جامعة أبو بكر بلقايد
كلية التكنولوجيا
UNIVERSITÉ DE TLEMCEN
Faculté de Technologie

# A3 ARCHITECTURE

## SUBJECT: STRUCTURE IN ARCHITECTURE 1

# CHAPTRE 3 : BRIDGES SYSTEM OF ARCHES AND CABLES

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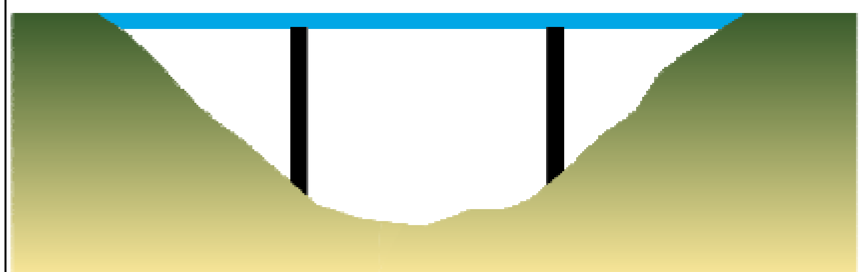
# INTRODUCTION

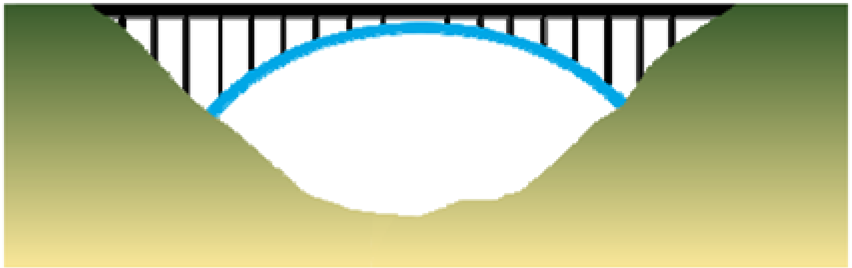
Bridges are engineering structures designed to span obstacles such as rivers, roads, or valleys. They ensure the continuity of traffic and must withstand loads, climatic conditions, and safety requirements. Their design combines engineering principles, material selection, and structural performance, making bridges essential elements of modern transportation networks.

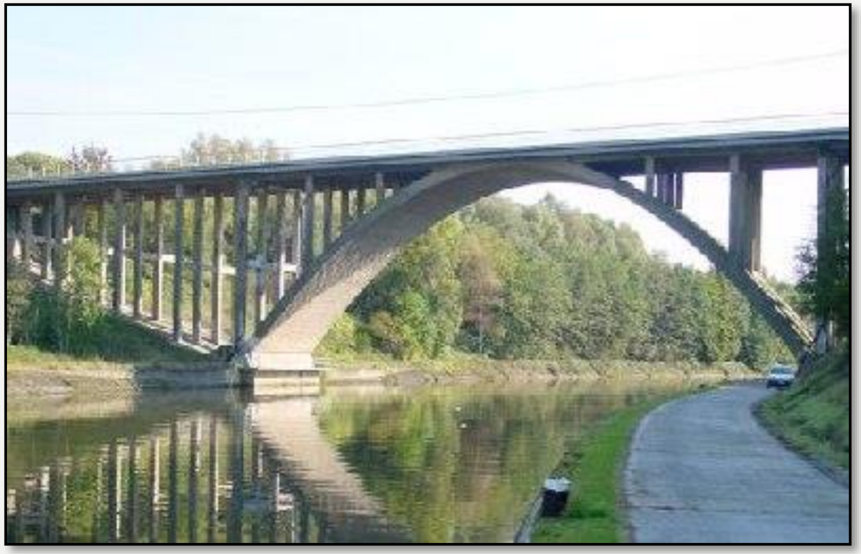
# TYPES OF BRIDGES

Bridges can be classified into several types according to their structural form, their load-carrying mechanism, and the materials used:

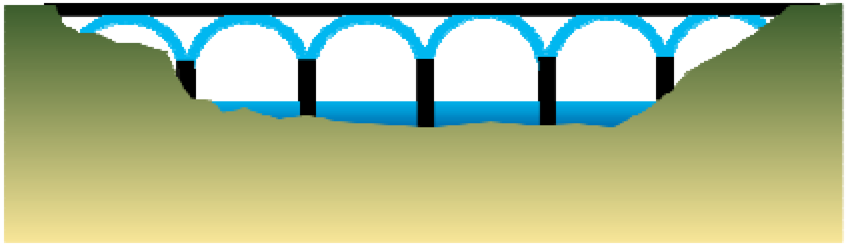
| GIRDER BRIDGES | |
|---|---|
| The structure can be likened to a straight beam. A symbol of simplicity, it works in bending. |  |

# TYPES OF BRIDGES

| ARCH BRIDGES | |
|---|---|
| **ARCHED BRIDGES** | |
| In an arch bridge, the river or gap is crossed in a single span by a single arch, whereas in a vault bridge the deck rests on intermediate piers. The arch bridge combines compression and bending. |  |



# TYPES OF BRIDGES

| Arch Bridge | |
|---|---|
| **Vaulted Bridge** | |
| These are the first durable bridges ever built. They work only in compression. The construction material is stone. The vault is made of radial stones, which are compressed under the load of vehicles crossing the bridge. The forces are distributed to the piers and to the abutments at each end. |  |

# TYPES OF BRIDGES

| CABLE BRIDGES | |
|---|---|
| **Suspension Bridge** | |
| A suspension bridge is a bridge whose deck is suspended from pylons by a system of cables. It belongs to the family of cable bridges, combining tension, compression, and bending, resulting in a more complex structural behavior than the previous bridge types. The pylons rise above the deck and support one or two main cables, called load-bearing cables, which run from one abutment to the other, one on each side of the deck. These cables support the deck through a set of vertical cables called hangers (suspenders). |  |

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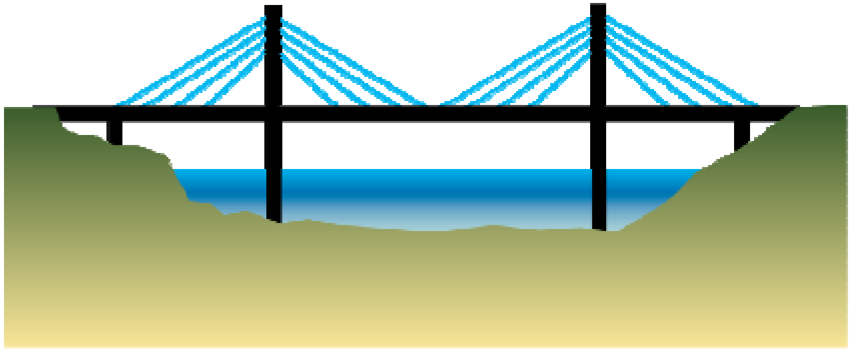
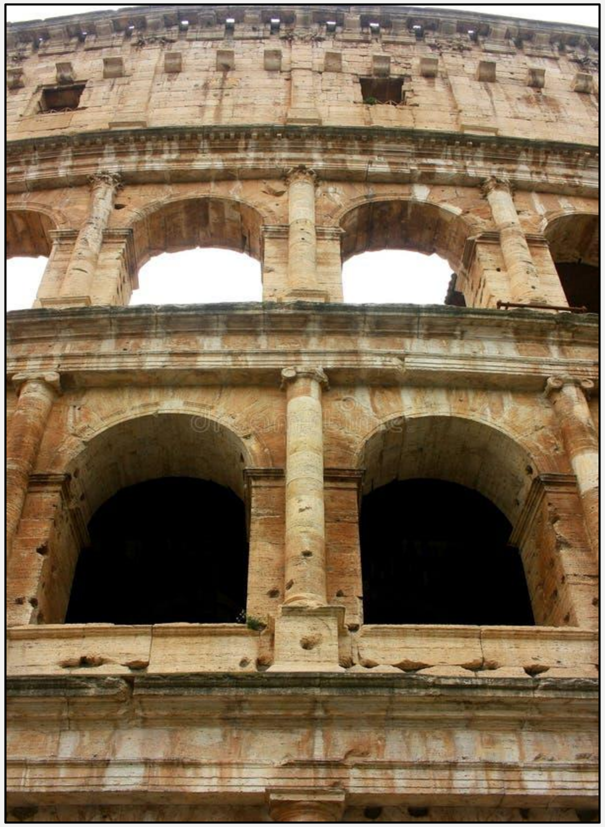
# TYPES OF BRIDGES

| CABLE BRIDGES | |
|---|---|
| **Cable-Stayed Bridge** | |
| A cable-stayed bridge is a type of steel cable bridge.<br>The deck is supported by a network of cables directly tensioned between the top (or a point close to the top) of the pylons and attached at regular intervals along the deck. |  |

# THE ARCHS

# INTRODUCTION

An arch is a structure designed to span a linear space, more or less wide, using a curved form. Arches can be made of stone, brick, or reinforced concrete.

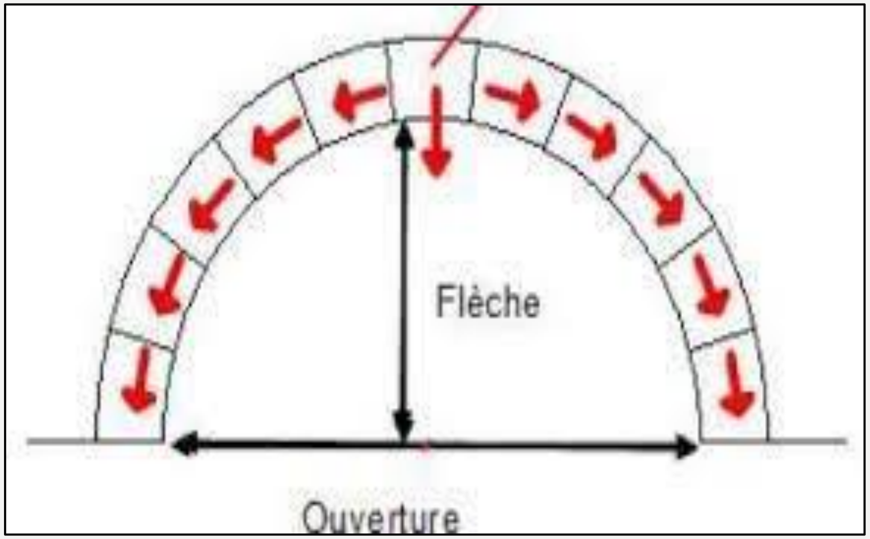


# ROLE OF THE ARCH

An arch is a curved structure used to span a space (opening, passage, doorway, bridge, etc.) by transferring loads to its supports through compression. Unlike a straight beam, the arch works almost entirely in compression, making it highly efficient for materials that perform well under compression, such as stone, brick, or concrete.

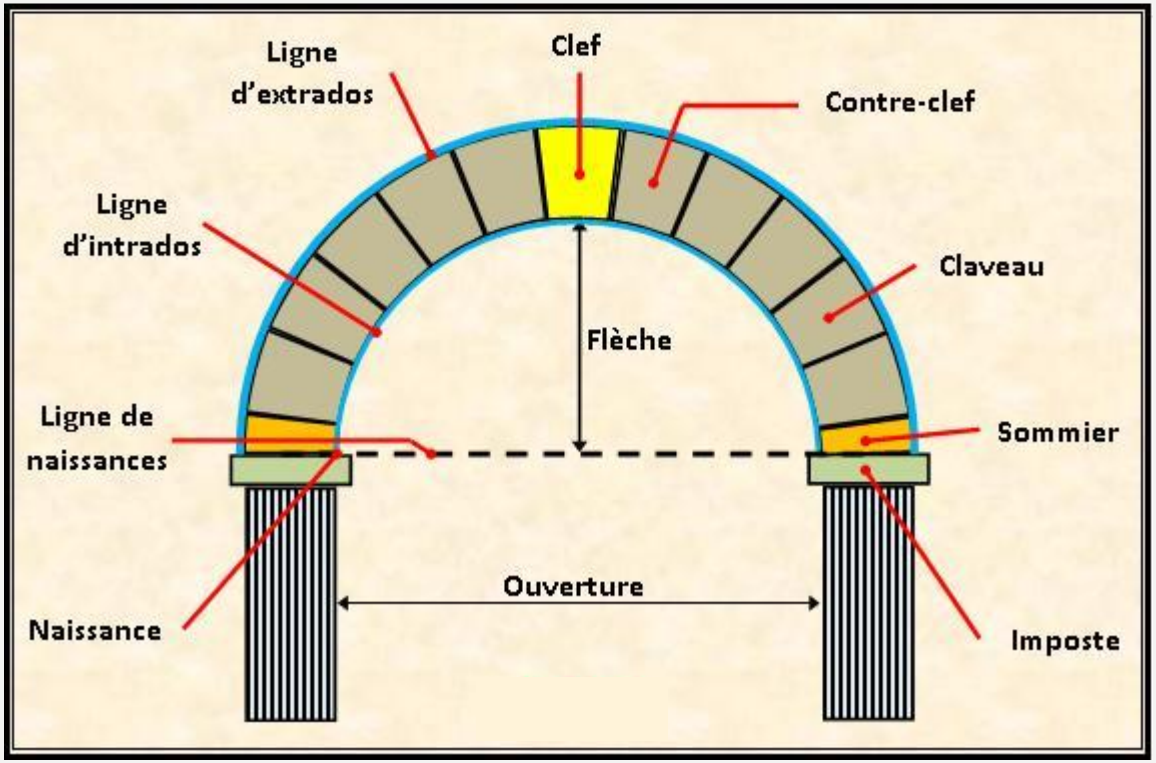
# WHY USE ARCHES ?

In ancient times, structures were mainly built using masonry (stone or brick), which could only withstand compressive forces.



# COMPOSITION OF ARCHES

In the past, masonry arches were constructed from individual units (stone or brick) and were composed of the elements shown in the figure below.



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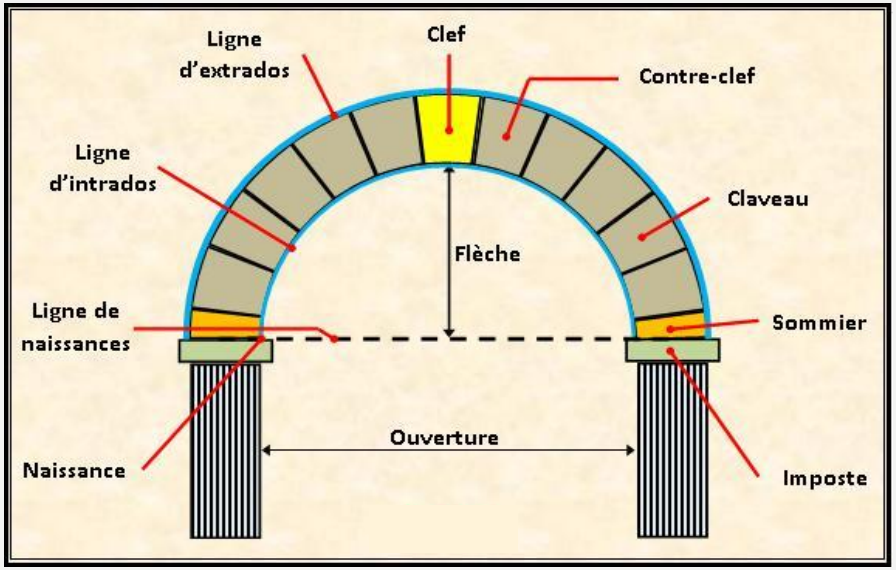
# COMPOSITION OF ARCHES

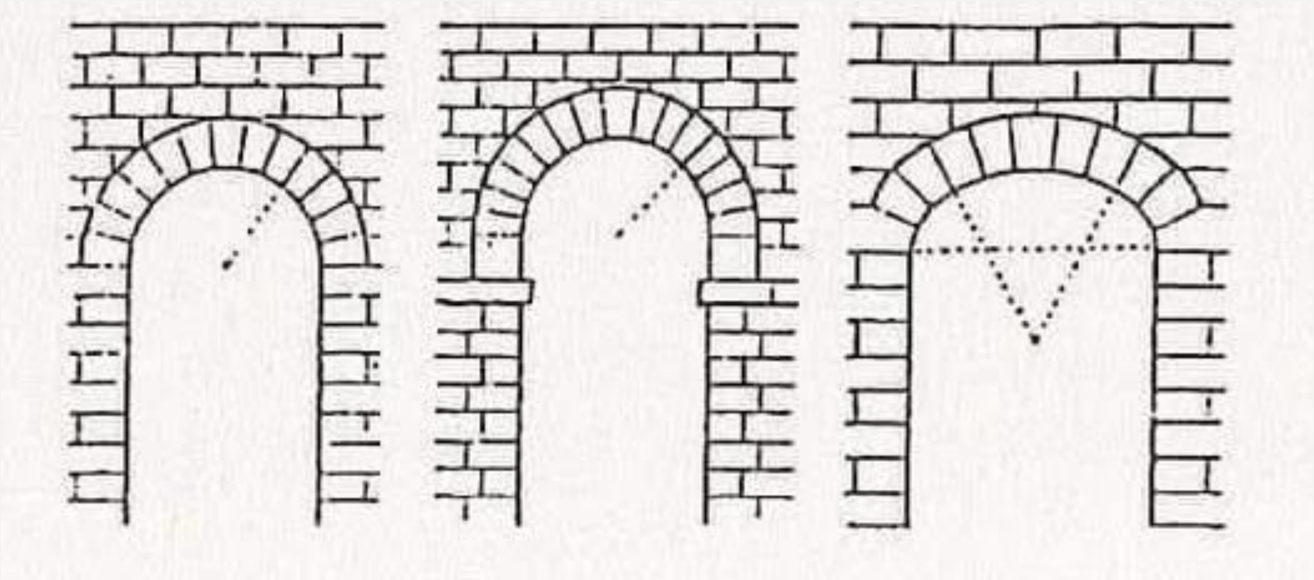



| Element | Role |
|---|---|
| **Keystone** | Locks the arch, transfers compression, stabilizes the structure |
| **Counter-keystone** | Receives the load from the keystone and transfers it to the voussoirs |
| **Voussoirs** | Distribute compression along the arch |
| **Crown (or Apex stone)** | Receives horizontal thrust and transfers it to the support |

# CLASSIFICATION OF ARCHES

The classification of arches is based on the ratio between the rise (height) and the span (opening), as shown in the figure below :

**Semicircular arch** **Raised arch** **Segmental arch**



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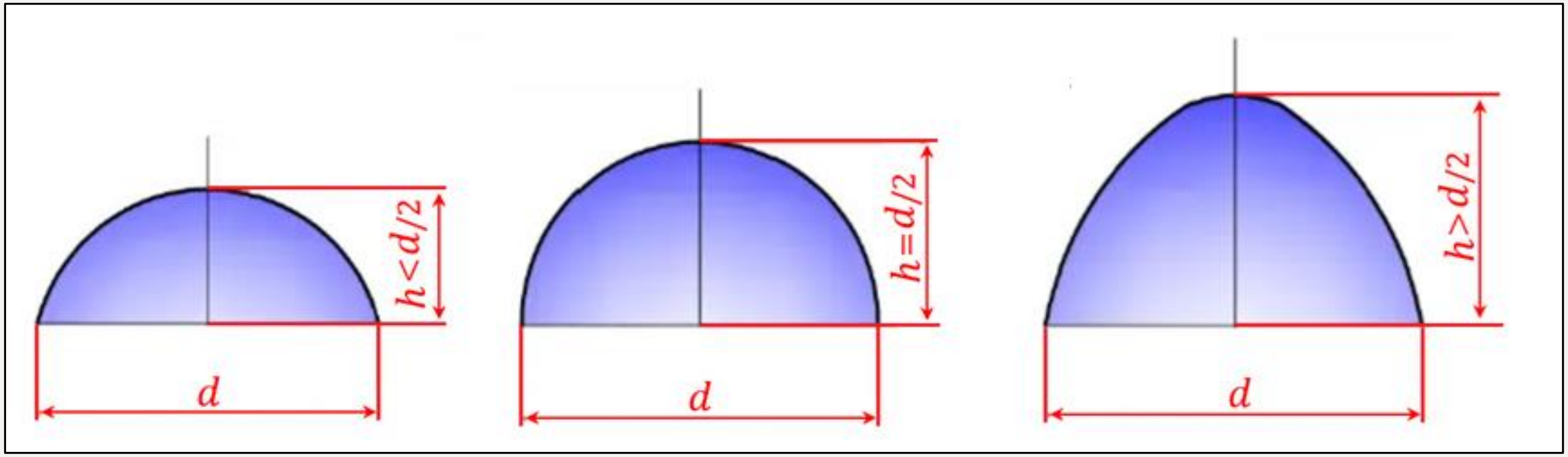
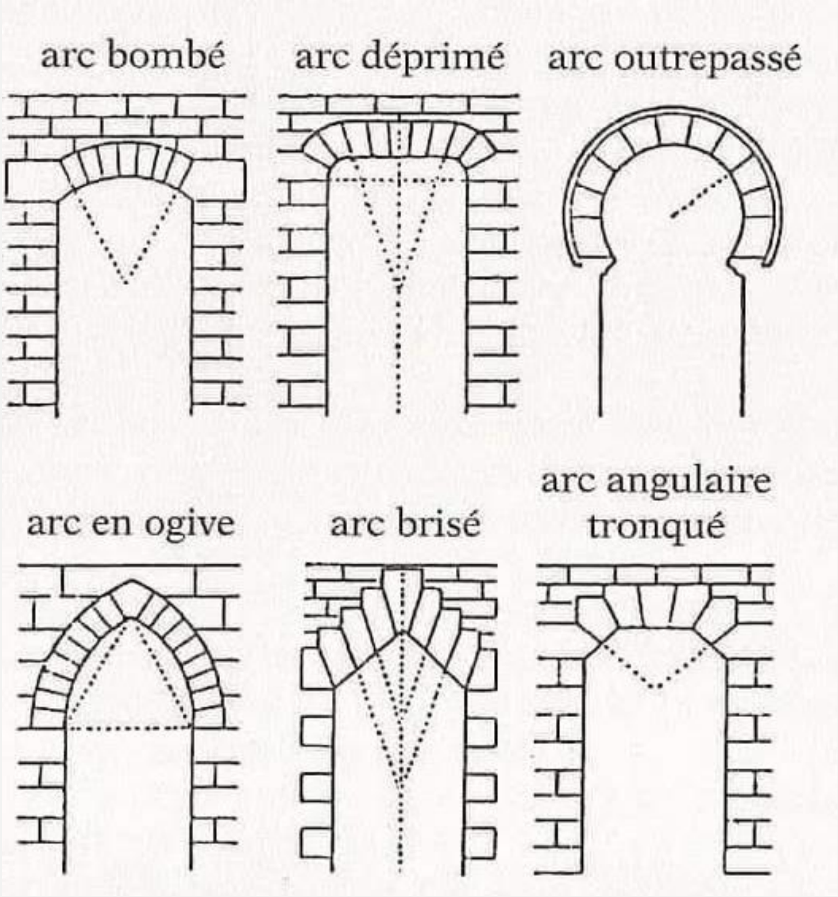
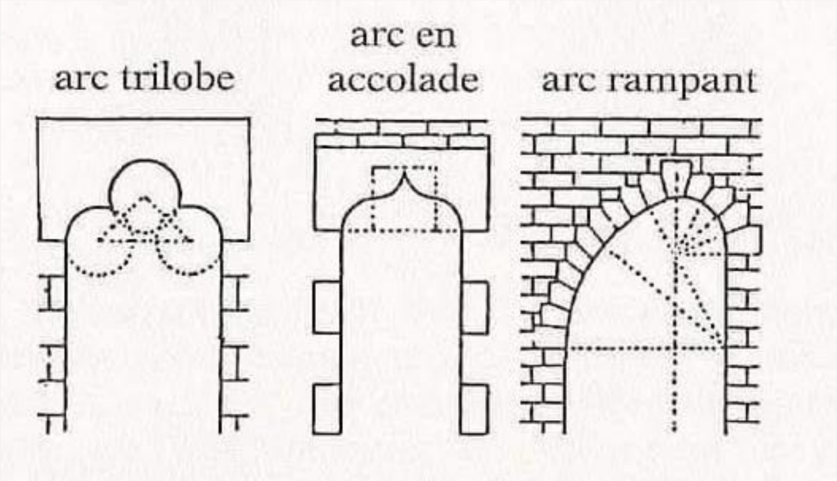



**Low-rise archs** **Semicircular archs** **Hight-rise archs**

# TYPES OF ARCHES

There are several types of arches, depending on structural requirements as well as the local architectural style (Moorish, Roman, Gothic, etc.).

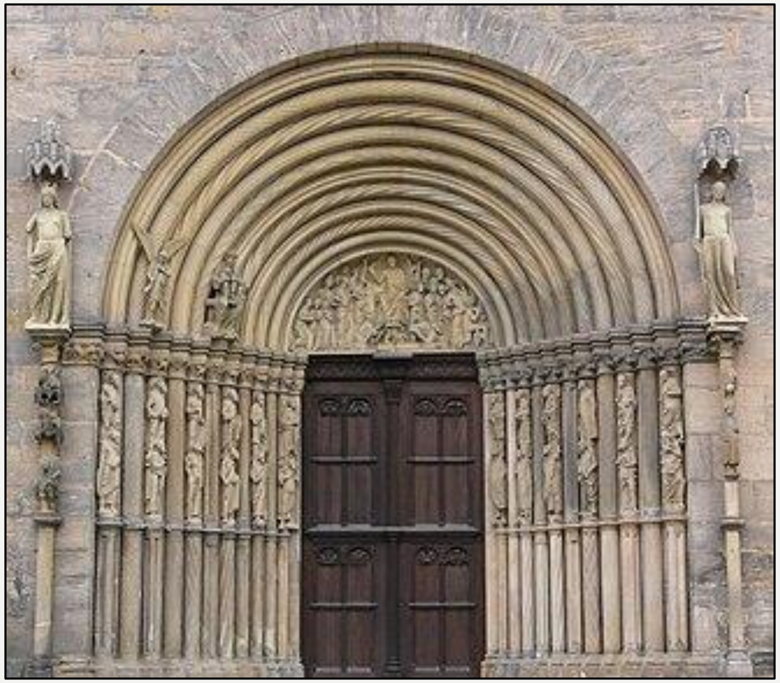


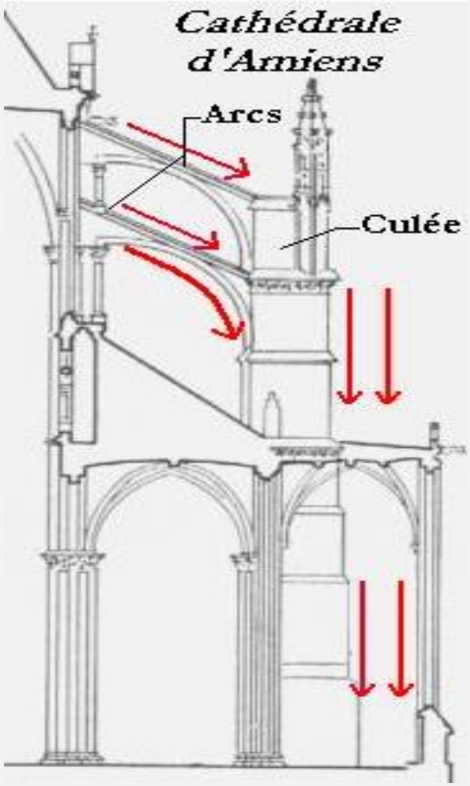
# TYPES OF ARCHES

There are various types of arches, depending on structural needs and the local architectural style (Moorish, Roman, Gothic, etc.).

Arch with Archivolts

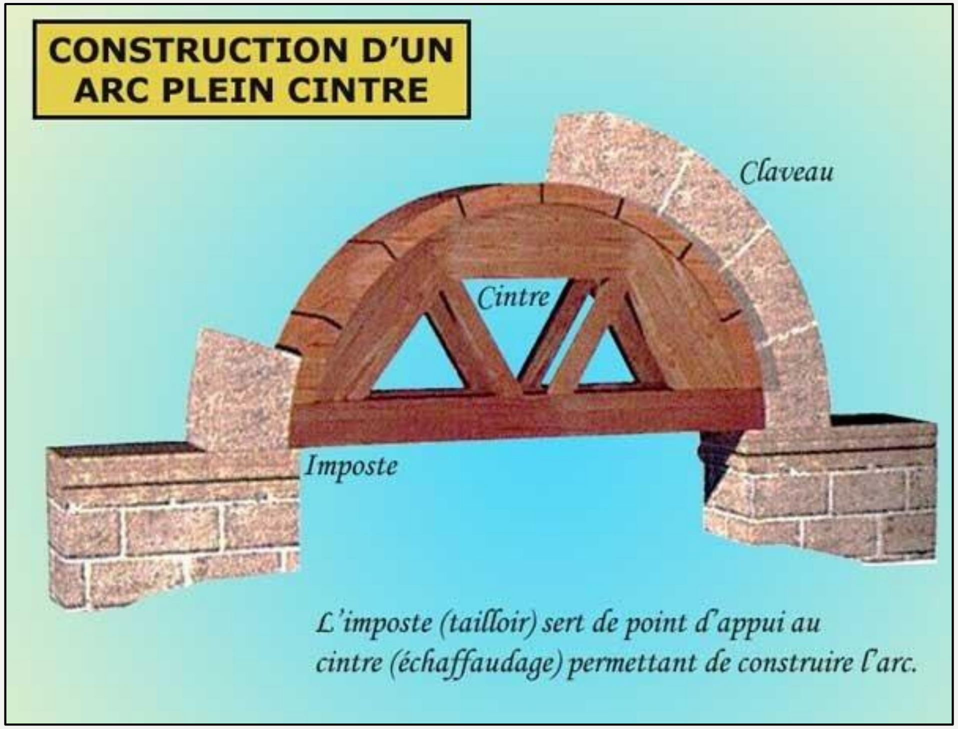


Flying Buttress Arch



# CONSTRUCTION OF ARCHES

The construction of an arch involves preparing solid supports, placing a wooden centering, arranging the voussoirs on each side up to the keystone that locks the assembly, and then removing the centering so that the arch becomes stable and works in compression.




Video : https://www.youtube.com/watch?v=-mD2lpUsdVs

# CONSTRUCTION OF ARCHES

The construction of a reinforced concrete arch involves installing the centering and reinforcement on top, followed by pouring the concrete.

Photos : https://mamaisondeaaz.gedimat.fr/article/288/78-libelle.htm

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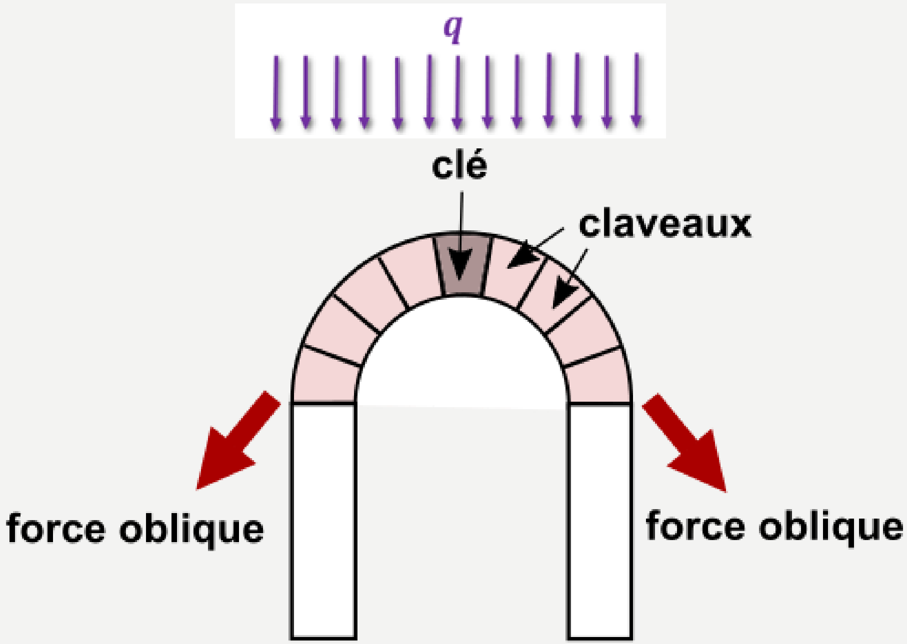
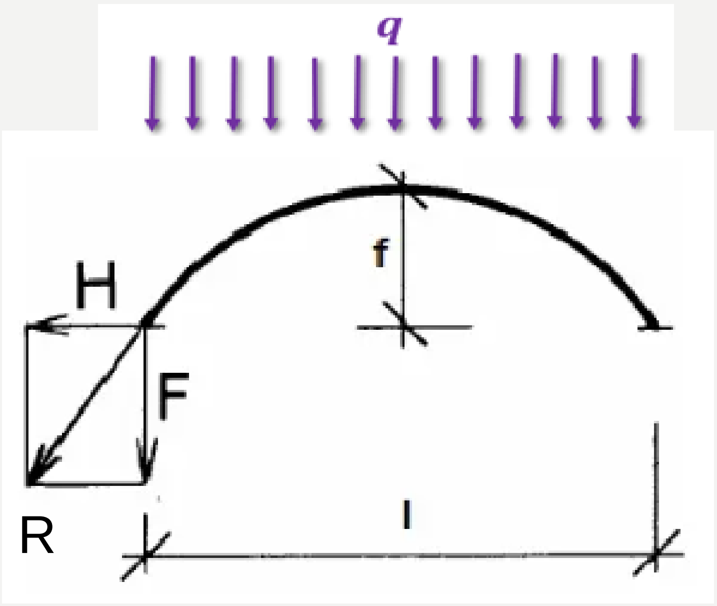
# FUNCTIONING OF ARCHES

The loads applied to an arch are transmitted to the supports through compression. However, at the springing points, the force is oblique (R), and by projection, there is a vertical compressive force (F) and a horizontal thrust (H).



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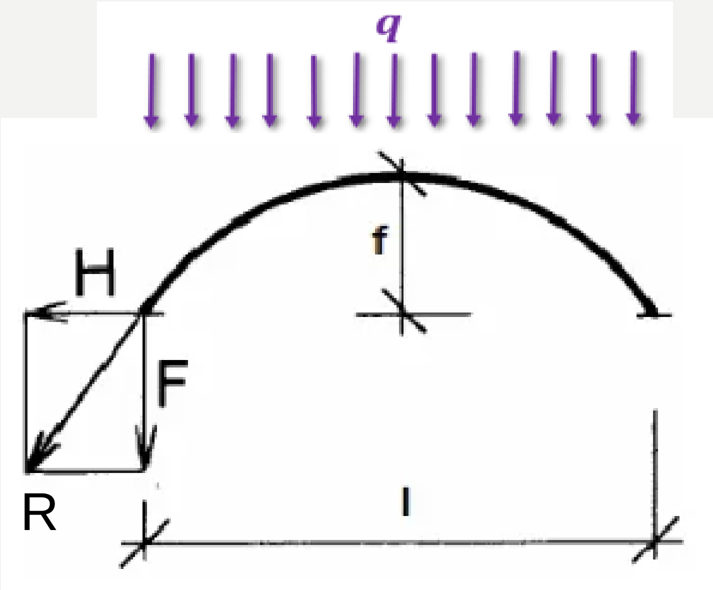



$$F = \frac{qL}{2}$$

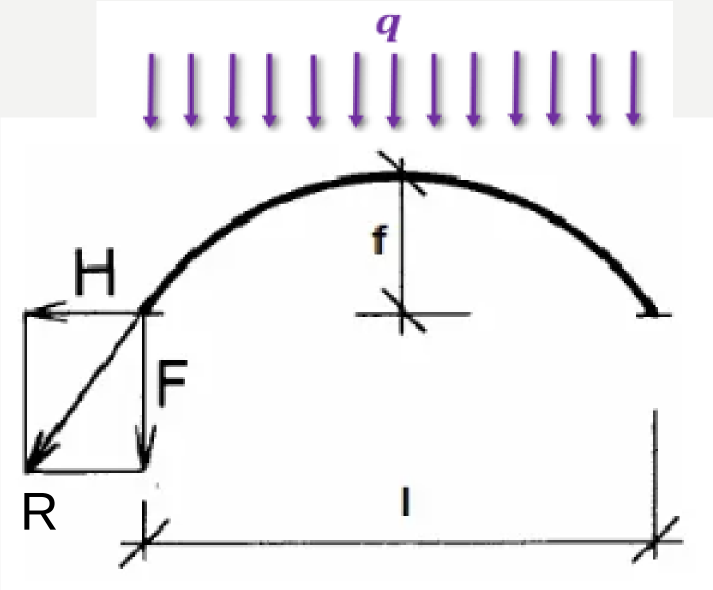
$$H = \frac{qL^2}{8f}$$

$$R = \sqrt{H^2 + F^2}$$

# DESIGN OF ARCHES

The thickness of an arch can be calculated based on the oblique force applied using the stress formula:

$$\sigma = \frac{R}{A} = \frac{R}{B \times t}$$




Avec

$$R = \sqrt{H^2 + F^2}$$

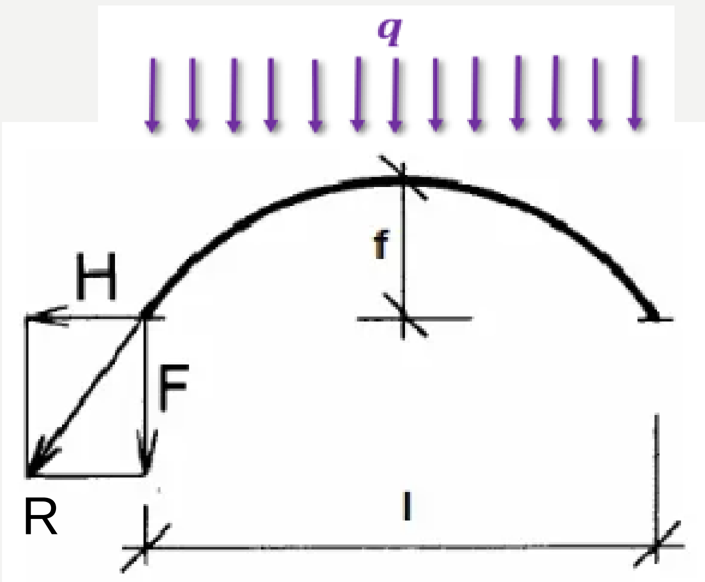
Donc :

$$\boxed{t = \frac{R}{\sigma_{\text{adm}} \times B}}$$

- Concrete : $\sigma_{adm} = 20 \text{ à } 50\ MPa$
- Rocks : $\sigma_{adm} = 6 \text{ à } 12\ MPa$
- Brick : $\sigma_{adm} = 3 \text{ à } 6\ MPa$

# DESIGN OF ARCHES

For reinforced concrete arches, calculating the compression reinforcement may be necessary and is done as follows:




## I-COMPRESSION SIMPLE

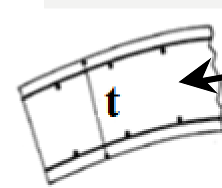
**I-CALCUL DES ARMATURES LONGITUDINALES**

**1- ELU de résistance**

$$As = \frac{N_u - Bf_{bu}}{f_{sc}}$$

$$f_{bu} = \frac{0{,}85\, f_{c28}}{\theta\, \gamma_b} \quad \textit{Section rectangulaire}$$

$$f_{bu} = \frac{0{,}8\, f_{c28}}{\theta\, \gamma_b} \quad \textit{Section circulaire}$$




$\gamma_b = 1.5$ *situations courantes*

$\gamma_b = 1.15$ *situations accidentelles*

$$f_{sc} = \frac{f_e}{\gamma_s}$$

$\gamma_s = 1.15$ *situations courantes*

$\gamma_s = 1$ *situations accidentelles*

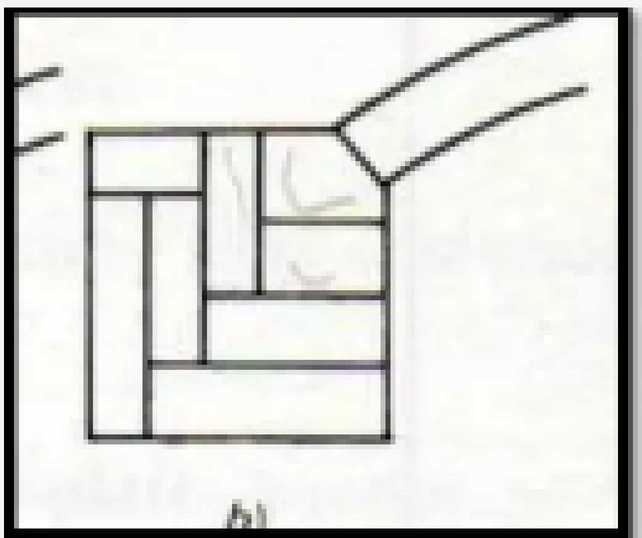
**Vérification des contraintes à l'ELS**

$$\sigma_{bc} = \frac{N_{ser}}{B + 15A_s} \leq \bar{\sigma}_{bc} = 0{,}6 f_{c28}$$

# SPRINGERS OF ARCHES

The springers of an arch, located at its base, must resist the horizontal thrust (H); therefore, they need to be reinforced to prevent the arch from spreading.

<u>Masonry Springer</u>

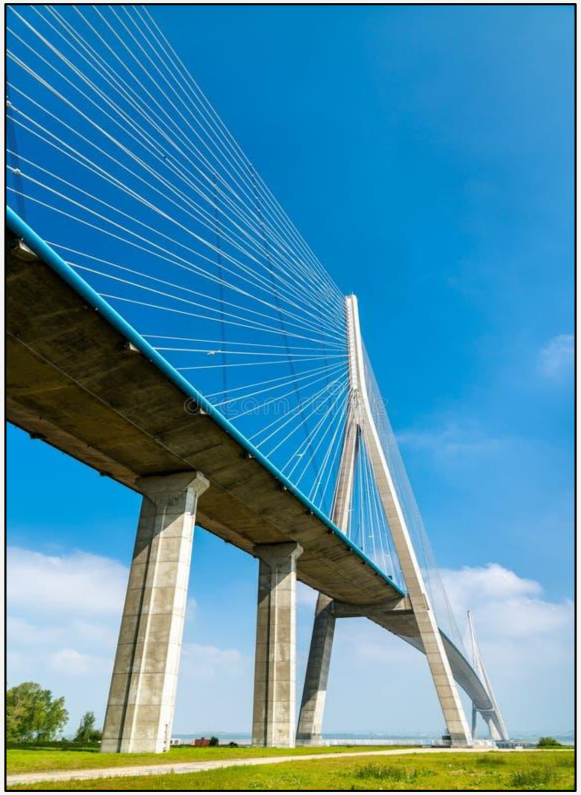


<u>Reinforced Concrete Springer</u>

# CABLES

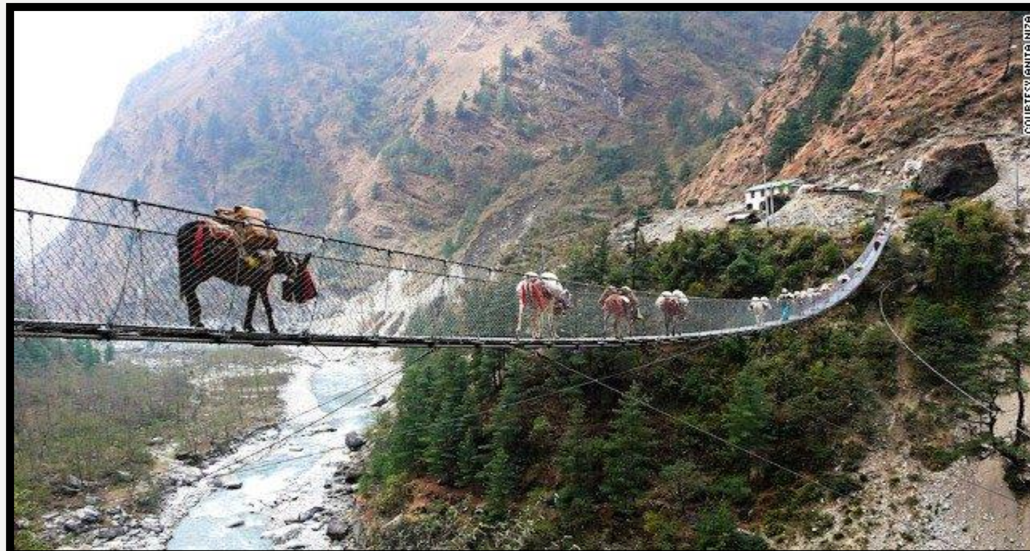
# INTRODUCTION

Cables are essential elements in many structures, such as bridges, tensile roofs, pylons, or suspended equipment. Made of high-strength steel, they transmit loads to the supports and ensure the stability of the structure.



# WHERE CAN THEY BE FOUND?

**Bridges**
(In ancient times)




# WHERE CAN THEY BE FOUND?

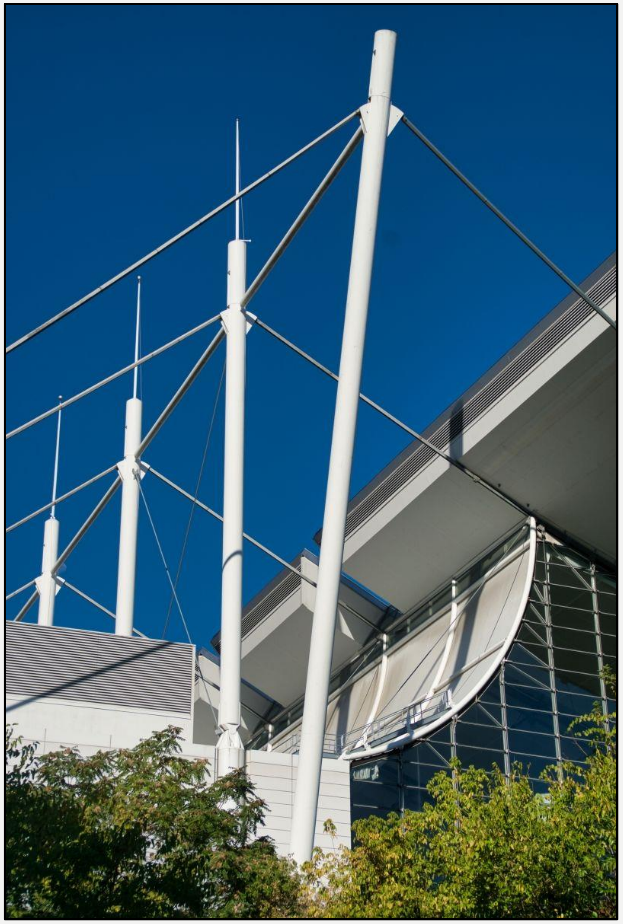
**Bridges**
(In modern times)

**Cable-Stayed Bridges**

**Suspension Bridges**

# WHERE CAN THEY BE FOUND?

## Roofs of structures



# WHERE CAN THEY BE FOUND?

## Masts


**<u>Network masts</u>**

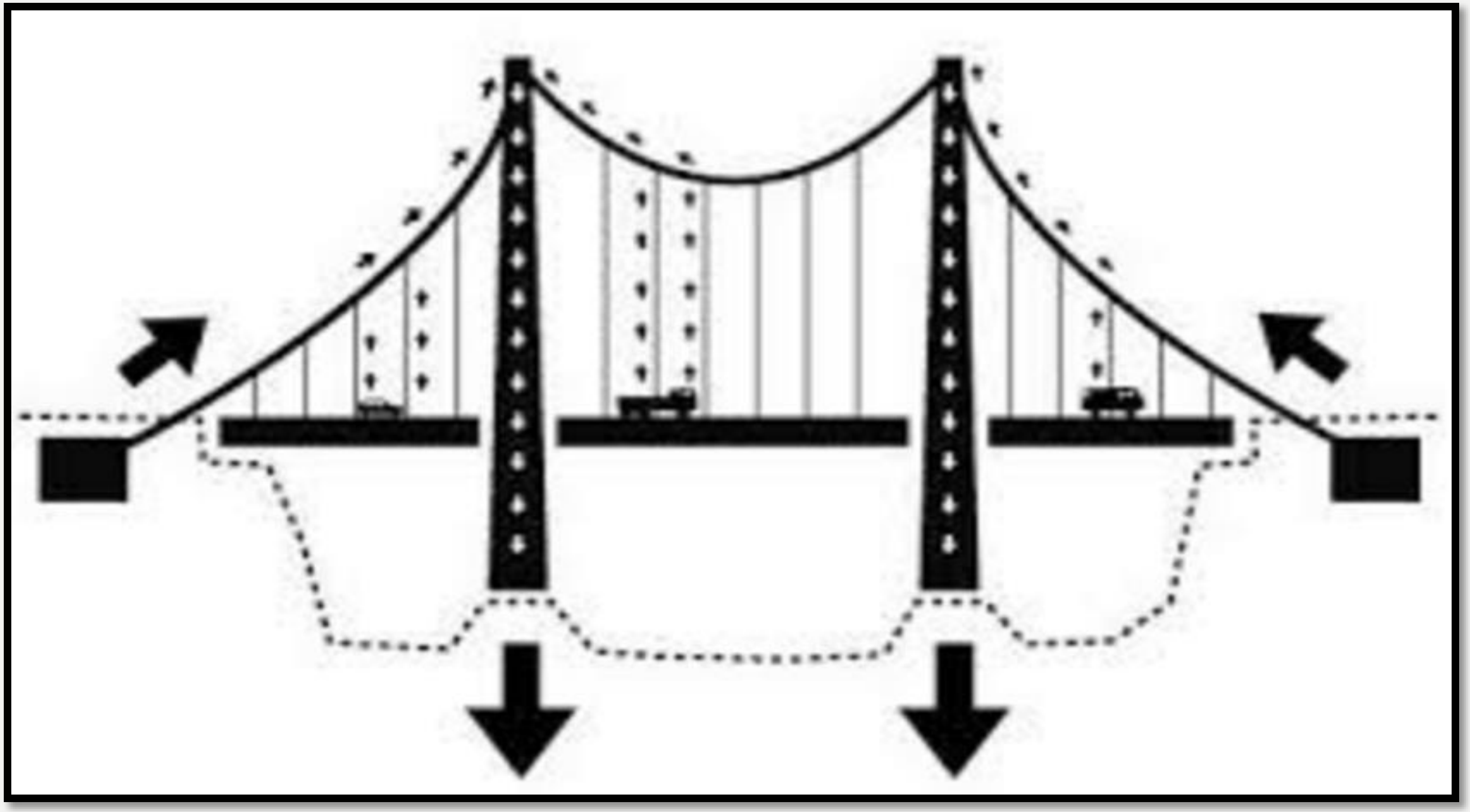
**<u>Ship masts</u>**

# ROLE OF THE CABLE

Cables are used in construction to ensure:

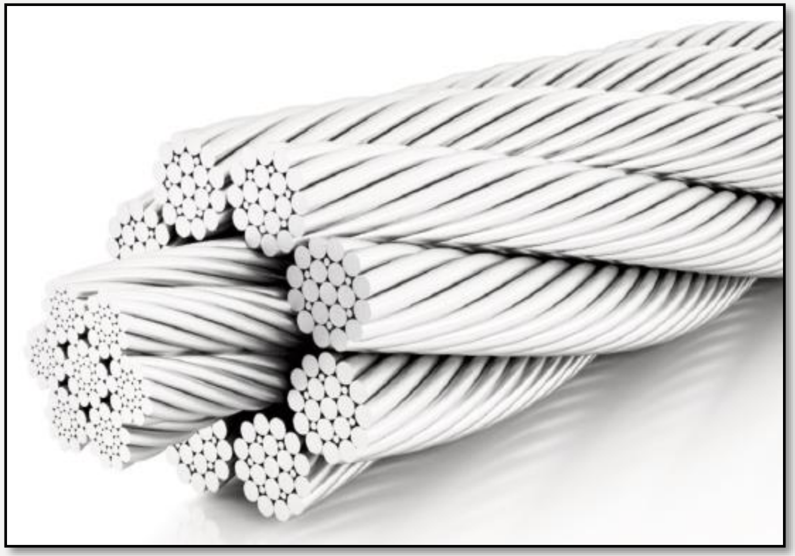
- **Load support:** They transmit the weight of the deck, vehicles, and pedestrians to the pylons and anchorages.
- **Stability maintenance:** They keep the deck balanced and limit its bending.
- **Resistance to dynamic forces:** They absorb vibrations, wind effects, seismic forces, and moving loads.
- **Load distribution:** They evenly distribute forces across the structure to prevent stress concentrations.
- **Durability and safety:** Made of high-strength steel and designed with safety margins, they provide a long service life and high resistance to failure.

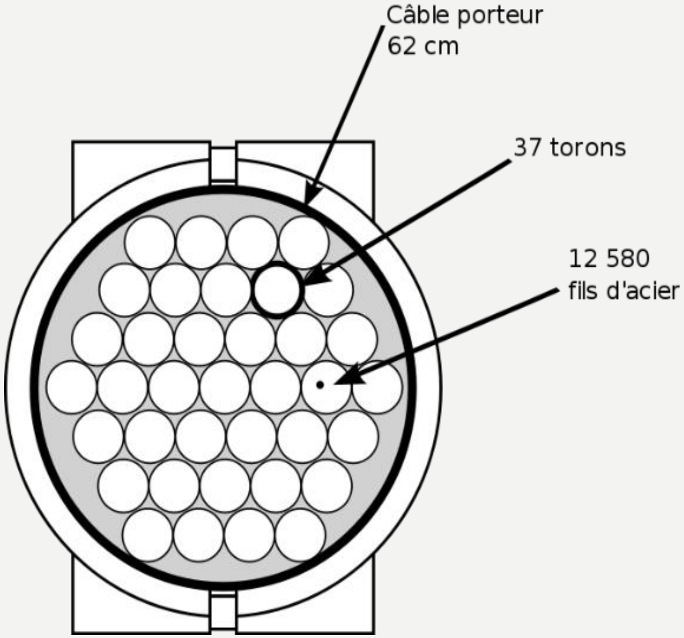
# ROLE OF THE CABLE



# CABLES

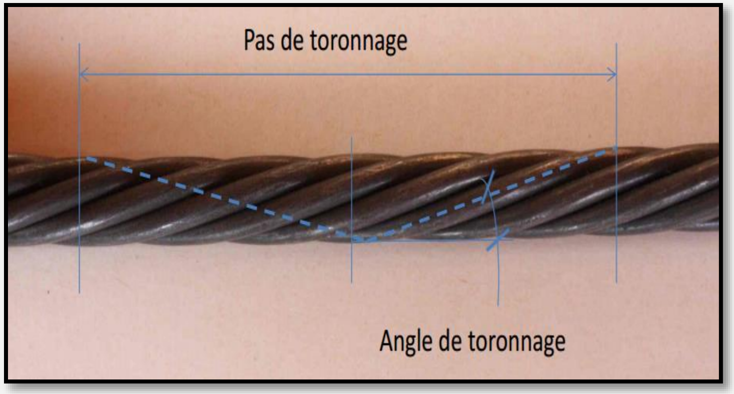
A cable consists of a set of strands arranged regularly in a helix, made up of high-strength steel wires also laid in a helical pattern. It works exclusively in tension.





# CABLE FABRICATION

Cables are made by twisting steel wires into strands, which are then bound together to tighten them. Finally, a waterproof layer is added. The twisting process involves winding multiple layers of wires in a circular helix around a central wire.




**Video :** https://www.youtube.com/watch?v=18kKdhk3y7I

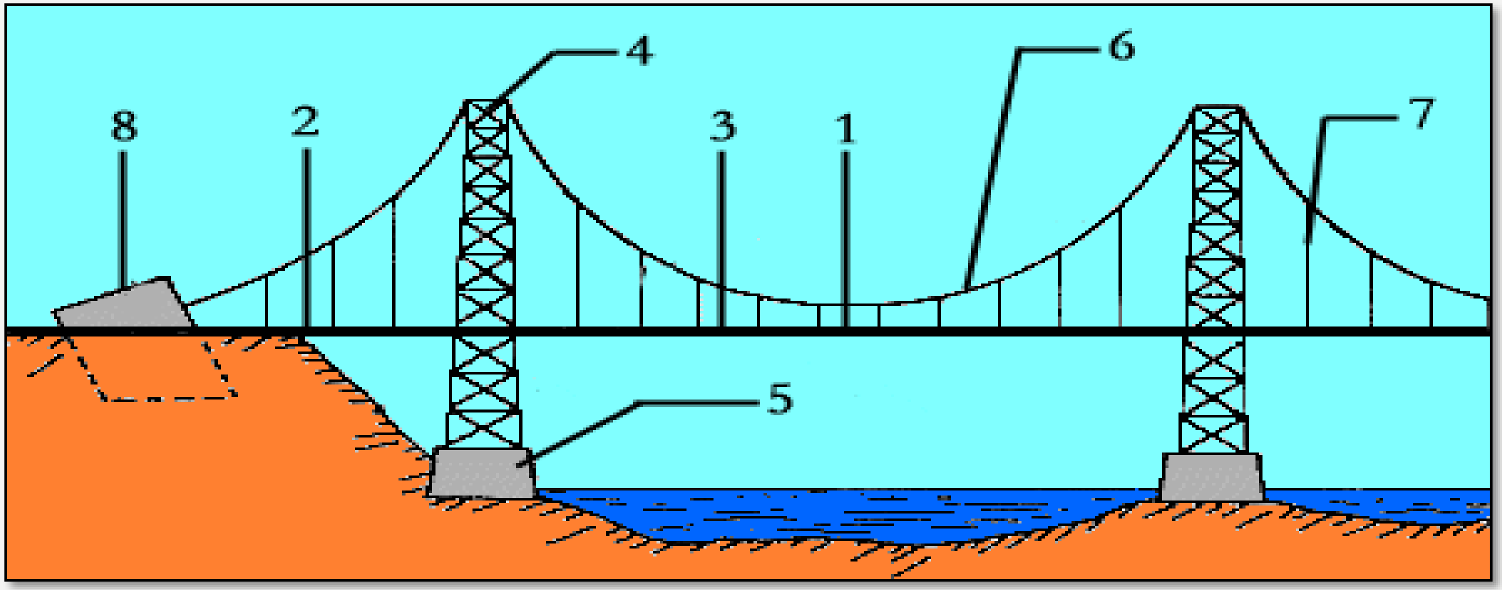
# CABLE STRENGTH

Cables work in tension, and their strength depends on their diameter. Nowadays, thanks to twisted steel rods, the strength of large-diameter cables (used for bridges) can reach up to 550,000 kN.

| Cable diamitre | Approximate Cross-Section ($mm^2$) | Steel Strength (MPa) | Total Strength (kN) | Uses |
|---|---|---|---|---|
| 300 mm | ~70 000 | 1570–1960 | 110 000 – 137 000 | Medium-Sized Suspension Bridges |
| 350 mm | ~96 000 | 1570–1960 | 150 000 – 188 000 | Long-Span Bridges |
| 400 mm | ~125 000 | 1570–1960 | 196 000 – 245 000 | Very Long-Span Bridges |
| 450 mm | ~159 000 | 1570–1960 | 250 000 – 312 000 | Long Spans |
| 500 mm | ~196 000 | 1570–1960 | 308 000 – 384 000 | Bridge > 1000 m |
| 600 mm | ~283 000 | 1570–1960 | 445 000 – 555 000 | Giant Bridges |

# CALCULATION OF CABLE TENSION IN BRIDGES

The calculation applies to suspension bridges, which consist of:




1 – Deck
2 – Side span
3 – Main span
4 – Pylons
5 – Foundations
6 – Main cable
7 – Hanger
8 – Anchorage block

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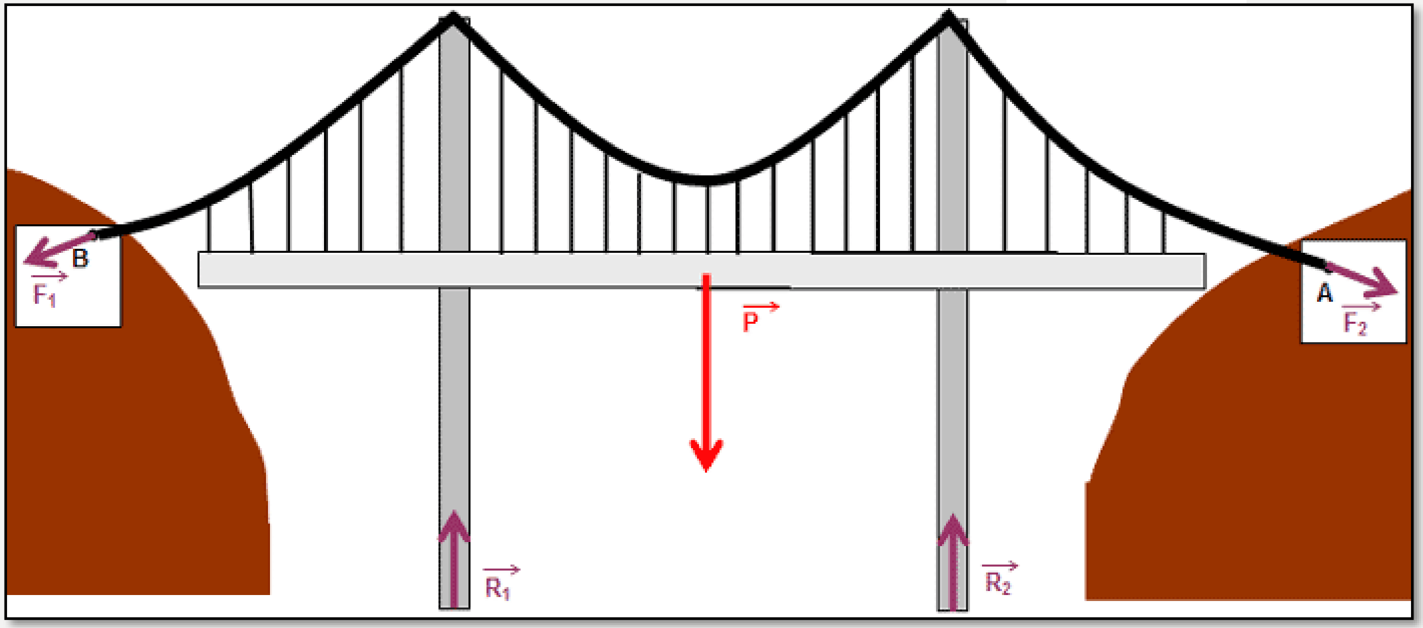
# CALCULATION OF CABLE TENSION IN BRIDGES

Using the principle of inertia (Newton's First Law) $\sum \vec{F} = \vec{0}$




**F1** et **F2** : Tension forces in main cables

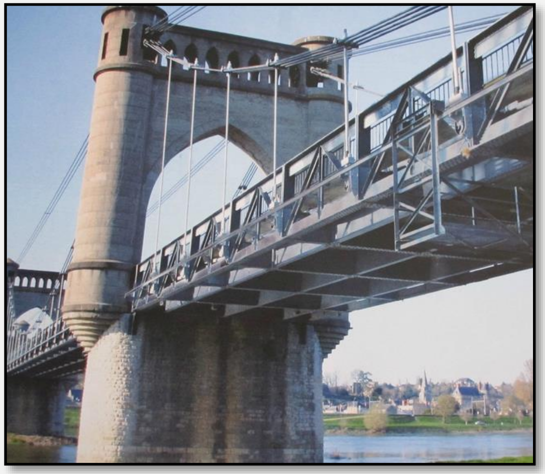
**P** : Global weight of bridge

**R1** et **R2** : Reaction of brigde

# CALCULATION OF CABLE TENSION IN BRIDGES

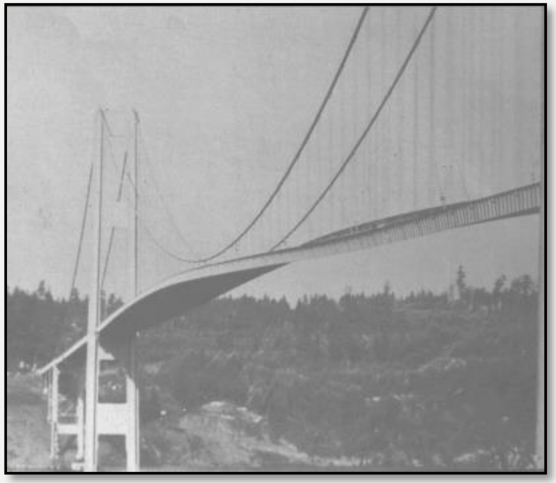
La charge **P** vient de sollicitations suivantes :

<u>Charges permanentes</u>



<u>Charges d'exploitation</u>


<u>Charges dynamiques</u>



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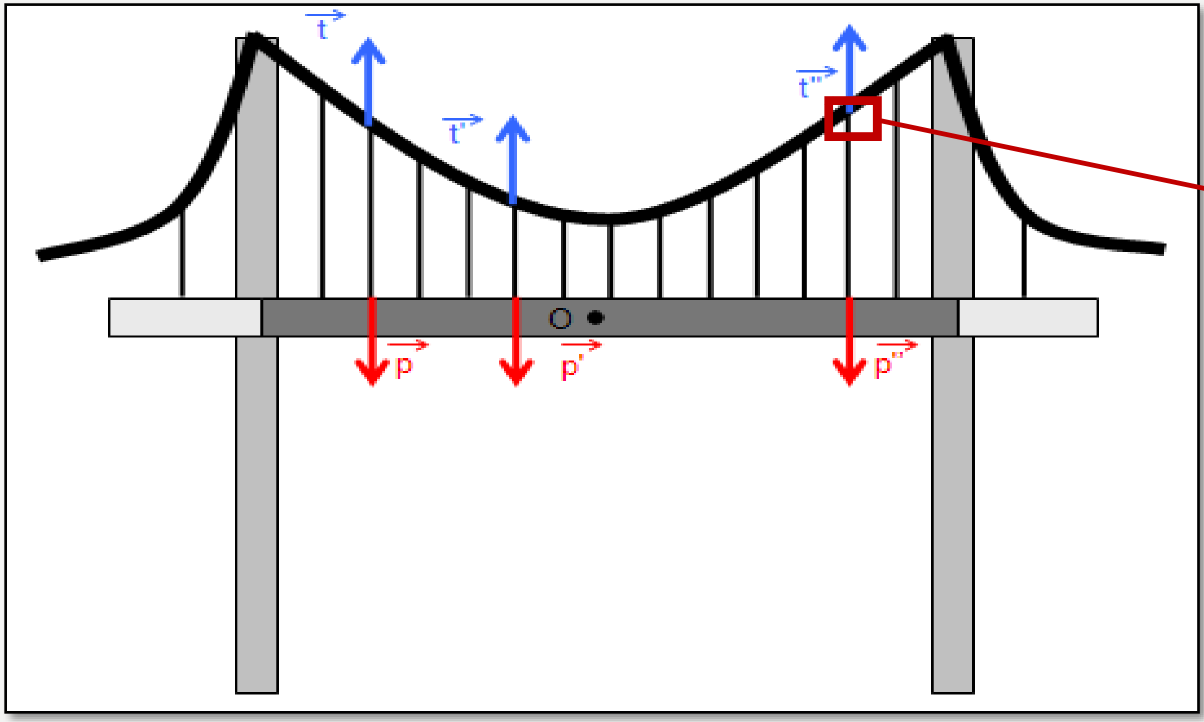
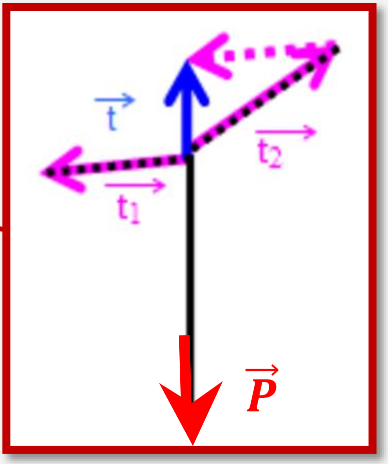


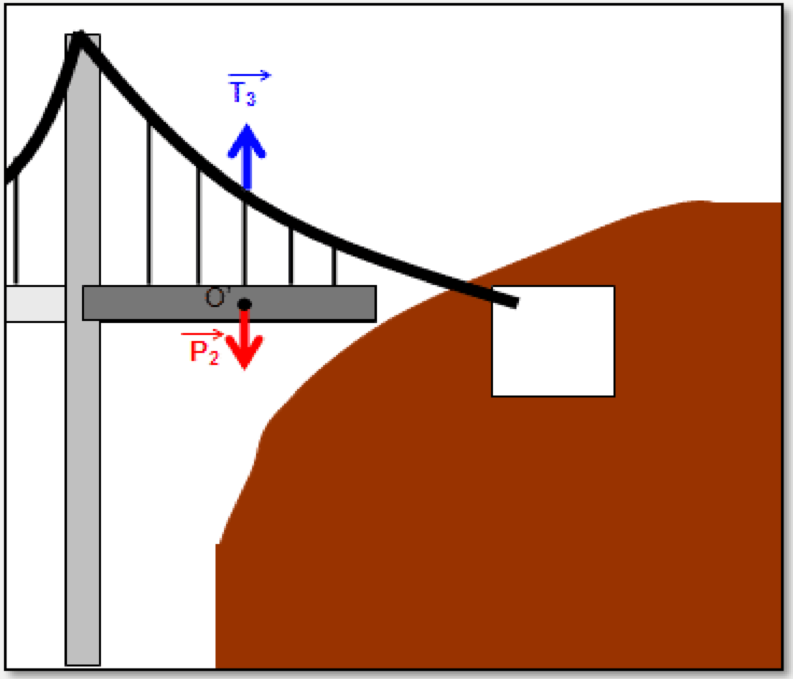



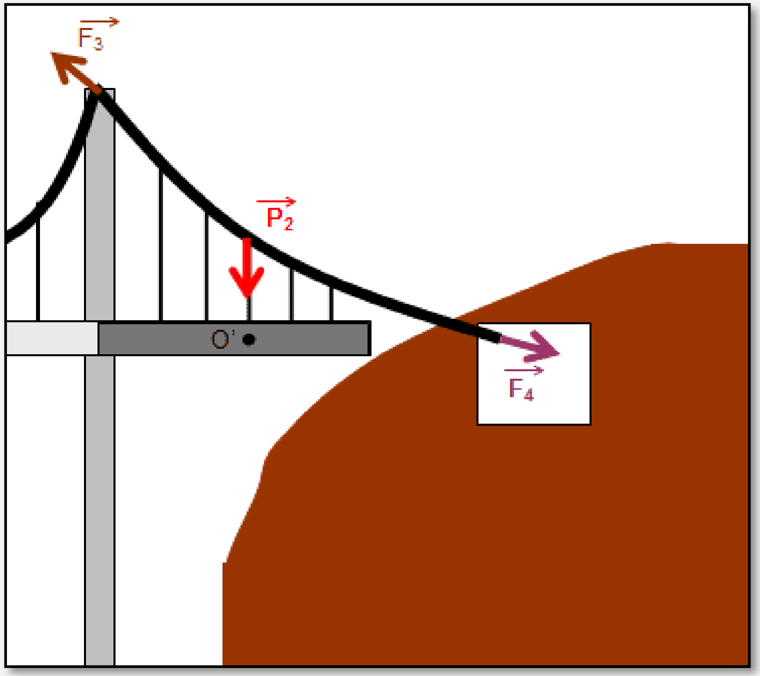

$$\sum F_V = 0$$

$$\sum F_H = 0$$

# CALCULATION OF CABLE TENSION IN BRIDGES

Using the principle of inertia (Newton's First Law) $\sum \vec{F} = \vec{0}$




$$\sum F_V = 0 \quad \sum F_H = 0$$

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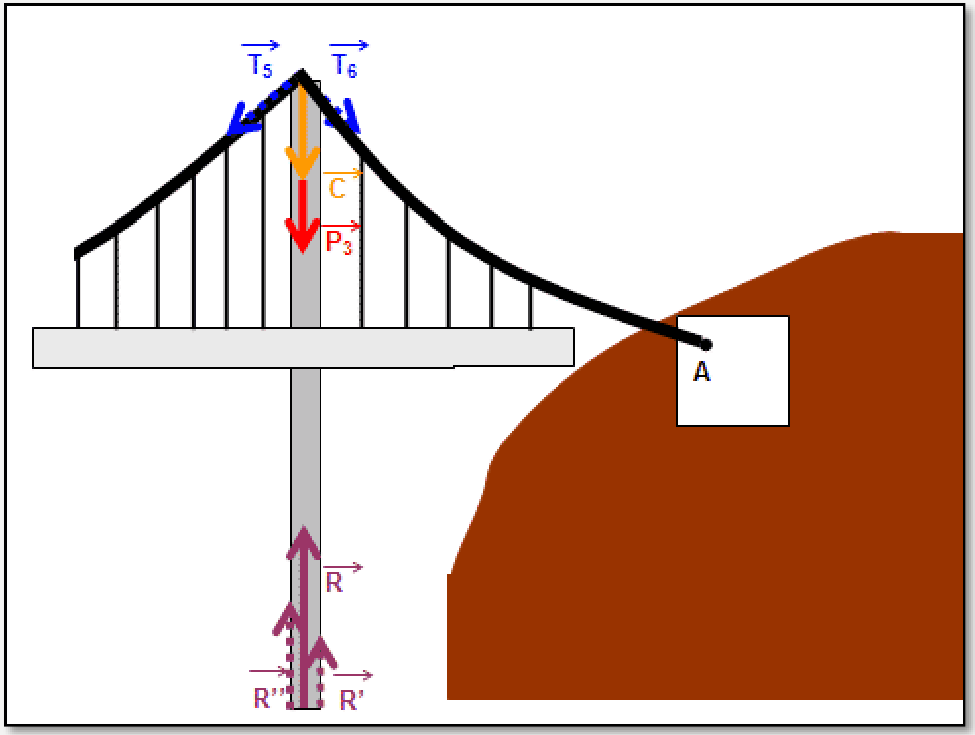
# CALCULATION OF CABLE TENSION IN BRIDGES

Using the principle of inertia (Newton's First Law) $\sum \vec{F} = \vec{0}$




**C = T5Y + T6Y**

Avec :

C : compression due to T5 et T6

**R = R' + R''**

Avec :

**R''**: is reaction due to weight of **P3** du pylône

**R' :** is reaction against force **C**

**R :** The resultant of the ground reactions

$$\sum F_V = 0 \quad \sum F_H = 0$$

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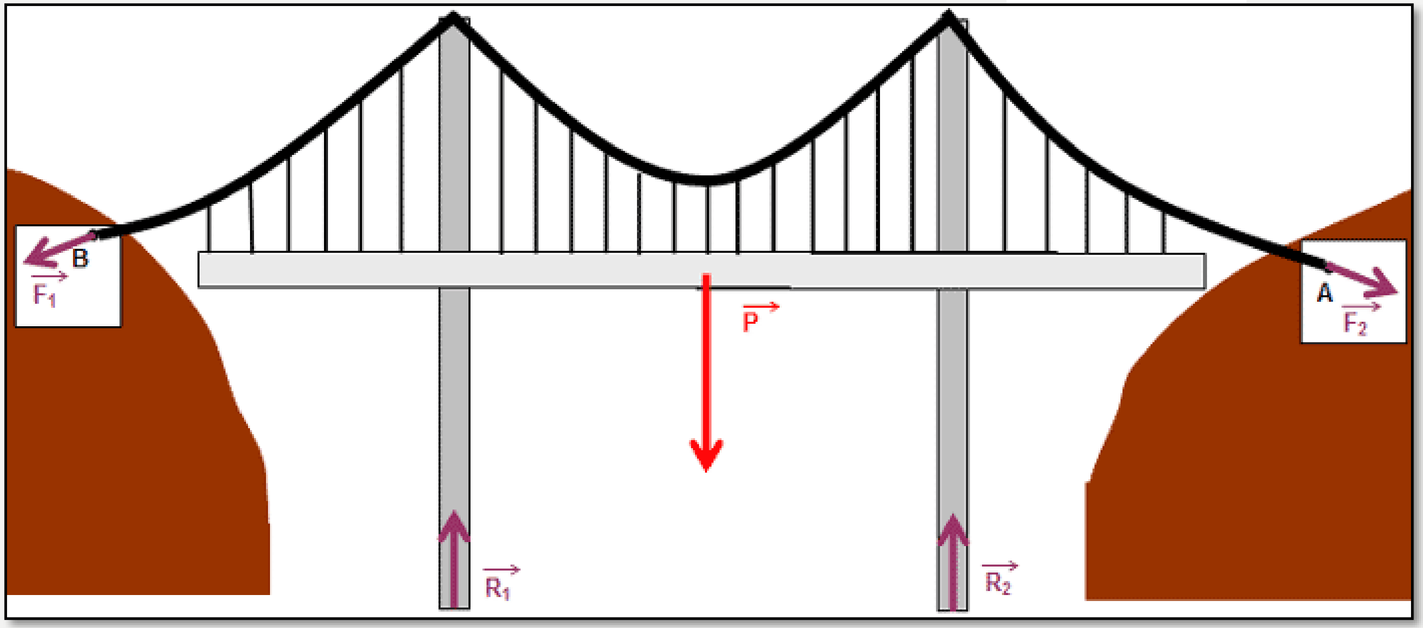
# CALCULATION OF CABLE TENSION IN BRIDGES

Using the principle of inertia (Newton's First Law) $\sum \vec{F} = \vec{0}$




**F1** et **F2** : Tension forces in main cables

**P** : Global weight of bridge

**R1** et **R2** : Reaction of brigde

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# CONSTRUCTION OF SUSPENSION BRIDGES

1 – Pouring the piers (pylons)

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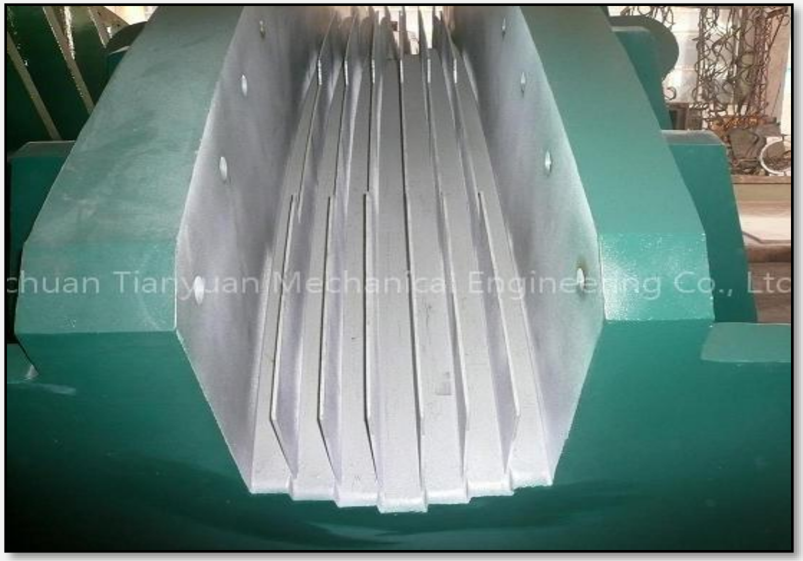
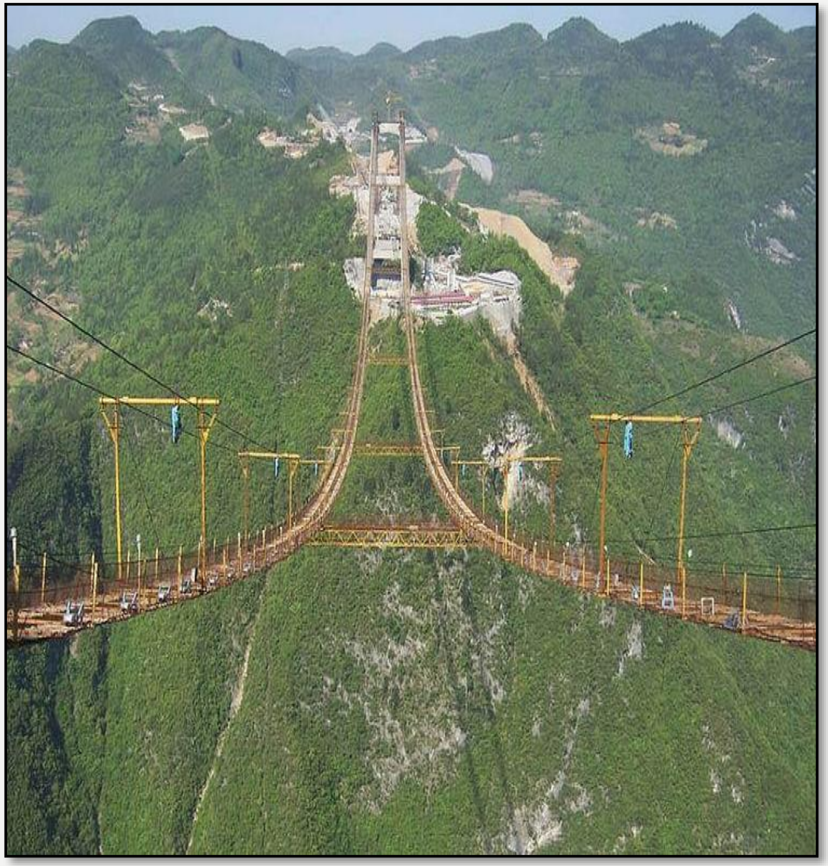
# CONSTRUCTION OF SUSPENSION BRIDGES

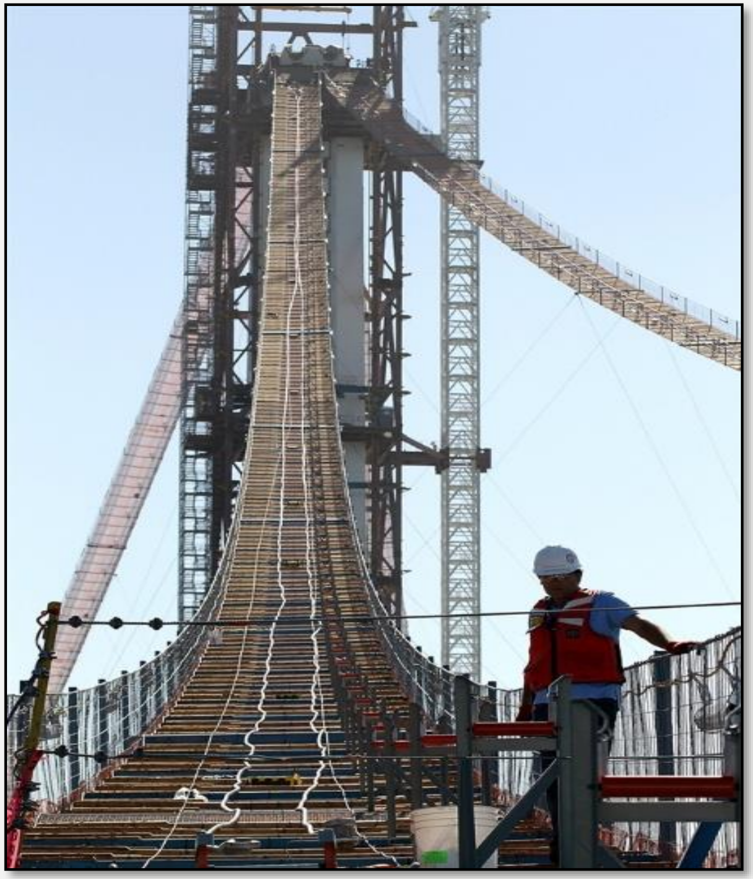
2 – Installing the main cable saddles




# CONSTRUCTION OF SUSPENSION BRIDGES

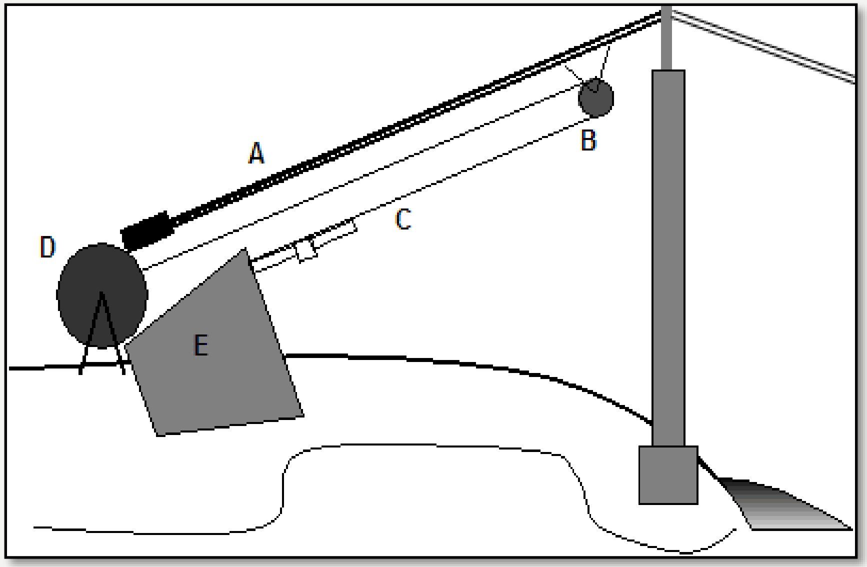
3 – Installing the work platforms

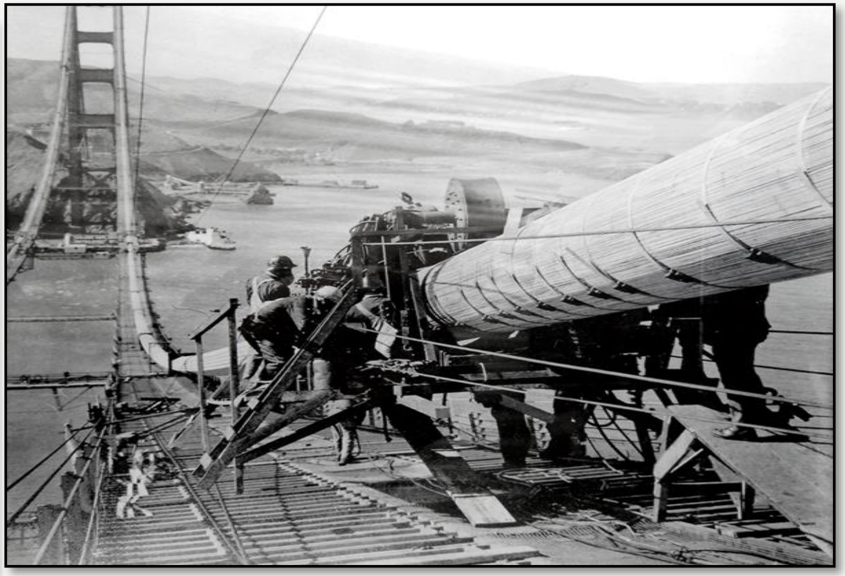




# CONSTRUCTION OF SUSPENSION BRIDGES

4 – Stringing the main cables of the suspension bridge



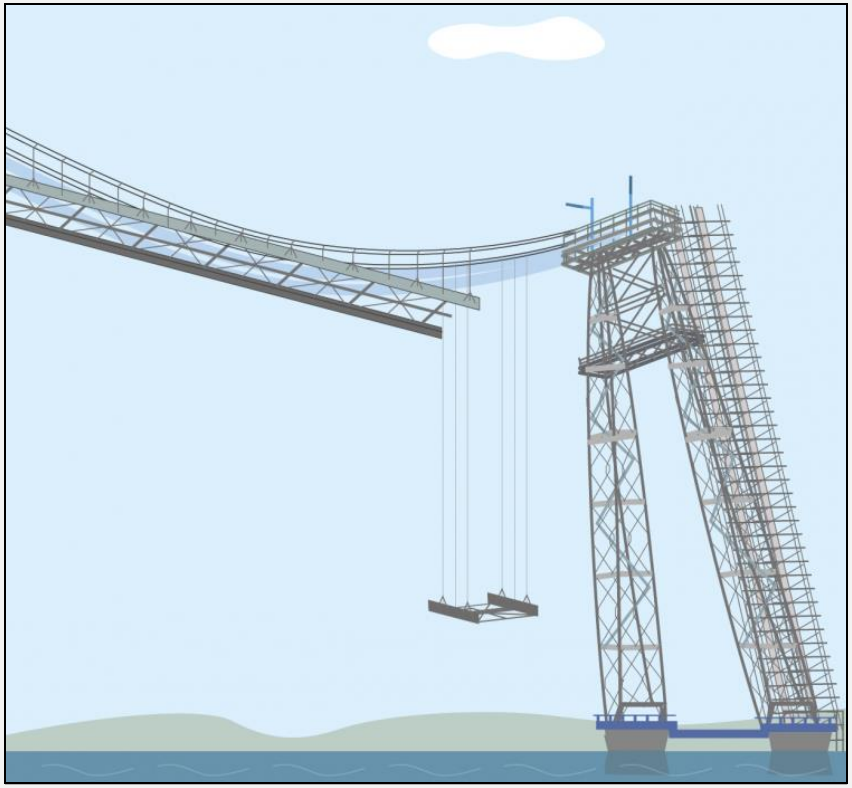



# CONSTRUCTION OF SUSPENSION BRIDGES

5 – Assembling the hangers onto the main cables

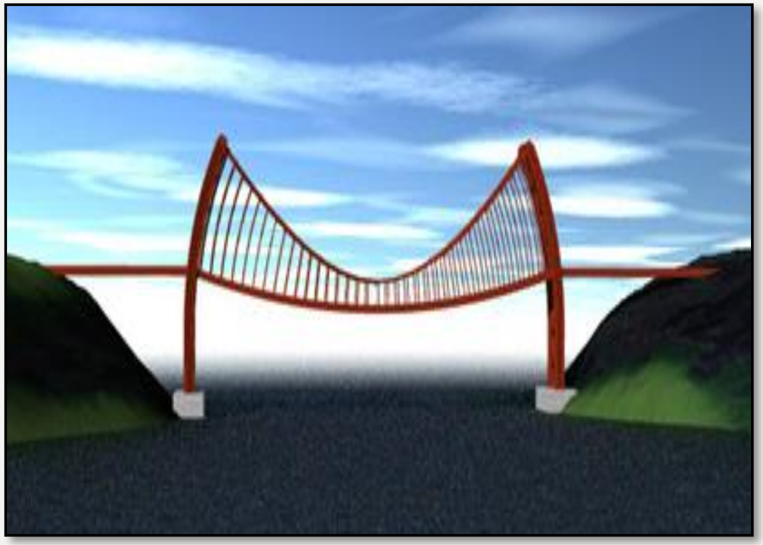
# CONSTRUCTION OF SUSPENSION BRIDGES

6 – Installing the deck piece by piece by lifting it from the work platform



# CONSTRUCTION OF SUSPENSION BRIDGES

7 – Attaching the main cables to the anchorage blocks to maintain the balance of the suspension bridge



# CONSTRUCTION OF SUSPENSION BRIDGES

8 – Securing the main cables to the anchorage blocks to ensure the balance of the suspension bridge