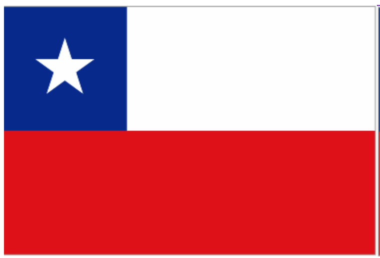
Comparison of Chilean and U.S. Seismic Design Provisions for Timber Structures



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SWST Annual Meeting
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Introduction

- Significant advances in the understanding of wood-frame construction response to seismic forces have been made in recent years.
  - Detailing requirements
  - Defined yield mechanisms
  - Full-scale shake table tests
  - CUREE and NEESWood projects
  - Building Seismic Safety Council

Introduction

- However, Chile’s Timber Design Code has not been updated to take advantage of many of these advances.

- Currently, there is a project to introduce a new prescriptive design and construction code for wood houses

Introduction

- The outline for the new prescriptive housing code was written by BCIT and is being filled in by personnel at CORMA

- In addition, the design code for engineered timber structures is being reviewed and new proposals for change will be made to both the seismic force determination section of the standard and to the timber design standard.

Introduction

- As part of this process, a comparison of the Chilean design process with other countries design processes is being made

- This presentation summarizes the findings of the comparison of the design load determination between the Chilean and United States design standards.

Introduction

- The two standards being compared are
  - Chile: NCh 433.Of96 (1996) *Diseño sismico de edificios*
  - U.S. ASCE 7-05 (2005) *Minimum Design Loads for Buildings and Other Structures*

Objectives of Standards

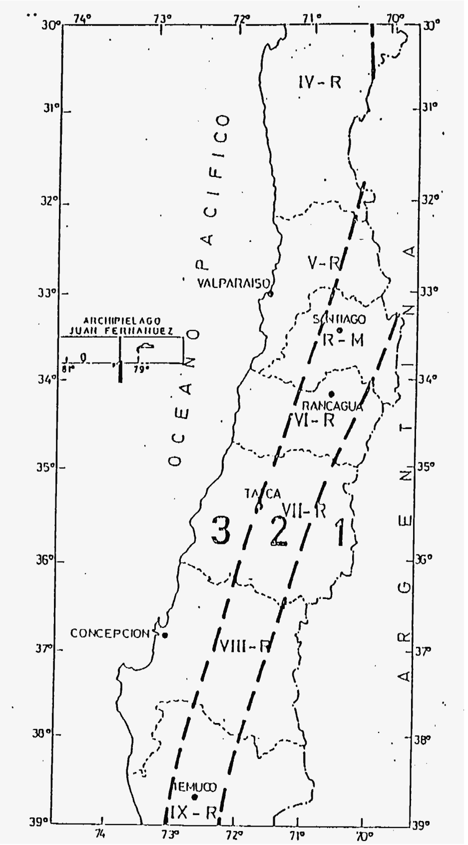
- Both countries' standards have the same objectives for seismic design:
  - Experience no damage during moderate events
  - Limit damage to architectural components for moderate or normal events
  - Prevent collapse during extreme events

Basis of Chilean Standard

- The Chilean Standard is based on the 1995 Uniform Building Code (U.S.)
- Several modifications were made to adapt the code to the Chilean needs
  - Subduction faults vs slip faults
  - Calibrated to reinforced concrete construction due to volume of construction and experience of committee members

Basis of Chilean Standard

- Return period of design earthquake is 472 years (Maps are Zone maps)



Basis of Chilean Standard

- Return period of design earthquake is 472 years (Maps are Zone maps)
- 5% damping is assumed in the design process
- Most low-rise simple buildings are designed using Equivalent “Static” Lateral Force Analysis

Basis of U.S. Standard

- Maps are based on a 2% probability of exceedence in 50 years.

- This translates into a return period of approximately 2500 years

- However, the design event is 2/3 of the map earthquake

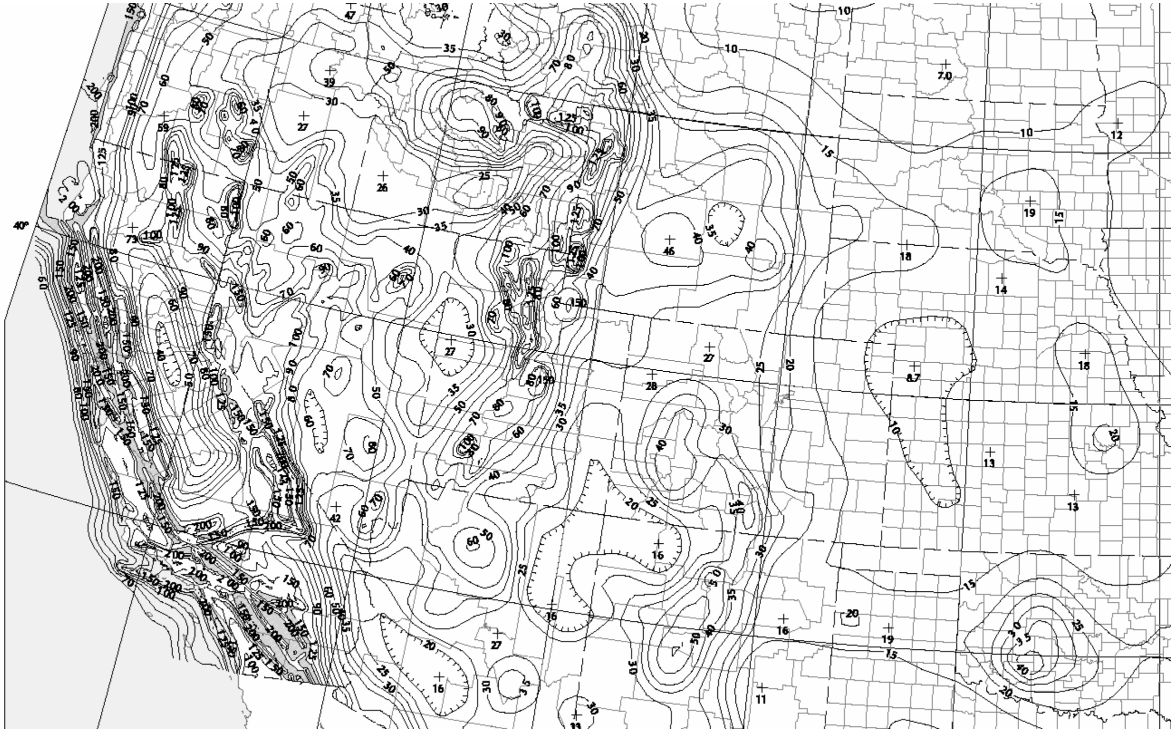
Basis of U.S. Standard

- This means that the design event is approximately the same as a 10% probability of exceedence in 50 years.

- This has a return period of about 475 years, or approximately the same level as the Chilean design event.

Basis of U.S. Standard

- The U.S. Seismic hazard is mapped on a contour basis and interpolation is allowed.



Basis of U.S. Standard

- The U.S. Seismic hazard is mapped on a contour basis and interpolation is allowed.

- 5% damping is assumed in the design process

- Most low-rise simple buildings are designed using Equivalent “Static” Lateral Force Analysis

Basis of Comparison

- The following is the basis of the design comparison

Variable	U.S. Value	Chilean Value
Building Type **(Light-Frame, 3-story, Bearing wall system** **Area < 3,000** **Occupancy <100)**	**Type II**	**Category C**
Map Acceleration (g)	**0.4**	**0.4**
Soil Class	**D**	**II**
Response Modification Factor (R)	**6.5**	**5.5**
Overstrength Factor (Ω_0)	**3.0**	**N/A**
Displacement Amplification Factor	**4.0**	$R = 5.5$ *
Fundamental period of building	**0.2 sec**	**0.2 sec**

*** Not written in Chilean Code, but used by a few designers. Most designers use 1.0**

Note: While non-linear drift is checked in the US, elastic drift under reduced reduced forces is checked by Chilean designers.

Design Force Determination

Chile

$Q_0 = CIP$

$$C = \frac{2.75\,A_0}{gR}\left(\frac{T'}{T^*}\right)^n \leq \frac{0.40\,SA_0}{g}$$

Design Force Determination

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United States

$V = C_sW$

$$C_s = \frac{S_{DS}}{\left(\frac{R}{I}\right)}$$

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Base Shear

Building Weight

Importance Factor

Design Force Determination

Chile

$$C = \frac{2.75\, A_0}{gR}\left(\frac{T'}{T\,*}\right)^n \le \frac{0.40\, SA_0}{g}$$

United States

$$C_s = \frac{S_{DS}}{\left(\dfrac{R}{\xcancel{I}}\right)}$$

Differences are in the determination of C and C_s

Since the Importance Factor In the US equation is actually in the numberator, it has the same function as the Chilean equivalent

Design Force Determination

Chile

$$C = \frac{\cancel{2.75}\,\cancel{A_0}}{\cancel{g}R}\left(\cancel{\frac{T'}{T^*}}\right)^n \leq \frac{0.40\,SA_0}{g}$$

United States

$$C_s = \frac{\cancel{S_{DS}}}{R}$$

Put in minimum value

Remove the map acceleration and soil effects

The real differences lie in the values used for R

Final Load Comparison

Chile

$$Q_0 = \frac{2.75(0.4g)}{g(5.5)}\left(\frac{0.35}{0.20}\right)^{1.33}(1.0)P = 0.42P$$

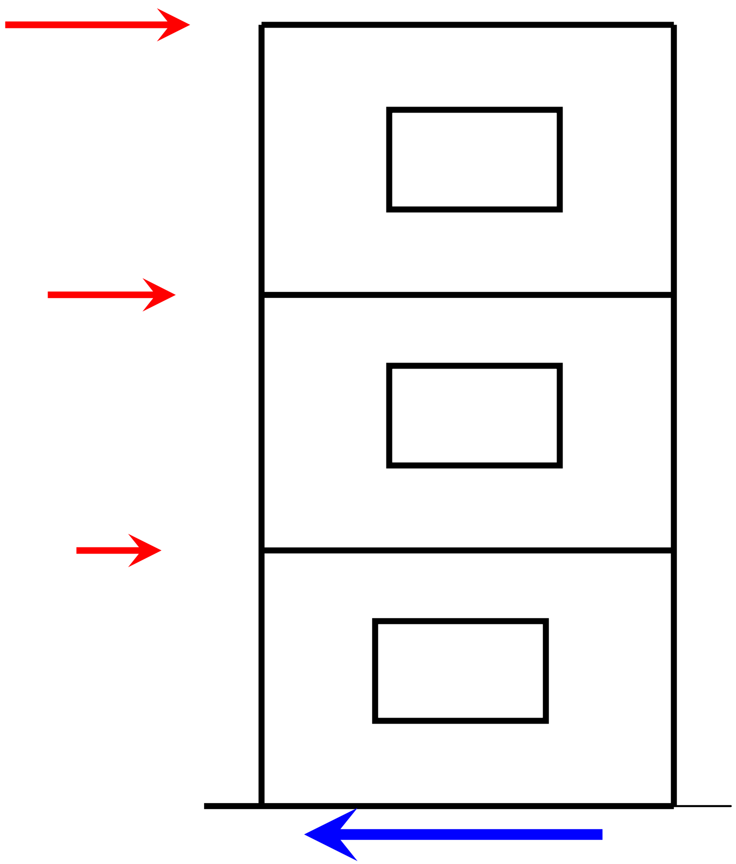
$$Q_0 \leq [0.40(1.0)(0.4g)/g]P = 0.16P$$

United States

$$V = \left(\frac{0.40}{6.5/1.0}\right)W = 0.062W$$

Chilean society wants its buildings to be 2.6 times as strong as the citizens of the United States expect their buildings to be

Final Load Comparison



Q_b, V

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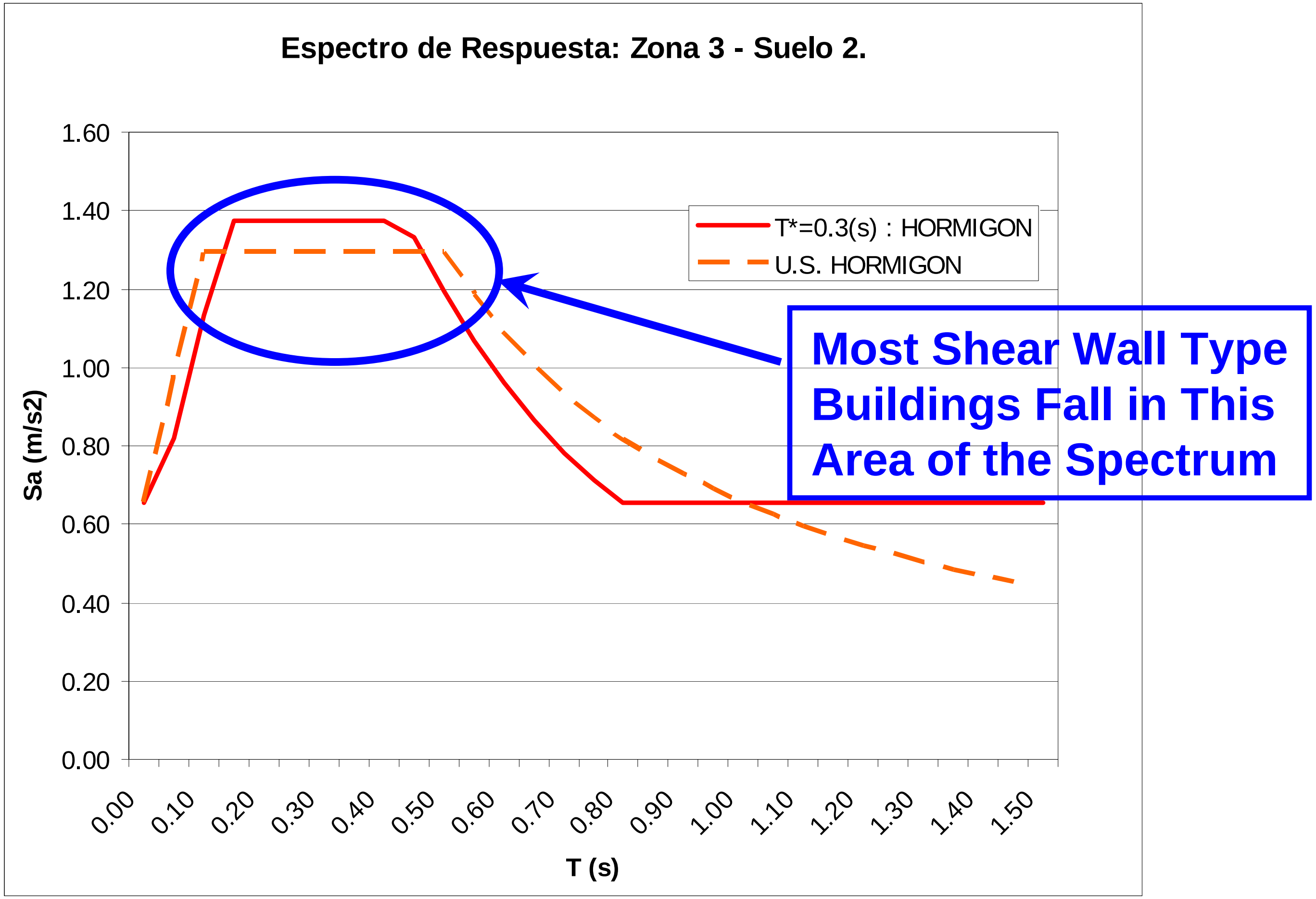
Material Differences

- More important to determining the materials used for a structure is the relative design spectrum
- The Chilean design spectrum for reinforced concrete is about the same as the one used in the United States

Design Spectra Comparison

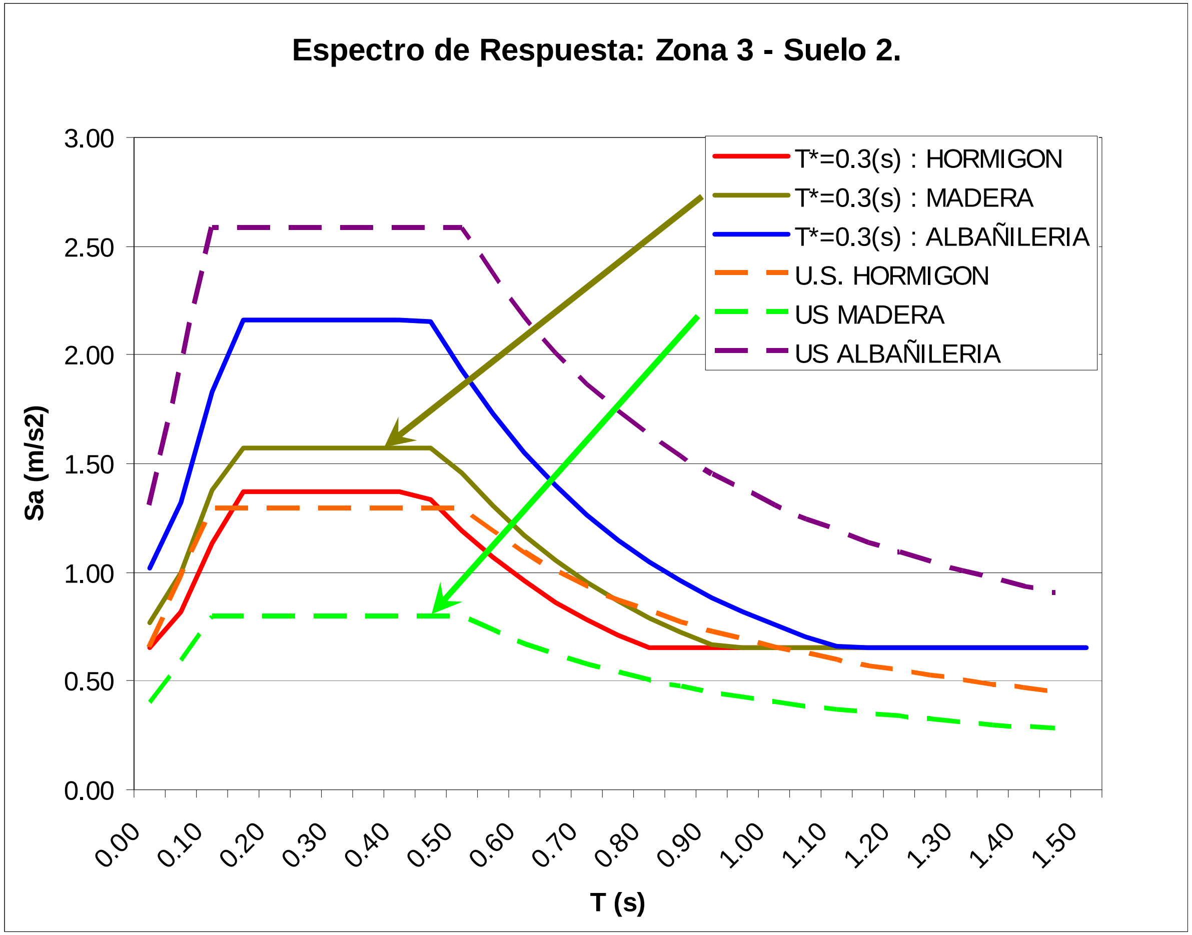


Material Differences

- When the design spectra for timber and reinforced masonry are compared, it becomes obvious that the committee members for the Chilean standard were not familiar with timber construction

- Wood structures in Chile must be designed to resist higher forces than concrete

Design Spectra Comparison



Seismic Design Factors

- The relative values of R are important to which material is chosen for a given project.

Material	ASCE 7-05	NCh 433.Of96
Light-Frame Shear Walls with Wood Structural Panels	6.5	5.5
Special Detailed Reinforced Concrete	5.0	N/A
Reinforced Concrete	4	7
Special Detailed Reinforced Masonry	5	N/A
Intermediate Reinforced Masonry	3.5	N/A
Confined Reinforced Masonry*	N/A	6
Ordinary Reinforced Masonry	2	4

***Confined reinforced masonry has reinforced concrete beams and columns confining the masonry walls and restricting the displacements of the masonry when racked. The concrete must resist more than 50% of the story shear.**

Incidental Torsion

Chile

$\pm\ 0.10\ b\ Z_k/H$

Applied with linear
Amplification effect
Z_k/H
(Effect is larger for
fewer stories)

Incidental Torsion

Chile	United States
$\pm$ 0.10 b Z_k/H	$\pm$ 0.05 b
Applied with linear Amplification effect Z_k/H (Effect is larger for fewer stories)	Uniformly applied to all stories

Force of Differences

- Chilean buildings are designed for 2.75 – 3.0 times the forces the same buildings would be designed for in the United States

Deflection Allowances

Chile

All buildings are required to meet an allowable drift of 0.2% drift

The standard is not explicit on the limit between elastic and inelastic drifts

Deflection Allowances

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United States

Light-frame buildings are allowed an inelastic drift of 2.5%

Elastic drifts are calculated using reduced forces and then multiplied by a displacement amplification factor, C_d

Deflection Allowance

- Since most designers in Chile will simply check an estimated elastic drift against the drift allowance, the U.S. allowance can be converted to an equivalent elastic drift allowance

$$2.5\% / (Cd) = 2.5\% / (4.0) = 0.625\%$$

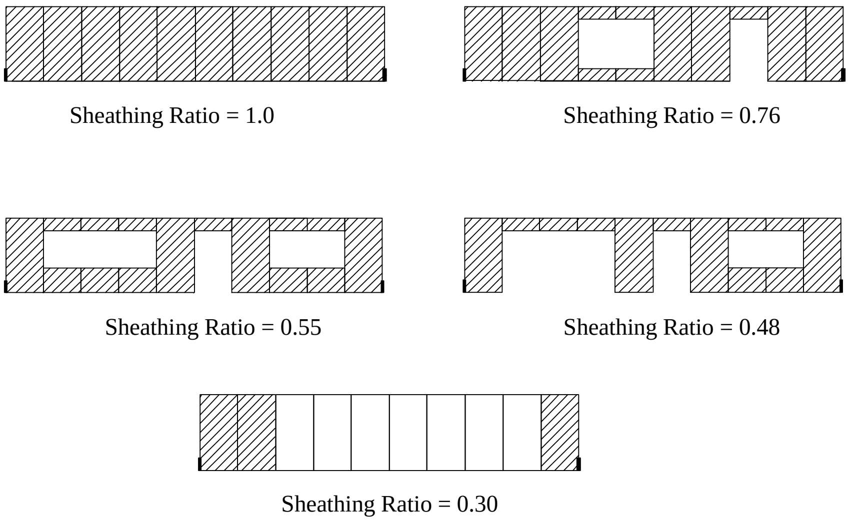
- As compared to Chilean Standard of 0.2%

Deflection Allowance

- Differences require Chilean buildings to be over 3 times as stiff
- An observation about the Chilean restriction is that it is impossible for the typical light-frame building to meet.

Chilean Drift Restriction

- When typical construction detailing is considered, the uplift slip alone will cause drifts greater than the Chilean allowable.
- A wall with 2:1 aspect ratio will have a drift 2.5 times the allowable before the wall even begins to resist load!



Chilean Drift Restriction

- Required drift allowance results in effective allowable resistance of walls being approximately 1/10 of capacity.

- U.S. design is based on strength with a drift check.
- Chile effectively is based on drift design with a strength check.

Conclusions

- If timber is to be competitive in Chile two changes to the design standard are needed
  - The drift allowance needs to be either relaxed for elastic drift checks or a drift amplification factor needs to be introduced with an associated inelastic drift allowance set.
  - The relative R-factors for all materials need to be rationalized in a manner similar to the current effort in the United States (ATC-63)

Fin
Gracias

End
Thank You