# Introduction

In the family of bridge systems the cable supported bridges are distinguished by their ability to overcome large spans. At present, cable supported bridges are enabled for spans in the range from 200 m to 2000 m (and beyond), thus covering approximately 90 per cent of the present span range.

For the vast majority of cable supported bridges, the structural system can be divided into four main components as indicated in Figure 0.1:

(1) the deck (or stiffening girder);
(2) the cable system supporting the deck;
(3) the pylons (or towers) supporting the cable system;
(4) the anchor blocks (or anchor piers) supporting the cable system vertically and horizontally, or only vertically, at the extreme ends.

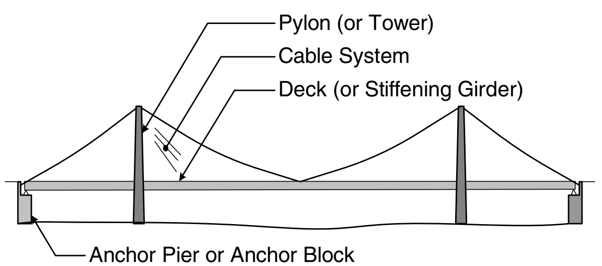


***Figure 0.1*** *Main components of a cable supported bridge*

The different types of cable supported bridges are distinctively characterized by the configuration of the cable system.

The suspension system (Figure 0.2) comprises a parabolic main cable and vertical hanger cables connecting the deck to the main cable. The most common suspension bridge system has three spans: a large main span flanked by shorter side spans. The three-span bridge is in most cases symmetrical with side spans of equal size, but where special conditions apply, the side spans can have different lengths.

In cases where only one large span is needed, the suspension bridge may have only the main span cable supported. However, to transmit the horizontal component of the main cable pull acting at the pylon tops, the main cable will have to continue as free backstays to the anchor blocks.

A single-span suspension bridge will be a natural choice if the pylons are on land or close to the coasts/river banks so that the traffic lanes will continue on viaducts outside the pylons.

*Cable Supported Bridges: Concept and Design*, Third Edition. Niels J. Gimsing and Christos T. Georgakis.

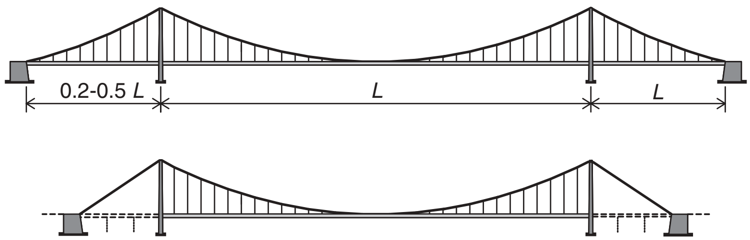


***Figure 0.2*** *Suspension bridge systems with vertical hangers and cable support of three spans (top) or only the main span (bottom)*

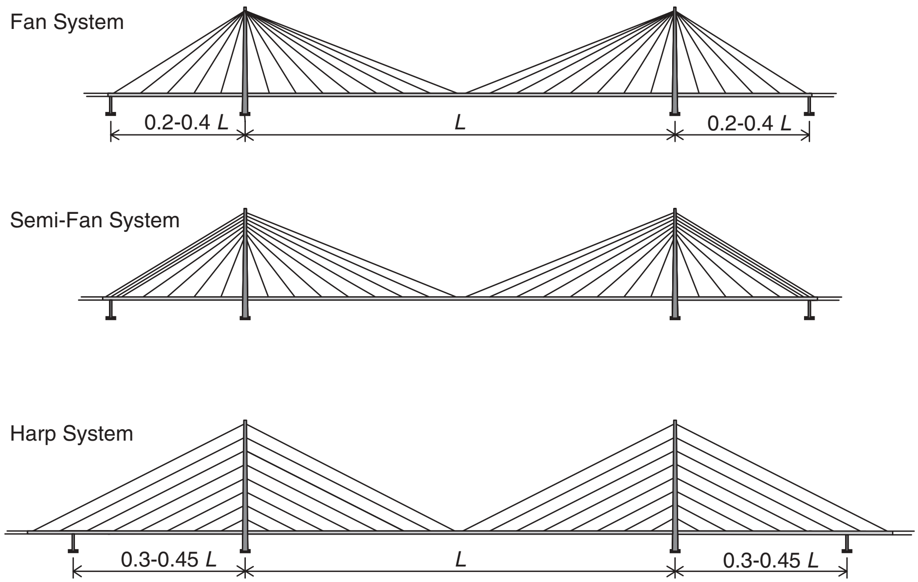


***Figure 0.3*** *Cable stayed bridge systems: (top) pure fan system; (centre) semi-fan system; (bottom) harp system*

The cable-stayed system (Figure 0.3) contains straight cables connecting the deck to the pylons. In the fan system, all stay cables radiate from the pylon top, whereas parallel stay cables are used in the harp system.

Besides the two basic cable stayed systems (the fan system and the harp system), intermediate systems are often found. In the semi-fan system, the cable anchorages at the pylon top are spread sufficiently to separate each cable anchorage and thereby simplify the detailing. With cable anchorages positioned at minimum distances at the pylon top, the behaviour of the semi-fan system will be very close to that of the pure fan system.

The stay cable anchorages at the deck will generally be spaced equidistantly so in cases where the side spans are shorter than half of the main span, the number of stay cables leading to the main span will be greater than the number of stay cables leading to the side span. In that case the anchor cable from the pylon tops to the anchor piers will often consist of several closely spaced individual cables (as shown for the semi-fan system).

In the harp system, the number of cables leading to the main span will have to be the same as in the side spans. With the anchor pier positioned at the end of the side span harp, the length of the side span will be very close to half of the main span length. That might prove inconvenient in relation to the overall stiffness of the system. It can then be advantageous to position the anchor pier inside the side span harp as indicated in Figure 0.3.

The position of the anchor pier closer to the pylon can also prove favourable in a fan system, if designed with fans of equal size in the main and side spans (Figure 0.4).

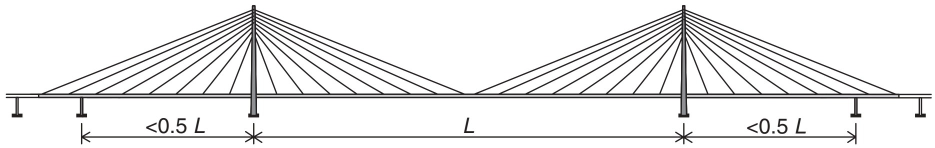


***Figure 0.4*** *Semi-fan system with side span pier inside the fan*

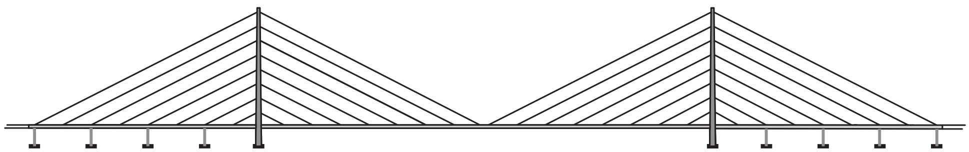

***Figure 0.5*** *Harp system with intermediate supports in the side spans*

For the harp system the most efficient structural system will be achieved if a number of intermediate piers can be positioned under the side span harps (Figure 0.5). This will be the preferred solution if the side spans are on land or in shallow water.

The most common type of cable supported bridge is the three-span bridge with a large main span flanked by two smaller side spans. However, especially within cable stayed bridges, there are also examples of a symmetrical arrangement with two main spans of equal size or an asymmetrical two-span arrangement with a long main span and a somewhat shorter side span (Figure 0.6). If the two spans are of equal size, it will be necessary to stabilize the pylon top with two anchor cables whereas the asymmetrical arrangement often can be made with only an anchor cable in the shorter span.

The vast majority of cable supported bridges are built with three or two spans, but in a few cases this has not been sufficient. A straight forward solution that maintains the advantages of the three-span configuration is then to arrange two or more three-span bridges in sequence, as shown in Figure 0.7 (top). In appearance, the bridge will have every second opening between pylons without a central pier and the other openings with a central anchor pier (or anchor block).

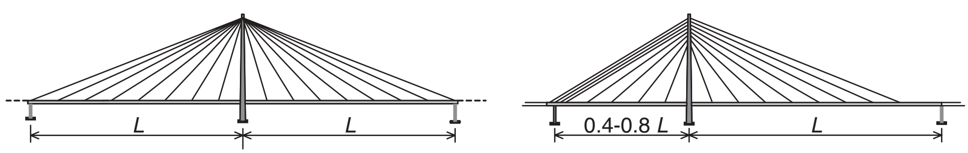


***Figure 0.6*** *Two-span cable stayed bridges*

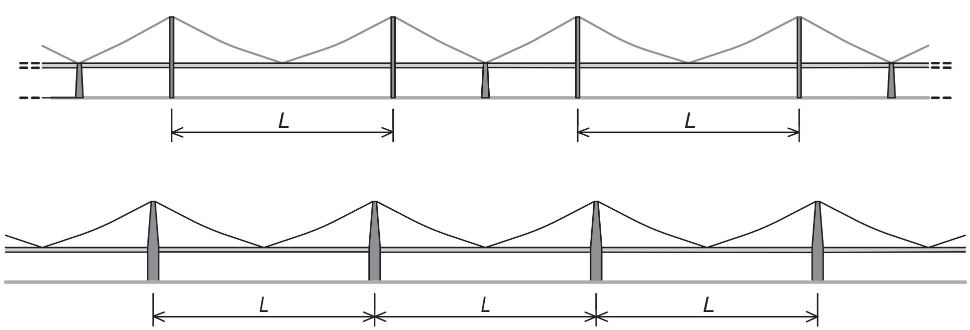


***Figure 0.7*** *Multi-span cable supported bridges*

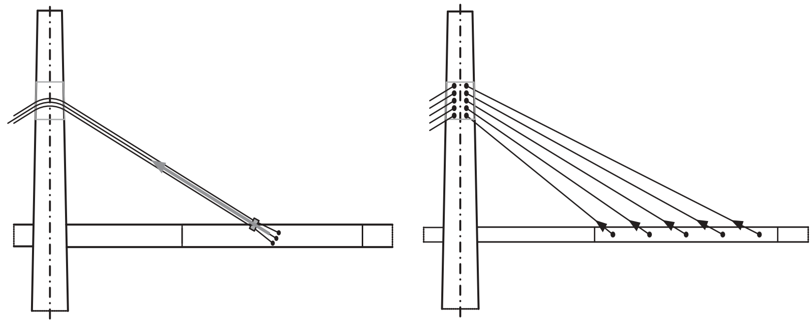

***Figure 0.8*** *Cable stayed system with few multi-strand cables (left) and a multi-cable system (right)*

A true multi-span cable supported bridge will consist of a number of main spans back-to-back as shown in Figure 0.7 (bottom).

In many cases, a true multi-span cable stayed bridge (bottom) will be preferable to a series of three-span bridges (top) from the point of view of appearance and function. However, from a structural viewpoint, the true multi-span arrangement presents a number of problems.

Due to the lack of anchor cables leading from vertically fixed points at the deck level to the pylon tops, the pylon must possess a considerable flexural stiffness to be able to withstand (with acceptable horizontal displacement at the top) a loading condition with traffic load in only one of the two spans adjacent to the pylon. In such a loading condition, the cable pull from the loaded span will be larger than from the unloaded span so the pylon must be able to withstand the difference between the horizontal force from the cable system in the loaded span and in the unloaded span.

In the early cable stayed bridges built from the mid-1950.s to the mid-1970s, the distance between cable anchorages at deck level was generally chosen to be quite large and as a consequence each stay cable had to carry a considerable load. It was therefore necessary to compose each stay of several prefabricated strands joined together (Figure 0.8, left).

It was necessary to let the multi-strand cable pass over the pylon on a saddle as the space available did not allow the splitting and individual anchoring of each strand, and at the deck the anchoring of the multi-strand cable made it absolutely necessary to split it into individual strands.

In modern cable stayed bridges, the number of stay cables is generally chosen to be so high that each stay can be made as a mono-strand. This will ease installation, and particularly replacement, and it will render a more continuous support to the deck (Figure 0.8, right).

With the multi-cable system it will be possible to replace the stays one by one if the deck is designed for it, which will often be required in the Design Specifications. The advantages gained in relation to erection, maintenance and replacement have to some extent been set against an increased tendency for the stays in a multi-cable system to suffer from wind-induced vibrations.

Besides the configuration of the cables, cable supported bridges can also be distinguished by the way the cable system is anchored at the end supports. In the self-anchored system, the horizontal component of the cable force in the anchor cable is transferred as compression in the deck, whereas the vertical component is taken by the anchor pier (Figure 0.9, left). In the earth anchored systems, both the vertical and the horizontal components of the cable force are transferred to the anchor block (Figure 0.9, right).

In principle, both earth anchoring and self-anchoring can be applied in suspension bridges as well as in cable stayed bridges. However, in actual practice, earth anchoring is primarily used for suspension bridges and self-anchoring for cable-stayed bridges.

For the suspension bridges, self-anchoring is especially unfavourable in relation to structural efficiency and constructability. In modern practice, self-anchored suspension bridges are therefore only seen when the decision to use the system is taken by people without structural competence and who are not concerned about construction costs.

In the transverse direction of the bridge, a number of different solutions for the arrangement of the cable systems can be found. The arrangement used traditionally in suspension bridges comprises two vertical cable planes supporting the deck

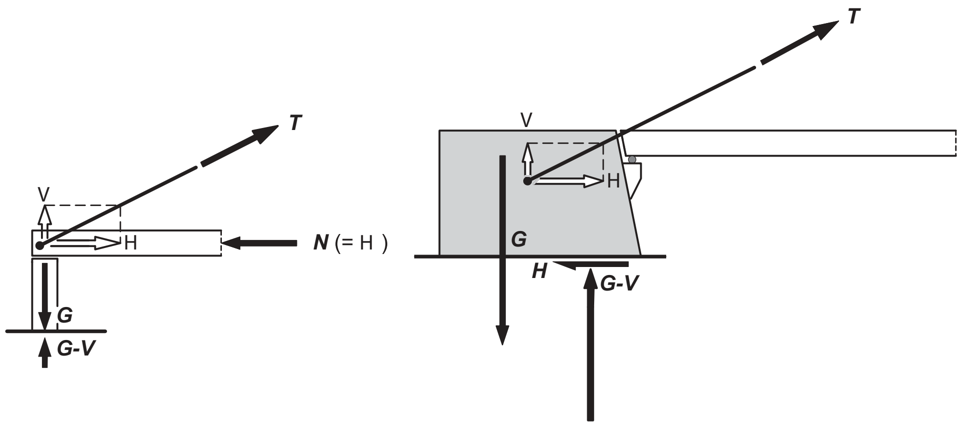


*Figure 0.9* Connection between the side span cable and the anchor pier/block in a self-anchored system (left), and in an earth-anchored system (right)

along the edges of the bridge deck (Figure 0.10). In this arrangement (which is also seen in many cable stayed bridges), the deck is supported by the cable systems both vertically and torsionally.

In cases where the bridge deck is divided into three separate traffic areas, e.g. a central railway or tramway area flanked by roadway areas on either side, the two vertical cable planes might be positioned between the central area and the outer areas (Figure 0.11, left). This arrangement is especially attractive if the central area is subjected to heavy loads that would induce large sagging moments in the transverse girders if the cable planes were attached along the edges of the bridge deck. On the other hand, with the cable planes moved in from the edges towards the centre of the deck, the torsional support offered by the cable system will be drastically reduced. A more moderate displacement of the cable planes from the edges of the deck is found in bridges with cantilevered lanes for pedestrians and bicycles (Figure 0.11, right).

The application of more than two vertical cable planes (Figure 0.12) was seen in some of the large American suspension bridges from the end of the nineteenth century and the beginning of the twentieth century. In bridges with a wide

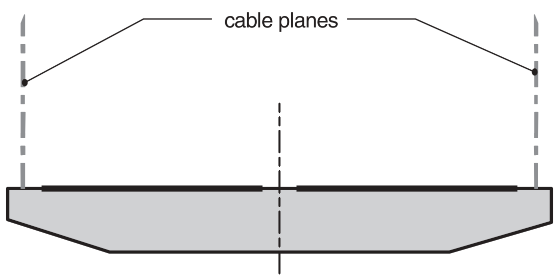


*Figure 0.10* System with two vertical cable planes attached along the edges of the bridge deck

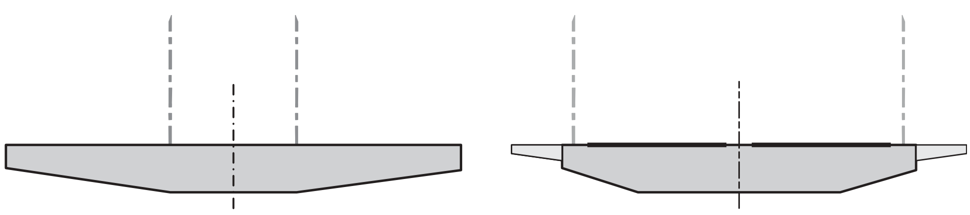

*Figure 0.11* Systems with two vertical cable planes positioned between three separate traffic lanes

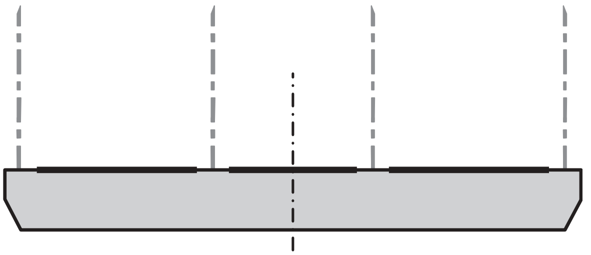

***Figure 0.12*** *System with four vertical cable planes positioned outside and between three separate traffic lanes*

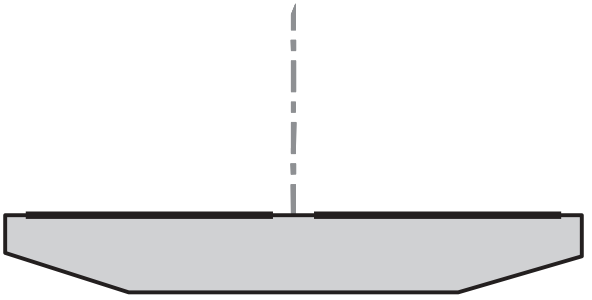

***Figure 0.13*** *System with one central cable plane*

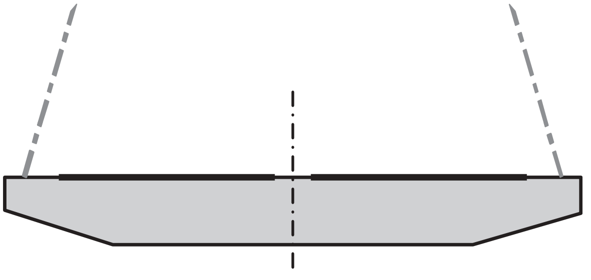

***Figure 0.14*** *System with two inclined cable planes*

bridge deck, more than two cable planes could still be considered, as the moments in the transverse girders will be significantly reduced.

Only one vertical cable plane (Figure 0.13) has been widely used in cable stayed bridges. In this arrangement, the deck is only supported vertically by the cable system, and torsional moments must therefore be transmitted by the deck. Consequently, the deck must be designed with a box-shaped cross-section.

Inclined cable planes (Figure 0.14) attached at the edges of the bridge deck and converging at the top are found in cable stayed bridges with A-shaped pylons. In this arrangement the deck is supported both vertically and torsionally by the cable system.

Two inclined cable planes converging at the top can also be supported on a single vertical pylon penetrating the deck in the central reserve or in the gap between two individual box girders.