

"Research on natural disaster prevention measures attuned to the needs of developing countries"

Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru



2nd Japan-Peru Workshop on Enhancement of Earthquake and
Tsunami Disaster Mitigation Technology,
Chiba University, March 9-11, 2011

Effects of the 27 February 2010 Earthquake in (Industrial Facilities) in Chile

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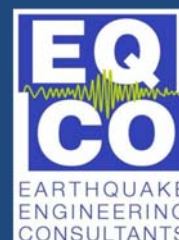


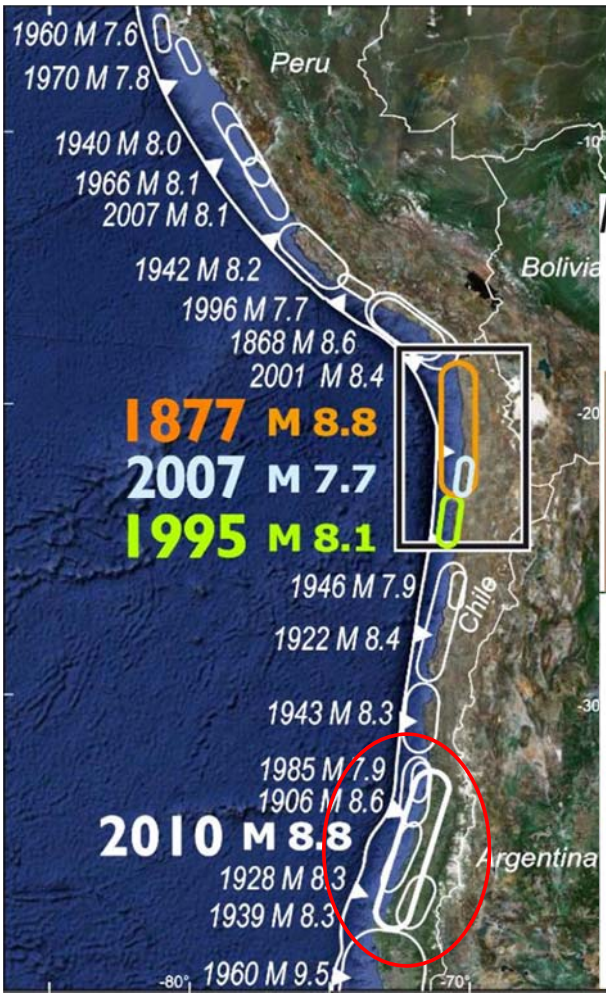
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Contents:

Description of the Event
Damage Observations
 Industrial Facilities
 Infrastructure
 Buildings
Final Remarks

(Codes Revision)

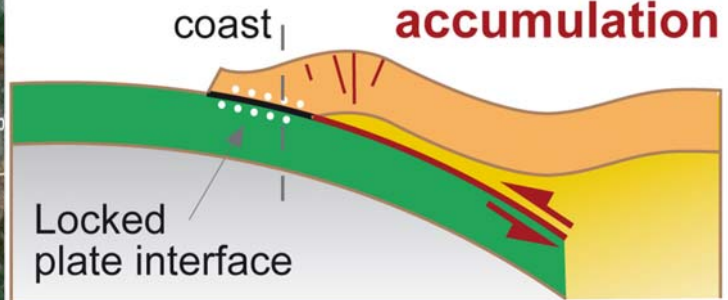




Subduction Mechanism

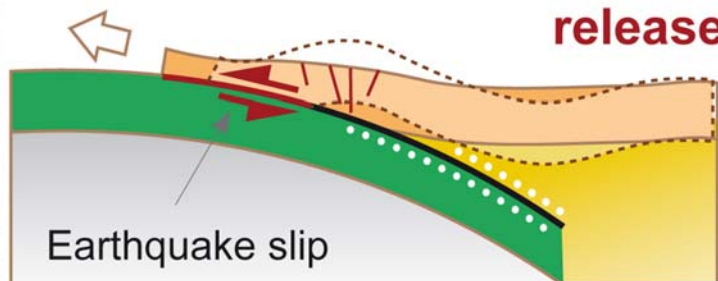
Interseismic (decades)

Strain accumulation



Coseismic (seconds)

Strain release



HIPOCENTRO

Hora UTC:	06:34:12 27/02/2010
<u>Latitud:</u>	-36 12' 28"
<u>Longitud:</u>	-72 57' 46"
Profundidad:	47.4 km
<u>Magnitud:</u>	8.8 (Mw) GS
Fuente:	<u>Servicio Sismológico (U. de Chile)</u>

REFERENCIA GEOGRAFICA: 63 km al SO de Cauquenes

Intensidades Teóricas Simuladas

Intensidades (Escala de Mercalli)

Fuente: ONEMI Y DIREMER

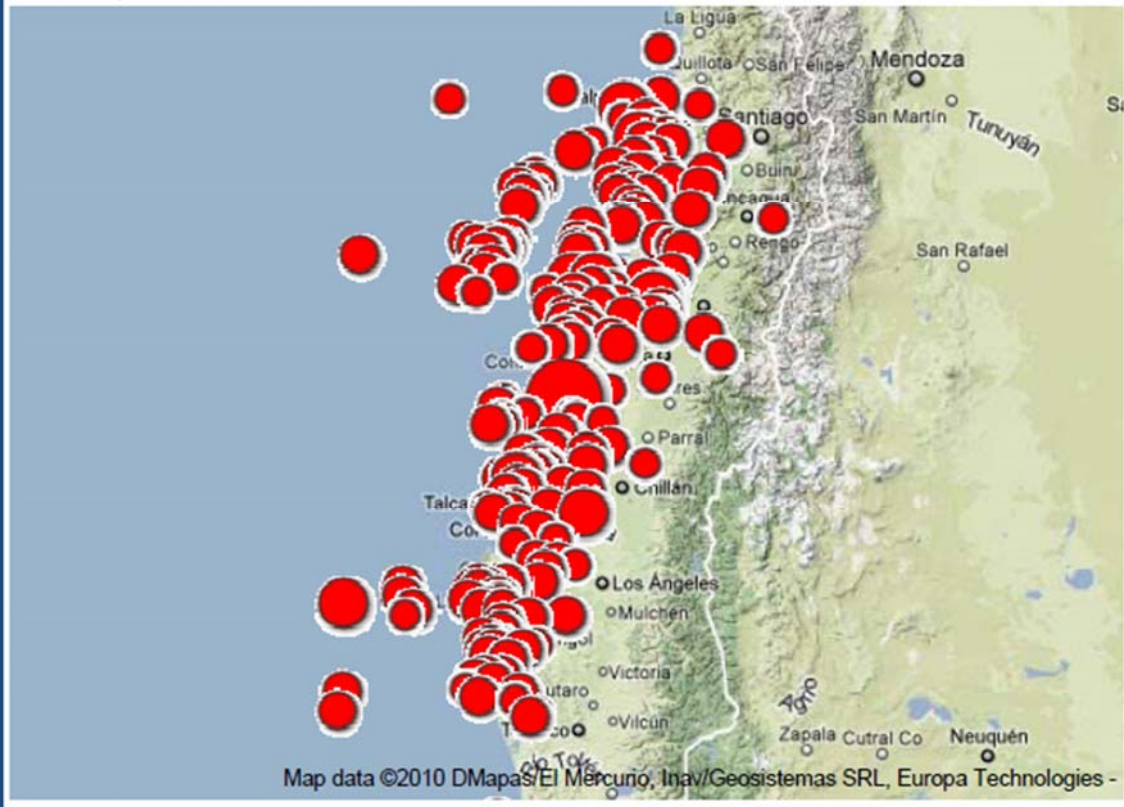
Concepcion	IX	Valdivia	VI	Copiapo	III
Temuco	VIII	Valparaiso	VI	Antofagasta	II
Talca	VIII	Puerto Montt	V	Calama	II
Rancagua	VIII	Vicuna	IV		
Santiago	VIII	La Serena	III		



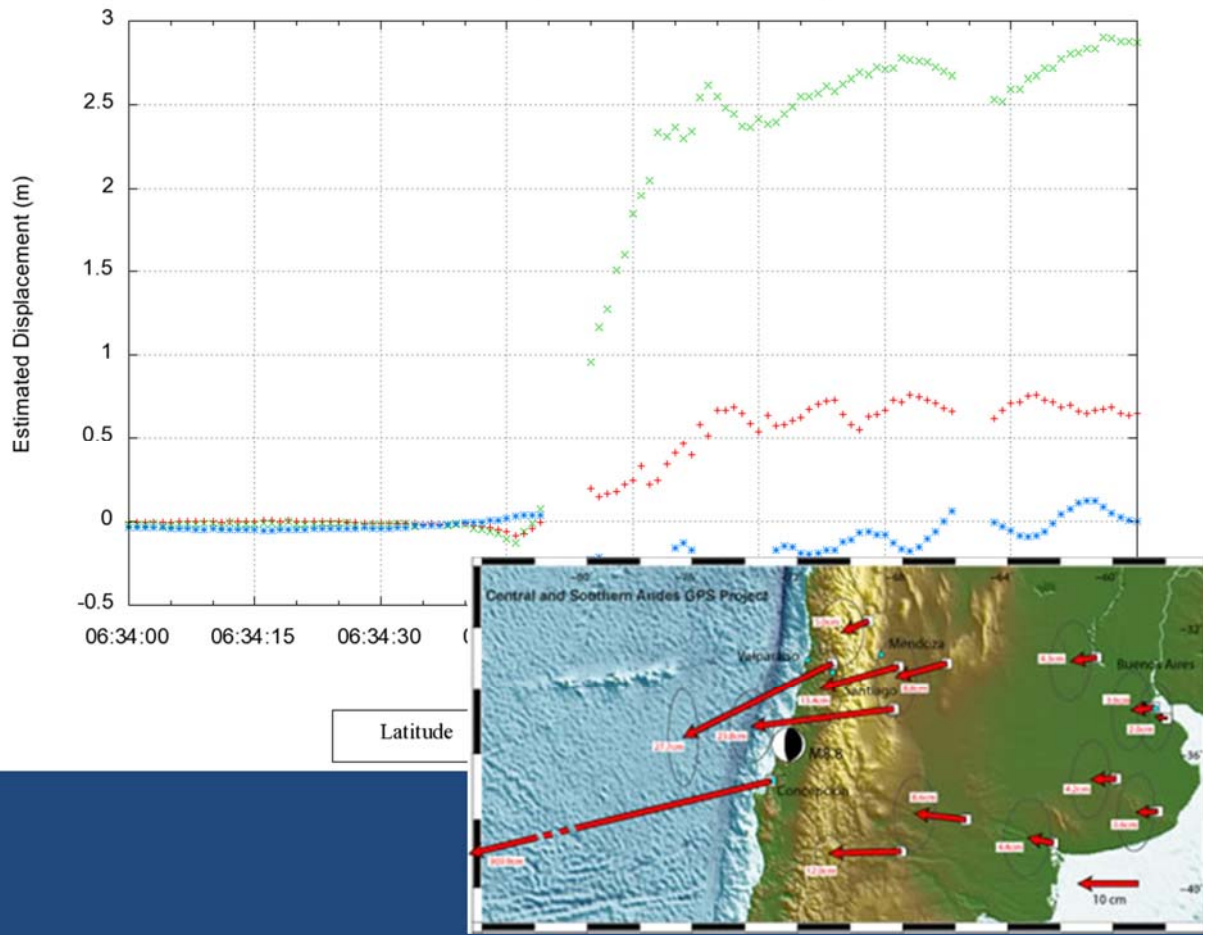
Source: <http://ssn.dgf.uchile.cl/>

Aftershock Map - Mainshock and 209 Aftershocks

Last Updated: 05 March 2010, 15:34:22 UTC

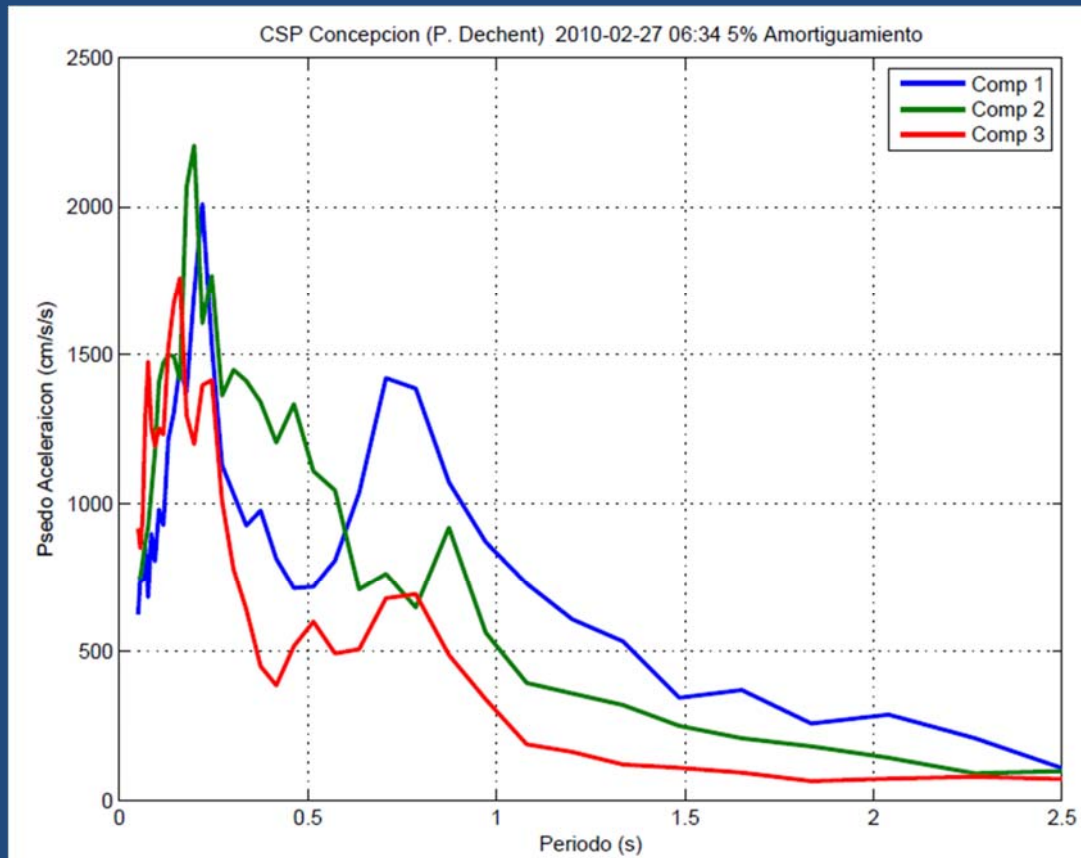
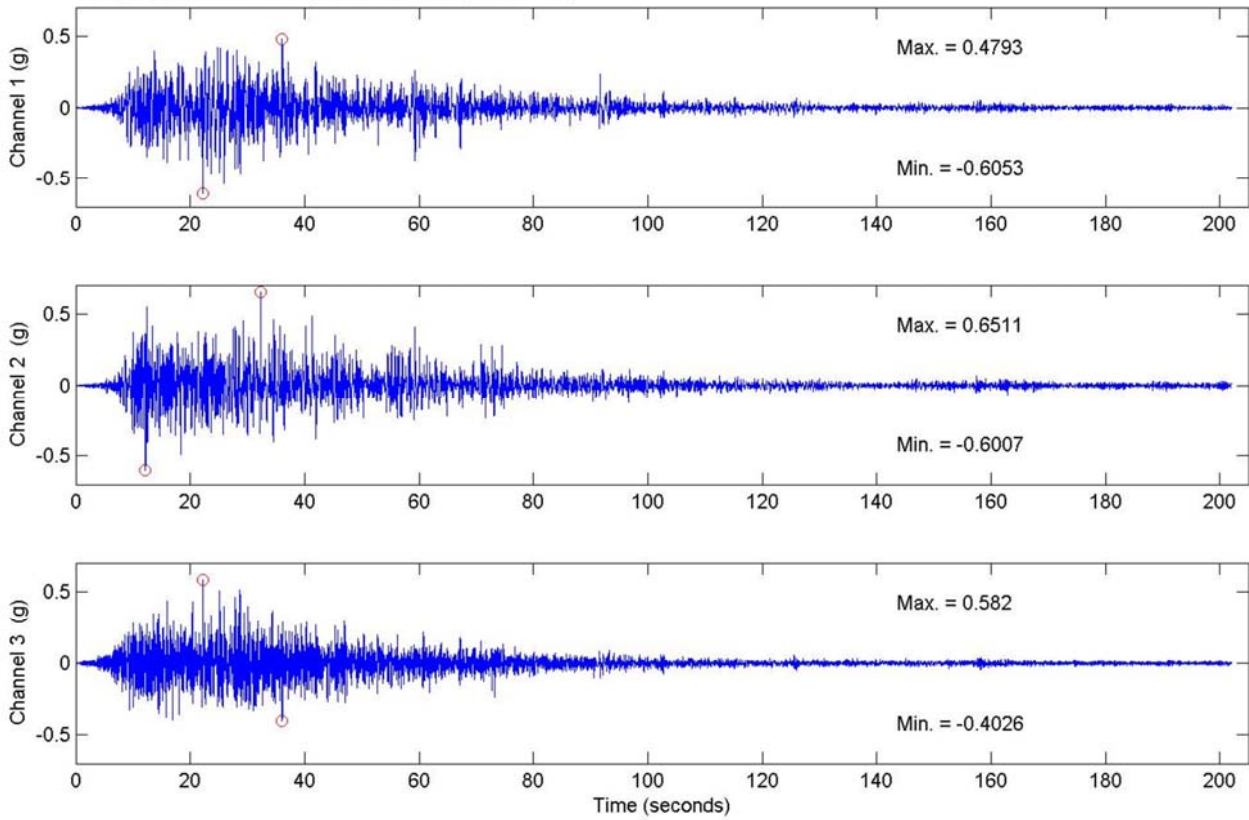


Station CONZ, 2010/02/27 - Chile Earthquake



Acceleration Records (few released)

UNCORRECTED ACCELERATION (TYPE OF INSTRUMENT : K2 / QDR)
Colegio San Pedro Concepcion Main Event (P. Dechent)



Damage Observation

- Industrial Facilities



Transformadores de Corriente y
Medición
Current and Measuring
Transformers

Sub-estación Eléctrica, cercana a
Quillota, Aislador inclinado,

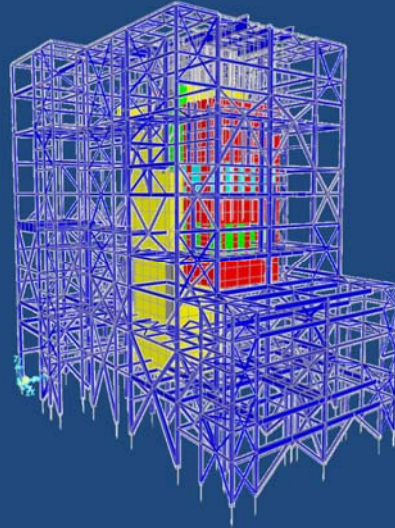
Electrical Substation, near Quillota,
inclined Isolator





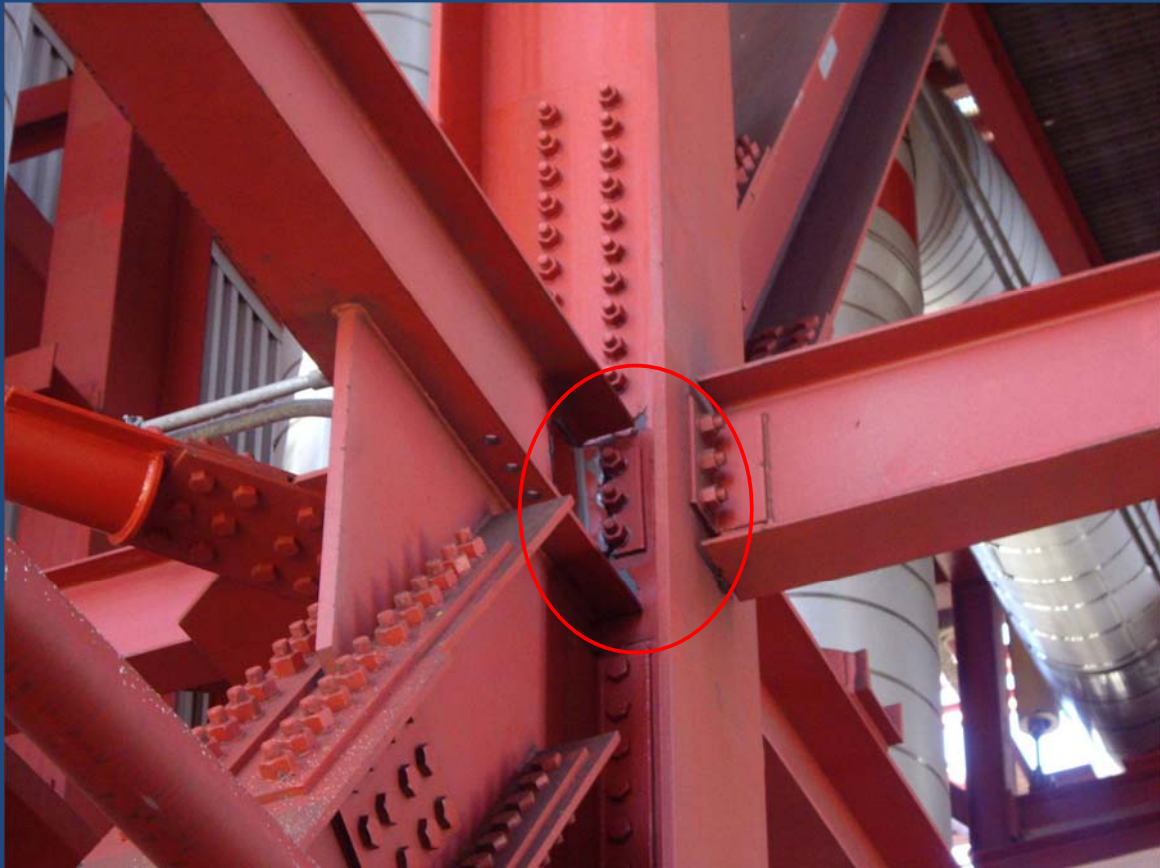
Transformador Principal, Central Termo-eléctrica, cercano a Codegua.
Main Transformer, Diesel Fired Power Station , near Codegua

- Steel Support Structure of Coal Fired Boiler, SAP2000 Model
- 15,093 mass degrees of freedom
- Total weight: 10,290 tonf



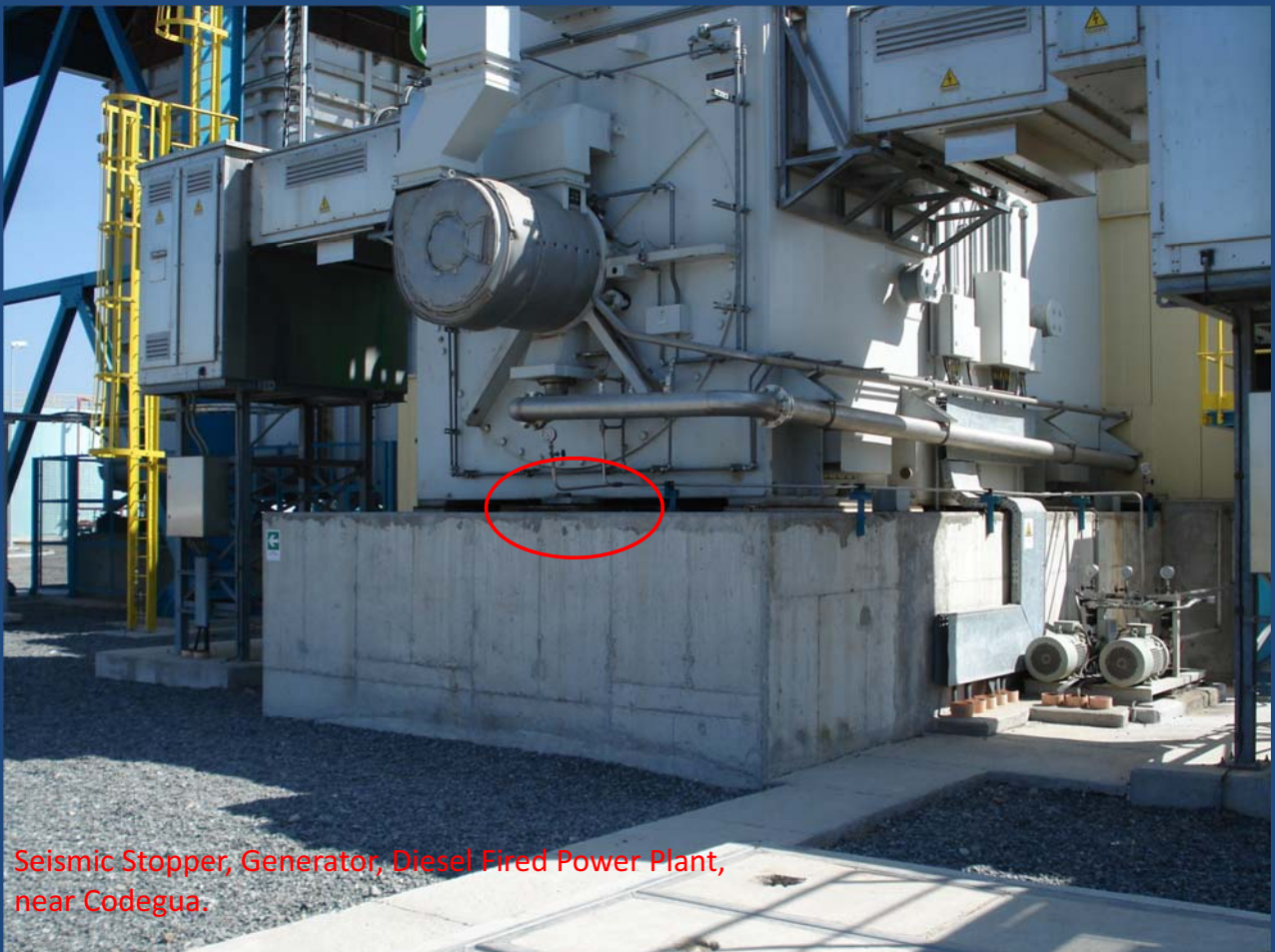
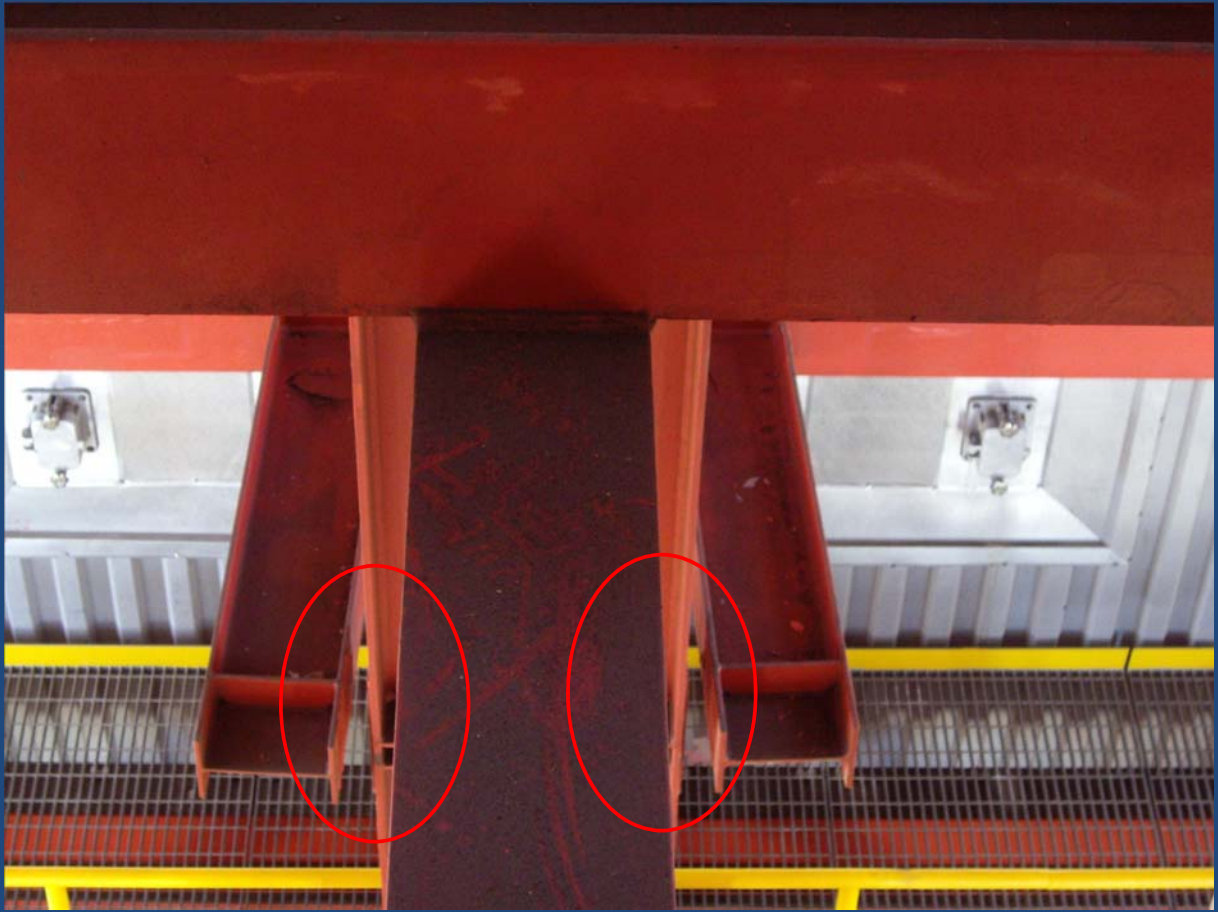
2,264 tonf

8,026 tonf



Estructura de Soporte Caldera de Vapor, Central Termo-Eléctrica, cercano a Puchuncavi
Support Structure, Steam Generator Boiler, Coal Fired Power Station, near Puchuncavi





Seismic Stopper, Generator, Diesel Fired Power Plant,
near Codegua.

Seismic Stopper,
Steam Turbine,
Combined Cycle
Power Plant, near
Quillota.



Falla Base Estanques de Acero Inoxidable para Almacenamiento de Vino. Cercano a Curicó.
Failure at Base of Stainless Steel Storage Tanks, Winery near Curicó

Damage to contents , Storage Racks, Winery near Curico



Cepas Apilador de Carbón,
Central Termo-eléctrica, Zona
Coronel (en construcción)

Support Structure for Coal
Tripper, Coal Fired Power
Station, near Coronel
(under Construction)





Correa Apilador de Carbón, Central Termo-eléctrica, Zona Coronel
Conveyor for Coal Tripper, Coal Fired Power Station, near Coronel (under Construction)



Coal Tripper Car, Coal Fired Power Station,
near Coronel (under Construction)

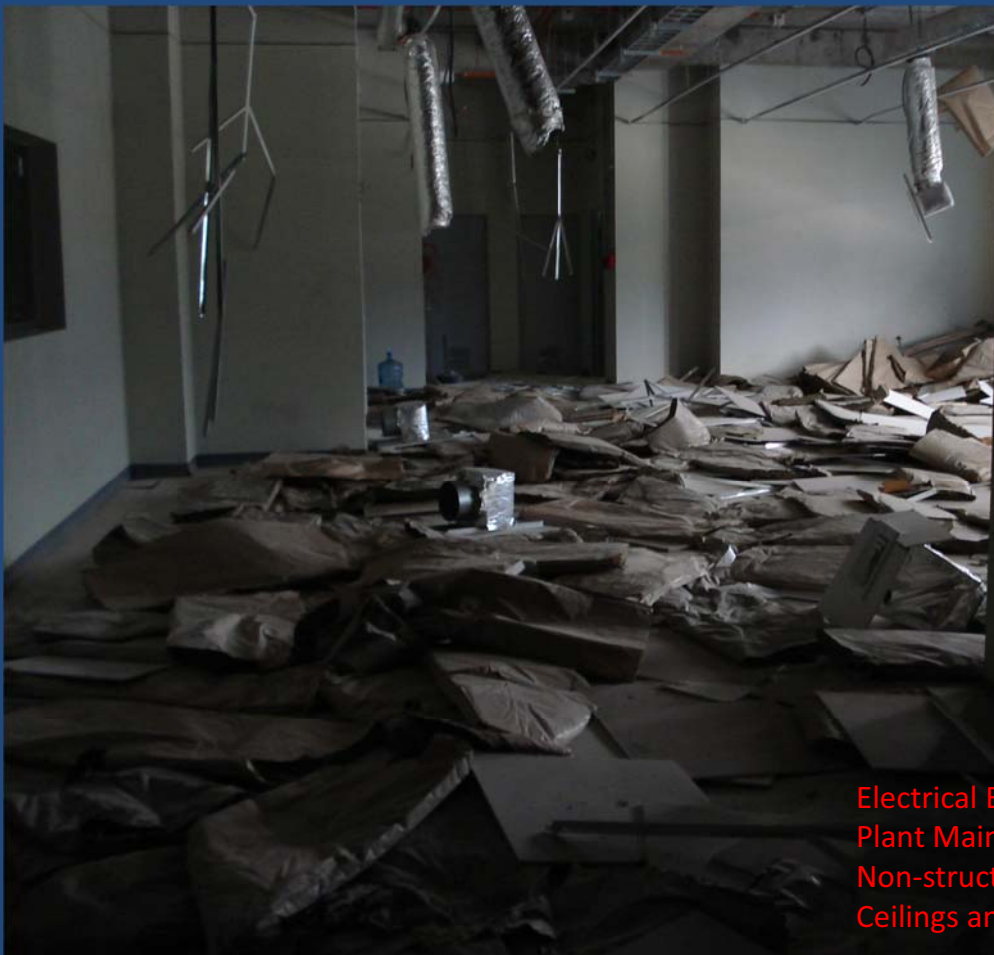


Coal Tripper Car, Coal Fired Power Station near Coronel. Failure at Moment Connections Details

(under Construction)



Carro Apilador de Carbón, Central Termo-eléctrica, Zona Coronel; Falla conexión de momento. Detalles



Electrical Building – Power Plant Main Control Room
Non-structural elements
Ceilings and Air conditioning

Wharf for cooling water intake pipe, Power Station at Coronel Port



Estructura de Soporte Caldera Carbón Pulverizado, Central Termo-eléctrica, Zona Coronel

Daños menores debido a montaje parcial de la estructura y los equipos

Steel Support Structure Coal Fired Power Plant Steam Generator Boiler

Minor damage due to incomplete erection of structure and equipment

In Coronel (under Construction)



Silos de carbón, Estructura de Soporte Caldera Carbón Pulverizado, Central Termo-eléctrica, Zona Coronel

Daños debido a montaje parcial de la estructura y los equipos.

Steel Support Structure
Coal Fired Power Plant
Steam Generator Boiler

Minor damage due to incomplete erection of structure and equipment

In Coronel
(under Construction)



Steel Support Structure
Coal Fired Power Plant
Steam Generator Boiler
In Coronel
(under Construction)
Heavy Equipment,
(GGH, approx. 300 ton)
Damage to anchor
bolts, NO seismic
stoppers installed





Column Base, damage to grout, spalling of concrete cover on the top part (no rebars)



Damage to overhead crane girder, non-structural elements

Older Coal Fired Power Plant (before 1970),
Steam Generator Boiler, Damage to Seismic Stoppers (Coronel)





Huachipato, Vista General bajo el Muelle Pilotes Diagonales cortados.,
Wharf near Concepcion, Diagonal piles were sheared off at the top



Huachipato, Bajo el Muelle Pilotes Diagonales cortados, Detalle,
Wharf near Concepcion, Diagonal piles were sheared off at the top



Huachipato, Large crane for Bulk cargo, Failure of columns at base (rails), due to overturning. Temporary diagonal support.

Damage Observation

- Infrastructure
- Buildings

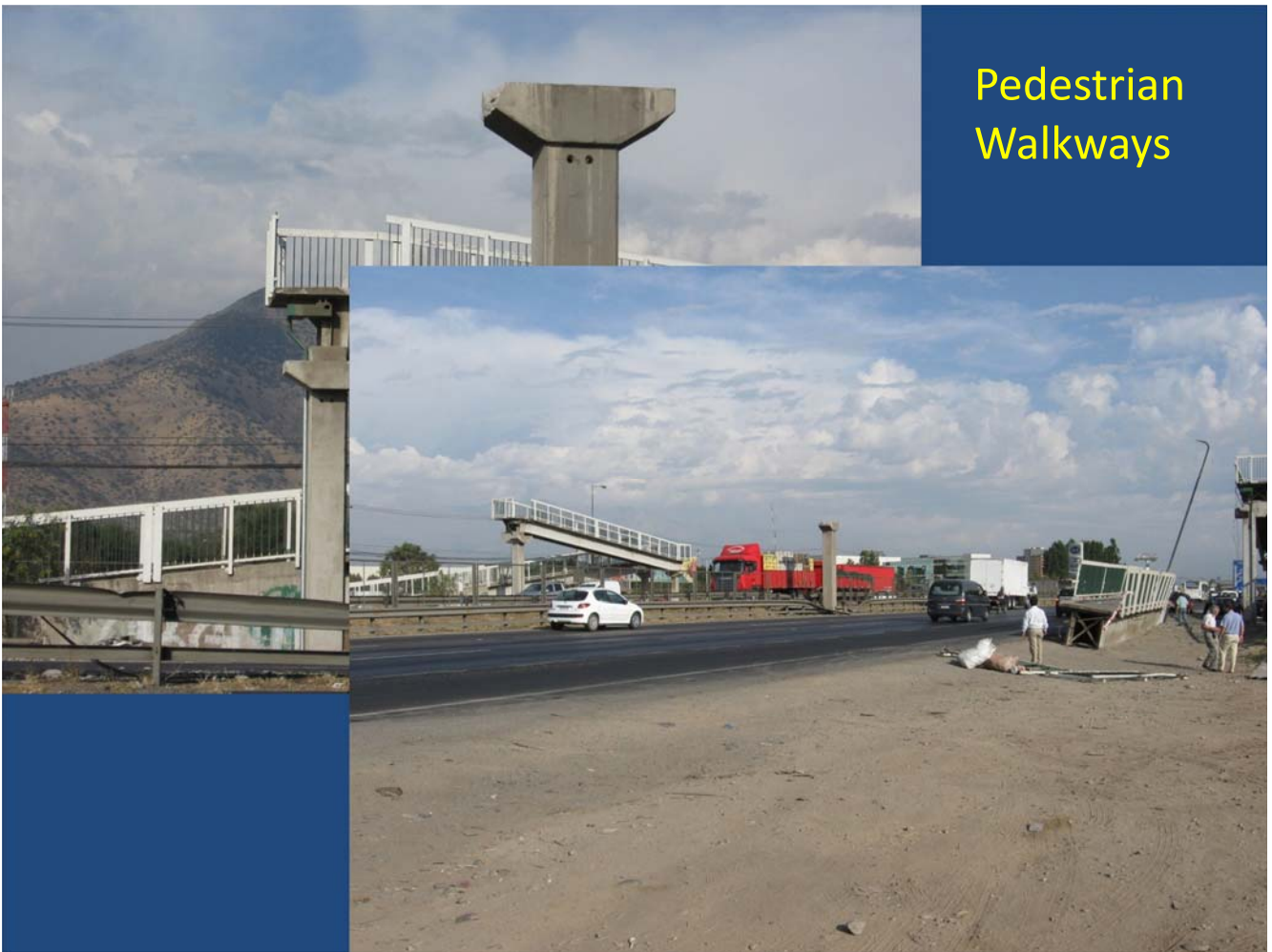
Santiago Airport



Santiago Expressways



Pedestrian Walkways



Ground Failures at Port Facilities



San Antonio



Valparaíso



Coronel : Settlements / Displacements, Sand boils, Piles damage

Embankment Failures along Ruta 5



Possible liquefaction
of thin soil layers
under the main fill
caused lateral
spreading



CIUDAD EMPRESARIAL, Santiago





Viña del Mar, V Region

Compression failure in walls at ground or basement levels



Irregularities (inplan and over the height)



Some general remarks

In general, engineered structures together with adequate standards in construction practices performed well. There are a few exceptions that need to be studied in depth to be able to understand the causes of the observed failures or poor behavior.

There are a few instances where it is apparent that the existing codes have not been able to succeed in providing appropriate behavior; consequently they need to be improved.

The effects of site soil conditions and of irregularities in the building / structure configuration appear as the main cause of problems, more so than the actual very large size of the earthquake.

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Some remarks about codes

Applicable codes are used regularly in the design of engineered structures.

Appropriate quality control both in design and construction practices.

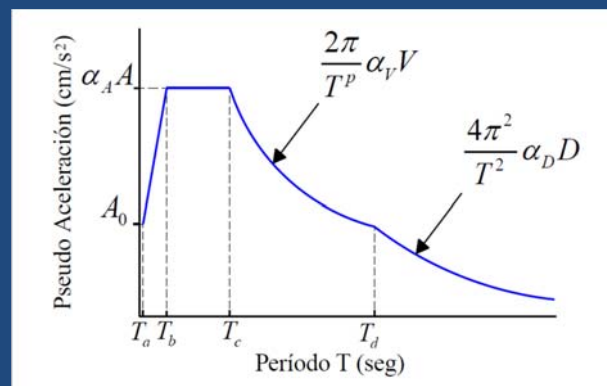
Peer review process has been implemented, as a legal requirement, for several years now (since 2005).

After the earthquake, the level of damage observed, mainly in tall engineered buildings, created the "need" for an "Emergency Revision of the codes."

	Name	Title	Date	Notes
Actions	NCh431	Snow Loading	1977	
	NCh432	Wind Loading	1971	Being revised
	NCh1537	Permanent and Live Loading	1986	To be updated soon
Materials / Design	NCh427	Steel Design	1977	Being revised (AISC)
	NCh430	Reinforced Concrete (Modified ACI 318)	2011	Revised after EQ
	NCh1198	Wood Structures	2006	
	NCh1928	Reinforced Masonry	2003	
	NCh2123	Confined Masonry	2003	
Earthquake	NCh433	Earthquake Design of Buildings	2011	Revised after EQ
	NCh2369	Earthquake Design of Industrial Structures	2003	
	NCh2745	Design of Base Isolated Structures	2003	

Building code revision:

New definition of the design spectrum, and changes to some of the existing additional requirements regarding irregularities and modeling assumptions.



Soil site characterization procedure requirements significantly upgraded. Soft soil sites definition must be based on V₃₀.

In general, for soft soil sites the level of earthquake action increases, most importantly for intermediate period structures (from about 1s and up).

Reinforced Concrete design code revision:

Confinement requirements at structural shear wall ends increased to a level equivalent to ACI 318 requirements.

Several additional requirements for structural walls, mainly related to need for confinement, minimum reinforcement, maximum rebar sizes, maximum amount of edge reinforcement, etc.

There is some controversy on the applicability of these new requirements, probably a new revision will be implemented soon.

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