Civil Engineering Handbook

Civil Engineering

Handbook

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Editorial

What is Civil Engineering and where is it present?
How can Civil Engineers transform the world and what is their role in modern society?

These are the main questions that the Educational Lab - Big Machine (ELBigMAC) project intends to answer. ELBigMAC is an ERASMUS+ project with the aim of disseminating Civil Engineering among secondary school students.
To help illustrate these issues, we can look at a house as a big machine, built by the articulation of different systems and different forms. This project aims to show how this "Big Machine" is built and how it works, from its Design Concepts to the construction and performance phases. During this project, a collection of activities were designed to describe Civil Engineering as a contemporary and a thriving field of study to attract students in pursuing a career in this field, from hands-on workshops to Immersive Virtual experiences. Inviting students to develop projects where the role of a Civil Engineer is decisive is part of the strategy which comprises the accomplishment of a series of activities and workshops designed specifically for each discipline of Civil Engineering.
The book is intended for teachers, educators and researchers who wish to bring and apply the project's vision for class use and into their own institutions. These exercises will be a complement to the theoretical and practical classes in related disciplines.
15 activities and challenges, as well as 12 interactive equipment manuals are described so that they can be replicated and adapted to the needs and restrains of other institutions. Each guide includes illustrations to provide a detailed description of each challenge.
Led by the Faculty of Engineering of the University of Porto, in partnership with the Faculty of Civil Engineering of the University of Zagreb and the University of Aristotle of Thessaloniki, ELBigMAC intends to show students how Civil Engineering is spread around us, building and shaping the future of modern civilizations.

Instructions for use: Guides

The section comprises two types of documents: General Guides and Activity Guides. The General Guides introduce a more extensive challenge, including several activities. These guides cover the methodology to be followed and suggest a set of tasks and work-plans including several sessions to be conducted.
Activity Guides include the name of each activity, its expected duration, a brief introduction, materials needed, summary and procedures.

Instructions for use: Manuals

The manuals are related to the interactive equipment developed throughout the project which can be replicated in any educational institution. Each manual includes an illustrative example, to scale CAD detailed drawings, as well the application of some equipment demonstrated within the scope of civil engineering.

Civil Engineering Today

Civil Engineering is manifested all around the environment that surrounds us. Still, will we recognize the importance of Civil Engineering activities in our society? Do we understand its extent, impact, tools and methods it uses?

Civil Engineering is vital to the progress of society, strongly supporting the economical activity, designing and building cities and towns, housing, transportation networks, energy distribution structures, industrial and manufacturing units. In detail, its presence can also be found in the design and construction of bridges and tunnels, ports and airports, dams and wind towers, oil and natural gas exploration platforms, and public and private buildings. Civil Engineering is also fundamental for society through the design and assembly of potable water supply networks, as well as sanitation and energy distribution infrastructure. The protection of the maritime coastline, which is increasingly at risk from climate change, is also an activity in which Civil Engineering is heavily involved. Civil Engineering also has a strong social relevance, notably in the construction of infrastructures and accessibility for a progressively ageing population as well as in the maintenance and restoration of historic buildings.

Ecology and sustainability establish an essential relation with Civil Engineering. As an increasingly critical issue, examples include the importance of energy efficiency in buildings, the reduction of hazardous industrial waste and the treatment of polluted water, as well as the capture of new sources of drinking water and the inertization of residuals.

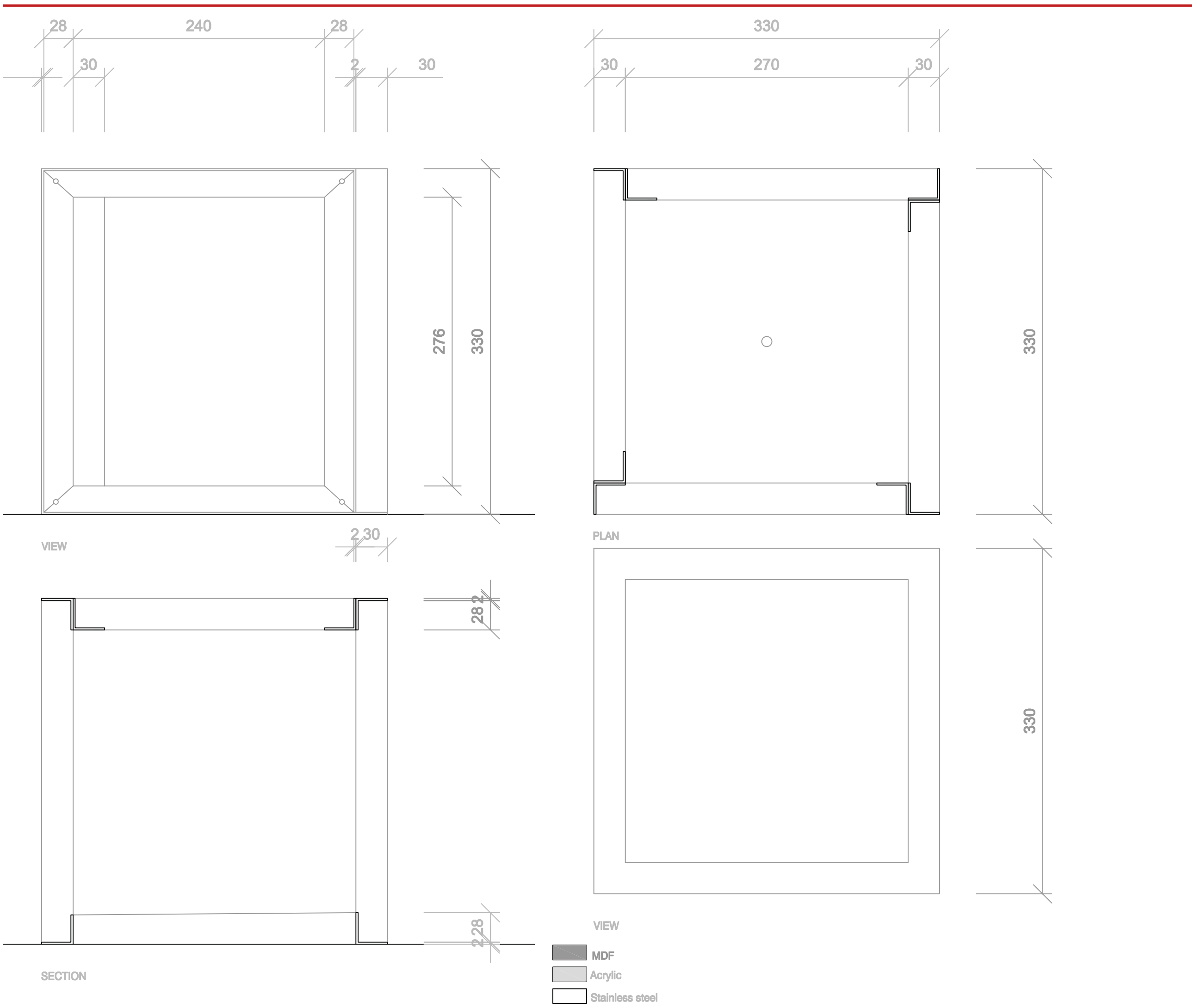
Civil Engineers combine various skills and work in multidisciplinary teams, using cutting-edge Information and Communication Technologies (ICT) to develop new interventions, always in search of the best solutions. Throughout this process, they seek to achieve an appropriate balance between safety, economy and performance optimization and quality of the assets to be built, or in the recovery and rehabilitation of the built environment and cultural heritage.

Civil Engineering today is constantly changing and evolving to meet the world's current and future needs. Civil Engineers are prepared professionals fitted with a wide skill set that enables them to design, research, lead teams and manage the built environment.

manuals

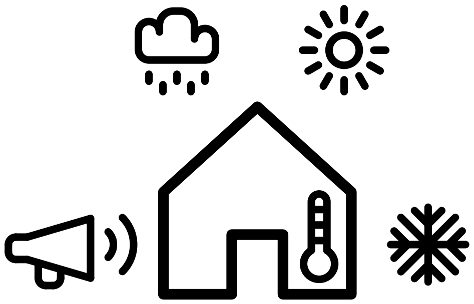
activities

Building Physics Box



What is happening?

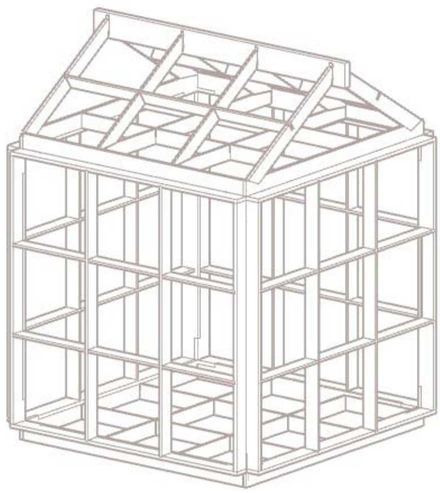
The materials that make up the building's envelope (walls, spans, roof and floors) must be characterized by:
– Load Bearing (user loads, furniture, wind, earthquakes, etc.);
– Waterproof (preventing rainwater from entering);
– Heat and cold insulator (maintaining temperature and interior comfort);
– Soundproof (avoiding the annoyance of outside noises or the neighborhood);
– Shock absorbent, fire action, among others.

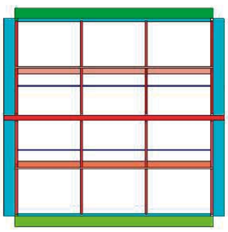


Where?

Buildings in general: dwellings, hospitals, schools, industries, etc.

Big Machine House





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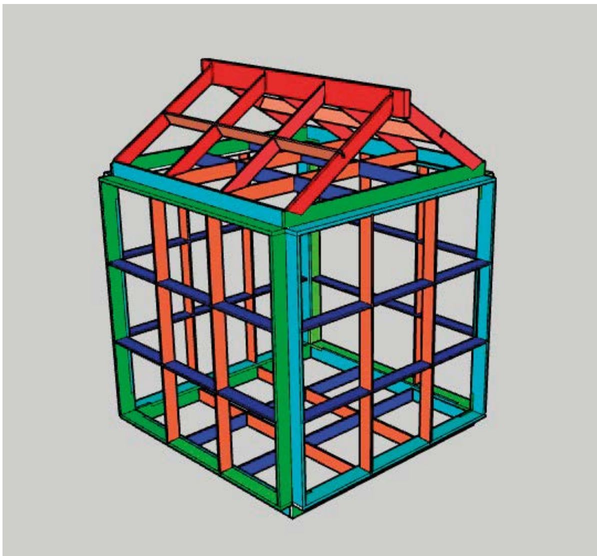
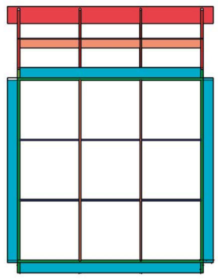
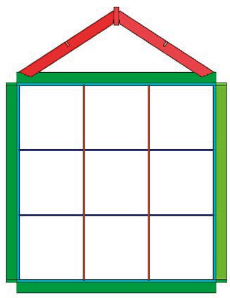




Side view



Front view

Bill of quantities

Part number	Quantity
1	8
2	4
3	2
4	4
5	6
6	12
7	12
8	1
9	4
10	4
11	54
12	6
13	6
14	2
15	2
TOTAL	127

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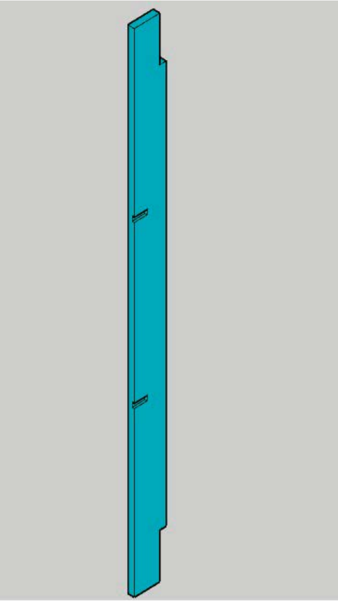

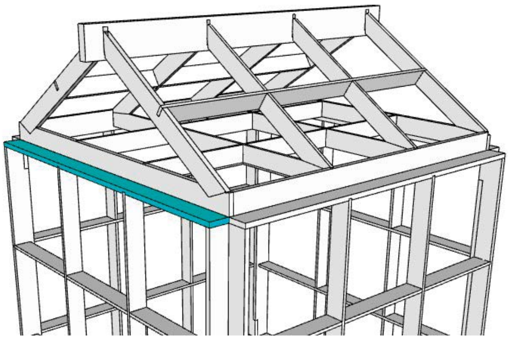

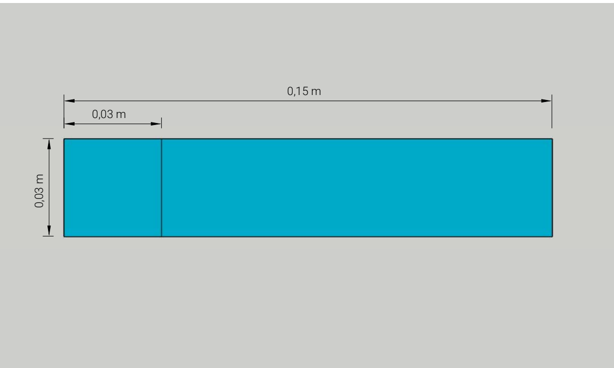

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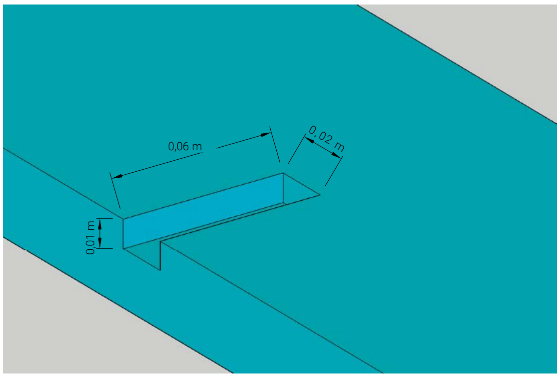

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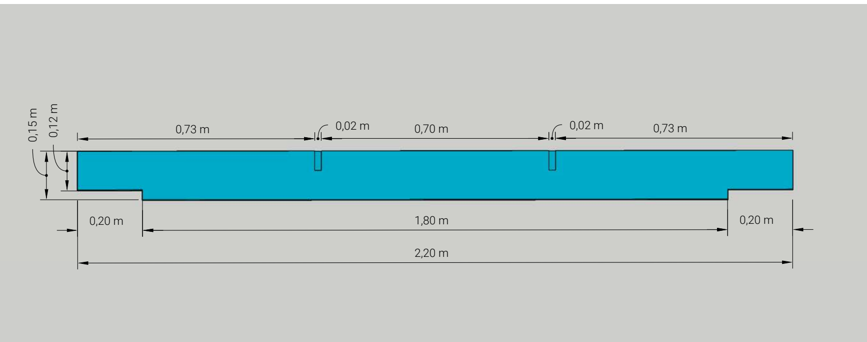

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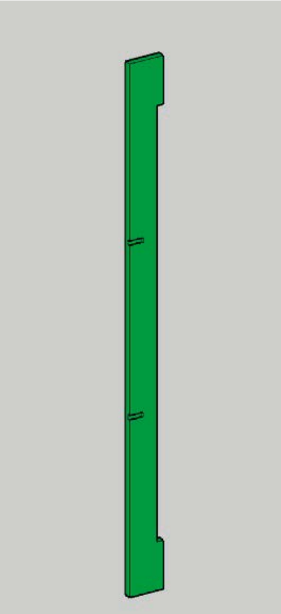

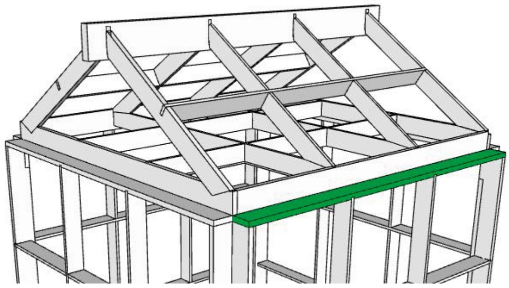

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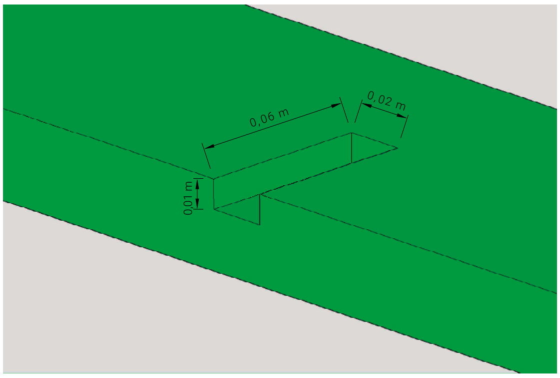

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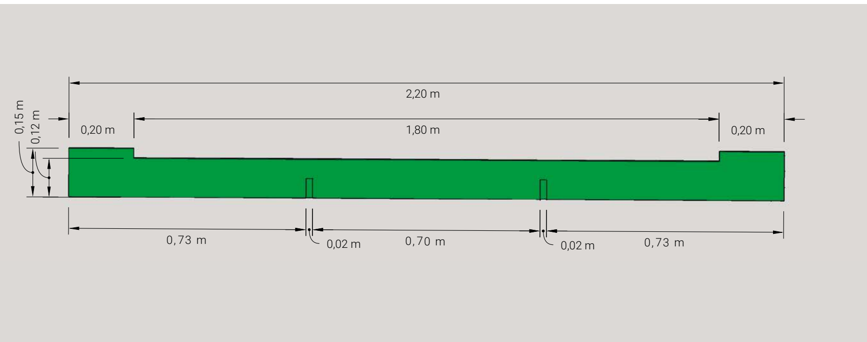

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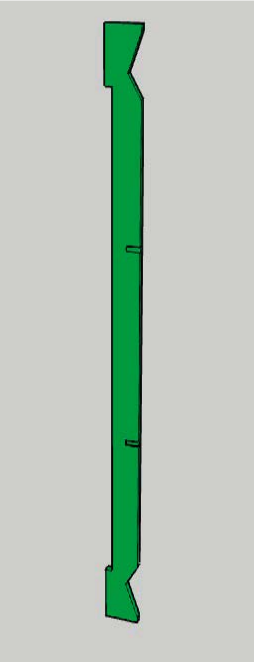

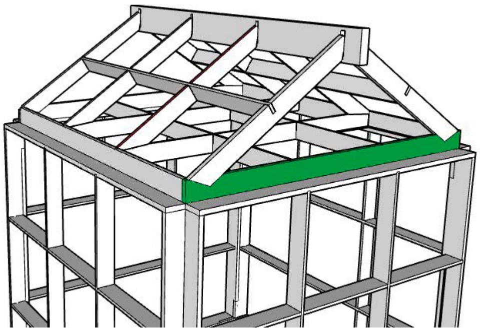

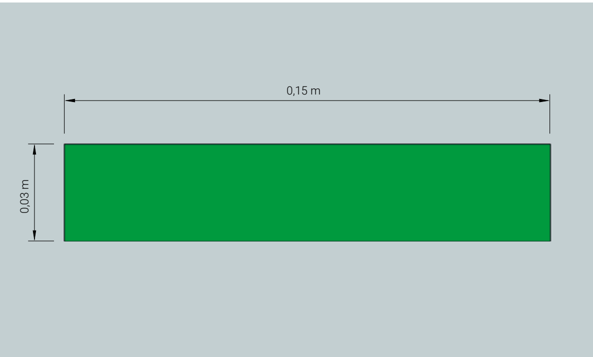

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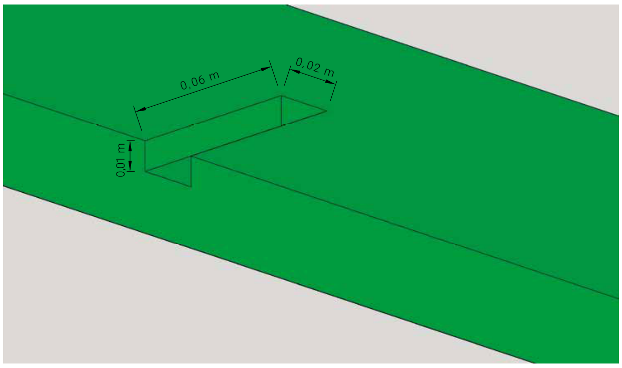

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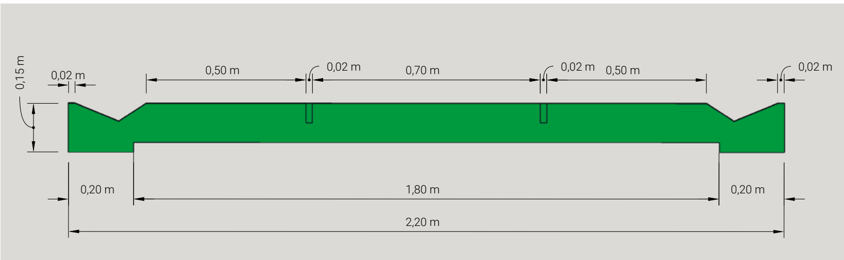

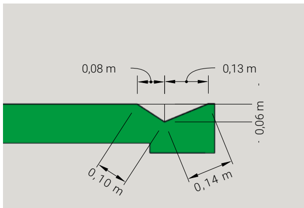

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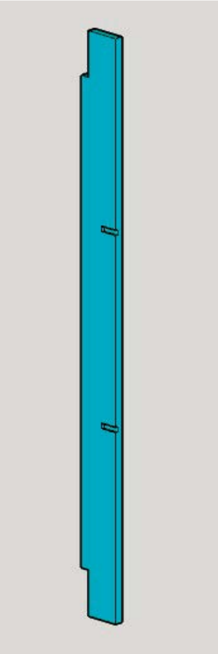

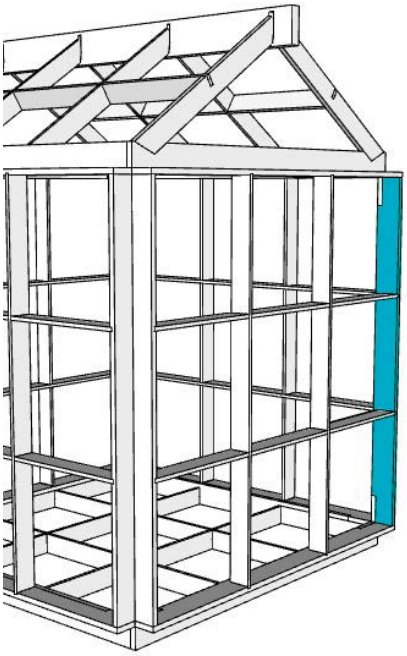

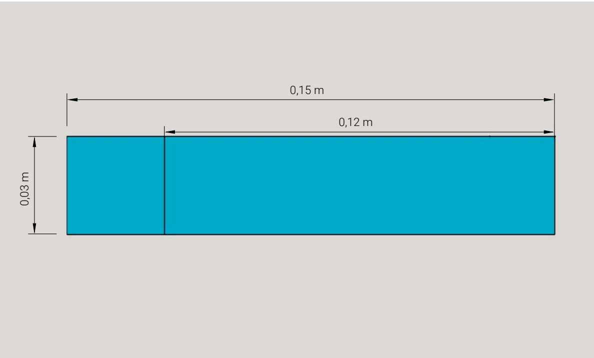

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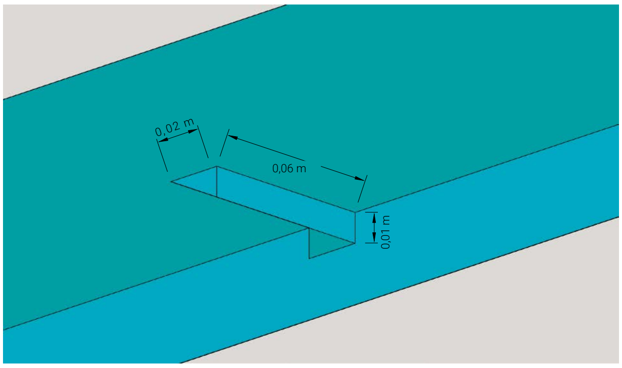

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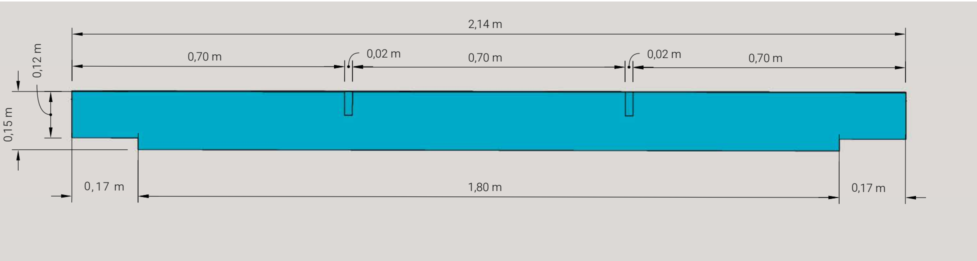

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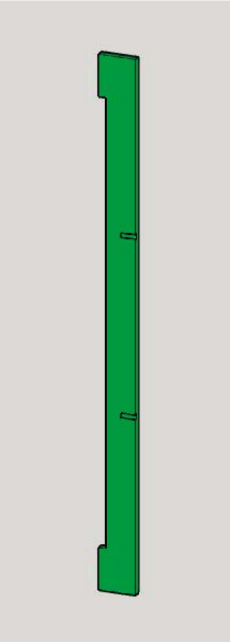

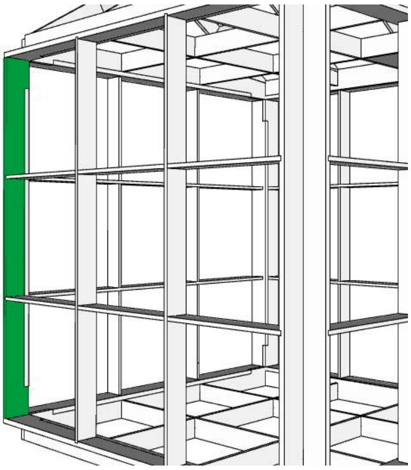

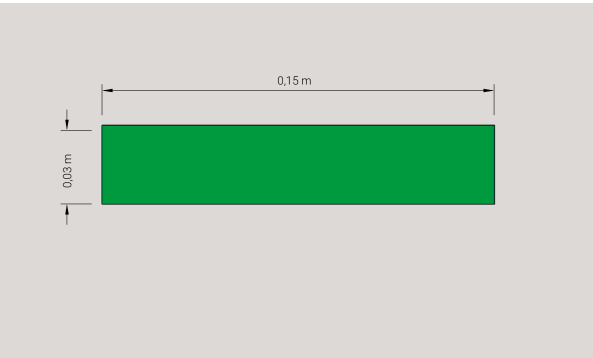

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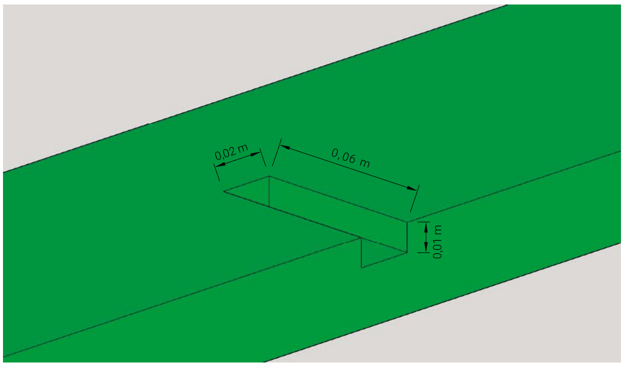

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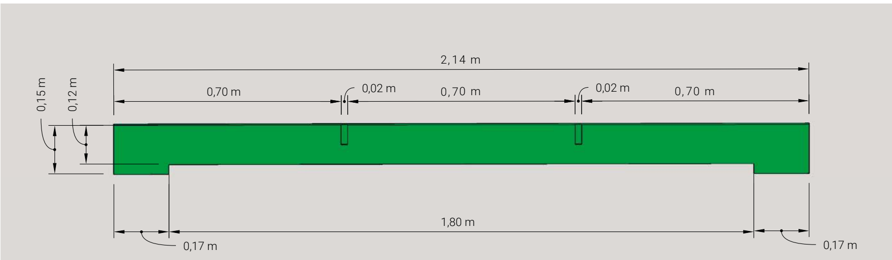

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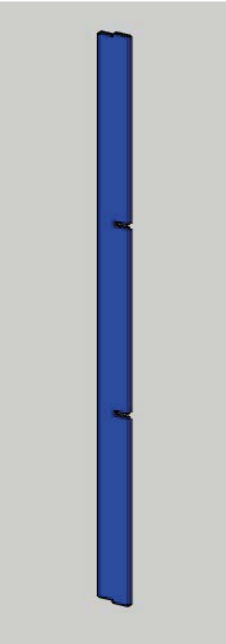

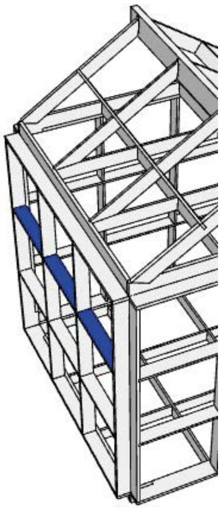

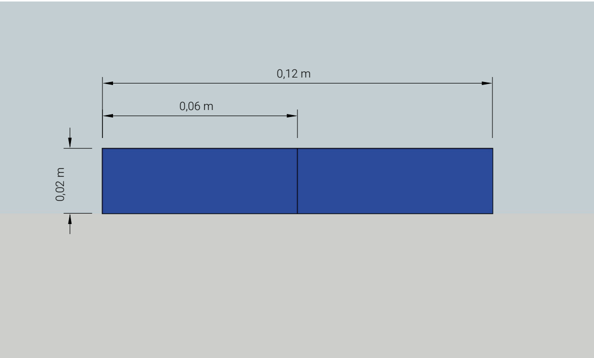

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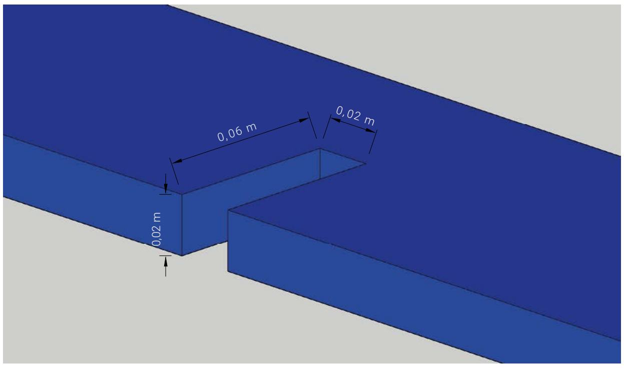

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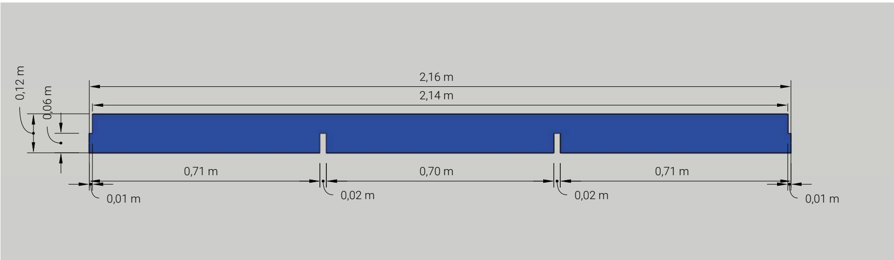

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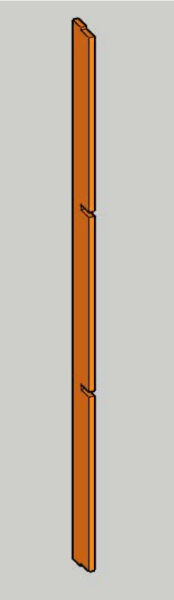

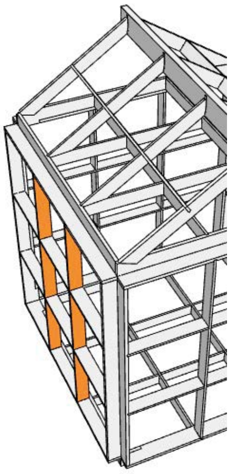

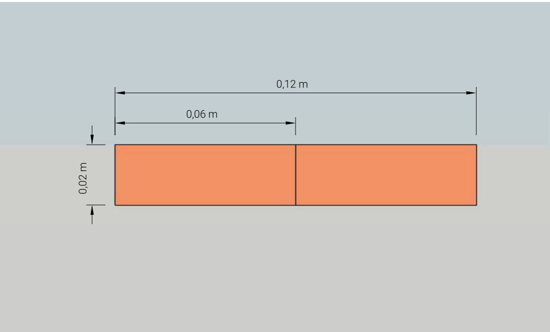

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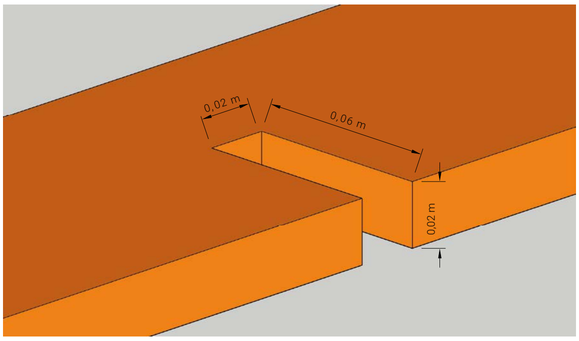

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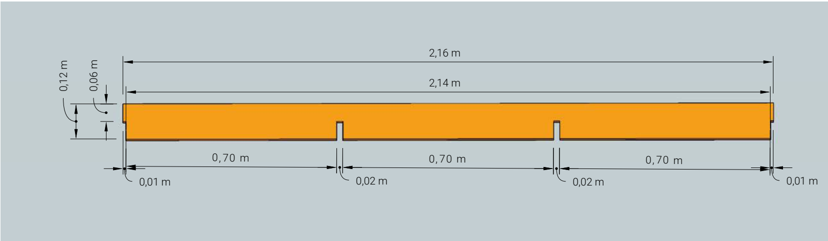

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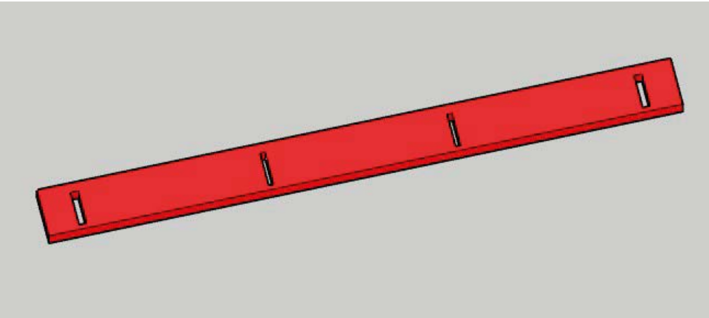

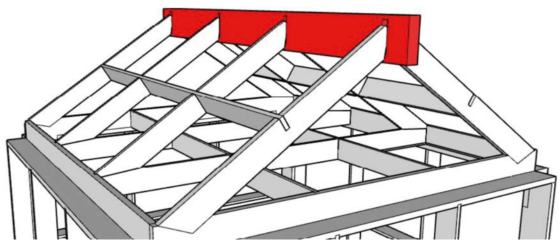

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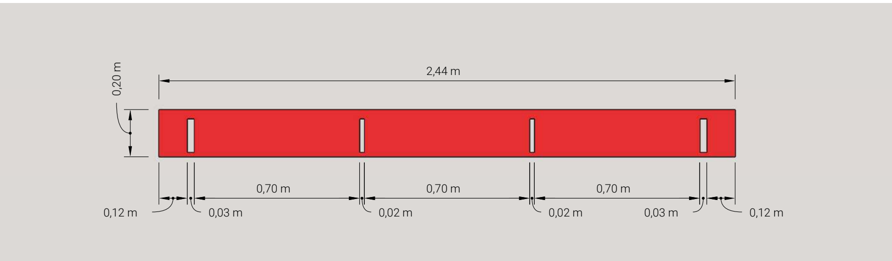

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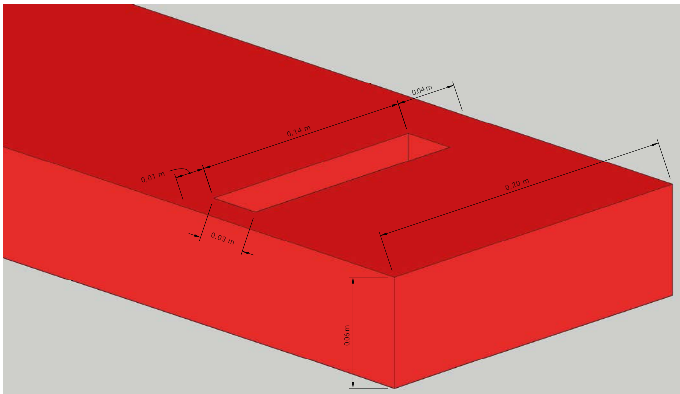

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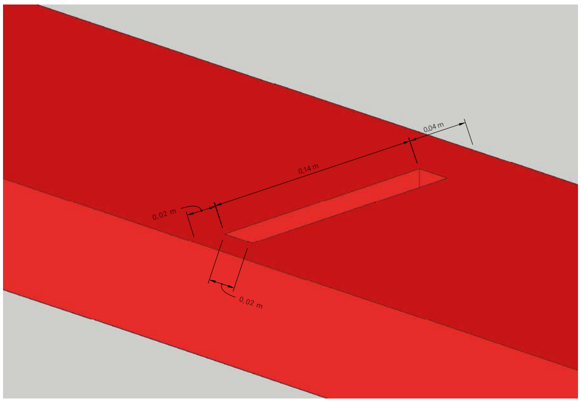

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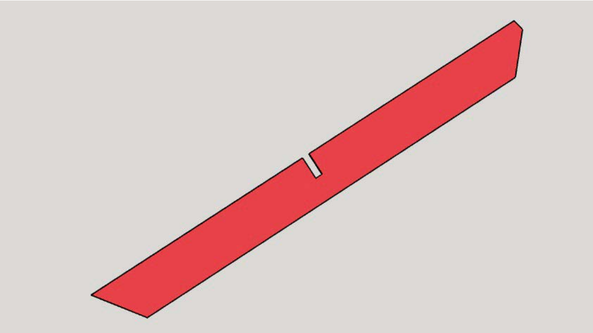

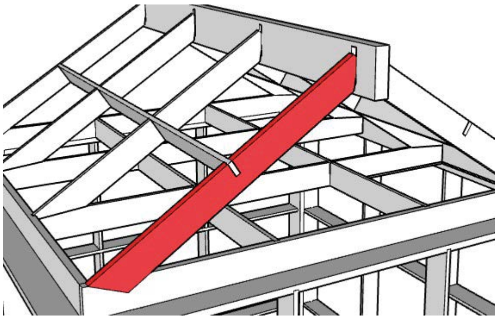

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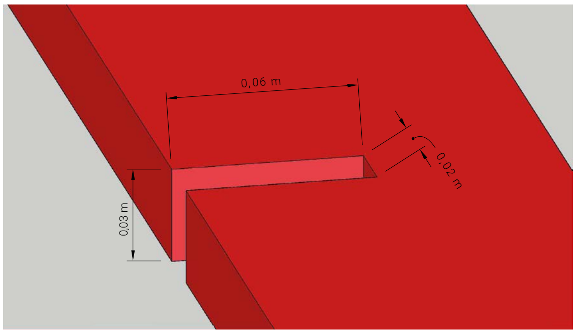

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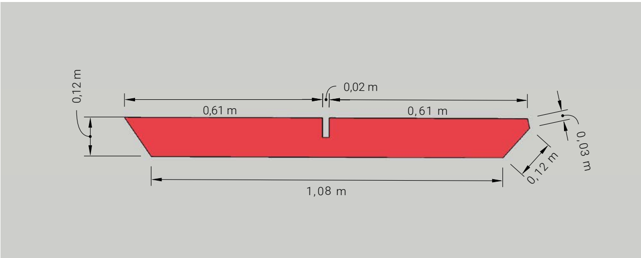

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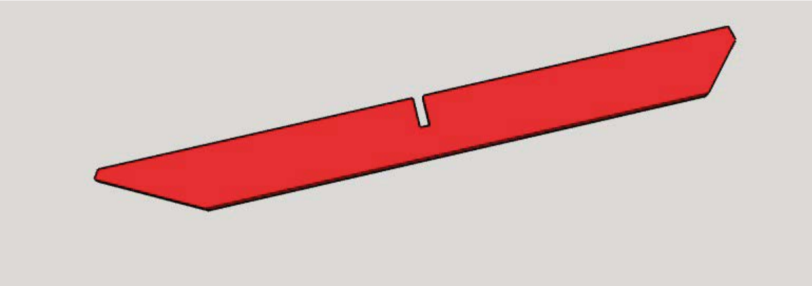

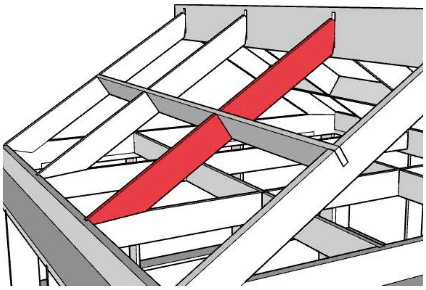

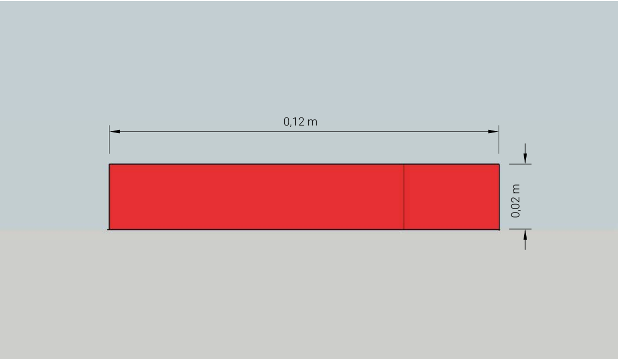

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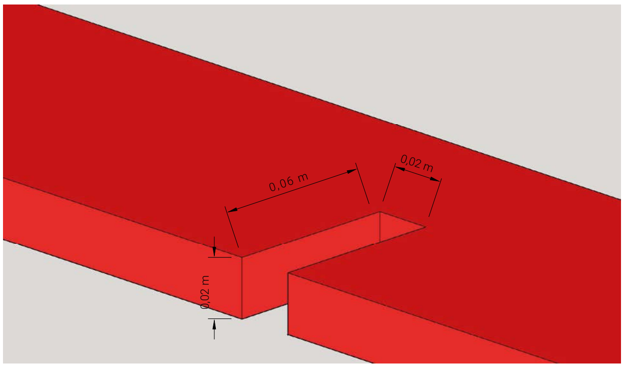

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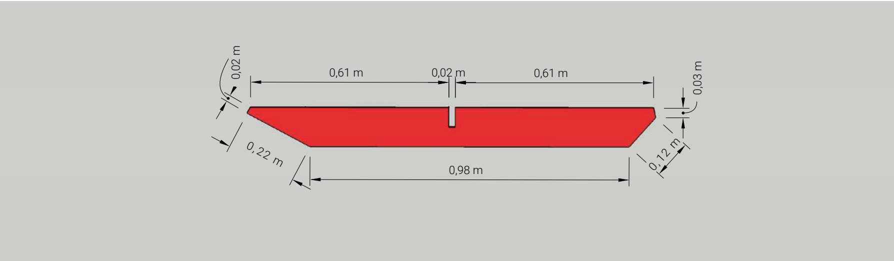

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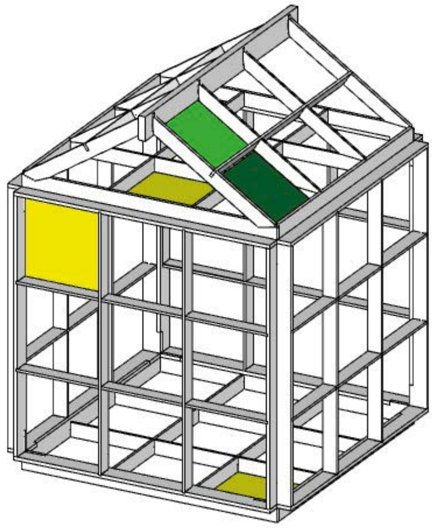

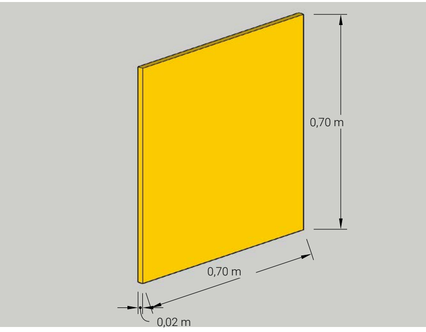

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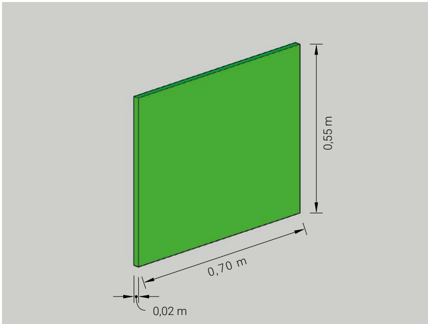

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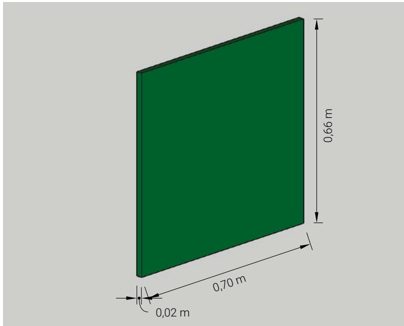

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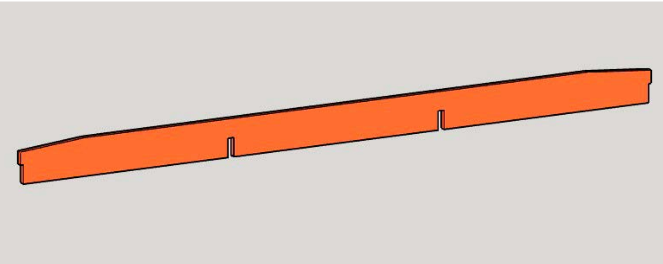
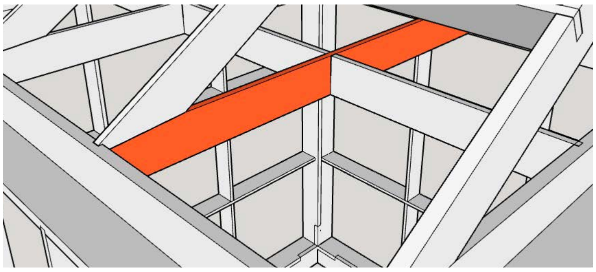
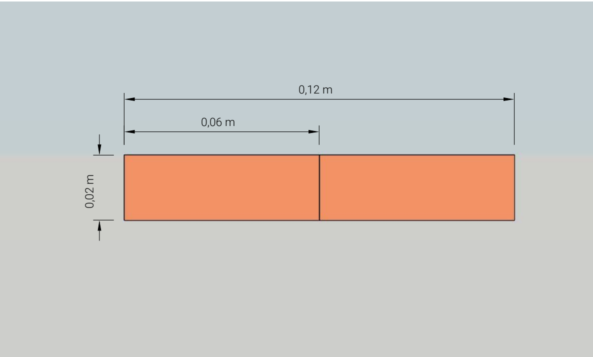
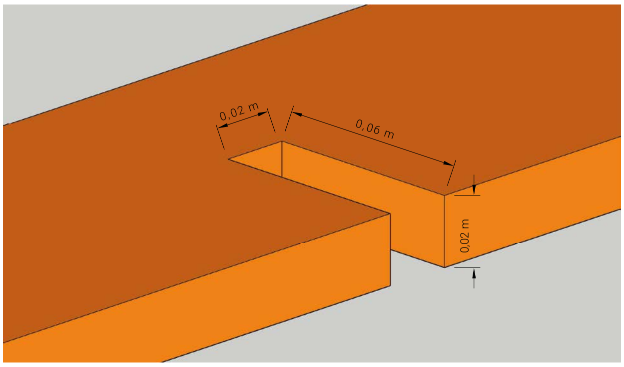


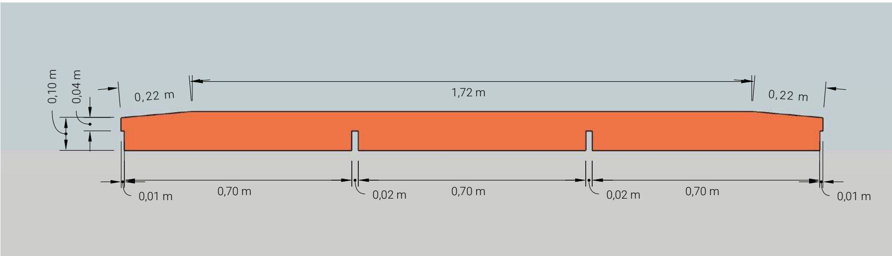




Top view - scale 1:1

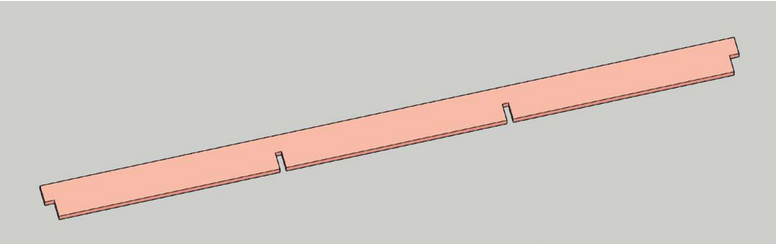


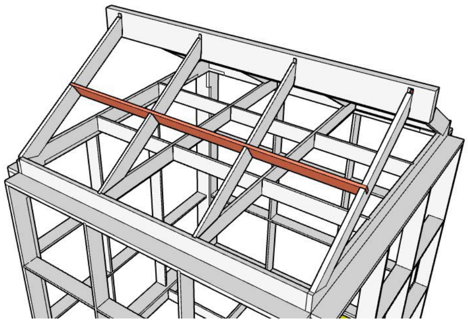
Detail - scale 1:1

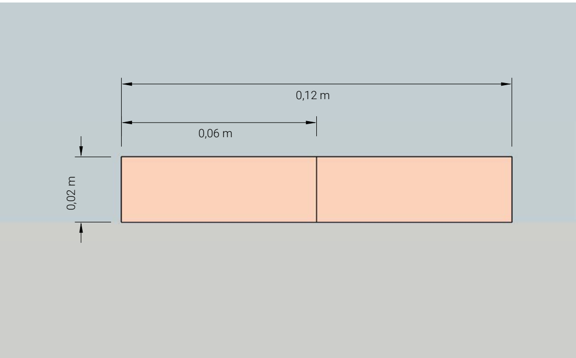


Front view - scale 1:10

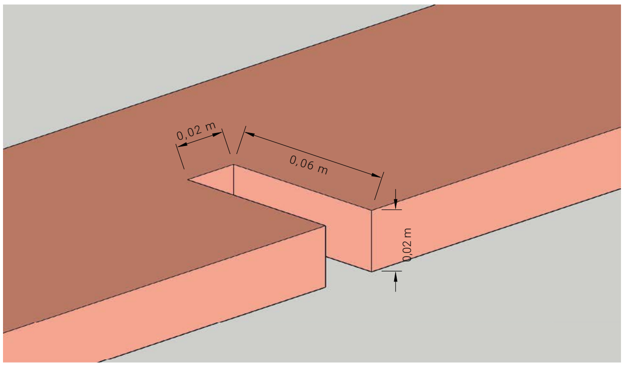
Part Number 15 – Quantity 2



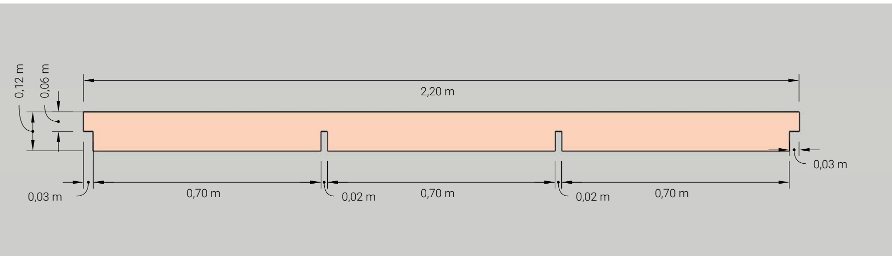




Top view - scale 1:1



Detail - scale 1:1



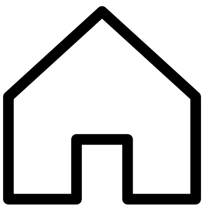
Front view - scale 1:10

What is happening?

This structure supports different wall system solutions that can be tested in outdoor conditions.

Where?

In all buildings, houses, schools and other constructions.



Environmental Monitoring System

The project includes three independent monitoring systems with:

1. Weather Monitoring System:

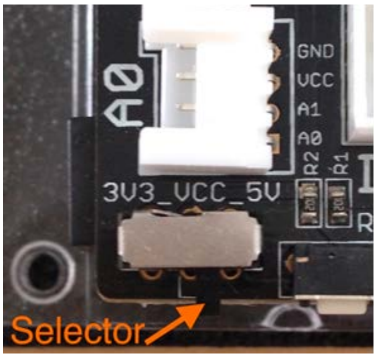
Hardware

Weather Meters- SEN-08942

parts:
– Wind Vane
– Cup Anemometer
– Tipping Bucket Rain Gauge
– Two-Part Mounting Mast
– Rain Gauge Mounting Arm
– Wind Meter Mounting Bar
– 2 x Mounting Clamps
– 4 x Zip Ties

– Arduino UNO R3
– Ethernet shield for Arduino UNO -Ethernet Shield W5100 for Arduino
– SEN-08942 wind and rainfall sensors
– Grove shield for Arduino
– Grove Temperature and Humidity Sensor Pro

Arduino UNO R3 + Grove Shield



Wind&rain sensors

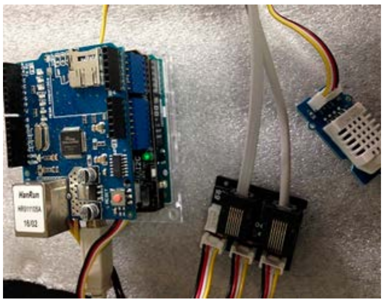
Temperature and humidity Sensor:

This sensor is connected to D5 on the Grove base shield. To read from this sensor, we need a Library called dht22.

The Ethernet shield

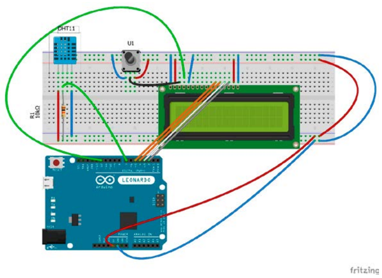
Once the sensors have been tested, it’s time to look at the Ethernet Shield. The Arduino shield from SUNFOUNDER is directly supported by the Ethernet library from Arduino.
To see the UDP packets on MAC use “nc -l -c 8888”
https://www.sunfounder.com/

The final assembly

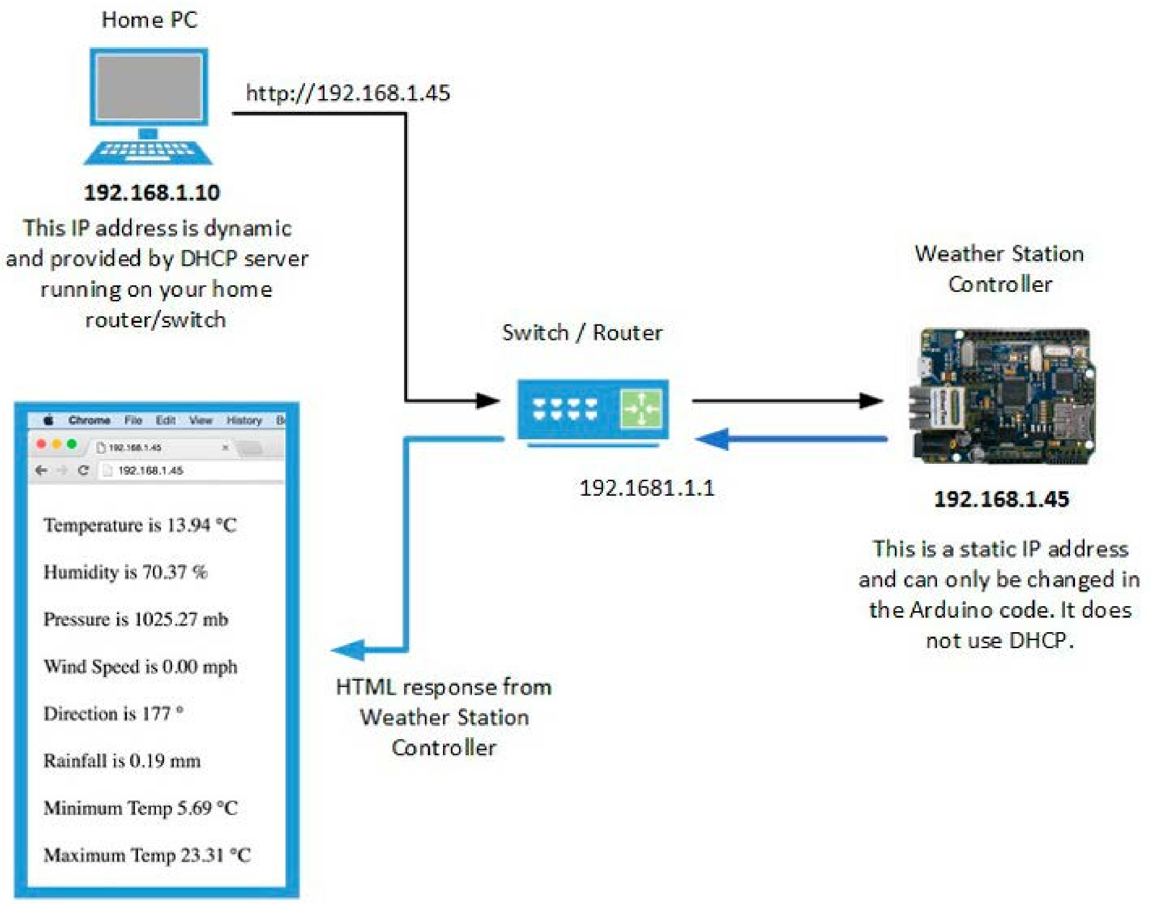


2. Environmental Monitoring System- Inside House:

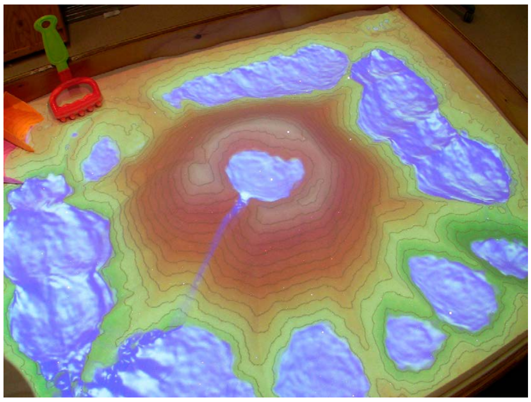
Hardware
Arduino WIFI
DHT11 Temperature & Humidity Sensor (4 pins)
Adafruit Standard LCD - 16x2 White on Blue
Rotary potentiometer (generic)
Resistor 10k ohm

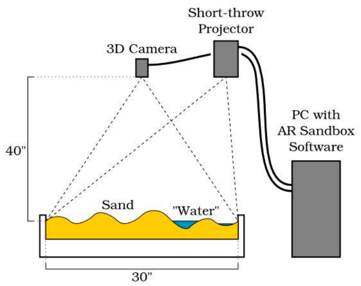


3. Weather Station Web Server



Augmented Reality Sandbox





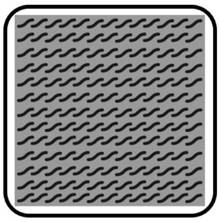
Projector and Kinect camera above a 40"x30" (1mx0.75m) AR Sandbox.
Source: http://idav.ucdavis.edu/~okreylos/ResDev/SARndbox/Instructions.html#Figure1

What is happening?

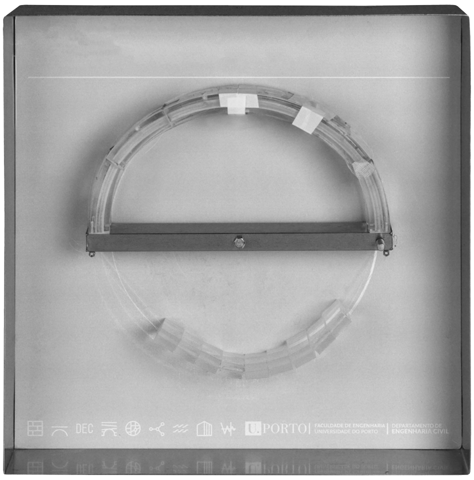
The interactive equipment allows users to create topography, shaping sand, which is then augmented in real time, creating an elevation colour map, topographic contour lines, and visually simulated water movement.

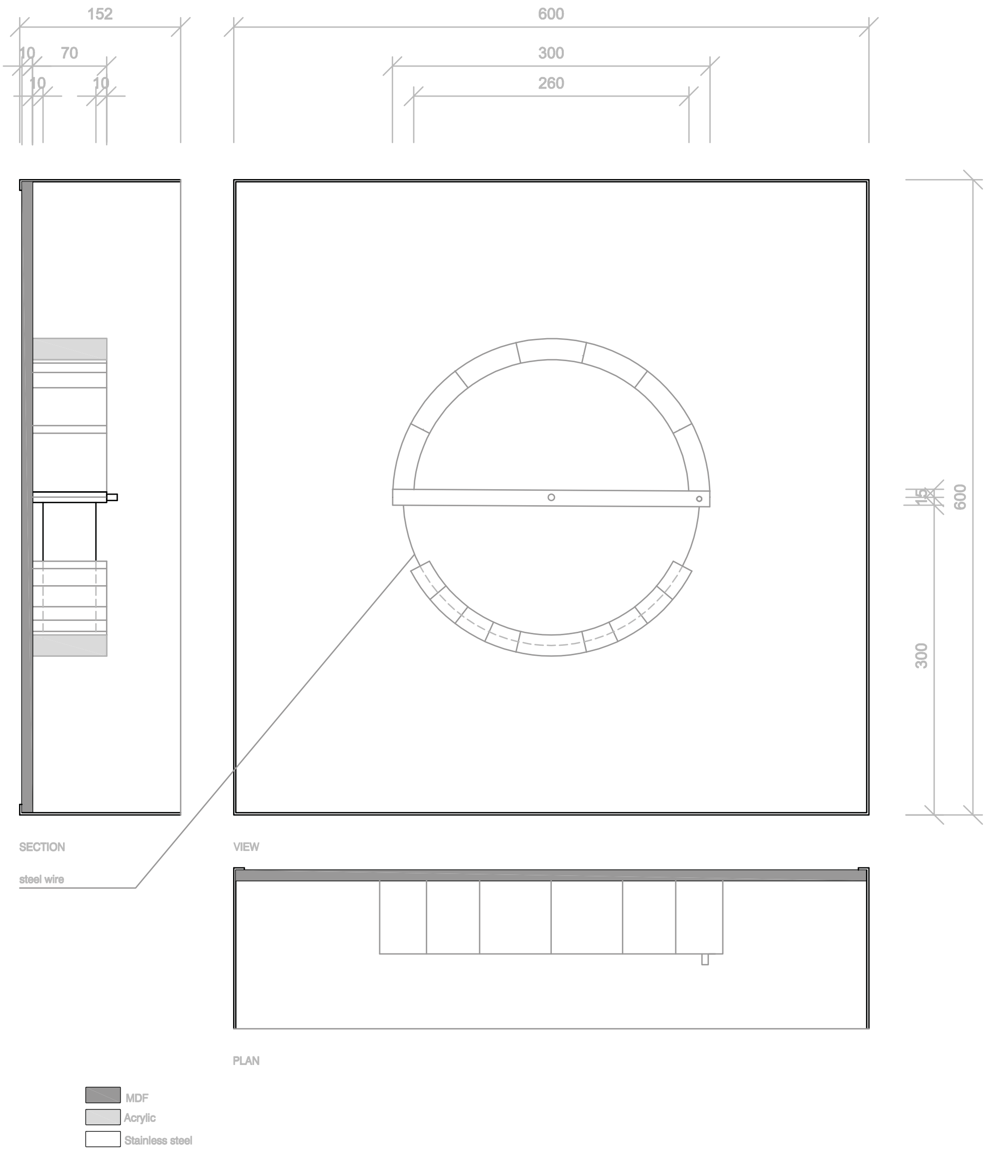
Where?

The AR sandbox can be used to convey hydrological concepts, as well as how to read a topographical map, the meaning of contour lines, watersheds, catchment areas, levees, etc.

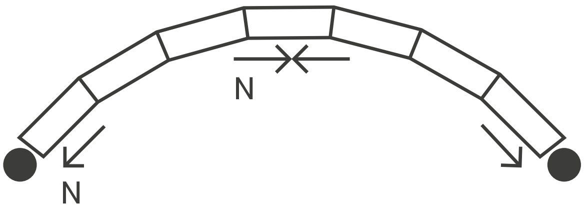


Arch Bridges

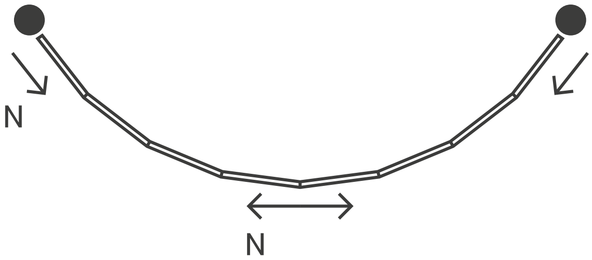




What is happening?

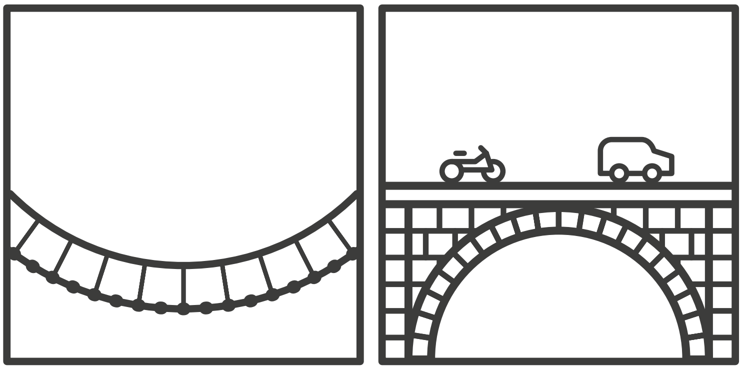


The arch resists the compression loads.



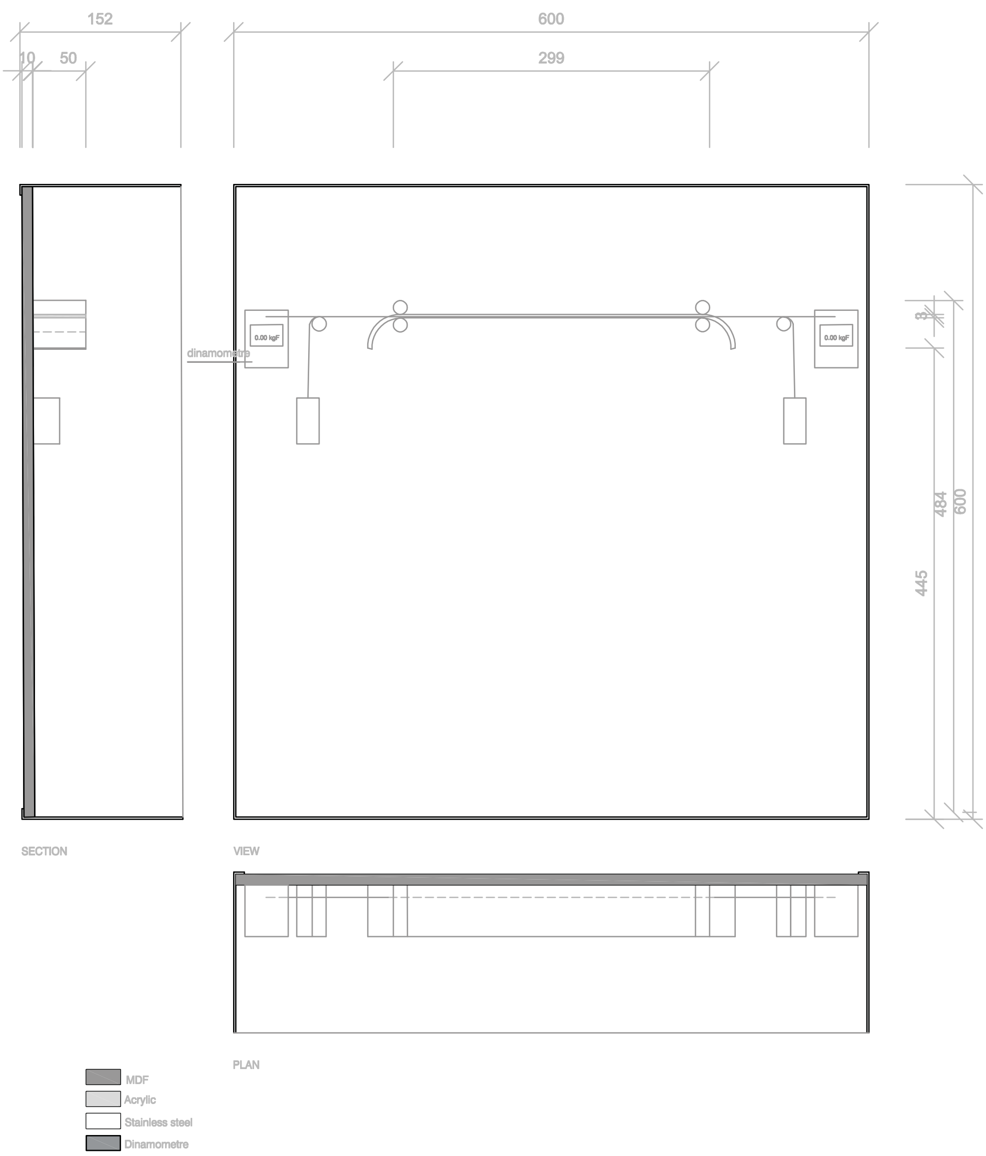
The cables are subject to a tensile load.

Where?



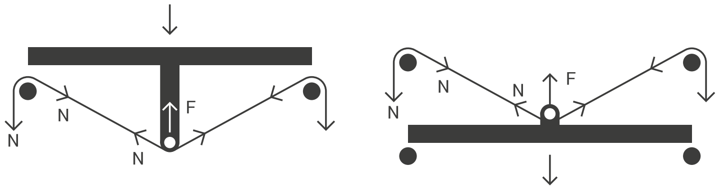
Suspension bridge and arch bridge.

External Prestressing

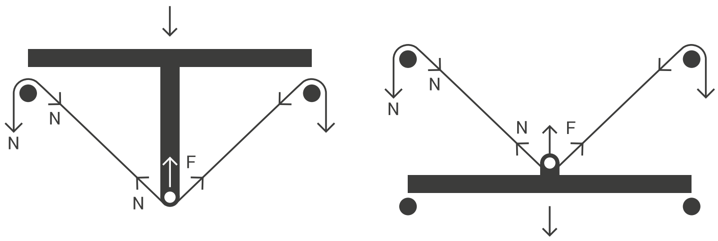


What is happening?

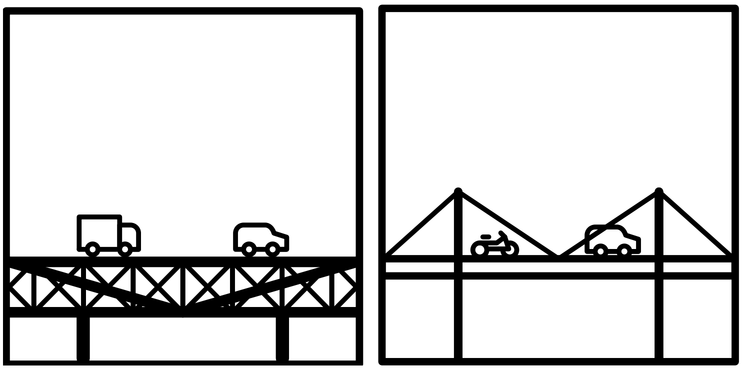
The force F depends on the angle of the cable.



The force F depends tensile force in the cables N.

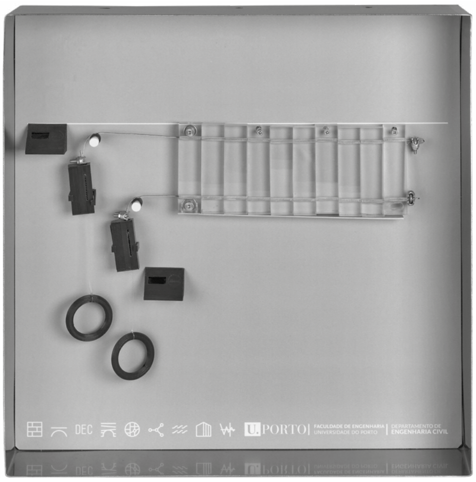


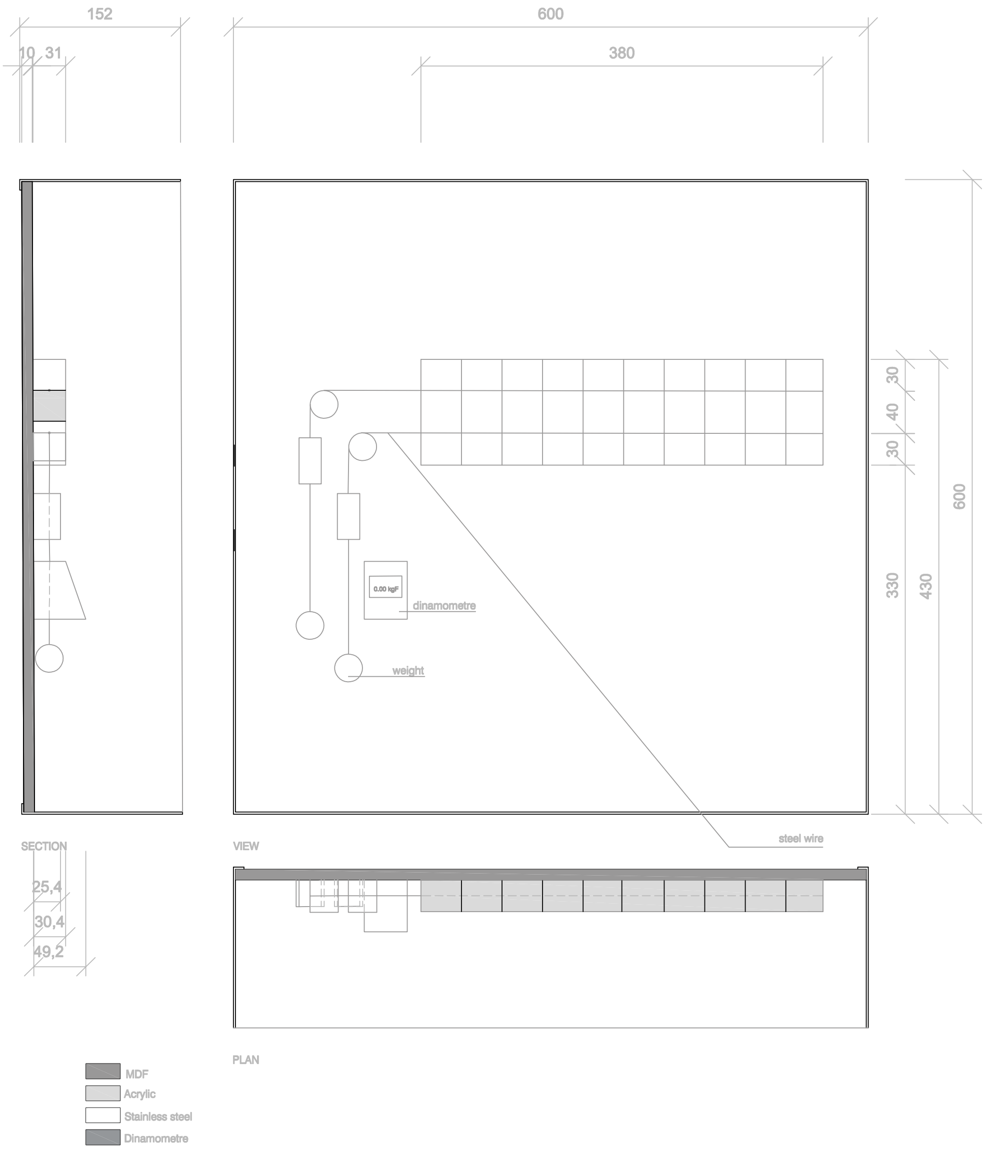
Where?



Lattice bridge with external cables and a cable-stayed bridge.

Internal Prestressing

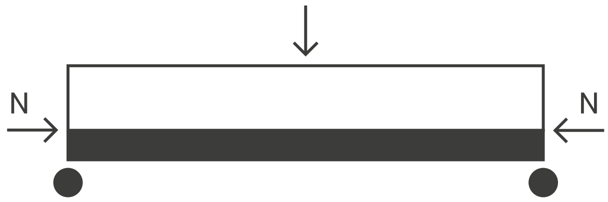




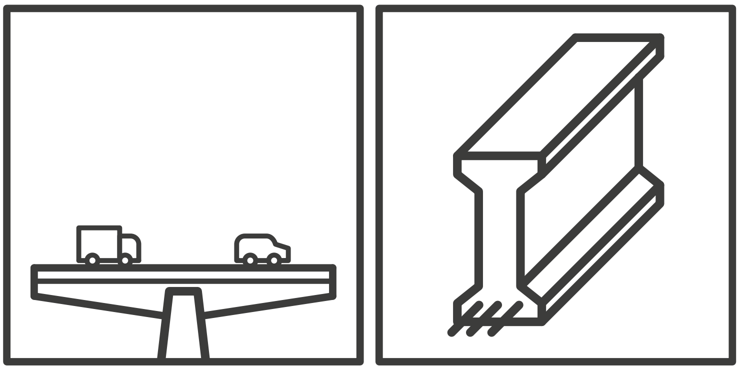
What is happening?

The cables compress the parts so that they do not crack by traction.

The cables introduce compressive stresses that reduce the deformation under vertical loads.

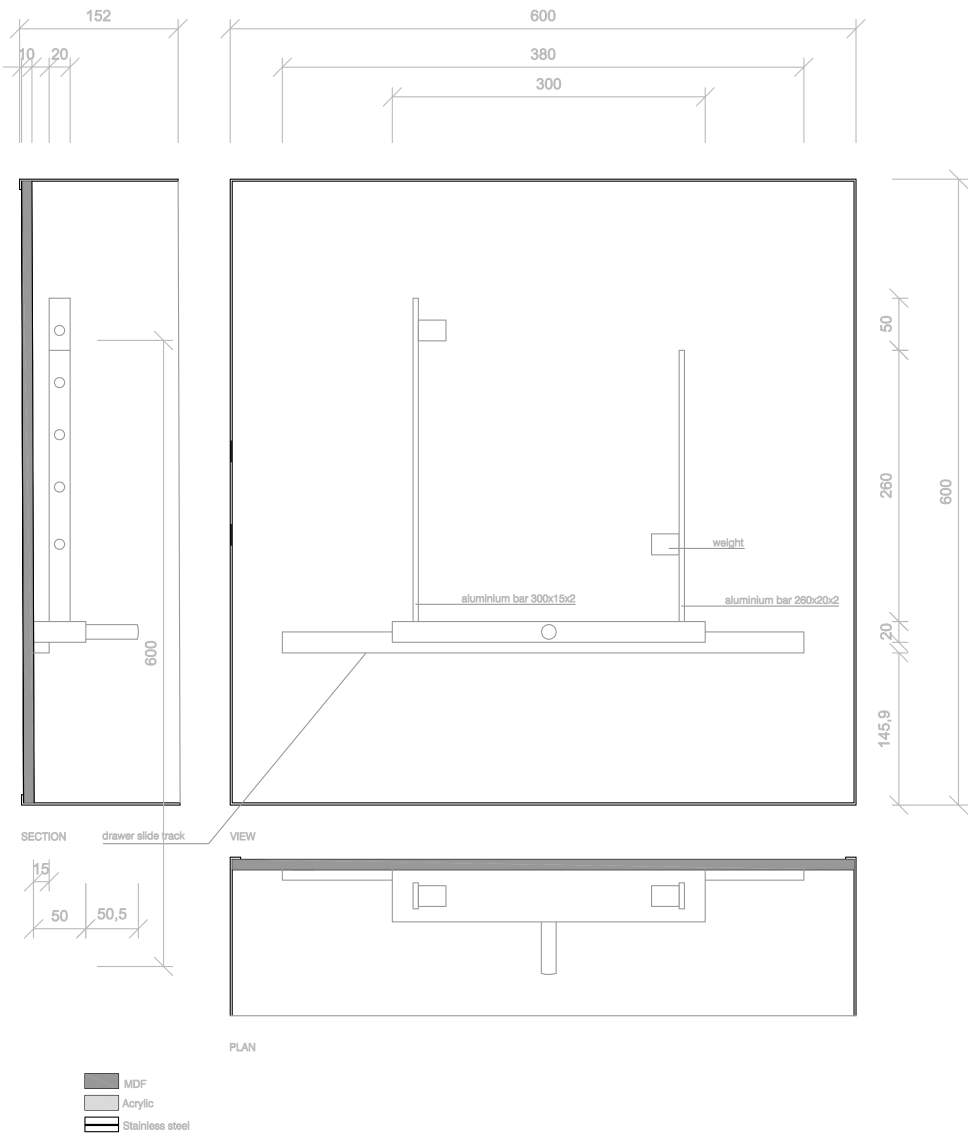


Where?



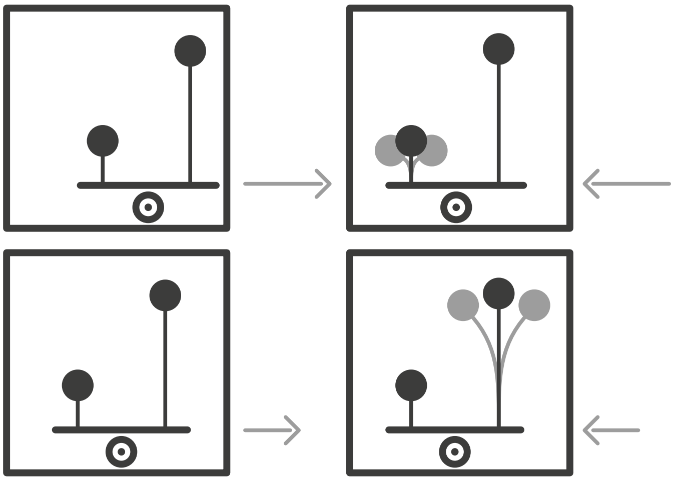
Cantilever bridge and prestressed beam.

Vibration

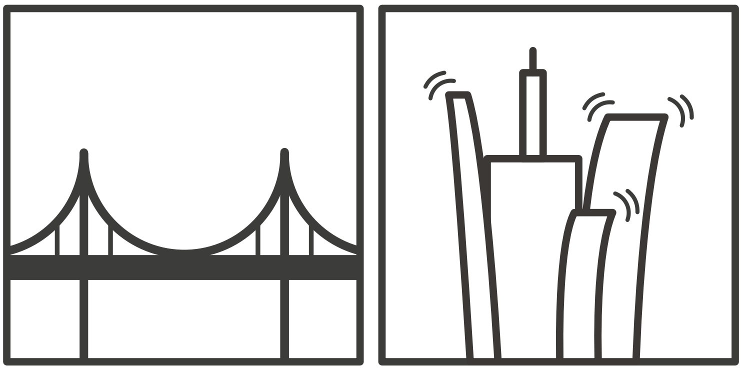

152
10
20
600
380
300
50
260
20
145,9
600
600
weight
aluminium bar 300x15x2
aluminium bar 260x20x2
SECTION
drawer slide track
VIEW
15
50
50,5
PLAN
MDF
Acrylic
Stainless steel

What is happening?

When structures are exposed to a dynamic action with a frequency (cadence) equal to one of their natural frequencies, a phenomenon called resonance takes place. Resonance leads to high vibrations and displacements, which in turn can lead to the collapse of the structure.

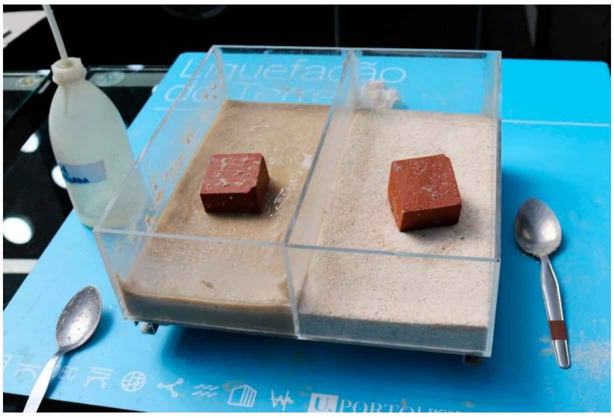


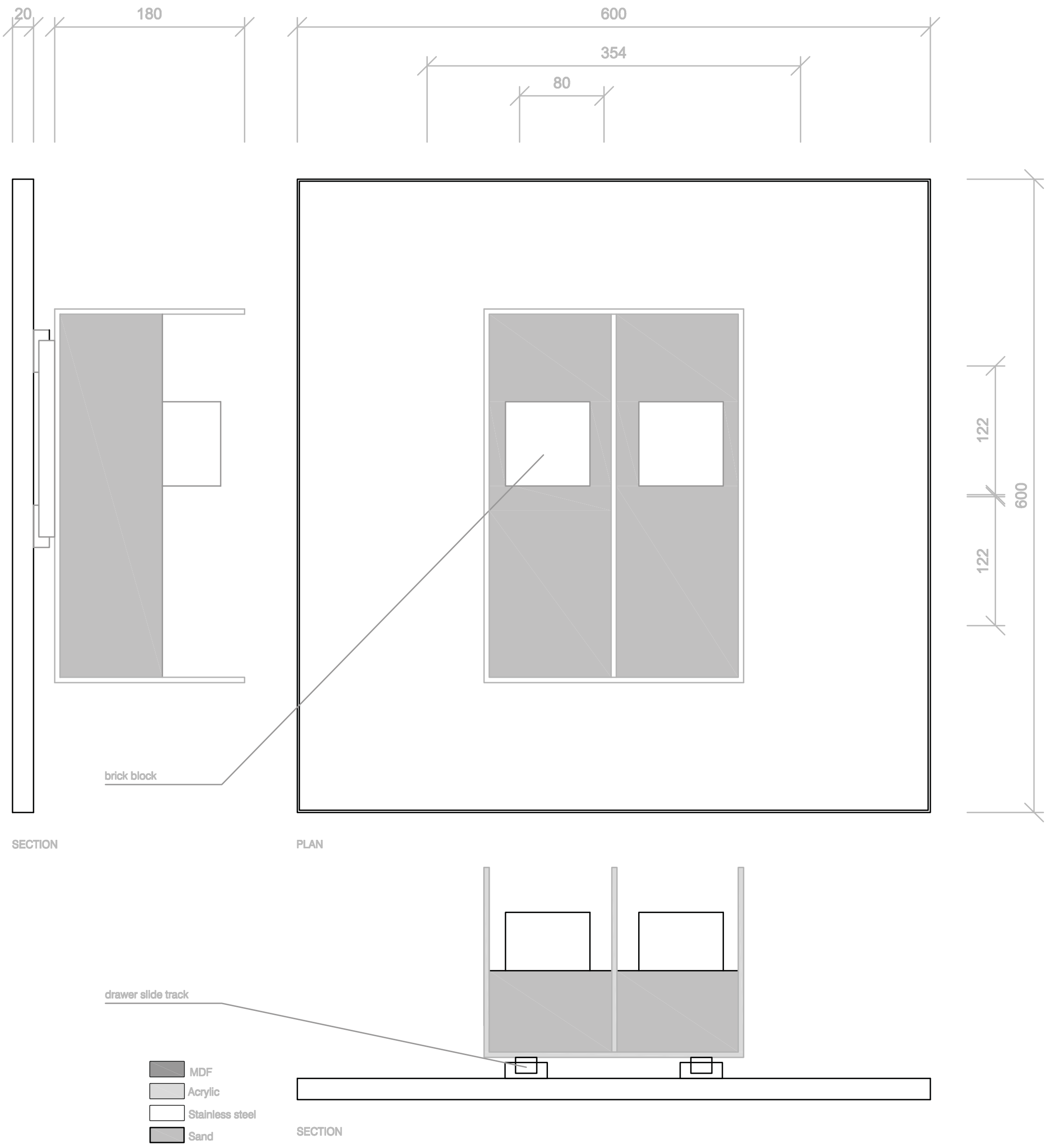
Where?



Takoma bridge – USA, and the effect of the vibration on towers and skyscrapers

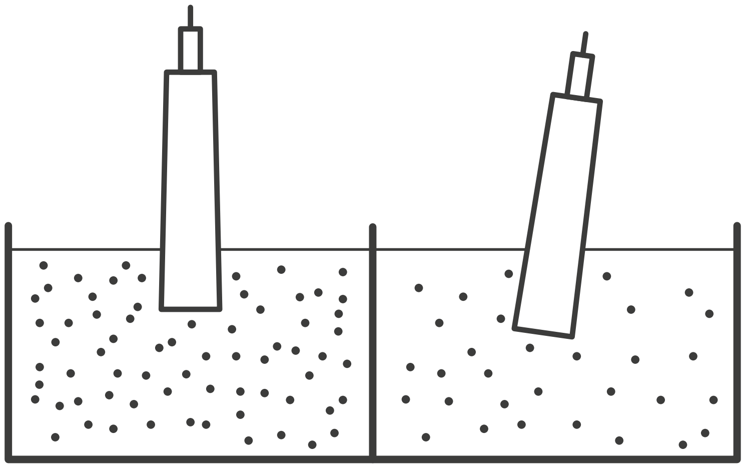
Liquefaction





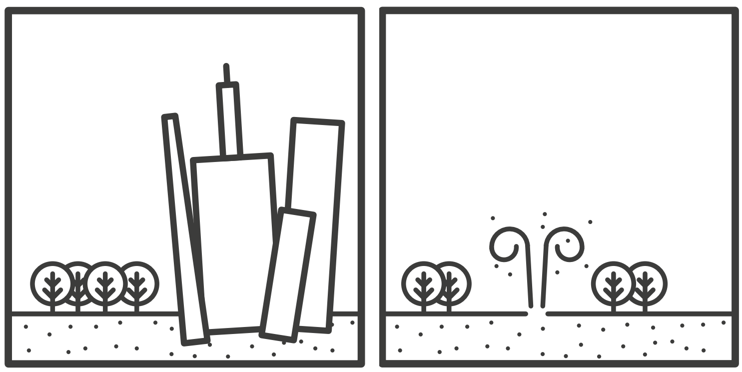
What is happening?

The liquefaction is one of the most interesting, complex, but also the most destructive phenomena that can occur in soils. Geotechnical civil engineers study and research this field to know and understand what conditions can trigger it.
Liquefaction occurs in loose and saturated soils subjected to rapid loads and terrain oscillations, such as earthquakes, explosions and even during crimping piles. As a consequence of these actions, the water pressure in the soil increases, not allowing the solid particles to remain in contact, reducing the interparticle forces until the effective stresses are canceled out. Since the soil resistance is directly dependent on the effective stress, when they are cancelled displacements and open cracks take place, which may lead to the collapse of buildings, infrastructures and bridges, breaking of embankment dams and natural slopes.



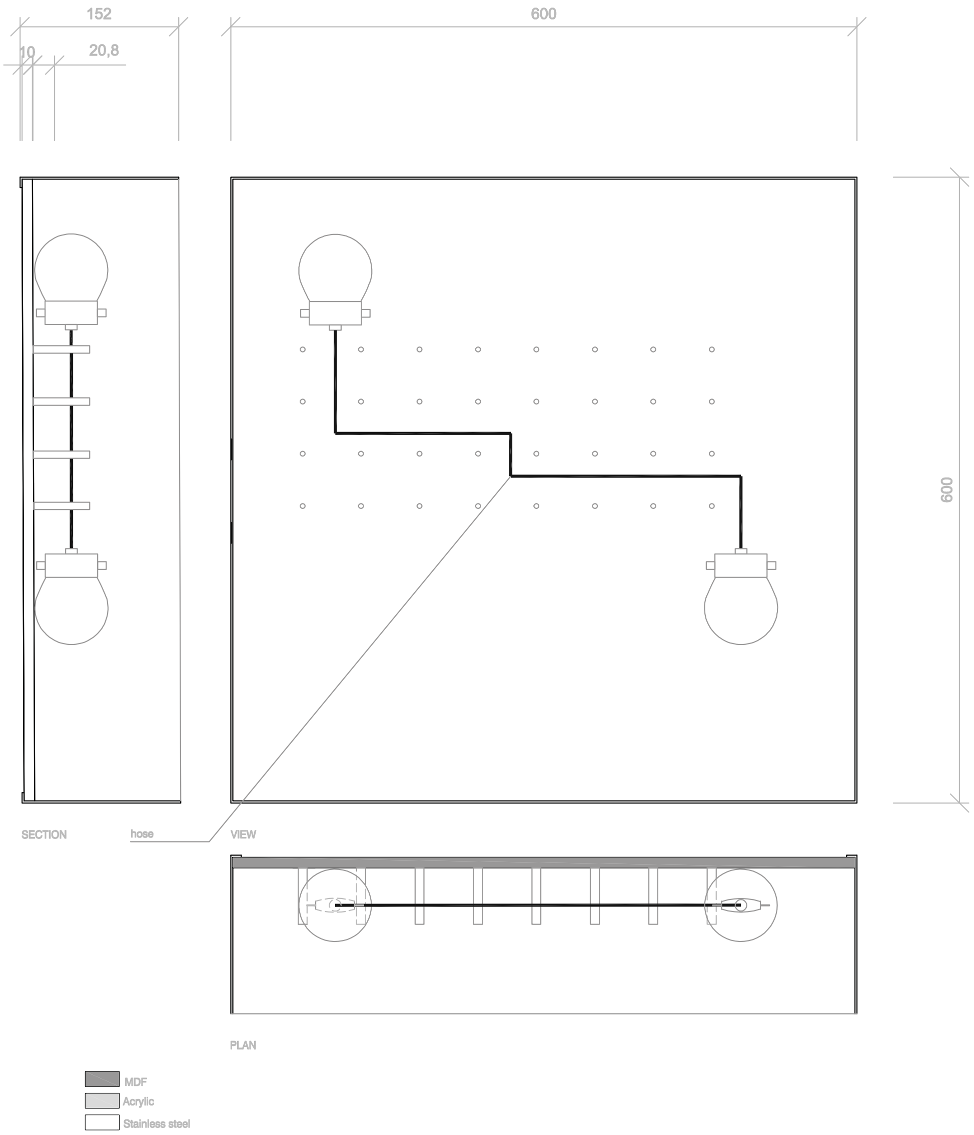
Earth Earth+Water

Where?



Take down of residential buildings due to the failure of the foundation being caused by the phenomenon of liquefaction. In addition, the liquefaction of the inner layer soil will cause water and sand eruptions on the surface.

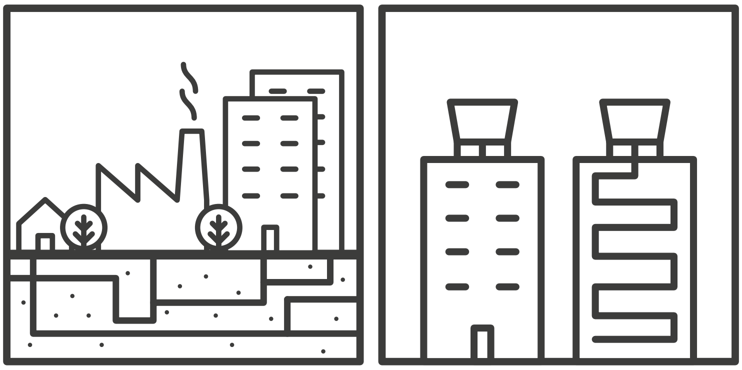
Water Supply



What is happening?

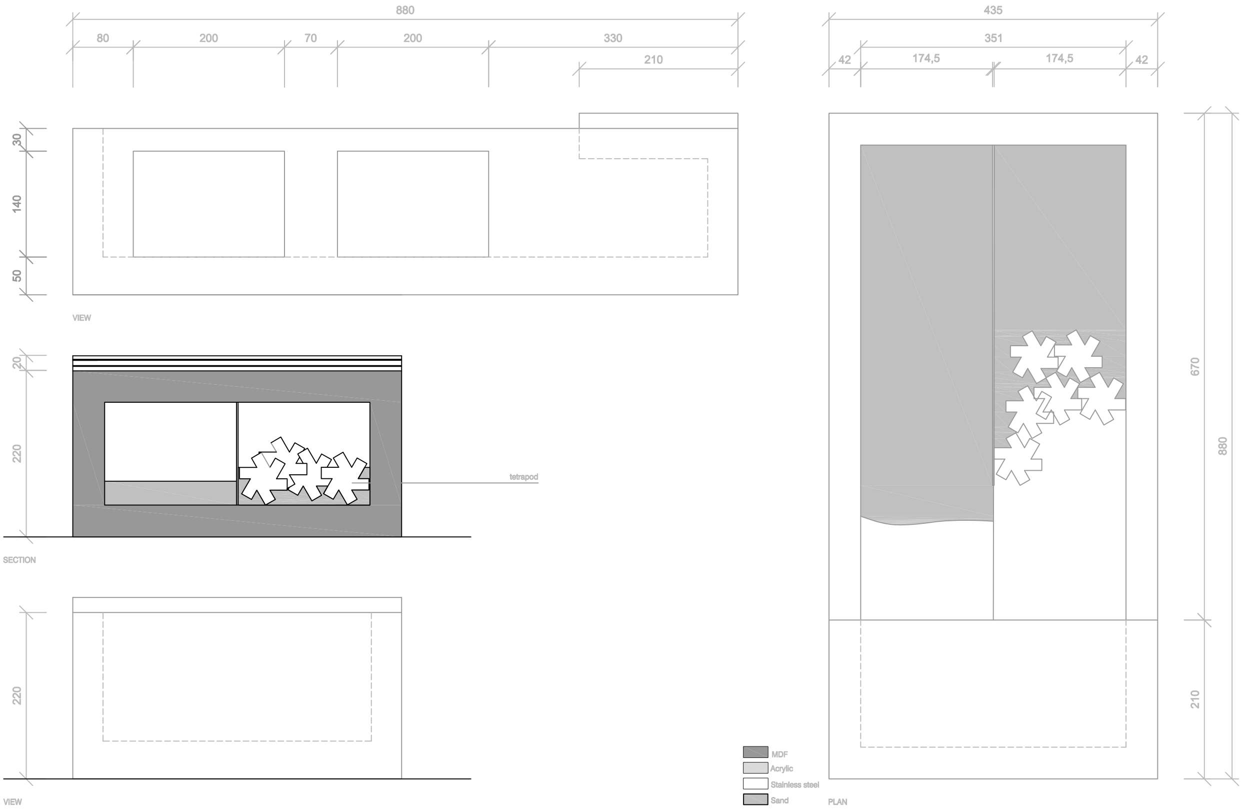
Gravity moves water in pipes throughout the building. After use, the wastewater is directed to the drainage network that exists in the nearby street.

Where?



Wastewater and Rainwater drainage systems and water supply network.

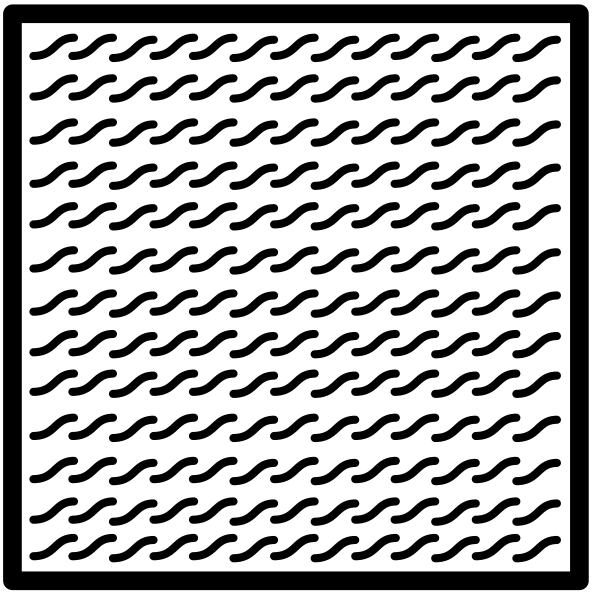
Wave Tank



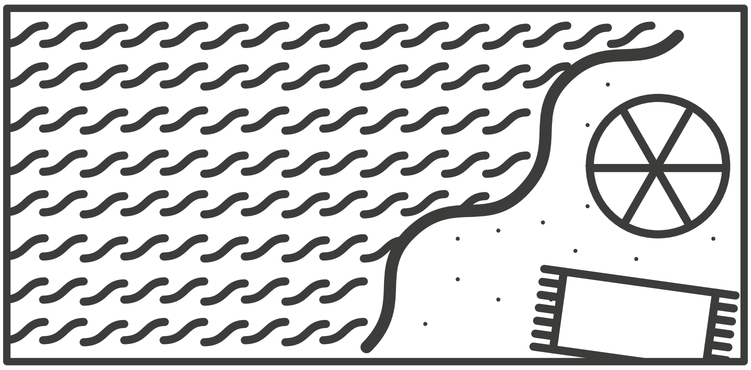
880
80
200
70
200
330
210
435
351
42
174,5
174,5
42
30
140
50
VIEW
20
220
tetrapod
SECTION
220
VIEW
670
880
210
MDF
Acrylic
Stainless steel
Sand
PLAN

What is happening?

The generator transfers mechanical energy to the water which gains kinetic and potential energy causing the waves to move.

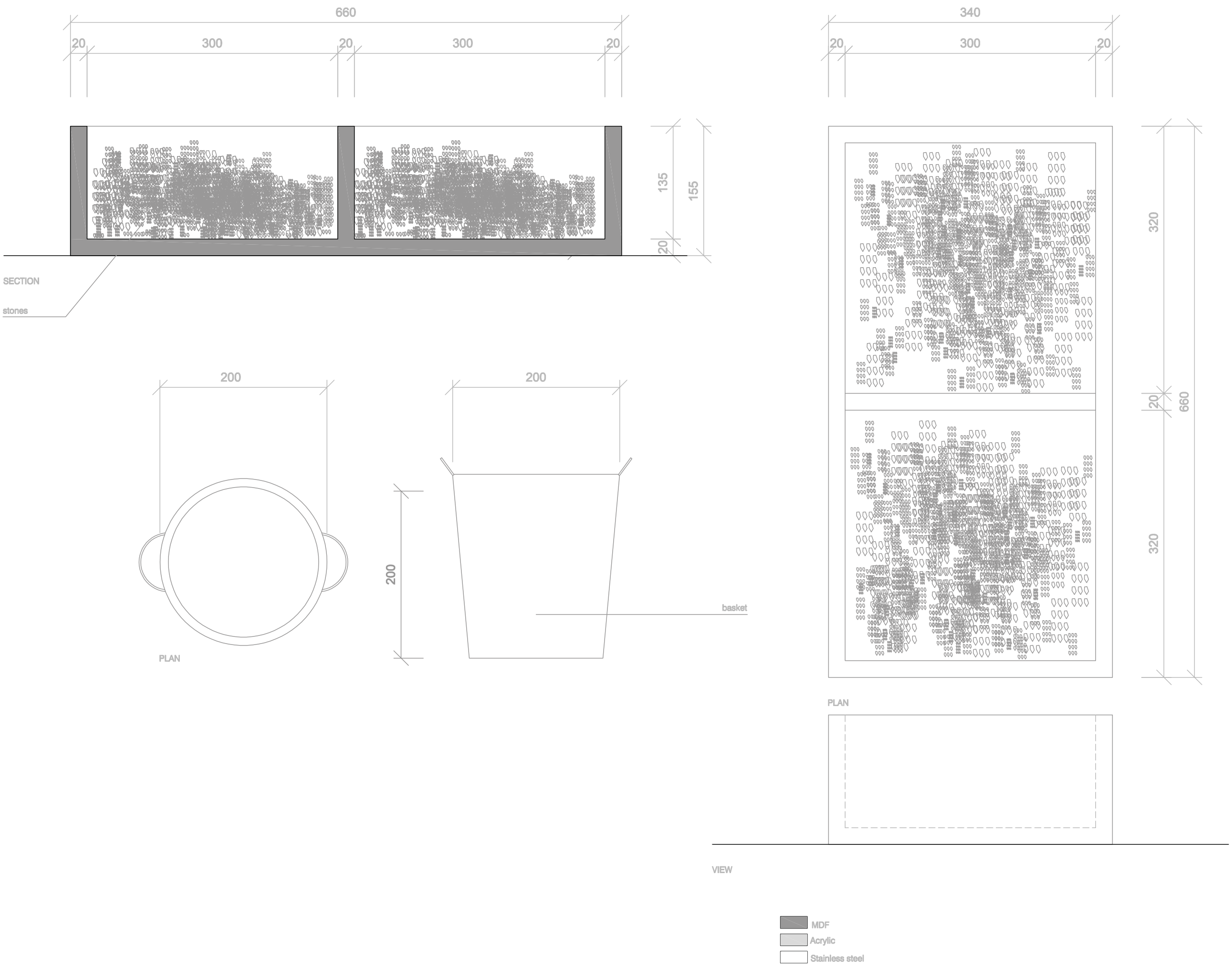


Where?



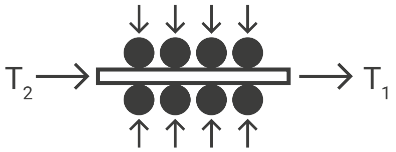
Beach

Reinforced Earth

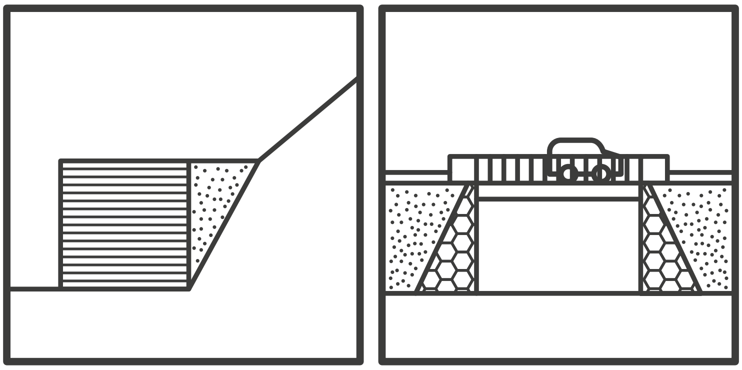


What is happening?

Reinforcement of soil
Constructive method that consists in increasing the support capacity of a soil through the introduction of elements that, through friction, allow the distribution of the loads to which the soil is subjected, making the set to function as a solid body. It is used in the construction of meetings of bridges and viaducts, walls and embankments.
Although this technique was applied several times in history using trunks and roots as reinforcement of the soil, the invention of the technology of reinforced earth was patented by the French engineer Henri Vidal in 1960. This process is recognized as one of the great innovations in the field of Civil Engineering.



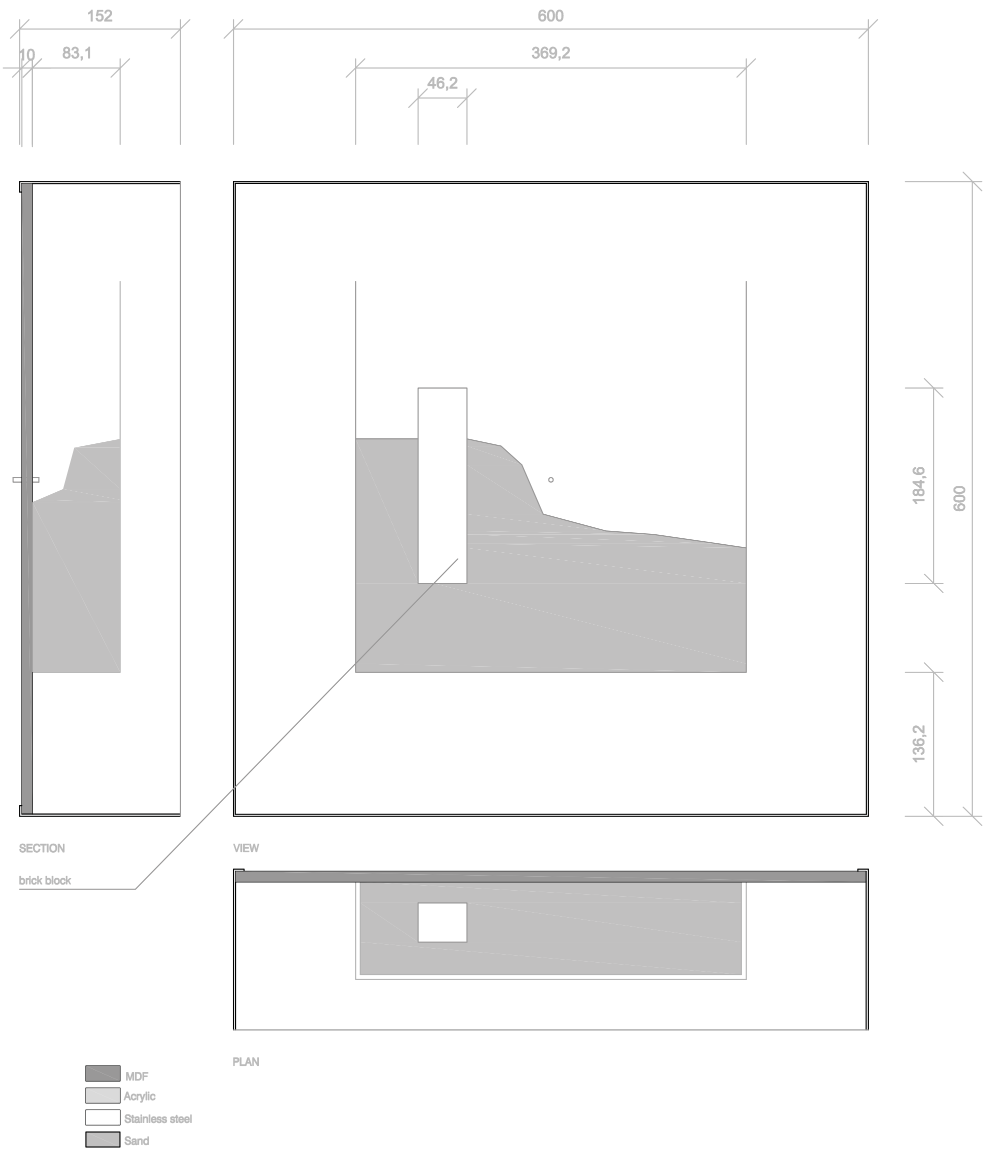
Where?



Earth application diagram armed on road works. Application of reinforced soil in road works.

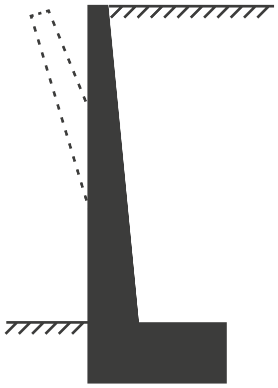
Retaining Wall

Models Guide

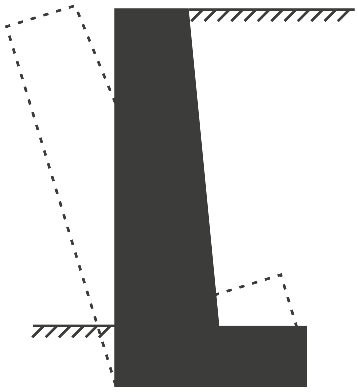


What is happening?

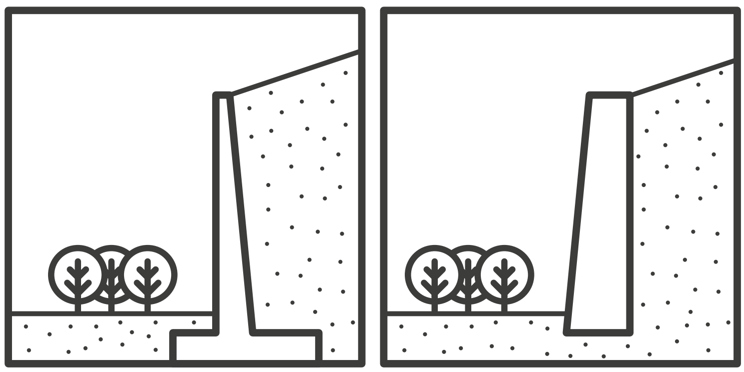
Walls may collapse due to insufficient structural strength.



Walls can collapse due to loss of equilibrium.

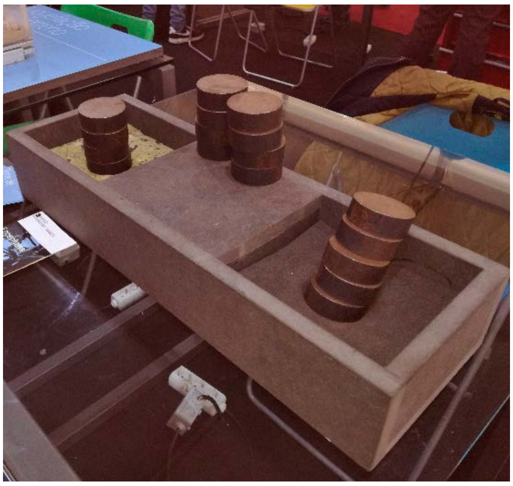


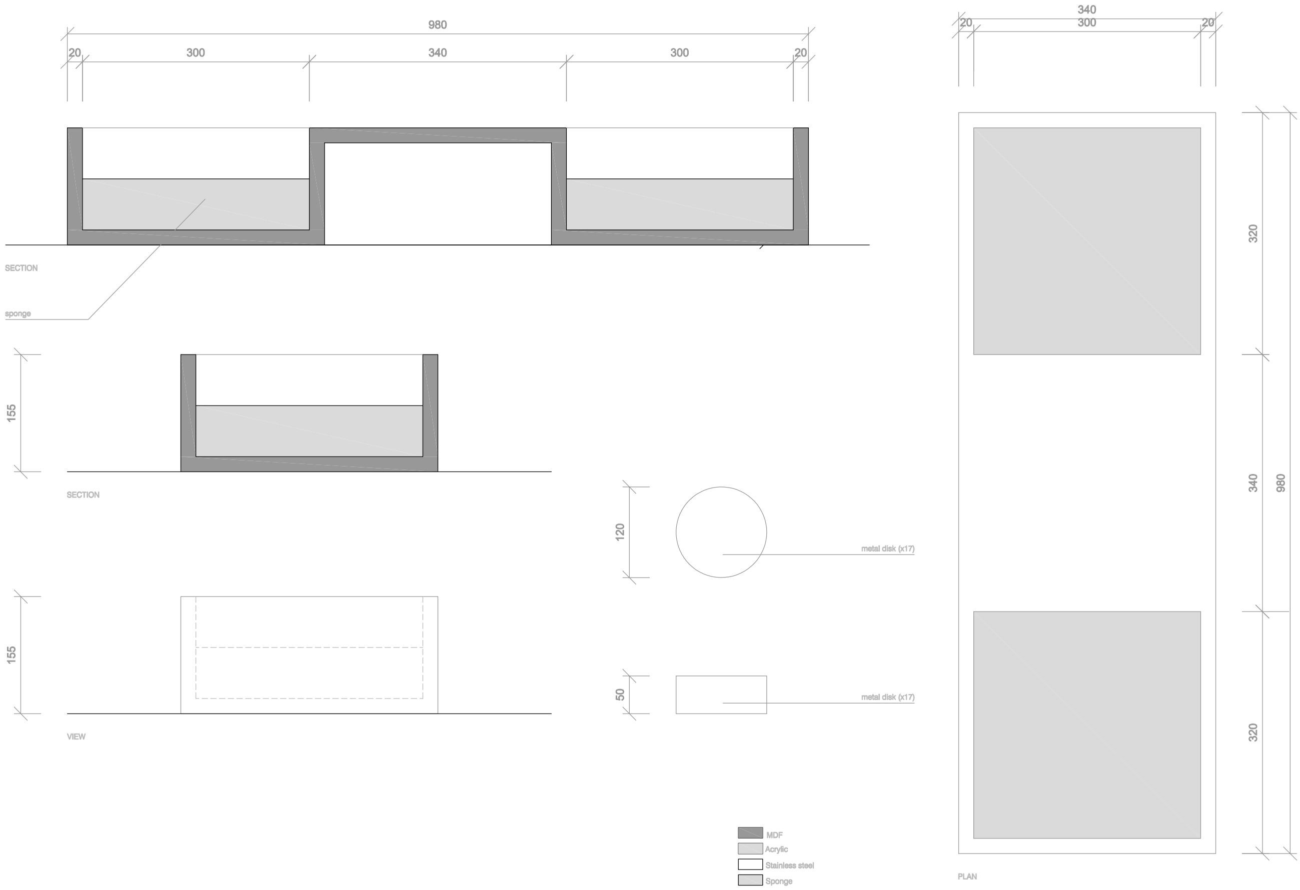
Where?



Cantilevered retaining wall (Gravity Wall).

Tower of Pisa

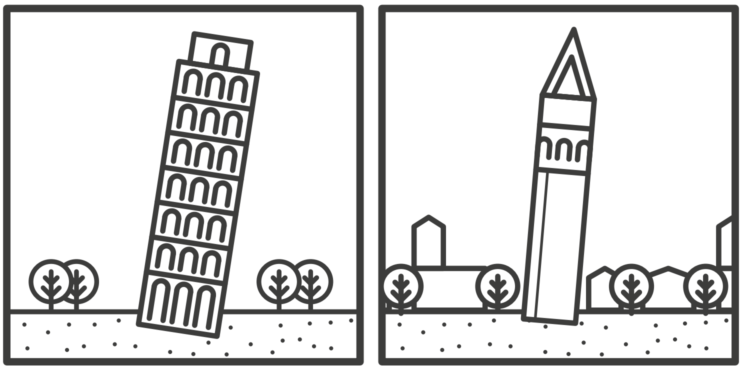




What is happening?

The weight of the structure (building) deforms the terrain. On the ground, there is sometimes a more deformable (weak) side. This causes the structure to be tilted. In certain cases, such as very tall structures, this inclination increases the deformation of the weaker side. This increases the inclination even more, causing even larger deformations and so on until... COLLAPSE! This process of DEFORMATION-INCLINATION-DEFORMATION-INCLINATION took place in the case of the Tower of Pisa for centuries. It would certainly lead to the collapse of the Tower in this twenty-first century, if a very ingenious recent intervention had not stabilized the process. There are many cases in the world similar to that of the Tower of Pisa, although less well known. In many other cases, this process led to the collapse, such as St. Mark's Bell Tower in Venice, which collapsed suddenly in the early twentieth century. The current tower is a copy of the original.

Where?



Tower of Pisa and St. Mark's Bell Tower in Venice.

WasteHouse

General Guide

Introduction

Building a house with local traditional and modern techniques.
Assess building systems performance.

Methodology

Arrange competition amongst students.
Each team should select materials from the list to build its own constructive solution, for example:

- Earth;
- Adobe;
- Wood;
- Rock masonry;
- Tires;
- Concrete;
- Brick masonry;
- Other.

Tasks

1. Research of construction techniques

Theoretical Research.	Historical, technological and scientific research.

2. Testing the technology

Mock-ups.	Building mock-up of a wall. Instrumenting the model.

3. Testing the behaviour

Testing.	Testing the mock-ups in the laboratory: – Thermal – Acoustic – Mechanical

4. Public Event

Presentation.	Each team will present their prototype.

5. Students' involvement in the construction of the Big Machine house

Implementation.	The winning team's building system prototype will be implemented in the Bigmachine house.

Workplan

WHERE?

Session 1

School

Presentation: Basic concepts;
Students will be organized in teams;

- Each team will study a solution made of one or a combination of the following materials:
  - Earth;
  - Adobe;
  - Wood;
  - Rock masonry;
  - Tires;
  - Concrete;
  - Brick masonry.

Students may also suggest other materials to be added to the list.

Session 2

Visit the University's campus.

HEI

Session 3

Student's research presentation.

Local school

Survey: Where is Civil Engineering?

Session 4

Workshop about sustainable building systems:

Local school

Building walls with the following materials:

- Bottles;
- Cans;
- Tires;
- Adobe.

Bottle cutting process;
Laying tires;
How to produce plaster with a minimum amount of cement.

(See also Sustainable Construction Workshop guide for detailed information about this session)

Session 5

Virtual Reality workshop:

Local school

Construction Physics class.

(See also Virtual Reality Workshop guide for detailed information about this session)

Session 6, 7 and 8

Building mock-ups of the building systems.

Local school

(See mock-ups-construction guide for detailed information about these sessions)

Session 9

Testing the mock-ups in the laboratory:

HEI

- Thermal
- Acoustic

Session 10

Results and Discussions

HEI

Session 11

Preparation:

Local school

Teams' presentations:

- Poster (representing the building solution performance and results)
- Mock-up.

Session 12

Teams' presentations

HEI

Session 13

Participation at the public event organized by the HEI.

Session 14 and 15

Testing the mock-ups:

Local school

Acoustic and Thermal performance tests.

Session 16, 17 and 18

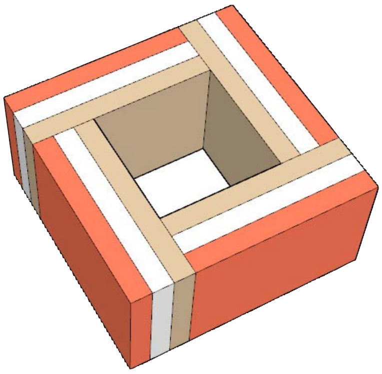
Students' involvement in the construction of the Bigmachine house.

Local school

The team with better presentation (mock-up performance + poster) will develop and assemble their building system in the Bigmachine house.

Mock-ups

Construction Guide



DURATION – 4H

Introduction

The mock-ups will allow the students to understand the composition and dimensions of the walls being represented.
The scale models are physical mediums for the project supporting the reasoning behind each individual solution.
Further tests will be conducted in the laboratory to assess the thermal and acoustic performance of the models.

Materials

– Scalpel;
– Glue.
Groups must gather the materials to form the different layers of their solution.

Summary

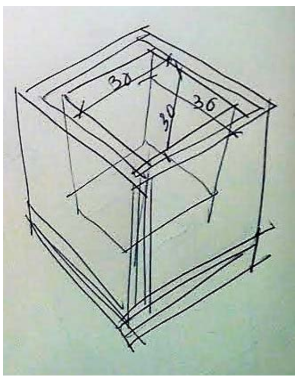
1. Cutting the different layers of each wall;
2. Gluing process.

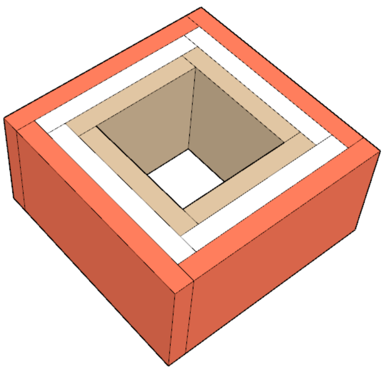
Procedure

Cutting the different layers of each wall
Students must cut the materials in squares to form the layers of the walls.
An inner square of 30 x 30 cm should be left free so that the acoustic and thermal tests can be performed.
There is no imposed limit for the thickness of the walls as long as adequate layer proportions are preserved.

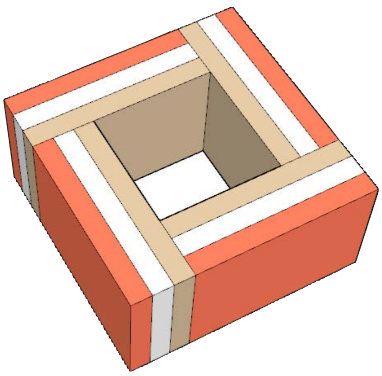
Gluing process
Mock-ups should look like a cube with an empty interior (30x30x30 cm).
Only four sides of the cube should be assembled, therefore leaving the upper and bottom sides "empty".
All solutions will be instrumented using sensors to collect temperature, moisture and acoustic related data.

Option 1





Option 2 – Easier to build and allows the walls to be replaced.



Sustainable Construction

Workshop Guide

DURATION – 4H

Introduction

Human activities lead to the production of excessive amounts of waste materials. These circumstances repeat themselves almost in every country, emphasizing the need for raising awareness to the possibility of using waste as feedstock. During the workshop, students will understand the importance of reusing materials which is often overlooked by the general society, and how could they be applied to construct new buildings. In addition, these techniques may be replicated almost everywhere, students will also recognize that building solutions cannot be deployed around the world regardless of climate and local contexts. Indeed, each country has a cultural heritage in construction techniques generally attuned with the surrounding environment, weather conditions and local resources that should be valued.

Materials

– Projector;
– Wooden slats (15 x 60 x 1,5 cm);
– Soil (clay gravel);
– Cans*;
– Glass bottles**;
– PET bottles*;
– Tires, water at disposal;
– Shovels;
– Sledgehammers;
– Screws;
– Cordless screwdriver;
– Glass cutting machine;
– Insulating tape.

*Each student is responsible for gathering two.
**Each student will bring two. Both bottles should have the same diameter.

Summary

1. Concept presentation – using waste as feedstock.
2. Applying the techniques:
    – Pounding tires;
    – Build wood frames;
    – How to build walls with glasses and low cement plaster;
    – Cutting glass bottles;
    – Clay/cement dosages and combinations.

Procedure

Concept presentation – using waste as feedstock
Students will understand the main objectives of the workshop which shall be explained with a brief overview of the activities that will take place.

A specialist with proven field experience will present a general introduction about the techniques used to build with waste materials.

Applying the techniques
Pounding tires
Tires can be used to build structural walls. The earth is placed inside the tire and pounded with the help of a sledgehammer. Like bricks, they are placed in misaligned joints thus granting superior contention.

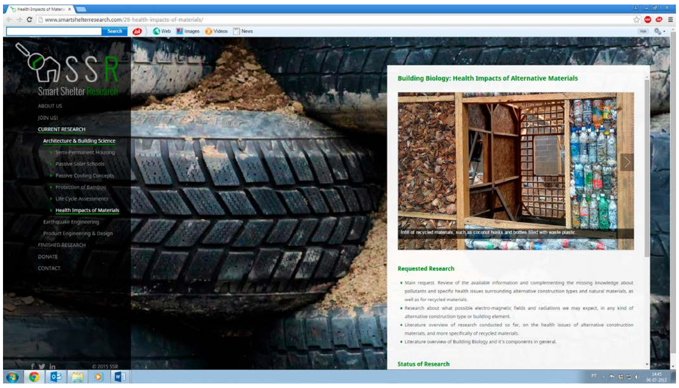
Build wood frames
Wooden slats (15 x 60 x 1,5 cm) act as confinement for the wall mock-ups.

How to build walls with glasses and low cement plaster
Walls are mainly made with a combination of clay and cement with a proportion of 5 to 1. Glass bottles, cans or PET bottles are used to minimize the quantity of plaster, therefore the quantity of cement

Cutting glass bottles;
The bottles are grouped in pairs with the same diameter.
If a wall width measures 15 cm, each bottle must be cut to match 7,5 cm length.
Then, the bottles must be cleaned and left to dry.
Insulation tape is used to attach the matching halves, forming a "glass cylinder".

Clay/cement dosages and combinations.
Two combinations can be made:
5 to 1 (clay/cement) measure and 5 to 1 plus some handfuls of straw.

Construwaste



Source: http://www.smartshelterresearch.com/28-health-impacts-of-materials/

DURATION – TWO QUARTERS OF THE SCHOOL YEAR.

Introduction

This guide describes the activity regarding the development of a construction system using waste as feedstock. The system should consist of 6 identical panels, forming a portable cube. The junctions between panels must allow the cubes to be assembled and disassembled whenever necessary.

All the activities will happen with theoretical and practical support from the organizing institutions.

The final solutions will be tested in a suitable laboratory.

Materials

Non-organic domestic waste materials such as cans, bottles, capsules, fabric, cardboard, etc.

Summary

1. Theory and technical support (Architecture, Structures and other specializations;
2. Report;
3. Assembling the constructive solutions;
4. Tests;
5. Assessment.

Procedure

Theory and technical support (Architecture, Structures and other specializations)
An introductory lecture shall be given on the subject of using waste materials in architectural and civil engineering solutions.

Report
The project will be developed in teams of 3 to 4 individuals.

Each team is responsible for writing a document (about 10 pages) comprising the reasoning behind their model and demonstrating the concepts acquired in the scope of physics and the lectures/theoretical support.

Assembling the constructive solutions
The cubes should be 60 x 60 x 60 cm.

The thickness of each panel must not exceed 6 cm.

The 6 panels should be as similar as possible (replicability and transferability).

The panels' links should be structurally effective and leakproof.

Tests
The cubes will be tested (quantitatively) for their mechanical resistance, water tightness, thermal resistance, sound insulation and weight performance.

the cubes will as well be assessed (qualitative) in terms of aesthetics and replicability.

Assessment
Evaluation criteria (solutions' quality):

- Aesthetics / weight / replicability (architecture)
- Resistance / deformation / resilience (structure)
- Water tightness;
- Thermal resistance;
- Acoustic insulation.

ELBigMAC Workshop

General Guide

DURATION

Introduction

Use Virtual Reality Interfaces as well as 3D modelling tools to design building systems.
Develop prototypes for the BIGmachine house with local traditional and modern techniques.
Assess building systems performance.

Methodology

Design solutions for a wall prototype.
Each team should select materials from the list to build its own constructive solution, for example:

- Cork;
- Egg boxes;
- Wood;
- Polystyrene;
- Etc.

Assess the building systems performance through an immersive Virtual Reality interface.
Select and present the best solution per group.
Conduct thermal and acoustics tests to verify the building systems performance.

Tasks

1. 3D modelling

Follow a step by step guide about the basic commands of a 3D modelling tool.	Tutorial - Sketchup

2. Select the best materials

Choosing the best materials. Learn about the materials dimensions and positioning as they influence both temperature and acoustics.	Design building systems – Sketchup.

3. Virtual Reality (VR) trial

Assess the thermal performance using an immersive VR interface (see the Virtual Reality workshop tutorial).	Testing the mock-ups in the laboratory: – Thermal – Acoustic – Mechanical

4. Public Event

Presentation.	Each team will present their prototype.

5. Assembling the prototypes Building mock-ups of the building systems.	Hands-on workshop.
6. Testing the behaviour Testing.	Testing the mock-ups in the laboratory: – Thermal – Acoustic

Workplan

Procedure	Resources:
Session 1 Students will follow a tutorial to learn the basic steps of 3D modelling.	Computers; Sketchup installed
Session 2 Students will be organized in teams; Each team will design 3D solutions combining different materials (layers), for example: – Earth; – Cork; – Egg boxes; – Wood; – Polystyrene; – Etc.	Computers; Sketchup installed
Session 3 Participants will use an immersive VR interface to promptly assess the thermal performance of their building systems. (See also Virtual Reality Workshop guide for detailed information about this session)	VR-ready computer; Head Mounted Display (HMD) (e.g., HTC Vive).
Session 4 Public presentation: each team will present their final building system to be tested at the laboratories.	PowerPoint Presentation.
Session 5 Building mock-ups of the building systems. (See the Sustainable Construction Workshop guide for detailed information about this session)	Materials: – Tools (e.g., tape, wood frames, scalpels).
Session 6 Testing the mock-ups in the laboratory: – Thermal – Acoustic.	Sound meter; Speaker; Thermal sensors. The speaker produces white noise and the sound meter determines how many dB(A) are felt in the interior side of a cube with one of its faces being the mock-up to be tested (mean value between frequencies ranging from 250 to 4000 Hz). Thermal tests consist of two probes measuring the difference in in the temperature (°C), between the heated interior (cube) and the external temperature. The prototype allowing the highest interior temperature after 10 minutes will hold the best performance in this test.

Big Machine House

Activities

Acoustics

Name	Description	Equipment
Reverberation time	Place the Sound Source in two different positions inside the house and with the digital sound level meters automatically measure the decay time when the Sound Source is silenced.	Sound Source and digital sound level meters
Rasti (Rapid Speech Transmission Index)	Place the Transmitter inside the house in two different positions making a modular sound in 500 Hz and 2000 Hz. With the Receiver automatically measure the RASTI in each position.	The instrumentation used was the Speech Transmission Meter, Transmitter Type 4225 and Receiver Type 4419
Airborne Sound Insulation Index	Place the Sound Source (with white noise) outside the house in different positions and with the Sound level meter automatically measure the sound pressure level in each place.	Sound Source and Sound level meter and spectrum analyser
Impact sound isolation	Place the Tapping Machine (with normalized sound) in the roof. Inside the house measure the sound pressure level in different positions.	Tapping Machine

Thermic

Name	Description	Equipment
In the laboratory (inside) Heating behaviour	Heat the air in the house with the Heating lamp. Measure the inside and outside Temperatures and relative humidities with the sensors while heating.	Heating lamp and Temperature and relative humidity sensors
In the laboratory (inside) Cooling behaviour	Measure the Temperature and relative humidity inside and outside the house with the sensors after heating to get the cooling curve.	Heating lamp and Temperature and relative humidity sensors
In real climatic conditions (outside)	With the house outside the laboratory, measure the Temperature and relative humidity (with the sensors, outside and inside) to obtain the thermal behaviour curve.	Temperature and relative humidity sensors

Waterproofing

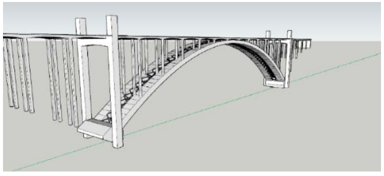
Name	Description	Equipment
In real climatic conditions (outside)	With the house outside the laboratory, measure the waterproofing with the Humidimetre.	Humidimetre CEBTP MX-HU

Weight

Name	Description	Equipment
Overall weight	Each panel solution should be weighted on a scale.	Scale

Cardboard, VR and AR Bridge

Models Guide



DURATION – 32H

Introduction

This guide is comprised of a set of sessions dedicated to the development of 3D and scale models. The sessions encompass a visit to a Civil Engineering office, multiple lessons on how to develop 3D models and build solutions in virtual and augmented reality.
Participants must select a Civil Engineering project, study its documentation and develop both real and virtual models.

Materials

– Projector;
– HTC VIVE Head Mounted Display (HMD), or equivalent;
– Computer (ready for immersive Virtual Reality games);
– Gamepad;
– Leap Motion sensor.

Students ensure the following software is installed:
 – BIM authoring software such as Graphisoft Archicad or Autodesk Revit;
 – Game Engine such as Unreal Engine or Unity 3D.

For detailed information about installation and minimum requirements, check the links below:
https://www.unrealengine.com/en-US/
https://unity.com/
https://www.vive.com/eu/ready/
https://www.graphisoft.com/support/system_requirements/archive.html
https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/sfdcarticles/sfdcarticles/System-requirements-for-Autodesk-Revit-2018-products.html
https://support.leapmotion.com/hc/en-us/articles/223783668-What-are-the-system-requirements-

Summary

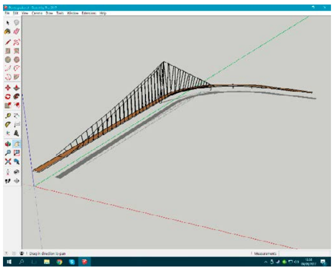
1. Visit a Civil Engineering office specialized in bridge projects;
2. Project's documentation – review;
3. 3D modelling using SketchUp;
4. Virtual Reality (VR) sessions:
 – Development of immersive VR environments using a game engine.
5. Augmented Reality session:
 – How to create an AR model.
6. Assembling the scale models.

Procedure

Visit a Civil Engineering office
Participants must attend a lecture about the buildings or structures to be studied. Each group will then choose which building or structure (in this case, which bridge project) to study during the following sessions.

Project's documentation – review
Students will be delivered projects' documentation and at least two sessions (4h) should be dedicated to projects' review.

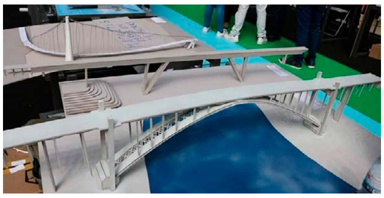
3D modelling using SketchUp
Three-dimensional modelling software sessions (16h) must be held with the supervision of a tutor, monitoring the development of each groups' models.



Virtual Reality (VR) sessions
Development of immersive VR environments using a game engine
During these sessions, students will understand the procedures required to build a VR environment, import their SketchUp model into a game engine as well as experience immersive VR navigation through their virtual solutions.

Augmented Reality session:
How to create an AR model using Unity and Vuforia plugin
Step by step lesson on how to build the students' solutions into Unity using the Vuforia plugin.

Assembling the models
Each group should develop a cardboard scale model based on the digital models' information and projects' data previously reviewed.



Evaluation

Use the following tables to grade each project

Quality and detail of the scale model	1 (0 points)	2 (10 points)	3 (15 points)	5 (20 points)
P1				
P2				
P3				

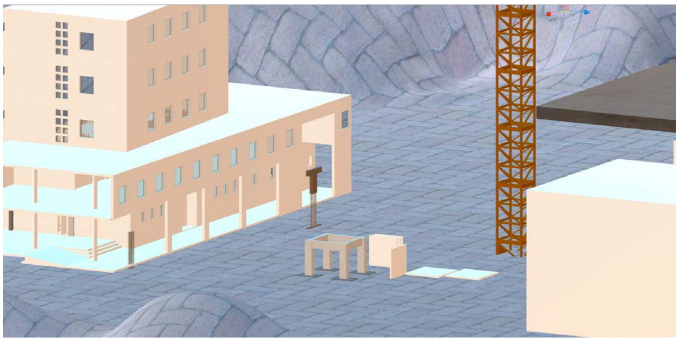
Quality and detail of the immersive virtual environment	1 (0 points)	2 (10 points)	3 (15 points)	5 (20 points)
P1				
P2				
P3				

Complexity level	Simple (10 points)	Average (15 points)	Complex (20 points)
P1			
P2			
P3			

Final grade = 0,4*T1+0,4*T2+0,2*T3

Virtual Reality

Workshop



DURATION – 2H

Introduction

Game Engines and BIM
Current 3D game engines are compatible with several data formats that can be exported by BIM applications and they provide tools for the development of immersive user interfaces. In this guide, game engines will be used to develop a project that allows users to navigate a BIM model in immersive Virtual Reality using a Head Mounted Display (HMD), gamepad and motion sensor. Users who are not familiar with BIM may experience a model in an intuitive and interactive way. These interfaces can be improved considerably by developers with programming skills, although this topic will not be explored in this class guide.

Materials

– Projector;
– HTC VIVE Head Mounted Display (HMD), or equivalent;
– Gamepad;
– Leap Motion sensor;
– Pre-installed software: game engine, Autodesk Revit (student license), Dynamo and Microsoft Excel.

For detailed information about installation and minimum requirements, check the links below:
https://www.sketchup.com/download
https://store.unity.com/pt
https://www.unrealengine.com/en-US/
https://www.vive.com/eu/ready/
https://support.leapmotion.com/hc/en-us/articles/223783668-What-are-the-system-requirements-

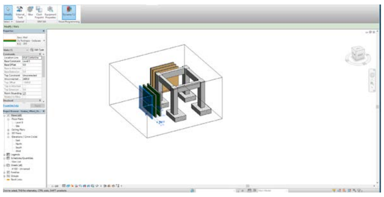
Summary

1. Building physics session – Building systems and their thermal properties.
2. Visualize each team solution in a BIM software.
3. Exporting non-geometric data to Excel
4. Exporting the data from Excel to XML file format
5. Creating an XML data file
6. Importing the XML file as a new asset to the game Engine
7. Interacting within the game environment.

Procedure

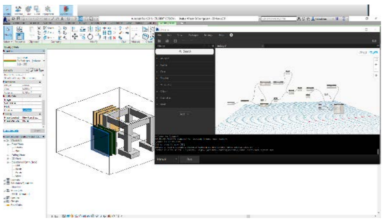
Building Physics session
An introduction to building physics shall be given by a specialist. This class will act as an introduction to concepts such as heat transmission and relevant thermal parameters like the Heat Transfer Coefficient (U).

Visualize each team solutions in a BIM software.
Each group will be shown the BIM model of the BIGmachine house as well as wall prototype models based on the students' drafts.

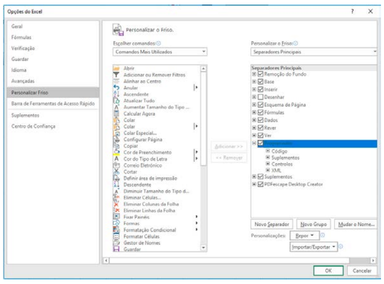


Exporting non-geometric data to Excel
Within the BIM software, an algorithm created using the Dynamo plugin allows users to export non-geometric information to an Excel Speadsheet.

By clicking the Run button (settings defined to manual) the code should generate an Excel worksheet with the IDs of the BIM elements and respective U values.



Exporting the data from Excel to XML file format
It is necessary to enable developer options to be displayed in a ribbon within Excel. To do this, choose File > Options >Customize Ribbon > Main Tabs > Developer check box.



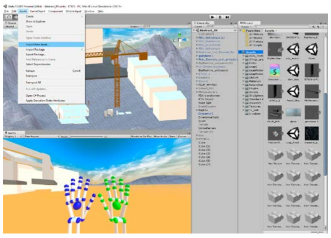
Creating an XML data file
Open a text editor, for example Notepad++, and create a blank document. In the editor, type the following lines and save the file as an XML.
Open a new Excel spreadsheet, in the Developer tab click Source > XML Maps > Add, and search for the location of the XML file you just created. Click open and conclude by pressing OK. Excel will infer an XML map from the .xml data file.
A mapping scheme of the XML will appear in the source pane. Drag the nodes to the corresponding cells of your worksheet to create a table.
In the Excel spreadsheet, click Developer > Export and choose the location to save an updated .xml file. The XML will be imported into game engine as a new asset.

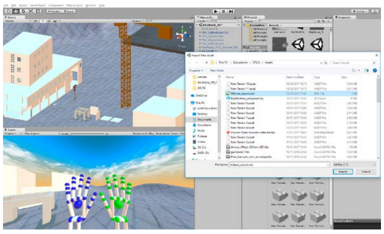
Note: For alternative methods about a custom XML Mapping schema by using Microsoft Visual Basic for Applications (VBA) and more detailed explanations, please consult:

https://msdn.microsoft.com/en-us/library/office/gg469857(v=office.14).aspx#odc_office14_gn_CreateBackstageCustomTab_AddXMLDocumentCreateCommand

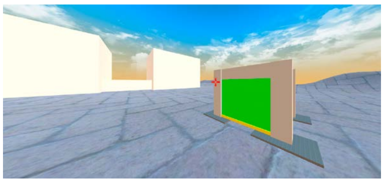
```
<?xml version="1.0" encoding="UTF-8"
standalone="yes"?>
<data-set xmlns:xsi="http://www.
w3.org/2001/XMLSchema-instance">
    <record>
        <ID>32571</ID>
        <U_value>1.2</U_value>
    </record>
    <record>
        <ID>32568</ID>
        <U_value>0.57</U_value>
    </record>
</data-set>
```

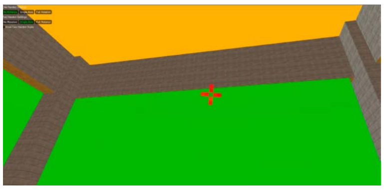
Importing the XML file as a new asset to the game engine.
Select Assets > Import new Asset > choose the XML document previously saved.





Interacting within the game environment.
In the game engine, click the play button and navigate through the game scenario. Use the programmed commands (gamepad and Leap Motion sensor) to interact with the game objects.
Place each wall and slab in the structure of the BIGmachine house. After all the elements are placed, hit the space key. You will notice that all walls and slabs changed their original colour. according to their specific Heat Transfer Coefficient (U) value. (Red – U => 0,8; Yellow 0,5 <= U < 0,8, Green 0,5 > U).





Resources

Web links: Description
http://www.unity3d.com: game engine (free version)
http://dynamobim.org/download/: Dynamo or unreal engine (Autodesk Revit visual programming extension)
https://www.unrealengine.com/en-US/
https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/sfdcarticles/sfdcarticles/System-requirements-for-Autodesk-Revit-2018-products.html

Civil Engineering Specializations

DURATION – 2H

Introduction

This activity aims to promote Civil Engineering amongst pre-university students, clarify the role, versatility and relevance of a career in this field.

Firstly, a presentation addresses the scope of Civil Engineering and its relevance to society.

The second part of the activity concerns the trial of Virtual and Augmented reality interfaces developed for Civil Engineering applications.
Both trials rely on hands-on tests designed to explain the different Civil Engineering specializations.

Materials

- Projector;
- Computer (ready for immersive Virtual Reality games);
- HTC VIVE Head Mounted Display (HMD), or equivalent;
- Gamepad;
- Smartphone with the Augmented Reality application installed.

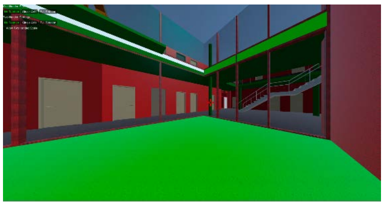
For detailed information about minimum requirements, check the link below:
https://www.vive.com/eu/ready

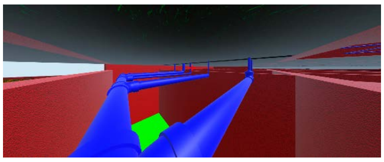
Summary

1. Presentation
   - Where is Civil Engineering? The scope, role and relevance of Civil Engineering.
2. Gaming Interfaces:
   - Virtual Reality trial;
   - Augmented Reality application test.

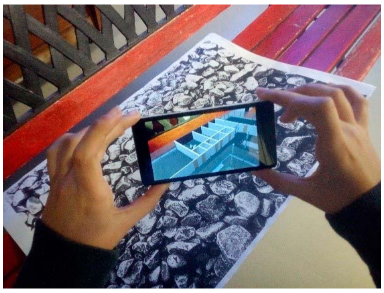
Procedure

Gaming Interfaces:
Virtual Reality trial
Within the Virtual Reality interface, students may navigate through the 3D model and highlight elements corresponding to different Civil Engineering disciplines: Structures, Constructions and Hydraulic.
Pressing a gamepad button changes the colour of a set of elements being displayed in the model. Green objects correspond to structural elements, the red colour is related to constructions and blue is associated with water supply/ drainage systems.

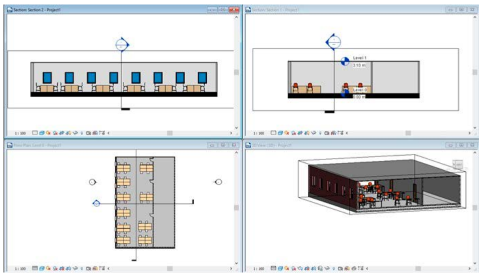




Augmented Reality application test
Using a smartphone and students will press virtual buttons that will allow them to toggle between civil engineering disciplines. Structural, construction and hydraulic elements will change their original colour when the student’s hand hovers over the corresponding virtual button.



BIM Event



DURATION – 2H

Introduction

Building Information Modelling (BIM) is a methodology designed for the Architecture, Engineering, Construction and Operations (AECO) sector, representing a leap into a more technologically advanced industry.
The BIM event is envisioned as a secondary student-driven session, comprising an introduction to the methodology (given by a specialist) followed by a workshop.
During the event, participants are introduced to the modelling aspects of BIM and how it differs from traditional approaches such as CAD software tools.
Virtual Reality (VR) integration is also presented as a technological tool to enhance communication during projects' design review, particularly amongst users who cannot work with BIM software.

Materials

– Projector;
– HTC VIVE Head Mounted Display (HMD), or equivalent;
– Computer (ready for immersive Virtual Reality games);
– Gamepad;
– Leap Motion sensor.

Students must ensure the following software is installed:
 – BIM authoring software such as Graphisoft Archicad or Autodesk Revit;
 – Game Engine such as Unreal Engine or Unity 3D.

For detailed information about installation and minimum requirements, check the links below:
https://store.unity.com/pt
https://www.vive.com/eu/ready/
https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/sfdcarticles/sfdcarticles/System-requirements-for-Autodesk-Revit-2018-products.html
https://support.leapmotion.com/hc/en-us/articles/223783668-What-are-the-system-requirements-

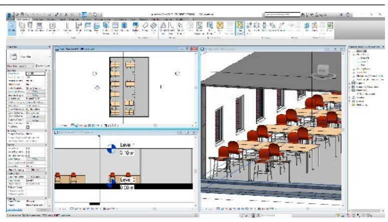
Summary

1. Presentation: Building Information Modelling: an introduction
2. BIM 101:
 – Modelling the classroom;
 – Development of a VR interface using a game engine.

Procedure

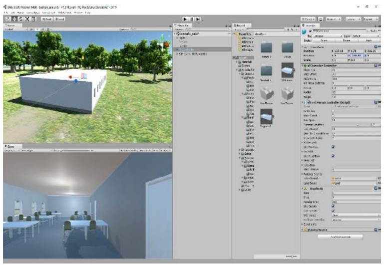
Presentation: Building Information Modelling: an introduction
The event should start with a presentation given by a BIM specialist focusing the basic aspects of the methodology, how it differs from CAD approaches and the level of development (LOD) used to develop BIM models.

BIM 101:
Modelling the classroom
The first part of the workshop is dedicated to the development of BIM models of the classroom (LOD 200) using BIM authoring software tool.
When completed, each model should be saved and exported as an FBX or OBJ file.



Note: Students should have individual workstations where they may follow the instructions required to complete the model. Otherwise, it is not recommended more than two students per workstation.

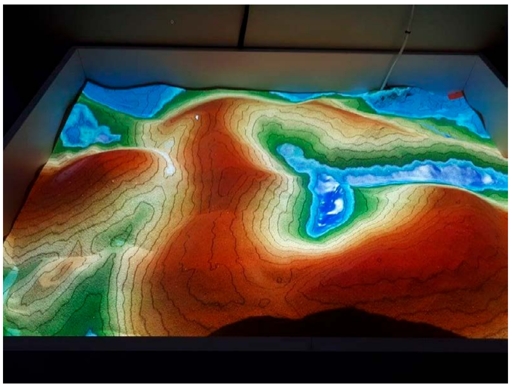
Development of a VR interface using a game engine
The second part comprises a tutorial on how to develop a simple Virtual Reality environment using a game engine (latest version). To do so, students must first create a terrain and assign adequate textures to it (import a Suitable assets package). Trees and a skybox may also be created to provide a more realistic feel to the scene.
A first-person character controller must be imported (characters package - asset), so users may move freely throughout the virtual environment.
The last step entails importing the FBX or OBJ file and setting proper textures to the model, since the BIM authoring software tool and the Game Engine's material libraries may not be compatible.



Resources

Web links: Description
http://www.unity3d.com: Unity 3D (free version)
http://www.unrealengine.com: Unreal Engine

Augmented Reality Sandbox



DURATION

Introduction

This guide comprises a set of sessions dedicated to the development of applications using the Augmented Reality Sandbox

Materials

- A **computer with a high-end graphics card running any version of Linux**. The AR Sandbox software, in principle, also runs on Mac OS X, but we advise against it.
- A **Microsoft Kinect 3D camera**. **The AR Sandbox software**, or rather the underlying Kinect 3D Video Package as of version 2.8, supports all three models of the first-generation Kinect (Kinect-for-Xbox 1414 and 1473 and Kinect for Windows). All three are functionally identical, so get the cheapest model you can find. **Note:** The second-generation Kinect (Kinect for Xbox One or Kinect for Windows v2) is **not yet** supported by the AR Sandbox software.
- A **digital video projector** with a digital video interface, such as HDMI, DVI, or DisplayPort.
- A **sandbox** with a way to mount the Kinect camera and the projector above the sandbox.
- **Sand**.

The webpage address of the original sandbox at UC Davis is https://arsandbox.ucdavis.edu/
National News Agency of Greece's publication about the AR Sandbox:
http://www.amna.gr/macedonia/article/195114/Eikoniki-anaparastasi-plimmuron-xirasias-apo-to-APTh-
Other media news: http://parallaximag.gr/epikairotita/ellada/mia-nea-prosthiki-sto-apth

Summary

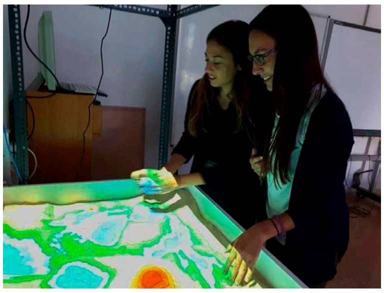
1. Visit the Department of Civil Engineering;
2. Presentation of the AR Sandbox;
3. Components and construction;
4. Capabilities and potentials;
5. Hands-on testing and implementation by the students;
6. Suggestions and remarks.

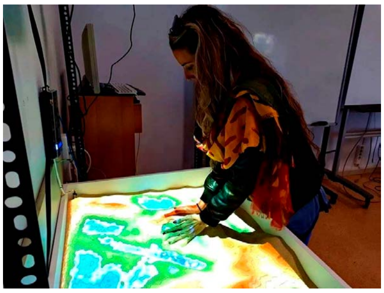
Procedure

Visit a Civil Engineering office
Senior high school students, who are interested in following university studies in the field of applied sciences, are invited to visit the Department of Civil Engineering and more specifically the Augmented Reality Sandbox.

Project's documentation – review
Students are requested to test the AR Sandbox and design different applications simulating the ground structure and the flow of water

AR Sandbox
Indicative implementations of the AR Sandbox.





QR Code Event

DURATION – 2H

Introduction

This guide comprises a set of sessions dedicated to the development of QR Code event.

Materials

Computer with medium performance characteristics, with MS PowerPoint or equivalent software installed;
Broadband internet access for video streaming;
Projector;
QR codes printed on sheets of paper to hand to students;
QR codes printed on sheets of paper and glued to the structural elements they represent (e.g. walls, windows, etc.)
Mobile phones with internet connection capable of scanning QR Codes (each student bring his/her own mobile phone).

Summary

Purpose of the event is to present the project and its goals to its primary beneficiaries – high-school students who are planning to enroll in undergraduate study programmes. The event starts by presenting the project in general but later focuses on presenting one of the project's intellectual outputs, QR Codes. For this purpose, a presentation is prepared, as well as QR codes which are printed on paper. Some papers are glued to their representative structural elements (QR Code for walls on a wall, QR Code for doors on a door, etc.) and some are given to students for a later stage. After QR codes, QR code library and connections between the codes are explained, students are asked to scan QR codes, to read database entries and to try and find as many connections between elements by following hyperlinks in the text for each of the QR codes. In the end, the event is concluded by gathering feedback from the students.

Procedure

Organising available time slot with the high-school
Preparing the classroom for the event (gluing QR Codes, preparing presentation)
Introduction to the ELBigMachine project and project goals
Presentation of building elements and QR Codes
Examining QR codes in the classroom
QR code quick game
Conclusions and feedback from the students

Wiki Pages Glossary with QR Codes

1.a. Structural members of buildings

https://drive.google.com/open?id=1BTISFQaMnIwt8Q5G6sBRu2PlzpeLaa5LHJqbCrumCiE

1.b Non-bearing elements

https://drive.google.com/open?id=1LrZQwHml_
oQpMz2NMiOt9GXHAhxepZreGPdr9YgDyTs

1.1 Foundations

https://drive.google.com/open?id=1F85SrnZRwuV0kZZG4CuOf2pyF8pgrsvPLL8WxlE3_h0

1.2 Columns

https://drive.google.com/open?id=1xKPkDOJdWJ3q8YaikYDrRM-28gk_X1u8heFXRrzcb4A

1.3 Beams

https://drive.google.com/open?id=1HdGanmiq4RmFbOg0s3dystkncmjhWYrWlps6MtbiAzY

1.4 Bearing Walls

https://drive.google.com/open?id=16uyEuhLSQtRRa7xzVtrd2pbwyhyO0aTtW_by9fL3NZc

1.5 Slabs

https://drive.google.com/
open?id=1EGMeXDUvZRnGwXRAhHQMqjFL2pUYM1h8gGOiPvC4BkQ

1.6 Roofs

https://drive.google.com/open?id=1odojmPH2Q79qn7JBJI-_nGo-q1xo2IVFK-jORYCdmgQ

1.7 Horizontal and vertical reinforcements

https://drive.google.com/open?id=1XyVMbWFao4AfnFu9_-8kLPnqodSPRBQD-j31Wls-tgY

1.8 Trusses

https://drive.google.com/open?id=1XPueedQhU0-Ue5fTbh4b5qHIprLs-zGDuEUJfGS7HFk

1.9 Non-structural walls

https://drive.google.com/open?id=1gG7yTnogTjyvK9rduTJPsBy3_Wgcths0V9haAXLQ6g8

1.10 Stairways

https://drive.google.com/open?id=1pPLzMN0cp-E6KVgxqNBZiak9C6ZwNCCltn8uj27Ocjk

1.11 Installation shafts

https://drive.google.com/open?id=1jIfeaibZEzqepdB5i4-18gqXnDyIxBrWhweHdpGomuA

1.12 External building elements

https://drive.google.com/open?id=1HyfRWAePdFrPAts6j_QT-pApT3fZF_Q8mBzR5sIAIEw

2. Construction materials

https://drive.google.com/
open?id=1yBIRO2G6XENJfS3RMUHKhYfjPW7L1rPcGUK4K1XZJ30

2.1 Concrete

https://drive.google.com/open?id=1CqlYDp8Wf1uVEjgbuYXRYkJRBDpJl8tjsasTs-gzf50

2.2 Reinforced concrete

https://drive.google.com/open?id=1xEhgEBlCzbUKz8U9LIaEoC2UBWTYeIEknrM5BzMB0Zc

2.3 Prestressed concrete

https://drive.google.com/open?id=1EdY1f2wF7_we9KENAOsvXC8UuJR2QjefUL_APMWU1LA

2.4 Brick

https://drive.google.com/open?id=1I_ofYibvHBvsYHL7E4hefB3x9b10z0R3CT8uyrU-D70

2.5 Wood

https://drive.google.com/open?id=1VJMc9vW-jMI7fhpLPLW4cJVY7jvCfR9qTUsomgeHDpM

2.6 Steel

https://drive.google.com/open?id=1E774BYLGhqmuPuJWj3dVi60lrd0csLB0YQ0fHt4odoY

2.7 Aluminium

https://drive.google.com/open?id=1HzIvSZh2djyEhZtTvYQAgHCfUTiJfEILXzGBEX-gopU

2.8 Stone

https://drive.google.com/open?id=1MphaSWUMj45FBSwqrjOgjcu0DulvnkMZtGgexla9aR8

2.9 Glass

https://drive.google.com/open?id=1H8gdGmEJA0ulbkSecqwbuqpXjHYHPfC9sN3_J4oVdfY

2.10 Drywall

https://drive.google.com/
open?id=1nSzabAJPAKmVpIE209KqRDaQuxdb3iEuUyLwDdRQ4k4

2.11 Polymers

https://drive.google.com/open?id=1HeBWi1pXmnC7ulqdzjORw2htbcadmaMTysBDf3R3r_g

2.12 Asphalt

https://drive.google.com/open?id=1lvlkH_x3SH6Io4dEawRTP9UqhvRyCKedPz6LcMJSHvQ

3. Finishing works

https://drive.google.com/open?id=1ursuNCSk7JWOJIKP8sltJa0Qz4l4CTHCB9R4KIUvwrE

3.1 Hydro-insulation

https://drive.google.com/open?id=1HAOUiye89fKJ4u42_WePEe5xM7O_qTyqAsDTQrJOVK0

3.2 Thermal insulation

https://drive.google.com/open?id=1Co9GSW4_Un02ecmRZWBgH4a1XUi5_ouRCJWSu9BMZOQ

3.3 Sound insulation

https://drive.google.com/open?id=1qTptBeGW6cfqO1ChiMZ9itewIbefvyMkW4kbSygTa_E

3.4 Wall cladding

https://drive.google.com/open?id=1kdsRznoMVbViUR5Pe3xQHXmMsjB_1XOICDKp8CotZec

3.5 Floor cladding

https://drive.google.com/open?id=1B3HEEuwgfT525x9CKVLg20fJQfMS_Vnp_WEPQU5NNfU

3.6 Ceiling cladding

https://drive.google.com/open?id=1gFyPvaEwInxONshr87uz6Mb1dhQNo3_
aMhoh2yPuvsM

3.7 Windows and doors

https://drive.google.com/open?id=14dL8HLcQj9TnueScA9wNNPqYhS5c_qJnFq7d3T8uLlI

4. Installation works

https://drive.google.com/open?id=17kttiYn1h0_x5NgQKkQ6t8DWpwqHOlNsHxiWxlfvfgw

4.1 Electrical works

https://drive.google.com/open?id=1UwShBvDMANeC52vKmcUPV96fEFXAR5UMRu4-
nlninJ8

4.2 Plumbing installations

https://drive.google.com/open?id=197JwOi-V7xe5Y8bbPBwgpiXORS_-J6jmRQqLaLCA-ts

4.3 HVAC installations

https://drive.google.com/open?id=1xRrlFjL2SbLOgSM6NHE7HnwocOPj2a7Su5if9GAJS5w

5.1 Loads

https://drive.google.com/open?id=1xRrlFjL2SbLOgSM6NHE7HnwocOPj2a7Su5if9GAJS5w

5.2 Engineering physics

https://drive.google.com/open?id=1f7mqevAW1J0D5x7ocmW4QDrn_
DYm3zfAFnPFfzhkIcw

0. Wiki pages glossary and QR codes page

https://drive.google.com/open?id=1E1gS7vLKJiXewqaFmClvjbzL-wngbT65_XZId_r1OKY

Let's Build with Virtual Reality

Junior University

DURATION – 4H

Introduction

During the event, participants are introduced to some of the latest Information Technologies for Civil Engineering. Virtual Reality (VR) integration is presented as a technological tool to enhance communication during projects' design review phase, particularly amongst users who cannot work with advanced software tools (steep learning curve).
This activity is complemented with QR Codes, as part of an Augmented Reality game.

Materials

– Projector;
– HTC VIVE Head Mounted Display (HMD), or equivalent;
– Computer (ready for immersive Virtual Reality games);
– Gamepad;

For detailed information about installation and minimum requirements, check the links below:
https://store.unity.com/pt
https://www.vive.com/eu/ready/
https://www.unrealengine.com/en-US/

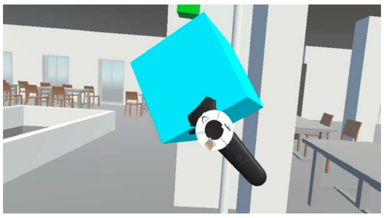
Summary

1. Introduction: Virtual Reality for Civil Engineering
2. Virtual Reality trial
3. QR Codes application

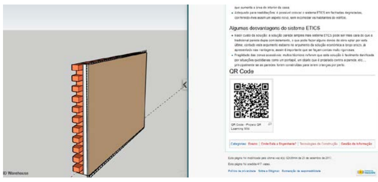
Procedure

Introduction: Virtual Reality for Civil Engineering
The activity starts with a brief introduction to Virtual Reality (VR) applications towards Civil Engineering, its recent developments within the Architecture, Engineering, Construction and Operations (AECO) sector, as well as related scientific research (related to Civil Engineering).
Hereinafter, the students will be divided into two groups so that the activities can be carried out simultaneously.

Virtual Reality trial
Students will test a VR interface that allows them to navigate through a 3D environment while learning about building systems. In detail, each student will have to use the HTC VIVE Head Mounted Display (HMD) and controllers to grab and throw cubes pertaining to different Civil Engineering building systems and elements. Green cubes stick to structural elements, yellow cubes to constructions and blues ones to hydraulic elements.
Time is also being accounted, so each student (player) must finish the game as fast as possible to achieve a better score.



QR Codes application
QR Codes are used as a complementary activity. Students will be able to visit a campus space and, through printed QR codes on sheets, access information about the building systems on that same space. The QR Codes used are found in the ELBigMAC project Wiki in the space (https://goo.gl/cj89Aq).



Bamboo Towers

DURATION – 10H

Introduction

Students should compete in order to build the strongest bamboo tower. During a week, organized in groups of 4 to 5 elements, students will be responsible for assembling a tower with the following dimensions:

- Base: 75 x 75 cm;
- Height: 150 cm.

At the end of the activity, all the towers will be put to the test on an earthquake shake table. The winning team will be the one whose scale model proves to be more resistant to seismic action.

This activity is complemented by an immersive Virtual Reality trial, where participants can develop a three-dimensional tower.

Throughout both sessions, aside from the development of team spirit and collaborative work skills, participants will be familiarized with the Civil Engineering lexicon and learn about the fundamental elements of Structural Engineering.

Materials

First session – cardboard models:

- Cardboard tubes;
- Tape;
- Flexible thin wires;
- Ropes;
- Handsaws.

Second Session – Virtual Reality:

- Computer;
- HTC VIVE Head Mounted Display (HMD), or equivalent.
- Gamepad;
- Leap Motion sensor.

For detailed information about installation and minimum requirements, check the links below:
https://store.unity.com/pt
https://www.vive.com/eu/ready/
https://support.leapmotion.com/hc/en-us/articles/223783668-What-are-the-system-requirements-

Summary

1. Assembling bamboo towers;
2. Developing a 3D model using an immersive VR interface;
3. Assessment.

Procedure

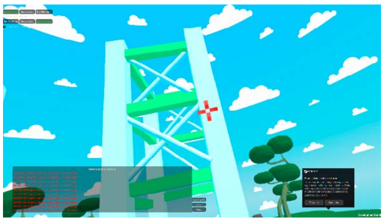
Assembling bamboo towers
In order to build the models, additional materials may be used, such as thin wire, tape, rope, among others.
This session should always be under the supervision of a tutor, particularly during the cutting of the bamboo canes.

Developing a 3D model using an immersive VR interface
Students must be organized in small groups (i.e. 3 or 4 students per group). During approximately 5 min, each student may use the Head Mounted Display (HMD) and test the interface.

Participants may rely on previous known gestures or use a traditional gamepad to interact and pick up the elements for the construction of a three-dimensional tower.

The session can last up to 20 minutes and each participant using the VR equipment is handed a relevant task to finish the VR model:
- Placing columns;
- Adding beams;
- Reinforce the structure with braces.

This activity takes place in parallel with the assembly of the bamboo towers.



Assessment
The towers will be tested for their mechanical performance during a seismic test as well as for aesthetics.

Evaluation criteria (solutions' quality):
- Aesthetics (architecture)
- Resistance / deformation / resilience (structure)

Paper Bridges

DURATION – 7H

Introduction

The main objective of this contest is to motivate pre-university students about Civil Engineering.
Participants should be organized in teams of 3 or 4 individuals, whose goal is to create a bridge able to withstand the highest possible vertical load.
Students shall be given practical and theoretical support by the organizing institutions.

Materials

– Paperboard (100 cm x 75 cm);
– Hot glue.
– Cutting tools.

Elastic bands or tape may be used as assembling aid systems, which should be removed prior to the testing of the structure.

Summary

1. Construction of the paperboard bridges.
2. Competition – vertical load test.

Procedure

Construction of paper bridge scale models
The bridge must overcome a span of 90 cm and each support should have a minimum length of 5 cm.
The bridge shall have a straight horizontal tray, allowing the movement of an object along its axis with the dimensions (horizontal span x height) of 10 x 10 cm.
The bridges' maximum height, above and below the deck, should not exceed 30 cm.
The parts will be connected only at the ends, and glue cannot be applied along the pieces of paper, both inside and outside, nor should there be any connections larger than 2 cm.
The bridge should only be supported at both ends, and no complementary supports are allowed. The total weight of the bridge at the beginning of the test should, in any case, exceed the weight of the initially supplied board.

Competition – vertical load test

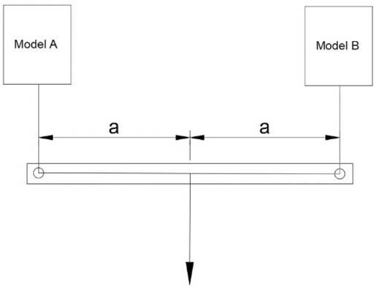
A circular hole with a minimum diameter of 1 cm shall be located over the axis of the deck and halfway through it. The vertical alignment shall be free of any obstacles. This hole will be the place of application of a vertical downward loading through a device to be provided by the organization.

All bridge models will compete in pairs, following a qualifying process, until the winning bridge is found.

A wire attached to the end of a rigid bar will be placed in the loading device of each bridge. The initial load will correspond to the weight of the loading system and will then be increased until one of the bridges collapses. The team whose model withstands the additional load wins and will move to the next round.

Between each round the winning team will have a five-minute interval to make any repairs it deems necessary.

The competing bridges will be assessed in two categories: Resistance and Aesthetics. The best performing models in both categories, respectively, win the competition.



Spaghetti Bridges

DURATION – 7H

Introduction

The main objective of this activity is to motivate pre-university students and triggering their interest in Civil Engineering through the interaction with Higher Education students and teachers.
Participants should be organized in teams of 3 to 4 individuals, whose goal is to build a spaghetti bridge able to support the highest vertical load according to the activity's guidelines.
Technical and theoretical support should be given by the organizing institutions.

Material

– Spaghetti;
– Hot glue.

Elastic bands or tape may be used as assembling aid systems, which should be removed prior to the testing of the structure.
The possibility of using materials not provided by the organization is except for complementary tools to cut the spaghetti bars.

Summary

1. Construction of the spaghetti scale models.
2. Competition – vertical load test.
3. Evaluation system.

Procedure

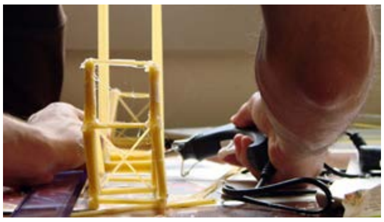
Construction of spaghetti scale models
The bridge must overcome a span of 90 cm and each support should have a minimum length of 5 cm.
Bridges shall have a straight horizontal deck, allowing the movement of an object along its axis with the dimensions (horizontal span x height) of 10 x 10 cm.
The maximum height of the bridge above and below the deck should not exceed 30 cm.
The parts will be connected only at the ends, and glue cannot be applied along the bars, both inside and outside, nor should there be any connections larger than 2 cm.
Bridges should only be supported at both ends and no complementary supports are allowed.
The total weight of each bridge at the beginning of the test should, in any case, exceed the weight of the initially supplied board.

Recommendations:
Spaghetti bars cannot be modified to gain strength.

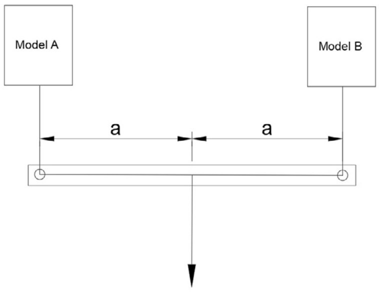
The use of other materials such as paint or glue to increase the spaghetti bars' resistance is expressly forbidden.

The minimum length for the bars is 5 cm.

Glue cannot be applied along the spaghetti bars. The bars may only be bound in the nodes



Competition – vertical load test
All bridge models will compete in pairs, following a qualifying process, until the winning bridge is selected.
A wire attached to the end of a rigid bar will be placed as the loading device of each bridge. The initial load will correspond to the weight of the loading system. An increased vertical load will be added until one of the bridges collapses.
The team whose model withstands the additional load wins and will move to the next round.
Between each round the winning team will have a five-minute interval to make any repairs it deems necessary.



Evaluation system.
The competing bridges will be assessed in two categories: Resistance and Aesthetics

Resistance:
The pairs of bridges in each match will be drawn only in the first round.
The following rounds will use an elimination system.
To obtain an initial number of bridges matching a power of two, it may be necessary to carry out some qualifying rounds. The models included in these qualifiers will be those who had inferior results in the aesthetic category.

Aesthetics:
The classification will be made through a scoring system.
The jury will have as many notes to be awarded as the number of bridges.
Prizes will be awarded to the best two models in both categories, respectively.
Awards may be cumulative.

Spaghetti Tower

DURATION – 7H30

Introduction

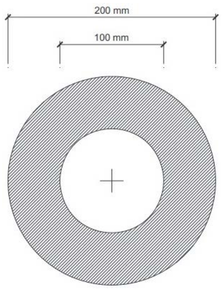
The main objective of this activity is to motivate pre-university students and triggering their interest in Civil Engineering through the interaction with Higher Education students and teachers.
Participants should be organized in teams of 3 to 4 elements, whose goal is to build spaghetti towers able to support the highest vertical load according to the activity's guidelines.
Technical and theoretical support should be given by the organizing institutions.

Summary

1. Construction spaghetti towers.
2. Competition – vertical load test.
3. Evaluation system.

Procedure

Construction of spaghetti tower scale models
The base of the tower shall be limited by a circle with 20 cm of diameter and an area corresponding to a circle with 10 cm of diameter must be left unfilled.
All towers must be 40 cm tall and the weight at the beginning of the test shall not exceed, in any case, 200 grams.
Each tower should be simply supported on the horizontal plane and no complementary supports are allowed that might hold the structure (both horizontally or along its longitudinal plane).
The top of every tower shall have a downward vertical load application point (the necessary device will be provided by the organization). The application point should be at least 40 cm tall in relation to the tower's base, and vertically aligned with the base's restrictive circle. This alignment shall be free from any obstacle.
The parts will be connected only at the ends and glue cannot be applied along the bars, both inside and outside, nor should there be any connections larger than 1 cm.
The tower should only be supported at both ends, and no complementary supports are allowed.



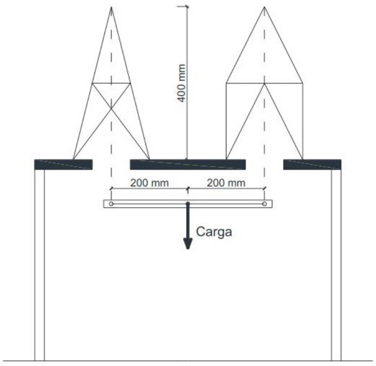
Recommendations:
Spaghetti bars cannot be modified to gain strength.

The use of other materials such as paint or glue to increase the spaghetti bars' resistance is expressly forbidden.

The minimum length for the bars is 5 cm.

Glue cannot be applied along the spaghetti bars. The bars may only be bound in the nodes

Competition – vertical load test
All tower models will compete in pairs, following a qualifying process, until the winning tower is found.
In each round, both towers will be placed on a smooth surface where the circles with the conditioning dimensions will be marked. Then, the towers will be aligned so that the vertical load application points become aligned with the center of the circles.
A wire attached to the end of a rigid bar will be placed as the loading device of each tower. The initial load will correspond to the weight of the loading system and will then be increased until one of the towers collapses.
The team whose model withstands the additional load wins and will move to the next round.
Between each round, the winning team will have a fifteen-minute interval to make any repairs deemed necessary.



Evaluation system.
The competing towers will be assessed in two categories: Resistance and Aesthetics

Resistance:
The pairs of towers for each match will be drawn only in the first round.
The following rounds will use an elimination system.
To obtain an initial number of towers matching the power of two, it may be necessary to carry out some qualifying rounds.
The models included in these qualifiers will be those who had inferior results in the aesthetic category.

Aesthetics:
The classification will be made through a scoring system.
The jury will have as many notes to be awarded as the number of towers
Will be awarded the best two models in both categories, respectively.
Awards may be cumulative.

Cardboard Tube Towers

DURATION – 2H

Introduction

Students will compete to build the strongest cardboard tower. During a session of approximately two hours, teams of 4 to 5 individuals will be responsible for assembling a tower with the following dimensions:
- Base: 75 x 75 cm;
- Height: 150 cm.

At the end of the activity, all the towers will be tested on an earthquake shake table. The team whose scale model proves to be more resistant to seismic action will win the competition.
The scale models' aesthetics will also be part of the assessment categories.
The cardboard tower activity is complemented by an immersive Virtual Reality trial, where participants can develop a three-dimensional tower.
Throughout both sessions, in addition to team spirit and development of collaborative work skills, participants will learn the basics of Civil Engineering lexicon and the fundamental elements of Structural Engineering.

Materials

First session – cardboard models:
- Cardboard tubes;
- Tape;
- Flexible thin wires;
- Ropes;
- Handsaws.

Second Session – Virtual Reality:
- Computer;
- HTC VIVE Head Mounted Display (HMD), or equivalent.
- Gamepad;
- Leap Motion sensor.

For detailed information about installation and minimum requirements, check the links below:
https://store.unity.com/pt
https://www.vive.com/eu/ready/
https://support.leapmotion.com/hc/en-us/articles/223783668-What-are-the-system-requirements-

Summary

1. Assembling cardboard tube towers;
2. Developing a 3D model using an immersive VR interface;
3. Assessment.

Procedure

Assembling cardboard tube towers
In order to build their model, students may use other materials at their disposal (thin wire, tape, rope, among others).
This session should always be under the supervision of a tutor, particularly during the cutting of the pipes.

Developing a 3D model using an immersive VR interface
Students must be organized in small groups (i.e. 3 or 4 students per group). During approximately 5 min, each student may use the Head Mounted Display (HMD) and test the interface.
Participants may rely on previous known gestures or use a traditional gamepad to interact and pick up the elements to build a virtual tower.
The session can last up to 20 minutes and each participant using the VR equipment is handed a relevant task to finish the VR model:

- Placing columns;
- Adding beams;
- Reinforce the structure with braces.

This activity takes place at the same time as the assembly of the cardboard towers.

Assessment
The towers will be tested for their mechanical performance. and aesthetics.

Evaluation criteria (solutions' quality):

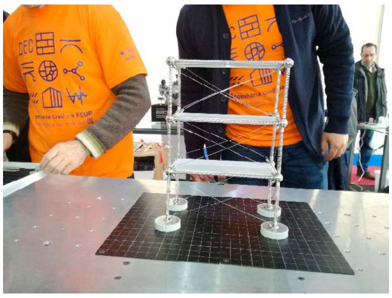
- Aesthetics (architecture)
- Resistance / deformation / resilience (structure)

Mola Structure

DURATION – 10H

Introduction

The students will compete to build the most creative structure using the Mola kit.



The structure should be that of a building, tower or a bridge structure.

The model consists of a set of modular parts, which are connected through magnetism, allowing countless combinations. With Mola Structural Kit, different structural systems can be built, visualize the movements and deformations of their elements.

The aim of such study is to develop, from the experience with the model, an intuitive knowledge of the structural behavior, which is essential for architects and Civil engineers, particularly in the conception phase of a project.

Materials

Mola Kit composed of springs and magnetic spheres.

Summary

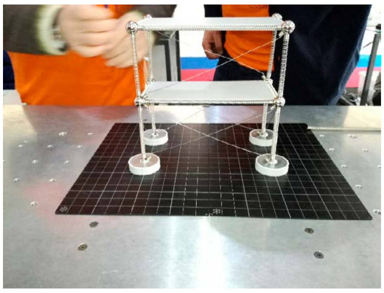
Assembling Mola Structure;
Assessment.

Procedure

Assembling the Mola Structure
No extra material is allowed to be used.

No additional Mola tools other than the 145 pieces.

Developing a 3D model using an immersive VR interface



Students must be organized in small groups (i.e. 2 to 4 students per group). During approximately 10 min.

Participants may use the manual from the Mola kit to refer to idea of structures made, but they need to be creative and not follow the guidelines from the manual, that will enable them to understand the way structures are connected and stabilized.

Assessment
The structure will be tested for their mechanical performance during a seismic test, load bearing test as well as for their aesthetics.

Evaluation criteria (solutions' quality):
Aesthetics (architecture)
Resistance / deformation / resilience (structure)

Paper Tower

DURATION – 7H

Introduction

The main objective of this contest is to motivate pre-university students about Civil Engineering.

Participants should be organized in several teams, whose goal is to erect a tower, as high as possible.

Students should be given technical and theoretical support by the organizing institutions.

Materials:

– Paper (size varies from A4 sheets to 100 cm x 75 cm cardboards);
– Hot glue.
– Cutting tools.

Elastic bands or tape may be used as assembling aid systems, which should be removed prior to the testing of the structure.

Summary

1. Construction of the paper towers.
2. Competition – vertical height stability
3. Evaluation system

Procedure

Construction of paper tower scale models
The base of the tower shall be limited by a 40 cm of diameter.

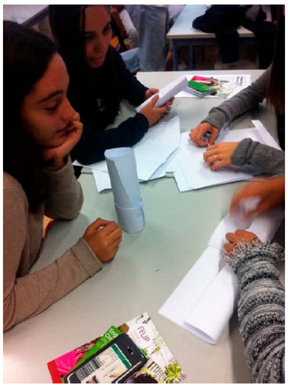
All towers must be at least 1m tall and the weight at the beginning of the test shall not exceed 200 grams.

Each tower should be simply supported on the horizontal plane and no complementary supports are allowed that might hold the structure (both horizontally or along its longitudinal plane).

The parts will be connected only at the ends, and glue cannot be applied along the bars, both inside and outside, nor should there be any connections larger than 1 cm.

The total weight of the towers at the beginning of the test should, in any case, exceed the weight of the initially supplied board.

The towers should only be supported from beneath, and no complementary supports are allowed.



Competition – height and vertical load test

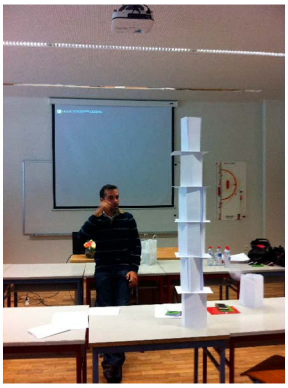
All tower models will compete in groups of 3 to 4 individuals, following a qualifying process, until the winning tower is found.

In each round, both towers will be placed on a smooth surface where the circles with the conditioning dimensions will be marked. Then, the towers will be aligned so that the vertical height and load application points become aligned with the center of the circles.

A wire attached to the end of a rigid bar will be placed as the loading device of each tower. The initial load will correspond to the weight of the loading system and will then be increased until one of the towers collapses.

The team whose model is the higher and withstands the additional load wins and will move to the next round.

Between each round the winning team will have a fifteen-minute interval to make any repairs deemed necessary.



Unveiling Hidden Construction Systems

DURATION – 15 MIN

Introduction

During the event, participants are introduced to some of the latest Information Technologies for Civil Engineering.
Virtual Reality (VR) integration is presented as a technological tool to enhance communication during projects' design review, particularly amongst users who cannot work with advanced software tools (steep learning curve).
This activity is complemented with QR Codes, as part of an augmented Reality game.

Materials:

– Projector;
– HTC VIVE Head Mounted Display (HMD), or equivalent;
– Computer (ready for immersive Virtual Reality games);
– Gamepad;

For detailed information about installation and minimum requirements, check the links below:
https://store.unity.com/pt
https://www.vive.com/eu/ready/

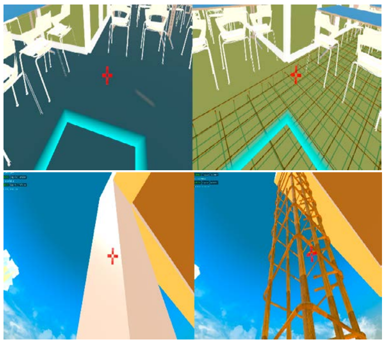
Summary

1. Introduction: Virtual Reality for Civil Engineering
2. Virtual Reality trial
3. QR Codes application

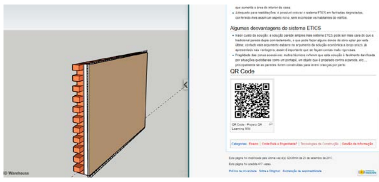
Procedure

Introduction: Virtual Reality for Civil Engineering
The activity starts with a brief introduction to Virtual Reality (VR) applications towards Civil Engineering, its recent developments within the Architecture, Engineering, Construction and Operations (AECO) sector, as well as related scientific research (related to Civil Engineering).
Hereinafter, the students will be divided into two groups so that the activities can be carried out simultaneously.

Virtual Reality trial
A walkthrough in the cafeteria at FEUP's Campus is designed In detail, each student will have to use the HTC VIVE Head Mounted Display (HMD) and controllers to a point target movement system, where users simply point to a target location using the hardware controllers and are instantly transported to this new position and toggle the visibility of groups of construction elements, allowing users to assess systems that are often hidden from view.



QR Codes application
QR Codes are used as a complementary activity. Students will be able to visit a campus space and, through QR Codes printed on sheets, access information about the building systems on that same space. The QR Codes used are found in the ELBigMAC project Wiki (https://s.up.pt).



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Αριστοτέλειο
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Θεσσαλονίκης

UNIVERSITAS STUDIORUM ZAGRABIENSIS MDCLXIX