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Dynamic Designs

Specification for model building and shaking-table tests

In partnership with
University of BRISTOL

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1. Introduction

This document provides the full specification for your model and the shaking-table tests. It includes all the details required for your structural design for Stages One and Two, and the details for the loading and shaking-table tests in the Stage Two Final. Only the qualifying teams from Stage One will go through to Stage Two.

For Stage One, you are required to design a model of a building that can stand up to artificial earthquakes generated on a shaking-table. Teams that qualify for Stage Two will construct their models and have them tested for earthquakes at the final event. Your model will be scaled to 1/100th of the size of a real building (i.e. to a scale of 1:100). For simplicity, the model will not include all the floors of the real building. One storey in your model will in fact represent 3 storeys in the real building. Remember, that for your architectural images you will need to show all storeys. See Figure 1 for an example of how a 3-storey model represents a real building with 9 storeys.

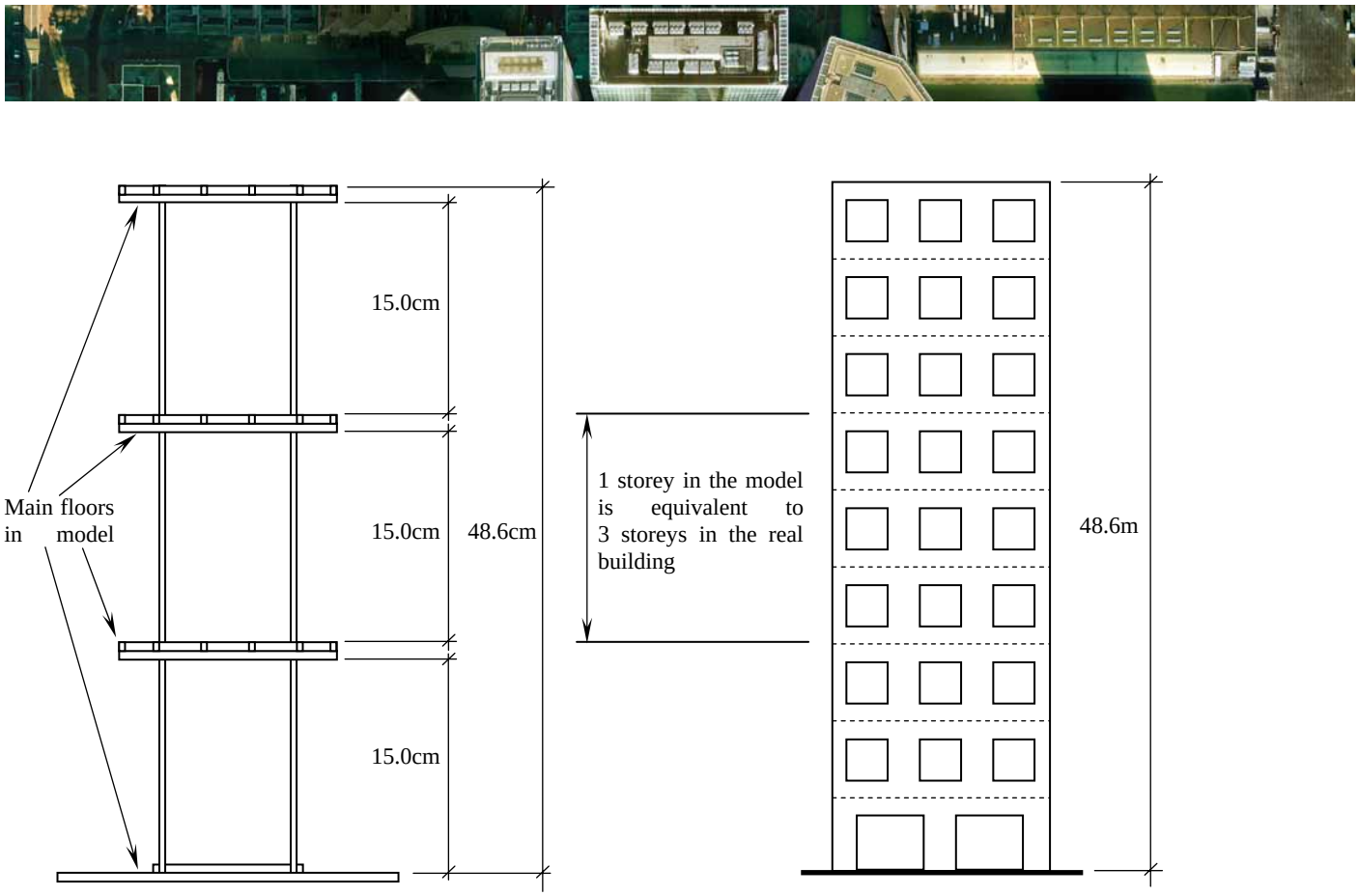

Figure 1: Sketch of 3-storey model (left) and equivalent 9-storey real building (right)

The model must:

- be made only from MDF, paper, glue and string
- have at least 4 floors and fit on a 25cm square MDF base board
- be able to carry 7.5 kilograms or more.

Teams that qualify for Stage Two will have their models tested on a shaking-table for a series of earthquakes. The first earthquake will be very small. Then the size of the earthquakes will be increased gradually, up to the maximum that the shaking-table can produce.

You can find out about designing earthquake resistant buildings on the IDEERS web-site at www.ideers.bris.ac.uk. Look at the section on “Resistant Buildings”.

2. Dynamic Designs Challenge Web-site

The specification for the model building is also given on the University of Bristol’s Dynamic Designs Challenge web-site where rules are illustrated with photographs, images and animations. It is recommended that you visit this web-site at www.ideers.bris.ac.uk/dynamicdesigns to gain a full understanding of the rules.

3. Materials for your Model and Costs

Only the materials shown in the table below can be used to make your model. Imaginary costs for the materials are also shown. The total cost (i.e. the imaginary cost) of your model must not exceed £20 Million. On the day of the final, you will be provided with play money to purchase the materials from the materials shop.

Material	Cost	Maximum permitted	Units of purchase
60cm long strip of MDF, with cross-sectional dimensions of 6mm x 4mm	£300,000 per strip	30 strips	A 60cm long strip
Sheet of A4 paper	£300,000 per sheet	Unlimited	A sheet
Cotton string	£100,000 per metre	Unlimited	1 metre
PVC hot melt glue stick	£750,000 per 30cm stick with diameter in 11mm	Unlimited	A glue stick
25cm square, 0.6cm thick, MDF base for the model	No cost	1	

4. The Final Build Day of Stage Two

4.1 Build Time

On the day of the final, you will be given 5 hours in which to construct your model. Make sure that your design can be constructed within this time.

4.2 Equipment and Materials

For teams that qualify for Stage Two, all materials and equipment for constructing models will be provided on the day of the Final. Teams **MUST NOT** bring any extra materials or tools with them – any team that breaks this rule will be disqualified.

Teams **MAY** however bring the following:

- Any complete test models that they have made in developing their design
- Photographs, drawings and other images of their designs
- Pencils, pens, rulers and erasers
- Notebooks with lined paper

On arrival at the Final, each team will be provided with play money totalling £20 Million. Teams will use this money to purchase the materials for their models from the materials shop throughout the day. Any unused material cannot be sold back to the shop. However, teams may trade unused materials with each other.

Materials available for purchase from the shop will include:

- 60cm strips of MDF, with cross-sectional dimensions of 4mm by 6mm
- Cotton string
- Sheets of A4 paper
- Hot melt glue sticks

You will collect your 25cm square MDF base board, for supporting the model, when you arrive.

The following equipment will be provided on each team's table:

- Scissors
- Hot melt glue gun
- Hacksaw
- A tape measure or 1 metre ruler
- Pencil
- Pencil sharpener

Drills with 8mm diameter bits will be available to all teams, at a central location, for drilling holes in the MDF base board.

5. Rules for the Structure of your Model

Your model only needs to include the main structural frame (i.e. the skeleton) of the building. You do not need to add the walls on the outside of the building or any stairs within. Figure 2 shows an example of a model. Your model can be any shape you like, but it must follow these rules:

- **Rule 1**: It must have at least 4 horizontal floors, with MDF edge beams defining all boundaries of the floor. A flat roof will be treated as a floor. You can use the base as the ground floor of your model. Note that when the base acts directly as a floor, MDF edge beams are not required at the boundaries.
- **Rule 2**: Not counting the ground floor, the total area of all other floors must be between 750 and 950cm2. The floor area includes the space taken by any columns. The maximum area that is allowed for each floor above the ground floor is 320cm2.
- **Rule 3**: The distance between the top of any floor and the bottom of the floor structure above must be at least 15cm (i.e. the clear distance). The fixings required for the steel blocks, your model must carry, do not count as part of the floors (See Section 6).
- **Rule 4**: You must leave the 25cm square MDF base board solid. However, you may drill up to sixteen holes in it to help fix your model to it. The diameter of the holes must not be more than 8mm.
- **Rule 5**: You must leave at least 12mm clear around the edges of the base board, so that your model can be fixed to the shaking-table with clamps.

- **Rule 6**: In a real building, you would need windows in every storey. So for each storey of your model, half the length of the outside perimeter must be left completely clear of any materials between the top of one floor and the bottom of the floor above. Figures 3 and 4 show examples for this rule. To help understand this rule, imagine being able to fit full height windows (with clear views) around half the perimeter of each storey.
- **Rule 7**: In a real building, people need access to all rooms on each floor. Allow for this in your model by making sure that access is not blocked by partitions, crosspieces or any other parts of the structure. You must leave enough space for at least one doorway 10cm high and 4cm wide into any rooms that you create.

6. Rules for the Load Your Model Must Carry

- **Rule 1**: Each floor of your model must be able to carry a load of 10 grams for every square centimetre of its area. Your model must be able to carry the required load on all floors at the same time.
- **Rule 2**: At the Final, your team will be provided with steel blocks to test your model to make sure it can carry the total load. Each steel block will be 6.0 x 4.5 x 3.0cm with a mass of 635 grams. The number of blocks you need to place on each floor will be the lowest number needed to provide the load required for that floor. If the ground floor of your model is directly on the base board, we will not put any blocks on the ground floor, because it does not affect the model when it is being shaken.
- **Rule 3**: You **MUST** provide fixings on each floor of your model to hold the blocks in place. Figure 5 shows an example of a fixing. The blocks will be placed on your model once it has been fixed to the shaking-table for testing. If the blocks fall out of their fixings during the earthquakes, your model will be disqualified. Make sure that you leave a slight gap between the blocks and your fixings, so that blocks can be taken out and put back in again. The blocks will vary slightly in size.

7. Checking and Mounting Your Model on the Shaking-Table

- When your model is complete, it will be checked by the judges to ensure that you have not broken any rules. No additional material can be added to your model, once it has been checked.
- At this stage, you will return all your unspent money to the judges, so that they can calculate and record the total cost of your model building.
- Your model will be fixed onto the shaking-table by clamping down its base. At that stage, the steel blocks will be placed on your model and glued firmly in place with hot melt glue.

8. The Shaking-Table Tests

8.1 The Earthquakes

In the final competition, models will be tested on a shaking-table for a series of earthquakes. The first earthquake will be very small. Then the size of the earthquakes will be increased gradually, up to the maximum the shaking-table can produce.

8.2 Criteria for the Most-Efficient Model

For every model, a record will be made of its cost and the size of the earthquake that causes it to fail. An efficiency ratio for your model will be calculated by dividing the size of the largest earthquake it survived by the cost of the model. The team with the model that has the highest efficiency ratio will win the prize for the “Most-Efficient Model”.

8.3 Failure Criteria

During the shaking-table tests, a model will be judged to have failed for any of the following conditions:

- Complete collapse of the model.
- At least one of the floors collapses.
- Steel blocks fall out of the building or move around excessively.
- The connections between the columns and the base are such that rocking of the model building occurs. (Note that sliding at the base is permitted).
- More than half the columns fail where they connect to the base.
- Any other failure that the judges decide would cause deaths within a building.

Note: The judges’ decision will be final.

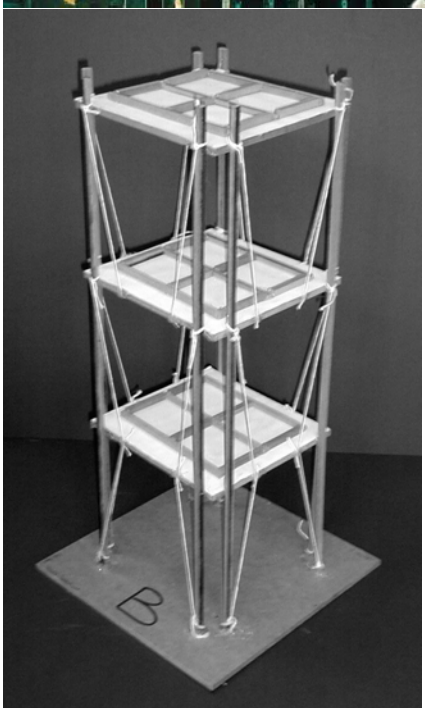

Figure 2: An example of a model with 4 floors. The top floor is a flat roof. The ground floor is on the base board.

Figure 3: On each face of this model only half the perimeter of each storey has material between the bottom of the floor above and the top of the floor

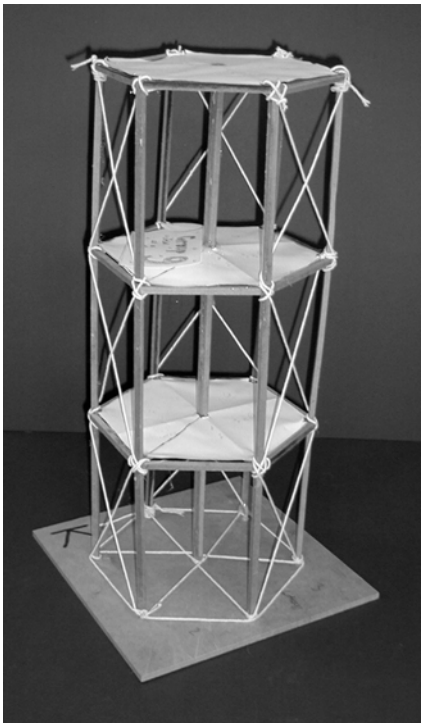

Figure 4: On this hexagonal model, only 3 of the 6 faces in each storey have material between the bottom of one floor and the top of the floor below, so that leaves half the perimeter clear of material.

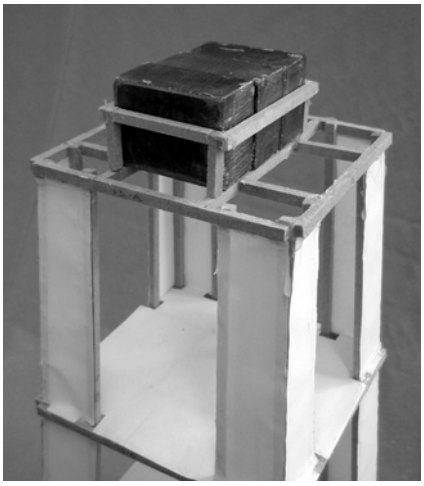

Figure 5: This model has the paper on the top floor missing to show how the steel blocks are supported by the frame of the floor. The fixing to hold the blocks in place is also shown.