

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

Brief Report on Earthquake Reconnaissance after the M 8.8 February 27th 2010 Maule, Chile Earthquake

Team Focus: Nonstructural Components
(particular emphasis on hospitals)

Also served as scouts to other EERI
teams that arrived later in Chile

Team Members: Eduardo Miranda
 Gilberto Mosqueda
 Gokhan Pekcan
 Rodrigo Retamales



Acknowledgements

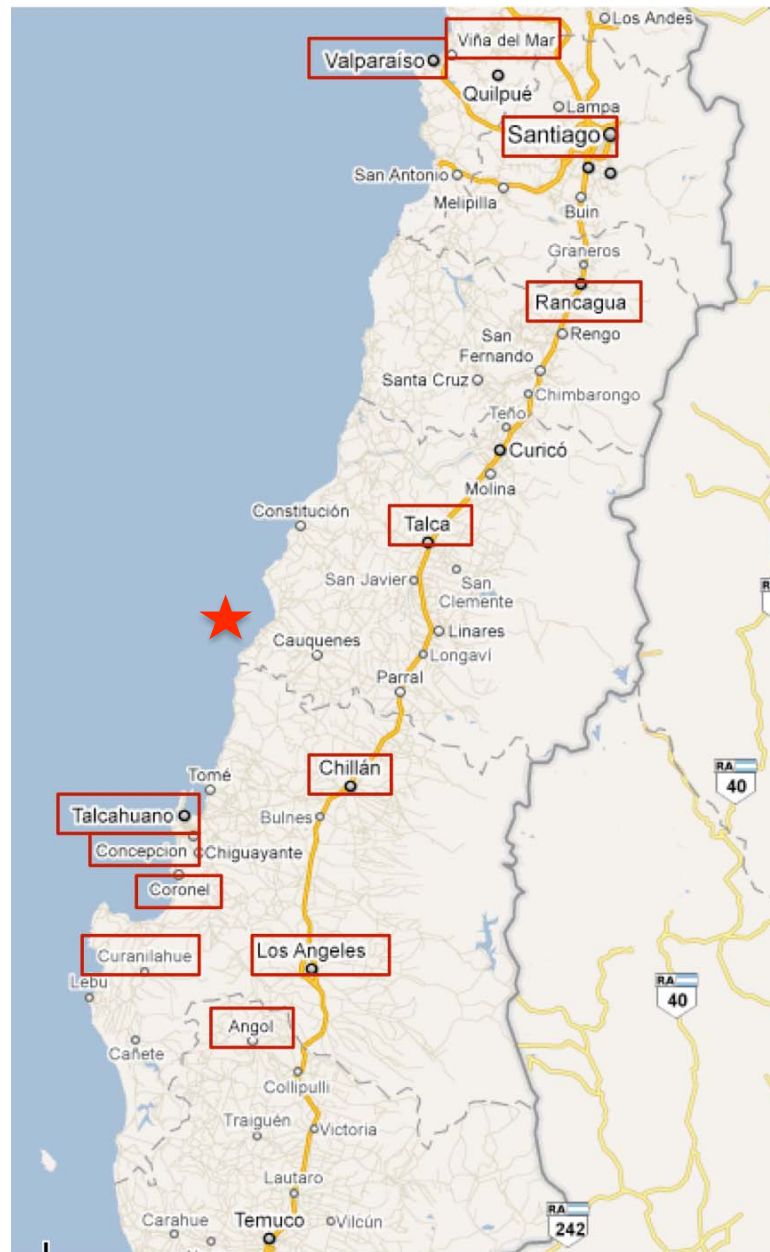
- The nonstructural team received technical support from the following individuals in identifying sites of interest and gaining access to them
 - Phillip Corra (AMEC Engineering)
 - Alicia Cerda Lucero (Ministry of Health Chile)
 - Victor Contreras (Ruben Boroschek and Associates)
 - Prof. Juan Carlos De La Llera (Pontificia Universidad Católica de Chile)
 - Prof. Matías Hube (Pontificia Universidad Católica de Chile)
- With no hotels available in some areas, the team was able to find a roof to sleep under and some meals through the generosity of personal contacts of our Chilean friends. We are specially thankful to
 - Maria Graciela Olivares and parents
 - Gisel Hasbun and family
 - GianCarlo Canata and family
 - Rodrigo Garcia and family



Partial List of Places Visited

- March 6-7: Santiago
 - Airport
 - 3 hospitals
 - 2 condo buildings
- March 8:
 - Hospital in Rancagua
 - Hospital in Talca
 - Courthouse in Talca
- March 9:
 - Clínica del Maule in Talca
 - Rice packing plant in El Retiro
 - Airport in Concepción
 - Hospital in Concepción
- March 10:
 - Hospital in Talcahuano
 - Concepción shopping mall
- March 11:
 - Port at Coronel
 - Hospital in Curanilahue
 - Hospital in Angol
 - Paper plant in Nacimiento
 - City of Los Angeles
- March 12:
 - Hospital in Chillan
 - Hospital in San Carlos
 - Chillan shopping mall
 - Mill in Talca
- March 13:
 - Various bldgs in Santo Domingo and Algarrobo
- March 14:
 - Various bldgs in Santiago
- March 15:
 - Three base isolated hospitals in Santiago
 - Felix Bulnes Hospital in Santiago
- March 16:
 - Various bldgs in Viña del Mar
- March 17:
 - Airport in Santiago

Some of these places on a map of central Chile





List of Hospitals Visited by the Team

1. Felix Bulnes Hospital in Santiago
2. Hospital Posta Central in Santiago
3. Hospital Sotero del Rio in Santiago
4. Military Hospital in Santiago (one bldg is base isolated)
5. Centro Hospitalidades Médicas – Hospital del Trabajador Santiago (one bldg is base isolated)
6. Clínica San Carlos Universidad Católica (one bldg is base isolated)
7. Hospital del Trabajador Viña del Mar – base isolated administrative building
8. Hospital in Rancagua
9. Hospital in Talca
10. Clínica del Maule in Talca
11. Hospital in Chillán
12. Hospital in San Carlos
13. Hospital Clínico Regional in Concepción
14. Higuera Hospital in Talcahuano
15. Hospital in Curanilahue
16. Hospital in Angol



Airport terminal at Santiago shut down mainly due to nonstructural damage



Photo by G. Mosqueda



Photo by G. Pekcan

Many suspended air handling units like this fell to the ground



Sheared off sprinkler braces at the Santiago Airport

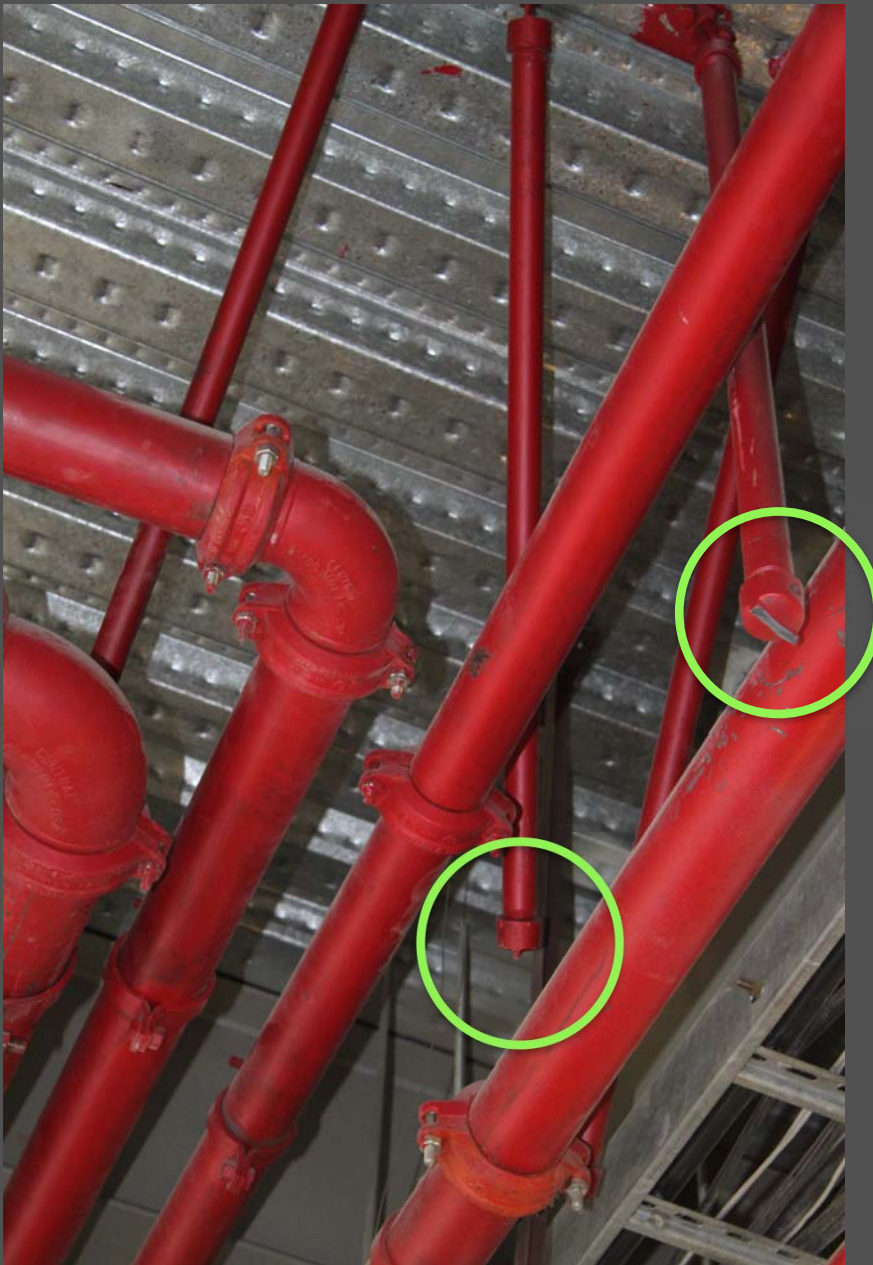
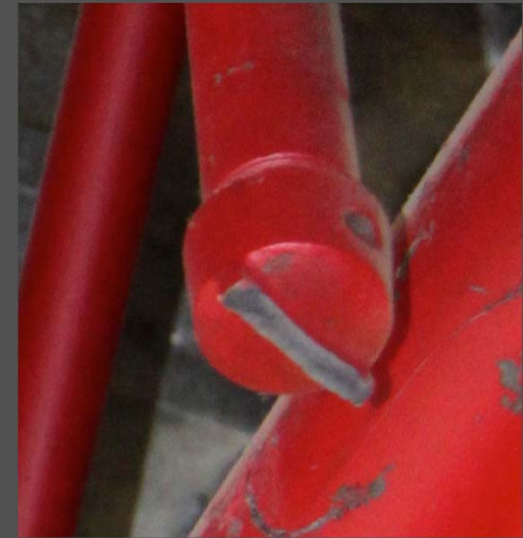


Photo by E. Miranda



Closeup view

Miranda, Mosqueda, Pekcan and Retamales



Broken sprinkler piping at the Santiago Airport

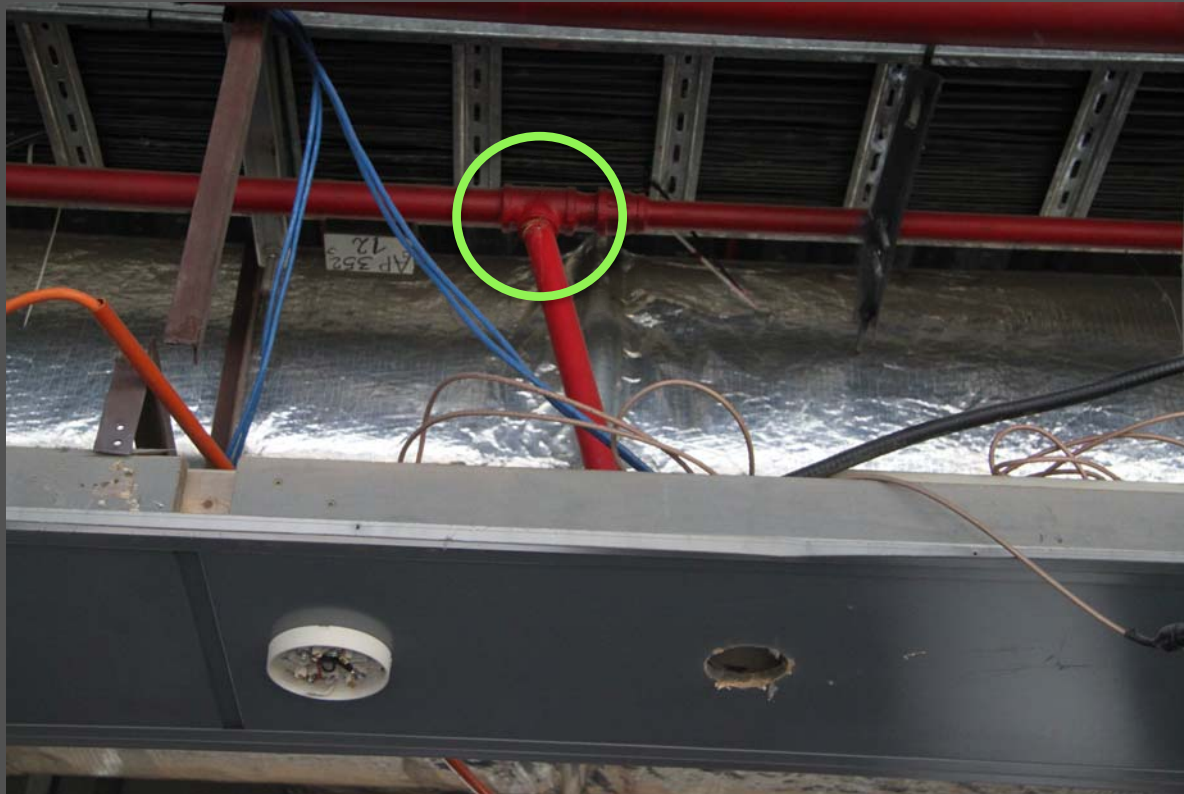


Photo by E. Miranda



Photo by E. Miranda

Closeup view



Water damage from broken sprinklers at the Concepción Airport



Overall view of wood ceiling



Photos by E. Miranda

Closeup view of some sprinkler heads sheared off

Miranda, Mosqueda, Pekcan and Retamales



Damage in Elevators at the Talcahuano Hospital



Photo by E. Miranda

Nearly overturned elevator machine



Photo by E. Miranda

Overturned switch control panel



Damage in Elevators at the Clínica del Maule in Talca



Photo by R. Retamales

Derailed and disassembled counterweight



Photo by G. Pekcan

Elevator cabin hit by derailed counterweight



Broken water pipes in residential buildings



Photo by G. Pekcan

Broken copper water pipe of hot water



Photos by G.Mosqueda

Evidence of sliding of an unanchored boiler



Example of broken water pipes in San Carlos Hospital



Photo by G.Mosqueda



Photos by G.Mosqueda

Broken copper water pipe of hot water caused by lack of lateral bracing of the boiler



Felix Bulne Hospital in Santiago shut down primarily due to nonstructural damage



Photo by G.Mosqueda



Photo by G.Mosqueda



Glazing damage was frequently observed in residential buildings, hospitals and commercial buildings



Photos by E. Miranda



Miranda, Mosqueda, Pekcan and Retamales



Ceiling-sprinkler head dynamic interaction at the Mall Plaza in Concepción



Photo by E. Miranda



Photo by E. Miranda

Closeup view



Damage to wall-mounted monitors at Talcahuano and San Carlos Hospitals



Photo by G. Pekcan

Wall-mounted monitors at this hospital fell from their brackets



Photos by G. Pekcan



Roof-mounted small AC units at the Clínica del Maule in Talca



Photo by G. Pekcan



Photo by G. Pekcan

75% of these roof-mounted small AC units overturned

Miranda, Mosqueda, Pekcan and Retamales



Examples of well anchored hospital equipment that performed well At Santiago General Hospital



Photo by G. Pekcan



Photo by G. Pekcan



Observations on the Chilean code for nonstructural components

- The Chilean code at the time of the earthquake was last revised in 1996 (NCh444.Of96).
- **Section 8 of the code provides loading requirements for design and anchorage of “secondary elements”** defined as *“permanent element not being part of the resistant structure, but that it is affected by its movements and eventually interacts with it, such as dividing partitions and non-structural facade elements, large windows, false ceilings, parapets, cornices, shelves, decorative elements, lamps, mechanical and electrical equipment, etc.”*
- **These requirements have many similarities to U.S. seismic provisions for nonstructural components** (e.g., the loading is an equivalent static force which is a percentage of the weight of the component, different loading are specified for flexible and rigid components, the importance of the nonstructural equipment is explicitly taken into account, etc.) however there are some differences.
- Some differences with U.S. seismic provisions are:
 - Loading for rigid components and differences in loading for components in different points in the structure (e.g., components in different stories or different heights) require either an equivalent static analysis or a modal spectral analysis of the structure.
 - There are three instead of two levels of design forces depending on the expected level of performance (importance) of the nonstructural component.
 - Dynamic amplification factors for flexible components are function of both *“the period of the mode with the highest translational equivalent mass of the building in the direction where resonance with the secondary element may develop”* and the fundamental period of vibration of the secondary component.
 - The vertical acceleration to be considered in the design of nonstructural components is two thirds of PGA instead of $0.2S_{DS}$ (approximately equal to half of PGA).



Observations on the Chilean practice for design and anchoring of nonstructural components

- **Similarly to U.S. practice, code requirements for design and anchoring nonstructural components in Chile are not always enforced.** In particular, bracing of nonstructural components typically falls outside of the services provided by the structural engineer of record and it is no clear who is responsible for the design, installation and inspection of installation of nonstructural components.
- **With few exceptions** (e.g. some newer hospitals we visited) **their practice on seismic anchoring of nonstructural components considerably lags their earthquake resistance design practice for structural components.**
- From our reconnaissance we believe it is fair to say that state of practice on seismic anchoring of nonstructural components in Chile is typically in a worse situation than common present practice in western U.S.
- While many observed failures of nonstructural components were due to the lack of anchorage/bracing, we observed many situations in which anchors, hangers and bracings similar to those currently used in the U.S. did not prevented the failure of the component, which suggests that the level of forces in these anchorage/bracing elements exceeded the expected level of forces in the components.



Preliminary conclusions

- Similarly to other earthquakes that have occurred in countries with good practice in earthquake resistance design, this earthquake highlights the need for:
 - Conducting research to significantly improve our present knowledge on the seismic response of nonstructural components
 - Improving code requirements and state of practice on seismic design and anchoring of nonstructural components
 - Requiring a performance level of nonstructural components that aims for full functionality of critical infrastructure such as hospitals, power plants and airports
- Despite the relatively low loss of life and injuries caused by this earthquake, relative to its magnitude and population/structures exposed, the considerable impact to the normal functioning of the country and the large economic loss sustained relative to their GDP highlights the need controlling economic losses and downtime in addition to life safety