

DESIGN OF STRUCTURES – Unit functioning**FUNCTIONING – Classes Online ; Exams Online (to be confirmed)**EVALUATION METHOD – <https://fenix.tecnico.ulisboa.pt/disciplinas/DEst364511132646/2020-2021/2-semester/metodos-de-avaliacao>**THEORETICAL CLASSES**

Monday – José O. Pedro, F. Virtuoso

13:00-14:30h

14:30-16:00h

17:30-19:00h (erasmus)

Thursday – José O. Pedro, F. Virtuoso

13:00-14:30h

14:30-16:00h

16:00-17:30h (erasmus)

Uploaded in fenix after the sections

PROBLEM CLASSES

Tuesday – José O. Pedro

16:00-17:30h

17:30-19:00h

Wednesday – Mário Lopes

14:30-16:00h (erasmus)

16:00-17:30h

Thursday – Luís Guerreiro

16:00-17:30h

Friday – Luís Guerreiro

14:30-16:00h

Uploaded in fenix at the beginning of the week

**DESIGN OF STRUCTURES – Unit program****Theoretical Classes**

- ST1 - Presentation of the unit. Introduction to structural design. Phases of a design
- ST2 - Structural materials proprieties
- ST3 - Basic concepts of structural analysis and design
- ST4 - Reinforced concrete slabs: cylindrical and spherical bending; load distribution
- ST5 - Reinforced concrete slabs: special cases of free edges and concrete walls
- ST6 - Reinforced concrete beams and slabs - Pre-design and deformability assessment
- ST7 - Influence lines of internal forces and support reactions - concept and application to isostatic structures
- ST8 - Influence lines of internal forces and support reactions. Worked example
- ST9 - Influence lines of displacements and of hyperstatic structures. Worked example
- ST10 - Structural safety and actions. Principles and application rules of EN 1990
- ST11 - Actions in building (EN 1991) - Dead and live loads, snow action and thermal action
- ST12 - Actions in building (EN 1991) - Wind actions
- ST13 - Actions in building (EN 1998) - Seismic actions
- ST14 - Building structures subjected to horizontal actions - Simplified methods of analysis
- ST15 - Seismic action in structural design of piers and wall
- ST16 - Steel structures - Examples and concept design; Design of steel columns
- ST17 - Design of steel beams considering the lateral buckling
- ST18 - Design of beam-columns. General concepts about composite steel-concrete floors
- ST19 - Design of the bracing systems
- ST20 - Design of the sections of the transverse bracing system
- ST21 - Design of the connections in steel structures
- ST22 - Design of welded and bolted connections
- ST23 - Design of bolted connections
- ST24 - Design of steel connections - Joint beam-column
- ST25 - Design of steel connections - Joint beam-beam

GENERAL CONCEPTS**DESIGN OF REINFORCED
CONCRETE FLOORS****ACTIONS AND
STRUCTURAL RELIABILITY****DESIGN OF STEEL
STRUCTURES**

DESIGN OF STRUCTURES – Unit program

Problems from Classes

- S1 - PROB.01 - Evaluation of internal forces in beam structures
- S2 - PROB.02 - Design of steel truss
- S3 - PROB.03 - Design of slabs and beams
- S4 - PROB.04 - Design of slabs and beams
- S5 - PROB.05 - Design of slabs and beams
- S6 - PROB.06 - Design of a reinforced concrete counterfort's wall
- S7 - PROB.07 - Wind action
- S8 - PROB.08 - Frames with seismic forces and temperature gradients
- S9 - PROB.09 - Water tank - seismic action
- S10 - PROB.10 - Building - seismic action
- S11 - PROB.11 - Design of steel columns and beam
- S12 - PROB.12 - Design of steel beam-columns
- S13 - PROB.13 - Design of steel beam-columns and bracings

GENERAL CONCEPTS

DESIGN OF REINFORCED CONCRETE FLOORS

ACTIONS AND STRUCTURAL RELIABILITY

DESIGN OF STEEL STRUCTURES



José Oliveira Pedro

Design of Structures 2020/2021

DESIGN OF STRUCTURES – Supporting elements



VOLUME 1

PARTE I: FUNDAMENTOS

01. O projeto de estruturas
02. Materiais estruturais
03. Comportamento estrutural e métodos de análise
04. Introdução à análise do risco e fiabilidade estrutural
05. Bases para o projeto de estruturas de acordo com os Eurocódigos
06. Ações em edifícios de acordo com o Eurocódigo 1
07. Ação sísmica: fundamentos e regras de aplicação do Eurocódigo 8

PARTE II: APLICAÇÕES

08. Estruturas de edifícios de betão armado

VOLUME 2

09. Vigas trianguladas de aço
10. Estruturas porticadas de aço
11. Vigas alveolares de aço
12. Vigas de aço de secção soldada
13. Elementos compostos comprimidos de aço
14. Reservatórios de betão armado
15. Silos
16. Chaminés



José Oliveira Pedro

Design of Structures 2020/2021

DESIGN OF STRUCTURES – Supporting elements

Teaching Notes

- (1) P. MENDES; J. PEDRO - [Basic concepts for the design of structures](#)
- (1.3) J. PEDRO - [Influence lines of beams and slabs](#)
- (2) P. MENDES; J. PEDRO - [Risk Analysis and Structural Reliability](#)
- (3) P. MENDES; J. PEDRO - [Introduction to EN 1990](#)
- (4) P. MENDES; J. PEDRO - [Determination of actions on buildings according to EC1](#)
- (5) P. MENDES; J. PEDRO - [Building struct. to horizontal actions - simplified methods](#)
- (6) P. MENDES; J. PEDRO - [Seismic action in the design of current building structures](#)
- (7) J. PEDRO; P. MENDES - [Notes on the design of framed steel buildings](#)

Formula Sheets and Tables

- [Miscellaneous \[in Portuguese\]](#)
- [CONTINUOUS BEAMS - tables \(elastic analysis\) \[in Portuguese\]](#)
- [SLABS - tables \(elastic analysis\)](#)
- [Steel profiles I, H, L and U](#)
- [Hollow sections \(CHS, SHS and RHS\) \(manufacturer Corus\)](#)
- [Combinations of actions and partial factors \(NP EN 1990\)](#)
- [Actions on buildings \(NP EN 1991\)](#)
- [Seismic action - buildings \(NP EN 1998-1\)](#)
- [\(EC3\) STEEL - properties; SECTIONS - classification and resistance](#)
- [\(EC3\) Buckling resistance of steel members](#)
- [\(EC3\) Resistance of joints](#)
- [Most used hot finished steel profiles](#)



José Oliveira Pedro

Design of Structures 2020/2021

TYPES OF STRUCTURES



Building at Expo, Lisbon



Dragon Football Stadium, Porto



Alqueva Dam



Marítimo Football Stadium, Funchal



Monsanto Tower, Lisbon



José Oliveira Pedro

Design of Structures 2020/2021



Bridge over the River Liz, Leiria



Third Tagus Bridge, Lisbon



Macau Airport



Madeira Island Airport

TYPES OF STRUCTURES

The structures can be classified taking as reference the purpose of the constructions; the following types can be listed:

- housing and/or office building structures;
- structures with special requirements, such as:
 - industrial structures (pavilions, chimneys, cooling towers),
 - cultural structures (museums, congress centres, auditoriums),
 - hospitals, schools, sports facilities (pavilions, stadiums);
 - storage structures (reservoirs, silos, warehouses in general),
 - towers, spired masts and electric power distribution towers;
 - land support structures;
 - hydraulic structures (dams, canals, ports, docking of ships,...);
 - bridges, viaducts and walkways;
 - tunnels and underground structures;
 - temporary structures such as scaffoldings, temporary platforms and greenhouse covers.

OBJECTIVES OF THE DESIGN OF STRUCTURES

The design aims to define the structure for fulfilling a function, for a given location



Louis Vuitton Foundation, Paris, Arq. Frank Gehry

What is the main aspect of the development of the design?

The Conceptual Design, the Structural Analysis, or the Definition of Materials and Construction Processes

It is necessary to master all these areas

OBJECTIVES OF THE DESIGN OF STRUCTURES

The design aims to define the structure for fulfilling a function, for a given location

The design of structures must meet the following basic objectives, all equally important:

- (i) functionality
- (ii) safety
- (iii) economy and
- (iv) sustainability
- (v) aesthetic

FUNCTIONALITY : Defining the shape \Leftrightarrow Fulfil the function

SAFETY : Good behaviour in service and for exceptional situations



OBJECTIVES OF THE DESIGN OF STRUCTURES

The design aims to define the structure for fulfilling a function, for a given location

The design of structures must meet the following basic objectives, all equally important:

- (i) functionality
- (ii) safety
- (iii) economy and
- (iv) sustainability
- (v) aesthetic

ECONOMY AND SUSTAINABILITY : Meet the construction budget; Take into account the costs of maintenance and demolition/recycling of the structure



OBJECTIVES OF THE DESIGN OF STRUCTURES

The design aims to define the structure for fulfilling a function, for a given location

The design of structures must meet the following basic objectives, all equally important:

- (i) functionality
- (ii) safety
- (iii) economy and
- (iv) sustainability
- (v) aesthetic

AESTHETICS : Balance, symmetry, lightness and simplicity are concepts that enhance a good aesthetic integration of buildings



DESIGN OF STRUCTURES – PART OF THE OVERALL ENTERPRISE



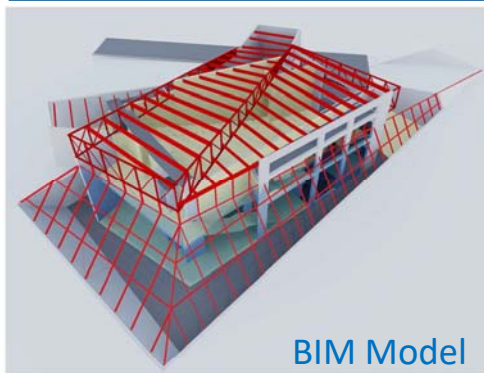
DESIGN OF STRUCTURES – PART OF THE OVERALL ENTERPRISE



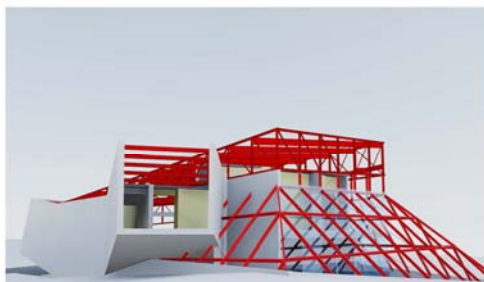
The **Structures Design** is essential to the success and good performance of the enterprise.

Even in the case of Buildings, where the Structure represents, in general, only 15% to 25% of the total cost of construction, it is responsible for the safety of the generality of materials and equipment related to the various fields.

DESIGN PRODUCTION



BIM Model



Auditorium NOVA School of Business & Economics

- 00 | escavações
- BETÃO**
- 01 | laje térrea + elementos verticais piso -2
 - 02 | vigas piso -1
 - 03 | laje piso -1
 - 04 | elementos verticais piso -1
 - 05 | vigas piso 0
 - 06 | lajes piso 0
 - 07 | elementos verticais piso 0
 - 08 | vigas + lajes piso 1
- METÁLICAS**
- 09 | treliças 1 e 2
 - 10 | treliças 3 e 4
 - 11 | perfis transversais IPE
 - 12 | arquitectura [interior]
 - 13 | estrutura leve de fachada

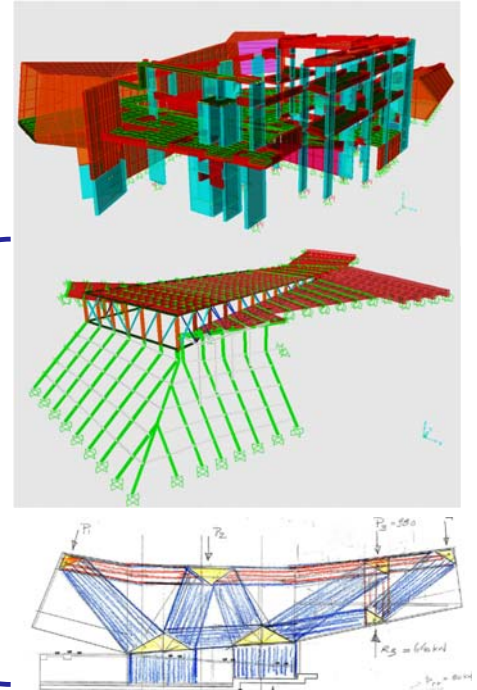


DESIGN PRODUCTION

- CONCEPTUAL DESIGN AND PRE-DIMENSIONING
- STRUCTURAL MODELING AND ANALYSIS
- ↓
- SAFETY SECURITY CHECKS
- ↓
- PRODUCTION OF WRITTEN PARTS AND DRAWINGS
- ↓
- FOLLOW-UP AND TECHNICAL ASSISTANCE DURING CONSTRUCTION

Global Models

Local Models

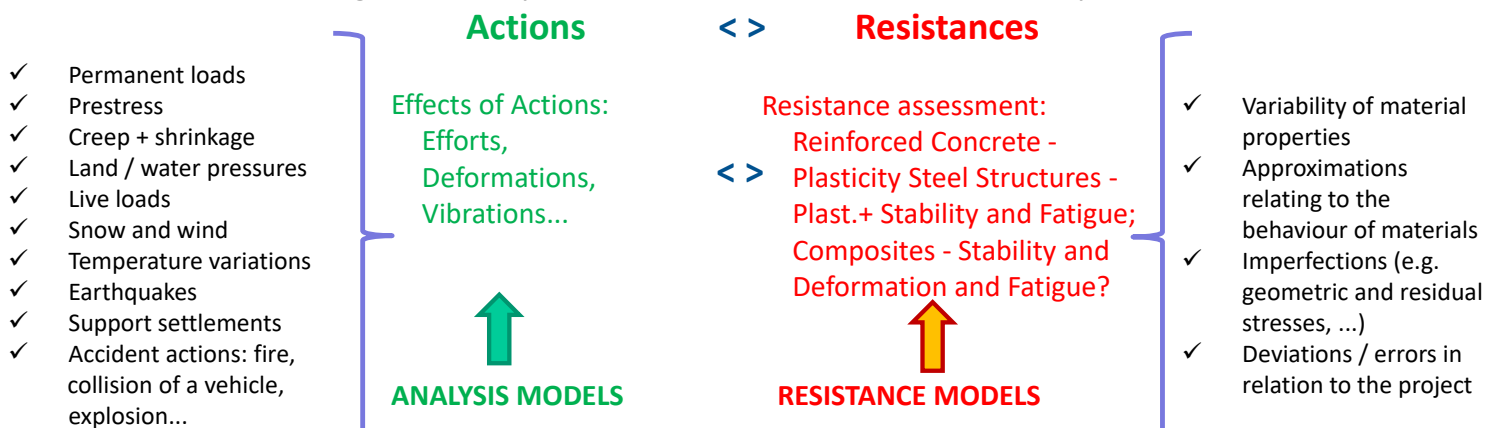


DESIGN OF STRUCTURES – General procedure

FINAL OBJECTIVE => Define the characteristics of the structure ⇔ **STRUCTURE DESIGN**

PROCEDURE => Production of the Design in phases with greater detail

CRITERIA => Pre-design; Security Check – ultimate and serviceability limit states



PRELIMINARY PROGRAM and BASE PROGRAM

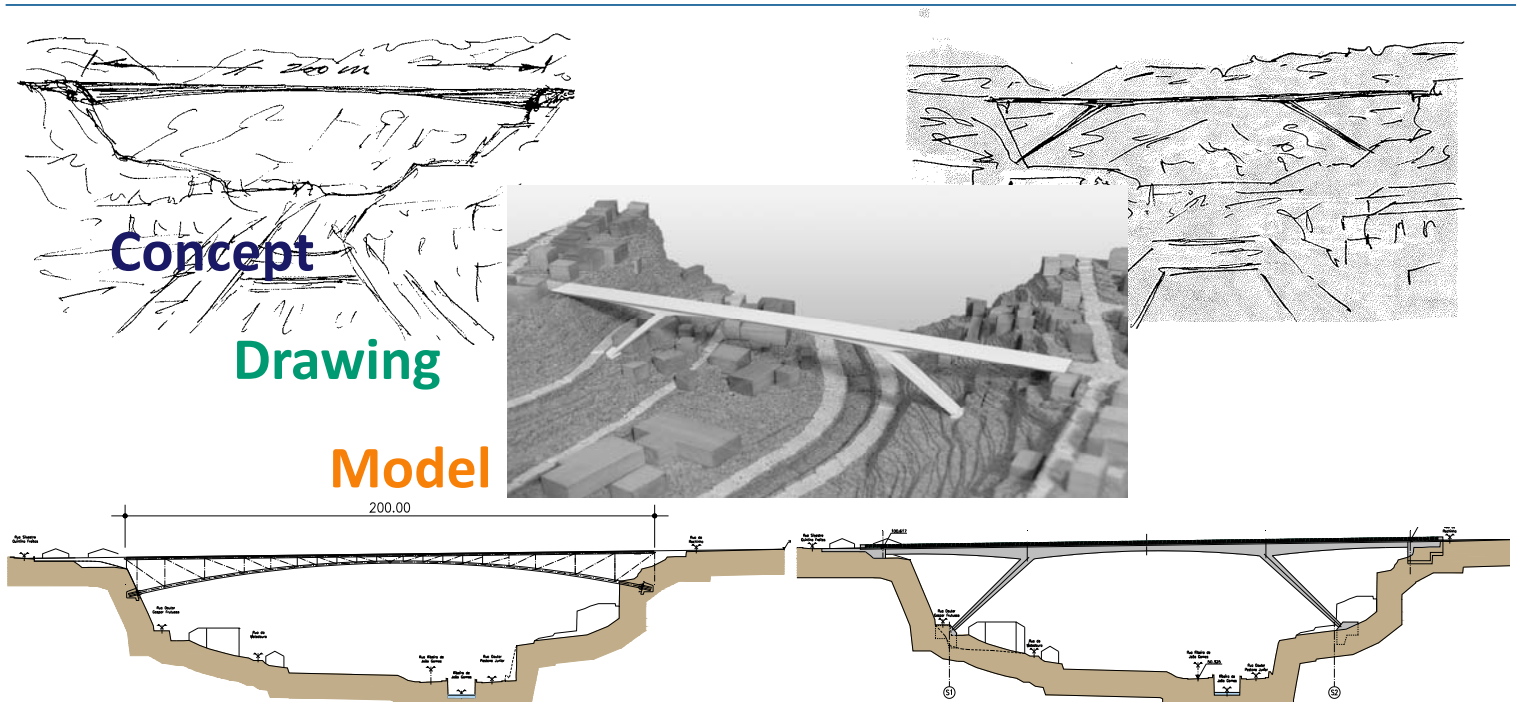


PRELIMINARY PROGRAM –

Produced by the Owner, defines the objectives and general characteristics of the project: location, topographic and geotechnical elements, local conditionings such as existing constructions and infrastructure networks, functional and financial restraints, and the general deadlines for the preparation of the project and for the execution of the work

BASE PROGRAM – Prepared by the Designer, it discusses the feasibility of the objectives defined by the Owner from the technical and financial points of view, and the solutions considered most appropriate to respond to the request are presented

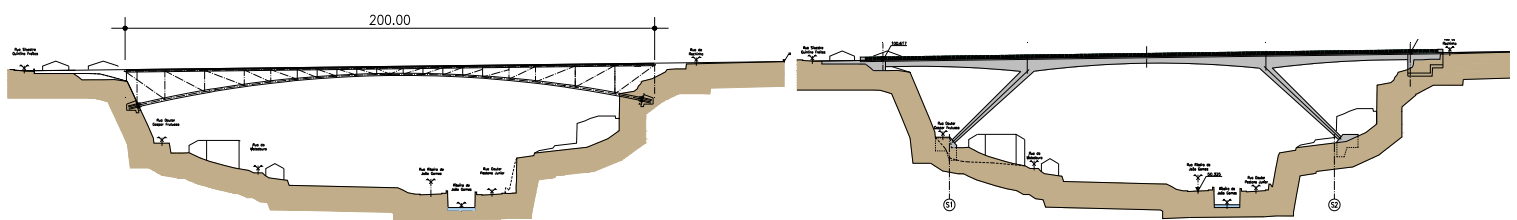
PRELIMINARY DESIGN => CONCEPTUAL DESIGN STAGE



PRELIMINARY DESIGN => ESTUTURAL CONCEPTION PHASE

Although the content of the **Preliminary Design** may vary depending on the type of structure, the written parts and drawings to be presented at this stage should include the following information:

- description and justification of the solutions developed (approved by the Owner in the Base Program);
- graphic elements (such as plan views, elevations, cuts and/or profiles) that clarify the design and characteristics of the work for each of the solutions;
- pre-design of the fundamental elements of the work;
- general definition of construction processes and the most significant materials and equipments;
- estimation of the cost and execution time of the work, for each proposed solution.



DETAILED DESIGN => CONSOLIDATION OF THE SOLUTION

In the **Detailed Design** stage, the solution selected by the Construction Owner is developed.

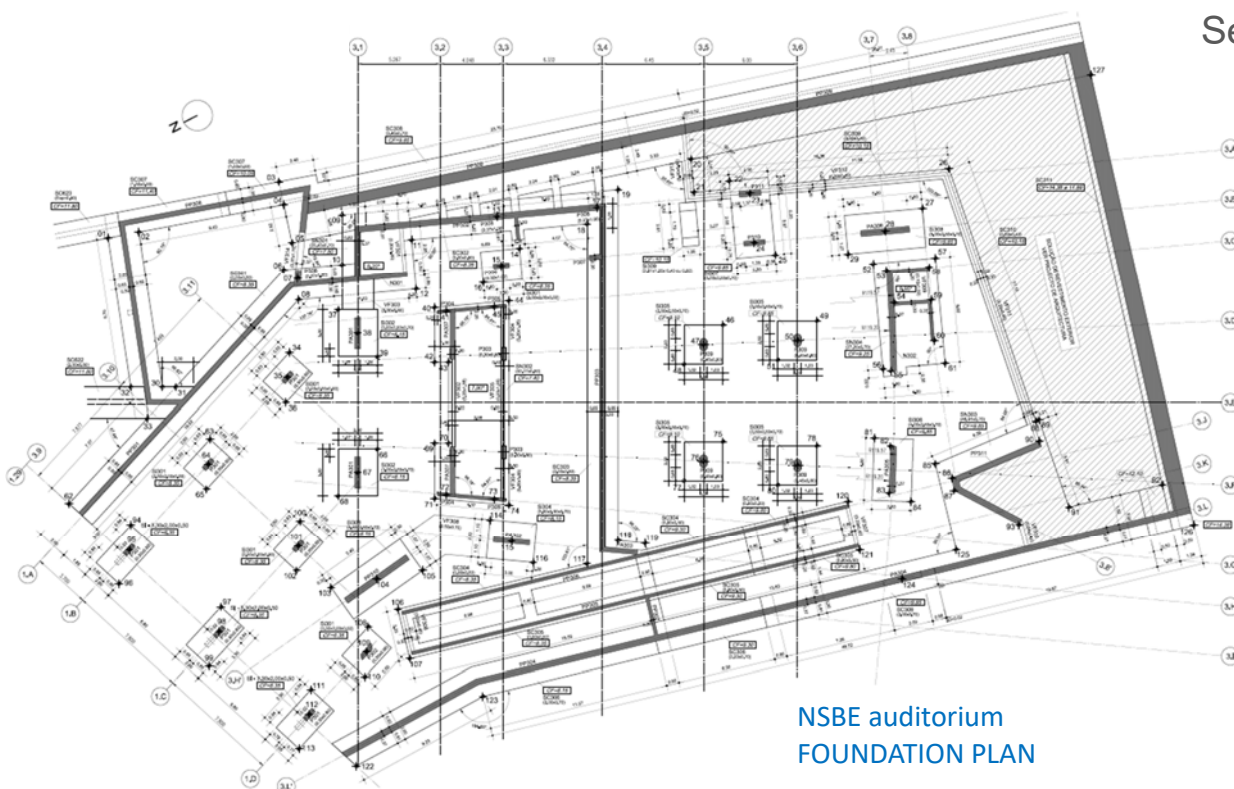
Although the content of the **Detailed Design** may vary depending on the type of structure, the written parts and drawings to be presented at this stage should include the following information:

- design note of the approved solution, with description of the systems and construction processes provided and the characteristics of materials, building elements, and equipment;
- evaluation of the amounts of work to be performed by large items, and updated cost estimation;
- drawings that explain the location of the work, the planimetry and the altimetry of its different parts and its dimensioning;
- the study elements that served as the basis for the options taken;
- a general programme of work to support the proposed implementation period.

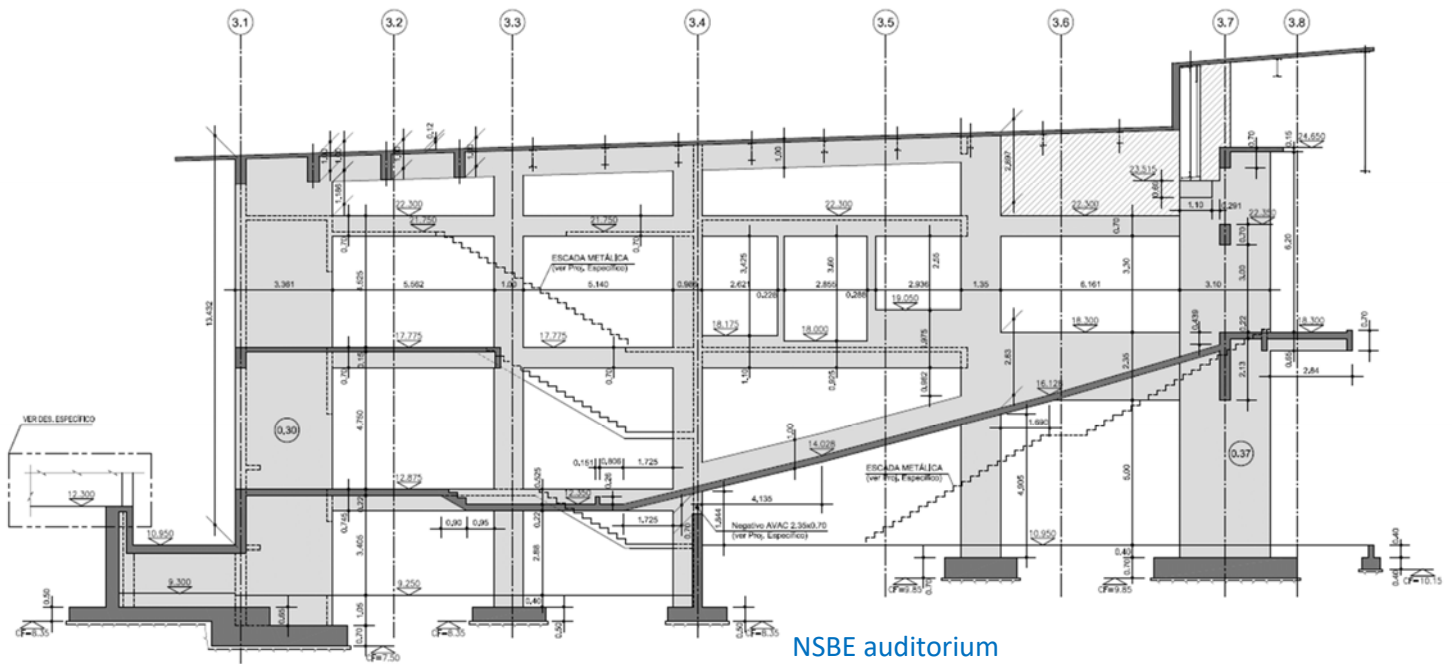
CONSTRUCTION DESIGN => DETAILING THE STRUCTURE FOR CONSTRUCTION

The **Construction Design** shall include written parts and drawings justifying and enabling the construction of the structure, in particular:

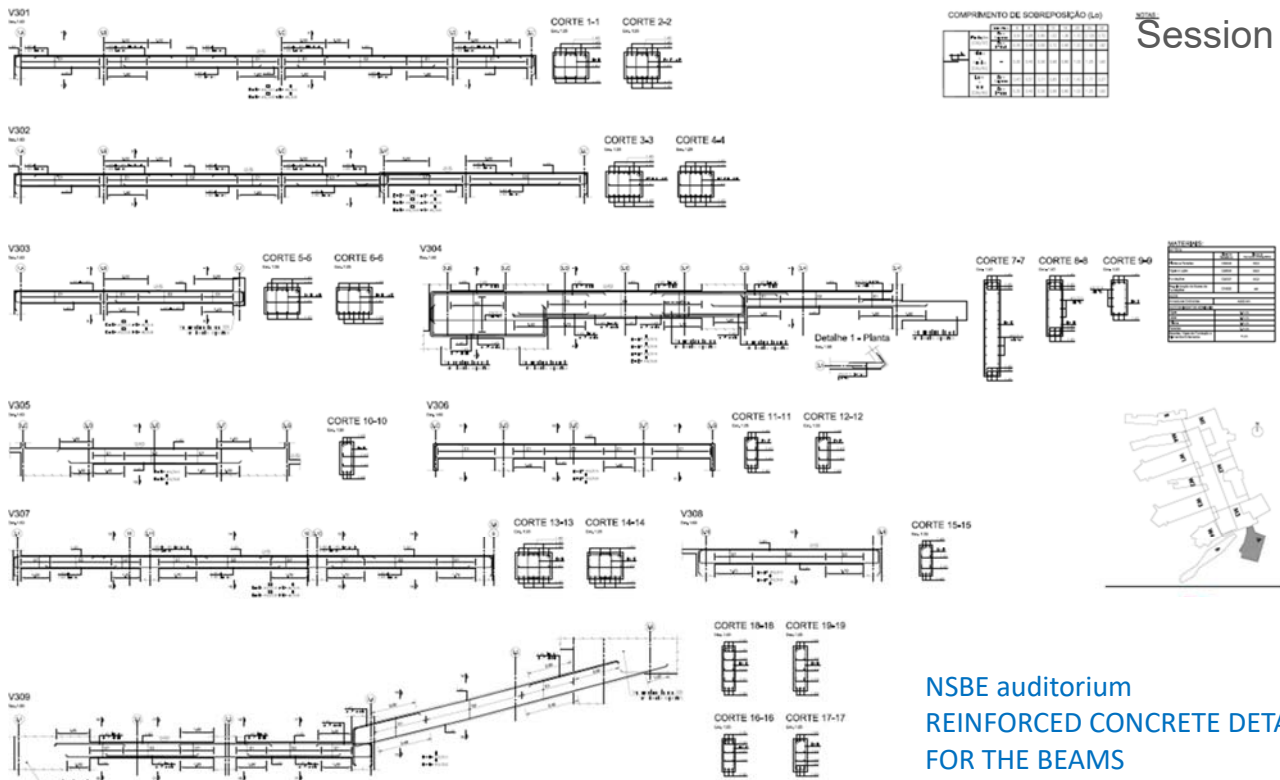
- **Design Note**, including the general description of the work and the solution adopted, and the indication of the characteristics of the materials and elements of the construction;
- **Supporting Calculations** relating to the complete and detailed design of all the elements that make up the structure;
- **Maps with the Material Quantities**;
- **Budget** based on the quantities and working qualities contained in maps of material quantities and the estimated unit prices;
- **Drawings**, which must contain the numerical indications and the representation of all the details necessary for the perfect understanding and execution of the work;
- **Technical Conditions**, general and special, **of the Specifications**, which includes the definition:
 - characteristics of the materials to be used in the work and the associated standards;
 - procedures for the execution of all the work planned, as well as the tolerances, acceptance criteria and tests to be carried out.



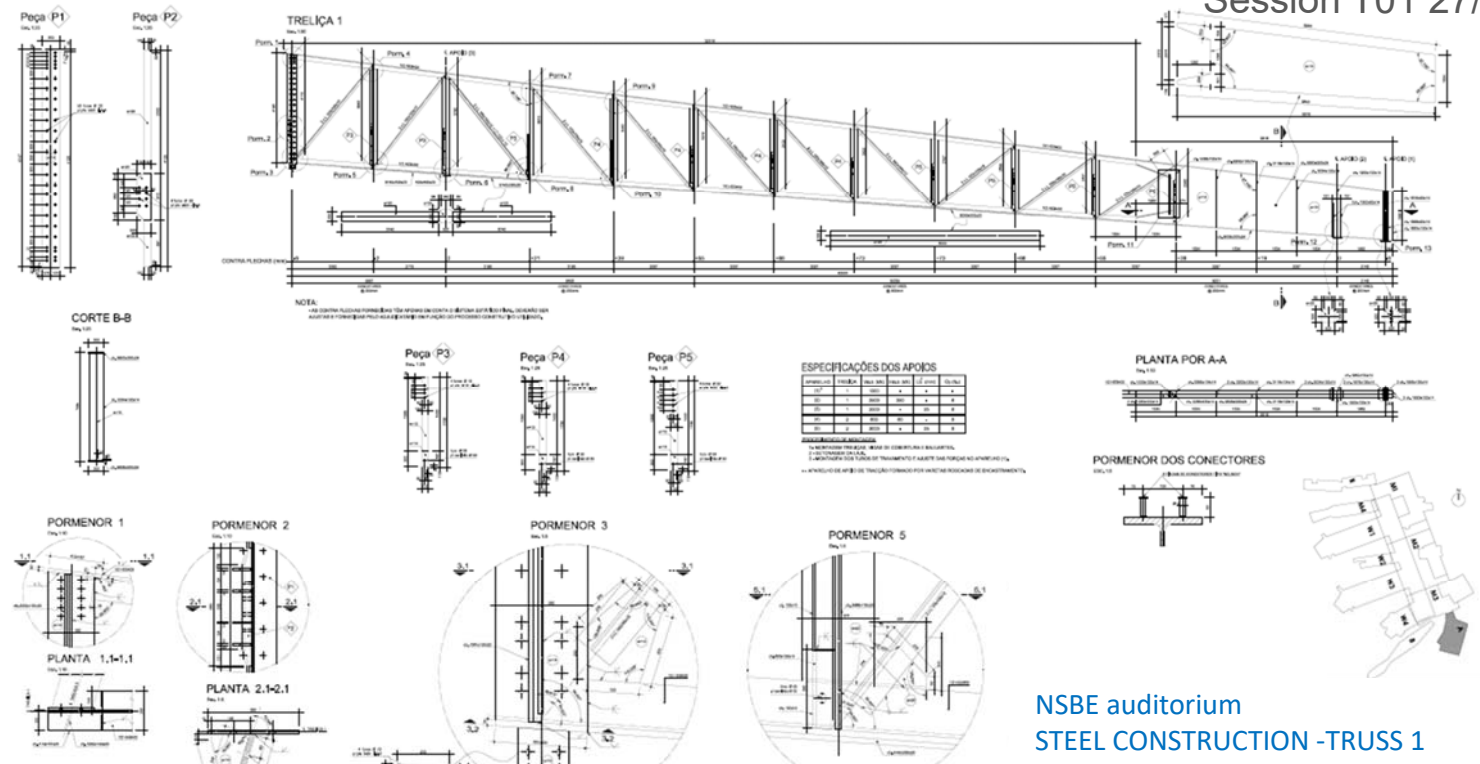
NSBE auditorium
FOUNDATION PLAN



NSBE auditorium
LONGITUDINAL CUT BY AXIS 3.B



NSBE auditorium
REINFORCED CONCRETE DETAILING
FOR THE BEAMS



NSBE auditorium
STEEL CONSTRUCTION - TRUSS 1

TECHNICAL ASSISTANCE => CONSTRUCTION MONITORING

The **Technical assistance** constitutes both an obligation and a right on the part of the Designer, comprises the following activities:

- clarification of doubts relating to the design during the tender phase for the award of the project;
- the provision of support to the Owner in the assessment and comparison of the technical proposals submitted by the competitors;
- the provision of information and clarifications, requested by the Contractor, on aspects relating to the interpretation of the written parts and drawings of the design.

DESIGN REVIEW => CONFIRMATION OF THE QUALITY OF THE DESIGN

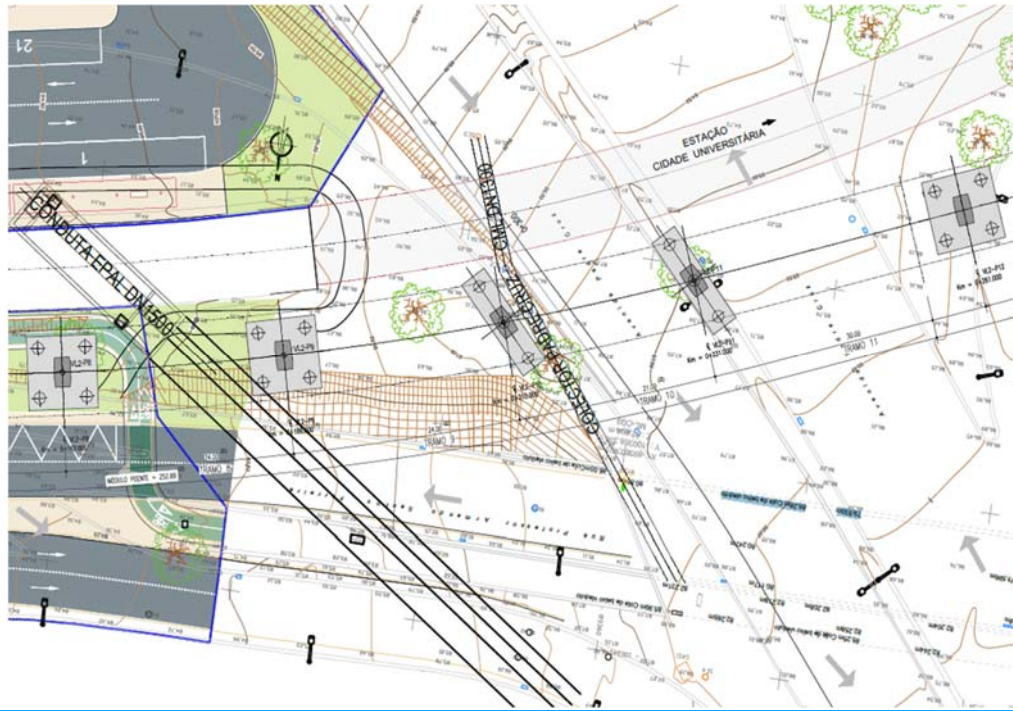
The **Design Review** carried out by a qualified entity independent of the Designer is a positive and necessary practice in the major projects.

The Reviewer is responsible for assessing and issuing reports on the technical quality of the design, it is not the Reviewer task to assess the design solutions unless for structural safety reasons.

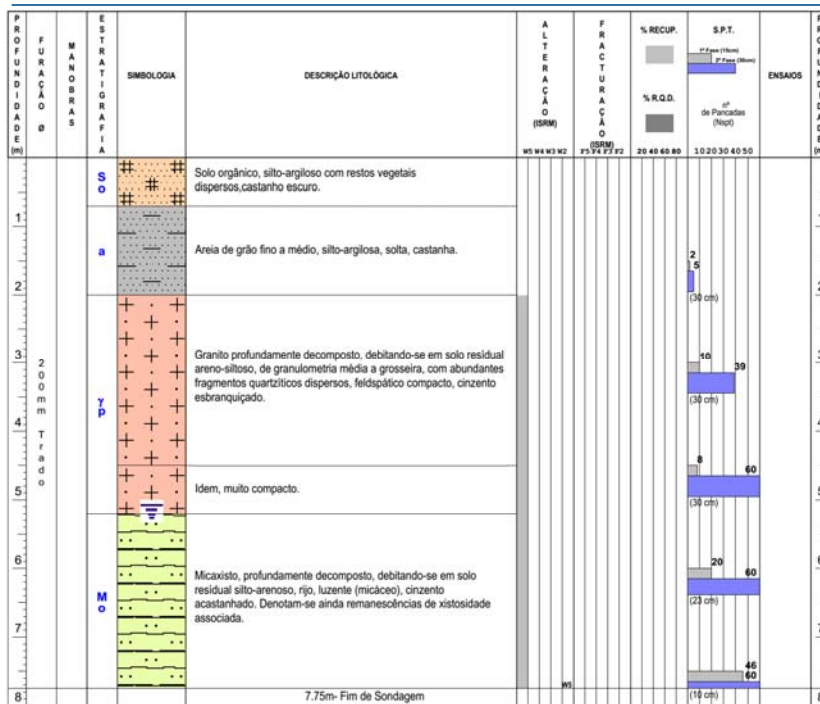
COMPLEMENTARY WORK TO SUPPORT THE DESIGN

To support the Structural Design, some **Complementary Works** are needed, such as:

- Field surveys (e.g., topographic surveys and affected services);
- Geological, geotechnical and hydraulic studies;
- Reports of studies and laboratory tests;
- Environmental studies including environmental impact statement;
- Plan for prevention and management of construction and demolition wastes.



COMPLEMENTARY WORK TO SUPPORT THE DESIGN



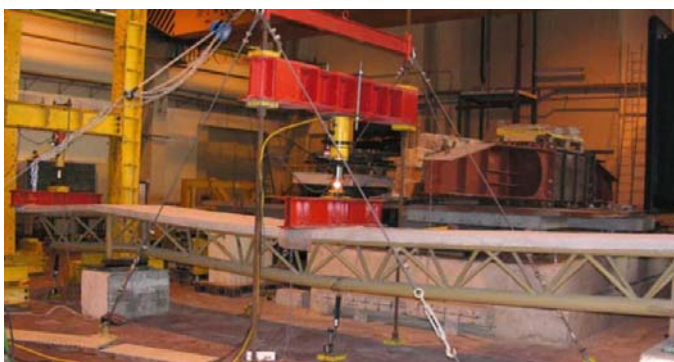
Geotechnical survey

Results of a rotation survey with sample collection and SPT tests

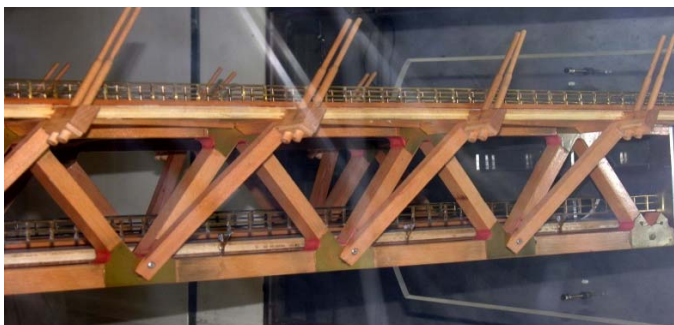


COMPLEMENTARY WORK TO SUPPORT THE DESIGN**Tests of physical models in the laboratory**

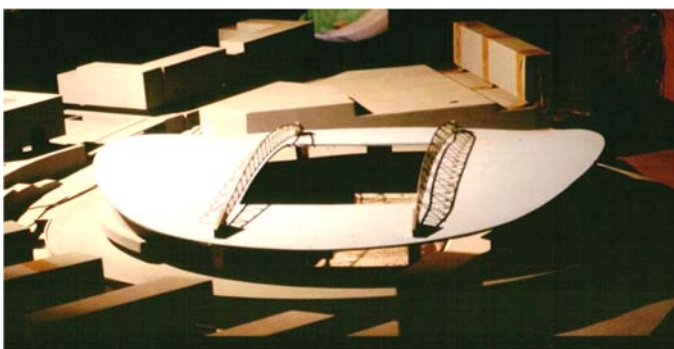
Test until failure of a steel-concrete composite beam



Test until failure of a steel-concrete composite for a pedestrian bridge deck

COMPLEMENTARY WORK TO SUPPORT THE DESIGN**Wind tunnel tests**

Sectional model of a cable-stayed bridge



Global model for the Dragon football stadium