

# *Ninth Annual Undergraduate Seismic Design Competition (SDC)*

*Memphis, TN*

## *Appendix*

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

**Competition Website:** <http://slc.eeri.org/SDC2012.htm>

**Email:** [seismic.design.competition@gmail.com](mailto:seismic.design.competition@gmail.com)



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## A. Data Processing

Two accelerometers will be utilized in the competition: one accelerometer will be attached onto the shake table, and the other accelerometer will be attached onto the roof plate.

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<sup>rd</sup> 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 to the noise. Highly unrealistic displacements would be obtained if the raw data were integrated in time without first filtering 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.

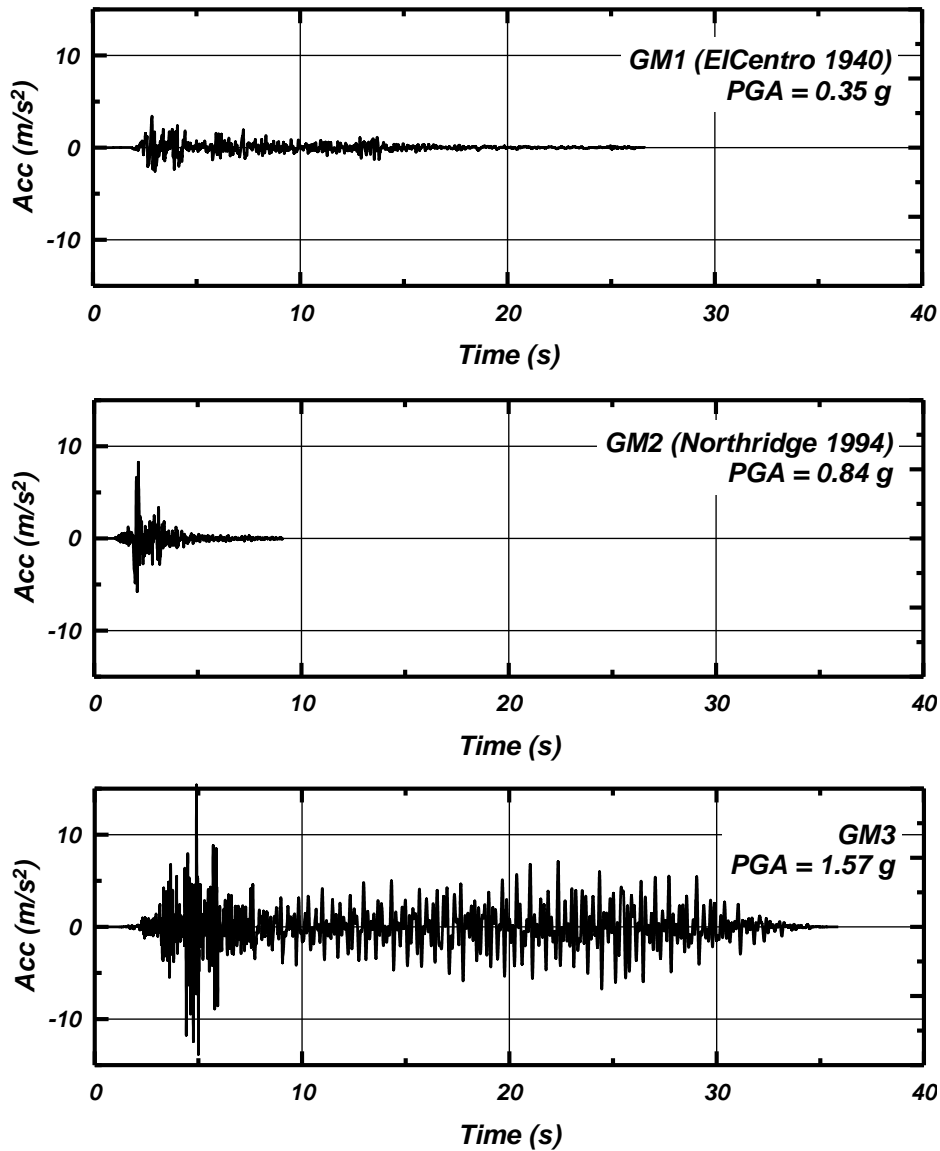


Figure C-1: Time histories of the ground motions

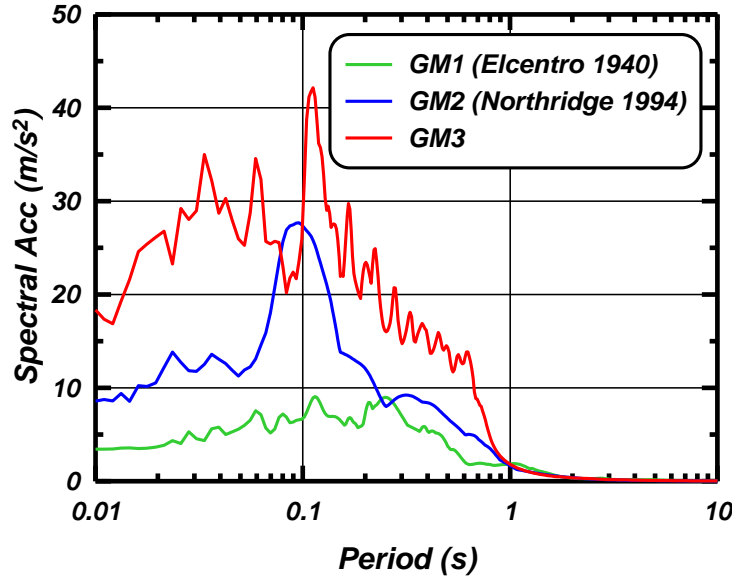


Figure C-2: Pseudo-Acceleration response spectra of the three ground motions

## D. Example Problem

In this section, evaluation of Team A's structure is used to illustrate the scoring procedure, and will be computed according to the 2012 rules.

### 1. Annual Revenue

The structure is 15 stories tall, and the useable floor area is  $2.8 \text{ m}^2$  ( $4,340 \text{ inch}^2$ ). The annual revenue per square meter is \$125 since all of the floors are lower than 15 stories. Hence, the revenue for the building is  $(4,340 \text{ in}^2) \times (\$125 / \text{in}^2 / \text{year}) = \$542,500 / \text{year}$ .

### 2. Annual Initial Building Cost

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

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

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 structure resisted GM1 and GM2 but it collapsed during GM3. The time series from which the EDP's are computed for GM1 and GM2 are shown in Figures D-1 and D-2, respectively. The EDP's are summarized in Table D-1.

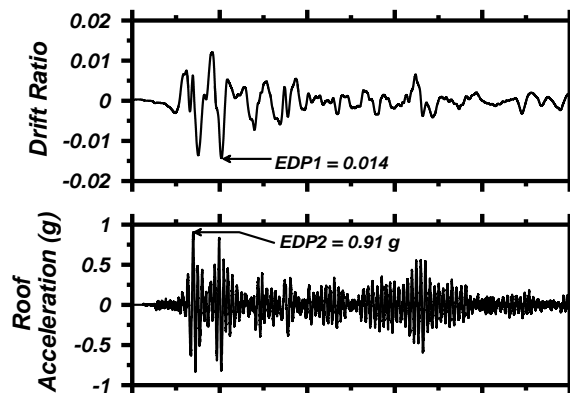


Figure D-1: Time series for the Team A structure during the GM1.

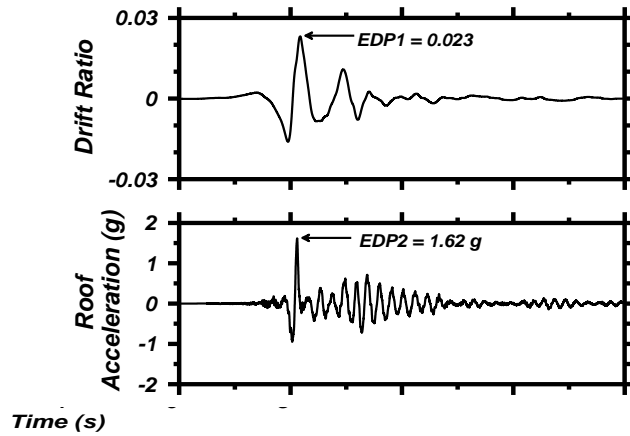


Figure D-2: Time series for the Team A structure during the GM2.

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	-	-

The seismic costs for GM1 and GM2 computed from the EDP's in Table D-1 are shown in Figure D-3. For GM3, the seismic cost is the sum of the two multiplied by the construction cost ( $2 \times \$15,000,000$ ), the equipment cost ( $\$20,000,000$ ) and three years of revenue ( $3 \times \$542,500$ ). These values are also summarized in Table D-2, along with the annual seismic cost for each case obtained by dividing the seismic cost by the ground motion return period.

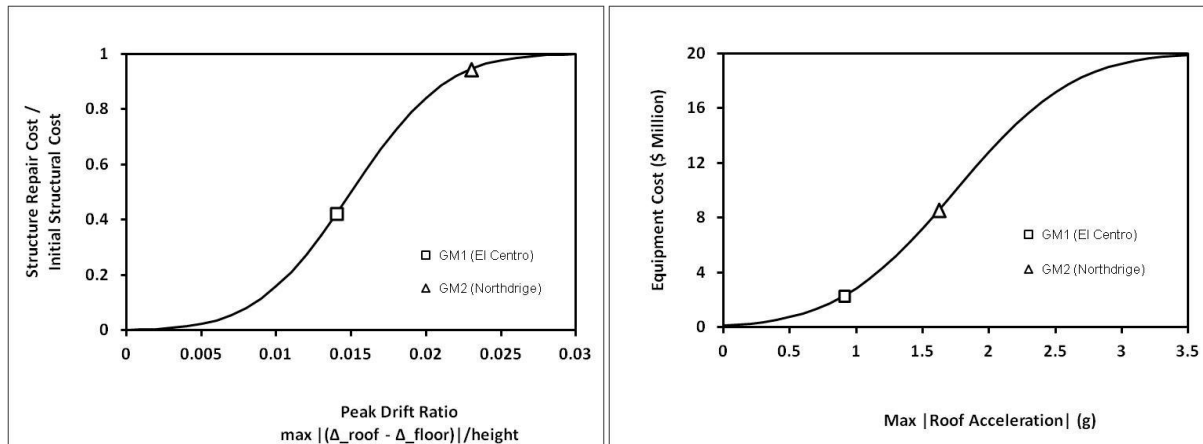


Figure D-3: Seismic cost summary for Team A's structure for GM1 and GM2

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

Motion	Cost \$ (Annual Cost \$/year)		
	EDP1	EDP2	Collapse
GM1	6,311,104 (126,222)	2,301,393 (46,028)	-
GM2	14,178,011 (94,520)	8,526,688 (56,845)	-
GM3	-	-	51,627,500 (172,092)

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

$$\begin{aligned} \text{Annual Seismic Cost} &= \$126,222 + \$46,028 + \$94,520 + \$56,845 + \$172,092 \\ &= \$495,706 \end{aligned}$$

#### 4. Annual Revenue Increase

According to the judges' scores, Team A ranked first in presentation, second in poster, and third in architecture. As a result, they received a bonus in the annual revenue of 15%, 9%, and 10%.

$X = +15\%$                       Annual Revenue Increase from Presentation  
 $Y = +9\%$                          Annual Revenue Increase from Poster  
 $Z = +10\%$                         Annual Revenue Increase from Architecture

$$\begin{aligned} FAR &= (1 + X + Y + Z) \times AR \\ &= (1 + 0.15 + 0.09 + 0.10) \times \$542,500 \\ &= \$726,950. \end{aligned}$$

## 5. Annual Building Cost Increase

The structure's lobby floor height is 4.75 in. The structure has three floors that measure 2.25in (center to center). The team is penalized for exceeding the lobby's floor height limit by 0.75 in and by exceeding the floor height by 0.25 in for three floors. No weight penalty is applied because the weight of the building (1.5 kg, 3.3 lb) is lower than the maximum permitted (2.2 kg, 4.85 lb). Their annual building cost increase is as follows:

$$N = 3 \times 2\% \text{ (lobby height)} + 3 \times 2\% \text{ (floors)} = 12\%$$
$$M = 0$$

$$FABC = (I + N + M) \times ABC$$
$$= (1 + 0.12 + 0) \times \$228,750$$
$$= \$256,200$$

## 6. Annual Seismic Cost Modification

Five connections fail during GM2. They are penalized for it and their seismic cost is increased. However, since Team A had the best performance prediction for GM1 they receive a 15% reduction. The annual seismic cost modification is as follows:

$$D = 5 \times 5\% \text{ (connection failure)} = 25\%$$
$$APS = 15\%$$

$$FASC = (I + D - APS) \times ASC$$
$$= (1 + 0.25 - 0.15) \times \$492,630$$
$$= \$545,277$$

## 7. Final Annual Building Income

The final score is calculated in the following:

Final Annual Revenue, FAR:

$$FAR = \$726,950$$

Final Annual Building Cost, FABC:

$$FABC = \$256,200$$

Final Annual Seismic Cost, FASC:

$$FASC = \$545,277$$

The Final Annual Building Income, FABI:

$$FABI = FAR - FABC - FASC$$
$$= \$726,950 - \$256,200 - \$545,277$$
$$= -\$74,527$$

## E. Score Sheet 1: Presentation

Team: \_\_\_\_\_ Judge: \_\_\_\_\_

### **Presentation**

Structural Concept/Innovation	_____ / 10
Analysis Method	_____ / 10
Clarity and Organization	_____ / 10
Communication Skills	_____ / 10
<hr/>	
Average	_____ / 10

## F. Score Sheet 2: Poster and Architecture

Team: \_\_\_\_\_ Judge: \_\_\_\_\_

### Poster

Technical Merit \_\_\_\_\_ / 10

Organization \_\_\_\_\_ / 10

Readability \_\_\_\_\_ / 10

Visual Appeal \_\_\_\_\_ / 10

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Average \_\_\_\_\_ / 10

### Structure

Architecture \_\_\_\_\_ / 10

## **G. 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. 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. 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.

## H. Competition History

### **First Competition: May 12<sup>th</sup>, 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 30<sup>th</sup>, 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 21<sup>st</sup> - 22<sup>nd</sup>, 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 8<sup>th</sup> – 10<sup>th</sup>, 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 6<sup>th</sup>– 9<sup>th</sup>, 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 6<sup>th</sup>– 9<sup>th</sup>, 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, Columbia
16. Georgia Institute of Technology
17. Cal State University, Sacramento
18. University of Florida

**Seventh Competition: February 3<sup>rd</sup>–6<sup>th</sup>, 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 Columbia
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

**Eighth Competition: February 10<sup>th</sup>– 12<sup>th</sup>, 2011**  
**Hyatt Regency La Jolla, San Diego, California**

1. Oregon State University
2. California Polytechnic State University, San Luis Obispo
3. University of Illinois Urbana Champaign
4. University of Southern California
5. California Polytechnic University, Pomona
6. Brigham Young University
7. Penn State University
8. UC Davis
9. San Jose State University
10. University of Texas, Austin
11. UC San Diego
12. California State University, Fullerton
13. UC Irvine
14. UC Berkeley
15. California State University, Los Angeles
16. Technical University Cluj-Napoca, Romania
17. University of Nebraska-Lincoln
18. Johns Hopkins University
19. University of British Columbia
20. Roger Williams University
21. Purdue University
22. Georgia Institute of Technology
23. San Francisco State University
24. University of Missouri
25. UC Los Angeles
26. University at Buffalo
27. Universiti Teknologi Malaysia
28. University of Massachusetts Amherst