Twentieth Annual Undergraduate
Seismic Design Competition (SDC)

DESIGN GUIDE

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

Competition Website: https://slc.eeri.org/2023-sdc/

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.

2. Member Requirements

2.1. Frame Members

According to Section 7.2.a, each frame member before any glue is applied and in its final state attached to the model must fit in the box (not to scale) shown in Figure 1 below with the dimensions shown:

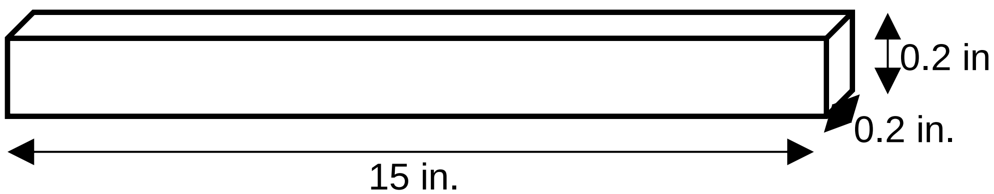


Figure 1: Max Dimension Size

Each individual frame member must not fit in the box shown in Figure 2 below with the dimensions shown:

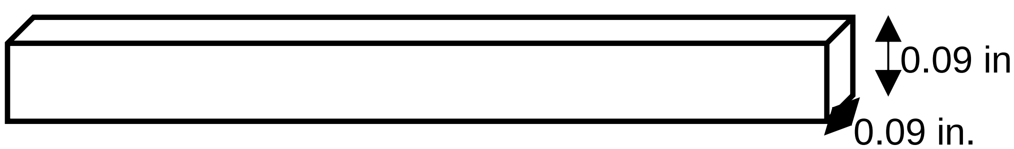


Figure 2: Minimum member size

Section 7.2.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 7.3.a, each wall member before any glue is applied and in its final state attached to the model must fit in the box (not to scale) shown in Figure 3 below with the dimensions shown:

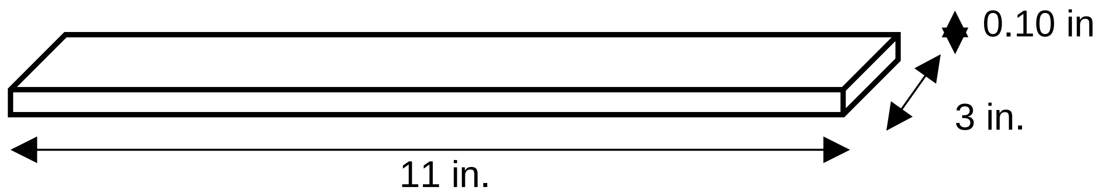


Figure 3: Maximum wall member sizing.

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. Teams should take note that there are restrictions on the orientation of wall members (Section 7.3.b). Members that fit in the wall member box will be classified as a wall member and subject to orientation restrictions (Section 7.3.b). Judges will use discretion when determining the intended type of member, for members that do not fit in either box.

According to Section 7.3.b, the grain of a wall member must be normal to the top surface of the base plate. Each wall member must span at least 1.00 in. vertically as shown in Figure 4 below.

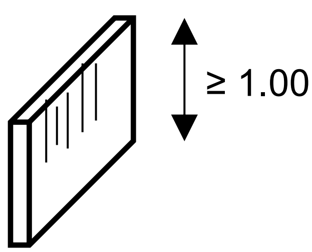


Figure 4: Grain of wood normal to the baseplate.

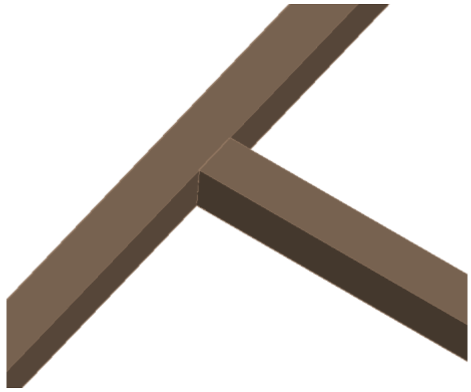
3. Connection Requirements

Individual members in contact shall have glue between the contact surfaces or faying surfaces (Sections 7.4.a, 7.4.b, 7.4.c, and 7.4.d).

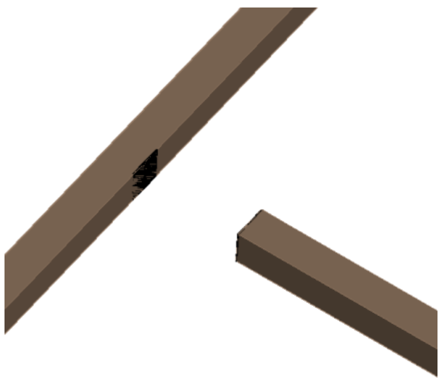
3.1. Faying Surfaces

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 7.4.a, 7.4.b, 7.4.c, and 7.4.d). Two examples of faying surfaces are shown in Figure 5 below.

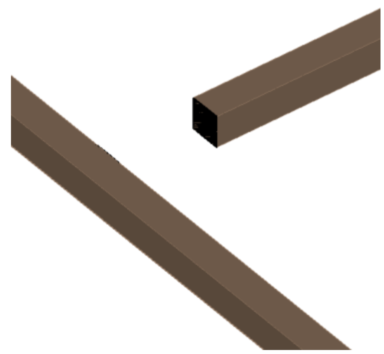
For frame members, no single faying surface shall exceed 1 in. in any direction from the centroid of the faying surface (Section 7.4.b).



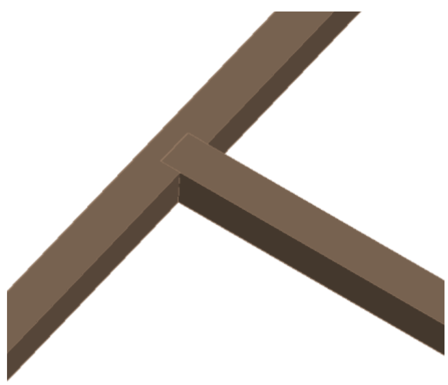
Completed connection of two frame members (one faying surface per member)



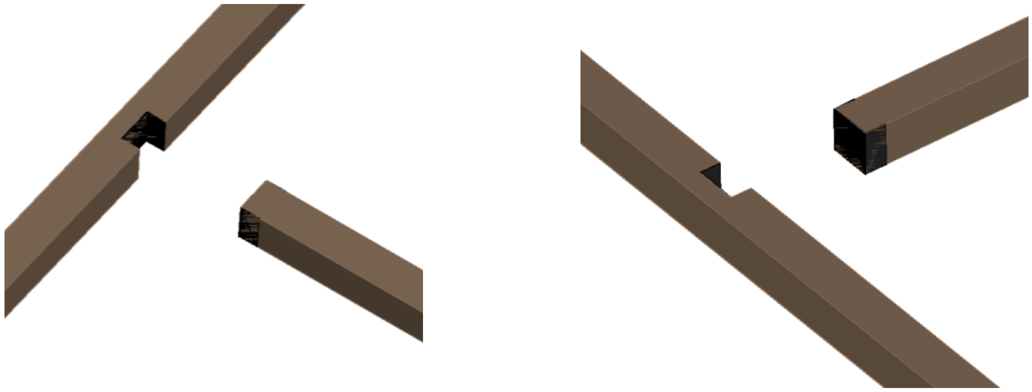
Faying surfaces are shaded



Faying surfaces are shaded



Completed connection of two frame members (3 faying surfaces per member)

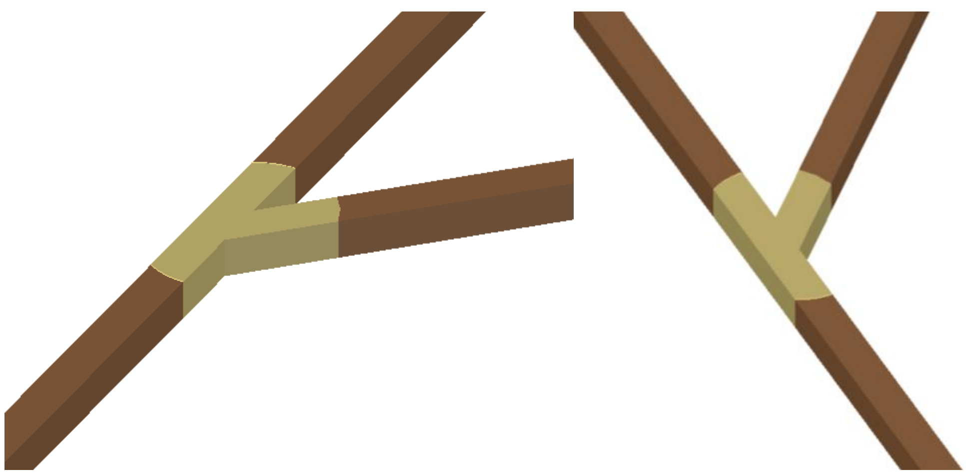


Faying surfaces are shaded   Faying surfaces are shaded

Figure 5: Faying surfaces 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 7.4.a). Excess glue from each connection shall not be in contact (Section 7.4.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.



Excess glue permitted in lightly shaded areas (3/16 in. x 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 7.4.c). Each gusset plate shall fit in a box with dimensions 1 in. by 1 in. by 0.10 in. (Section 7.4.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 7.4.c).

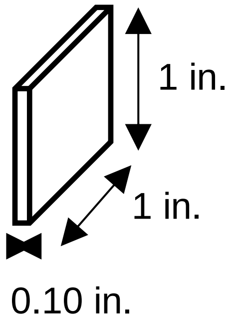


Figure 7: Maximum dimensions of a gusset member

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 7.4.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 7.4.a).

4. Floor Requirements

With the unique design challenge of the 2023 SDC, this section should be especially understood to ensure total compliance of the structure within the guidelines of this edition Design Guide and the 2023 Official Rules. All units are in inches [in.] unless otherwise noted.

The design challenge posits that two separate towers will be constructed on the same base plate and **connected to one another via a minimum of three and a maximum of four separate skybridges (SB)**. Typical floor plans of maximum buildable areas for floors with and without skybridges is shown in Figure 8.

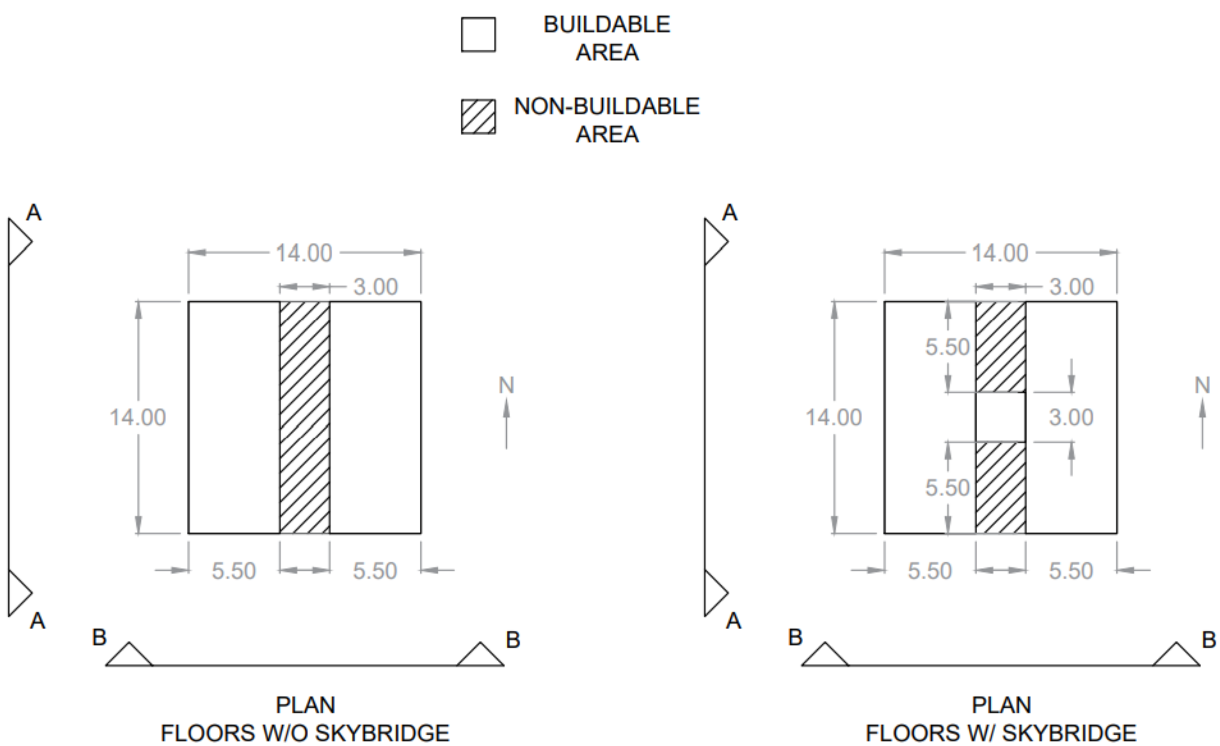


Figure 8: Buildable floor areas for (a) floors without a SB and (b) floors with a SB. No members can be placed within the hatched area.

Rentable floor area (Section 7.7.c) 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 7.7.b, each floor shall have a continuous set of perimeter beams (labeled with a black dot on the top) and have at least 40 square inches of rentable floor area per tower at a given level (80 square inches total between both towers). Section 7.7.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 Figures 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 7.7.a states the minimum number of floors, *f*, is 13 and maximum number of floors, *f*, 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. Figure 9 shows two elevation views of an example of a model, Section A-A (facing E-W) and Section B-B (facing N-S) with the maximum and minimum number of floors allowable specified.

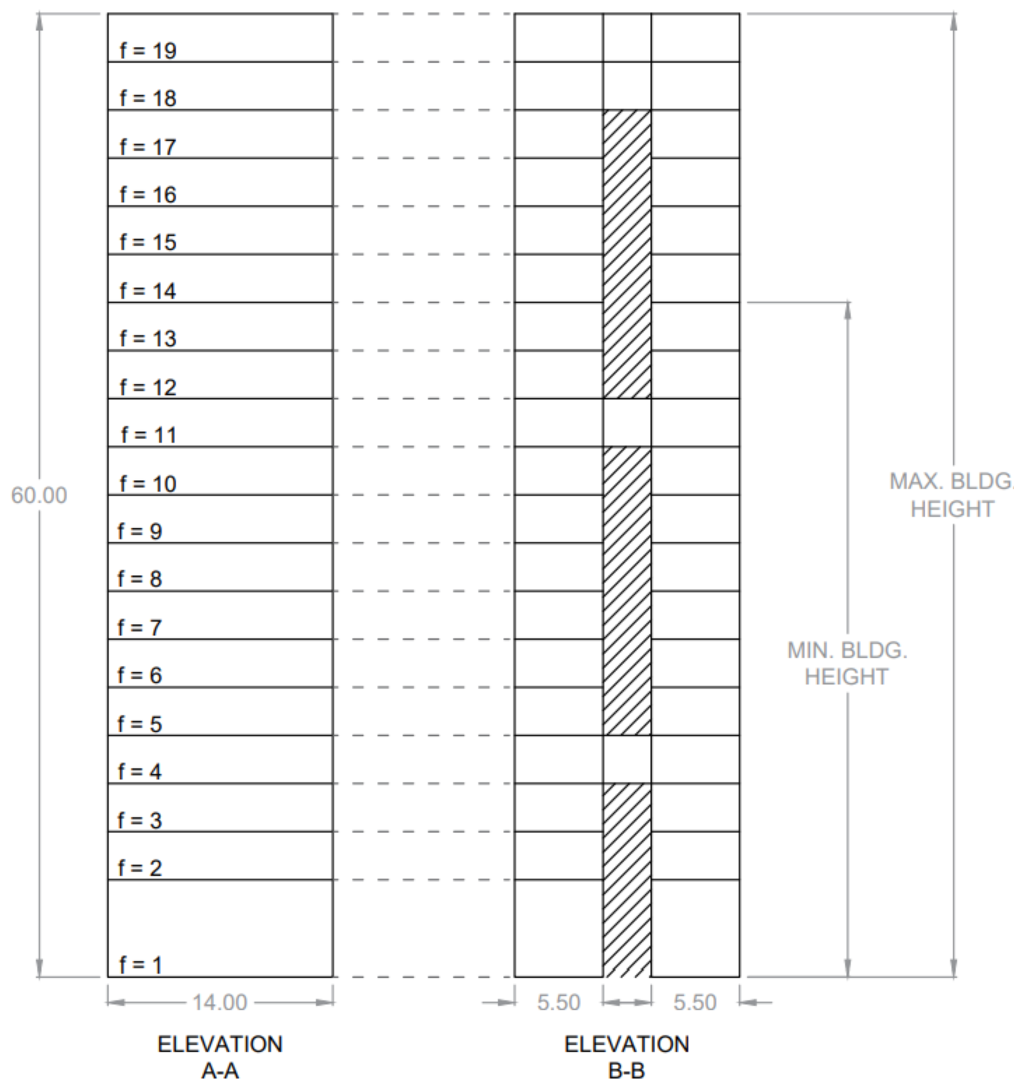


Figure 9: Buildable floor areas for (a) floors without a SB and (b) floors with a SB. No members can be placed within the hatched area.

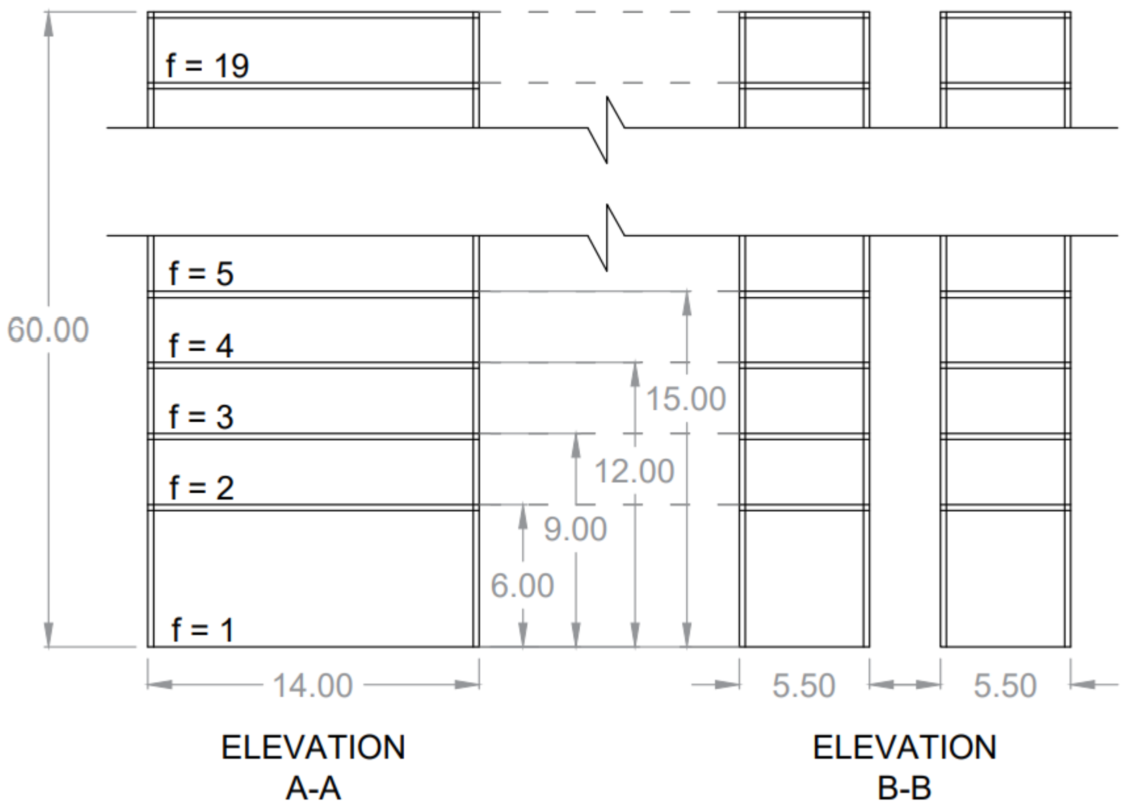


Figure 10: Typical floor heights and maximum number of floors (19). (SBs are not shown and non-buildable areas are not hatched for clarity - refer to Figures 8 & 9 for non-buildable areas in plan and elevation, respectively).

As previously stated, **the two towers shall be connected via a minimum of three SBs and a maximum of four SBs**. **The design team is responsible to construct a minimum of three required SBs regardless of the height of the structure though it is up to the discretion of the design team to include the additional fourth SB, but this is not required**. The above diagram, Figure 9, is provided to help teams visualize the maximum buildable area along the height of the structure. The elevation shows the location of each floor plan from Figure 8 within the structure. The hatched area in Figure 9 is used to indicate the non-buildable area in Figure 8. If teams build to the maximum plan dimensions and height, the structure profile would look similar to that shown in Figure 9. However, teams may choose to design their structure with plan dimensions or a total height less than the maximum allowed. Figure 10 is provided for teams to visualize the elevation requirements of a given floor as specified in Section 7.7.a of the Official Rules.

The SBs pictured in Figure 9 shows one possible configuration of the minimum three required SBs if constructed to maximum height; i.e. they are not required to be at the exact locations shown in Figure 9. The placement of the SBs within the structure is up to the discretion of the design team; however, **a SB may not be placed at the base level of the structure (f = 1), and thus, the lowest level a SB could be constructed is at the second level (f = 2). It is also required that the upper most SB, be located at the top two floors of the structure, regardless of height, similar to that shown in Figures 9 and 11.** The clear distance between any SB, L_C, is defined by the clear distance between the top surface of the top beam of a given SB, SB_i, and the bottom surface of the lower beam of the next SB, SB_{i+1}, as seen in Figure 11. The minimum clear distance between any two SBs, $L_{C,MIN}$, is 11.75 in. and the maximum clear distance between any two SBs, $L_{C,MAX}$, is 20.75 in.

If three SBs are constructed: The first two SBs shall have heights, H_{SB1} and H_{SB2}, of one story (3.00 in.). The height of the uppermost SB, H_{SB3}, is required to be double-height of the lower two SBs, with a height of 6.00 in. These terms are defined in Figure 11 (a). The width of any given SB is limited to a maximum of 3.00 in., as pictured in Figure 8.

If four SBs are constructed: The first three SBs shall have heights, H_{SB1}, H_{SB2} and H_{SB3}, of one story (3.00 in.). The height of the uppermost SB, H_{SB4}, is required to be double-height of the lower three SBs, with a height of 6.00 in. These terms are defined in Figure 11 (b.) The width of any given SB is limited to a maximum of 3.00 in., as pictured in Figure 8.

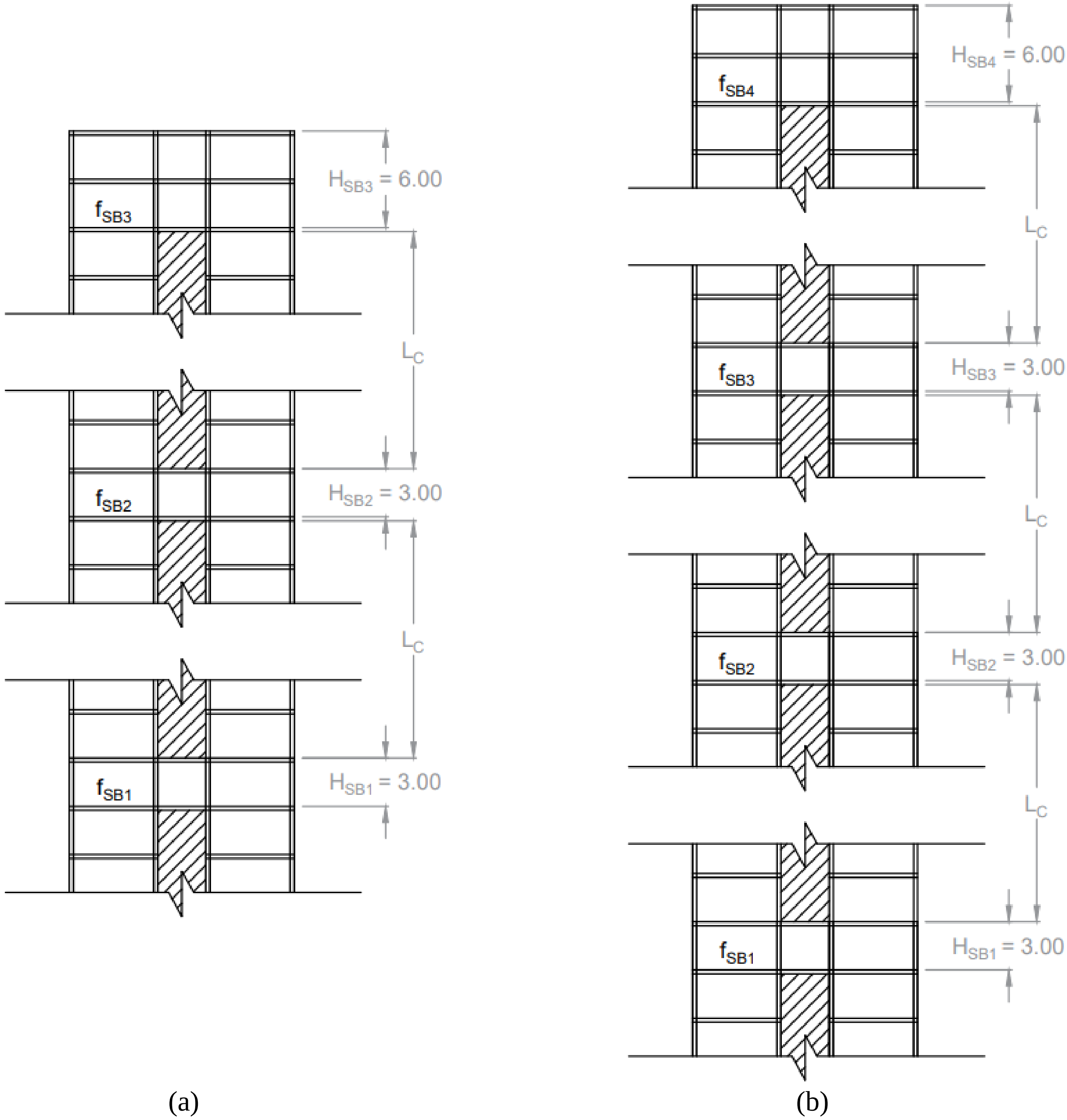


Figure 11: Definition of the location of SBs, their height requirements and the clear distance between them for (a) the minimum of three SBs and (b) the maximum of four SBs.

In the below diagram, Figure 12, 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.

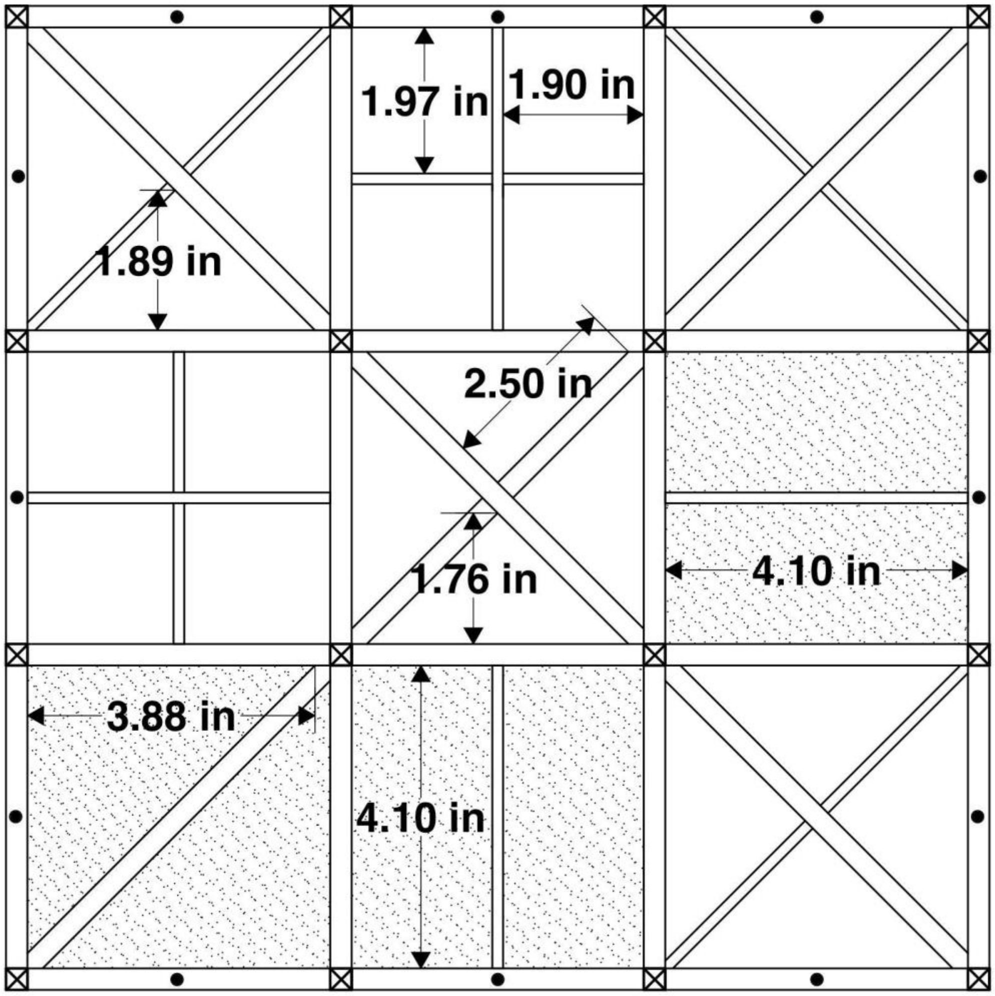


Figure 12: Typical floor plan illustrating member spacing.

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 13. 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.

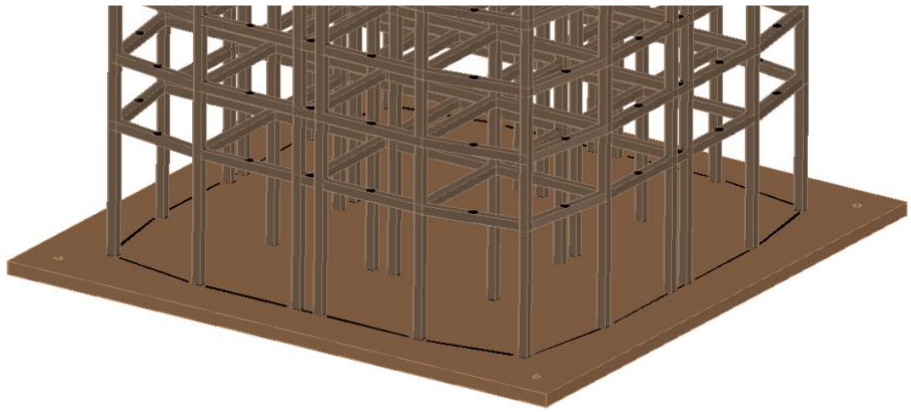


Figure 13: How to draw black lines to define lobby floor area.

5. <u>Floor Dead Load Connections</u>

Floor dead load connections are required at the floors specified in the Official Rules in both the East-West and North-South directions. Due to the unique design of the structure, requirements of this structure, the floor dead load connections are defined differently in the N-S and E-W shaking directions. Please refer to Figure 14 for the different potential dead load layouts. In the E-W direction of shaking, Figure 14 (a), the floor dead loads shall be located 2.75 in. from the outer 14 in maximum buildable area. Because shaking in the E-W requires two rods per floor level, the weight will be equally divided in two, to approximately match the weights typically applied to one rod, such as in the N-S direction. In the N-S direction of shaking, Figure 14 (b), the floor dead loads shall be centered in plan view in relation to the center of the base plate. 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 7.5.a). After installing the rod, a washer will be placed on the rod and a nut 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. A diagram is shown below in Figure 14.

For N-S shaking the floor dead load connections should be designed to allow all floor dead loads to be installed **within 8 minutes** regardless of the number of people installing the floor dead loads. Because double the amount of rods would be required for E-W shaking, the floor dead loads are required to be installed **within 16 minutes** (Section 8.4.a).

Not all floors will have the same dead load applied (Section 8.3.a)— for N-S shaking, the highest relevant floor will have a larger dead load (3.55 [lb]) compared to the others (3.15 [lb]). For E-W shaking, the highest relevant floor will have a larger dead load (3.90 [lb]) compared to the others (3.10 [lb]). The difference in applied load for different shaking scenarios is unavoidable due to the use of two rods in the E-W shaking scenario, but the difference is minimized so the weight is similar in both possible scenarios.

<u>Note:</u> Dead load rods will be checked for translation before the structure is placed on the shake table and following each ground motion. Penalties for each unsecured weight rod will be applied per section 8.9.a. A floor can be considered collapsed if any of the conditions described in section 8.9.c are met. However, this does not necessarily mean all floors of the structure are collapsed, as defined in section 8.9.c. An SDC chair will check if the dead weight rods are secured to the structures by trying to move them. **The amount of force applied by the SDC chair to the floor dead load rods will be at the discretion of the SDC chair. The check of the rods will be consistent for all teams. To minimize the amount of surprise technical collapses, and in an effort to make the process transparent, the SDC chairs will notify team captains of the floors considered collapsed and/or structure technical collapse following each check on shake day. The decision of which floors are collapsed is final, and no appeals may be made. It is the responsibility of the teams to ensure the weights are properly secured.**

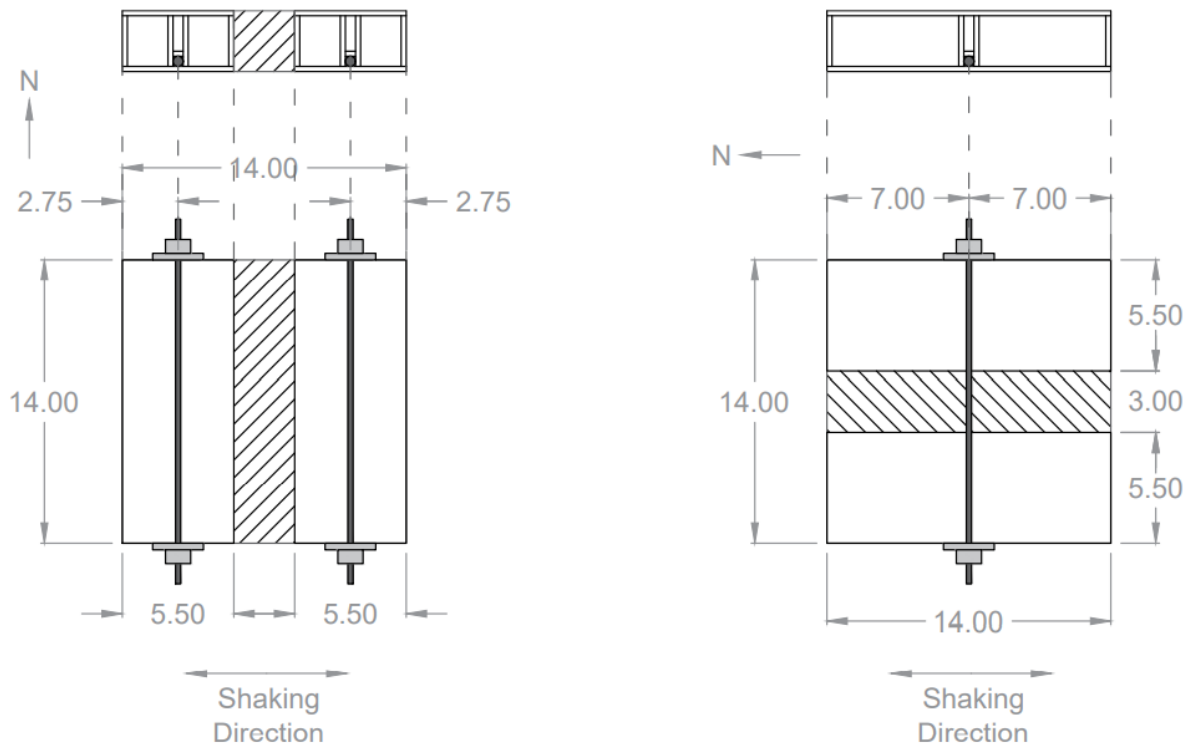


Figure 14: Typical mass attachment to the building model for (a) E-W shaking direction and (b) N-S shaking direction.

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 7.8.a) and between 0.250 in. and 0.50 in. thick (Section 7.8.b). The bottom of the base plate must be flat and smooth (Section 7.8.c).

None of the models may be attached to the structural model base plate within 1.25 in. of any edge (Section 7.8.a).

An optional 1/4 in. diameter hole may be drilled within 2 in. of each corner to secure the model during shipping (Section 7.8.c).

The designated side must be labeled North with a black permanent marker (Section 7.8.c).

Figure 15 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, Ws (Section 7.13) 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 7.8.c).

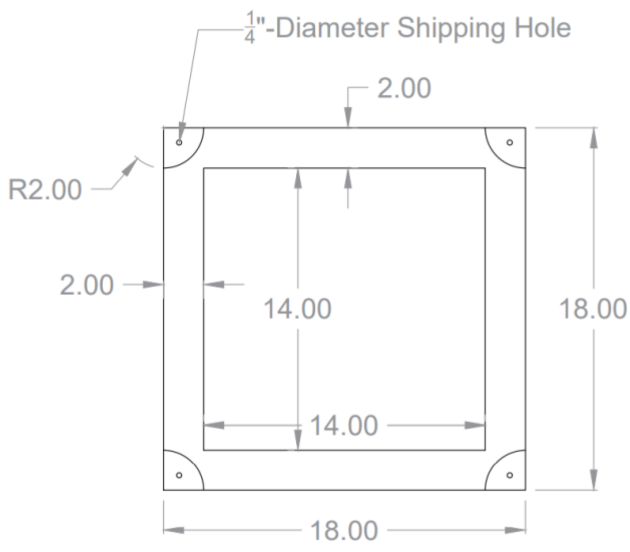


Figure 15: Typical base plate for model.

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 7.8.c).

An example is shown in Figure 16 below:

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.

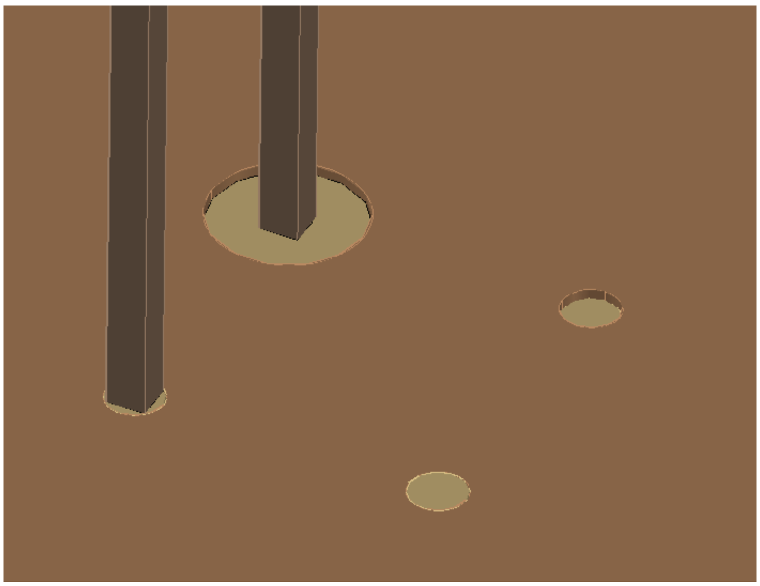


Figure 16: Notching example

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 8.5).

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 17 for where the angles will be located. A clamp will be installed at the locations with a black circle on the diagram.

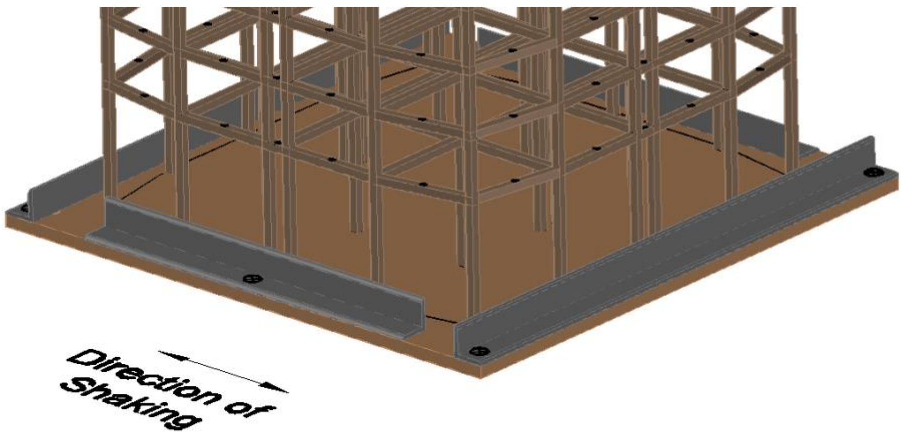


Figure 17: Typical attachment of base plate to the shake table.

7. Roof Plate Requirements

The roof plate shall be made of plywood (at least 3-ply) or MDF, 6 in. by 6 in. (Section 7.9.a), and between 0.3 in. and 0.4 in. thick (Section 7.9.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 7.9.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 7.9, 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 Ws (Section 7.13) used for scoring purposes (Section 4.4). Notching holes are not required in the second roof plate (Section 7.9.c).

Roof plate notching is permitted (Section 7.9.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 7.12).

Each floor shall be labeled with a number according to the official rules (Section 7.12) 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 18 below:

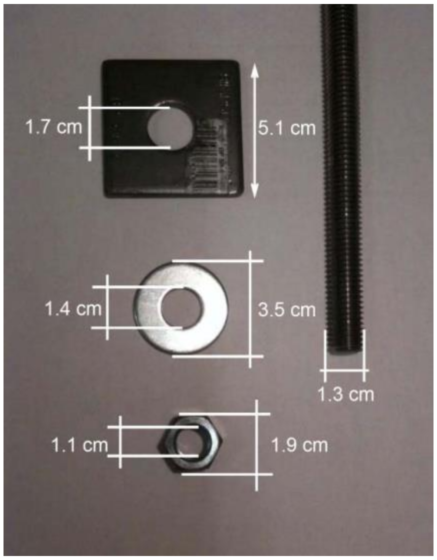
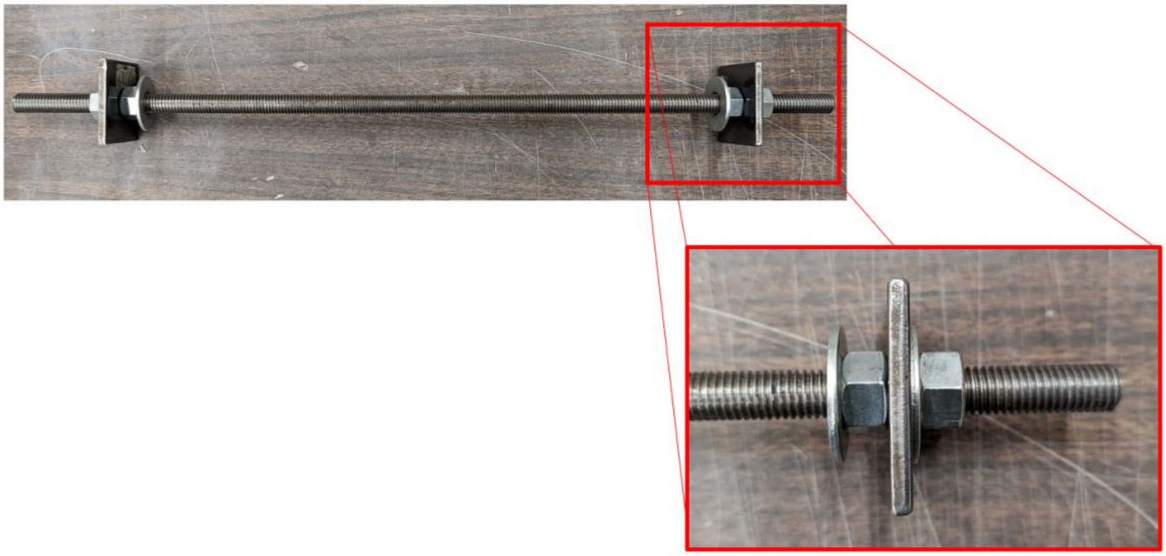


Figure 18: Dimensions of dead-weight components used throughout structure (1" = 2.54 cm).



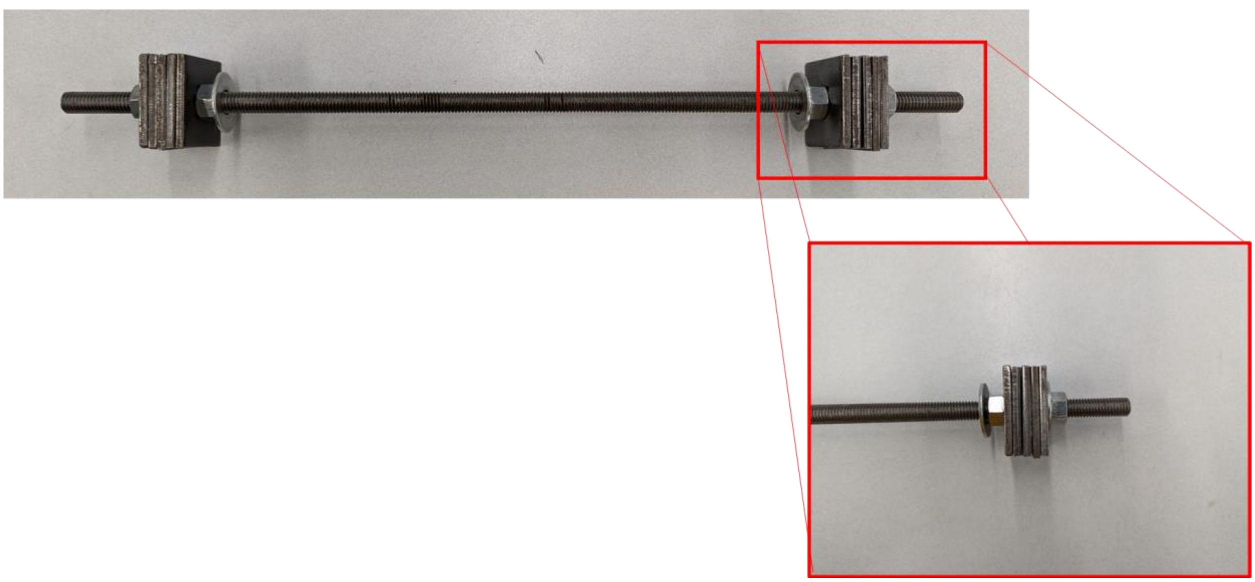


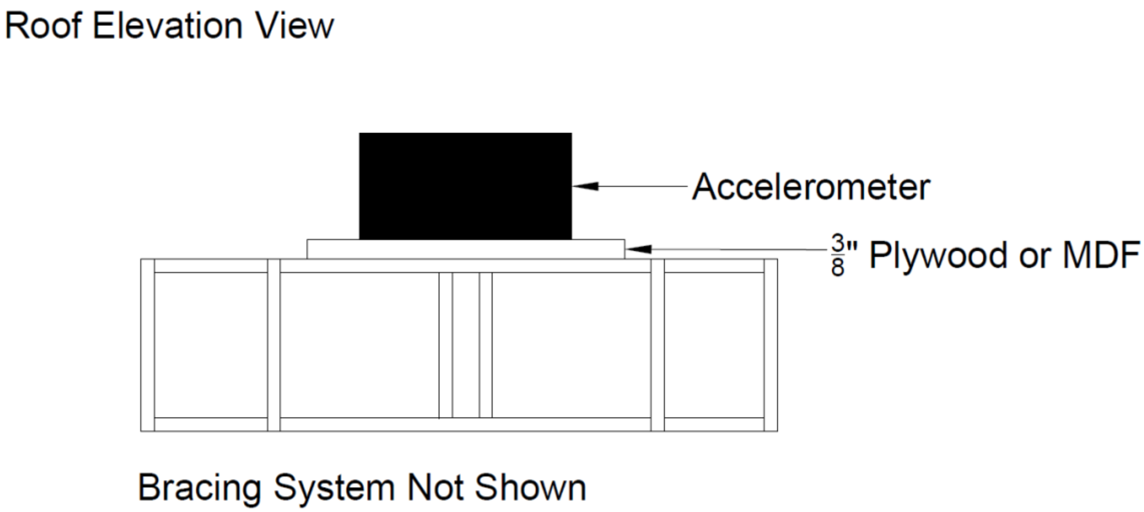
Figure 19:

(TOP) Typical dead weight configuration used throughout the structure for East-West Shaking - on the highest relevant floor, the number of plates on each side of the rod will be increased to two.

(BOTTOM) Typical dead weight configuration used throughout the structure for North-South Shaking - on the highest relevant floor, the number of plates on each side of the rod will be increased to six.

10. Roof Dead Load

The roof dead load schematic is shown in Figure 20 below:



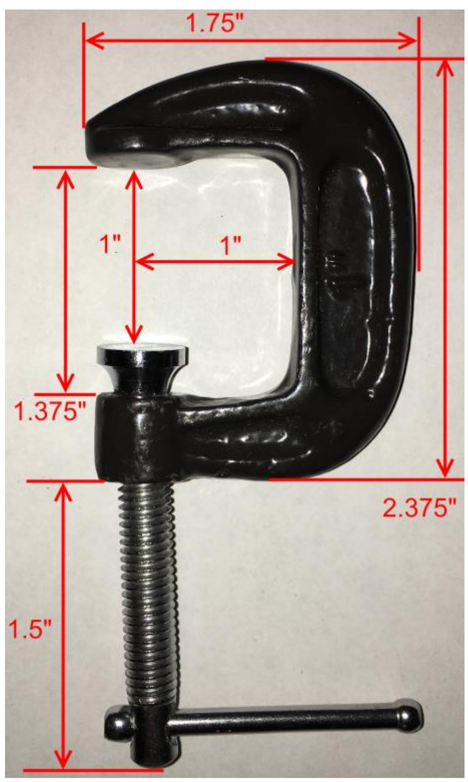


Figure 20: Location of roof accelerometer and dimensions of c-clamps used to secure roof accelerometer (1" = 2.54 cm).

11. Instrumentation Schematic

The instrumentation setup is illustrated in Figure 21 below:

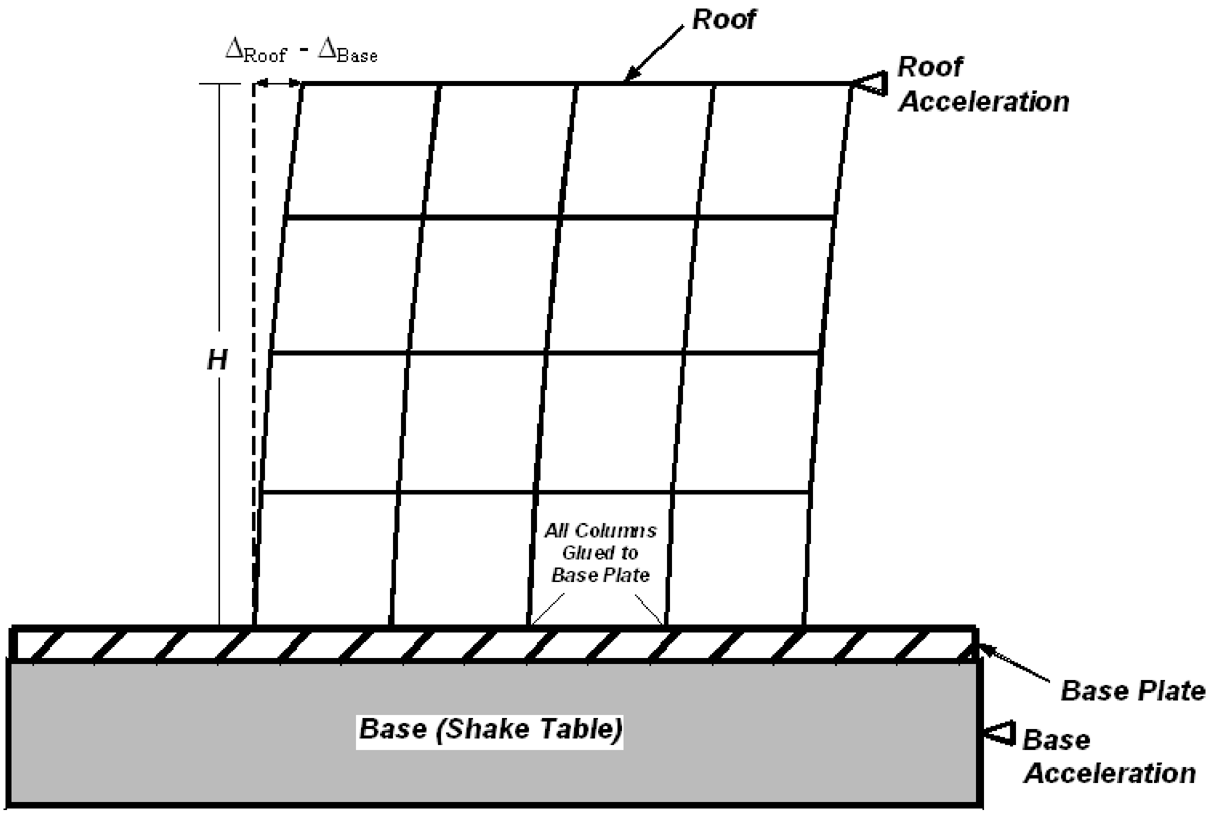


Figure 21: Typical set-up of model shakedown.

12. Ground Motions

The scaled ground motions described in Section 8.1. will be provided on the 2023 SDC website.

For both motions, the acceleration trace is given in g's, where g is the unit of acceleration (32.2 ft/s^2 or 9.81 m/s^2). The acceleration trace files are titled, EQ1_acc.txt and EQ2_acc.txt for Ground Motions 1 and 2, respectively. The files are organized with time (sec) in the first column and acceleration (g) in the second column.

Additionally, for each ground motion the spectral acceleration (units of g), spectral velocity (units of m/s), and spectral displacement (units of m) are provided. The response spectra were generated using a single degree of freedom oscillator and a Newmark average acceleration integrator. The response spectra files are titled, EQ1_spectra.txt and EQ2_spectra.txt for Ground Motions 1 and 2, respectively. The columns from left to right are the following: period, spectral acceleration, spectral velocity, and spectral displacement.