Eighth Annual Undergraduate Seismic Design Competition

San Diego, CA

Appendix

Organized and Run by:

EERI Student Leadership Council (SLC)

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

Email: *seismic.design.competition@gmail.com*

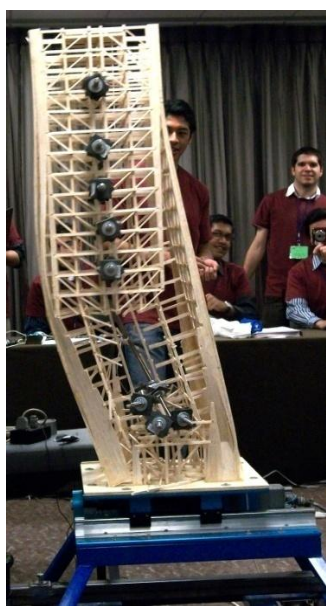

Table of Contents

A. Data Processing 3

B. Shake Table 4

C. Ground Motions 5

D. Example Problem 7

E. Score Sheet 11

F. Expenses / Shipping 12

G. Competition History 13

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^{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).

Figure B-1: University Consortium for Instructional Shake Tables (UCIST)

C. **Ground Motions**

Time histories of the three ground motions are shown in Figure C-1. The first two motions are scaled versions of historic earthquakes. They are scaled to fit the maximum capacity of the shake table. The third ground motion is an artificial ground motions made from historic earthquakes and sinusoidal waves. Figure C-2 shows pseudo-acceleration response spectra of the three motions.

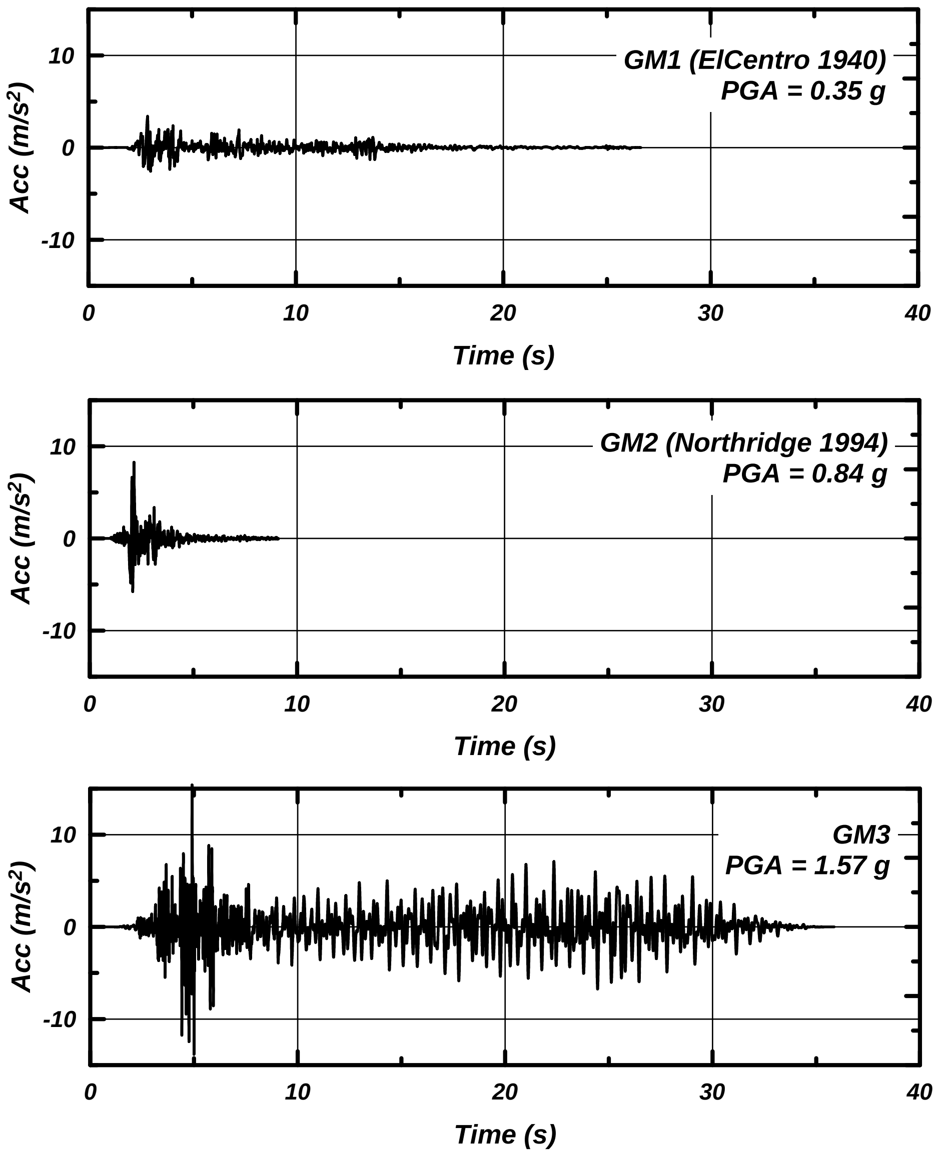

Figure C-1: Time histories of the ground motions

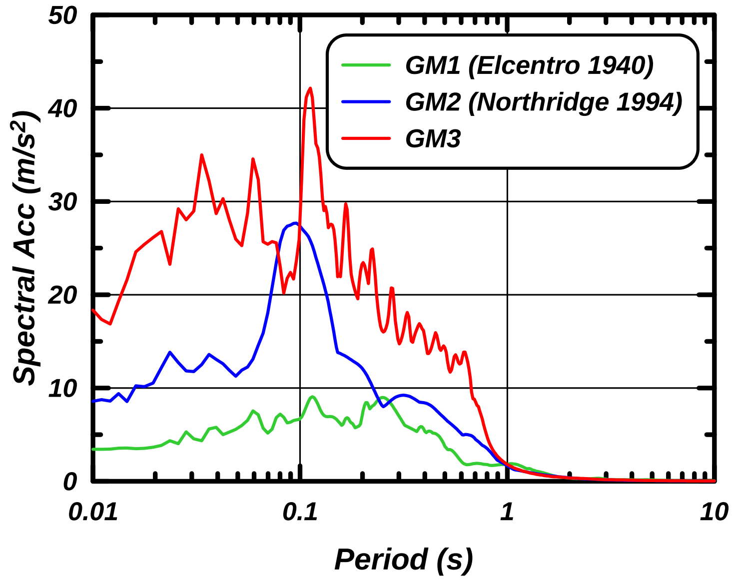

Figure C-2: Pseudo-Acceleration response spectra of the three ground motions

D. **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 design 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 m^2 (4,340 $inch^2$). 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 in^2) x ($125 / in^2 / year) = $542,500/ year.

2. Annual Initial Building Cost

The structure occupied a footprint area of 225 $inch^2$ (0.14 m^2). Hence, the cost of land beneath the building was (225 in^2) x ($35,000 / in^2) = $7,875,000. Divided by the design life of the structure, the annual cost of land is ($7,875,000) / (100 years) = $78,750/ year.

The mass of the structure was 1.5 kg (3.3 lb). Hence, the initial construction cost was (1.5 kg) x ($10,000,000 / kg) = $15,000,000. Divided by the design life of the structure, the annual construction cost of the building is ($15,000,000) / (100 years) = $150,000 / 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/ year + $150,000 / year = $228,750 / year.

3. Annual Seismic Cost

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

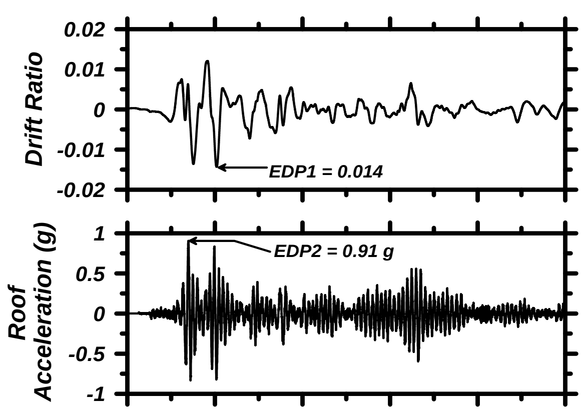

Figure D-1: Time series for the 2004 UCSD structure during the GM1.

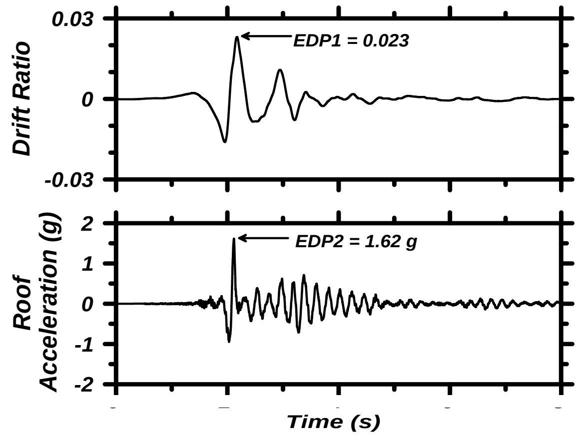

Figure D-2: Time series for the 2004 UCSD structure during the GM2.

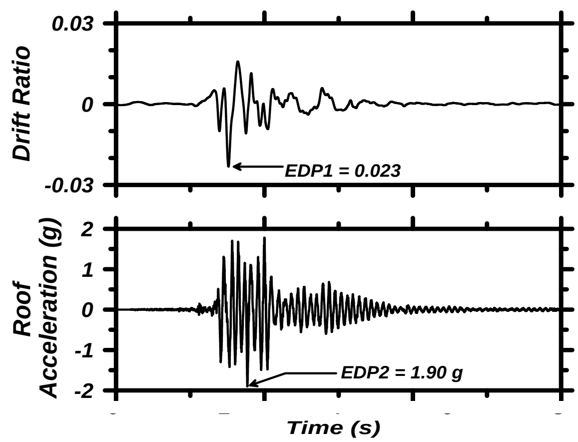

Figure D-3: Time series for the 2004 UCSD structure during the GM3.

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

Motion	Engineering Demand Parameter (EDP)	
	Max |Drift Ratio| (EDP1)	Max |Roof Acc| (g) (EDP2)
GM1	0.014	0.91
GM2	0.023	1.62
GM3	0.023	1.90

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

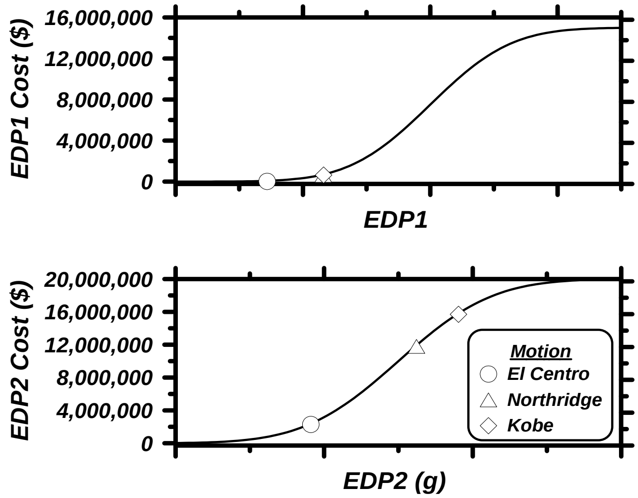

Figure D-4: Seismic cost summary for 2004 UCSD structure.

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

Motion	Cost $ (Annual Cost $/year)	
	EDP1	EDP2
GM1	75,900 (1,518)	2,352,840 (47,057)
GM2	681,830 (4,546)	11,866,110 (79,107)
GM3	681,830 (3,409)	15,769,820 (78,849)

The annual seismic cost is calculated as follows, annual seismic cost =[(seismic cost of GM1/ return period of GM1) + (seismic cost of GM2/ return period of GM2) + (seismic cost of GM3/ return period of GM3)] x (1+D). The seismic cost of each GM comes from two parts: EDP1 (related to the drift ratio) and EDP2 (related to the roof acc); D comes from the structural damage per section 7.2. The $ for EDP1 is calculated by multiplying the EDP1 by the initial construction cost. And the $ for EDP2 is calculated by multiplying the EDP2 by $20'000'000 (price of an assumed equipment sensitive to acc).

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

Annual Seismic Cost = $1,518 + $47,057 + $4,546 + $79,107 + $3,409 + $78,849

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

FABC = (1+N+M+L) x ABC=(1 + 0.32 + 0.20 + 0.25)x $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

E. **Score Sheet**

Team: ______________________________ Judge: ______________________________

Presentation

Structural Concept/Innovation	____ / 10
Analysis Method	____ / 10
Clarity and Organization	____ / 10
Communication Skills	____ / 10
Average	____ / 10

Poster

Technical Merit	____ / 10
Organization	____ / 10
Readability	____ / 10
Visual Appeal	____ / 10
Average	____ / 10

Structure

Architecture	____ / 10

F. **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 Wednesday, February 9th, 2011. 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 (repairs are OK) are allowed after the deadline provided in the main rules.

The shipping address and details will be posted on the competition website.

G. **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)
2. 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
4. 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

Seventh Competition: February 3rd – 6th, 2010
Parc 55 Hotel, San Francisco, California

1. University of California, San Diego
2. University of Missouri
3. University of Nebraska, Lincoln
4. Brigham Young University
5. University of California, Los Angeles
6. Purdue University
7. California State University, Los Angeles
8. University of Illinois, Urbana Champaign
9. San Jose State University
10. University of California, Berkeley
11. University of California, Davis
12. University of British Colombia
13. University of Texas, Austin
14. Oregon State University
15. Cal Poly San Luis Obispo
16. Cal Poly Pomona
17. California State University, Fullerton
18. University of Massachusetts, Amherst
19. University of Southern California
20. University at Buffalo
21. Roger Williams University
22. Georgia Tech