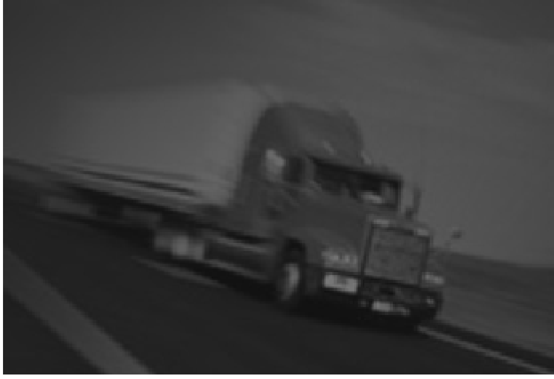
Loads

Perhaps the most **important** and most **difficult** task faced by the structural designer is the accurate estimation of the types and magnitude of loads which may be applied to a structure during its life. Miscalculation can lead to catastrophic failures. Unfortunately, an engineer seldom knows the exact loads that a bridge may have to withstand and that is why bridge codes specify using a safety factor.

Dead Load

CLICK ON GOLD TYPE FOR MORE INFORMATION

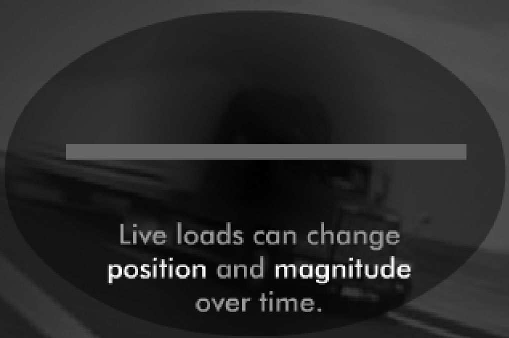
LOADS



The **dead load** is sometimes also called the **gravity** load. Basically, it is the weight of the bridge itself, and it is frequently the heaviest load the bridge must support. Dead loads are defined as being **permanent** (they will always be acting on the structure), **constant** (the magnitude of the dead load never changes), and **stationary** (the position of the load load doesn't change with time). Estimating the dead load can be tricky.

Live Loads

LOADS



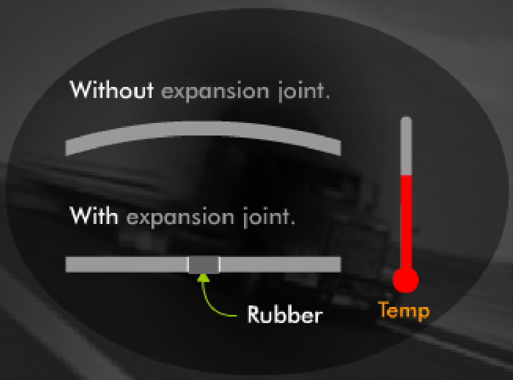
The **live load** is the weight of the people, trucks, snow, etc. that the bridge has to support. The **position** (where it lies on the bridge) and the **magnitude** of the live load can **change** with time.

Live loads are **difficult to predict** exactly, because it is hard to estimate how many trucks and how much snow might be on a bridge at a given time. So, safety factors for live loads tend to be **higher** than those for dead loads.

Thermal Loads

CLICK ON GOLD TYPE FOR MORE INFORMATION

LOADS



Air temperatures over the course of a year can vary by more than 100 def F. **Thermal loads** arise when **changes in temperature** cause bridges to **expand** (when it gets hotter) or **contract** (when it gets colder). All materials undergo shape changes when they are subjected to temperature fluctuations. These changes may be imperceptible to the eye, but they can result in **high stresses** in bridges. That is why bridges frequently have **expansion joints**.

Dynamic Loads

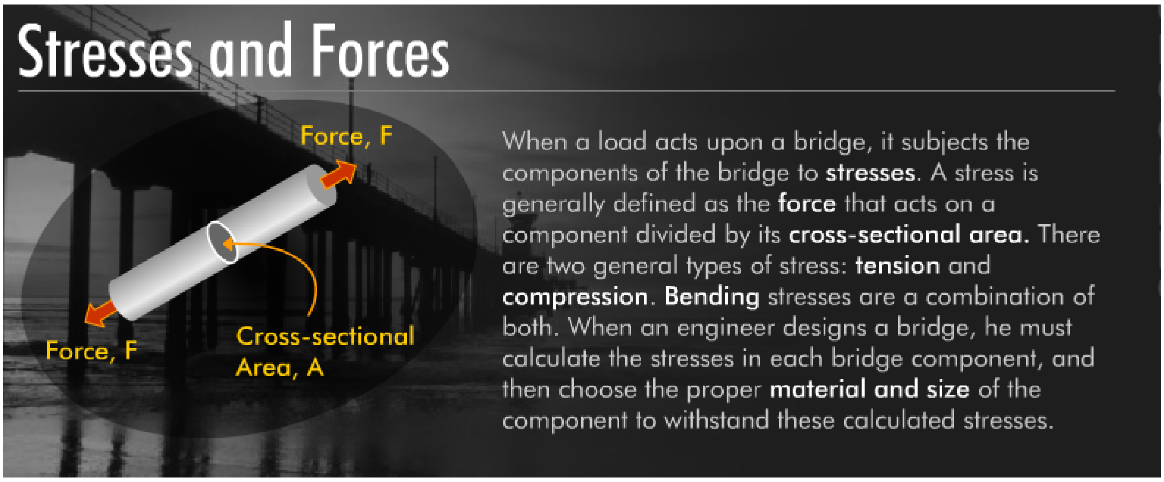
CLICK ON GOLD TYPE FOR MORE INFORMATION

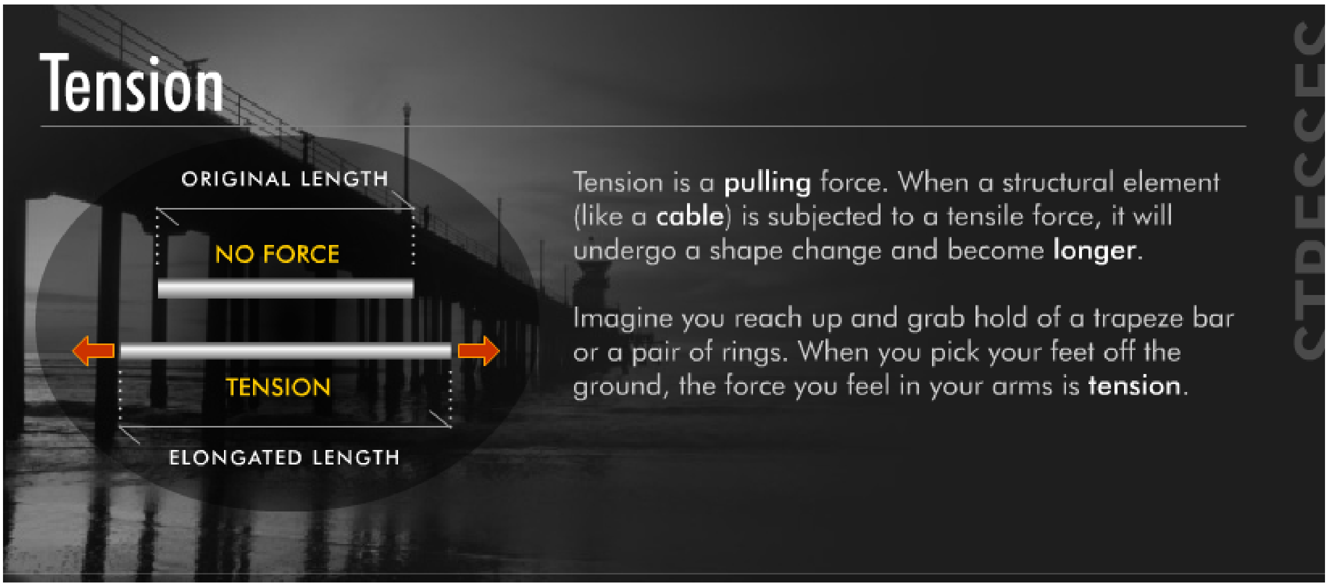
LOADS

Dynamic loads grow rapidly or suddenly and can cause disastrous failures and high losses of life. **Wind** loads, **impact** loads, and **earthquake** loads are all examples of dynamic loads. The Tacoma Narrows bridge (shown in photo) failed as a result of wind loads.

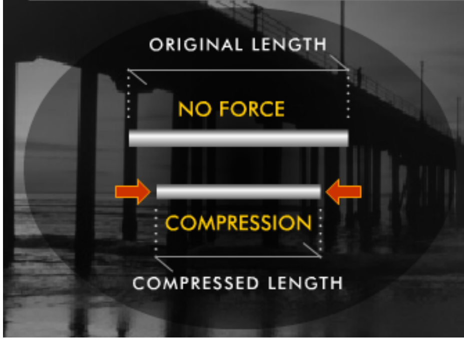
Although it appears **not** to have been the case with this bridge, the effect of a dynamic load can also be influenced by the **natural frequency** of the bridge.

Stresses


Stresses and Forces
Force, F
Force, F
Cross-sectional
Area, A
When a load acts upon a bridge, it subjects the components of the bridge to stresses. A stress is generally defined as the force that acts on a component divided by its cross-sectional area. There are two general types of stress: tension and compression. Bending stresses are a combination of both. When an engineer designs a bridge, he must calculate the stresses in each bridge component, and then choose the proper material and size of the component to withstand these calculated stresses.


Tension
ORIGINAL LENGTH
NO FORCE
TENSION
ELONGATED LENGTH
Tension is a pulling force. When a structural element (like a cable) is subjected to a tensile force, it will undergo a shape change and become longer.
Imagine you reach up and grab hold of a trapeze bar or a pair of rings. When you pick your feet off the ground, the force you feel in your arms is tension.
STRESSES

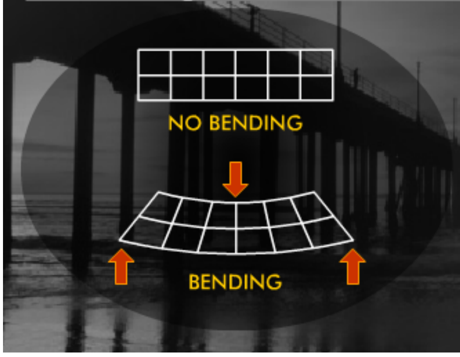
Stresses and Forces



Compression is a **squeezing** force. When a structural element (like a **column**) is subjected to a compressive force, it will undergo a shape change and become **shorter**.

Imagine you are standing on your hands. The force you feel in your arms is **compression**.

Bending



When a load is placed on a structural element (such as a **beam**) that causes it to bend, it is simultaneously subjected to **both** tensile and compressive stresses. For instance, imagine bending a sponge so that it looks like the figure to the left. The top of the sponge has gotten **shorter** (it is in compression), and the bottom has gotten **longer** (it is in tension). Note that the middle of the sponge has not changed in length. This section is called the **neutral axis** and it is not subjected to any stress.

Materials

Material Properties

CLICK ON GOLD TYPE FOR MORE INFORMATION

UNDEFORMED BAR

NO APPLIED FORCE

CLICK: ELASTICITY | PLASTICITY

Each structural material has unique **properties** that determine how well-suited the material is for a particular purpose. One of the key properties is the material's **yield stress** which determines how much stress a material can withstand before it deforms **plastically**. If a material deforms plastically, it does not bounce back to its original shape when the force is removed. If the material does bounce back to its original shape, it is said to behave **elastically**. All bridge components should behave elastically.

Steel

CLICK ON GOLD TYPE FOR MORE INFORMATION

Steel alloys are **high strength** materials that are used in a wide array of structural applications from columns to cables. Because steel is **equally strong** when resisting squeezing or pulling stresses, it is especially well-suited for members that will be subjected to **bending**. When designing compressive structural elements (such as an arch or column), the designer must weigh the costs of using steel with those of using a lower cost material, such as concrete.

Wood

Wood is arguably one of the ealiest bridge materials, dating back to when a log was first placed across a short stream or gap. Historically, wood was relatively abundant and inexpensive; so, many of the early bridges (including the New England covered bridge) were constructed using timber. Although not as durable or strong as steel, wood lends itself well to bending situations, because of its relatively **similar** tensile and compressive strengths.

Stone

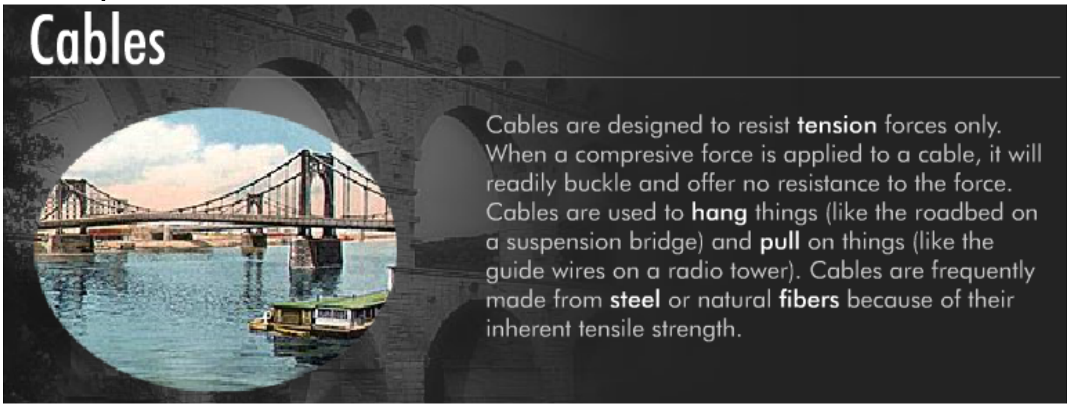
Stone is a durable and relatively inexpensive building material and—in past centuries—it was one of only a few options readily available for some applications. Stone is much stronger resisting **compressive** forces than it is resisting tensile forces. Consequently, it's use has been historically limited to structural elements such as **columns** and **arches**.

Reinforced Concrete

CLICK ON GOLD TYPE FOR MORE INFORMATION

Reinforced concrete (invented in 1857) combines the best properties of concrete (low-cost and good compressive strength) with the best properties of **steel** (durability and high tensile strength). Because concrete is susceptible to tensile and shear fracture, steel bars are **embedded** into the concrete primarily in regions that will be subjected to tensile and shear stresses. The resulting material is an excellent choice for bridge structural elements, such as **columns** and **beams**, and is used throughout the world today.

Components

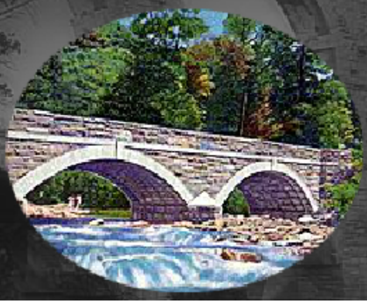

Cables
Cables are designed to resist **tension** forces only. When a compresive force is applied to a cable, it will readily buckle and offer no resistance to the force. Cables are used to **hang** things (like the roadbed on a suspension bridge) and **pull** on things (like the guide wires on a radio tower). Cables are frequently made from **steel** or natural **fibers** because of their inherent tensile strength.


Columns
Columns are designed to resist **compressive** forces only. They are used to **hold** things up (like the pillars on a building or the piers in the middle of a bridge). Cables are frequently made from **stone** or **concrete** because these materials are relatively inexpensive and have excellent compressive strength.

Beams

Beams are designed to resist **bending** stresses (i.e., both tension and compression). They are used to **support** floors and road beds. The beam derives most of its strength from its **height**. Doubling the height of a beam will increase its strength by a factor of eight. But, doubling the beam width will only double its strength. **I-Beams** are specifically designed to take advantage of this relationship. Beams are typically made from **steel**, **wood** or concrete that has steel bars embedded in it.

Arches



Arches are designed to resist **compressive** forces along a curve. They have been used in both buildings and bridges for centuries. Arches are frequently made from **stone** or **concrete** because these materials are relatively inexpensive and have excellent compressive strength. However, **steel** arches are quite commonly used in bridge construction, as well.

Trusses

The elements in trusses are designed to be in either **pure tension** or **pure compression**. Truss elements (**bars**) are pinned together so that they are not subjected to bending. They are used in both bridges and roofs. Depending on the **placement** and **direction** of the applied load, a truss bar may have to resist both tension and compression. Consequently, **steel** and **wood** are good truss materials because they are both almost equally strong when being compressed or stretched.

Bridge Types

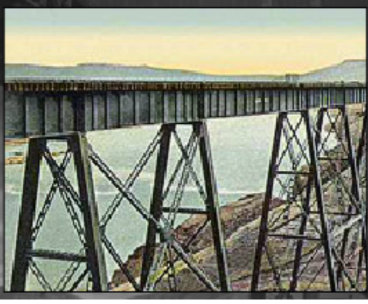
Common Bridge Designs

CLICK ON GOLD TYPE FOR MORE INFORMATION

Bridges come in a variety of **sizes** and **shapes**, and new bridge designs are constantly being tested. An engineer's choice of which bridge type to implement is usually dictated by the **length of span** the bridge must cross. Today engineers are not only searching for ways to build longer bridges, but they are also concerned with coming up with more **economical** ways to design and build existing types of bridges.

Girder Bridges

CLICK ON GOLD TYPE FOR MORE INFORMATION



The most-common bridge type is the **girder** (or **beam**) bridge. Girders are built on top of two **end supports** which carry the weight of the bridge and the traffic. The girders must be strong enough so they do not **bend** excessively. Girder bridges are used to span **short** lengths (frequently less than 250 ft). Girders come in a variety of **shapes** (such as I-beams or box beams) and are most commonly made of steel, reinforced concrete, or wood.

Truss and Frame Bridges

CLICK ON GOLD TYPE FOR MORE INFORMATION

Truss and **frame** bridges are usually made of steel (and formerly made of iron) and tend to span **relatively short** lengths. All parts of a truss bridge are **pinned** together so that the components are either in pure tension or pure compression (i.e., there is no bending). Frame bridges have **fixed** connections so that the parts of the frame are subjected to some bending.

See a list of the longest steel truss bridges.

Arch Bridges

CLICK ON GOLD TYPE FOR MORE INFORMATION

Some of the **oldest** bridges in the world are **arch** bridges; early arch bridges are constructed with **stone**. Stones are very strong in **compression**, and arches are designed so that the entire structure is only subjected to compressive forces. **Abutments** support the end of the arches and prevent it from spreading out. Today arch bridges span **medium lengths** and are built with steel and concrete.

See a list of the longest steel-arch bridges.

Suspension Bridges

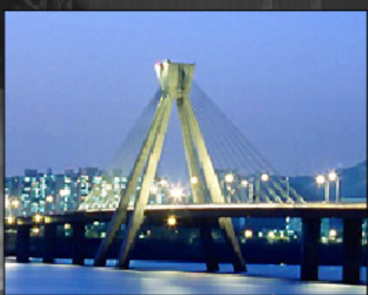
CLICK ON GOLD TYPE FOR MORE INFORMATION

The **longest** bridges in the world are **suspension** bridges. While they are quite majestic-looking, they also tend to be quite expensive. Huge **cables** (typically made of thousands of bound-together wires) are draped over high **towers** and are secured on the ends by **anchorages** which are embedded in stone or concrete. The road is suspended from the cables which transmit the load to the anchorages.

See a list of the longest suspension bridges.

Cable-Stayed Bridges

CLICK ON GOLD TYPE FOR MORE INFORMATION



Cable-stayed bridges are the newest additions to the bridge designer's options for **medium to longer length** spans. They are strikingly beautiful and economically efficient because the towers can be constructed out of pre-cast concrete sections. Unlike those in the suspension bridge, the **towers** of a cable-stayed bridge support all the force transmitted through the cables holding up the road.

See a list of the longest cable-stayed bridges.