27 February 2010 M_w 8.8 Maule Earthquake

Discussion on Pre 1985 and Post 1996 Reinforced Concrete Buildings in Viña del Mar

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OUTLINE

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1. INTRODUCTION

In a way, earthquake engineering is a cartoon of other branches of engineering. Earthquake effects on structures systematically bring out the mistakes made in design and construction – even the most minute mistakes"

Emilio Rosenblueth and Nathan Newmark (1971)

Intensities 1985 vs. 2010

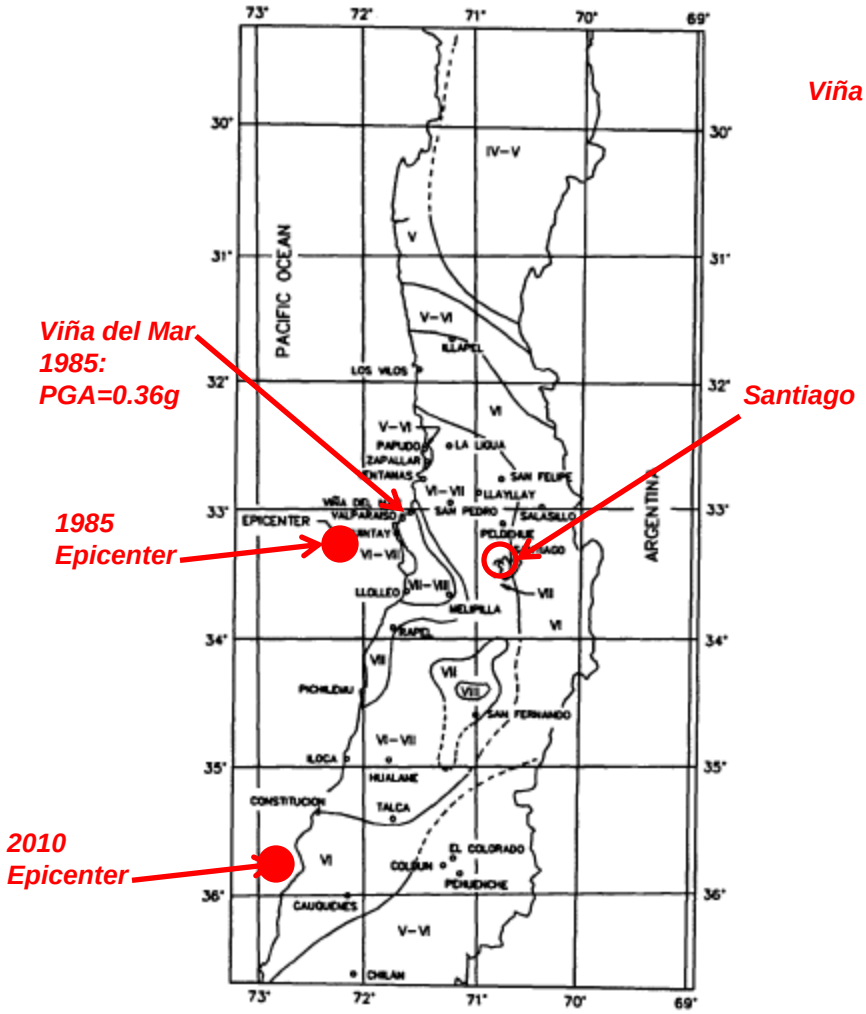
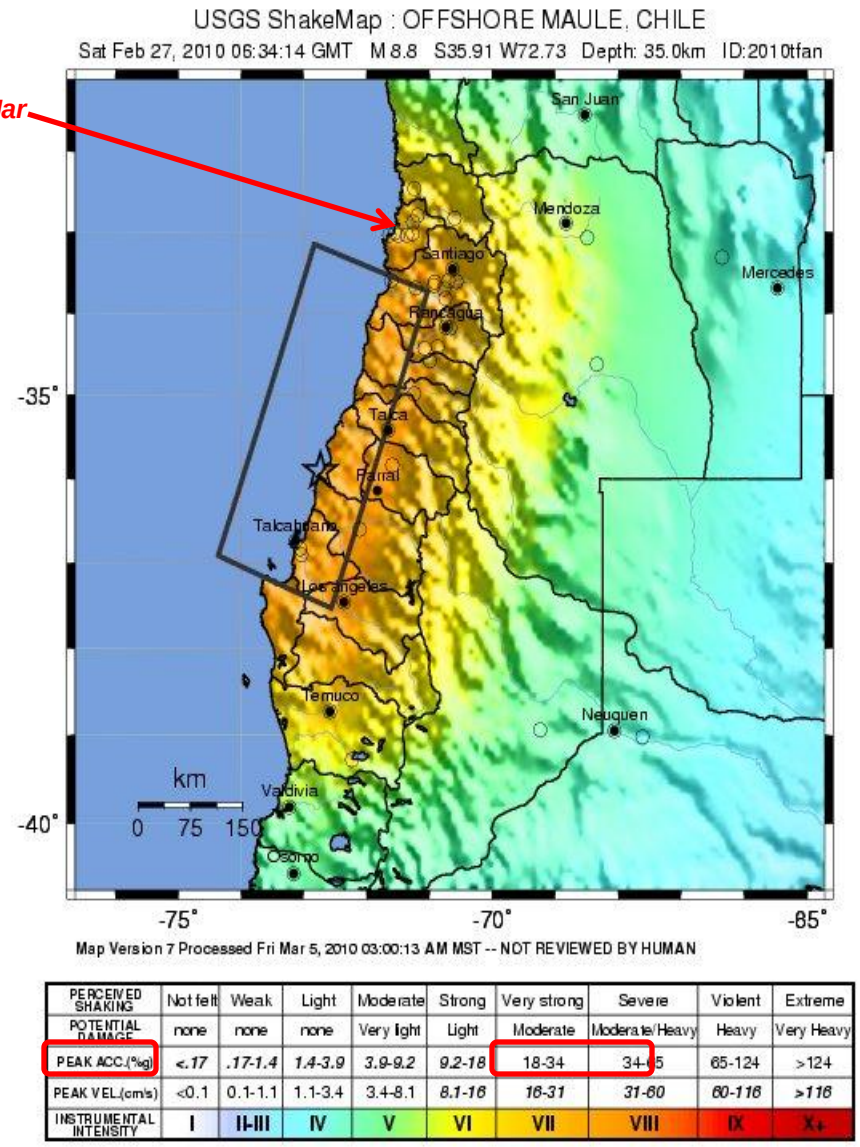
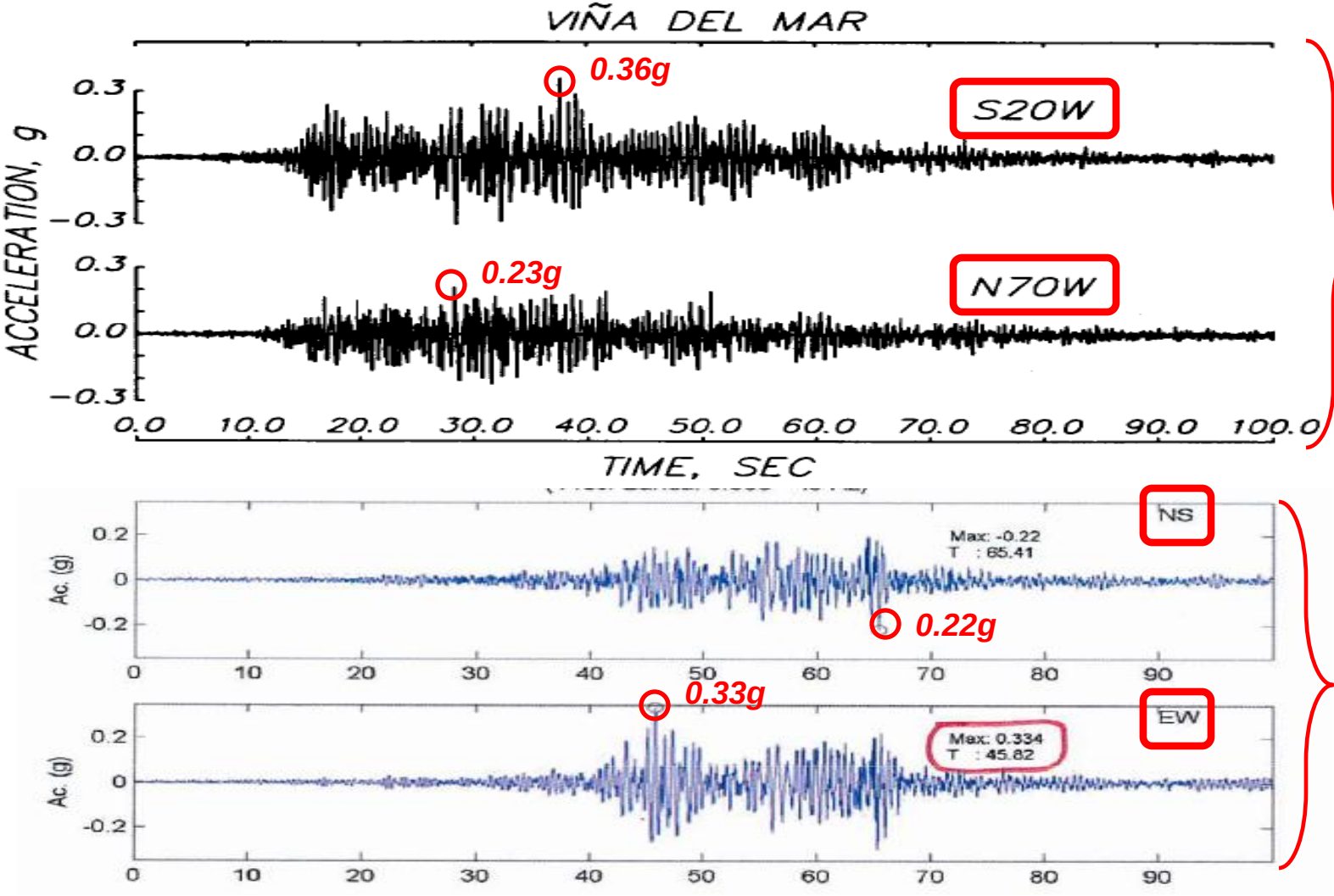


Figure 2 *Epicentral zone of 1985 earthquake in central Chile (after Saragoni et al. 1985).*

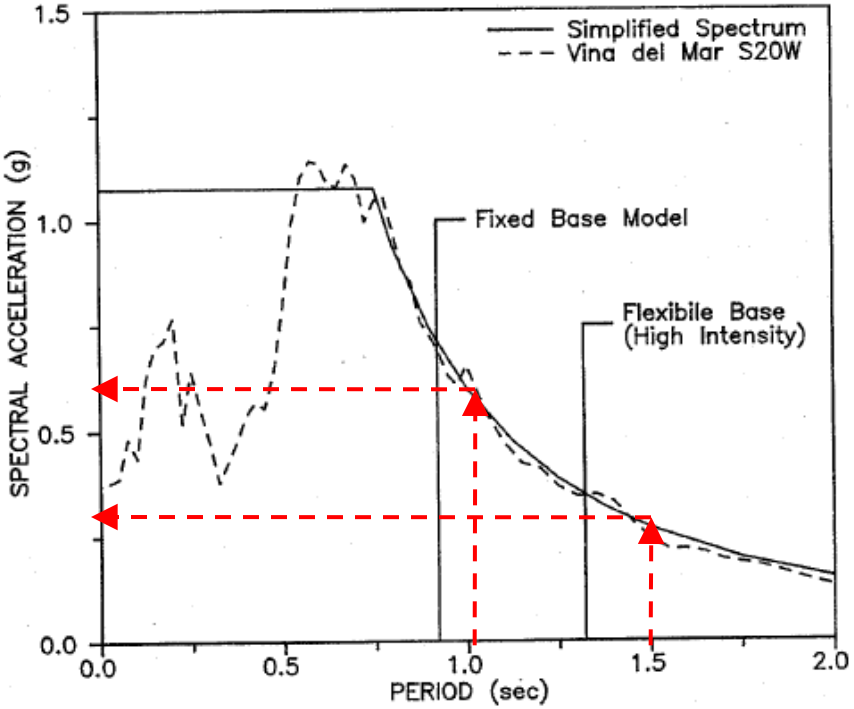


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

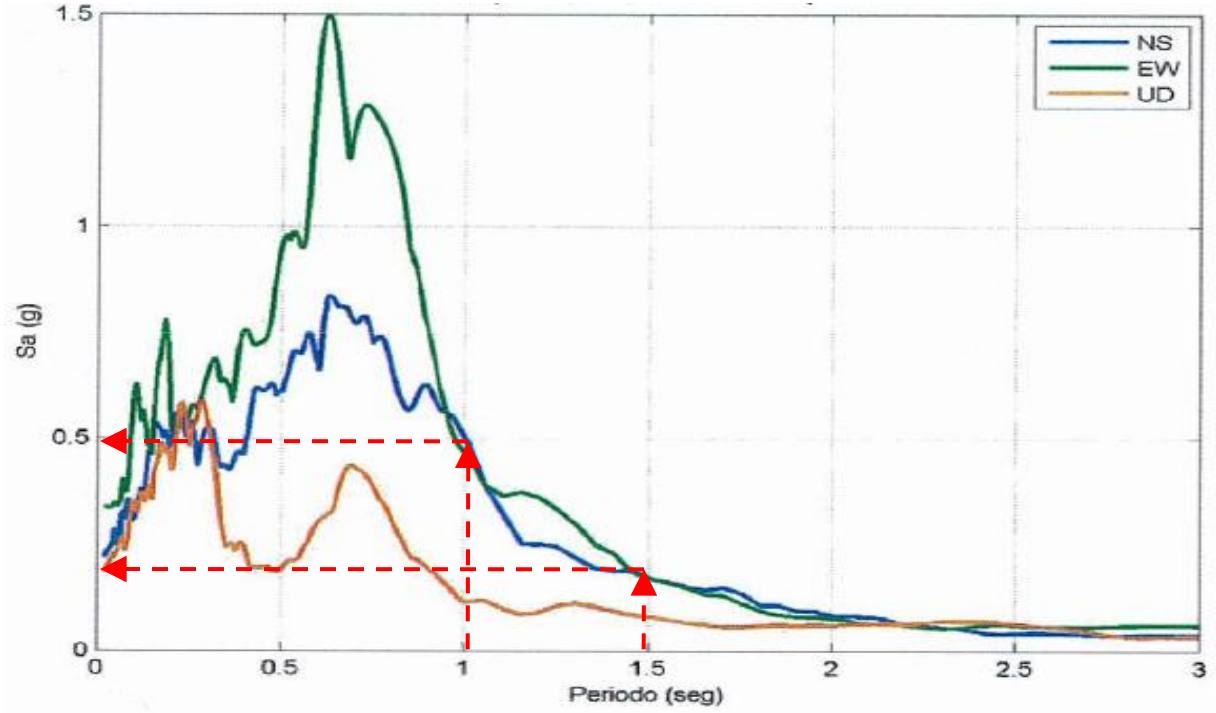
Recorded Ground Motions



Rec tions Spectra

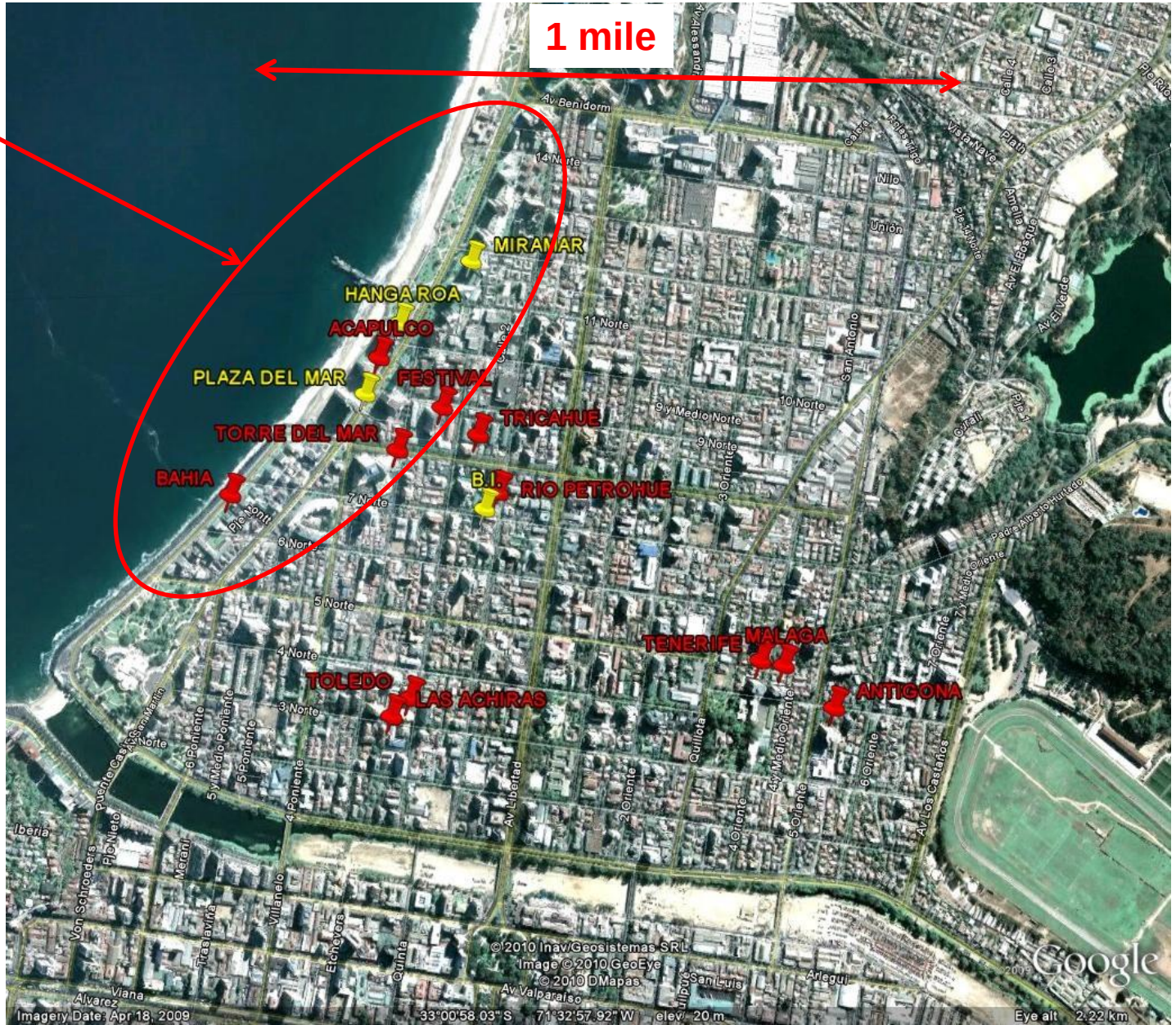


1985

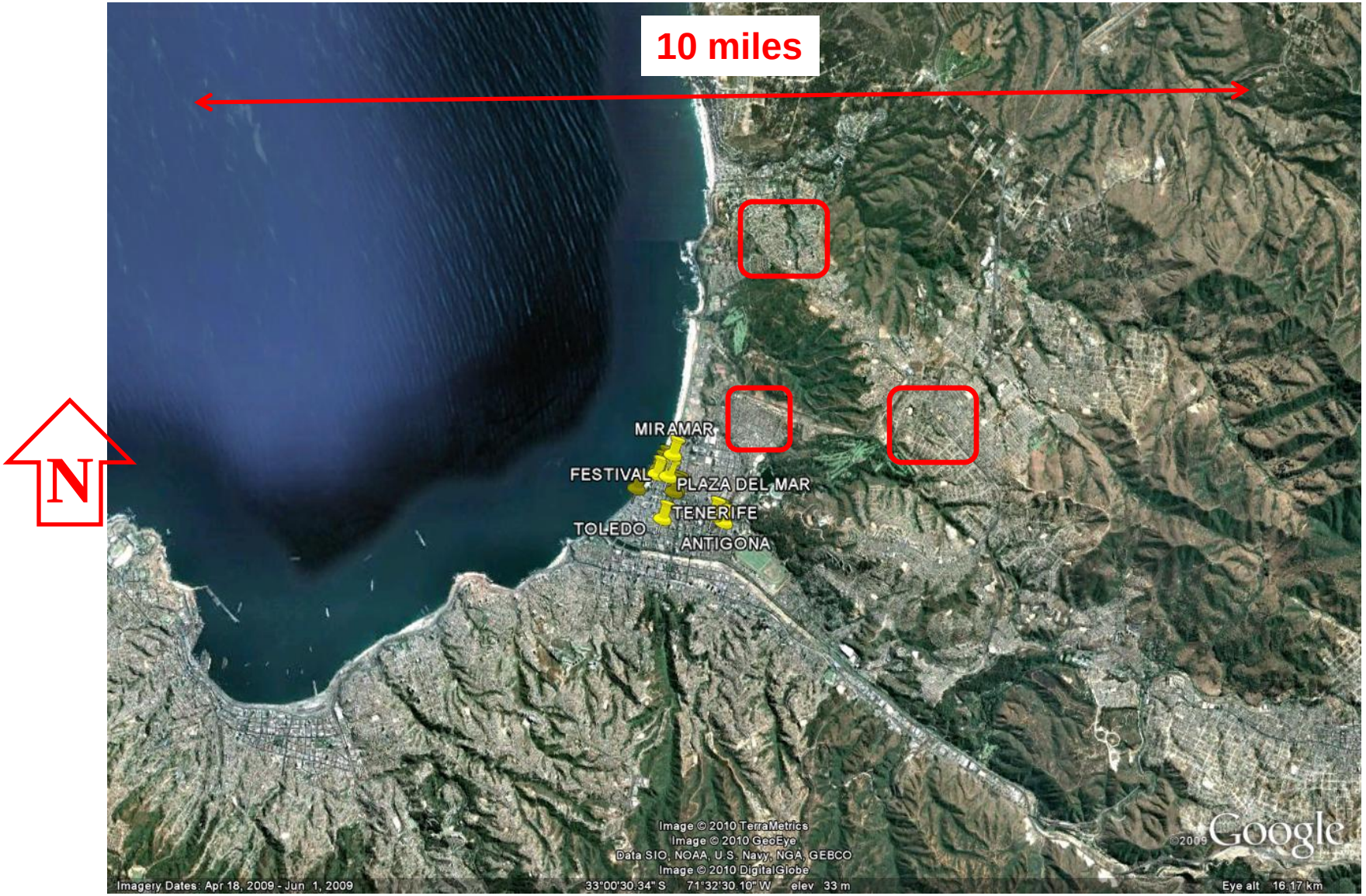


2010

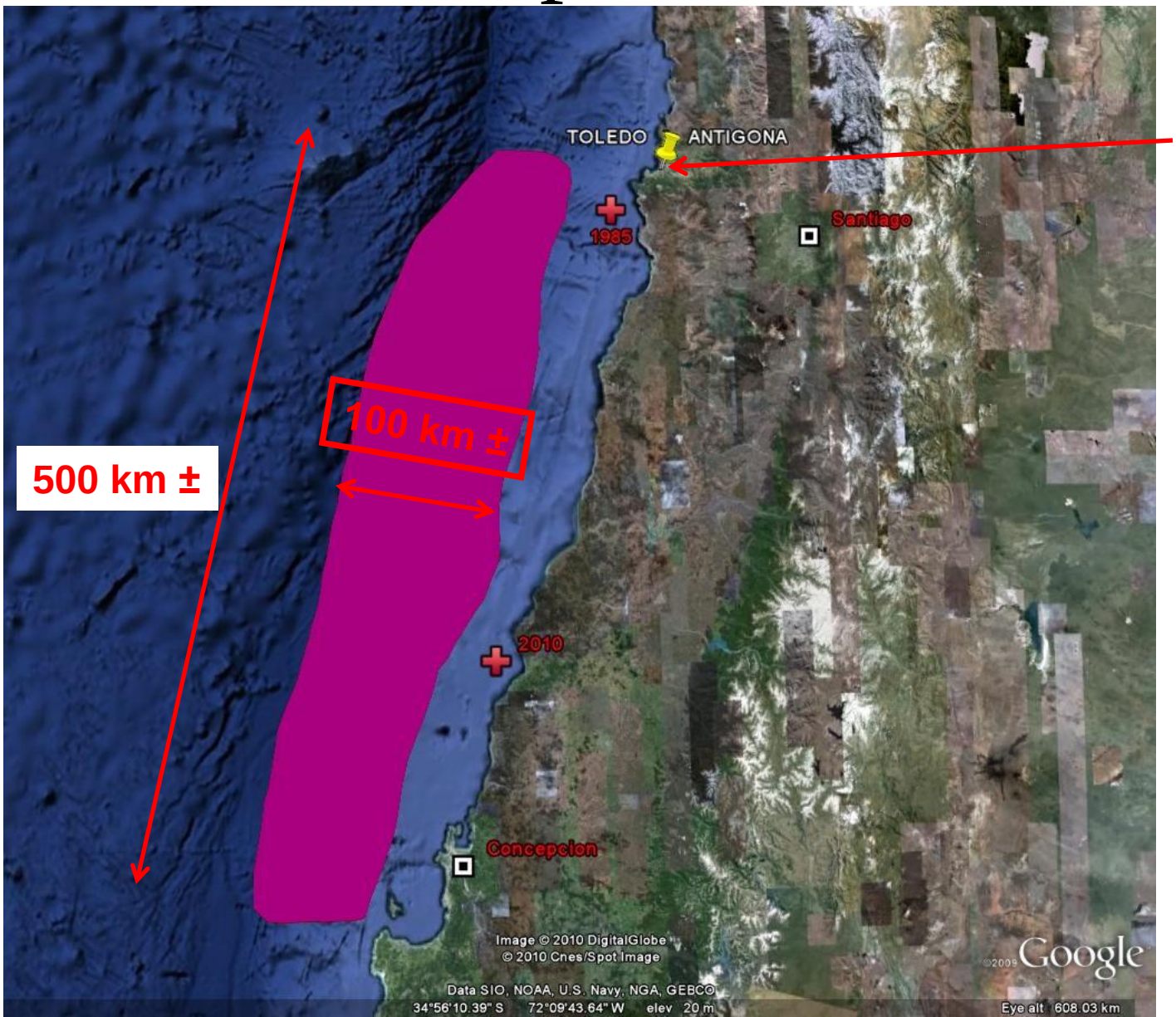
Viña del Mar Area



Viña del Mar Area



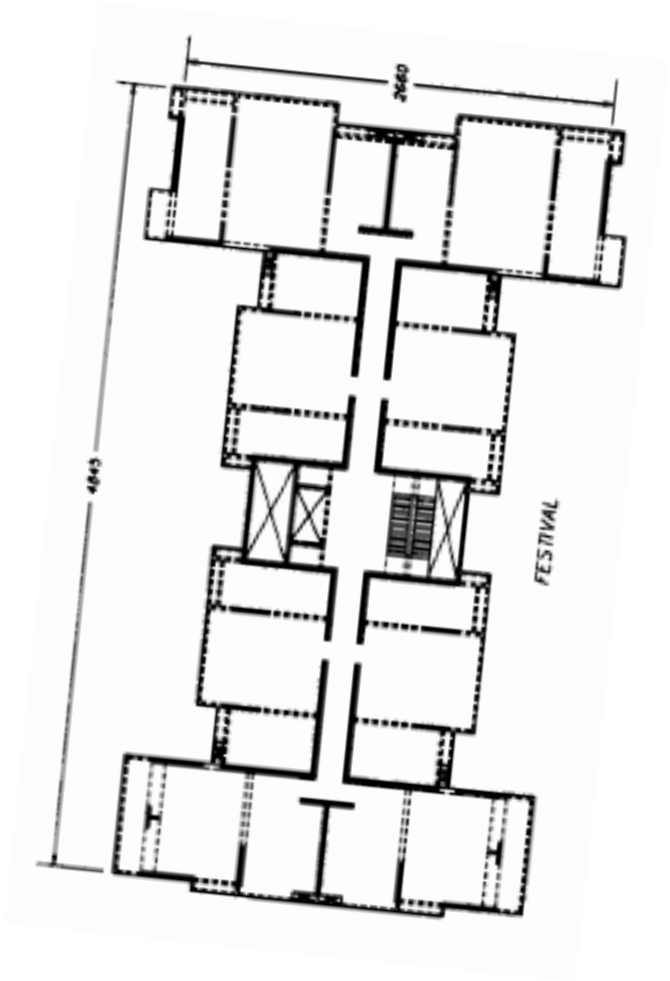
Fault Rupture Area



N

2. PRE 1985 BUILDINGS IN VIÑA DEL MAR

FESTIVAL (1979 – 14stories)

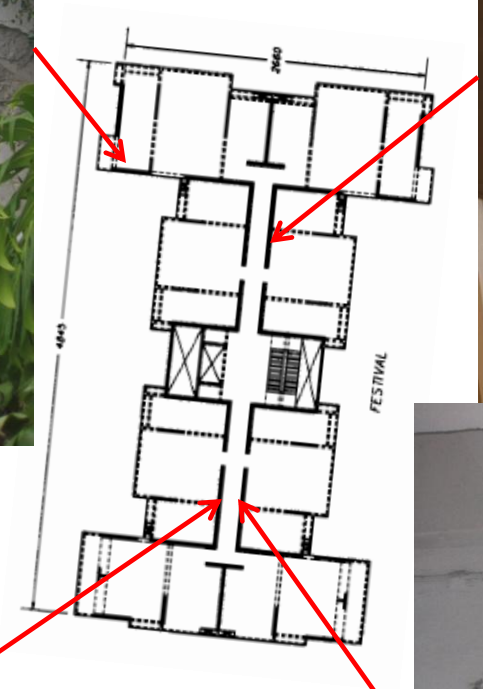


1985 Damage: Diagonal cracking in N-S walls on 1st, 2nd floors.

Retrofit Scheme: damaged walls sandwiched with 4” thk. (N) R.C. walls.

Damage 2010: Severe crushing, rebar buckling, rebar fracture on N-S and E-W walls

FESTIVAL (1979 – 14stories)



N

FESTIVAL (1979 – 14stories)

HANGA ROA (1970 – 15stories)

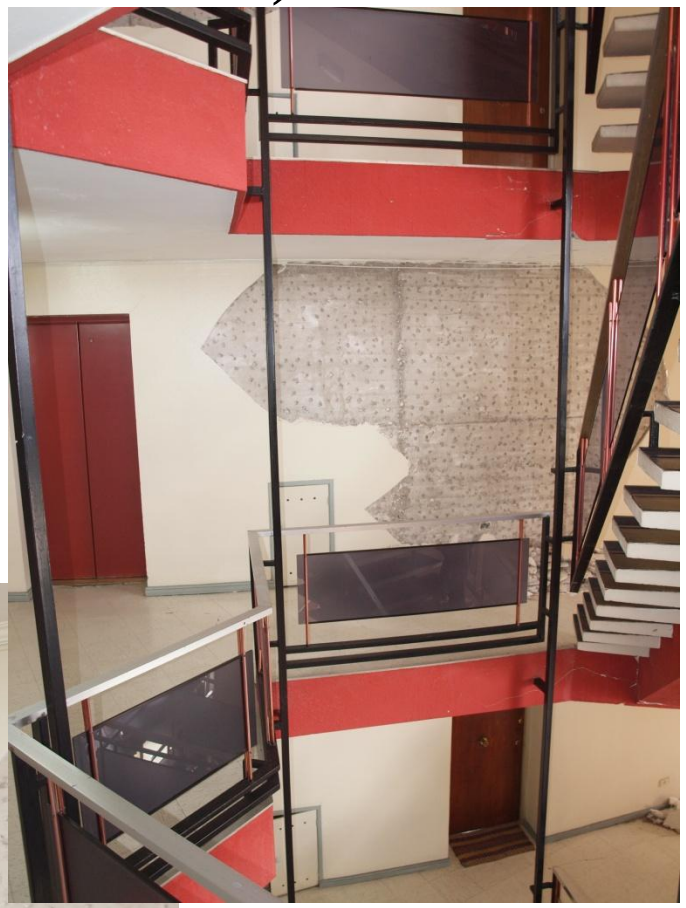
1985 Damage: 1-foot wide full-height vertical crack in one shear wall.

Retrofit Scheme: possibly (N) thicker wall was poured.

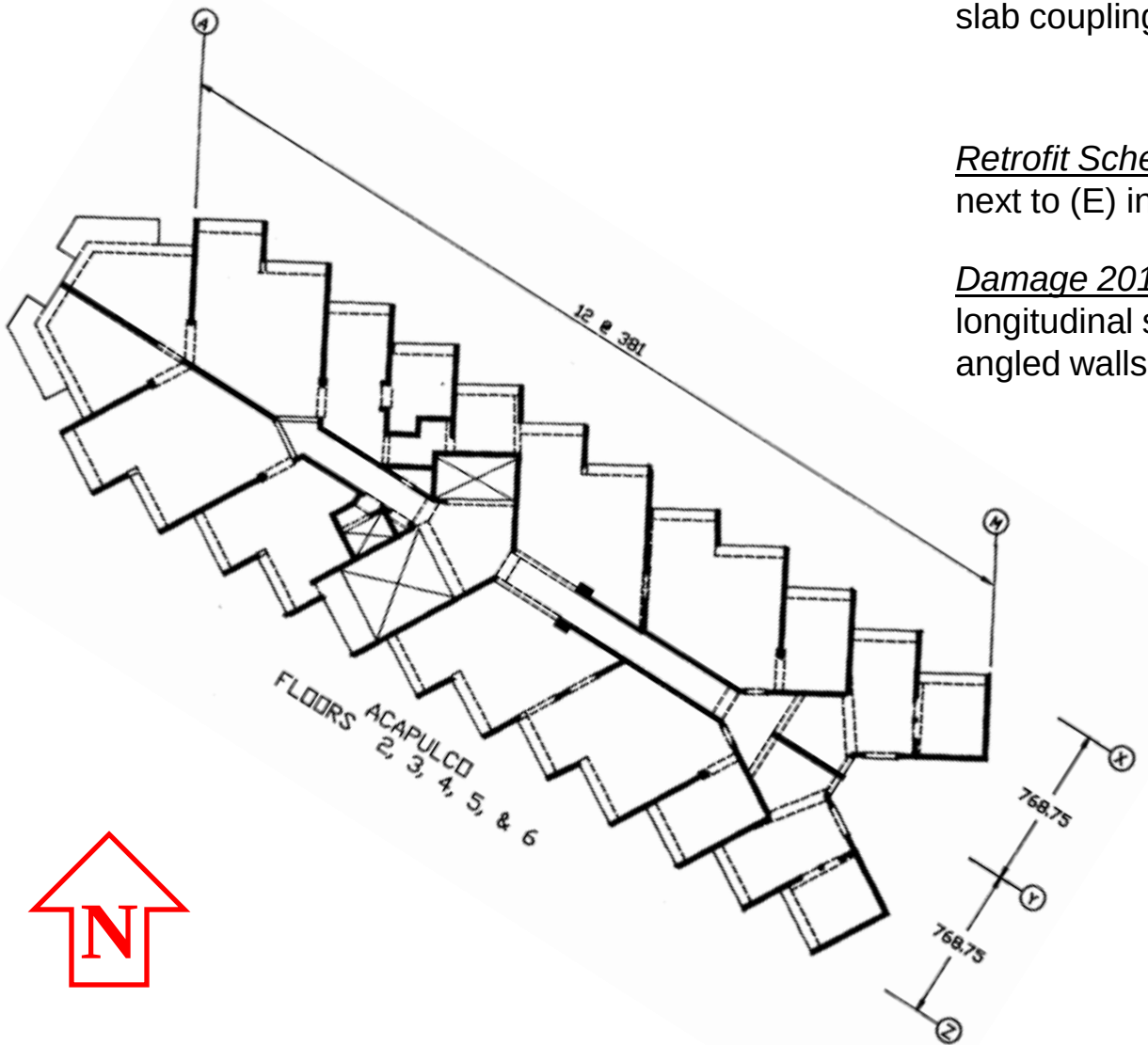
Damage 2010: Diagonal cracking, minor plaster spalling

HANGA ROA (1970 – 15stories)

HANGA ROA (1970 – 15stories)



ACAPULCO (1964 – 15stories)



1985 Damage: shear walls angled from corridor crushed at boundaries; slab coupling; slip at construction joints

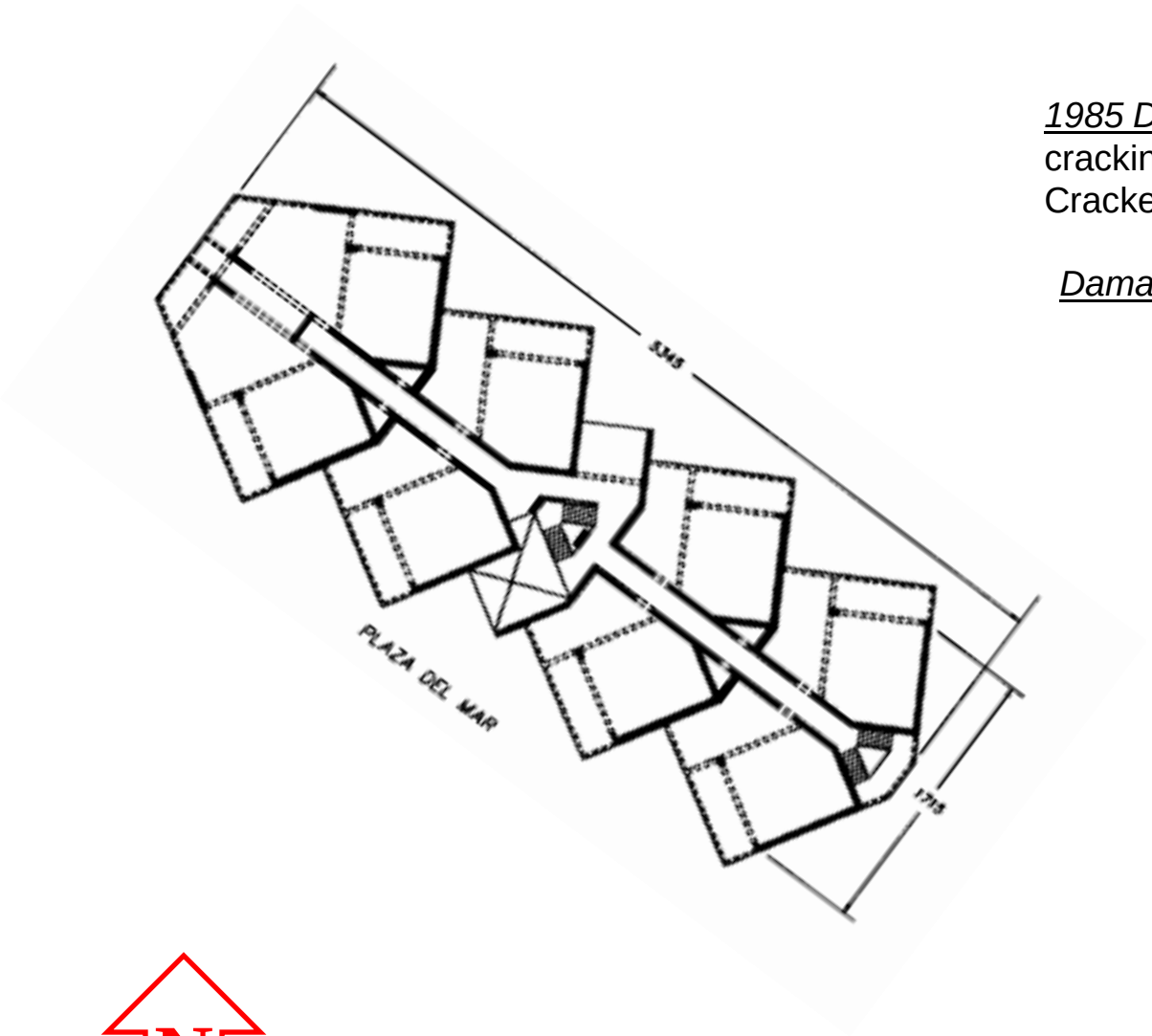
Retrofit Scheme: (N) walls were poured next to (E) in some locations.

Damage 2010: Severe crushing/buckling at longitudinal shear walls. Diagonal cracks in angled walls.

ACAPULCO (1964 – 15stories)

ACAPULCO (1964 – 15stories)

PLAZA DEL MAR (1982 – 23stories)



1985 Damage: minor diagonal cracking in shear walls at ground floor. Cracked lintels.

Damage 2010: minor

PLAZA DEL MAR (1982 – 23stories)

BAHIA (1960s? – 10 stories)

BAHIA (1960-1970? – 10 stories)

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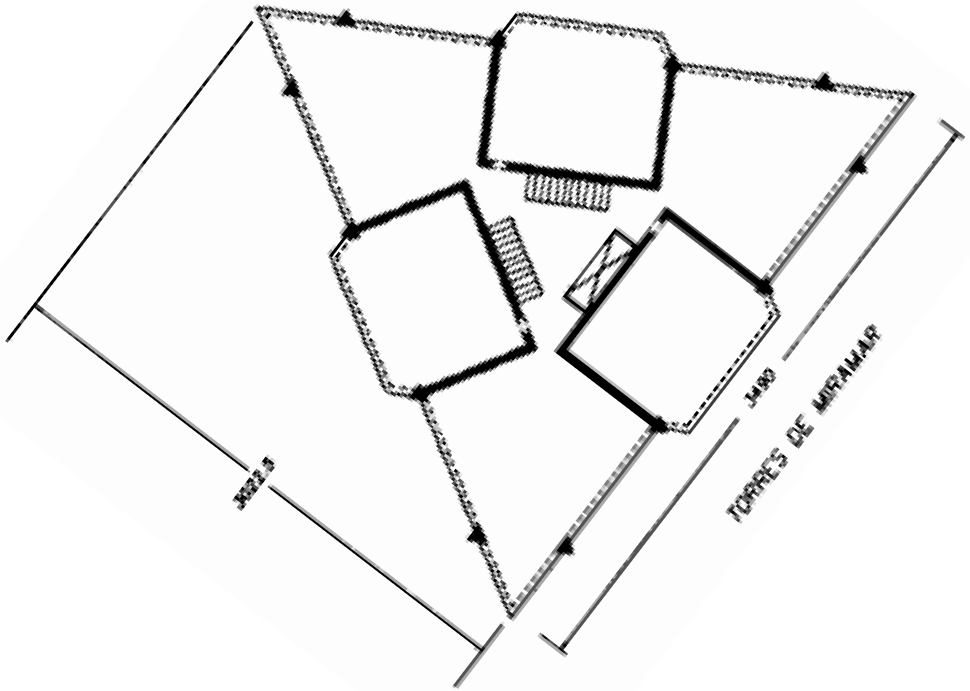
MIRAMAR (1975 – 21stories)



1985 Damage: none/minor; signs of foundation rocking were reported.

Damage 2010: none/minor

MIRAMAR (1975 – 21stories)

3. SOME HISTORY AFTER 1985

1. *"Evaluation of El Faro building indicates that lightly reinforced walls are susceptible to fracture of the longitudinal reinforcement (in flexure)."* (Wood 1991)

2. *"For rectangular, symetrically reinforced walls… concrete confinement... is not indicated. For walls having T- and L-shaped cross sections... some confinement may be justified in the stem".* (Wallace & Moehle, 1992, on a discussion of bearing walls with very specific features. Their conclussions led to changes to the ACI boundary element section of ACI 318-99, focusing on strain instead of strength)

3. *"When the total cross section of walls is large enough, i.e. 0.02 to 0.03 times the floor plan area in each direction… for buildings up to 25 stories high, flexural yielding of boundary reinforcement of walls is kept at a moderate level… These facts yield… to a system where collapse is almost unthinkable."* (Hidalgo 1996)

4. *"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."* (Chilean Code NCh433.Of96, 1996)

5. *"It's a fact that structural engineers are not required by NCh433, to design buildings with the same structural features of pre-1985 buildings. These results in inconsistencies that warrant future studies"* (Hidalgo 2002, in Spanish).

(References at end of presentation)

4. POST 1996 BUILDINGS IN VIÑA DEL MAR

TOLEDO (POST 1996 – 11 stories)

N

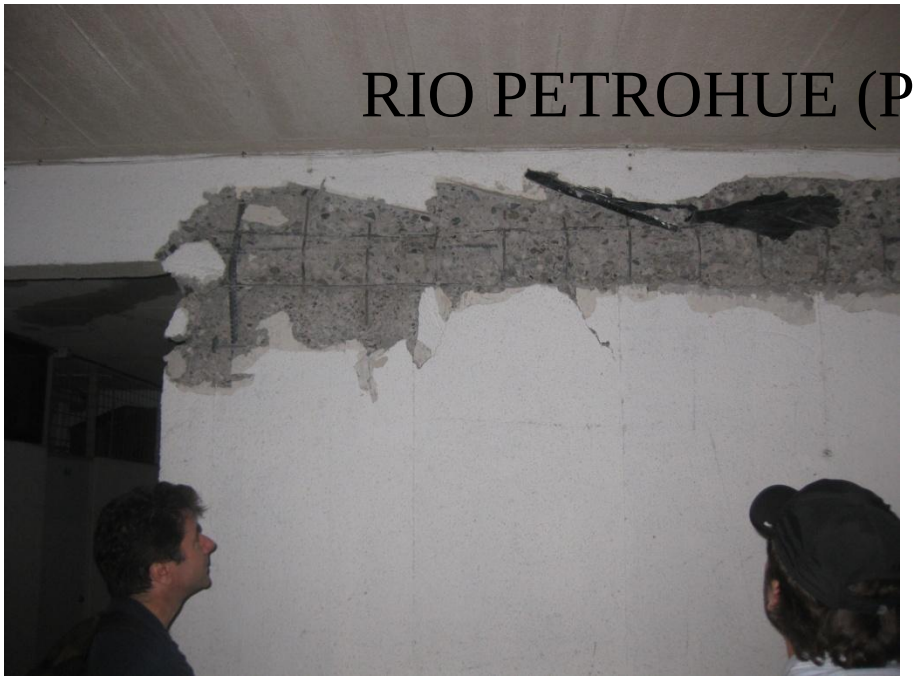
TOLEDO (POST 1996 – 11 stories)

TOLEDO (POST 1996 – 11 stories)

RIO PETROHUE (POST 1996 – 17 stories)

RIO PETROHUE (POST 1996 – 17 stories)

RIO PETROHUE (POST 1996 – 17 stories)



BASED ISOLATD BUILDING (2010 – 7 stories)

ANTIGONA (POST 1996 – 16 stories)

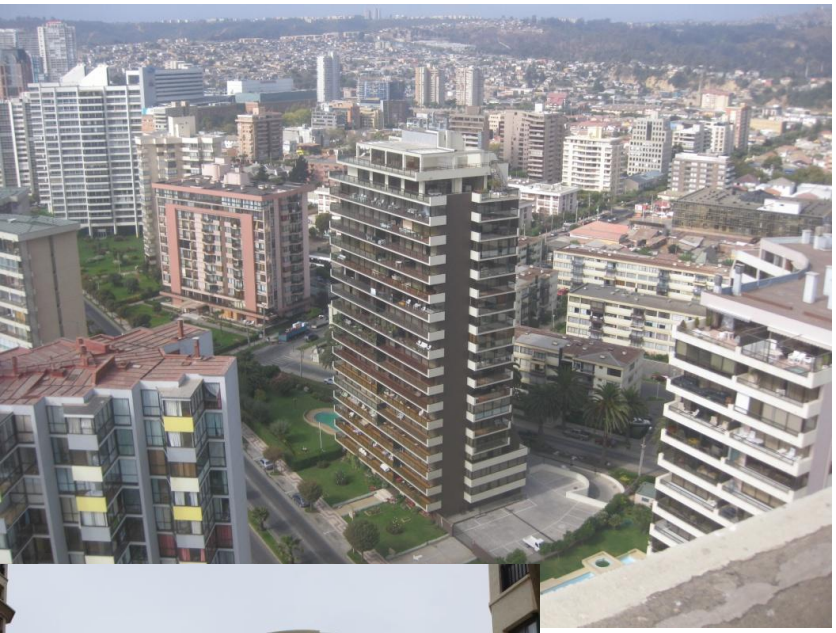
N

ANTIGONA (POST 1996 – 16 stories)

1996 – 16 stories)

5. BUILDINGS WITH NO DAMAGE IN VIÑA DEL MAR

BUILDINGS WITH NO DAMAGE



WIT

BUILDINGS WITH NO DAMAGE

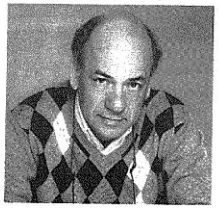
Nacional

Experto dice que sólo 0,3% de edificios sufrió daños severos

Pese a que en Chile miles de viviendas sufrieron daños estructurales tras el terremoto, Gonzalo Santolaya, ingeniero civil de la PUC, resalta la respuesta que tuvieron la gran mayoría de los edificios. "Somos un ejemplo mundial de calidad y de seriedad", afirmó.

Edificios con daños e inmobiliarias cuestionadas ha sido la tónica sobre la cual han tenido que trabajar varios ingenieros durante más de dos semanas después del terremoto y posterior tsunami que azotaron a gran parte del país la madrugada del 27 de febrero. A esto se suma también la presión de miles de personas que reclaman por la reparación de sus viviendas y que han tenido que recurrir a albergues o casas de familiares.

Frente a este escenario es que Gonzalo Santolaya, ingeniero civil estructural de la Universidad Católica y de la U. Politécnica de Madrid, sale al paso de las críticas haciendo una férrea defensa al trabajo de los profesionales encargados de los edificios que hoy están con problemas. Eso sí, comparte la opinión de que los casos más graves, como el del inmueble Alto Río, en Concepción, debieran ser revisados con detención. "En los edificios colapsados debiera haber un error técnico garrafal y deben ser investigados", señaló.



Gonzalo Santolaya, ingeniero UC.

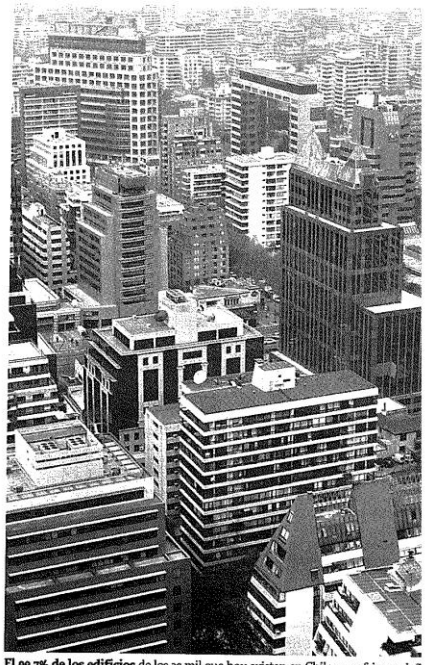
Según los datos que maneja, existen del orden de 20 mil edificios construidos desde 1985, de los cuales hay tres colapsados y 60 con daños estructurales severos, pero reparables y que hoy están en proceso.

"Cómo no va a ser aplaudible que el 99,7% de los edificios construidos haya tenido un comportamiento espectacular. Que no tengan daños mayores, aunque sean estructurales (...) quedaron perfectamente habitables, sin poner en riesgo la vida de nadie", dijo Santolaya. "Es un tremendo éxito de la ingeniería, de las inmobiliarias y constructoras que, por supuesto detrás de los colapsos, debe haber una negligencia", agregó.

A su juicio, este hecho puso de manifiesto la calidad y seriedad de los profesionales que participan en las construcciones, afirmando que el caso chileno en particular ha recibido reconocimientos importantes, como de Estados Unidos y Japón.

Con respecto al efecto que el sismo provocó en los edificios, dijo que superó entre 1,5 y dos veces las aceleraciones de la norma, lo cual afirma que tiene que ser revisada.

Asimismo, señaló que por mucho que el sismo haya sido severo, los edificios tienen que ser construidos para quedar en pie y que deben ser reparables. "Siempre, en este análisis, no hay que olvidar que fuimos enfrentados a un terremoto y que no podemos esperar a que nuestras estructuras no sufran daños", agregó el ingeniero.



El 99,7% de los edificios de los 20 mil que hoy existen en Chile no sufrieron daño por el terremoto, según señaló Santolaya.

"Only 0.3% of the 20,000 buildings constructed after 1985 have severe damage"

"We are a worldwide example of quality"

"In the 3 collapsed buildings there must be a technical error and they must be investigated"

"Design spectra must be revised"

Gonzalo Santolaya, UC

6. CONCLUSIONS

1. 1985 to 2010 ground motion comparison:
   - PGAs: 036g against 0.33g in 2010
   - Duration: 40 sec against 25 sec of GM > 0.1g in 2010
   - Acceleration Spectra: Similar shapes. Slightly lower S_a at the long period range in 2010.
2. Pre 1985 and post 1996 buildings fared well.
3. 25-35% of evacuated buildings in Viña del Mar were pre 1985 buildings. Number of mid-, high-rise buildings has at least doubled or tripled since 1985.
4. Pre 1985 buildings features: parking outside of building footprint; no wall discontinuities; slightly higher area of shear wall; wall thickness usually 12" minimum.
5. Post 1996 buildings features: building footprint area at 1st floor and below ground commonly used for parking; wall discontinuities to allow for parking requirements; slightly lower area of shear wall; wall thickness usually 6" to 8" minimum.

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- Ruben Boroschek, Rodolfo Saragoni (Universidad de Chile)
- John Wallace (UCLA), Jack Moehle (UCB), Joe Maffei (R&C)

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5. Hidalgo, P; Martinez, M; Jordan, R (2002). "Modelo Para Predecir el Comportamiento Sismico Inelastico de Edificios Estructurados con Muros de Hormigon Armado." Proceedings of the VIII Jornadas Chilenas de Sismologia e Ingenieria Antisismica (in Spanish).