

# Chile Earthquake of February 27, 2010 Reconnaissance Report on Hospitals

Bill Holmes

William T. Holmes

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# EERI Hospital Reconnaissance Team Members



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

## Rick Bissell

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

## Francisco de la Masa

Ministerio de Salud

## Judith Mitrani-Reiser

Assistant Professor of Civil Engineering,  
Johns Hopkins University, Baltimore, MD

## Bill Holmes

Structural Engineer, Rutherford & Chekene,  
San Francisco

## Thomas Kirsch

Associate Professor and Director of  
Operations of Emergency Medicine,  
Johns Hopkins University, Baltimore, MD

## Mike Mahoney

Senior Geophysicist of Building Science  
Branch, DHS/FEMA, Washington, DC

## Nicolas Santa Cruz Marin

Pontificia Universidad Catolica

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## Goals of Hospital Team

- Assess the physical and medical similarity of Chilean Hospitals to US practice.
- Identify vulnerabilities that can
  - Threaten patients
  - Reduce the ability to provide emergency medical care
- Develop a protocol to collect detailed data measuring effectiveness and vulnerabilities of regional medical care.
  - Size and other medical characteristics of facility
  - Numbers of in-patients present, injured, evacuated, moved to other facilities
  - Numbers of outside patients treated

# Chilean Hospital System

- Public Health System
  - Regional (we covered parts of 4 regions)
- ACHS
  - Began to provide care similar to Workman's Comp
  - Now essentially a hospital system
- Private hospitals and clinics
  - Catolica, etc.
- Systematic listing of facilities, damage, etc, available only on Public Health System.
  - Several other hospitals visited in Santiago

# Overall performance of Public Health Hospital System according to Ministry of Health Website

- Total in shaken region: 100
- 17 to be completely rebuilt
- 8 with major damage
- 54 requiring minor repair
- 21 apparently undamaged

## Reconnaissance of Hospitals

- Santiago area
  - Military Hospital
  - San Carlos Catolica Clinic
  - ACHS (Trahabador)
  - Victor Bulnes (Santiago Sotero del Rio, Felix Bulnes)
- Talca Regional Public
- Los Angeles Regional Public
  - Six satellite facilities
    - de Hupiel
    - Laja
    - Santa Barbara
    - Nacimiento
    - Yumbel
    - Mulchen
- Concepcion Regional Public
  - Talcahuano



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# Structural Systems

- Typical systems
  - Masonry bearing wall—only in very old buildings
  - Concrete Frame with infill
  - Concrete frame
  - Concrete frame with concrete shear wall
  - Steel brace frame-3 story (tube columns and braces)
- Structural Performance
  - Lack of damage to one story hospital buildings compared to high rise non-hospital concrete buildings suggests different input energy levels.
  - Older buildings beat up—often masonry
  - Mid-rise hospital buildings constructed after 1985 generally performed well structurally, with some exceptions.
  - Seismically isolated buildings (3) performed well but joint damage was common.

# Nonstructural Systems

- Systems used are very comparable to US practice
- Only the newest hospitals in Chile have systematic seismic protection for nonstructural systems
- The nonstructural seismic performance observed should be expected in similar levels of ground motion in older US hospitals or where code-specified nonstructural protection is not enforced.
  - 0.2-0.25 g in Santiago
  - Higher, up to 0.5 g elsewhere
  - Effects of long duration on nonstructural systems has not been studied.

# Organization of Findings

- By issues known to affect patient safety or functionality
  - Communications
  - The need for evacuations
  - Elevators
  - Loss of power
  - Loss of water
  - Water damage
  - Loss of bulk oxygen tanks
  - General disruption from ceiling damage
  - General disruption from nonstructural masonry damage
  - Disruption to fragile areas like paper medical records, pharmacies, and laboratories
  - Damage to medical equipment
  - Damage to MEP equipment
  - Damage to MEP distribution systems

# Known Hospital Seismic Issues

- **Communications**

- Over-reliance on cell phones, no plan for emergency communication in facility or between facilities—particularly to headquarters of public health system.
- Perhaps explains remarkable self reliance at each site
- Administrators interviewed wanted to address this issue for future emergencies

# Evacuations

- San Carlos de Catolica (Santiago)
  - Fifth floor of fixed base wing due to nonstructural chaos
- Felix Bulnes (Santiago)
  - 200 patients from tower due mostly to nonstructural but also damage to infill masonry
  - Administrative building severely damaged, and would have caused casualties if occupied.
  - Entire facility is now closed. Clinic building under construction/renovation is being rushed to completion



Patient room. Felix Bulnes

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Felix Bulnes

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# Evacuations

- Talca
  - Older light concrete frame with heavy masonry severely damaged and evacuated
  - Chilean military hospital set up across street is still in operation.
- Los Angeles
  - Older buildings slated for replacement in 3 years evacuated due to nonstructural, infill, and water damage
  - Several floors of newer building evacuated for repairs
- Concepcion
  - Older building evacuated due to water and sanitation piping systems leaks



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Evacuated building at Talca Hospital

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Evacuated building at Los Angeles Hospital

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# Known Hospital Seismic Issues

- **Elevators**

- Significant failures. Over 50% of all elevators were out, most due to counterweights off rails.
- In every building evacuated, elevators were inoperable, requiring patients to be carried down stairs-often rubble strewn.
- Elevator machine rooms and shafts are typically accessible only by elevator maintenance service or one person on site.
- Evacuations required use of stairs.



Anchor bolt failure of elevator generator set due to inadequate edge distance.  
Los Angeles Regional Public Hospital

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Security camera at Military Hospital (Santiago) captures counterweight failure

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# Known Hospital Seismic Issues

- **Loss of Power**
  - Outside power lost for various times at every facility
  - Seldom caused an ongoing problem due to availability of emergency generators and at least 3 days fuel.
- **Loss of Water**
  - Unlike most of the US, many sites had on-site storage for 3 or more days (or wells).
  - Water provided that was not pumped through facility system did not provide sufficient pressure for toilets and some medical equipment.

# Known Hospital Seismic Issues

- **Damage/disruption from water**
  - Not statistically frequent but caused at least three buildings to be evacuated, and shut down 3 of 6 ORs in relatively new building.



2005 building; Los Angeles Hospital. Infill masonry wall collapses on to distilled water equipment, spilling two 150 gallon containers; water leaks past perimeter edge of slab to OR suite below, closing 3 or 6 ORs

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Continuing water damage at Talca Hospital. Water is leaking from water heater on right. Building was closed due to nonstructural damage, dominated by water.

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# Known Hospital Seismic Issues

- **Bulk oxygen storage tanks**
  - Standard of practice is to anchor. No overturning reported, but close calls....



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Oxygen tank legs punched through support slab but did not overturn and remained functional.  
Felix Bulnes-Santiago

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Overturning tension stretched anchor bolts. Talcahuano Hospital.

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## Known Hospital Seismic Issues

- **Suspended lay-in ceilings.** Generally without any seismic detailing. The “American Ceiling”
  - 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)

# The story of the American Ceiling



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The morning after. Los Angeles Hospital. Note fallen light fixtures and mechanical registers, in addition to ceiling panels.

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Add clips to hold down tiles



Fallen tile despite clips. Talca Hospital.

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Close up of clips used at Talca Hospital in new building.

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## ICU with perfect performance



ICU. Talca Hospital older building-evacuated

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Packing tape is almost as good as duct tape as a cure-all!



ICU Talca Hospital

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# Known Hospital Seismic Issues

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



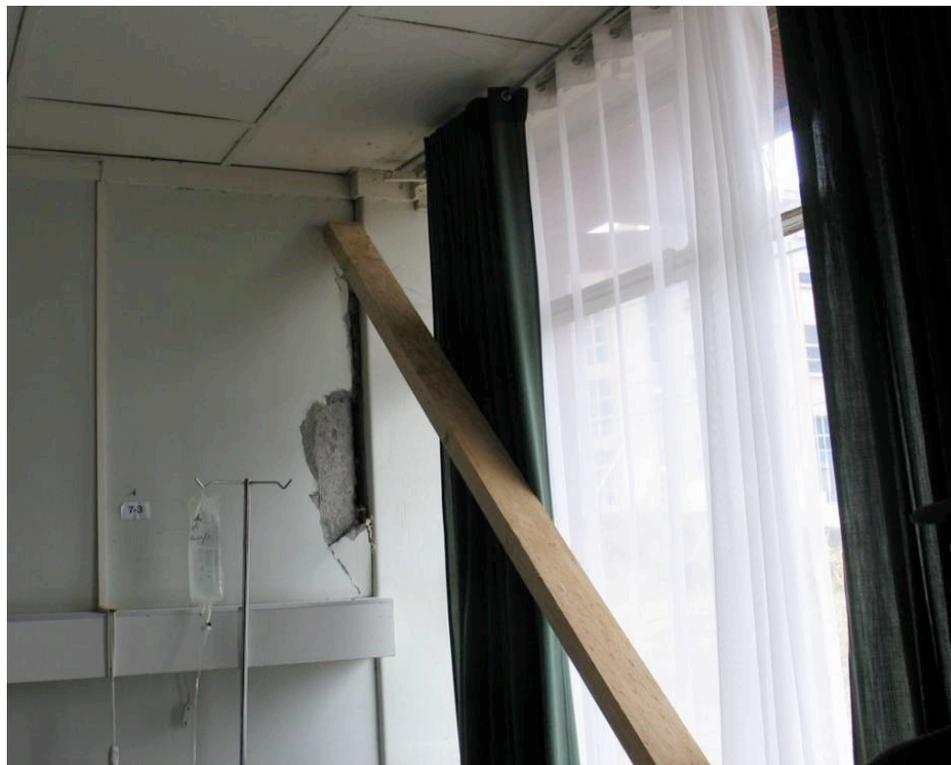
Cracked and spalled infill in patient room. Felix Bulnes (Santiago)

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Temporary braces at loose precast partitions. Laja



Braces supported at bottom with cabinet

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# Known Hospital Seismic Issues

- **Vulnerable areas**
  - Paper medical records, pharmacies, and laboratories
  - Medical Equipment
  - Mechanical/Electrical/Plumbing Equipment
  - Mechanical/Electrical/Plumbing Distribution Systems
- Did not “stand out” as vulnerable. Damaged when building had other nonstructural damage

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Lessons for the  
Disaster Resistant University Program  
University of Concepcion

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# University of Concepcion

- School was out for the “summer”
  - Scheduled to start March 15, now April 5 (questionable)
  - Student housing is off campus residential, much now damaged.  
Amount now available is unknown. Plan for housing not formulated
- Little structural damage on campus, but much nonstructural
  - No power for 7 days
  - Water out for 7-14 days (still fixing leaks on March 19)
- Lost Chemistry Department due to fire following
- Lost Marine Biology Department -extensively outfitted ship
  - Tsunami and looting
- Losses in Civil Engineering Labs
  - Essentially all equipment out of calibration at a minimum
  - All theodolites fell off shelves—have not been tested
- Severe losses in Microbiology lab
- Campus not completely investigated—library?, computer center?  
Student Records?

Large  
Chemistry  
Building,  
containing  
the entire  
department,  
destroyed by  
fire,  
exacerbated  
by chemicals



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## Four year old Micro Biology Lab Building



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Structure  
had  
several  
joint, all  
beat up  
by  
pounding



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# Protection of Equipment

- Equipment on wheels vs. anchorage: Wheels apparently are better. No injuries and no reported overturning. This issue needs systematic testing.

# Centrifuge on wheels ok



V  
Ch

## Incubator ruined



- Hit by overturning equipment
- Loss of power for 5-10 days

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## Microbiology Lab

- Lost most of work done in 4 years at micro biology lab
  - will take 2 years to recover to previous point
- 8 PhD work lost
- 100 M Peso total lost equipment (\$500,000)
  - Lost a \$70,000 piece that will take 6 mo to replace
  - Lost another that will take 12 mo to replace

Not the  
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of  
Concepcion  
Marine  
Biology  
Department



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