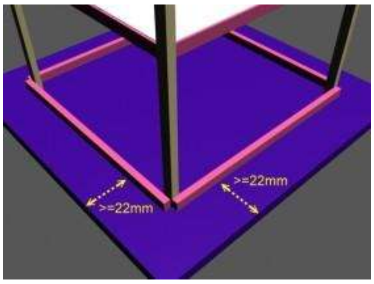
TREMOR
Takneek 2010

Rules and Guidelines

1. Configuration of Models

1.1 Base board: The model shall be constructed on a base board of thickness 1cm provided by the Organizer. The weight of the baseboard, M_B, shall be weighed and recorded before the construction of a model. A clearance of 22 mm must be left around the edges of the baseboard such that the model can be fixed easily onto the 1- Dimensional Earthquake Simulator at Structural Engineering Laboratory.



1.2 Number of holes: The screws on the shake table are at center to center distance of 25cm. Hence holes drilled on the base board should be in the multiples of 25cm.

1.3 Number of floors: The building may have one bay or **two bays** in each direction as shown in figure A and B. The building model shall have 5 to 7 storeys and hence 6 to 8 horizontal floors inclusive of the base board, which may be supported in any way desired. A flat roof shall be treated as a floor. The base board can be used as the ground (first) floor of the model.

1.4 Clear distance: As shown in Figures A and B, the distance between the top of the girder (beam which connects the columns) of any floor and the bottom of the girder of the floor above it (i.e. the clear distance) must be a minimum of 12 cm and a maximum of 15cm. The fixings for the steel blocks (para. 3.2 below) on floors of a model are not counted as part of the floor.

$15cm \geq H_3 \geq 12cm$

$15cm \geq H_2 \geq 12cm$

$15cm \geq H_1 \geq 12cm$

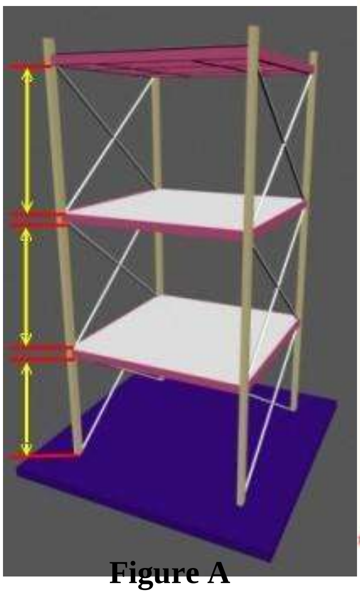


Figure A

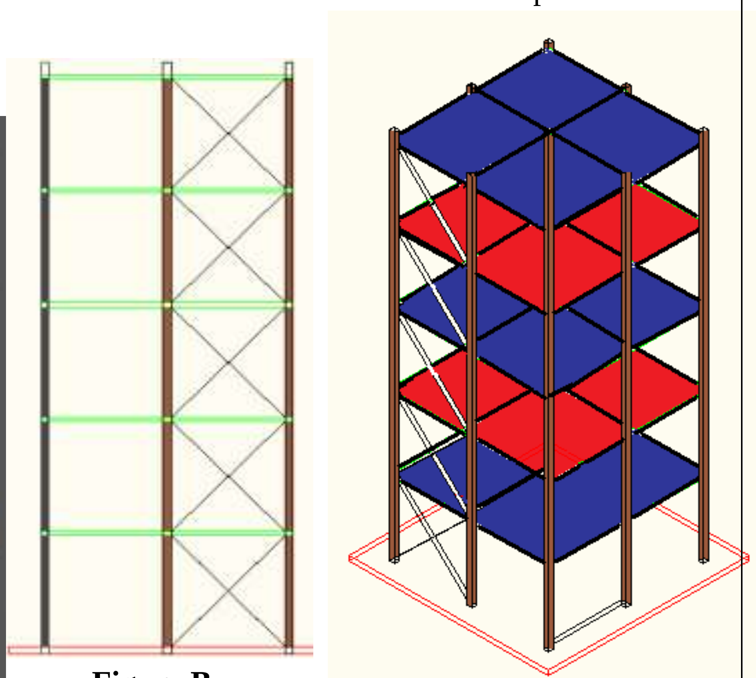


Figure B

1.5 Location of Columns: In order to eliminate the obstruction of fixing steel blocks onto each floor, columns are only allowed to be placed at a minimum spacing of 12cm with any neighboring column. They may be placed in the interior but should adhere to the spacing requirement. Figure C shows a typical column arrangement along with shear walls.

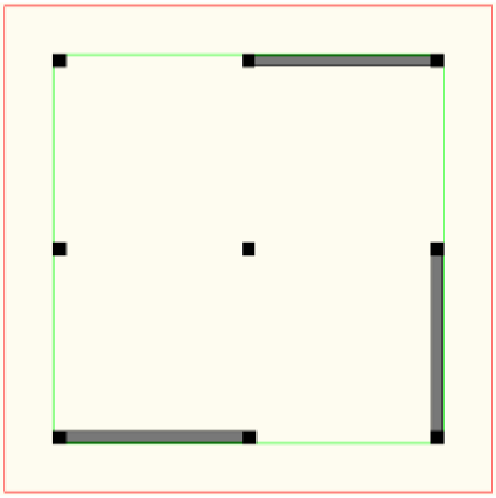
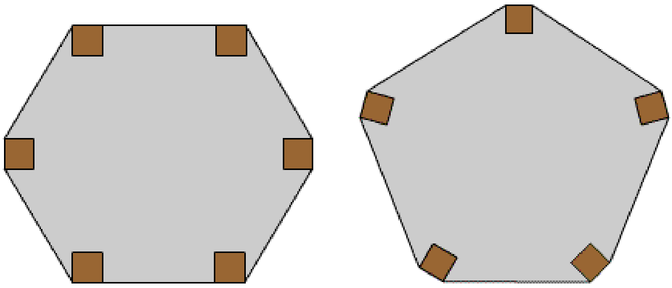


Figure C



Other arrangements

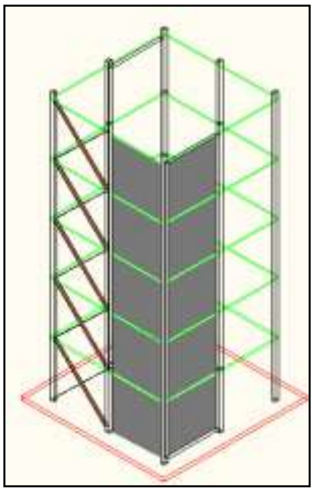
Figure D

1.6 Area of floors: The minimum plan area of each floor should be 400cm2 and the minimum distance between any two columns should be 12cm.The maximum plan dimensions of any floor should not exceed 32cmx32cm.The floor area of each floor is the area surrounded by the outmost columns including the space taken up by columns. In Figure D this is the shaded area. Any structural components that are projected from the exterior side of the outmost columns are not counted as a part of the floor area. For example, beams may be cantilevered from the outmost columns.

1.7 Size of Structural Members: Maximum size of structural members are:-

Beam	:	12mm*20mm
Column	:	20mm*20mm
Bracings	:	10mm*12mm

1.8 Shear Wall: Shear wall are optional. The length of shear wall should be atleast 8 cm and thickness should not exceed 8 cm.



2. Materials

The participating teams shall only use the materials provided by the Organizer to construct the building models. The specifications and quantities of the materials are listed in Table 2.1 below.

Table 2.1 Materials provided

Materials	Specifications	Quantity
Timber strips	1000mm x 10mm x 4mm	190 sticks
Cotton string	Cotton Twines No. 6	4m
PVC hot melt glue stick	For column base connection	-
Fevicol	85gm	2
Baseboard	400mm x 400mm x 10mm	1
Plywood(for Shear Walls)	40mm x 120 mm x 8mm	1
Plywood (for slabs)	40mm x 40mm x 6mm	7

3. Construction of Models

3.1 Exterior Clearance: In a real building, windows are needed on every storey. For each storey of the model, at least half the length of the perimeter (on plan) must be left completely clear of any obstructions arising from bracings or shear walls between two immediate adjacent floors.

Figure D shows a side view of two immediate adjacent floors of a model with straight columns. The green arrow shows the distance between the outmost columns (including the width of the columns), and the red arrows show the projection lengths that are taken up by the bracings.

Figure E shows the lower floor plan view of the same model as in Figure D. The perimeter, **L**, of the lower floor of the model is calculated by adding up the lengths of all the green arrows. The total length occupied by bracings and shear walls put together, **x**, is equal to the summation of the projection lengths of all the bracings and shear walls to the lower floor beams marked by red arrows. For each model, the following equation must be satisfied:

$$\frac{x}{L} \leq \frac{1}{2}$$

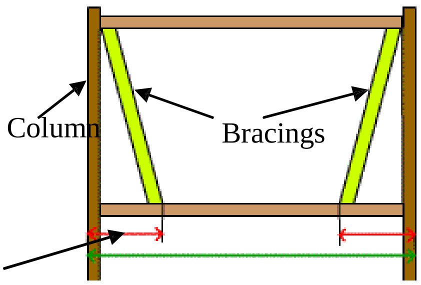


Figure D

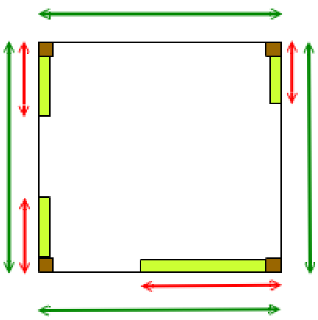


Figure E

Projection length of the bracing

Figures F and G show side views of projection lengths to the lower floor beam of different types of bracings of a model with inclined columns. The method to calculate x and L is the same as that shown in Figures D and E.

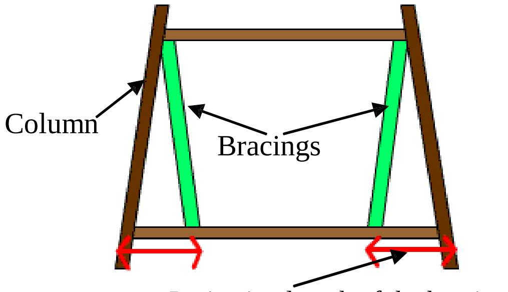


Figure F

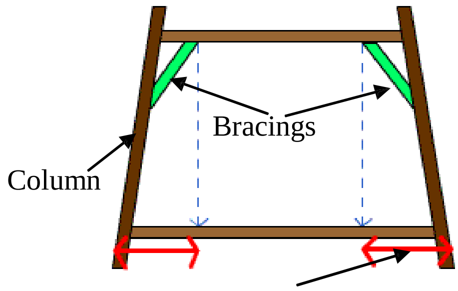


Figure G

3.2 Interior Clearance: In order to eliminate the obstruction of fixing steel blocks onto each floor, strings and bracings are not allowed to be placed inside a model.

3.3 Additional Weights: Additional weights will be applied to the model at each storey level using steel weights to simulate the mass in a real building. Therefore additional fixings should be constructed for securing the steel weights onto your model. Fixings should be used only for holding the steel weights in place. It shall not be connected to the structural frame (columns, girders and braces) directly. If the fixings are also used as structure supporting components, they will be counted as part of the floor which may result in insufficient clearance for the floor height.

Every floor of a model must be able to carry at least 4 pieces of lead weights of diameter 60mm, height 28mm and 865g in weight. Figure H shows the steel weights that will be used. Load will be placed on the floor based on its area.

Floor area (cm^2)	No. of lead weights
400- 500	4
500-600	5
600-750	6
750-900	7
900-1024	8

Figure H: Lead Weights

Holes in slabs should be drilled beforehand to facilitate the fixing of lead weights using screws.
It is responsibility of the participants to decide the position of holes so that the required number of weights can be placed easily.
It is advisable that the loads be placed symmetrically on the slabs.

3.4 Qualification: Once a model is completed, the total mass of the model (including the base board), M_M will be weighed and recorded. The panel of judges will then check the model, and the additional penalty weight (M_P) will be determined and included in the calculation of its efficiency ratio if it does not meet the specified rule.

4. Competition

4.1 Mounting of the Model and Fixing of Steel Weights: The Organizer will arrange for each model to be securely mounted onto the 1-Dimensional Earthquake Simulator and to fix the steel weights to the floors of each model.

4.2 Earthquake-Resistant Test: All models will be tested by simulated shaking tests along a single direction. The direction of excitation will be decided by the judges. The peak shaking accelerations or Peak Ground Acceleration (PGA) will be 0.17g, 0.22g, 0.28g, 0.36g with frequencies ranging from 0.5Hz to 6Hz and duration of about 30 seconds for each round. The following flow chart shows in detail the earthquake resistance test.

Series 1 PGA =0.11g

↓

Check for failure and remove any failed models

Series 2 PGA =0.18g

↓

Check for failure and remove any failed models

Series 3 PGA =0.27g

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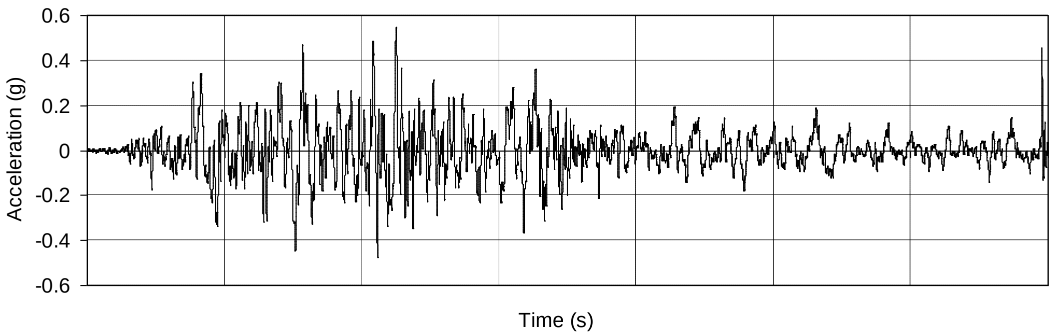
Check for failure and remove any failed models

Series 4 PGA =0.36g

↓

Stop

Acceleration Time History Curve



4.3 Failure of Building Model: A model is deemed to have failed under following conditions:

- Complete collapse of the model.
- Collapse of one or more storeys.
- The model has deformed excessively (maximum lateral permanent deformation is more than 14% of the gross building height).
- Half or more than half of the columns are detached from the base board.
- Any of lead weights falling off from one of the floors.

4.4 Efficiency Ratio: The score in the competition is based on the efficiency ratio, which is calculated by dividing the maximum intensity the model system is able to survive (**I**) by its mass (**M_M - M_B + M_P**). A higher efficiency ratio means that the model can survive a stronger earthquake using less amount of material which means the model is more efficient in terms of earthquake-resistance. The efficiency ratio is defined as follows:

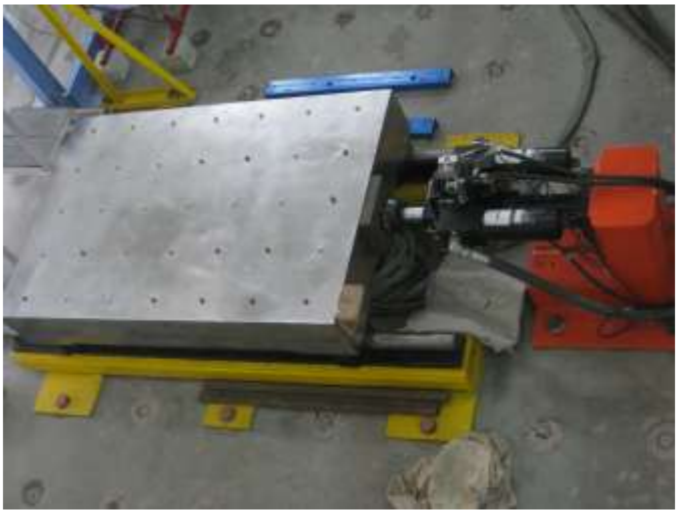
$$Efficiency\ \ Ratio = \frac{I}{M_M - M_B + M_P}$$

Where:
I = Maximum intensity that a model system can survive
M_M = Total mass of the model system (excluding steel weights)
M_B= Mass of the base board
M_P= Penalty weight

4.5 Violation Penalty: Teams will be disqualified if:

- Using other materials that are not specified in the rules.
- The Dimensions are not adhered to.

<u>Material properties of strips:</u>
E~10GPa
Tensile Capacity~110-120Mpa



Uni-Axial Shake Table at the Structural Engineering Lab, IIT Kanpur