POLICIES FOR SAFER BUILDING/HOUSING
Ministry of Land, Infrastructure and Transport (MLIT),
Government of Japan

Past, Present And Future: What Works In Achieving Safer Buildings

Prof. Javier R. Piqué
President, Peruvian Permanent Committee for Seismic Design
Policies

- Limiting displacement codes: the Peruvian experience
- Existing non-engineered construction: effective inexpensive reinforcing
- Use of land: planning for safe construction
## Use of damaged buildings (Peru 1971-1980)

<table>
<thead>
<tr>
<th>Use or category</th>
<th>Number of buildings</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>School buildings</td>
<td>68</td>
<td>47</td>
</tr>
<tr>
<td>Office buildings</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>Hospitals</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Hotels</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Industrial</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Other uses</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>144 buildings</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

(*) Kuroiwa, J. “Disaster Reduction” pp.186

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## Seismic Type damage (Peru, 1971-1980)

<table>
<thead>
<tr>
<th>Predominant Damage Type</th>
<th>Number of buildings</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short columns and change in stiffness in plant and height (irregularities)</td>
<td>100</td>
<td>69</td>
</tr>
<tr>
<td>Wall shear failure</td>
<td>18</td>
<td>12.5</td>
</tr>
<tr>
<td>Beam columns joint failure</td>
<td>8</td>
<td>5.5</td>
</tr>
<tr>
<td>Bending in walls</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Poor concrete quality</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>Beam failure, bending or shear</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Impact between adjacent buildings</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>144 buildings</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Evolution of Peruvian Seismic Standards

- 1964: First project of Peruvian Standard, based on SEAOC
- 1970: First Peruvian Standard nationwide
- 2003: Revision of 3rd Standard
School building

NAZCA 1996
LAB BUILDING

Earthquake in X direction
Maximum Displacements (RNC-1977)

<table>
<thead>
<tr>
<th>FLOOR</th>
<th>Displacements (cm)</th>
<th>Drift</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>y</td>
</tr>
<tr>
<td>2do floor</td>
<td>6.494</td>
<td>0.000</td>
</tr>
<tr>
<td>1er floor</td>
<td>4.091</td>
<td>0.013</td>
</tr>
</tbody>
</table>

Allowable Displacements = Damage
ATICO Earthquake, Southern PERU
23 June 2001 - Magnitude $M_s$ 8.2, $M_w$=8.4

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TIME HISTORY of CORRECTED ACCELERATIONS
PEAK GROUND ACCELERATION : 295.3 cm/seg²
(300 km from epicenter)

MOQUEGUA CITY STATION, E-W COMPONENT

ACCELERATION (GAL)

0  20  40  60  80  100  120
TIME (SEC)

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1977 Standard: Allowable Displacements = damage

Photo: E. Fierro

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1997 = Change of Standards

$V = \frac{ZUSC}{R} \cdot P$

$V_{\text{earthquake}} = V = ZUSC$

$V_{\text{design}}$

$V = \text{Base shear}$

$\Delta_{\text{analysis}}$

$\Delta_{\text{actual}}$

$\Delta (\text{Lateral Displacement})$

Elastic Behavior

Inelastic Behavior

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Comparison between base shear coefficients

<table>
<thead>
<tr>
<th>Seismic Standard</th>
<th>1977</th>
<th>1997</th>
</tr>
</thead>
<tbody>
<tr>
<td>factor Z</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>factor U</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>factor S</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>factor C (short periods)</td>
<td>0.4</td>
<td>2.5</td>
</tr>
<tr>
<td>ZUCS</td>
<td>0.4</td>
<td>1</td>
</tr>
</tbody>
</table>

To obtain similar base shear, $R$ factors had to be increased: 2.5 times
Drift Limits were also reduced

<table>
<thead>
<tr>
<th>Standard</th>
<th>1977</th>
<th>1997</th>
<th>Increment of demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREDOMINANT MATERIAL</td>
<td>( \frac{\Delta_I}{he_i} )</td>
<td>( \frac{\Delta_I}{he_i} )</td>
<td>( \left( \frac{\Delta_{77}}{\Delta_{97}} - 1 \right) \cdot 100 )</td>
</tr>
<tr>
<td>Reinforced Concrete</td>
<td>0.010</td>
<td>0.007</td>
<td>43%</td>
</tr>
<tr>
<td>Steel (*)</td>
<td>0.015</td>
<td>0.010</td>
<td>50%</td>
</tr>
<tr>
<td>Masonry</td>
<td>0.010</td>
<td>0.005</td>
<td>100%</td>
</tr>
<tr>
<td>Timber</td>
<td>0.015</td>
<td>0.010</td>
<td>50%</td>
</tr>
</tbody>
</table>

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Displacements 1997 = 2.5 x 4/3 = 3.33 times larger and compared against a stringent drift

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1997 Standard = Stiffer structures. Regular structural system mandatory = No damage.

Photos
E. Fierro
CONCLUSIONS 1

- All school buildings in Southern Peru designed with 1977 Standard experienced structural and nonstructural damage. None of the schools designed and built under the 1997 Standard suffered damage.

- Change in Peruvian Seismic Standards resulted in higher computed lateral displacements. Structures designed using 1997 new Standard have to be much more rigid than before.
CONCLUSIONS 2

- Schools continue to operate unharmed, even when peak ground acceleration must have been higher than design acceleration (0.3g was registered 100km south, even further from epicenter).
- Changes in structural element dimensions to achieve additional stiffness increase structural costs by 30%. No cost was involved after the earthquake because of absence of damage.
CONCLUSIONS 3

- Structures designed with 1977 Standards had to be repaired, they could not be used for several months and cost of retrofitting and stiffening reach up to 40% of initial cost

- It is recommended Codes should incorporate:
  - Restrict displacements
  - Limit irregularities severely. Essential buildings should be regular
  - Either assure safe collapse mechanisms or limit use of frame systems alone
Existing non engineered buildings: improvement in adobe housing

50% of world housing is non-engineered
The built environment

Vernacular

Engineered
Prof. J Gutiérrez
Costa Rica.
XIII WCEE

Non-engineered
Limón, Costa Rica, Earthquake
(April, 22, 1991 ML = 7.5 MMI = IX)

30 ‘bahareque’ houses with prefabricated panels at epicenter, none was damaged

Prof. J Gutiérrez
Costa Rica.
XIII WCEE
Proposed reinforcing for less vulnerability (Kuroiwa-CISMID)
Laboratory tests show high strength and improved ductility

Full scale model . 0,8g pga

Kuroiwa, J. “Disaster Reduction” pp.143

Full scale model . 1,0g pga. Roff has not fallen
CONCLUSION

- Implement programs to support retrofittting with training and long term credit or subsidies
- Non-engineered heavy housing in high intensity areas should be relocated
Planning for future occupation: The importance of location

Plan land use
Avalanche caused by earthquake: Huaraz 1970
67 000 dead

Kuroiwa, J.
“Disaster Reduction”
pp.143
Hazard map of Ica, Peru

Kuroiwa, J. “Disaster Reduction” pp.44
Land use plan for Ica, Peru

Kuroiwa, J. “Disaster Reduction” pp.44

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CONCLUSIONS

- Good location is essential in reducing vulnerability to all natural hazards
- Once estimated, prepare land-use plan and enforce compliance
- Effective policies should concentrate in:
  - Simple Codes, low cost retrofittling, location
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Thanks for your kind attention