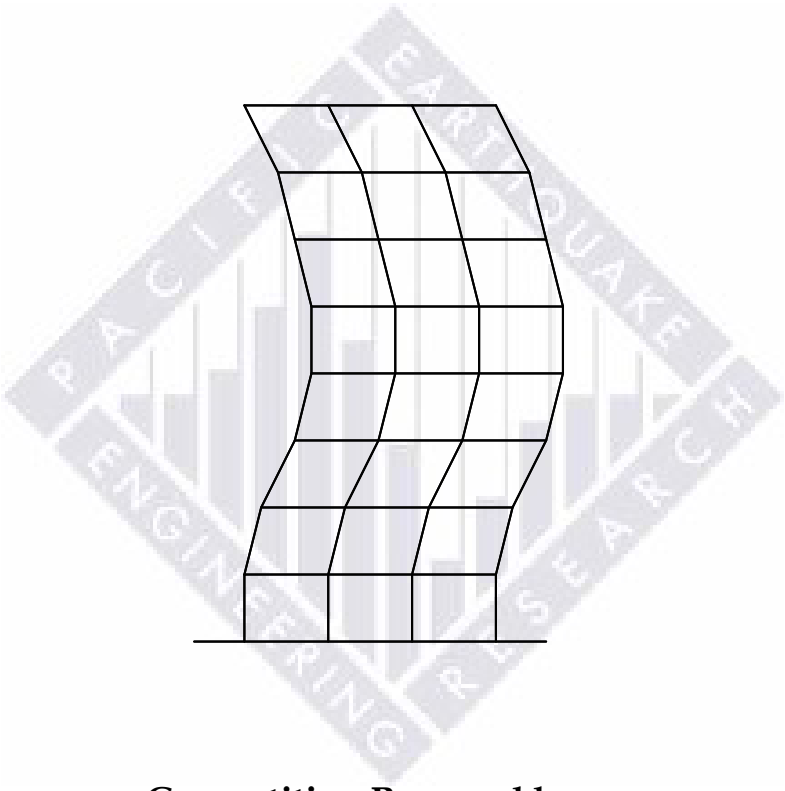
Undergraduate Seismic Design Competition

2004 Competition Rules

Sponsored by:
Pacific Earthquake Engineering Research (PEER) Center



Competition Prepared by:

PEER Student Leadership Council

UC Berkeley UC San Diego UCLA UC Davis
Stanford Caltech UC Irvine Washington USC
PEER SLC

http://peer.berkeley.edu/students

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1.0 Introduction

The objectives of this first Undergraduate Seismic Design Competition sponsored by the Pacific Earthquake Engineering Research (PEER) Center are:

- To provide civil engineering undergraduate students an opportunity to do a hands on project and gain practical experience by designing and fabricating a cost effective frame structure, which will withstand severe earthquake simulation.

- To build the awareness of the versatile activities at PEER among the civil engineering students and faculty at the core universities as well as the general public in order to encourage national-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 PEER students and the PEER center.

The competition will be held on May 12th, 2004 at:

PEER Richmond Field Station (RFS)

Schedule for May 12th, 2004:

Time period	**Activity**	**Location**
8:00 – 8:30 AM	Registration, and Breakfast	RFS
8:30 – 9:00 AM	Weighing of Structures	RFS
9:00 – Noon	Shake Table Testing	RFS
Noon – 1:00 PM	Lunch	RFS
1:00 – 5:00 PM	Shake Table Testing	RFS
5:00 – 5:15 PM	Judges meeting	RFS
5:15 PM	Closing and announcement of scoring	RFS

2.0 Eligibility Requirements

The participating student teams shall satisfy the following requirements:

A. Participants must be currently enrolled undergraduate students in a Civil/Structural Engineering department at one of the PEER core universities or affiliated universities, as listed in Section 2 Part F. Undergraduate teams from Civil/Structural Engineering Departments not associated with PEER are welcome to compete; however, such teams will not be eligible for financial support from PEER.

B. A team can register up to 5 participants, who are the only persons eligible to construct, to document, to present and to answer questions on behalf of their university.

C. Each competing university can enter only one student team and one structure at the competition.

D. Completed registration must be submitted by March 1st, 2004

E. General information about the competition is available online at: http://peer.berkeley.edu/students.

F. The following universities are eligible to enter one team:

PEER Core Institutions:
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of California, San Diego
California Institute of Technology
Stanford University
University of Southern California
University of Washington

PEER Affiliate Institutions:
Oregon State University
University of Hawaii
California Polytechnic State University, San Luis Obispo

3.0 Building Description

Your team has been hired to design and construct a multi-story office building. To verify the design and construction concepts, a scaled model must be constructed from balsa wood and will be tested under severe earthquake simulation. Structures shall be constructed at a scale of 12 ft (floor height in actual building) = 2 in (floor height in model). A unidirectional earthquake shake table, with dimensions of 18 in by 18 in and a capacity of 50 lb, will be used for structure testing. Structures should withstand ground motion simulation from the 1940 El Centro, 1994 Northridge and 1995 Kobe earthquakes.

Seismic performance of the designated structure will be evaluated by monitoring the acceleration and the relative displacement, at the roof level, of the structure during testing. A structure that has minimum acceleration and maximum displacement (at the roof level) will be assessed to have the best seismic performance.

Structures will be tested with scaled earthquake ground motions, for the three seismic events previously mentioned. Ground motions will be available online at the following website: http://peer.berkeley.edu/students.

Model dimension details are as specified:

Number of floors:	15 levels, including lobby level
Building Plan Dimensions:	18 in x 18 in
Note: no level in the model can exceed this building dimension	
Floor height:	2 in for levels 2 through 15
Lobby level height (1st level):	4 in for first level
Maximum model height:	32 in
Diaphragms (floors):	Actual floors need not be constructed, beam members are adequate

Zoning Issues:

City redevelopment ordinances require your structure to meet the following requirements:

Setback of 15% of the first floor area is required for levels 6 to 12.

Setback of 25% of the first floor area is required for levels 13, 14 and 15.

Scoring:

Each structure will be scored on the following: seismic performance, economics, construction cost, architecture, and workmanship (see Section 5).

4.0 Competition Rules

The following rules shall be strictly followed:

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

B. Sponsor's name cannot appear on the structure. However, teams can wear clothing with sponsor's logo during competition.

C. 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 in and a height of 1 in.

D. 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.

E. Participating teams are responsible for transportation of their structure to and from the competition site. See section 9 for details.

F. PEER will be responsible for selecting three judges (from the structural engineering profession), to score all aspects at the competition. Faculty, staff or graduate students from the participating universities will not qualify as judges.

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

H. Structural damping devices, such as base isolation or tuned mass dampers, are allowed in the design. If a tuned mass damper is used, it will need to be designed so that it can be removed from the structure, so that the structure can be weighed. It is advised to place such a device on the roof level, secured to a hardboard plate covering the roof level. Any material is allowed to manufacture the tuned mass damper. Also note the attachment of weights at all levels, including the roof (section 4.0 rule K).

I. Structures shall be made of balsa wood. Columns can have a maximum cross section of 1/8 in by 1/4 in. Beams can have a maximum cross section of 1/4 in by 1/8 in.

J. Each structure shall be constructed at a scale of 12 ft (actual floor height) = 2 in (model floor height).). Real estate without a 2" vertical clear space, from center to center of floor beams (e.g., space occupied by mass dampers) cannot be considered as useable for rent income.

K. A dead load of 1.25 lb will be placed on floors: 2, 3, 4, 5, 6, 7, 8, 9 and 10. A dead load of 2 lb will be placed on floors: 11, 12, 13, 14, and 15. A dead load of 6 lb, including the accelerometer, will be placed at the roof level. Total dead load on the structure will be 27.25 lb. See section 6 for details about the connection of weights to the structure.

L. Weights will be attached in the direction perpendicular to shaking. Hence proper weight connection members will be needed on all four sides of the structure.

M. The maximum base dimension of the structure shall be 18 in × 18 in. Maximum height is 32 in.

N. No paint or other coating will be allowed on the structure.

O. Connections of structural members can be made only from wood glue. Connections of structural members to the base plate must be made using hot glue.

P. Maximization of open exterior wall space, and of corner offices (not blocked by a wall or brace), is preferred (see Scoring section).

Q. A hardboard base plate of minimum thickness 1/8 in, with dimensions of 19 in × 19 in should be fixed to the base of the structure, and will attach the structure to the shake table. Note this will provide an overlap of 1/2 in on all four sides to accommodate connection of base columns using hot glue.

R. The hardboard base plate will need holes of 3/16 in diameter, at 3.25 in on center, at the locations shown on the attached shake table diagram (figure 6.1). Teams will need to ensure access to a minimum of 12 holes, distributed throughout the base plate, to allow attachment of the base to the shake table using 3/16 in diameter allen cap screws. It is strongly recommended to drill all 36 holes on the base plate (figure 6.1) prior to structure attachment.

S. At the very top of the structure, a hardboard plate of thickness 1/8 in will need to be attached to the structure. Hot glue can be used to attach this plate to the beams and columns. The plate should have four 1/4 in diameter holes drilled at 5 in on center to allow for bolt attachment of roof weight and accelerometer, as shown in figure 6.4.

T. Scaled Earthquake Ground Motion Records to be used for the testing can be downloaded from: http://peer.berkeley.edu/students

U. Questions should be directed to the PEER student leadership council (SLC) via email to: SeisComp@peer.berkeley.edu

V. Under 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.

5.0 Scoring:

A. Economic Assessment (10%)

– Complete the following spreadsheets and submit at competition

- Rent Income for Usable Floor Area

Level	Rent Income per in^2 (model)	Floor Area in^2 (model)	Floor Income
Ground Floor	$20		
2	$15		
3	$15		
4	$15		
5	$20		
6	$20		
7	$20		
8	$20		
9	$25		
10	$25		
11	$25		
12	$25		
13	$30		
14	$30		
15	$30		

Total Floor Rent Income =

Note: floor space occupied by mass dampers will not have the required clear space, and will not be counted for rent income.

- Rent Income for Exterior Open Space

Level	Rent per inch of exterior wall length	Wall Length (in)	Income
Ground Floor	$8/in if free of obstacle		
	$4/in if bracing used		
	$0 if shear wall used		
2 through 15	$4/in if free of obstacle		
	$2/in if bracing used		
	$0 if shear wall used		

Total Rent Income for Exterior Open Space =

- Rent Income for Corner Offices

  For each corner office (measuring 3 in by 3 in on model) that is not blocked by a brace or wall, an additional rent income will be collected. This amount will be $150 for each corner office not blocked by a brace or wall.

Floor	Number of Corner Offices	Rent Income
2		
.		
.		
.		
15		

Total Income for Corner Offices =

B. Architecture (10%)

- The building owner and potential tenants desire a building with architectural style and pleasing aesthetics (such as one bracing style used throughout the structure).

C. Performance Evaluation (65%)

- The structure with weights applied at each floor level, will be tested with earthquake ground motion from the following earthquakes, and in order starting with: El Centro, Northridge and Kobe. A "Yellow Tag" will be given to the structure with any minor failure, which is determined by the judges to allow the structure to sustain the next earthquake. Any major threatening structural failure (in which the structure will be considered on the verge of collapse) will result in a "Red Tag" and hence an end to testing.
- For structures that survive El Centro and Northridge with no damage or a Yellow Tag, the Kobe earthquake will be simulated and the roof acceleration and displacement will be recorded. The structure with the lowest ratio of acceleration to displacement (and no structural damage) will be deemed the winning structure in this category.
- Acceleration will be measured at the roof level and at the base. The peak roof displacement will be the maximum of the absolute value of the raw roof acceleration recording. The absolute displacement of the roof and base will be calculated by digitally high-pass filtering the acceleration recordings and double integrating in time. The relative roof displacement will be calculated as the absolute roof displacement minus the absolute base displacement. The

peak roof displacement used in performance evaluation will be the maximum of the absolute value of relative roof displacement.

D. Workmanship (5%)

- The quality of model construction will be assessed. Points will be deducted for construction flaws.

E. Construction Cost (10%)

- A lighter structure, which can survive the severe simulated earthquake loading, is preferred. The weight of the structure can be reduced by minimizing the number of structural members, in which way the material cost and labor cost to construct the structure is minimized. Thus the cost to the building owner is reduced, resulting in greater profits.
- Construction Cost will be determined by weighing each model prior to placement on the shake table, and prior to attachment of weights.

POINTS BREAKDOWN

Points will be awarded as shown in the table below. Maximum score is 100, minimum score is 42 (provided no point deductions).

	Competition Category				
Place	**A.** ***Economics***	**B.** ***Architecture***	**C.** ***Performance Evaluation***	**D.** ***Workmanship***	**E.** ***Construction Cost***
1st	10	10	65	5	10
2nd	9	9	63	4	9
3rd	8	8	61	3	8
4th	7	7	58	2	7
5th	6	6	55	1	6
6th	5	5	50	1	5
7th	4	4	45	1	4
8th	3	3	40	1	3
9th -	2	2	35	1	2

PRIZE:
First Place: $250 certificate to the team's campus bookstore
Second Place: $100 certificate to the team's campus bookstore

6.0 Structural Loading

The unidirectional earthquake shake table to be used for testing has the dimensions and bolt hole pattern as shown in figure 6.1. Structures will be loaded with the weight distribution as shown in figure 6.2.

Weights will consist of a threaded bar with a length of 24 in and will be attached at the centers of the beams at each floor. Anchorage of the threaded bar to the structure will be provided via nuts and washers, as shown in Figure 6.3. A weight of 1.25 lb will be simulated at levels 2 through 10 with a bar of diameter 3/8 in, and a washer of diameter 1 in. A weight of 2 lb will be simulated at levels 11 through 15 with a bar of diameter 1/2 in and a washer of diameter 1.75 in.

At the roof level, a steel plate of dimensions: 6 in by 6 in and thickness of 0.5 in (weight of 5.5 lb) will be attached at the center. An accelerometer will be attached to this plate, as shown in figure 6.4. Note that a hardboard plate of 1/8 in thickness will need to be attached to the roof level. If a tuned mass damper is used, space at the roof needs to be left for the accelerometer (dimension details see Figure 6.4).

Additional vertical members at the location of weights are required, as shown in Figure 6.3. The weights must be secured from translation that might occur during shaking. **Weights cannot be secured to the beam alone.**

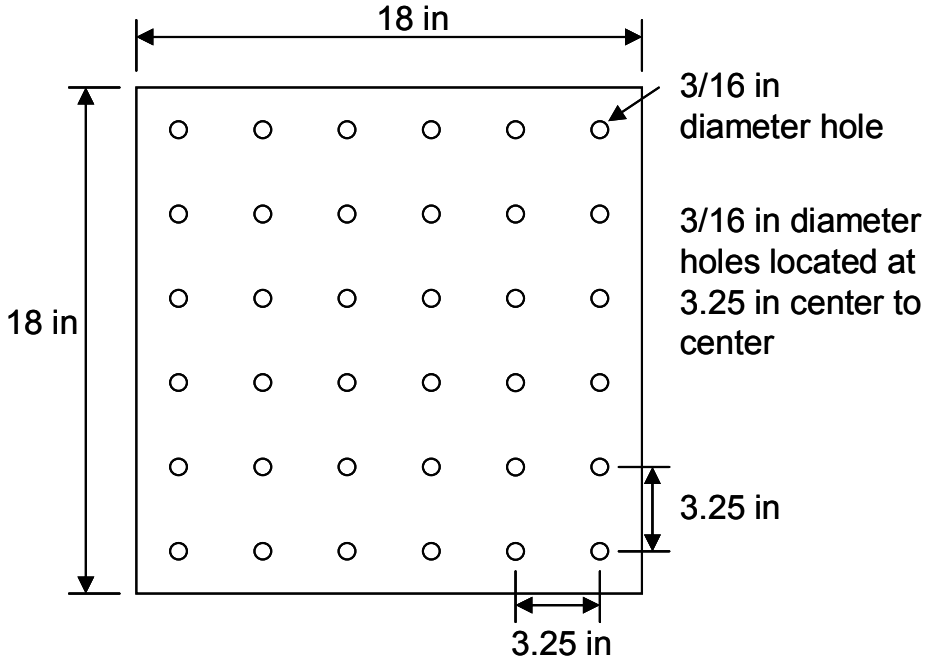


Figure 6.1 Earthquake Shake Table

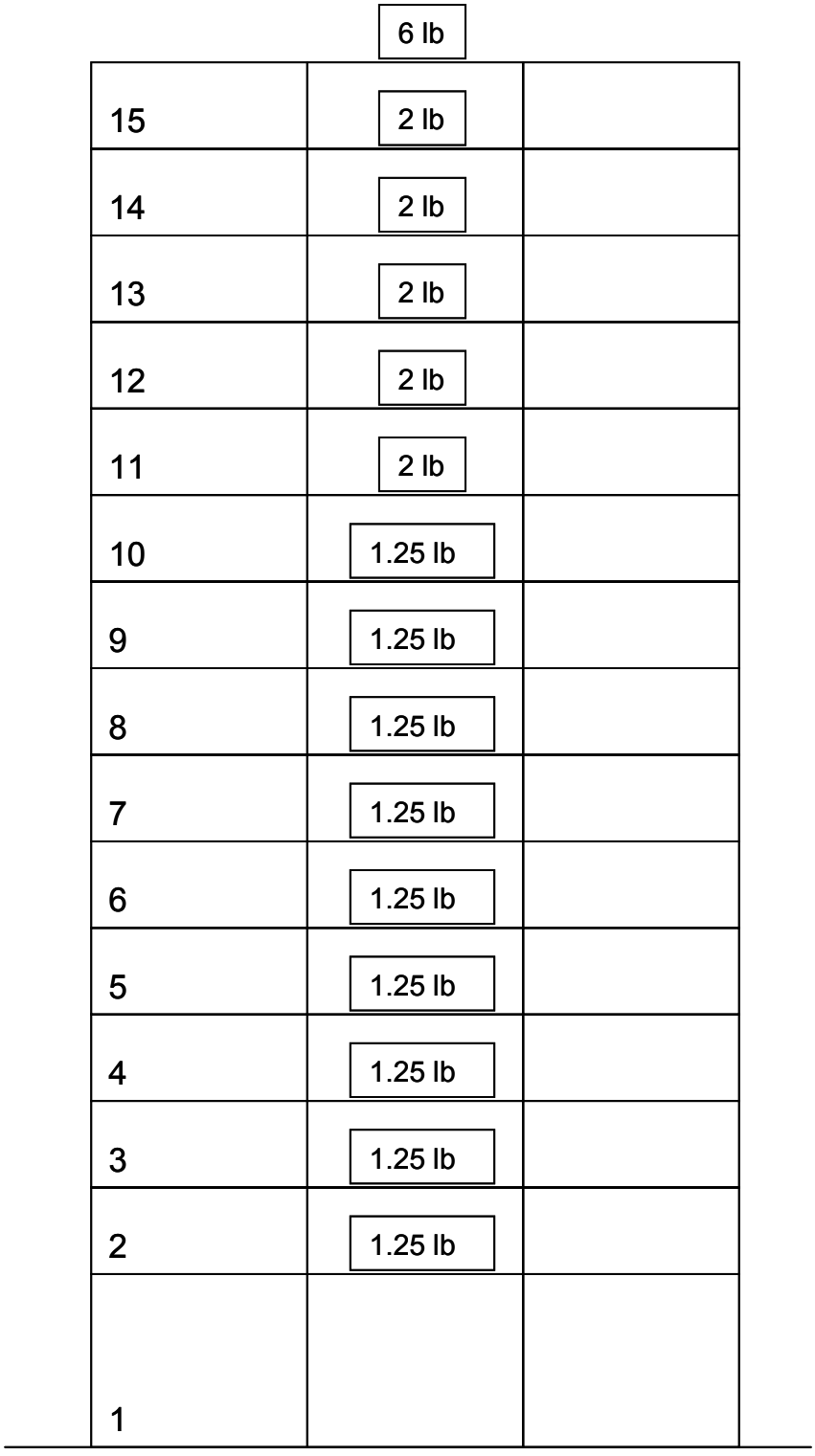


Figure 6.2 Weight Distribution

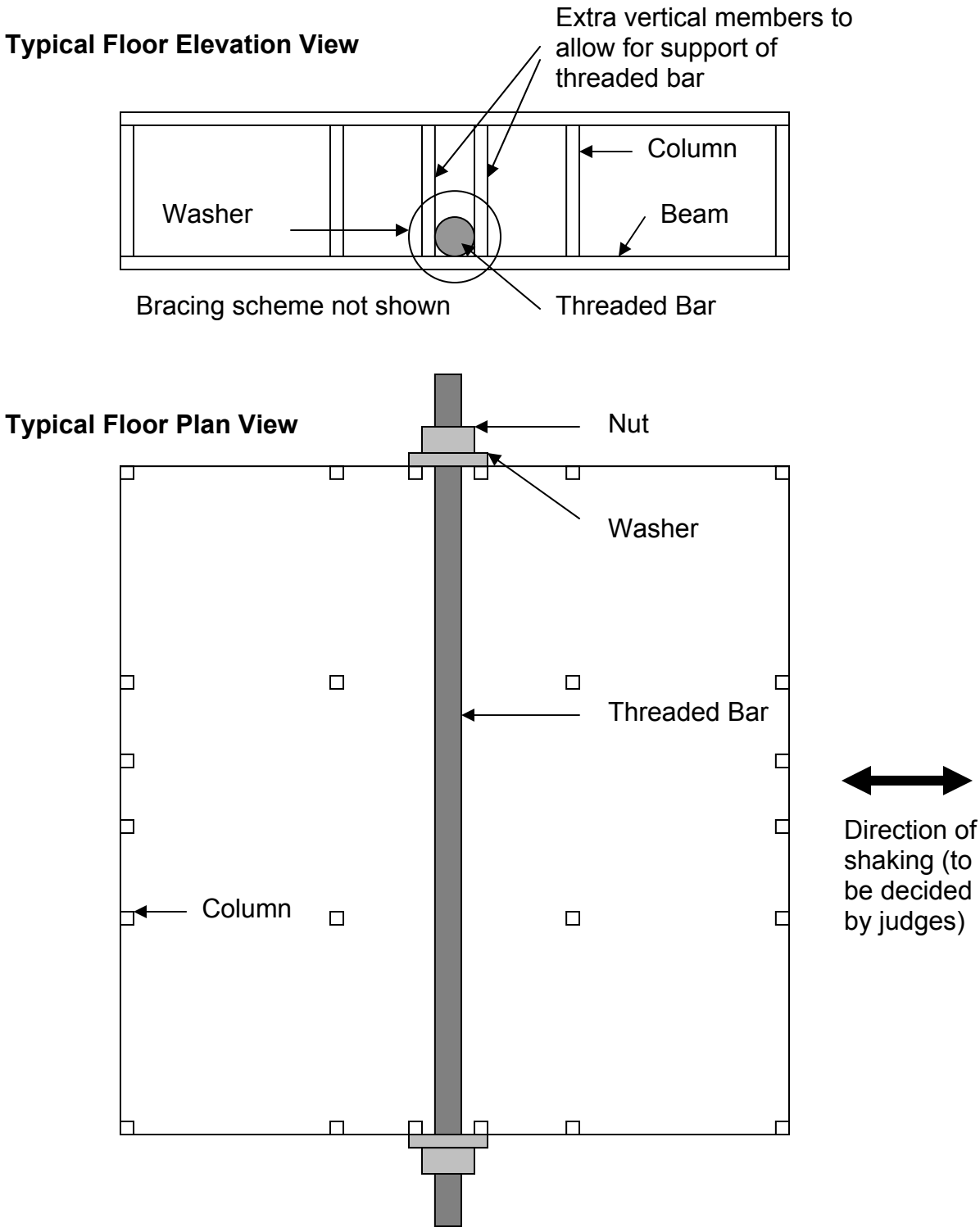
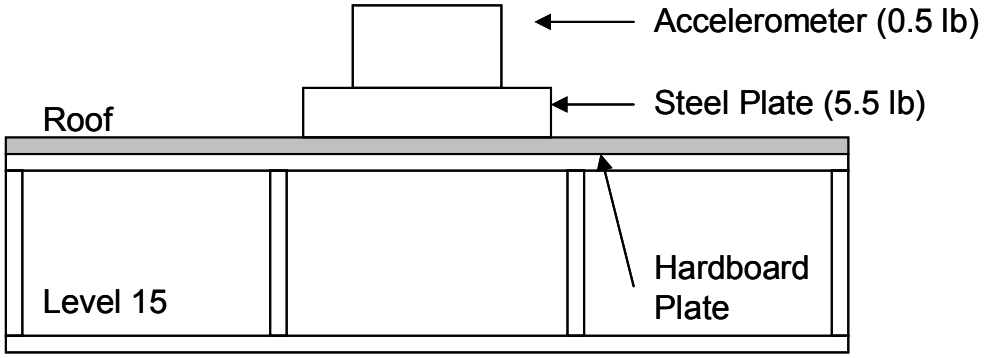


Figure 6.3 Anchorage of Weights to Structure (floors 2 through 15)

Roof Elevation View



Bracing scheme not shown

Note: the steel plate will be attached at the center of the roof. Four holes need to be drilled into the hardboard roof as shown for bolt attachment of steel plate and accelerometer.

Roof Plan View

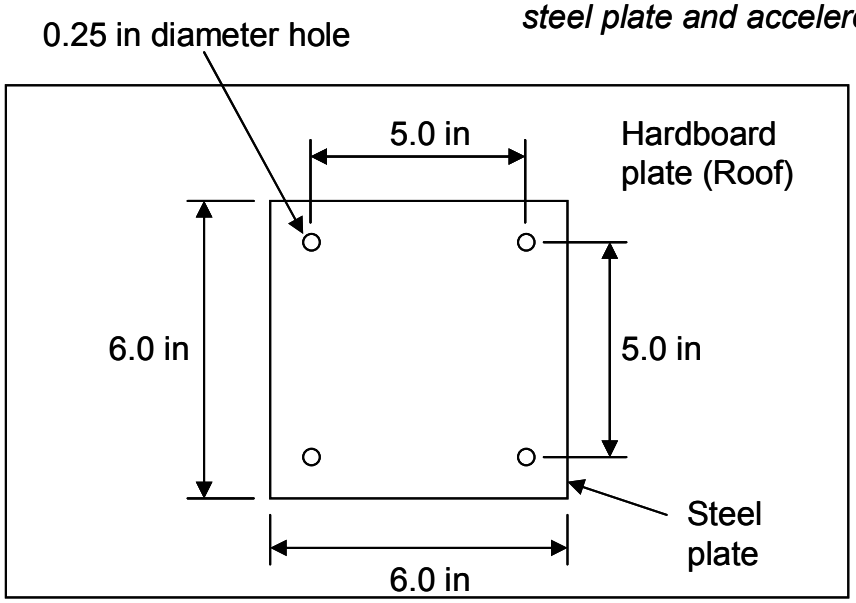


Figure 6.4 Weight and Accelerometer at Roof Level

7.0 Registration

The following information needs to be sent via email to: SeisComp@peer.berkeley.edu by March 1st, 2004:

University: _____

Team Captain: _____ Year _____

Email Address: _____

Team Member 1 _____ Year _____

Team Member 2 _____ Year _____

Team Member 3 _____ Year _____

Team Member 4 _____ Year _____

8.0 Expenses/Shipping

As the sole sponsor of the competition, PEER will provide funds to each competing PEER Associated University Team and to any PEER Affiliated University Team to help cover competition related expenses. Financial support for each PEER Associated and Affiliated University Team will be determined based on travel distance to the competition site.

If the model will be shipped to the competition via FedEX or UPS, then a strong box (crate like) with minimum of 3 in of padding surrounding the 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.

Models being shipped via FedEX or UPS should be sent to:

PEER
1301 S. 46th Street
UC Berkeley Richmond Field Station
Richmond, California, 94804
Tel: 510-231-9554
Attn: SLC