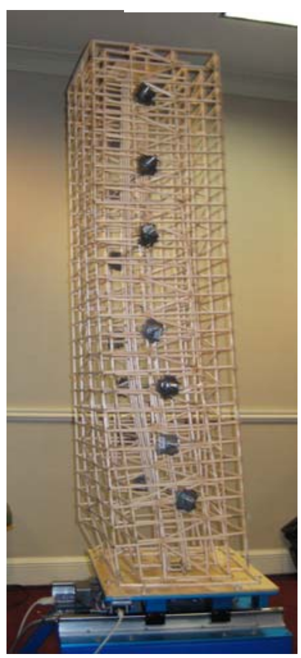
2009 Undergraduate Seismic Design Competition Rules

Sixth Annual Competition

Sponsored by:

- Earthquake Engineering Research Institute (EERI)
- Computers & Structures, Inc. (CSI)
- Federal Emergency Management Agency (FEMA)
- Degenkolb – Consulting Structural Engineers



Competition Developed, Planned and Hosted by:

EERI Student Leadership Councils
(Formerly PEER SLC)

New EERI website, TBA

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1.0 Introduction

This section describes the competition objectives, the major rule changes for 2009 and the structural design objective. A tentative competition schedule will be presented as well.

1.1 2009 Competition Objectives

The objectives of this Sixth Annual Undergraduate Seismic Design Competition sponsored by EERI are:

- To provide civil engineering undergraduate students an opportunity to do a hands on project within a performance-based seismic design framework by designing and fabricating a cost effective frame structure that performs well under earthquake simulation.
- To promote the study of earthquake engineering amongst undergraduates.
- To build the awareness of the versatile activities at EERI among the civil engineering students and faculty at the core universities as well as the general public in order to encourage nation-wide participation.
- To increase the attentiveness of the value and benefit of the Student Leadership Council (SLC) representatives and officers among the core universities for the recruitment and development of SLC, which is a key liaison between students and the research centers.

The competition will be held February 11-14 at the Hilton Salt Lake City Center hotel in Salt Lake City, Utah. This event will be held in conjunction with the EERI Annual Meeting. Undergraduate teams are strongly encouraged to attend the sessions of this conference. More information about this conference is available online at: *http://www.eeri.org/site/content/category/14/123/254/*

The competition will be open to teams from any university, and it will be organized by the Earthquake Engineering Research Institute.

1.2 Summary of Rule Changes

1.2.a Just as in the 2008 competition hosted by the three research centers and EERI, a performance based scoring method will be used, and is based on three primary components: annual income, annual initial building cost, and annual seismic cost. These three components will be used to calculate the structural performance, in terms of annual revenue. The team with the largest annual revenue will be the winning team. Details of each component are given in Sections 5 and 6.

1.2.b SLC will send a paper layout of the base and roof plates after the registration deadline. Each team will be responsible for manufacturing their own base and roof plates. Further details are included in sections 2.10 and 2.11.

1.2.c The maximum weight of the structure has been reduced to 3kg (6.6 lb).

1.2.d The weights to be attached to the structure have been increased to 10.8 kg (23.75 lb).

1.2.e Openings for access to the core are required.

1.2.f The architectural contribution to the score has been doubled from last years, as noted in section 6.4.

1.2.g All columns must be securely fastened to the base plate and no base isolation of any kind is permitted. Refer to section 2.9 for more details.

1.3 Structural Design Objective

Your team has been hired to submit a design for a multi-level commercial office building. To verify the seismic load resistance system, a scaled model must be constructed from balsa wood and will be tested under severe earthquake simulation. Model structures shall be constructed at a scale of 72:1. 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). Structures should withstand scaled versions of ground motions recorded during the 1940 El Centro, 1994 Northridge and 1995 Kobe earthquakes, which will be available online at the following website: http://peer.berkeley.edu/students/Seismic.html

Seismic performance of the designated structure will be evaluated by monitoring the accelerations at the roof and on the shake table. Accelerations will be integrated, as discussed in Section 3.0, to obtain displacements. A structure that has a low peak drift ratio between the roof and the shake table is desired, as well as a low peak roof acceleration.

1.4 Tentative Competition Schedule

The competition schedule presented below is subject to change. Teams will be notified of the final schedule in the weeks leading up to the event. See the competition website for updates to the competition schedule.

To be determined

NOTE: This schedule allows a lot of free time for participating students to take advantage of conference events, presentations and social functions.

2.0 <u>Overview of Rules and Eligibility Requirements</u>

2.1 **Eligibility:**

The following rules shall be strictly followed:

2.1.a Participants must be currently enrolled undergraduate students and may come from any university in the USA or internationally. For teams who wish to enter and desire assistance in finding financial support, the organizing committee will assist the search for funding.

2.1.b Teams may have as many undergraduate student participants as they wish; however, cost of travel and lodging should be considered as EERI funding for each team will be limited.

2.1.c Each competing university can enter one student team and one structure at the competition.

2.1.d Completed registration and preliminary structural plans must be submitted by November 12th and December 5th, 2008, respectively. See section 6.0 for registration details.

2.2 There is no limit to the number of sponsors supporting the materials supplied, transportation, and other expenses.

2.3 If financial assistance was provided by external sponsors, those sponsors' names and/or logos may appear on the structure or on any clothing worn by the team. However, it should be below the school name, which is at the top of the structure, as described in section 2.4.

2.4 The university name should be placed at the top of the structure, on a banner or paper (non-structural element). The size of this banner shall not exceed a length of 6 inch and a height of 1 inch.

2.5 The structure shall be constructed prior to competition. No structural modifications will be allowed at the competition. If a structure is damaged in transport, it may be repaired to its original design at the competition.

2.6 Participating teams are responsible for transportation of their structure to and from the competition site. Transportation of structure should be considered in the design and construction of the model. See Section 8.0 for transportation details.

2.7 EERI SLC will be responsible for selecting three to five judges from the structural and earthquake engineering industry and academia to score all aspects at the competition.

2.8 Judges will determine the direction of shaking on the structure.

2.9 **Structural Model**

2.9.a Structures shall be made of balsa wood. Columns may have a maximum cross section of 6.4 mm (1/4 inch) by 6.4 mm (1/4 inch). Beams may have a maximum cross section of 6.4 mm (1/4 inch) by 3.2 mm (1/8 inch). Built up beams or columns, consisting of two or more balsa wood members glued together, are not permitted. Circular balsa wood columns are permitted with a diameter up to 6.4 mm (1/4 inch).

2.9.b Allowable lateral force resisting systems include: X-bracing, diagonal bracing, eccentric bracing, moment connections, and shear walls.

2.9.c Diagonal bracing elements, including X-braces, shall be constructed only in vertical planes, in the North-South, or East-West directions. A brace in a three dimensional space will not be allowed and will result in no income for the space. Braces in three dimensional space will be allowed only if used on an exterior portion of the structure with such three dimensional geometry.

2.9.d Shear walls constructed of balsa wood with a thickness not exceeding 3.2 mm (1/8 inch) are allowed. Shear walls must have a minimum length of 25.4 mm (1.00 inch). Shear wall height is not restricted. Columns can be attached to the ends of a shear wall.

2.9.e Moment frame connections are allowed. The height and length of such connections shall not exceed 3 times the maximum cross sectional dimension (width or thickness) of the members being joined, as shown in Figure 2-2. The thickness shall not exceed the minimum cross sectional dimension of the members being joined.

2.9.f The interior building core usually reserved for elevators, emergency exit staircases, and utilities, etc, must not be blocked by braces, shear walls and columns. To be specific, for each floor, a minimum of one access opening in the E-W direction and a minimum of one access opening in the N-S direction are required. Each access opening should have minimum model dimensions of 25.4 mm (1.00 inch) width by 38.1 mm (1.50 inch) height. The model will need adequate space at floors which will have a weight installed through it during shaking. See section 2.13 for details of added dead weight.

2.9.g Each structure shall be constructed at a scale of 72:1. This corresponds to a prototype floor height of 3.66 m (12 ft) and a model scale floor height of 50.8 mm (2 inch).

2.9.h Floor level diaphragms need not be constructed. Weights, to be attached at the competition, will simulate the dead load of floor diaphragms, office walls, furniture, and live load.

2.9.i Structural damping devices, such as viscous dampers, are allowed in the design.

2.9.i.1 A damper will be included in the weight of the structure. Any material is allowed to manufacture a mass damper, however it must be homemade. (For example, premanufactured RC dampers are not allowed.) The implementation of such a device needs to allow for the placement of weights as discussed in Sections 2.14 and 4.2. Damper attachments to the structure may not reinforce any other structural connections.

2.9.i.2 Teams should consider that damping devices installed in 3-dimensional space (not in the same plane as an existing wall) will reduce rentable floor space as the dampers render the space unusable.

2.9.i.3 Limits on the dimensions of column and beam cross sections are outlined in section 2.9.a. Dampers may be connected to beams or columns, but a single damper-to-structure connection may not be made to both a beam and a column.

2.9.i.3.1 If a damper is connected to a column, the column's cross-section may not be increased beyond the limits in section 2.9.a by the connection.

2.9.i.3.2 If a damper is connected to a beam, the beam's cross-section may not be increased beyond twice the limits listed in section 2.9.a. That is to say that if a beam is constructed of 1/8" X 1/4" balsawood section, the damper connection may expand the cross-section of the beam to 1/4" X 1/4".

2.9.i.3.3 The length of the connections described above, in the direction of the connected beam or column, may not exceed 1 inch.

2.9.j Connections of structural members can be made only from wood glue. Connections of structural members to the base plate or to the roof plate can be made using wood glue or hot glue.

2.9.k The connection between the base plate and first level columns should be carefully designed to prevent uplift (or separation of the columns from the base plate).

2.9.l All columns on the first floor must be connected directly to the base board. No base isolation of any kind is permitted.

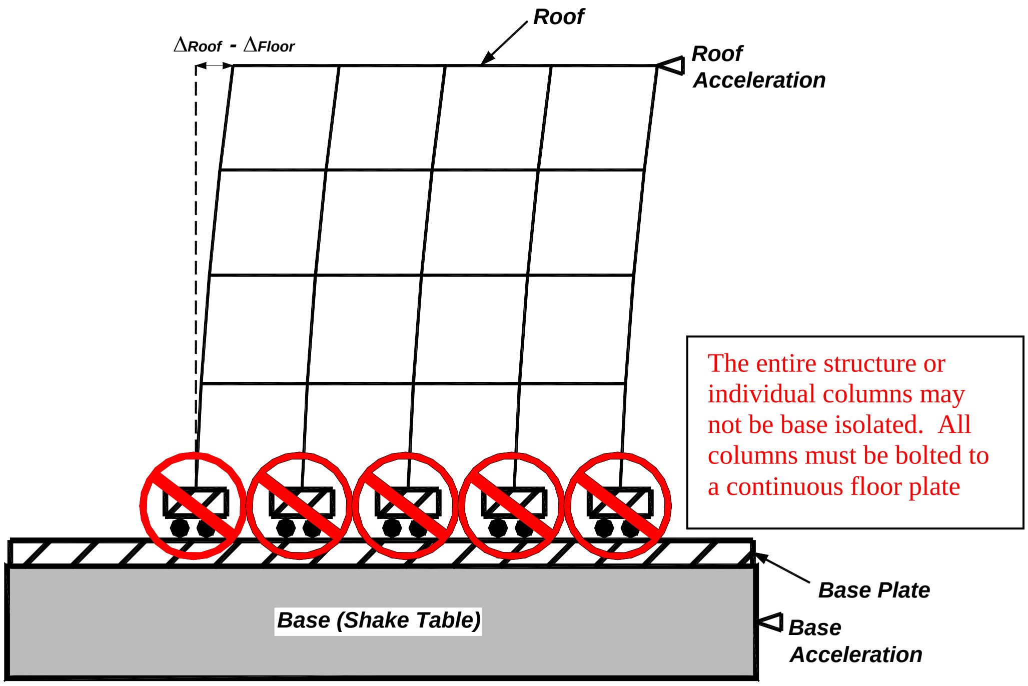


Figure 2-1: Schematic of a structure with base isolation used for individual columns. Such configurations are not allowed.

2.10 **Structural Model Base Plate**

2.10.a A plywood base plate will be used to attach the structure to the shaking table. SLC will send a paper layout of the base plate after the registration deadline. Each team will be responsible for manufacturing their own base plate.

2.10.b An engineering diagram depicting the manufactured base plate is shown in Figure 2-3.

2.11 **Structural Model Roof Plate**

2.11.a A plywood roof plate will be used to attach the accelerometer to the structure. Roof plate templates (paper copies) will be mailed to each team after the registration deadline. Teams are responsible for fabricating their own roof plates and installing them in accordance with section 2.11.b. After the registration deadline, more details will be provided to all registered teams.

2.11.b The roof plate will be a plywood plate of thickness 7.62 mm (3/8 inch) with dimensions of 152 mm by 152 mm (6 inch by 6 inch). The plate will have four 6.35 mm (1/4 inch) diameter holes drilled at 12.7 mm (5 inch) on center to allow for attachment of accelerometer, using bolts, as shown in Figure 4-4. The roof plate needs to be centered and aligned with the base plate. Teams will need to ensure total access to all four holes to allow attachment of weighted mass and accelerometer to roof plate.

2.12 **Structure Dimensions**

2.12.a The maximum base plan dimension of the structure shall be 45.7 cm (15.5 inch) square.

2.12.b The minimum plan area for any single floor is 232 cm^2 (36.0 $inch^2$).

2.12.c No floor plan area shall exceed the floor plan area of the level beneath.

2.12.d Structural height is limited to 1.52 m (5 ft). Structural height shall be measured from the top of the base floor to the uppermost beam member of the top level. The base floor is defined as the top of the base plate

Model dimension details are as specified:

Maximum number of floor levels:	29 levels
Minimum number of floor levels:	15 levels
Maximum building plan dimensions:	38.1 cm (15.0 inch) square
Minimum individual floor plan area:	232 cm^2 (36.0 $inch^2$)
Total building floor plan area (all floors):	**1 m^2 to 3 m^2 (10.76 ft^2 to 32.3 ft^2)**
Required floor height:	5.08 cm (2.00 inch), See section 6.4 for tolerances
Required lobby level height (1st level):	10.2 cm (4.00 inch), See section 6.4 for tolerances
Maximum Model height:	1.52 m (5 ft)
Diaphragms (floors):	Actual floors need not be constructed, beam members are adequate

2.13 **Structural Loading**

2.13.a A dead load of 1.02 kg (2.25 lb) will be placed on floors at increments of one tenth of the structural height (H/10). The dead load (weights) will be placed starting at floor levels corresponding to (1/10) * H up to (9/10) * H. In cases where a floor does not exist at an exact increment of H/10, the weight will be attached to the nearest higher floor.

2.13.b Dead loads will consist of a threaded bar, with a length of 914 mm (36.0 inch), and a diameter of 12.7 mm (1/2 inch). Each threaded bar will have washers and nuts to generate a weight of 1.02 kg (2.25 lb) at the floor level.

2.13.c Weights will be attached to the frame in the direction perpendicular to shaking. Vertical weight connection members (columns) will be needed on all four sides of the structure, since judges will decide the direction of shaking. See Figure 4-3 for a typical weight attachment. Note that some moderate compressive force is required to secure the weights from moving relative to the structure during shaking and the structures should be designed to accommodate these compressive forces and should provide support so that the threaded rods do not move relative to the structure during shaking.

2.13.d A dead load of 1.59 kg (3.5lb), including the accelerometer, will be placed at the roof level. The weight will consist of a steel plate with dimensions of 15.24 cm by 15.24 cm by 1.27 cm (6 inch by 6 inch by 0.5 inch), with a weight of 0.45 kg (3.0 lbs), and the accelerometer, which weighs 0.23 kg (0.5 lbs). See Figure 4-4 for roof configuration.

2.14 Mass of the structural model, including the base and roof plate and any damping devices, should not exceed **3.0 kg (6.61 lb)**. The payload capacity of the shake table is 15.0 kg (33 lb), and approximately 10.8 kg (23.75 lb) of weights will be attached to the floors and roof, leaving 4.2 kg (9.3 lb) to accommodate the structural mass as well as miscellaneous weight.

2.15 The structural finish must be bare wood. Paint or other coatings will *not* be allowed on the structure.

2.16 Scaled Earthquake Ground Motion Records to be used for the testing can be downloaded from:

New EERI website, TBA

2.17 Questions should be directed to the EERI student leadership council (SLC) via email to: seismic.design.competition@gmail.com

2.18 In the Spirit of the Competition, the Judges and/or SLC may take disciplinary action, including warnings, point deductions, or disqualification of a team or entry for inappropriate use of materials, language, alcohol, uncooperativeness, or general unprofessional behavior of team members or persons associated with a team. The judges have the final authority to determine what constitutes a violation of the "spirit of the competition" and may take appropriate action towards point deduction or disqualification.

2.19 **Oral Presentation**

2.19.a Each team will give a five-minute oral presentation to a panel of judges. Judges will have 5 minutes to ask questions following the presentation. Presentations will be open to the public.

2.19.b Presentations should review the structural design, lateral force resisting system, performance prediction, and any other details of relevance.

2.19.c An LCD projector and laptop, running Microsoft Windows XP, and PowerPoint (Office XP) will be provided.

2.19.d Teams will be allowed to run presentations from their own laptops. However, it is strongly recommended that presentations be brought on a USB memory stick and/or CD-ROM in case of technical difficulties with the LCD projector.

2.19.e Judges will determine the order for team presentations and structural testing by random draw.

2.20 **Poster**

2.20.a A poster shall be displayed to show the structural design (plan view, elevation views, and 3D views – if generated), performance prediction, economics, project management, and any other relevant details.

2.20.b The university name and EERI logo should appear at the top of the poster.

2.20.c Posters shall have a height of 1.1 m (42 inch) and a width of 0.91 m (36 inch).

2.20.d A minimum font size of 20 is recommended for general text, and a font size of 40 for the university name.

2.21 A unique architectural form and quality workmanship is highly desired by the owner, as shown in Figure 2-4. See Scoring Section 6.

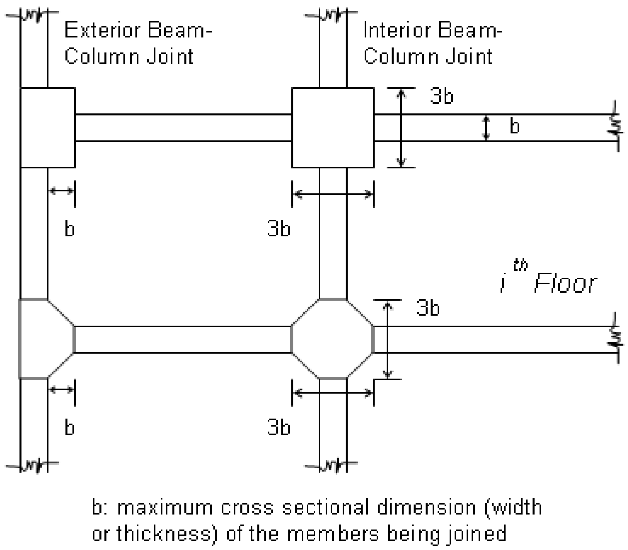


Figure 2-2: Allowable Moment Frame Connection Detail

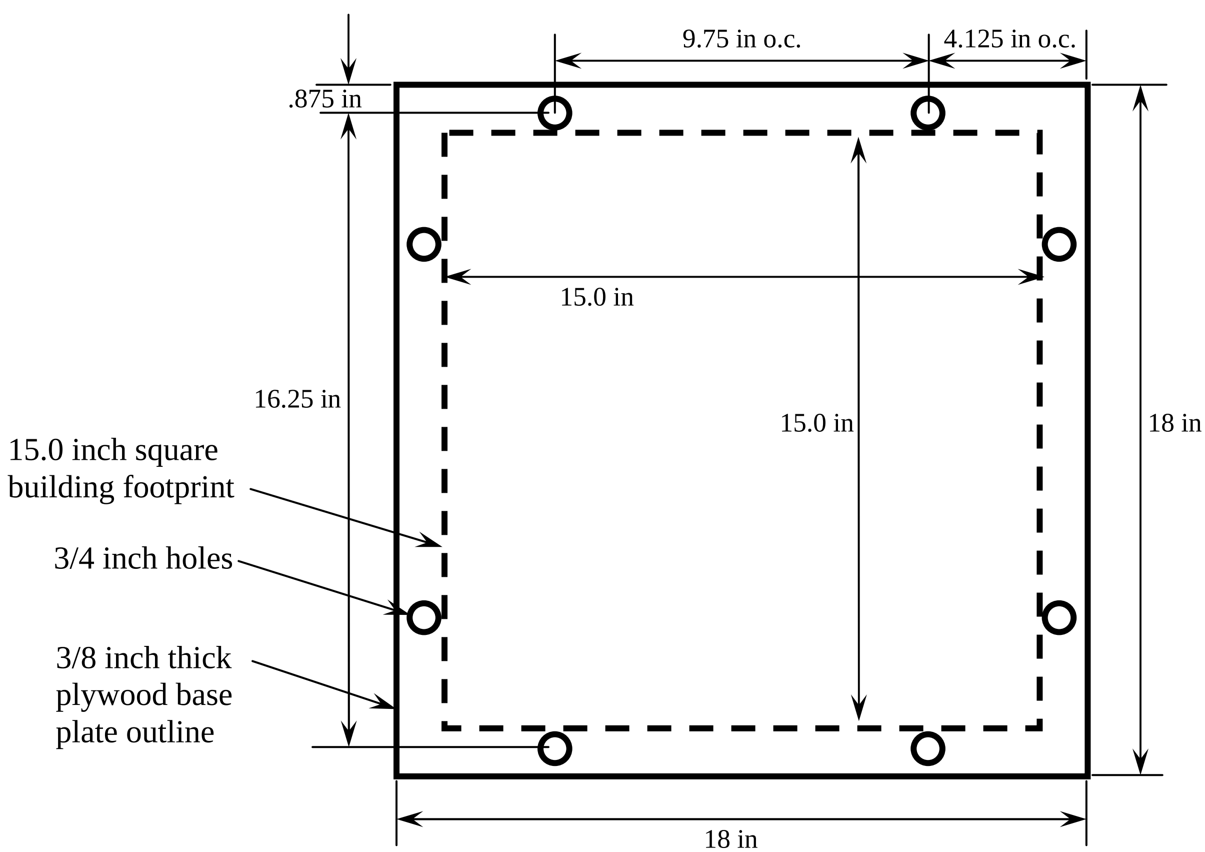


Figure 2-3: Engineering drawing of base plate to be fabricated by each team.

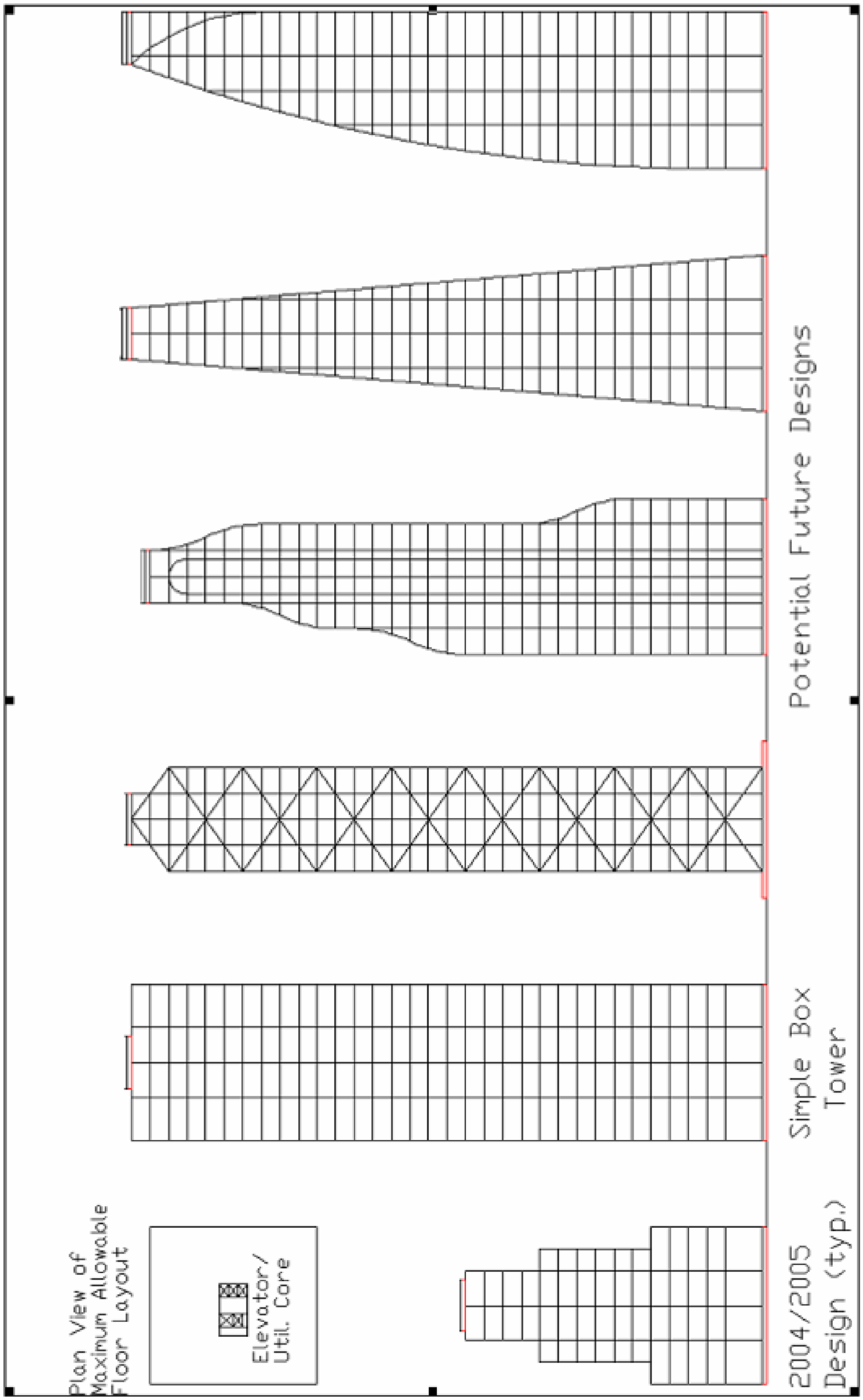


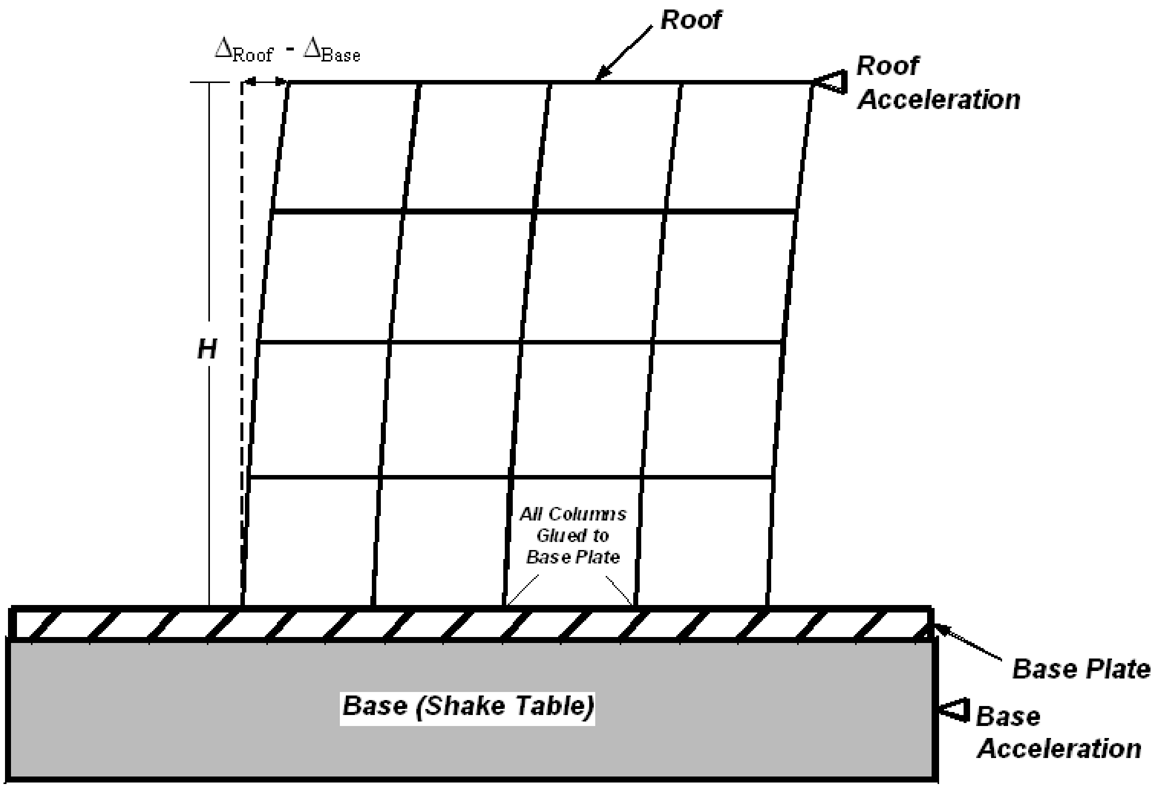
Figure 2-4 Structural/Architectural Concepts

3.0 <u>Instrumentation and Data Processing</u>

This section describes the instrumentation setup used to collect the acceleration data, and the methods of data processing used to obtain transient displacements from the recorded accelerations.

3.1 Instrumentation

Horizontal acceleration will be measured in the direction of shaking using accelerometers mounted on the roof of the structure and on the base shaker (Fig. 3-1).



$$EDP1 = \max\left(\left|\frac{\Delta_{Roof} - \Delta_{Floor}}{H}\right|\right)$$

$$EDP2 = \max\left|RoofAcceleration\right|$$

Figure 3-1: Schematic of instrumentation layout and measured engineering demand parameters for structure without base isolation.

Technical specifications of the shaker table, data acquisition system and accelerometers can be found at:

[New EERI website, TBA]

3.2 **Data Processing**

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.

4.0 Structural Testing

This section will present an overview of the structural testing requirements. Details for the shake table, weights placed at floor levels, roof weight, and accelerometers will be presented.

4.1 Shake Table

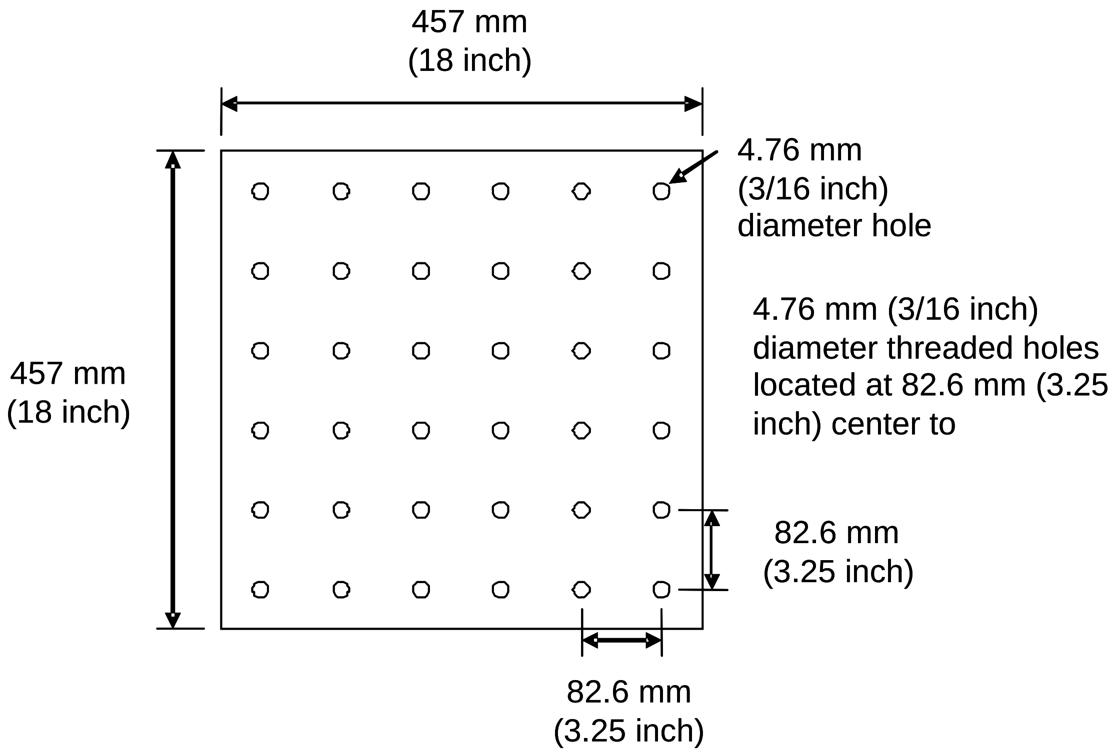
The unidirectional earthquake shake table to be used for testing has the dimensions and bolt hole pattern as shown in Figure 4-1. Shake table payload capacity is 15.0 kg (33 lb).

4.2 Structural Weights at Floor Levels

Details for the threaded bar weights are discussed in Section 2.13. It is strongly recommended that your team purchase a sample weight to ensure proper attachment and fit to your structure at the competition. Additional vertical members (columns) at the location of weights will be needed, as shown in Figures 4-2 and 4-3. The weights must be secured from translation that might occur during shaking. **Weights cannot be secured to the beam alone.** Weights will be secured to the structure using nuts and washers, as discussed in Section 2.13. Weights will be hand tightened to the structure; this will result in a potential inward deformation of the exterior frame, if the weight location is not braced with beams, as shown in Figure 4-3.

4.3 Accelerometer Placement

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.



(a.) Plan View of Shake Table

(b.) Photograph of Shake Table and Operation PC (Data Acquisition not shown)

Figure 4-1: University Consortium for Instructional Shake Tables (UCIST) Earthquake

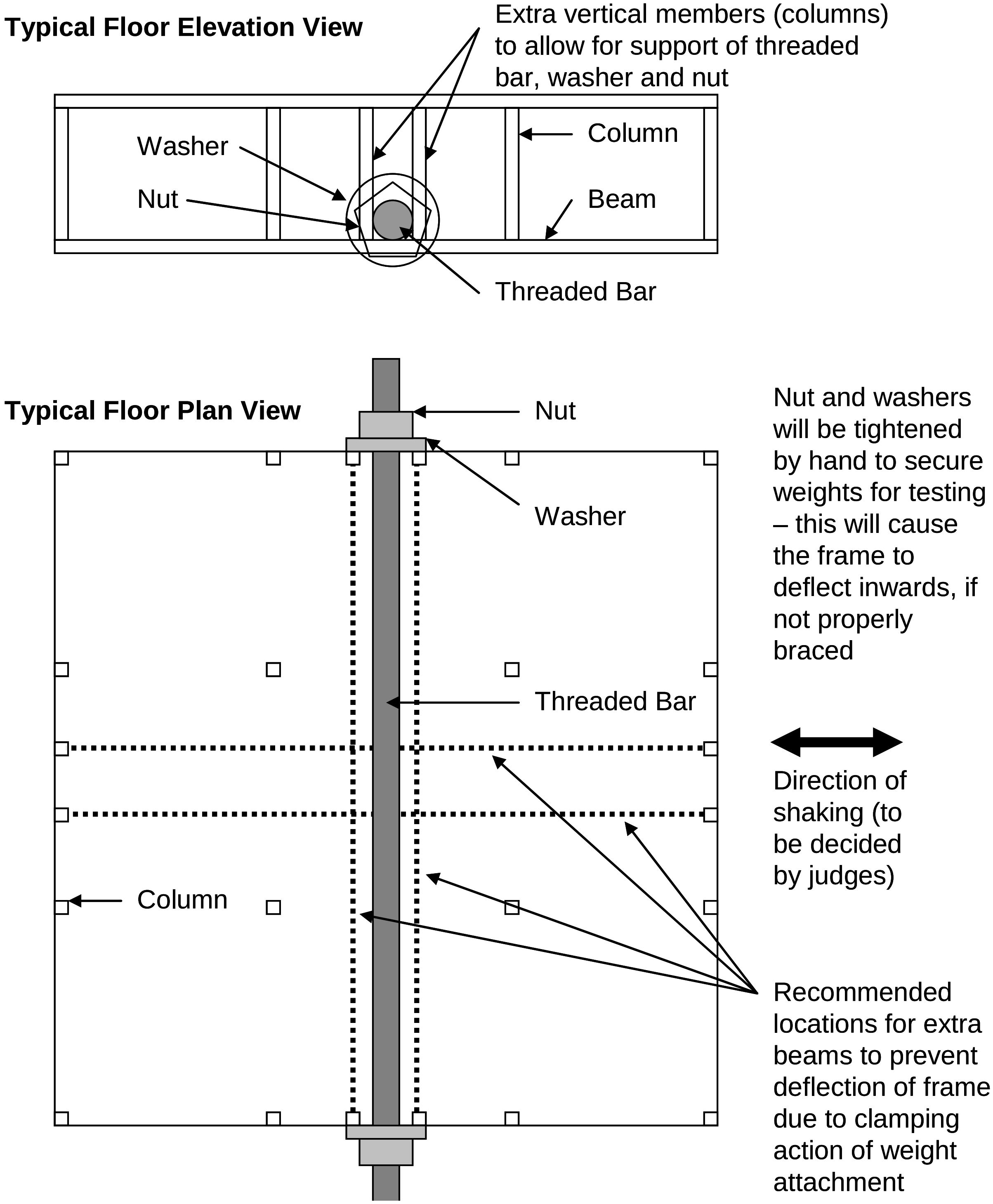
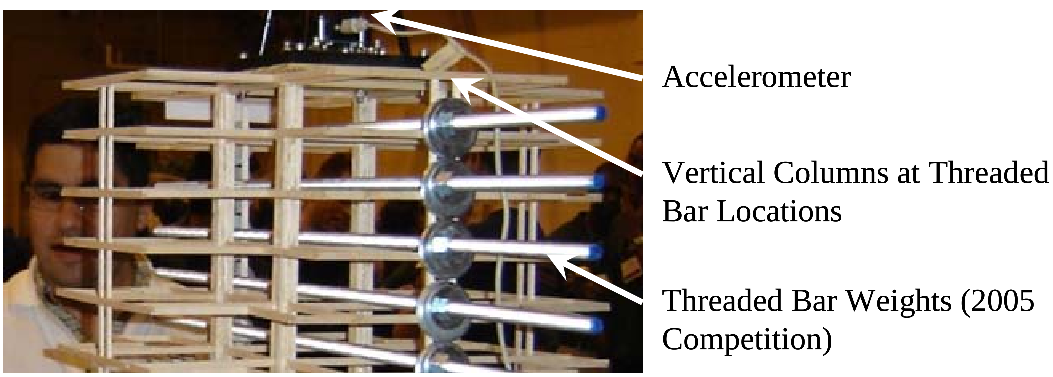


Figure 4-2: Anchorage of Weights to Structure

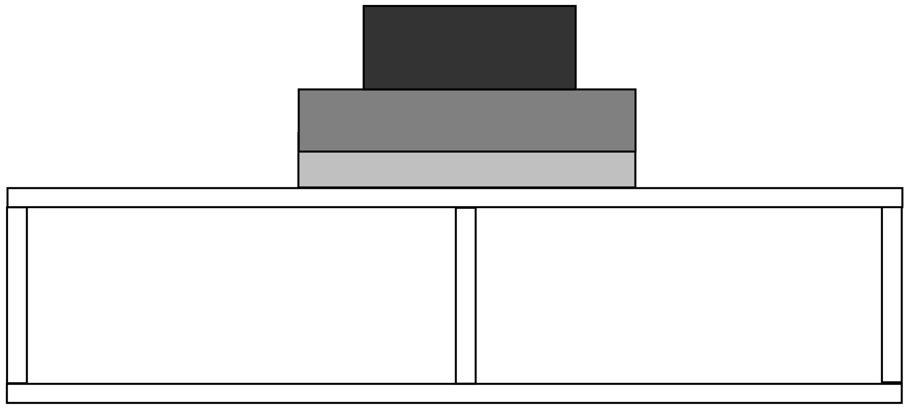
(a.) Example of insufficient support for threaded bars that prevent the requisite tightening of the nuts, thereby permitting the bars to move relative to the structure during shaking. Vertical columns at the location of threaded bars would have facilitated weight attachment, including tightening of the nuts to prevent rolling and sliding of the bars during shaking.



(b.) Example of an ideal support for threaded bars. Vertical columns facilitated weight attachment, and prevented rolling and sliding of the bars during shaking. Photo taken at 2005 competition, when weight distribution differed from this year's configuration.

Figure 4-3: Typical Weight Attachment

Roof Elevation View



Bracing scheme not shown

Note: roof plate will be attached at the center of the roof to ensure even weight distribution and must be aligned with the base plate.

Roof Plan View

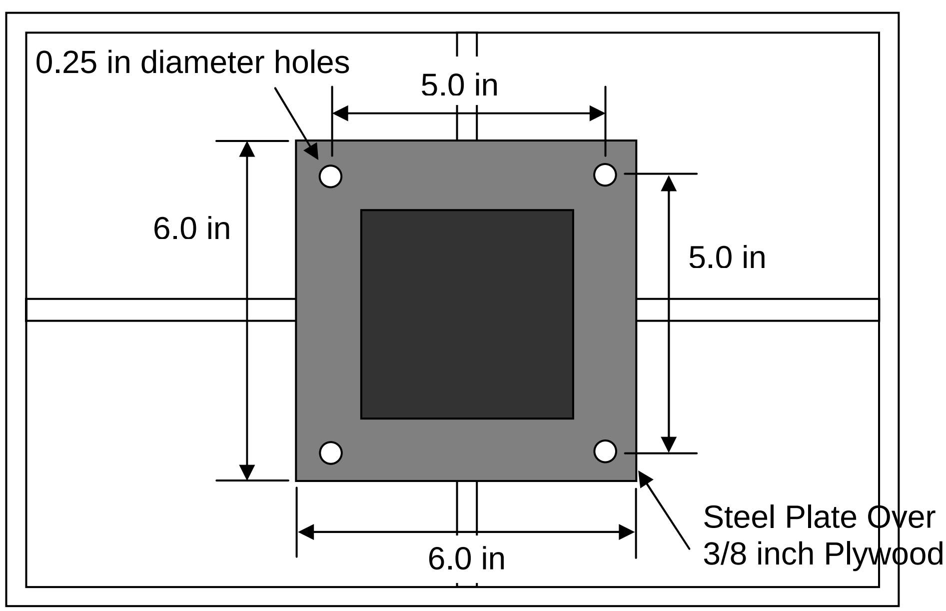


Figure 4-4: Weight and Accelerometer at Roof Level

5.0 <u>Performance-Based Scoring Method</u>

This section describes the performance-based method used to score the seismic performance of the structures in the seismic competition. The method consists of three primary components: 1. Annual income, 2. Annual initial building cost, and 3. Annual seismic cost. The final measure of structural performance is the annual revenue, computed as annual income minus annual building construction cost minus annual seismic cost. An example problem in Section 7.0 demonstrates the scoring method.

5.1 Annual Income

Annual building income will be based on useable floor space, with higher floors bringing in more income than lower floors as follows:

$250 per year per square inch for floors 1 through 15.
$350 per year per square inch for floors between 16 through 24.
$450 per year per square inch for floors 25 and taller.

The floor area will be counted from the bottom up, such that if the maximum total area is reached before reaching the roof, any floors above will not be counted, thus imposing a penalty for exceeding the maximum area.

5.2 Annual Initial Building Cost

The cost of the building will be the cost of the land beneath the building footprint plus the cost of the structure. The cost of land is $35,000 per square inch of building footprint. Building footprint is defined as the floor plan area of the first level (note that no level can exceed the floor plan area of the first level). The initial cost of the building is $10,000,000 per kilogram of building mass. The building mass includes the mass of the structure and any energy dissipation devices (e.g. viscous dampers). Building mass will include the mass of the base and roof plate, but not threaded bars. The mass of these aforementioned items is known and will be subtracted from the mass measured at the competition. The annual building construction cost will be computed by dividing the cost of land and the initial cost of the building by the design life of the building (100 years).

5.3 Annual Seismic Cost

The structures will be subjected to a series of three ground motions with increasing intensity. Small design ground motions occur more frequently than large design ground motions, and the frequency with which each ground motion is anticipated to occur is represented by its return period (Table 5-1).

Table 5-1: Return periods for ground motions used in competition.

Motion	Return Period (Years)
El Centro	50
Northridge	150
Kobe	200

Economic damage from each earthquake will be assessed using loss functions that relate dollar loss to different engineering demand parameters (EDP's) that will be measured when the structures are shaken with the ground motions. The EDP's are:

- EDP1 = Peak absolute value of drift ratio between the roof and floor of the structure.
- EDP2 = Peak of absolute value of roof acceleration.

The engineering demand parameters are illustrated schematically in Figure 3-1. Annual economic damage for a given motion will be computed by summing the economic loss for each EDP for that motion, and then dividing by that motion's return period. Annual seismic economic damage will be computed by summing the annual economic damage for the three ground motions imposed. Each loss function is discussed in detail in the sections that follow.

5.3.a Loss Caused by Structural Damage (EDP1)

Structural damage to the buildings will be correlated with the peak drift ratio between the roof and the first floor [Drift Ratio = $(\Delta_{Roof} - \Delta_{Floor})/H$]. The maximum cost of repairing structural damage will be assumed equal to the initial construction cost of the structure (does not include the cost of land, only the cost of the structure itself). The loss function relating cost of structural damage to drift ratio will be defined as a cumulative normal probability density function with mean drift ratio of 0.04 and standard deviation of 0.01. The distribution function can be computed using many commercially-available software packages (e.g. the NORMDIST function in Microsoft Excel, with the 'cumulative' field set to TRUE). The function is plotted in terms of normalized cost in Figure 5-1.

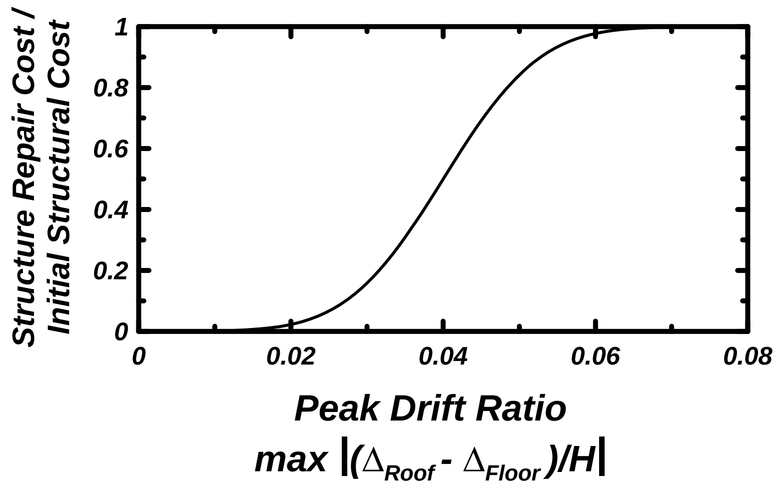


Figure 5-1: Loss function relating structural replacement cost to peak drift ratio.

5.3.b Loss Caused by Equipment Damage (EDP2)

The structure will house equipment with a total value of \$20,000,000 that is sensitive to structural acceleration. Damage to this equipment will be related to the peak of the absolute value of roof acceleration using a loss function that is a cumulative normal probability density function with mean peak roof acceleration of 2.25 g, and standard deviation of 0.75 g. The loss function is plotted in Figure 5-2.

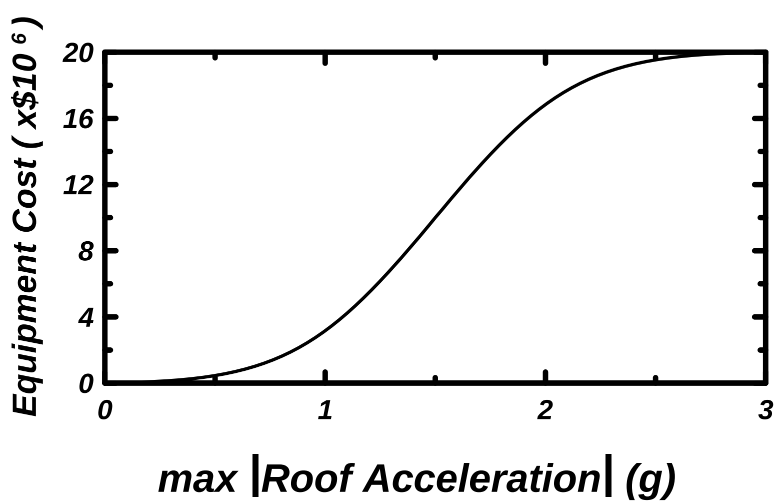


Figure 5-2: Loss function relating equipment cost to peak roof acceleration.

6.0 **Scoring**

The following section will describe the procedure to generate the overall final competition score. The final competition score will depend on the annual revenue, as determined from Section 5.0, the oral presentation, the poster, workmanship of structure, and architecture of structure. Scores in terms of an annual revenue will be assigned for the oral presentation and poster. The final competition score will be in terms of annual revenue, hence the team with the greatest annual revenue will be the winning team.

6.1 **Annual Income**

As determined by performance and rental income described in Section 5.0.

6.2 **Oral Presentation**

A maximum of 5 team members will be eligible to give the 5 minute presentation. The oral presentation, as discussed in Section 2.19, will be assigned a score based on annual revenue. A high quality oral presentation will give your team the reputation as being one of the top structural firms. The building owner will get to "brag" that your high quality team did the structural design for his/her building, and charge higher rents.

The presentations will be given a scored from 0 to 10. A score of 10 is best while a score of 0 is a very poor presentation. The annual income will then be multiplied by the score as a percentage. A complete breakdown of annual income increases for presentations is shown in the Table 6-1. For example, a presentation score of 8 will increase the annual income by 8%, etc.

Score	Annual Income Increase, X
10	10%
9	9%
8	8%
7	7%
6	6%
5, etc.	5%, etc

Table 6-1: Annual Income Increase for Oral Presentations.

6.3 **Poster**

The poster, as discussed in Section 2.20, will be assigned a score based on annual revenue. A high quality poster will have a similar effect as a high quality presentation. A complete breakdown of annual income increases for posters is shown in the Table 6-2.

Score	Annual Income Increase, Y
10	10%
9	9%
8	8%
7	7%
6	6%
5, etc.	5%, etc

Table 6-2: Annual Income Increase for Posters.

6.4 **Architecture**

A unique architectural design is highly desired by the owner. The architecture of the model, as discussed in Section 2.21, will be assigned a score based on annual revenue. Like the poster and presentation, an aesthetically pleasing structure will have a similar effect as a high quality presentation. Vice-versa, a rectangular box-like structure will receive a low architectural score. A complete breakdown of annual income increases for architecture is shown in the Table 6-3.

Score	Annual Income Increase, Z
10	20%
9	18%
8	16%
7	14%
6	12%
5, etc.	10%, etc

Table 6-3: Annual Income Increase for Architecture

6.5 **Workmanship**

The distance between any two floors, center to center, should be:

Lobby Floor Height = 4in +/- 3/16in
Floor spacing = 2in +/- 3/16in .

The total height of the building, from top of base board to bottom of roof plate, should be:

Building Height = (2*number of floors + 2in) +/- 3/8 in.

Failure to comply with dimensional tolerances will result in increased building costs according to the following criteria:

M = +2% of total building cost per 3/16 inch per floor height deviation from specified dimension

N = +5% of total building cost per 3/8 inch building height deviation from specified dimension

Heights between dimensional increments will be rounded to the next increment. For example, a floor height of 2.3 in will receive a building costs increase of M = +2%, and a building height of 50.7 in, when the design height was 50.0 inch, will receive an increase of N = +5%.

6.6 **Final Scoring**

The final score will be in terms of annual revenue, ideally a profit. The team with the greatest final annual building revenue will be the winning team. Annual building revenue will be the final annual income minus final annual building cost and final annual seismic cost.

Final Annual Income, FAI, can be stated as:

FAI = (1+X+Y+Z) * AI

Where:

- AI: Annual Income
- X: Annual Income Increase from Presentation
- Y: Annual Income Increase from Poster
- Z: Annual Income Increase from Architecture

Final Annual Building Cost, FABC, can be stated as:

FABC = (1+M+N) * ABC

Where:

- ABC: Annual Building Cost
- M: Annual Building Cost Increase from inadequate tolerances on floor height
- N: Annual Building Cost Increase from inadequate tolerances on total height

Final Annual Seismic Cost, FASC, can be stated as:

FASC = Annual Seismic Cost

The Final Annual Building Revenue, FABR, can be stated as:

FABR = (1+X+Y+Z) * AI - (1+M+N) * ABC - FASC
= FAI-FABC-FASC

7.0 Example Problem

It should be noted that allowable building footprint dimensions from 2004 differ than those required by this year's competition.

In this section, the performance of the structure from the UCSD team from the 2004 PEER seismic competition will be computed to demonstrate the performance-based scoring system. Data for the structure can be downloaded from *New EERI website, TBA*

7.1 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 \$250 since all of the floors are lower than 1 meter. Hence, the income for the building is (4,340 in^2)·(\$250 / in^2 / year) = \$1,085,000 / year.

7.2 Annual Initial Building Cost

The structure occupied a footprint area of 0.21 m^2 (324 $inch^2$). Hence, the cost of land beneath the building was (324 in^2) · (\$35,000 / in^2) = \$11,340,000. Divided by the design life of the structure, the annual cost of land is (\$11,340,000) / (100 years) = \$113,400 / year.

The mass of the structure was 1.5 kg (3.3 lb). Hence, the initial construction cost was (1.5 kg) · (\$10,000,000 / kg) = \$15,000,000. Divided by the design life of the structure, the annual 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 building, which is \$113,400 / year + \$150,000 / year = \$263,400 / year.

7.3 Annual Seismic Cost

The time series from which the EDP's are computed are shown in Figs. 7-1 through 7-3 for the three earthquake motions. The structure did not utilize base isolation, so there is zero displacement between the floor and the base. The EDP's are summarized in Table 7-1.

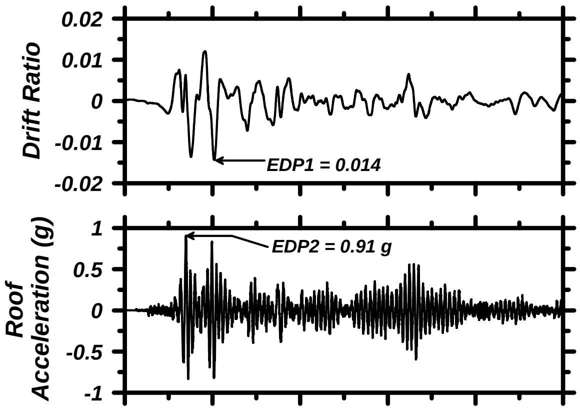


Figure 7-1: Time series for the 2004 UCSD structure during the El Centro motion.

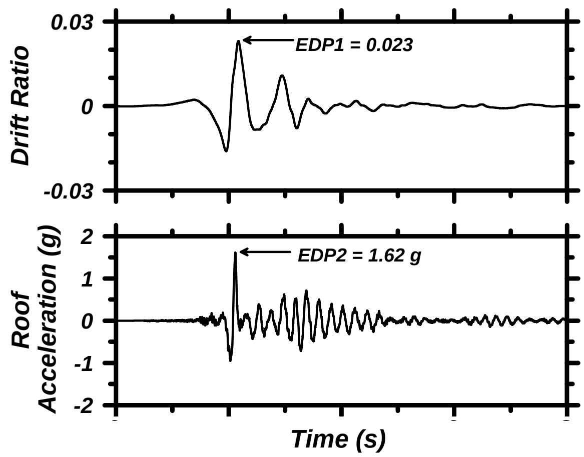


Figure 7-2:: Time series for the 2004 UCSD structure during the Northridge motion.

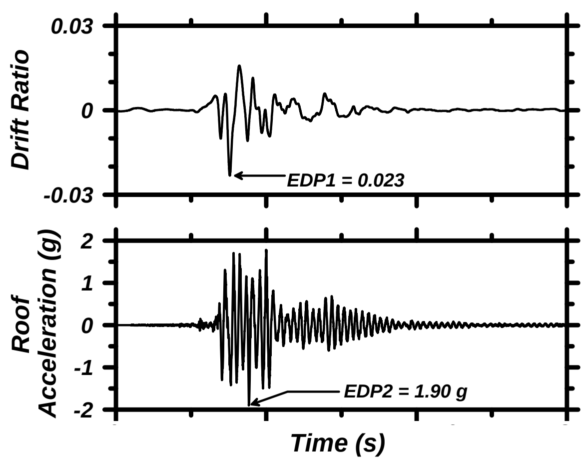


Figure 7-3: Time series for the 2004 UCSD structure during the Kobe motion.

Motion	Engineering Demand Parameter (EDP)	
	Max |Drift Ratio| (EDP1)	Max |Roof Acc| (g) (EDP2)
El Centro	0.014	0.91
Northridge	0.023	1.62
Kobe	0.023	1.90

Table 7-1: Engineering demand parameters measured during ground motions for example structure.

The seismic costs for each ground motion computed from the EDP's in Table 7-1 are shown in Figure 7-4. The values are also summarized in Table 7-2, along with the annual seismic cost for each EDP obtained by dividing the seismic cost by the ground motion return period.

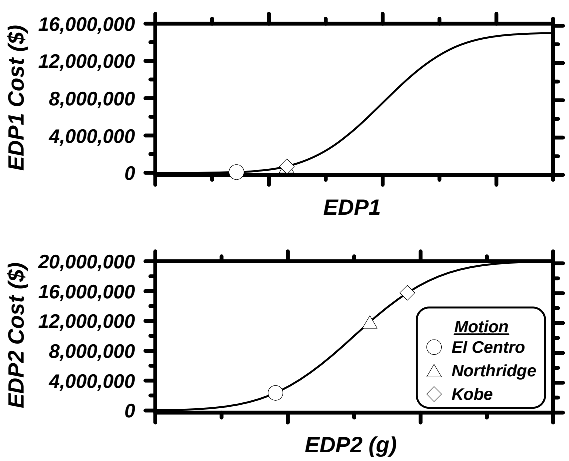


Figure 7-4 : Seismic cost summary for 2004 UCSD structure.

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

Table 7-2: Seismic cost caused by imposed ground motions.

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

7.4 **Annual Income Increase from Presentation, Poster, and Architecture**

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 2. 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

FAI = (1+X+Y+Z) * AI= (1 + 0.10 + 0.10 + 0.04) * $1,085,000
= $1,345,400

7.5 **Annual Building Cost Increase from inadequate tolerances on floor height and building height**

In this example, assume the structure's lobby floor height was 4.80 in. Also assume that the structure had 3 floors that measured 2.25in (center to center) and that the building height, measured to be 60.8 in., from top of base board to bottom of roof plate, when their original design building height was 60 in. Their building cost increased as follows:

M=4*2% (lobby height) + 3*2% =+14%
N= 2*5% =+10%

FABC = (1+M+N) * ABC=(1+0.14+0.10)* $263,400
= $326,616

7.6 **Final Annual Building Revenue**

The final score is calculated in the following:

Final Annual Income, FAI:

FAI = $1,345,400

Final Annual Building Cost, FABC:

FABC = $326,616

Final Annual Seismic Cost, FASC:

FASC = \$214,457

The Final Annual Building Revenue, FABR:

FABR = FAI -FABC – FASC
= \$803,927

8.0 Special Awards

8.1 Charles Richter Award for the Spirit of the Competition

One of the most well known earthquake magnitude scales, the Richter Scale, was developed in 1935 by Charles Richter, of the California Institute of Technology. In honor of his contribution to earthquake engineering, the team which best exemplifies the spirit of the competition will be awarded the Charles Richter Award for the Spirit of Competition. This award will be determined by the judges.

8.2 Egor Popov Award for Structural Innovation

Egor Popov, was a Professor at UC Berkeley for almost 55 years when he passed away in 2001. Popov conducted research that led to many advances in seismic design of steel frame connections and systems, including eccentric bracing. Popov was born in Russia, and escaped to Manchuria in 1917 during the Russian Revolution. After spending his youth in China, he immigrated to the U.S. and studied at UC Berkeley, Cal Tech, MIT and Stanford. In honor of his contribution to structural and earthquake engineering, the team which makes the best use of technology and/or structural design to resist seismic loading will be awarded the Egor Popov Award for Structural Innovation. This award will be determined by the judges.

9.0 Registration

9.1 Team Registration

A team registration form must be submitted via e-mail to seismic.design.competition@gmail.com by November 12th, 2008. The team registration form can be found at the end of this document.

9.2 Model Details Required for Registration

After registration, teams must also submit the following preliminary plans for your structure by December 5th, 2008. Acceptable formats include Word documents or .PDF. The overseeing committee will review plans to ensure that competing structures will meet the requirements, particularly for weight attachment and attachment to the shake table. It is recommended that if construction is scheduled to begin before the December 5th deadline, plans should be submitted for approval before construction begins.

1. Plan View for the first level, showing column layout, and any braces and/or walls
2. Plan View for typical levels
3. Plan View for the roof level
4. Elevation View (N-S) and (E-W)
5. Total building floor plan area (Square footage for all floors)

9.3 Review of Submitted Drawings

All preliminary plans which are submitted by December 5th will be promptly reviewed by the Seismic Design Competition planning committee and returned approved or with recommended revisions by December 12th, 2008.

10.0 **<u>Expenses / Shipping</u>**

Expenses associated with individual team participation in the competition will 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 (from EERI, CSI, FEMA, and Degenkolb Engineering) is intended to offset transportation, lodging and conference registration fees for up to four members per team. 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 months of notice 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 design of shipping boxes. Models should be shipped early enough such that final delivery will occur several days prior to the competition. A late model cannot be tested.

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

Address for travel purposes:

Hilton Salt Lake City Center
255 South West Temple
Salt Lake City, Utah, 84101

11.0 **Maps**

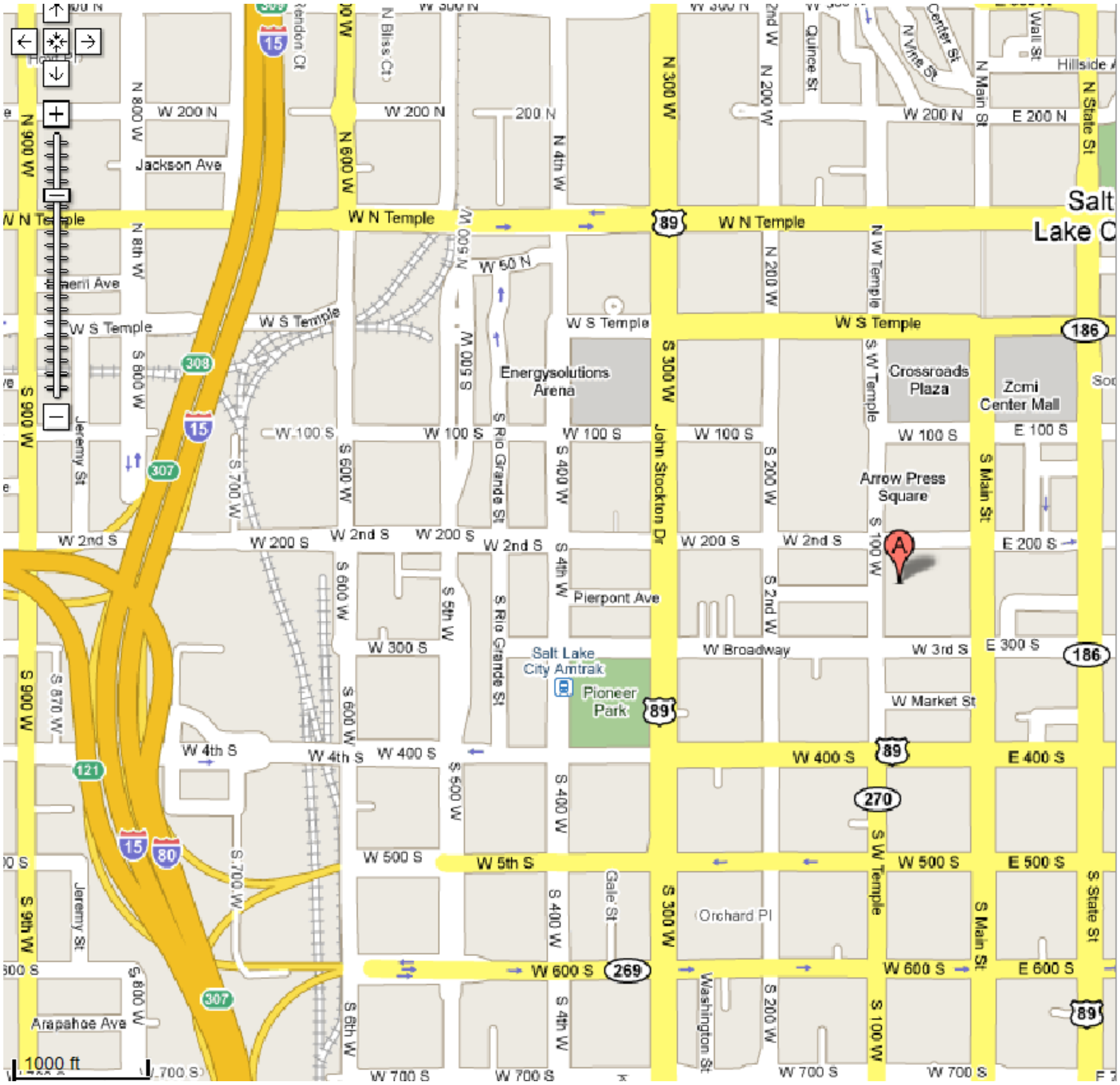


Figure 11-1: Detail Map of Hilton Salt Lake City Center and surrounding area

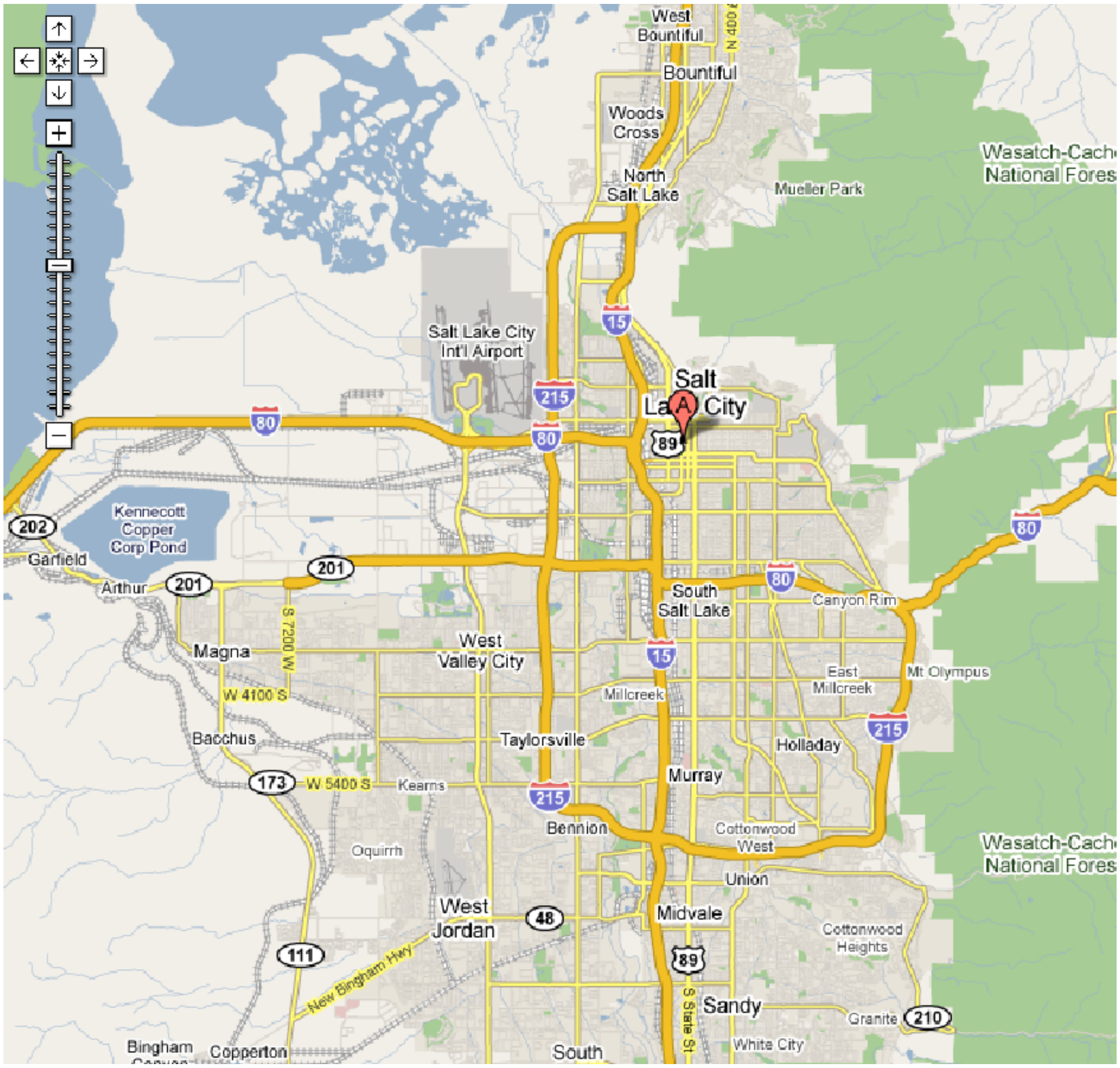


Figure 11-2: Area map of Hilton Center in proximity to Salt Lake City

12.0 **Competition Sponsors**

Earthquake Engineering
Research Institute

Earthquake Engineering Research Institute (EERI)
http://www.eeri.org/

The Earthquake Engineering Research Institute is a national, nonprofit, technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. EERI members include researchers, practicing professionals, educators, government officials, and building code regulators.

The objective of EERI is to reduce earthquake risk by advancing the science and practice of earthquake engineering, by improving understanding of the impact of earthquakes on the physical, social, economic, political and cultural environment, and by advocating comprehensive and realistic measures for reducing the harmful effects of earthquakes.

CSI Computers and Structures, Inc.
http://www.csiberkeley.com/

Founded in 1975 by company President Ashraf Habibullah, CSI is recognized worldwide as an innovative leader in the development of software tools for the analysis and design of civil structures. CSI products are licensed to thousands of structural engineering firms throughout the USA and in more than 100 other countries.

The development of CSI software spans three decades, starting with the research of Dr. Edward L. Wilson at the University of California at Berkeley. The revolutionary SAP program was first released in 1970, and Dr. Wilson has subsequently been recognized by national and international engineering societies as one of the preeminent researchers in the field of computer aided structural analysis.

Each of CSI's programs is tailored to specific classes of structures, allowing the engineering community to work at more productive and efficient levels than are possible with "general purpose" type programs. SAP2000 is intended for use on civil structures such as bridges, dams, stadiums, industrial structures and buildings. ETABS has been developed specifically for multi-story building structures, such as office buildings, apartments and hospitals. The SAFE System provides an efficient and powerful program for the analysis and design of concrete slabs and foundations.

Not only is CSI known for analytically sophisticated software, but for unsurpassed product support as well. User support activities include advice on structural systems, interpretation of structural behavior, clarification on various aspects of building codes, and opinions on special modeling problems and other subjects related to computerized structural analysis and design.

Degenkolb - Consulting Structural Engineers
http://www.degenkolb.com

Established in 1940, Degenkolb is one of the nation's oldest and largest earthquakes engineering firms with an expansive structural engineering practice. Degenkolb provides a wide spectrum of structural engineering services to architects, Fortune 500 companies, healthcare institutions, major universities, historic building owners, and government entities.

Degenkolb has served thousands of clients on tens of thousands of projects and in the process, pioneered the use of innovative technologies over the life of the firm. This breadth of experience is applied to all of their projects. Along with the tried and true solutions that serve clients well, these include steel shear walls, eccentric braced frames, top down basement construction, deep excavation shoring using slurry walls, advanced analysis techniques, fiber wrapped concrete columns, passive dampers, sustainable materials, and building information modeling.

FEMA

On March 1, 2003, the Federal Emergency Management Agency (FEMA) became part of the U.S. Department of Homeland Security (DHS). The primary mission of the Federal Emergency Management Agency is to reduce the loss of life and property and protect the Nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the Nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation.

13.0 **Competition History**

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

1. University of California, Irvine (Team 1)
2 (tie). University of California, Irvine (Team 2)
2 (tie). 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 (tie). Oregon State University
4 (tie). 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, 2007
Astor Crowne Plaza Hotel, New Orleans, Louisiana

1.0 University of California, San Diego
2.0 University of Texas, Austin
3.0 University of Buffalo
4.0 University of Nevada, Reno
5.0 Purdue University
6.0 University of Florida
7.0 Oregon State University
8.0 Washington University
9.0 University of California, Los Angeles
10.0 San Jose State University
11.0 Cal State University, Sacramento
12.0 New Jersey Institute of Technology
13.0 University of California, Davis
14.0 Cal State University, Los Angeles
15.0 Florida A&M University
16.0 Roger Williams University
17.0 Cal Poly San Luis Obispo

NOTES:

TEAM REGISTRATION FORM—DUE November 12th, 2008

e-mail to: seismic.design.competition@gmail.com

University: ____

Team Captain: _________________________ Year _____________

Email Address: _________________________

Team Member 1 _________________________ Year _____________

Team Member 2 _________________________ Year _____________

Team Member 3 _________________________ Year _____________

Team Member 4 _________________________ Year _____________

Team Member 5__________________________ Year______________

Team Member 6 _________________________ Year _____________

Team Member 7 _________________________ Year _____________

Team Member 8 _________________________ Year _____________

Don't forget to submit Construction Plans before construction and before December 5th, 2008. See section 9.2.