*Twenty-First Annual Undergraduate Seismic Design Competition (SDC)*

# DESIGN GUIDE

**Organized and Run by:**

**EERI Student Leadership Council (SLC)**

**Competition Website:**

**https://slc.eeri.org/2024-sdc/**

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# 1. DISCLAIMER

This guide is meant to supplement the *Official Rules* and does not override any of the requirements in the *Official Rules*. The *Official Rules* are not subject to change from the time the *Official Rules* are released to the end of the competition, but this guide may be altered during that time.

The computer-generated images are examples to illustrate conformity to the rules. Note that many of the images only demonstrate conformity for the specific sections in the *Official Rules* that they directly refer to. Also, please be aware that the images of sample models are not designed to resist seismic ground excitation.

All mentions of sections highlighted in red within this guide pertain to sections outlined in the *Official Rules*. Conversely, when referring to figures, consider them as figures from this guide, unless stated otherwise.

# 2. MEMBER REQUIREMENTS

## 2.1 Frame Members

According to Section 8.4.a, each frame member before any glue is applied and in its final state attached to the model must fit in a box with the dimensions shown in Figure 1 (not to scale).

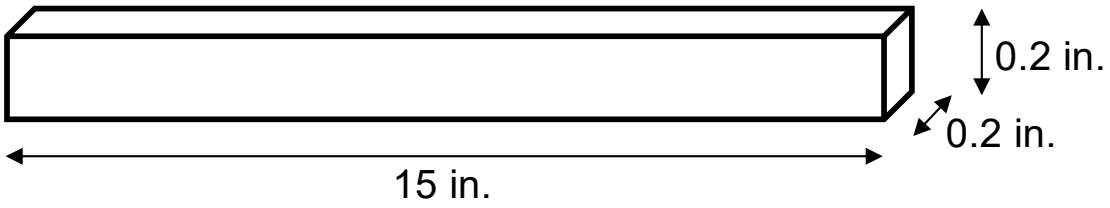



**Figure 1** Maximum dimensions for frame members.

Each individual frame member must not fit in the box with the dimensions shown in Figure 2 (not to scale).

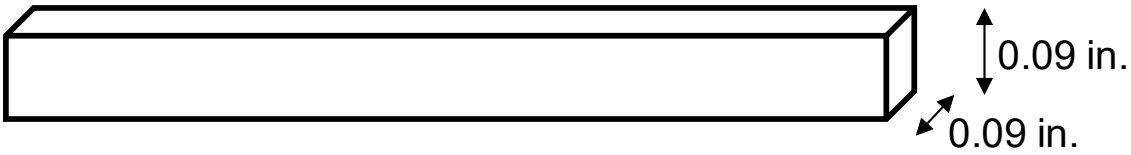



**Figure 2** Minimum dimensions for frame members.

Section 8.4.a also applies to any curved frame member. The frame member in its final state must fit in a box of the given dimensions. If a member already has the maximum cross section, then the member could not be curved, since it would no longer fit inside of the box.

There are no restrictions on how each member is cut as long as it is able to fit in the box in its final state before any glue is applied. A frame member may fit in a wall member box and vice versa. Judges will classify any member that can fit in the frame member box as a frame member. Judges will use discretion when determining the intended type of member, for members that do not fit in either box.

## 2.2 Wall Members

According to Section 8.5.a, each wall member before any glue is applied and in its final state attached to the model must fit in the box with the dimensions shown in Figure 3 (not to scale).

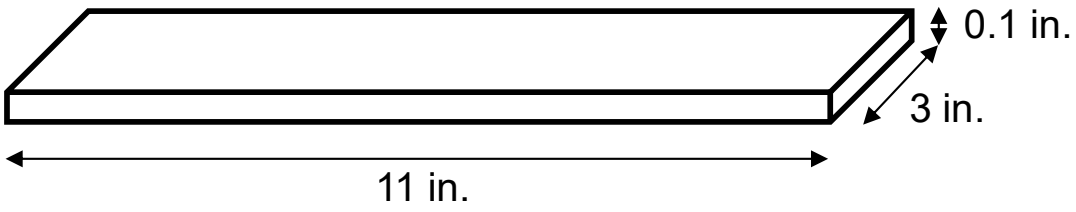



**Figure 3** Maximum dimensions for wall members.

Minimum dimensions for wall members have been added for the 2024 SDC. These include:

- A wall member must span vertically (measured perpendicular to the base plate) at least 2.75 in.
- When measured along the base plate, one of its dimensions (referred to as the wall width) should also be a minimum of 1.0 in. Consequently, walls with a triangular shape do not meet these requirements. Teams should take note that there are restrictions on the orientation of wall members (Section 8.5.b).

These minimum requirements are illustrated in Figure 4.

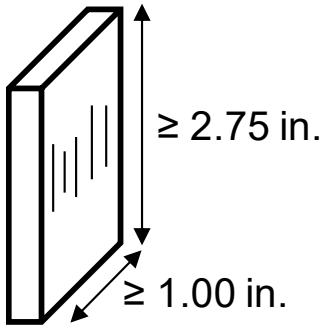



**Figure 4** Minimum dimensions for wall members.

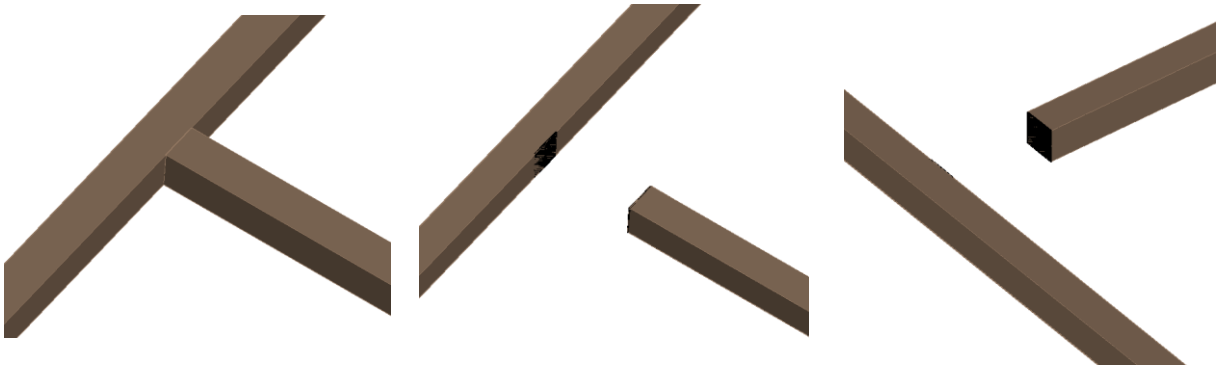
# 3. CONNECTION REQUIREMENTS

Individual members in contact shall have glue between the contact surfaces or faying surfaces (Sections 8.6.a, 8.6.b, 8.6.c, and 8.6.d).

## 3.1 Faying Surfaces

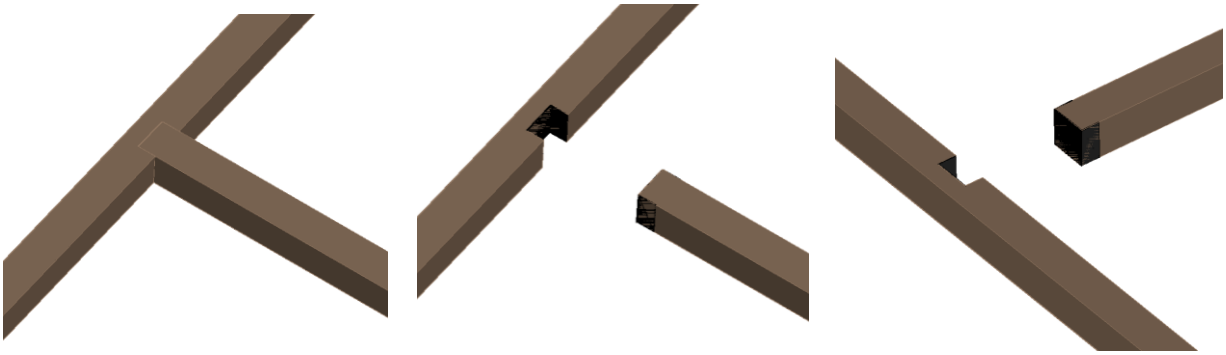
The faying surface is defined as the surface or portion of a surface of a frame or wall member in direct contact with the surface or portion of a surface of another frame or wall member. Glue shall be between these surfaces (Sections 8.6.a, 8.6.b, 8.6.c, and 8.6.d). Two examples of faying surfaces are shown in Figure 5 below.

For frame members, no single faying surface shall exceed 1 in. in any direction from the centroid of the faying surface (Section 8.6.b).



Completed connection View 1 View 2

(a) Connection with one faying surface per member.



Completed connection View 1 View 2

(b) Connection with three faying surfaces per member.

**Figure 5** Faying surfaces (shown as shaded areas) for framing members.

## 3.2 Excess Glue

Excess glue is any glue that is not between the faying surfaces but is in contact with glue from a faying surface. Excess glue shall not be more than ½ inch in any direction from the edge of a faying surface (Sections 8.6.a). Excess glue from each connection shall not be in contact (Section 8.6.a). An example of locations where excess glue is permitted is shown below in Figure 6 for 3/16 in. by 3/16 in. frame members.

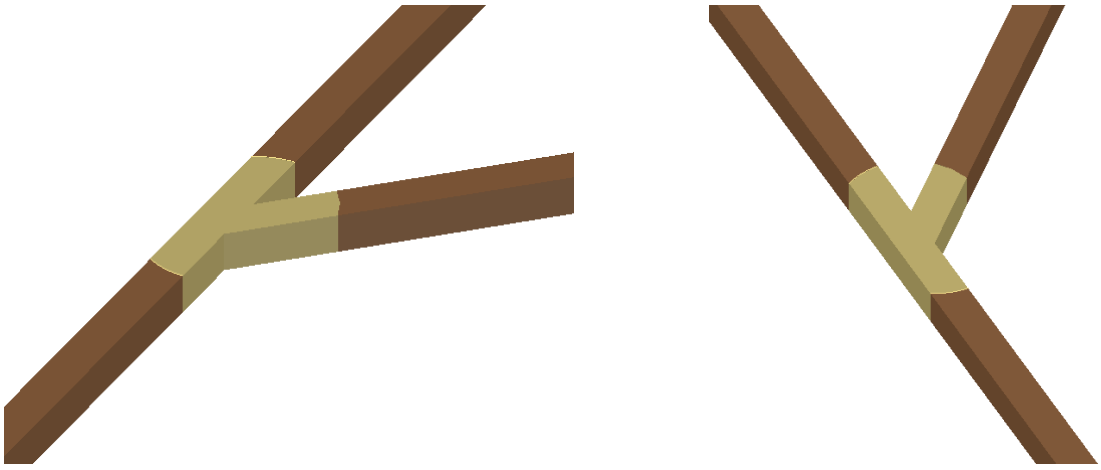


**Figure 6** Example of excess glue at faying locations.

## 3.3 Gusset Plates

Gusset plates are permitted. Gusset plates are defined as sections that add additional reinforcement at the interface between two frame members; they shall not be in contact with any wall members (Section 8.6.c). Each gusset plate shall fit in a box with dimensions 1 in. by 1 in. by 0.10 in. (Section 8.6.c and as shown in Figure 7 below). Similar to the excess glue requirements for frame members and wall members, excess glue is confined to ½ inch from the contact surfaces of the gusset plate and frame members (Section 8.6.c).

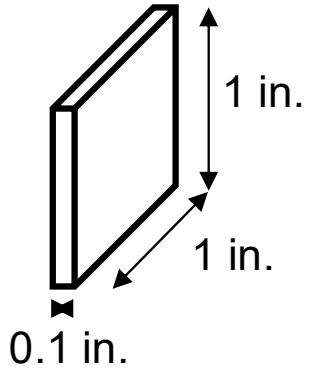



**Figure 7** Maximum dimensions of a gusset member.

## 3.4 Base Plate and Roof Plate Connections

Frame members and/or wall members in contact with the base plate must have glue between the contact surfaces of the member(s) and the base plate (Section 8.6.a). Frame members and/or wall members in contact with the roof plate must have glue between the contact surfaces of the member(s) and the roof plate (Section 8.6.a).

# 4. FLOOR REQUIREMENTS

With the unique design challenge of the 2024 SDC, this section should be especially understood to ensure total compliance of the structure within the guidelines of this edition of the Design Guide and the *2024 Official Rules*. All units are in inches [in.] unless otherwise noted.

The design challenge requires creating a building where the floor plan dimensions increase as the height of the building rises. Typical floor plans of maximum buildable areas for different zones of the building are shown in Figure 8.

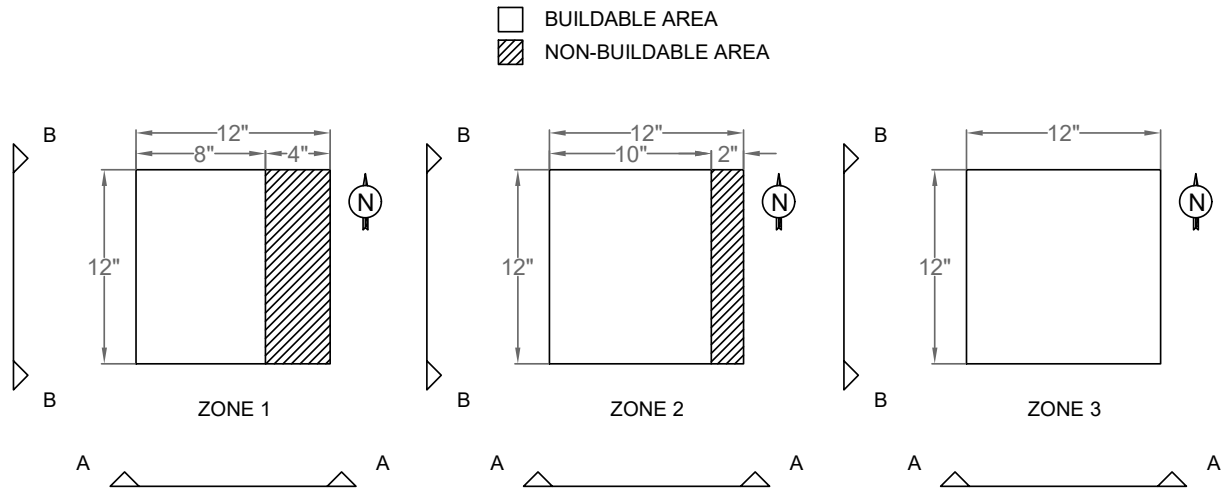



**Figure 8** Buildable floor areas for a typical floor in different building zones.

Rentable floor area (Section 8.2.d) must be within the perimeter beams and have spans less than 2.5 inches measured perpendicular to any beam. Rentable floor area must have a minimum ceiling height of 2.25 in. and at least one access point to any area at least 1 in. wide and 2.25 in. high. According to Section 8.2.b, each floor shall have a continuous set of perimeter beams (labeled with a black dot on the top) and have at least 80 square inches of rentable floor area at a given. Section 8.2.d of the *Official Rules* states that any floor plan area shall be confined within the buildable areas as shown in Figure 8. No members may be placed within the hatched areas shown in these figures. Templates shaped and dimensioned like Figure 8 will be passed over the structure without any tilting or rotation to confirm compliance to these limits. The templates will have a tolerance of 1/16" in each dimension.

Section 8.2.a states the minimum number of floors, $F$, is 15 and maximum number of floors is 19. The top of the perimeter beams shall be no further than ¼ in. from the required floor elevation. The roof shall be vertically 3 in. from the topmost floor, F. The roof plate shall be attached to the roof.

The structural model of the building is divided into distinct building zones, each characterized by specific features and floor areas. Building zones are illustrated for the cases of buildings with $F = 15$ to $F = 19$ in Figure 9 and Figure 10, where $F$ is the number of floors.

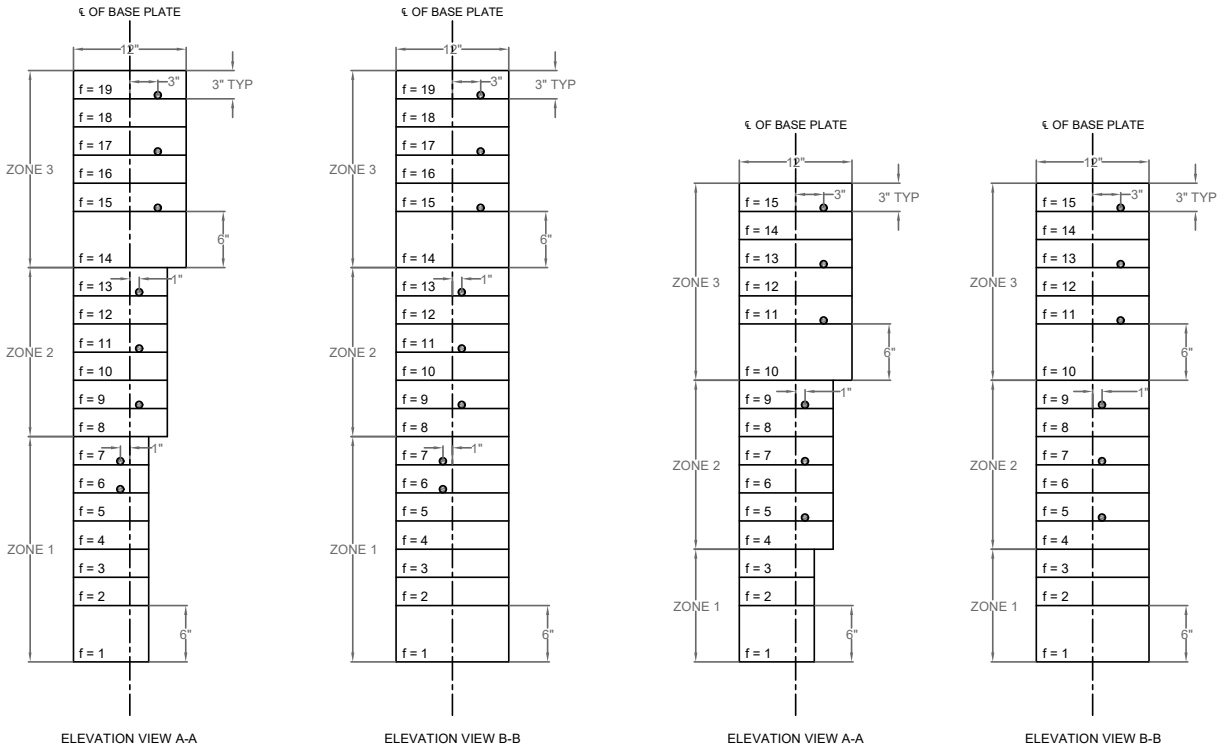



**Figure 9** Illustration of building zones in the structural model for $\boldsymbol{F = 19}$ and $\boldsymbol{F = 15}$. Refer to Figure 8 for notation used in elevation views. Black-filled circles represent the location of dead loads for shake-table testing.

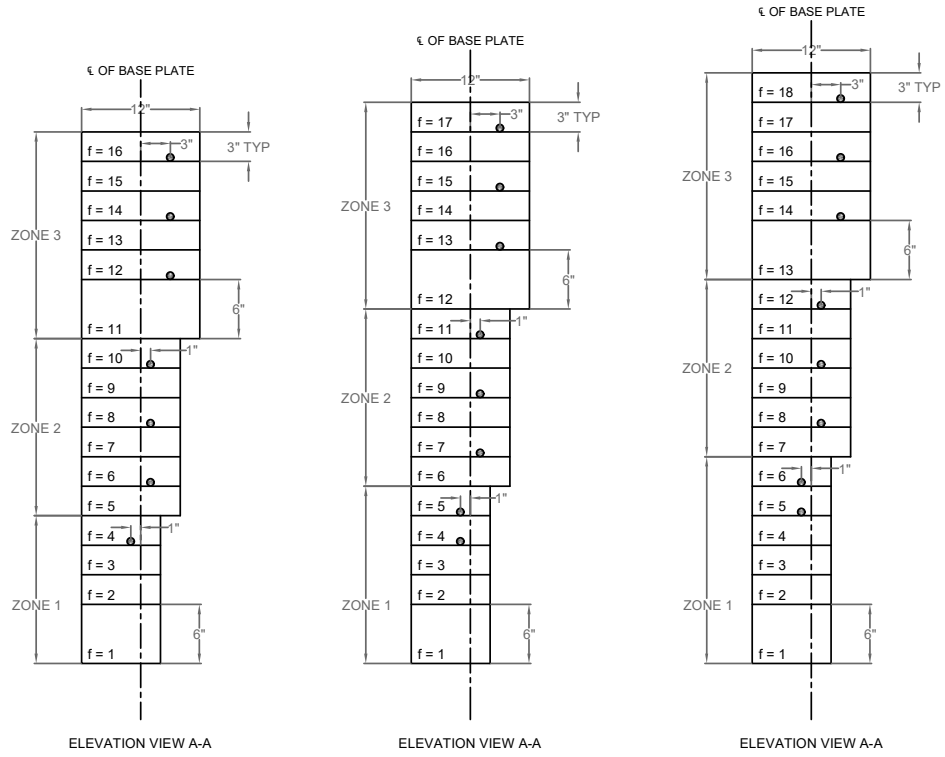



**Figure 10** Illustration of building zones in the structural model for $\boldsymbol{F = 16}$, $\boldsymbol{F = 17}$, and $\boldsymbol{F = 18}$. Refer to Figure 8 for notation used in elevation views. Black-filled circles represent the location of dead loads for shake-table testing.

In the below diagram, Figure 11, sample frame member spacings are shown for an arbitrary cross-section. Black dots are drawn on the tops of the perimeter beams. Areas hatched with dots are areas that do not count as rentable floor area due to spans greater than 2.5 inches measured from any point perpendicular to a beam bordering the opening. The independent rentable floor area (bottom right) does not count as rentable floor because it cannot be accessed from the larger rentable floor area in the upper half of the floor plan.

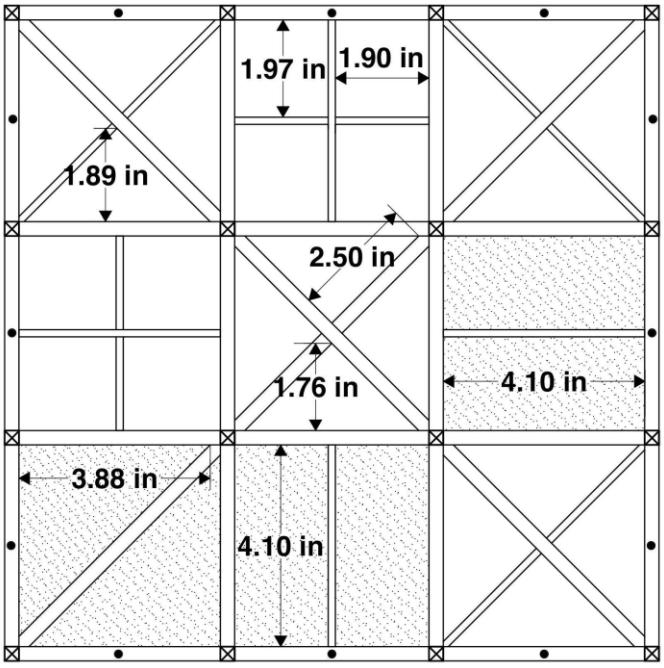



**Figure 11** Typical floor plan illustrating member spacing.

The lobby floor is defined by black lines drawn between the frame or wall members attached to the structural model base plate, shown in Figure 12. A beam at the second-floor level shall be directly vertical and parallel to any straight black line drawn on the base plate. Also note the black dots on the perimeter beams in the floors above.

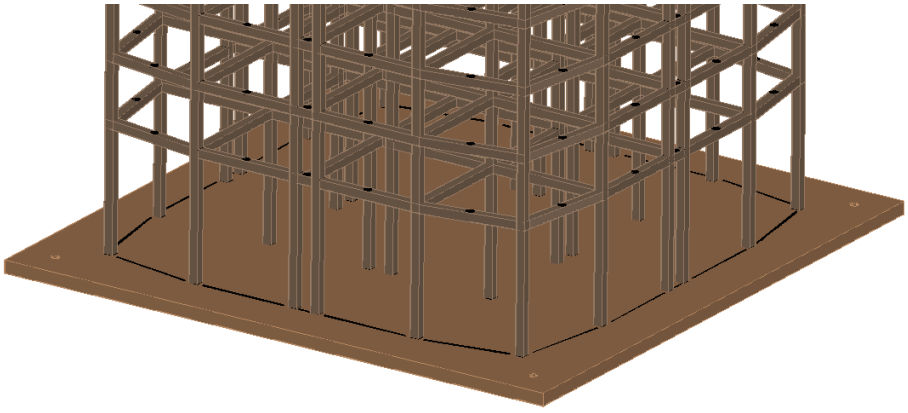


**Figure 12** How to draw black lines to define lobby floor area.

# 5. FLOOR DEAD LOAD CONNECTIONS

Floor dead load connections are required at the floors specified in the *Official Rules* in both the East-West (E-W) and North-South (N-S) directions. Due to the unique design of the, the floor dead load connections are defined at different locations across floors. Please refer to Figure 9 and Figure 10 for the different potential dead load layouts. Note that the location of the dead loads is defined relative to the centroid of the base plate for both E-W and N-S directions.

The dead load will be simulated using rods spanning across the E-W and N-S directions. The bottom of the dead load rod shall be in contact with the top of the perimeter beam of the floor in which the dead load is to be installed on (Section 8.7.a). After installing the rod, a series of washers and plates will be placed on the rod, and nuts will be used to hand-tighten the rod in place. Proper bracing should be included so no members or connections break after tightening the nuts.

# 6. BASE PLATE REQUIREMENTS

## 6.1 Base Plate

The base plate shall be made of plywood (at least 3-ply) or MDF, 18 in. by 18 in. (Section 8.8.a) and between 0.250 in. and 0.50 in. thick (Section 8.8.b). The bottom of the base plate must be flat and smooth (Section 8.8.c).

None of the models may be attached to the structural model base plate within 1.25 in. of any edge (Section 8.8.a).

An optional 1/4 in. diameter hole may be drilled within 2 in. of each corner to secure the model during shipping (Section 8.8.c).

The designated side must be labeled North with a black permanent marker (Section 8.8.c). The North should match the direction indicated in Figure 8.

Figure 13 shows a typical base plate for your reference.

A second identical base plate shall be provided for weighing. 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 8.13) used for scoring purposes (Section 4.4).

The 1/4 in. diameter holes used for shipping and notching holes are not required in the second base plate (Section 8.8.c).

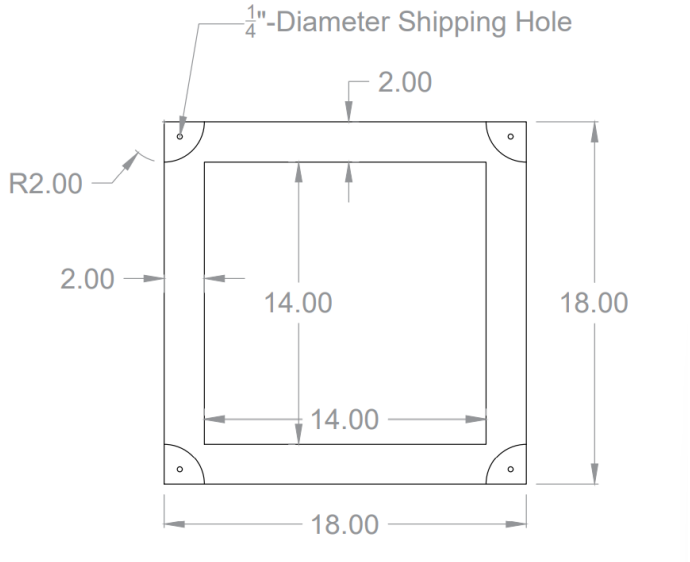



**Figure 13** Typical base plate for model.

## 6.2 Base Plate Notching

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 can only be present within 1/4 in. from the edge of a member breaking the plane of the top of the base plate (Section 8.8.c).

An example is shown in Figure 14:

- The far-left notch has a 3/16 in. x 3/16 in. frame member and glue filling the 5/16 in. diameter void, which meets the criteria for base plate notching.
- The top-most notch has a 3/16 in. x 3/16 in. frame member and glue filling most of the 3/4 in. diameter void which does not meet the criteria for base plate notching due to insufficient glue in the hole and glue extending 1/4 in. beyond the frame member edge breaking the top plane of the base plate. This will result in 10 added to $V$ for two violations.
- The bottom-most notch has glue filling a notch without a member within 1/4 in. breaking the top plane of the base plate. This will result in 5 added to $V$.
- The far-right notch has glue mostly filling a notch without a member within 1/4 in. breaking the top plane of the base plate. This will result in 10 added to $V$ for two violations of not filling the void and glue 1/4 in. beyond a member breaking the top plane of the base plate.

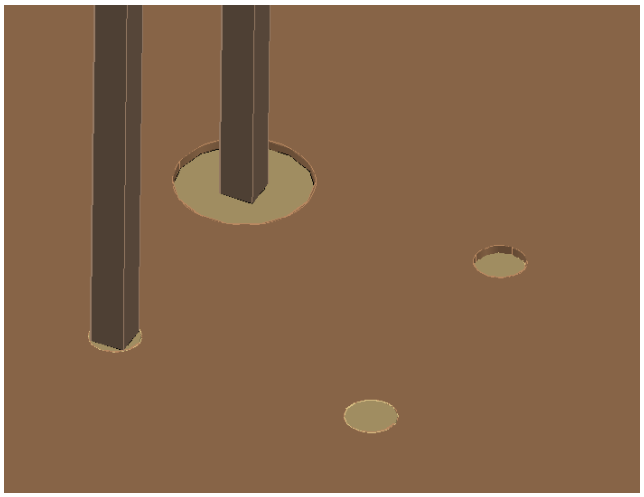


**Figure 14** Notching example.

## 6.3 Securing the Base Plate to the Shake Table

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 (Section 9.6).

Two 18 in. long steel angles (1 in. legs and 1/8 in. wall thickness) will span on top of the structural model base plate perpendicular to the direction of shaking on each side of the building. The two steel angles will be secured with the 4 corner clamps. Two 12 in. long 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 steel angle, and the base plate. A Seismic Design Competition Chair will check each clamp after installation. See the diagram below in Figure 15 for where the angles will be located. A clamp will be installed at the locations with a black circle on the diagram.

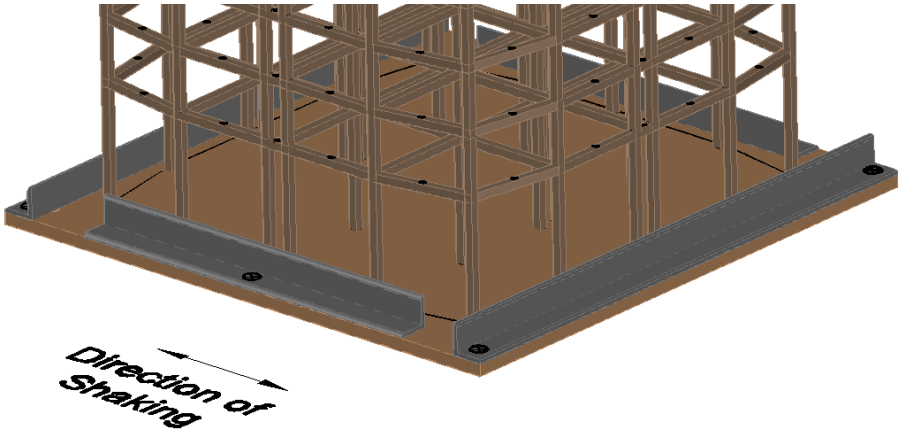



**Figure 15** Typical attachment of base plate to the shake table.

# 7. ROOF PLATE REQUIREMENTS

The roof plate shall be made of plywood (at least 3-ply) or MDF, 6 in. by 6 in. (Section 8.9.a), and between 0.3 in. and 0.4 in. thick (Section 8.9.b). Teams are advised to use a 3/8 in. plywood and independently verify that the measured thickness falls within the required range. The top of the roof plate must be flat and smooth (Section 8.9.c).

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 that the roof plate is not level or centered, or that it is not made of the allowed materials, or that the accelerometer cannot be attached for any other reason, then the accelerometer will not be attached to the model and the team will receive an $APS$ equal to 100% (Section 8.9, Section 4.2).

A second identical roof plate shall be provided for weighing. 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 8.13) used for scoring purposes (Section 4.4). Notching holes are not required in the second roof plate (Section 8.9.c).

Roof plate notching is permitted (Section 8.9.c). See the base plate notching example. The framing into the roof plate should allow for the roof dead load to be installed using two C-clamps with a one-inch throat and one-inch jaw opening.

# 8. DISPLAY REQUIREMENTS

Four pieces of paper no larger than 1.5 inches by 6 inches shall be affixed to the building with the name of the university. One paper shall be facing each of the four cardinal directions (Section 8.12).

Each floor shall be labeled with a number according to the *Official Rules* (Section 8.12) with either a number written on a piece of paper taped to the floor or the number written directly on the balsa wood.

# 9. FLOOR DEAD LOAD DIMENSIONS

The floor dead load dimensions are shown in Figure 16 and Figure 17.

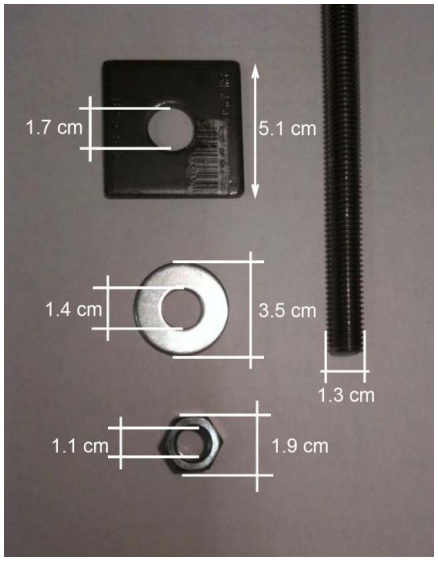



**Figure 16** Dimensions of dead-weight components used throughout structure (1 in = 2.54 cm).

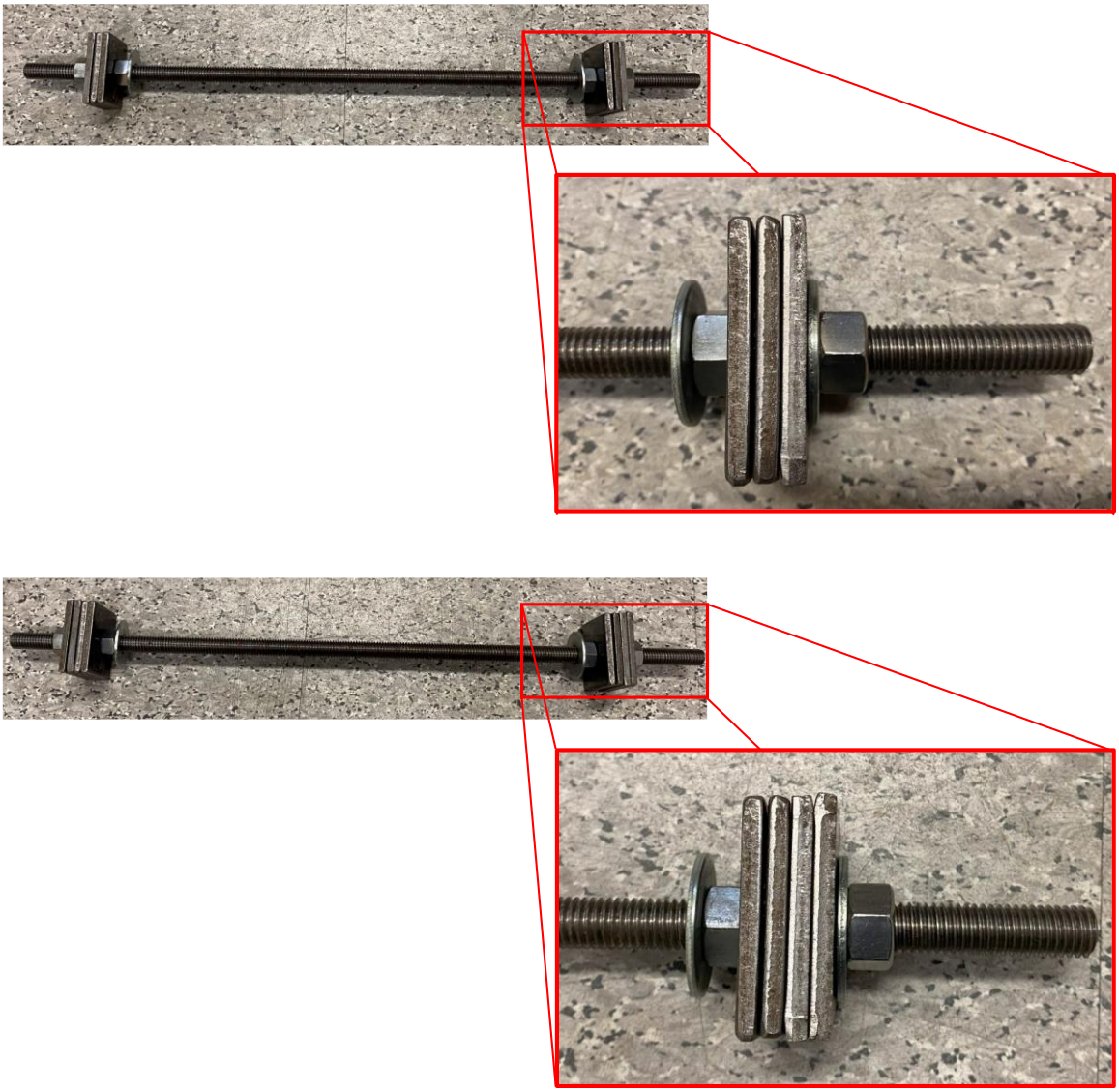


**Figure 17** (TOP) Dead weight configuration for a typical floor. (BOTTOM) Dead weight configuration on the highest relevant floor.

## 10. ROOF DEAD LOAD

The roof dead load schematic is shown in Figure 18 below:

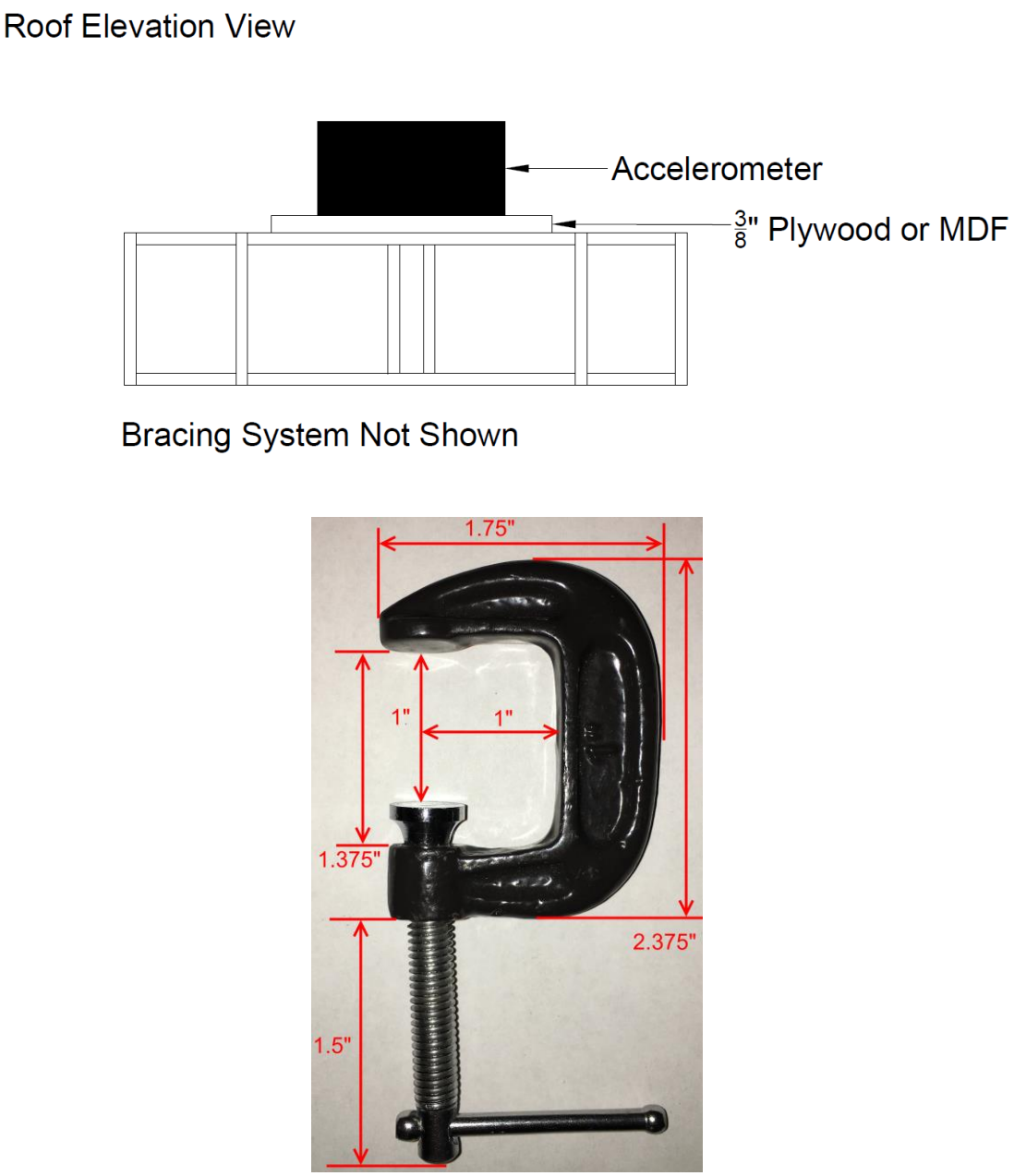



**Figure 18** Location of roof accelerometer and dimensions of c-clamps used to secure roof accelerometer (1” = 2.54 cm).

## 11. INSTRUMENTATION SCHEMATIC

The instrumentation setup is illustrated in Figure 19 below:

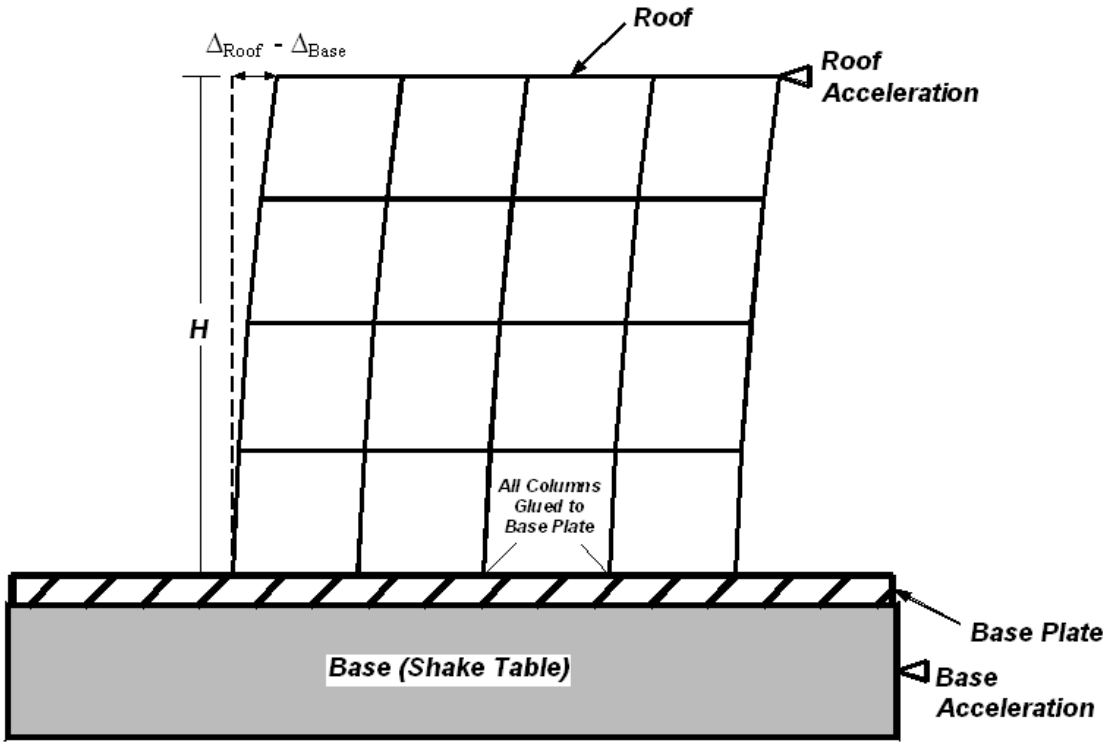



**Figure 19** Typical set-up of model shakedown.

# 12. GROUND MOTIONS

The building will be subjected to two ground motions of increasing intensity, named Ground Motion 1 (**GM#1**) and Ground Motion 2 (**GM#2**) (Section 9.1 and 9.2). Both the ground motions will be based on the hazard level and soil condition at the building site in Seattle. These two ground motions will be selected and released to the participants as follows:

- **GM#1** will be selected to approximately represent the Design Earthquake (DE) hazard level at the building site as defined in ASCE 7-22 [1]. **GM#1** will be released on the competition website listed on the cover page.

- **GM#2** will be selected to approximately represent the Risk-Targeted Maximum Considered Earthquake ($MCE_R$) hazard level as defined in ASCE 7-22 [1]. Recall that the $MCE_R$ response spectral coordinates can be directly obtained by scaling up the DE response spectrum by a factor of 3/2. Note that **GM#2** will not be released until the day of the competition.

More information about the ground motions is available in Section 9.1 and 9.2.

For **GM#1**, the acceleration trace is given in *g*'s, where *g* is the standard gravity acceleration (32.2 ft/s$^2$ or 9.81 m/s$^2$). The acceleration trace file is titled, *EQ1_acc.txt*. The file is organized with time (sec) in the first column and acceleration (*g*) in the second column. Additionally, the spectral acceleration (units of *g*), spectral velocity (units of m/s), and spectral displacement (units of m) are provided. The response spectrum is generated using a single degree of freedom oscillator and a Newmark average acceleration integrator. The response spectrum file is titled *EQ1_spectra.txt*. The columns from left to right are the following: period, spectral acceleration, spectral velocity, and spectral displacement.

Because **GM#2** will not be known by the teams until the day of the competition, teams are required to select ground motions from the PEER NGA West-2 Database that align with the definition of **GM#2**. The selected ground motions can be used for the design and seismic performance assessment of the structural model. For comprehensive guidance, teams can follow the step-by-step procedure outlined in the *Ground Motion Selection Guide* available on the competition website.

# 13. REFERENCES

[1] ASCE 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures, ASCE/SEI 7-22, Reston, Virginia: American Society of Civil Engineers, 2022.