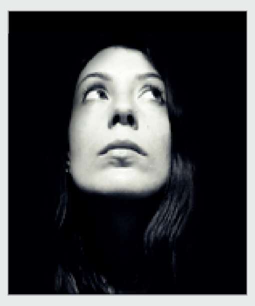


Laureanda: Chiara Corradetti

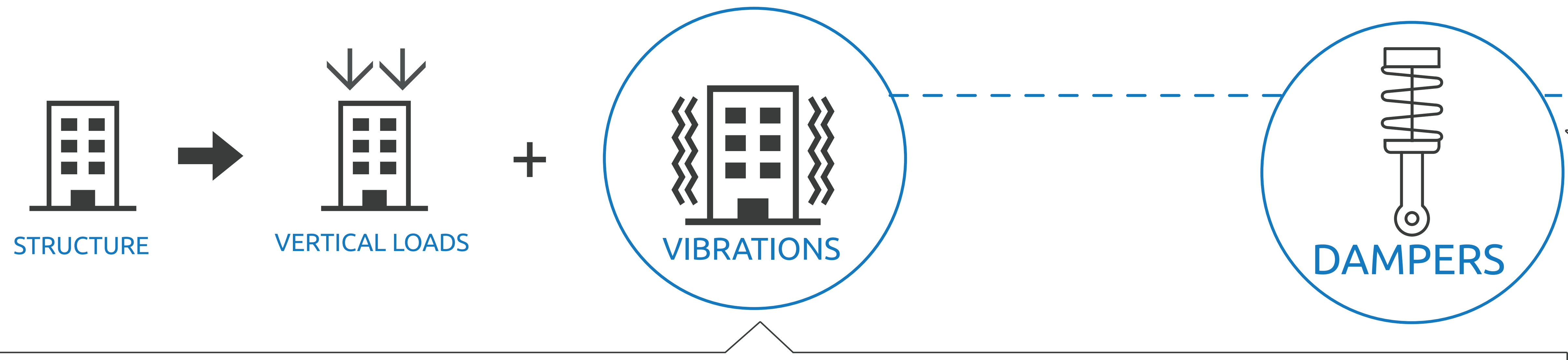
UNIVERSITA' DEGLI STUDI DI CAMERINO _Scuola di Architettura e Design "Eduardo Vittoria" _sede di Ascoli Piceno _Laurea Magistrale in Architettura A.A. 2016/2017

TITOLO TESI: IL CONTROLLO DELLE VIBRAZIONI DELLE COSTRUZIONI PER MEZZO DI DISPOSITIVI DI DISSIPAZIONE DELL'ENERGIA

Relatore: Prof. Graziano Leoni

Correlatore: Prof. Emanuele Marcotullio

La gestione delle sollecitazioni a cui le strutture sono sottoposte durante la loro vita è un tema importante; oltre ai carichi statici esistono sollecitazioni dinamiche da controllare per garantire il funzionamento e la sicurezza degli edifici. L'intento di questa tesi è di passare in rassegna i sistemi di dissipazione utilizzabili al fine di ottenere edifici sicuri, scegliendo quello più adatto. Un caso studio è stato analizzato progettualmente: si tratta di un struttura molto particolare che andrebbe a sostituire l'attuale ponte dell'Accademia a Venezia, con la duplice funzione di ponte-museo come richiesto dal bando "Venice 2006" del sito internazionale Arquitectuum, e che quindi presenta diverse problematiche legate alla destinazione d'uso.



EARTHQUAKE

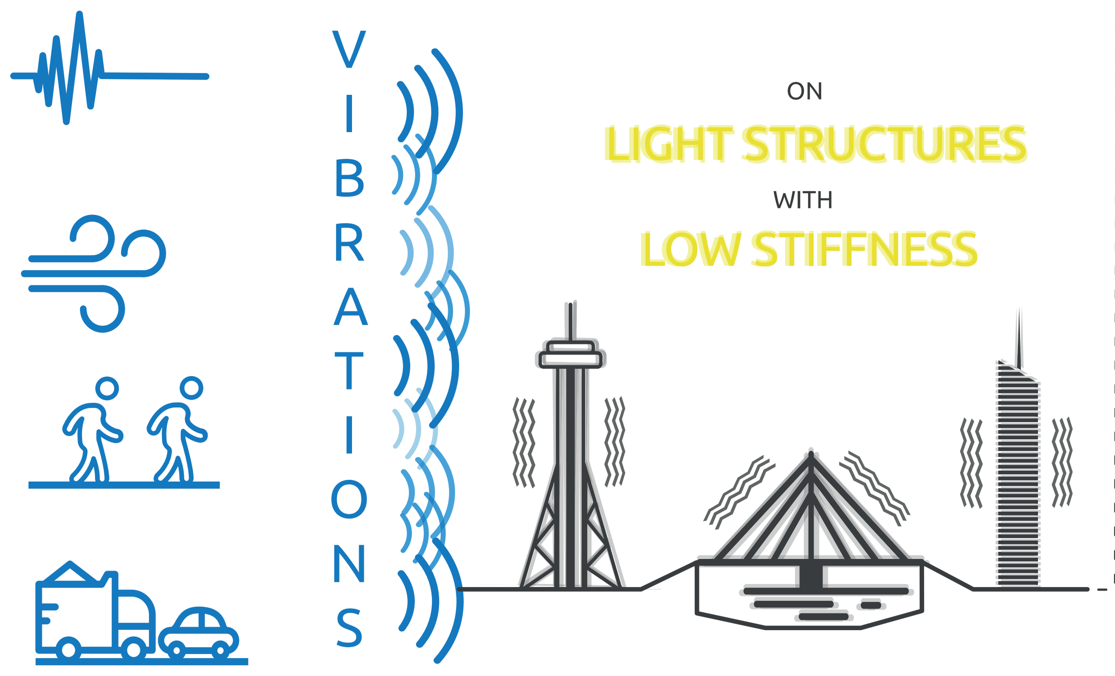
WIND

PEDESTRIANS

TRAFFIC

V I B R A T I O N S

ON **LIGHT STRUCTURES** WITH **LOW STIFFNESS**



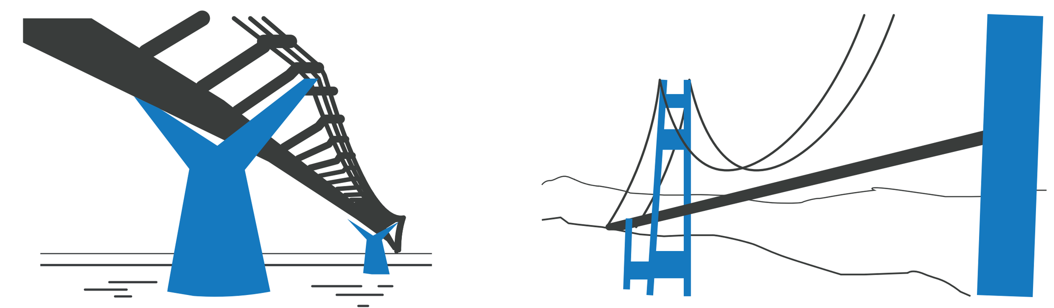
GENERATE

DISCOMFORT

MILLENNIUM BRIDGE - LONDON

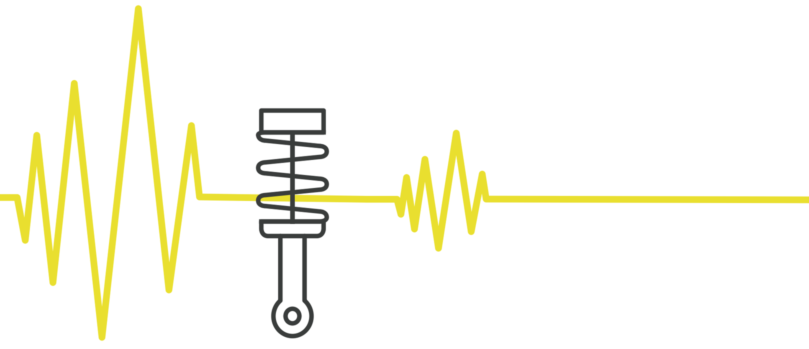
STRUCTURAL DAMAGES

TACOMA NARROWS BRIDGE - TACOMA



The bridge was opened on the 10th of June 2000; closed after just two days due to vibrations inducted by pedestrians, it was opened again after adding vibration dampers on 22nd of February 2002.

It was opened to traffic on 1st of July 1940; wind produced strong vibration on the deck, with high fluctuations, and made it collapse on 7th of November. It was opened again in 1950.

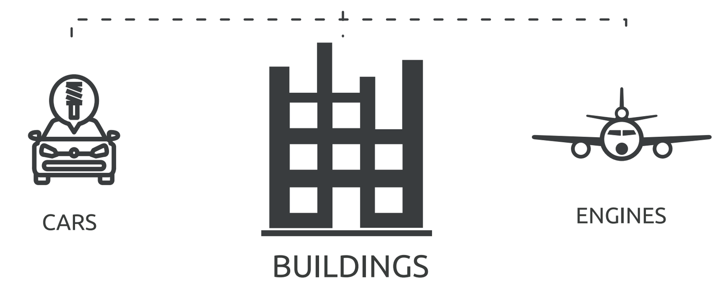


VIBRATIONS CONTROL

CAN BE REACHED BY USING

DAMPERS

IN



Dampers are devices that reduce vibrations. They are used not only to prevent unbearable vibrations in buildings, but also in aircraft engines and cars.
All dampers have the same function, but they can be calssified by the way they work: there are active, passive and semi-active dampers.

ACTIVE

SENSORS

EXTERNAL CONTROL

WIDE RANGE OF FREQUENCIES

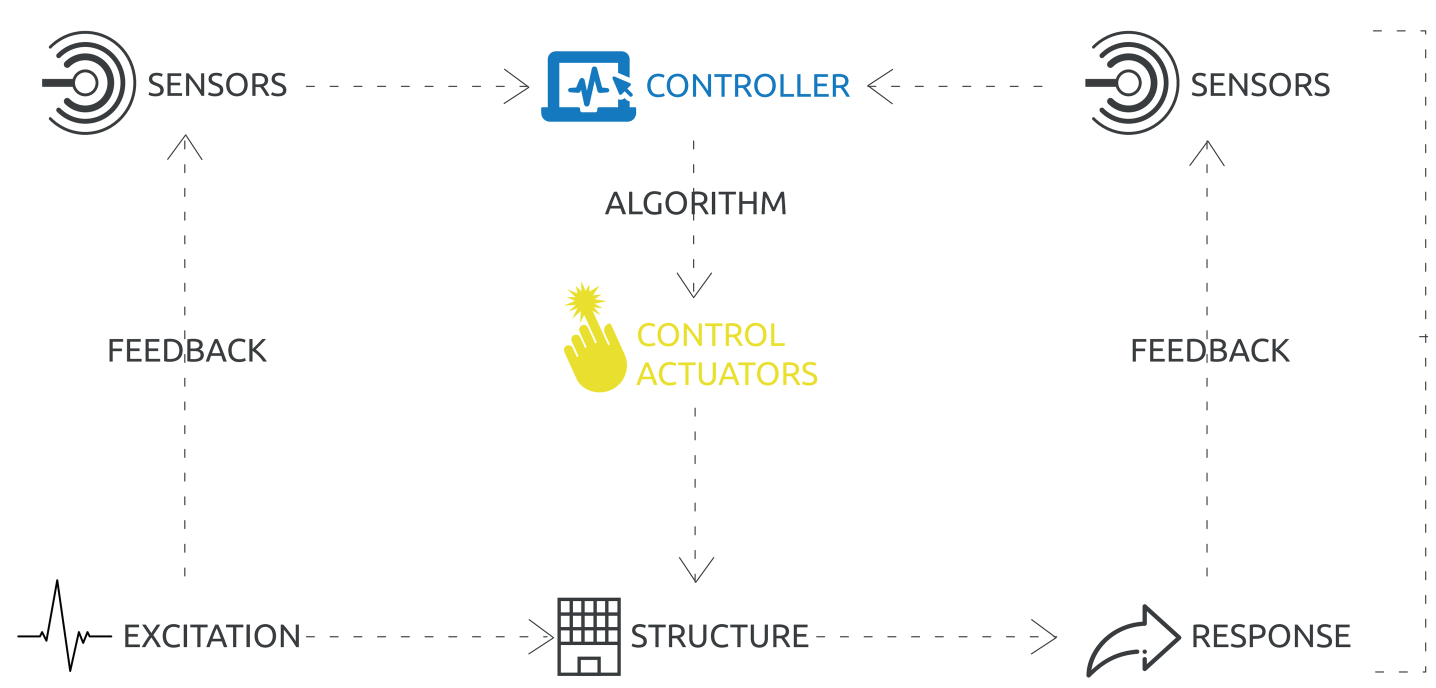
CONTROLLED STRUCTURAL RESPONSE

REAL-TIME CONTROL

Structrues with Active Dampers have a control system that can monitor in real-time their response and adapt dampers to face it.

FLEXIBILITY

Changing with structure response, Active Dampers can cover a wide range of frequecies and flexibly answer to different kinds of excitations.

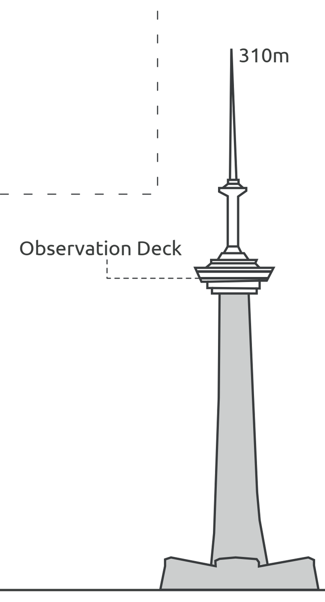


ACTIVE MASS DAMPER

They have the same properties of a TMD but they're monitored by a control system that can adapt their behaviour to the structure excitation and response, covering a wide range of frequencies.

ACTIVE LIQUID DAMPER

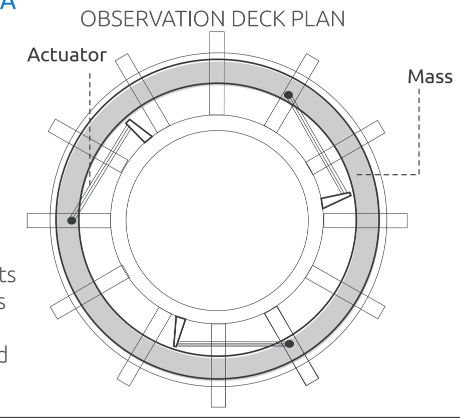
They have the same properties of a TLD or a TLCD but they're monitored by a control system that can adapt their behaviour to the structure excitation and response, covering a wide range of frequencies.



TV TOWER, NANJING, CHINA

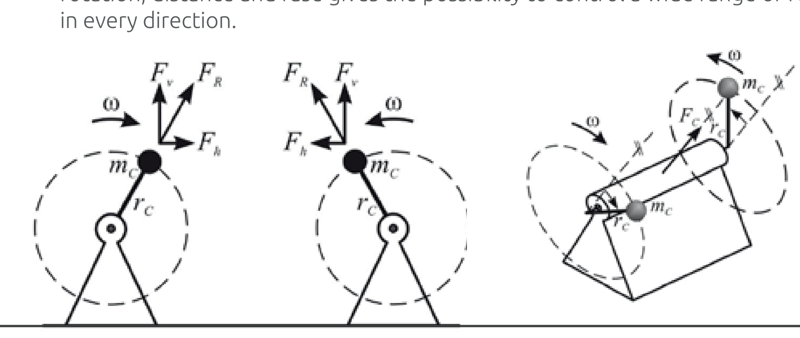
This TV tower in Nanjing had problems with wind inducted vibrations, which generated unacceptable acceleration on the structure.

An anular AMD has been installed into its observation deck, designed to respect assigned weight and space limits given by the built structure. It is linked to three actuators that control its behavior during wind and earthquake ectitations.



TWIN ROTOR DAMPERS

Presented on EURODYN 2011, they're made of two rotating masses that generate opposite forces to the ones they must counteract. Verying their rotation, distance and fase gives the possibility to control a wide range of forces in every direction.

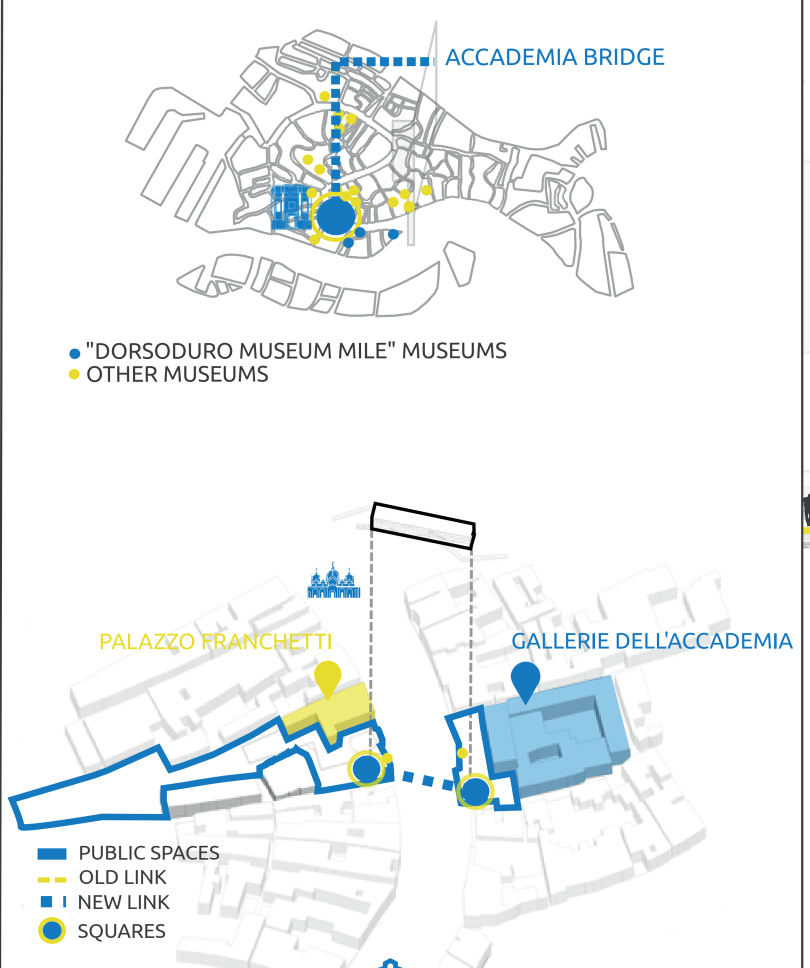


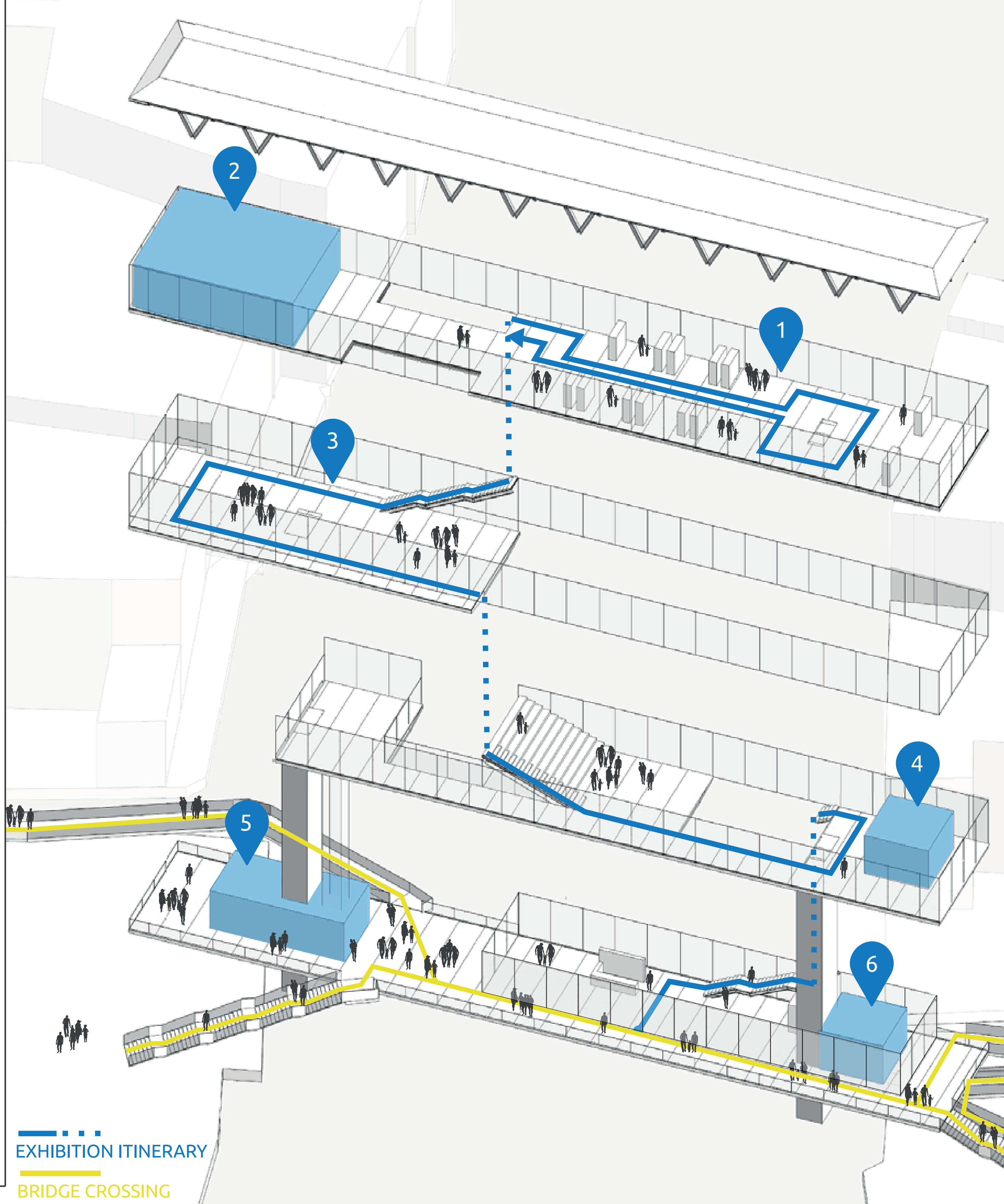
CASE STUDY: VENICE 2006

INTERNATIONAL ARCHITECTURE CONTEST BY ARQUITECTUUM

NEW ACCADEMIA BRIDGE

- _New Academia Bridge as a Museum-Bridge
- _1000 sq meters of exhibition
- _Temporary Exhibition space
- _Permanent Exhibion space, about the history of Venice
- _Cafè, restrooms, bookshop and services





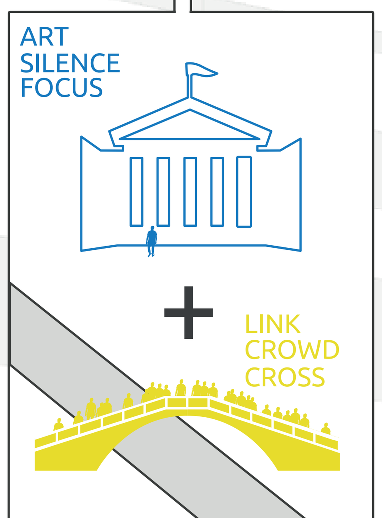
MUSEUM

1_PERMANENT EXHIBITION

2_OFFICES

3_TEMPORARY EXHIBITION

4_BOOKSHOP



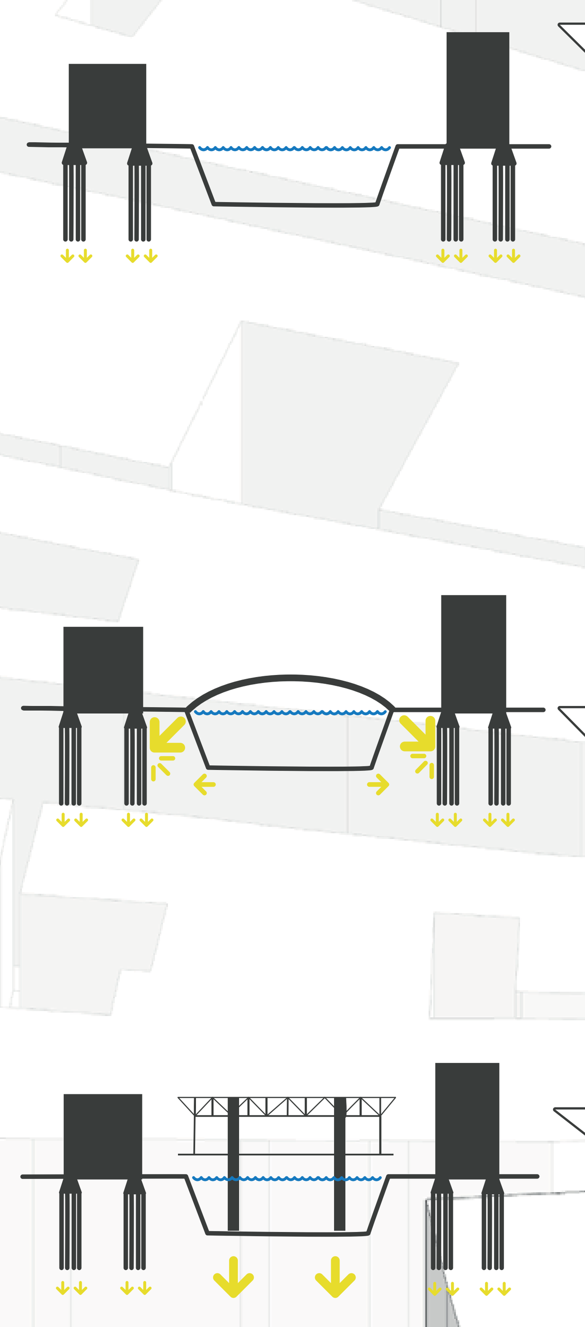
BRIDGE

5_CAFE'

6_RESTROOMS

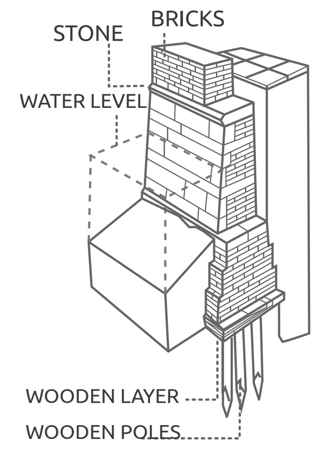
STRUCTURAL CONCEPT

1 FORCES AND SUBSTRUCTURES



VENICE SUBSTRUCTURES

Due to particular ground conditions, Venice buildings' substructures are built with long wooden poles under brick layers.

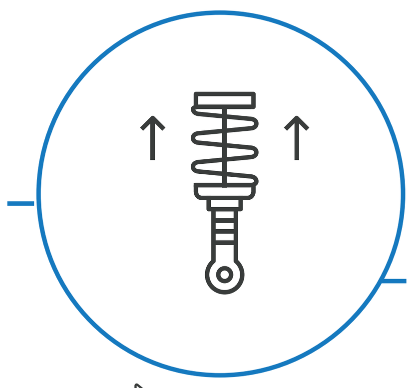


ARCH BRIDGES

Arch structures generate both vertical ad horizontal forces. The more the arch is a segmental arch, the grater horizontal forces will be.

FRAME STRUCTURES

Frame structure work with vertical loads, avoiding horizontal forces pushing against other buildings foundations.



PASSIVE

NO ENERGY REQUIRED
NO EXTERNAL CONTROL
OPTIMIZATION

NO ADDITIONAL ENERGY

Passive dampers don't need additional energy to work; their damping properties are defined by their materials or their mass.

NO EXTERNAL CONTROL

Passive dampers don't need an external control system to ensure their function; they are designed for the structure they work for.

OPTIMIZATION

Properties of dampers are designed to work for selected frequencies they have to control during the excitation of the structure.

PASSIVE DAMPERS

CAN WORK WITH

MATERIAL DAMPING PROPERTIES

ELASTOPLASTIC DAMPERS
Beyond the elastic deformation limit, they show permanent deformations. Load cycles enable their damping effect.

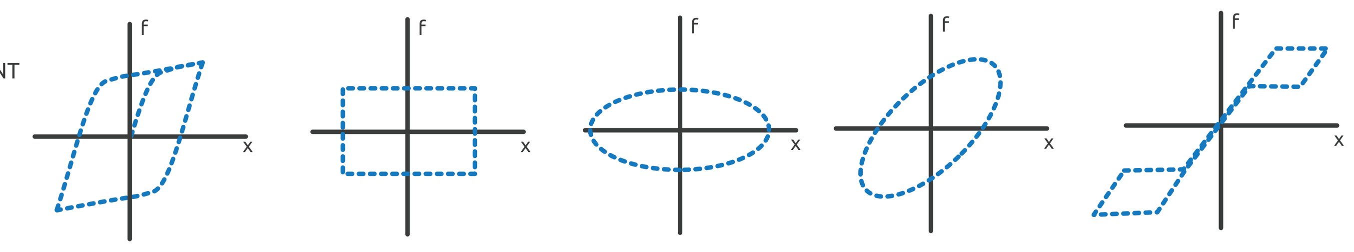
FRICTION DAMPERS
Friction force between damper's surfaces is exploited, opposing excitation force and dissipating energy.

VISCOUS DAMPERS
Filled with a viscous fluid, they dissipate energy exploiting te flow of this fluid through orifices.

VISCO-ELASTIC DAMPERS
Made with viscoelastic materials, which combine properties of a viscous fluid and an elastic material.

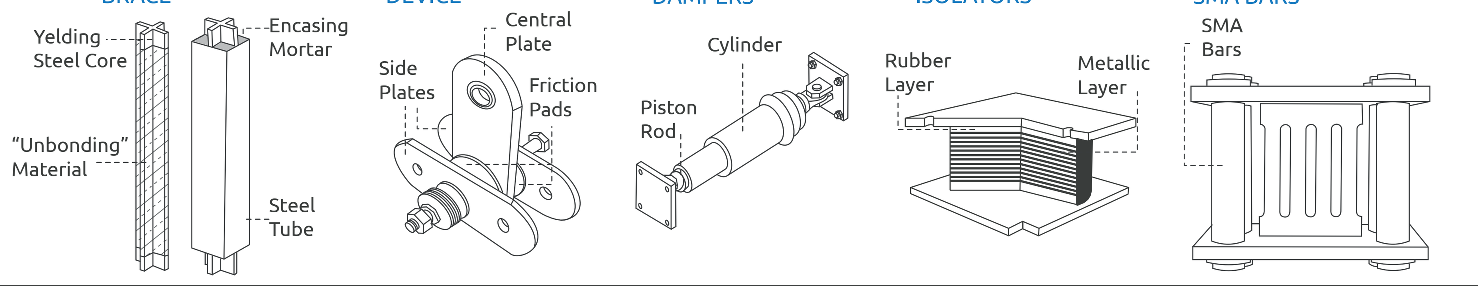
SHAPE MEMORY ALLOYS
SMA are "smart"materials that can show different cristalline structure depending on force or temperature.

FORCE - DISPLACEMENT



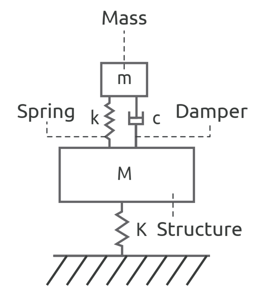
EXAMPLES

BUCKLING RESTRAINED BRACE — DAMPETCH FRICTION DEVICE — FLUID VISCOUS DAMPERS — ELASTOMERIC ISOLATORS — SLIT DAMPERS WITH SMA BARS

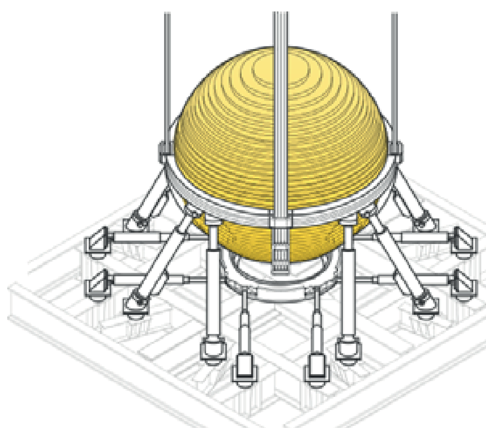


TUNED MASSES

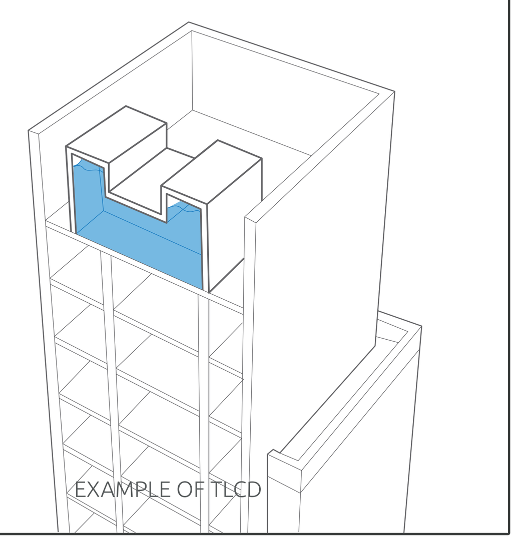
TUNED MASS DAMPERS
Made with and additional mass, a spring and a damper; mass is tuned to the structure's main frequency and its damping effect is due to its out-of-fase oscillation, which reduce structure vibrations.



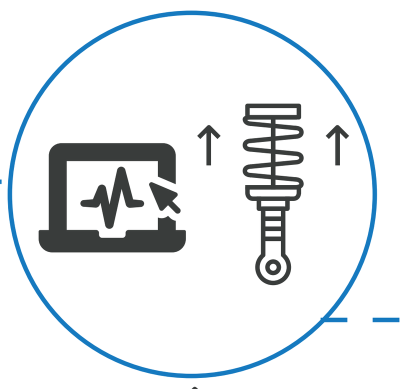
TUNED LIQUID DAMPERS
They have the same properties of TMD, but mass is replaced with water. There are Tuned Sloshing Dampers, working with sloshing water inside a tank, and Tuned Liquid Columns, which dissipate energy through the movement of water and loss of hydraulic pressure inside the tube.



TAIPEI-101 TOWER TMD



EXAMPLE OF TLCD



SEMI-ACTIVE

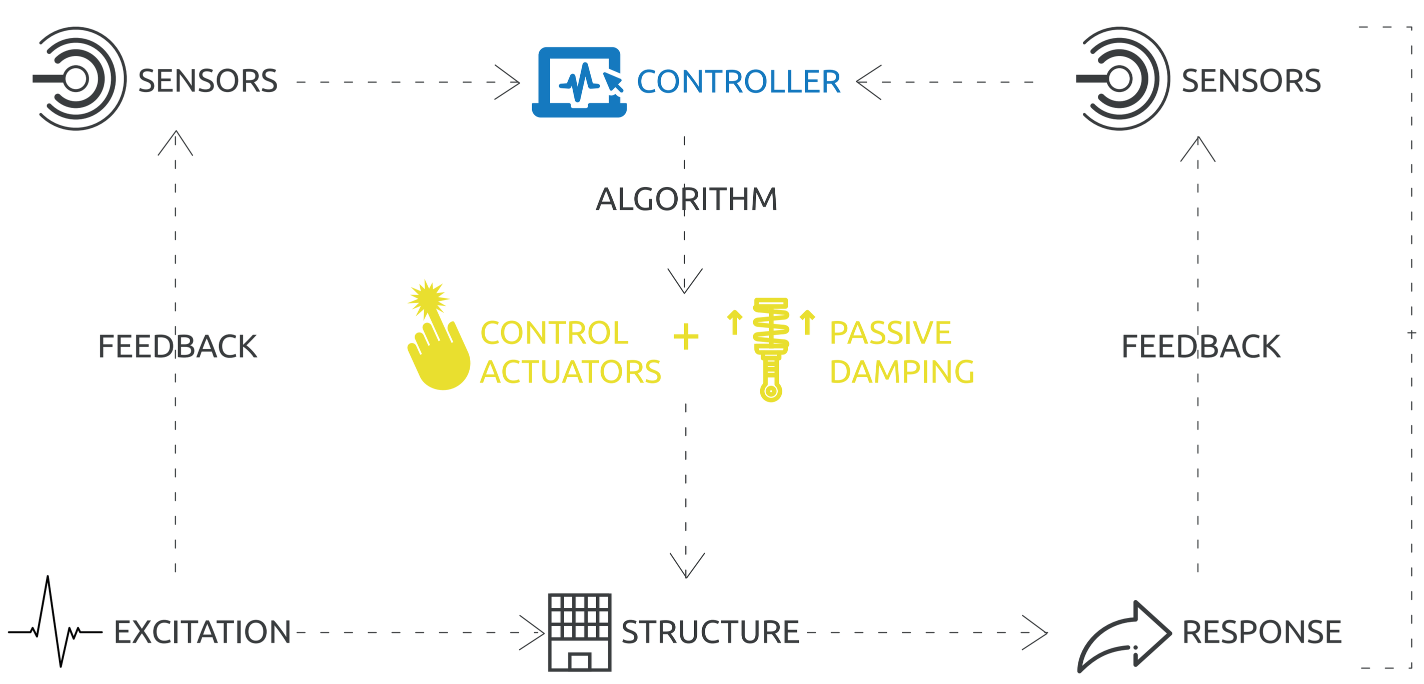
OPTIMIZED RESPONSE
LOW ENERGY
REAL-TIME CONTROL
FLEXIBILITY

REAL-TIME CONTROL

Structrues with Semi-Active Dampers can monitor in real-time their response to excitation and adapt some dampers properties to face it.

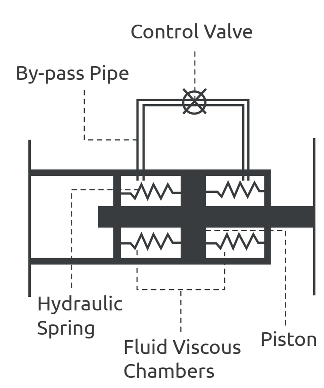
LOW ENERGY REQUIRED

Semi-Active systems need much less energy than active systems to work.



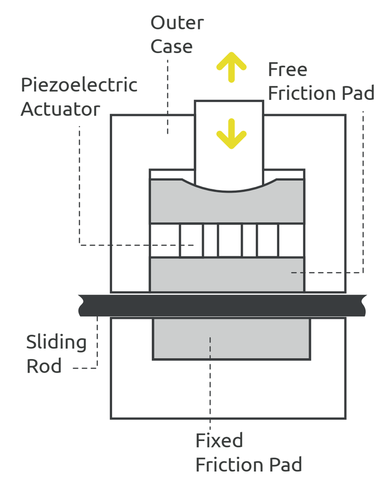
VARIABLE ORIFICE DAMPERS
Hydraulic semi-active systems, made up of a viscous damper with a controllable orifice inside a by-pass pipe between the chambers of the cylinder.

The control valve can be open or closed and it can be celectro-mechanically controlled.



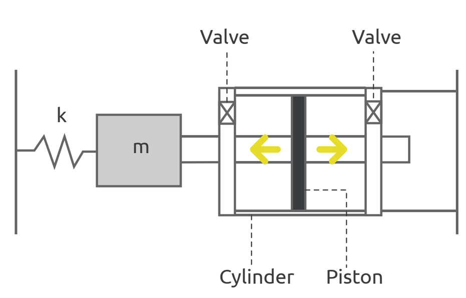
VARIABLE FRICTION DAMPERS
VFD control structural vibrations by changing their friction force.

They are made of a case containing two friction pads (one fixed and one free) connected to piezoelectric actuators and crossed by a sliding rod . Variations on pressure on the rod make friction force change.



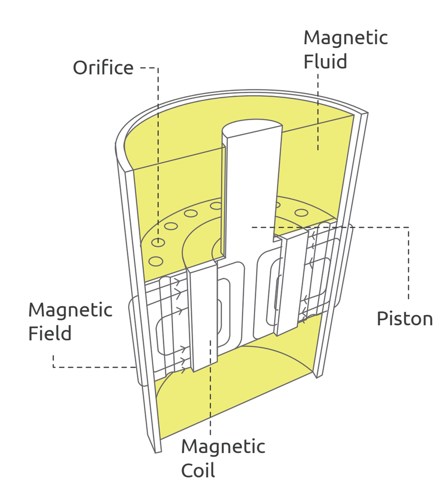
CONTROLLABLE TMD/TLD
Controllable TMD/TLD work like passive TMD/TLD but there is a real- time control of properties like stiffness or damping.

In resettable devices, for example, two controlling valves can release the energy accumulated by the piston, changing damping properties of the TMD.

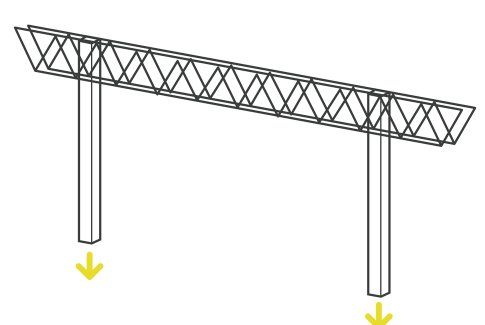


ELECTRO/MAGNETO-REOLOGICAL DAMPERS
ER/MR dampers properties can be contrelled by the application of an electric or a magnetic field on the fluid inside the damper.

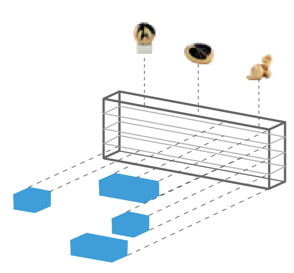
These special fluids react to the fields by changing their viscous behavior and so they can be adapted to a wide range o frequencies to control.

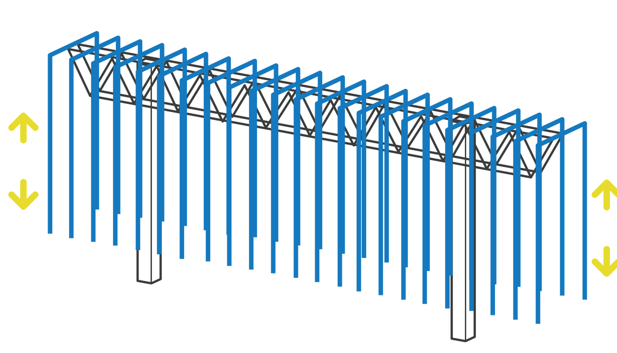


2 LIGHTNESS

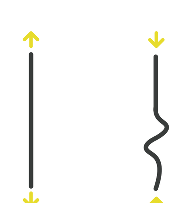


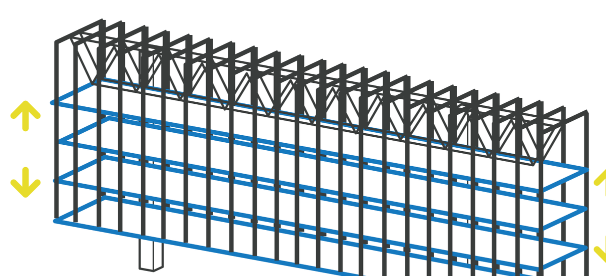
TRANSPARENCY
The museum-bridge is seen as a big transparent showcase inside the city, with all artworks shown. So, structure has to be as light as possible, to communicate the idea of the showcase inside a musem-city like Venice.



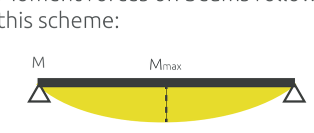


TIE-RODS
Steel works better with traction, avoiding instability problems and obtaining smaller sections under the same force.



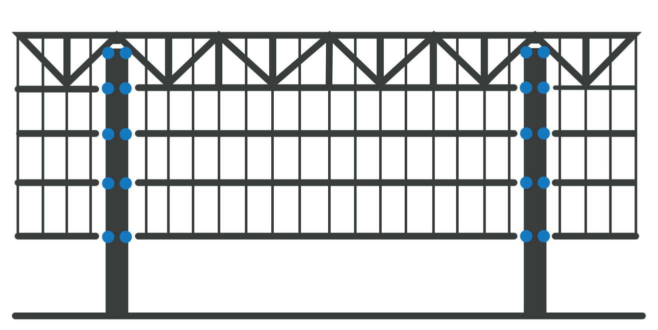


BEAMS
Moment forces on beams follow this scheme:



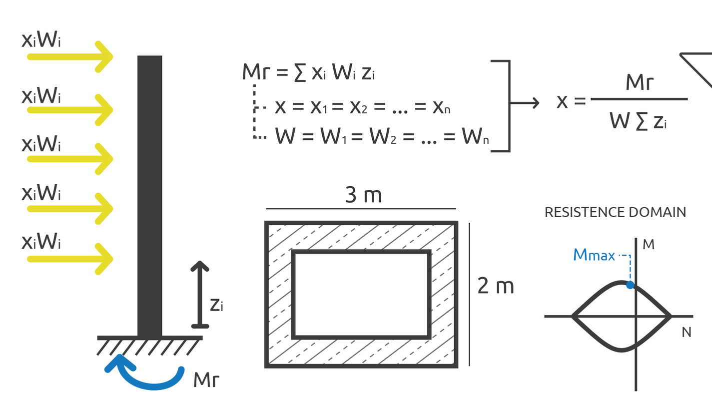
So, beams have the following shape, a smaller section on edges and a bigger one in the middle.

3 EARTHQUAKE



HORIZONTAL FORCES
The structure is thought to bear horizontal forces by two big steel columns filled with concrete.

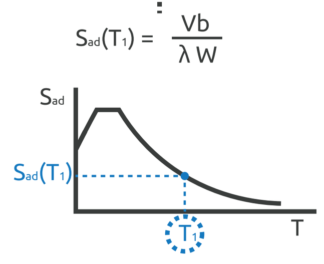
To prevent the different floors from moving too much, the columns and the rest of the steel structures are linked by dampers.



$Mr = \sum x_i W_i z_i$
$x = x_1 = x_2 = ... = x_n$
$W = W_1 = W_2 = ... = W_n$
$\rightarrow x = \frac{Mr}{W \sum z_i}$

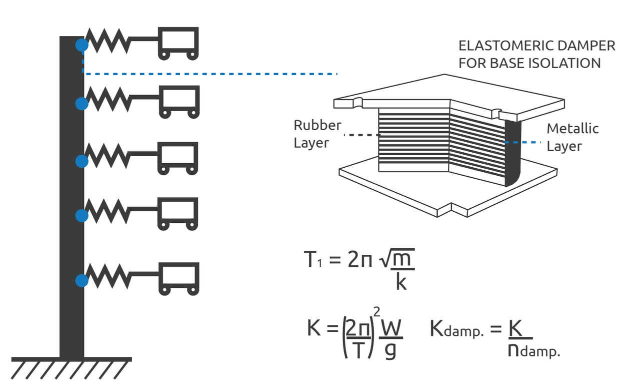
$Vb = x_i W_i$ $\quad$ $Vb = \lambda\, Sad(T1)W$

$$S_{ad}(T_1) = \frac{Vb}{\lambda W}$$



MAIN COLUMNS' SECTION
For main columns section's design, a reverse proceedings has been used:
dimensions were decided before, and then the resistence domain was calculated to obtain the maximum moment this section could bear.

Following the scheme on the left, shear force for every floor was calculated, and then the corresponding acceleration and period of the structure were found.



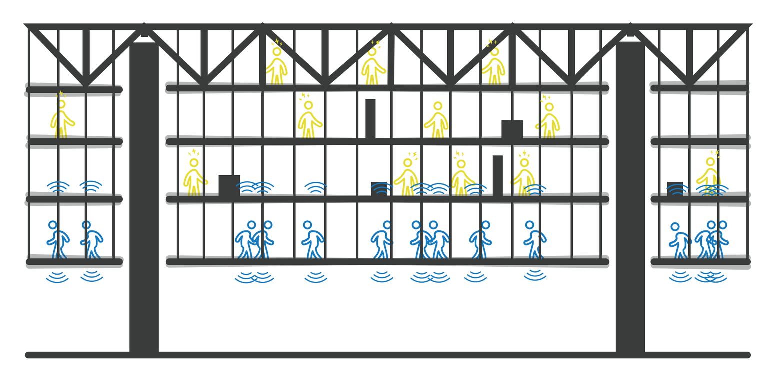
$T_1 = 2\pi\sqrt{\frac{m}{k}}$

$K = \left(\frac{2\pi}{T}\right)^2 \frac{W}{g}$ $\quad$ $K_{damp.} = \frac{K}{n_{damp.}}$

ISOLATION
Different floors are considered as indipendent structures, linked to the ground by the column; so a base isolation system is used to link the column and the floors.

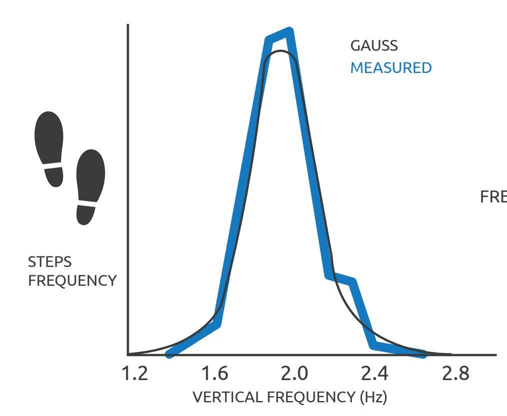
Elastomeric dampers were chosen calculating required stiffness from the period obtained for the structure.

4 PEDESTRIAN VIBRATIONS + MUSEUM PROGRAM



PEDESTRIAN CROSSING
The structure has two main functions: museum and crossing.

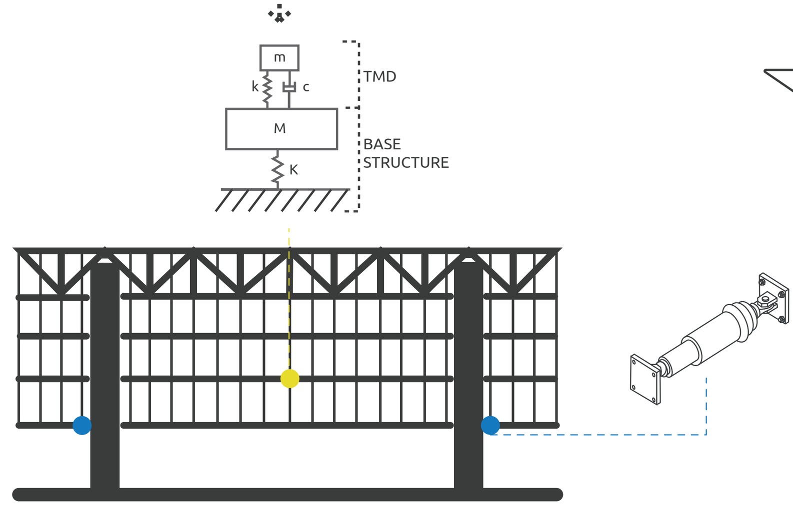
People crossing the bridge produce vertical and horizontal vibration to the structure, that could disturb the exhibitions taking place on the upper floors.



LIGHTNESS
LOW STIFFNESS
LOW FREQUENCIES
FREQUENCIES ≅ STEP FREQUENCIES
RESONANCE
TMD + VD

FREQUENCIES
Light structures have low frequencies; usually their fundamental frequency is near 2Hz, which is also considered human step frequnecy.

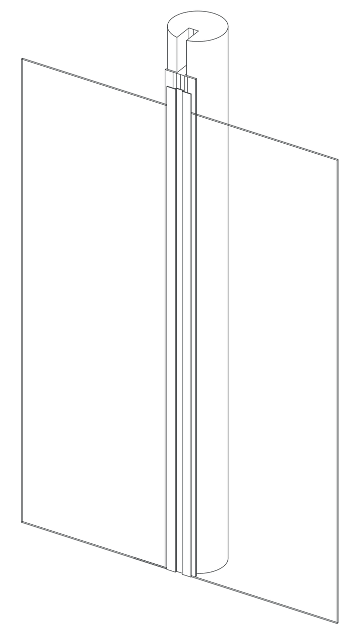
So, these structures can have resonance problems due to pedestrian crossing exitations



TMD + VD
To avoid resonance problems and high accelerations, two viscous dampers control horizontal vibration on the lowest floor, and a TMD controls vertical vibration on the upper floor, all placed near points with highest displacemetnt values under specific excitations.

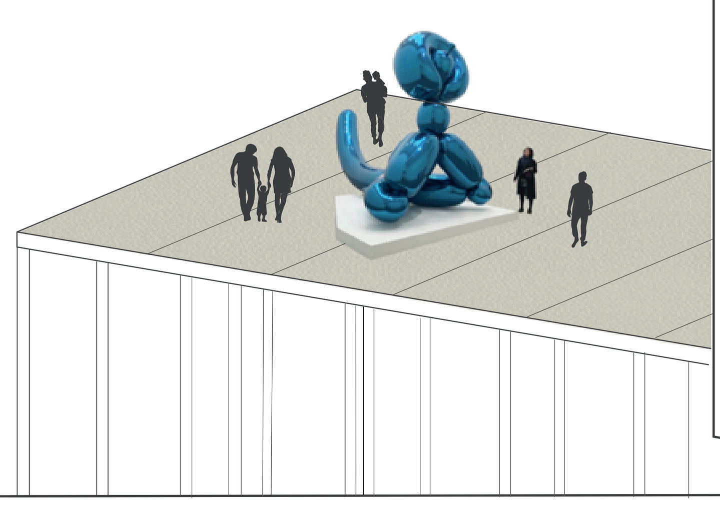
GORILLA GLASS FACADES

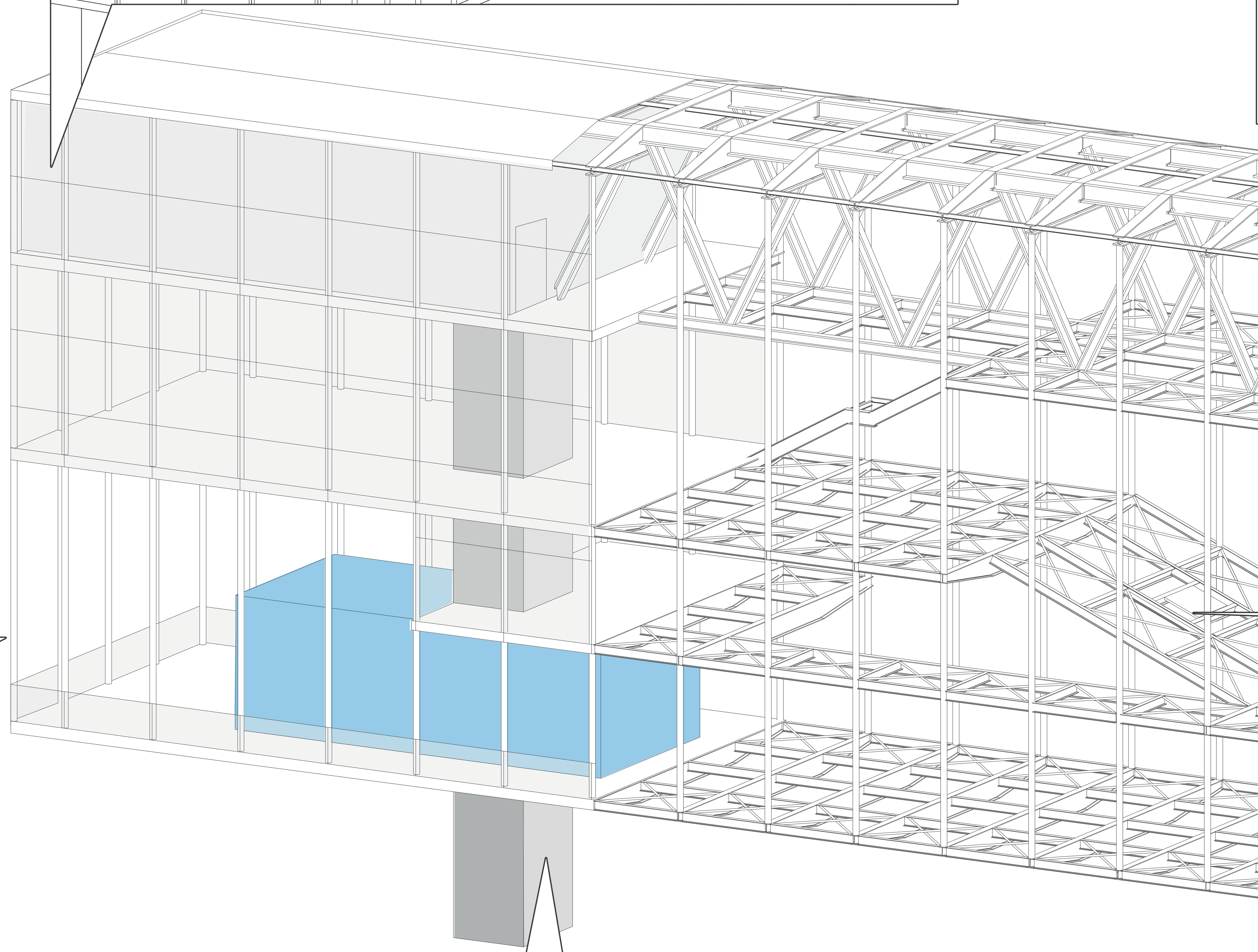
Gorilla class is used for this muesuem facades because of its lightness (4 times lighter than a regular glass), its resistance to hard impacts and its higher transmission performance and superior optical clarity in the visible range, which emphasise the architectural concept of the showcase.



CARPET FLOOR

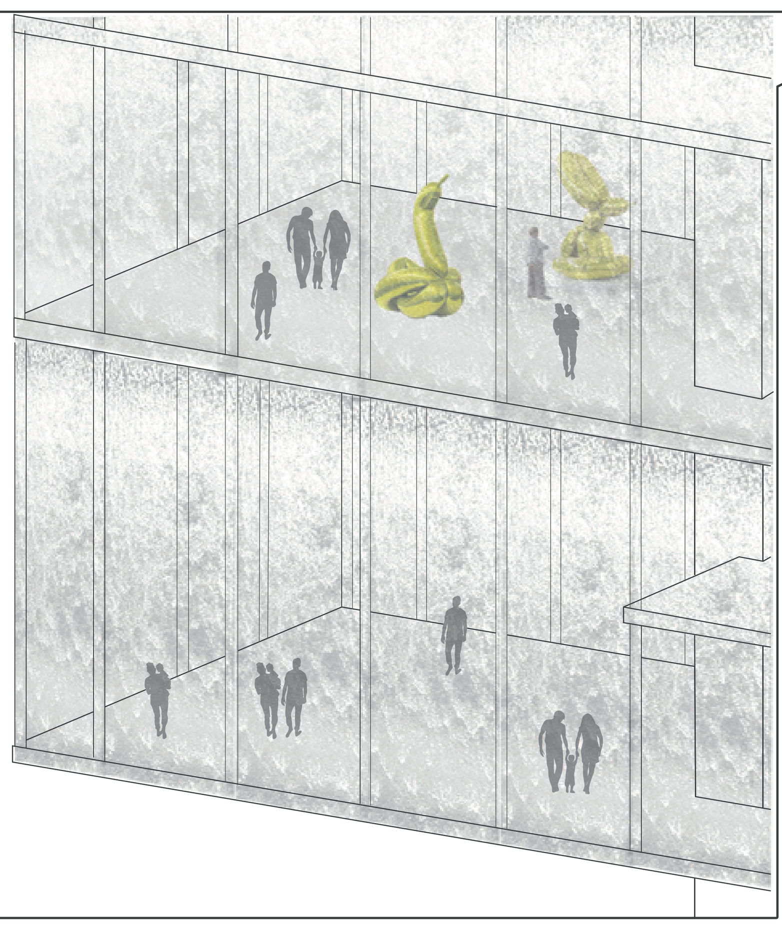
Museum floor is coverd with a carpet flooring system, chosen for its lightness, which helps keeping the structure light as well, for its acoustic properties and for its resistance.

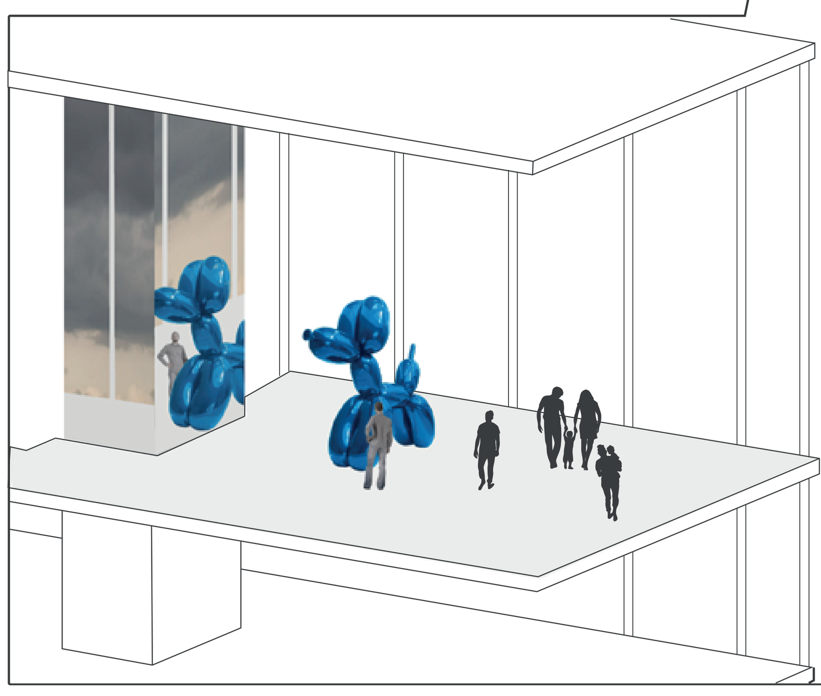




FLOWING WATER ON FACADES

Building facades are thought to be always washed by flowing water, which helps keep the interior fresh during hot sunny days.



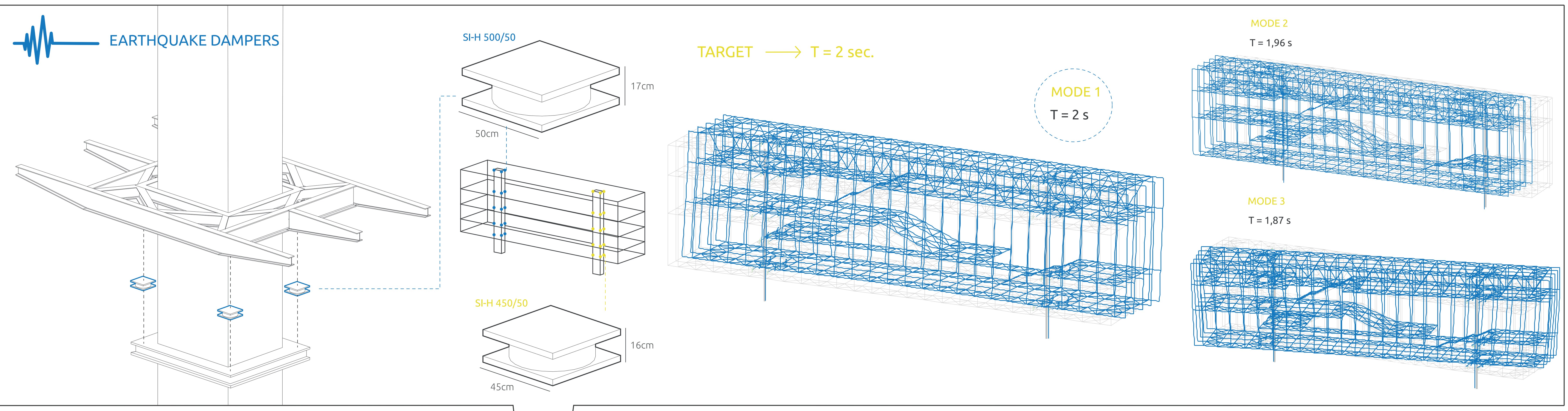


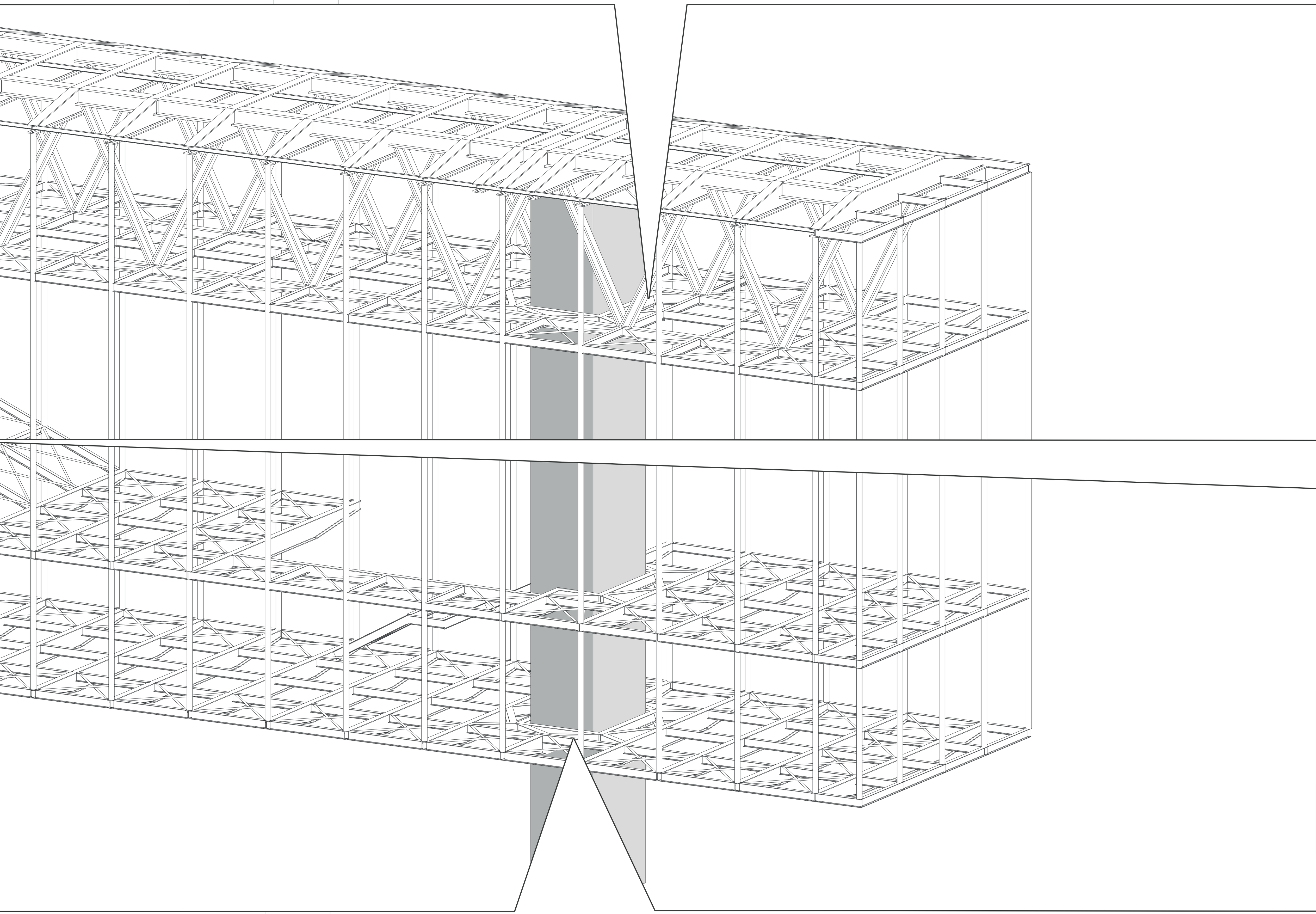
MIRROR PAINT

The two big columns are painted with a mirror finish, to make them disappe-ar inside the building and give more transparency to the showcase.

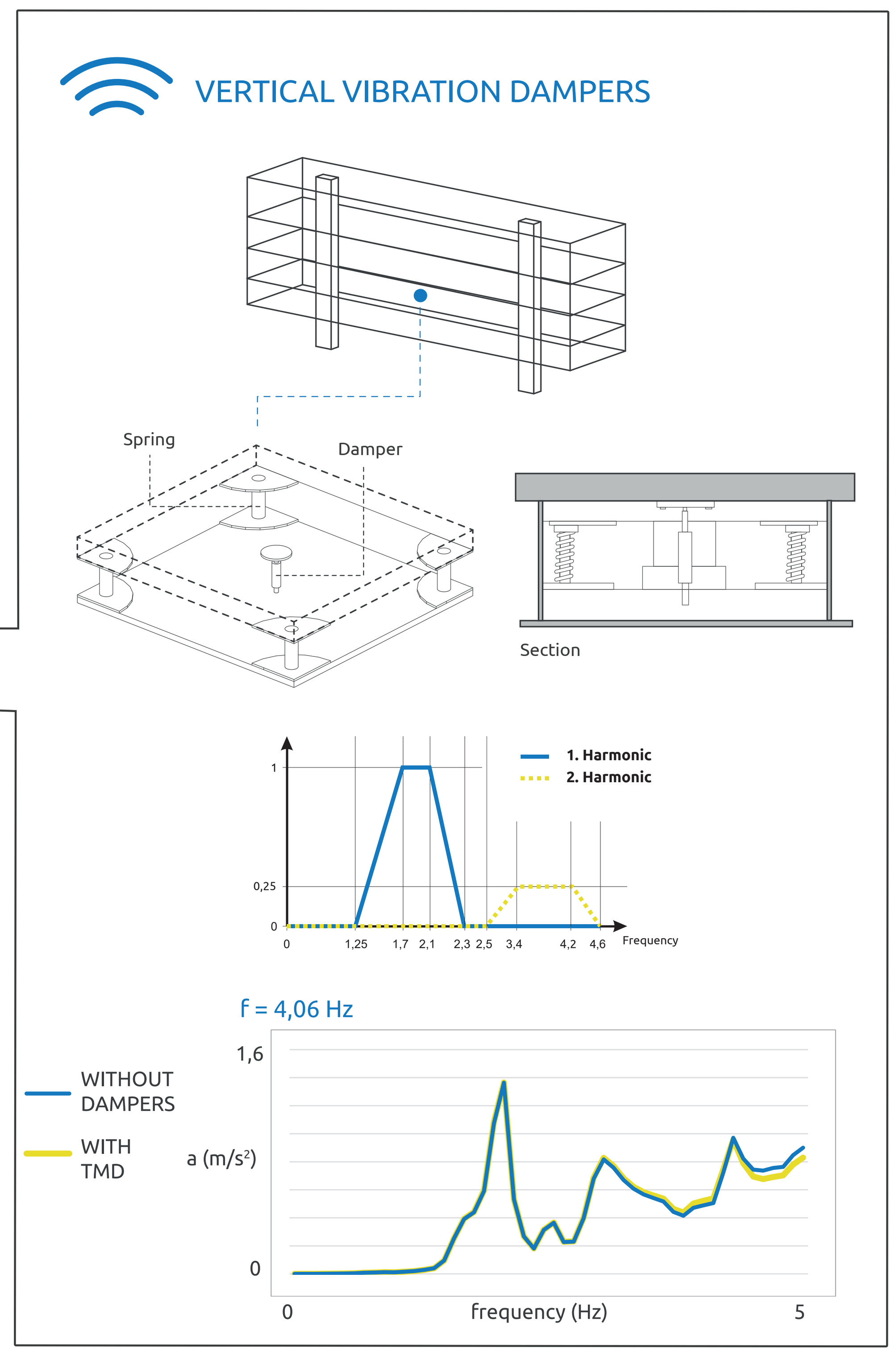
Painting them avoids to add extra weight to the structrure, that can be kept as light as possible.

EARTHQUAKE DAMPERS





VERTICAL VIBRATION DAMPERS



HORIZONTAL VIBRATION DAMPERS