Conservation and management of modern historic buildings: Recent works on heritage of Portuguese origin

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Why are good technical skills needed for existing structures?

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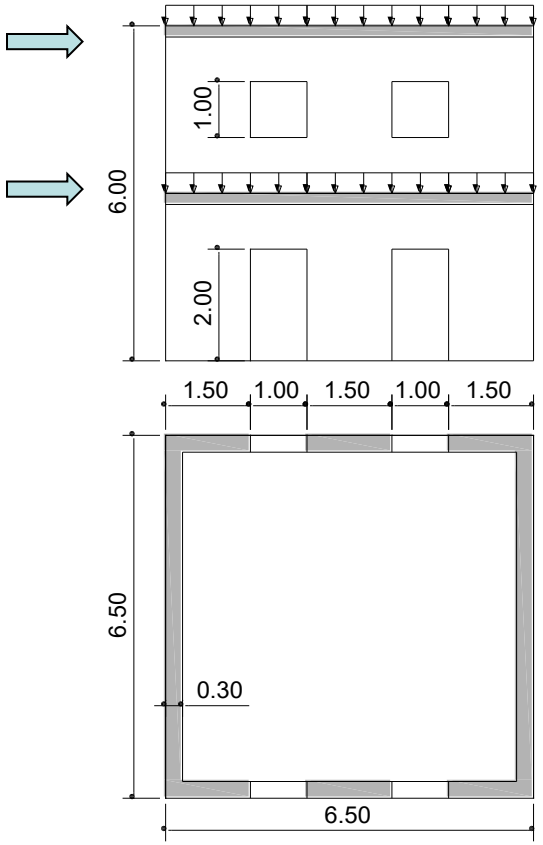
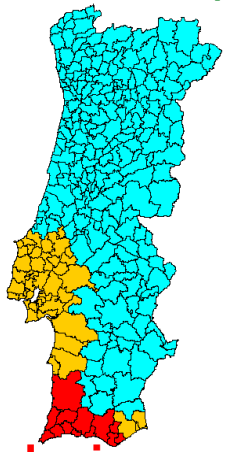
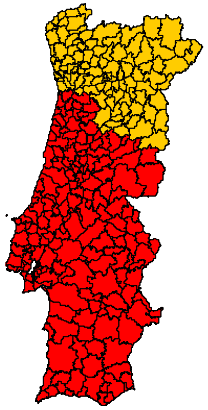
A perturbing fact: We need adequate assessment and design tools



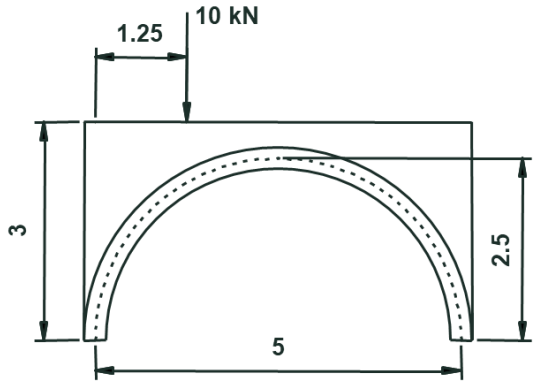
Good designer (nonlinear)



Bad designer and code (elastic)



Unsafe
Safe for good soil (rock)
Safe also for less good soil



Good designer (nonlinear, f_t = 0.2 N/mm^2)

Bad designer (elastic , f_t = 0.2 N/mm^2)

Built heritage and extreme events

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Buildings that must live forever





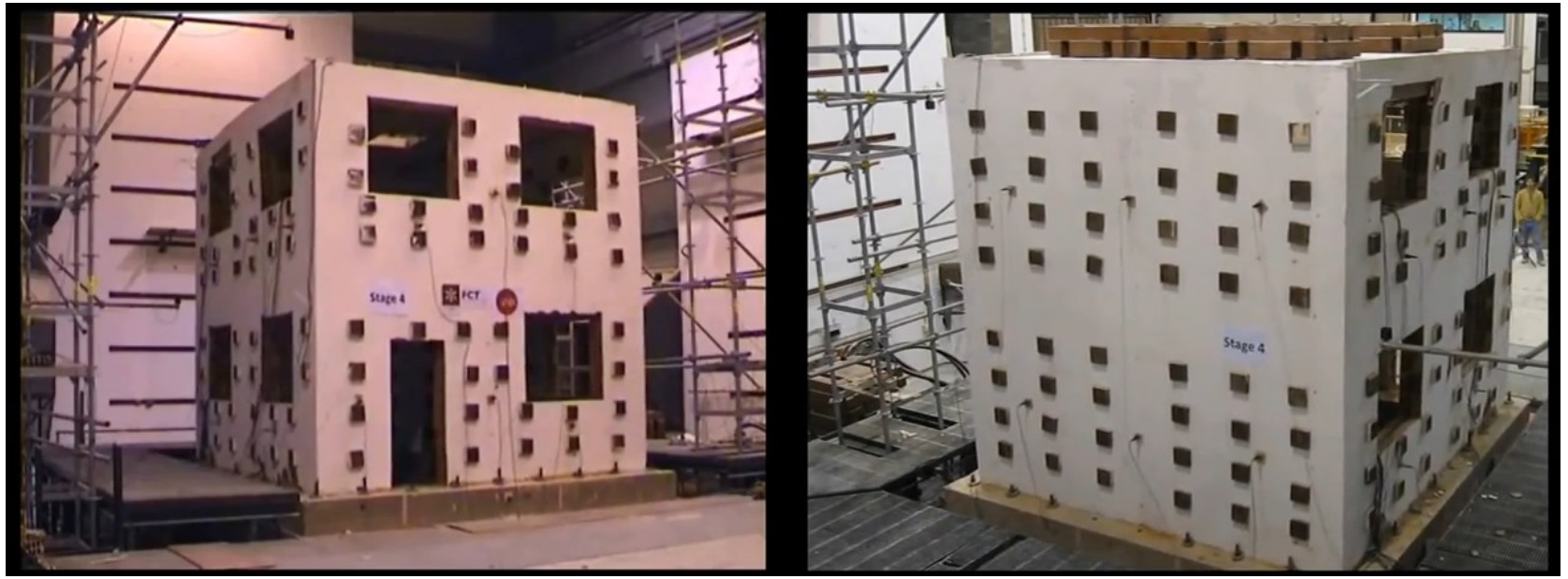

Lack of maintenance

Extreme events

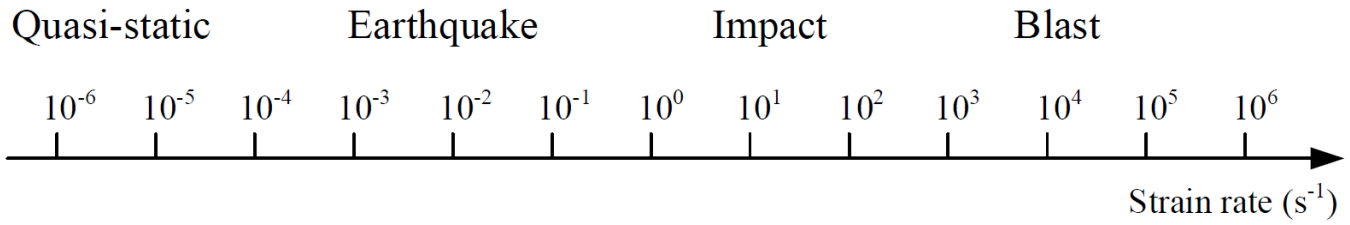
Earthquakes

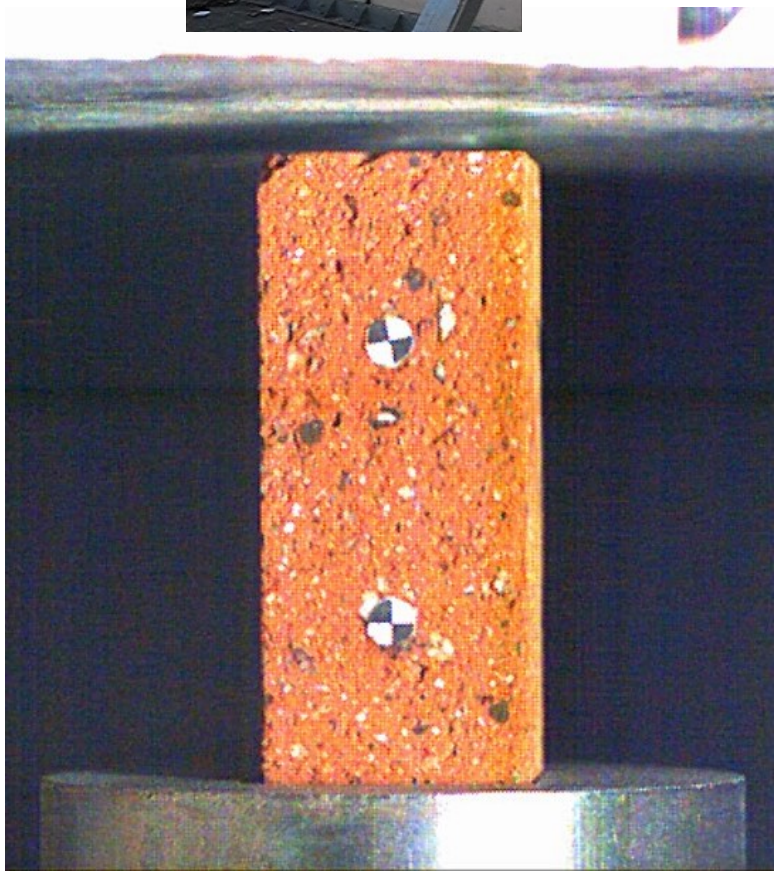
Existing buildings are often rather vulnerable (only conceived for gravitational loading):

- ❑ fragile materials
- ❑ heavy construction
- ❑ inadequate connections
- ❑ inadequate design and construction



Blast



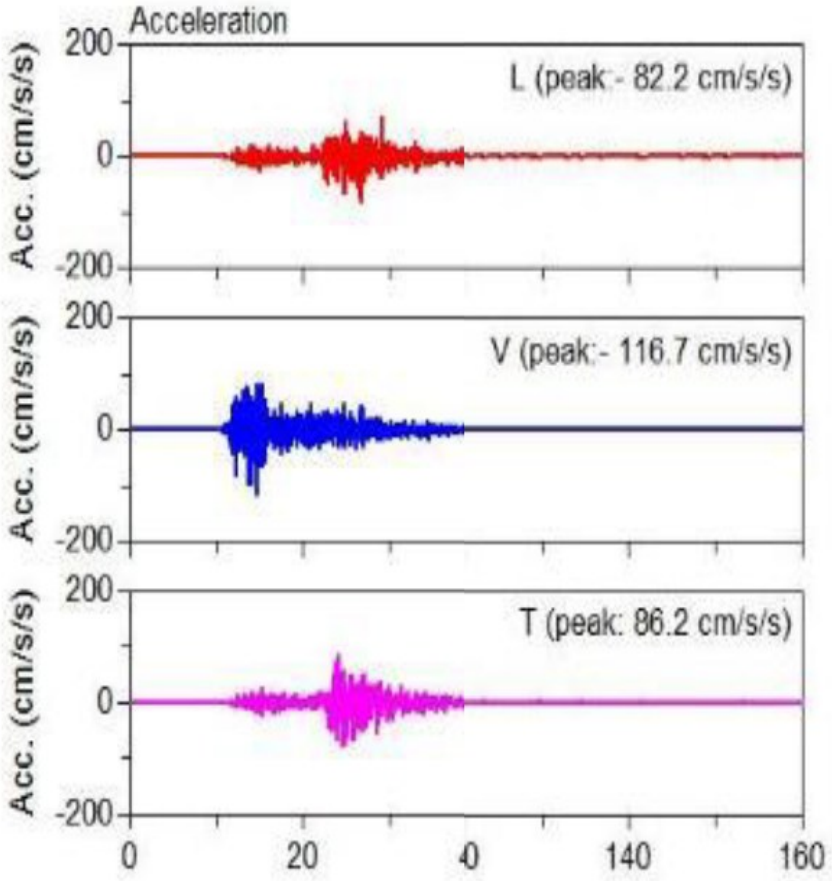


- Material properties change: Dynamic Increase Factor (DIF)
- Fast dynamics: Usually explicit analysis
- Much information for concrete & steel. Almost none for masonry

Example 1: Bagan, Myanmar (2016 Earthquake)

- Strong vertical component
- Minor damage
- 4 people killed

Type	Building	%	Damaged	%	% Damaged
C3L	62	0.89%	1	10.00%	1.61%
BB	5036	72.41%		0.00%	0.00%
S3		0.00%		0.00%	0.00%
TFM 1	622	8.94%	5	50.00%	0.80%
URML	84	1.21%	4	40.00%	4.76%
W1	1151	16.55%		0.00%	0.00%
Total	6955	100.00%	10	100.00%	0.14%



Seismic Amplification

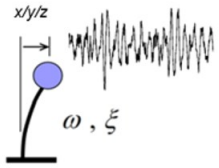


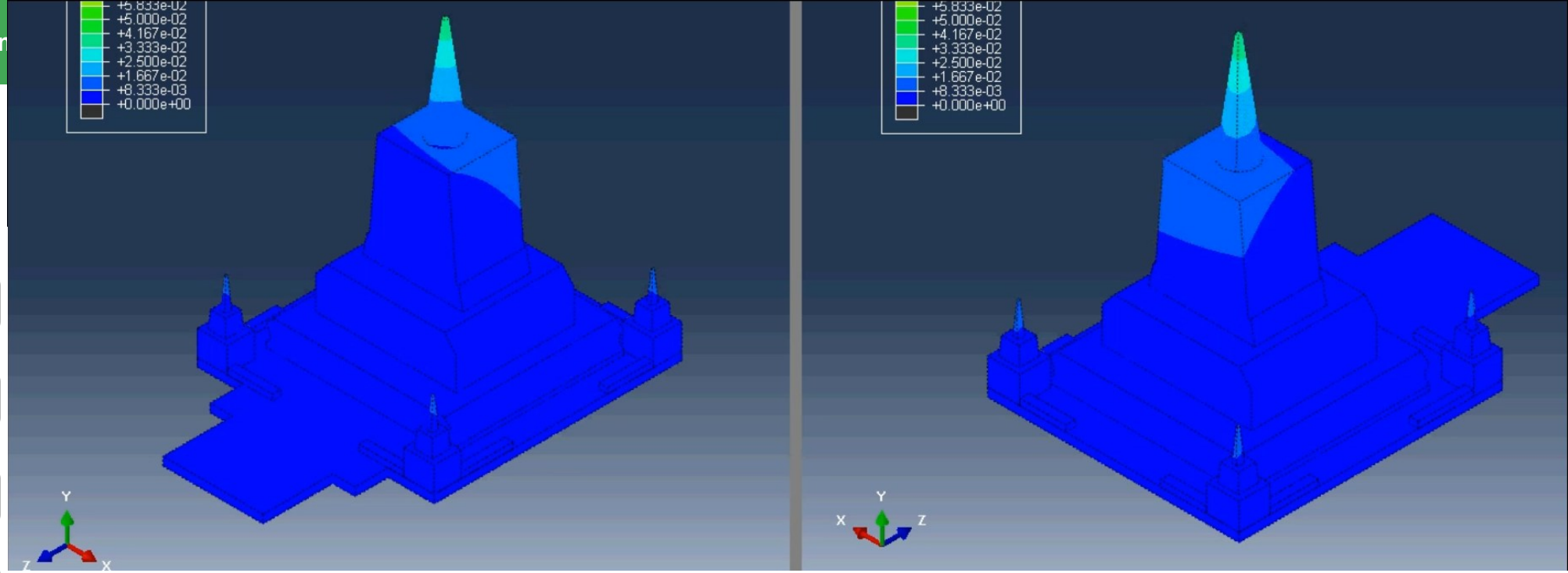


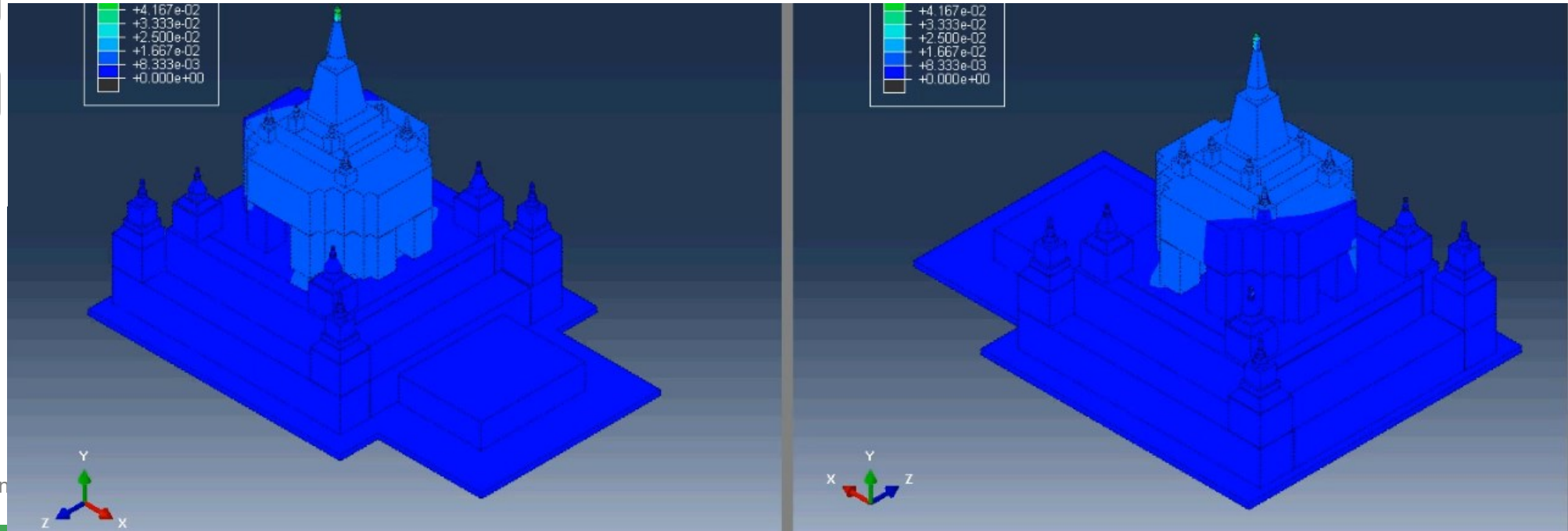

Collapse analysis of the stupas

1. Choice of the system's structural characteristics
2. Choice of the GM
3. Equations of motion
4. Computation of top displacements
5. Numerical Model's BC

$$\ddot{x} + 2\xi\omega\dot{x} + \omega^2 x = \ddot{x_g}$$
$$\ddot{y} + 2\xi\omega\dot{y} + \omega^2 y = \ddot{y_g}$$
$$\ddot{z} + 2\xi\omega\dot{z} + \omega^2 z = \ddot{z_g}$$



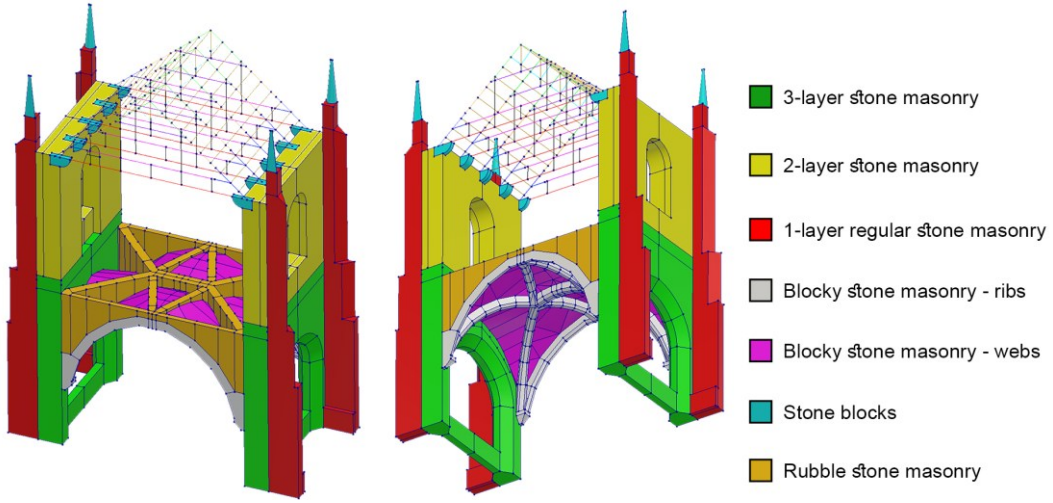


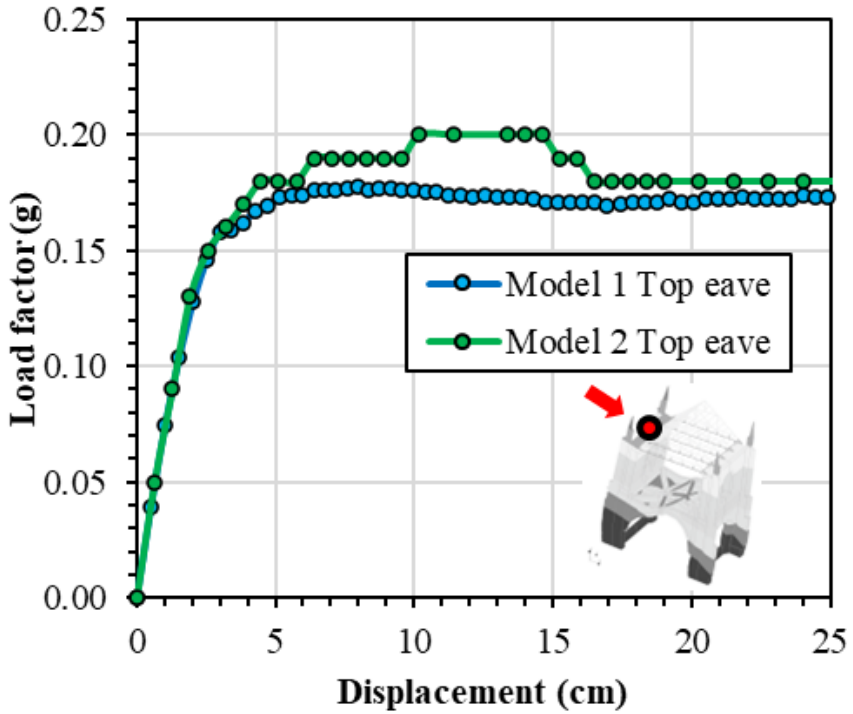


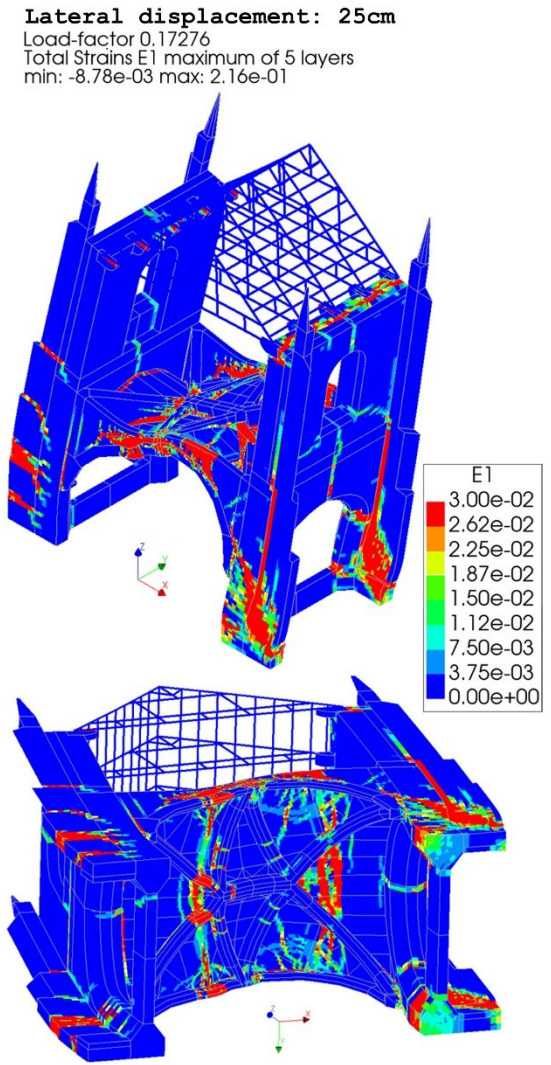
Example 2: National Museum of Archaeology, Lisbon

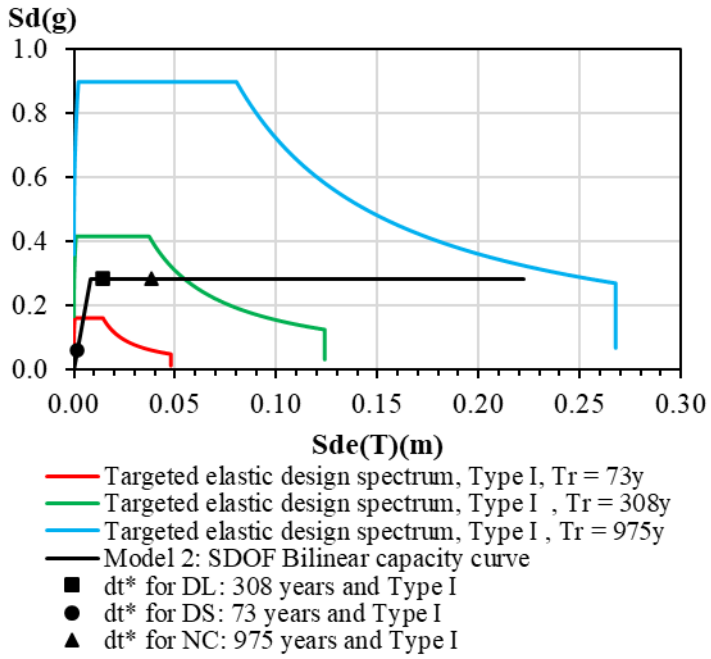
- Erected in the early 1500s near the launch point of Vasco da Gama's first journey
- Longest monument in Portugal (300 m in length), by approximately 50 m in width
- Largest renovation works in Portugal (50 M€?)

Safety Assessment

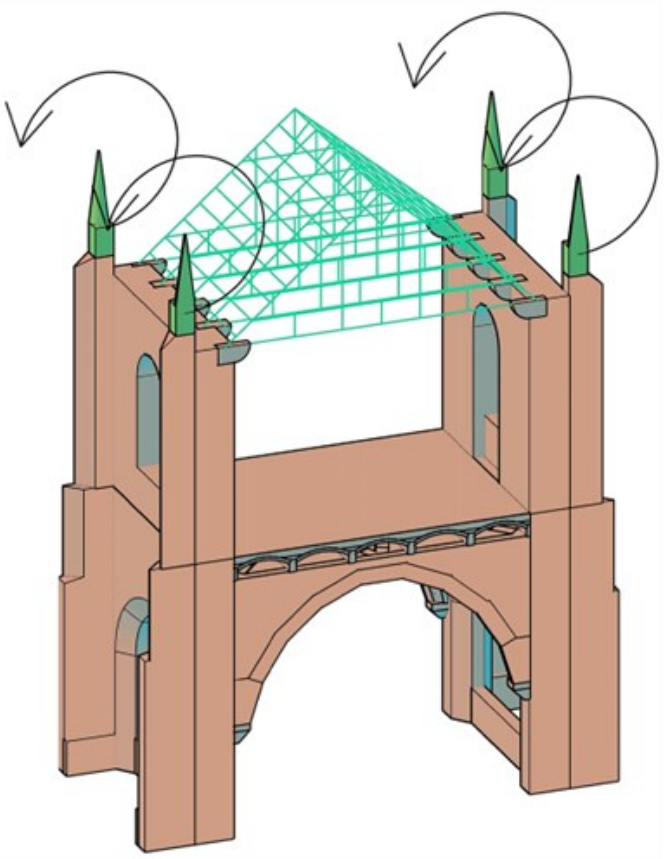


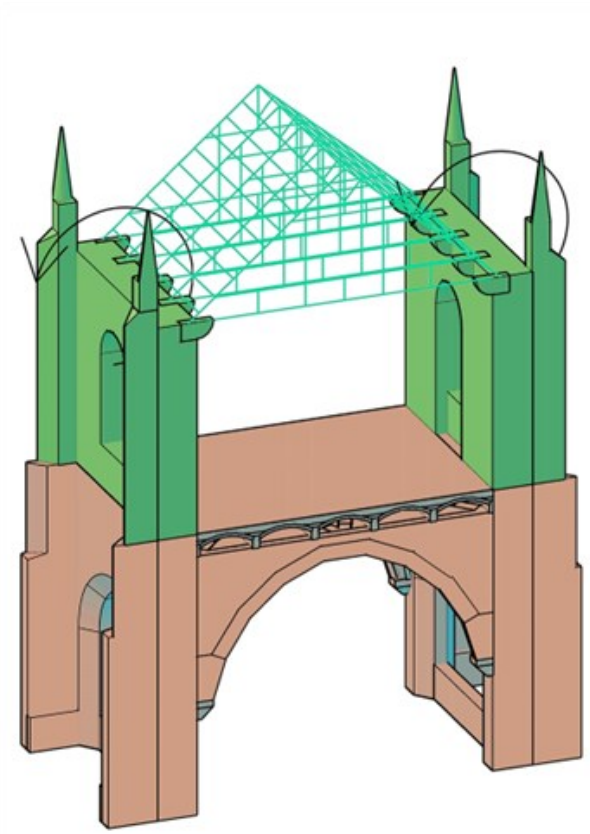


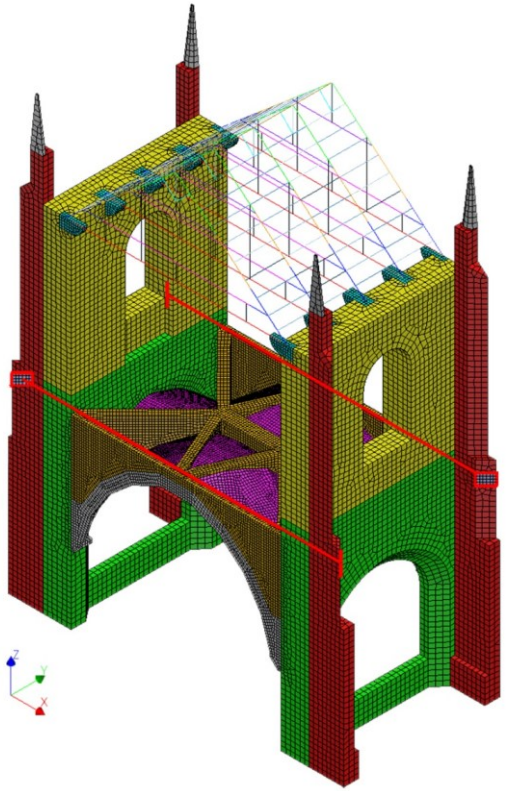




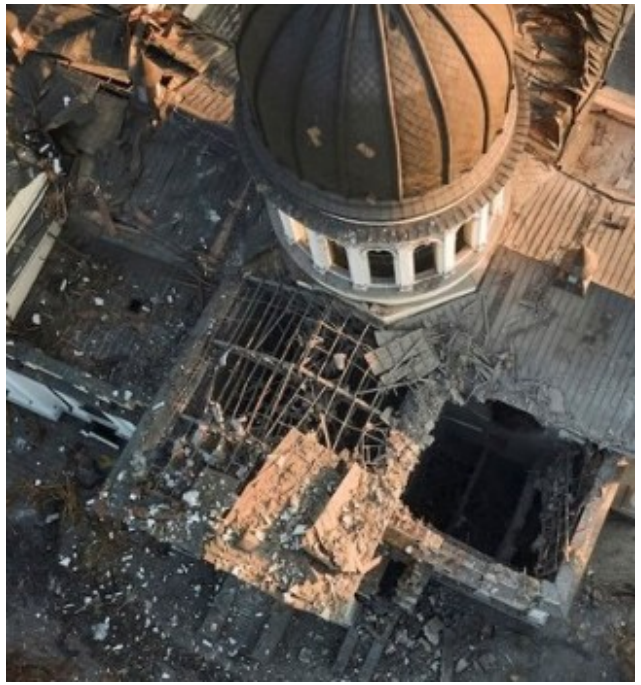
Strengthening

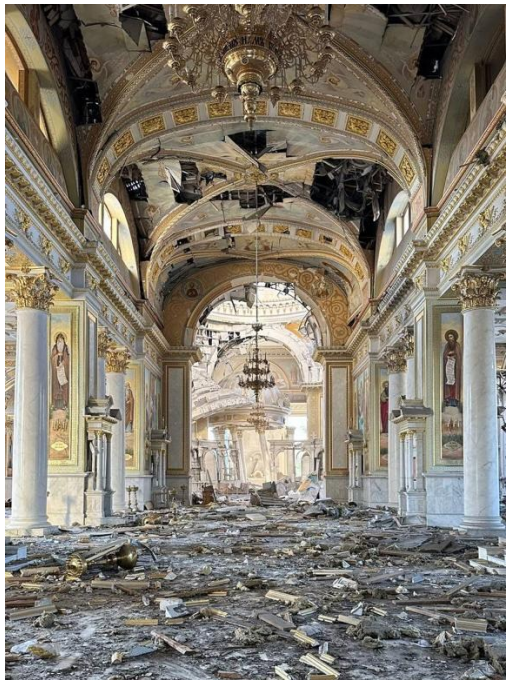






Example 3: Transfiguration Cathedral in Odesa, Ukraine

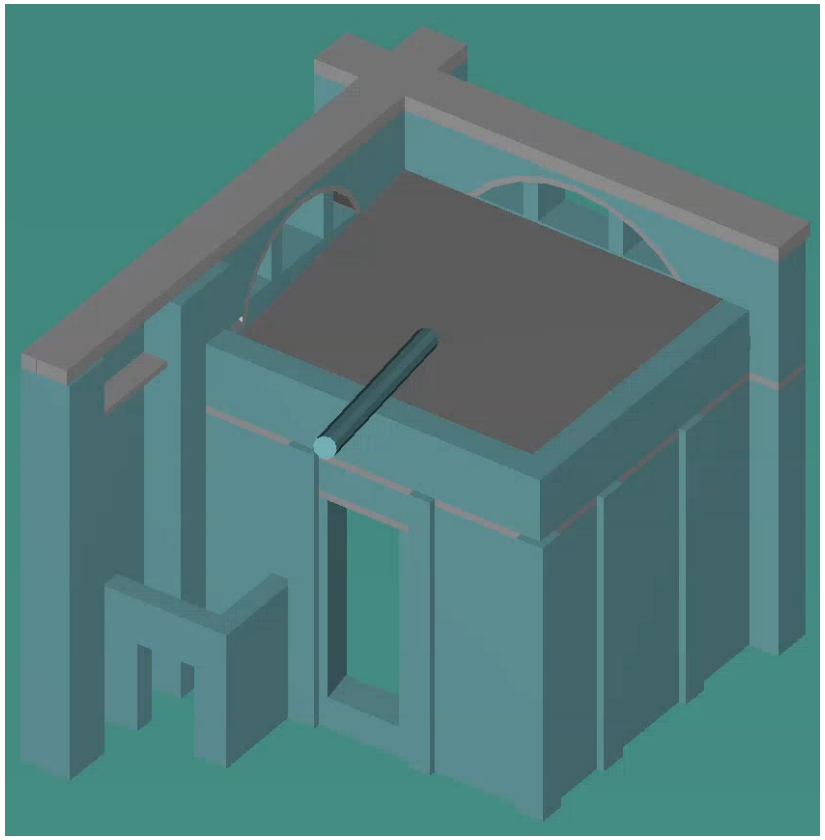


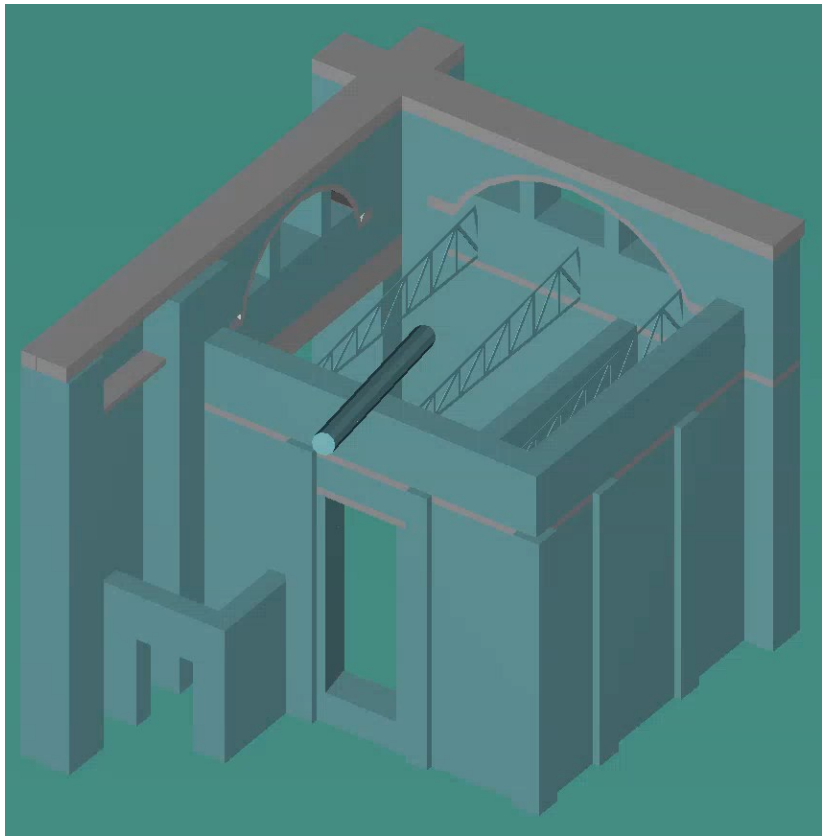


Attack

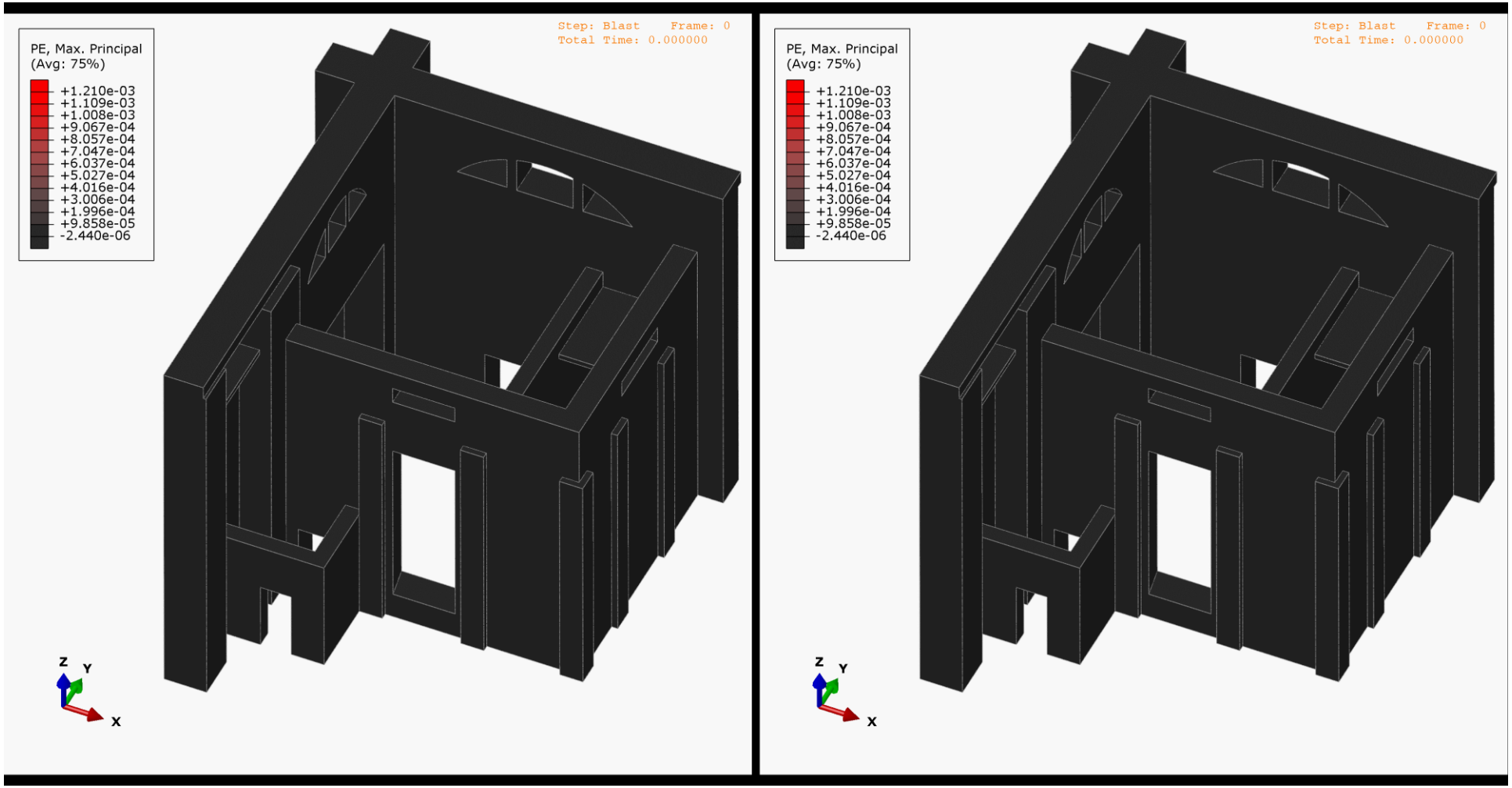
- Largest cathedral in the northwestern Black Sea region
- Demolished 1936 (Soviet struggle against organized religions). Rebuilt 2010
- Night July 22nd, 2023, hit by a missile

Justify damage, assess robustness, recommendations





Justify damage, assess robustness, recommendations



Approach to be used in conservation of heritage structures

“Guidelines for the Analysis, Conservation and Structural Restoration of Architectural Heritage”, ICOMOS – Iscarsah (2005)

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Our Technical Role

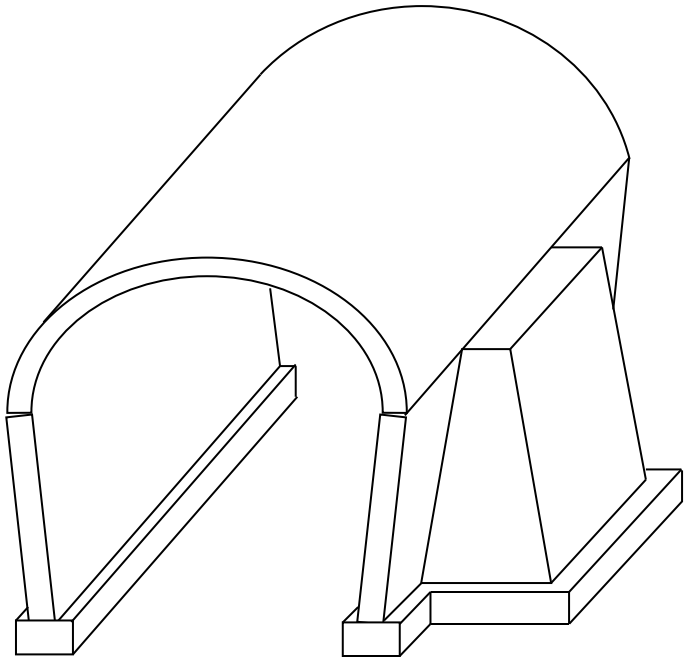
- Conservation is difficult and requires a different approach and skills from those employed in designing new construction

- Often historic fabric has been mutilated or destroyed by engineers who do not recognize this fact, with the approval of the authorities and other experts involved

- Even when conservation skills are employed, there are frequent attempts by regulating authorities and engineers to make historic structures conform to modern design codes

- The need to recognize the distinction between modern design and conservation is also of relevance in the context of fees. Taking no action may actually involve more investigative work and hence more cost to than recommending some major intervention

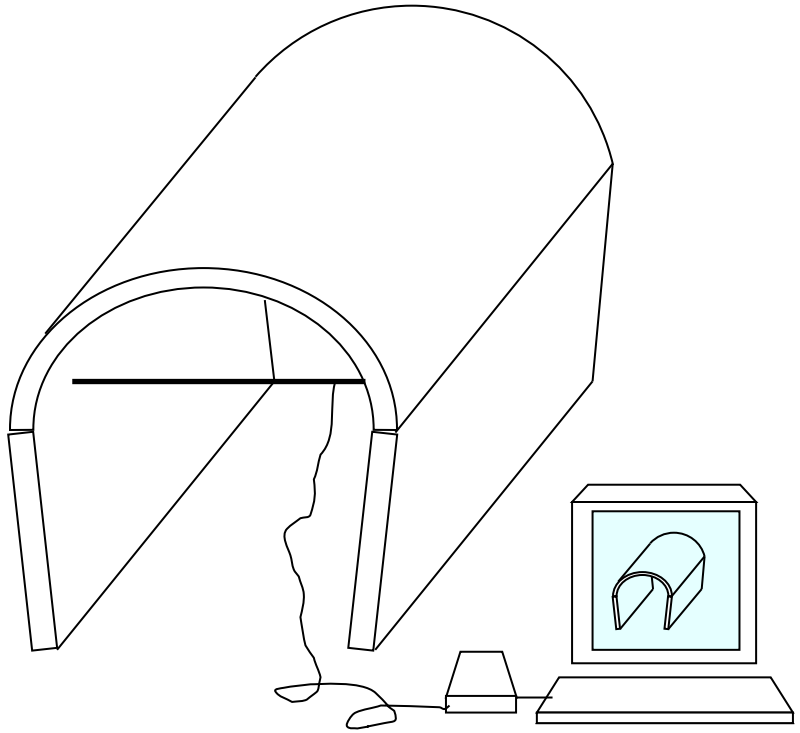
Past Understanding



- **“Conservation” is warranted by the powerfulness of the intervention**
- **Blind confidence in modern materials and technologies**
- **Mistrust towards original or ancient materials and original resisting resources of the building**
- **The value of original / ancient structure and structural principles is not recognized**
- **The importance of previous studies is not fully recognized**
- **Significant negative experience accumulated**

Athens Charter (1931)
Recommends the use of concrete and other modern material and techniques for restoration purposes. Added materials and components should be hidden to avoid altering the historical aspect of the building.

Current Understanding



- **Respect towards authenticity of the structure and structural principles governing its response**
- **Conservation should lie on knowledge and understanding of the nature of the structure and real causes of possible damage or alterations**
- **Minimal and respectful interventions (minimal, non-intrusive and reversible)**
- **Importance of previous study (comprising historical, material and structural aspects)**
- **The previous study and the intervention are multidisciplinary tasks requiring the cooperation of historians, architects, engineers, physicists,…**

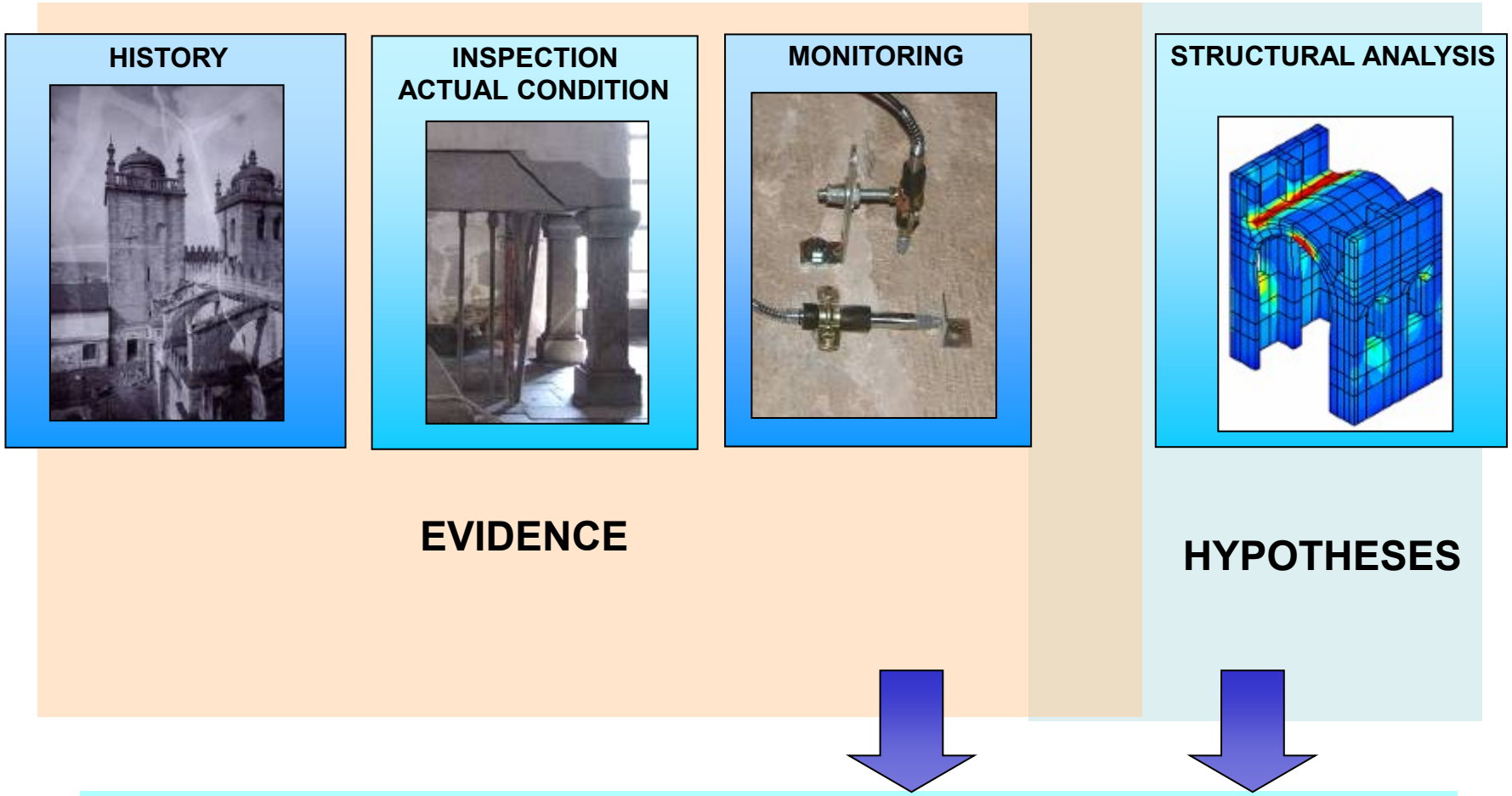
Venice Charter (1964)
Recommends the use of traditional or historical materials for stabilization or restoration. Suggests the use of modern materials / techniques for cases where it is not possible to stabilize or restore by means of traditional / historical techniques.

It must be possible to distinguish new materials or components from the original ones.

Current Understanding

The peculiarity of heritage structures, with their complex history, requires the organisation of studies and analysis in steps that are similar to those used in medicine. Anamnesis, diagnosis, therapy and controls, corresponding respectively to the condition survey, identification of the causes of damage and decay, choice of the remedial measures and control of the efficiency of the interventions.

Methodology to be adopted in the study of existing structures



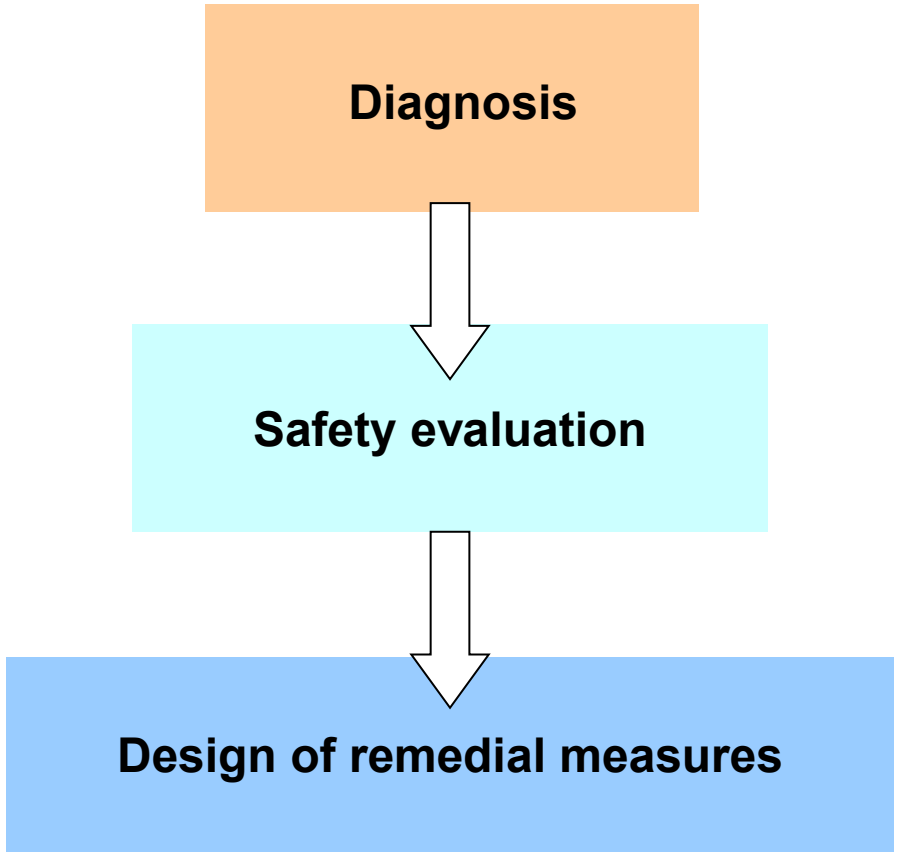
Specificity

Complexity

Subjectivity

Specialized engineering

Steps of the study



Identify causes of damage and decay

Determine acceptability of safety levels by analyzing present condition of structure and materials

Lay-out repair or strengthening actions to ascertain the required safety

Diagnosis and safety evaluation of the structure are two consecutive and related stages on the basis of which the effective need for and extent of treatment measures are determined. If these stages are performed incorrectly, the resulting decisions will be arbitrary: poor judgement may result in either conservative and therefore heavy-handed conservation measures or inadequate safety levels

Safety. Uncertainty and subjectivity

- Historical approach
  - Knowledge of the history (Building as a full scale / real time test)

- Qualitative approach
  - Inductive process (Comparison and extrapolation of similar cases)

- Quantitative approach
  - Deductive process (Structural analysis)

- Experimental approach
  - Tests in components or structures

Key aspects

- ❑ Scientific approach
- ❑ Combination of different sources and approaches
- ❑ Methodological consistency
  - Using similar approaches for diagnosis, safety evaluation and design of intervention
- ❑ Subjectivity is still possible
- ❑ Importance of personal judgment
  - Recognize the need for experts and the value of their personal judgment
- ❑ Need for an explanatory report

Version 2.0 (2024)
Iscarsah Guidelines

20th century and beyond: The making of a new world

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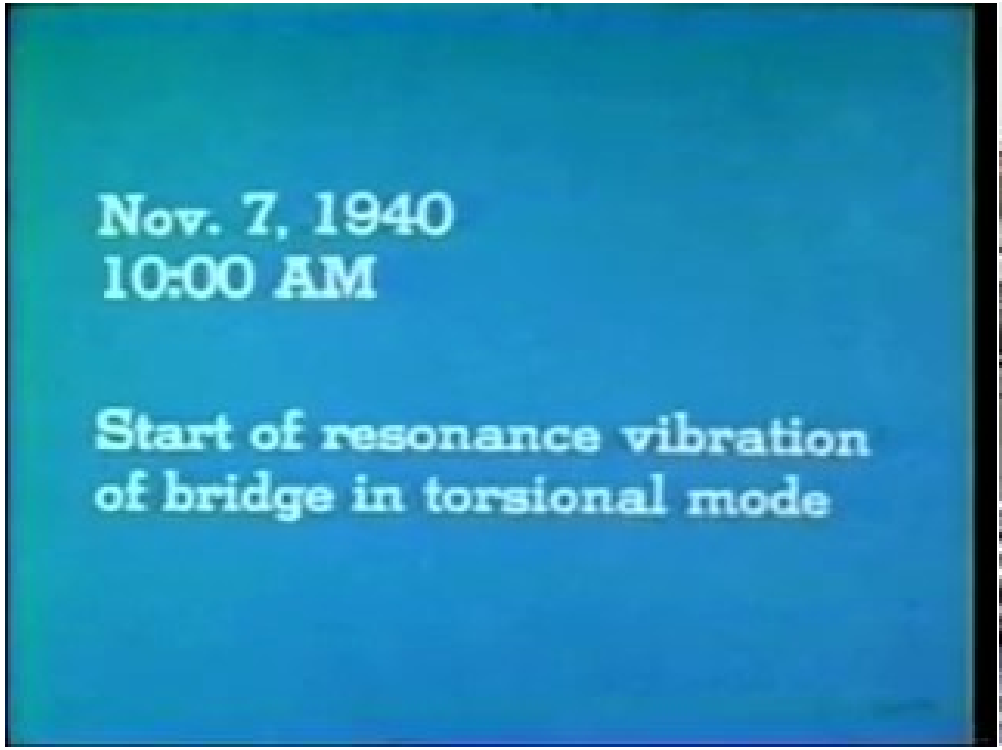
Conceptual errors and code changes

Ronan Point, 1968
Disproportionate collapse



Tacoma Narrows Bridge, 1940
Flutter instability

Millennium Bridge, 2020
Lateral frequency modes

Other critical examples

- Prestressed bridge ban in UK, after several post-tension bridges collapsed in a short period of 10 years
- 25 September 1992: Department of Transportation banned post-tensioned grouted duct techniques from UK bridge construction. Lifted after 4 years and 20-million-euro study

- A timber bridge in Norway ‘built to last 100 years’ collapses after a decade on 15 August 2022
- Bridge was inspected along with other wooden truss bridges in 2016 following the collapse of Perkolo Bridge, another timber crossing in Norway

Built cultural heritage and the 20th century heritage

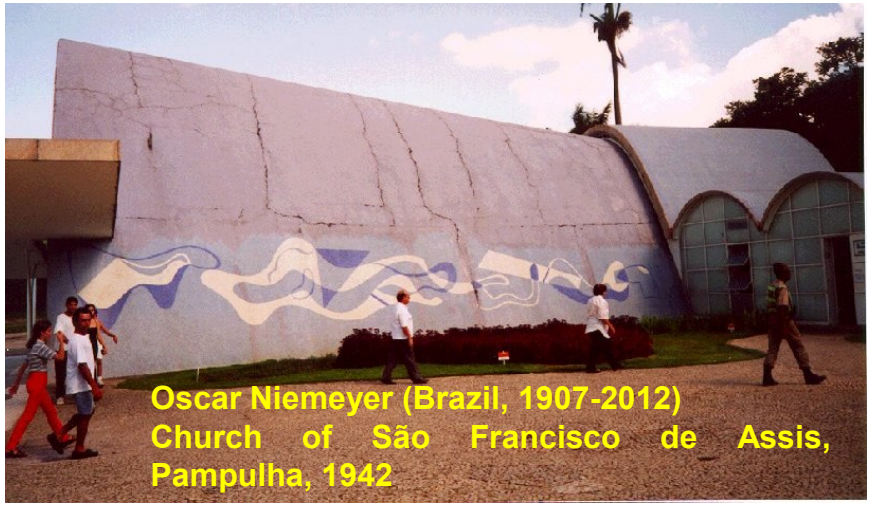
- In the 20th century, architects and engineers used experimental materials and new construction techniques to create innovative forms and promote new philosophical approaches to architecture

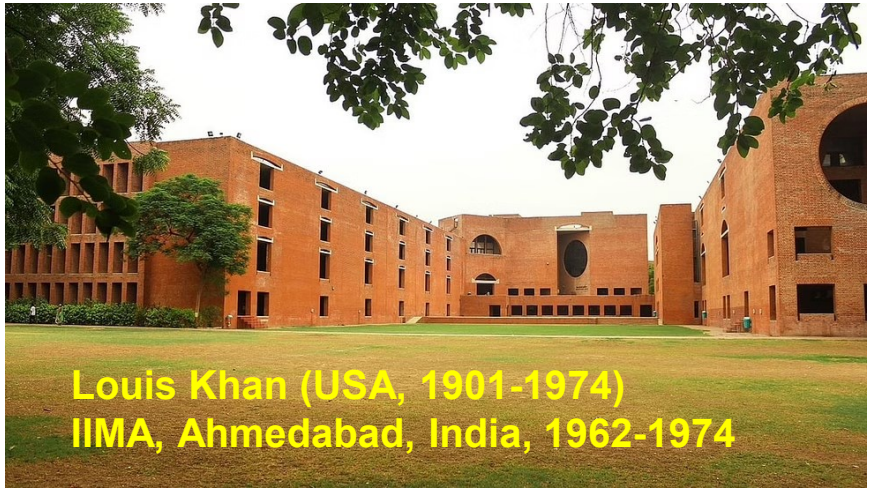
- This heritage is at considerable risk. Many of these building materials and structural systems have not been tested and have not performed well over time

Deterioration

- RC shells are very expressive and organic. However, the material exhibits a short durability as, commonly, reinforcement bars have a thin cover

- You say to brick, “What do you want, brick?” Brick says to you, “I like an arch.” if you say to brick, “arches are expensive, and I can use a concrete lintel over an opening. What do you think of that, brick?” Brick says: “I like an arch.” - Louis Kahn
- I’m now wiser from that time. Now I can say that reinforcement was a recipe for a disaster” Architect MS Satsangi from the team in Ahmedabad, 2015


Oscar Niemeyer (Brazil, 1907-2012)
Church of São Francisco de Assis, Pampulha, 1942


Louis Khan (USA, 1901-1974)
IIMA, Ahmedabad, India, 1962-1974

Example 1: Swimming Pools at Leça da Palmeira, Portugal, by Álvaro Siza

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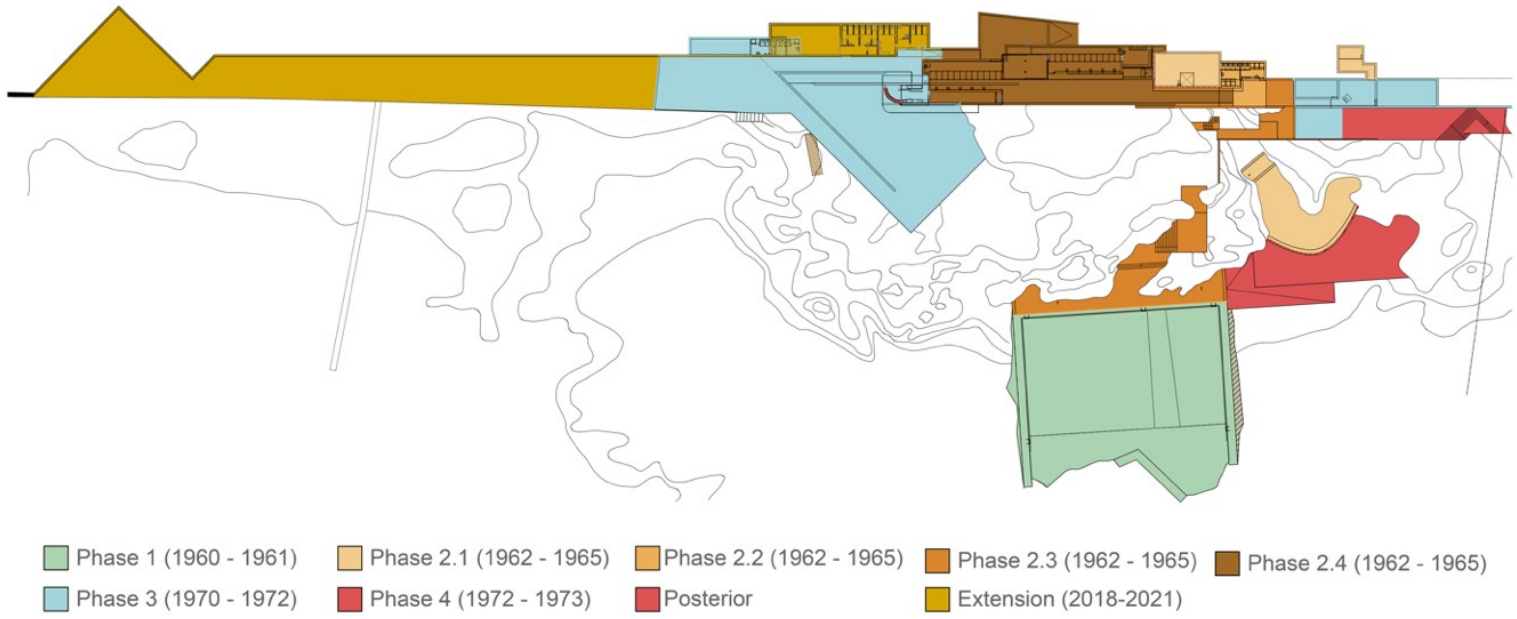
Swimming Pools at Leça da Palmeira, Portugal
Keeping It Modern Grant 2020: Getty Foundation



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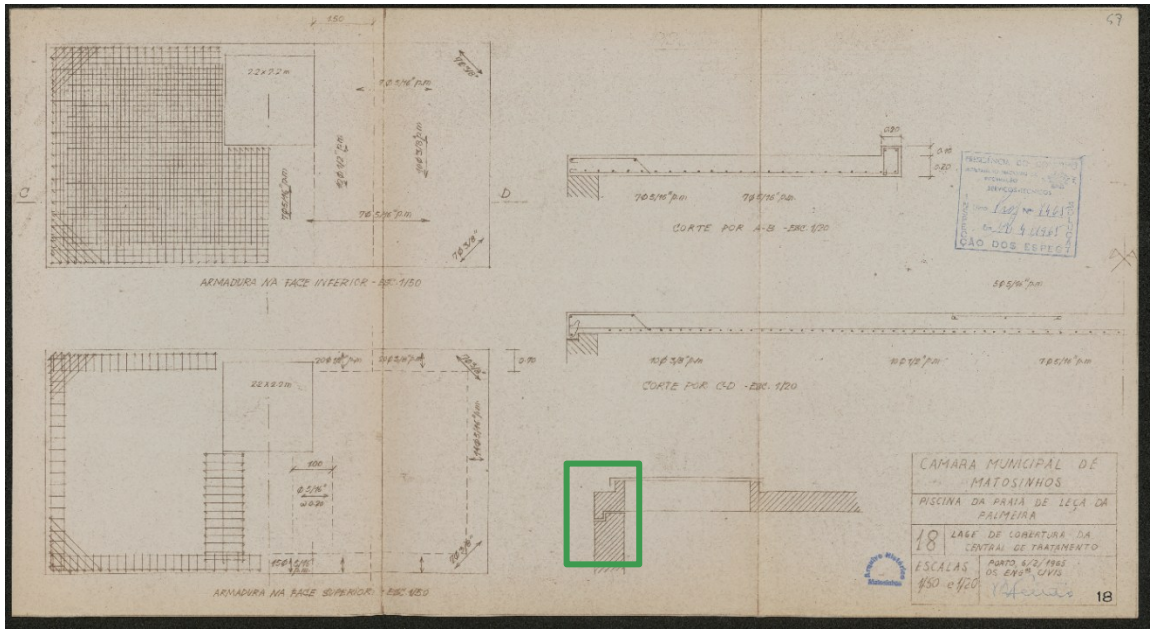
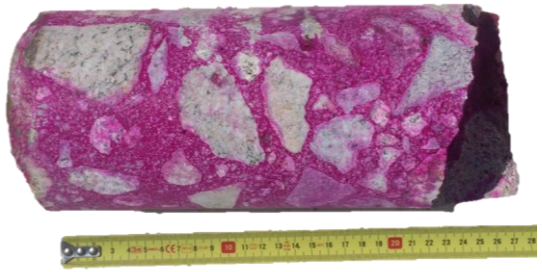
Prof. Teresa Ferreira

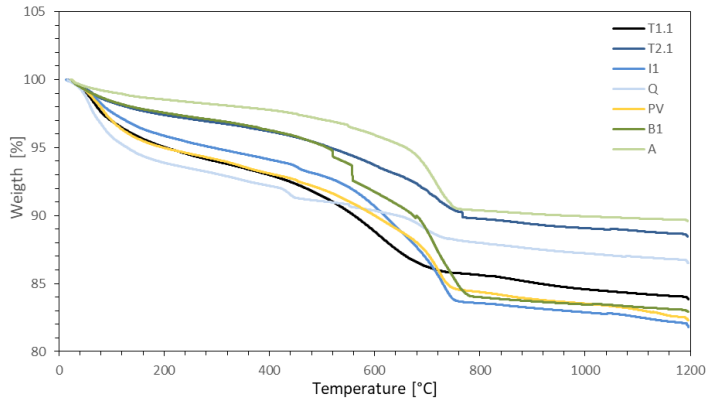
Selected works

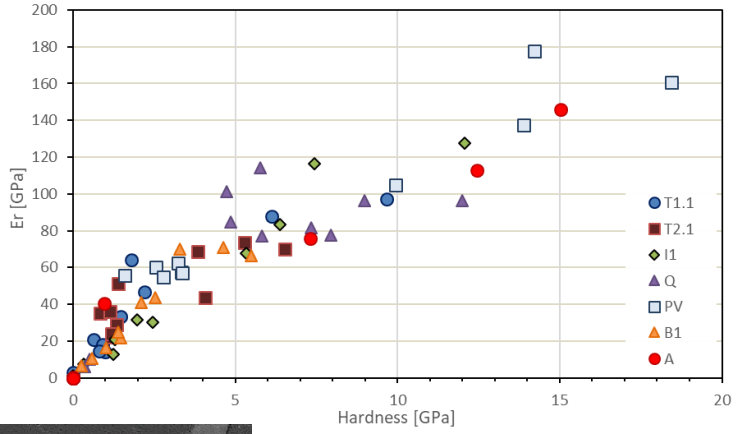


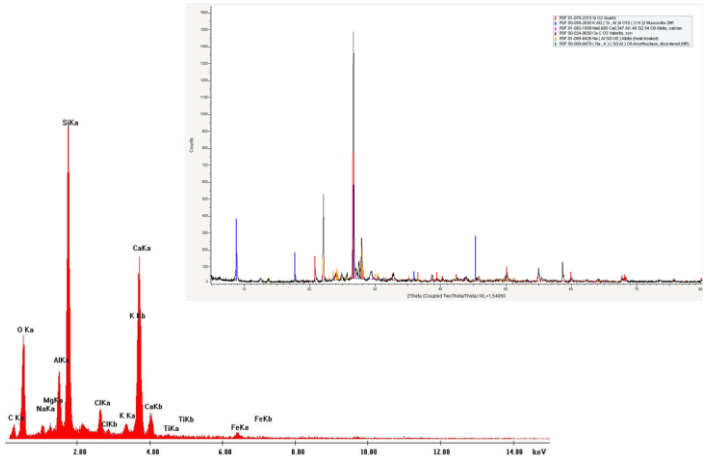


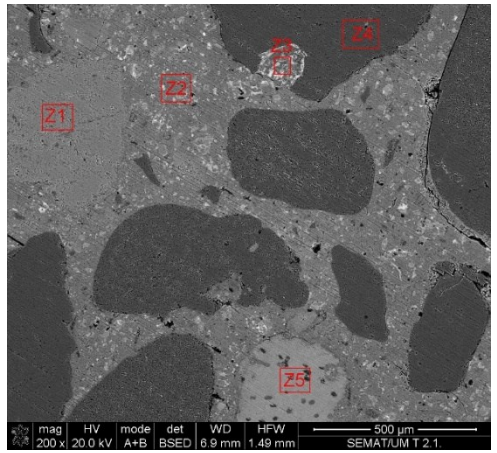
Concrete and steel strength testing

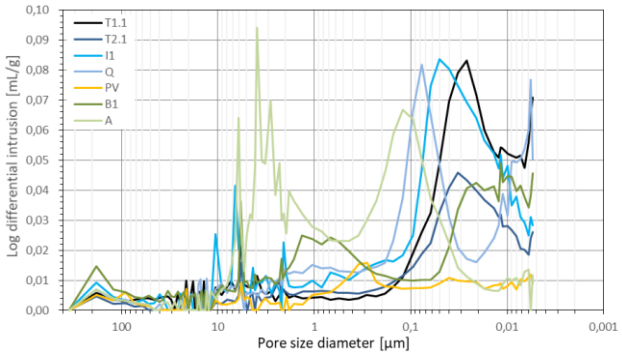
Non-destructive testing: Sonic, chloride content, water penetration, Schmidt hammer, color



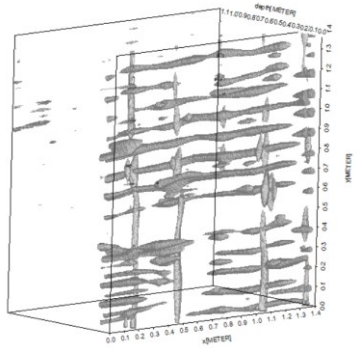


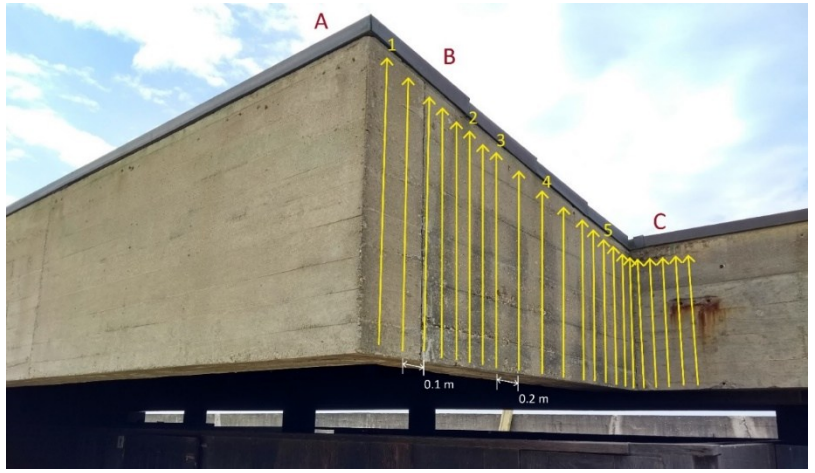


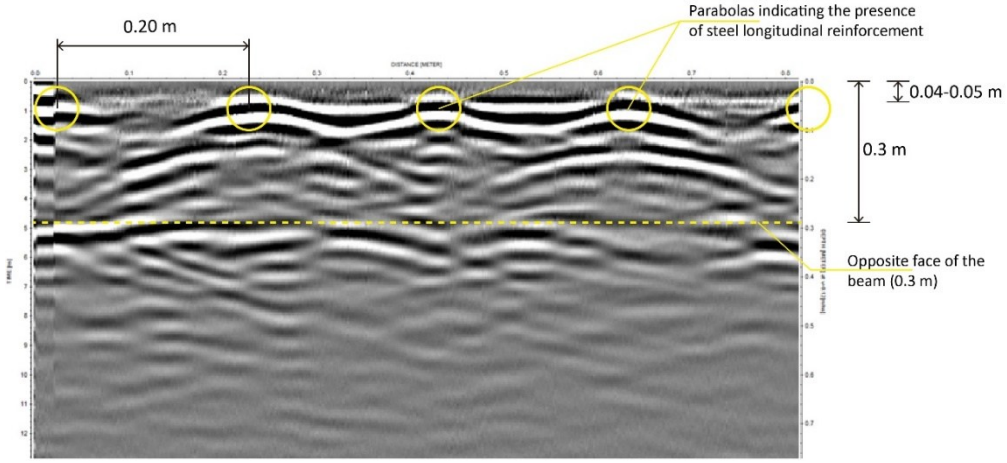




Cement paste characterization: Thermogravimetry, nanoindentation, X-ray analysis and diffraction, scanning electron microscopy, mercury intrusion porosimetry




A
B
C
1
2
3
4
5
0.1 m
0.2 m

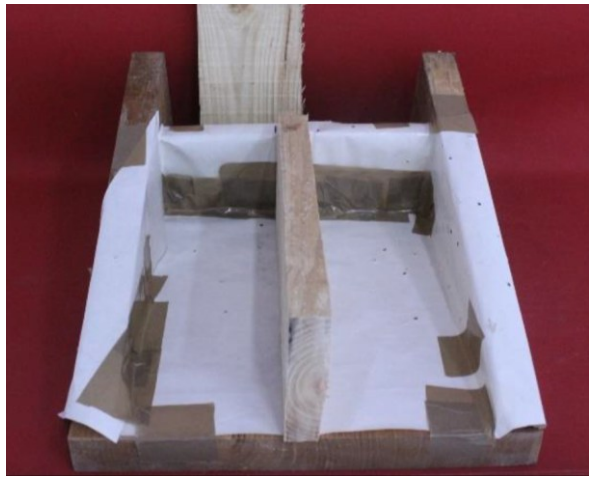

0.20 m
Parabolas indicating the presence of steel longitudinal reinforcement
0.04-0.05 m
0.3 m
Opposite face of the beam (0.3 m)

GPR testing

Repairs

Large volume loss and shrinkage / thermal movement

Displaced fragment, volume loss and biological colonization



Wooden molds

Replicating original formwork

Materials: Sand, gravel, yellow granite powder, black limestone powder, pigments, natural cement and regular cement

Selection of the sample by Arch. Álvaro Siza

Cleaning and biocide

Stainless steel installation

Mold, silicon paper and mortar filling

And the NO repair approach (or correcting inadequate past repairs)



Example 2:
Social housing in Porto

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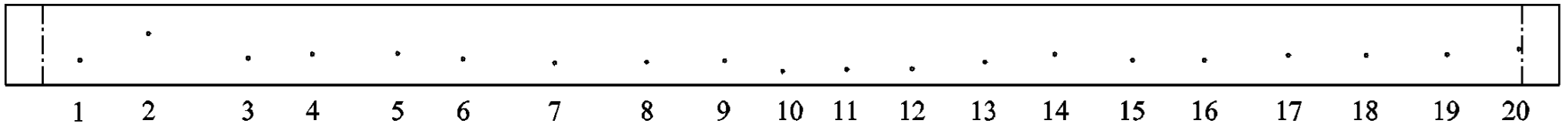
Example 2: Social housing in Porto

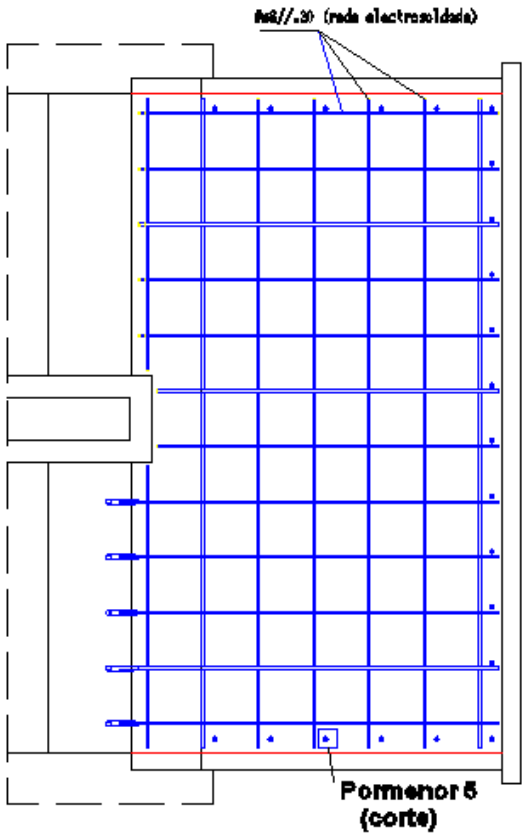
- **Municipality of Porto is the largest landlord in Portugal (40.000 tenants)**
- **Built around 1960's with reinforced concrete / structural masonry systems**
- **Include 4500 balconies**
- **An accident occurred: collapse of one balcony with three injured, after 200-million-euro investment in rehabilitation**

Inspection

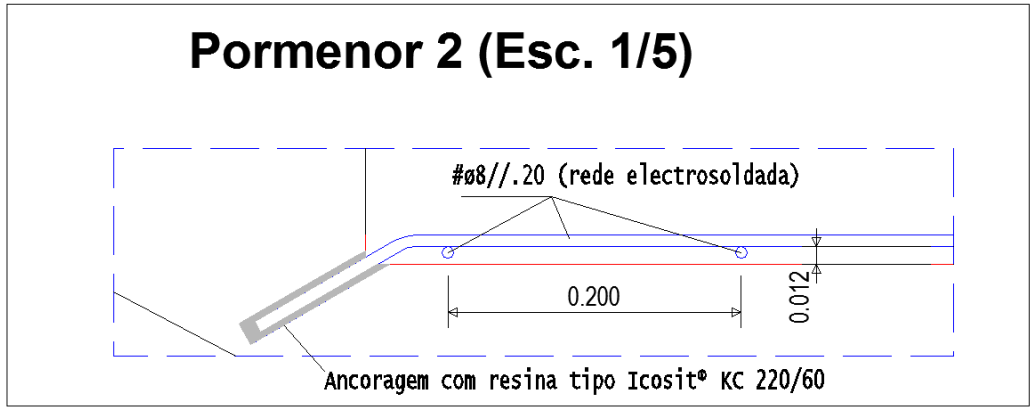


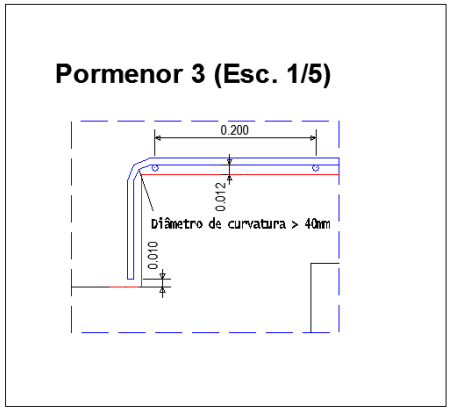
Reinforced concrete overlay

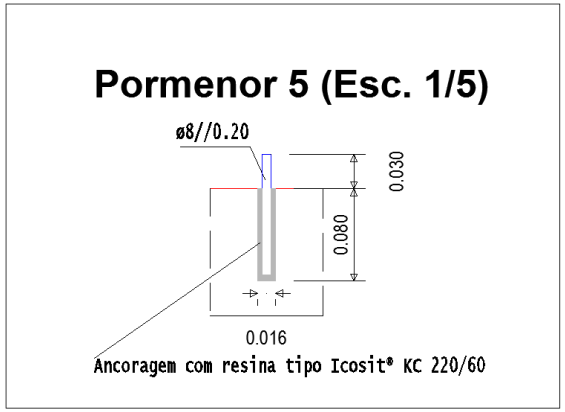
Planta



(Esc. 1/25)







Execution

Staircase (go down)

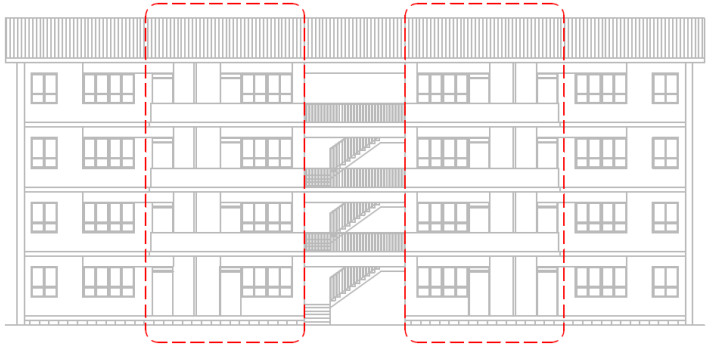
Staircase (go up): Upper view

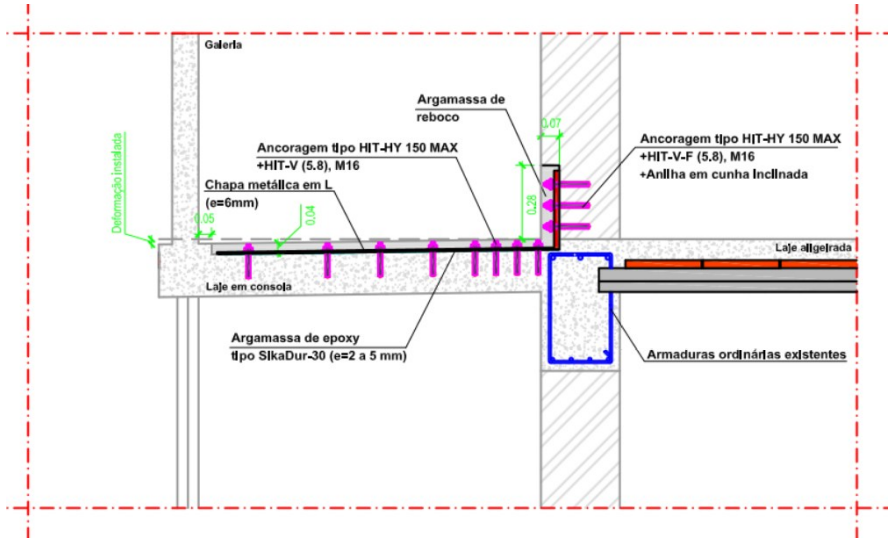
Lower view

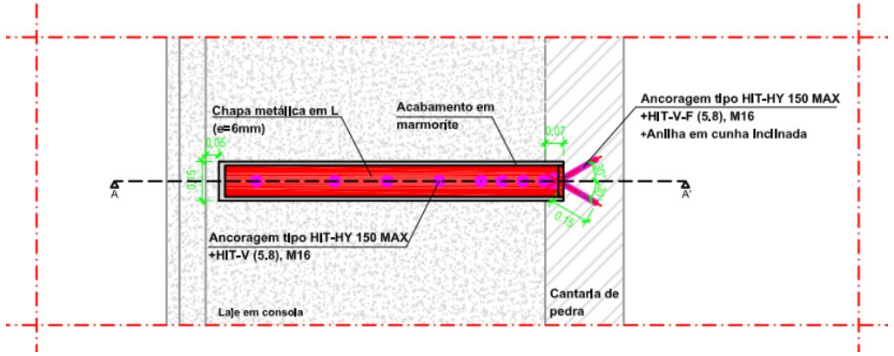
Steel Plates

Studied solutions:

- **External steel solution**
- **Steel profiles placed in the lower part of the slab**







Notes:

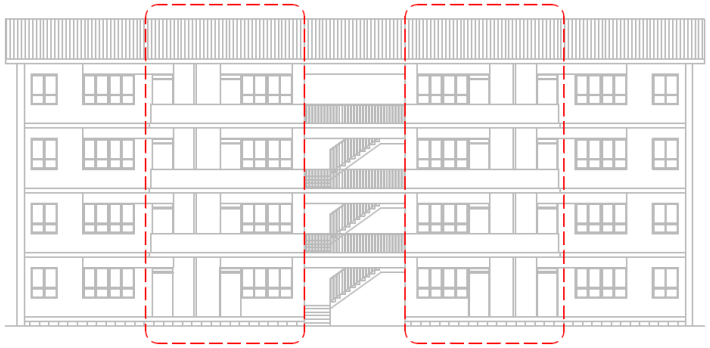
- **Steel protection**
- **Welding control (before EN1090)**

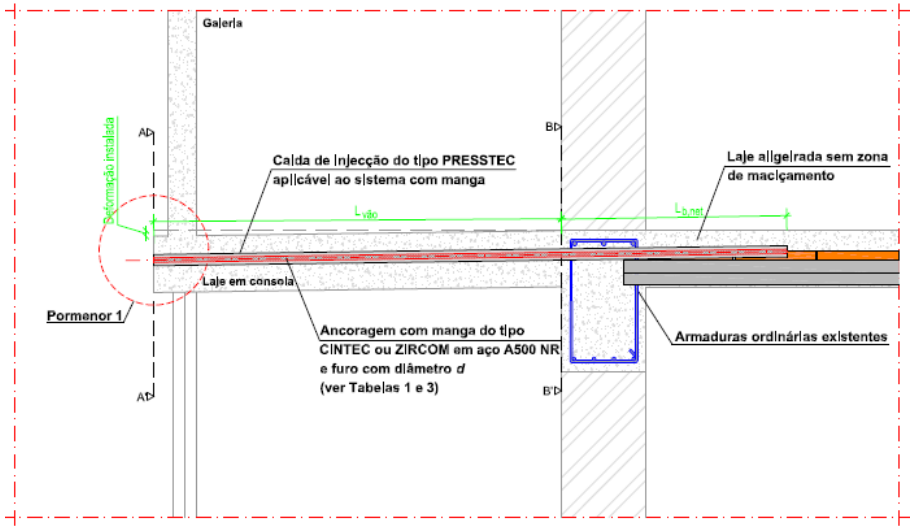
Execution






Coring new bars

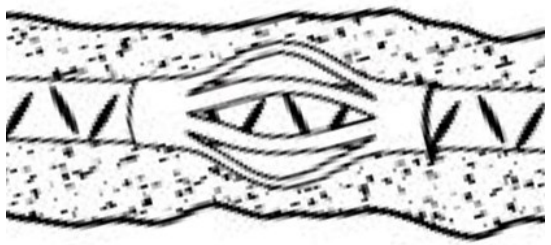


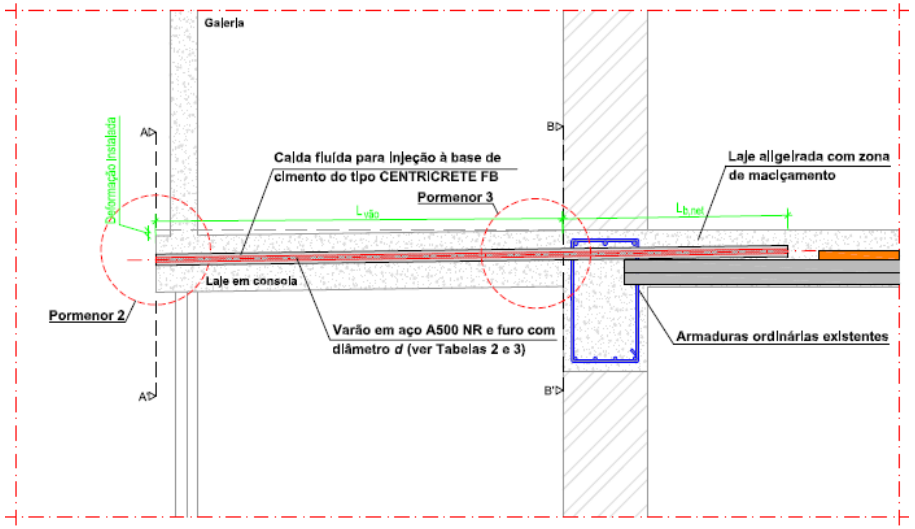


Nailing with and without socket

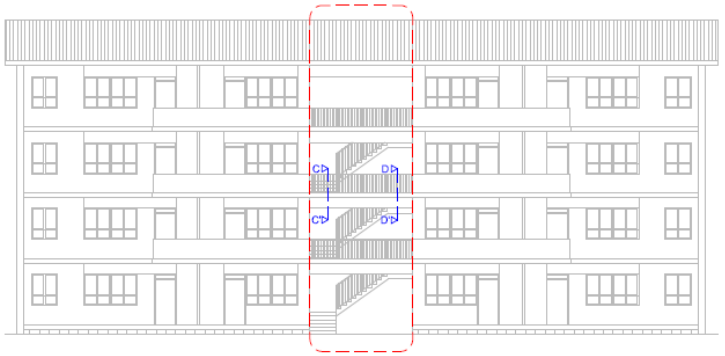
Notes:

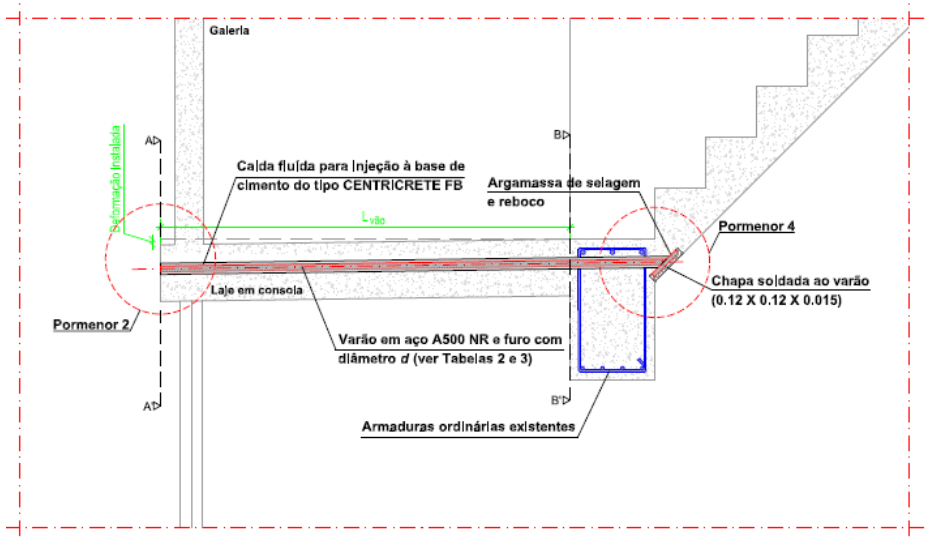
- **Spacers**
- **Injection inlet / outlet**

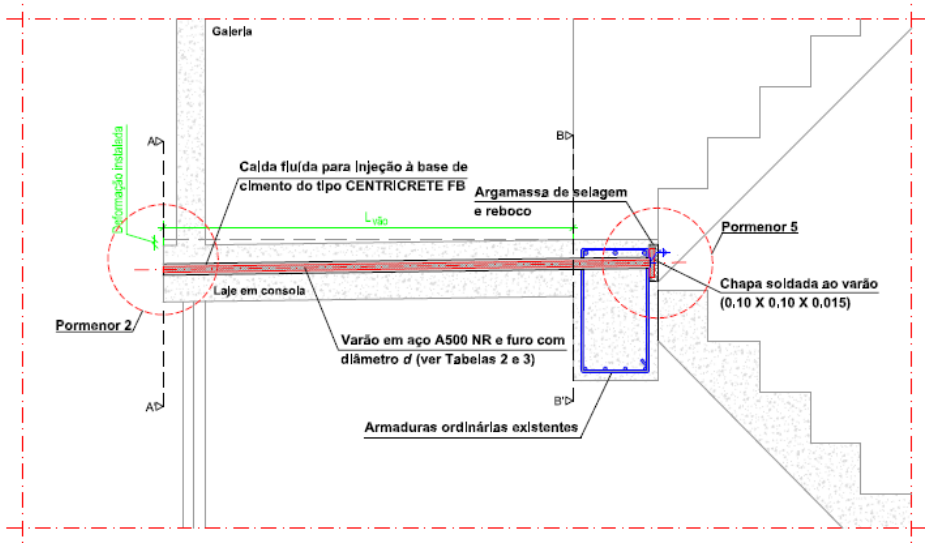




Staircase







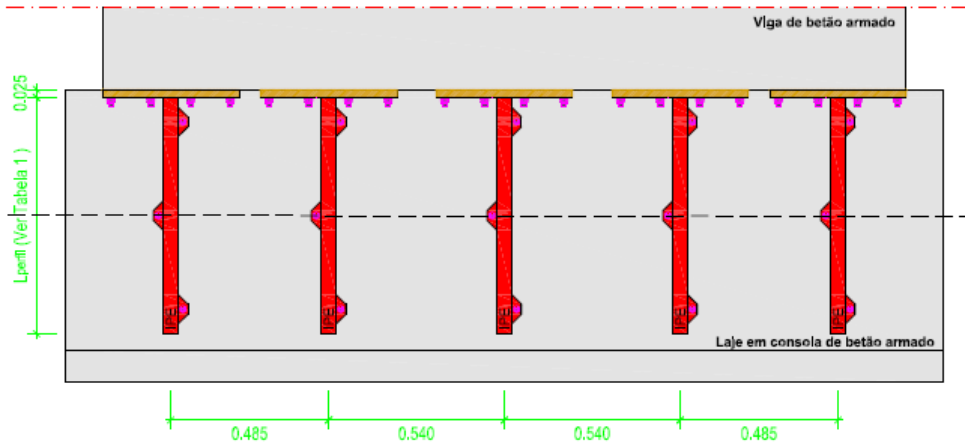
Staircase ramps (ascending / descending)

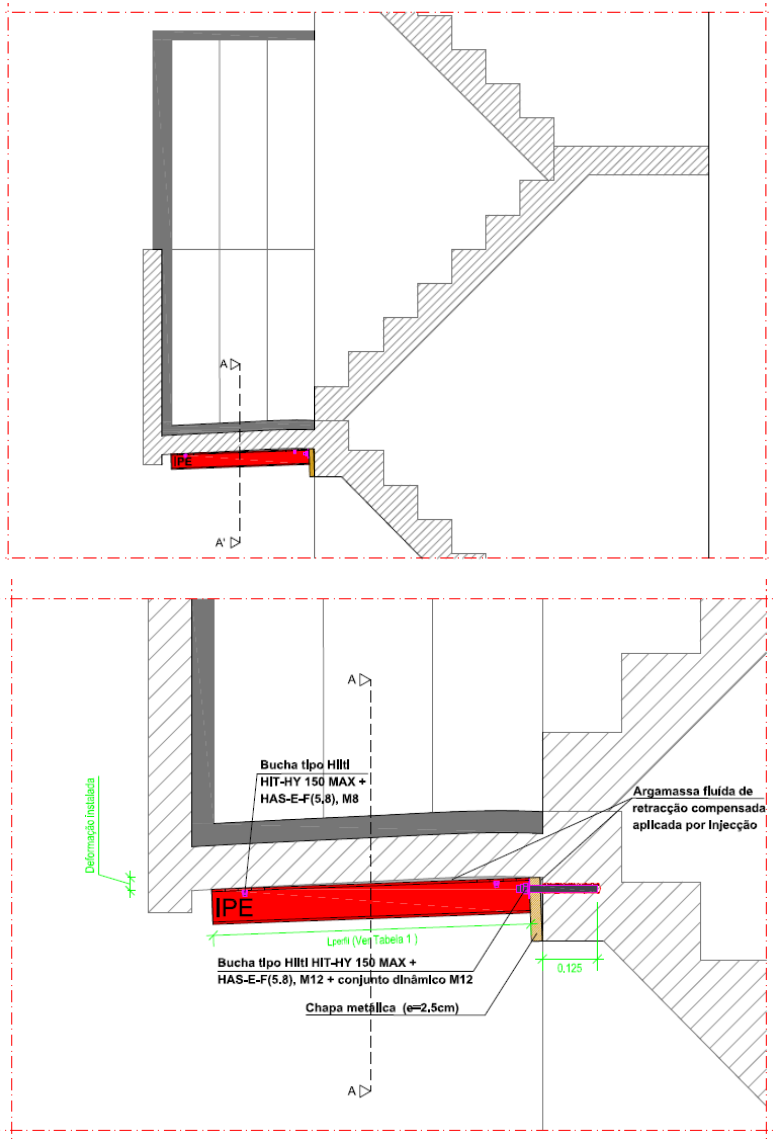
Execution





Steel profiles under





Notes:

- **Bedding Mortar**
- **Hot-dip galvanized anchors (45 micron vs. 5-10)**
- **Steel protection**
- **Welding control**

Execution

Example 3:
Beira Central Station in Mozambique

Universidade do Minho

Keeping It Modern Grant 2019: Getty Foundation

- Dates:
  - June 2019 – March 2023
- Coordinators:
  - Paulo B. Lourenço & Elisiário Miranda (Universidade do Minho)
- Local partners:
  - Portos e Caminhos de Ferro de Moçambique (CFM) – building owner
  - Universidade Eduardo Mondlane

Conservation Management Plan: Burra Charter

- Understand the building (documentary and physical evidence)
- Assess significance (heritage values, statement of significance)
- Identify factors and issues (physical condition, vulnerabilities, risk and opportunities)
- Conservation policies
- Maintenance, monitoring and priorities

Team Involved

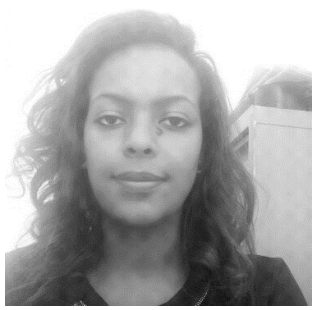
Elisiário Miranda
Professor, Arch

Mª Manuel Oliveira
Professor, Arch

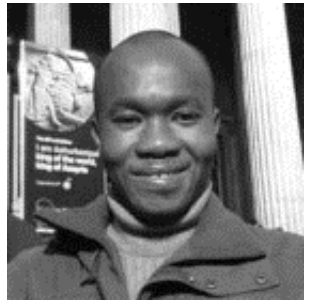
Javier Ortega, PhD, CSIC, Spain

Estefanía Chaves
PhD student, Eng, Spain

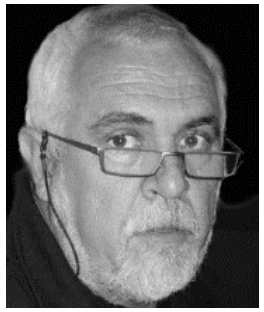
Jorge Santos
PD student, Arch, Portugal



Belen G. Alemu
MSc student, Eng, Ethiopia



Benjamin Afagbegee
MSc student, Arch, Ghana



Luis Lage, Professor, Arch

Erménio Zandamela, Arch

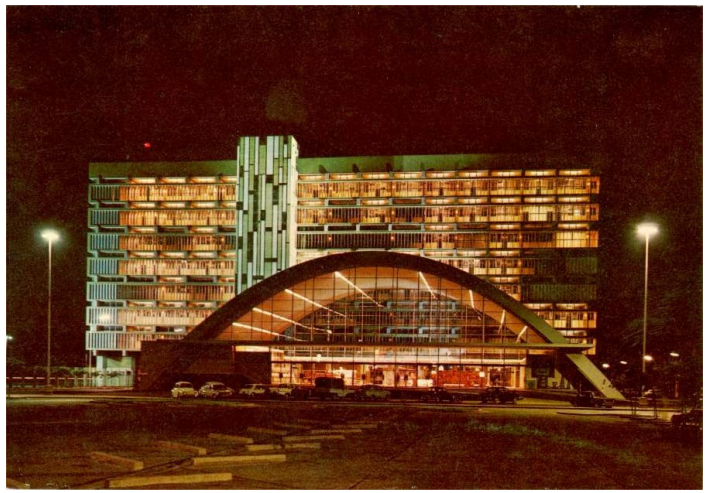
UNIVERSIDADE EDUARDO MONDLANE

Fernando Ferreira Mendes, Eng

Edmundo Cândido, Arch

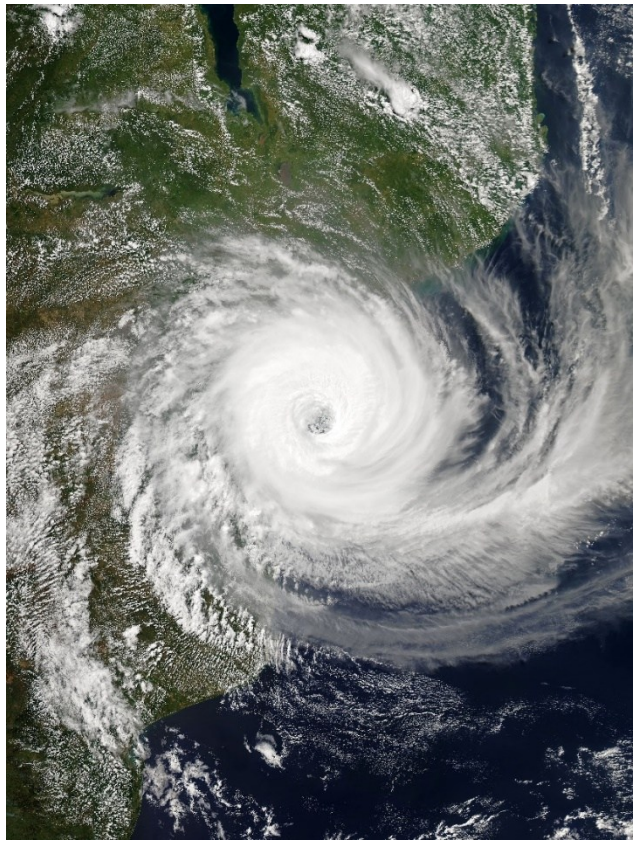
Portos e Caminhos de Ferro de Moçambique

Significance



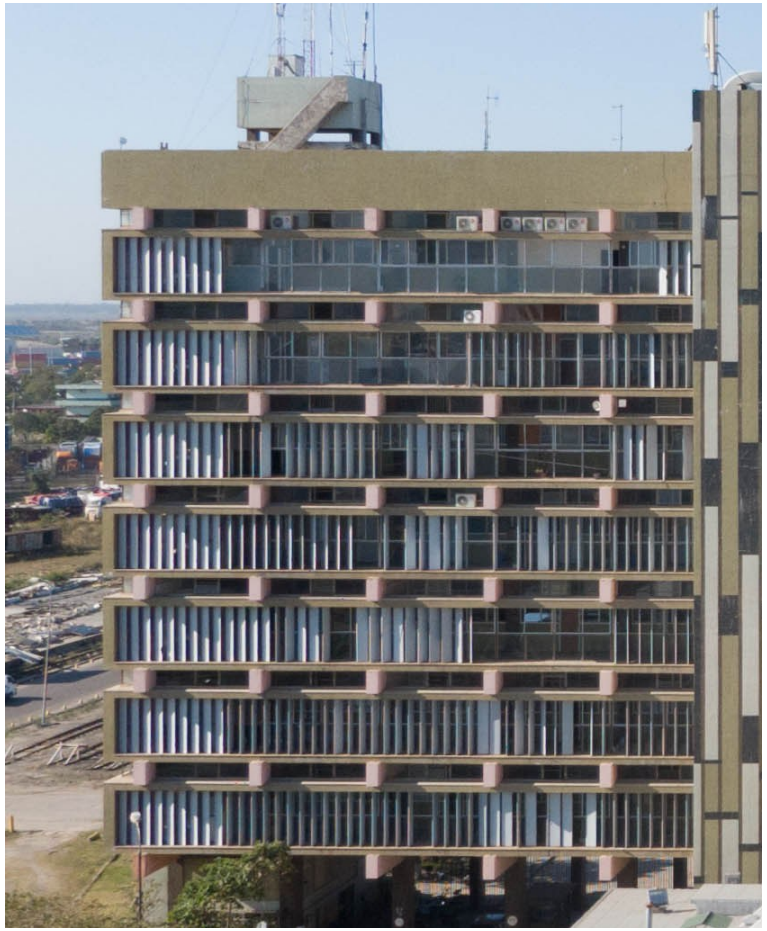
Cyclones in Beira

- Mozambique was hit by 9 cyclones in the last century
- 2019: **Idai (Center)** and Kenneth (North)
- 2021: Eloise (Center)
- 2022: Gombe and Ana (Center and North), 50+ killed and 300k affected
  - Idai: Over 700 fatalities
  - Affected Madagascar, Malawi, Mozambique, Zimbabwe, South Africa
  - The rapid water inflow has caused an "inland ocean" in Mozambique



Damage 2019

- Plenty of water ingress
- Loss of roof
- Damage to facade elements (windows and shading)



Work done

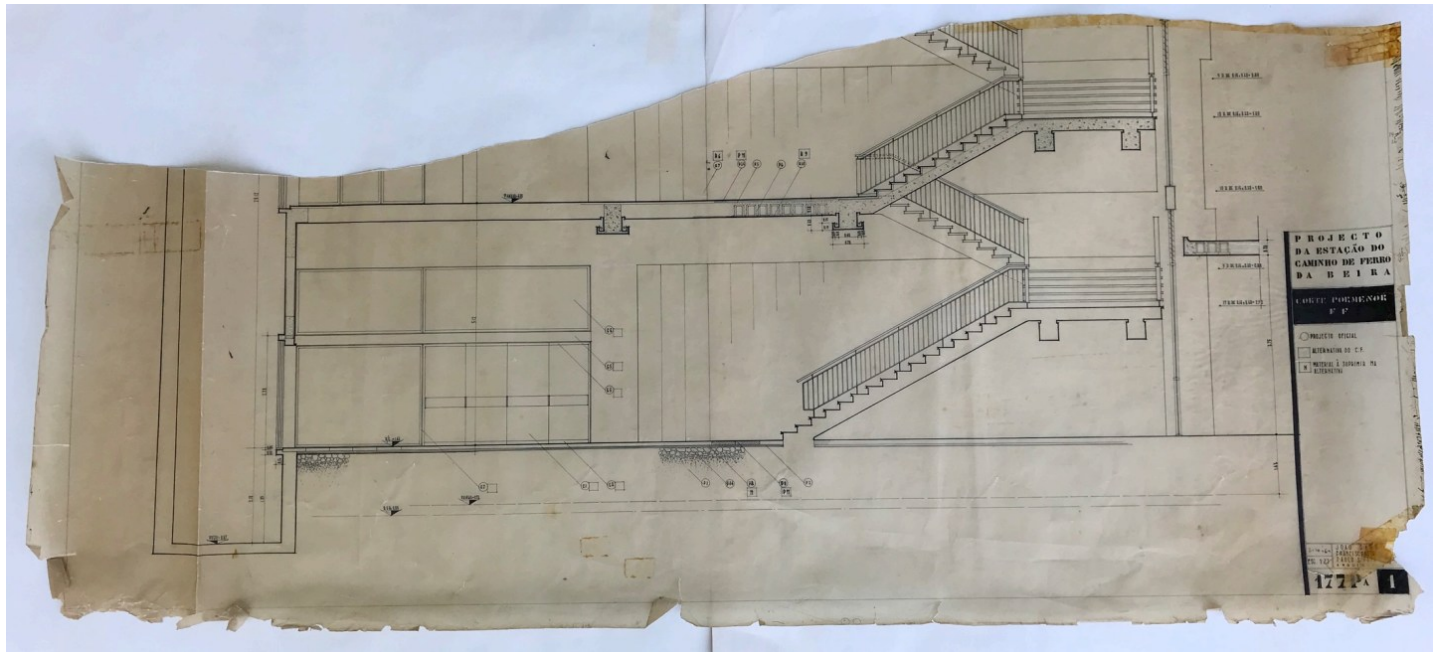
Universidade do Minho

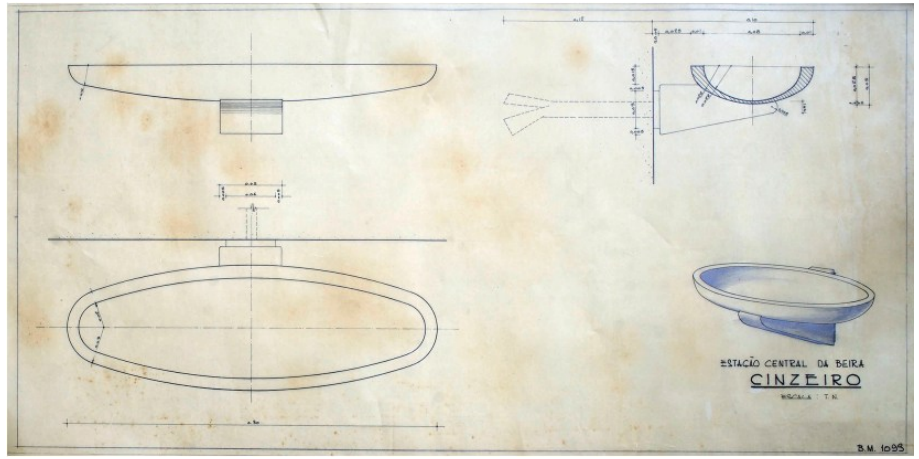
Data collection, inventory and context information

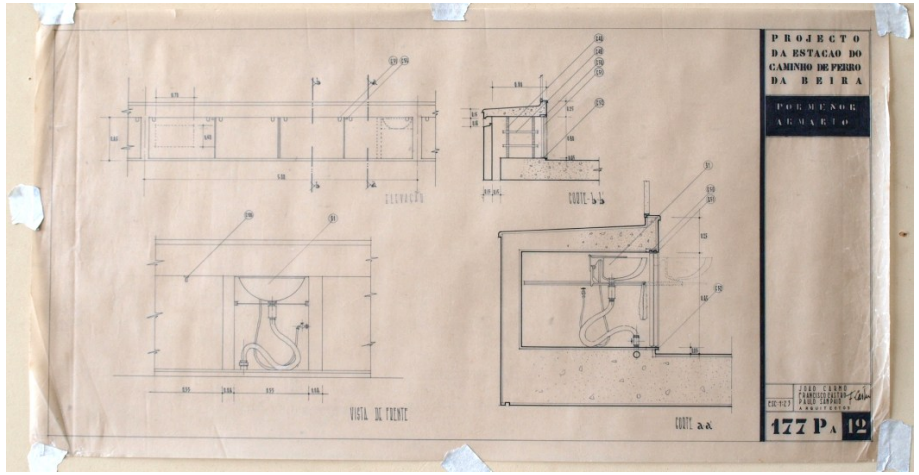
- Digital archive

Data collection, inventory and context information

- Archival organization, digitization and safeguard of technical and historical information





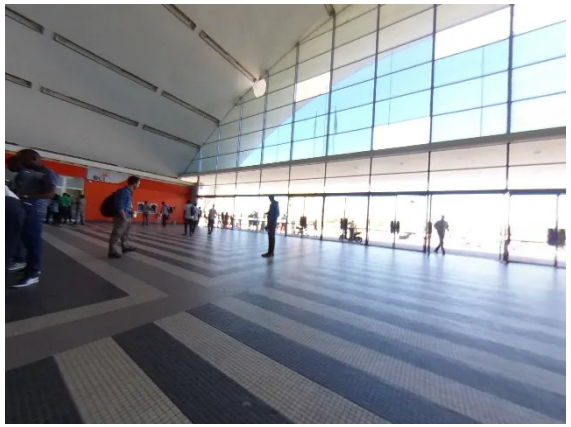


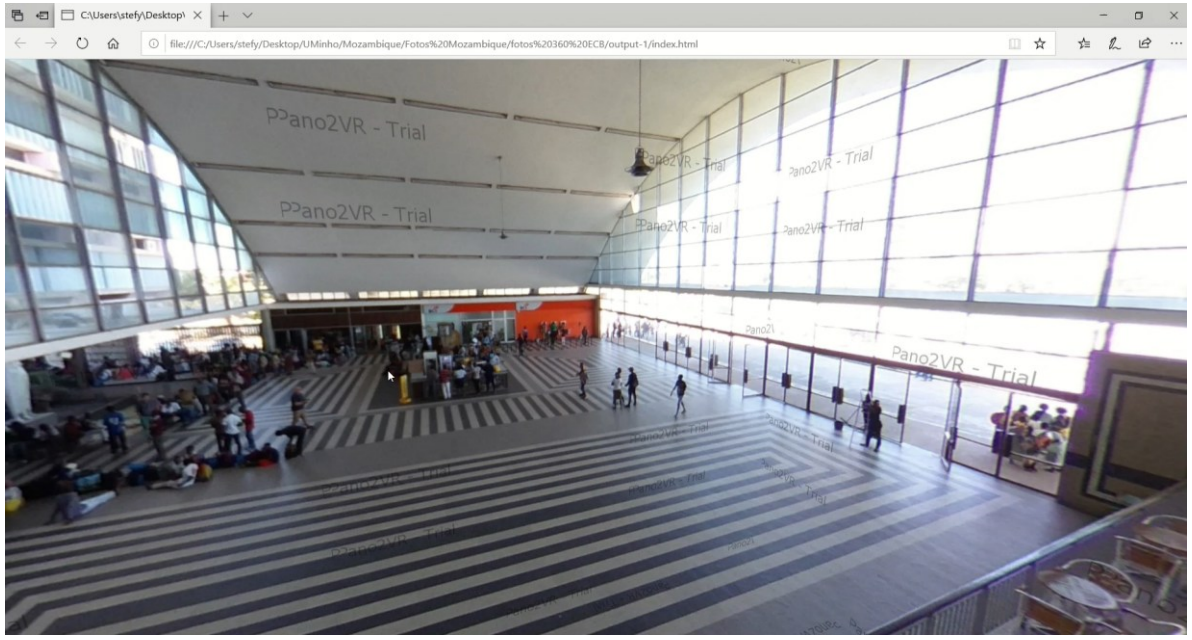
Drone survey and photogrammetry

- Graphic documentation of the current state of the building with photos and videos
- Creating a photogrammetric model using the flight photos

360º photography and virtual tour

- Graphic documentation of the current state of interior spaces

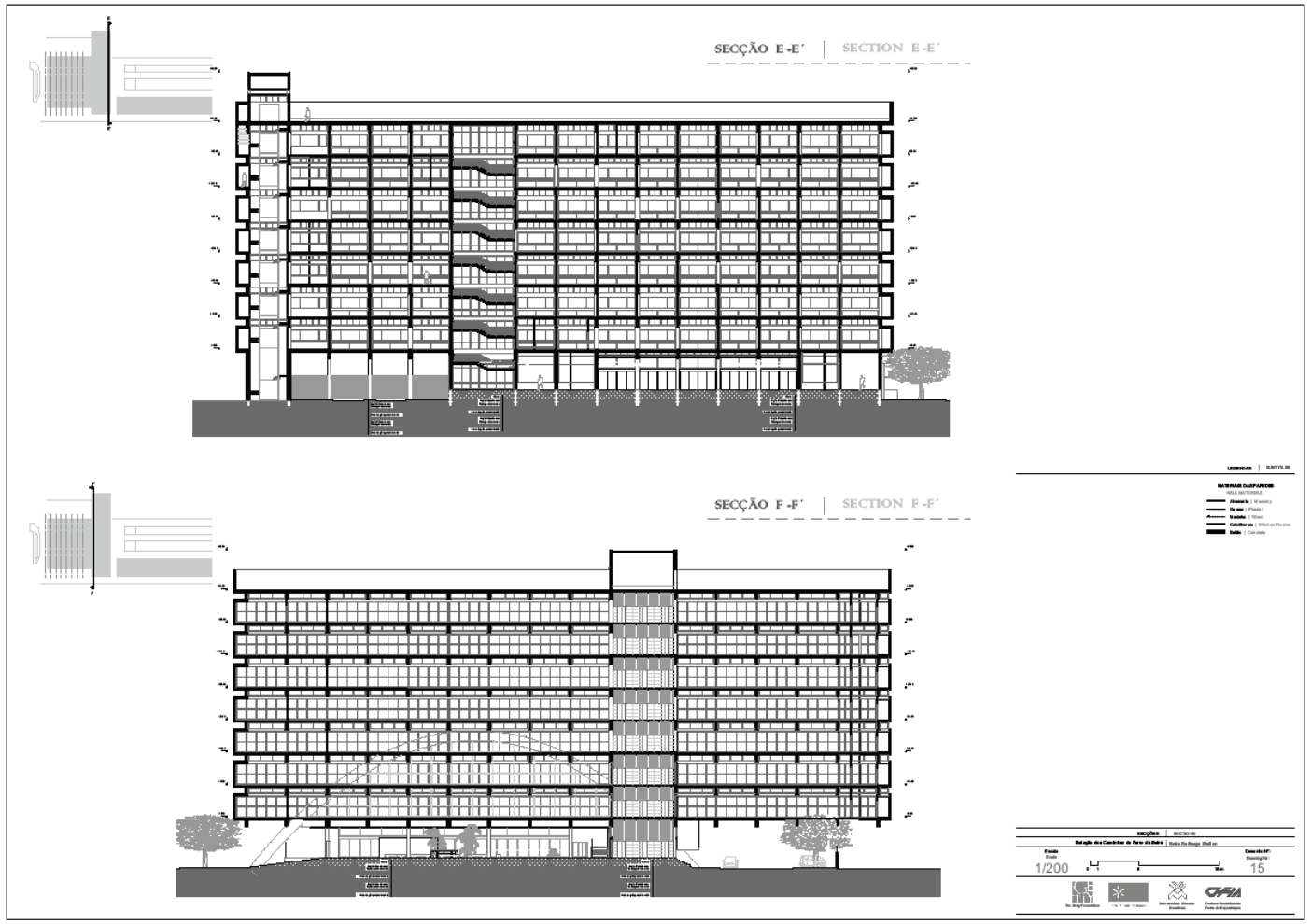




Geometrical and functional survey

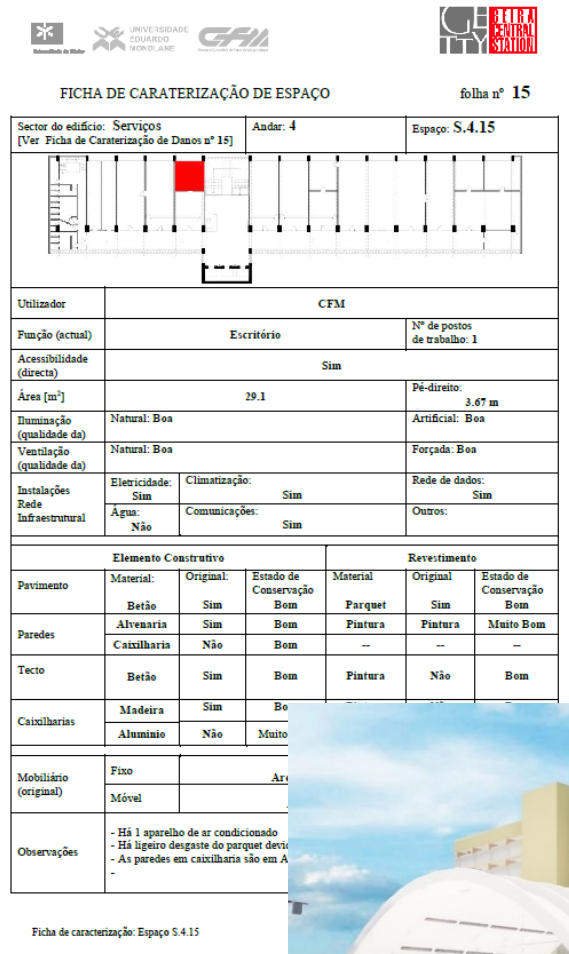
- Preparation of new plans of the current state of the building

- Plans include identification of uses of the different spaces (functional survey of the building)



Geometrical and functional survey

- Preparation of new plans of the current state of the building
- Plans include identification of uses of the different spaces (functional survey of the building)
- A BIM model was considered the most adequate approach, including material and construction details
- Database with information about material, architectural and functional characteristics of each space



FICHA DE CARATERIZAÇÃO DE ESPAÇO folha nº 15

Sector do edifício: Serviços [Ver Ficha de Caraterização de Danos nº 15]		Andar: 4	Espaço: S.4.15
Utilizador	CFM		
Função (actual)	Escritório		Nº de postos de trabalho: 1
Acessibilidade (directa)	Sim		
Área [m²]	29.1		Pé-direito: 3.67 m
Iluminação (qualidade da)	Natural: Boa		Artificial: Boa
Ventilação (qualidade da)	Natural: Boa		Forçada: Boa
Instalações Rede Infraestrutural	Eletricidade: Sim	Climatização: Sim	Rede de dados: Sim
	Água: Não	Comunicações: Sim	Outros:

Elemento Construtivo				Revestimento		
	Material:	Original:	Estado de Conservação	Material	Original	Estado de Conservação
Pavimento	Betão	Sim	Bom	Parquet	Sim	Bom
Paredes	Alvenaria	Sim	Bom	Pintura	Pintura	Muito Bom
	Caixilharia	Não	Bom	--	--	--
Tecto	Betão	Sim	Bom	Pintura	Não	Bom
Caixilharias	Madeira	Sim	Bo			
	Aluminio	Não	Muito			

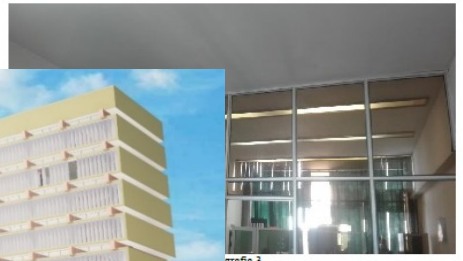
Mobiliário (original)	Fixo	Ar
	Móvel	
Observações	- Há 1 aparelho de ar condicionado - Há ligeiro desgaste do parquet devi - As paredes em caixilharia são em A -	

Ficha de caracterização: Espaço S.4.15

Fotografias

Fotografia 1

Fotografia 2



grafia 3

Data: 17.12.2020

Urban context

- Understand how Beira Central Station can fit into the general urban development plans of the city

- Find opportunities to improve the surroundings, relate the Station to the public space and play a more significant social role in the collective life of the city

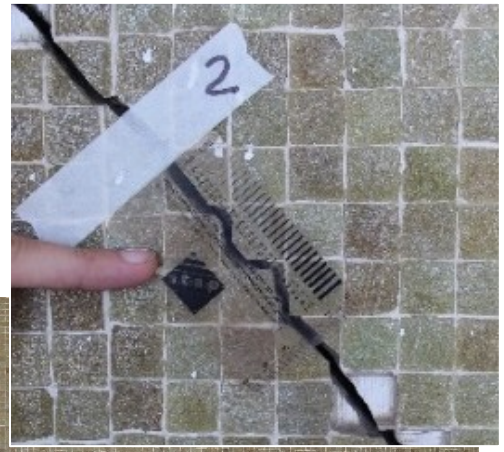
- Analyze the current urban plans and Masterplans for the city of Beira (recently completed Chiveve river park plan)

Urban context

- Understand how Beira Central Station can fit into the general urban development plans of the city
- Find opportunities to improve the surroundings, relate the Station to the public space and play a more significant social role in the collective life of the city
- Analyze the current urban plans and Masterplans for the city of Beira (recently completed Chiveve river park plan)
- Meetings with regional and municipal authorities

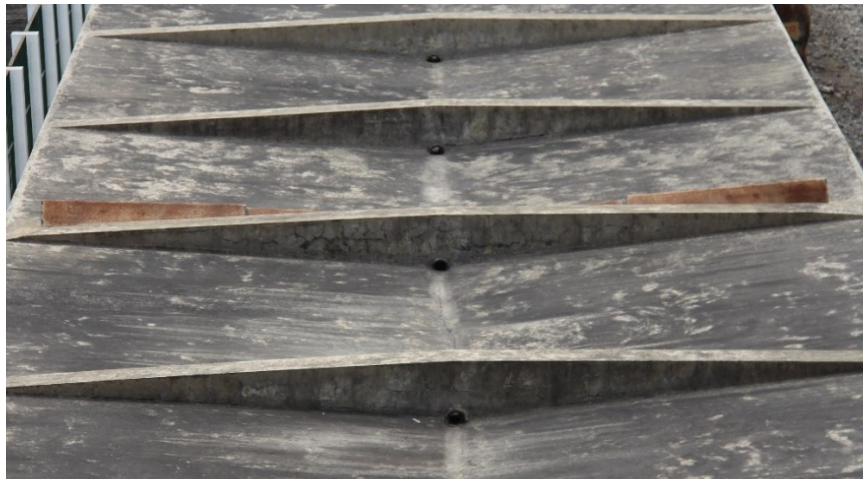
Damage survey

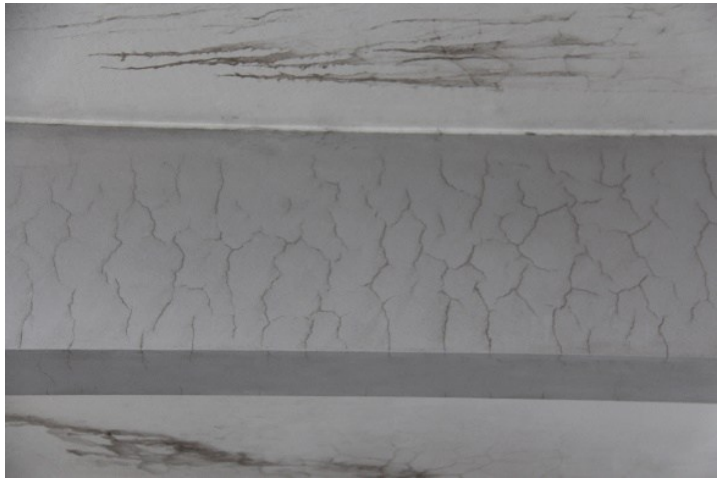
- Fair state of conservation:
  - Cracks are widespread in the building, particularly in the masonry elements. Most of the exterior façade walls are severely cracked, including the exterior tiled walls of the main vertical communication core, the lateral façades and the rear façades
  - Some of the cracks are being monitored since September 2019



Damage survey

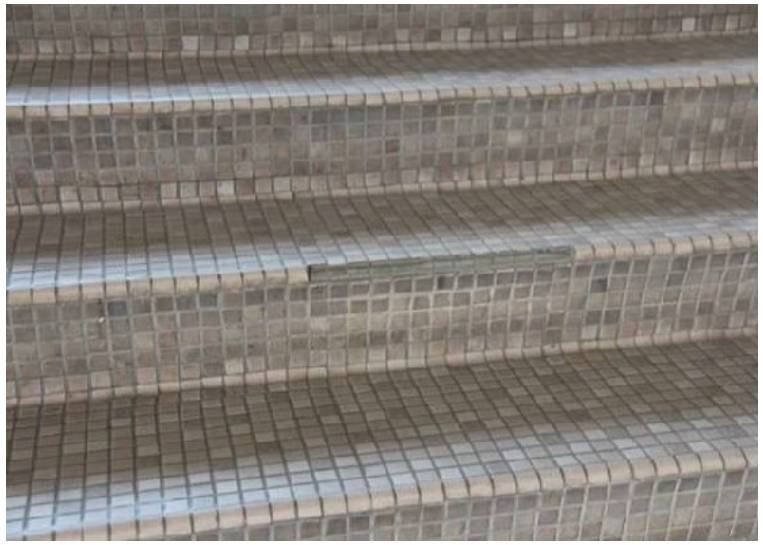
- Fair state of conservation:
  - Reinforced concrete structural elements are also cracked, in addition to corrosion induced cracking
  - A random map crack pattern was observed together with other symptoms such as surface deposits (stains and efflorescence) and color changes, which may be an indicator of Alkali-Silica or Alkali-Aggregate Reaction of the concrete.





Damage survey

- Fair state of conservation:
  - General damage and low level of maintenance is observed leading to: heavy staining, efflorescence, corroded elements, broken lamps and electrical fixtures, missing and broken wooden and ceramic decorative elements, etc.
  - One of the most significant damage observed of this type is the systematic loss of the small ceramic tiles used as finishing in walls, columns and interior floors.



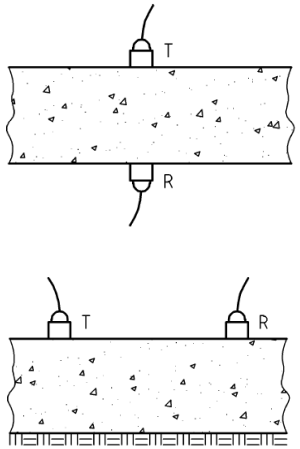
Damage survey

- Fair state of conservation:
  - Several recent interventions can be observed in the building that are detrimental from the point of view of aesthetics and authenticity: installation of new air-conditioning units, the renovation of toilets, new shopfronts in the atrium, hanging of advertisement signs, etc.

Material characterization

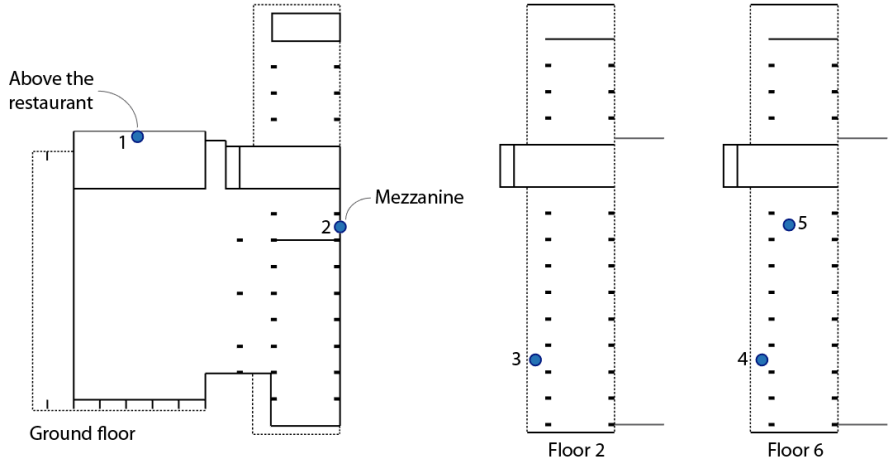
- Tests:
  - Ultrasound and sclerometer
  - Rebar detection
  - Cores, carbonation, compressive strength and chloride / sulfate tests

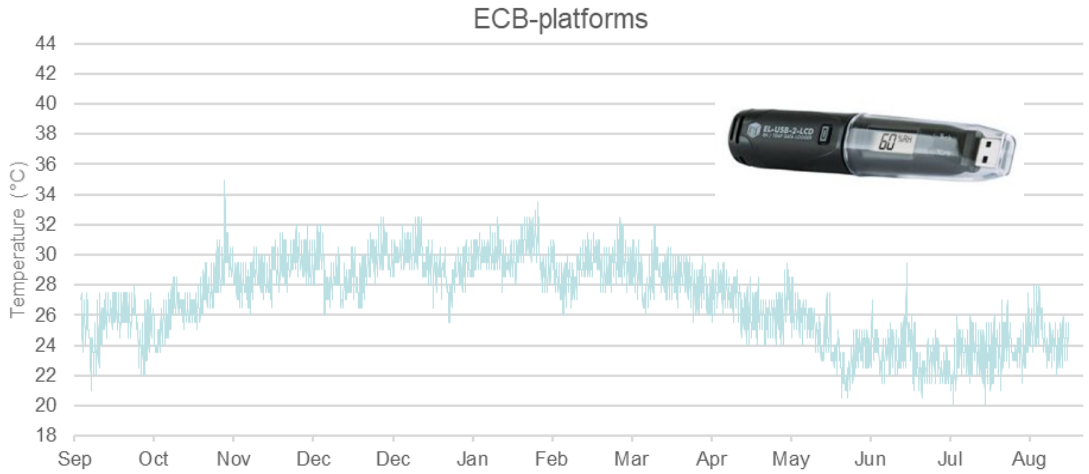
Specimen #	Compressive strength, f_c (MPa)
1	29.91 (26.02)
1	10.82 (9.41)
1	23.38 (20.34)
2	20.34 (17.70)
1	12.03 (10.47)
2	18.37 (15.98)
1	18.22 (15.85)
2	28.11 (24.46)
1	21.16 (18.41)
1	24.07 (20.94)
2	28.00 (24.36)
1	33.73 (29.35)
2	24.50 (21.32)
1	28.84 (25.10)
2	36.48 (31.74)

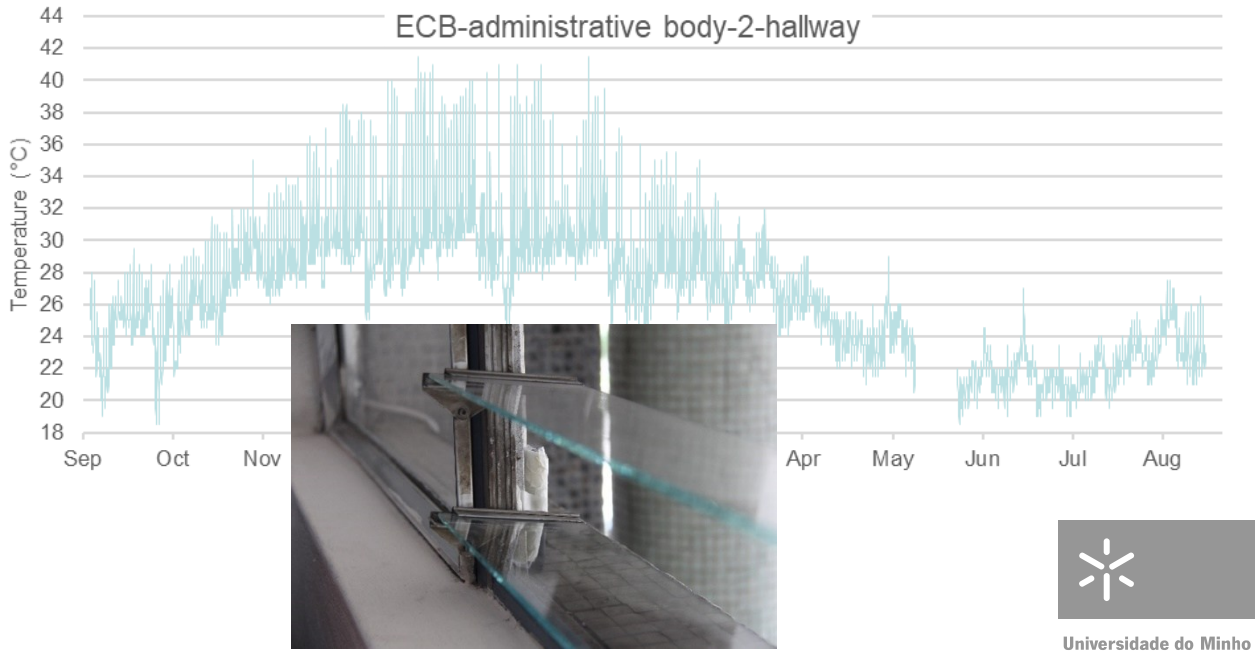


Monitoring and comfort analysis

- The monitoring works are mainly intended to obtain a better understanding of the current comfort conditions in the building
- Installed in September 2019
- Overall low and uniform daily variation of temperatures at all locations during the year, but for sensors located in hallways.







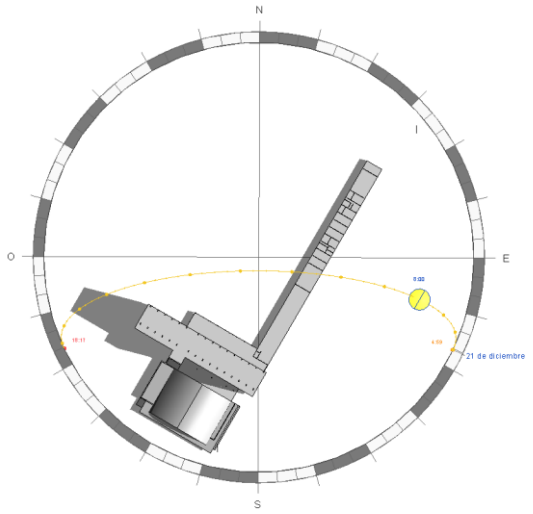
Monitoring and comfort analysis

- **Solar study** focused on the analysis of the exposition of the longitudinal façades of the administrative building.

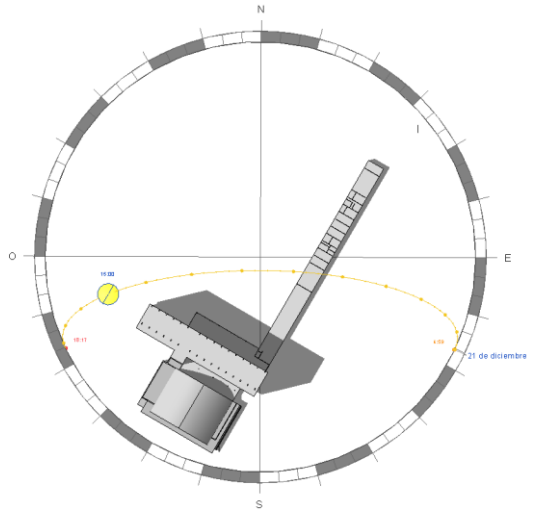
- BIM model with information about the location and the orientation, which allowed to generate a pattern of shadows for each time and day of the year.

December 21

8:00

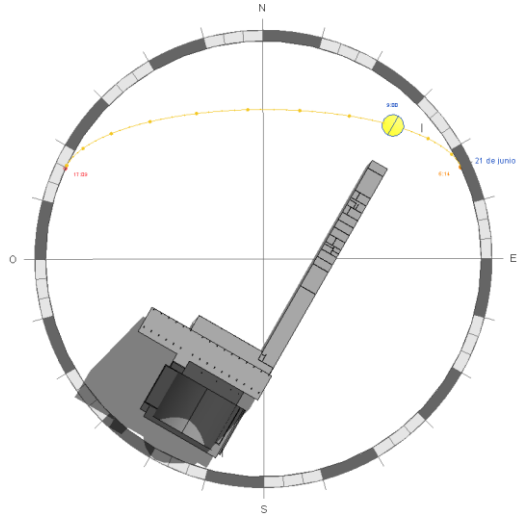


15.00

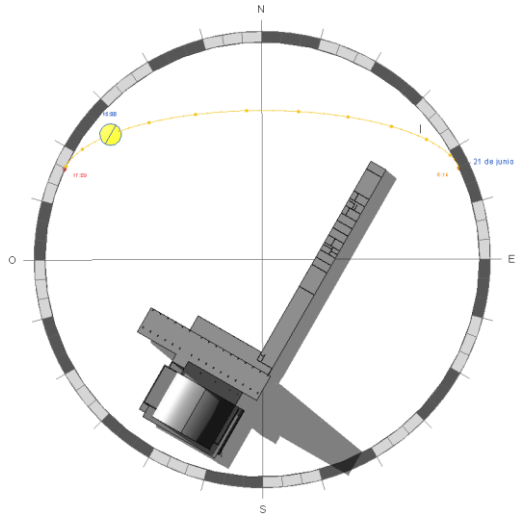


June 21

9:00



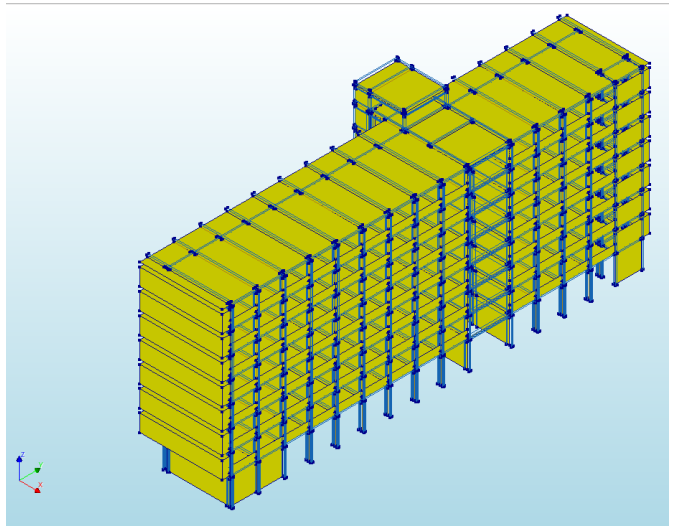
15.00

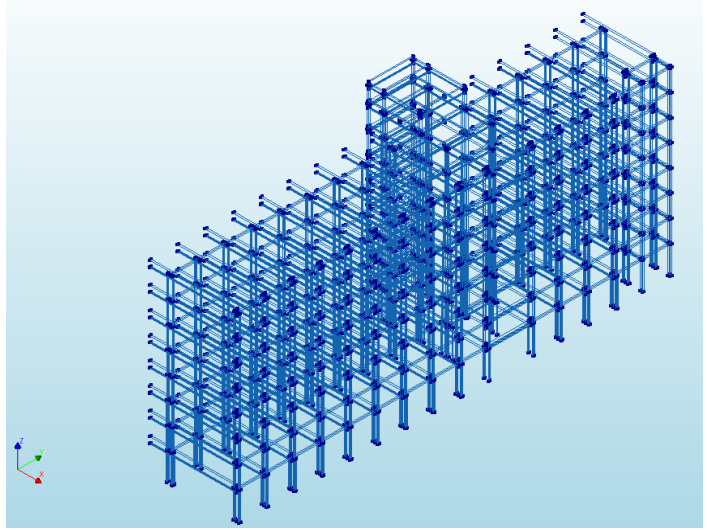


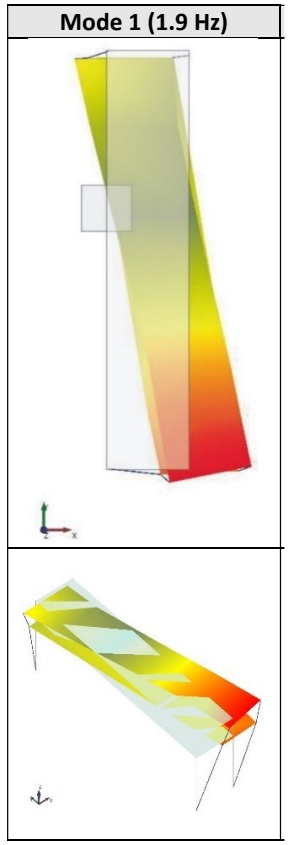
Structural assessment of the Beira Railway Station

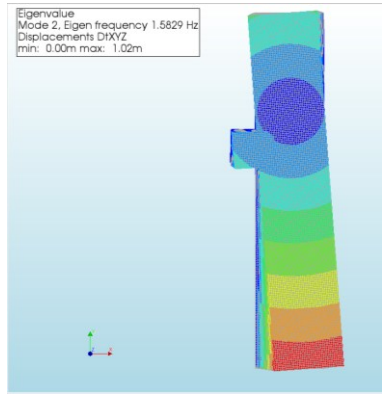
- Numerical models to assess the structural safety of the administration building of the Beira Railway Station under different loading conditions (gravity, wind and seismic)

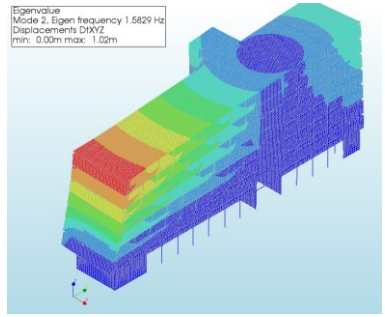
- Complex finite element model including all reinforcement elements of the structure and calibrated with the data from the non-destructive experimental campaign









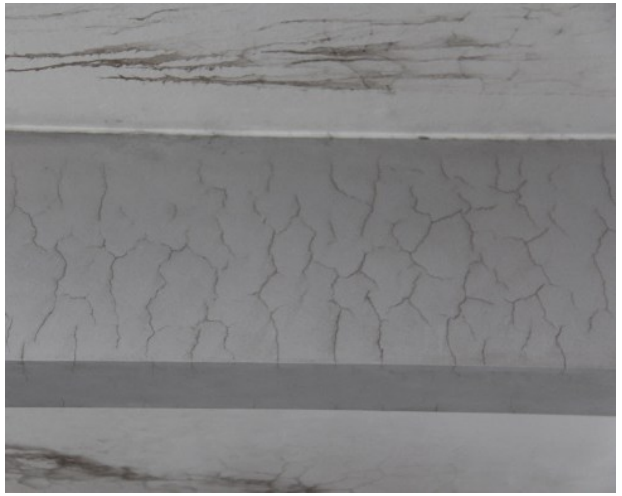


Remedial actions

- Draft guidelines for intervention: define process for each typified damage (recurrent in the building)
- Define plan of action: urgent, necessary and desirable types of actions



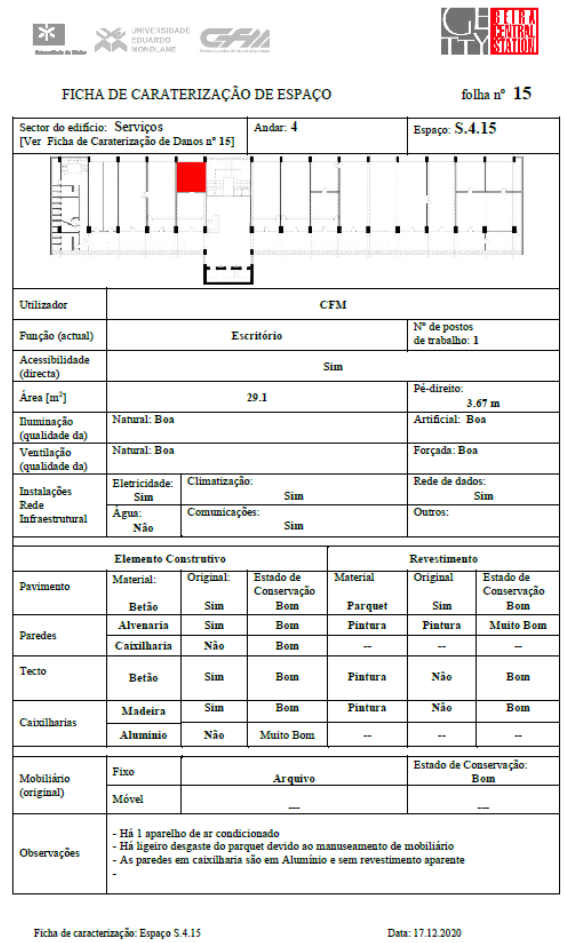




Maintenance Plan

- ❑ Define cyclical inspections for an early identification of problems
- ❑ Define preapproved list of local specialists (consultants and contractors) with skills to undertake the work
- ❑ Define mechanism for recording maintenance activities

Element	Inspection detail	Frequency
Drainage systems (valleys, scuppers, gutters, storm water pipes, etc.)	- Check for open joints and seams, cracks, splits, loose brackets, corrosion. - Check for blockages from leaf litter, nests, other debris, in particular at outlets. - Check that outlets are clear at discharge points. - If required, CCTV camera to determine cause of any blockages.	Twice per year
Windows and doors (glazing and frame)	- Check the condition of paint finish generally. Look for evidence of decay and corrosion. - Inspect for cracks and deep scratches in the glazing and condition of the putty. - Test functionality i.e. ability to open and close (in conjunction with internal inspection).	Annually
Tiles	- Check for any loose pieces of ceramic tiles finishing or lack of boundary and collect the piece and repair following the guide.	Twice per year



FICHA DE CARATERIZAÇÃO DE ESPAÇO folha nº 15

Sector do edifício: Serviços [Ver Ficha de Caraterização de Danos nº 15]			Andar: 4		Espaço: S.4.15
Utilizador	CFM				
Função (actual)	Escritório				Nº de postos de trabalho: 1
Acessibilidade (directa)	Sim				
Área [m²]	29.1				Pé-direito: 3.67 m
Iluminação (qualidade da)	Natural: Boa				Artificial: Boa
Ventilação (qualidade da)	Natural: Boa				Forçada: Boa
Instalações Rede Infraestrutural	Eletricidade: Sim	Climatização: Sim			Rede de dados: Sim
	Água: Não	Comunicações: Sim			Outros:

	Elemento Construtivo			Revestimento		
Pavimento	Material: Betão	Original: Sim	Estado de Conservação Bom	Material Parquet	Original Sim	Estado de Conservação Bom
Paredes	Alvenaria	Sim	Bom	Pintura	Pintura	Muito Bom
	Caixilharia	Não	Bom	--	--	--
Tecto	Betão	Sim	Bom	Pintura	Não	Bom
Caixilharias	Madeira	Sim	Bom	Pintura	Não	Bom
	Alumínio	Não	Muito Bom	--	--	--

Mobiliário (original)	Fixo	Arquivo	Estado de Conservação: Bom
	Móvel	--	--
Observações	- Há 1 aparelho de ar condicionado - Há ligeiro desgaste do parquet devido ao manuseamento de mobiliário - As paredes em caixilharia são em Alumínio e sem revestimento aparente -		

Ficha de caracterização: Espaço S.4.15 Data: 17.12.2020

Conservation and managment plan (CMP)

- A conservation management plan (CMP) is a document that establishes the meaning of a place and, consequently, what is most appropriate for it to be maintained in its future use and development. For most sites, this plan deals with the management of change

Preserve the values of the original design

Documentation process

Define a methodology to approach change

- The main objective of the CMP is to establish regulations and the long-term strategy that guide the conservation, maintenance and development of the place.

Guarante optimal operation

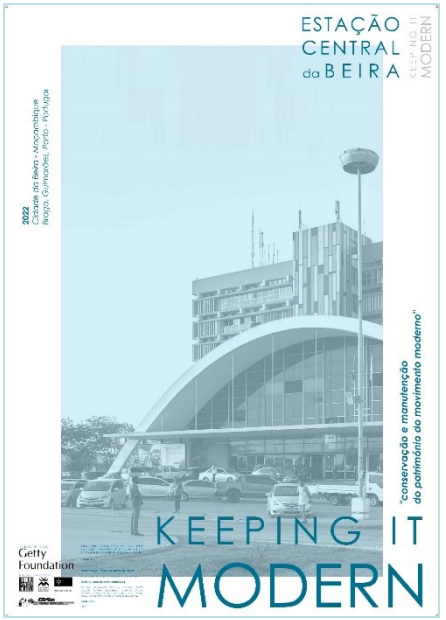
Ensure compatbility

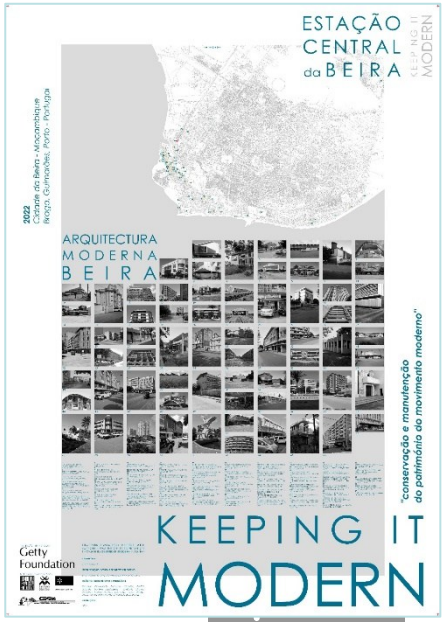
Identify vulnerabilities

Dissemination

- Exhibition: Guimarães, Porto, Coimbra and Lisbon (Portugal); Beira and Maputo (Mozambique) with poster and city guide

- Seminar for the local community (students and professionals).





Conclusions

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Conclusions

- The safety assessment of existing buildings poses a strong demand on structural engineering skills and adopted structural analysis techniques

- Structural conservation is an exciting topic, challenging engineers and architects to think out of the box and go beyond standard practices

- 20th century heritage is challenging often due to experimental materials, new construction techniques and innovative forms. Lessons and experience from conservation of older structures are important for more recent structures

- Conservation management plans are essential to define a maintenance strategy and manage change

Conservation and management of modern historic buildings: Recent works on heritage of Portuguese origin

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