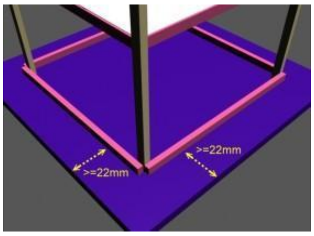
TREMOR, TAKNEEK 2012

PROBLEM STATEMENT

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, $\mathbf{M_b}$, 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 1, 2 or 3 **bays** in each direction as shown in figure A and B. The building model shall have 5 to 7 storeys and hence also 5 to 7 horizontal floors excluding 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 floor of the model where no additional weights (refer section 3.3) will be applied.

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≥H_3 ≥12cm

15cm≥H_2≥12cm

15cm≥H_1 ≥12cm

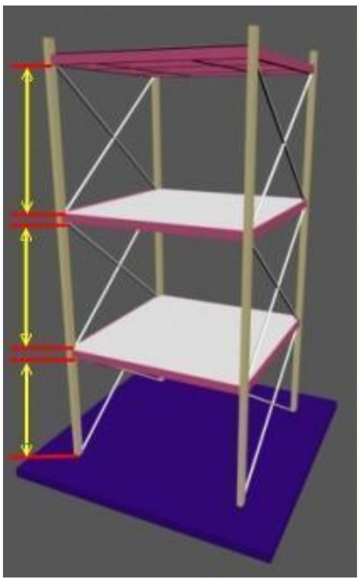


Figure A

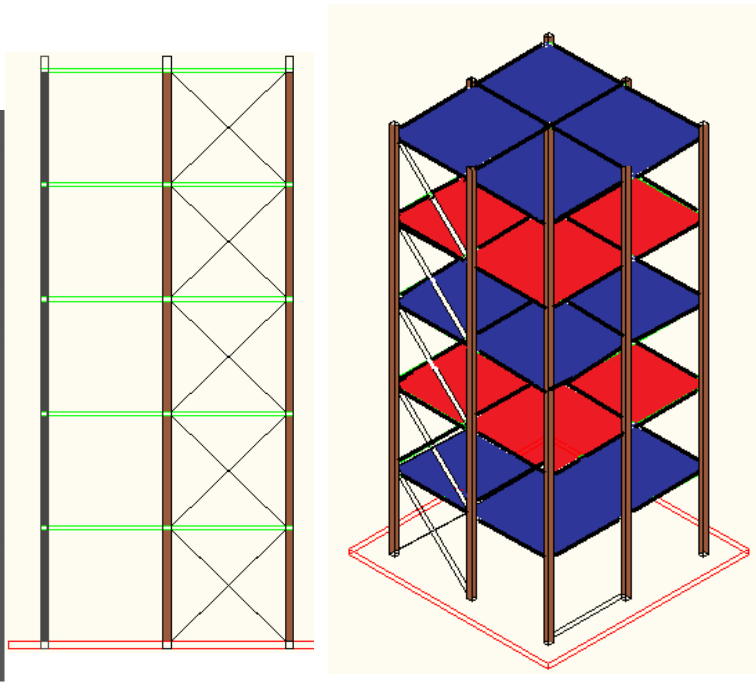


Figure B

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 clear spacing of 10cm 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.

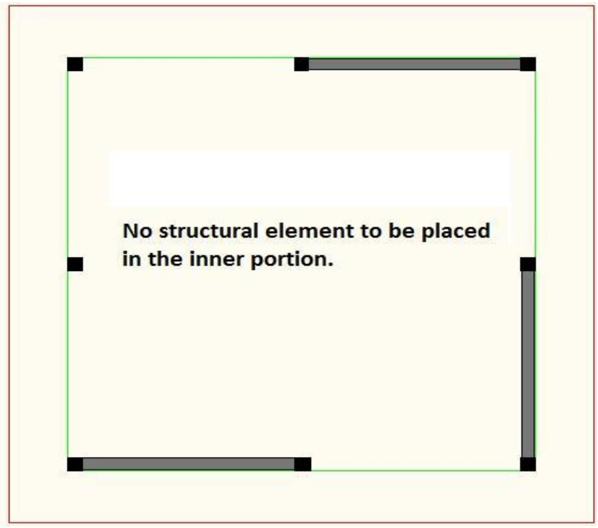
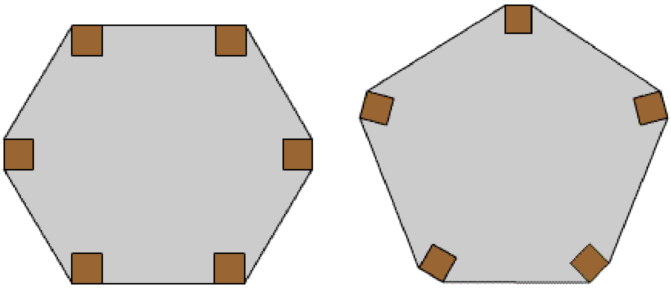


Figure C



Other arrangements

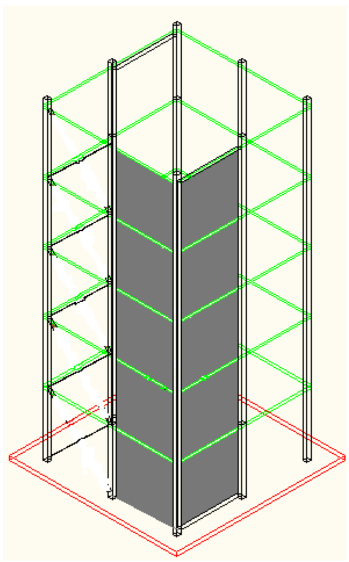
Figure D

1.6 Area of floors: The minimum plan area of each floor should be $625cm^2$ and the minimum *clear* distance between any two columns should be 10cm.The maximum plan area should not exceed $1225cm^2$. *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	:	10mm*4mm
Column, shear core	:	10mm*6mm
Bracings	:	10mm*2mm

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



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 2mm	150 sticks
Cotton string	Cotton Twines No. 6	2m
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
Fevicol	-	200 gm
Sand paper	-	-

****Cotton strings must not be present in the final structure. They are only for temporary connections.***

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 or shear walls put together, **x**, is equal to the summation of the projection lengths of all the bracings or shear walls to the lower floor beams marked by red arrows. For each model, the following equation must be satisfied:

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

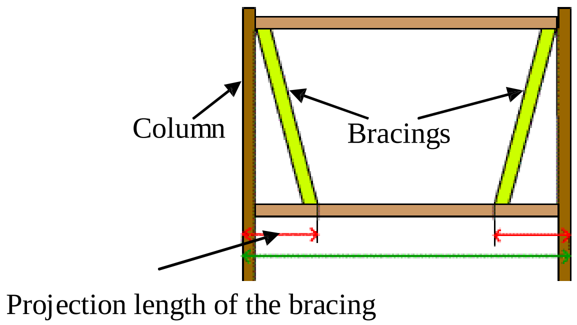


Figure D

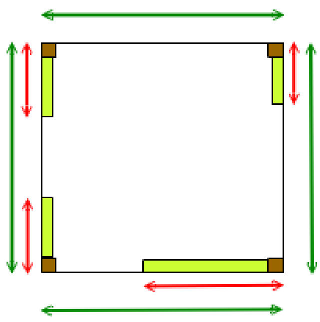


Figure E

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.

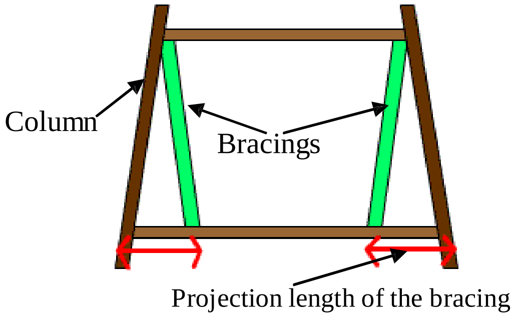


Figure F

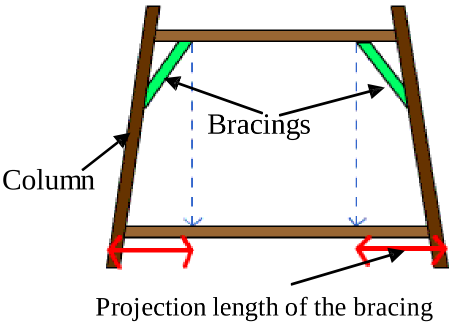


Figure G

3.2 Interior Clearance: In order to eliminate the obstruction of fixing steel blocks onto each floor, strings, columns and bracings are not allowed to be placed inside a model. Also no diagonal elements must be present inside the model as in actual cases majority of the area is left free to build passage for elevator, staircase, etc.

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 5 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. *The floor area of each floor is the area surrounded by the outmost columns including the space taken up by columns.*

Floor area (cm^2)	No. of lead weights
625-699	7
700-774	8
775-849	9
850-924	10
925-1024	11
1025-1124	12
1125-1225	13

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.

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 0.10g, 0.16g, 0.24g, 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 =0.10g

↓

Check for failure and remove any failed models

Series 2 PGA =0.16g

↓

Check for failure and remove any failed models

Series 3 PGA =0.24g

↓

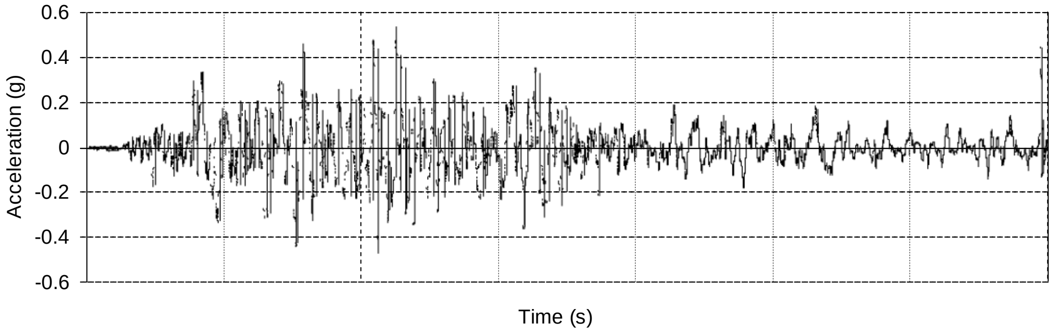
Check for failure and remove any failed models

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 2% 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 Scoring Method: The scoring method is primarily dependent on the economy of building and is given by the following expression:

$$\mathbf{S} = \frac{(\mathbf{I} - \mathbf{C}) * \mathbf{PGA}}{\mathbf{0.36g}} - \sum\left(\frac{\mathbf{0.36g} * \mathbf{R}}{\mathbf{PGAr}}\right)$$

S: Score

I: Income of the building which will be calculated by the following expression:

I=K*A

A: Area of the floor freely available for usage in cm^2

K= 1000`/cm² (for 1-5 floors)

1100`/cm² (for 6th floor)

1200`/cm² (for 7th floor)

C: Cost of the building will be based on the mass of the material used and the rate of the material will be taken as 1500`/gm

PGA: Peak Ground Acceleration at which the building fails (refer 4.3)

R: Repair cost (R) = 1500*m ` (m- mass of the structural element that failed in gm)

PGAr: Peak Ground Acceleration at which the above described structural element in the repair cost fails.

4.5 Bonus: The bonus will be given on two bases:

- Oral Presentation(A laptop with Windows7 OS and MS office2010 will be provided)
- Prediction of base shear and the value of PGA up to which the structure will not fail.

There will be an oral presentation for 5 minutes for every team where they will explain their structural design. The jury will be given 2 minutes to ask questions to the team. The presentation must address the main design issues in the model and any innovation that is incorporated. The rankings of the team in the presentation will decide the bonus score by the following equation:

$$\mathbf{B} = \frac{\mathbf{0.25S(21 - R)}}{\mathbf{20}}$$

S: Score

R: Rank in the presentation given by the jury

This implies that the 1st ranked team out of 20 teams will get 25% of his score as bonus.

Bonus for the calculated values will be given by the following:

$$\mathbf{B1} = \mathbf{0.1S} - \left(\frac{|\mathbf{Actual} - \mathbf{Expected}|}{\mathbf{Actual}}\right) * \mathbf{0.1S}$$

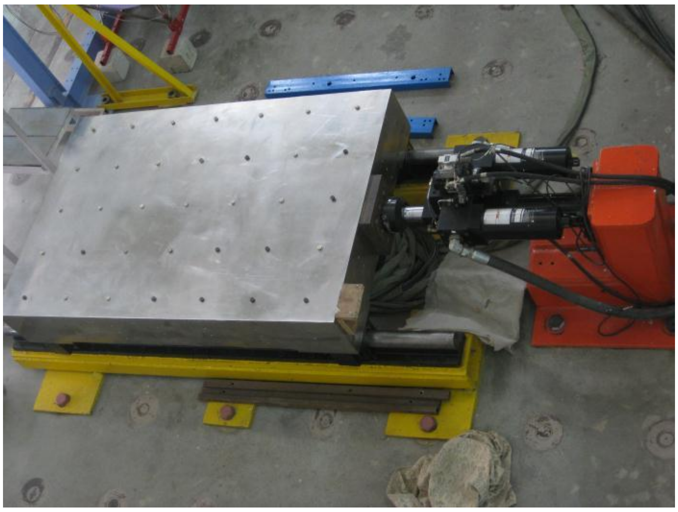
All the terms are as defined before

4.6 Final Score: Final score (**FS**) will be given by the following

$$\boxed{\mathbf{FS = (S + B + B1)}}$$

4.7 Violation Penalty: Teams will be descored if:

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



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

Material Properties:

1. **European Beech sticks**
   - Young's modulus of elasticity ~ 9 GPa
   - Tensile Strength 80 - 110 MPa
   - Width = 10 mm ; Thickness = 2 mm
   - Maximum length of provided stick = 1 m
   - Specific gravity ~ 0.7
2. **Epoxy Fevicol MR**
   - Young's modulus of elasticity ~ 3-4 GPa
   - Setting time ~ 24 hrs

Some suggestions and guidelines:

- Always remember: best design is the one in which each and every member has a purpose and used according to its capability. Don't put un-necessary elements. Try to keep your structure as light as possible because weight is the main criteria in judging (refer 4.4).

- New and innovative designs will be preferred, but **innovation must be actionable** i.e. the design should be such that it can be actually built in reality.

- Read the problem statement carefully. Avoid any kind of controversies. Don't violate the specified rules, otherwise your design may be disqualified or penalty weight may be added to the original weight of structure.

- **The decision of judges will be final and no further debate will be allowed**. Therefore it's advisable that don't violate any of the specified rules.