***Nineteenth Annual Undergraduate Seismic Design Competition (SDC)***

# OFFICIAL RULES

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

**Competition Website:** https://slc.eeri.org/2022-sdc/

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# 1. Introduction

## 1.1 Competition Objectives

The objectives of the 19th Annual Undergraduate Seismic Design Competition sponsored by EERI during the 12th National Conference on Earthquake Engineering are:

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

## 1.2 Problem Statement

Salt Lake City, Utah, located at the eastern end of the Great Basin and surrounded by breathtaking nature, is a thriving hub for outdoor enthusiasts, artists, business owners, and worshippers alike. First planned by Mormon pioneers, Salt Lake City has experienced rapid cultural and economic growth ever since the construction of the first transcontinental railroad. Straddling the intermountain seismic belt between the Great Basin and the Rocky Mountains, the city frequently experiences earthquakes. As recently as March of 2020, a M5.7 earthquake struck Salt Lake City and caused non-negligible property damages. Several major fault systems contribute to the seismicity of the area. Amongst them are the Wasatch Fault, the West Valley Fault, and the Taylorsville Fault. Most concerningly, two individual faults of the Salt Lake City segment of the Wasatch Fault – the Warm Springs fault and East Bench fault – are connected to one another directly under downtown Salt Lake City, further increasing its susceptibility to earthquake damage. Utah Geological Survey's research has predicted that there is a 16.5 percent chance that the Wasatch Fault will cause a M7.0+ earthquake within the next century.

Given the challenges posed by the seismicity of the area, your company has been tasked with responding to a Request for Proposal (RFP) to construct a new building in downtown Salt Lake City. Fortunately, downtown Salt Lake City is built on relatively flat ground, and the client has acquired a leveled piece of land for this development. To fully take advantage of the year-round abundant natural light and to create a striking structure, the architect decided to make two unique decisions. First, on the first (bottom) 7 floors, the central section of the building will be hollow to allow for a tall atrium. Then, between the $11^{th}$ floor and the $15^{th}$ floor, the inverse will occur. Those floors will only have the central sections, creating a high-ceiling terrace. The additional wall space from the design can be used to incorporate aesthetic features such as a vertical garden, a waterfall, or an art installation. All other floors (i.e. floors 8-10 and 16-19) of the building will have the full square-shaped floor area. More details about the floor plan can be found in Section 5.6.d. Additionally, the architect specified that there should be no bulky columns so that the building can maintain an airy look. Consistent with conventional urban use of multi-story buildings, the client would like to lease the lowermost level of the structure as retail space. To maximize the value of this space, the height of the first floor will be double of the typical floor height. The client also plans to lease the top floor as retail space, capitalizing on the scenic views of the Wasatch Mountain Range. The client has given you, the engineer and the designer, the ability to decide how the remaining stories in the building will be rented (residential, office, etc.).

Salt Lake City is known for its progressive action in green energy and resilient structures, and your building should feature efficient and creative approaches to minimize the building's carbon footprint. As the United States has pledged to achieve net-zero carbon emissions by 2050, Salt Lake City building council is taking the lead on that initiative by encouraging green and resilient structures. Therefore, your building should try to incorporate sustainable features and maximize energy efficiency. Furthermore, this year, in an effort to advance damper technology, your company has been offered a grant to develop damping devices for your structure at no additional cost to the client. You may choose to accept the grant by including dampers in your structure with no financial penalties, or you can decline it by simply designing your structure without damping devices. More information regarding damping devices can be found in Section 4.

In the process of designing your structure, you should consider the geologic setting of Salt Lake City. It is complex due to the city's location in a deep, sediment-filled basin flanked by two uplifted range blocks, the Wasatch Range and the Oquirrh Mountains. During the late Pleistocene Epoch, the Salt Lake City region was dominated by a succession of inter-basin lakes. Lake Bonneville was the last and the largest of these lakes. Approximately 11,000 years ago, Lake Bonneville receded to approximately the size of present-day Great Salt Lake. Additionally, repeated normal-slip faulting has occurred on the Wasatch Fault Zone, which traverses the Salt Lake City metropolitan area. West-facing scarps of a few to tens of feet high are common. The immediate subsurface of the downtown area is typically characterized by a thin layer (about 0 to 10 feet) of fill material, underlain by a Quaternary alluvium layer made up of loose, silty-to-clayey sand and silty clay. Subsurface investigation information from an adjacent site, including boring logs and geophysical measurements, have been provided as part of the RFP to assist your company in providing preliminary foundation design recommendations.

To verify the performance of the seismic load-resisting system, a scaled balsa wood model of the proposed building design will be constructed and tested. The model will be subjected to two ground motions and must not collapse during either of the ground motions. The roof drift and roof acceleration will be used to estimate monetary losses due to damage. If collapse occurs, the monetary losses will account for demolition, reconstruction, and downtime.

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 a function of the rentable floor area. Bonuses in revenue will be given to those teams with the best design proposal, architecture, presentation, and poster. These bonuses account for the positive effect that quality architecture and effective communication skills can have on increasing the value of the floor area to be sold or rented.
- The *Annual Building Cost* (Section 2.4) will be 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 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 and lead to desired seismic performance.

The winner of the competition will be the team with the highest *Final Annual Building Income* (Section 2.6) whose building is not deemed collapsed after both ground motions. 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 participate in the competition will be determined by the Student Leadership Council (SLC). The Design Proposal (Section 4) 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. Historically, most teams have earned an invitation to participate in the SDC by submitting a competitive Design Proposal, and meeting eligibility requirements. However, a growing interest in the SDC has led to an increasing number of applicants. The SLC continues to encourage all eligible teams to submit Design Proposals, but retains the ability to restrict the number of invited teams based on time limitations and space availability at the conference venue. Therefore, the SLC recommends paying particular attention to the Design Proposal.

Team registration and eligibility questions should be directed to:

sdc@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 in good standing. To start a student chapter, please reference the following website:
  https://www.eeri.org/get-involved/student-chapters/how-to-start-an-eeri-student-chapter
  Exceptions for first year teams creating a new EERI Chapter will be made on a case-by-case basis by the SLC Co-Presidents and EERI staff.
- 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 permitted to advise undergraduate students and provide feedback; however, all work must be done by undergraduate students and 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. Exceptions to this will be made on a case-by-case basis by the SLC Co-Presidents. Decisions by the Co-Presidents are final and may not be appealed.
- Each competing university shall enter only one undergraduate student team and one structure at the competition.
- Each team must complete all registration requirements.
- Any team member who has earned their undergraduate degree between the submittal of the design proposal and the start of competition shall be permitted to participate in the competition, provided that their name appears on the design proposal. Team members meeting eligibility requirements can be added to the team roster after the design proposal has been submitted.
- Each team shall identify a team captain who will act as the team liaison for correspondence with the Seismic Design Competition Chairs (SDC Chairs, hereafter).

1.3.b Team Registration Requirements

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

- Proposal Submittal (Section 4.1)
- Final Registration (Invitation Only)
- Floor Area Calculations and Performance Predictions (Section 2.2)

1.3.c Important Deadlines and Deliverables

The following are the deadlines for the deliverables listed in Section 1.3.b.

Cutoff will be at 11:59 PM Pacific Time.

| ***Submittal*** | ***Deadline*** |
|---|---|
| Interest Survey | Friday, November 12, 2021* |
| Proposal Submittal | Monday, January 17, 2022 |
| Final Registration | TBD |
| Floor Area Calculations & Performance Predictions | Friday, June 24, 2022 |

*If a team has not submitted the interest survey but would like to participate in the competition, please contact sdc@eeri.org.

Teams will be invited to participate by February 7, 2022.

### 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 for this Year**

- Proposal, presentation, and poster requirements have been moved to separate documents and combined with their respective rubrics (Sections 2.1.a, 2.1.b, and 4.1).
- Architecture bonuses have changed (Section 2.1.d).
- Teams must leave the accelerometer in place during both Ground Motions. The Annual Prediction Score has been modified to include prediction accuracy for both Ground Motions (Section 2.2.a).
- Annual revenue per floor has changed (Section 2.3).
- Damping device(s) cost has been removed (Section 2.4) and the damping device approval process has been modified (Section 4.2).
- A summary of rule violations resulting in automatic disqualification has been added (Section 2.7).
- A minimum limit has been imposed for the spacing between vertical frame members (Section 5.2.a).
- Wall member minimum dimensions have changed (Section 5.3.a).
- Maximum floor area has changed (Section 5.6.c).
- Doorway/access point requirements have changed (Section 5.6.c).
- Maximum floor dimensions have been changed (Section 5.6.d).

## 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 two ground motions, which represent earthquake ground motions with different return periods. To ensure life safety, the client requires a design that does not collapse for either of the two ground motions. In addition, the response of the model in terms of roof drift and roof acceleration will be measured for both ground motions. The value of the peak relative roof drift will be used to estimate the monetary loss from damage to 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 (as defined in Section 6.9), the monetary losses will account for demolition, reconstruction, and downtime. Finally, the annual seismic cost will be the sum of the economic loss estimated for each of the earthquakes divided by their respective return periods.

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 analysis prediction score will be used as the tiebreaker.

## 2.1 Design Proposal, Presentation, Poster, and Architecture

The design proposal portion is detailed in Section 4.1. Bonuses in revenue will be given to teams that rank highest in the design proposal, 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 the factor $V$ (Section 2.4). Specific penalties are quantified in each section.

### 2.1.a Presentation

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

Teams must follow the instructions and guidelines for the presentation that will be provided in the Presentation Requirements document on the competition website.

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

Teams must submit their presentation files by email *before* the week of the competition (check the official website for exact deadline). Any team that does not email their final presentation by the deadline will have 10 added to $V$ (Section 2.4).

### 2.1.b Poster

Teams are required to display a poster providing an overview of the project. Teams must submit their poster by email *before* the week of the competition (check the official website for exact deadline). Individual teams are responsible for providing the physical poster for display.

Teams must follow the instructions and guidelines for the poster that will be provided in the Poster Requirements document on the competition website.

Any team that does not email their poster by the deadline will have 10 added to $V$ (Section 2.4).

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 receive up to 50 added to $V$ (Section 2.4).

2.1.c Architecture

The architecture will be judged based on the aesthetic appeal of the architectural renderings, functionality of the design, and consideration of the structural model. Renderings on the poster and design of the tower will be used in the architecture score. Refer to the competition website for the score rubric that will be used.

Because not all teams have access to laser cutting, quality of member 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 design proposal, oral presentation, poster, and architecture. Only the top 9 teams in each category will receive this benefit. See Table 1 for the percentage increase per rank.

**Table 1:** Annual Revenue Bonus

| Rank | Proposal | Presentation | Poster | Architecture |
|---|---|---|---|---|
| 1st | 15% | 15% | 12% | 12% |
| 2nd | 12% | 12% | 10% | 10% |
| 3rd | 10% | 10% | 8% | 8% |
| 4th | 8% | 8% | 6% | 6% |
| 5th | 6% | 6% | 5% | 5% |
| 6th | 4% | 4% | 4% | 4% |
| 7th | 3% | 3% | 3% | 3% |
| 8th | 2% | 2% | 2% | 2% |
| 9th | 1% | 1% | 1% | 1% |
| ≥10th | 0% | 0% | 0% | 0% |

## 2.2 **Performance Predictions and Floor Area Calculations**

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 both ground motions with shaking in both the North-South direction and East-West direction (a total of 8 predictions: GM1 N-S drift, GM1 N-S acceleration, GM1 E-W drift, GM1 E-W acceleration, and the same values for Ground Motion 2).

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. If performance predictions are not submitted by the deadline, the SDC chairs will assume zero for all predictions.

### 2.2.a Performance Predictions Requirements

The *Annual Seismic Cost* will be reduced based on the team's rank in the performance predictions for both ground motions. 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*:

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

$$Accl_{n\ Predicted} = |Accl_{n\ Predicted}\ [g]|$$

The *Analysis Prediction Score* (*APS*) is used to evaluate the accuracy of the predicted performance (taken to two significant figures). $APS_{disp}$ is for the maximum roof drift prediction while $APS_{accl}$ is for the peak roof absolute acceleration. See Section 2.5 for how $XPeak_1$, $XPeak_2$, $APeak_1$, and $APeak_2$ are determined.

$$APS_{disp} = 0.6 \times \frac{\left| \frac{Disp_{1\ Predicted}}{Structural\ Model\ Height} - XPeak_1 \right|}{XPeak_1} + 0.4 \times \frac{\left| \frac{Disp_{2\ Predicted}}{Structural\ Model\ Height} - XPeak_2 \right|}{XPeak_2}$$

$$APS_{accl} = 0.6 \times \frac{|Accl_{1\ Predicted} - APeak_1|}{APeak_1} + 0.4 \times \frac{|Accl_{2\ Predicted} - APeak_2|}{APeak_2}$$

$$APS = APS_{disp} + APS_{accl}$$

Each team will be ranked based on the accuracy of the predictions for both ground motions. 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*, and with an *APS* value under 100%, are awarded an *Analysis Prediction Score Bonus* (*APS Bonus*). If less than 10 teams have *APS* values under 100%, then the *APS Bonus* will only be applied to those teams (i.e. some bonus percentages may not be given). See Table 2 for the percentage increase per rank.

**Table 2:** Analysis Prediction Score Bonus

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

2.2.b Floor Area Calculations

Along with performance predictions, teams are required to submit their rentable floor areas (Section 5.6). Submitted floor areas will be verified by the SDC Chairs. Any team that does not submit their rentable floor areas by the deadline will receive the minimum value (Section 5.6.b) for those floors.

2.3 **Annual Revenue**

The *Annual Revenue* will be based on the total rentable floor area (Section 5.6.c):

$325 per year per square inch for floors 1 through 2
$250 per year per square inch for floors 3 through 10
$300 per year per square inch for floors 11 through 15
$350 per year per square inch for floors 16 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*. No discounting rate is considered in these annual cost calculations.

$$Construction\ Cost = C_c = 2{,}000{,}000\ \left[\frac{\$}{lb^2}\right] \times (W_s\ [lb])^2 + 6 \times 10^6\ [\$]$$

$$Additional\ Construction\ Cost = C_a = 150{,}000\ [\$] \times V$$

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

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

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

Any violations will result in an increase in *V* and will contribute to the *Additional Construction Cost*, $C_a$. The structural model weight, $W_s$, is defined in Section 5.12. 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*$_n$, $XD_n$ (Section 6.8.a), $AD_n$ (Section 6.8.b), and *Construction Cost* (Section 2.4).

$$Equipment\ Cost\ = 15{,}000{,}000\ [\$]$$

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

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 6.8) 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 6.7), and *Structural Model Height* (Section 5.6.a) and are defined as follows:

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

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

If the structural model is not deemed collapsed (Section 6.9.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 must be left in place for Ground Motion 2. However, the data from the accelerometer will not be used for computing $XD_n$ and $AD_n$ for Ground Motion 2. If the structural model does not collapse after Ground Motion 2, both $XD_n$ and $AD_n$ will be equal to 50%.

If the structural model is deemed collapsed (Section 6.9.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 6.9.a).

The *Annual Seismic Cost* is equal to:

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

2.6 **Final Annual Building Income**

The team with the largest 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 + *Prop. Bonus* + *Pres. Bonus* + *Poster Bonus* + *Arch. Bonus*) × *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*) × *Annual Seismic Cost*

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

*FABI* = *FAR* – *FABC* – *FASC*

2.7 **Summary of Disqualification Rules**

- *Structural Model Materials (Section 5.1)*
  All frame members and wall members shall be made of balsa wood.

- *Floor Isolation (Section 5.6.e)*
  Floor isolation of any kind is strictly prohibited. This includes isolating floor dead loads and the roof plate.

- *Structural Model Base Plate (Section 5.7)*
  The structural model base plate must conform to the dimensions specified in Section 5.7. Additionally, the base plate must be level and attachable to the shake table.

- *Damping Devices (Section 5.9)*
  Any use of a damping device that is not pre-approved or in a pre-approved location will result in disqualification.

- *Building Finish (Section 5.10)*
  The finish on all frame and wall members must be bare wood. Paint or other coatings will not be allowed on any portion of the model.

- *Structural Weight (Section 5.12)*
  The final structure including the base plate shall weigh no more than 5 lbs.

- *Floor Dead Loads (Section 6.4.a)*
  If a floor dead load is physically unable to be installed while centered in plane with the center of the base plate, or 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 will be assumed collapsed for both ground motions.

- *Defining Collapse of a Structural Model (Section 6.9.c)*
  Section 6.9.c describes how a structural model is deemed collapsed during shaking.

- *Appealing after Signing Scoring Sheet(s) (Section 7)*
  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 they attempt to continue appealing for penalties assessed on the scoring sheet(s) already signed, the team will be disqualified.

- *Judging and Appealing (Section 9)*
  Under no circumstances may anyone other than the team captain approach a SDC Chair regarding penalties or scoring. This includes but is not limited to other teammates, alumni, professors, and especially other SLC members. If this becomes an issue, the team captain will be warned, and in extreme cases, the SDC Chairs reserve the right to disqualify the team.

- *Code of Conduct and Plagiarism (Sections 4.1 and 10)*
  Plagiarism is strictly prohibited and may result in disqualification or non-invitation to compete. Individuals who treat the SLC with extreme disrespect may be dismissed from the tournament, and their team may also be disqualified from the tournament.

## 3. Competition Awards

### 3.1 Competition Winner and Ranking

The team that designs the building with the highest Final Annual Building Income (*FABI*) that is not deemed collapsed in any of the two ground motions will be the winner of the competition.

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 to a team that exemplifies strong performances in individual aspects of the competition:

- An Honorable Mention for Best Architecture will be awarded to the team ranked 1st in architecture.
- An Honorable Mention for Best Seismic Performance will be awarded to the team with the lowest Final Annual Seismic Cost, *FASC*.

3.3 **Best Communication Skills Award**

An award will be given to the team that best exemplifies professional communications throughout all facets of the competition. The communications score will be primarily considered for this award, but the SLC reserves the right to consider other variables as needed to determine the winner.

Communications score = 1.5(Presentation Score) + Poster Score + Proposal Score

The SLC reserves the right to assess a penalty of a 5% reduction in the communications score to any team which demonstrates unprofessional written or oral communications to the SLC members at any time leading up to or during the competition.

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 was a Professor at the University of California, Berkeley for almost 55 years before he passed away in 2001. 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. Popov conducted research that led to many advances in seismic design of steel frame connections and systems, including eccentric bracing. 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. Design Proposals and Damping Device Approval Process

### 4.1 Design Proposals

Your team is required to submit a proposal for evaluation by the SDC Chairs. Invitation to participate in the competition will be determined by the proposal score. If a team fails to submit their proposal by the deadline, they will not be invited to participate in the competition. The number of accepted teams will be based on time limitations and space availability at the conference venue. No funding will be offered to teams for their proposals—instead, funds will be used to improve the quality of the venue and activities that benefit all attendees. A bonus score multiplier will be awarded to the nine best proposals (Section 2.1.d).

Teams must follow the instructions and guidelines for the proposal that are provided in the Proposal Requirements document on the competition website.

### 4.2 Damping Device Approval Process

All proposed damping devices shall be subjected to the approval process. A separate PDF document, no more than 2 pages (including figures), shall be submitted to sdc@eeri.org. More than one damping device proposal may be submitted, each for different damping device designs. The damping device proposal(s) will not have any effect on the team's score. Two dates will be provided on the competition website for damping device proposal submissions. The first date is the recommended submittal date for the initial damping proposal(s). The second date is the final deadline for any damping device proposals or damping device proposal revisions. Each proposed damping device must be described in detail, explaining the materials used and the device's placement(s) within the structural model. Figures are highly recommended to aid in describing the damping device.

Prior to approval, the SDC Chairs will evaluate the proposed damping device(s) and may ask for additional information if the original proposal lacks clarity or thoroughness. If the SDC Chairs ask for additional information about the proposed damping device(s), a revised damping device proposal must be submitted before the device is approved. This revision will be subjected to the same approval process. Any number of revisions is permitted prior to the final deadline. Approved damping devices are not required to be used in the submitted structural model at the competition. However, if a damping proposal is not submitted, then damping devices may not be used.

The criteria used by the judges to approve a damping system are as follows:

- 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 primary 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 should dissipate energy at each location used in the structural model.
- Any material is allowed to be used in a damping device.

If a damping device is approved, the damping device shall not deviate from the proposed design approved through this process in the final structural model. If a team wishes to change their damping device in any way (e.g., installation location, connection to structure, material, etc.), they must submit a revised damping device proposal. The damping device may only be located at the approved locations. The damping device must not interfere with dead load installation locations.

Teams must submit all damping device proposals and proposal revisions by the final deadline. The SDC Chairs will determine if a device is approved within 14 days of the proposal being submitted. If the device is not approved and it is after the final deadline, teams are not allowed to use the disapproved device on their model and may not submit further revisions to their damping device proposal.

All damping devices will be checked during pre-judging of structures. Damping devices that have not been approved by the SDC Chairs, or deviate from the approved damping device proposal (e.g., installation location, connection to structure, material, etc.) will have to be removed. If a team is unable to remove an unapproved damping device, the structure will be considered collapsed for all ground motions.

## 5. 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 in accordance with the official rules and at the discretion of the judges. The SLC reserves the right to cap violations as needed in accordance with the spirit of the competition.

Structural models shall be constructed of only balsa wood (Section 5.1) frame members (Section 5.2) and balsa wood wall members (Section 5.3) that are attached to a structural model base plate (Section 5.7) with a structural model roof plate attached on top of the structural model (Section 5.8). Pre-approved damping devices may be made of any material (Section 5.9). All connections requirements are provided in Section 5.4. Floor labels (Section 5.11) and the school name at the top of the building (Section 5.11) may be constructed out of paper.

Any architectural features (i.e., features not intended for structural purposes) on the model must be made of balsa wood (Section 5.1) and meet all the requirements for a frame member (Section 5.2) or wall member (Section 5.3) including all connection requirements (Section 5.4).

## 5.1 **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.

## 5.2 **Frame Members**

### 5.2.a Frame Member Dimensions

Each member found to be in violation will be assessed a penalty of 2 V for every 0.100 in. increment in unit length found to be in violation. Dimensions between increments will be rounded up. A tolerance of 0.01 in. shall apply.

Each individual frame member in its final state attached to the model shall fit in a 0.200 in. by 0.200 in. by 15.000 in. box.

Each individual frame member shall have no individual dimension smaller than 0.09 in.

**Any two adjacent vertical frame members must have a clear space of at least 0.25 in. between them.** This requirement does not apply to horizontal or inclined frame members.

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 to assess penalties in this section.

### 5.2.b Frame Member Requirements

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

Any frame member to frame member connections not easily visible to the naked eye shall be marked with a black arrow pointing to the connection.

## 5.3 **Wall Members**

### 5.3.a Wall Member Dimensions

Each member found to be in violation will be assessed a penalty of 3 V for every 0.100 in. increment in unit length found to be in violation. Dimensions between increments will be rounded up. A tolerance of 0.01 in. shall apply.

Each individual wall member in its final state attached to the model shall fit in a 0.100 in. by 3.000 in. by 11.000 in. box.

A wall member shall span at least 1 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.

5.3.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.

5.4 **Connections**

5.4.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. There are no restrictions on the type of glue.

Glue shall only be present at the faying surfaces of individual members unless deemed excess glue. The faying surface is defined as the surface or portion of a surface of a member in direct contact with the surface or portion of a surface of another member. Excess glue must be confined to 1/2 in. in any direction of the edge of any faying surface.

**Any members in contact must have glue between the faying surfaces of the two members.** It is the discretion of the SDC Chairs to assess *V* for unglued connections if that connection (regardless of if the two adjoining members are close but are not touching) is reasonably expected to be joined. For example, floor beam elements can be reasonably expected to be connected to perimeter beams and are typically not cantilevered within a footprint of perimeter beams. This requirement is applicable for connections between any types of members (frame, wall, or gusset).

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.

5.4.b Frame Member to Frame Member Connections

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

A faying surface shall not exceed 1 in. in any direction from the centroid of the faying surface. For each inch that a faying surface exceeds the 1 in. maximum from the centroid (e.g. 2 in. faying surface), an additional 3 V will be added. Each surface in contact with another surface will be considered a faying surface.

5.4.c Gusset Plates

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

Gusset plates are permitted but shall not be in contact with any wall members. A gusset plate shall be in contact with and glued to at least two frame members in contact. Individual gusset plates shall not be in contact with one another. Each gusset plate shall fit in a 0.100 in. by 1 in. by 1 in. box.

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.

5.4.d Wall Member to Wall Member Connections

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

There is no restriction on length of faying surface in wall member to wall member connections.

All wall members in their final glued state must have a thickness less than or equal to 0.1 in.

## 5.5 **Floor Dead Load Connections**

Floor dead loads will be added to the structural model prior to shake testing (Section 6.3 and 6.4). The floor dead load will require sufficient support for gravity loading and lateral seismic loading.

5.5.a Floor Dead Load Connection Design Requirements

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

All members used in floor dead load connections must conform to frame or wall member requirements (Sections 5.2 to 5.4).

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: 5, 7, 9, 11, 13, 15 (if $F \geq 15$), 17 (if $F \geq 17$), and 19 (if $F \geq 19$). See Section 5.6.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.

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

5.5.b Floor Dead Load Connection Recommendations

A time limit will be implemented for teams installing floor dead loads (Section 6.4.a). Ensure the connections are not too intricate that they require an excessive amount of time to install.

The connection should be strong enough for the team to tighten the nuts enough to engage adequate friction between the innermost washer and the exterior face of the building to ensure the floor dead load is secure (see Section 6.4.a)

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 6.9.b and 6.9.c).

## 5.6 **Floors**

5.6.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 5.6.b.

Maximum number of floors: 19
Minimum number of floors: 13

A floor, *f*, as defined in Section 5.6.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:

$$Floor\ Elevation_f = 6\ [in.] + (f - 2)(3\ [in.])$$

A roof, at the elevation $Floor\ Elevation_F + 3\ in.$, is required above the top-most floor, *F*, and **does not** count as a floor. The structural model roof plate (Section 5.8) shall be affixed to the roof.

For a given elevation, there shall not be more than one independent floor as defined in Section 5.6.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 top of the base plate.**

5.6.b Floor Definition

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

To be considered a floor, the following requirements must be met:

- 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). Interior floor beams shall be flush with the top of the perimeter beams. The plane defined by the top of the perimeter beams, the floor, shall be flat and level.

- Using a black permanent 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 permanent 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 parallel to any straight black line drawn on the base plate.

- A floor shall have at least 25 $in^2$ of rentable floor area (Section 5.6.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.

5.6.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 5.6.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 2.5 in or smaller than 0.5 in.

Each rentable floor area is calculated using the total plan area defined by the perimeter beams, meeting the Section 5.6.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: 1915 $in^2$

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 2.25 in.

Occupants on the rentable floor must be able to access any area of the rentable floor through at least one access point or doorway originating from the interior of the structure. The exterior of the building may not be used as an access point. Additionally, occupants on the lobby floor, or $f$ =1, should be able to access the exterior of the building 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: 2.25 in.

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

5.6.d Maximum Floor Plan Dimensions

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

The maximum floor plan dimensions (inches) are defined in Figure 1, Figure 2, and Figure 3 below. All floors of the model must fit within the specified floor plan dimensions. No members may be placed within the hatched areas of these figures.

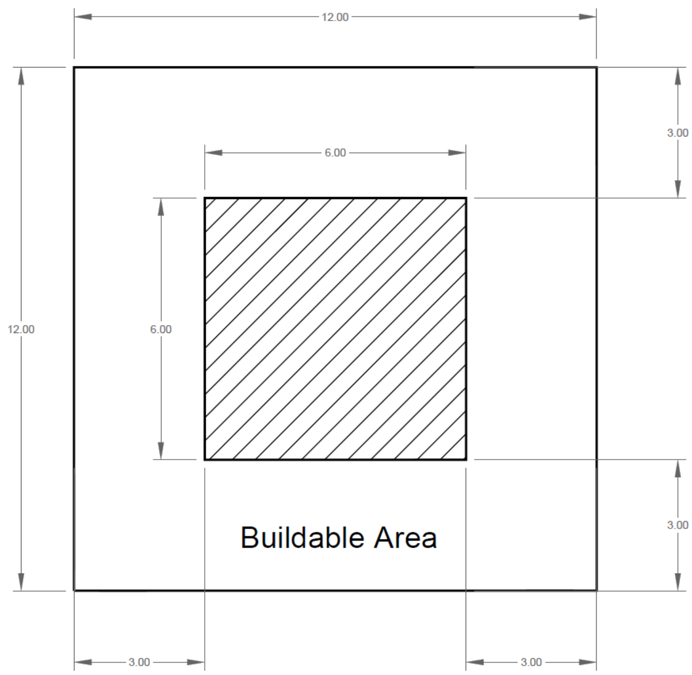


**Figure 1:** Maximum floor plan dimensions for Floors 1-7

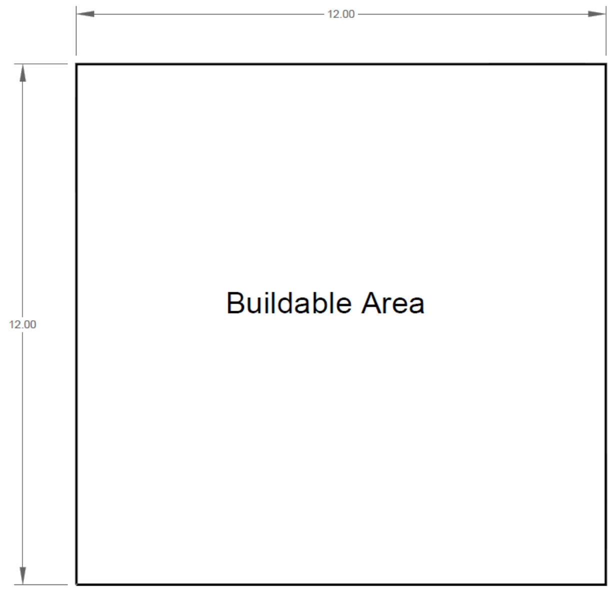


**Figure 2:** Maximum floor plan dimensions for Floors 8-10 and 16-19

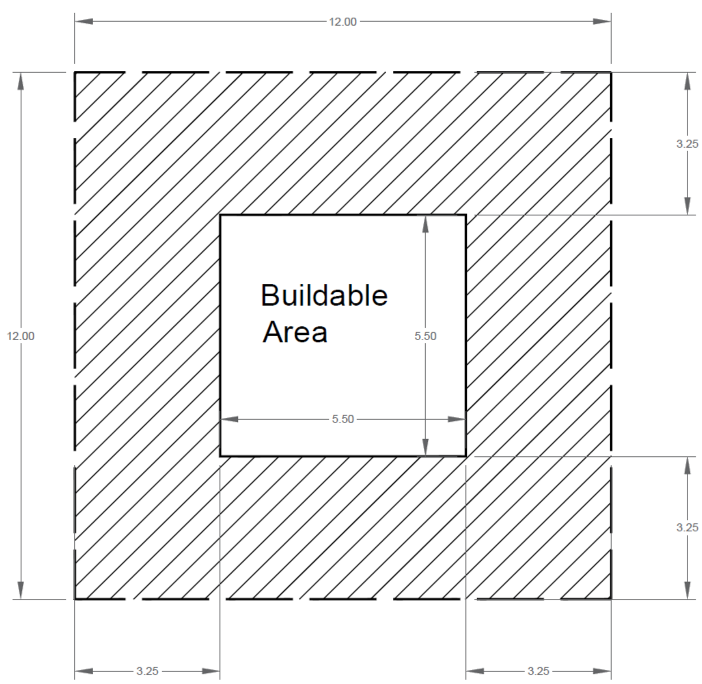


**Figure 3:** Maximum floor plan dimensions for Floors 11-15

To check this requirement, a template with a cutout of the maximum floor plan dimensions will be passed over the structural model. Said template will have a tolerance of 1/16 of an inch in each dimension. The template shall remain parallel to the top surface of the structural model base plate as it passes over the structural model. The template cannot be rotated as it is passed over the structure. The floor(s) where the template cannot freely pass over will be in violation of this section. Teams will not be allowed to bend or force the template over any floors.

5.6.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.

## 5.7 **Structural Model Base Plate**

5.7.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, therefore, the model will be assumed collapsed for both ground motions.

An 18.00 in. by 18.00 in. square continuous wooden (Plywood or MDF) 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 the structural model shall be centered on the structural base plate, and be no 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 6.5).

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

5.7.b Structural Model Base Plate Thickness Dimensions

Any dimensional violation in this section resulting in the base plate thickness falling outside of the indicated range may result in the judges not allowing the structural model to be tested on the shake table and assuming the model is collapsed for both ground motions.

The wood base plate shall be between 0.25 in. to 0.50 in. thick.

All measurements will be checked with a caliper.

5.7.c Structural Model Base Plate Requirements

The model will not be tested if the base plate does not meet the requirements in Sections 5.7.a and 5.7.b. In this case, the model would be considered collapsed for both ground motions.

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 the word 'North' shall be written with black permanent marker within 1 in. from the North edge and within 6 in. of the East edge of the base plate.

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 the first ground motion. 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 both ground motions. Failure of the base plate (i.e delamination, crushing or fracture) that causes the structure to become unstable, to rock back and forth unattached from the base, or to fall off the shake table is considered a collapse of the structure.

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. The second identical base plate shall have the name of the school written in black permanent marker. If the judges deem the second base plate is not identical, the judges will assign the base plate a tare weight of 0.0 lbs. Identical notching is not necessary in the second base plate. Failure to provide a second identical wood base plate will result in the tare weight of the plate to be 0.0 lbs. Therefore, the weight of the base plate will be included in the Structural Model Weight $W_s$ (Section 5.12) used for scoring purposes.

### 5.8 **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 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. If the accelerometer cannot be attached to the model for any reason, the team will receive an *APS* equal to 100% (Section 2.2).

5.8.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.

A 6.00 in by 6.00 in square continuous wood roof plate is needed to attach the accelerometer to the building. The roof must contain the entire square roof plate on its surface. No part of the roof plate is allowed to not land on the roof surface.

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

5.8.b Structural Model Roof Plate Thickness Dimensions

Any dimensional violation resulting in the roof plate thickness falling outside of the indicated range will result in 20 added to *V* and may also result in the judges not allowing the accelerometer to be attached to the structural model during shaking.

The roof plate thickness shall be between 0.3 in. and 0.4 in. Therefore, teams are recommended to use 3/8 in. plywood or MDF plates and independently verify that the measured thickness falls within the indicated range.

All thickness measurements will be checked with a caliper.

5.8.c Structural Model Roof Plate Requirements

Due to safety concerns, **the roof accelerometer will not be attached if the roof plate does not meet the requirements in Sections 5.8.a and 5.8.b.**

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 (scaled drawings of the C-clamps will be provided in the design guide), the accelerometer will not be attached to the structural model.

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. The second identical roof plate shall have the name of the school written in black permanent marker. If the judges deem the second roof plate is not identical, the judges will assign the roof plate a tare weight of 0.0 lbs. Identical notching is not necessary in the second roof plate. Failure to provide a second identical wood roof plate will result in the tare weight of the plate to be 0.0 lbs. Therefore, the weight of the roof plate will be included in the Structural Model Weight $W_s$ (Section 5.12) used for scoring purposes.

5.9 **Innovative Damping Devices**

All damping devices must be approved in the Damping Device Approval Process (Section 4.2). 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 6.4.

5.10 **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 finish on all frame and wall members must be bare wood. Paint or other coatings will **not** be allowed on any portion of the model. Burned surfaces from laser cutting are permitted.

5.11 **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.

5.12 **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 <u>5.0lb</u>.**

## 6. <u>Strong Ground Motion Testing</u>

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

### 6.1 **Scaled Ground Motions**

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

### 6.2 **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.

### 6.3 **Dead Load Specifications**

6.3.a Floor Dead Loads

A floor dead load shall be installed at the locations specified in Section 5.5 following the instructions in Section 6.4.a. At the highest relevant floor specified in Section 5.5, the floor dead load will be represented by a 20 in. long ½ in. diameter steel threaded rod, 8 plates (Simpson Strong Tie BP 5/8-2), 4 washers and 4 nuts. The total weight at the highest relevant floor will be 2.69 [lb]. The remaining floor dead loads will be represented by a 20 in. long ½ in. diameter steel threaded rod, 4 plates (Simpson Strong Tie BP 5/8-2), 4 washers and 4 nuts. The total weight of these individual dead loads is 1.96 [lb].

6.3.b Roof Dead Loads

The roof dead load will be represented by the accelerometer and two C-clamps. The two C-clamps will be used to secure the 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 0.85 [lb].

### 6.4 **Dead Load Installation**

6.4.a Floor Dead Loads

Each floor dead load shall be securely attached to the structural model at the floors indicated in Section 5.5.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 (including the vertical direction). Movement of the floor dead loads can be restricted with frame or wall members and/or using friction from tightening the nut at each end of the threaded rod (keep in mind nuts can become loose during shaking). Each team is responsible for installing and securing the floor dead loads. See Section 6.9.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, or 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 will be assumed collapsed for both 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 5.5). 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, 2 plates (per Section 6.3.a), 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 8 minutes to install and tighten the dead loads. If 8 minutes have passed and the team has not finished installing the floor dead loads, a penalty of 20 will be added to *V*. Teams may recruit other non-team members (excluding SDC Chairs) to assist in installing floor dead loads.

A SDC Chair shall be present while the team is installing the floor dead loads to ensure proper installation of the floor dead loads. Another SDC Chair shall check the floor dead loads before the structural model is attached to the shake table (Section 6.5). If the SDC Chair finds any weights free to move in any translational direction, the SDC Chair shall notify the team captain prior to shaking. After the 8 minutes, 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 as described in Section 6.9.a.

6.4.b Roof Dead Load

The roof dead load shall be attached to the structural model roof plate with two C-clamps at opposing corners (scaled drawings of the C-clamps will be provided in the design guide). It is the responsibility of the SDC Chair(s) to secure the roof dead load to the structural model roof plate before installing the structural model to the shake table (Section 6.5). The time required to attach the roof accelerometer will not be included in the time each team has for installing the dead loads. 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 Ground Motion 1. The roof dead load is considered not level if the bubble of the level is completely outside of the lines. See Section 6.9.b for penalties associated with an unsecured or not level roof dead load.

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

SDC Chairs will determine the direction of shaking by flipping a coin prior to the beginning of shaking. The coin flip will determine if shaking is in the North-South direction or East-West direction and apply to all structures for the duration of the competition.

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 aluminum 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 aluminum angles will be secured with the 4 corner clamps. Two 12 in. long aluminum 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 aluminum angles will be secured with a center clamp. If the base plate is warped, the corners of the base plate will be clamped so there are no gaps at the corners between the shake table base, the aluminum angle, and the base plate. A SDC Chair will check each clamp after installation.

6.6 **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 6.3).

6.7 **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 $3^{rd}$ 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.

6.8 **Damage Calculations**

6.8.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 4.

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).

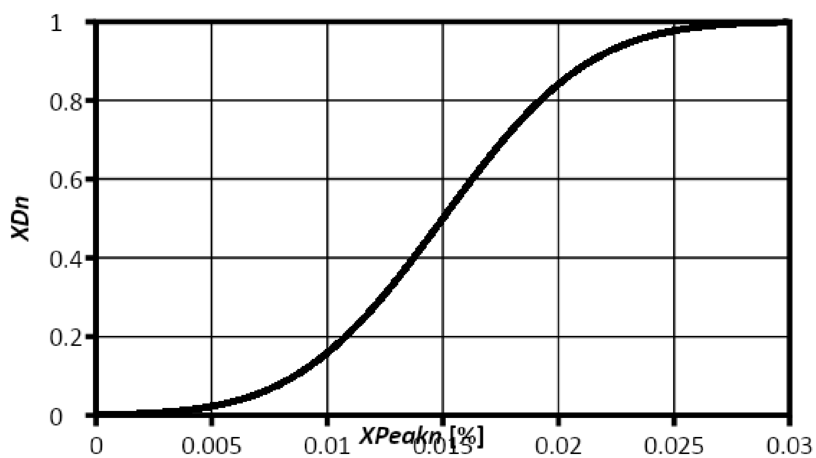


**Figure 4:** Function relating peak roof drift, $XPeak_n$, and structural damage as a percentage of construction cost ($XD_n$)

6.8.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 ($AD_n$) is a function of $APeak_n$ and is plotted in Figure 5.

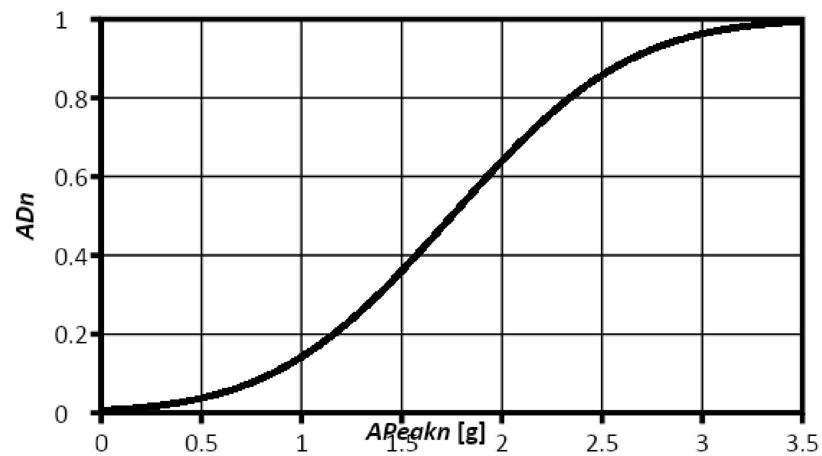


**Figure 5:** Function relating peak roof acceleration, $APeak_n$, and equipment damage as a percentage of equipment cost ($AD_n$)

### 6.9 **Penalties and Determining Collapse**

6.9.a Unsecured Floor Dead Load Penalties

After each ground motion, an SDC Chair will inspect the building for any unsecured floor dead loads (Section 6.4.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 SDC Chair (Section 6.9.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%.

A floor dead load is considered unsecured:

- 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
- If any end of the floor dead load can be moved more than ½ in. in any translational direction measured at the exterior face of the building. This includes the vertical direction. The amount of force applied by the SDC Chair to the floor dead loads will be enough to check for movement and is at the discretion of that SDC Chair.

- If one floor dead load is in contact with another floor dead load, both are considered unsecured.

6.9.b Unsecured or Not Level Roof Dead Load

Before each ground motion, an SDC Chair will inspect the roof dead load. If an SDC 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 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.

6.9.c Defining Collapse of a Structural Model

An SDC 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 unsecured (Section 6.9.a)
- The structural model base plate has delaminated to the point where the structural model is rocking on the shake table.

The floor levels will be checked 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.

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

If collapse occurs during Ground Motion 1, collapse will be assumed to happen for Ground Motion 2 for scoring purposes.

## 7. <u>Score Sheets</u>

All score sheets can be reviewed and signed by the team captain immediately after judging has completed. Only team captains shall discuss penalties and score sheets with the SDC Chairs (Section 9).

At the team meeting, the SDC Chairs will indicate a time when team captains can begin to come by the judging table to review the judging sheets. The indicated time may change depending on the time required to review all the models.

The SDC Chairs will specify a cut-off time for appeals when the final competition schedule is released (check the website for updates). After this time, the judges can refuse to review any score sheets and hear any appeals. The score sheets will be signed by two SDC Chairs and the penalties assessed can no longer be appealed.

The judging sheet review process will occur as follows:

- The judging sheet will be explained by an SDC Chair to the team captain **and only the team captain.**
- The SDC Chair will show the violation(s), if any, on the model.
    - If applicable, penalties will be marked with red permanent marker or stickers on each structural model for quick visual identification.
- An SDC Chair will show the team captain the rule/violation and penalty assessed in the official rules (or clarifications) if needed.
- If no penalties were found, the team captain may sign the judging sheet or let two SDC Chairs sign the scoring sheet.
- If a penalty is assessed, a team captain may do one of the following:
    - Sign the scoring sheets and forfeit the opportunity to appeal the penalty(s).
    - Review the penalties with his or her team members to prepare for an appeal.
        - The SDC Chair will continue reviewing other team's scoring sheets and the team captain will need to wait for the next available SDC Chair for the appeal.
    - Appeal the penalties.

The appeal process is explained in Section 9.1.

Once the scoring sheets have been signed either by the team captain or two SDC 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 they attempt to continue appealing for penalties assessed on the scoring sheet(s) already signed, **the team will be disqualified**.

### 7.1 **Verification of Electronic Score Sheet Entry**

Either during or at the end of shaking day, teams will receive a "shaking day score sheet" via email or hard copy. This score sheet will be a version of the final score sheet: it will contain information including but not limited to building weight, total penalties (V), and shake table performance; it will *not* contain any information about other scores or bonuses received.

It is the duty of the team captain to review the information on this sheet for typographical errors. Any such errors, especially those affecting the calculation of scores, must be reported to the SDC Chairs, either in person or by email, before 9:00

PM competition local time of the evening before the awards ceremony. The SDC Chairs will review the hard-copy score sheets, and will rectify any errors that are reported in this way. If a team captain has not reported any errors by the deadline, it is assumed that they have reviewed their score sheet and accept all information as typographically accurate.

Please note that this is *not* an opportunity to initiate any appeals (Section 9), or to dispute the scores in any other way. This is only an opportunity to verify that the information entered electronically is typographically consistent with the information recorded on hard-copy (which has already been signed by the team captain or two SDC Chairs, as explained above).

## 8. Rule Clarifications

All rule clarification 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, which can be found on the competition website. Questions or clarifications about the rules sent via email will not be answered. Be sure to read the rules, guide, and any other current-year clarifications thoroughly before submitting a question.

## 9. Judging and Appeals

The SDC 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 SDC Chairs are final. If any questions arise during the competition, the team captain should ask one of the SDC Chairs, not other SLC members.

Only a team captain may discuss decisions or appeals to SDC Chairs. SDC 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 SDC Chair regarding penalties or scoring. This includes but is not limited to other teammates, alumni, professors, and especially other SLC members. If this becomes an issue, the team captain will be warned, and in extreme cases, the SDC Chairs reserve the right to disqualify the team.

The SDC 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 SDC Chairs when making an appeal. The SDC Chairs strive to be fair and consistent with all teams regarding the official rules.

### 9.1 **Appeals Process**

A team captain can make an appeal about a penalty or decision before signing a score sheet. An appeal begins the very instant the team captain questions the penalty(s) to a Seismic Design Competition Chair(s). Only one appeal per team can be made for all penalties assessed. The team captain must explain using the official rules and clarifications why the penalty or decision should be changed. An SDC Chair will hear the team captain's appeal and may consult other SDC Chairs before making a final decision. After a final decision has been made by the SDC Chair(s), the team captain cannot appeal the penalty any further. If the team captain refuses to sign the score sheet, two SDC Chairs will sign the score sheet instead and the score sheet will be considered signed by the team captain.

In the interest of time, **no appeals are allowed once shaking of the structures has begun.** The team captain may ask for an explanation on why their structure was determined collapsed, but the buildings must be tested and moved along.

### 9.2 **Rule Modifications**

In very rare cases, unexpected circumstances may arise that threaten the spirit of the competition. In these cases, the SDC Chair(s) reserve the right to modify the rules, if such a modification would preserve the quality of the competition.

## 10. Code of Conduct and Plagiarism

The SDC Chairs and other SLC members understand that teams have worked very hard to compete in the event, but would also like the teams to recognize that they, too, have worked very hard to organize and run the event. As such, individuals who treat the SLC with extreme disrespect may be **dismissed from the tournament, and their team may also be disqualified from the tournament.** Individuals include but are not limited to teammates, team advisors, alumni, professors, and team sponsors.

EERI is committed to fostering the exchange of ideas by providing a safe, productive, and welcoming environment at the 12th National Conference on Earthquake Engineering (12NCEE). We value the participation of every member of the community and want all participants to have an enjoyable and fulfilling experience. All 12NCEE participants, including seismic design competition team members, are expected to be considerate and collaborative, communicating openly with respect for others, and critiquing ideas rather than individuals. Behavior that is acceptable to one person may not be acceptable to another, so use discretion to be sure that respect is communicated. By accepting an invitation to participate in the seismic design competition, participants agree to abide by the EERI Code of Conduct posted here: https://12ncee.org/registration/code-of-conduct.

Plagiarism is strictly prohibited throughout the competition. Taken from [1], examples of plagiarism include:

- Taking credit for any work created by another person.
- Copying any work belonging to another person without indicating that the information is copied and properly citing the source of the work.
- If not directly copied, using another person's presentation of ideas without putting it in your own words or form and not giving proper citation

- Creating false citations that do not correspond to the information you have used.

So-called common knowledge does not need to be cited; for more information, see [2].

[1] OSSJA (2016). “UC Davis Code of Academic Conduct.” <http://sja.ucdavis.edu/cac.html>.

[2] MIT (2016). “What is Common Knowledge.” <https://integrity.mit.edu/handbook/citing-your-sources/what-common-knowledge>.