Seismic Risk for Data Centers

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Presentation Outline

- Seismic Risk
- Code Requirements
- Data Center Components
- Issues and Solutions
- Data Center Buildings
Seismic Risk

A Function of:

Seismic Hazard and Building Performance
Bay Area 30-year Probabilities

- 70% odds (±10%) for one or more magnitude 6.7 or greater earthquakes from 2000 to 2030. This result incorporates 9% odds of quakes not on shown faults.

- 21% New odds of magnitude 6.7 or greater quakes before 2000 on the indicated fault.

- 18% Odds for faults that were not previously included in probability studies.

- Increasing quake odds along fault segments.

- Individual fault probabilities are uncertain by 5 to 10%.
USGS Seismic Hazard Map
Seismic Performance – Buildings

Northridge Earthquake
ST – RISK

% Damage vs. MMI

Loss to Facilities (%) vs. MMI

- PML
- PML ± Sigma
- Median
- Median ± Sigma

%PE: 91 66 35 16 3 <1

Critical Facility Round Table    Seismic Risk for Data Centers    October 16, 2003
Intensity vs. Peak Ground Acceleration

<table>
<thead>
<tr>
<th>PERCEIVED SHAKING</th>
<th>Not felt</th>
<th>Weak</th>
<th>Light</th>
<th>Moderate</th>
<th>Strong</th>
<th>Very strong</th>
<th>Severe</th>
<th>Violent</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>POTENTIAL DAMAGE</td>
<td>none</td>
<td>none</td>
<td>none</td>
<td>Very light</td>
<td>Light</td>
<td>Moderate</td>
<td>Moderate/Heavy</td>
<td>Heavy</td>
<td>Very Heavy</td>
</tr>
<tr>
<td>PEAK ACC (%g)</td>
<td>&lt;0.17</td>
<td>0.1-1.1</td>
<td>1.1-3.4</td>
<td>3.4-8.1</td>
<td>8.1-16</td>
<td>16-31</td>
<td>31-60</td>
<td>60-116</td>
<td>&gt;116</td>
</tr>
<tr>
<td>PEAK VEL cm/s</td>
<td>&lt;0.1</td>
<td>0.1-1.1</td>
<td>1.1-3.4</td>
<td>3.4-8.1</td>
<td>8.1-16</td>
<td>16-31</td>
<td>31-60</td>
<td>60-116</td>
<td>&gt;116</td>
</tr>
<tr>
<td>INSTRUMENTAL INTENSITY</td>
<td>I</td>
<td>II-III</td>
<td>IV</td>
<td>V</td>
<td>VI</td>
<td>VII</td>
<td>VIII</td>
<td>IX</td>
<td>X+</td>
</tr>
</tbody>
</table>
Seismic Performance – Data Centers

Seattle Earthquake
Equipment Damage vs. MMI

FROM ATC – 13

Loss to Nonstructural Items (%)

VI VII VIII IX X XI XII

MMI

Equipment Anchorage
Code Requirements

1. Pre – 1997 UBC
   Including all editions of BOCA and SBC

2. Post 1997
   2a. 1997 UBC
   2b. 2000 IBC, 2003 IBC
       2003 NFPA 5000
       2002 ASCE - 7
Code Requirements – 1994 UBC

**Lateral Force On Nonstructural Components**

\[ F_p = ZC_p I_p W_p \]

Where:
- \( F_p \) = Equivalent static horizontal design force
- \( Z \) = Seismic Zone Coefficient
- \( C_p \) = Coefficient (Generally 0.75 for equipment)
- \( I_p \) = Importance Factor (1.0, 1.25 or 1.5)
- \( W_p \) = Weight of the Item
Lateral Force On Nonstructural Components

\[ F_p = \frac{a_p C_a I_p}{R_p} \left(1 + 3 \frac{h_x}{h_r}\right) W_p \]

Where:
- \( a_p \) = Component Amplification Factor (rigid or flexible structure) (varies from 1.0 to 2.5)
- \( C_a \) = Seismic Coefficient (dep. on Zone and Soil Type)
- \( I_p \) = Importance Factor
- \( R_p \) = Component Response Modification Factor (ductility of support anchorage)
- \( h_x \)/\( h_r \) = height in building where equipment is located divided by total height of building
Code Related Issues

Lateral Forces on Nonstructural Components
1994 UBC vs. 1997 UBC

1994 UBC

Roof Level

Grade Level

1997 UBC

Near Fault

Shallow Anchors
Shallow Anchors

Shallow Anchors are those with an embedment length to diameter ratio of less than 8.
Installation Related Issues

No Anchorage

Inadequate Anchorage
Data Center Components

- Server Racks
- Other Equipment – AC and UPS
- Access Floors
- Ceiling and Fire Sprinklers
- Emergency Generators
Servers

Seattle Earthquake

Building 3-801
Seismic Anchorage of Servers
Anchorage Solution
Anchorage Solution

- Anchor servers to prevent sliding and overturning
- Brace access floor to prevent lateral collapse

Diagram:
- Threaded rod into concrete floor prevents overturning
- Brace access floor
- Anchor to floor prevents sliding
Rack Design Issues

Standard Rack

Seismic Rack
Rack Design Issues

Anchorage of seismic rack to floor.
Alternative Solution – Rack Isolation
Alternative Solution - Rack Isolation

- Single isolator
- Isolator allows floor to move underneath equipment. Forces on equipment above are greatly reduced

WORKSAFE TECHNOLOGIES
Alternative Solution - Rack Isolation
Alternative Solution - Rack Isolation

141% Amplitude

WORKSAFE TECHNOLOGIES
Other Equipment on Raised Floor

UPS Equipment

Approach is similar to server racks.
Heavy Equipment

AC Units
Heavy Equipment Anchorage

- LARGE EQUIPMENT
- ANCHOR THRU INTERNAL FRAME OF EQUIPMENT
- ACCESS FLOOR
- SUPPORT FRAME DESIGNED FOR GRAVITY AND SEISMIC FORCES
- POST

CONCRETE SLAB
Emergency Power

Anchorage of emergency generator
Access Floors
Access Floors
Bracing of Access Floors

- Access floors must be braced or pedestals designed to cantilever.
- Mass to include floor system and weight of equipment (normally 25% of floor LL.)
- Need mechanical attachment to base slab, glue alone IS NOT acceptable.
Bracing of Access Floors

Standard pedestals are not adequate for high seismic areas
Design Anchorage Detail: Access Floor

- POST
- CONC. WAFFLE SLAB
- CONC. BEAM
- FLOOR TILE
- DIAGONAL STRUT
- EXPANSION ANCHORS

Critical Facility Round Table  Seismic Risk for Data Centers  October 16, 2003
Access Floor Bracing – Installation Problems
Access Floor Bracing – Installation Problems
Ceilings and Fire Sprinklers
Northridge Earthquake 1994
Ceilings and Fire Sprinklers
Pipe Bracing

Pipe Run

Longitudinal Brace
(Use Transverse Brace at the Adjacent Run)

24" (610 mm) MAX

Longitudinal Brace
(Use Transverse Brace at the Adjacent Run)

24" (610 mm) MAX
Pipe Bracing

**NOTE:** NFPA 13 editions prior to 1999 may not be adequate in high seismic areas.

NFPA-13 Detail

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Acceptable Bracing

[Diagram showing seismic brace assembly detail with notes and specifications]
Relative Costs – Bricks and Mortar

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Office</th>
<th>Hospital</th>
<th>Data Center</th>
<th>Pharm Mfg.</th>
<th>Chip Fab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost / Square Foot</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$1,500</td>
</tr>
</tbody>
</table>

- **22%** Structural
- **15%** Exterior
- **7%** Arch. Interiors
- **6%** MEP

Relative Structural Cost
Relative Costs – Fully Equipped

Cost / Square Foot

Building Type

Office  Hospital  Data Center  Pharm Mfg.  Chip Fab

Relative Structural Cost

$0  $2,000  $4,000  $6,000  $8,000  $10,000

15%  7%  1%  3%  1%

- Structural
- Exterior
- Arch. Interiors
- MEP
- Soft Costs
- FF&E
Seismic Performance Levels

Operational
Immediate Occupancy
Life Safe
Near Collapse
Collapse

1997 UBC
Seismic Upgrade Solution with BRBF’s
Seismic Upgrade – BRBF's
Damper Solution

4-5 Link Structure
Viscous Dampers
Damper Solution

4-5 Link Structure Viscous Dampers
Base Isolation

Seismic Isolation provides major economic advantages:

- Protection of occupants, contents, structure
- Dramatic reduction in damage
- Minimal business disruption

Seismically Isolated Structure

Lead-Rubber Seismic Isolator
Base Isolation

Base Isolator During Testing
USGS

Base isolators in laboratory tests—(left) undeformed isolator, (right) deformed isolator with sizeable horizontal displacement (Δ). Such displacement of isolators prevents large displacements of floors of the building above.
Base Isolation
AboveNet Building

New Isolator Under Existing Building
Conclusions

1. Data Centers are subject to severe damage and loss of operations in moderate (frequent) earthquakes.

2. Code requirements related to equipment anchorage have recently changed significantly.

3. Equipment bracing (even for critical equipment) is often nonexistent or second-rate.

4. Access floors are critical to data center performance and most are not intended for use in high seismic areas.

5. Seismic upgrades can generally be undertaken without severe disruption of the data center.
Questions?

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