

LEVEL 4 ASSIGNMENT

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Introduction

Bridges are among the oldest and most well-known instances of engineering, providing essential connections for commerce, communication and transportation by circumventing natural barriers. From the earliest arches of Mesopotamia to today's cable supported viaducts such as construction architectural ambition and engineering necessity.



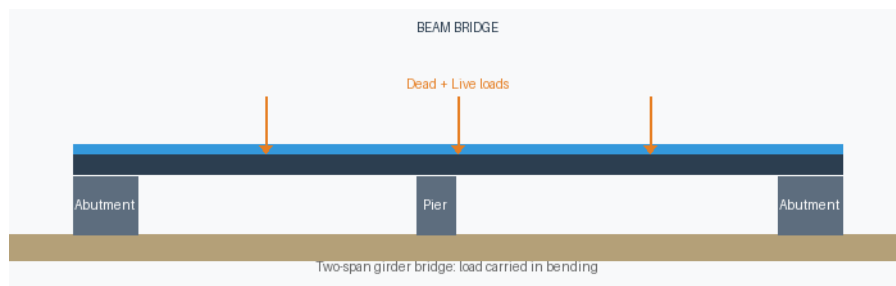
Bridge Structural Systems

The categorization of bridge structural systems can be done according to load carrying mechanisms and load distribution within the structure.

There are five main categories of bridges namely beam/girder, truss, arch, cable stayed and suspension bridges which employ different mechanical principles in transferring loads to the ground.

1: Beam and Girder Bridges

The beam bridge is one of the oldest and simplest structural systems which consists of horizontal beams supported on either side.

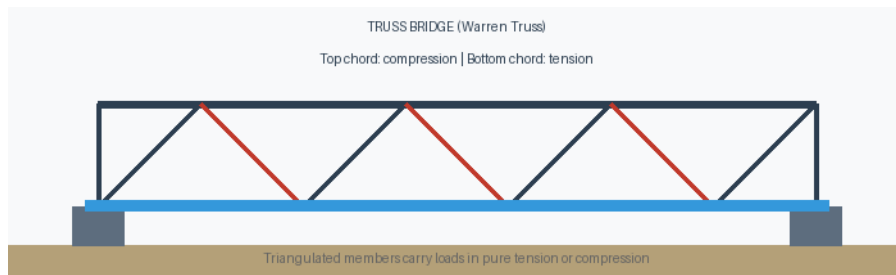


Girder Types: some common types of girders are I-beams economical for spans up to 30m, plate girders efficient for spans between 30m-100m and box girders.

Span Ranges: 5m – 100m

2: Truss Bridges

The trusses are made up of straight bars put together in a triangular manner in to convert load requirements into axial actions compression and tension.



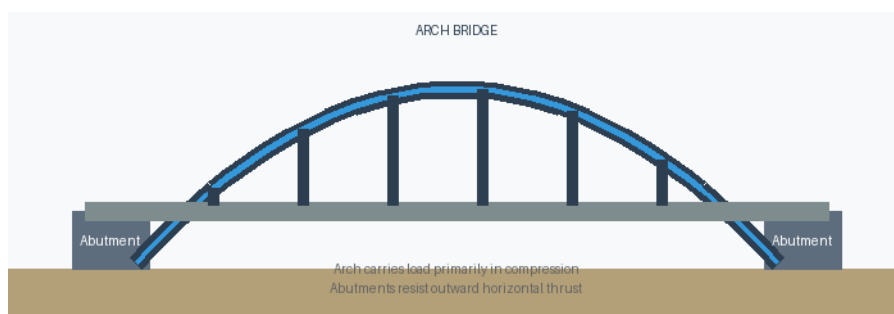
Warren truss bridge. Blue = tension members (bottom chord and some diagonals); dark = compression members (top chord and alternate diagonals).

Economical Spans:

Generally, applied for spans of 50m – 600m.

3: Arch bridges

One of the most ancient type of bridges which can resist loads through axial compressions rather than bending.



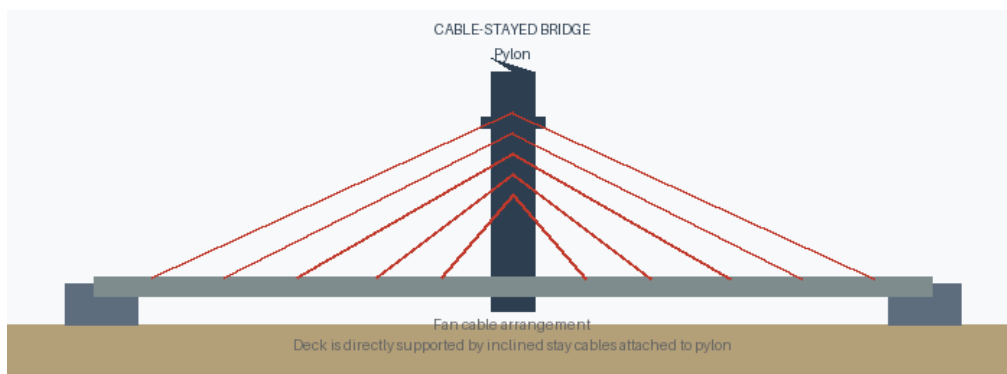
Variations:

Types include through arch, deck arch and modern network arch having overlapping tension hangers.

Span Ranges: 30-600+m

4: Cable Stayed Bridges

A cable-stayed bridge has a series of inclined stay cables attached to one or more tall towers or pylons to support a stiffened deck.

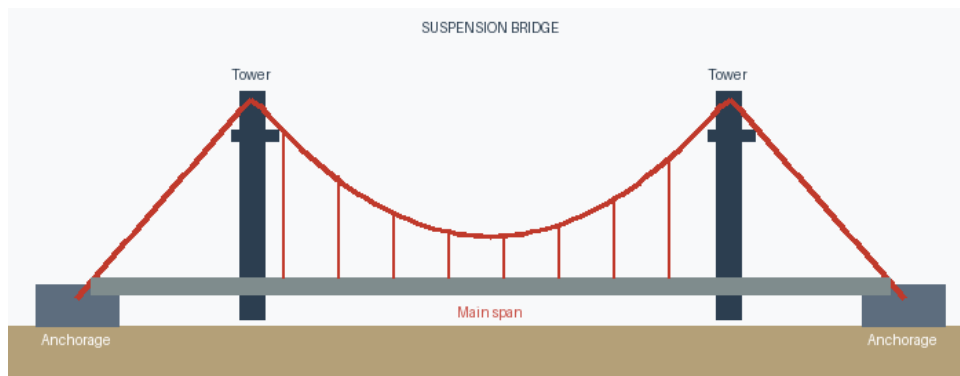


Cable-stayed bridge with central pylon and symmetrical fan cable arrangement. Cables apply both vertical support and horizontal compression to the deck.

Span Ranges: 200m- 1100m

5. Suspension Bridges

The suspension bridge relies on a cable hanging in a curved profile (catenary curve) between towers to achieve its maximum span lengths among all other bridge categories.



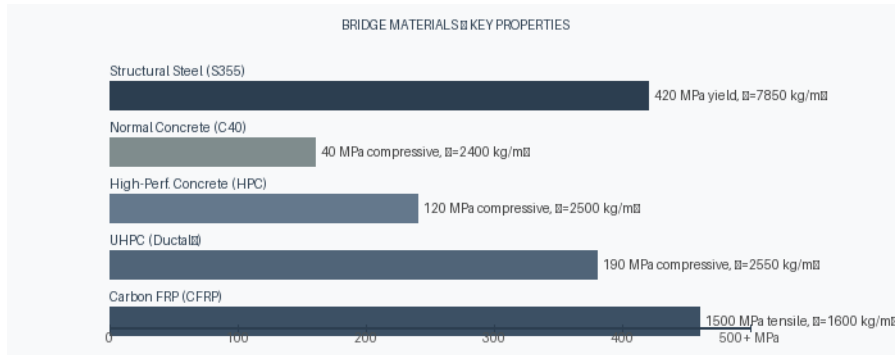
Span Ranges: 400m – 2000+m

Modern bridge engineering may involve hybrid system and synergy between materials like steel and concrete to overcome span limitations.



Bridge Construction Materials

Selection of bridge materials is a core stage in the design of such structures, which will influence the efficiency, durability and economics of the structure.



Approximate strength ranges of principal bridge materials. Note that FRP composites offer very high tensile strength with very low density, but at high initial cost.

Based on the sources four types of bridge building materials may be distinguished:

Stone and masonry, structural steel, reinforced and prestressed concrete and innovative composite material.

Stone and Masonry

For about two thousand years, masonry made from stones or bricks served as the predominant material bridge engineering.

Present Usage:

Currently, masonry is utilized for reconstruction purposes only however, tens of thousands of historic masonry arch bridges still perform their functions in the modern highway system.

Structural Steel

In the late 19th century, with the development of steel production technologies, bridges with large spans became possible with suspension and through- truss designs.

Steel Properties:

Steel possesses excellent mechanical properties characterized by relatively high tensile and compressive yield strength 275-690 MPa.

Maintenance:

The primary disadvantage of steel is the high vulnerability to atmospheric corrosion and chemical attack, which are mitigated using paint or zinc coating or weathering steel varieties like Cor-Ten.

Reinforced and Prestressed Concrete

Concrete is the most flexible material, used extensively in modern bridge engineering often in combination with steel.

Reinforced Concrete:

A reinforced composite of steel and concrete takes advantages of the strength of concrete for compression and of that steel for tension.

Prestressed Concrete:

For ensuring concrete does not crack under large loads, it should be subjected to pre-compression before the beginning of operation.

Pre-tensioning:

In case of post-tensioning, tendons are stretched after hardening of the concrete in situ which is especially common when creating the box girder spans.

High-performance Concrete HPC:

Present day HPC can withstand loads in the range of 60 to 120 MPa and has a high durability in harsh marine and de-icing conditions.

Advanced and Innovative Materials

Modern materials, being ultra-strong and light, open new opportunities for bridge engineers.

Ultra-High Performance Concrete UHPC:

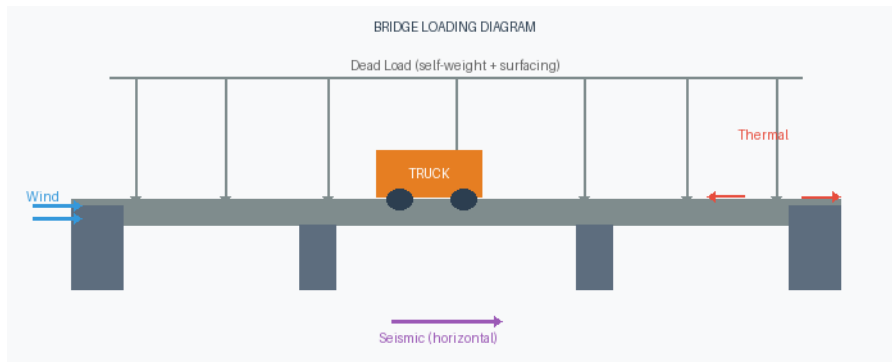
Carbon-fibre reinforced Polymers FRP:

Carbon-fibre reinforced polymeric material CFRP or glass-fiber reinforced polymer GFRP are materials with unmatched strength-to-weight ratios and absolute corrosion resistance.

Design Considerations and Loads

Bridge designs follow a limit state concept, where a bridge structure should be safe with respect to ultimate limit states failure and satisfies certain for serviceability limit states functionality and comfort.

Modern bridge design is governed by Eurocode and AASHTO codes, among others.



Summary of principal load types acting on a bridge structure. Each load type is characterised, combined, and factored according to the design code

1: Type of Loads

The engineer should consider different types of loads that act upon a bridge throughout its design life:

Dead Loads (Permanent Loads):

These include self-weight of structural members (beams, deck, slab and cross frames. In long span bridges, dead loads are very large.

For example:

Superimposed Dead Loads SDL:

These include non-structural items such as road surface thickness around 80-100mm kerbs, parapets, waterproofing and utilities

Live Load (Variable Loads):

These include loads due to vehicle weight and dynamic effect.

According to Eurocode 1, there are special Load Models LM.

Wind Load:

Wind produces drag force, lift force and pitching moment on the bridge deck.

For spans above 200m, aerodynamic stability of the bridge is vital to prevent flutter effect, which is a catastrophic coupled bending-torsional instability.

Seismic Load:

In areas prone to earthquakes, bridge structures should be capable of resisting ground acceleration.

Two approaches may be considered:

Elastic resistance of forces acting on the bridge structure or ductile design, which involves creating plastic hinges at bridge piers and allowing controlled deformations without collapsing.

Thermal Load:

Changes in ambient temperature affect bridges causing them to expand and contract.

Uniform temperature change or differential temperature change (the temperature at the top of the deck is hotter than the bottom) causes bending of the bridge structure and bending stresses.

2: Mechanics of Structures

The analysis of loads on bridges is necessary in determining stresses within members and failure modes:

Bending and Flexural Analysis:

In beam or girder structures, bending stress controls loading capacity.

Buckling:

In slender compressive members, such as columns or trusses, buckling occurs as a limit state failure mode.

The maximum axial forces a member can take until buckling occurs is called the Euler load.

3: Load Combinations

It is extremely rare for maximum loads such as maximum wind to happen at the same time.

These expressions apply partial factors 1.35 for permanent loads and 1.5 for variable loads and combination factors.

Bridge Construction Methods

Construction techniques play an important role in bridge building since they influence the type of loads to consider in the design process.

There are different techniques depending on structural form, economy space limitations.

Traditional In-Situ Technique

A typical conventional construction technique is based on the falsework erection to support concrete deck casting.

Balanced Cantilever Construction

To avoid falsework usage when constructing long-span bridge with concrete box girders, a special construction technique was invented.

Incremental Launching

Suitable for multi-span bridges of similar geometry, the fabrication takes place in a factory behind one of the abutments.

Precast Segmental Construction

It involves prefabricating segments of the box girder with lengths of 2-5m, transporting them to the site and then assembling with the use of a crane or gantry.

Erection Techniques for Cable-Supported Bridges

Usually installed using a balanced free cantilever system with immediate support from permanent stay cables without any falsework in span.

Suspension Bridges

Accelerated Bridge Construction

ABC represents a group of techniques aimed to decrease construction time and minimize traffic disruption.

Innovations in Bridge Engineering

The innovation of bridge engineering in the present day is mainly caused by digitalization, advanced material development and sustainability.

All those factors seek to prolong the life span of structures, minimize their maintenance expenses and facilitate complicated geometries.

Conclusions

This study identifies important consideration in bridge engineering where structural system selection is presented as multi criteria optimization process affected by span length, ground conditions and the environment.

Modern bridge designs incorporate components from several systems.

The progress in material science including UHPC and FRP, improves the design but limits its implementation due to economic constraints.

Design standards have developed significantly, especially with Eurocode, although there remains a need for future research on aspects such as fatigue resistance and material durability.

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