Sixteenth Annual Undergraduate Seismic Design Competition (SDC)

OFFICIAL RULES

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

Competition Website: https://slc.eeri.org/2019-seismic-design-competition/

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1. Introduction

1.1 **Competition Objectives**

The objectives of the 16th Annual Undergraduate Seismic Design Competition sponsored by EERI 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 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 undergraduate students as well as the general public, and to encourage international participation in these activities.

1.2 **Problem Statement**

Vancouver, British Columbia, located on the western coast of Canada, is known for its urban livability and stunning natural backdrop. Vancouver, full of famous parks and delicious seafood, is located near the edge of the Cascadia subduction zone, where the Juan de Fuca, Pacific, and North American plates meet. Due to the Juan de Fuca plate moving under the less dense North American plate, a prospective megathrust earthquake is expected to develop approximately 300 kilometers off the coast of Vancouver. In addition to this, deformation of the North America plate has created many small shallow faults that could rupture as few as 10 kilometers beneath the city. While not a megathrust earthquake, these smaller crustal ruptures could cause more damage for the city due to their proximity.

Your company has been tasked with responding to a Request for Proposal (RFP) to construct a new building in downtown Vancouver. The client has high expectations that this new building will be an iconic structure and a celebrated addition to the downtown area. Vancouver is the most densely populated city in Canada and as such the client has purchased a smaller piece of land than anticipated. Additionally, Metro Vancouver's Regional Growth Strategy (RGS) encourages mixed-use development. The client plans to leave two corners of the land for a small park and bike garage leaving a T-shaped area for the building footprint. 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 that downtown Vancouver offers. The client has given you, the engineer and designer, the ability to decide how the remaining stories in the building will be rented (residential, office, etc.). With its Greenest City Initiative approved in July 2011, Vancouver is aiming to become the greenest city in the world by 2020 and your building should feature efficient and creative approaches to minimize the building's carbon footprint.

Vancouver is primarily situated on Ice Age sediments creating layers of sandstone and shale. As mentioned previously, your building will be in the heart of downtown Vancouver, and existing tunnels, city utility lines, and neighboring buildings might affect the seismic response of a new high-rise structure. Although the structural model does not need to account for the subsurface conditions, your proposal must demonstrate an understanding of the geotechnical challenges posed by these considerations.

To verify 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, representing earthquakes with different return periods. To ensure life safety, the building model must not collapse during either of the ground motions. The response of the model, quantified through 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 losses 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 contained inside the building. If collapse occurs, the monetary losses will account for demolition, reconstruction, and downtime. Finally, the annual seismic cost will be determined 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 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:
  http://www.eeri.org/about-eeri/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 welcomed 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. 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 5)
- 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 2nd, 2018
Proposal Submittal	Friday, November 2nd, 2018
Final Registration	Tuesday, January, 15th, 2019
Floor Area Calculations & Performance Predictions	Friday, March 1st, 2019

Teams will be invited to participate by November 19th, 2018.

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**

- Predictions are required for both shaking directions.
- Minimum member sizes are implemented.
- Maximum floor dimensions have been changed.
- Floor access requirements have been changed.
- Maximum floor area has changed.
- Proposal requirements have changed.
- Poster size has changed.
- Revenue per floor has changed.

2. <u>Scoring</u>

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 earthquakes 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 the first ground motion and the value of the peak relative roof drift will be used to estimate the monetary loss from damage to the structure. The response of the model in terms of roof drift and roof acceleration is expected for shaking in both the North-South and East-West directions. 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 architecture score will be used as the tiebreaker.

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

The design proposal portion is detailed in Section 5.1. 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 seven 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.

A projector and laptop, running Microsoft Windows 7 or newer, and PowerPoint (Office 2007 or newer) will be provided. The presentation files will be uploaded to the competition laptop by the SLC prior to the first presentation. Teams must submit their presentation files by email *before* the week of the competition (check the official website for exact deadline). Teams are responsible for software compatibility. Teams may check software compatibility during the scheduled time for Check-in and Registration

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)

For more information, please see the presentation judging rubric on the competition website. Any team that does not present at the scheduled time will have 100 added to *V* (Section 2.4).

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.

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

The dimensions of the poster are restricted to a height of 30 in. and a width of 20 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 for both shaking directions (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 receive 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. 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 the design proposal, presentation and poster category will receive this benefit. Only 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	Proposal	Presentation	Poster	Architecture
1^{st}	15%	15%	12%	8%
2^{nd}	12%	12%	10%	6%
3^{rd}	10%	10%	8%	4%
4^{th}	8%	8%	6%	2%
5^{th}	6%	6%	5%	1%
6^{th}	4%	4%	4%	0%
7^{th}	3%	3%	3%	0%
8^{th}	2%	2%	2%	0%
9^{th}	1%	1%	1%	0%
$\geq 10^{th}$	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 and the East-West Directions (a total of 4 predictions). Although performance predictions for both 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. 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 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*, and with an *APS* values 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 2-2 for the percentage increase per rank.

Table 2-2: 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.b and 5.6.c):

$250 per year per square inch for floors 1 through 2
$175 per year per square inch for floors 3 through 9
$225 per year per square inch for floors 10 through 15
$275 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*, *Damping Device(s) cost*, *Land Cost*, and *Design Life*.

$$Construction\ Cost = C_c = 2{,}500{,}000\ \left[\frac{\$}{lb^2}\right] \times (W_s\ [lb])^2 + 6 \times 10^6\ [\$]$$

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

$$Damping\ Device(s)\ Cost\ = C_d = (0.00625\ \times\ N_d + 0.0125) \times C_c\ if\ N_d \leq 10.$$
$$Otherwise\ C_d = 0.075\ \times C_c$$

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

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

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

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. The number of approved damping device(s) is N_d.

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).

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

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

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:

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

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

If the structural model is not deemed collapsed (Section 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:

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

Teams will have the option of leaving the accelerometer in place during Ground Motion 2. The data from the accelerometer will not be used for judging, therefore, 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:

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

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 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 whom 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 communication score to any team which demonstrates unprofessional written or oral communication 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 ten best proposals (Section 2.1.d). The following is an itemized list of the deliverables required in the proposal:

- The proposal shall not exceed 3 pages. Any proposal exceeding the page limit will not be scored.
- Plagiarism is strictly prohibited and may result in disqualification or non-invitation to compete. Any citation style is accepted, as long as it is consistent.

Works Cited or References pages are required but do not count toward the page limit. See Section 10 for more information.

- Format requirements: 11pt, single-spaced, US Letter (8.5 in x 11 in), Times New Roman font with 1 inch margins.
- Page 1: Title Page
  - Name of the school, overall computer-generated image of the exposed structural system (an optional computer-generated image of the final architectural state may also be included), names of all team members and the designated team captain.
    (Note: the designated team captain will be the only point of contact between the team and the SDC Chairs from the start of the design to the completion of the competition).
- Pages 2 - 3: Proposal Content
  - Proposals will be judged on the following:
    - A summary of the site conditions and seismic activity expected for the Vancouver, B.C. region (e.g., soil type, historic earthquakes, major faults, magnitude and shaking expected for future earthquakes, and any other information relevant for seismic design considerations)
    - Description of the structural system and elaboration on the plans for predicting the structural behavior (computer modeling, small-scale testing, etc.)
    - Explanation of how the client's architectural requirements (as detailed in the problem statement) will be met and any other economic considerations.
    - Professionalism demonstrated through concise and clear writing with a good command of grammar and spelling.
  - 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 4.2).
  - Diagrams and photos are recommended but must fit within the page limit.
  - For additional information, please see the Design Proposal Rubric on the competition website.
- Page(s) 4(+): Works Cited
  - Teams must cite the references that they use in creating their proposal.
  - No additional content for the proposal may be included on the Works Cited page(s).

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. The SDC Chairs will confirm the submission.

sdc@eeri.org

Teams are not bound to the designs submitted in the design proposal process. Design proposals are not evaluated for rule violations. Selected designs are still subject to penalization or disqualification. Teams are responsible for ensuring that their buildings follow the competition rules. For any clarification, refer to the clarifications section on the competition website, or the team captain can submit a clarification request (See Section 8).

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 by the date listed on the competition website. More than one damping device proposal may be submitted. Each proposed damping device must be described in detail, explaining the mechanism used to dissipate energy and its placement within the structural model. Figures are highly recommended to aid in describing the damping device.

Prior to approval, judges will evaluate the proposed damping device(s) and may ask for testing results and predicted design forces from a computer model (e.g., subjected to Ground Motion 2) to prove the damping devices would dissipate energy. If the judges ask for additional information about the proposed damping device(s), that information must be provided within fourteen days of the initial request. Failure to provide the requested information to the judges within the specified time frame will result in the damping device(s) not being approved. Pre-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 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 not 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. The damping device must not interfere with dead load installation locations.

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 submitted damping device proposal (e.g., installation location, connection to structure, material) 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. <u>Structural Model</u>

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.

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 1.50 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.

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. 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.

It is the discretion of the SDC Chairs to assess *V* for ungluded connections if that connection (regardless if the two adjoining members are close, but are not touching) is reasonably expected to be jointed. For example, floor beam elements can be reasonabaly expected to be connected to perimeter beams and are typically not cantilevered within a footprint of perimeter beams.

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*.

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 1 in. in any direction from the centroid of the faying surface. For each inch that a faying surface exceeds the 1 in. maximum (e.g. 2 in. faying surface), an additional 3 V will be added. If frame members are laminated, such as in a column, each surface in contact with another surface will be considered a faying surface.

Excess glue is any glue more than ½ an inch away in any direction from a fraying surface (Teams should take care when choosing and applying glue to connections).

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 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. For each member that was designed as a gusset plate that exceeds the 0.100 in by 1 in by 1 in box, a penalty of 3 will be added to *V*. 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 1/2 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.

5.4.d 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 more than ½ an inch away in any direction from a faying surface (Teams should take care when choosing and applying glue to connections). There is no restriction on length of faying surface in wall member to wall member connections.

5.4.e 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.

Excess glue is any glue not between the faying surfaces but in contact with glue between a faying surface and shall be confined to 1/2 in. in any direction of the edge of any faying surface (Teams should take care when choosing and applying glue to connections). There is no restriction on length of faying surface in frame member to wall member connections.

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*.

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.

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.

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

The connection should be strong enough for the team to tighten the nuts enough to engage adequate friction between the inner-most 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

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 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 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: 1600 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 two access points or doorways 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 are defined in Figure 1 below. All floors of the model must fit within the specified floor plan dimensions.

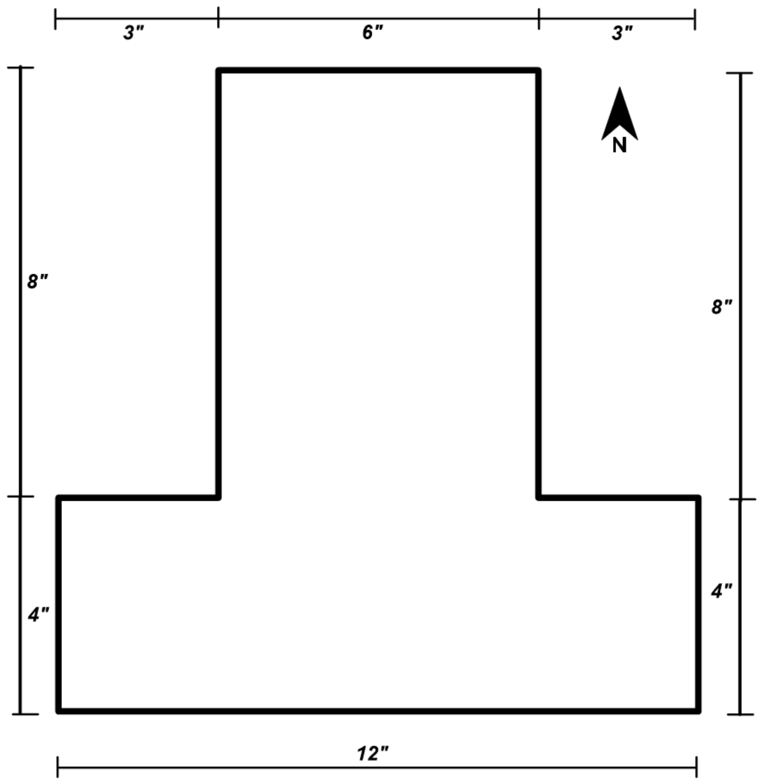

Figure 1: Maximum Floor Plan Dimensions

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 6.12) 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.

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 6.12) 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 7.4.

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 5.0lb.

6. Strong Ground Motion Testing

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. The Ground Motions this year are identical to the Ground Motions from the 2018 competition.

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 individual weight of the rod and total weight of the floor will be 2.69 [lb]. The remaining floor dead loads will be represented by a 20 in. long ½ in. diameter steel threaded rods, 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]. The roof dead load will be removed after Ground Motion 1 if the team elects to not leave the accelerometer in place for Ground Motion 2.

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 at least 8 minutes to install 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. The team will have <u>one minute</u> to tighten 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 as described in Section 7.9a.

6.4.b Roof Dead Load

The roof dead load shall be attached to 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 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 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.

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 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).

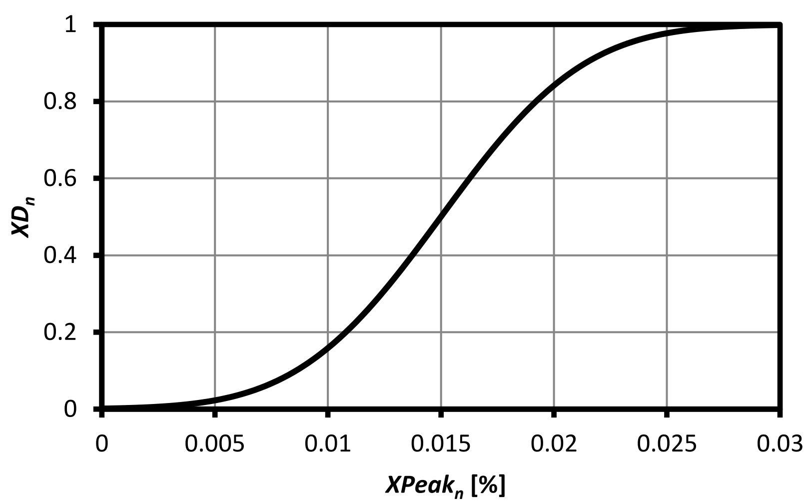

Figure 7-1: Function relating peak roof drift, $XPeak_n$, and structural damage as a percentage of construction cost (XD_n)

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 (XD_n) is a function of $APeak_n$ and is plotted in Figure 7-2.

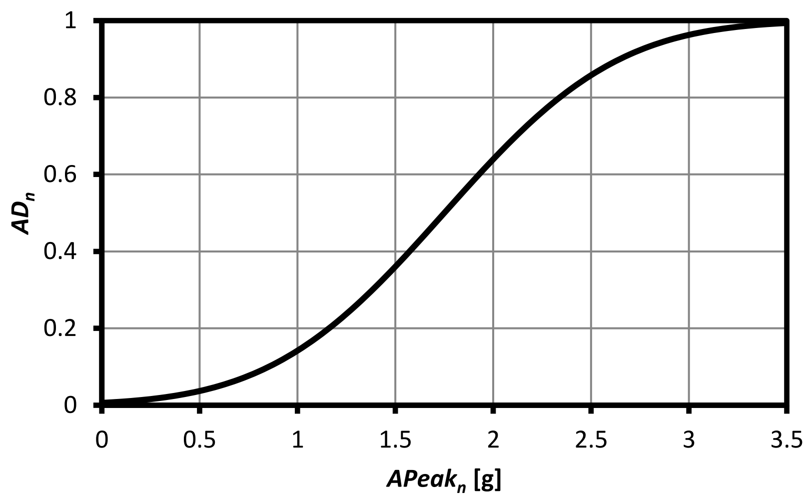

Figure 7-2: Function relating peak roof acceleration, $APeak_n$, and equipment damage as a percentage of equipment cost (AD_n)

6.9 **Penalties and Determining Collapse**

6.9.a Unsecured Floor Dead Load Penalties

After each ground motion, a 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 damaged.

6.9.b Unsecured or Not Level Roof Dead Load

Before Ground Motion 1, a SDC Chair will inspect the roof dead load. If a 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

A 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. Score Sheets

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 a 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.
- A 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. A 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 Seismic Design Competition 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 Seismic Design Competition 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.

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>.