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Introduction of a Suspension Bridge Suspension bridges are one of the most popular choices in Bridge construction nowadays, due to the numerous advantages a suspension bridge provides over other bridge structures. As the name indicates, a suspension bridge is the one in which the bridge deck slab suspends between two towers, or in other words, in a suspension bridge, the deck slab is hanging between two towers of the bridge. In shape and structural components used in construction, it is very much similar to the cable-stayed bridge structure. The only difference between a cable-stayed and a suspension bridge is that in case of a cable-stayed bridge, only one tower is constructed at the middle of the bridge. From which the cables support the bridge deck slab, on either side, while in case of a suspension bridge, two towers are constructed from which the cables extents and support the bridge deck slab. The history of suspension bridge goes back go the 15th Century, where rope and woods were the prime materials of construction. Some of the examples of suspension bridges as famous iconic projects are Golden Gate Bridge, Brooklyn Bridge, Akashi Kaikyo Bridge (Longest suspension bridge till now: spans 6523 feet or 1991 meters, Japan), Humber Bridge (United Kingdom) etc. Also, Read: How Are Bridges Built How to Build a Suspension Bridge? The construction procedure of a Suspension bridge is similar to that of ordinary bridge construction, the only exception is in this type of bridge. Cables are required to hold up the bridge deck slab, while ordinary bridge construction does not require it. Before starting on how to build a suspension bridge, it necessary go look at the structural components of a suspension bridge, and for which purpose it is being used for. The structural components of a suspension bridge include Piers (in the form of large towers), main supporting cables (which are often called “catenary”). Suspenders, and anchorages which are fixed at both ends of the bridge to anchor the main supporting cables. The initial construction procedure of a suspension bridge involves the construction of the piers or towers following the traditional methods, that is, from foundation to superstructure. In parallel with the construction of towers, the anchor blocks are fixed on both ends of the bridge in order to anchor the main supporting cables. Once the towers and anchor blocks are in place, the placing of the main cable will take place. The main supporting cables (Catenary), consists of hundreds and thousands of thin wires which are then threaded individually by mechanical equipment, which are placed within two end anchor blocks. Once all the wires are placed, it is then tied together by wrapping it with steel wires and finally coating it with resin compound, to prevent corrosion. After the main cables are constructed, the suspenders (vertical steel short ropes) are put in place from the main cables. Which generally varies in height and length (smallest in middle span, to the largest in end spans, due to the parabolic shape of main cables). Then the final phase of the construction starts, which involves placing the bridge deck. The bridge decks are generally placed in segments, each segments being prefabricated. Steel girders/trusses or steel boxes are generally being used for the construction of bridge decks. The placing of the bridge decks is done incrementally from both the towers towards the middle span, which are progressed simultaneously in order to connect the bridge at the middle span. After the construction of the main bridge, much smaller approaches at the to the bridge are constructed, which then followed by completion & the delivery of the project, and maintenance after. Also, Read: West Point Bridge Designer How Does a Suspension Bridge Work? The functions of the different structural components of a suspension bridge are as follows: Suspenders: The suspenders overhang from the main supporting cables, which carry the dead and live loads (generally traffic loads) from a bridge and transfer it to the catenary. Main Supporting Cables: Parabolic shaped main supporting cables takes the dead & live load of the bridge deck slab from the suspenders and transfers it go the towers/piers. Towers: The towers carry the whole load of the bridge deck slab from either side, by taking it from the main supporting cables and transferring it to the foundation, which is further transferred to the subsoil under it. Anchor Blocks: The function of the anchor blocks are to fix the main cables at the end of the bridges, at either side of the bridge. The suspension bridge works on the principle of transferring tension by converting it onto the compressive forces. The dead and live loads from the bridge decks are first transferred to the suspenders, by tension, which is then transferred into the main supporting cables. Which then further transferred into the towers by converting it into compressive forces. The two towers of the suspension bridge carry equal loads in order to stay into equilibrium. The weight of the whole suspension bridge is transferred to the towers, which is again transferred to the foundation of the structure and the subsoil below it. In a suspension bridge, the main cable tension is concentrated in the anchorages at each end. By contrast, the cable tension in a cable-stayed bridge is distributed over many anchorages along the deck. The more stays the more supports there are to the deck and the lighter and less costly the bridge. Also, Read: What Is Bridge Pier | Type of Bridge Pier Suspension Bridge Facts A suspension bridge is a type of bridge in which the deck (the load-bearing portion) is hung below suspension cables on vertical suspenders. This type of bridge has cables suspended between towers, with vertical suspender cables that transfer the live and dead loads of the deck below, upon which traffic crosses. Suspension Bridge-Strength & Weaknesses There are numerous advantages of a suspension bridge which is being preferred nowadays as an effective choice for bridge re-construct as well as new bridges construction. Although not many, suspension bridges do provide some disadvantages. In contrast, the number of advantages of a suspension bridge far exceeds the disadvantages, which is why suspension bridges are seen as a popular choice of bridge construction. The Advantages and Disadvantages of a Suspension Bridge includes Advantages of Suspension Bridges Suspension bridges are very affordable to construct as only a minimal amount of materials, and supplies are necessary to construct the bridge. It needs anchor blocks, cables and steel boxes for the bridge deck. One of the biggest advantages of a suspension bridge is that it can cover a long span. So it is very suitable for busy waterways and where the length of the waterways are large. It is easier to maintain suspension bridges when compared to other bridge structures. Suspension bridge needs little and a nominal amount of maintenance which preferably includes new coats of paints every year. So it is very affordable as it requires one-time large investment behind the construction of the structure. There is more flexibility in the configuration of the suspension bridges. As the suspension bridges are constructed into different segments which are then joined to form the bridge, it is very much possible to modify any part of the structure for maintenance or other structural reasons. This type of bridge design requires very little access from the bottom of the deck. As the design of a suspension bridge requires the design of cables and suspenders, there is no necessity to access the bottom of the deck, which again proves to be economical for a technical audit of the structure. Suspension bridges can be visually appealing from the aesthetic viewpoint. The parabolic shape of the cable and the shape of the structure provides an aesthetically pleasing experience, which results in increased tourism, affecting the economy of the country as a whole. Disadvantages of Suspension Bridges Suspension bridges can struggle to focus on heavy loads. As this type of bridge can be used to cover very large spans, it’s the inability to carry concentrated focused loads may become a major drawback for the high traffic cities and countries. Suspension bridges are weak against high wind. Due to the lower stiffness of the bridge, high winds and earthquakes can cause major damages to the bridge resulting in vibration, and ultimately, failure of the bridge. A little amount of access from the bottom deck may be necessary during the construction of a suspension bridge, which can be avoided in cable cable-stayed. A suspension bridge has lower feck stiffness compared to other bridge structures. There are many other pros and cons of a suspension bridge, within which the included ones may be considered important. Suspension Bridge Pros and Cons Pros of Suspension Bridge It can span over long distances It is inexpensive to build It is easy to maintain It is incredibly versatile It is aesthetically pleasing Cons of Suspension Bridges It is vulnerable to the wind It has load limitations It costs time and money It has limited applications A suspension bridge is a type of bridge in which the deck is hung below suspension cables on vertical suspenders. The basic structural components of a suspension bridge system include stiffening girders/trusses, the main suspension cables, main towers, and the anchorages for the cables at each end of the bridge. What Is the Construction Material of a Suspension Bridge? The towers of most suspension bridges are made of steel, although a few have been built of steel-reinforced concrete. Suspension Bridge Disadvantages Suspension bridges can struggle to support focused heavy weights. There is less flexibility with a suspension bridge. High winds can cause a suspension bridge to start vibrating. Some access below the deck may be necessary during construction. Suspension Bridge Advantages Advantages of Suspension Bridges Economic Advantage: The realm spanned by a bridge is extremely long in proportion to the number of materials needed to construct bridges. Height Advantage: Built over waterways, suspension bridges are engineered high, permitting the passage of tall ships unrestrained by the bridge. Suspension Bridge Advantages and Disadvantages Suspension Bridges Advantages of a Suspension Bridge. Best bridge type for creating the longest spans with minimum piers. Disadvantages of a Suspension Bridge. A combination of vertical pressures and extreme side wind speeds can lead to a failure of the span. Suspension Bridge Materials Bridge materials. Some of the main materials found on a bridge are steel, concrete, stone and asphalt. Other materials include iron, timber, aluminum, rubber and other joint materials. Pros and Cons of Suspension Bridges Suspension bridges are impressive engineering marvels that have both advantages and disadvantages. Here are some pros and cons of suspension bridges: Pros: Long-Span Capability Aesthetically Pleasing Flexibility Cost-Effective Easy Maintenance Cons: Construction Complexity Vulnerability to Wind Limited Load Capacity Bridge Deck Movement Maintenance Challenges What Are the Disadvantages of a Suspension Bridge? The cables and towers will be a visual obstruction that some people would rather not have. Security: The last and arguably most significant disadvantage of suspension bridges is that security. These bridges are susceptible to attack, including from terrorists. Suspension Bridge Strengths and Weaknesses Suspension bridges are unique structures that have several strengths and weaknesses. Here are some of the key strengths and weaknesses of suspension bridges: Strengths: Long Span Capability Aesthetically Pleasing High Load-Carrying Capacity Flexibility and Resilience Weaknesses: Vulnerability to Wind High Construction and Maintenance Costs Potential for Cable Corrosion Limited Flexibility in Deck Configuration Challenging Construction Process Suspension Bridge Cons Suspension bridges, like any other infrastructure, have their share of advantages and disadvantages. Here are some cons or disadvantages associated with suspension bridges: High Construction and Maintenance Costs Vulnerability to Extreme Weather Conditions Limited Load Capacity Limited Span Length Maintenance Challenges Sensitivity to Vibrations Limited Flexibility for Expansion Advantages of a Small Suspension Bridge Small suspension bridges offer several advantages compared to other types of bridges. Here are some of the advantages: Cost-Effective Flexibility in Site Selection Minimal Environmental Impact Aesthetically Pleasing Efficient Use of Materials Long Spans Reduces Transportation Barriers How Are Suspension Bridges Built The deck is suspended by strong ropes running from the deck level to the main cables. The main cables can consist of parallel strong wires that are aerially spun in place or prefabricated wire ropes. The deck can be stiffened by a truss or by girder elements. Suspension Bridge Construction Suspension bridges are impressive engineering structures that rely on tension and compression forces to span long distances. Here’s a general overview of the construction process for a suspension bridge: Feasibility Study Design and Planning Foundation Construction Tower Construction Cable Installation Deck Construction Substructure and Approach Construction Testing and Inspection Opening and Maintenance Disadvantages of a Small Suspension Bridge While small suspension bridges can offer certain advantages, they also come with a few disadvantages. Here are some of the potential drawbacks of a small suspension bridge: Limited Span Weight Restrictions Vulnerability to Wind and Vibrations Higher Construction Costs Maintenance Challenges Limited Aesthetics Suspension Bridge Structure A suspension bridge is a type of bridge that is supported by cables suspended from towers and anchored at each end. It is designed to carry the load primarily through tension forces in the cables rather than compression forces in the bridge deck. Here are the main components of a suspension bridge structure: Towers Main Cables Anchorages Bridge Deck Suspension Cables or Stay Cables Piers or Pylons Diaphragms and Trusses How Is a Suspension Bridge Built? A suspension bridge is typically built using the following steps: Site Preparation Foundation Construction Tower Erection Cable Installation Deck Construction Anchorage Construction Finishing Touches Type of bridge This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "Suspension bridge" – news · newspapers · books · scholar · JSTOR (April 2025) (Learn how and when to remove this message) Suspension bridgeThe 1915 Çanakkale Bridge on the Dardanelles strait in Turkey, connecting Europe and Asia, is the suspension bridge with the longest main span in the world.[1][2]AncestorSimple suspension bridgeRelatedUnderspanned suspension bridge; see also cable-stayed bridgeDescendantSelf-anchored suspension bridgeCarriesPedestrians, bicycles, livestock, automobiles, trucks, railed vehiclesSpan rangeMedium to longMaterialSteel rope, multiple steel wire strand cables or forged or cast chain linksMovableNoDesign effortmediumFalsework requiredNo The double-decked George Washington Bridge, connecting New York City to Bergen County, New Jersey, is the world's busiest suspension bridge by traversing vehicles, carrying 106 million vehicles annually.[3][4] A suspension bridge is a type of bridge in which the deck is hung below suspension cables on vertical suspenders. The first modern examples of this type of bridge were built in the early 1800s.[5][6] Simple suspension bridges, which lack vertical suspenders, have a long history in many mountainous parts of the world. Besides the bridge type most commonly called suspension bridges, covered in this article, there are other types of suspension bridges. The type covered here has cables suspended between towers, with vertical suspender cables that transfer the live and dead loads of the deck below, upon which traffic crosses. This arrangement allows the deck to be level or to arc upward for additional clearance. Like other suspension bridge types, this type often is constructed without the use of falsework. The suspension cables must be anchored at each end of the bridge, since any load applied to the bridge is transformed into tension in these main cables. The main cables continue beyond the pillars to deck-level supports, and further continue to connections with anchors in the ground. The roadway is supported by vertical suspender cables or rods, called hangers. In some circumstances, the towers may sit on a bluff or canyon edge where the road may proceed directly to the main span. Otherwise, the bridge will typically have two smaller spans, running between either pair of pillars and the highway, which may be supported by suspender cables or their own trusswork. In cases where trusswork supports the spans, there will be very little arc in the outboard main cables. For bridges where the deck follows the suspenders, see simple suspension bridge. The earliest suspension bridges were ropes slung across a chasm, with a deck possibly at the same level or hung below the ropes such that the rope had a catenary shape. Chushul Chakzam, one of Thangtong Gyalpo's chain bridges, in 1904 The wooden 1808 Burr Suspension Bridge in Schenectady, NY, USA, during demolition in 1871, showing wooden cables.[7][8] Spans of 160, 190, 180 and 157 feet on 3 piers began to sag, and 4 supporting piers were added in 1833 making 8 spans.[9] The Tibetan siddha and bridge-builder Thangtong Gyalpo originated the use of iron chains in his version of simple suspension bridges. In 1433, Gyalpo built eight bridges in eastern Bhutan. The last surviving chain-linked bridge of Gyalpo's was the Thangtong Gyalpo Bridge in Duksum en route to Trashi Yangtse, which was finally washed away in 2004.[10] Gyalpo's iron chain bridges did not include a suspended-deck bridge, which is the standard on all modern suspension bridges today. Instead, both the railing and the walking layer of Gyalpo's bridges used wires. The stress points that carried the screed were reinforced by the iron chains. Before the use of iron chains it is thought that Gyalpo used ropes from twisted willows or yak skins.[11] He may have also used tightly bound cloth. The Inca used rope bridges, documented as early as 1615. It is not known when they were first made. Queshuachaca is considered the last remaining Inca rope bridge and is rebuilt annually. An early plan for the chain bridge over the Menai Strait near Bangor, Wales, completed in 1826 The first iron chain suspension bridge in the Western world was the Jacob's Creek Bridge (1801) in Westmoreland County, Pennsylvania, designed by inventor James Finley.[12] Finley's bridge was the first to incorporate all of the necessary components of a modern suspension bridge, including a suspended deck which hung by trusses. Finley patented his design in 1808, and published it in the Philadelphia journal, The Port Folio, in 1810.[13] Early British chain bridges included the Dryburgh Abbey Bridge (1817) and 137 m Union Bridge (1820), with spans rapidly increasing to 176 m with the Menai Bridge (1826), "the first important modern suspension bridge".[14] The first chain bridge on the German speaking territories was the Chain Bridge in Nuremberg. The Sagar Iron Suspension Bridge with a 200 feet span (also termed Beose Bridge) was constructed near Sagar, India during 1828–1830 by Duncan Presgrave, Mint and Assay Master.[15] The Clifton Suspension Bridge (designed in 1831, completed in 1864 with a 214 m central span), is similar to the Sagar bridge. It is one of the longest of the parabolic arc chain type. The current Marlow suspension bridge was designed by William Tierney Clark and was built between 1829 and 1832, replacing a wooden bridge further downstream which collapsed in 1828. It is the only suspension bridge across the non-tidal Thames. The Széchenyi Chain Bridge, (designed in 1840, opened in 1849), spanning the River Danube in Budapest, was also designed by William Clark and it is a larger-scale version of Marlow Bridge.[16] One variation is the Thornewill and Warham's Ferry Bridge in Burton-on-Trent, Staffordshire (1889), where the chains are not attached to abutments as is usual, but instead are attached to the main girders, which are thus in compression. Here, the chains are made from flat wrought iron plates, eight inches (203 mm) wide by an inch and a half (38 mm) thick, rivetted together.[17] The Manhattan Bridge, connecting Manhattan and Brooklyn in New York City, opened in 1909 and is considered to be the forerunner of modern suspension bridges; its design served as the model for many of the long-span suspension bridges around the world. The first wire-cable suspension bridge was the Spider Bridge at Falls of Schuylkill (1816), a modest and temporary footbridge built following the collapse of James Finley's nearby Chain Bridge at Falls of Schuylkill (1808). The footbridge's span was 124 m, although its deck was only 0.45 m wide. Marc Seguin suspension bridge near Annonay, 1825 Development of wire-cable suspension bridges dates to the temporary simple suspension bridge at Annonay built by Marc Seguin and his brothers in 1822. It spanned only 18 m.[18] The first permanent wire cable suspension bridge was Guillaume Henri Dufour's Saint Antoine Bridge in Geneva of 1823, with two 40 m spans.[18] The first with cables assembled in mid-air in the modern method was Joseph Chaley's Grand Pont Suspendu in Fribourg, in 1834.[18] In the United States, the first major wire-cable suspension bridge was the Wire Bridge at Fairmount in Philadelphia, Pennsylvania. Designed by Charles Ellet Jr. and completed in 1842, it had a span of 109 m. Ellet's Niagara Falls suspension bridge (1847–48) was abandoned before completion. It was used as scaffolding for John A. Roebling's double decker railroad and carriage bridge (1855). The Otto Beit Bridge (1938–1939) was the first modern suspension bridge outside the United States built with parallel wire cables.[19] Drawing of the Tibetan-built Chaksam bridge south of Lhasa, constructed in 1430, with long chains suspended between towers, and vertical suspender ropes carrying the weight of a planked footway below. View of the Chain Bridge invented by James Finley Esq. (1810) by William Strickland. Finley's Chain Bridge at Falls of Schuylkill (1808) had two spans, 100 feet, and 200 feet. Sagar Iron Suspension Bridge, by Major Presgrave, 1828–1830, near Sanodha, Sagar district India constructed using locally produced iron. Wire Bridge at Fairmount (1842, replaced 1874). The slender lines of the Severn Bridge Two towers/pillars, two suspension cables, four suspension cable anchors, multiple suspender cables, the bridge deck.[20] Comparison of a catenary (black dotted curve) and a parabola (red solid curve) with the same span and sag. The main forces in a suspension bridge of any type are tension in the cables and compression in the pillars. Since almost all the force on the pillars is vertically downwards, and the bridge is also stabilized by the main cables, the pillars can be made quite slender, as on the Severn Bridge, on the Wales-England border. In a suspended deck bridge, cables suspended via towers hold up the road deck. The weight is transferred by the cables to the towers, which in turn transfer the weight to the ground. More details The catenary represents the profile of a simple suspension bridge or the cable of a suspended-deck suspension bridge on which its deck and hangers have negligible mass compared to its cable. The parabola represents the profile of the cable of a suspended-deck suspension bridge on which its cable and hangers have negligible mass compared to its deck. The profile of the cable of a real suspension bridge with the same span and sag lies between the two curves. The main cables of a suspension bridge will form a catenary when hanging under their own weight only. When supporting the deck, the cables will instead form a parabola, assuming the weight of the cables is small compared to the weight of the deck. One can see the shape from the constant increase of the gradient of the cable with linear (deck) distance, this increase in gradient at each connection with the deck providing a net upward support force. Combined with the relatively simple constraints placed upon the actual deck, that makes the suspension bridge much simpler to design and analyze than a cable-stayed bridge in which the deck is in compression. Cable-stayed bridges and suspension bridges may appear to be similar, but are quite different in principle and in their construction. In suspension bridges, large main cables (normally two) hang between the towers and are anchored at each end to the ground. The main cables, which are free to move on bearings in the towers, bear the load of the bridge deck. Before the deck is installed, the cables are under tension from their own weight. Along the main cables smaller cables or rods connect to the bridge deck, which is lifted in sections. As this is done, the tension in the cables increases, as it does with the live load of traffic crossing the bridge. The tension on the main cables is transferred to the ground at the anchorages and by downwards compression on the towers. Difference between types of bridges Suspension bridge Cable-stayed bridge, fan design In cable-stayed bridges, the towers are the primary load-bearing structures that transmit the bridge loads to the ground. A cantilever approach is often used to support the bridge deck near the towers, but lengths further from them are supported by cables running directly to the towers. By design, all static horizontal forces of the cable-stayed bridge are balanced so that the supporting towers do not tend to tilt or slide and so must only resist horizontal forces from the live loads. A suspension bridge can be made out of simple materials such as wood and common wire rope. Longer main spans are achievable than with any other type of bridge. Less material may be required than other bridge types, even at spans they can achieve, leading to a reduced construction cost. Except for installation of the initial temporary cables, little or no access from below is required during construction and so a waterway can remain open while the bridge is built above. They may be better able to withstand earthquake movements than heavier and more rigid bridges. Bridge decks can have deck sections replaced in order to widen traffic lanes for larger vehicles or add additional width for separated cycling/pedestrian paths. Considerable stiffness or aerodynamic profiling may be required to prevent the bridge deck from vibrating under high winds. The relatively low deck stiffness compared to other (non-suspension) types of bridges makes it more difficult to carry heavy rail traffic in which high concentrated live loads occur. Some access below may be required during construction to lift the initial cables or to lift deck units. That access can often be avoided in cable-stayed bridge construction. In an underspanned suspension bridge, also called under-deck cable-stayed bridge,[21] the main cables hang entirely below the bridge deck, but are still anchored into the ground in a similar way to the conventional type. Very few bridges of this nature have been built, as the deck is inherently less stable than when suspended below the cables. Examples include the Pont des Bergues of 1834 designed by Guillaume Henri Dufour;[18] James Smith's Micklewood Bridge;[22] and a proposal by Robert Stevenson for a bridge over the River Almond near Edinburgh.[22] Roebling's Delaware Aqueduct (begun 1847) consists of three sections supported by cables. The timber structure essentially hides the cables; and from a quick view, it is not immediately apparent that it is even a suspension bridge. Micklewood Bridge as illustrated by Charles Drewry, 1832 Squibb Park Bridge, Brooklyn, built 2013 Eyebar chain cables of Clifton Suspension Bridge The Yichang Bridge, a plate deck suspension bridge, over the Yangtze River in China A former steam pipeline suspension bridge on the Lake Näsijärvi in Tampere, Finland, in 1979 The main suspension cables in older bridges were often made from a chain or linked bars, but modern bridge cables are made from multiple strands of wire. This not only adds strength but improves reliability (often called redundancy in engineering terms) because the failure of a few flawed strands in the hundreds used pose very little threat of failure, whereas a single bad link or eyebar can cause failure of an entire bridge. (The failure of a single eyebar was found to be the cause of the collapse of the Silver Bridge over the Ohio River.) Another reason is that as spans increased, engineers were unable to lift larger chains into position, whereas wire strand cables can be formulated one by one in mid-air from a temporary walkway. Poured sockets are used to make a high strength, permanent cable termination. They are created by inserting the suspender wire rope (at the bridge deck supports) into the narrow end of a conical cavity which is oriented in-line with the intended direction of strain. The individual wires are splayed out inside the cone or 'capel', and the cone is then filled with molten lead-antimony-tin (Pb80Sb15Sn5) solder.[23] Most suspension bridges have open truss structures to support the roadbed, particularly owing to the unfavorable effects of using plate girders, discovered from the Tacoma Narrows Bridge (1940) bridge collapse. In the 1960s, developments in bridge aerodynamics allowed the re-introduction of plate structures as shallow box girders, first seen on the Severn bridge, built 1961–1966. In the picture of the Yichang Bridge, note the very sharp entry edge and sloping undergirders in the suspension bridge shown. This enables this type of construction to be used without the danger of vortex shedding and consequent aeroelastic effects, such as those that destroyed the original Tacoma Narrows bridge. Three kinds of forces operate on any bridge: the dead load, the live load, and the dynamic load. Dead load refers to the weight of the bridge itself. Like any other structure, a bridge has a tendency to collapse simply because of the gravitational forces acting on the materials of which the bridge is made. Live load refers to traffic that moves across the bridge as well as normal environmental factors such as changes in temperature, precipitation, and winds. Dynamic load refers to environmental factors that go beyond normal weather conditions, factors such as sudden gusts of wind and earthquakes. All three factors must be taken into consideration when building a bridge. Cable-suspended footbridge at Dallas Fort Worth Airport Terminal D The principles of suspension used on a large scale also appear in contexts less dramatic than road or rail bridges. Light cable suspension may prove less expensive and seem more elegant for a cycle or footbridge than strong girder supports. An example of this is the Nescio Bridge in the Netherlands, and the Roebling designed 1904 Riegelsville suspension pedestrian bridge across the Delaware River in Pennsylvania.[24] The longest pedestrian suspension bridge, which spans the River Paiva, Arouca Geopark, Portugal, opened in April 2021. The 516 metres bridge hangs 175 meters above the river.[25] Where such a bridge spans a gap between two buildings, there is no need to construct towers, as the buildings can anchor the cables. Cable suspension may also be augmented by the inherent stiffness of a structure that has much in common with a tubular bridge. The Little Belt suspension bridge in Denmark was opened in 1970. Manhattan Bridge in New York City with deck under construction from the towers outward. Suspender cables and suspender cable band on the Golden Gate Bridge in San Francisco. Main cable diameter is 36 inches (910 mm), and suspender cable diameter is 3.5 inches (89 mm). Lions' Gate Bridge with deck under construction from the span's center Typical suspension bridges are constructed using a sequence generally described as follows. Depending on length and size, construction may take anywhere between a year and a half (construction on the original Tacoma Narrows Bridge took only 19 months) up to as long as a decade (the Akashi-Kaikyō Bridge's construction began in May 1986 and was opened in May 1998 – a total of twelve years). Where the towers are founded on underwater piers, caissons are sunk and any soft bottom is excavated for a foundation. If the bedrock is too deep to be exposed by excavation or the sinking of a caisson, pilings are driven to the bedrock or into overlying hard soil, or a large concrete pad to distribute the weight over less resistant soil may be constructed, first preparing the surface with a bed of compacted gravel. (Such a pad footing can also accommodate the movements of an active fault, and this has been implemented on the foundations of the cable-stayed Rio-Antirio bridge.) The piers are then extended above water level, where they are capped with pedestal bases for the towers. Where the towers are founded on dry land, deep foundation excavation or pilings are used. From the tower foundation, towers of single or multiple columns are erected using high-strength reinforced concrete, stonework, or steel. Concrete is used most frequently in modern suspension bridge construction due to the high cost of steel. Large devices called saddles, which will carry the main suspension cables, are positioned atop the towers. Typically of cast steel, they can also be manufactured using riveted forms, and are equipped with rollers to allow the main cables to shift under construction and normal loads. Anchorages are constructed, usually in tandem with the towers, to resist the tension of the cables and form as the main anchor system for the entire structure. These are usually anchored in good quality rock but may consist of massive reinforced concrete deadweights within an excavation. The anchorage structure will have multiple protruding open eyebolts enclosed within a secure space. Temporary suspended walkways, called catwalks, are then erected using a set of guide wires hoisted into place via winches positioned atop the towers. These catwalks follow the curve set by bridge designers for the main cables, in a path mathematically described as a catenary arc. Typical catwalks are usually between eight and ten feet wide and are constructed using wire grate and wood slats. Gantries are placed upon the catwalks, which will support the main cable spinning reels. Then, cables attached to winches are installed, and in turn, the main cable spinning devices are installed. High strength wire (typically 4 or 6 gauge galvanized steel wire), is pulled in a loop by pulleys on the traveler, with one end affixed at an anchorage. When the traveler reaches the opposite anchorage the loop is placed over an open anchor eyebar. Along the catwalk, workers also pull the cable wires to their desired tension. This continues until a bundle, called a "cable strand" is completed, and temporarily bundled using stainless steel wire. This process is repeated until the final cable strand is completed. Workers then remove the individual wraps on the cable strands (during the spinning process, the shape of the main cable closely resembles a hexagon), and then the entire cable is then compressed by a traveling hydraulic press into a closely packed cylinder and tightly wrapped with additional wire to form the final circular cross-section. The wire used in suspension bridge construction is a galvanized steel wire that has been coated with corrosion inhibitors. At specific points along the main cable (each being the exact distance horizontally in relation to the next) devices called "cable bands" are installed to carry steel wire ropes called Suspender cables. Each suspender cable is engineered and cut to precise lengths, and are looped over the cable bands. In some bridges, where the towers are close to or on the shore, the suspender cables may be applied only to the central span. Early suspender cables were fitted with zinc jewels and a set of steel washers, which formed the support for the deck. Modern suspender cables carry a shackle-type fitting. Special lifting hoists attached to the suspenders or from the main cables are used to lift prefabricated sections of the bridge deck to the proper level, provided that the local conditions allow the sections to be carried below the bridge by barge or other means. Otherwise, a traveling cantilever derrick may be used to extend the deck one section at a time starting from the towers and working outward. If the addition of the deck structure extends from the towers the finished portions of the deck will pitch upward rather sharply, as there is no downward force in the center of the span. Upon completion of the deck, the added load will pull the main cables into an arc mathematically described as a parabola, while the arc of the deck will be as the designer intended – usually a gentle upward arc for added clearance if over a shipping channel, or flat in other cases such as a span over a canyon. Arched suspension spans also give the structure more rigidity and strength. With the completion of the primary structure various details such as lighting, handrails, finish painting and paving is installed or completed. Main article: List of longest suspension bridge spans Suspension bridges are typically ranked by the length of their main span. These are the ten bridges with the longest spans, followed by the length of the span and the year the bridge opened for traffic: Bridge Country Length Year Çanakkale 1915 Bridge Turkey 2023 m (6637 ft) 2022 Akashi Kaikyō Bridge Japan 1991 m (6532 ft) 1998 Yangsigang Bridge China 1700 m (5577 ft) 2019 Xihoumen Bridge China 1650 m (5413 ft) 2009 Great Belt Bridge Denmark 1624 m (5328 ft) 1998 Osman Gazi Bridge Turkey 1550 m (5085 ft) 2016 Lee Sun-shin Bridge South Korea 1545 m (5069 ft) 2012 Runyang Bridge China 1490 m (4888 ft) 2005 Fourth Nanjing Yangtze Bridge China 1418 m (4652 ft) 2012 Humber Bridge United Kingdom 1410 m (4626 ft) 1981 Yavuz Sultan Selim Bridge Turkey 1408 m (4619 ft) 2016 See also: History of longest vehicle suspension bridge spans The Mackinac Bridge in Michigan, opened in 1957 (Chronological) Union Bridge (England/Scotland, 1820), the longest span (137 m) from 1820 to 1826. The oldest suspension bridge in the world still carrying road traffic. Roebling's Delaware Aqueduct (USA, 1847), the oldest wire suspension bridge still in service in the United States. John A. Roebling Suspension Bridge (USA, 1866), then the longest wire suspension bridge in the world at 1,057 feet (322 m) main span. Brooklyn Bridge (USA, 1883), the first steel-wire suspension bridge. Bear Mountain Bridge (USA, 1924), the longest suspension span (497 m) from 1924 to 1926. The first suspension bridge to have a concrete deck. The construction methods pioneered in building it would make possible several much larger projects to follow. Benjamin Franklin Bridge (USA, 1926), replaced Bear Mountain Bridge as the longest span at 1,750 feet between the towers. Includes an active subway line and never-used trolley stations on the span.[26] San Francisco–Oakland Bay Bridge eastern span (USA, 2013). The eastern portion is a self-anchored suspension bridge, the longest of its type in the world. It replaced a cantilever bridge. Golden Gate Bridge (USA, 1937), the longest suspension bridge from 1937 to 1964. It was also the world's tallest bridge from 1937 to 1993, and remains the tallest bridge in the United States. Mackinac Bridge (USA, 1957), the longest suspension bridge between anchorages in the Western hemisphere. Si Du River Bridge (China, 2009), the highest bridge in the world, with its deck around 500 meters above the surface of the river. Rod El Farag Axis Bridge (Egypt, 2019), a modern Egyptian steel wire-cables based suspension bridge crossing the river Nile, which was completed in 2019 and holds the Guinness World Record for the widest suspension bridge in the world with a width of 67.3 meters, and with a span of 540 meters. This section does not cite any sources. Please help improve this section by adding citations to reliable sources. Unsourced material may be challenged and removed. (December 2023) (Learn how and when to remove this message) The Tacoma Narrows Bridge collapse on 7 November 1940 Broughton Suspension Bridge (England) was an iron chain bridge built in 1826. One of Europe's first suspension bridges, it collapsed in 1831 due to mechanical resonance induced by troops marching in step. As a result of the incident, the British Army issued an order that troops should "break step" when crossing a bridge. Silver Bridge (USA) was an eyebar chain highway bridge, built in 1928, that collapsed in late 1967, killing forty-six people. The bridge had a low-redundancy design that was difficult to inspect. The collapse inspired legislation to ensure that older bridges were regularly inspected and maintained. Following the collapse a bridge of similar design was immediately closed and eventually demolished. A second similarly-designed bridge had been built with a higher margin of safety and remained in service until 1991. The Tacoma Narrows Bridge, (USA), 1940, was vulnerable to structural vibration in sustained and moderately strong winds due to its plate-girder deck structure. Wind caused a phenomenon called aeroelastic fluttering that led to its collapse only months after completion. The collapse was captured on film. There were no human deaths in the collapse; several drivers escaped their cars on foot and reached the anchorages before the span dropped. Yarmouth suspension bridge (England) was built in 1829 and collapsed in 1845, killing 79 people. Peace River Suspension Bridge (Canada), which was completed in 1943, collapsed when the north anchor's soil support for the suspension bridge failed in October 1957. The entire bridge subsequently collapsed. Kutai Kartanegara Bridge (Indonesia) over the Mahakam River, located in Kutai Kartanegara Regency, East Kalimantan district on the Indonesia island of Borneo, was built in 1995, completed in 2001 and collapsed in 2011. Dozens of vehicles on the bridge fell into the Mahakam River. As a result of this incident, 24 people died and dozens of others were injured and were treated at the Aji Muhammad Parikesit Regional Hospital. Meanwhile, 12 people were reported missing, 31 people were seriously injured, and 8 people had minor injuries. Research findings indicate that the collapse was largely caused by the construction failure of the vertical hanging clamp. It was also found that poor maintenance, fatigue in the cable hanger construction materials, material quality, and bridge loads that exceed vehicle capacity, can also have an impact on bridge collapse. In 2013 the Kutai Kartanegara Bridge rebuilt the same location and completed in 2015 with a Through arch bridge design. On 30 October 2022, Jhulto Pul, a pedestrian suspension bridge over the Machchhu River in the city of Morbi, Gujarat, India collapsed, leading to the deaths of at least 141 people. Cable-stayed suspension bridge Floating cable-stayed bridge Floating suspension bridge List of longest suspension bridge spans Timeline of three longest spans—Whether bridge, aerial tramway, powerline, ceiling or dome etc. Steel bridge ^ "Why Turkey Built the World's Longest Suspension Bridge". The B1M. 11 May 2022. Retrieved 22 May 2022. ^ "Groundbreaking ceremony for bridge over Dardanelles to take place on March 18". Hürriyet Daily News. 17 March 2017. Retrieved 22 May 2022. ^ "Port Authority of New York and New Jersey - George Washington Bridge". The Port Authority of New York and New Jersey. Archived from the original on 20 September 2013. Retrieved 14 February 2023. ^ Bod Woodruff; Lana Zak & Stephanie Wash (20 November 2012). "GW Bridge Painters: Dangerous Job on Top of the World's Busiest Bridge". ABC News. Archived from the original on 28 September 2013. 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