Eleventh Annual Undergraduate
Seismic Design Competition (SDC)

OFFICIAL RULES

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

Competition Website: http://slc.eeri.org/SDC2014.htm

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1. Introduction

1.1 Competition Objectives

The objectives of the 11th Annual Undergraduate Seismic Design Competition sponsored by EERI are:

- To promote the study of earthquake engineering among undergraduate students.
- To provide civil engineering undergraduate students with an opportunity to work on a hands-on project designing and constructing a cost-effective frame building to resist seismic loading.
- To promote EERI activities among civil engineering students as well as the general public, and to encourage international participation in these activities.

1.2 Problem Statement

Alaska is recognized as one of the most seismically active locations in the world; the most powerful recorded earthquake in North America occurred in the southern part of this state fifty years ago. Since that time there has been significant population growth in this region and Anchorage, as the state's largest city, is in need a multi-story building that provides commercial office space to accommodate this growth. Your team has been hired to design a building to serve as an icon of the city that celebrates modern architectural aesthetic and complements the breathtaking natural beauty for which this state is known. The building owner owns a parcel of land in the downtown Anchorage area. The building owner wants to construct a cost-effective structure that is designed for seismic loading as there is significant potential for future damaging earthquakes. Furthermore, with six mountain ranges surrounding Anchorage, the building owner would like to capitalize on the beauty of the natural environment by maximizing the percentage of window area for the exterior walls.

To verify the seismic load resistance system, a scaled balsa wood model, representative of the real building design will be constructed and tested. The model will be subjected to three ground motions, which represent different return period earthquakes. In order to ensure life safety the building model must not collapse during shaking. In addition, the response of the model in terms of roof drift and roof acceleration will be measured during the shaking. For each ground motion, the value of the roof drift will be used to estimate the monetary loss due to damage in the structural and non-structural building components. Likewise, the roof acceleration will be used to estimate the monetary loss due to damaged equipment that is contained inside the building. If collapse occurs, the monetary losses will account for demolishment, reconstruction, and downtime. Finally, the annual seismic cost will be obtained as the sum of the economic loss estimated for each of the earthquakes divided by its return period.

A cost-benefit analysis will be carried out to determine the most cost-effective building. This will be done by balancing the revenue with the initial building cost and seismic cost.

- The *Annual Revenue* (Section 2.3) will be computed as a function of the floor area to be sold or rented. Bonuses in revenue will be given to those teams with the best architecture, presentation and poster. These bonuses account for the positive effect quality architecture and effective communication skills can have on increasing the value of the floor to be sold or rented.
- The *Annual Building Cost* (Section 2.4) will be obtained as a function of the weight of the building model. Penalties that increase the initial cost will be applied to those models that do not meet all the structural model requirements.
- The *Annual Seismic Cost* (Section 2.5) will be based on the building's seismic performance. A bonus will be given to the teams with the best performance predictions. This bonus will reduce the seismic cost of the building. This accounts for the fact that a detailed structural analysis can improve structural design leading to better seismic performance.

The winner of the competition will be the team whose building is not deemed collapsed after all three ground motions with the highest *Final Annual Building Income* (Section 2.6). Teams whose buildings are deemed collapsed will be ranked in a lower category than teams whose buildings are not deemed collapsed.

1.3 **Eligibility and Registration**

All deadlines, instructions and forms will be posted on the competition website listed on the cover page. Any team failing to meet all eligibility requirements or complete the registration requirements by the deadlines shall not be eligible to compete in the competition.

The number of teams invited to compete in the competition will be determined by the Student Leadership Council. The Design Proposal (Section 5) will be used to evaluate which teams will be invited to the competition. Invitations will be announced by email to the team captain and advisor by the date listed on the competition website.

Team registration and eligibility questions should be directed to:

slc@eeri.org

1.3.a Team Eligibility Requirements

The following eligibility requirements will be strictly enforced:

- Teams **must** be affiliated with a registered EERI student chapter. To start a student chapter, please reference the following website:
  http://www.eeri.org/about-eeri/student-chapters/how-to-start-an-eeri-student-chapter/

- Teams shall be comprised of undergraduate students only. A team shall have at least two registered participants and may have as many undergraduate student participants as they wish. Graduate students are welcome to assist undergraduate student participants in the competition; however, graduate students **cannot** register as team members.
- Each undergraduate student registered for a team must be a student member of the national EERI organization and a member of the EERI student chapter for the school being represented.
- Each competing university shall enter only one undergraduate student team and one structure at the competition.
- Each team must complete all of the registration requirements.
- Each team will identify a team captain who will act as the team liaison for correspondence with the Seismic Design Chairs.

1.3.b Team Registration Requirements

All participating teams are required to complete the following registration requirements:

- Pre-Registration
- Proposal Submittal (Section 5)
- Final Registration (Invitation Only)
- Floor Area Calculations and Performance Predictions (Section 2.2)

1.4 **Units**

All measured and specified parameters in the competition will be in English units, inches and pounds.

1.5 **Summary of Notable Rule Changes from 2013**

- Team eligibility requirements have been revised.
- Presentation and poster requirements have been added.
- Bonus scoring has increased.
- Revenue on the first two floors has increased.
- Penalties are no longer associated with percentages of scoring.
- Design proposals and the damping device approval process (optional) are two separate deliverables.
- Descriptions of how judges will measure requirements are described.
- Individual member dimensional requirements have been changed.
- Connection gluing requirements have been changed.
- Floor requirements have been changed.
- The total weight of the model including the base plate and roof plate is limited to 7 pounds.
- Building display requirements have been added.
- Definition of "collapsed" has changed.

2. Scoring

To test the seismic performance of the design, a scaled balsa wood model that is representative of a real building design must be constructed and tested. The model will be subjected to three ground motions, which represent different return period earthquakes. In order to ensure life safety, the building owner requires a design that does not collapse for any of the three ground motions. In addition, the response of the model in terms of roof drift and roof acceleration will be measured for the first two ground motions. For each of the two first ground motions, the value of the peak relative roof drift will be used to estimate the monetary loss due to damage in the structure. The roof acceleration will be used to estimate the monetary loss due to damaged equipment contained inside the building. If a building is deemed collapsed, the monetary losses will account for demolishment, reconstruction, and downtime. Finally, the annual seismic cost will be obtained as the sum of the economic loss estimated for each of the earthquakes divided by its return period.

This section describes the method used to score the performance of the buildings in the seismic competition. Scoring is based on three primary components: 1. *Annual Revenue*, 2. *Annual Building Cost*, and 3. *Annual Seismic Cost*. The final measure of structural performance is the *Final Annual Building Income*, which is calculated as the *Annual Revenue* minus the *Annual Building Cost* minus the *Annual Seismic Cost*.

In the event of a tie for an award in any category, the architecture score will be used as the tie breaker.

2.1 **Presentation, Poster, and Architecture**

Bonuses in revenue will be given to teams whom rank highest in either the presentation, poster, or architecture scores. These bonuses account for the positive effect of having effective communication skills or architectural appeal that could increase the value of the floor to be sold or rented.

Failure to complete any of the requirements in Sections 2.1.a and 2.1.b will result in an increase in V (Section 2.4). The penalties are quantified in each section.

2.1.a Presentation

Each team is required to give an oral presentation no longer than five minutes to a panel of judges at the scheduled time for the team. Judges will have up to three minutes to ask questions following the presentation. The presentations will be open to the public.

A projector and laptop, running Microsoft Windows 7, and PowerPoint (Office 2007 or newer) will be provided. The presentation files will be uploaded to the competition laptop before the first presentation. Teams are responsible for software compatibility. Teams may check software compatibility during scheduled time for presentation drop-off only.

Teams can email their presentations to sdc@eeri.org or drop off the presentation on a USB memory stick during the scheduled time for presentation drop-off only by the deadline listed in the competition schedule.

Presentations shall include the following:

- Name of school on title slide
- Name of building on title slide
- Description of structural system concept
- Architectural concept
- Performance predictions and analysis method
- Damping devices (optional)
- Structural design innovation (optional)

Any team that does not present at the scheduled time will have 100 added to *V* (Section 2.4).

Any team that does not drop off or email their presentation by the deadline will have 10 added *V* (Section 2.4).

2.1.b Poster

Teams are required to display a poster providing an overview of the project.

The dimensions of the poster are restricted to a height of 42 in. and a width of 36 in. The minimum font size for all text shall not be less than 18.

The poster shall include the following:

- Name of school (font size 40 recommended)
- Name of building
- EERI logo (available on the competition website)
- SLC logo (available on the competition website)
- 3D rendering of the building (either of structure skeleton or finished building with cladding)
- Typical floor plan
- Performance predictions and analysis method
- Description of balsa-wood fabrication (photos recommended)
- Estimated overall score prediction (Final Annual Building Income, *FABI*)

Any team that does not have a poster in the display area meeting all requirements in this section by the time listed in the schedule will result in 50 added to *V* (Section 2.4).

2.1.c Architecture

The architecture will be judged based on the aesthetic appeal of the structural model. Renderings on the poster will be considered in the architecture score. See the competition website for the score rubric that will be used.

As some teams have access to laser cutting, quality of fabrication will not be considered in the architectural judging.

2.1.d Bonus Scoring

The increase in *Annual Revenue* will be determined by the team's rank in the oral presentation, poster, and architecture. Only the top 10 teams in the presentation and poster category will receive this benefit. The top 5 teams in the architecture category will receive this benefit. See Table 2-1 for the percentage increase per rank.

Table 2-1: Annual Revenue Bonus

Rank	Presentation	Poster	Architecture
1st	20%	15%	8%
2nd	15%	12%	6%
3rd	12%	10%	4%
4th	10%	8%	2%
5th	8%	6%	1%
6th	6%	5%	0%
7th	4%	4%	0%
8th	3%	3%	0%
9th	2%	2%	0%
10th	1%	1%	0%
11th>	0%	0%	0%

2.2 **Performance Predictions**

A bonus will be given to the teams with the best performance predictions. This bonus will reduce the seismic cost of the building. This accounts for the fact that a detailed structural analysis can improve structural design leading to better seismic performance.

Teams are required to predict the absolute value of the peak roof drift and the peak roof absolute acceleration for all three ground motions. Although performance predictions for all three ground motions are required, only the performance predictions for Ground Motion 1 will affect the annual income.

The performance predictions must be submitted by the deadline listed on the competition website. Instructions for submitting performance predictions will be posted on the competition website.

2.2.a Performance Predictions Requirements

The *Annual Seismic Cost* will be reduced based on the team's rank in the performance predictions for Ground Motion 1. Each team is required to report the peak relative roof displacement in inches and the peak absolute roof acceleration in g's for each ground motion, *n*:

$$Disp_{n\,Predicted} = \max\left|\Delta_{Roof\,n\,Predicted}[in] - \Delta_{Base\,n\,Predicted}[in]\right|$$
$$Accl_{n\,Predicted} = \max\left|Accl_{n\,Predicted}\ [g]\right|$$

The Analysis Prediction Score (APS) is used to evaluate the accuracy of the predicted performance (taken to two significant figures). *APS1* is for the maximum absolute roof drift prediction while *APS2* is for the peak roof absolute acceleration. See section 2.5 for how $XPeak_1$ and $APeak_1$ are determined.

$$APS1 = \frac{\left|\frac{Disp_{1\,Predicted}}{Structural\ Model\ Height} - XPeak_1\right|}{XPeak_1}$$

$$APS2 = \frac{\left|Accl_{1\,Predicted} - APeak_1\right|}{APeak_1}$$

$$APS = APS1 + APS2$$

Each team will be ranked based on the accuracy of the predictions for Ground Motion 1. Any team that does not submit a prediction by the deadline will receive an *APS* equal to 100%. Any team with an *APS* value greater than 100% will receive an *APS* value of 100%. The top ten teams with the lowest *APS* are awarded an Analysis Prediction Score Bonus (*APS Bonus*). See Table 2-2 for the percentage increase per rank.

Table 2-2: Analysis Prediction Score Bonus

Rank	*APS Bonus*
1st	15%
2nd	12%
3rd	10%
4th	8%
5th	6%
6th	5%
7th	4%
8th	3%
9th	2%
10th	1%
11th>	0%

2.3 **Annual Revenue**

The *Annual Revenue* will be based on the total rentable floor area (Section 6.6.b):

$200 per year per square inch for floors 1 through 2
$125 per year per square inch for floors 3 through 15
$175 per year per square inch for floors 16 through 24
$225 per year per square inch for floors 25 and above

The *Annual Revenue* is equal to the sum of each rentable floor area multiplied by its respective revenue per square inch factor.

2.4 **Annual Building Cost**

The *Annual Building Cost* will be obtained as a function of the *Construction Cost*, *Additional Construction Cost*, *Land Cost*, and *Design Life*.

$$Construction\ Cost = C_c = 9{,}000{,}000 \left[\frac{\$}{lb}\right] \times W_{sm}\ [lb]$$

$$Additional\ Construction\ Cost = C_a = 200{,}000\ [\$] \times V$$

$$Land\ Cost = 35{,}000 \left[\frac{\$}{in^2}\right] \times A_f [in^2]$$

$$Design\ Life = 100\ [years]$$

$$Annual\ Building\ Cost\ = \frac{C_c[\$] + C_a[\$] + Land\ Cost[\$]}{Design\ Life\ [years]}$$

The structural model weight, W_s, is defined in Section 6.12. Any violations will result in an increase in V and will contribute to the *Additional Construction Cost*, C_a. The building footprint, A_f, is defined as the maximum floor plan area projected onto the base plate with units squared inches.

2.5 Annual Seismic Cost

The *Annual Seismic Cost* will be based on the building's seismic performance, the *Equipment Cost*, *Return Period*$_n$, XD_n, AD_n, and *Construction Cost* (Section 2.4).

$$Equipment\ Cost\ = 20{,}000{,}000\ [\$]$$

$$Return\ Period_1 = 50\ [years]$$
$$Return\ Period_2 = 150\ [years]$$
$$Return\ Period_3 = 300\ [years]$$

The structural damage as a percentage of the construction cost, XD_n [%], and equipment damage as a percentage of the equipment cost, AD_n [%], for a given ground motion *n*, are calculated using a cumulative distribution function (Section 7.8) and are defined as follows:

$$XD_n = CDF(\mu_X[\%], \sigma_X[\%], XPeak_n[\%])$$
$$AD_n = CDF(\mu_A[g], \sigma_A[g], APeak_n[g])$$

The mean and standard deviation peak roof drift and mean and standard deviation peak roof acceleration are defined as follows:

$$\mu_X = 1.5\ [\%]$$
$$\sigma_X = 0.5\ [\%]$$
$$\mu_A = 1.75\ [g]$$
$$\sigma_A = 0.7\ [g]$$

The measured peak roof drift, $XPeak_n$ [%], and measured peak roof acceleration, $APeak_n$ [g] for a given ground motion *n*, are calculated using the absolute roof displacement, absolute base displacement, absolute roof acceleration (Section 7.7), and *Structural Model Height* (Section 6.6.a) and are defined as follows:

$$XPeak_n = \frac{\max\left|\Delta_{Roof\ n}[in] - \Delta_{Base\ n}[in]\right|}{Structural\ Model\ Height\ [in]}$$

$$APeak_n = \max|Accl_n\ [g]|$$

If the structural model is not deemed collapsed (Section 7.9.c) after ground motion *n* and all previous ground motions, the *Economic Loss* for the given ground motion, *n*, will be equal to:

$$Economic\ Loss_n = XD_n\ [\%] \times Construction\ Cost[\$] + AD_n[\%] \times Equipment\ Cost[\$]$$

The accelerometer will not be attached to the structural model during Ground Motion 3; therefore, if the structural model does not collapse after Ground Motion 3, both XD_n and AD_n will be equal to 50%.

If the structural model is deemed collapsed (Section 7.9.c) after ground motion *n*, the *Economic Loss* for the given ground motion, *n*, and subsequent ground motions will be equal to:

$$Economic\ Loss_n = Equipment\ Cost\ [\$] + 2 \times Construction\ Cost\ [\$] + 3 \times Annual\ Revenue\ [\$]$$

The Annual Economic Loss, *AEL*, for a given ground motion, *n*, is equal to:

$$AEL_n = \frac{Economic\ Loss_n}{Return\ Period_n}$$

A penalty, D_n, for unsecured floor dead loads will be applied after each ground motion (Section 7.9.a).

The *Annual Seismic Cost* is equal to:

$$Annual\ Seismic\ Cost = AEL_1(1 + D_1) + AEL_2(1 + D_2) + AEL_3\ (1 + D_3)$$

2.6 **Final Annual Building Income**

The team with the greatest Final Annual Building Income (*FABI*) will be the winning team. *FABI* is equal to the Final Annual Revenue (*FAR*) minus the Final Annual Building Cost (*FABC*) and Final Annual Seismic Cost (*FASC*).

Final Annual Revenue (*FAR*) is equal to:

$$FAR = (1 + Pres.\ Bonus + Poster\ Bonus + Arch.\ Bonus) \times Annual\ Revenue$$

Final Annual Building Cost (*FABC*) is equal to:

$$FABC = Annual\ Building\ Cost$$

Final Annual Seismic Cost (*FASC*) is equal to:

$$FASC = (1 - APS\ Bonus) \times Annual\ Seismic\ Cost$$

The Final Annual Building Income (*FABI*) is equal to:

$$FABI = FAR - FABC - FASC$$

3. Competition Awards

3.1 **Competition Winner and Ranking**

The team that designs the building that is not deemed collapsed in any of the three ground motions with the highest Final Annual Building Income, *FABI*, will be the winner of the competition. In the case of a tie, the team ranking higher in the architecture category will win.

Teams whose buildings collapse will be ranked in a lower category than teams whose buildings do not collapse. Within each category, teams will be ranked based on the Final Annual Building Income, *FABI*.

The teams ranked overall 2nd and 3rd will also be awarded.

3.2 **Honorable Mentions**

Two honorable mentions will be awarded for the best teams in individual aspects of the competition:

- An Honorable Mention for best architecture will be awarded to the team ranked 1^{st} in architecture.
- An Honorable Mention for best seismic performance will be awarded to the team with the lowest Final Annual Seismic Cost, *FASC*. In the case of a tie, the team ranking higher in the architecture category will win.

3.3 **Best Communication Skills Award**

An award will be given to the team whom has the highest combined presentation and poster scores using the equation below. In the case of a tie, the team ranking higher in the architecture category will win.

Total score = 1.5 x Presentation score + Poster score

3.4 **Charles Richter Award for the Spirit of the Competition**

The most well-known earthquake magnitude scale is the Richter scale which 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. The winner for this award will be determined by the participating teams.

3.5 **Egor Popov Award for Structural Innovation**

Egor Popov had been a Professor at the University of California, Berkeley for almost 55 years before 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. The winner for this award will be determined by the SLC members.

4. Competition Schedule

The following events happen at the competition. Any team fully registered and failing to show up at all by the start of the captain's meeting will be assumed not showing and disqualified. The schedule is subject to change and will be announced after the final registration date.

4.1 **Day 1 of the Competition**

- Drop off model (in final state) and poster at designated time
- Witness partial measurement judging
- Drop off secondary base plate and roof plates (Sections 6.7.c and 6.8.c)
- Drop off or email presentation, submit floor area calculations, and submit predictions for Ground Motion 1 (if not already done)
- Pick up competition packet

If structural models are shipped to the conference hotel, ensure the delivery date is on or before Day 1 of the competition. Structural models can be unpacked in a designated area. If a structure is damaged during transportation, it may be repaired before dropping off the model in its final state. The designated area will be open at a designated time on Day 1 of the competition for teams to unpack and/or repair their structural models (if this room is unavailable, teams will have to find their own area to work). The designated area will remain open for the entirety of the competition. The designated area may or may not be supervised by an SLC member.

The display area will be open the afternoon of Day 1 of the competition. Each team will have a designated time to drop off the structural model and other items. Up to three team members may be present to drop off the structural model and other items.

Once a structural model is dropped off and judging begins, absolutely no changes may be made to the structural model (including adding floor labels or the school name at the top of the building). If the judges witness any team members altering their structural model or another team's structural model, the team will be disqualified from the competition.

4.2 **Day 2 of the Competition**

- Mandatory team captains meeting (morning)
- Presentations (all day)
- Sign judging sheets (all day)
- Calcutta auction and poster session (evening)

A mandatory team captains meeting will occur the morning before oral presentations begin on Day 2. The judges will go over the schedule and procedures for the competition. One representative from each team is required to attend. If the team captain cannot attend the meeting, another team member may attend in place of the official team captain. Lack of attendance to the captain's meeting will not constitute an excuse for not knowing the competition schedule and procedures.

Oral presentations will take place on Day 2 of the competition. The order of the presentations will be announced at the beginning of each session for that session. The judges may only announce the order of several teams at a time.

The display area will be open at a designated time before the start of the oral presentations and be open the entire day until the Calcutta auction and poster session are over.

During the presentations, judges will continue judging. Do not disturb individual judges while judging in the display area. After a team has presented, team captains may stop by the display area after the presentation session is over and review the judging sheets. If no team captain shows up to review the score sheets by the end of the Calcutta auction and poster session, the Seismic Design Competition Chairs will sign the score sheets and the team will not be allowed to appeal any penalties assessed. See Section 8 for more information about signing scoring sheets.

A poster and structural model display session will occur at the end of the day after judging is complete and will coincide with the EERI Annual Meeting poster session. A Calcutta auction will take place at the poster session. Professionals, alumni, and/or professors will bid on structures they think will perform best in the competition. Teams will be asked to bring their structure to the stage during the bidding. Proceeds from the auction will go to the winning bidders and the SLC for future competitions.

4.3 **Day 3 of the Competition**

- Shake table testing

Structural model shake testing will occur the next day after the presentations, display and poster session. Team order will be determined and announced before the competition. The judges will flip a coin to determine the direction of the building for shaking (Section 7.5) at the captains meeting. The procedure for attaching floor dead loads and roof dead load are explained in Section 7.4. The procedure for attaching the structural model to the shake table is explained in Section 7.5. Penalties and evaluation are explained in 7.9.

4.4 Day 4 of the Competition

All competition awards will be announced at the closing EERI Annual Meeting Banquet.

5. Design Proposals and Damping Device Approval Process

5.1 Design Proposals

Your team is required to submit a proposal for evaluation by the Seismic Design Competition Chairs. The proposal will be used to evaluate which teams are invited to compete in the competition. The number of teams invited will be based on competition time limitations and available space at the conference venue. Only the top 10 teams (subject to change) will receive partial funding from the SLC for travel and/or lodging expenses. The following is an itemized list of the deliverables required in the proposal:

- The proposal shall not exceed 3 pages. Any team that exceeds the 3 page limit will be penalized by not being eligible for any partial funding regardless of ranking.
- Format requirements: 11pt, single-spaced, Times New Roman font with 1” margins.
- Page 1: Title page
    - Name of the school, overall computer-generated image of the exposed structural design (an optional computer-generated image of the final architectural state may also be included), all team member names, and the name of the designated team captain.
      (Note: the designated team captain will be the only point of contact between the team and the SDC chairs for the duration of the design and until the completion of the competition).
- Pages 2 and 3: Proposal content
    - Proposals will be judged on the following: general description of the design, noting key concepts with regards to design emphasis, predicted structural behavior, material efficiency, structural innovation/creativity, architecture, spelling, grammar, and overall quality of the proposal.
    - Proposed damping devices may be included in the proposal but are not necessary. Final approval of the damping devices must be made through the Damping Device Approval Process (Section 5.2).
    - Figures are recommended but must fit within the page limit.

A PDF of the document must be emailed to the SDC chairs at the following email address by the date listed on the competition website.

sdc@eeri.org

Design proposals are not being evaluated for rule violations. Selected designs are still subject to penalization and even disqualification.

Teams are not bound to the designs submitted in the design proposal process. Teams are responsible for ensuring that their buildings follow the competition rules. For any clarification, see the clarifications section posted on the competition website or the team captain can submit a clarification request (See Section 9).

5.2 Damping Device Approval Process

All proposed damping devices shall be subject to the approval process. A separate PDF document, no more than 2 pages (including figures), shall be submitted to sdc@eeri.org by the date listed on the competition website. The proposed damping device should be described in detail explaining how energy would be dissipated. The locations of the damping device(s) within the structural model are also required. Figures are highly recommended to aid in describing the damping device.

Judges will evaluate the proposed damping device(s) and may ask for testing results and predicted design forces from a computer model (Ground Motion 3) to prove the damping devices would dissipate energy before being approved. Pre-approved damping devices are not required to be used in the submitted structural model at the competition.

The criteria used by the judges to determine if a damping system is legal:

- If the damping system is removed, the balsa wood structure, with all dead load weights attached, should be stable and firmly fixed to the base plate.
- The sole purpose of the pre-approved damping devices is to dissipate energy.
- Base or floor isolation of any kind is prohibited.

General notes:

- Damping devices may be attached to the base plate.
- All damping devices must dissipate energy at each location used in the structural model.
- Any material is allowed to manufacture a damping device.
- Nonlinear springs may be used for hysteretic damping but testing data and expected model forces at the desired use locations will most likely be required.

If a damping device is approved, the damping device shall not deviate from the damping device approved through this process in the final structural model. The damping device may only be located at the approved locations.

6. Structural Model

This section describes the rules and limitations to be followed for the structural model. Most violations will result in penalties added to *V* (Section 2.4). Some violations may result in disqualification. Penalties will be given at the discretion of the judges.

Structural models shall be constructed of frame members (see Section 6.2) and wall members (see Section 6.3) that are attached to a structural model base plate (see Section 6.7) with a structural model roof plate attached on top of the structural model (see Section 6.8). All connections requirements are in Section 6.4.

6.1 Structural Model Materials

Any violation of this section will result in the structural model not being tested on the shake table and the team disqualified.

All frame members and wall members shall be made of balsa wood.

6.2 Frame Members

6.2.a Frame Member Dimensions

Each dimensional violation of 0.100 in. deviation in this section will result in 2 added to *V*. Dimensions between increments will be rounded up.

Each individual frame member in its final state attached to the model shall fit in a 0.400 in. by 0.400 in. by 15.000 in. box.
Individual frame members will not be removed from the model to check the requirements for this section. Instead, a caliper or other measuring device will be used to check the requirements for this section. Judges must be able to visually observe the extent of all members for measuring. Judges reserve the right to use destructive inspection methods after completion of shaking and assess penalties in this section.

6.2.b Frame Member Requirements

Each violation of this section will result in 3 added to *V*.

A frame member shall not have more than 50% of its entire exposed surface area covered with excess glue from connections regardless if permitted in Section 6.4.

6.3 Wall Members

6.3.a Wall Member Dimensions

Each dimensional violation of 0.100 in. deviation in this section will result in 2 added to *V*. Dimensions between increments will be rounded up.

Each individual wall member in its final state attached to the model shall fit in a 0.150 in. by 3.000 in. by 15.000 in. box.

A wall member shall span at least 1.50 in. vertically. Measured parallel to the plane of the base plate, one of the measured dimensions shall measure at least 1 in.

Individual wall members will not be removed from the model to check the requirements for this section. Instead, a caliper or other measuring device will be used to check the requirements for this section. Judges must be able to visually observe the extent of all members for measuring. Judges reserve the right to use destructive inspection methods after completion of shaking and assess penalties in this section.

6.3.b Wall Member Requirements

Each violation of this section will result in 3 added to *V*.

- A wall shall be oriented so that the direction of the grain of wood is normal to the top surface of the structural model base plate.
- A wall member shall not have more than 25% of its entire exposed surface area covered with excess glue from connections regardless if permitted in Section 6.4.

6.4 **Connections**

6.4.a Connection Requirements

Each violation of this section will result in 3 added to *V*.

Only glue shall be used between the contact surfaces of individual members. Glue shall only be present at the contact surfaces of individual members unless deemed excess glue. There are no restrictions on the type of glue.

Glue from one connection shall not be in contact with glue from another connection. This includes excess glue.

All frame members and wall members in contact with the base plate must be glued to the base plate.

All frame members and wall members in contact with the roof plate must be glued to the roof plate.

6.4.b Frame Member to Frame Member Connections

Each violation of this section will result in 3 added to *V*.

Any frame members in contact shall have glue between the faying surfaces of the frame members. The faying surface is defined as the surface or portion of a surface of a frame member in direct contact with the surface or portion of a surface of another frame member.

A faying surface shall not exceed ½ in. in any direction from the centroid of the faying surface.

Excess glue is any glue not between the faying surfaces but in contact with glue between a faying surface and shall be confined to ¼ in. in any direction of the edge of any faying surface (Teams should take care when choosing and applying glue to connections).

Gusset plates are permitted but shall not be in contact with any wall members. A gusset plate shall be in contact with at least two frame members. Individual gusset plates shall not be in contact with one another. Each gusset plate shall fit in a 0.150 in. by 1 in. by 1 in. box. All gusset plate surfaces or portion(s) of gusset plate surfaces in contact with frame members shall be glued. Excess glue shall be confined to ¼ in. in any direction of the edge of any faying surface between a frame member and gusset plate.

Individual gusset plates will not be removed from the model to check the requirements for this section. Instead, a caliper will be used to check the requirements for this section.

6.4.c Wall Member to Wall Member Connections

Each violation of this section will result in 3 added to *V*.

Any wall members in contact shall have glue between the faying surfaces of the wall members. The faying surface is defined as the surface or portion of a surface of a wall member in direct contact with the surface or portion of a surface of another wall member.

Excess glue is any glue not between the faying surfaces but in contact with glue between a faying surface and shall be confined to ¼ in. in any direction of the any faying surface edge (Teams should take care when choosing and applying glue to connections).

6.4.d Frame Member to Wall Member Connections

Each violation of this section will result in 3 added to *V*.

Any frame member and wall member in contact shall have glue between the faying surfaces of the frame member and wall member. The faying surface is defined as the surface or portion of a surface of a frame member in direct contact with the surface or portion of a surface of a wall member.

A faying surface shall not exceed 1 in. in any direction from the centroid of the faying surface.

Excess glue is any glue not between the faying surfaces but in contact with glue between a faying surface and shall be confined to ¼ in. in any direction of the edge of any faying surface (Teams should take care when choosing and applying glue to connections).

6.5 **Floor Dead Load Connections**

Floor dead loads will be added to the structural model prior to shake testing (see Section 7.3 and 7.4). The floor dead load will require sufficient support for gravity loading and lateral seismic loading.

6.5.a Floor Dead Load Connection Design Requirements

Each violation of this section will result in 5 added to *V*.

Floor dead load connections are required in both North-South and East-West directions and to be centered in plan-view in relation to the center of the base plate.

The floor dead load connection shall be designed so that the bottom of the threaded rod is resting on top of the perimeter floor beams at the following floors: 3, 6, 9, 12, 15, 18 (if $F \geq 18$), 21 (if $F \geq 21$), 24 (if $F \geq 24$), and 27 (if $F \geq 27$). See Section 6.6.a for *F*.

The dead weights should be able to be installed and nuts be tightened to ensure a snug fit without breaking any of the connections, frame members, or wall members in the structural model.

6.5.b Floor Dead Load Connection Recommendations

A time limit will be implemented for teams installing floor dead loads (Section 7.4.a). Ensure the connections are not too intricate that they require an excessive amount of time to install.

Floor dead loads will be secured to the structure using nuts and washers**.**

It is *strongly* recommended that each team purchase a sample weight to try out and ensure proper attachment. Penalties will be assessed for dead weights that are not secured to the structural model after each ground motion testing and may result in judges deeming the building collapsed (Sections 7.9.b and 7.9.c).

6.6 **Floors**

6.6.a Floor and Roof Requirements

Each violation of this section will result in 5 added to *V*. The total number of floors, *F*, of the structural model must be equal to or between the minimum or maximum number of floors. A floor is defined in Section 6.6.b.

Maximum number of floors: 29
Minimum number of floors: 16

A floor, *f*, as defined in Section 6.6.b, is required to be within ¼ in. at the following elevations measured from the top of the base plate to the floor, *f* (top of the perimeter beams).

The lobby, or $f = 1$, shall be at an elevation equal to zero inches. For floors $f = 2$ to $f = F$, the elevation shall be equal to:

$$Floor\ Elevation_f = 4\ [in.] + (f - 2)(2\ [in.])$$

A roof, at the elevation $Floor\ Elevation_F + 2\ in.$, is required above the top-most floor, F, and **does not** count as a floor. The structural model roof plate (Section 6.8) shall be affixed to the roof.

For a given elevation, there shall not be more than one independent floor as defined in Section 6.6.b.

The requirements in this section will be checked with a measuring device along the side of the structural model. All floor height measurements will be measured from the base plate.

6.6.b Floor Definition

To be considered a floor, a floor shall meet the following requirements:

- A continuous set of perimeter beams shall clearly define the floor where the top of the perimeter beams defines the floor. Walls and non-horizontal frame members may interrupt the continuous set of perimeter beams as long as two horizontal members acting as perimeter beams are at the same elevation and connected to the interrupting member(s). The plane defined by the top of the perimeter beams, the floor, shall be flat and level.
- Using a black magic marker, a dot should be centrally placed on the top of each perimeter beam so judges know which beams define the floor area for a given floor.
- The lobby floor is defined by straight black magic marker lines drawn on the base plate between frame or wall members attached to the base plate. A beam at the second floor level shall be directly vertical and parallel to any straight black line drawn on the base plate.
- A floor shall have at least 36 in^2 of rentable floor area (Section 6.6.c).

The continuous set of perimeter beams will be checked visually. Rentable floor area will be checked with a ruler or other measuring device. The floor will be checked for levelness by using a level. If the bubble on the level is completely outside of the level lines, the floor is not considered level. The structural model will be placed on a level floor or table when performing this check.

6.6.c Rentable Floor Area

Any floor area that violates the requirements in this section shall not count towards rentable floor area.

Rentable floor area may only be within the continuous perimeter beams of the floor (Section 6.6.b).

Measured perpendicular along the plane of the floor from any perimeter beam, interior beam, or vertical wall member at the floor elevation, no span to another perimeter beam, interior beam, or vertical wall member shall be greater than 3.00 in.

Each rentable floor area is calculated using the total plan area defined by the perimeter beams, meeting the Section 6.6.b and this section's requirements. Individual structural members penetrating the rentable floor area (frame members and wall members) are not subtracted from the rentable floor area.

Maximum rentable total floor area: 5000 in^2

The total rentable floor area will be calculated by summing the individual rentable floor areas from the bottom up. If the maximum rentable total floor area is reached, the remaining rentable floor areas above will not count.

The minimum height clearance for rentable floor area is 1.50 in.

Occupants on the rentable floor should be able to access any area of the rentable floor through at least two access points or doorways. A sufficient access point is defined as a clear opening with the following minimum dimensions:

Width: 1 in.
Height: 1.5 in.

If there are more than one independent floor areas for a given floor, the largest rentable floor area for that floor will count as the only rentable floor area.

6.6.d Maximum Floor Plan Dimensions

Each floor in violation of the requirements in this section will result in 5 added to *V*.

Maximum floor plan dimensions: 15 in. x15 in.

To check this requirement, a template with a cutout of the maximum floor plan dimensions will be passed over the structural model. The template shall remain parallel to the top surface of the structural model base plate as it passes over the structural model. The floor(s) where the template cannot pass over will be in violation of this section.

6.6.e Floor Isolation

Any violation of this section will result in the structural model not being tested on the shake table and the team disqualified.

Floor isolation of any kind is strictly prohibited. This includes isolating floor dead loads and the roof plate.

6.7 **Structural Model Base Plate**

6.7.a Structural Model Base Plate Plan Dimensions

Any dimensional violation in this section greater than 0.25 in. may result in the judges not allowing the structural model to be tested on the shake table and assuming the model is collapsed for all 3 ground motions.

An 18.00 in. by 18.00 in. square continuous wood base plate will be used to attach the model to the shake table. Teams are responsible for providing a wood base plate. All components of structural model shall not be closer than 1.25 in from the outside edge of the structural model base plate to allow securing the structural model to the shake table (Section 7.5) with C-clamps (jaw opening and throat size may vary).

All measurements will be check with a tape measure or other measuring device.

6.7.b Structural Model Base Plate Thickness Dimensions

Any dimensional violation in this section greater than 0.065 in. may result in the judges not allowing the structural model to be tested on the shake table and assuming the model is collapsed for all 3 ground motions.

The wood base plate shall be between 0.375 in. to 0.500 in.

All measurements will be checked with a caliper.

6.7.c Structural Model Base Plate Requirements

Notching the base plate is allowed but only at locations where a frame member or wall member are in contact with the base plate. The notched area must be filled in completely with the frame member, wall member, or glue. Glue may not be present 1/4 in. from the edge of any member breaking the plane of the top of the base plate visible from the top of the base plate. Each violation of the requirements for notching the base plate will result in 5 added to *V*.

On the top of the base plate, a letter 'N' or word 'North' shall be written with black permanent marker within 1 in. from the edge and 9 in. from any corner the team desires.

The bottom of the base plate must be flat and smooth. If the judges deem the structural model cannot be firmly affixed to the shake table, the accelerometer will not be attached to the structural model and maximum damage will be assumed for both the first two ground motions. If the structural model cannot be physically attached to the shake table, the structural model will not be tested and the structural model will be assumed collapsed for all ground motions.

A hole, no larger than 1/4 in. diameter, may be drilled no further than 2 inches from each corner to secure the structural model for shipping. That means a total of four holes may be drilled in the base plate for securing the model to ship.

A second identical wood base plate shall be provided by the team for judges to weigh in lieu of weighing the base plate attached to the structural model. If the judges deem the second base plate is not identical, the judges will remove the structural model from the original base plate after testing and weigh the original plate instead. Identical notching is not necessary in the second base plate.

6.8 **Structural Model Roof Plate**

The structural model roof plate will be where the accelerometer is attached for shaking. Care must be taken when designing the roof beams to allow for two C-clamps (1 in. opening and 1 in. throat) to clamp the accelerometer to two diagonally opposing corners of the structural model roof plate. The structural model roof plate shall be level and centered on the roof so that the centroid of the roof plate coincides vertically with the centroid of the base plate. If the judges deem the roof plate is not level or centered, the accelerometer will not be attached to the model and maximum damage will be assumed for the first two ground motions.

6.8.a Structural Model Roof Plate Plan Dimensions

Any dimensional violation in this section greater than 0.25 in. may result in the judges not allowing the accelerometer to be attached to the structural model during shaking and assuming maximum damage for the first two ground motions.

A 6.00 in by 6.00 in square continuous wood roof plate is needed to attach the accelerometer to the building.

All measurements will be check with a tape measure or other measuring device.

6.8.b Structural Model Roof Plate Thickness Dimensions

Any dimensional violation greater than 0.065 in. may result in the judges not allowing the accelerometer to be attached to the structural model during shaking and assuming maximum damage for the first two ground motions.

The wood roof plate thickness shall be 0.375 in.

All measurements will be checked with a caliper.

6.8.c Structural Model Roof Plate Requirements

Notching the roof plate is allowed, but only at locations where a frame member or wall member are in contact with the roof plate. The notched area must be filled in completely with the frame member, wall member, or glue. Glue may not be present 1/4 in. from any edge of a member breaking the plane of the bottom of the roof plate visible from the bottom of the roof plate. Each violation of the requirements for notching the roof plate will result in 5 added to *V*.

The top of the roof plate must be flat and smooth. If the judges deem the accelerometer is not firmly affixed to the structural model using two C-clamps (1.00 in. jaw opening, 1.00 in. throat opening), the accelerometer will not be attached to the structural model and maximum damage will be assumed for both the first two ground motions.

A second identical wood roof plate shall be provided by the team for judges to weigh in lieu of weighing the roof plate attached to the structural model. If the judges deem the second roof plate is not identical, the judges will remove the roof plate from the structural model after testing and weigh the original plate instead. Identical notching is not necessary in the second roof plate.

6.9 **Innovative Damping Devices**

All damping devices must be approved in the Damping Device Approval Process (Section 5.2). Any use of a damping device that is not pre-approved or in a pre-approved location will result in disqualification. The implementation of such a device needs to allow for the placement of weights as discussed in Section 7.4.

6.10 Building Finish

Any violation of this section will result in the structural model not being tested on the shake table and the team disqualified.

The building finish must be bare wood. Paint or other coatings will **not** be allowed on the building. Burned surfaces from laser cutting are permitted.

6.11 Building Display Requirements

Failure to meet all requirements in this section by the designated time listed in the schedule will result in 5 added to *V*. (Section 2.4).

The school name shall be displayed at the top of the building facing all four cardinal directions (North, East, South, and West), on paper (a non-structural element). The dimensions of each paper are restricted to 6 in. by 1.5 in.

Each floor must be legibly labeled for judges to see. The floor at the base of the building is not required to be labeled. The floor above the lobby shall be labeled '2', and so on. The label may be written on the balsa wood structure with a pen or marker, or small pieces of paper may be attached with the floor labels written on the pieces of paper. The label must not be designed to assist in the structural performance or interfere with the installation of the dead weights.

6.12 Structural Model Weight

For scoring purposes, the Structural Model Weight, W_s, is equal to the weight of the structural model including damping devices but **does not** include the weight of the floor dead loads, roof dead load, base plate, or roof plate.

Due to the capacity limits on the shake table, the structural model shall not be approved for shake table testing and will be deemed collapsed for all ground motions if the weight of the structural model, damping devices, base plate and roof plate exceed **7.00 lb.**

7. Strong Ground Motion Testing

The building will be subjected to three ground motions of increasing intensity. The structural response to all three ground motions will contribute to the annual seismic cost.

7.1 Scaled Ground Motions

Structures will be subjected to 3 scaled and modified ground motions named Ground Motion 1, Ground Motion 2, and Ground Motion 3. The ground motion records are available at the competition website listed on the cover page.

7.2 Shake Table

Structures will be tested on the University Consortium for Instructional Shake Tables (UCIST) unidirectional earthquake shake table, with plan dimensions of 18.0 in. by 18.0 in.

7.3 **Dead Load Specifications**

Each floor dead load will be represented by a 18 in. long ½ in. diameter steel threaded rod, 8 plates (Simpson Strong Tie BP 5/8-2), 4 washers and 4 nuts. A floor dead load shall be installed at the locations specified in Section 6.5 following the instructions in Section 7.4.a. The total weight of each floor dead load is 2.69 [lb].

The roof dead load will be represented by the accelerometer, a 6 in. by 6 in. by 5/16 in. steel plate, and two C-clamps. The two C-clamps will be used to secure the steel plate and accelerometer to the structural model roof plate. Each C-clamp has a jaw opening of 1 in. and a throat opening of 1 in. The total weight of the roof dead load is equal to 3.48 [lb]. Note, the roof dead load will be removed after Ground Motion 2.

7.4 **Dead Load Installation**

7.4.a Floor Dead Loads

Each floor dead load shall be securely attached to the structural model at the floors indicated in Section 6.5.a in the direction perpendicular to shaking. A floor dead load is defined as secured if it is restricted from movement in any translational direction after installation. Each team is responsible for installing and securing the floor dead loads. See Section 7.9.a for penalties associated with unsecured floor dead loads.

If a floor dead load connection is not available at a floor required to have a floor dead load connection, the judge may have the team install a floor dead load on the required floor and try to secure the floor dead load using the nuts and washers. If the floor dead load is physically unable to be installed while centered in plane with the center of the base plate, that floor dead load will not be installed and that floor dead load is considered unsecured and damaged (Sections 7.9.a and 7.9.c). If the judges deem the floor dead load connections are intentionally not available at a required floor or direction, the model will not be allowed to be tested and assumed collapsed for all three ground motions.

Each floor dead load shall be installed by inserting the ½ in. threaded rod through structural model at the dead load connection locations (Section 6.5). From the building to the end of the threaded rod, the order of the washers, nuts, and plates for each end of the threaded rod are as follows: 1 washer, 1 nut, 4 plates, 1 washer, and 1 nut. The nut immediately following the washer touching the building on each side of the rod are recommended to be tightened by hand to ensure the floor dead loads are restricted from movement in any translational direction.

Each team will have at least 8 minutes to install the dead loads. If 8 minutes have passed, the shake table is cleared for the team to install their model, and the team has not finished installing the floor dead loads, a penalty of 20 added to *V*. Teams may recruit other non-team members (except Seismic Design Competition Chairs) to assist in installing floor dead loads.

A Seismic Design Competition Chair shall be present while the team is installing the floor dead loads to ensure proper installation of the floor dead loads. Another Seismic Design Competition Chair shall check the floor dead loads after the structural model is attached to the shake table (Section 7.5). If the Seismic Design Competition Chair finds any weights not restricted from movement in any translational direction, he or she shall notify the team captain prior to shaking. The team will have one minute to fix any of the floor dead loads. After one minute, the team will not be able to make any changes to the structural model or dead loads, shaking shall commence, and unsecured floor dead loads will be penalized after each ground motion.

7.4.b Roof Dead Load

The roof dead load shall be attached to structural model roof plate with two C-clamps at opposing corners. The two C-clamps have a throat opening of 1 in. and a jaw opening of 1 in. It is the responsibility of the team to secure the roof dead load to the structural model roof plate before installing the structural model to the shake table (Section 7.5). A secured roof dead load is defined as a roof dead load that cannot be moved in any direction by applying the same force required to lift the roof dead load. Also, if the roof dead load is not level before Ground Motion 1, then the roof dead load will be removed from the structural model for both Ground Motion 1 and Ground Motion 2. The roof dead load is considered not level if the bubble of the level is completely outside of the lines. See Section 7.9.b for penalties associated with an unsecured or not level roof dead load.

Each team will have one minute to install the roof dead load. If one minute has passed and the team has not finished installing the roof dead load, a penalty of 20 will be added to *V*.

7.5 **Attachment of Structural Model to the Shake Table**

Seismic Design Competition Chairs will determine the direction of shaking by flipping a coin at the captains meeting (Section 4). The coin flip will determine if shaking is in the north-south direction or east-west direction. One coin will be flipped and all structural models will be tested in the same direction.

Each team will attach the structural models to the shake table with at least 6 C-clamps at the corners and center along the two sides of the structural model base plate parallel with the direction of shaking. Two 18 in. long steel angles (1 in. legs and 1/8 in. wall thickness) will span on top of the structural model base plate perpendicular to the direction of shaking on each side of the building. The two steel angles will be secured with the 4 corner clamps. Two 12 in. long steel angles (1 in. legs and 1/8 in. wall thickness) will span on top of the structural model base plate parallel to the direction of shaking on each side of the building. The two steel angles will be secured with a center clamp. If the base plate is warped, the corners of base plate will be clamped so there are no gaps at the corners between the shake table base, the steel angle, and the base plate. A Seismic Design Competition Chair will check each clamp after installation.

Upon completion of attachment of the structural model to the shake table, unless the Seismic Design Chair grants the team time to secure any unsecured floor dead loads (Section 7.4.a), the team will not be allowed to touch the structural model until all ground motions are complete or the structural model is deemed collapsed.

7.6 **Instrumentation**

Two accelerometers will be used in the competition: one accelerometer will be attached to the shake table, and the other accelerometer will be part of the roof dead load (Section 7.3).

7.7 **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 3rd order Butterworth filter with a corner frequency of 0.8 Hz.
3. Transfer the acceleration from the frequency domain to the time domain.
4. Numerically 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.

For each ground motion n, a roof acceleration record, $Accl_n$, and absolute roof displacement record, $\Delta_{\text{Roof n}}$, and absolute base displacement record, $\Delta_{\text{Base n}}$, will be available after post-processing.

7.8 **Damage Calculations**

7.8.a Structural Damage Calculations

Structural damage to the building will be calculated using a function of the measured peak roof drift, $XPeak_n$. This function is a cumulative normal probability density function with peak roof drift mean and standard deviation listed in Section 2.5. The structural damage as a percentage of the construction cost (XD_n) is a function of $XPeak_n$ and is plotted in Figure 7-1.

Tip: The cumulative 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).

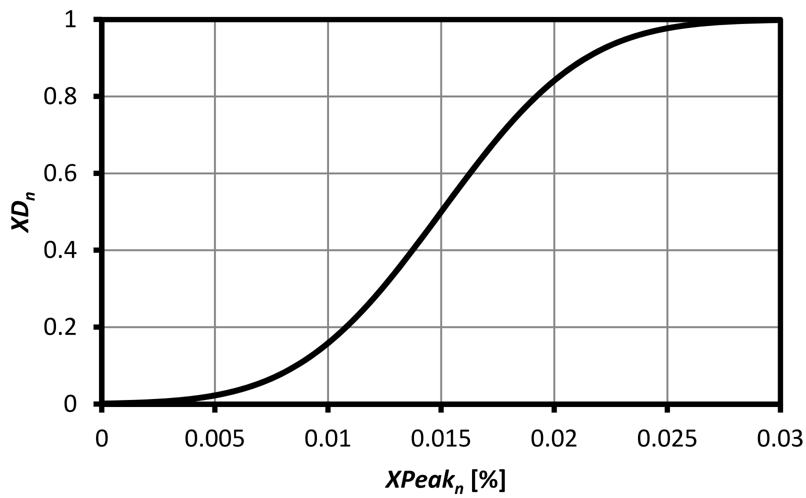

Figure 7-1: Function relating peak roof drift, $XPeak_n$, and structural damage as a percentage of construction cost (AD_n)

7.8.b Equipment Damage Calculations

The building is assumed to house equipment that is sensitive to acceleration. Damage to this equipment will be a function of the measured roof acceleration, $APeak_n$. This function is a cumulative normal probability density function with peak roof acceleration mean and standard deviation listed in Section 2.5. The equipment damage as a percentage of the equipment cost (XD_n) is a function of $APeak_n$ and is plotted in Figure 7-2.

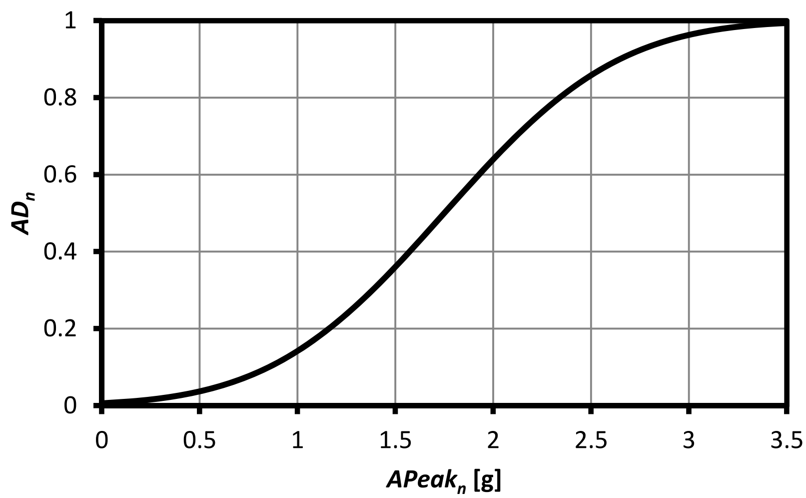

Figure 7-2: Function relating peak roof acceleration, $APeak_n$, and equipment damage as a percentage of equipment cost (AD_n)

7.9 **Penalties and Determining Collapse**

7.9.a Unsecured Floor Dead Load Penalties

After each ground motion, a Seismic Design Competition Chair will inspect the building for any unsecured floor dead loads (Section 7.4.a). 5% will be added to D for each unsecured floor dead load. If a penalty D is applied, it will only affect the monetary structural and equipment damage for the ground motion immediately following the inspection. If a structural model is deemed collapsed by a Seismic Design Chair (Section 7.9.c), a penalty D will not be applied for the ground motion(s) in which the structural model is deemed collapsed.

For example, if all of the floor dead loads remain secured after Ground Motion 1, the penalty D for Ground Motion 1 will be equal to 0%. If two of the floor dead loads are found to be unsecured after Ground Motion 2, the penalty D for Ground Motion 2 will be equal to 10%. If the structural model does not collapse and the same two floor dead loads are unsecured after Ground Motion 3, the penalty D for Ground Motion 3 will be equal to 10%. If, instead, the structural model is deemed collapsed after Ground Motion 3, the penalty D for Ground Motion 3 will be equal to 0%.

7.9.b Unsecured or Not Level Roof Dead Load

Before Ground Motion 1 and Ground Motion 2, a Seismic Design Competition Chair will inspect the roof dead load. If a Seismic Design Competition Chair deems the roof dead load is not secured to the structural model or not level, the roof dead load will be removed from the structural model and the score will assume maximum structural and equipment damage for any of the first two ground motions where the roof dead load is not attached to the structural model. An unstable roof plate is not grounds to declare a structural model collapsed.

7.9.c Defining Collapse of a Structural Model

A Seismic Design Competition Chair deems a structural model has collapsed if any of the following happens:

- 50% or more of the floors are not level
- 50% or more of the frame members or walls attached to the base plate are separated from the base plate or the structural model
- 50% or more of the floor dead loads are considered damaged
- The structural model base plate has delaminated to the point structural model is rocking on the shake table.

The floor levels will be check with a level. If the whole bubble is outside of the lines on the level, the floor is considered not level.

The frame members and/or walls attached to the base plate will be visually inspected to see if separation has occurred between the member and the base plate and/or the rest of the structural model.

A floor dead load is considered damaged if any end of the floor dead load has moved more than ½ in. in any translational direction from its original pre-shaking location measured at the exterior face of the building, any end can be moved more than ½ in. in any translational direction measured at the exterior face of the building. If one floor dead load is in contact with another floor dead load, both are considered damaged.

If any of the three conditions for collapse are met prior to Ground Motion 1, the structural model will still be shaken but deemed collapsed for all three ground motions regardless of the outcome after shaking has completed.

If collapse occurs during Ground Motion 1 or Ground Motion 2, collapse will be assumed to happen for the subsequent ground motions for scoring purposes.

8. Score Sheets

All score sheets can be reviewed and signed by the team captain immediately after judging has completed. If applicable, penalties will be marked with red permanent marker or stickers on each structural model for quick visual identification. Team captains are not required to sign scoring sheets at the very instant upon first review. The team captain can discuss the penalties with his or her team and can appeal a penalty only once (see Section 10.1). If the team captain does not sign off on the score sheet after the appeals process, two Seismic

Design Competition Chairs will sign the score sheet instead and the score sheet will be considered signed by the team captain.

Also, the Seismic Design Competition Chairs will not be available all night for appeals. The display area will be closed soon after the Calcutta auction, and the Seismic Design Chairs will be busy setting up the shake table for Day 2. Once the scoring sheets have been signed either by the team captain or two Seismic Design Competition Chairs, a team captain may not make any appeals for the penalties assessed on the scoring sheets already signed. If a team captain tries to make an appeal for penalties assessed on the scoring sheet(s) already signed, the team captain will be warned. If after the team captain is warned and he or she attempts to continuing appealing for penalties assessed on the scoring sheet(s) already signed, the team will be disqualified.

Note, only team captains shall discuss penalties and score sheets with the Seismic Design Competition Chairs (Section 10).

9. Rule Clarifications

All rule clarifications requests and answers will be posted on the competition website. The posted question and answer will also include the name of the school submitting the question.

To submit a rule clarification, the team captain must fill out and submit an online submission form. Questions or clarifications about the rules sent via email will not be answered. Be sure to read the rules and guide thoroughly before submitting a question. Be very specific when submitting a clarification. The official rules, interpreted by the Seismic Design Competition Chairs, always overrule the clarifications.

A weekly email, if necessary, will be sent out to the team captains and advisors when an update is made to the clarifications page.

10. Judging and Appeals

The Seismic Design Competition Chairs have complete authority over the interpretation of the rules and oversight of the competition and are responsible for scoring and decisions. All decisions made by the Seismic Design Competition Chairs are final. If any questions arise during the competition, the team captain should ask one of the Seismic Design Competition Chairs, not other SLC members.

Only a team captain may discuss decisions or appeals to Seismic Design Competition Chairs. Seismic Design Competition Chairs will refuse to discuss a decision or appeal to anyone other than the team captain. A team captain may only make an appeal regarding his or her team.

Under no circumstances may anyone other than the team captain approach a Seismic Design Competition Chair regarding penalties or scoring. This includes but is not limited to other teammates, alumni, professors, and especially other Student Council Leadership members. If this becomes an issue, the team captain will be warned, and in extreme cases, the Seismic Design Competition Chairs reserve the right to disqualify the team.

10.1 Appeals Process

A team captain can make an appeal about a penalty or decision before signing a score sheet. The team captain must explain using the official rules and clarifications why the penalty or decision should be changed. The official rules, interpreted by the Seismic Design Competition Chair, always overrule the clarifications. A Seismic Design Competition Chair will hear the team captain's appeal and may consult another Seismic Design Competition Chair before making a final decision. After a final decision has been made by the Seismic Design Competition Chairs, the team captain cannot appeal the penalty any further. If the team captain refuses to sign the score sheet, two Seismic Design Competition Chairs will sign the score sheet instead and the score sheet will be considered signed by the team captain.

Note, the clarifications are meant to supplement the official rules and shall not supersede the official rules.

The Seismic Design Competition Chairs are not out to assess extraneous penalties. During judging process, the judges are trained and supervised to evaluate all of the structural models for the same requirement(s) so there is a consistency in judging. Please be considerate and respectful to the Seismic Design Chairs when making an appeal. The Seismic Design Competition Chairs strive to be fair and consistent with all teams regarding the official rules.