Seventh Annual Competition

2010 Undergraduate Seismic Design Competition

Appendix

Organized and Run by:
EERI Student Leadership Council (SLC)

Competition Website: http://slc.eeri.org/seismic.htm

Email: seismic.design.competition@gmail.com

Sponsored by:
- Earthquake Engineering Research Institute (EERI)
- Federal Emergency Management Agency (FEMA)
# Table of Contents

A. Data Processing ................................................................................................................................... 3
B. Shake Table ......................................................................................................................................... 4
C. Example Problem.......................................................................................................................... 5
D. Score Sheet........................................................................................................................................ 9
E. Expenses / Shipping ....................................................................................................................... 10
F. Competition History ......................................................................................................................... 11
A. **Data Processing**

Two accelerometers will be utilized in the competition. For each structure, one accelerometer will be attached to the shake table (on the bottom), and one accelerometer will be placed at the roof level.

Displacements will be computed from each recorded acceleration time series by performing the following steps:

1. Transfer the acceleration records into the frequency domain using a Fourier transform.
2. Digitally high-pass filter the acceleration recordings in the frequency domain using a 3\textsuperscript{rd} order Butterworth filter with a corner frequency of 0.8 Hz.
3. Double integrate the filtered acceleration records over time to obtain displacements.

A portion of the low-frequency range of the raw acceleration signals must be removed using a digital filter prior to double integration because the low frequency content of the signals is small compared with the noise in the signals. Highly unrealistic displacements would be obtained if the raw data were integrated in time without first filtering off some of the low frequency content because of the low-frequency noise. An undesired but unavoidable consequence of the filtering is that the low-frequency portion of the acceleration signals, which contains permanent displacements, must be removed. As a result, the displacements computed by double-integrating the acceleration records are transient displacements; the low-frequency permanent component will not be reflected in the computed displacement time series.
B. **Shake Table**

Structures will be tested on the UCIST unidirectional earthquake shake table, with plan dimensions of 45.7 cm by 45.7 cm (18.0 inch by 18.0 inch) and a payload capacity of 15.0 kg (33 lb).

![Image of Shake Table]

**Figure B-1: University Consortium for Instructional Shake Tables (UCIST)**
C. Example Problem

It should be noted that there have been many changes since the competition in 2004 (i.e. building dimensions, earthquakes, etc.). This example problem should be used to understand the general scoring procedure.

In this section, the performance of the structure from the UCSD team from the 2004 PEER seismic competition will be computed to demonstrate the scoring system. Some parameters have been modified to fit better with the current rules.

1. Annual Income
The structure was 15 stories tall, and the useable floor area was 2.8 m² (4,340 inch²). The annual income per square meter is $125 since all of the floors are lower than 15 stories. Hence, the income for the building is \((4,340 \text{ in}^2)(\frac{125}{\text{in}^2/\text{year}}) = \$542,500/\text{year}\).

2. Annual Initial Building Cost
The structure occupied a footprint area of 225 inch² (0.14 m²). Hence, the cost of land beneath the building was \((225 \text{ in}^2)(\frac{35,000}{\text{in}^2}) = \$7,875,000\). Divided by the design life of the structure, the annual cost of land is \((\frac{7,875,000}{100 \text{ years}}) = \$78,750/\text{year}\).

The mass of the structure was 1.5 kg (3.3 lb). Hence, the initial construction cost was \((1.5 \text{ kg})(\frac{10,000,000}{\text{kg}}) = \$15,000,000\). Divided by the design life of the structure, the annual construction cost of the building is \((\frac{15,000,000}{100 \text{ years}}) = \$150,000/\text{year}\).

The annual initial building cost is the sum of the cost of the land and the cost of the construction, which is \$78,750/\text{year} + \$150,000/\text{year} = \$228,750/\text{year}.

3. Annual Seismic Cost
The time series from which the EDP's are computed are shown in Figures C-1 through C-3 for the three earthquakes. The EDP's are summarized in Table C-1.

![Drift Ratio and Roof Acceleration](image.jpg)

Figure C-1: Time series for the 2004 UCSD structure during the EQ1 motion.
Figure C-2: Time series for the 2004 UCSD structure during the EQ2 motion.

Table C-1: Engineering demand parameters measured during ground motions for example structure.

<table>
<thead>
<tr>
<th>Motion</th>
<th>Max</th>
<th></th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Drift Ratio</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(EDP1)</td>
<td></td>
</tr>
<tr>
<td>EQ1</td>
<td>0.014</td>
<td>0.91</td>
<td></td>
</tr>
<tr>
<td>EQ2</td>
<td>0.023</td>
<td>1.62</td>
<td></td>
</tr>
<tr>
<td>EQ3</td>
<td>0.023</td>
<td>1.90</td>
<td></td>
</tr>
</tbody>
</table>

The seismic costs for each ground motion computed from the EDP's in Table C-1 are shown in Figure C-4. The values are also summarized in Table C-2, along with the
annual seismic cost for each EDP obtained by dividing the seismic cost by the ground motion return period.

Figure C-4: Seismic cost summary for 2004 UCSD structure.

Table C-2: Seismic cost caused by imposed ground motions

<table>
<thead>
<tr>
<th>Motion</th>
<th>Cost $ (Annual Cost $/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EDP1</td>
</tr>
<tr>
<td>EQ1</td>
<td>75,900 (1,518)</td>
</tr>
<tr>
<td>EQ2</td>
<td>681,830 (4,546)</td>
</tr>
<tr>
<td>EQ3</td>
<td>681,830 (3,409)</td>
</tr>
</tbody>
</table>

The total annual seismic cost is equal to the sum of annual seismic cost for each EDP for each ground motion:

\[
\text{Annual Seismic Cost} = 1,518 + 47,057 + 4,546 + 79,107 + 3,409 + 78,849
\]

\[
\text{Annual Seismic Cost} = 214,457
\]

4. **Annual Income Increase**

The team had both an excellent presentation and poster, and thus received scores of 10 on both. Since a unique architecture was not encouraged then, the structure was box-like in shape, and thus would have received an architecture score of 4. Let’s assume that the team got 15% for their performance prediction. As a result, their annual income increased as follows:
X = +10%  Annual Income Increase from Presentation
Y = +10%  Annual Income Increase from Poster
Z = 4%    Annual Income Increase from Architecture
APS = 15% Annual Income Increase from performance prediction

FAI = (1+X+Y+Z+APS) * AI= (1 + 0.10 + 0.10 + 0.04 + 0.15) * $542,500
     = $754,075.

5. Annual Building Cost Increase
In this example, assume the structure’s lobby floor height was 4.75 in. Also assume
that the structure had 3 floors that measured 2.25in (center to center) and that the
building height, measured to be 60.9 in., from top of base board to bottom of roof
plate, when their original design building height was 60 in. Let’s also assume that the
building mass is 5.00 lb and 5 weight bars failed connection in one of the ground
motions. Their building cost increased as follows:

N = 3*2% (lobby height) + 3*2% (floors) + 4*5% (total height) = 32%
M = 2*10% (mass) = 20%
L = 5*5% (connection failure) = 25%

FABC = (1+N+M+L) * ABC=(1 + 0.32 + 0.20 + 0.25)* $228,750
     = $404,888

6. Final Annual Building Revenue
The final score is calculated in the following:

Final Annual Income, FAI:

FAI = $754,075

Final Annual Building Cost, FABC:

FABC = $404,888

Final Annual Seismic Cost, FASC:

FASC = $214,457

The Final Annual Building Revenue, FABR:

FABR = FAI -FABC – FASC
     = $134,730
### D. Score Sheet

Team: _________________________    Judge: _________________________

#### Presentation
- Structural Concept/Innovation: ___ / 10
- Analysis Method: ___ / 10
- Test Results on material property and/or structure response: ___ / 10
- Clarity/ Organization of Slides: ___ / 10
- Communication Skills: ___ / 10

Average: ___ / 10

#### Poster
- Technical Merit: ___ / 10
- Organization: ___ / 10
- Readability: ___ / 10
- Visual Appeal: ___ / 10

Average: ___ / 10

#### Structure
- Architecture: ___ / 20
E. **Expenses / Shipping**

Expenses associated with individual team participation in the competition can be funded by multiple sources. Competition sponsors will subsidize some expenses, but the amount of financial assistance that each team receives depends on the number of registered teams. This financial support is only intended to offset costs for up to four members per team, but will generally not be sufficient by itself for an entire team. When the number of teams is known after the registration deadline, registered teams will be notified of the amount of support they will be given. Any remaining expenses will be the responsibility of the individual team.

Teams are strongly encouraged to seek funding from their departments, ASCE Student Chapters, local engineering community or other local businesses. Sponsors may need to be notified well ahead of time so it may be prudent to begin to seek sponsorship as early as October or November.

If the model will be shipped to the competition via FedEx or UPS, then a strong box (crate like) with minimum of 2 inches of padding surrounding the entire model is recommended. The box or crate should be labeled fragile, insured for an appropriate amount, and if possible instructed to be transported with great caution. A heavy box will be costly to ship, so be efficient in designing the shipping boxes. Models should be shipped early enough such that final delivery will occur prior to the competition. A structure should be presented to the organizing committee prior to noon on Thursday, February 4th, 2009. Any structure arriving after that deadline will not be tested. Damage due to shipping is always a risk, so plan accordingly. Keep in mind that no structural modifications or repair are allowed after the deadline provided in the main rules.

The shipping address and details will be posted on the competition website.
F. **Competition History**

**First Competition: May 12th, 2004**  
University of California, Berkeley – Richmond Field Station

1. University of California, Irvine (Team 1)  
2. University of California, Irvine (Team 2)  
3. University of California, San Diego  
4. University of California, Davis  
5. Oregon State University

**Second Competition: April 30th, 2005**  
University of California, Berkeley – Davis Hall Structures Lab

1. University of California, Davis (Team 2)  
2. Florida A&M University (MCEER)  
3. University of California, Berkeley  
4. Oregon State University  
5. University of California, Davis (Team 1)  
6. University of Illinois, Urbana-Champaign (MAE)

**Third Competition: April 21st - 22nd, 2006**  
Moscone Center, San Francisco, California

1. University of Washington  
2. University of California, Berkeley  
3. University at Buffalo  
4. University of California, Davis  
5. Georgia Tech  
6. University of Hawaii  
7. Oregon State University  
8. University of California, San Diego

**Fourth Competition: February 8th – 10th, 2007**  
Universal City Hilton Hotel, Los Angeles, California

1. Oregon State University  
2. San Jose State University  
3. University of California, Davis  
4. University of Hawaii  
5. Washington University  
6. University at Buffalo  
7. University of Washington  
8. University of California, San Diego  
9. New Jersey Institute of Technology  
10. University of California, Berkeley  
11. University of Texas, Austin  
12. Cal Poly, San Luis Obispo  
13. University of California, Irvine  
14. Florida A & M University
Fifth Competition: February 6th – 9th, 2008
Astor Crowne Plaza Hotel, New Orleans, Louisiana

1. University of California, San Diego
2. University of Texas, Austin
3. University of Buffalo
4. University of Nevada, Reno
5. Purdue University
6. University of Florida
7. Oregon State University
8. Washington University
9. University of California, Los Angeles
10. San Jose State University
11. Cal State University, Sacramento
12. New Jersey Institute of Technology
13. University of California, Davis
14. Cal State University, Los Angeles
15. Florida A&M University
16. Roger Williams University
17. Cal Poly San Luis Obispo

Sixth Competition: February 6th – 9th, 2009
Salt Lake City Center Hilton Hotel, Salt Lake City, Utah

1. Cal Poly San Luis Obispo
2. Brigham Young University
3. Oregon State University
4. University of Texas, Austin
5. University of California, San Diego
6. San Jose State University
7. University of Buffalo
8. Roger Williams University
9. Purdue University
10. University of California, Davis
11. University of California, Los Angeles
12. Cal Poly Pomona
13. University of Nebraska
14. Cal State University, Los Angeles
15. University of Missouri, Colombia
16. Georgia Institute of Technology
17. Cal State University, Sacramento
18. University of Florida