**Consideration in structural design of a bridge**

1. Site Conditions

* Design of the bridge depends on the condition of the site where it is being built. If a site includes water crossing, intersections or steeper elevations, additional considerations should be made during the design process

1. Geotech Analysis

* Geotech Analysis can be used for learning details about the site. For example, the analysis helps determine if deeper foundations are necessary. Knowing the surrounding soil condition helps in designing the footing required to keep the bridge structurally sound.

1. Superstructure and Substructure

* To understand bridge design, you’ll have to learn the difference between the bridge’s superstructure and its substructure. By the bridge’s superstructure, we mean anything above the bearings, including the hard surface drivers used to travel from one side to the other. By the substructure, we mean the bridge’s foundation, including the columns supporting it. The superstructure and the substructure work together but have different goals. Choosing the shape of the structure of your bridge, for example, will affect the substructure. A bridge can be shaped like an arc, suspended by cables, built primarily using powerful beams and more. These design considerations, of course, are more complex than simply asking “What shape do you prefer?” Even if you’re designing a mock bridge as a project for a course at your [CAD school](https://www.digitalschool.ca/), you should take the time to factor in the environment around the bridge and various economic considerations, such as costs of materials, among others.

1. Tension and compression

* Regardless of the shape of your bridge, its key structural components will be beams, arches, trusses, and suspensions. How you use these elements will determine the quality of your bridge. Two forces you should make sure you understand are tension and compression. To understand the tension, imagine a rope being pulled on from both sides during a game of tug-of-war. This is tension, and it’s a force that will act on your bridge to add stress. To understand compression, just imagine what happens to a spring when you apply pressure on it. That’s right – it collapses into itself, which shortens its length. Compressional stress will also affect your bridge, and it will act in direct opposition to tensional stress. The bridge’s design, therefore, must be able to handle these forces without buckling or snapping.

1. Resonance

* Resonance is another force that can act on your bridge. Imagine a snowball rolling down a hill and increasing in size and speed. This is resonance. It starts with small vibrations, such as when wind attacks a bridge, and those vibrations can continue increasing over time until they take down the entire structure! There are several ways to deal with resonance, but one of the most popular methods is to incorporate dampeners into the bridge design, which can interrupt the resonant waves and prevent them from growing.

**Type of load in bridge design and design method**

Various design loads to be considered in the design of bridges are:

1. Dead load
2. Live load
3. Impact load
4. Wind load
5. Longitudinal forces
6. Centrifugal forces
7. Buoyancy effect
8. Effect of water current
9. Thermal effects
10. Deformation and horizontal effects
11. Erection stresses
12. Seismic loads
13. Dead Load

* The dead load is nothing but a self-weight of the bridge elements. The different elements of bridge are deck slab, wearing coat, railings, parapet, stiffeners and other utilities. It is the first design load to be calculated in the design of bridge.

1. Live Load

* The live load on the bridge, is moving load on the bridge throughout its length. The moving loads are vehicles, Pedestrians etc. but it is difficult to select one vehicle or a group of vehicles to design a safe bridge. So, IRC recommended some imaginary vehicles as live loads which will give safe results against the any type of vehicle moving on the bridge.

1. Impact load

* The Impact load on bridge is due to sudden loads which are caused when the vehicle is moving on the bridge. When the wheel is in movement, the live load will change periodically from one wheel to another which results the impact load on bridge. To consider impact loads on bridges, an impact factor is used. Impact factor is a multiplying factor which depends upon many factors such as weight of vehicle, span of bridge, velocity of vehicle etc.

1. Wind Loads

* Wind load also an important factor in the bridge design. For short span bridges, wind load can be negligible. But for medium span bridges, wind load should be considered for substructure design. For long span bridges, wind load is considered in the design of super structure.

5. Longitudinal Forces

* The longitudinal forces are caused by braking or accelerating of vehicle on the bridge. When the vehicle stops suddenly or accelerates suddenly it induces longitudinal forces on the bridge structure especially on the substructure. So, IRC recommends 20% of live load should be considered as longitudinal force on the bridges.

1. Centrifugal Forces

* If bridge is to be built on horizontal curves, then the movement of vehicle along curves will cause centrifugal force on to the super structure. Hence, in this case design should be done for centrifugal forces also. Centrifugal force can be calculated by C (kN/m) = (WV2)/(12.7R) **Where** W = live load (kN) V = Design speed (kmph) R = Radius of curve (m)

1. Buoyancy Effect

* Buoyancy effect is considered for substructures of large bridges submerged under deep water bodies. Is the depth of submergence is less it can be negligible.

1. Forces by Water Current

* When the bridge is to be constructed across a river, some part of the substructure is under submergence of water. The water current induces horizontal forces on submerged portion. The forces caused by water currents are maximum at the top of water level and zero at the bottom water level or at the bed level. The pressure by water current is P = KW [V2/2g] Where P = pressure (kN/m2) K = constant (value depending upon shape of pier) W = unit weight of water V = water current velocity (m/s) G = acceleration due to gravity (m/s2)

1. Thermal Stresses

* Thermal stresses are caused due to temperature. When the temperature is very high or very low they induce stresses in the bridge elements especially at bearings and deck joints. These stresses are tensile in nature so, concrete cannot withstand against this and cracks are formed. To resist this, additional steel reinforcement perpendicular to main reinforcement should be provided. Expansion joints are also provided.

1. Seismic Loads

* When the bridge is to be built in seismic zone or earthquake zone, earthquake loads must be considered. They induce both vertical and horizontal forces during earthquake. The amount of forces exerted is mainly depends on the self-weight of the structure. If weight of structure is more, larger forces will be exerted.

1. Deformation and Horizontal Effects

* Deformation stresses are occurred due to change is material properties either internally or externally. The change may be creep, shrinkage of concrete etc. similarly horizontal forces will develop due to temperature changes, braking of vehicles, earthquakes etc. Hence, these are also be considered as design loads in bridge design.

1. Erection Stresses

* Erection stress are induced by the construction equipment during the bridge construction. These can be resisted by providing suitable supports for the members.

**Input data (data collection) for bridge selection and design**

1. General Description of Local Conditions Covering:

* General Engineering Requirements. There should be a narrative of the project area, which includes a brief description of the surrounding area, the size of the nearest population centers, the condition of bridges and other structures and roads. This description shall include the following (if available):

1. Location (structure name, structure number, state, county or route number, distance to nearest city or town, etc).
2. Project description (new structure, replacement, or modification required due to necessary improvements, etc.).
3. Site description (information relating to access for possible site visit by the design team, access for foundation exploration, and construction, and access limitations due to environmental restrictions, etc.).
4. Weather and climate conditions that may affect design or construction (temperature extremes, local building code requirements for wind velocities, snow and ice loading, etc.).
5. Utilities such as power lines, waterlines, or telephone lines that require installation on the bridge superstructure or are in the vicinity and may be impacted by the project. Include names, telephone numbers, and internet and email addresses of the local utilities and names of contacts within their organization.
6. Provide copies of relevant correspondence to and from stakeholders such as Federal, State or local agencies or private entities. These stakeholders input may have an impact in the design reviews or permitting process. Provide name of contact person, address, telephone number, internet and email address for potential direct contact by the design team.
7. Provide copies of previous reports or studies that have been prepared by Reclamation or by others.
8. The approximate distance from the nearest railroad shipping terminal to the structure site; load restrictions and physical inadequacies of existing roads and structures and an estimate of remedial improvements to accommodate construction hauling; and possible alternative means for delivering construction materials and equipment at the structure site.
9. Local freight or trucking rates.
10. Surface Data:
11. Survey Control. Survey control is required for all surveys including surveys associated with aerial topography. Show coordinate system and existing land survey monuments and special control points established for the survey. All preceding survey work and all subsequent survey work, including topography and location, and ground surface elevations of subsurface exploration, should be revised to conform to the permanent control system. All points contained in the electronic files should have coordinates for northing and easting and values which correspond to the ground level elevations. Specify the vertical datum, such as National Geodetic Vertical Datum (NGVD), and the horizontal datum, such as the State Plane Coordinates (NAD83) along with epoch date. Legends should show grid factors and reduction to sea level factor, or a combination of the two. Feasibility phase: Tying to the State plane coordinate system or national coordinate system is recommended. Specifications phase: Permanent horizontal and vertical survey control should be established at the earliest possible time. The coordinate system should be related to a State or national coordinate system.
12. Topographic Map. When the horizontal alignment of the proposed bridge is known, the topographic map should embrace a minimum area of 100 feet upstream and 100 feet downstream and 100 feet beyond the ends of the structure. This area may have to be enlarged to cover any alternate alignments being evaluated or specific construction items such as cut and fill limits and channel modifications. Generally, both a map and an electronic file, in AutoCAD or compatible format, of the topography covering the structure site should be provided. The topographic map should be plotted to a scale of 1 inch equals 10 feet to 1 inch equals 20 feet with a maximum contour interval of 2-feet. Elsewhere, larger contour intervals may be acceptable. Details to be included are:
    * + - * Proposed bridge location.
          * Locate and identify existing site features which would be important design information such as roads, parking, turnarounds, buildings, structures, power lines, buried utility lines, campgrounds, picnic areas, springs, marsh areas, overflow channels, channel changes, edge of water, high water marks, types of vegetative cover, large boulders, exposed rock, etc.
          * Existing right-of-way and proposed acquisition of additional right of-way should be discussed.
          * Provide a profile along the existing or proposed road centerline extending at least 500 feet beyond the ends of the bridge. The profile should be plotted to a horizontal scale of 1 inch equals 20 feet. Indicate recommended grade; elevations of extreme low, present and extreme high water; elevations of the stream bottom in the vicinity of the proposed piers or abutments; and type of foundation material underlying the substructure locations.
13. Photographs. Digital color photographs of all existing facilities or structures in the vicinity of the proposed bridge site with close-up views of any features which may affect designs. These photographs should be taken to best show the proposed structure and, if possible, indicate known tie points to the topographic maps.
14. Foundation Investigation Data:

General Engineering Requirements. The need for foundation data should be established by originating office personnel with assistance from the region and TSC representatives. For major bridge structures and unusual or difficult road alignments, it is recommended that an onsite inspection and a field conference be held.

Geologic Data. The amount and detail of foundation data required for a feasibility design will vary greatly because of the wide range of size and complexity encountered in bridge design. The guiding criteria should be to provide sufficient data to allow the designer to determine the type of foundation required for the structure and to identify major foundation problems. Adequate foundation data may be obtained for small structures from an inspection of surface conditions and one or two exploratory holes or test pits to determine type of overburden and foundation conditions some distance below the base of the structure. These data, and any other data in the following paragraph that are relevant, along with a brief description of geologic conditions of the site, can be included in the design data. For larger and more complex structures, a more comprehensive geologic program will be required, including a geologic report. For structures of this magnitude, a field conference should be held, including an inspection of the site to determine the geologic investigations program. In developing the geologic program and in preparing the geologic report, the following should be considered.

1. A resume of the regional geology.
2. Bridges Compilation, summary, and reporting of Reclamation and non-Reclamation geologic information on the area with attention being paid to the sequence of explorations and historical geologic events.
3. A surface geologic map of the bridge site, plotted on the topographic map of the bridge site, showing surface geology and the location of geologic sections, soil profiles, and of all subsurface explorations, including coordinates or stationing.
4. A description and interpretation of site geology including physical quality and geologic structure of the foundation strata, seasonal ground water, ground subsidence, existing and potential landslide, snow slide and rock fall areas, surface water runoff; and engineering geologic interpretations as appropriate. (e) Geologic logs of all subsurface exploration.
5. Geologic sections, with soil profiles as required, showing known and interpreted subsurface conditions.

* A classification, in accordance with the Unified Soil Classification System, of the soil in each major stratum.
* A description of the undisturbed state of the soil in each major stratum.
* A delineation of the lateral extent and thickness of critical, competent, poor, or potentially unstable strata, in foundations and excavation slopes, especially those to be permanently exposed.
* An estimate or a determination by tests of the significant engineering properties of the strata, such as density, permeability, shear strength, and consolidation or expansion characteristics; and the effect of structure load, changes in moisture, and fluctuations or permanent rise of ground water on these properties.

1. Digital color photographs of pertinent geologic and topographic features of the terrain.
2. Samples of foundation strata as needed for visual examination or laboratory testing. Test pits and results of material testing should be included.
3. A determination of natural ground water conditions at the site.
4. Hydrologic Data (Required for bridges crossing rivers and streams):
5. Annual periodic fluctuations of stream or river water levels.
6. Drainage area located upstream of the bridge site.
7. Anticipated occurrence and amounts of sediment, ice (thickness), and drift (trash).
8. Erosion protection requirements and calculated scour depths, which will be used for support structure foundation design.
9. User and Operating Data:
   * + 1. For road and highways:

* Number of traffic lanes, including shoulders.
* Pedestrian sidewalk requirements.
* Typical roadway cross section.
* Deck protection or rehabilitation.
* Existing cross drainage structures located within the proposed construction site, including hydraulic requirements.
  1. For railroad bridges:
* Track classification, type of service, design load limits, typical roadbed section.

1. Construction Materials Data Including:
2. Inventory of available borrow areas for permeable and impermeable soil materials required for fill or embankment; distance to quarry or stockpile for riprap required for channel or slope protection.
3. Information on concrete aggregates.
4. Data on commercial concrete and precast concrete plants within practical hauling distance from the bridge site.
5. Results of sampling and analysis of materials, including previous tests conducted at the Technical Service Center (TSC).
6. Information, including catalogues, on firms within practical hauling distance from the bridge site which manufacture precast concrete products such as beams and piles.
7. Cost Data
8. Estimate of cost of right-of-way or easements. Include supporting data.
9. Estimates of cost for relocating public utilities within the construction area.
10. Estimates of cost for removal of buildings and other structures within the construction area.
11. Provide any pertinent cost estimates or information that has been prepared or obtained by Reclamation or the owner.
12. Environmental Considerations

* Implementation of design features should be consistent with the environmental commitments listed in the project’s NEPA Compliance Document. Implementation of design features should be consistent with agreements reached between Interior bureaus, Federal agencies, and other governmental agencies. Design data should include, as a minimum, a brief description of the environmental resources that could be affected by the proposed development. The emphasis should be on those areas within the range of alternatives open to the designers in developing a railroad or highway relocation, an access road alignment, or a bridge structural design

1. Site Security

* Many Reclamation projects may require a security risk assessment. The need for a site-specific security risk assessment should be considered for feasibility designs where an assessment may impact the field cost estimate and for specifications designs.

**Foundation investigation for bridge design**

The foundation of bridge and abutments require a serious geological investigation.

* Ideal site for the construction of a bridge in is the one across the valley cut in a sound rock and where the river flow is free from scouring due to bends, tributaries and other causes.
* The chief factors which govern the stability of bridges are lateral forces, earthquake forces and scouring action of river. Pressure from bridge and running water are the main lateral forces. Piers should be founded at depth safe from scouring erosion. In many cases, the location of a bridge is decided more by socio-economic factors than geological considerations. In big cities divided by streams and rivers, a bridge has to be places where necessary irrespective of subsurface geology. But in highways there is often some flexibility available in the choice of placement of a bridge. In any major bridge construction project, the bridge abutment and piers should be kept on sound, strong and stable rock foundation below as possible. River bed are covered by varying thickness of unconsolidated natural deposits of sand, gravels and boulders not safe for foundation of bridge pier. The piers placed directly on them would be unstable. The depth of sound rock may vary from 5-20 m in some to more than 100 m in others. Drill holes are made all along the center line of the proposed bridge, even on the banks sound rock sequence are reached. Height of individual piers may vary according to the depth of the sound bedrock below the surface as each them should be founded on the stable rock. The nature of the bed rock is commonly determined by the study of petro logical characters and engineering properties, especially the strength values, using the core samples obtained during drilling of test bore holes. A decision to place the pier on a particular rock at a particular depth is matter of judgment and design requirement. Most igneous and massive sedimentary and metamorphic rocks like gneiss, quartzite are considered sound for bridge foundation. Weak rocks which might behave badly in presence of water include cavernous limestone, fractured sandstone especially with clayey cements, shale’s, clays, slate, schist and the layer of peat and compressible organic material. Presence of harder rock over weaker rocks, rock heterogeneity, zones of weathering etc. are not favorable sites for bridge foundation which should be treated. Horizontal attitude and uniformly massive structure with depth are desirable characters on the foundation rocks as these offer resistance against failure. Even inclined rock in a confined situation are considered safe if they possess normal strength values. Fracturing and highly jointing is undesirable for the foundation as they might cause settlement beyond allowable limits. When bridge is aligned across the strike, various types of rocks with varying strength may be encountered along the foundation, which necessitates a close examination of foundation rock under each pier and abutment. Fault zones are to be avoided as the foundation, as any further displacement along these planes will adversely affect the bridge.

**Bridge construction and maintenance techniques**

New technologies are expected to meet the challenging and varying requirements, and also offer options that will guide to innovative engineering and bridge construction standards. With the beginning of the new century, bridge construction is being revolutionized. Modern construction methods and the latest advanced materials are being evolved.

1. Different methods of bridge construction

* Described below are the different methods employed in the construction of bridges.

Cast-in-situ Method of Bridge Construction

* This method is a flexible method of bridge construction where complex and unusual geometrical shapes of dams can be constructed easily. Situations when it is hard to transport pre-fabricated elements either due to size or unreachability, this method is a good choice.

Balanced Cantilever Method of Bridge Construction

* This method is used for constructing bridges with span 50 to 250m. The bridge constructed can either be cast-in-place or precast. Here, the segments are attached in an alternative manner at opposite ends of the cantilevers supported by piers. This is the best choice for the construction of long span length bridges, irregular length, and cable-stayed bridges.

Precast Method of Bridge Construction

* In this method, the bridge is constructed with the help of precast concrete elements.  The prefabrication is performed in different methods.

The precast elements include:

* Precast Beams
* Precast Decks
* Precast Segmental Decks

Span by Span Casting method of Bridge Construction

* This method is associated with cantilever construction method but with many advancements in the technique, it is considered as most economic and rapid in construction. For long bridges and viaducts with an individual span up to 60m, the method is feasible. Decks are begun at one abutment and constructed continuously by placing segments to the other end of the bridge. Segments can be positioned by either a temporary staying mast system through more commonly using an assembly truss.

Incremental Launching Method of Bridge Construction

* The Incremental Launching Method (ILM) method of bridge construction is employed mainly for the construction of continuous concrete bridges or steel girder bridges. The method performs the procedure in increments. With this method of construction, the bridge deck is built in sections by pushing the structure outwards from an abutment towards the pier. The ILM method can be used for bridge decks with a length greater than 250m.

Cable-Stayed Method of Bridge Construction

* In the cable-stayed method of construction, cables are used to carry the bridge deck from one or both sides of the supporting tower. The cables carry and transfer all the loads to the foundations. Cable-stayed method of construction is used for constructing bridges that span more than 300m.

Arch Method for Bridge Construction

* Arch shaped bridge construction is one of the most economical choices when the bridge under consideration is required to cross over landscapes that are inaccessible. Many modern arch construction methods have made the arch construction more economical. The arch construction can be built with concrete or pre-cast concrete. The cast-in-situ free cantilever method and slip formed sections are two main construction techniques coming under arch methods.

1. Bridge maintenance technique

* The maintenance of bridge means the up-keeping of the bridge components in good and serviceable condition so as to ensure a longer life of the bridge as envisaged at the time of its design and construction.
* Even if the bridges are well designed and properly constructed, periodic maintenance, if needed, is very essential to keep them in good serviceable condition. Therefore, the bridges should be regularly inspected and properly maintained.

The bridge maintenance may be broadly classified into two type:

1. Routine maintenance or annual maintenance
2. Quarterly maintenance

Routine maintenance is the annual maintenance done on the basis of routine inspection and includes the following:

1. For concrete structures-protection against exposed reinforcement and repairs to cracks.
2. Maintenance of bearings and expansion joints
3. Maintenance of wearing coat.
4. Maintenance of kerbs, railing etc.
5. Maintenance of weep holes & drainage spouts
6. Maintenance of protective works.

Quarterly maintenance based on detailed inspection shall cover the following items of works and shall be undertaken once in four years:

1. Major repair to piers, abutments, wing walls.
2. Major repairs to guide bunds and bridge protection works.
3. Major repairs to the superstructure such as wearing course, railing, footpath slab, deck slab, girders etc.

In addition to the routine maintenance and quarterly maintenance, another sort of maintenance which may be termed as “Special Repairs” shall be undertaken as and when necessary.