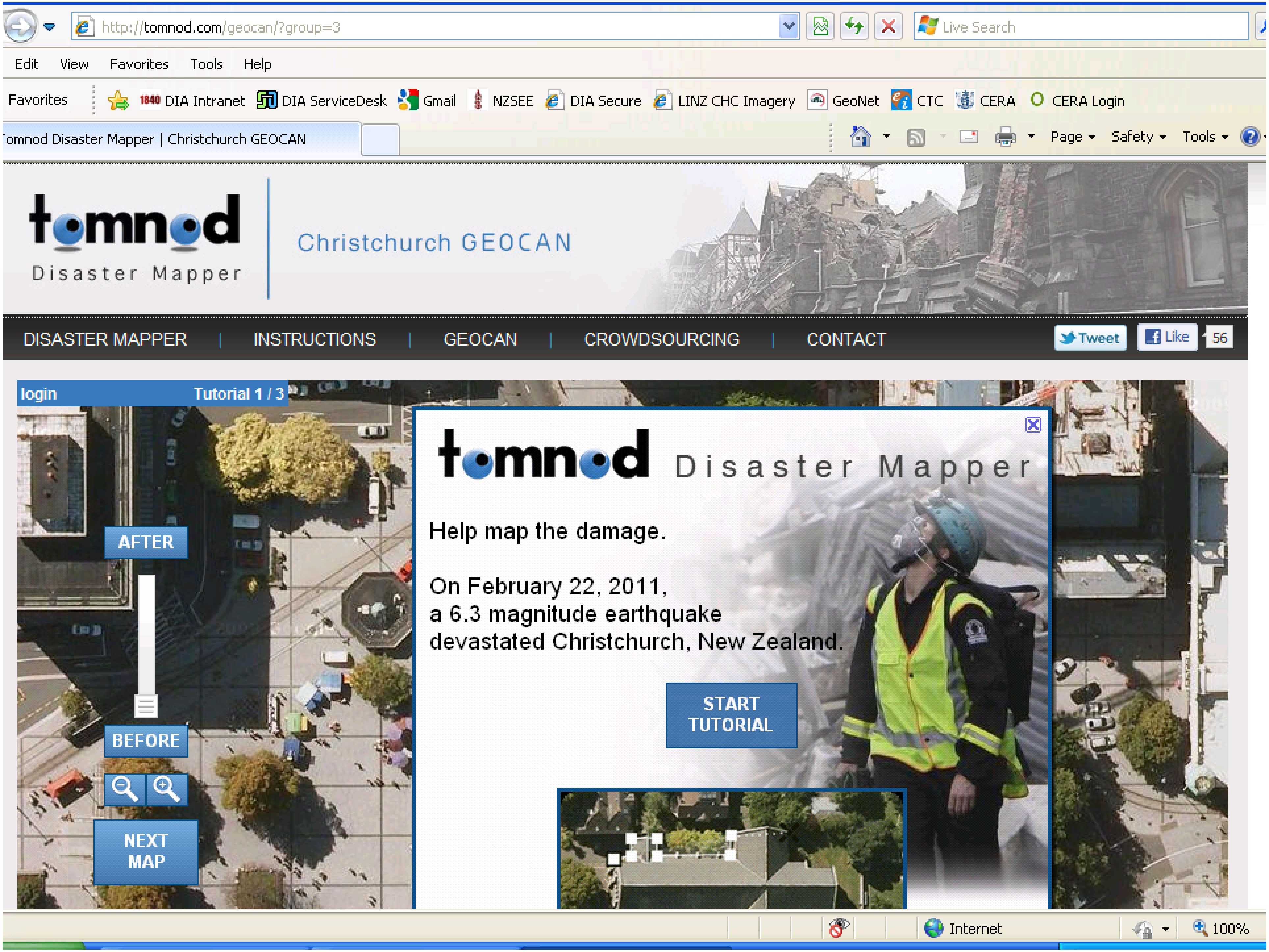



Image correlation processing by Sebastien Leprince, Caltech


http://tomnod.com/geocan/?group=3
Live Search
Edit View Favorites Tools Help
Favorites DIA Intranet DIA ServiceDesk Gmail NZSEE DIA Secure LINZ CHC Imagery GeoNet CTC CERA CERA Login
Tomnod Disaster Mapper | Christchurch GEOCAN
Page Safety Tools
tomnod Disaster Mapper
Christchurch GEOCAN
DISASTER MAPPER | INSTRUCTIONS | GEOCAN | CROWDSOURCING | CONTACT
Tweet Like 56
login Tutorial 1 / 3
AFTER
BEFORE
NEXT MAP
tomnod Disaster Mapper
Help map the damage.
On February 22, 2011,
a 6.3 magnitude earthquake
devastated Christchurch, New Zealand.
START TUTORIAL
Internet
100%

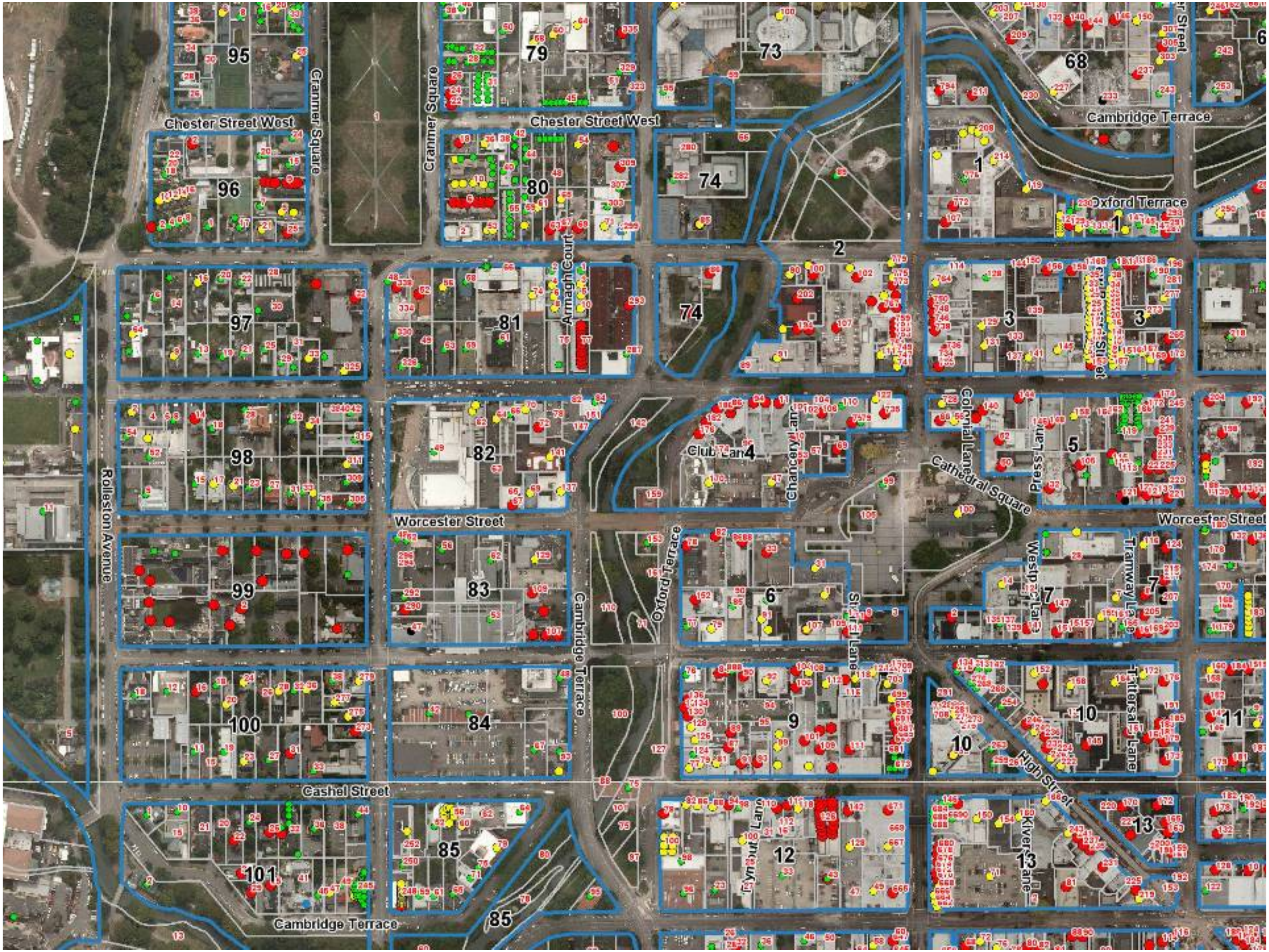
A272

# 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

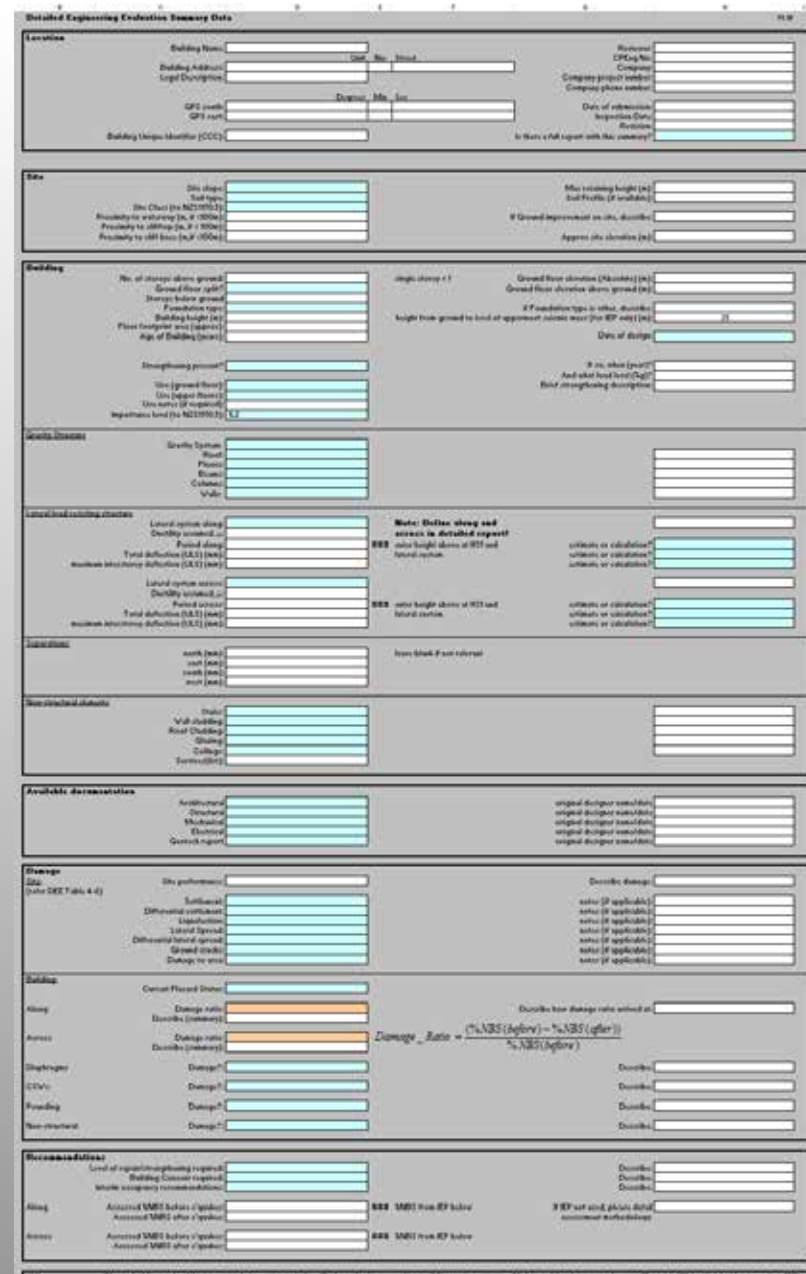

Chester Street West
Cranmer Square
Chester Street West
Cambridge Terrace
Oxford Terrace
Armagh Court
Rolleston Avenue
Worcester Street
Club Lane
Chancery Lane
Colonial Lane
Press Lane
Cathedral Square
Worcester Street
Oxford Terrace
Cambridge Terrace
Tramway Lane
Cashel Street
Cambridge Terrace
High Street
Tattersalls Lane
Kivers Lane
95
79
73
68
96
80
74
1
97
81
74
2
3
3
98
82
4
5
99
83
6
7
7
100
84
9
10
10
11
101
85
85
12
13
13

# 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

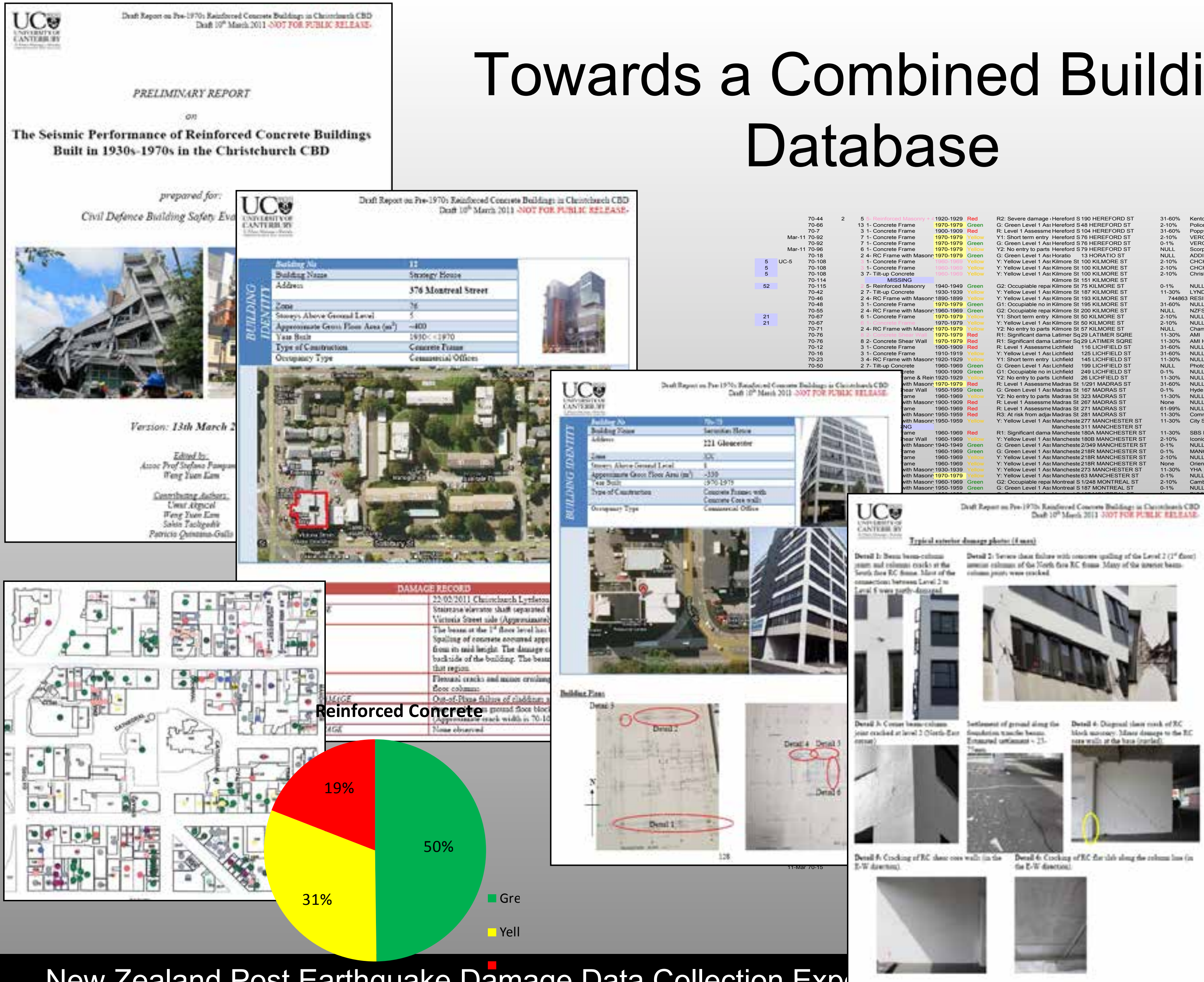
- Excel spreadsheet
  - Most common platform for engineers
- Used drop-down lists where thought possible and practical
- Limited free-field descriptions
- Included simple IEP capacity calculator – voluntary use
- *Next time*:
  - Add simple damage states
  - Even more drop-downs
  - Different platform?



# Building Damage Evaluation (2)

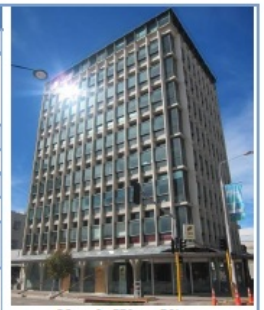
- *Data storage*: Electonic reports (pdf) and Detailed Engineering Evaluation (DEE) summary spreadsheets submitted to CERA; stored in CERA database until 'approved' by CERA then passed to Council Building Reports
- *Data retrieval:* Council considers their building records open to public as with building 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

# Towards a Combined Building Database



**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 ($m^2$) | ~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**

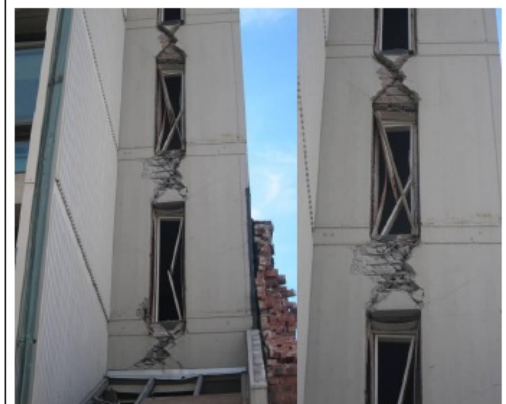
Photos of SBS Building under construction in the 1960s.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

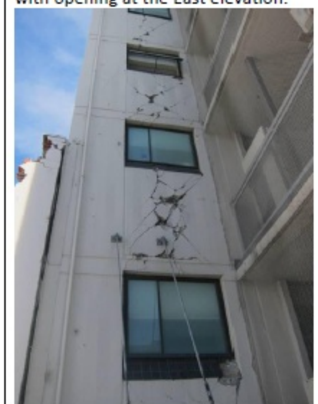
Draft Report on Pre-1970s Reinforced Concrete Buildings in Christchurch CBD
Draft 22nd March 2011 -NOT FOR PUBLIC RELEASE-

**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

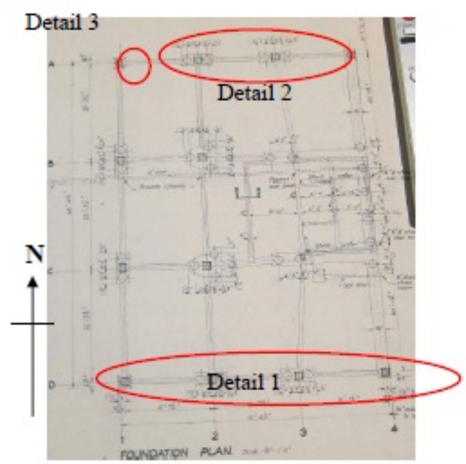


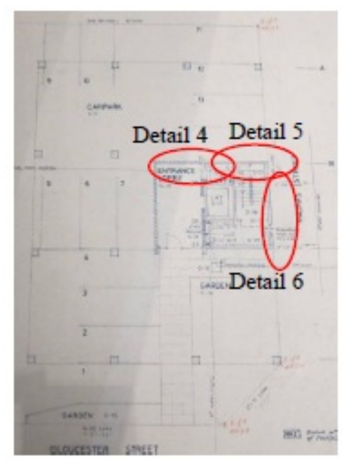
UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha CHRISTCHURCH NEW ZEALAND
Draft Report on Pre-1970s Reinforced Concrete Buildings in Christchurch CBD


*BUILDING IDENTITY*

| | |
|---|---|
| *Building No* | 70s-302 |
| Building Name | Securities House |
| Address | **221 Gloucester** |
| Zone | 3a |
| Storeys Above Ground Level | 8 |
| Approximate Gross Floor Area ($m^2$) | ~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.

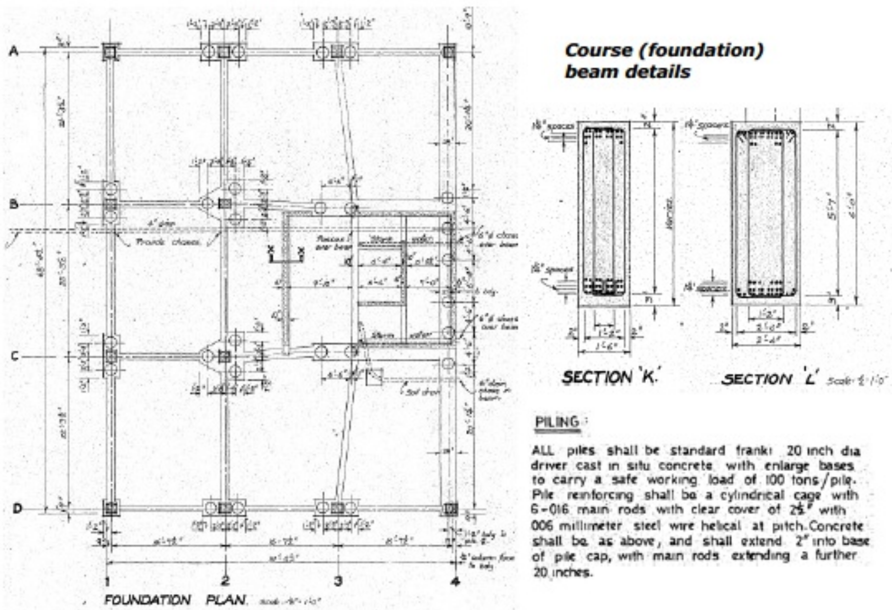



**Figure 2: Foundation system. Left: foundation pan view; right: course beam details and piling information**

## *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).

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

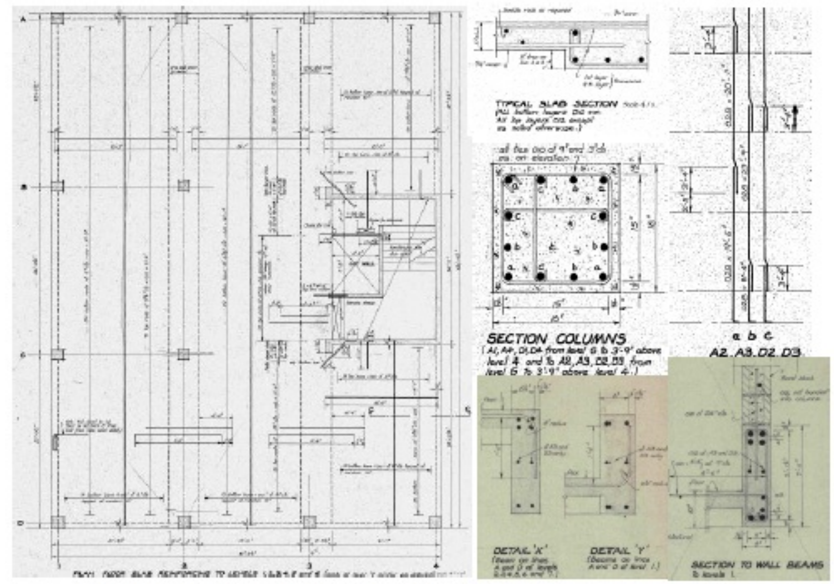



**Figure 3: Structural System. Left: typical plan view; right: Column, beam and slab details**

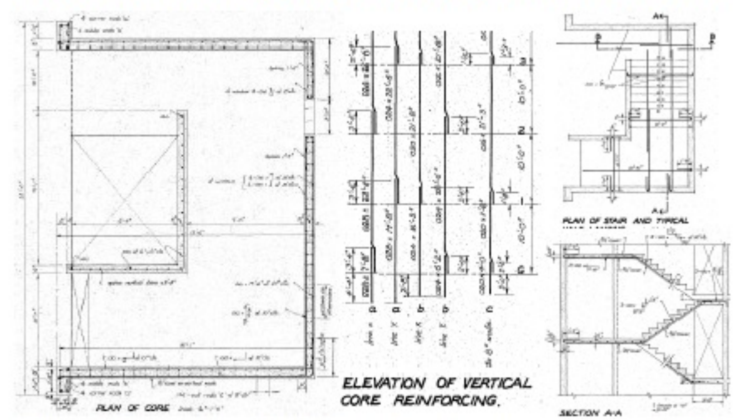


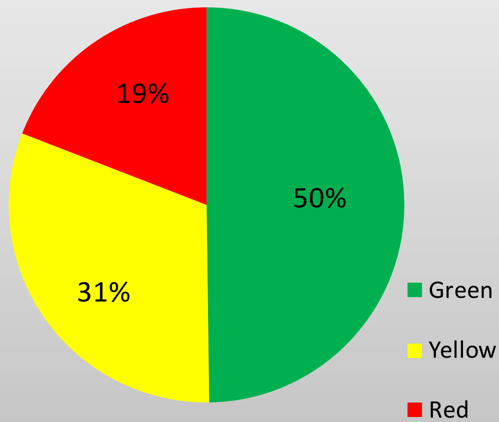

**Figure 4: Structural System. Left: C-shaped wall details; right: stairs connection details**



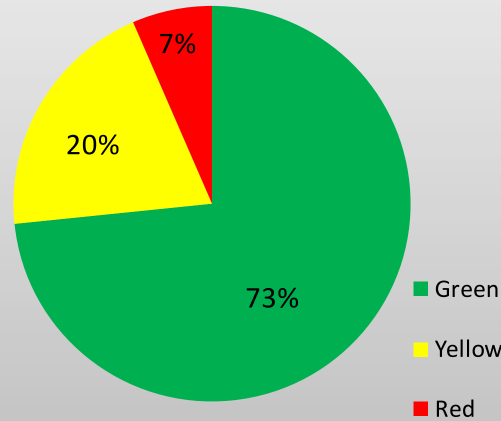
New Zealand Post Earthquake Damage Data Collection Experience

# Damaged buildings (22 Feb 2011)

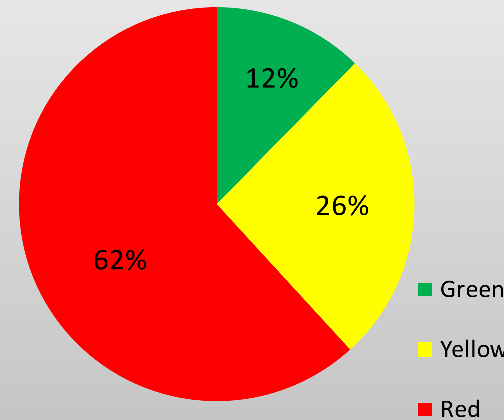
**Reinforced Concrete**



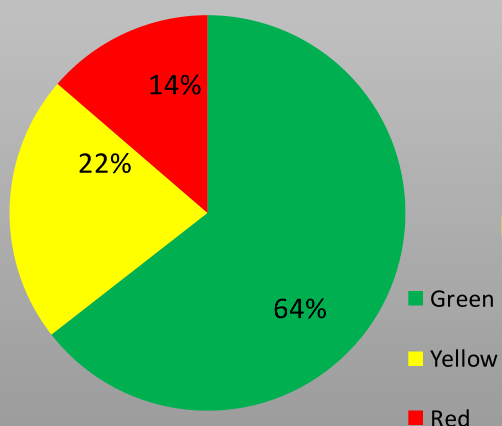

**Steel**



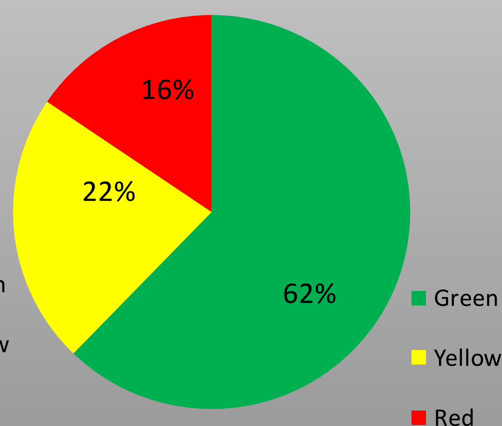

**Unreinforced Masonry**



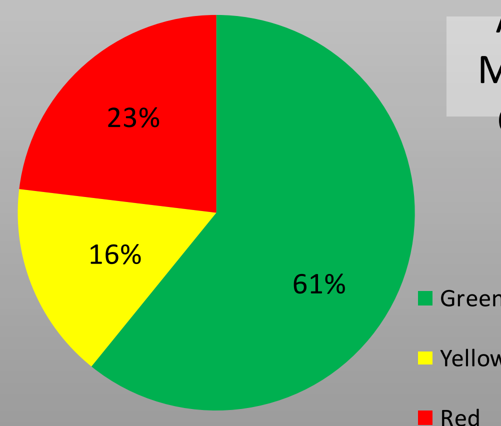

**Timber**



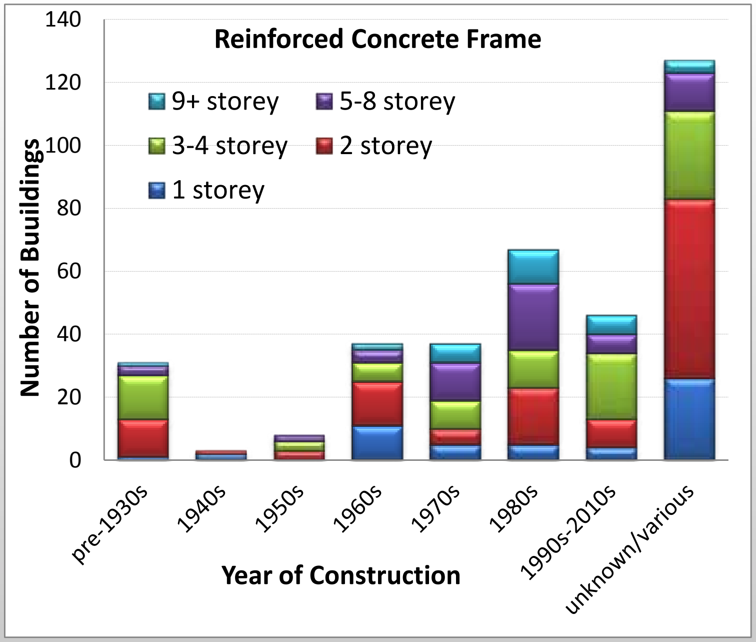

**Reinforced Masonry**

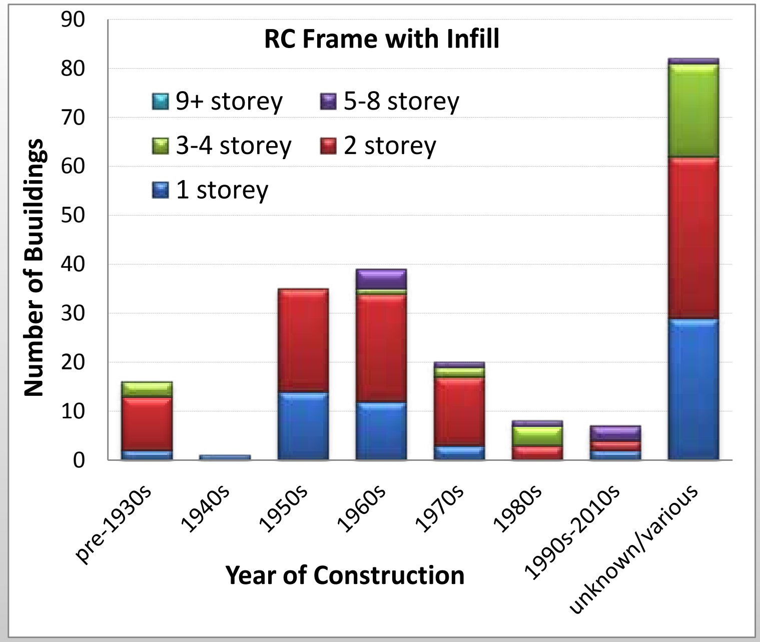


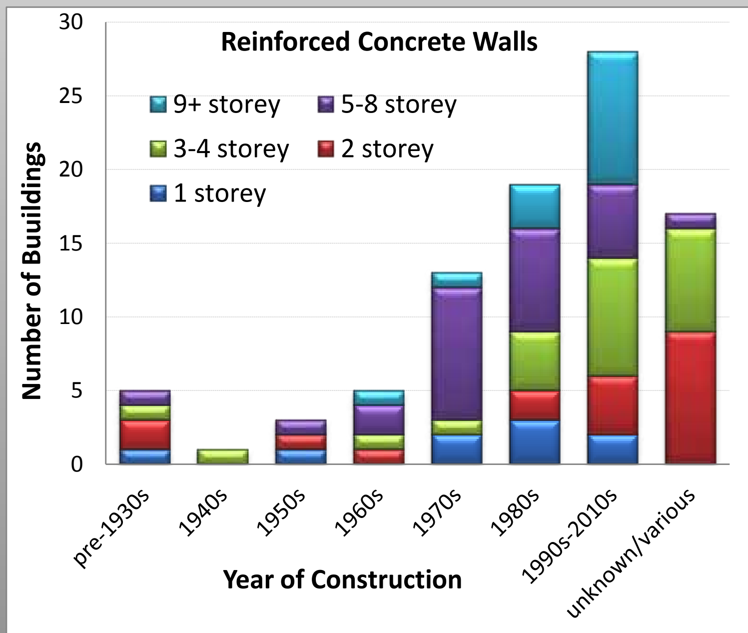

**Unknown / Not reported**

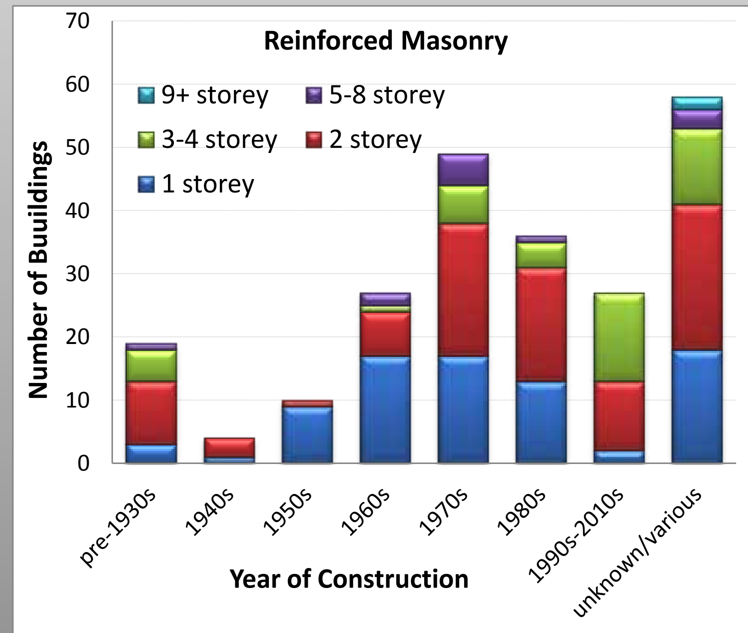



As per 18 Mar 2011 – CCC Data

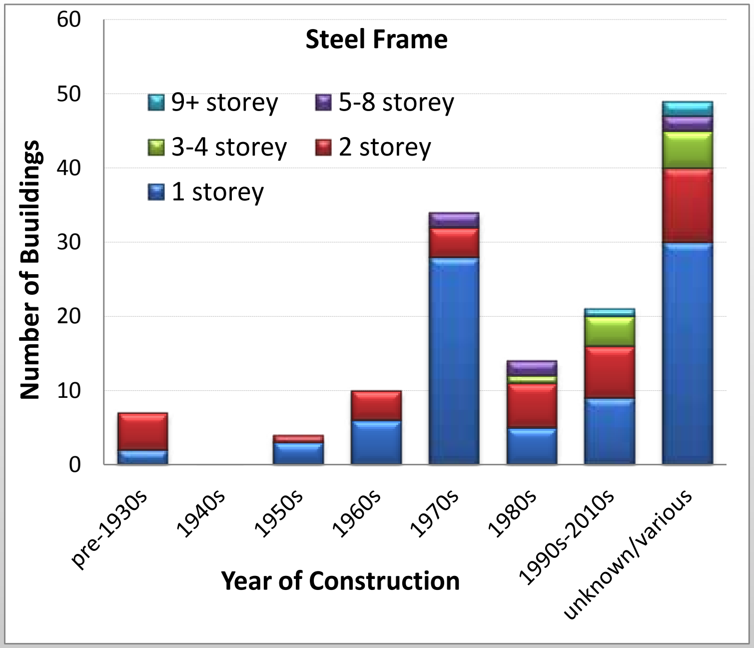


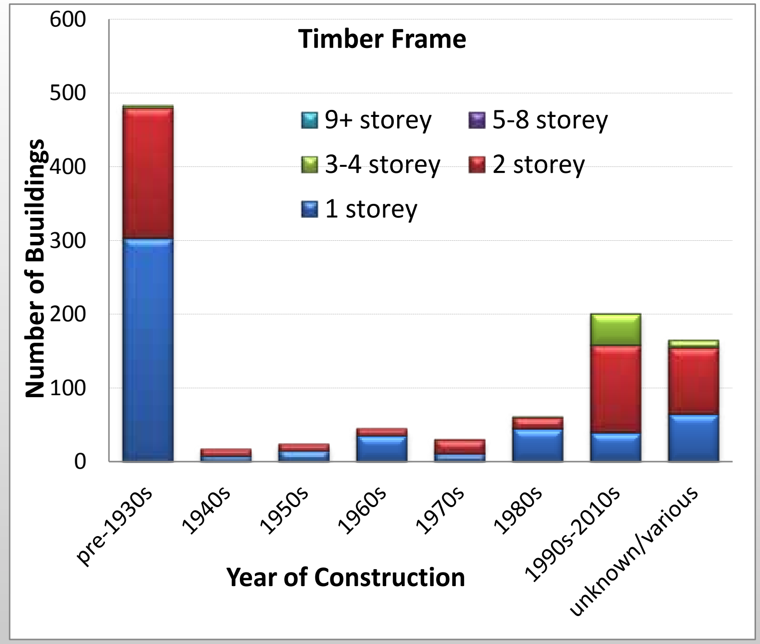



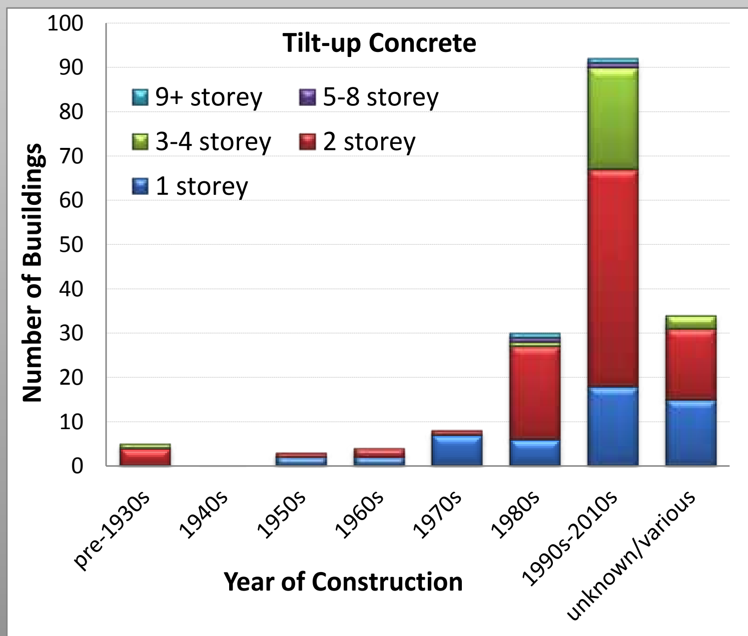



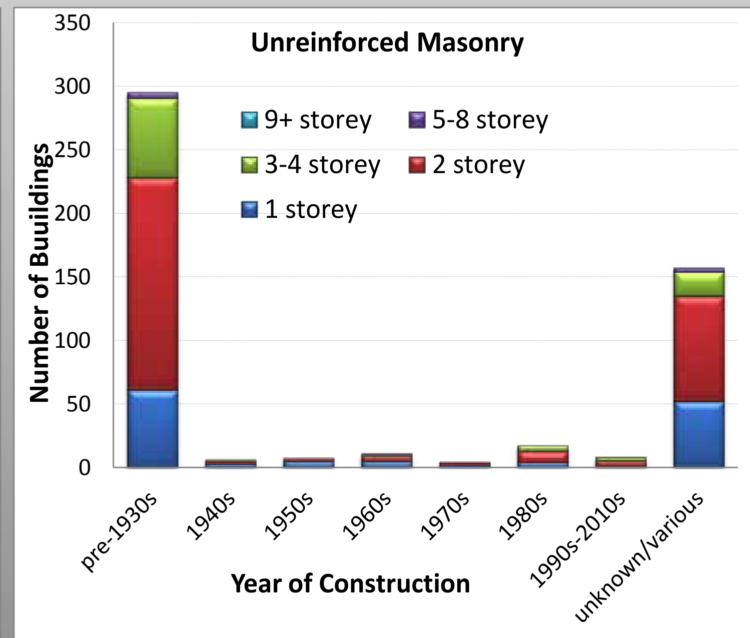




New Zealand Post Earthquake Damage Data Collection Experience

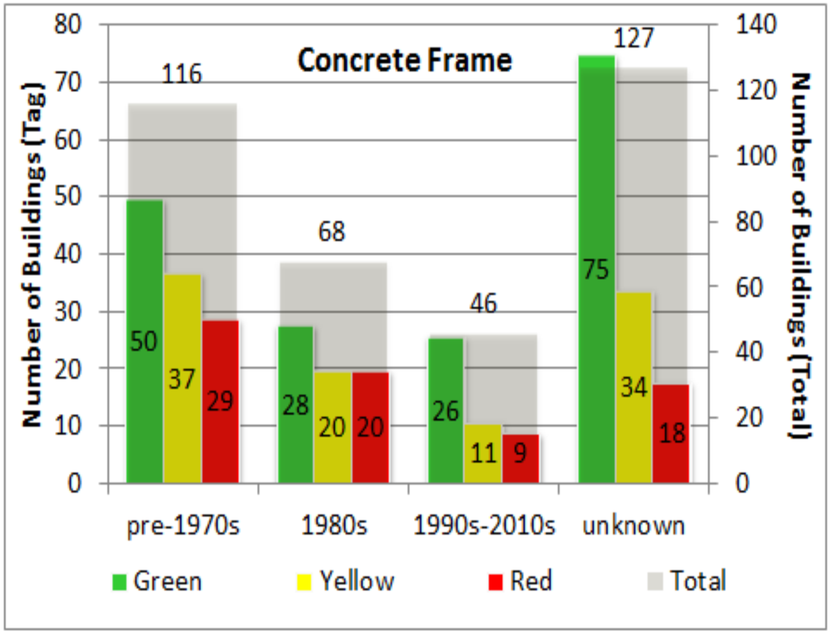


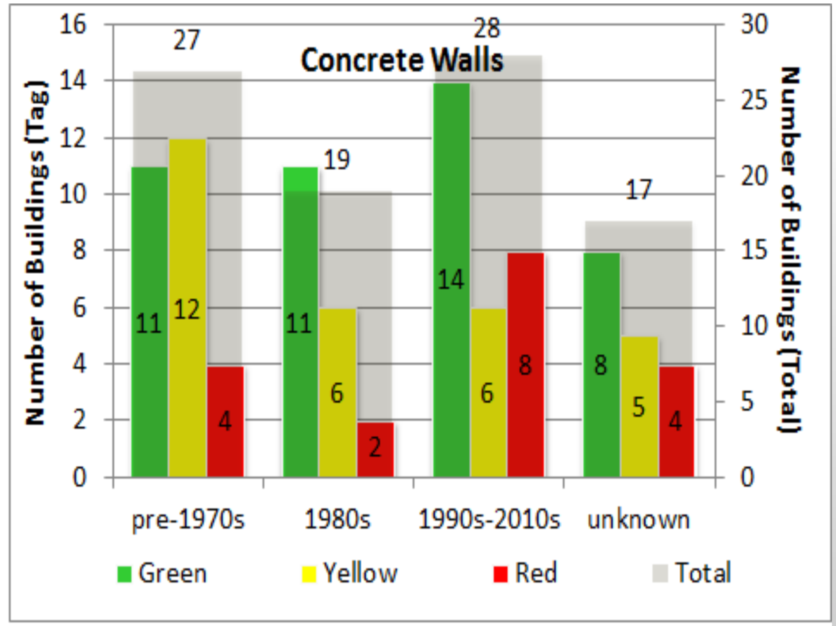



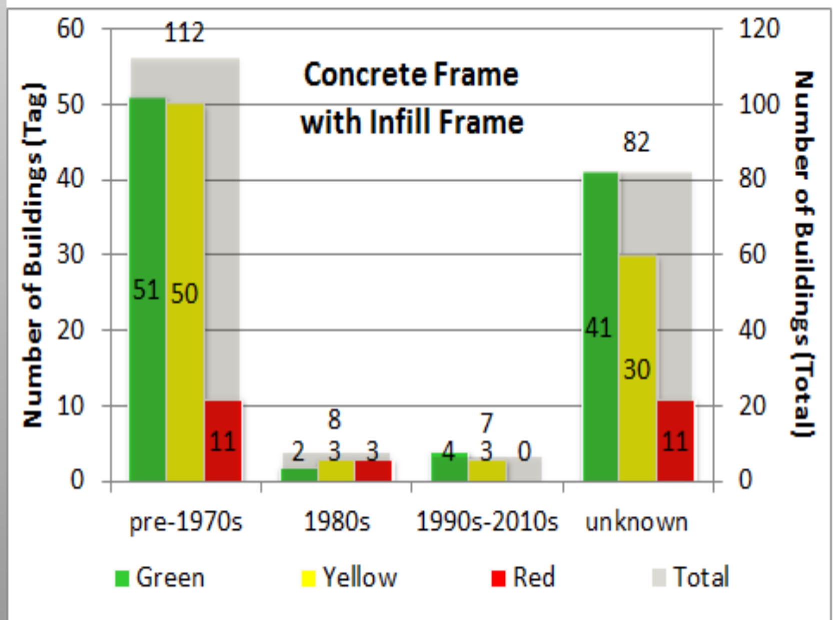



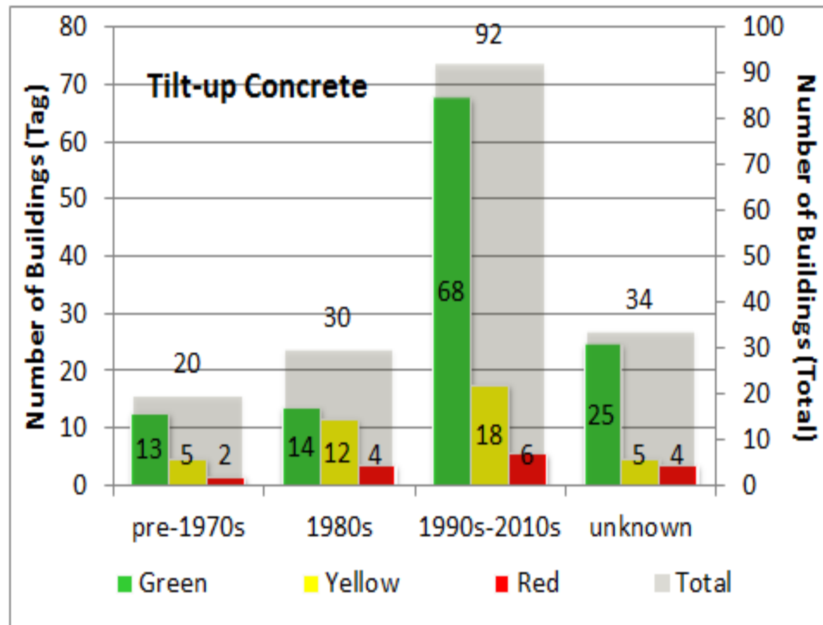




New Zealand Post Earthquake Damage Data Collection Experience

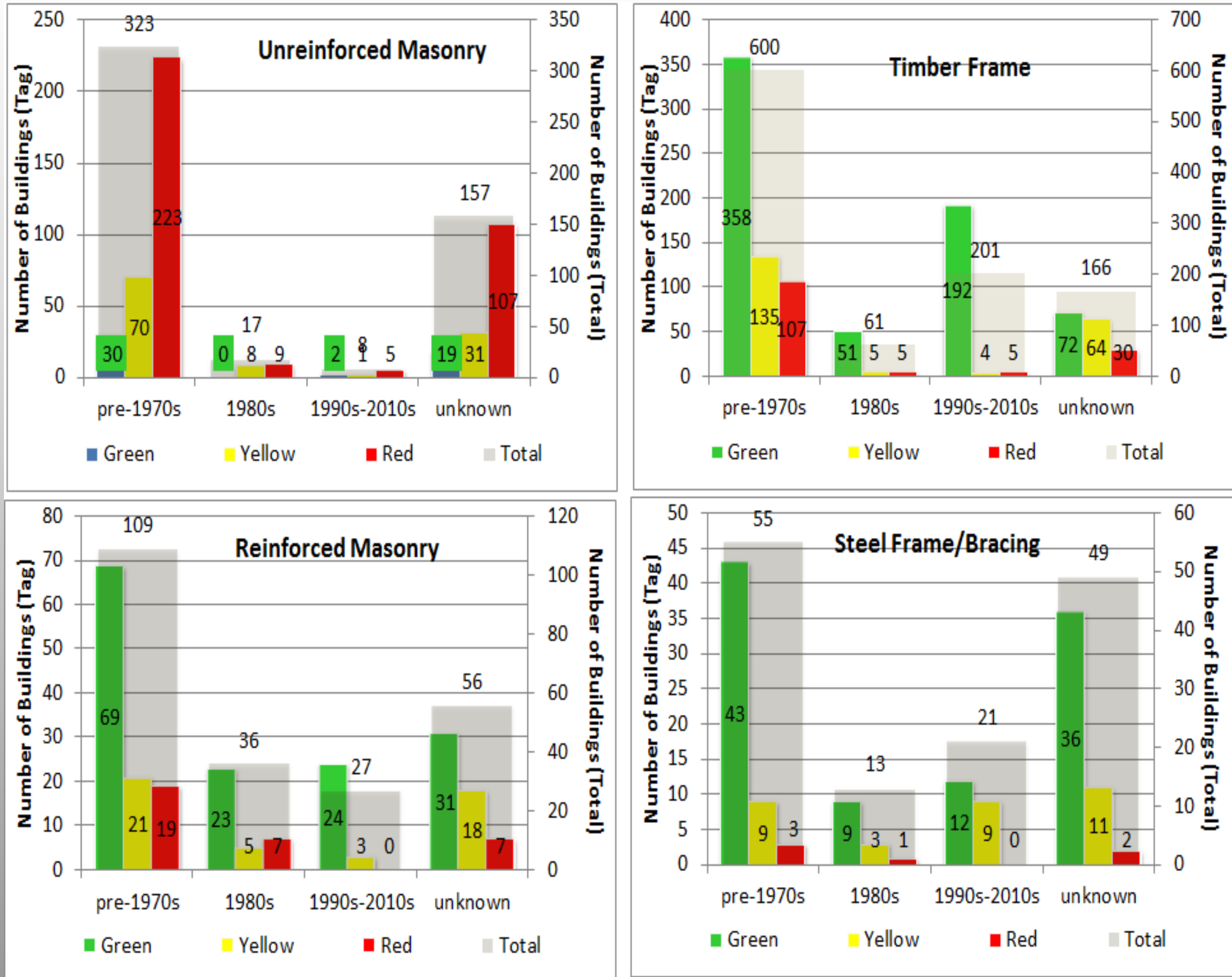


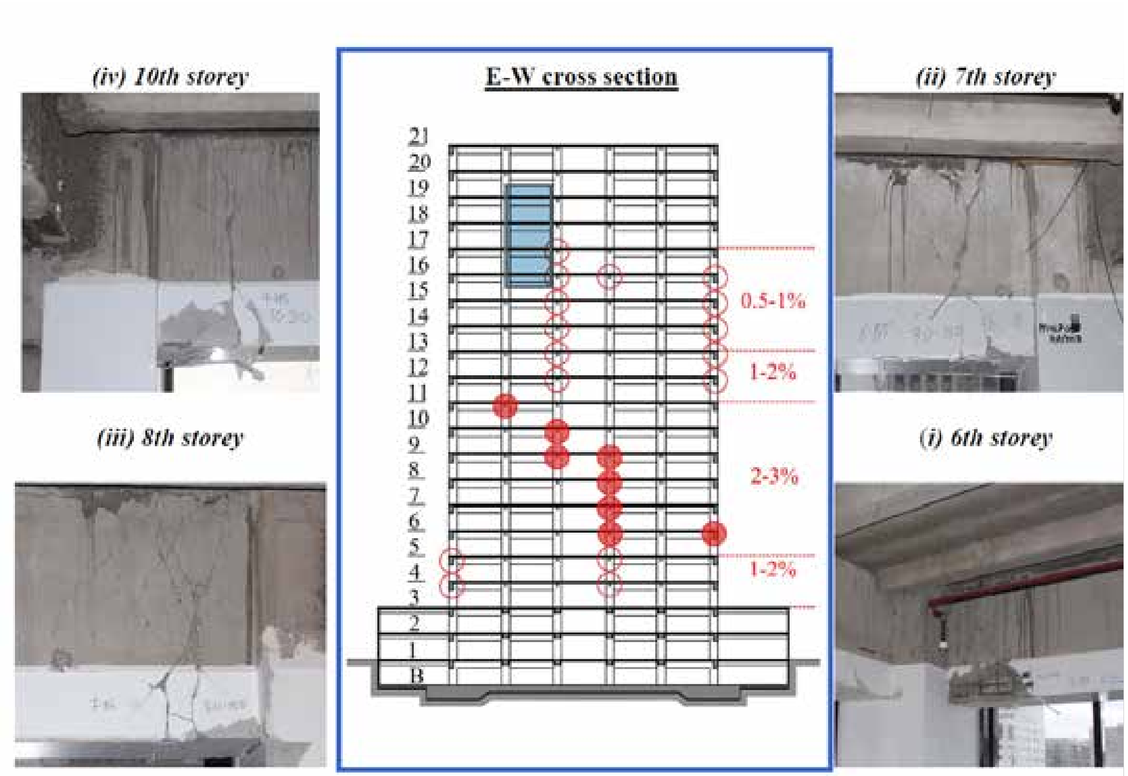



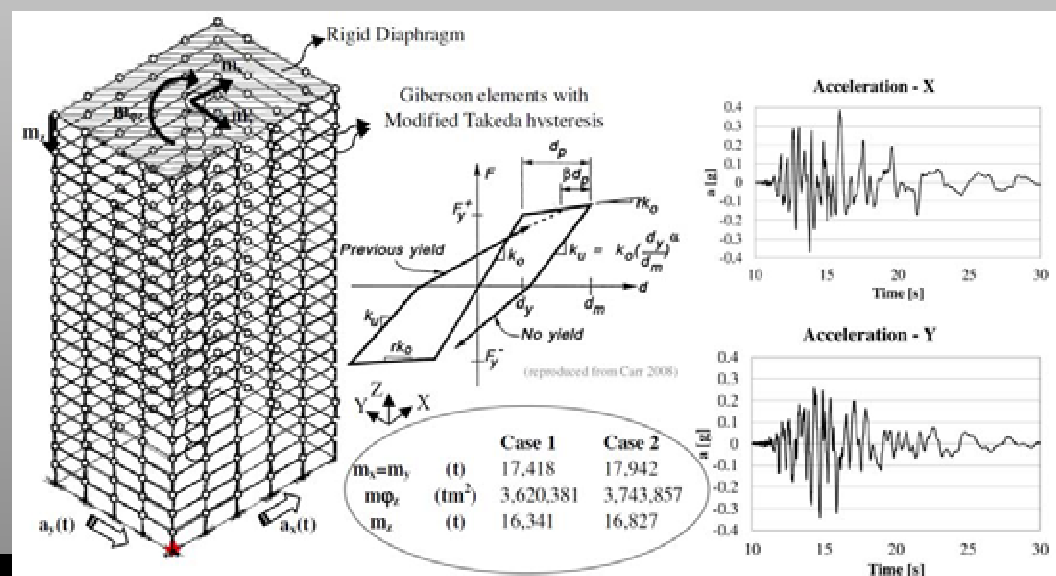

New Zealand Post Earthquake Damage Data Collection Experience




New Zealand Post Earthquake Damage Data Collection Experience




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

- Globaly 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 2

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:* date sharing protocols between agencies

Nat Hazards
DOI 10.1007/s11069-014-1094-7

ORIGINAL PAPER

# 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 Deely · 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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Published online: 27 February 2014 

New Zealand Post Earthquake Damage Data Collection Experience

## Relative risk by gender and age

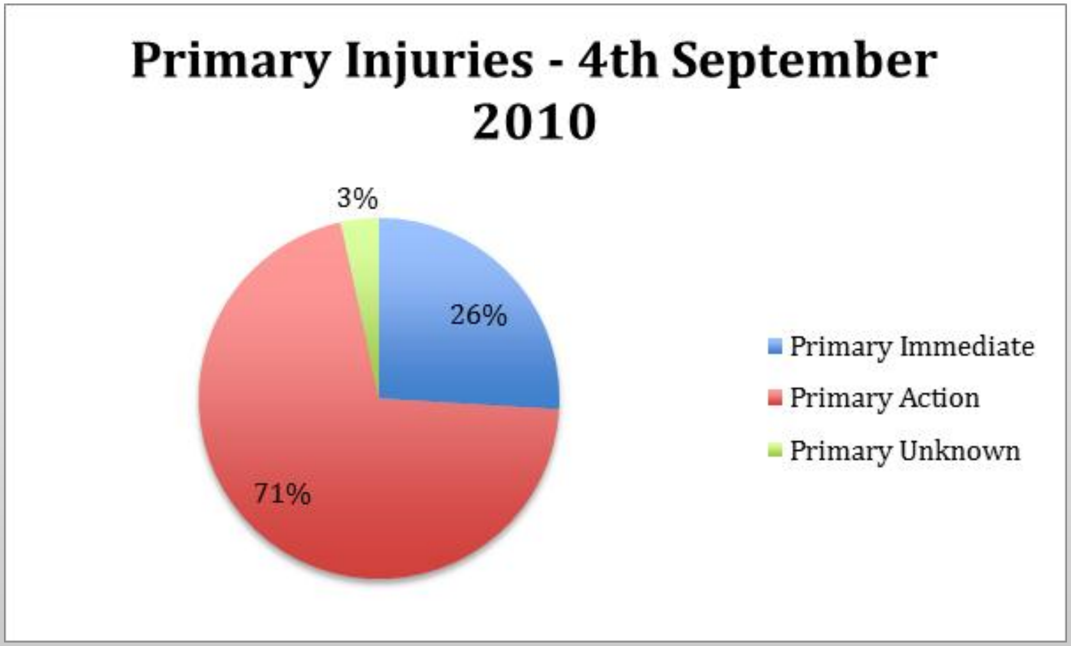
| | Christchurch | Darfield | | | Christchurch | | |
|---|---|---|---|---|---|---|---|
| | Population | Total Injuries (n) | Injuries per 10,000 | Risk | Total injuries (n) | Injuries per 10,000 | Risk |
| **Gender** | | | | | | | |
| **Male** | 168,423 | 803 | 47.7 | 1.0 | 2525 | 149.9 | 1.0 |
| **Female**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

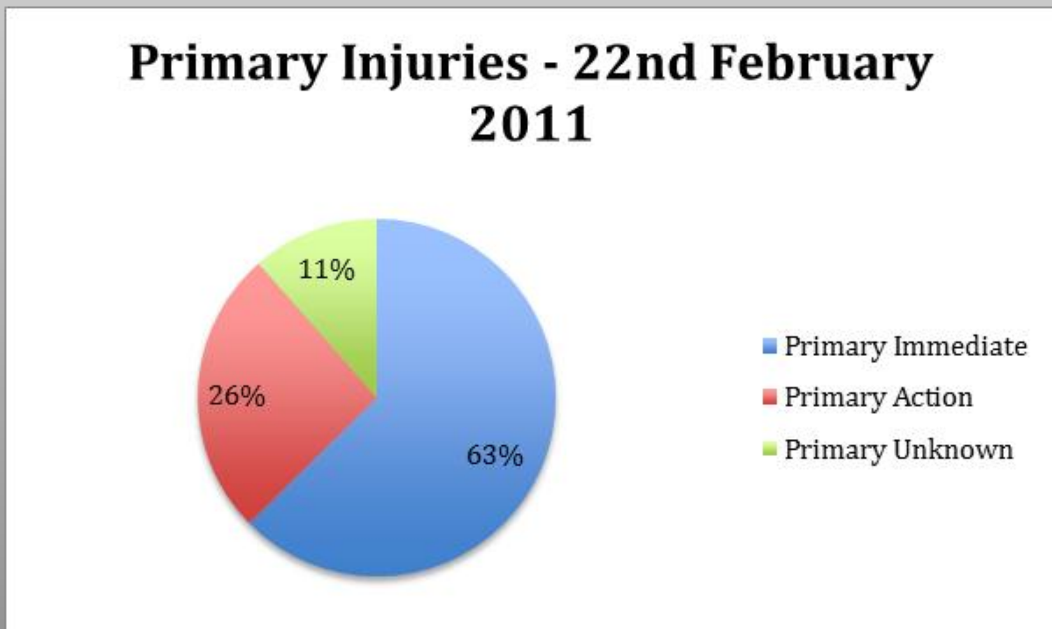
## Relative risk by gender and age

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

## Context of injury

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


Primary Injuries - 4th September 2010
3%
26%
71%
Primary Immediate
Primary Action
Primary Unknown


Primary Injuries - 22nd February 2011
11%
26%
63%
Primary Immediate
Primary Action
Primary Unknown

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

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


**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**


**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)**


# 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

A305

# Reconnaissance framework in Architectural Institute of Japan

**Headquarters**

- Information Command Post
- Disaster Committee
- Research and Proposal Committee
- Recovery Aid Committee

Steering committees

Reinforced Concrete committee

1) School buildings
2) Public halls →BRI
3) Houses →UR
4) Commercial bldgs →BCS, JSCA

Post-earthquake investigation and evaluation on school buildings in commission from MEXT

School Facilities committee

Seismic performance committee

1）RC-WG
2）S-WG

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

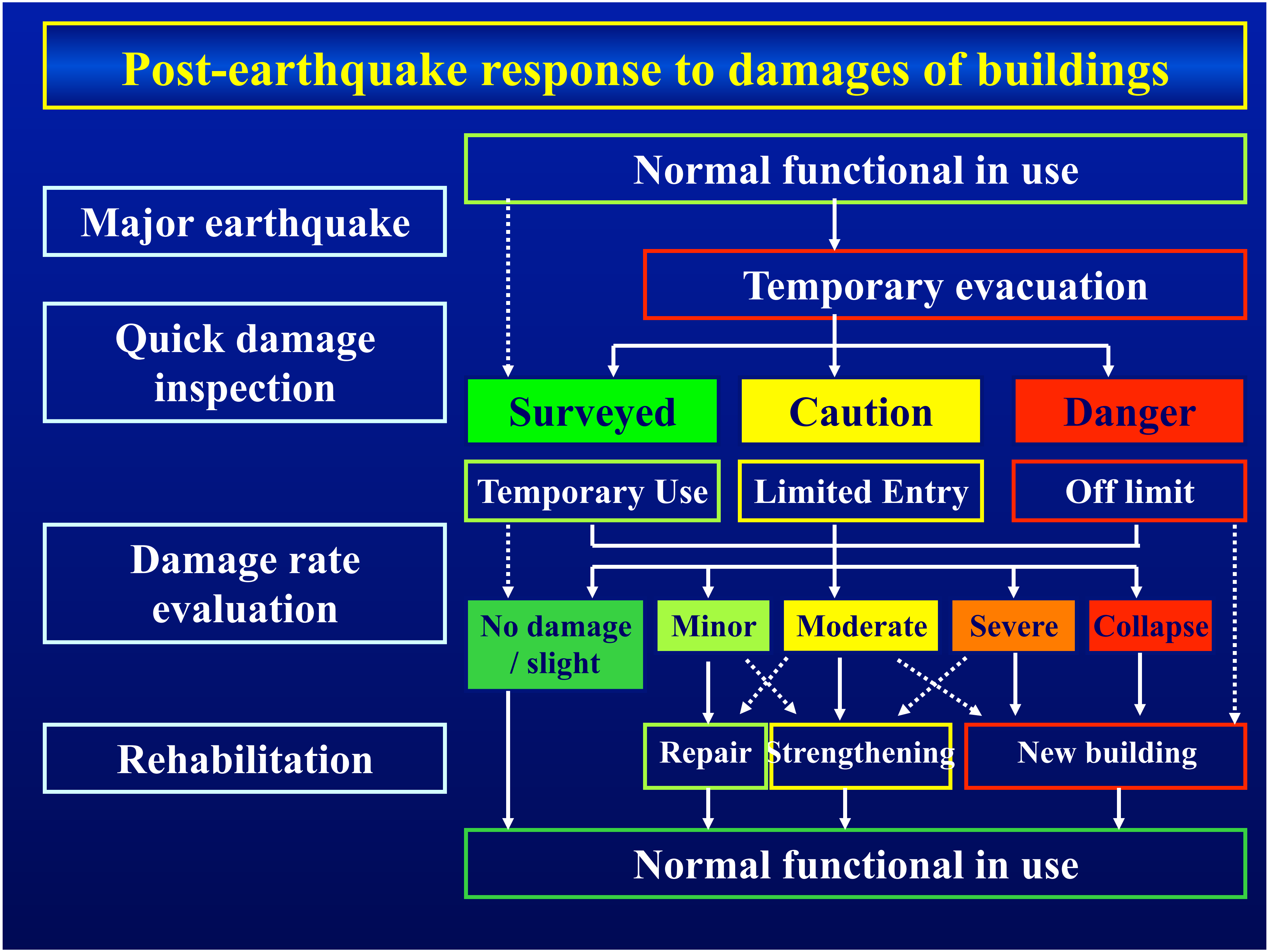
**Ground motions**: Free field earthquake motions were recorded at 2000 K-net stations in 20km mesh and 2000 others

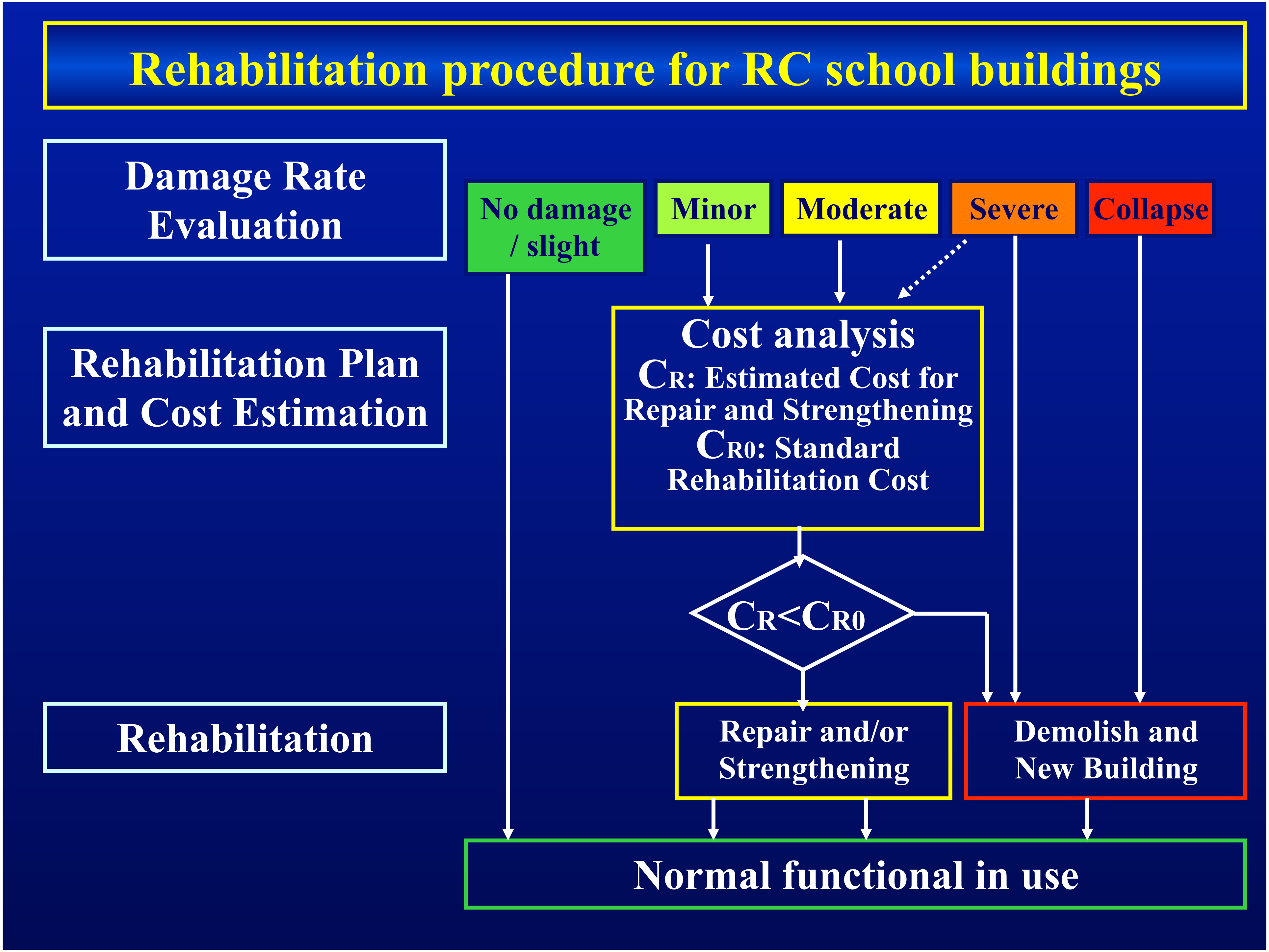
**Lost data:**

**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

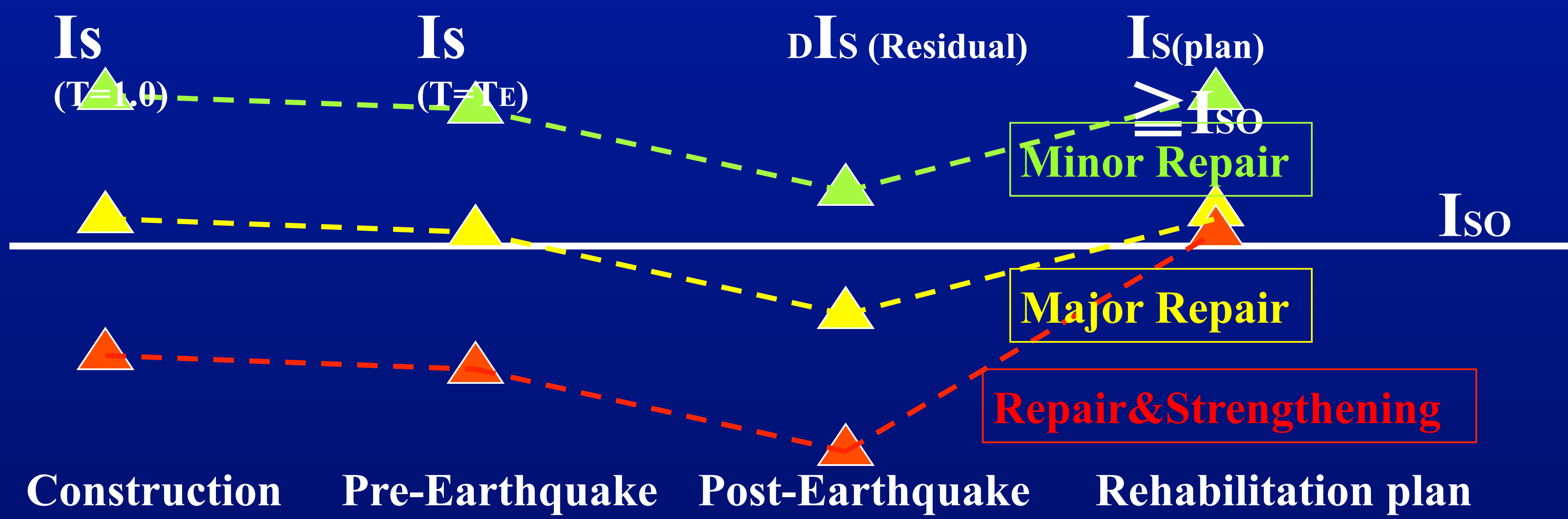
**Input motions to buildings**: Inputs and responses were recorded at some buildings, but very few in cases with severe damages


Post-earthquake response to damages of buildings
Major earthquake
Quick damage inspection
Damage rate evaluation
Rehabilitation
Normal functional in use
Temporary evacuation
Surveyed
Caution
Danger
Temporary Use
Limited Entry
Off limit
No damage / slight
Minor
Moderate
Severe
Collapse
Repair
Strengthening
New building
Normal functional in use
A308


Rehabilitation procedure for RC school buildings
Damage Rate Evaluation
Rehabilitation Plan and Cost Estimation
Rehabilitation
No damage / slight
Minor
Moderate
Severe
Collapse
Cost analysis
CR: Estimated Cost for Repair and Strengthening
CR0: Standard Rehabilitation Cost
CR<CR0
Repair and/or Strengthening
Demolish and New Building
Normal functional in use

# Rehabilitation procedure for RC school buildings

## Target performance for with moderate/minor damage




Seismic Index after rehabilitation shall be planned as:

$I_{S(plan)} = {}_{D}I_{S} + \Delta I_{S} \geqq I_{SO}$

$I_{S(plan)}$=: 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

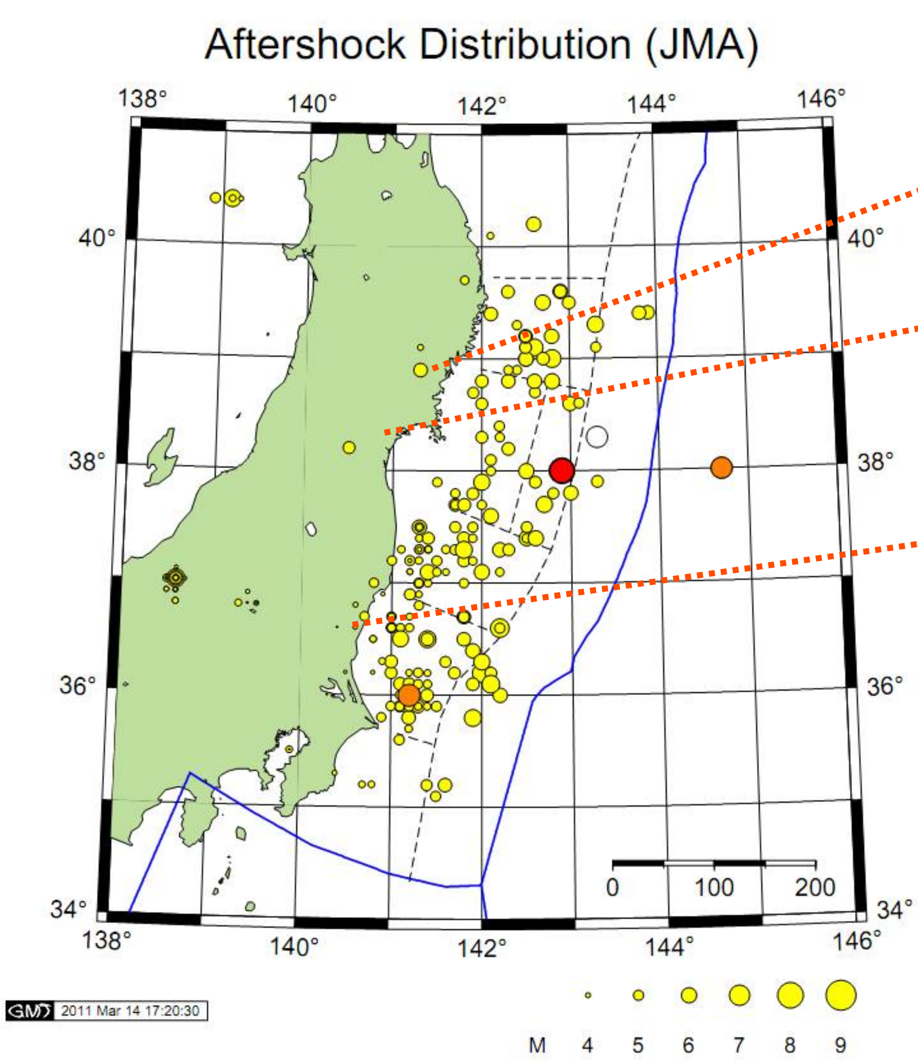
$I_{SO}$ : Seismic Index required for school (≧0.7 or 0.75)

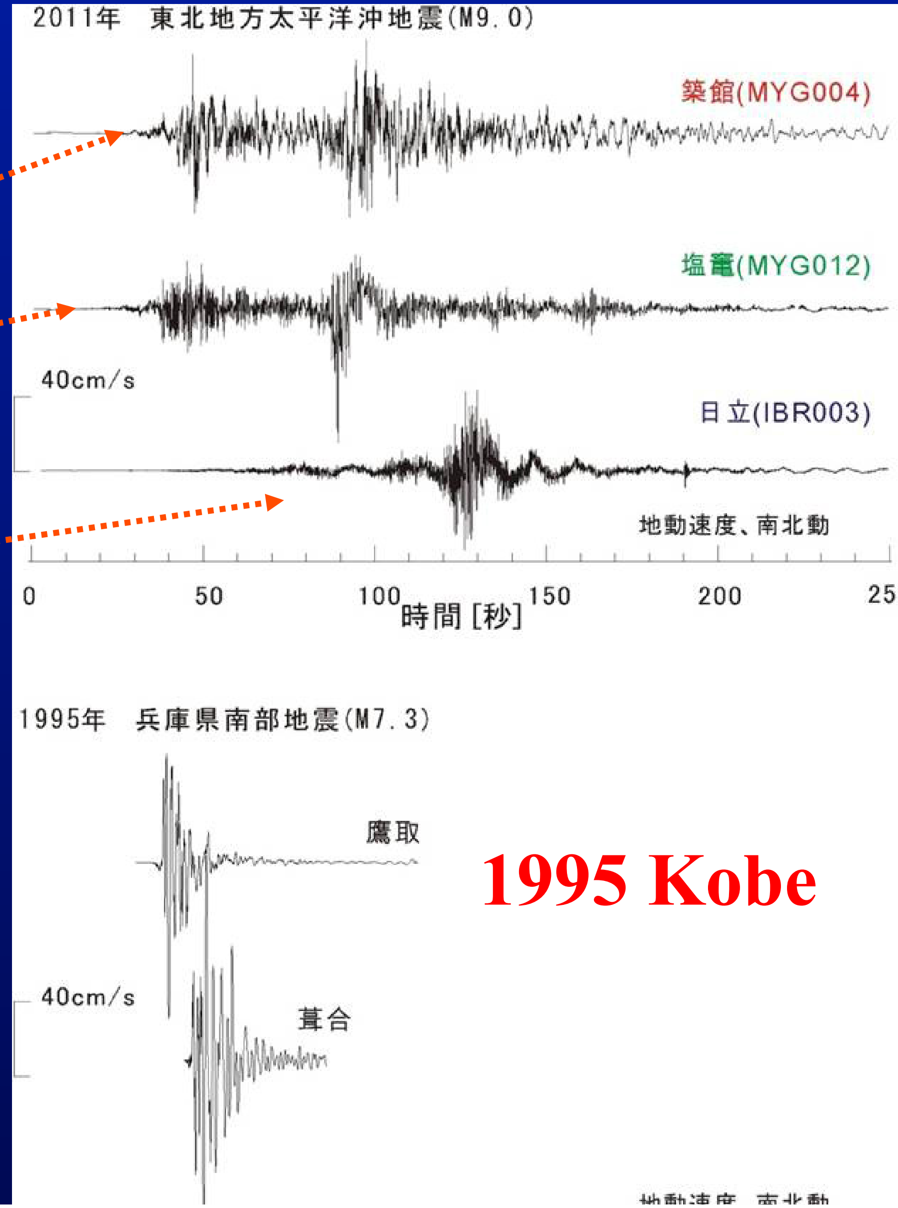
# 3.11 2011 East Japan Earthquake

- ✓ 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

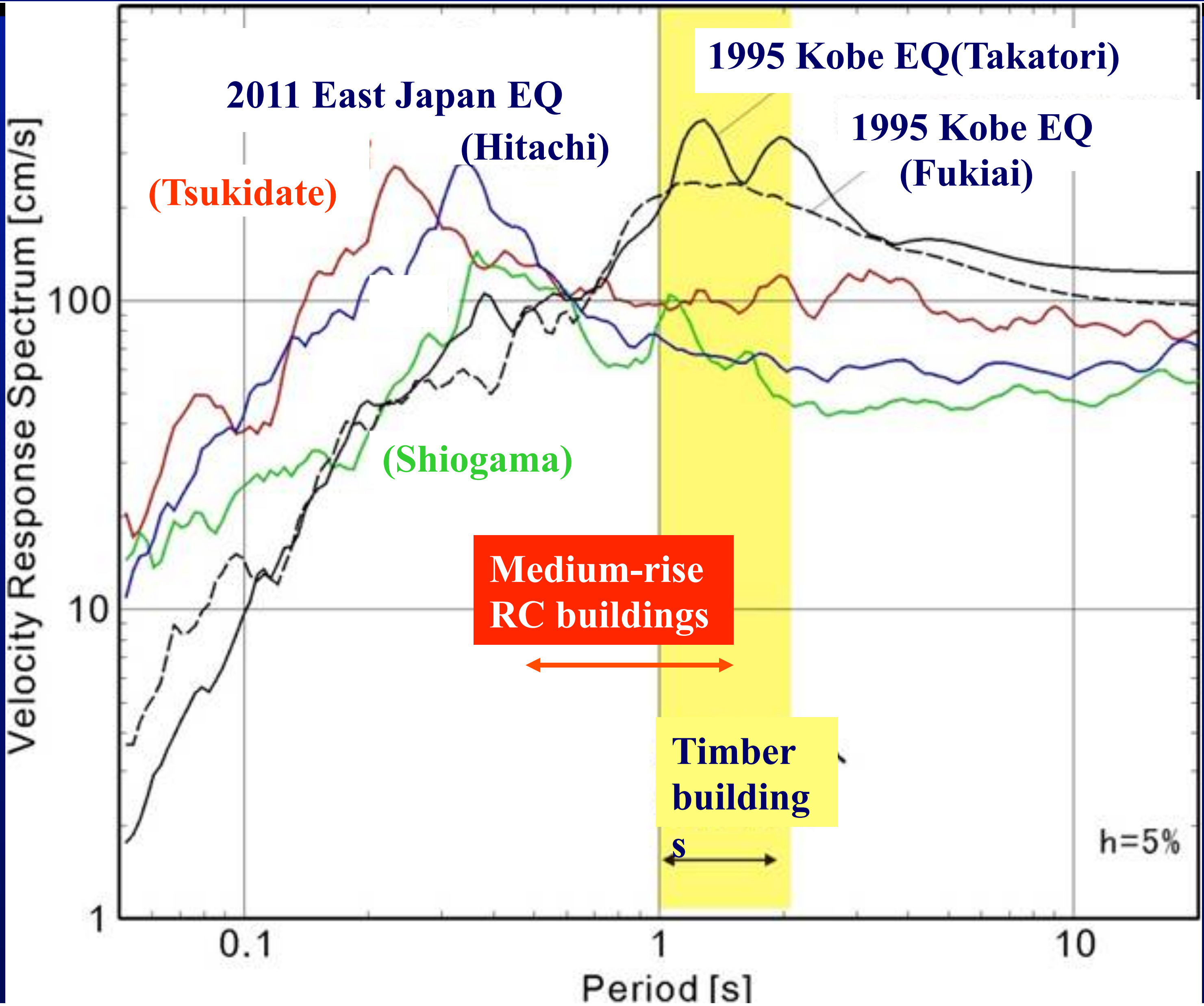


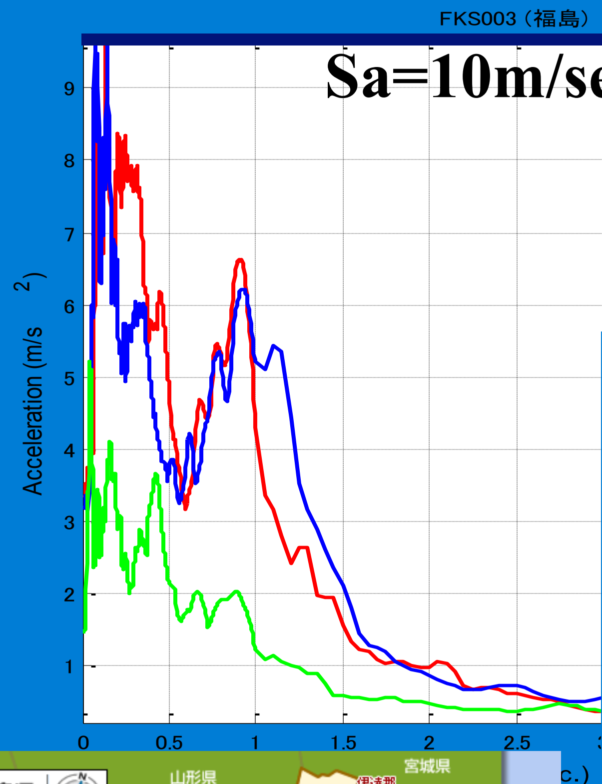

1995 Kobe

A312

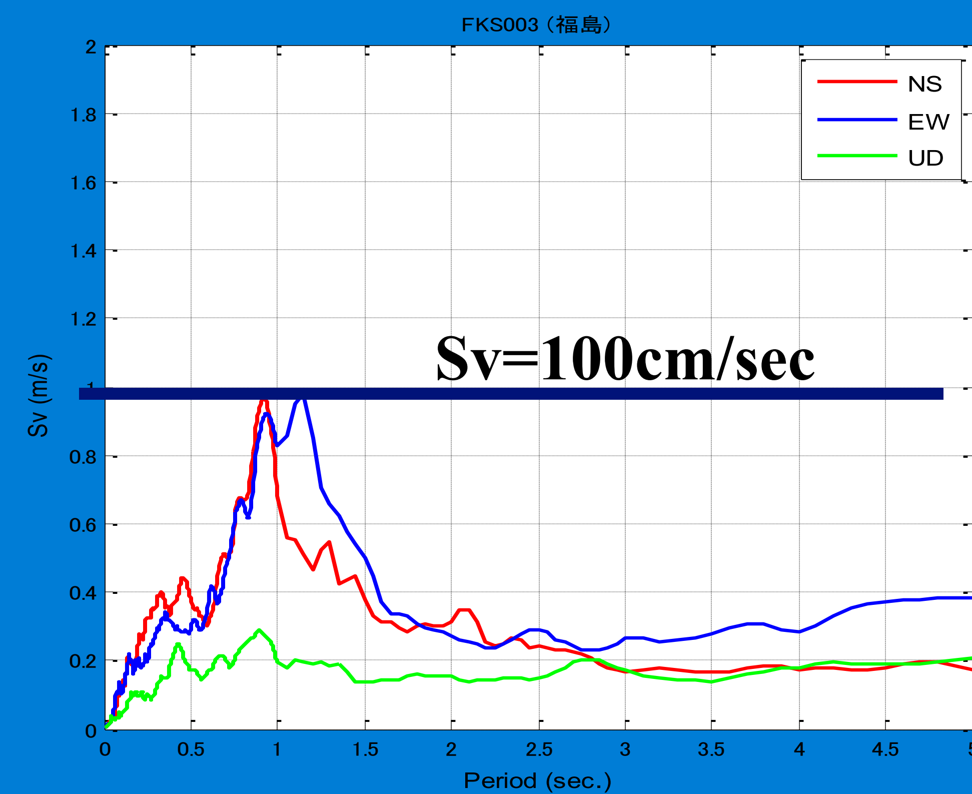
# Frequency components of far/near field motions
## (2011 East Japan/1995 Kobe)



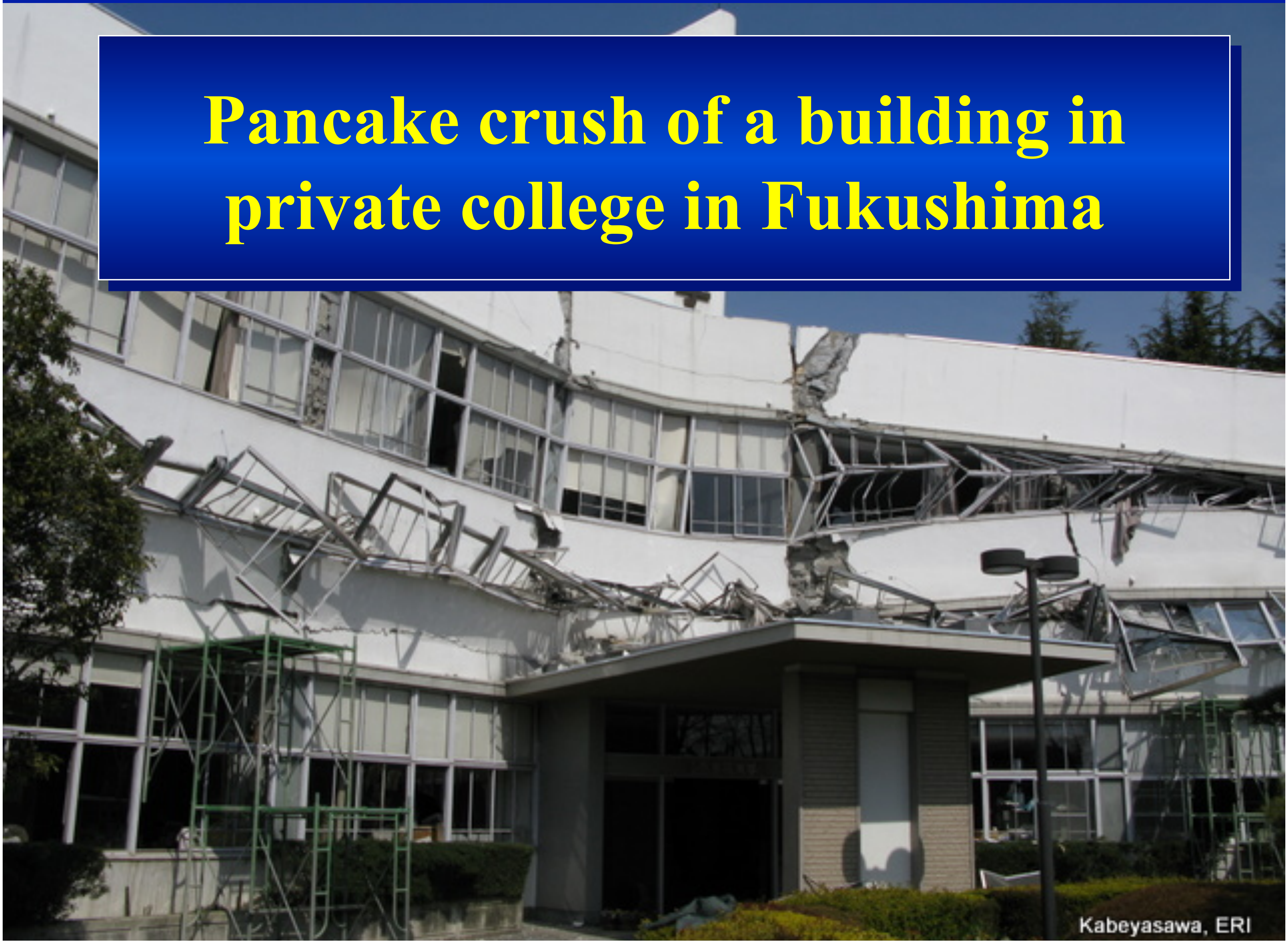
# Acceleration and Velocity Spectra (Fukushima, FKS003)



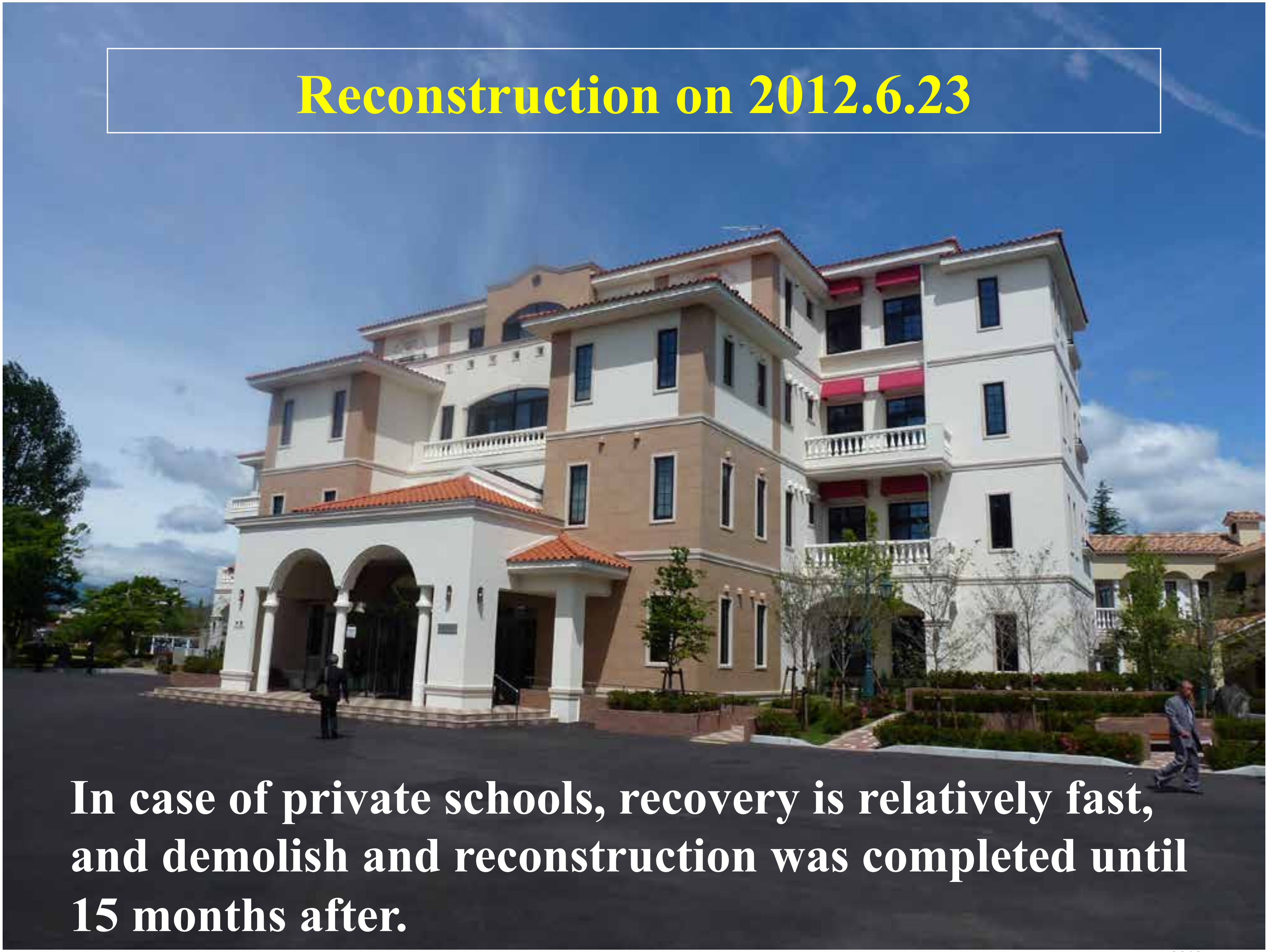

## K-net Fukushima city




# Pancake crush of a building in private college in Fukushima



# Reconstruction on 2012.6.23



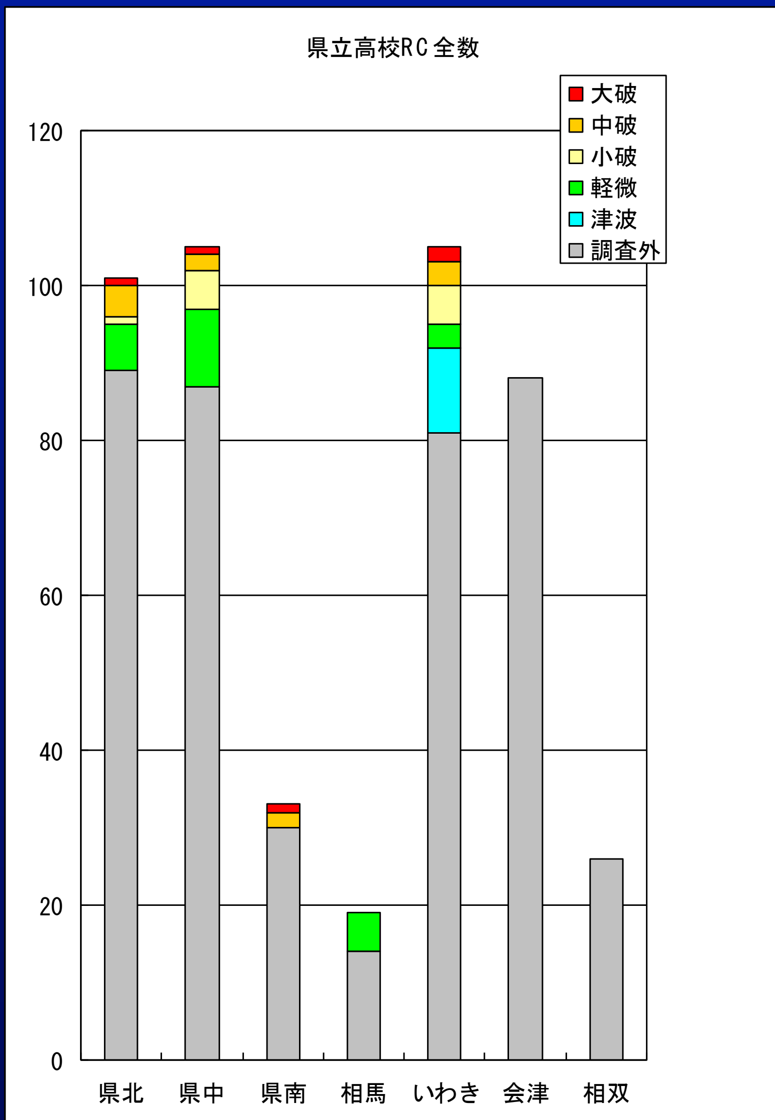
**In case of private schools, recovery is relatively fast, and demolish and reconstruction was completed until 15 months after.**

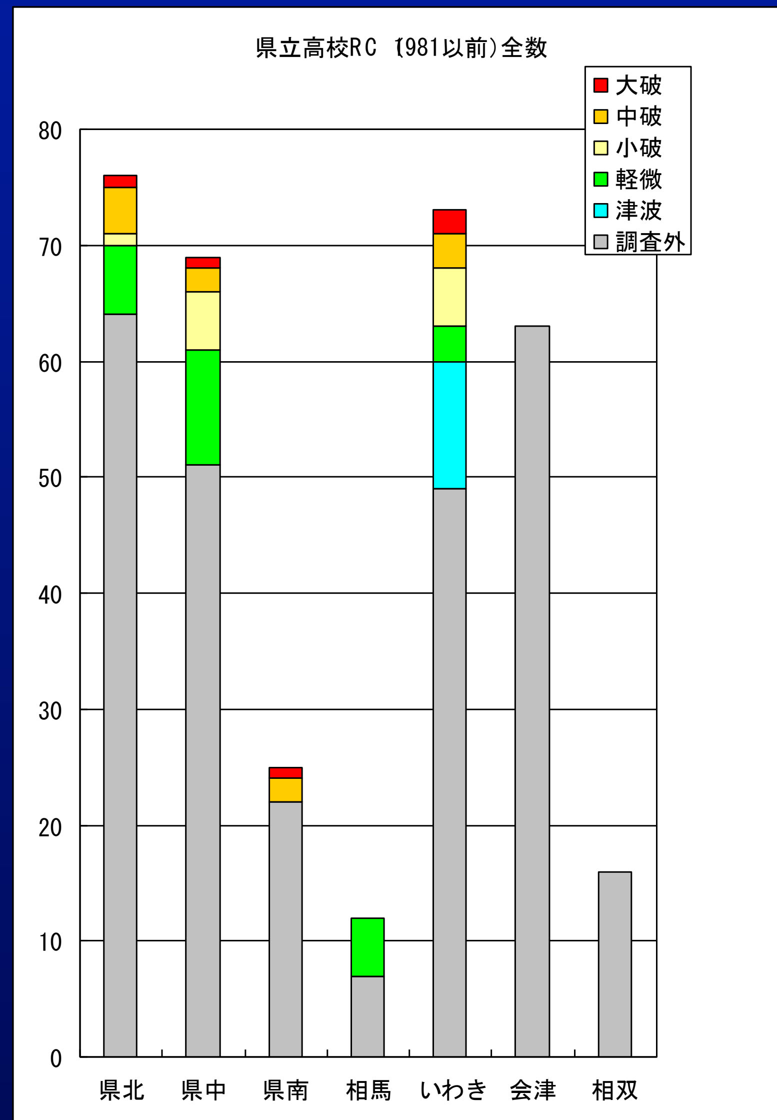
# No. 4 Building of Public F-High School
# ( F-cities, RC3, 1961-1963)

# 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.**

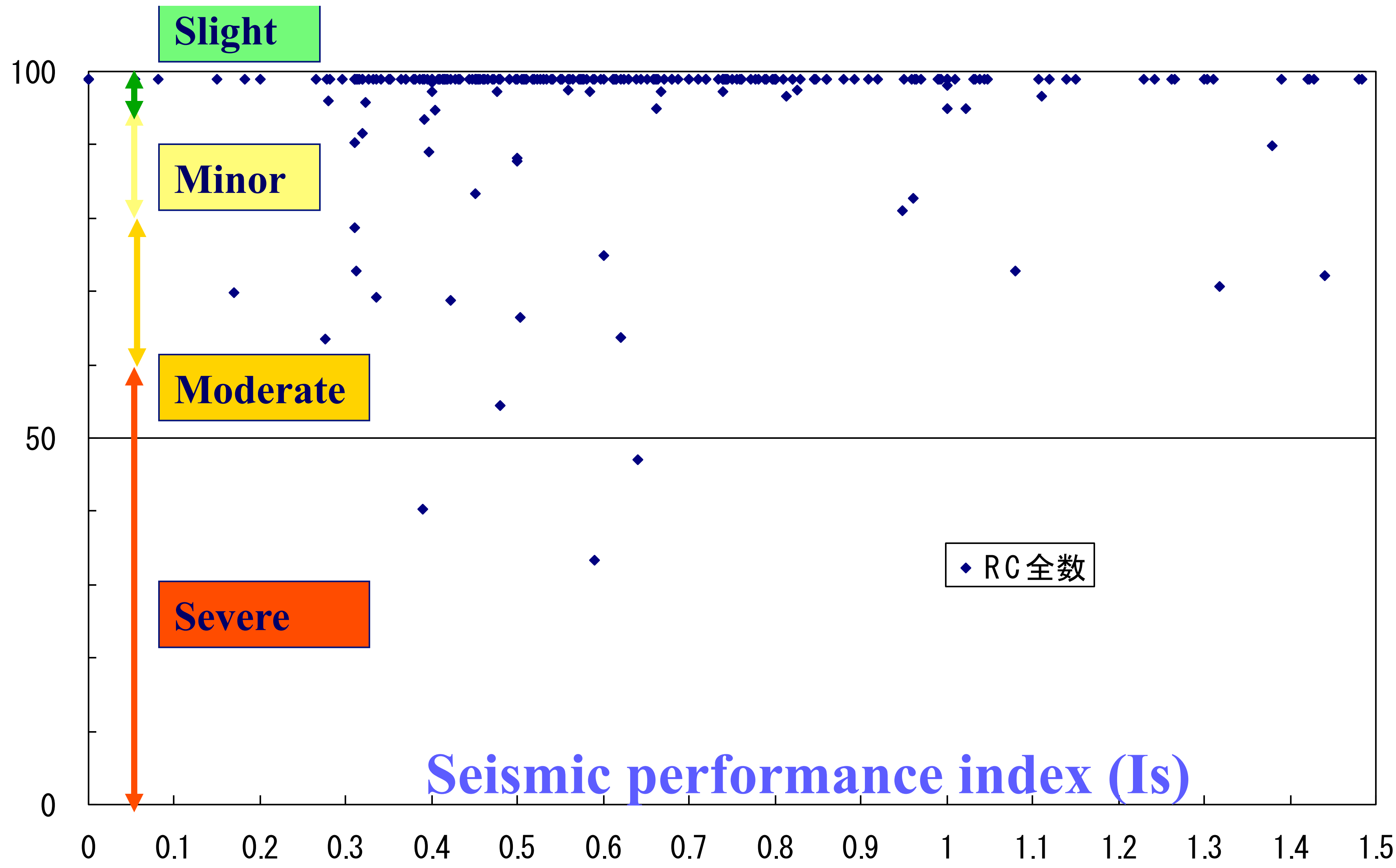
# Damage statistics for RC bldgs of public high-schools in Fukushima



# Relations between seismic performance indices Is and residual seismic capacity R

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

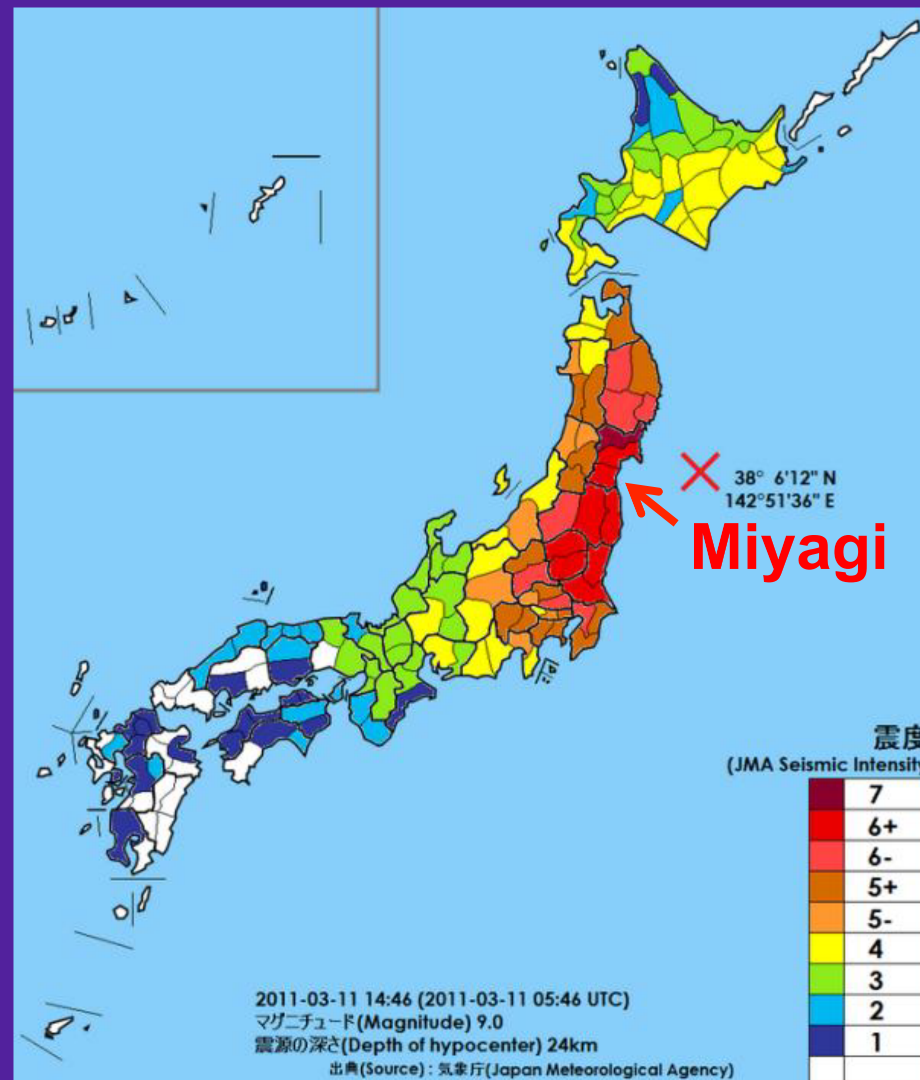


# *Report from Japan Damage level evaluation and 3.11 Tohoku experience*

Masaki MAEDA
Tohoku University

# Miyagi prefecture and 3.11 EQ

## 2011/03/11 14:46(JST)



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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

TOHOKU UNIVERSITY

# *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.

# 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

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

RC

整理番号 00-000　調査日時 1 月 25 日 午前・午後 3 時　調査回数 1 回目

調査者氏名（都道府県／No）　0000（H県／00-0123）　△△△△（H県／△△-9876）

建築物概要

1 建築物名称　A集合住宅　1.1 建築物番号 △△△

2 建築物所在地　神戸市○○区△△町1-2-3　2.1 住宅地図整理番号 ×××

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、遊戯場等　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 約ア 40 m×イ 25 m

調査　調査方法：（1.外観調査のみ実施　②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・落階 | 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 |
|---|---|---|---|---|
| 判定(1) | ①損傷度III以上の損傷部材の有無 | 1.無し | ②あり | |
| 判定(2) | 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 |
| | 柱の被害（上記⑤⑥の調査階（被害最大の階） 2 階）（壁構造の場合は柱を壁の長さに読みかえる） | | | |
| | ⑤損傷度Vの柱本数／調査柱本数　損傷度Vの柱総数 9 本　調査柱 32 本（調査率 94 %） | 1. 1%以下 | 2. 1%～10% | ③ 10%超 |
| | ⑥損傷度IVの柱本数／調査柱本数　損傷度IVの柱総数 1 本　調査柱 32 本（調査率 94 %） | ① 10%以下 | 2. 10%～20% | 3. 20%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 判定(1)と判定(2)のうち大きな方の危険度で判定する | 1.調査済み（要内観調査） | 2.要注意 | ③危険 |

判定(1) ① 2　② 1　③ 1　④ 1　柱の被害最大の階 2　⑤ 3　⑥ 1　判定(2) 3　判定 3

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.落下の危険有り |
| ②外装材（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、隙間 | 3.顕著なひび割れ、剥離 |
| ③外装材（ALC板・PC板・金属・ブロック等） | 1.目地の亀裂程度 | ②板に隙間が見られる | 3.顕著な目地ずれ、板破壊 |
| ④看板・機器類 | 1.傾斜無し | ②わずかな傾斜 | 3.落下の危険有り |
| ⑤屋外階段 | 1.傾斜無し | 2.わずかな傾斜 | 3.明瞭な傾斜 |
| ⑥その他（屋外煙突） | 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 |

① 2　② 2　③ 2　④ 2　⑤ -　⑥ 3　判定 3

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）

総合判定 3

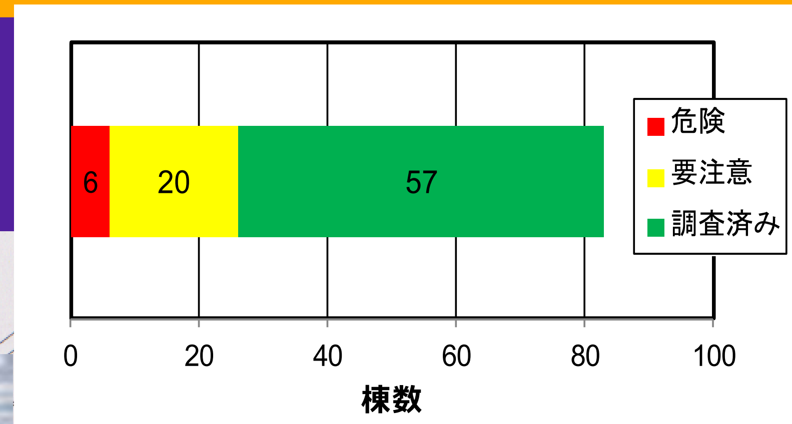
コメント（構造躯体等が危険か、落下物等が危険かなどを記入する。）

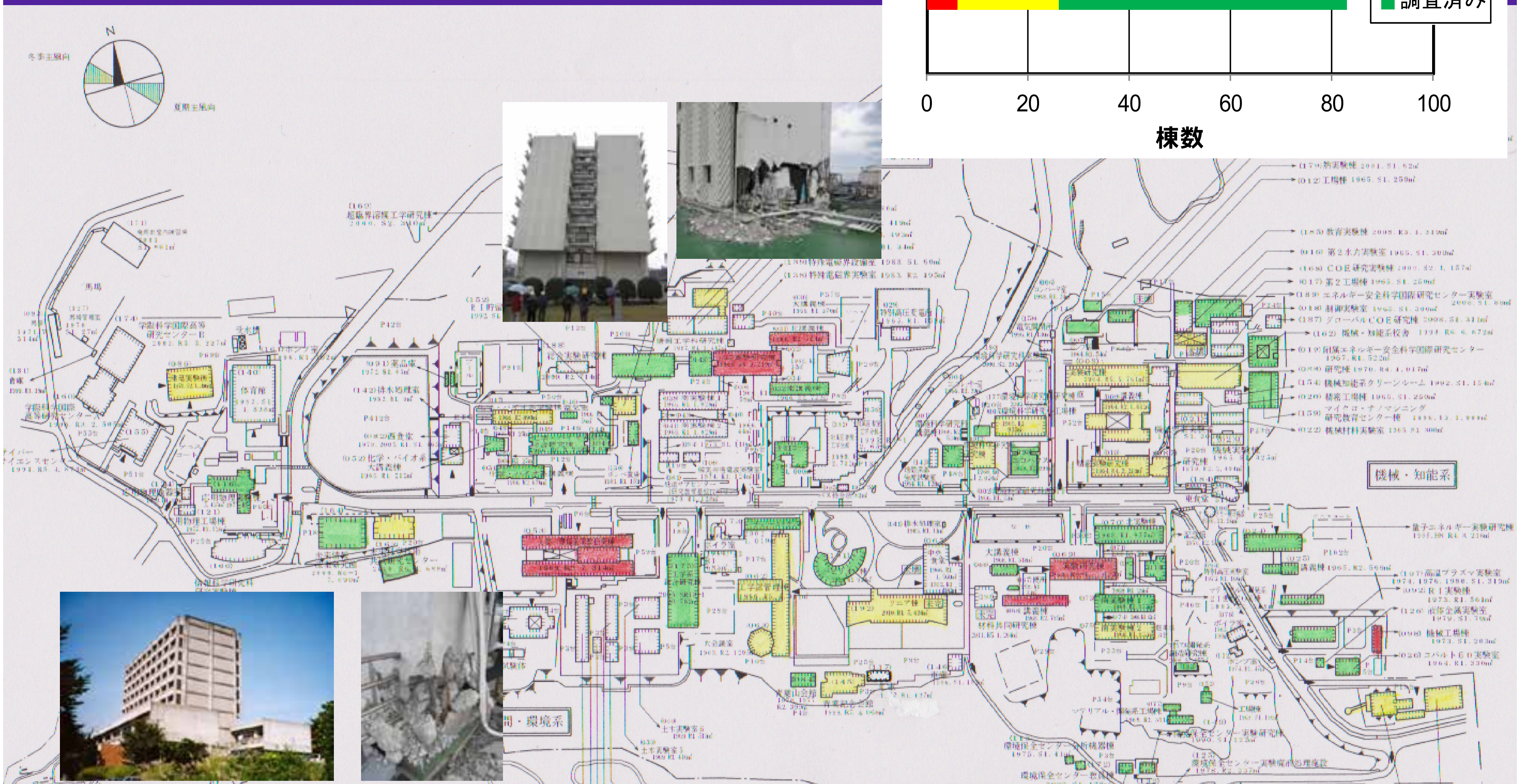
2階と3階の柱に被害大。危険。

屋外煙突は仕上げ材のはく離、落下の可能性有り。危険。

コメントは判定ステッカーの注記と同じとする。

# Damage survey at Tohoku Univ. campus



# *Post-EQ inspection and rehabilitation*

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# 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**


| | *R – index (%)* | *Limit state* |
|---|---|---|
| [Slight] | 95 - 100 | |
| [Minor] | 80 - 95 | **Serviceability** |
| [Moderate] | 60 - 80 | |
| [Severe] | - 60 | **Reparability** |
| [Collapse] | ≒0 | **Safety** |

# Basic concept of Damage level evaluation

Residual Seismic Capacity Ratio $R$

$$R = \frac{{}_{D}I_s}{I_s}$$

${}_{D}I_s$ ← residual capacity

$I_s$ ← original capacity

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

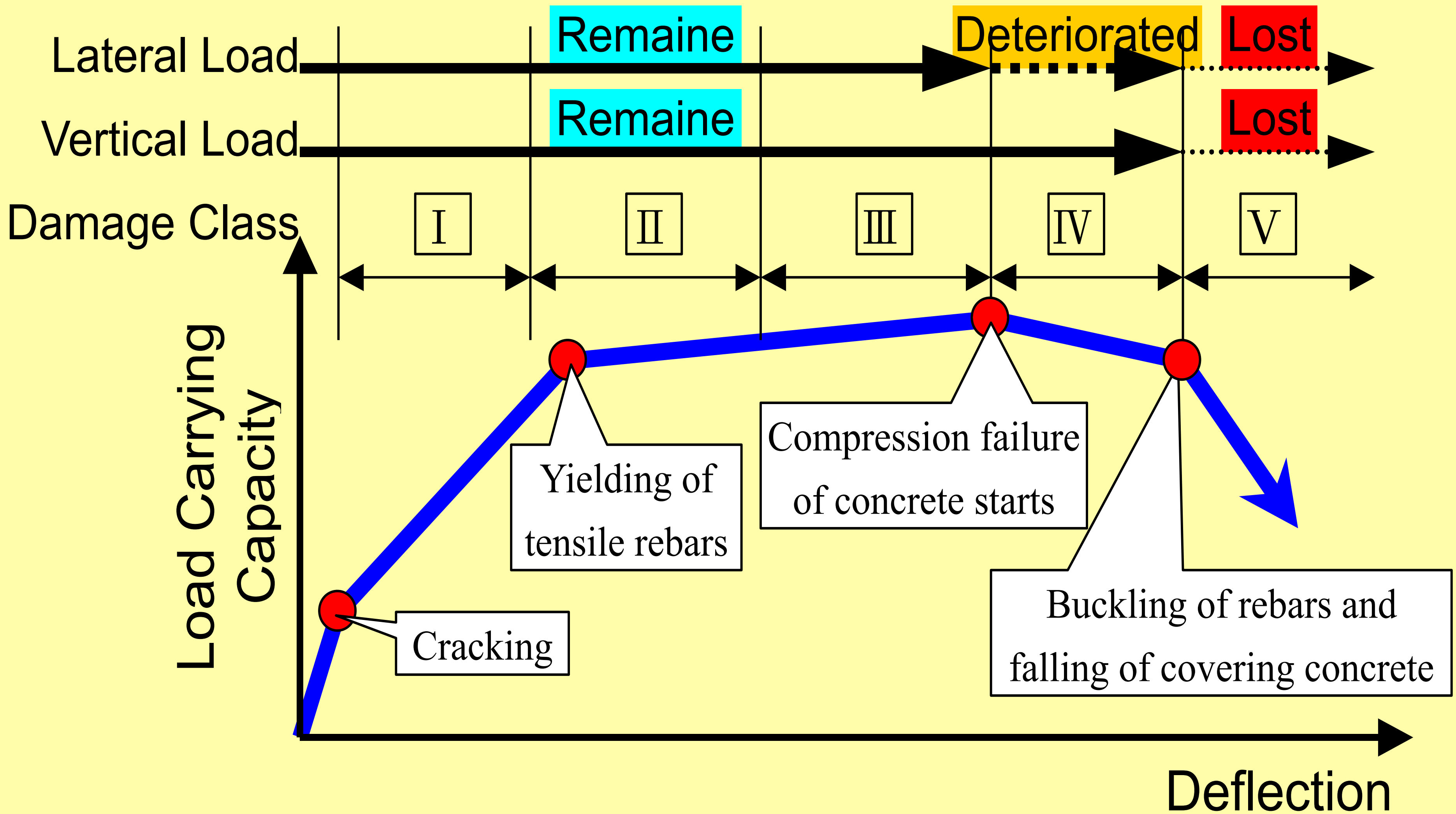
$$I_s = E_0 \times S_D \times T$$

$E_0 = C \times F$ : 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



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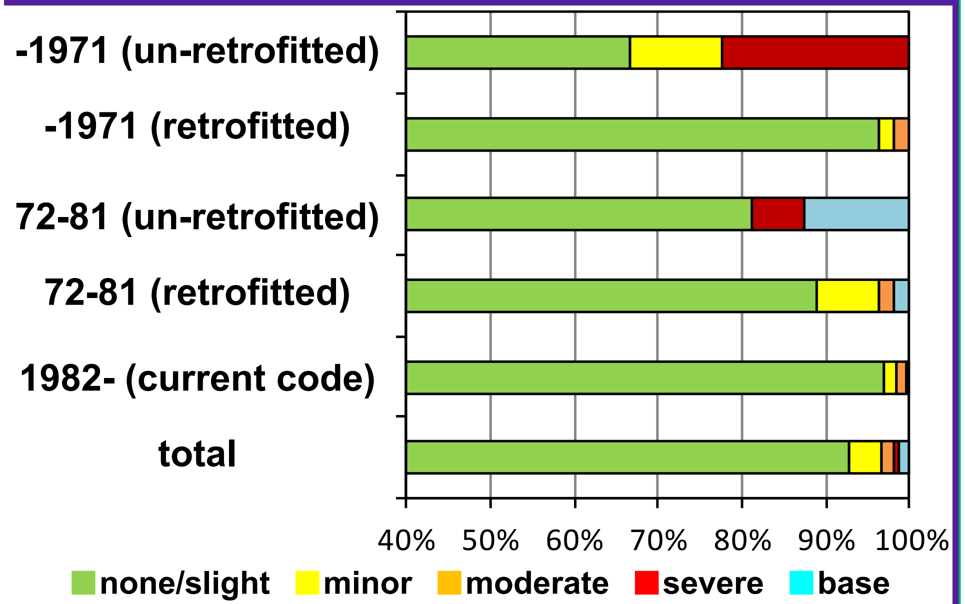
# Damage class of structural member

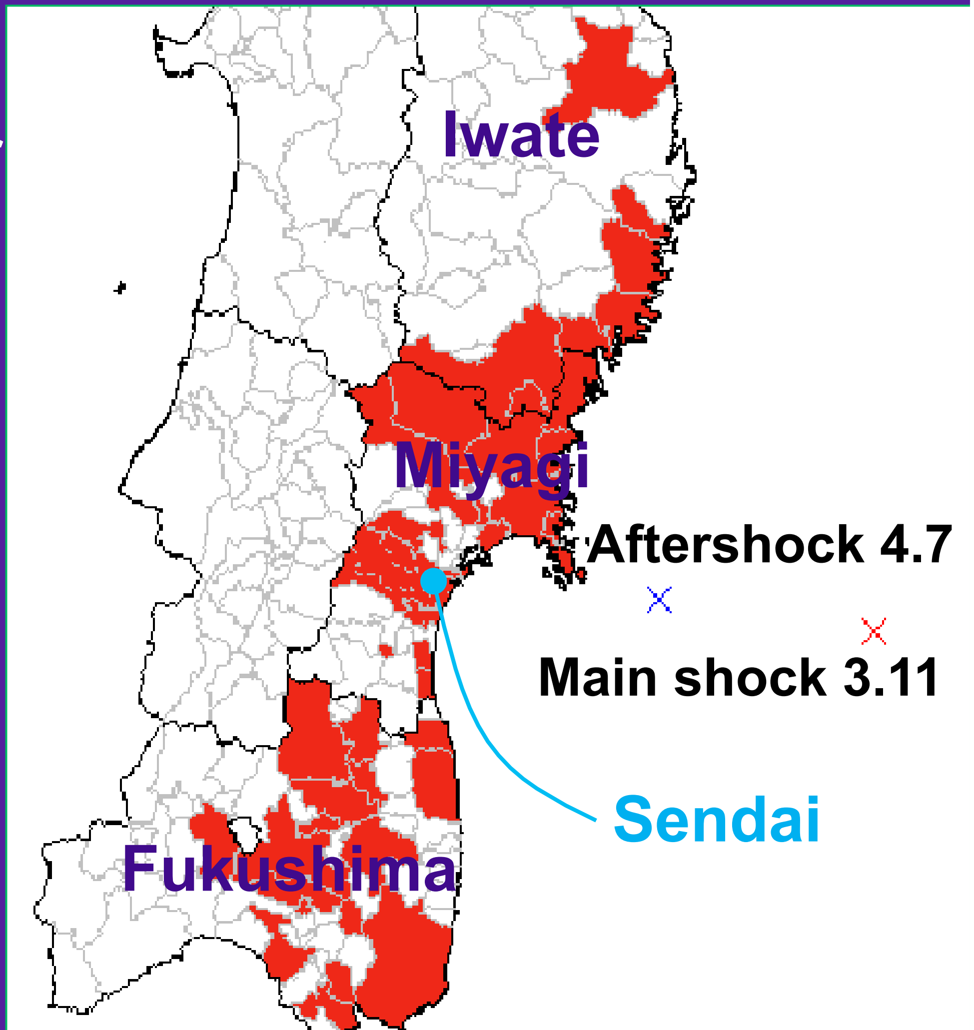
## Damage Level Classification Standard (1991)

| Damage Class | Observed Damage to Structural Members |
|---|---|
| I | Some cracks are found.<br>Crack width is narrower than 0.2 mm. |
| II | Cracks of 0.2 - 1 mm wide are found. |
| III | Heavy cracks of 1 - 2 mm wide are found. Some spalling of concrete is observed. |
| IV | Many heavy cracks are found. Crack width is 2 mm or wider. 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. | Wall | Wall | Wall | 合計 | |
|---|---|---|---|---|---|---|---|
| 総部材数 | ( 25 ) | + ( ) | + ( ) | + ( 4 ) | + ( 2 ) | = ( 31 ) | |
| 調査部材数 | ( 25 )① | + ( )② | + ( )③ | + ( 4 )④ | + ( 2 )⑤ | = ( 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 $R \fallingdotseq 0$ とみなせる）

# Pictures and comments

文科省学校調査　写真票

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（$3{,}708m^2$）　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）AM 9：00~12：00　応急危険度：危険　被災度：中破

写真 1

校舎全景。写真右が西校舎、左が東校舎。渡り廊下を通して連結され、Exp.J が、渡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。

写真 2

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。

写真 3

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。

文科省学校調査　写真票

写真 4

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。

写真 5

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）。

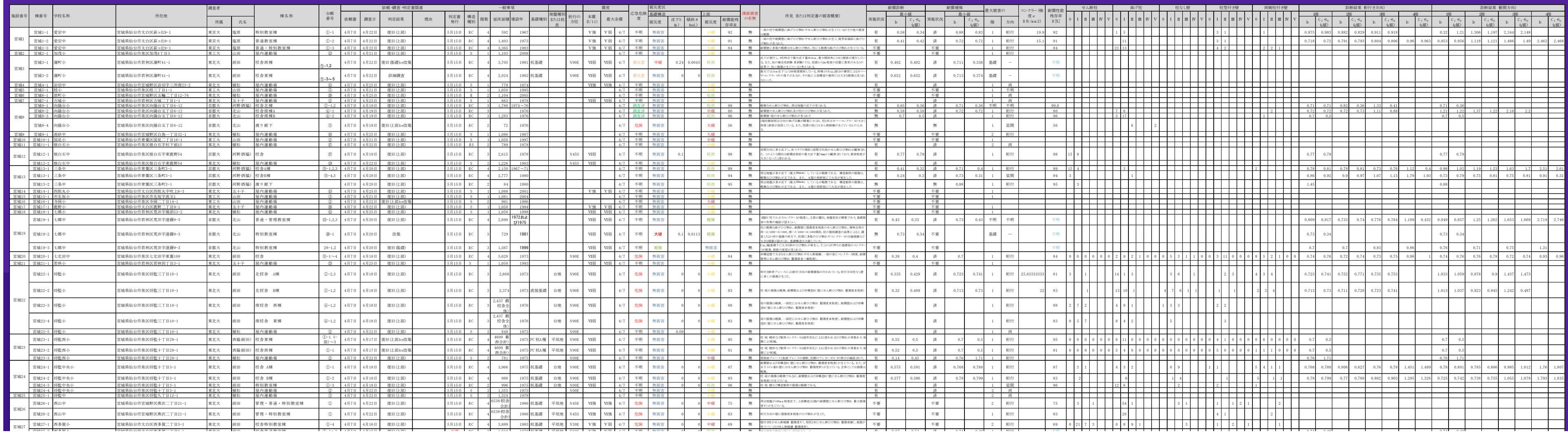
写真 6

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。

# 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
- ✓ *Is*-indeces
- ✓ Strengthening & retrofit



## 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

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# 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.

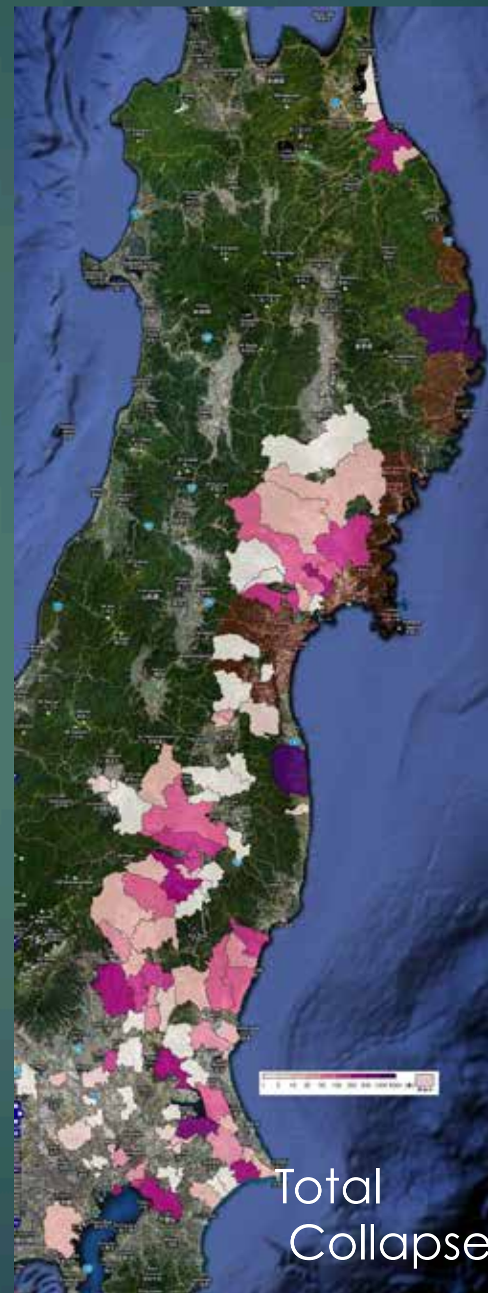

Inspection is based on Visual Investigation.

# Post earthquake survey organizations in Japan (Q3)

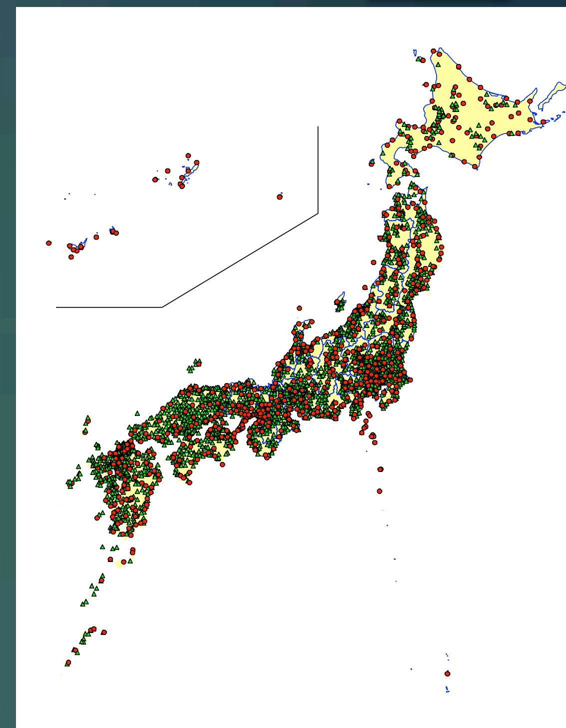
- Governments and national research institutes
  - Ministry of Land, Infrastructure, and transportation
    - To check the Building code and building administrations
    - Building Research Institute(BRI)
    - National Institute for Land and Infrastructure Management (NILIM)
  - Ministry of Education, 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

NIED 防災科学技術研究所

National Research Institute for Earth Science and Disaster Prevention


Cabinet Office

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

NIED 防災科学技術研究所

# 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)

National Institute of Land and Infrastructure Management
Toshikazu Kabeyasawa

国土交通省
国土技術政策総合研究所
NILIM National Institute for Land and Infrastructure Management

# What forms of data were collected ?

① Inundation depth of the building

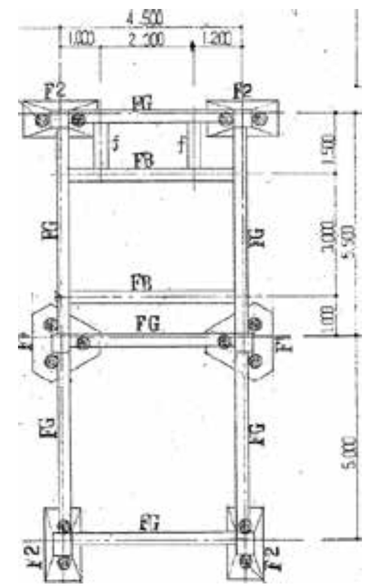
② Onsite investigation of damaged building

(1) State (Location, Damage)

(2) Dimension (Plan, Height, Openings)

(3) Detail (Member, Material)

③ Collecting drawings of Public buildings

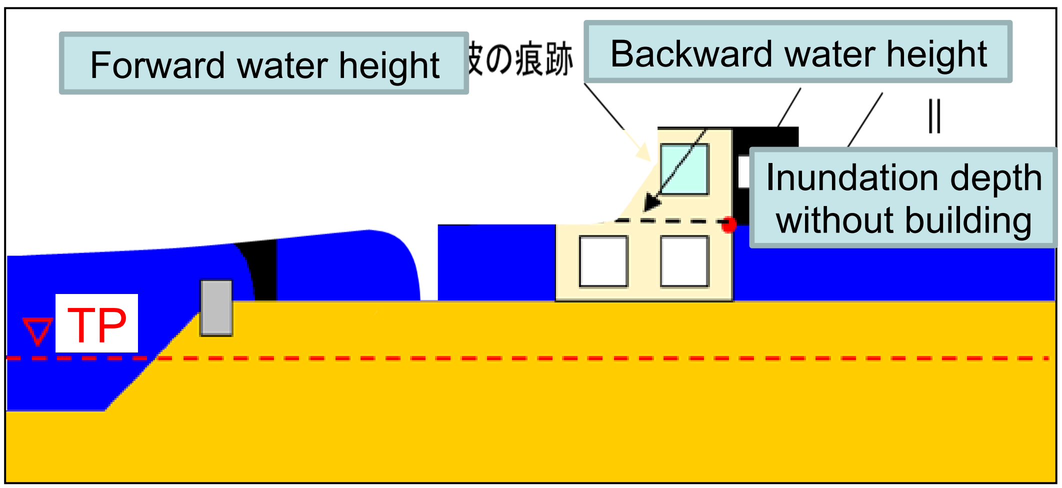


# How were the data collected?

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



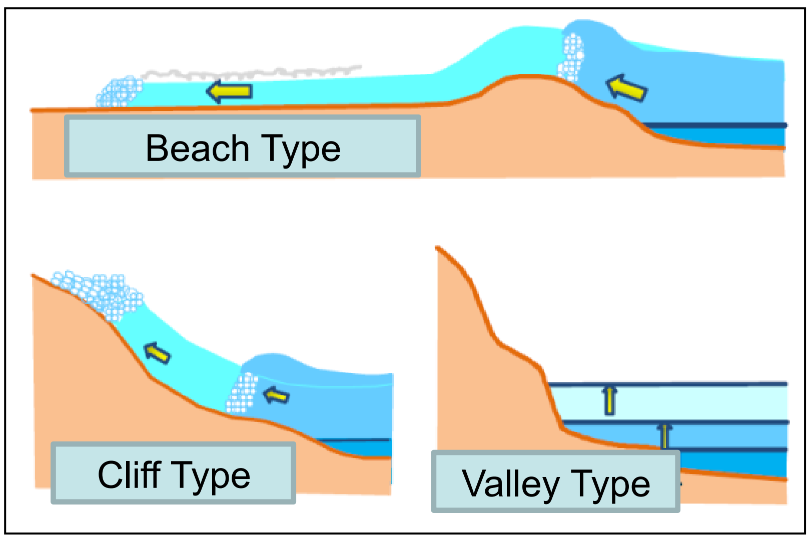

# Difficulty in collecting data

① Water traces disappears one month after earthquake by rain
Tsunami flow characteristic is affected by topography

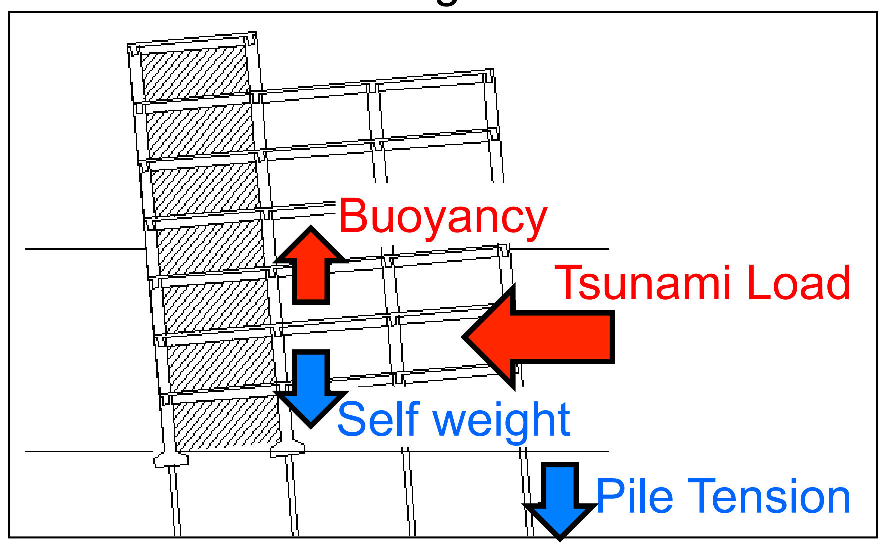
② Damage process or mechanism is not clarified
Effect of Buoyancy, Debris Impact or Damming

③ Most of drawings and buildings are washed out

Tsunami Flow Characteristic




Overturning Mechanism



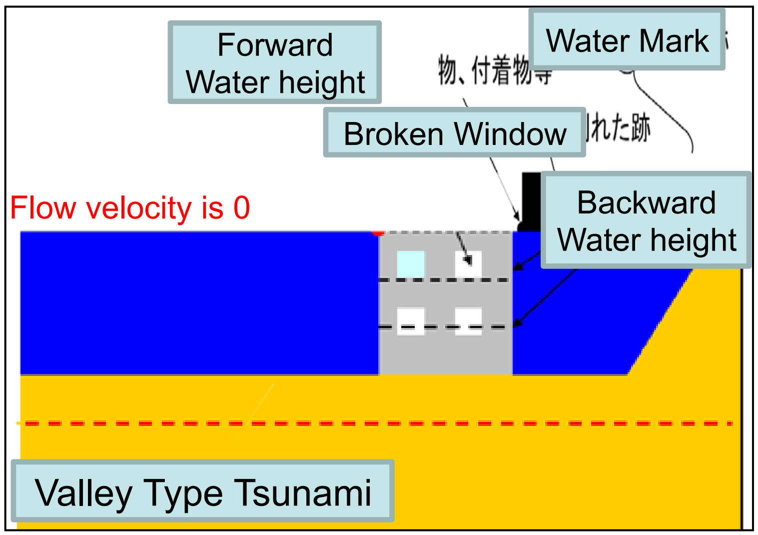
# What data were missed?

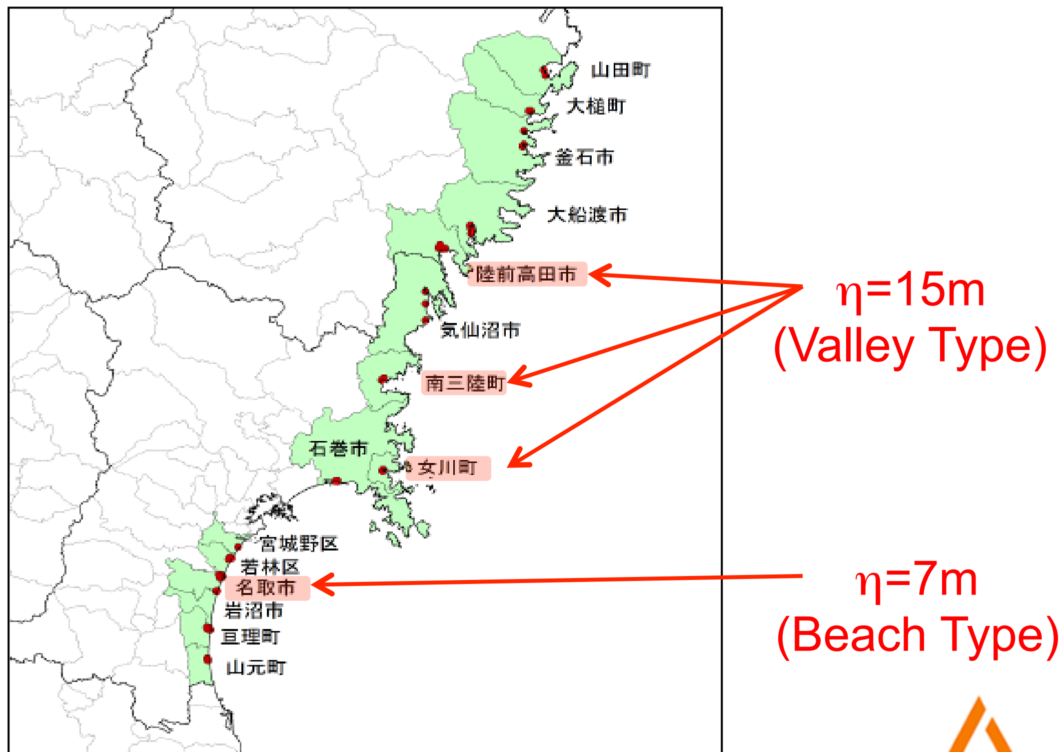
① Difference of water height disappears in valley type tsunami

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，非構造部材のみ被害が見られた | |
| | 躯体の被害 | 被害なし | | |
| | 非構造部材の被害 | 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)に開口付き耐震壁を有し、桁行構面には大きな開口を有している
・内部には梁せい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計測浸水深は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階妻壁の損傷（写真6.2.6-2）が見られたものの，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

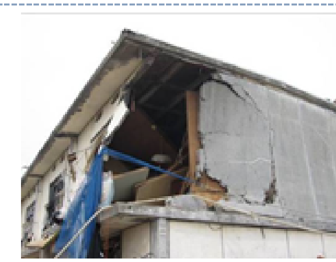


写真6.2.6-2　2階妻壁の損傷

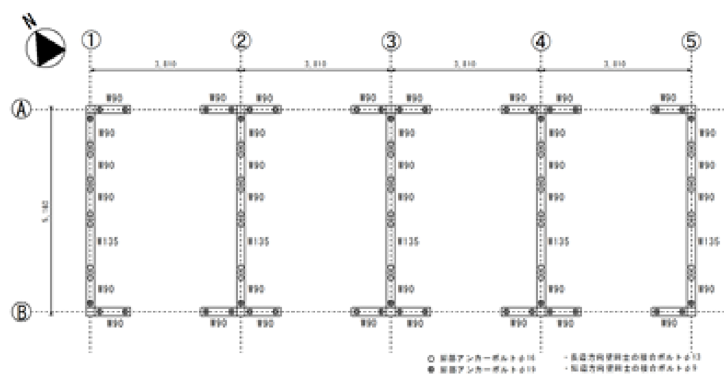


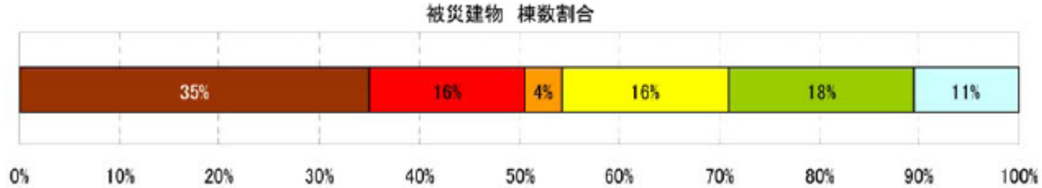

図6.2.6-1　耐力壁割付図

# Statistical Damage Survey

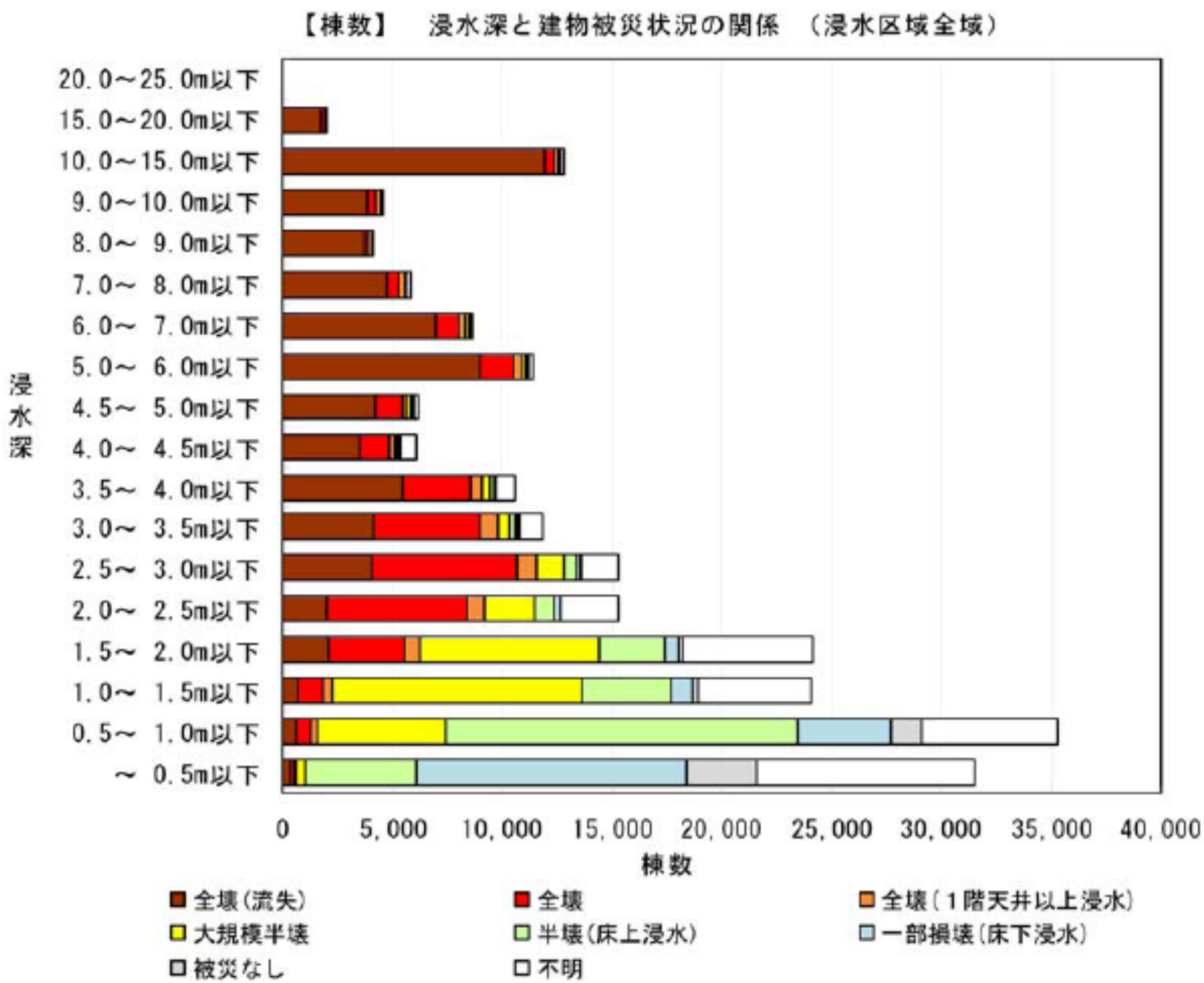
| 区分 | 全壊（流失） | 全壊 | 全壊（1階天井以上浸水） |
|---|---|---|---|
| 主な建物状況 | 基礎だけ残して、建物が完全に流されている | 主要構造が損壊しており補修により元通りに再使用することが困難 | 1階天井以上浸水しており、大規模修繕等による再使用も可能 |
| サンプル写真 |  |  |  |
| 棟数※ | 約 78,000 | 約 34,000 | 約 8,000 |
| 区分 | 大規模半壊 | 半壊（床上浸水） | |
| 主な建物状況 | 床からおおむね1m以上（天井未満）浸水している | 床から概ね1m未満の床上浸水（一部補修により再利用可能） | |
| 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 | | |
| サンプル写真 |  | 被災建物総計 / うち全壊 | |
| 棟数※ | 約 23,000 | 約 219,000 / 約 120,000 | |

建物被災状況（イメージ）

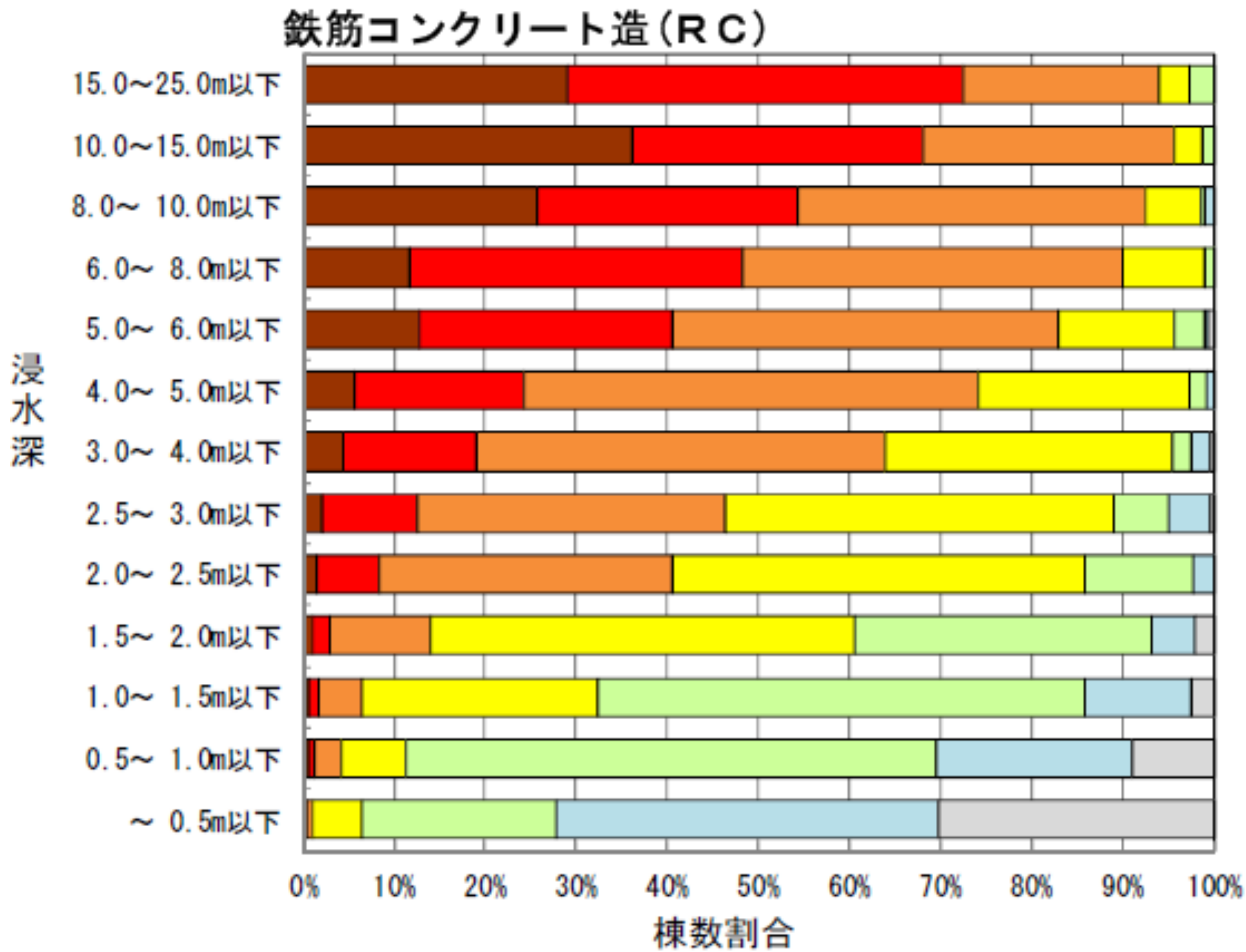
被災建物　棟数割合



# Statistical Damage Survey



# Statistical Damage Survey




NILIM



A360

# Sharing data across different organization

## Official study purpose is important for sharing data

**BRI / NILIM**
Development of new design guideline of tsunami shelter
(Damage survey of Building)

**IIS (University of Tokyo)**
Collaborate Study on Tsunami Load on building
(Damage survey of Plain structures)

**PARI**
Collaborate Study on Tsunami Load on building
(Joint survey & Hydro dynamic test)

**ASCE**
Revising ASCE-07 Code (2016)
(Joint survey & Information exchange )

**AIJ**
3.11 Earthquake Damage Investigation Report
Revising recommendation for design load
(Provision of Information)

# 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' | Kanto | 1961 | No | — | 6 Lower | Moderate |
| C | | 1970 | (NG) | NG | 6 Upper | Severe |
| D | Kanto | 1968 | (NG) | NG | 6 Upper | Minor |
| E | Kanto | 1967 | (NG) | NG | 5 Upper | Minor |
| F | | 1960 | (NG) | NG | 6 Lower | Severe |
| G | Kanto | 1958 | No | NG | 6 Upper | Moderate |
| H | Kanto | 1966 | No | NG | 6 Upper | Moderate |
| I | Kanto | 1964 | No | NG | 6 Upper | Severe |
| J | Kanto | 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

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

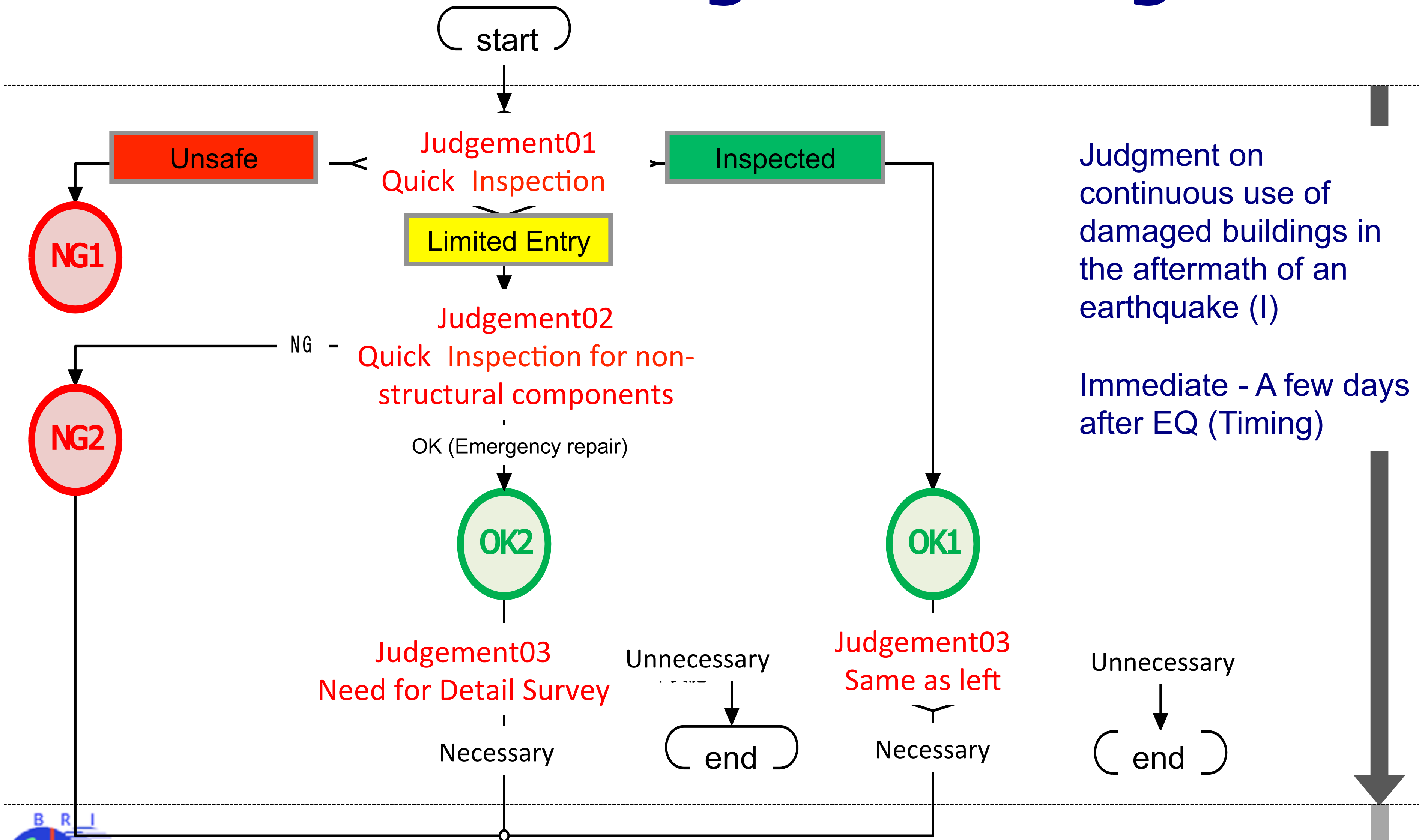
→drawings, structural documents, information on situation of post-EQ continuous use

②Factor Analysis of situations on post-EQ functionality :

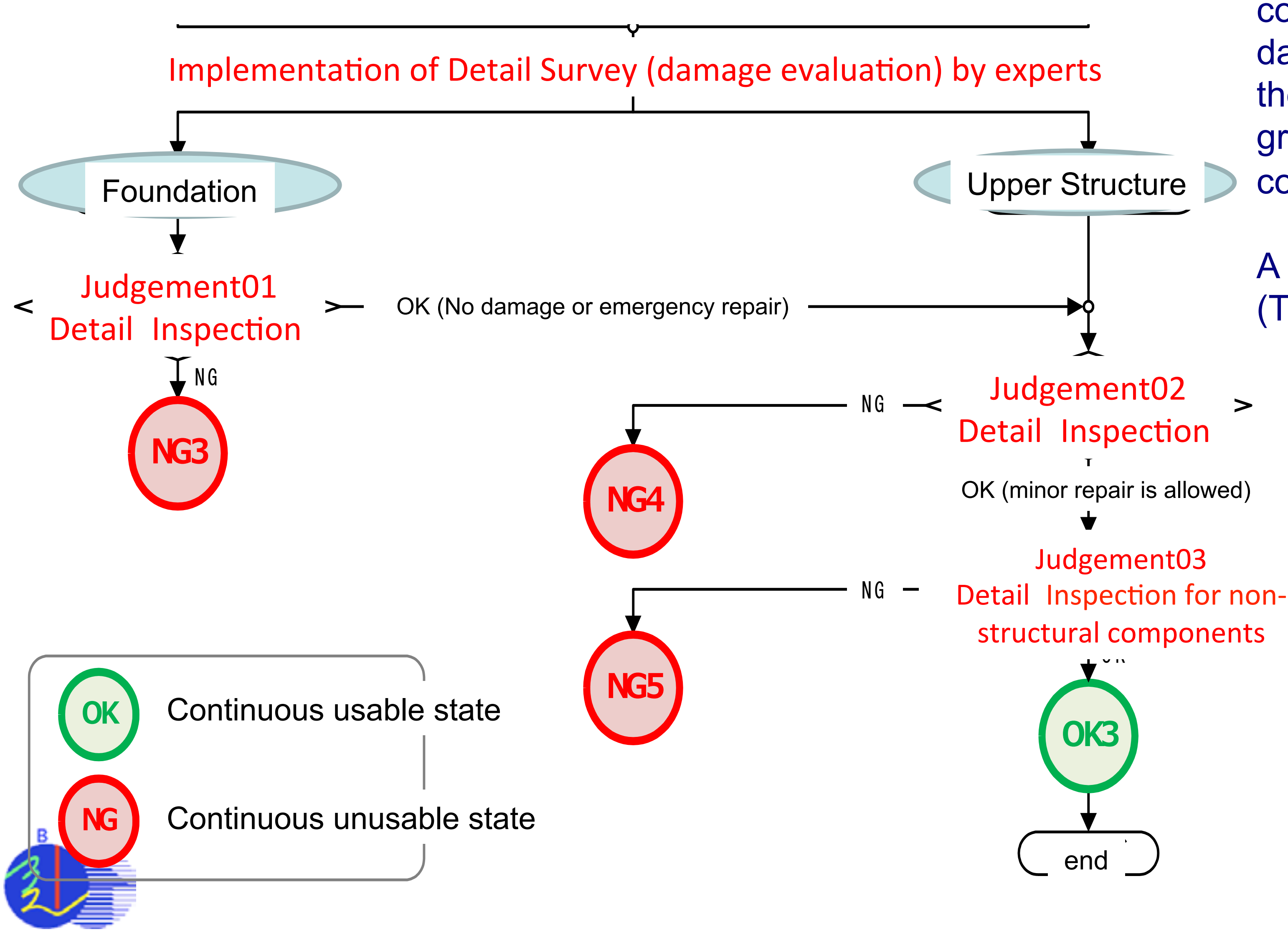
→Making the Flowchart which can explain the situation of post EQ continuous use for damaged buildings considering the collected data

B R I

# Flowchart for post-EQ continuous use of damaged buildings



# Flowchart for post EQ continuous use of damaged buildings




Judgment on continuous use of damaged buildings in the time when growing out of the confusion ( Ⅱ )

A few weeks after EQ (Timing)



A367

# Conclusions

①Objectives・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 publlic 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 he data immediately. The system to collect the building's data is needed before occurrence of earthquake.**

# Post Earthquake Date Collection by Local Government

Satoshi TANAKA

Tokoha University

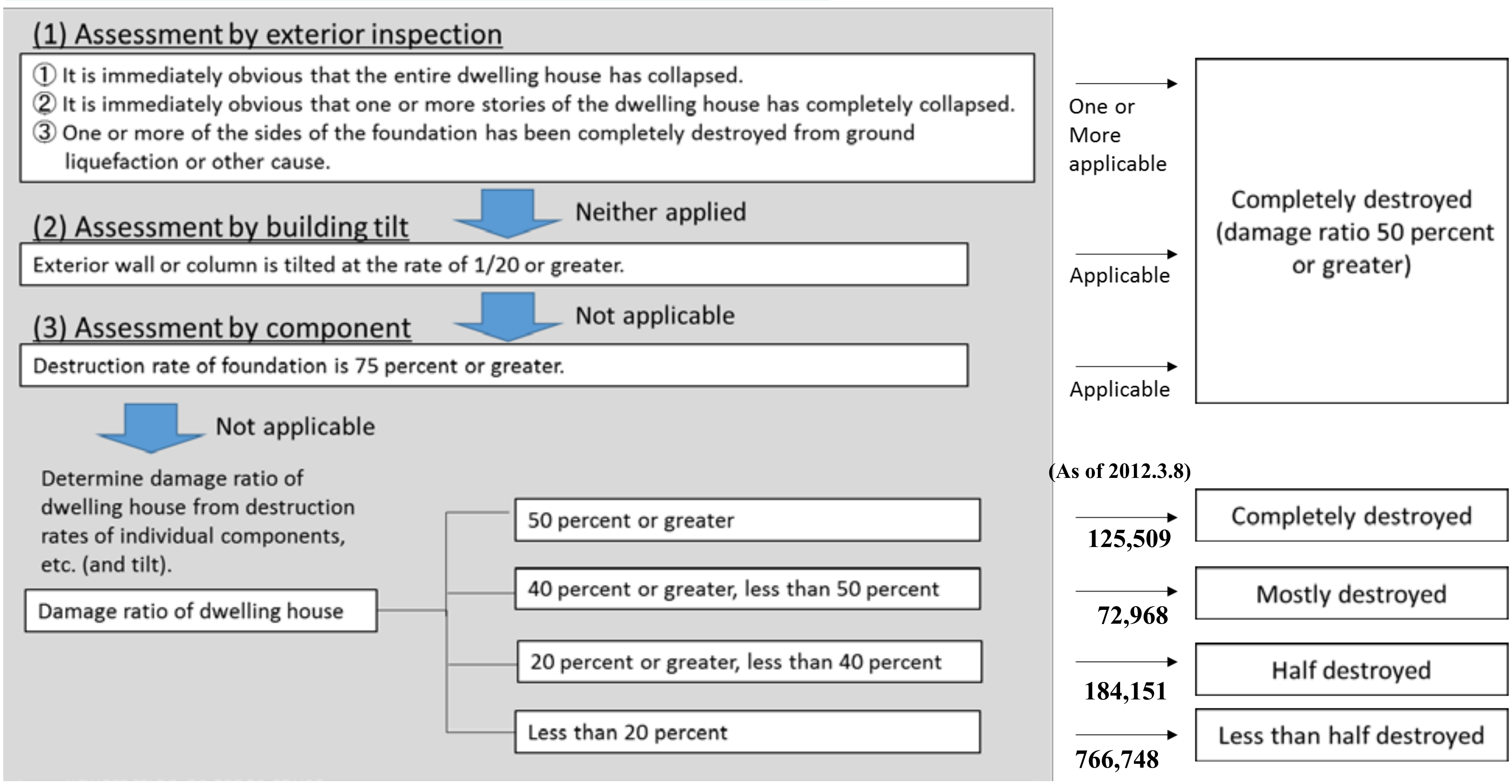
# Summary of the Inspection

- 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 ratio = Economic Damage /Entire Value**

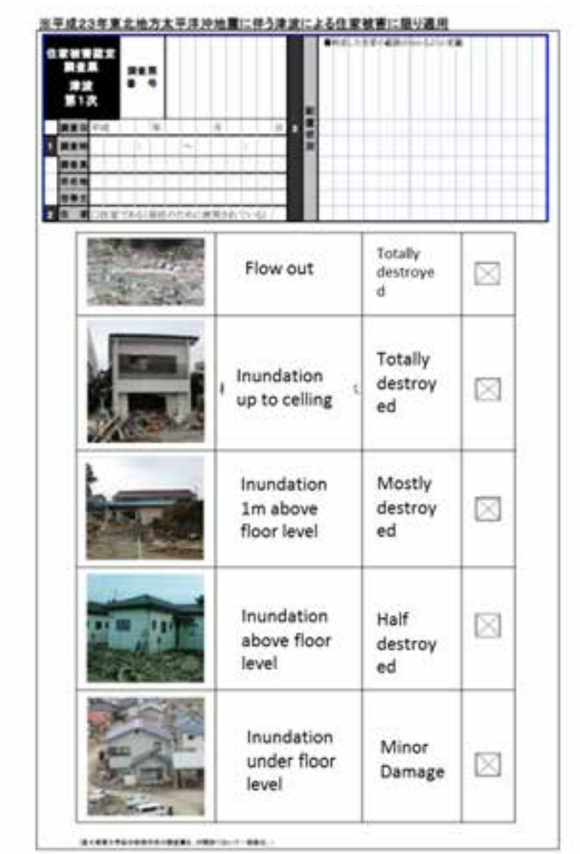
## Damage Assessment by Local Government



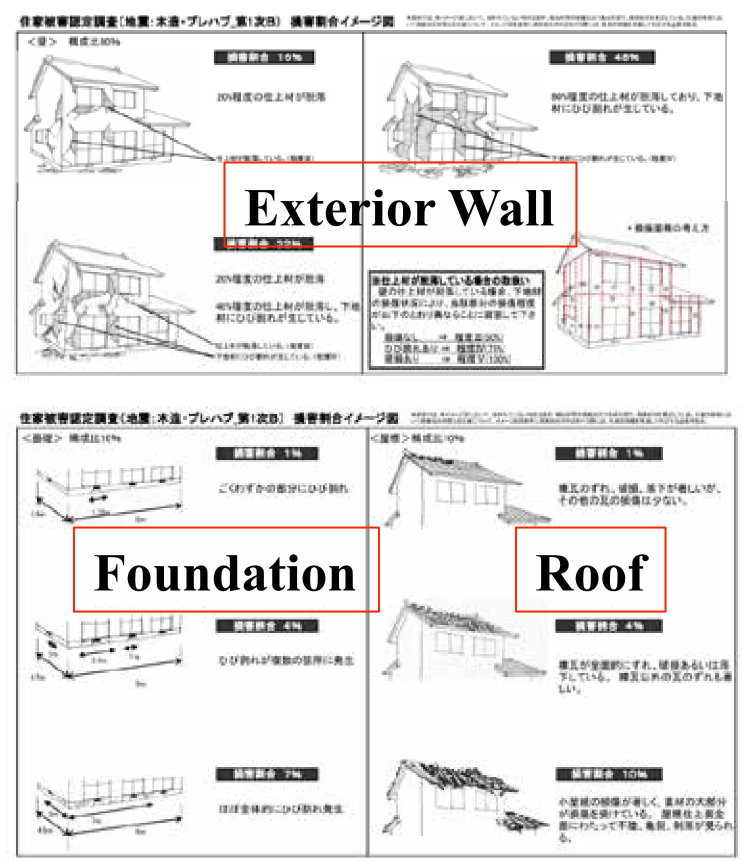

**Operational Guideline for Damage Assessment of Residential Houses in Disaster (Cabinet Office)**

**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**




Tsunami

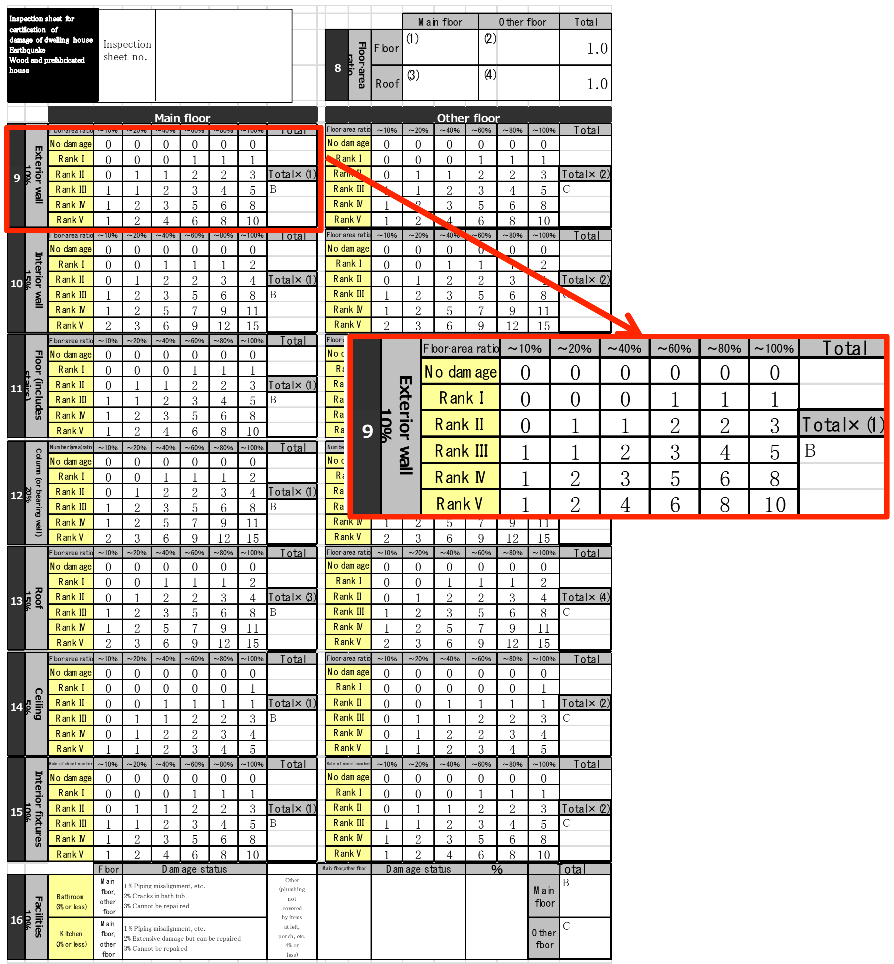



Earthquake

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

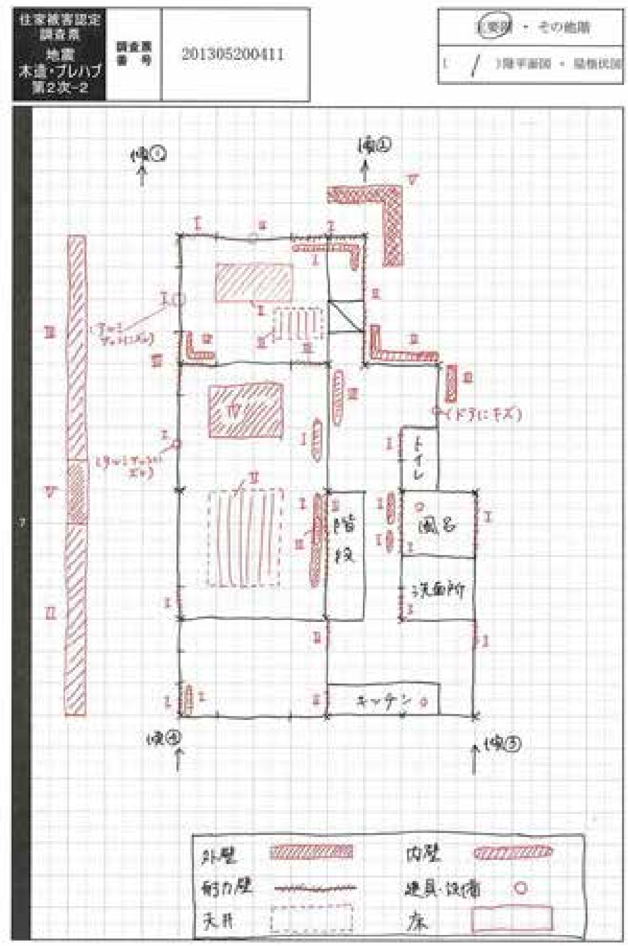
**Record damaged parts on building floor plan**

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



| 9 Exterior wall 10% | Floor area ratio | ~10% | ~20% | ~40% | ~60% | ~80% | ~100% | Total |
|---|---|---|---|---|---|---|---|---|
| | No damage | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Rank I | 0 | 0 | 0 | 1 | 1 | 1 | |
| | Rank II | 0 | 1 | 1 | 2 | 2 | 3 | Total× (1) |
| | Rank III | 1 | 1 | 2 | 3 | 4 | 5 | B |
| | Rank IV | 1 | 2 | 3 | 5 | 6 | 8 | |
| | Rank V | 1 | 2 | 4 | 6 | 8 | 10 | |

**Inspection form**




**Floor plan with results of damage inspection noted**

# Damage Rank of Column for wooden house



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

1701
柱と梁の仕口にわずかなずれが生じている。

1702
柱脚コンクリートのひび割れが見られる。

### • 程度 II

1703
柱、梁が若干たわんでいる。

1704
アンカーボルトの伸びが見られる。

### • 程度 III

1705
柱と梁の仕口にずれが生じている。

1706
柱、梁に割れが見られる。



### • 程度 IV

1801
柱、梁に大きな割れが見られる。

1802
柱、梁の仕口に著しいずれが見られる。

### • 程度 V

1803
柱、梁の割れ、断面欠損が著しい。

1804
柱、梁に著しい折損が生じており、交換が必要である。

### • 損傷の判定　＜例 柱 傾斜比 20%）＞

| 程度 | 損傷の例示 | | 損傷程度 |
|---|---|---|---|
| | 【在来工法】 | 【鉄骨系プレハブ】 | |
| I | 柱と梁の仕口にわずかなずれが生じている。 | 柱脚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めり込み等の損傷が見られる。<br>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。<br>高力ボルトのすべりが見られる。 | 25% |
| III | 柱と梁の仕口にずれが生じている。<br>柱、梁に割れが見られる。 | 柱脚座屈による小さな変形が柱に生じている。<br>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。<br>柱、梁に断面欠損が見られる。<br>柱、梁に折損が見られる。<br>柱、梁の仕口に著しいずれが見られる。 | 柱脚座屈による中くらいの変形が柱に生じている。<br>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。<br>柱、梁に著しい折損が生じており、交換が必要である。 | 柱脚座屈による大きな変形が柱に生じている。<br>梁接合部に破断が見られる。 | 100% |

# Damage Rank of Columns for Steel and RC



## 柱（又は耐力壁）A. 鉄骨造 ア. 柱

⇨地震 p1-51 1-1 ア. 柱（又は梁）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

8101

柱脚コンクリートのひび割れが見られる。

●程度 IV

8104

局部座屈による中ぐらいの変形が柱に見られる。

●程度 II

8102

アンカーボルトの伸びが見られる。

●程度 V

8105

接合部の破断が見られる。

●程度 III

8103

局部座屈による小さな変形が柱に見られる。

●損傷の判定

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

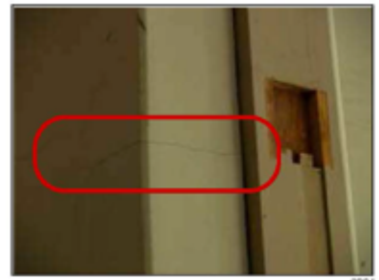
| 程度 | 損傷の例示 | 損傷程度 |
|---|---|---|
| I | ・柱脚コンクリートのひび割れが見られる。 | 10% |
| II | ・アンカーボルトの伸びが見られる。<br>・高力ボルトのすべりが見られる。 | 25% |
| III | ・局部座屈による小さな変形が柱に見られる。 | 50% |
| IV | ・局部座屈による中ぐらいの変形が柱に見られる。 | 75% |
| V | ・局部座屈による大きな変形が柱に見られる。<br>・接合部の破断が見られる。 | 100% |



## 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（又は梁）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



8201

近寄らない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。

●程度 IV

8204

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。

●程度 II

110025

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。

●程度 V

8205

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崩れ落ち、柱の高さ方向の変形が生じている。

●程度 III

110026

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極くわずかで、鉄筋は露出していない。

●損傷の判定

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

| 程度 | 損傷の例示 | 損傷程度 |
|---|---|---|
| I | ・近寄らない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極くわずかで、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崩れ落ち、柱の高さ方向の変形が生じている。 | 100% |

# Damage Rank of Non-Structural Components



## 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】 9301
仕上材のわずかな剥離、目地のずれが見られる。

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

### ●程度 II

【外部仕上】 9303
仕上やパネ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。

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

### ●程度 III

【外部仕上】 9305
大きなひび割れ又は仕上の剥離が見られる。

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



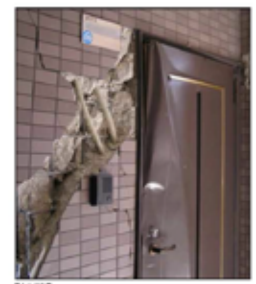
### ●程度 IV 《仕上材》 《雑壁》

【外部仕上】 9401
仕上材の破壊、崩落が一部見られる。

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

### ●程度 V

【外部仕上】 9403
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、大きな剥落が見られる。

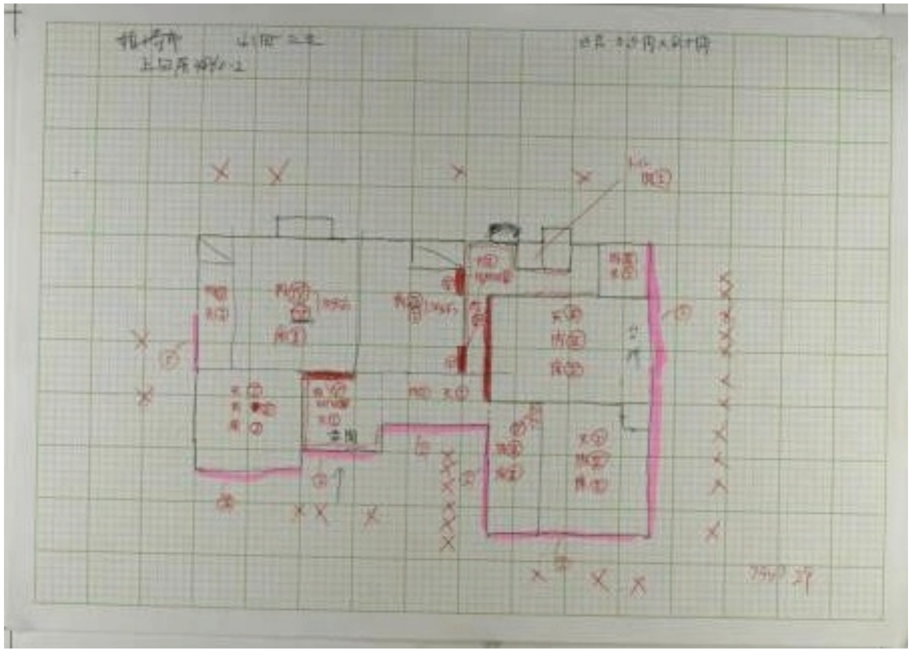


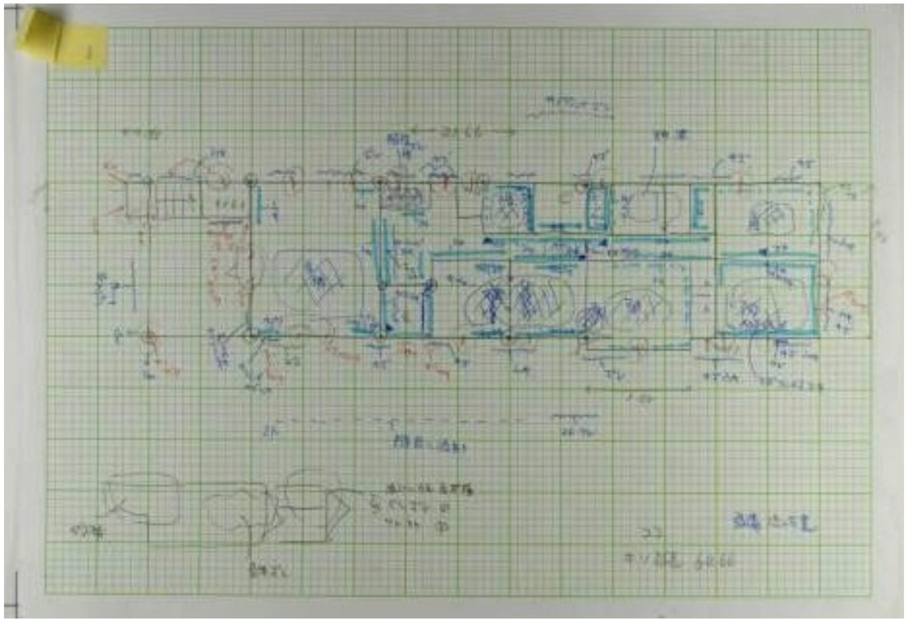
【雑壁】 9404
全体が変形し、仕上の大部分が剥落している。

### ●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%>

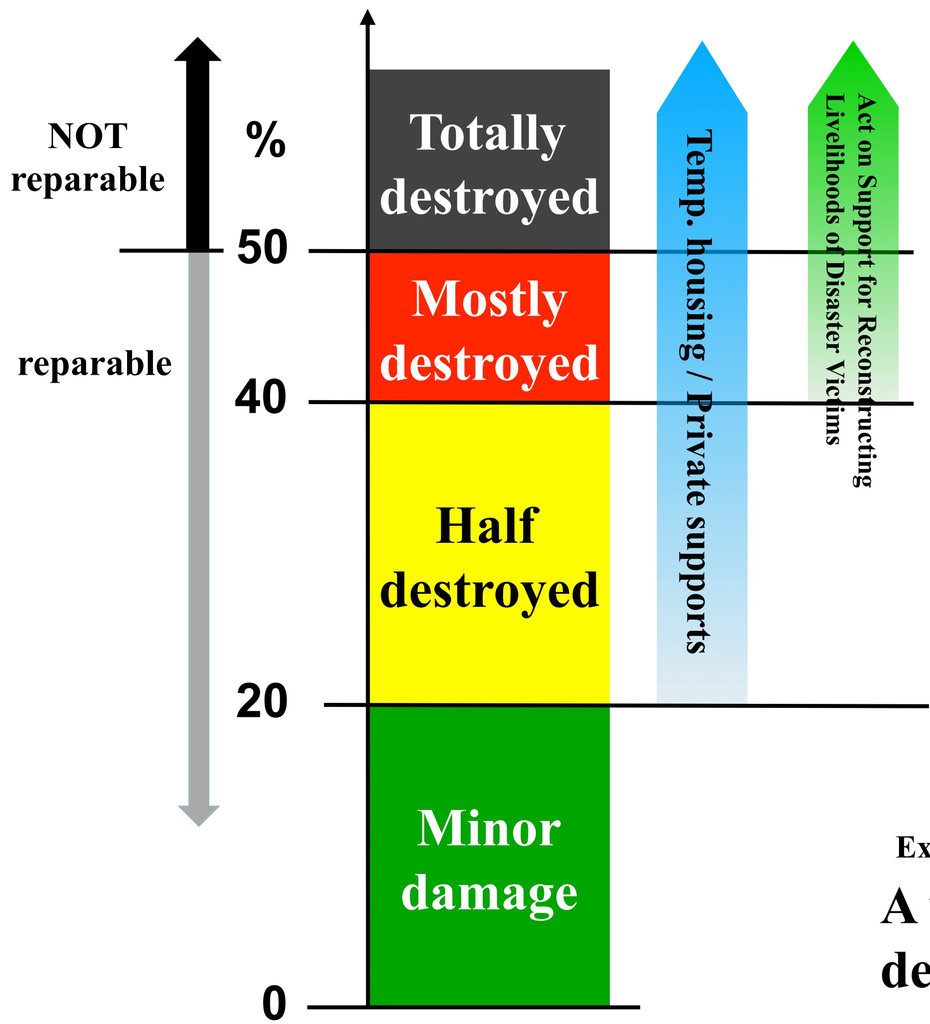
| 程度 | 損傷の例示 | | 損傷程度 |
|---|---|---|---|
| | 【外部仕上】 | 【屋根・雑壁】 | |
| I | ・仕上や仕上材の目地にわずかなひび割れ（幅約0.2mm）が見られる。<br>・仕上材の隅角部にわずかな亀裂が生じている。<br>・仕上材のわずかな剥離、目地のずれが見られる。 | ・一部にひび割れ（幅約0.2mm～1mm）やはがれが生じている。 | 10% |
| II | ・仕上やパネルの目地にはっきりとしたひび割れが見られる。<br>・仕上材の目地にずれが見られる。<br>・仕上材が部分的に剥離している。<br>・一部に飛来物による軽微な衝突痕がある。 | ・各所にひび割れ（幅約0.2mm～1mm）やはがれが生じている。<br>・一部に飛来物による軽微な衝突痕がある。 | 25% |
| III | ・大きなひび割れ又は仕上の剥離が見られる。<br>・仕上材が部分的に剥離・剥落している。<br>・一部に飛来物による突き刺さり、貫通痕がある。 | ・全体にひび割れ（幅約0.2mm～1mm）やはがれが生じている。<br>・一部に飛来物による突き刺さり、貫通痕がある。 | 50% |
| IV | ・仕上の面外へのはらみ出し、又は剥落が見られる。<br>・仕上材の破壊、崩落が一部見られる。<br>・大半にわたって飛来物による衝突痕、突き刺さり、貫通痕がある。 | ・全体にひび割れ（幅約1mm～5mm）やはがれが生じている。<br>・大半にわたって飛来物による衝突痕、突き刺さり、貫通痕がある。 | 75% |
| 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、大きな剥落が見られる。<br>・全面にわたって飛来物による衝突痕、突き刺さり、貫通痕がある。 | ・全体が変形し、仕上の大部分が剥落している。<br>・全面にわたって飛来物による衝突痕、突き刺さり、貫通痕がある。 | 100% |





# 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 |
|---|---|
| **■共通編（3編）** | |
| 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 |
| **■土木学会編（8編）**（幹事学会：土木学会） | 2014年～2016年 |
| 土木編1　土木構造物の地震被害と復旧 | |
| 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 | |
| **■日本建築学会編（11編）**（幹事学会：日本建築学会） | 2014年～2016年 |
| 建築編1　鉄筋コンクリート造建築物 | |
| 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 | |
| **■地盤工学会編（3編）**（幹事学会：地盤工学会） | 2014年 |
| 地盤編1　地盤構造物の被害，原因検討，復旧 | |
| 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 | |
| **■日本機械学会編（1編）**（幹事学会：日本機械学会） | |
| 機械編 | 2013年8月刊行 |
| **■日本都市計画学会編（1編）**（幹事学会：日本都市計画学会） | 2014年 |
| 都市計画編 | |
| **■日本地震工学会編（1編）**（幹事学会：日本地震工学会） | 2014年 |
| 原子力編 | |
| **■総集編（1編）** | 2017年 |
| 総集編・資料編　（幹事学会：日本建築学会） | |

# 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

- Building Officials Institute of New Zealand
- Canterbury Development Corporation
- Canterbury District Health Board
- Canterbury Earthquake Recovery Authority
- Canterbury Employers Chamber of Commerce
- Christchurch and Canterbury Tourism Board
- Christchurch City Council
- CORE Education Ltd
- GNS Science
- Healthy Christchurch
- Holmes Consulting Group
- Human Rights Commission
- Lincoln University

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- Pegasus Health
- Reserve Bank of New Zealand
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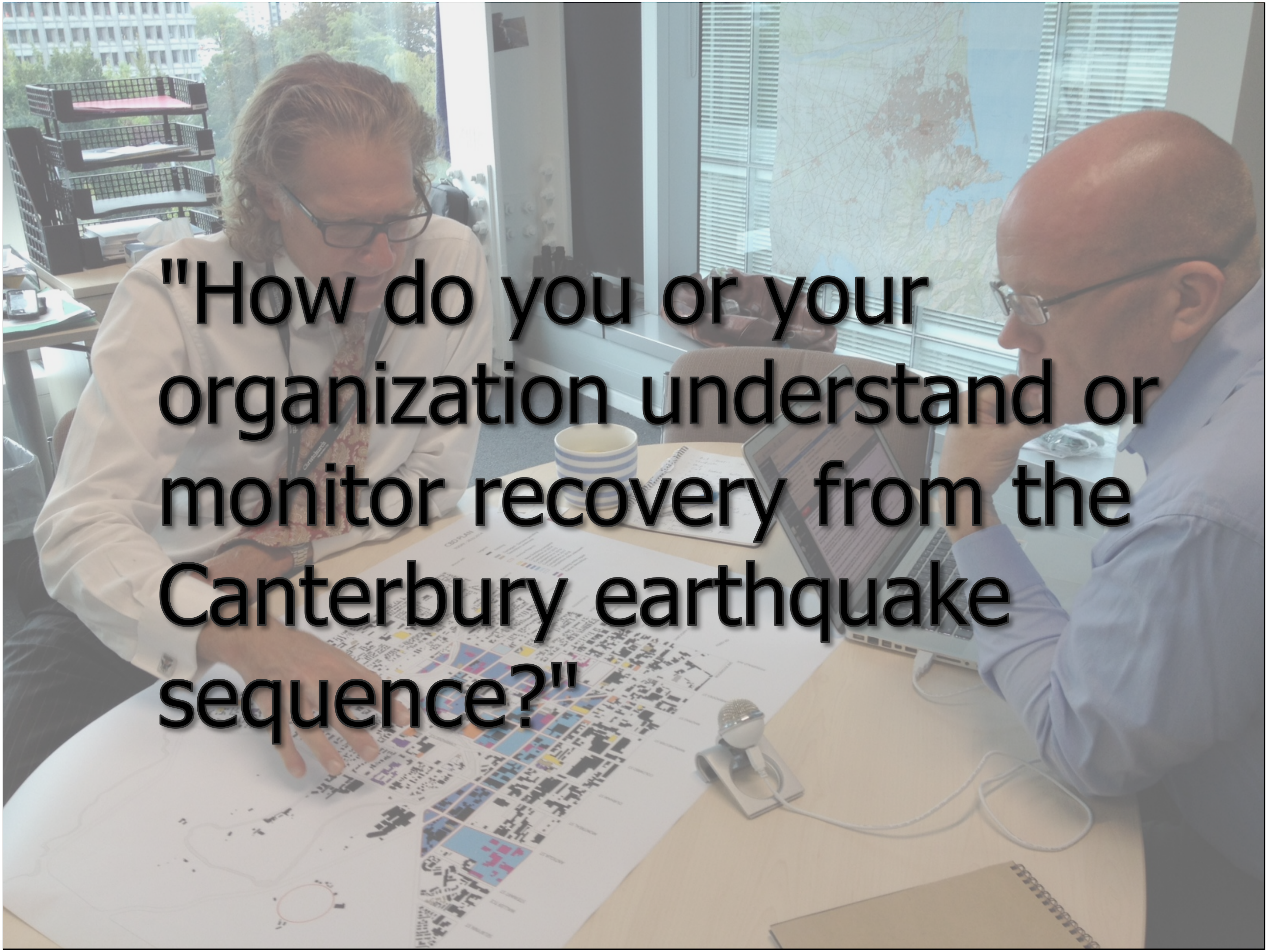
- Statistics New Zealand
- University of Canterbury
- University of Otago
- Victoria University

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.

# 45 Meetings

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


"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*

Post-Eq Data Workshop, July 20, 2014

EE RI

A409

# 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

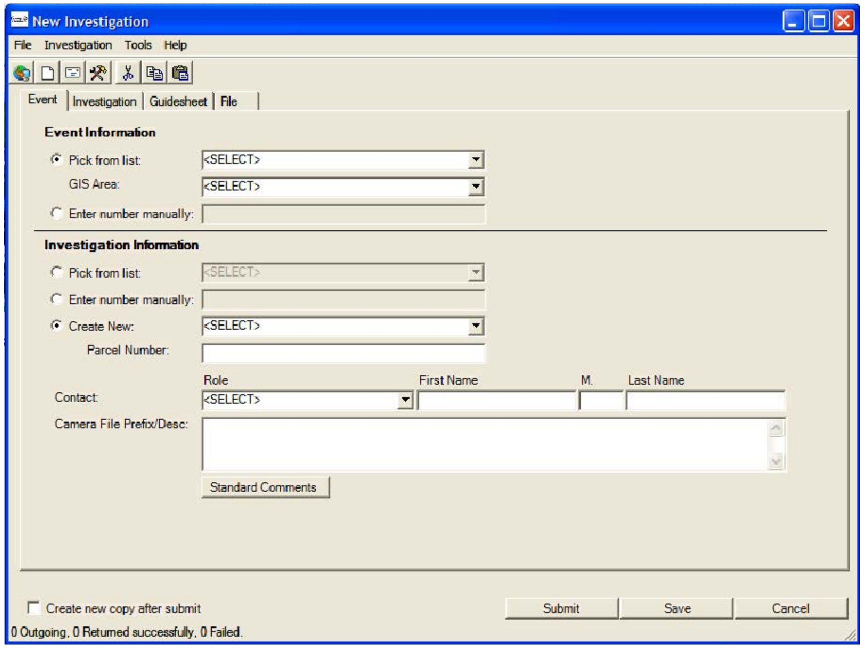
# Challenge: Technology Outdated Quickly

- 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

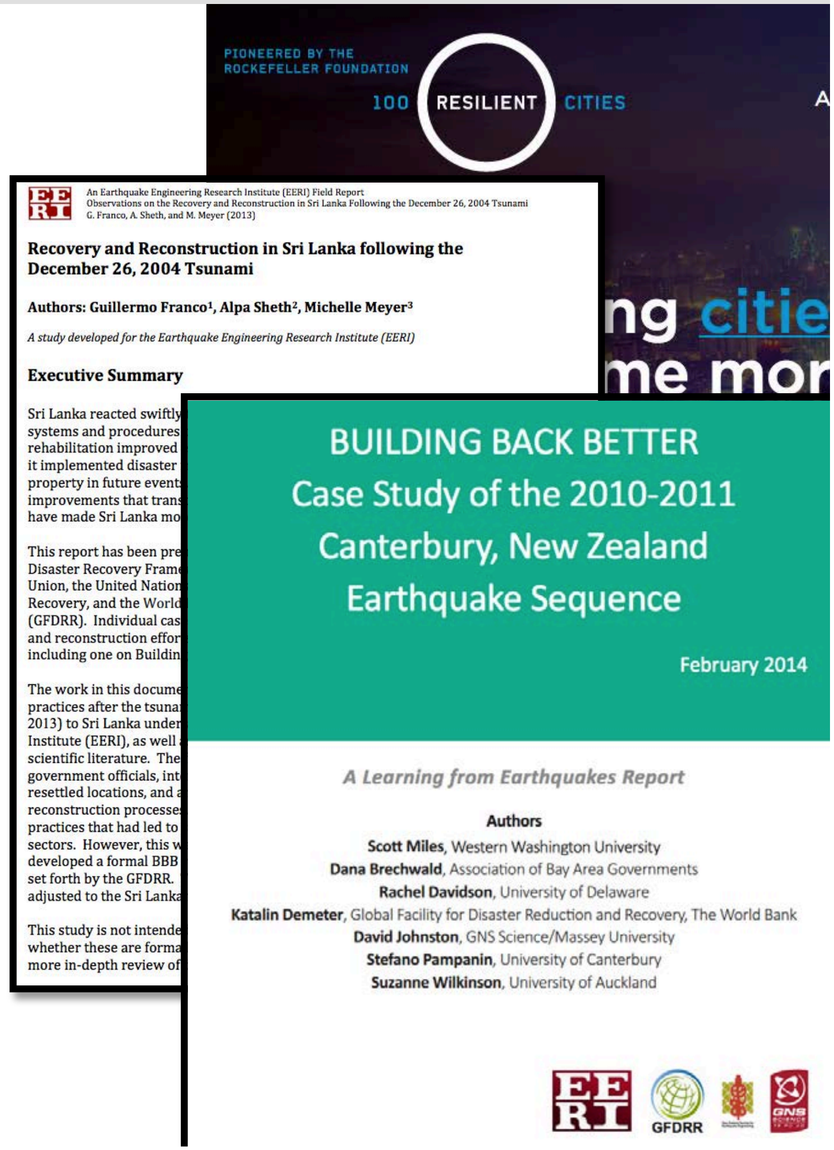
A414

# 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?

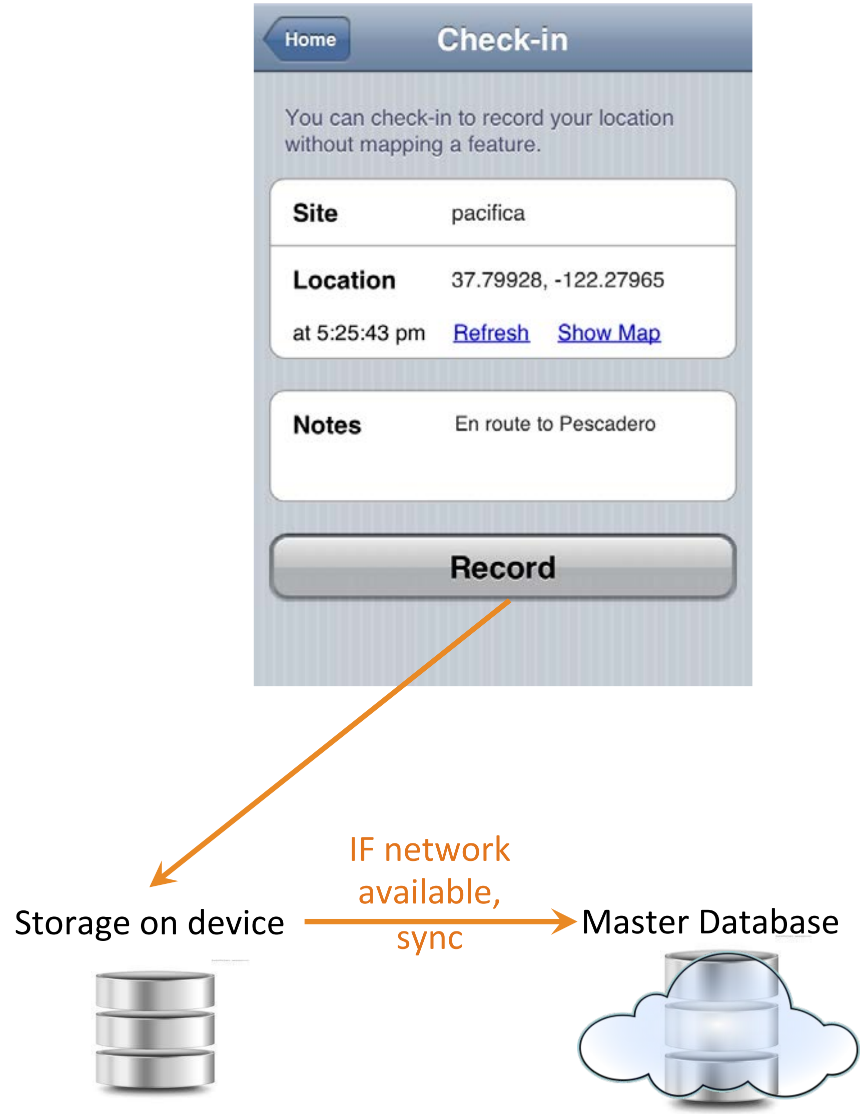


# Challenge: Large Number of Tools

- 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

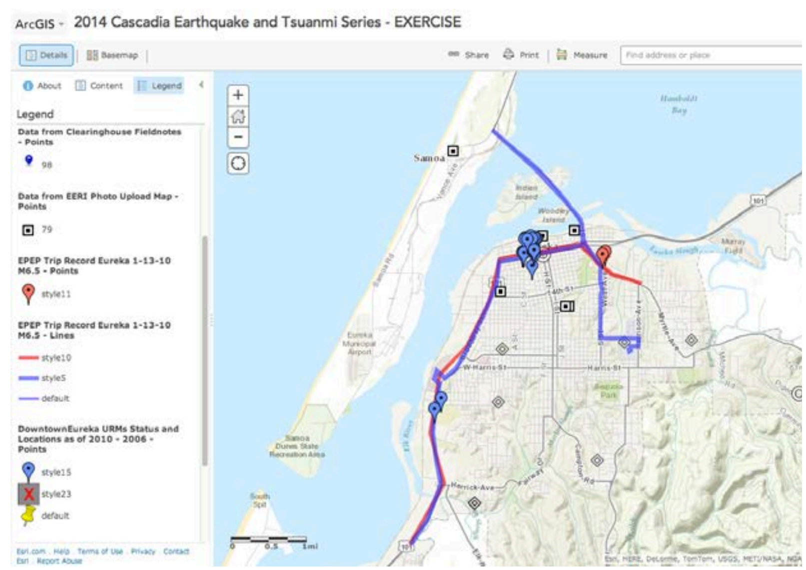
- Change to constant internet connectivity in modern life leads to expectations of near-immediate data collection, sharing, and visualization
- With limited cellular or internet access many tools may not be operable
- Example: USGS html5 web-app tool has some functionality off line (but limited)




A418

# Challenge: Visualization

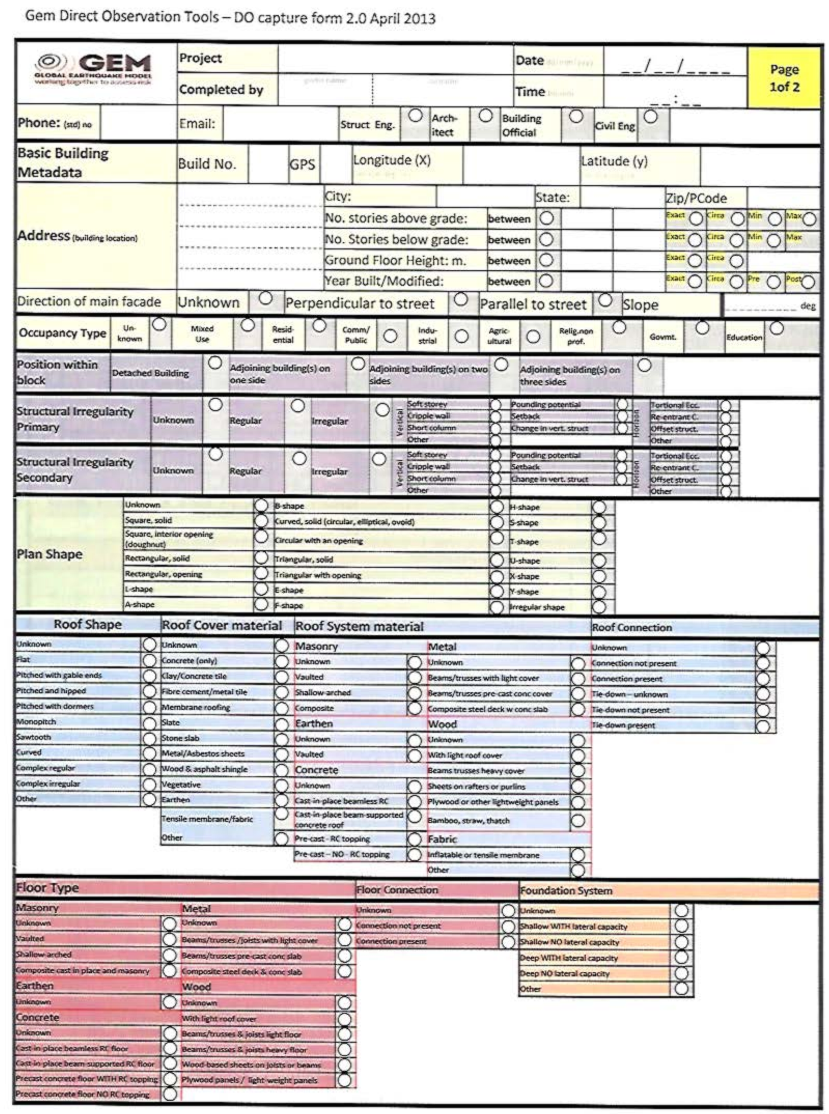
- Geo-located data is becoming easier to collect, thus map interfaces are becoming more common
- KMZ & KML map data layers exports are becoming easier and allow overlayment with other data
- With many levels of data and meta-data, other visualization may be needed beyond mapping
  - Search & Filter by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



# 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

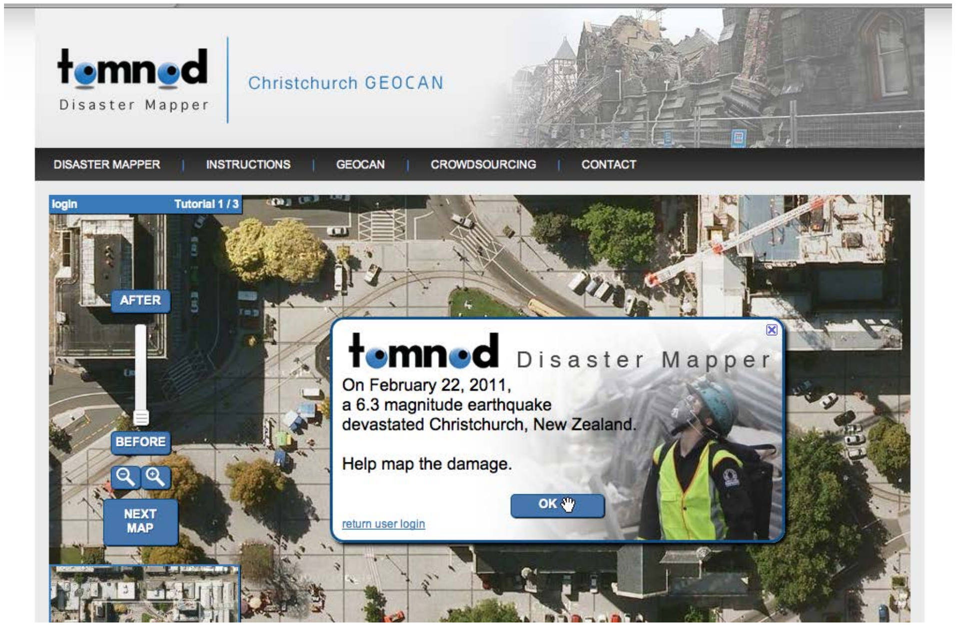

*Image captured by SOPAC using various satellite imagery, and extracted from GNS Slides at 2012 EERI-EEFIT Workshop*

# 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




A424

# 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?

EERI

# 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.

EERI

# 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 | |
| | **Date** | |
| | Ground Record(s) | |
| | Response Record(s) | |

# STRUCTURE

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

# STRUCTURE

| CATEGORY | DATA | DEFINITION |
|---|---|---|
| Structure | ID | |
| | **Coordinates** | |
| | **Address** | |
| | **Number of Stories** | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | **Nonstructural Elements** | |

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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)<br>Mike Stannard (NZ)<br>Marco Di Ludovico (IT)<br>Juan Carlos de la Llera (CHILE)<br>Tomohisa Mukai (JP)<br>Scott Miles (US)<br>Vesna Terzic (US)<br>Ayhan Irfanoglu (US)<br>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

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

- 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?