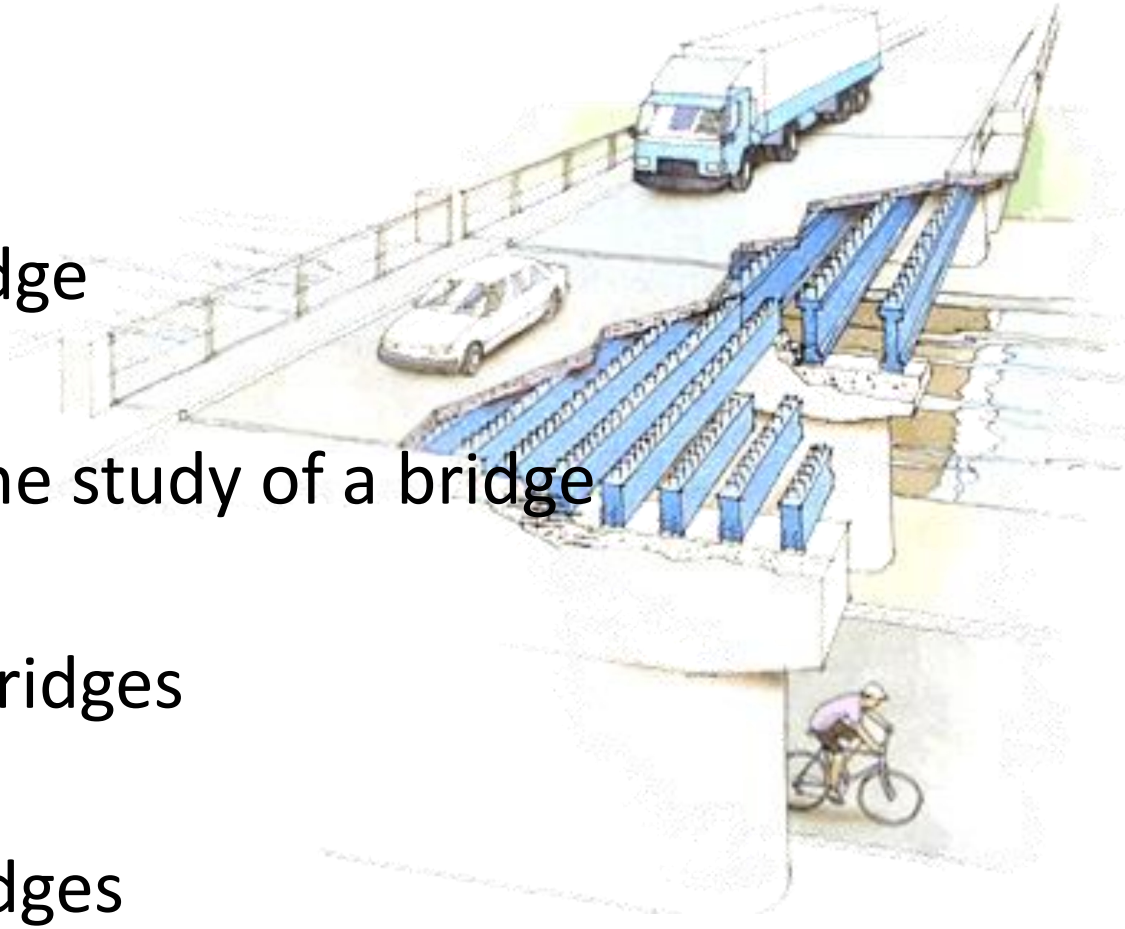
Chapter 3: bridges concepts

1. General
2. Elements of a bridge
3. Data relating to the study of a bridge
4. Classification of bridges
5. Main types of bridges



1. General 1/2

➢Definition

Bridges are structures designed to enable the crossing of an obstacle by going over it.

Antirion Bridge (Greece, 2004)

A bridge can support:

- Roadway
- Pipeline
- Track
- Canal (canal bridge)

1. General 2/2

➢Definition

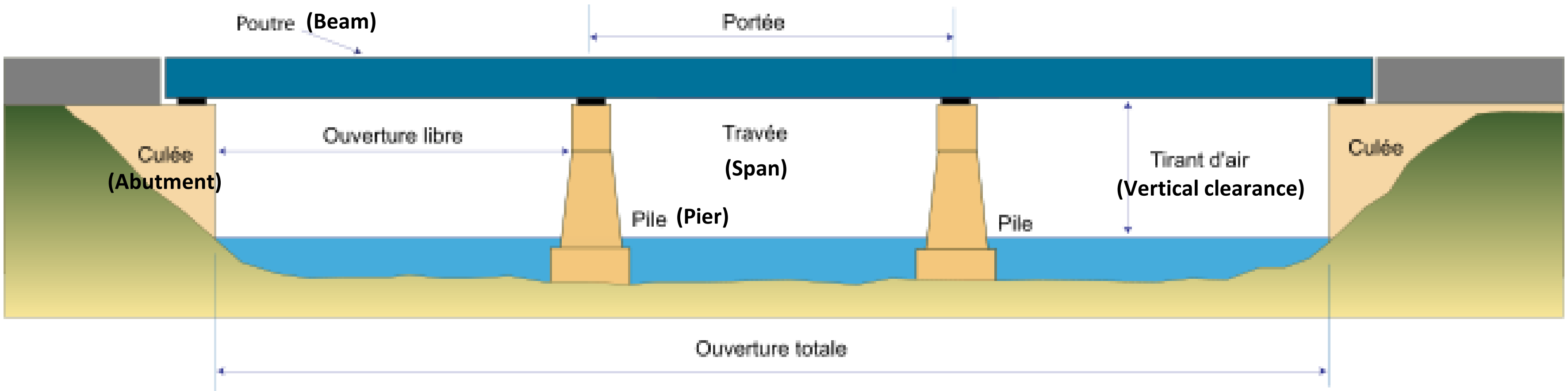
A bridge is originally a construction connecting the two banks of a watercourse. From the 19th century, the construction of bridges became essential to cross new lines of communication.

St. Martin (Torino, 25 BC)

Balinghe Bridge (China, 2009)

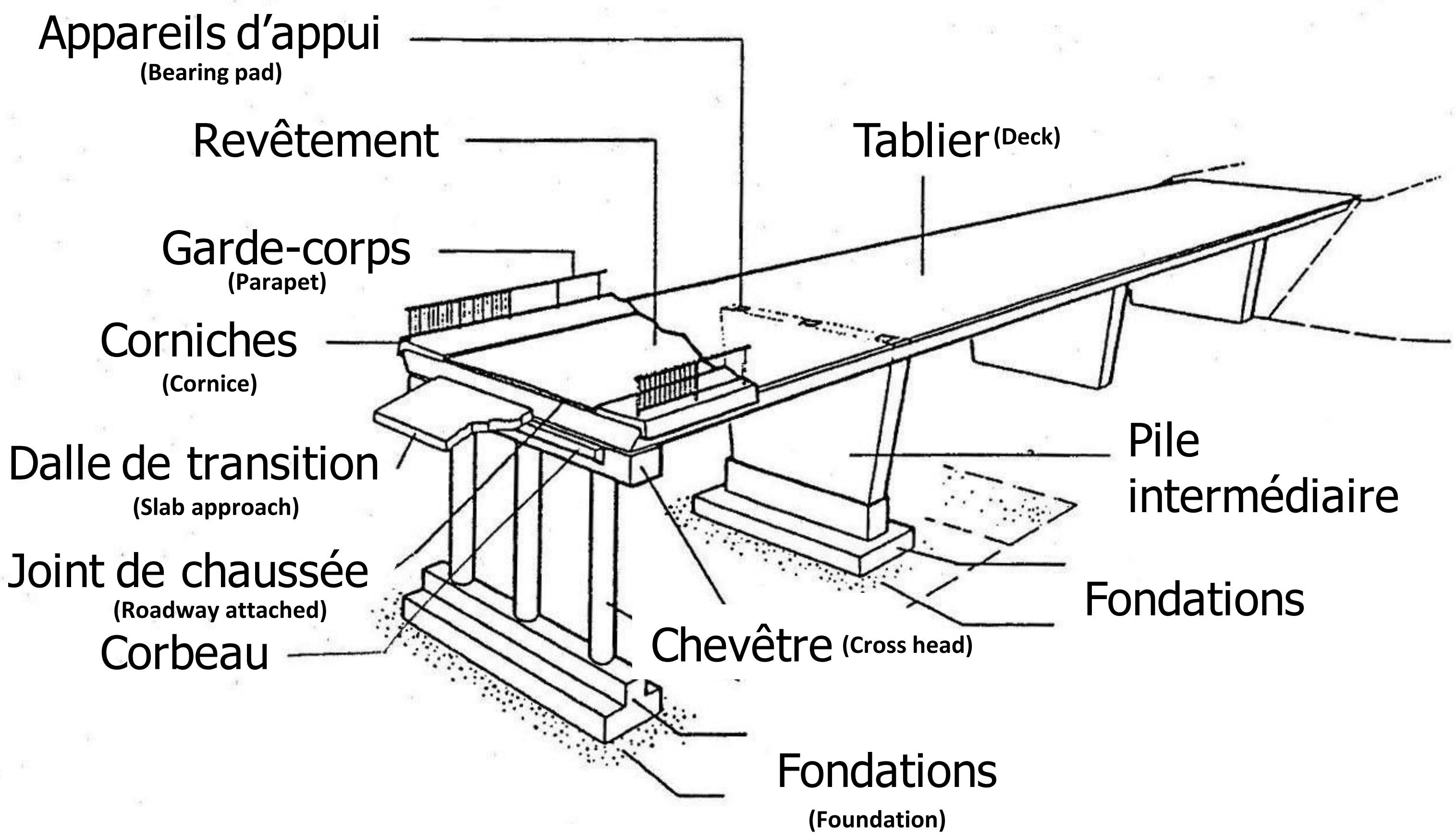
2. Elements of a bridge 1/4

➢Terminology



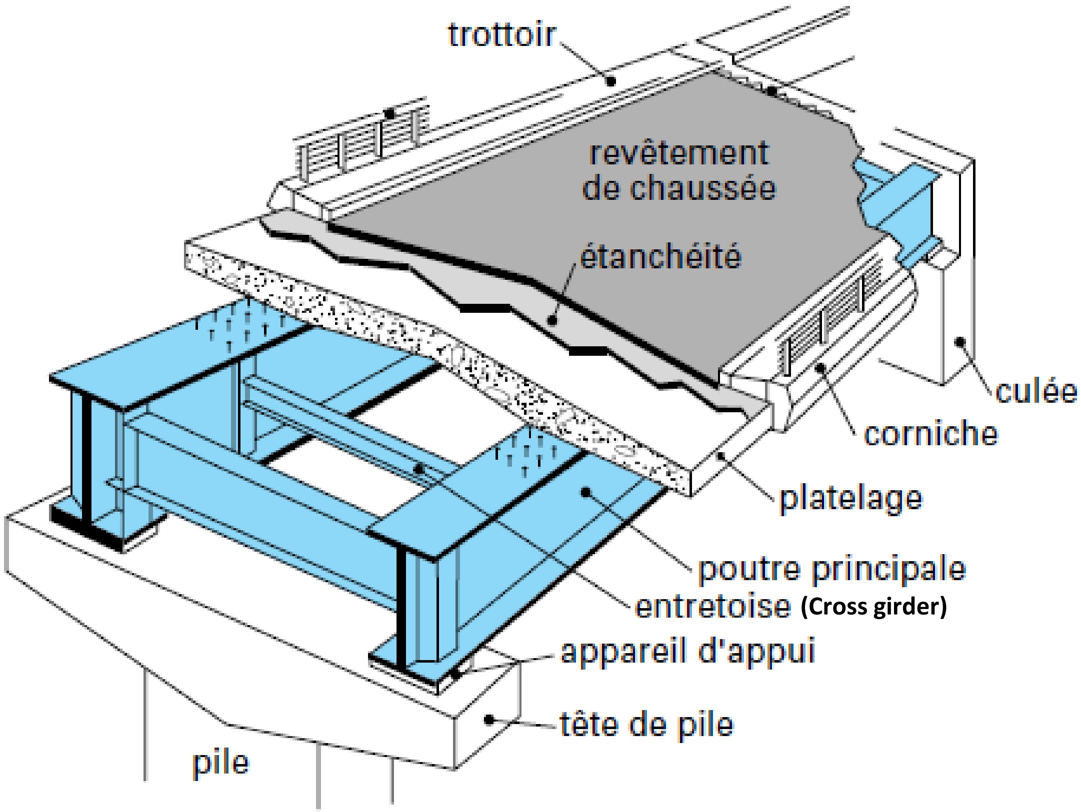
2. Elements of a 2/4 bridge

- Terminology



2. Elements of a 3/4 bridge

- Terminology (Metal bridge)



2. Elements of a 4/4 bridge

Example of a girder bridge

Example of an abutment

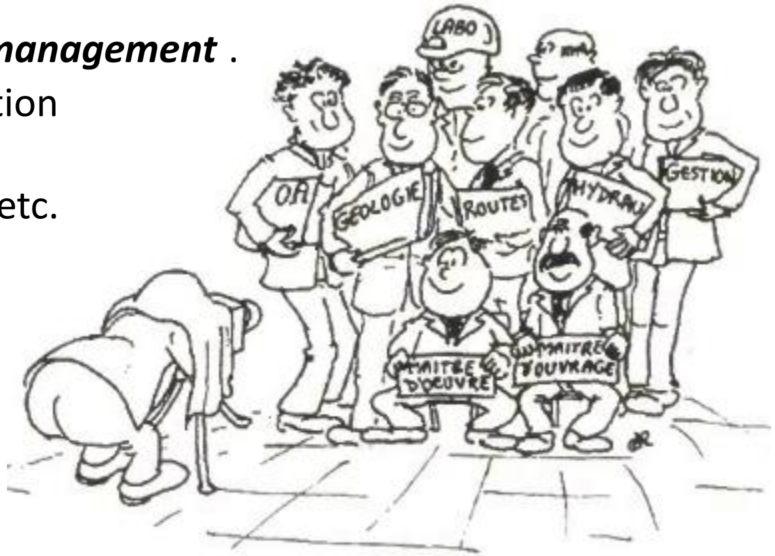
3. Data relating to the study of a bridge 1/13

1. Different stakeholders

Project owner is the legal entity for which the work is built (initiator, owner and manager).

Project manager sets up the operation leading to the completion of the work on behalf of the project owner. He is responsible for its smooth running (design, construction, reception), in compliance with the order from the project owner, standards, technical recommendations and rules of the art.

Project manager is the person responsible for ***project management*** .
He has a primary role as conductor of the compound operation
several specialists in the field: roads, structures,
architect, geotechnician, hydrologist, geologist, landscaper, etc.



3. Data relating to the study of a bridge 2/13

In a bridge construction project, the project owner must define ***the program*** which outlines the objectives of the operation, the needs it must satisfy and ***the constraints*** attached to it. The project manager helps him clarify and complete his expectations.

The different ***constraints*** or ***data*** of the engineering structure project (bridge) are classified according to the following categories:

- *administrative data* , intended to define the administrative and regulatory framework in which the project is located, in particular the deadlines and financing constraints of the operation.
- ***the functional data*** which constitute all the characteristics allowing the bridge to ensure its crossing functions. They integrate operating, in-service and construction data.
- ***natural data*** which brings together the technical elements of the terrain directly influencing its design.
- ***environmental data*** which brings together the ecological specificities of the site.
- *architectural and landscape data* which highlight the quality of the site.
- *management data* which reflect the sensitivity of the structure to surveillance, maintenance or repair operations.

3. Data relating to the study of a bridge 3/13

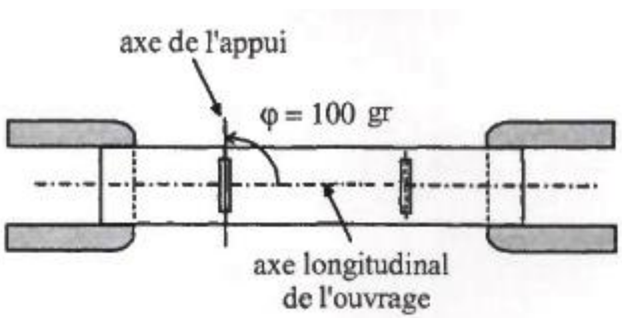
2. Functional data

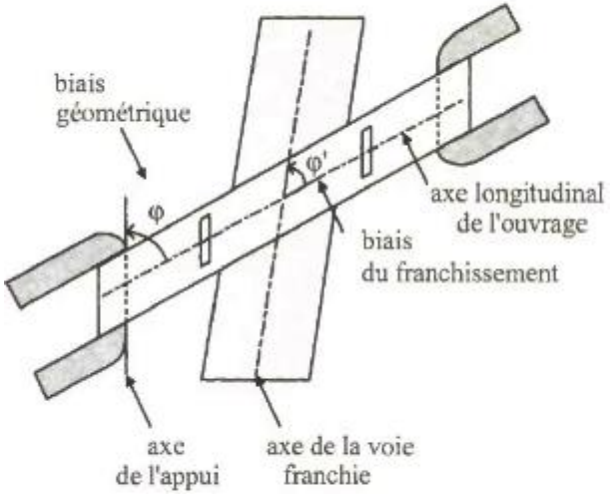
The functional data brings together all the characteristics allowing the bridge to ensure its function as a crossing structure when it is put into service. To do this, it is necessary to define the data relating to the ***track covered*** and the ***track*** or ***obstacle crossed*** .

2.1. Data relating to the track carried

a) Plan layout:

The projection of the axis of the road on a horizontal plane (topographic plane). In plan, the deck of a bridge can be **straight** , **biased** (depending on the inclination of the support line relative to the longitudinal axis of the bridge "skew angle φ "), or **curved** .



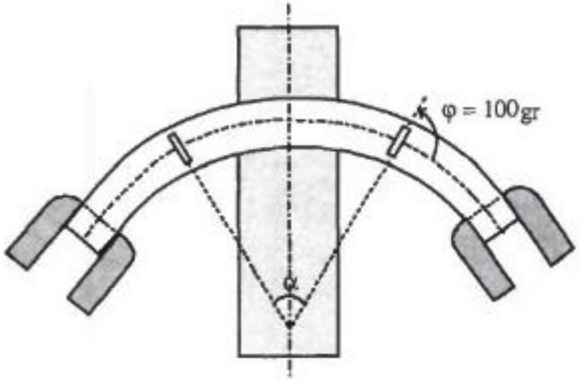


3. Data relating to the study of a bridge 4/13

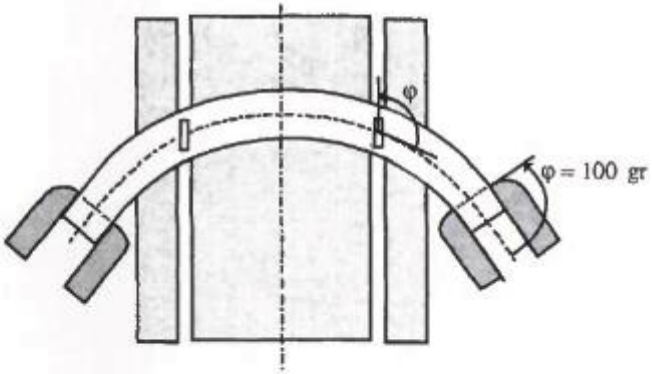
biases (below 60 grades) must be avoided
as much as possible given the additional cost and difficulties they generated at the time of completion of the work.

Curved bridges are more difficult structures to construct and generally more expensive than straight bridges.

Bridge on the East-West highway (Bouira)



a) appuis radiaux



b) appuis biais

3. Data relating to the study of a bridge 5/13

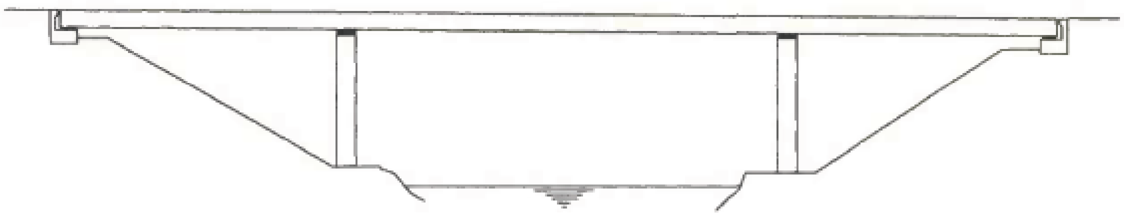
b) Long profile:

The longitudinal profile allows you to define the altitude (dimension) of the project axis according to the curvilinear abscissa of the project in the topographic plan.

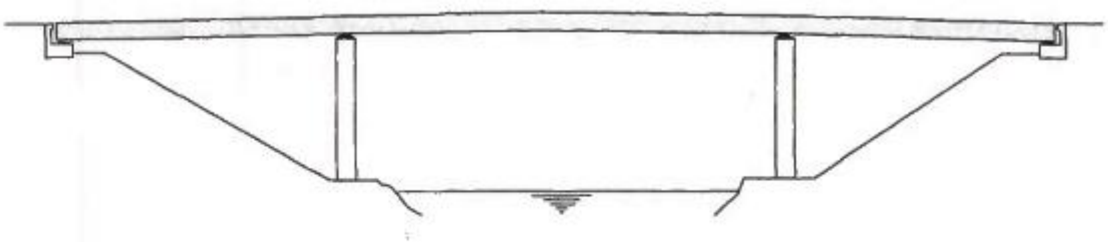
horizontal profile segments should be avoided for

allow correct water flow (minimum slope of 1%).

Slope

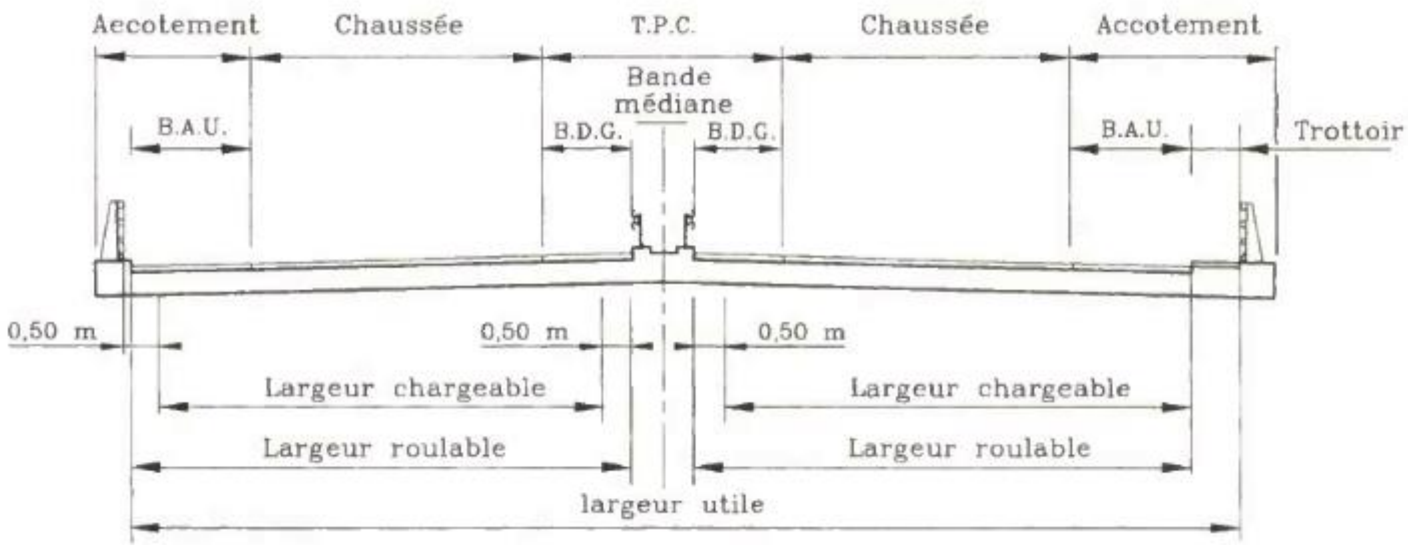


Convex



3. Data relating to the study of a bridge 6/13

c) Cross section on structure:



The useful width of the apron (L_U): the distance between the interior surfaces of the extreme retaining devices.

The rolling width (L_R): the width between retaining devices or curbs (road + clear strips + stop strips, etc.).

The loadable width (L_C): the rollable width by subtracting a strip of 0.50 m along each barrier type retaining device where they exist.

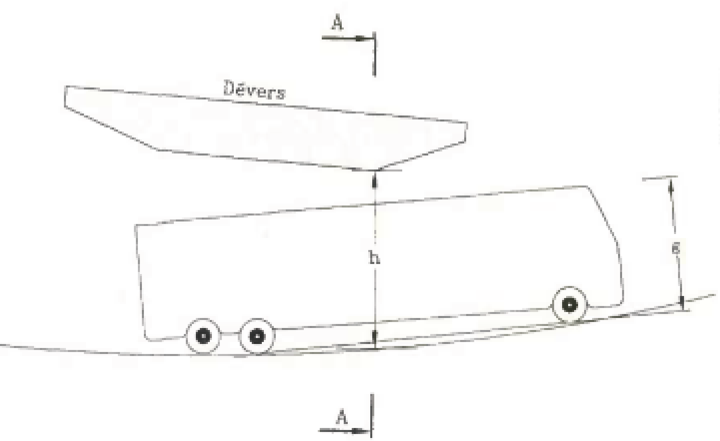
3. Data relating to the study of a bridge 7/13

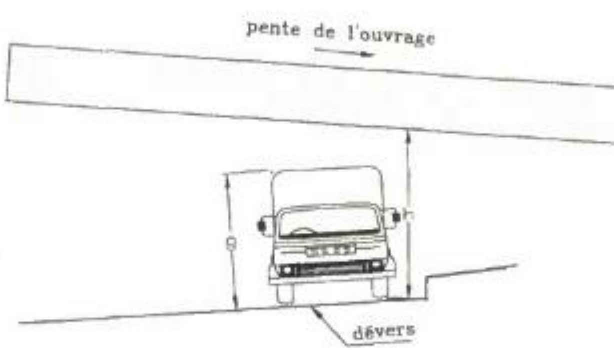
2.2. Data relating to the route or obstacle crossed

The planned bridge generally crosses communication routes (road, railway or waterway), it is necessary to respect the functional data relating to this route, namely the ***gauge*** and the ***free height*** :

The gauge (g) characterizes the maximum static height of a vehicle, including load, the passage of which can be accepted, under normal traffic conditions, under a structure. This quantity is associated with the vehicle.

The free height (h) represents the minimum distance between all points of the rolling part of the track crossed by the bridge and the underside of the structure. This size is associated with the structure (1.9 – 7m). It is equal to (g + 0.6m).





3. Data relating to the study of a bridge 8/13

3. Natural data

The natural data brings together all the technical elements of the terrain directly influencing the structure:

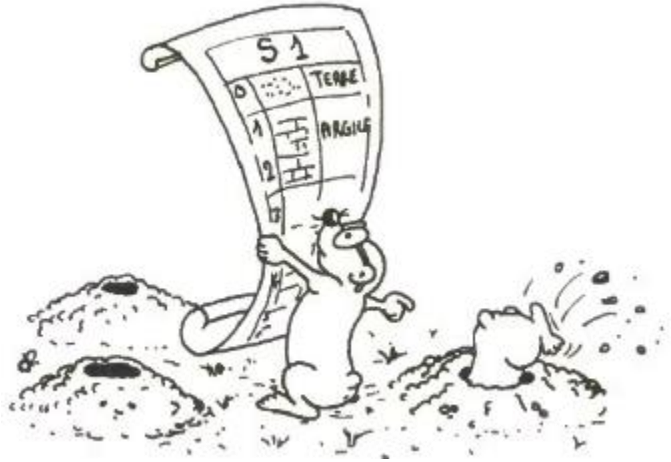
- data relating to the natural terrain (topography),
- data relating to the soil (geological, geotechnical and hydrogeological data),
- hydraulic data or characteristics (water flow, etc.),
- climatic data (temperature, snow, wind, etc.),
- seismic data.

a) Topography of the natural terrain

Analysis of the topography of the site allows the work to be correctly implemented, taking into account ***the contour curves*** , possible access for the different parts of the work, necessary earth movements, possibilities for setting up site installations or prefabrication areas, etc.

3. Data relating to the study of a bridge 9/13

b) Geological, geotechnical and hydrogeological data



A good knowledge of the characteristics of the terrain is essential in a bridge construction project because it constitute one of the elements of the choice of the solution for the crossing and for the foundations of the supports.

Typically required features include:

- the position, thickness and homogeneity of all soil layers,
- the possible presence of geological accidents (karsts, gypsum dissolution voids, etc.),
- the resistance parameters (mechanical parameters) of the soils,
- the rheological parameters of the soil (settlement, lateral displacements),
- the levels of water tables, water flow, soil permeability,
- other parameters linked to particular contexts: faults, zones of instability (scree, subsidence, etc.), scour and erosion phenomena, seismic zone (liquefaction), etc.

3. Data relating to the study of a bridge 10/13

c) Hydraulic data

When a structure crosses a watercourse, it is necessary to record information on:

- the topography of the bed,
- the regime of the watercourse (floods, navigation, etc.)
- risks of scouring due to the effect of sedimentation (filling) or erosion (digging) which can jeopardize the stability of the bridge by loosening of its foundations.

Flood

Digging around the piles

3. Data relating to the study of a bridge 11/13

d) Climatic data

Temperature, wind, snow, freeze-thaw,…

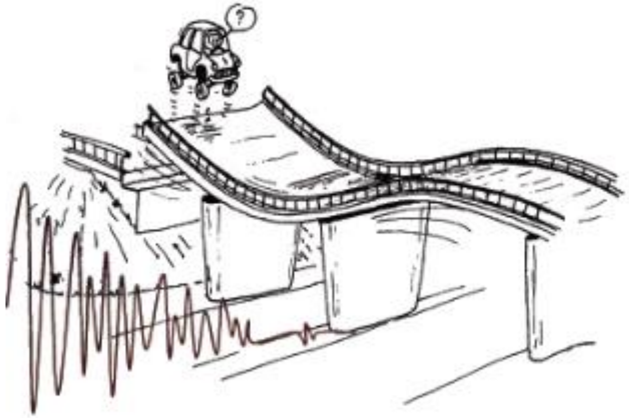
are parameters that have repercussions on

the design and sizing of bridges.

<u>Video example:</u> Tacoma Bridge (United States in 1940)

e) Seismic data

Bridges located in seismic zones must be justified according to the technical regulations in force (RPOA 2008).



3. Data relating to the study of a bridge 12/13

4. Environment data

This data makes it possible to measure the impact of the project on the environment (impact study) to better protect it.

This environmental study makes it possible to assess the consequences of the project on ***water*** , ***noise*** and ***fauna*** and ***flora*** .

a) Water protection

Water can be present in different ways on a site: watercourses, rivers, surface water bodies, groundwater tables, drinking water supply sources.

The pollution of this water can come from several sources, namely:

- pollution during the construction phase,
- chronic pollution caused by vehicle traffic,
- accidental pollution following a road accident.

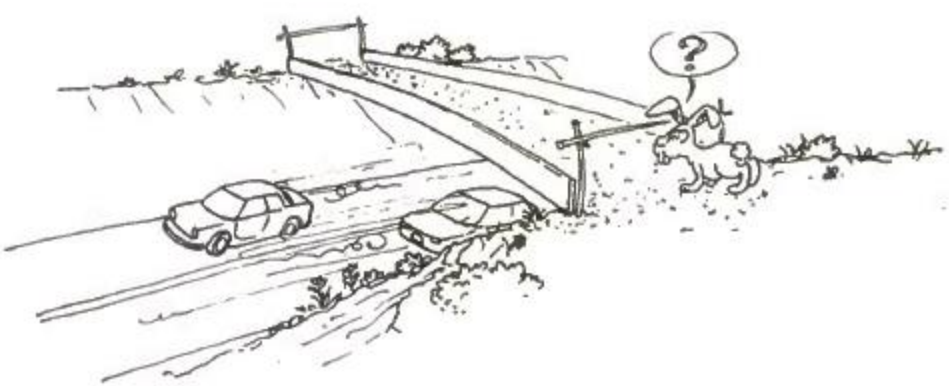
3. Data relating to the study of a bridge 13/13

b) Protection against noise

The maximum level of noise pollution must not exceed a threshold set by the regulations of each country (65 dB(A)).

c) Protection of fauna and flora

Avoid siting the bridge in preferred travel routes for wild and domestic animals, ***or if necessary*** , provide upper or lower passages adapted to the animal and plant species present in the area of the structure.



4. Classification of bridges 1/1

Bridges are classified in different ways:

1. Depending on the main material of which they are made:

In wood, masonry, cast iron, iron, steel, aluminum alloys (Canada), reinforced concrete, prestressed concrete…

2. Depending on the nature of the route carried:

Road bridges, rail bridges, canal bridges, pedestrian bridges…

3. Depending on their mechanical operation:

Girder bridges, arch bridges, cable bridges (suspended, cable-stayed), mobile bridges, etc.

5. Main types of bridges 1/22

There are three modes of mechanical operation of structures: Flexion, compression and traction). This gives 3 types of bridges:

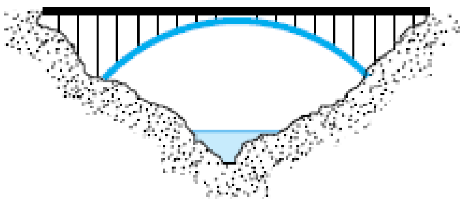
- Girder ***bridges*** : ***characterized*** by their simplicity

and ease of implementation. Mechanical operation in bending.

(a) à poutre

- Arched bridges **:** _

combines compression and flexion

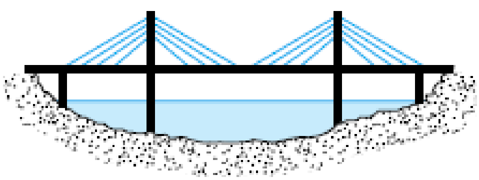


(b) en arc

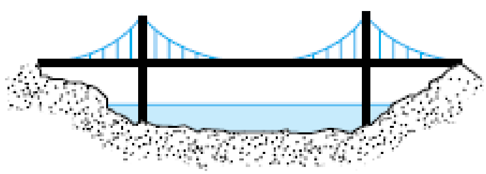
- Cable ***bridges*** : ***guyed*** and ***suspended*** type **,** _

combine traction, compression and flexion

(complex operation).



(c) haubané

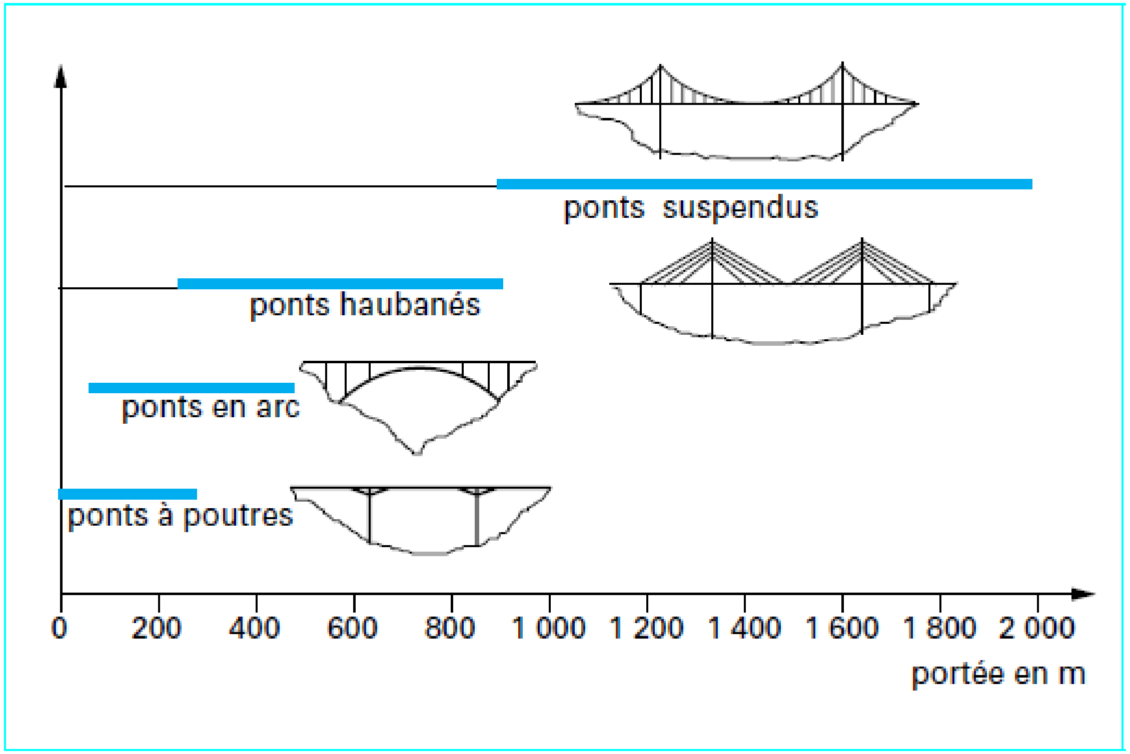


(d) suspendu

5. Main types of bridges 2/22

➢Areas of application for each type of bridge

The choice of the type of bridge is made according to the main span of the work.



Les grands systèmes de pont en fonction de la portée

5. Main types of bridges 3/22

1. Girder bridges

It is the most used and most developed technique for reasons of cost (very economical) and simplicity of production.

There are three types:

Solid web beams

Box beams

Truss beams

5. Main types of bridges 4/22

➢ ***Examples of girder bridges***

- ***Oued Rekham Viaduct*** (2008, Bouira):

  length 745m, height 110m,

  main span 200m, width 28m .

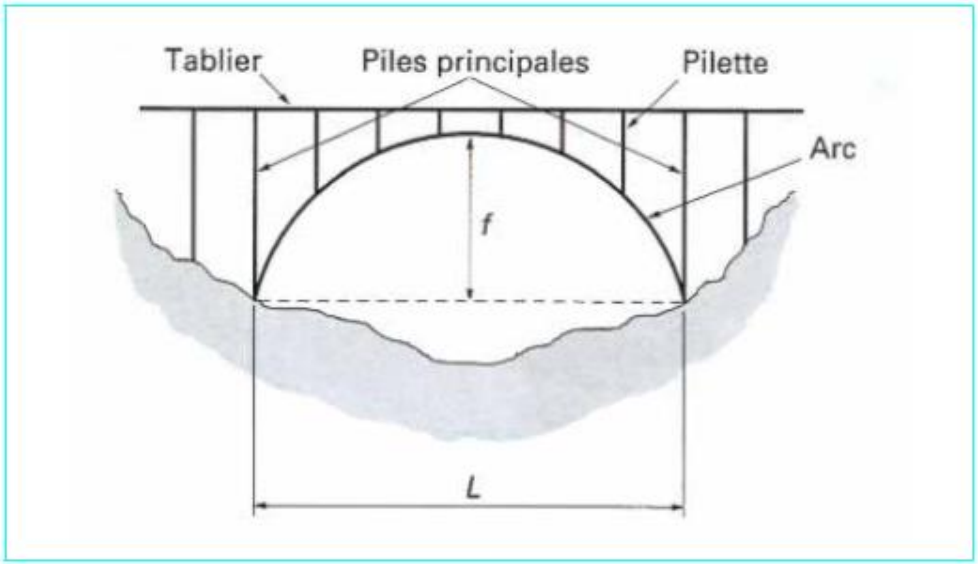
- ***Niteroi Bridge (Costa e Silva)*** (1974, Brazil):

  Length 13.3 km including 8.8 km on water, main span of 300 m.

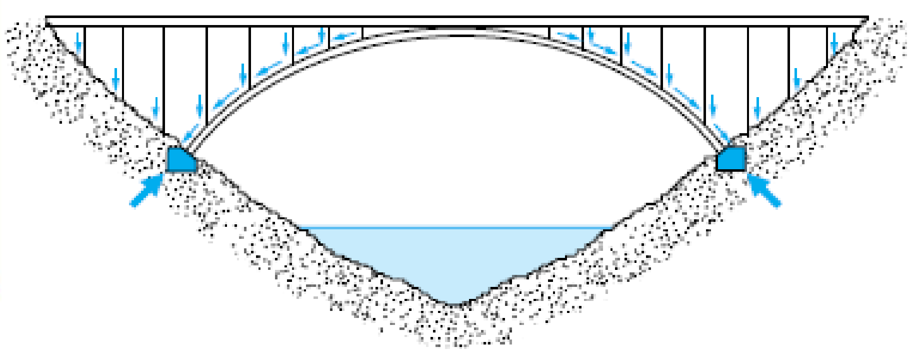
5. Main types of bridges 5/22

2. Arch bridges

To cross deep, wide gaps with difficult construction site access on its sides. The deck piers rest on an arched structure.



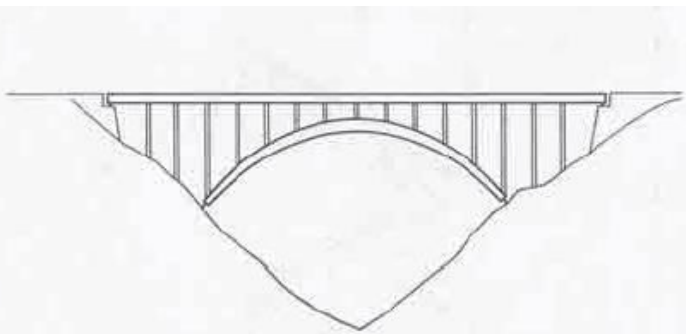
Représentation schématique d'un arc à tablier supérieur



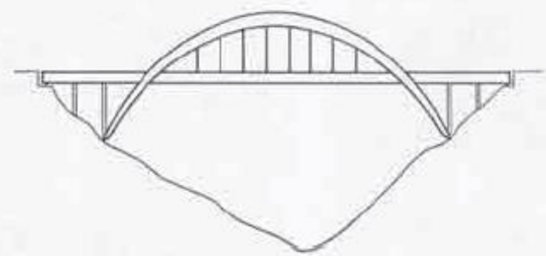
« Travail » de l'arc

5. Main types of bridges 6/22

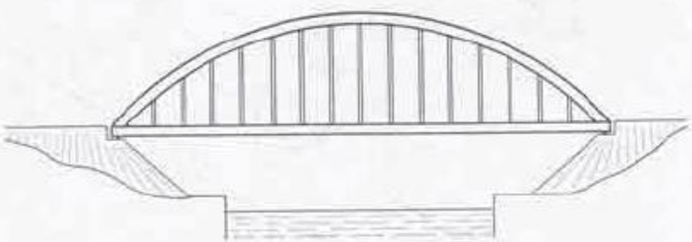
Arch bridges can have several shapes:



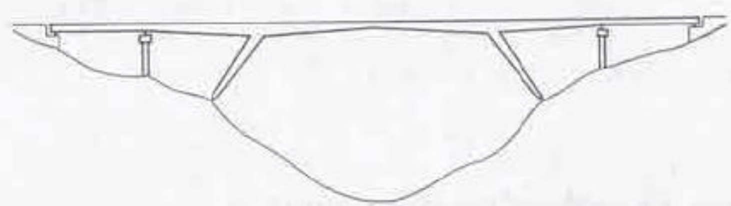
Upper deck bridge



Intermediate deck bridge



Bow-string bridge



Inclined crutch bridge

5. Main types of bridges 7/22

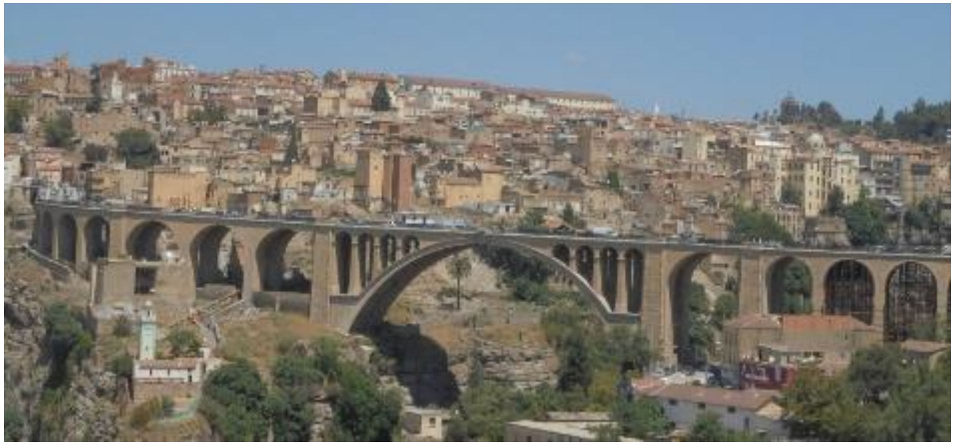
➢ ***Examples of arch bridges***

- ***Sidi Rached Bridge*** (1912, Constantine)

Length 447 m with 27 arches,

height 107 m.

(Reinforcement work in progress)



Ahras Bridge (2010):

Bow-string type metal bridge,

Length 244m, height 20m, width 9m.

SAPTA production company.

5. Main types of bridges 8/22

- ***Examples of arch bridges***

Chaotianmen Bridge (China, 2009):

Double-decker steel-concrete composite bridge (road, rail), Length 932 m,
height 142 m, main span 552 m.

- *Bridge on the island of Krk* (Croatia, 1980):

Reinforced concrete road bridge, total length 1430m, height of the arch 67m.
Main span of the 1st arc 390m, main span of the 2nd arc 244m.

5. Main types of bridges 9/22

➢*Examples of crutch bridges*

Offers a clear view of the route crossed to have more visibility, especially on the highway.

There are two types of crutches: single and double

Martigues Viaduct (France, 1972)
Length 300m, main span 130m.

Grand Duchess Charlotte Bridge (Luxembourg, 1965)
Length 355m, height 74m, main span 234m.

5. Main types of bridges 10/22

3. Cable bridges

Interest and field of application:

- the total release of the lower space,
- crossings of very large spans,
- the slender aprons,
- assembly facilitated by the suspension itself.

Grand bridge on the Loire (France, 2008)

There are two types:

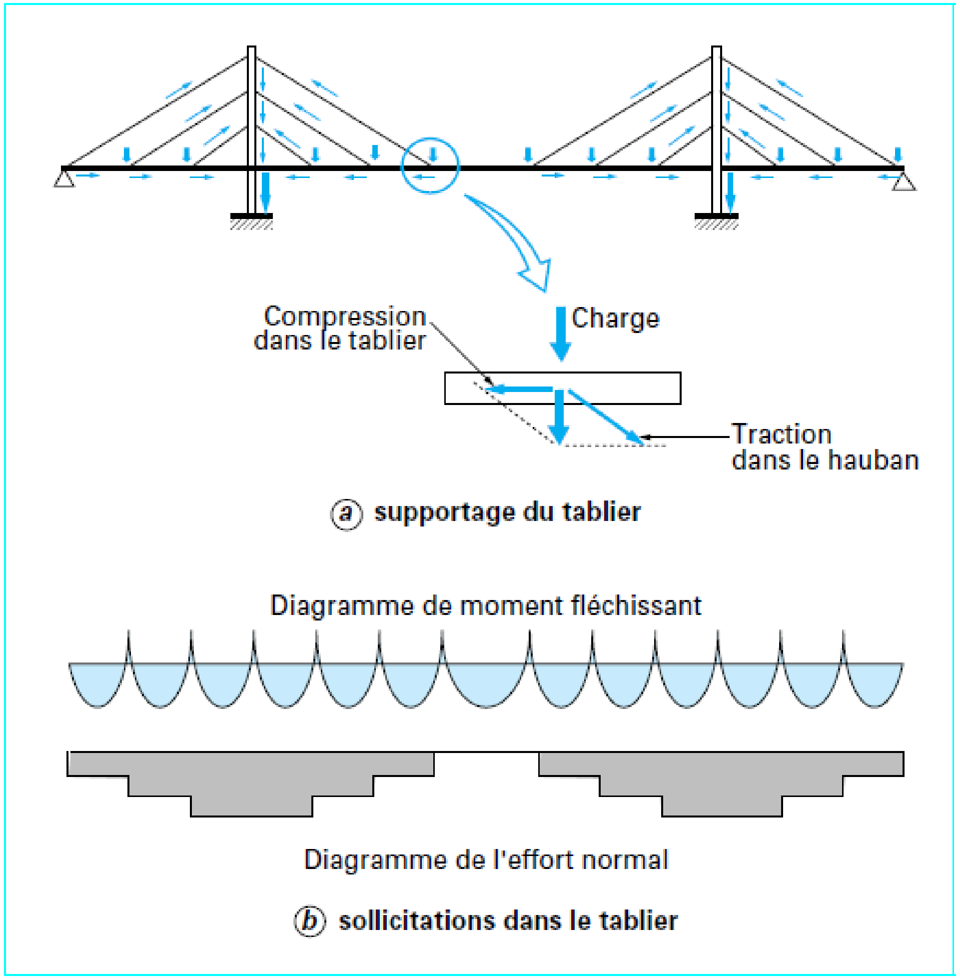
- ***Cable-stayed bridges:*** the deck is supported by a system of oblique cables (stays)

- ***Suspension bridges:*** The deck is held by a system of supporting cables.

5. Main types of bridges 11/22

3.1. Cable-stayed bridges:

The deck is supported by cables obliques (***stays***) which carry the vertical loads at the top of the ***pylons*** extending the ***main piers*** of the work.



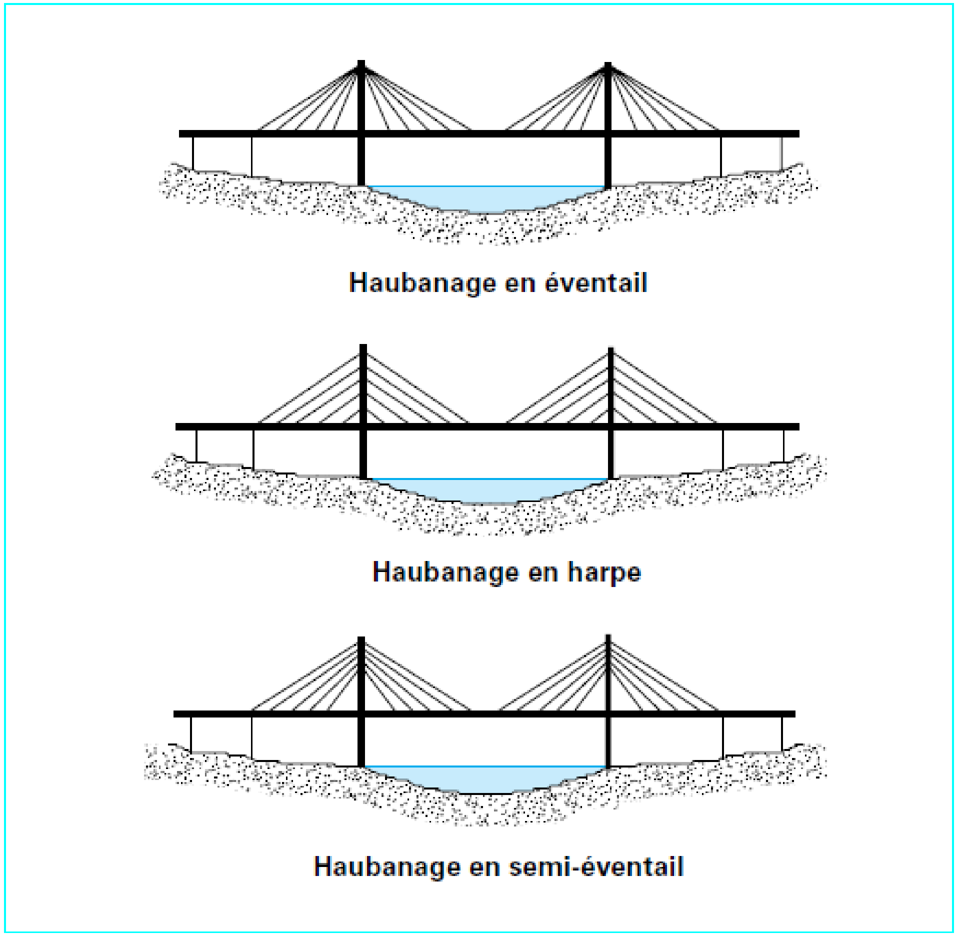
Principe de fonctionnement du pont haubané

5. Main types of bridges 12/22

guying configuration is influenced by mounting method of the apron.

➢ ***Longitudinally*** :
there are three ways to attach the stays on the pylon:

- fan-shaped: the shrouds converge at the head pylon,
- harp: the shrouds are parallel and distributed over the height of the pylon,
- in a semi-fan, combination of the two previous provisions.



Haubanage dans le plan longitudinal

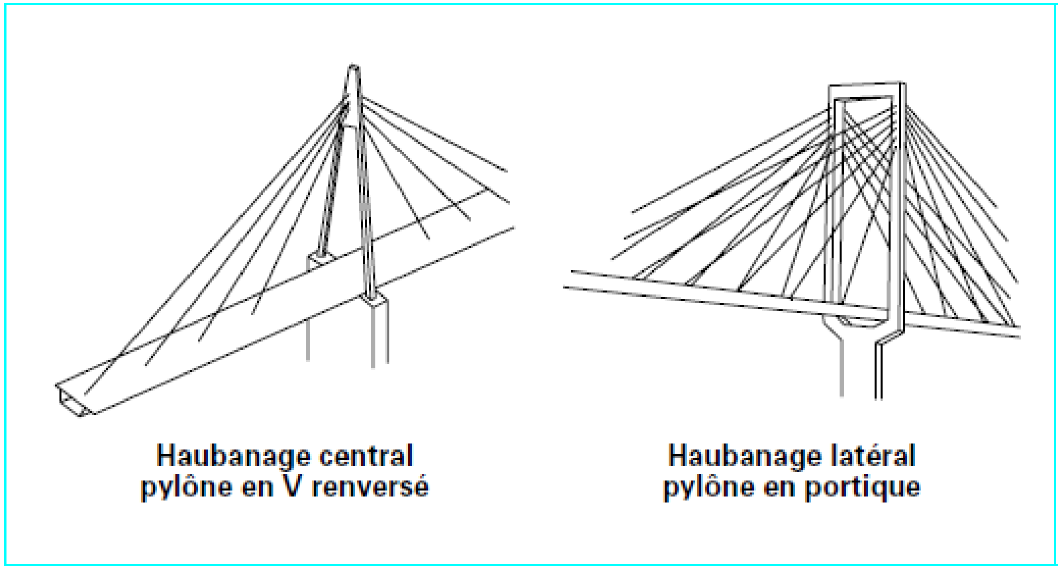
5. Main types of bridges 13/22

➢ ***Transversally*** :

The suspension can occupy two positions:

- either in the median plane of the work in a single central layer and it is often associated with a harp arrangement,

- either outside the roadway in a double lateral layer.



Disposition transversale des nappes de haubanage

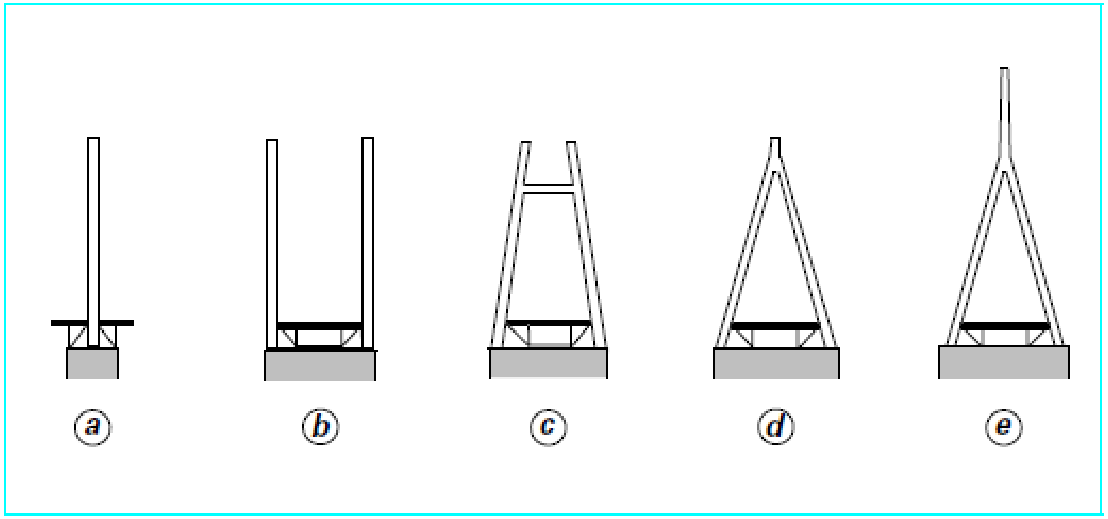
5. Main types of bridges 14/22

➢ ***Pylons***

They support all loads affecting the deck and carry them to the foundations.

Several shapes can be combined with the guying pattern and the type of deck:

- Single central mast (a),
- Double independent lateral mast (b) or braced (c),
- Inverted V (d) or inverted Y (e) pylon.



Formes de pylône

5. Main types of bridges 15/22

➢ ***Examples of cable-stayed bridges***

- ***Salah Bey Bridge*** (Constantine, 2014):

length 749 m, main span 245 m,
pylons height 70 m, width 27m.

- ***Beni -Haroun Viaduct*** (Mila, 1998):

Length 502m, main span 280 m,
Width 13 m.

5. Main types of bridges 16/22

➢ ***Examples of cable-stayed bridges***

- ***Millau Viaduct*** (France - 2004):

Length: 2,460 m

Width: 32 m

Maximum height: 343 m

Height of the highest pile (P2): 245 m

Height of pylons: 87 m

Number of batteries: 7

main range: 342 m

Number of stays: 154

Weight of the steel deck: 36,000 t, or 5 times the Eiffel Tower

Volume of concrete: 85,000 m^3, or 206,000 t

Cost of construction: €400 million

Guarantee of the work: 120 years

5. Main types of bridges 17/22

➢ ***Examples of cable-stayed bridges***

Roussky Island Bridge (Russia, 2012):

Length 3100m, main span 1104 m,
pylons height 321m, width 29.5m.

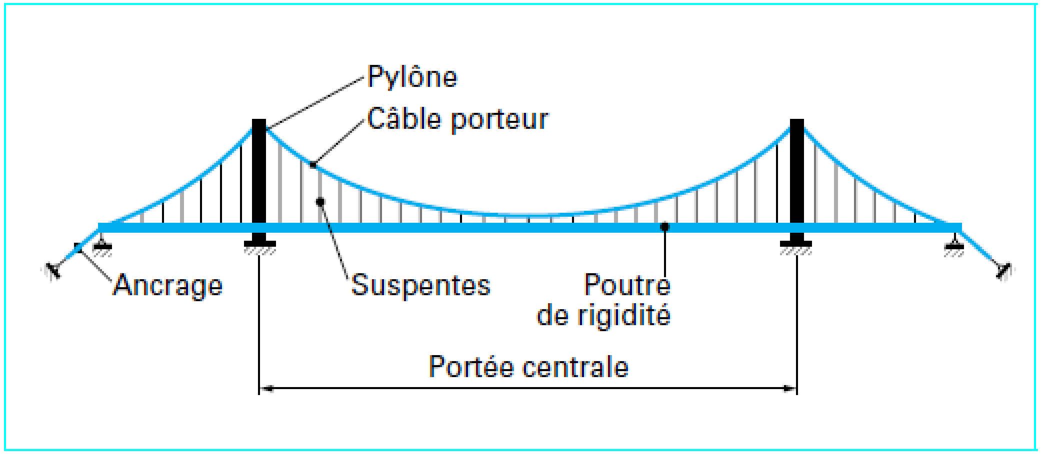
- *Normandy Bridge* (France, 1995):

Length 2.14 km, main span 856 m,
Width 24m, height 215m

5. Main types of bridges 18/22

3.2. Suspension bridges:

The deck is held step by step by hangers attached to a system of parabolic and continuous supporting cables, supported on the heads of the pylons and anchored in the rock or in powerful massive weights.



Suspension du tablier sur un câble porteur

Sidi M'Cid Bridge, Constantine (1908)

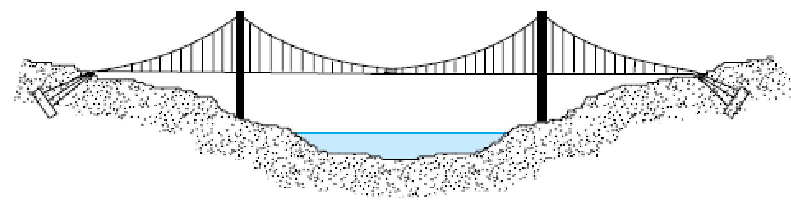
168 m long, 175 m above the Rhummel

5. Main types of bridges 19/22

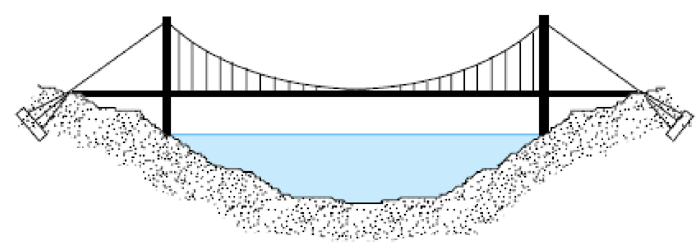
The suspended apron part is:

- is total and concerns both the span central and the two side bays,

- either partial and limited to the central span the side bays being independent.



Suspension totale



Suspension centrale

· Formes de suspension des ponts suspendus

Suspension à double nappe

5. Main types of bridges 20/22

➢*Examples of suspension bridges*

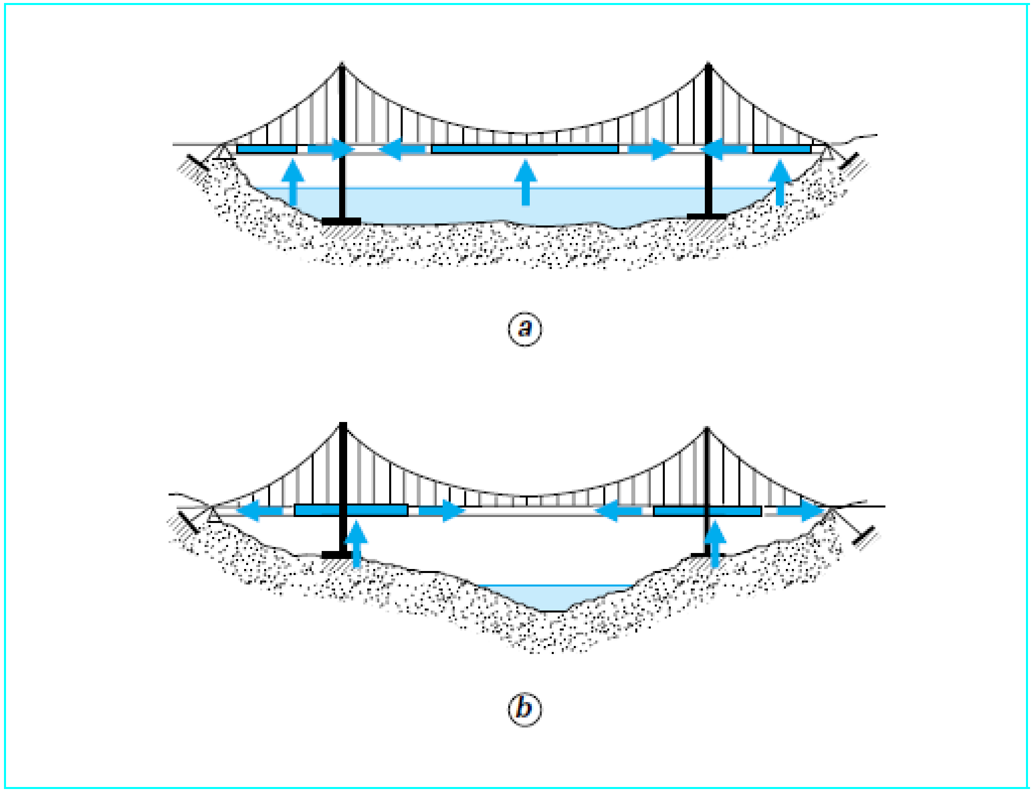
The maximum main range limit reached today is ***1,990 m with the Akashi - Kaikyo*** bridge built in Japan in 1998.

The ten largest suspension bridges built:

- Xihoumen Bridge (2009), China, 1650m
- Storebaelt East Bridge (1998), Denmark, 1624m
- Yi Sun-Sin Bridge (2012), South Korea, 1545m
- Nan-Cha Bridge (2005), China, 1490m
- Humber Bridge (1981), United Kingdom, 1410m
- Jiangyin Bridge (1999), China, 1385m
- Tsing Ma Bridge (1997), China, 1377 m
- Hardanger Fjord (2013), Norway, 1310m
- Verrazano Strait Bridge (1964), USA, 1298m

5. Main types of bridges 21/22

➢ ***Installation of suspension bridges***

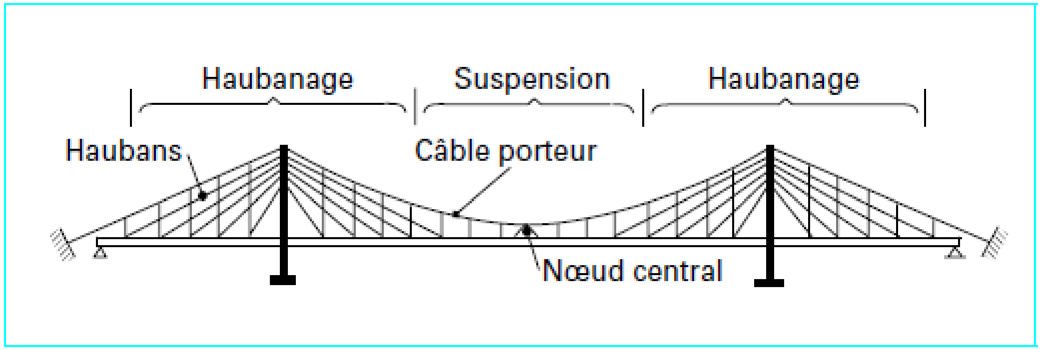


Méthodes de montage classiques du tablier d'un pont suspendu

5. Main types of bridges 22/22

➢*Shapes of tomorrow*

To go towards ranges of 2,500
at 3,000 m, it is necessary to ensure a c
aerodynamic stability in wind
(the pendulum effect of the cables).

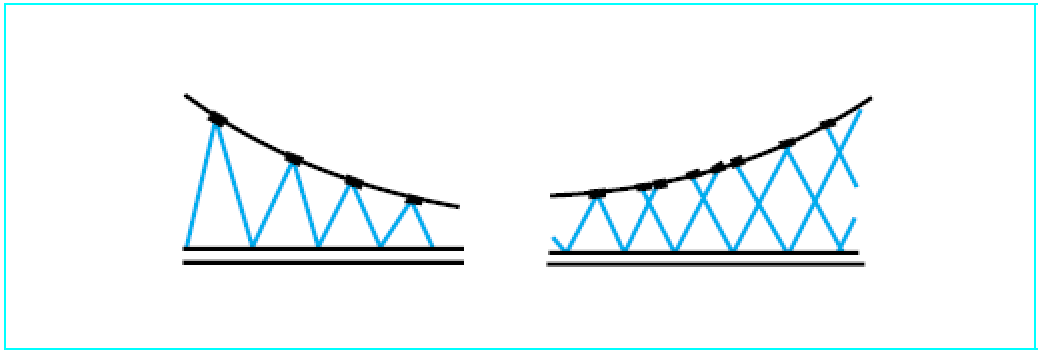


Pont à suspension mixte

Different solutions are imagined:

- add stays to the system
  carrier, we obtain a suspension
  mixed guyed-suspended,

- put inclined hangers
  V-shaped or crossed in X.



Suspentes inclinées et croisées

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