Hochschule Wismar
University of Technology, Business and Design

Bachelor-Thesis

Design and construction of a bridge for noise-protection-walls

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By: Dafni Konstantinidi – Sofrona born on 07.09.1988
in Athens, Greece

Abstract

In the world of today bridges are part of everyday life; their use facilitates the daily routine of people. Since antiquity mankind began to construct bridges imitating nature and the natural passages created by fallen stones or tree trunks. The ancient Greeks were among the first manufacturers with techniques that were the catalyst for the future development of bridges, as also the Romans with their massive arched stone bridges and the aqueducts.

The types of bridges vary depending on the use, the area and the materials which will be used at the construction. The most common use of a bridge is to transport vehicles, pedestrians or trains but they can also carry water as an aqueduct. The materials used in a bridge changed over time and the evolution of technology. Initially the basic materials were stone and wood, but due to the increased requirements on strength, new materials appeared such as concrete, iron and steel. Nowadays, the usual materials used in a bridge are steel and concrete.

The most common type of bridge is the beam bridge, the lightest form of construction with one beam and only two supports. Romans were the first who build curved shaped bridges, the arch bridges. In the bridge construction the longest and lighter are the suspensions bridges, while cantilever bridges are designed to carry heavy loads and the cable-stayed bridges are suitable for the unreachable areas. Truss bridges because of the simplicity of their construction used as secondary parts on other types to increase their stability, as in arch bridges.

In a successful bridge construction all the loads and forces should be taken into consideration. The static analysis of the bridge is a really important part on the construction; engineers have to be certain for the safety and the stability of the structure in all possible ways. There are three main types of loads that have to be calculated. Dead loads, a bridge has to be able to support itself as it will be the same for its whole life. Live loads are all the moving weights of a bridge, all the vehicles, trains or trucks that will pass over its deck. And dynamic loads consists the earthquakes, the wind and the impact loads of a structure.

The correct static calculation of a bridge, with the necessary knowledge on construction can reduce the failures and bridges can be a "tool" for every human being's life.

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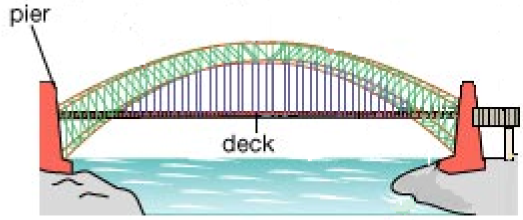
Introduction

Bridges

Bridge is an architectural or technique construction that achieves the couple of physical or technical obstacles such as road, dale or water, in order to provide the passage of people or vehicle over the intermediate barrier. The bridges vary depending on the morphology of the area where is constructed, the material used to make it, the function of the bridge and the available funds to build it.

The bridges are usually used to serve transportation purposes, but apart from these they also serve and other purposes, such as large pipelines that carry fuel to enormous distances or aqueducts to carry water over rivers or other physical obstacles.



The main components of each bridge are two: the piers and the deck,

Difficulties usually presented in the foundation because in many cases it must be done in sand bed of large rivers with rapids. A typical bridge has two supports which hold one beam, the supports function is to carry the vertical loads and they must be strong enough to hold the structure up. On the other the horizontal beam between supports must be strong enough to carry the loads.

Bridge design has three objectives to achieve the efficiency, the economy and the aesthetic of the structure, as far as possible for the safety of the bridge.
The efficiency aims to reduce the material while increase the performance. Then again economy tries to reduce the cost and the maintenance of the construction while retaining efficiency. Finally, aesthetic is the personal expression of the designer.
Bridges discern, depending on the material used for construction in wood, stone, reinforced concrete and iron.

1 History of Bridges

During the years the human species wrestle to reconcile with nature, to create culture and lift the isolation. Communication has been always the catalyst for formatting the societies and also has been the factor for integrating new elements into the culture of people. Human struggled to lift the isolation created by the natural barriers for the purpose of direct contact, the decrease of distances and to satisfy his basic needs. In this context was confronted with nature and create bridges.

From the early days of the world's history, bridges were made by nature. Fallen stones or tree trucks create the first physical passages.

Hymans began to construct bridges from cut wooden logs and planks and in time with stones. The early bridges were simple structures, comprised of a single support and a crossbeam, to pass over small rivers and ravines.

In 6th century BC bridges made of cypress and cedar wood, but during the years the have destroyed as wood is a material that needs constant maintenance, those that have survived are recent.

1.1 Ancient Greece

In antiquity, from the Mycenaean era there was mature enough expertise to build bridges to the various streets of the Greek area. The technology of ancient Greek bridges developed, based on mainly two systems to span the barriers: with horizontal tangents flat stones embedded in columns or rows of parallel bearers that are dividing the river into smaller streams and with a load displacing technique disposed in horizontal layers.

One of the first ancient bridges was found in ancient Greece is Arkadiko Bridge from the Mycenaean period; it was part of a military network of roads. Every bridge of that period has the same construction and belongs at the same network. Is an arch stone bridge and is located between Nauplion and Epidaurus, in Peloponnese. The Mycenaean bridge dated from 13th century BC, at Bronze Age and is still in existence and use. It has 4m high, 5.6m wide at the base and 2.4m at the top, 22m length and it was built from stones and limestones.

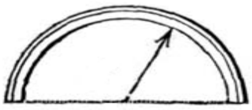
1.2 Ancient Rome

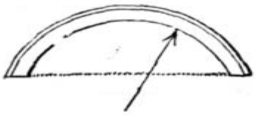
Ancient Romans were one of the greatest builders of antiquity. The main purpose of constructing bridges was to improve transportation, but there are also some examples of temporary military bridges. They were the first who built large bridges; most of them are more than 5m wide. A lot of bridges can be found in major rivers around their empire. Two of the greatest rivers, were Danube and Rhine, two of the largest European rivers. Rhine crossed by Roman bridge at Koblenz, Roman Bridge at Cologne, Roman bridge at Mainz and Caesar’s Rhine bridges, in the lower and middle part of the river. Danube crossed by Constantine’s bridge and Trajan’s bridge. The bridges had different layer of stonework, in one layer the stones were placed horizontally and outwards at the next. There were also indents in the stones for helping the engineers to hold onto with their tools.

Romans developed many techniques for bridge construction, as the cofferdam, which used to construct piers in rivers with a soft bed. Is a temporary watertight enclosure which was made from wooden piles and it was sealed with clay or steel. It pumps the body of water in order to expose the river’s bed. We can still find cofferdam foundations in Sant’Angelo Bridge, in Tiber River.

Pont du Gard aqueduct, Gard River, France, 19BC

Arch was used as the basic structure. Early arch bridges often describe a full circle with the half arch continuing under the water. But the most typical roman bridges were constructed with semi-circular arches or segmental arches.





A segmental arch bridge allows great amounts of water to pass from the span than a semi-circular arch bridge, as a segmental arch is less than a semi-circle. That makes the bridge more lightweight and it’s harder to drift away from rapids. Limyra Bridge in Turkey is a typical example of segmental bridge with 26 arches.

Ancient Romans had a variety of materials, stone was the most common. They also used brick, as is lighter and easier to transport and wood. Wood was soon replaced as was lees resistant. They also used marble to clad their most important bridges.

Romans were the first who worked with a type of cement that called Pozzolana. Pozzolana is a mixture of water, sand, volcanic ash and lime and discovered in Pozzuoli, in Italy. From reports we know that there were four types of this cement, white, black, red and grey. Is a material of aluminium oxide (Al_2O_3) and silicon oxide (**SiO_2**) and reacts with silicic acid ($Si(OH)_4$) and Portlandite (calcium hydroxide - $Ca(OH)_2$)

$$Ca(OH)_2 + H_4SiO_4 \rightarrow Ca^{2+} + H_2SiO_4^{2-} + 2\ H_2O \rightarrow CaH_2SiO_4 \cdot 2\ H_2O$$

Ponte Fabricio

Ponte Fabricio is one of the oldest still in use bridges in Italy. The original bridge built in 192BC and it was wooden. But in a great fire the bridge totally destroyed. It reconstructed in 62BC from Lusius Fabricius with concrete, iron, timber, cast iron and steel. Ponte Fabricio located over river Tiber and it is 62m long and 5.5m wide.

Alcantara Bridge

Alcantara Bridge built between 104 and 106AD over Tagus River, in Spain. Is a Roman bridge, with 6 arches, three of them are in the water surface and the other three in the ground. Alcantara Bridge is 194m, 8m wide, 60m high, the central arch is 70m high. The bridge is still in use, but only light motors are allowed to drive over it.

1.3 Ancient China

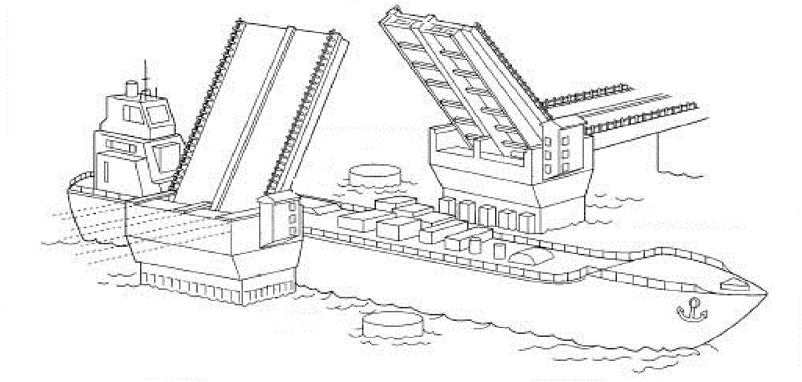
In ancient China, bridges were constructed from wood, bamboo and stones. Unfortunately, no wooden bridges have been saved from that period due to the decay of the material. But, one of the oldest arch stone bridges is in Hebei province over Jiao River. It called Zhaozhou or Anji Bridge and constructed by Li Chun. It took about 10 years to finish the construction, from 595 to 605AD. The unique design of the bridge, with one big stone-swallow arc and 4 smaller at the end in both sides, decrease the pressure of the water. Zhaozhou Bridge is 7.3m high, 9m wide and 50m long.

1.4 Inca

Some types of suspension rope bridges constructed by Inca civilization in South America, to span gorges and canyons in the mountains of Andes. The bridges were constructed from fibers as ropes and wood as floor and they were anchored with stones at each end. These bridges were strong enough to carry the weight of humans or even horses.

2 Types of bridges

2.1 Movable bridge



The purpose of a movable bridge is to create a passage for the transport and pedestrians while allowing the movement of ships on navigable rivers or other parts of water. Are usually constructed in places where the ground is not far above the water surface. In this case the height of the bridge is small and too large vessels can not pass beneath the bridge.

The first references in history of movable bridges were found in Leonardo da Vinci's drawings, in the end of 15th century. He has designed models of bascule, retractable and swing bridges. Movable bridges have also found in Egypt and Middle East. But, the most known were built in medieval castles. The castles were usually surrounded by a moat, crossed by a wooden bridge. The form of the bridge was simple, consisted of a wooden deck with one edge joined at gate's entrance and ropes or chains at sides, for raise or low it. This bridge was used as barrier to the entrance of the castle and it was designed to be destroyed in a possible attack. The handling was manually by workers who were in the gate. Nowadays, the construction of movable bridges has significantly decrease as the used materials are lighter and allows bridges to be higher, thereby large ships can easily pass under them. The most common used materials are concrete and steel.

The lift mechanism in movable bridges is usually powered by electric energy or hydropower and the biggest weakness of that kind is that the traffic on the deck must be temporary halted when the bridge is used for boat passage. Furthermore, they are expensive in their function and maintenance. For safety reasons and to avoid accidents there are traffic lights for road and water traffic.

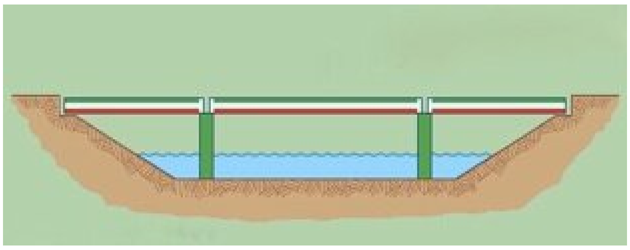
Around the world there is a variety of moving bridges, depends on the needs of each area, such as Drawbridge, Bascule bridge, Vertical-lift bridge, Retractable bridge, Swing bridge and Transported bridge. The most common movable bridge is Bascule bridge which consists of two decks hinged on pins, the balance in that bridge provided with a counterweight. When the movable parts are united in the middle of the river, road traffic is permitted.

A typical example of double-leaf bascule movable bridge is Tower Bridge (1894) in London, is located over Thames River and connects Tower Hamlets and Southwark boroughs. It has two twin towers and its 76m long and 61m high.

Millennium Bridge

A modern form of movable bridges is the Millennium Bridge or “Blinking Eye Bridge” in England. Is a pedestrian title bridge which rotated around firmly ends and allows boat traffic. Millennium Bridge is located in River Tyne and it was designed by the architecture firm, Wilkinson Eyre and Gifford Company.

2.2 Beam bridge



A beam or girder bridge has the simplest construction of all the bridges, is the most common type. A simply supported beam bridge consists of one beam and only two supports at each end. Due to bending, vertical loads carried by the beam and due to compression, the loads carried at the supports and then vertically to the foundations. The top of the beam undergoes horizontal compression while the bottom subjected to horizontal tension.

Beam bridges often used as motorways and they are usually constructed of concrete, steel or both of these materials. This bridge could also be continuous with more than two beams fully supported at the joints. The most important in this kind of bridges, is the foundation. Engineers should take into account the type of the ground before they decide which footings are appropriate for the abutments and piers. In cases with weak soil, steel or wooden piles could also support the footings. After the casting of footing, the structure begins. The beams can be I-beams, steel truss, box-girders or steel plates. For short spans commonly used prefabricated beams on site.

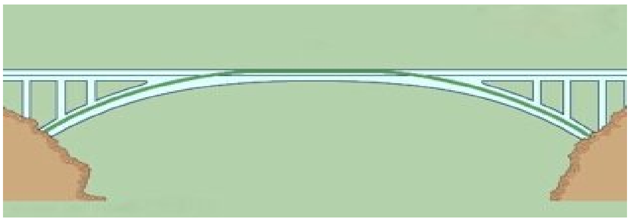
Presidente Costa e Silva

Presidente Costa e Silva Bridge is an example of box-girder bridge. It was built in 1974 and connects Rio de Janeiro and Niteroi cities, in Brazil. It is 13,290m long and the highest central spam is 72m high.

Neckar Viaduct

Neckar Viaduct is located in Germany, over Neckar River. It consists of five spans which are 234m, 134m, 134m, 134m, 264m each and has a total length of 900m. The bridge is 31,5m wide and 125m high and it was constructed in 1978.

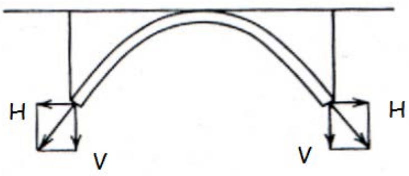
2.3 Arch bridge



Roman engineers were the first who built structures using an arch. It called arch bridge because of the curved shape of the structure. An arch bridge consists of abutments, connected by a curve at each end of the bridge and a deck. The deck connected with the arch with cables and can be designed on the top, underneath or even between the arch, depends on the aesthetic of the designer.

In an arch bridge, after the built of abutments, a temporary structure has to be constructed, called falsework. It's made of timber or metal and holds the component in place. When the structure can successfully support itself, the falsework removed. Abutments are significant parts in this bridge as they hold the ends of an arch stable.

An arch bridge carries horizontal and vertical forces on the foundation, because of compression.



From the Roman Empire, the most common material used in arced bridges was stone. Nowadays, arches may also be constructed of concrete or steel. In arch bridges with long spans, series of arches can be used instead of only one.

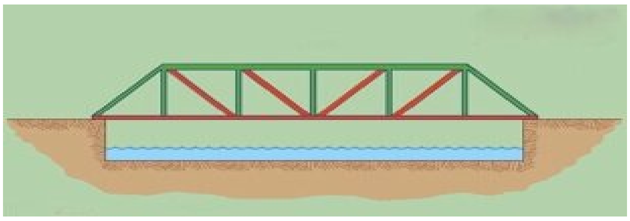
High bridge

The High Bridge or Aqueduct Bridge is located in New York City and connects The Bronx and Manhattan. It was part of the first water supply system in New York and has 440m long, 190m wide and 42m high. The High Bridge was completed in 1848 and it’s still in use from the pedestrians and bicycle traffic.

Sydney Harbour Bridge

The Sydney harbour bridge connects Sydney central business district and North Shore over Sydney harbour. The bridge is constructed from steel and concrete by Dorman Long and Co Ltd, in 1932. It consists of two pylons and an arch in the middle, the span of the arch is 503m long and 134m high. The total length of the bridge is 1,149m.

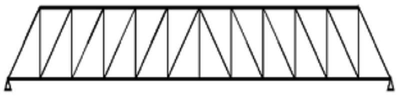
2.4 Truss bridge



The unique structure of trusses is makes them the most reachable option for bridge constructions. Their design is simple, it constitutes several triangles which support the beams and increase the rigidity. Straight elements are connecting to each other with pin joins, nodes. Due to bending, truss bridges carry vertical loads and that leads to tension in the bottom horizontal members, compression in the top horizontal members and depending on the orientation of vertical and diagonal members, tension or compression. The design of the bridge insures that none of the members is overwhelmed, because all the forces are distributed equally in each of them. The vertical members of a truss bridge called piles or pilings, there are long columns drilled into the ground. They are constructed from wood or steel, depends on the existing conditions and they offer support at vertical loads. Wood was the first material which used in truss bridges, it was cheap and it’s able to withstand the pressure. The earliest bridges were a combination of timber members and iron or steel rods. The iron rods took the tension and the timber members the compression.

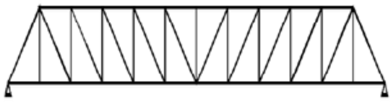
Nowadays, trusses are used mostly as secondary parts in arch, suspension or cantilever designs. They can also used as covered bridges for the protection of the bridge. There are a lot of different types of truss according to the needs of the structure.

Howe Truss



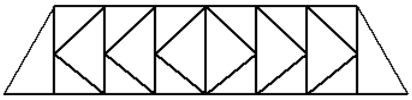
Howe truss consist of vertical and diagonal members. On this type diagonal members are under compression and incline towards the center. The vertical members take the tension. It was first constructed by Massachusetts millwright William Howe in 1840.

Pratt Truss



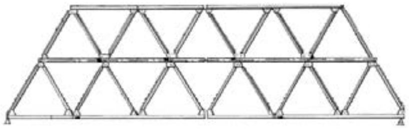
Pratt truss has the opposite form from Howe truss. On this type the diagonal members incline opposite to the center of the bridge. The inventors of Pratt truss were Thomas and Caleb Pratt in 1844.

K-Truss



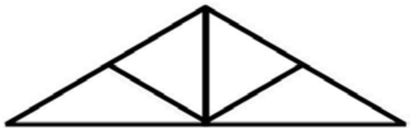
K-Truss took his name from the orientation of his vertical and diagonal members which create a “K” form. It’s one of the most difficult truss types.

Bailey bridge



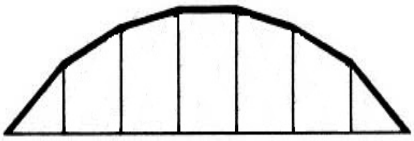
Bailey bridge is a military bridge and is really easy in construction. This bridge can cover 60m spans and bears the weight of tanks and other heavy military equipment.

King Post Truss or Crown Post



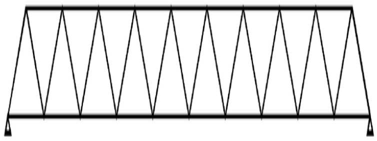
Crown Post is one of the simplest truss structures. The bridge is made up of two angled supports which are connected with a vertical member.

Bowstring Arch Truss or Tied Arch Bridge



The main part of the Bowstring arch truss is the arc and in 1840, Mr. Squire Whipple was the first who designed this type of bridge. Along the arc conveyed all the vertical loads which the construction takes by the thrust arches.

Warren Truss



The Warren truss is made up of horizontal members welded by diagonal members placed alternately and forming triangles all along the length of the structure. In the structure undergo forces of compression and tension which alternate at the diagonal members.

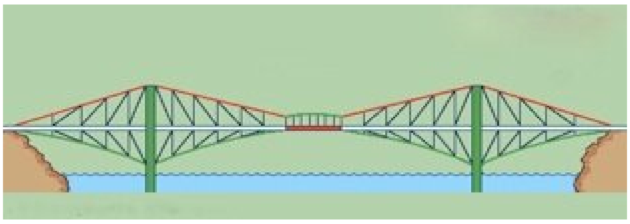
Smithfield Street Bridge

Smithfield Street Bridge connects Smithfield Street with Station Square in Pittsburgh, Pennsylvania, USA. Is one of the oldest truss bridges in the USA, with two spans of 110m each and total length, 361m. It has two pedestrian walkways and four roadway lanes. Smithfield Street Bridge constructed by Gustav Lindenthal, in 1883.

Astoria Bridge

The main span of the bridge is 376m long and the total length is 6,545m. It was constructed by the Delong Corporation and Pomeroy Gerwick, in 1966. The bridge has 2 traffic lanes and no pedestrian walkways and connects Astoria, Oregon and Point Ellice, Washington, over Columbia River, in the USA.

2.5 Cantilever bridge



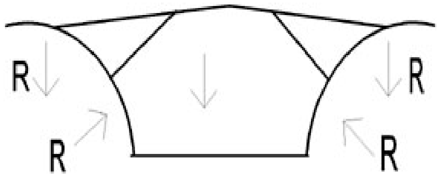
Cantilever models are the most common phenomenon in our daily lives, with featured example the trees. Nature itself is the first constructor of cantilever models. The trees have their trunk as the arm of a cantilever model and their roots as the support.

In this way cantilever bridges are constructed, with an arm stiffly supported at one end and free to move at the other end. Their construction is reliant on counterbalance, the weights offsets with another weight, as a diving board. A typical cantilever bridge consists of three parts; two cantilevers extend from each end and a beam bridge in the middle. They are suitable for unreachable areas, where is hard to build a bridge pier in the middle of a ravine or river, as they can easily span long distances of over 460m and they need some or no falsework. Due to their construction, cantilever bridges are designed to carry heavy loads, such as a heavy rail system or motorways with trucks. The materials usually used in these bridges are prestressed concrete, steel and iron.

The construction of cantilever bridges starts with the foundation that operates as counterweight for each arm. Then, each cantilever arm is extended towards outside until they finally meet in the middle of the crossing. The two arms are connected with a beam or in some occasions with a truss bridge.

Another type to construct cantilever bridges is with the balance cantilever. Is used when the structure needs more piers for support, this way each arm connected to a pier in contrary direct to balance the other.

The first who ever built a cantilever bridge was the engineer Heinrich Gerber in 1867, the Hassfurt Bridge in Germany. Is located over Main River and the central span of the bridge is 38m long. Gerber was the inventor of the hinge, in 1866. With the hinge, long and continuous spans were able to be statically determinate and to be constructed. The tension in this kind of bridge divided out from the arms to the outer supports as the foundation carries the compression.



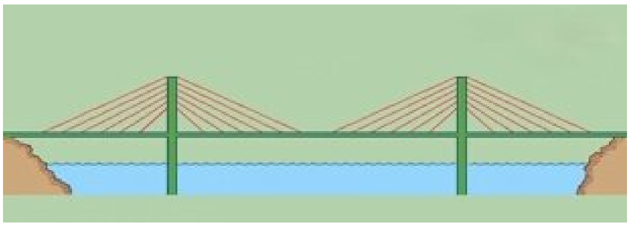
Forth Railway Bridge

Forth Railway Bridge is the most famous cantilever bridge and the second longest in the world. Is located in Scotland, over Firth-of-Forth waterway, between Edinburgh and Fife and it was constructed at the end of 19th century, in 1890. It was designed by John Fowler and Benjamin Baker. The bridge is 2.46km long and has two girder spans of 521.3m each. The Forth Railway Bridge consists of three double-cantilevers which are connected by girder spans, of 105m each.

Pont de Québec

The longest cantilever truss bridge in the world is located in Saint Lawrence River in Canada. It connects Quebec City and Levis City with a total length of 987m. It is 29m wide, 104m high and carries 3 roadway lines, a rail line and a pedestrian walkway. The Pont de Québec Bridge consists of four arms; each of them is 177m long and a structure of 195m, in the middle. Its construction took almost two decades and it was finished in 1917.

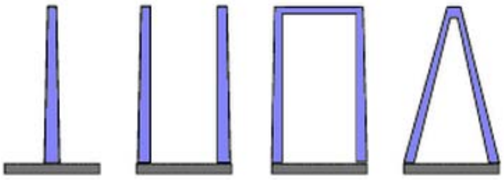
2.6 Cable-stayed bridge



A cable-stayed bridge consists of a continuous beam and one or more towers while cables connect diagonally the beam with the tower and keep the equilibrium of the bridge.

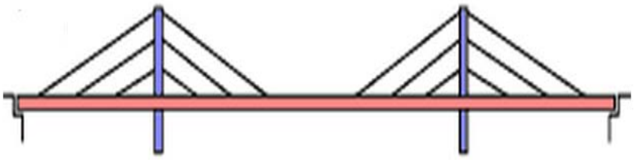
The construction of a cable-stayed bridge is approximately the same as the construction of a cantilever bridge. The first act in the construction of the bridge is the erection of the tower, when the tower is build; temporary cables are installed to keep the balance of the structure. Then, the extension of the central span is ready to start. In each side of the tower, a cable and a deck are concurrently constructed. The process repeats until the two opposite decks meet in the middle. Finally, the bridge is ready and the temporary cables removed.

During the years a variety of cable-stayed bridges have been constructed, with different shapes and sizes. We can separate them from the type of the tower or from the number of tension cables.

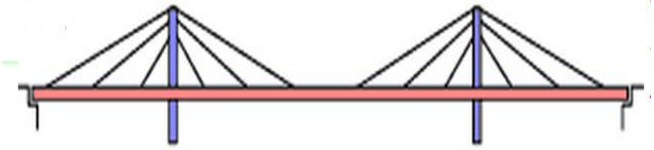


Some typical towers are the single, double, portal and the A-shaped.

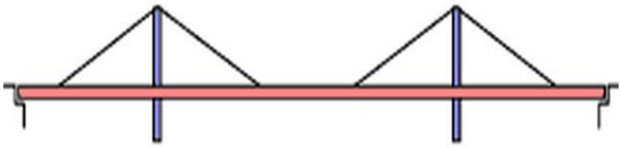
Furthermore, there are also four different categories of tension cables in cable-stayed bridges the harp, fan, mono and star.



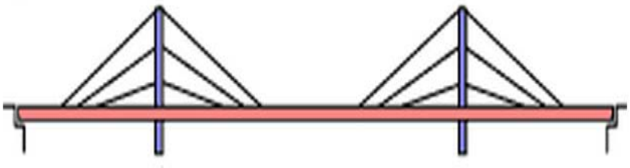
In harp type, the cables are parallel to each other and connected with the tower in different highs.



The fan type connects all the cables to a point on the top of the tower and with different points in the beam.



Mono cable-stayed bridge has only one cable which connects the top of the tower with a point in the deck.



In star type of bridge, cables are not parallel to each other, there are just connected in different highs of the bridge.

The cables are connected with the tower and the beam and create a triangle which has the ability to transfer the tension all across the cable to the towers and then with vertical compression to the foundations. That’s why cable-stayed bridges are suitable for carrying traffic loads, but they are weak to the wind forces. The cables as they are flexible can’t bear under strong forces of bending and compression, therefore careful measures have to be taken in order to be sure that the bridge will be stable under heavy winds.

We first meet cable-stayed bridges back to the 1600’s, in the books of a Venetian engineer Faustus Verantius but the first fully constructed bridge is dated in 1784 by a German carpenter C. T. Loescher. The bridge had a span of 32m.

Nowadays, the cable-stayed type of bridge is really common, as can be lighter than other constructions and more economical.

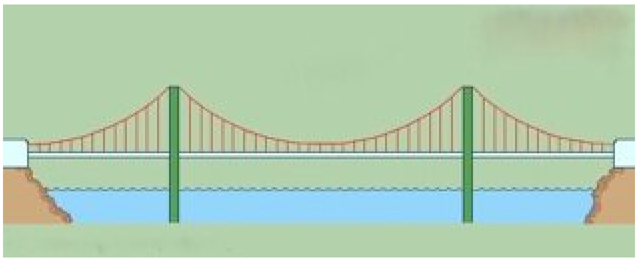
Sutong Bridge

Sutong Bridge is the world’s longest cable-stayed bridge, with a span of 1,088m. It was completed in 2007 and located over Yangtze River in China between the cities of Nantong and Changshu. The bridge is 8,206m long and the two towers are 306m high.

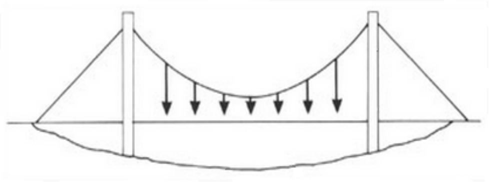
Rio-Antirion Bridge or Charilaos Trikoupis Bridge

Rio-Antirion is the longest multi-span cable-stayed bridge in the world. Is located over the Gulf of Corinth and connects Peloponnese with the mainland of Greece. The bridge is 2,880m long and 28m wide and carries four vehicle lines, one pedestrian walkway and one emergency line. Rio-Antirio Bridge consists of four pylons; the two pylons in the middle have 164m high and the other two 141m high. The construction of the bridge started in July, 1988 and it was completed on August, 2004. Special measures have taken due to the seismic activity and the morphology of the area.

2.7 Suspension bridge



Suspension bridges are the longest bridges in the world; their construction is simple, consisting of clean lines. Two large cables on each side of the deck and two towers are the main parts of a suspension bridge. The manufacture begins with the towers; they have to sink deep into the bedrock of the waterway, in order to be stable. Then, cables are strung across the towers and anchored to points on land. In some recent types of suspension bridges, the cables can also be anchored to the deck. A great advantage of this kind of bridges is that they can be constructed far above the water surface and ships can easily pass underneath.



The weight on this bridge is evenly distributed all along the structure and transferred by the cables to the towers and finally in the foundation. Tension forces absorbed from the suspended cables, while towers take the compression.

The lightness of the structure provides great flexibility to withstand earthquakes and possible movements of the bedrock. But, at same time can be susceptible to wind loads. Due to the length and the lightness of the bridge, wind cause vibrations and maybe a future collapse, as the Tacoma Narrows Bridge which collapses a few months after opening.

Early types of suspension bridge can found in mountains, where hanging bridges constructed of wood and suspension ropes, span gulches and ravines. The first references of suspension bridges come from Fausto Veranzio and his book “Machinae Novae”. But, the construction of suspension bridges as we know it today began in early 1800. Till then bridges were made of iron chains, the first how dared to use steel instead of iron, was John Augustus Roebling, in the construction of Brooklyn Bridge, in 1883.

Golden Gate Bridge

The golden gate bridge is located in San Francisco Bay in California and it was constructed by Joseph Baermann Strauss and Irving Foster Morrow, in 1937. It is 2.7km long, 27.4m wide and 227.4m high. During the construction designers had to deal with heavy winds, fog, tide and they also had to take into consideration the high seismic activity of the area.

Akashi Kaikyo Bridge or Pearle Bridge

Is the longest suspension bridge in the world with a span of 1,991 m and total length 3,911 m. Akashi Kaikyo Bridge is located in Japan, between the city of Kobe and Awaji Island. It has two towers of 282.8 m each and carries six roadways. The bridge opened on April, 1998.

3 Materials

Bridges can be built from different kind of materials or even with a combination of materials. Engineers have to take care in specifying the exact material needed for a structure that depends on the pressure that a bridge has to withstand. The most common materials used in the construction of a bridge are wood, stones, concrete, iron and steel.

3.1 Wood

Wood was the first material used by humans to construct bridges. The great elasticity of wood makes it appropriate to withstand deformation forces. Due to its strength, wood can last under forces of tension, compression and bending. On the downside, wood decays over time and needs constantly maintenance and protection. But the main disadvantage is that wood can be burned in fire. There are examples where bridges were completely destroyed during fire, as the wooden bridge across Monongahela River, in Pittsburgh which destroyed in a great fire, in 1845.

3.2 Stone

Stone is a material that can easily found in the most of areas. Nature has a variety of different kinds and sizes of stones which can be used without any special treatment. But when needed to change it shape, the handling of stone becomes difficult. Stone is usually used in the construction of piers as it can’t bear tension forces. However, the greatest advantage of stone, is durability, it can maintain its primal shape and features, over the pass of the years and under different climate conditions. Stones were widely used in antiquity for the construction of bridges from the ancient Greeks and Romans.

3.3 Concrete

Concrete is a quite flexible material, it can be mixed in different ways and also can stand the fluctuation of temperature and weather. Its durability and low maintenance makes it one of the most common materials in the world. Even thought concrete was already known since antiquity, by Romans (pozzalana), its use was restricted. Extensive use of concrete began in 1860s after the invention of reinforced concrete, which is a concrete with metal bars inside. One of the first reinforced bridges is

Chatellerault, France, in 1899. Nowadays, bridges are built with prestressed concrete which creates tension in the concrete using high strength steel.

3.4 Iron

Iron is a stronger material and in most causes cheaper than wood or stone. In late 1700 in England a series of iron bridges were constructed, the first one was Ironbridge, by Thomas Pritchard over Severn River in 1779. The resistance of iron in the weather conditions, as is not corrosion and due to its weight, it can withstand floods, makes it an ideal material for the engineers. It has great compressive strength than tensile and it can be used in many forms, as a column, an arch or even a whole structure can be constructed only from iron.

3.5 Steel

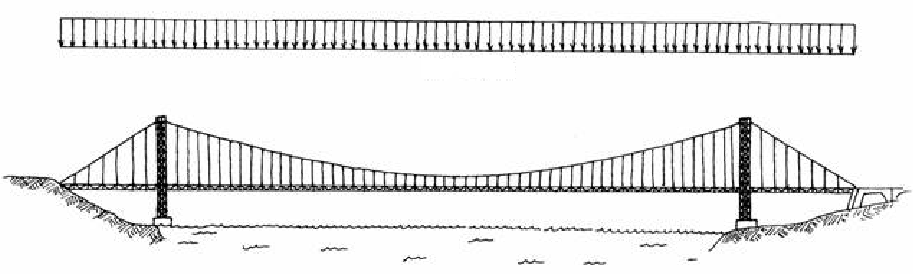
The evolution of technology, demands of increasing durability in bridges. With the use of steel, there was a revolution in bridge construction as it can carry heavy loads without increasing the weight of the structure. Eads Bridge is the first entirely steel bridge it was constructed by James Buchanan Eads in 1874, in the USA. Steel has large use in the manufacture of truss and suspension bridges because of its durability and strength. Due to the flexibility of steel, it can found in a variety of different shaped elements, as I-beams or plates.

4 Loads

For the design of a bridge factors as self-weight, wind, temperate or earthquakes must be taken into consideration. Bridges have to be able to hold the weight of heavy trucks, cars and people crossing it every day, but especially their own weight. Wind is also a major factor which has to be determined, high winds are able to destroy a bridge. The materials used in a bridge have to have the appropriate strength to last under high or low temperatures. Also, considering the area where the bridge is constructed, seismic activity has to be considered.

There are three main types of forces which act on any bridge, the dead load, the live load and the dynamic load. Any of these forces acts differently in the bridge and engineers have to take special measures to ensure the stability and the safety of the structure.

4.1 Dead loads

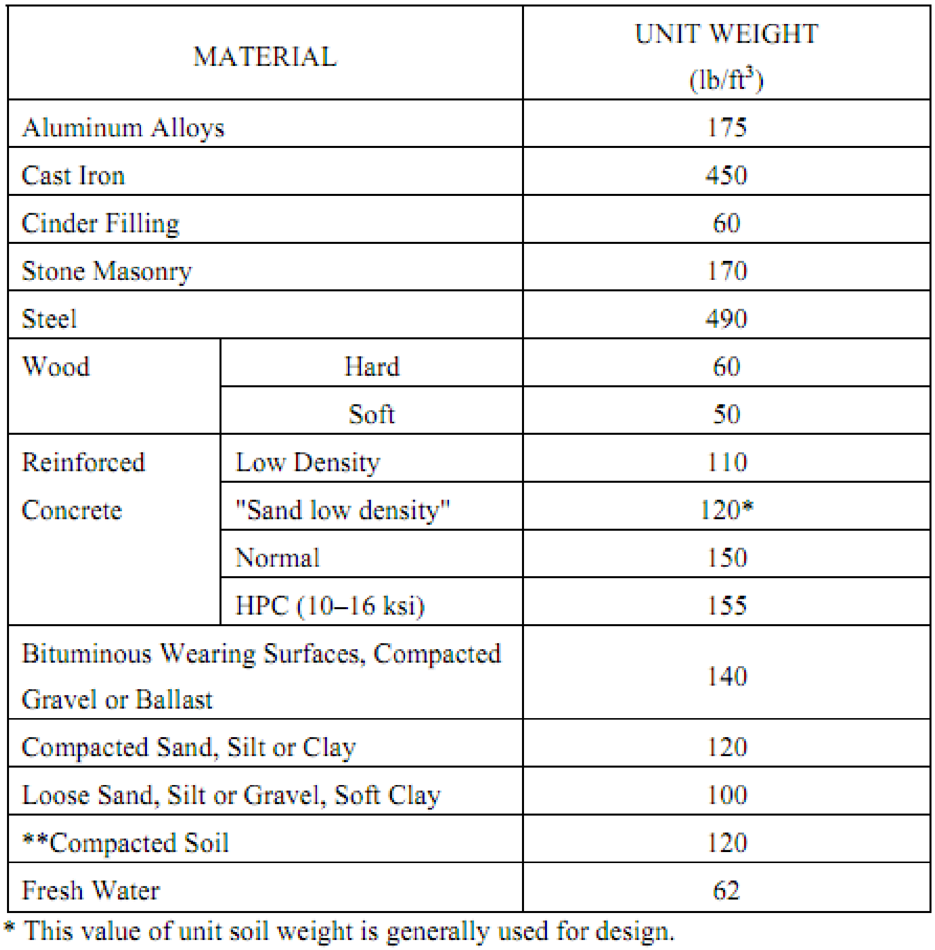


Dead loads (G) or permanent loads are the set of the self-weight and the permanent loads that the structure has. The self-weight consists of the forces that derived from the weight of all components of a bridge, such as the deck, the piers, the foundation, the cables, the connections, the towers and also the bolts. At same time, permanent structures connected in the bridge are considered as dead loads, such as signs, traffic lights or tollbooths. The self-weight remains the same over the life of the structure; it can’t be change or move. In sort structures dead load is not a major issue, but as the bridge getting longer and at the same time heavier, dead loads increased as well and the correct computation is really important. The calculation of the dead loads is significant, as the engineers have to be sure that the bridge can support itself. Otherwise, problems will occur in the future and there is also the possibility of a collapse. We have such examples in the past, where the calculation of dead loads was incorrect and failures appear during the construction, resulting in the injury or the death of workers. As at Pont de Québec Bridge; 11 workers were injured and 75 were killed when a part of the central section collapsed into water. The dead loads are vertical forces and it have to be calculated after the design of the bridge is completed. Engineers have to estimate the final dead loads used standardized information about known materials. In long structures, dead load is a major factor that has to consider. When modifications occur in design or weight changes, dead loads should be reassessed.

Engineers have to find the appropriate combination of lighter structures with less materials but also strength enough. To determine an accurate dead load of the structure, they have to calculate the volume of each member and multiply it by the weight of the material from which it is comprised. Finally, the different components added together to specify the dead load for the entire structure.

Dead load = volume of member x weight of material

Weights of various materials.

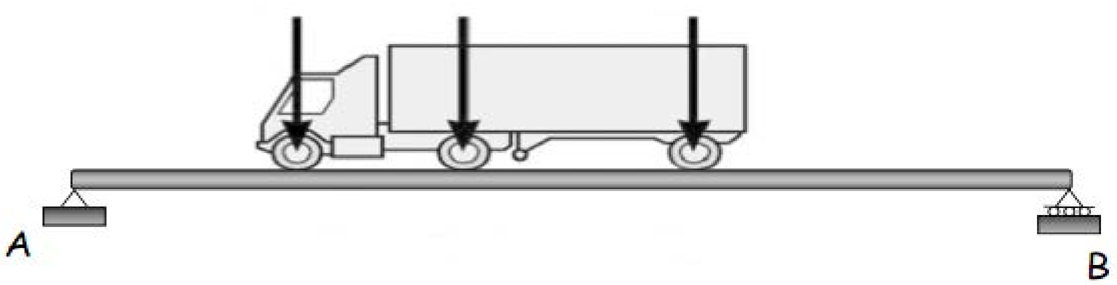


MATERIAL		UNIT WEIGHT (lb/ft^3)
Aluminum Alloys		175
Cast Iron		450
Cinder Filling		60
Stone Masonry		170
Steel		490
Wood	Hard	60
	Soft	50
Reinforced Concrete	Low Density	110
	"Sand low density"	120*
	Normal	150
	HPC (10–16 ksi)	155
Bituminous Wearing Surfaces, Compacted Gravel or Ballast		140
Compacted Sand, Silt or Clay		120
Loose Sand, Silt or Gravel, Soft Clay		100
**Compacted Soil		120
Fresh Water		62

* This value of unit soil weight is generally used for design.

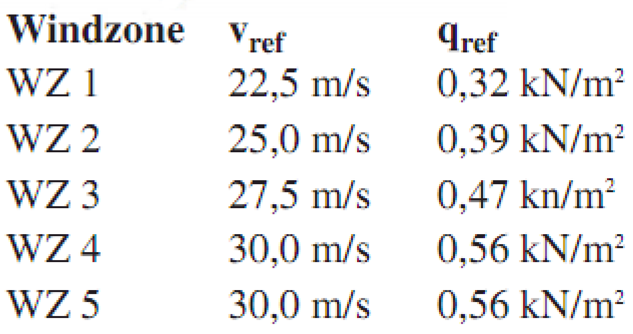
4.2 Live loads

Live loads (Q) consist of all the moving weights of a structure and vary with space and time during the life of the structure. The live loads of a bridge consists of what pass over the deck, such as vehicles, motors, pedestrians, bikes and most important trucks and train. The live loads in a bridge are vertical. As trucks are the heavier vehicles, the calculation of live loads depends on their dimensions and weight.



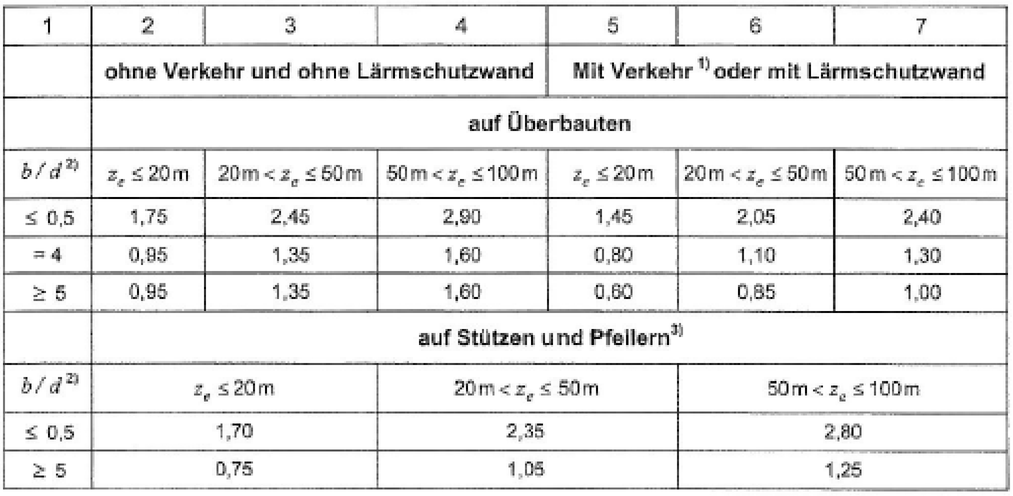
4.3 Wind loads

Wind loads are created form the deflection of the wind in a structure. In addition with dead or live loads which are vertical forces, wind can be either horizontal or vertical. Vertical wind loads can deal with the weight of the bridge itself, but horizontal forces applied as a uniformly distributed load to the entire structure. To prevent and minimize wind forces, soundwalls or braces are built on the bridges. According to DIN - Fachbericht 101:2009-03 “Windeinwirkungen auf Brücken” wind loads can be calculated from the following tables.

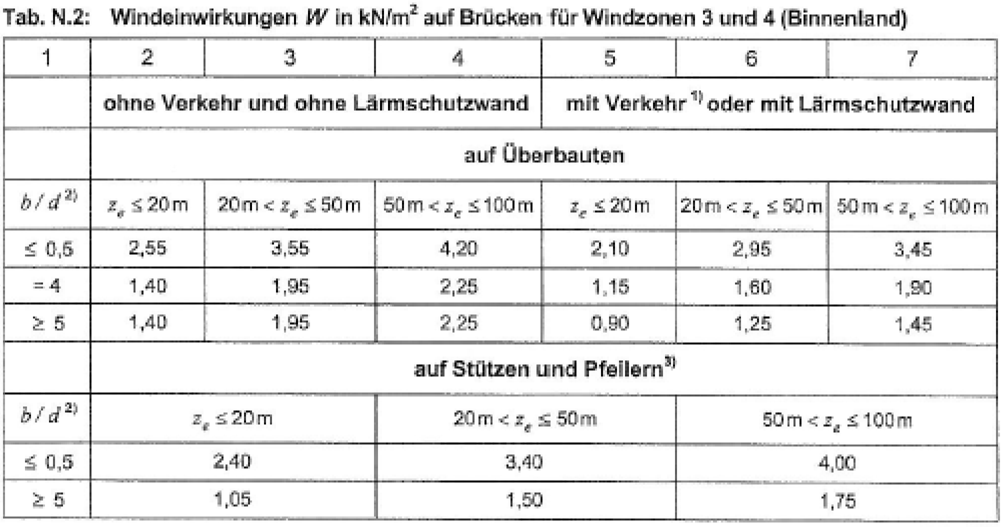


Windzone	v_{ref}	q_{ref}
WZ 1	22,5 m/s	0,32 kN/m^2
WZ 2	25,0 m/s	0,39 kN/m^2
WZ 3	27,5 m/s	0,47 kn/m^2
WZ 4	30,0 m/s	0,56 kN/m^2
WZ 5	30,0 m/s	0,56 kN/m^2

Tab. N.1: Windeinwirkungen W in kN/m² auf Brücken für Windzonen 1 und 2 (Binnenland)

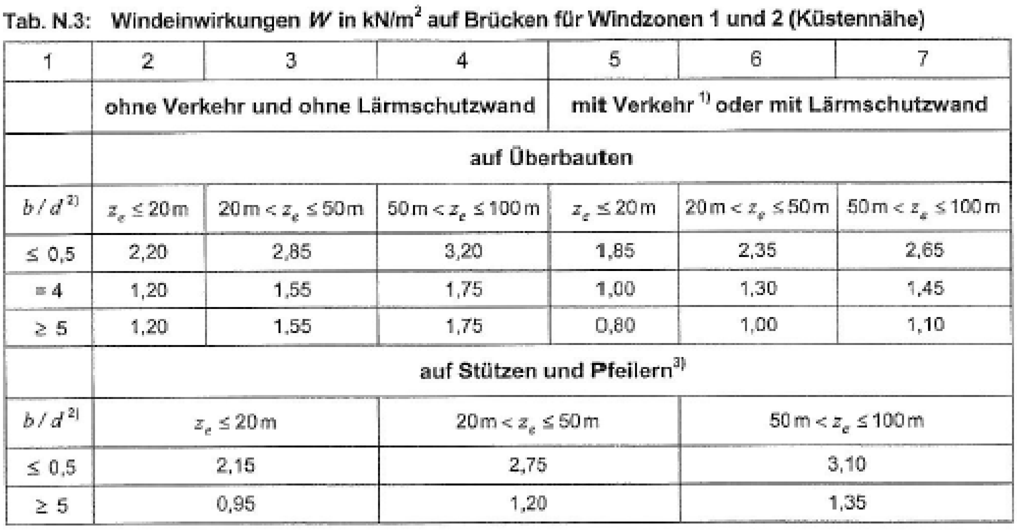


1	2	3	4	5	6	7
	ohne Verkehr und ohne Lärmschutzwand			Mit Verkehr [1)] oder mit Lärmschutzwand		
	auf Überbauten					
b/d [2)]	$z_e \leq 20\,m$	$20\,m < z_e \leq 50\,m$	$50\,m < z_e \leq 100\,m$	$z_e \leq 20\,m$	$20\,m < z_e \leq 50\,m$	$50\,m < z_e \leq 100\,m$
≤ 0,5	1,75	2,45	2,90	1,45	2,05	2,40
= 4	0,95	1,35	1,60	0,80	1,10	1,30
≥ 5	0,95	1,35	1,60	0,60	0,85	1,00
	auf Stützen und Pfeilern [3)]					
b/d [2)]	$z_e \leq 20\,m$		$20\,m < z_e \leq 50\,m$		$50\,m < z_e \leq 100\,m$	
≤ 0,5	1,70		2,35		2,80	
≥ 5	0,75		1,05		1,25	



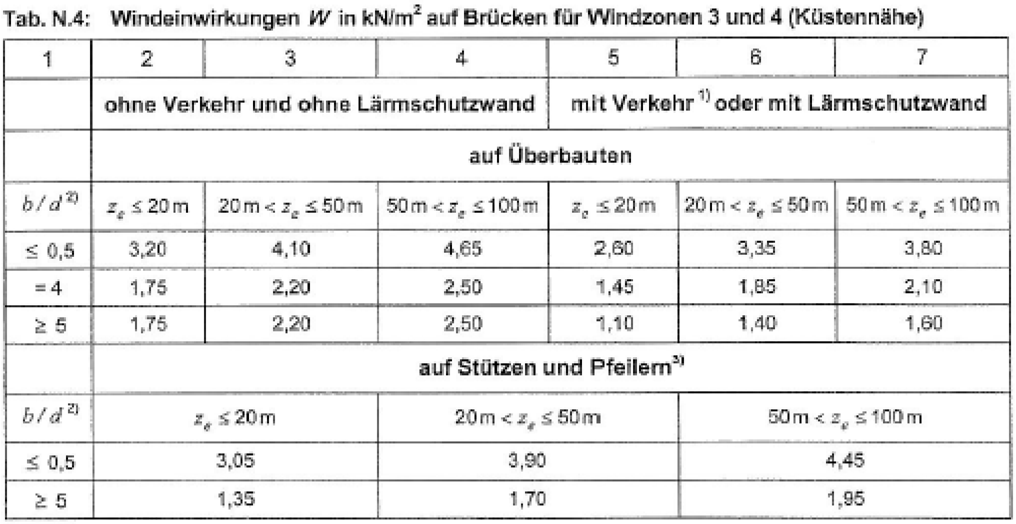
Tab. N.2: Windeinwirkungen W in kN/m^2 auf Brücken für Windzonen 3 und 4 (Binnenland)

1	2	3	4	5	6	7
	ohne Verkehr und ohne Lärmschutzwand			mit Verkehr 1) oder mit Lärmschutzwand		
	auf Überbauten					
b/d 2)	$z_e \le 20$ m	20 m $< z_e \le 50$ m	50 m $< z_e \le 100$ m	$z_e \le 20$ m	20 m $< z_e \le 50$ m	50 m $< z_e \le 100$ m
≤ 0,5	2,55	3,55	4,20	2,10	2,95	3,45
= 4	1,40	1,95	2,25	1,15	1,60	1,90
≥ 5	1,40	1,95	2,25	0,90	1,25	1,45
	auf Stützen und Pfeilern 3)					
b/d 2)	$z_e \le 20$ m		20 m $< z_e \le 50$ m		50 m $< z_e \le 100$ m	
≤ 0,5	2,40		3,40		4,00	
≥ 5	1,05		1,50		1,75	



Tab. N.3: Windeinwirkungen W in kN/m^2 auf Brücken für Windzonen 1 und 2 (Küstennähe)

1	2	3	4	5	6	7
	ohne Verkehr und ohne Lärmschutzwand			mit Verkehr 1) oder mit Lärmschutzwand		
	auf Überbauten					
b/d 2)	$z_e \le 20$ m	20 m $< z_e \le 50$ m	50 m $< z_e \le 100$ m	$z_e \le 20$ m	20 m $< z_e \le 50$ m	50 m $< z_e \le 100$ m
≤ 0,5	2,20	2,85	3,20	1,85	2,35	2,65
= 4	1,20	1,55	1,75	1,00	1,30	1,45
≥ 5	1,20	1,55	1,75	0,80	1,00	1,10
	auf Stützen und Pfeilern 3)					
b/d 2)	$z_e \le 20$ m		20 m $< z_e \le 50$ m		50 m $< z_e \le 100$ m	
≤ 0,5	2,15		2,75		3,10	
≥ 5	0,95		1,20		1,35	



Tab. N.4: Windeinwirkungen W in kN/m^2 auf Brücken für Windzonen 3 und 4 (Küstennähe)

1	2	3	4	5	6	7
	ohne Verkehr und ohne Lärmschutzwand			mit Verkehr 1) oder mit Lärmschutzwand		
	auf Überbauten					
b/d 2)	$z_e \le 20$ m	20 m $< z_e \le 50$ m	50 m $< z_e \le 100$ m	$z_e \le 20$ m	20 m $< z_e \le 50$ m	50 m $< z_e \le 100$ m
≤ 0,5	3,20	4,10	4,65	2,60	3,35	3,80
= 4	1,75	2,20	2,50	1,45	1,85	2,10
≥ 5	1,75	2,20	2,50	1,10	1,40	1,60
	auf Stützen und Pfeilern 3)					
b/d 2)	$z_e \le 20$ m		20 m $< z_e \le 50$ m		50 m $< z_e \le 100$ m	
≤ 0,5	3,05		3,90		4,45	
≥ 5	1,35		1,70		1,95	

In some cases, to prevent wind loads, sound barriers placed in the deck of a bridge. Sound barriers or soundwall is a structure which protects structures or residential areas from wind or noise pollution. There is a variety of materials that can be used for a soundwall such as concrete, steel, wood or plastic. The select of the material depends on the designer. Wind loads applied as a uniformly distributed load to the entire surface.

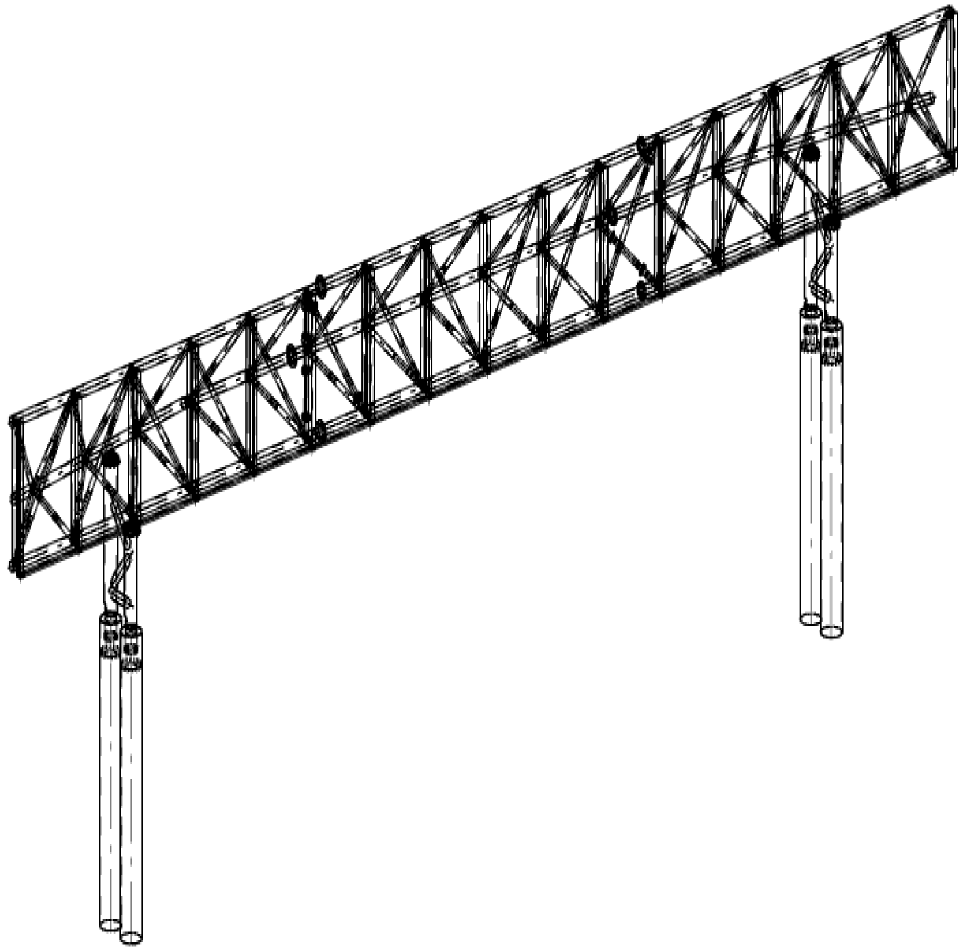
4.4 Dynamic loads

As dynamic loads may be deemed wind, earthquake and impact loads. There are also dynamic loads from the moving trucks in the deck of a bridge. Ground movements created by the earthquake, which can shift in any direction and the structure is vibrating. But in an earthquake, only horizontal movements have to take into consideration for a structural analysis, as for the vertical movement are adequate the calculations which have been done for dead and live loads. Impact loads, are vertical loads which can suddenly applied in structure. The deformation of a structure due to impact load depends on the ratio of live and dead load.

4.5 Temperature

A main factor to the calculation of the loads of a bridge is also temperature. The variation of temperatures affects directly the materials of a structure and it can cause movements or stresses at the elements. Temperature is related with the geomorphology of each area. In Germany there is a variety of temperatures from -24°C to 37°C.

5 Static Analysis of Bridge



The aim of a static analysis is to determine the loads of a structure and their behavior. The first load to be calculated is the self-weight of the structure. Then, wind loads have to be considered, all along the surface of the wall. Wind loads are horizontal and they can be either positive (+Y) or negative (-Y) depends on the wind forces. On the wall of the bridge vibration generated due to the pass of the train. These vibrations are dynamic loads which change as the train is moving. For their calculation, parts of the bridge are taken and not the whole surface. Finally, all the loads above have to consider in one load combination, as none of them acts singularly. The total sum of the loads process from the equation below;

$$\text{Self-weight} \times 1.35 + \text{wind loads} \times 1.50 + \text{dynamic loads} \times 1.50$$

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