

Catenary arch

More Details

A catenary curve (also called funicular curve or catenoid) is the curve that forms when a rope is suspended only at its ends and hangs loosely without being subjected to external load (Abb. 1). The shape of this curve is not dependent on the weight of the rope or chain, but only on its length and the distance between the two fixing points. A horizontally mirrored catenary curve is called a catenary arch.



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Fig. 1: Example of a catenary curve.

The weight is naturally distributed evenly. In the case of the catenary curve this is due to tensile forces, whereas in regard to the catenary arch it is a result of compressive forces. The forces only act in the direction of the curve. As the most stable and self-supporting arch form, it is an important element in architectural construction. If you build a bridge with building blocks in our experiment, which has the

shape of an upside-down catenary curve, it will remain stable without the use of an adhesive.

The Romans usually built arches in a semicircular shape, which can still be observed today in Romanesque architecture. A semicircular arch as a freestanding arch is unstable, since it would break out to the sides. When loaded with masonry from above, the semicircular arch becomes very stable and can be seen in many aqueducts and viaducts.

A modern example of a through arch bridge is the Harbour Bridge in Sydney (Abb. 2). This bridge is structurally stable, since the vertical loads, resulting mainly from the dead load and traffic load, are diverted into the subsoil by compressive forces in the arch.



Fig. 2: Harbour Bridge in Sydney.

Parabola and catenary

There is a strong similarity between the graphs of a parabola and a catenary (see Fig. 3). However, a parabola is much easier to determine (basic parabola: $y = x^2$), which is why it is still used as an approximation for simple architectural work today. The catenary follows the more complex hyperbolic cosine ($y = a \cosh(x/a) + y_0$).

Fig. 3: Catenary (red) and basic parabola (blue).

The parabolic shape can also be observed in suspension bridges, such as the Golden Gate Bridge. This shape is a result of a load being suspended onto a hanging cable that is evenly distributed over the span.

A catenary also appears in a variety of shapes as a vaulted arch. The Catalan architect Gaudí designed his buildings based on the catenary curve (Fig. 4). A catenary arch can also be constructed using exotic building material: The Icehotel in Jukkasjärvi, Sweden, is made entirely of snow and ice blocks (Fig. 5).



Fig. 4: Vault by Gaudí in the shape of a catenary arch.



Fig. 5: Icehotel in Sweden in the shape of a catenary arch.

