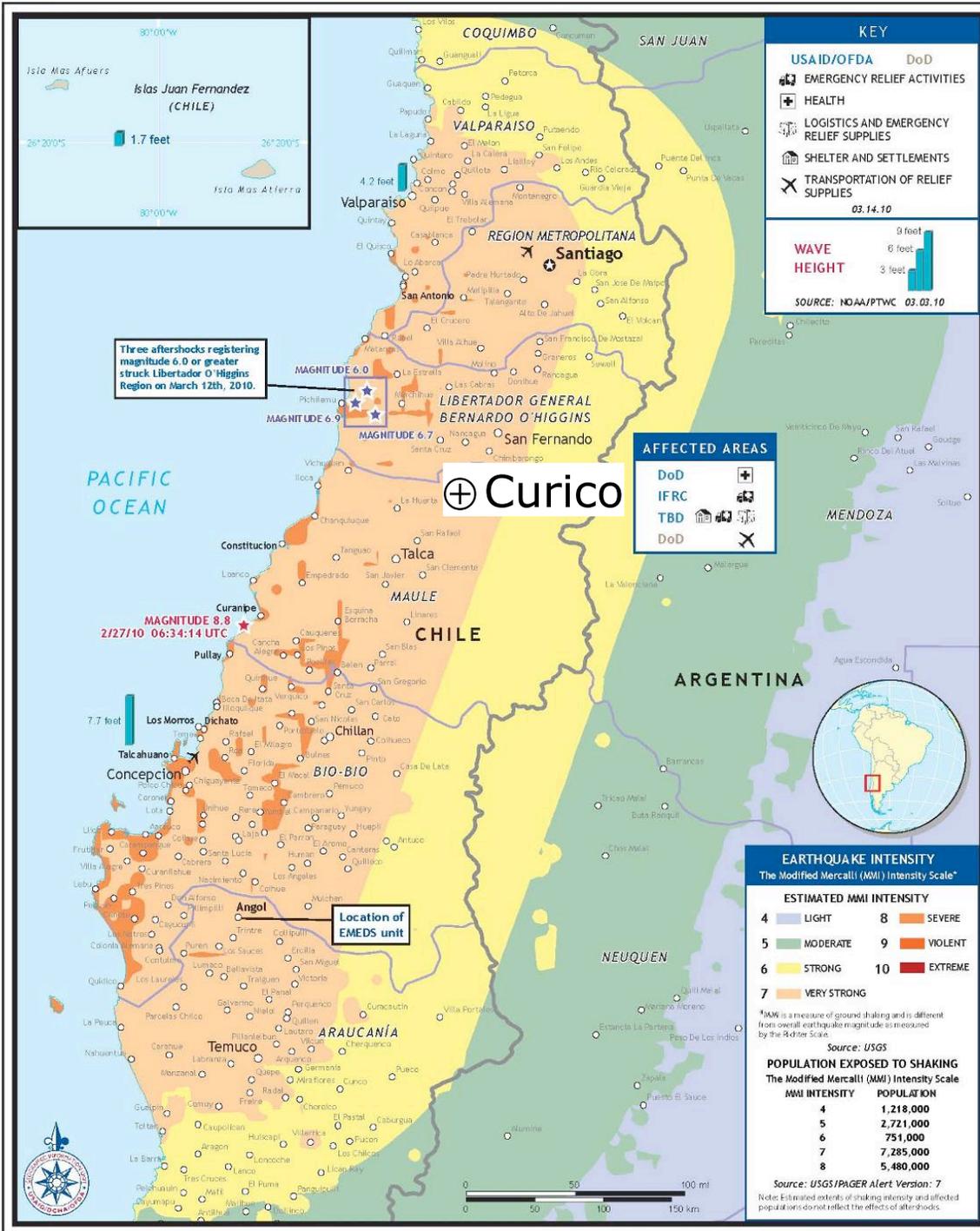


27 March 2010 Offshore Maule, Chile Earthquake





2010 Chile earthquake

3:34 am local time
27 February 2010

M_w 8.8

Fault rupture 100km x 500 km

Population affected > 8M*

452 confirmed deaths**

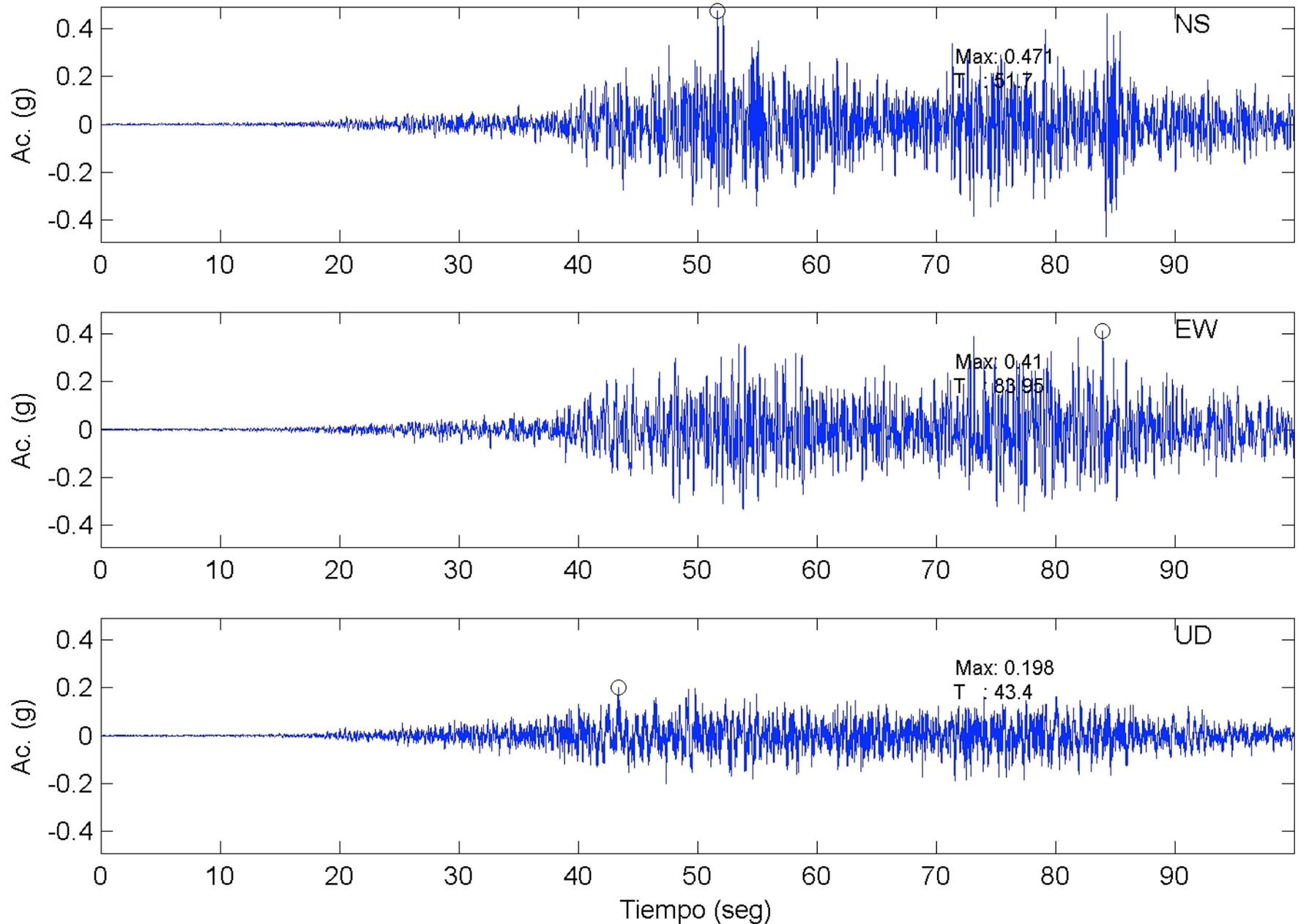
~800,000 homeless

~\$30B damages

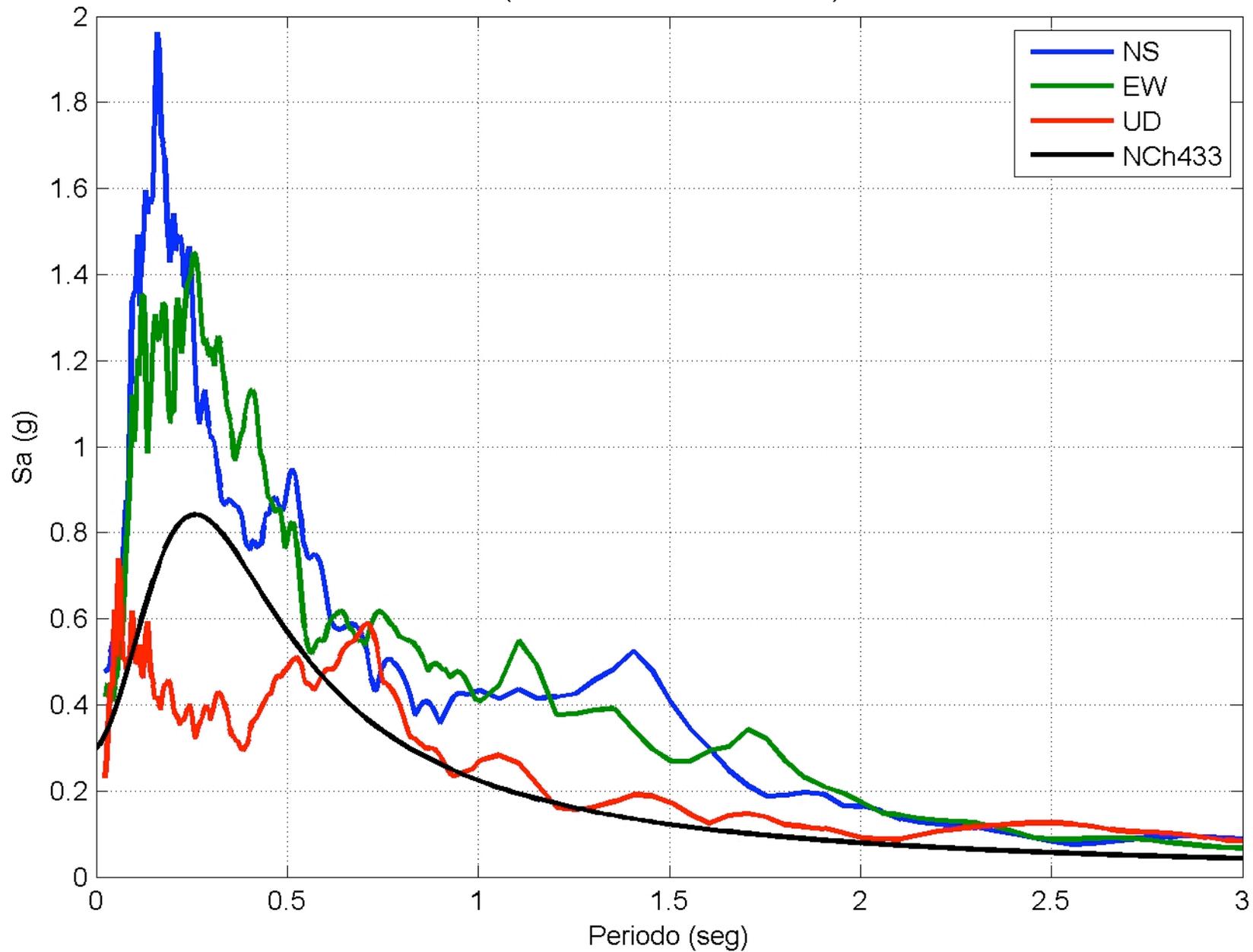
* ACHISINA

** USAID, 3/25/10

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



ESPECTRO de RESPUESTA $\beta = 5\%$
REGISTRO: RENADIC: ESTACION: HOSP CURICO / P. SOTO R. BOROSCHEK
UNIVERSIDAD DE CHILE RED NACIONAL DE ACELEROGRAFOS
(Banda Frec: 0.055 - 40 Hz)





Talca (AP Photo)



Santiago (AP PHOTO/Carlos Espinoza)



Concepcion (AP Photo)



Pelluhue (AP Photo)

EERI Learning From Earthquakes Program Reconnaissance Team

Team Leaders: Jack Moehle (UCB), Rafael Riddell (UC), Ruben Boroschek (UCh)

- Buildings
 - Reinforced Concrete
 - Alvaro Celestino (Degenkolb)
 - Jeff Dragovich (NIST)
 - Joe Maffei (R&C)
 - Jack Moehle (UCB)
 - Carlos Sempere (Forell/Elsesser)
 - John Wallace (UCLA)
 - Masonry
 - Jennifer Tanner (U. Wyoming)
 - Steel and Industrial Facilities
 - Roberto Leon
 - Farzin Zareian (UC Irvine)
 - Team Leaders
 - Non-structural
 - Eduardo Miranda (Stanford)
 - Gilberto Mosqueda (U. Buffalo)
 - Gokhan Pekcan (UNR)
 - Structural/Instrumentation
 - Mehmet Celebi (USGS)
 - Mark Sereci (Digitexx)
 - *nees@UCLA*
- Bridges
 - Scott Ashford (OSU)
 - Ian Buckle (UNR)
 - Luis Fargier (Venezuela)
 - Mark Yashinsky (Caltrans)
 - others yet to travel
- Hospitals/Health
 - Rick Bissell (U. Maryland, BC)
 - Bill Holmes (R&C)
 - Mike Mahoney (FEMA)
 - Tom Kirsch (Johns Hopkins U.)
 - Judy Mitrani-Reiser (John Hopkins U.)
- Social Science/Planning/Policy/Recovery
 - Guillermo Franco (AIR)
 - William Siembieda (Cal Poly, SLO)
 - Rick Tardanico (Florida International U.)
- Tsunami Effects on Structures
 - Gary Chock (Martin & Chock)
 - Ian Robertson (U. Hawaii)
- Geotechnical Engineering
 - Through collaboration with GEER

with onsite support from Juan Carlos De La Llera, Mattias Hube, and Carl Luders (UC);
Rodolfo Saragoni, Leonardo Massone, and Ofelia Moroni (UCh); and
and many outstanding students.

Topics

- OverviewJack Moehle, UC Berkeley
- Geology and Coastal Uplift.....Keith Kelson, FUGRO WLA
- Geotechnical Engineering.....Jonathan Bray, UC Berkeley
- Highways and Bridges.....Mark Yashinsky, Caltrans
- Buildings.....Jack Moehle
- Hospitals and Universities.....William Holmes, Rutherford & Chekene
- Closure.....Jack Moehle
- Questions and Discussion



Buildings / Structural Team



John Wallace, Alvaro Celestino, Joe Maffei
Arturo Millán, Santa María, Valparaíso
Claudio Frings & Juan Pablo Herranz, Católica

+

Jack Moehle, Jeff Dragovich, Carlos Sempere
Juan Jose Besa & Benjamin Westenenk, Católica



Concrete buildings focus



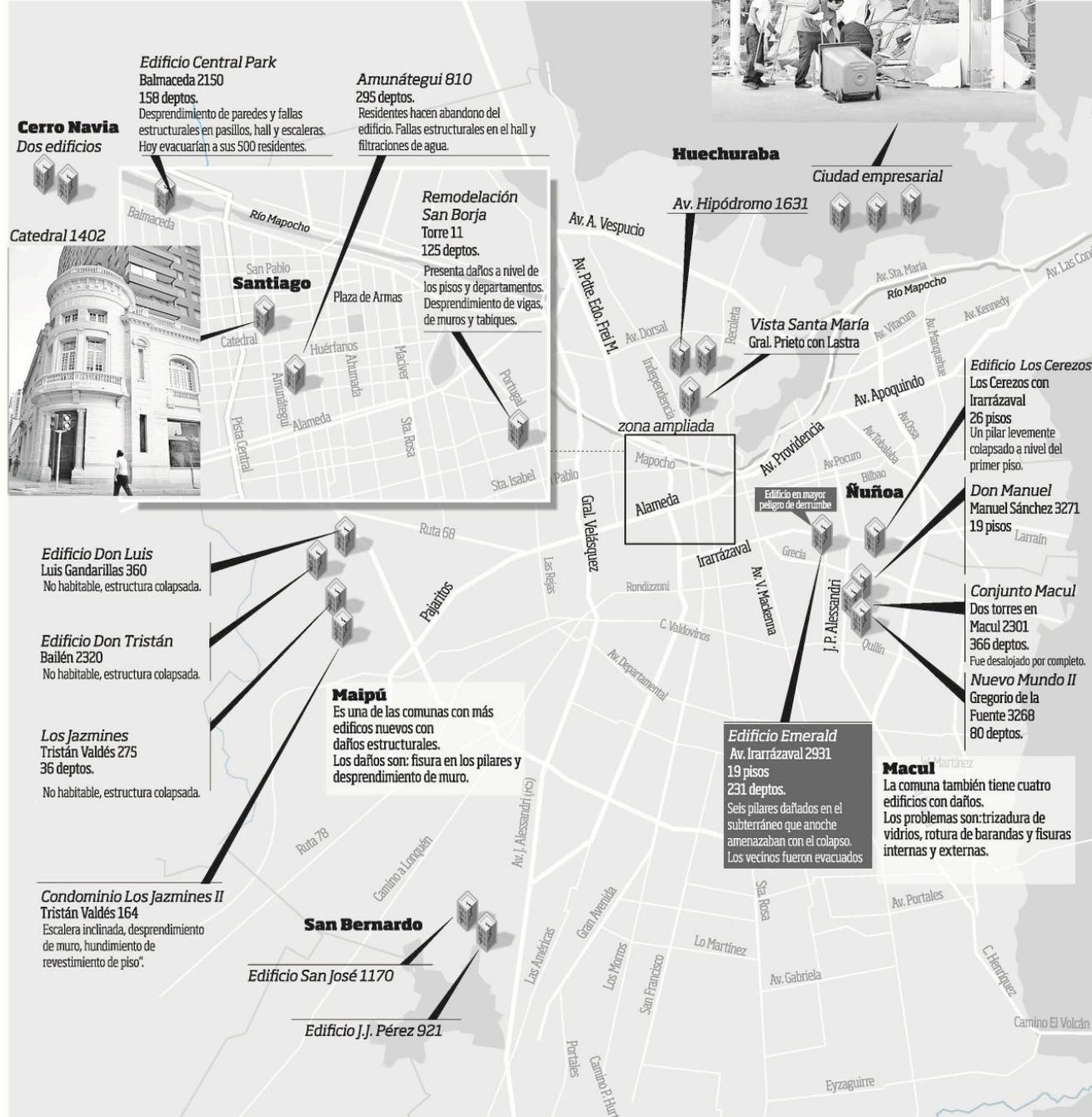
*Valparaíso,
UNESCO Heritage City*



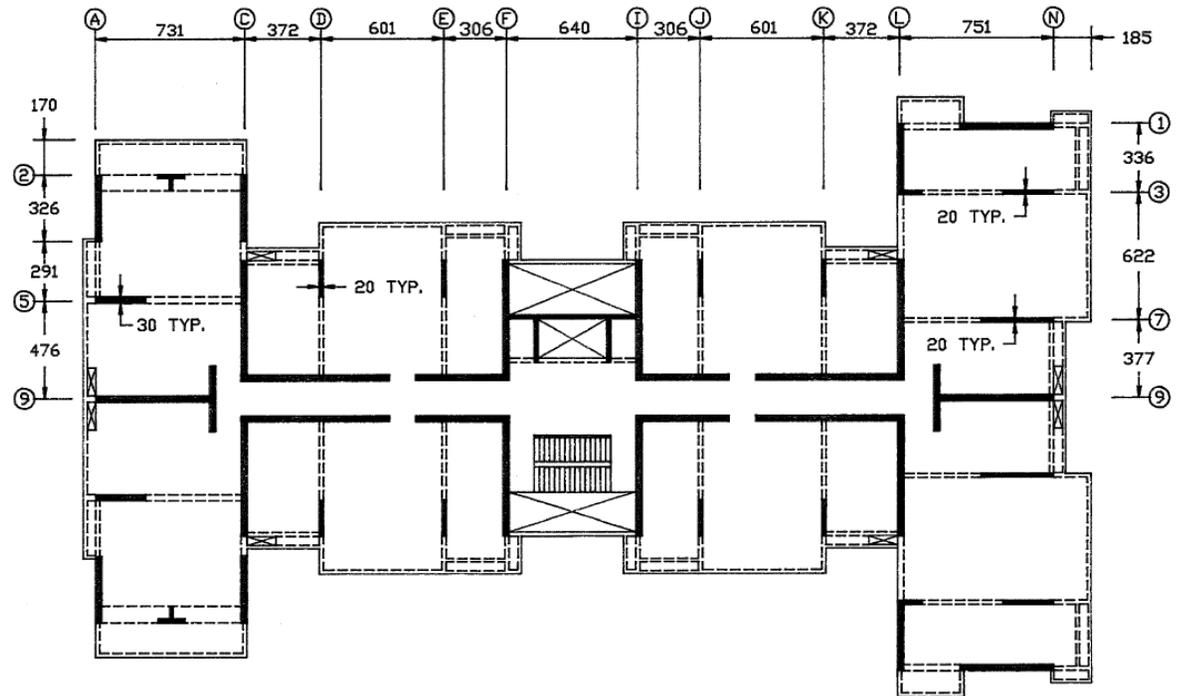
Talca

Catastro por comuna

Tras el fuerte sismo, las municipalidades de la Región Metropolitana han iniciado un catastro de sus construcciones para determinar los daños. Hasta el momento, más de 23 presentan daños severos.

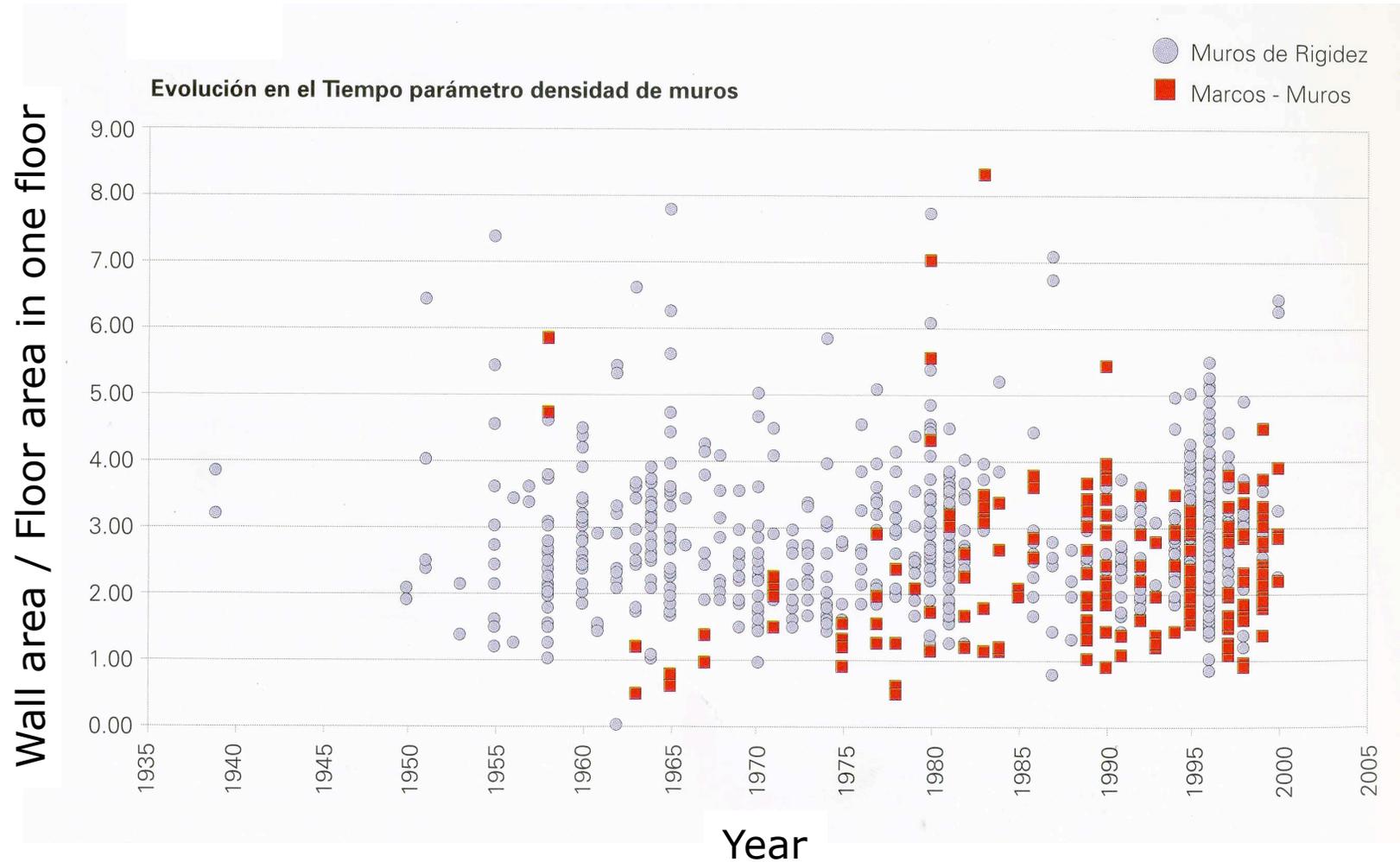


Festival Viña del Mar, 14 Stories, 1978

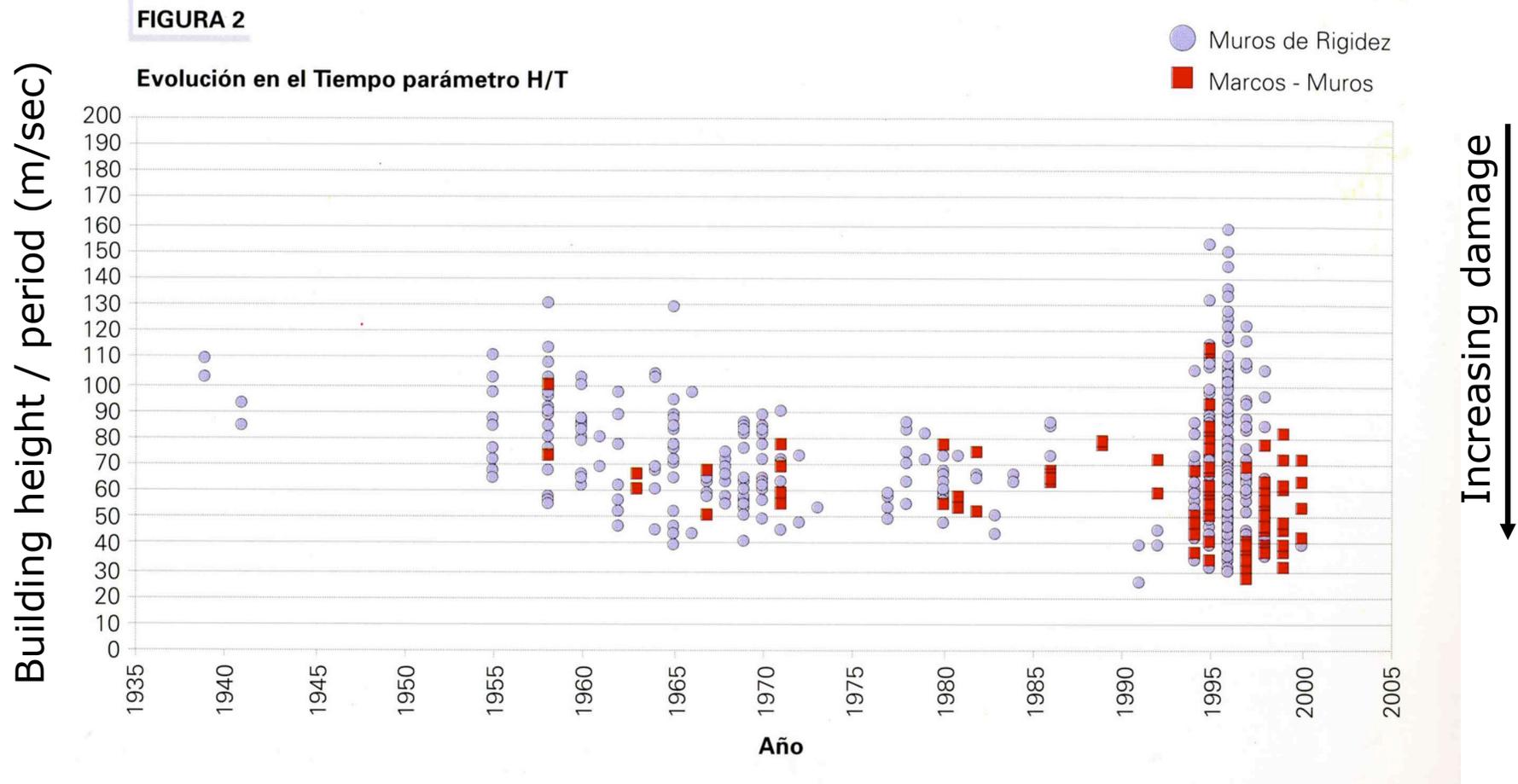


FESTIVAL
FIRST FLOOR

Ratio of wall to floor area



Increasing building flexibility



Building data after Guendelman, et al., 1997.
Damage rating after Moroni, EERI World Housing Encyclopedia

Chile Building Code, NCh433 (1996)

5.1.1 This standard ... aims to achieve structures that:

- a) resist moderate intensity seismic actions without damages;
- b) limit damage to non-structural elements during earthquakes of regular intensity;
- c) prevent collapse during earthquakes of exceptionally severe intensity, even though they show some damage.

...

In particular, the provisions for reinforced concrete wall buildings are based on their satisfactory behavior during the earthquake of March, 1985.

Chile Building Code, NCh433 (1996)

- **6.2.3.1** The seismic coefficient C , is obtained from the expression:

$$C = \frac{2.75A_o}{gR} \left(\frac{T'}{T^*} \right)^n$$

- There are no specific provisions or prohibitions for vertical irregularities.
- **B.2.2** When designing reinforced concrete walls it is not necessary to meet the provisions of paragraphs 21.6.6.1 through 21.6.6.4 of the ACI 318-95 code.

How did buildings perform?

Considering only buildings between 1985 to 2009

- Buildings that collapsed: 4 (app.)
- Buildings to be demolished: 50 (estimate)
- Number of buildings 3 + story 9.974
- Number of buildings 9 + story 1.939

- Failures 3 + story buildings: 0.5%
- Failures 9 + story buildings: 2.8%

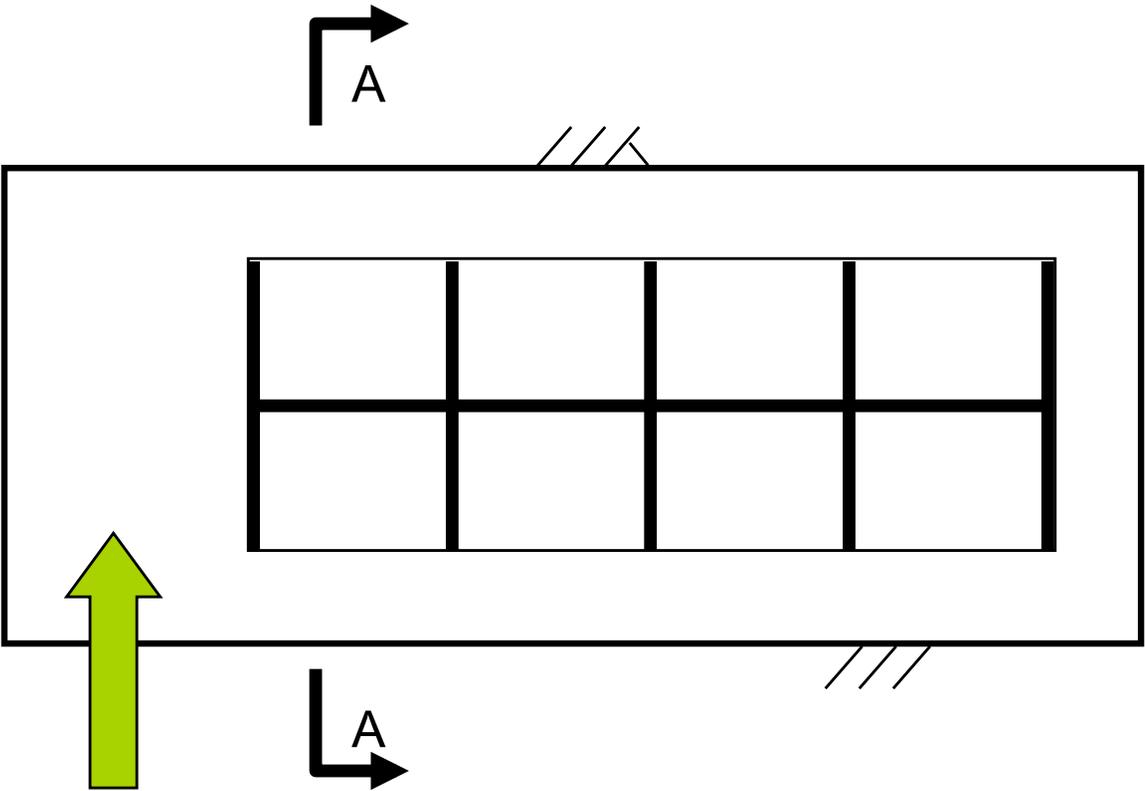


Santiago



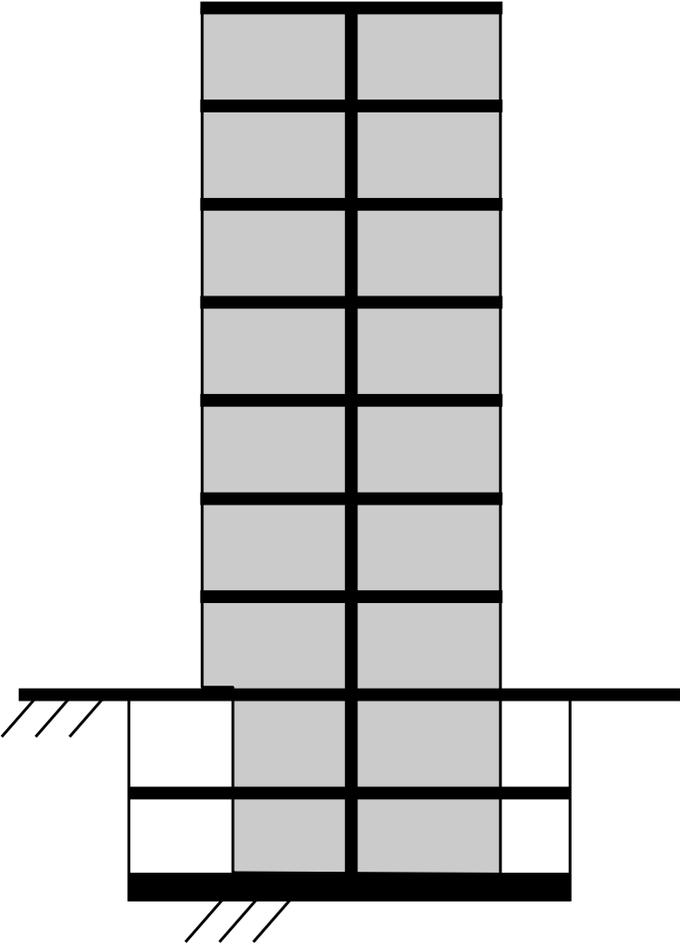
Santiago

Commonly observed configuration



Ramp into
subterranean
parking

Plan



A-A



CAPITOL
MEN SPORTSWEAR

Santiago



Santiago



Santiago



Santiago



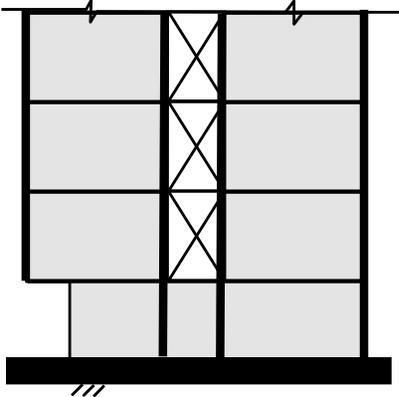
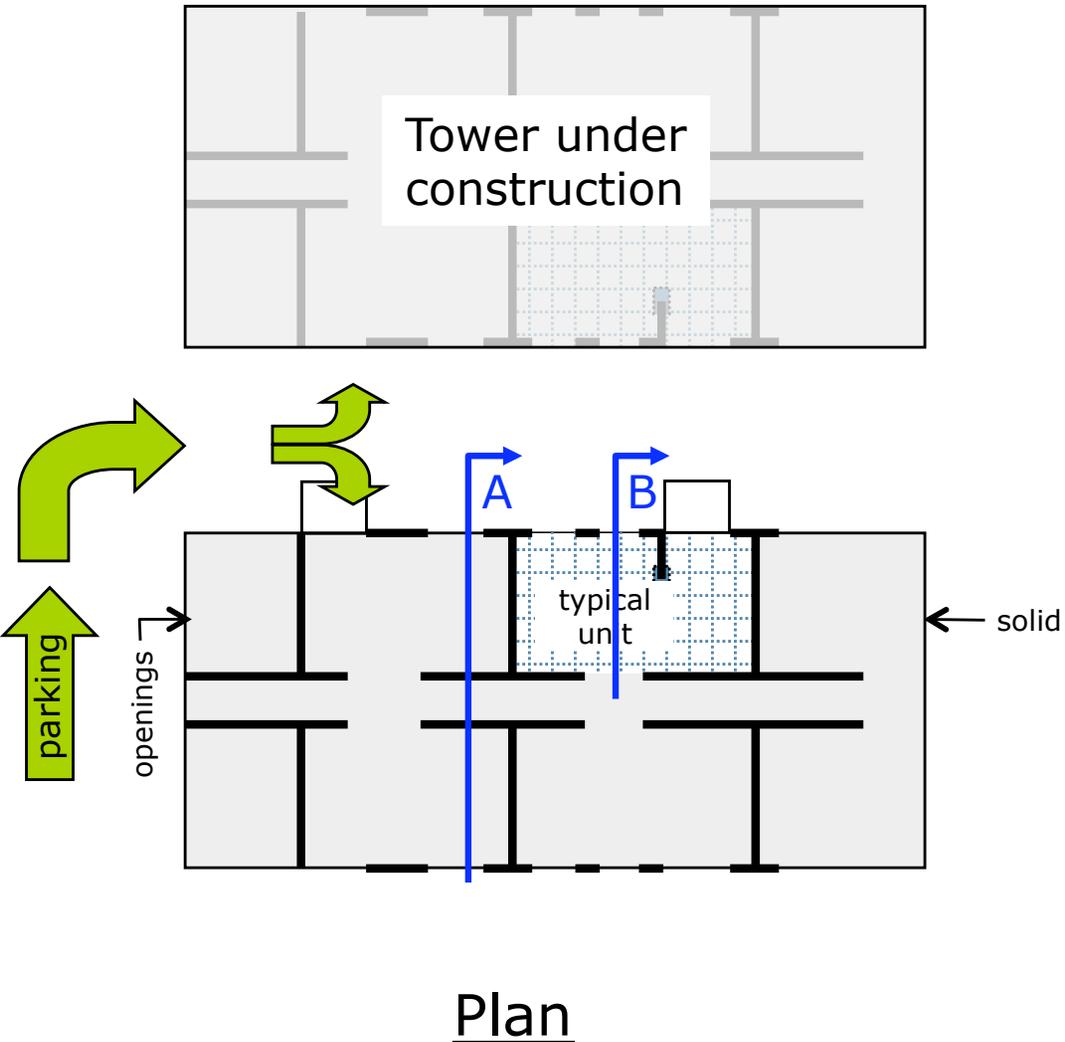
Concepcion (AP Photo)

Torre Alto Rio (Rio Alta) Apartment Building in Concepcion, Chile Before

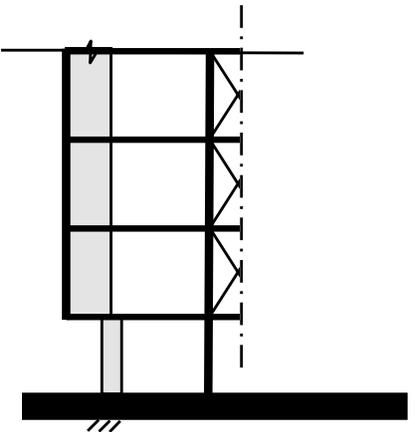




Collapsed building in Concepcion *(postulated conditions)*



Section A



Section B





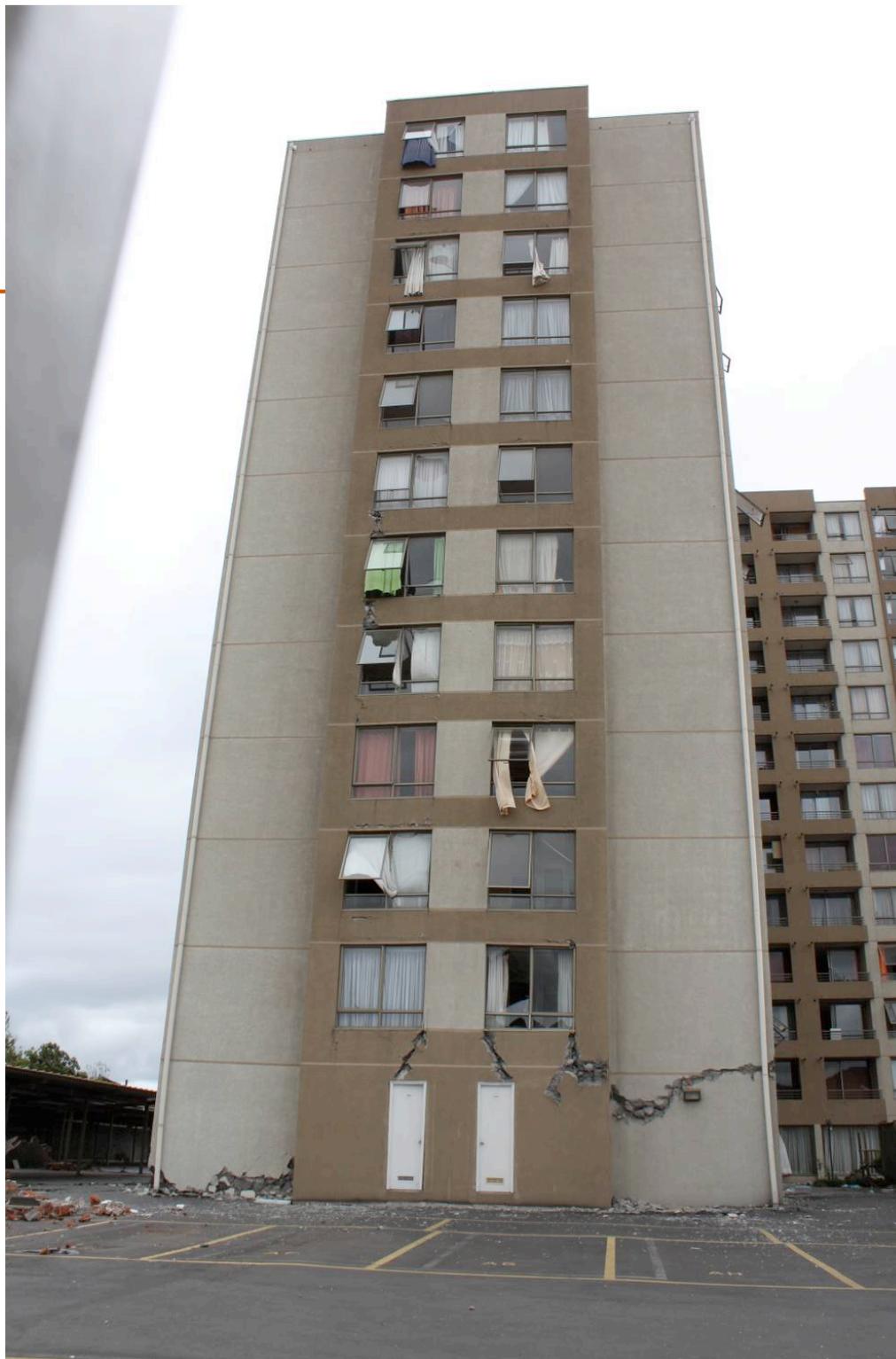
Concepcion



Concepcion



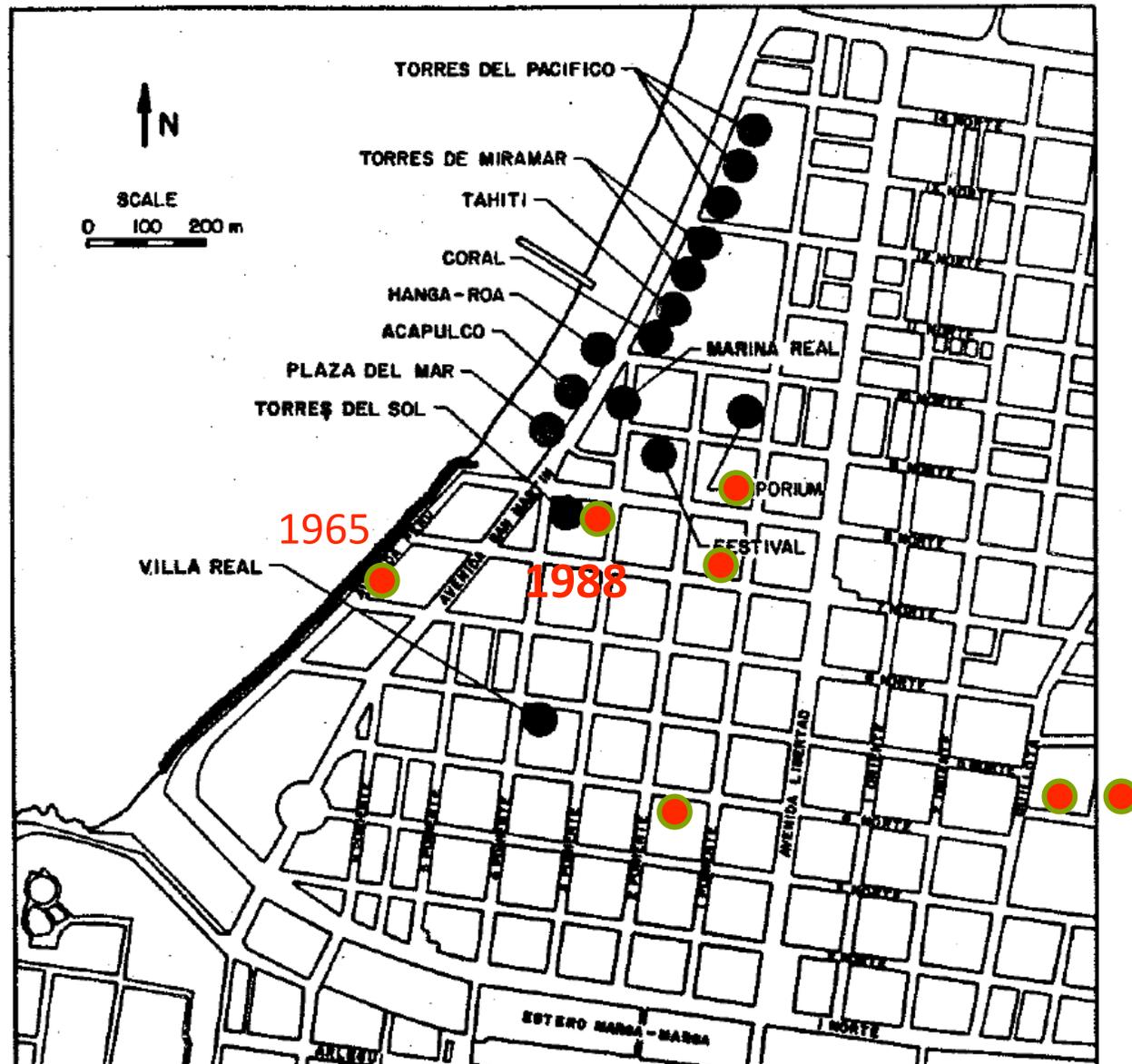
Concepcion



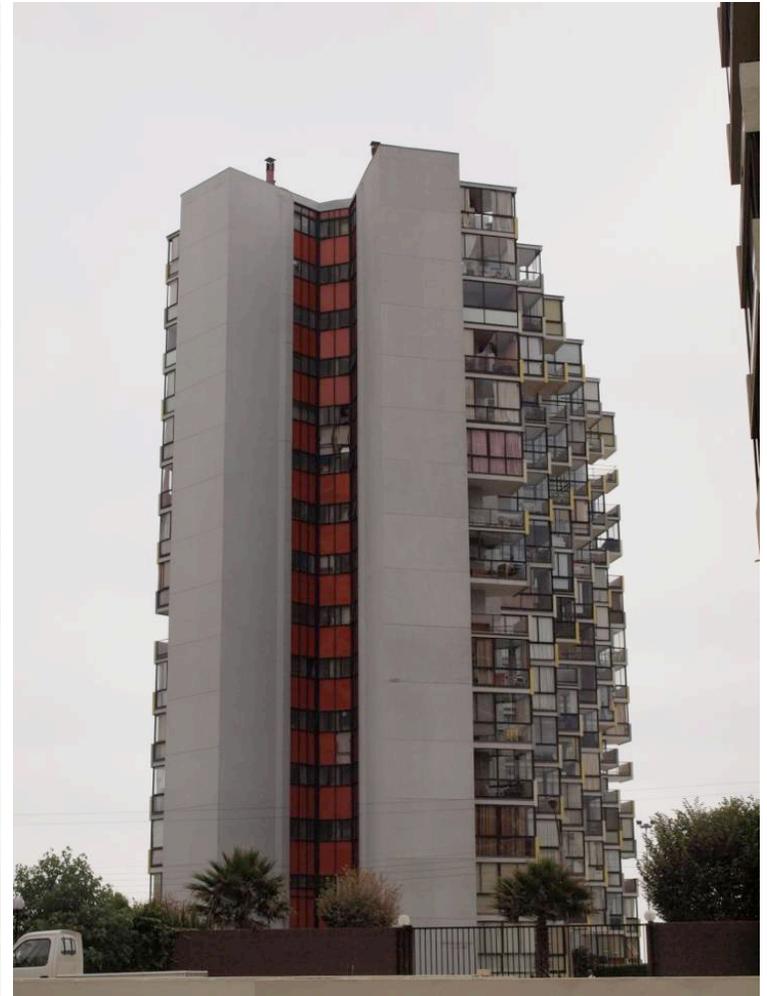




Vina del Mar - 1985

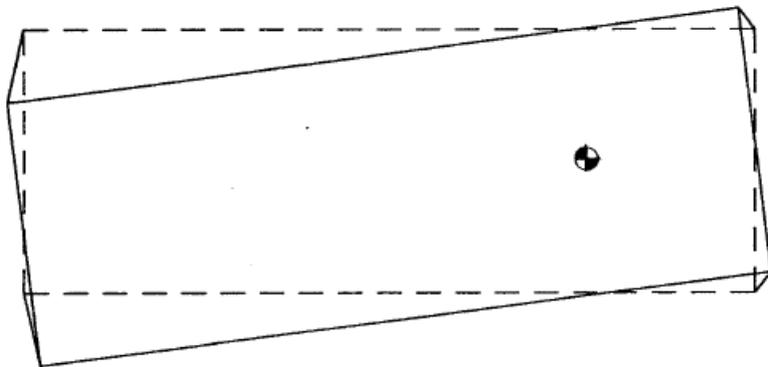
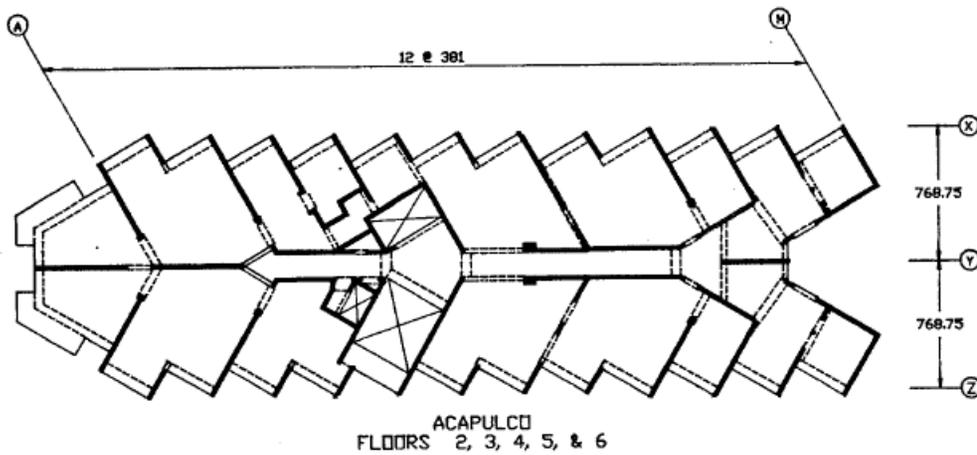


Acapulco – 1985 Damage and retrofit

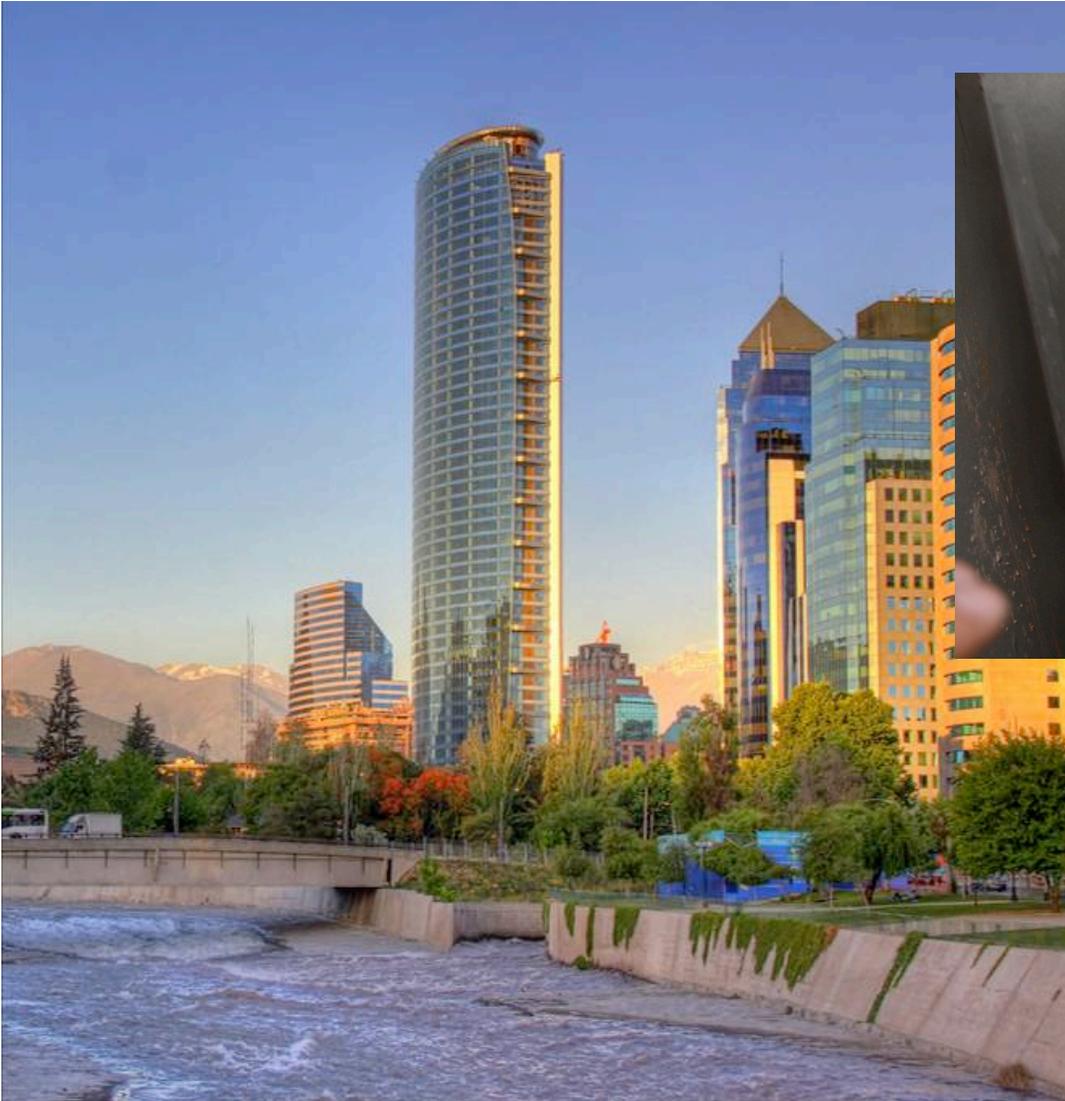


1964 15 Stories – 40m

Acapulco Damage



Highrise - Santiago



Tuned mass damper

Energy Dissipating Device in Titanium Building



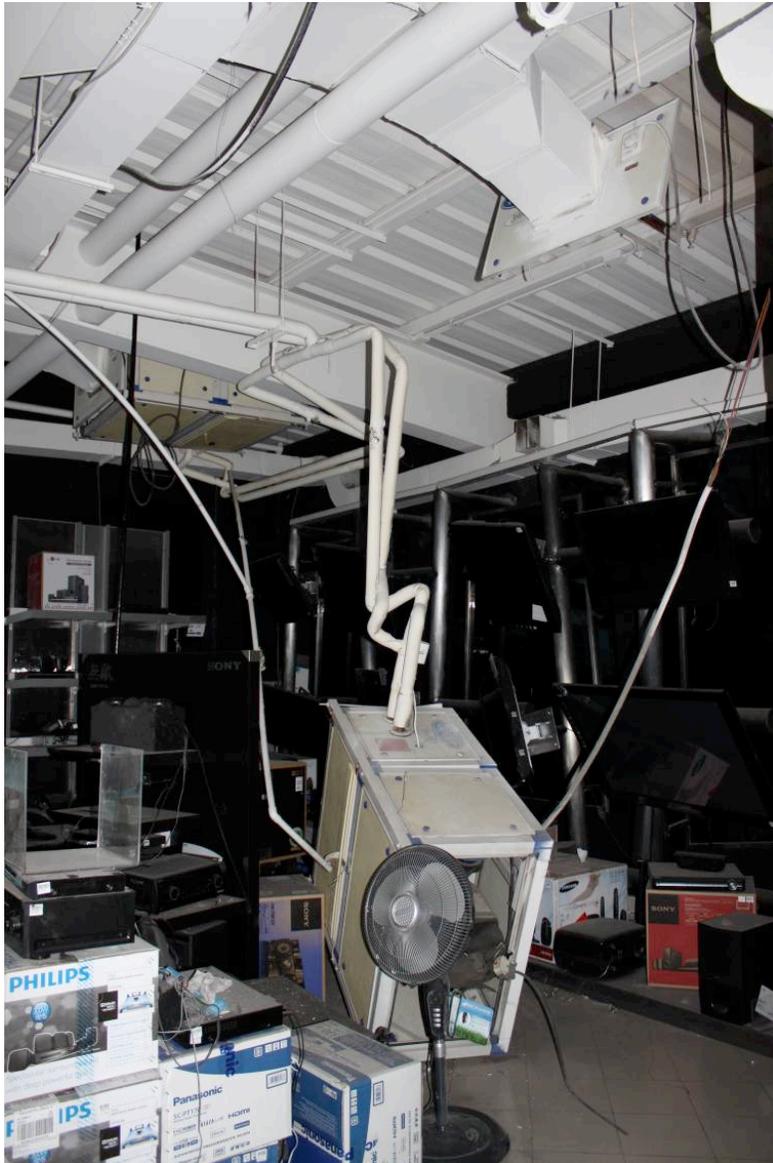
Summary

- Majority of engineered buildings performed well
- Structural damage to attributed to
 - Earthquake demands above code levels
 - Slender walls with high axial stress
 - Absence of confinement reinforcement
 - In some cases, vertical irregularities
 - (Unconfined lap splices in walls)





Nonstructural components



- Similarly to U.S. practice, code requirements for design and anchoring nonstructural components are not always enforced
- With few exceptions, practice for seismic anchoring of nonstructural components considerably lags practice for structural components.
- The state of practice for seismic anchoring of nonstructural components appears to be in worse situation than common practices in the western U.S.
- Many observed failures of anchors, hangers, and bracings similar to those currently used in the U.S.

Tsunami and Tsunami Impacts



Photo by International Federation of Red Cross and Red Crescent Societies



Talca

Social sciences

