METALLIC BRIDGES
STR403

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Previous lecture – Details

- Curtailment.
- Flange-to-web welds.
- Stiffeners:
  - Horizontal.
  - Vertical.
  - Bearing.

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This Lecture

- Spilces.
  - – Welded.
  - – Bolted.
- Bracing.
  - Deck Bridges.
  - Through Bridges.

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SPLICES

Apart from the simplest of bridges, with relatively short spans, the main girders of bridges are made up of elements connected together in the fabricating shop. Splices are required for fabrication and/or transportation purposes:

- Shop splices (welded).
- Field splices (bolted).

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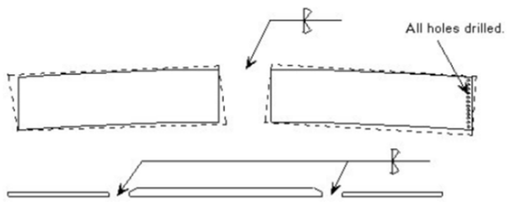
SPLICES

For example, a plate girder is normally fabricated by welding together top and bottom flanges, web plates and stiffeners. Normally, as much of the fabrication as possible is carried out in the fabricating shop



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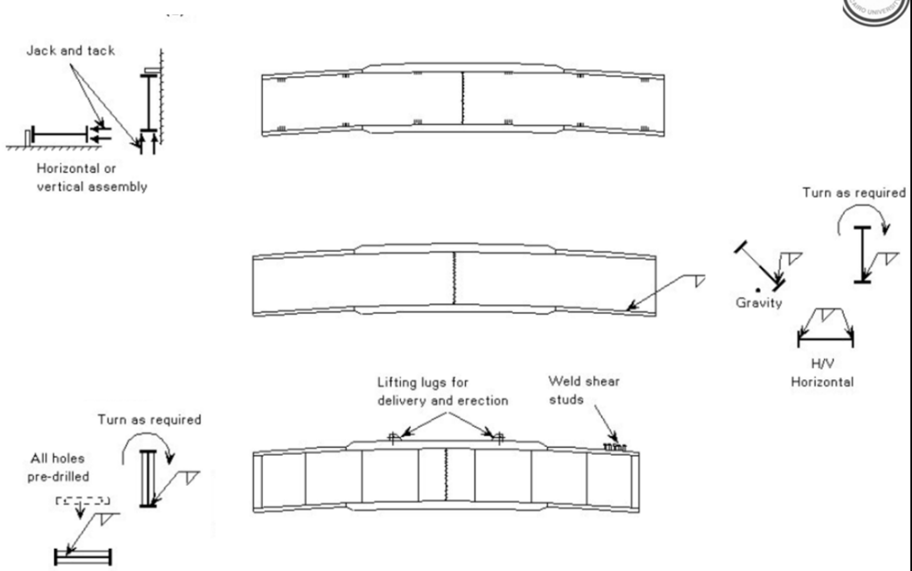
SPLICES



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SPLICES

Splices for girders should be avoided whenever possible. However, there are conditions when splicing of girders is unavoidable. One is the available length of plates and shapes; another is the length limit imposed by the transportation facilities from the fabricating shop to the site of the structure. Occasionally, the capacity of the erecting crane may set the maximum weight of one piece to be handled.

SPLICES

The maximum length of plates obtainable from local mills is 6 meters while the maximum length of rolled shapes is 12 meters. Transportation facilities vary greatly with local conditions. Where good highways lead from the fabricating shop to the site, special arrangement can be made to transport long and heavy pieces. Where direct railroad transportation is used, the length of the pieces is governed by tunnel and bridge clearances, especially on curves.

SPLICES

Sometimes it is a matter of balancing the extra cost of splice against the additional cost of transporting heavier and longer pieces.
The location of splices has a major influence on the economics of the design, fabrication and erection of bridges. In addition, the detailing of splices influences the fatigue and corrosion resistance of a bridge.

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SPLICES

The designer must always, from initial concept through design and analysis to final detailing of the bridge, keep the connections in mind. At all stages he must know where the connections will be, how they will be designed and detailed, how they will be fabricated and when they will be fitted together.

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SPLICES

The relative position and orientation of the elements to be joined can make the difference between a straightforward, effective connection and one that is difficult to design, detail, fabricate and erect. It is for this reason that the connections should be considered at an early stage in the design process.

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TYPES OF SPLICES

There are two basic methods of making splices. ***Welding***, using butt welds or fillet welds, and ***bolting.*** Where the main elements of the splice can be connected together with full strength butt welds, the design is simple and the effect of any loss of section due to the bolt holes does not arise.

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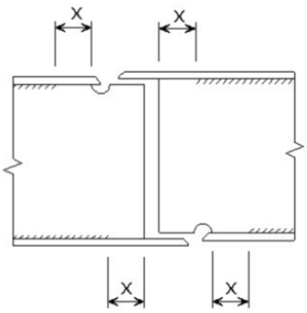
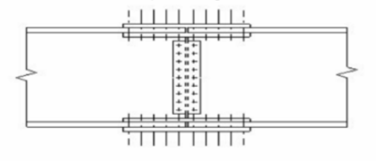
TYPES OF SPLICES





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TYPES OF SPLICES

When making a decision as to whether welding or bolting is to be used, the following are some of the points that should be considered:

- ***Aesthetics***: Butt-welded connections are normally less obtrusive than bolted connections.
- ***Access:*** Adequate and safe access is required for both methods of connection; but protection from wind and rain is also required for satisfactory welding.

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TYPES OF SPLICES

- ***Temporary support*:** The support of the member while the connection is being made has to be considered. This is particularly significant in a welded splice, where the location and alignment of the elements to be spliced must be maintained during welding. This often requires the use of temporary erection cleats and, if these are welded, the effect of the welding needs to be taken into account when making any fatigue checks (even if they are removed after erection).

TYPES OF SPLICES

- ***Corrosion:*** Particular care is required to ensure that the corrosion protection prevents rusting between the plates in a bolted connection and that the weld area is properly cleaned before painting in a welded connection. Both types of connection should then perform adequately as far as resistance to corrosion is concerned.

TYPES OF SPLICES

- ***Details***: Bolted cover plate splices take up additional space, compared with butt welded splices. This could be a problem, for example, where deck plates are fixed to top flanges, when a relatively thin wearing surface is to be applied to the deck plates.
- ***Cost***: The cost of the various options should also be taken into account when making decisions regarding the type and position of connections.

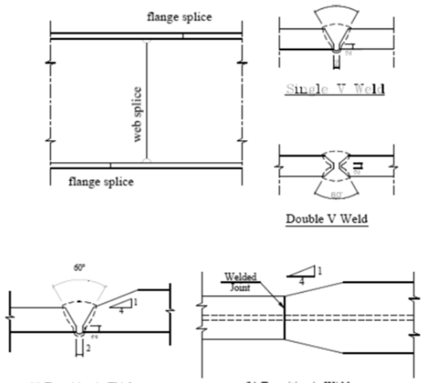
WELDED SPLICES

Welded Splices are usually made in the fabricating shop and therefore are called Shop Splices. The locations of these splices are usually dictated by the available plate lengths. Web and flange plates are usually spliced in the workshop by full penetration butt welds of the V-type. For thicker plates, usually above 20 mm, a double V weld is used to reduce the amount of welding and to balance the welding on both sides and thus eliminating angular distortions.

WELDED SPLICES

In large girders, web and flange plates may be formed of plates of various widths or thicknesses that are butt-welded together along both transverse and longitudinal seams. When plates of different thicknesses are butt-welded, design codes require a uniform transition slope between the offset surfaces not exceeding 1 in 4. If plates of different widths are joined, the wider plate must taper into the narrower plate with the same slope or with a radius of 60 cm,

WELDED SPLICES



(a) Transition in Thickness (b) Transition in Width

WELDED SPLICES

All details of welding procedures should be arranged to minimize distortion and residual stresses. All important welds, particularly field welds, should be inspected by one of the following weld inspection methods:

WELDED SPLICES

Inspection Method	Characteristics and Applications	Limitations
Visual (VT)	Most common, most economical. Particularly good for single pass.	Detects surface imperfections only.
Dye Penetrant (DPT)	Will detect tight cracks, open to surface.	Detects surface imperfections only. Deep weld ripples and scratches may give false indications.
Magnetic Particle (MT)	Will detect surface and subsurface cracks to ~ 2 mm depth with proper magnetization. Indications can be preserved on clear plastic tape.	Requires relatively smooth surface. Careless use of magnetization prods may leave false indications.
Radiographic (RT)	Detects porosity, slag, voids, irregularities, lack of fusion. Film negative is permanent record.	Detects must occupy more than ~ 1.2 % of thickness to register. Only cracks partial to impinging beam register. Radiation hazards.
Ultrasonic (UT)	Detects cracks in any orientation, Slag, lack of fusion, inclusions, lamellar tears, voids. Can detect a favorably oriented planar reflector smaller than 1mm. Regularly calibrate on 1 ½ mm dia. drilled hole. Can scan almost any commercial thickness.	Surface must be smooth, Equipment must be frequently calibrated. Operator must be qualified. Exceedingly coarse grains will give false indications. Certain geometric configurations give false indication of flaws.

BOLTED SPLICES

Splices made in the field are called Field Splices and are usually made using bolts because of the difficulty sometimes encountered in field welding. The location of field splices is usually dictated by length limits imposed by the available transportation facilities, or by weight limits imposed by the capacity of the erecting cranes.

BOLTED SPLICES

Bearing bolts in normal (2mm) clearance holes are not generally used for splices in bridges. In most splices the deformation associated with slip into bearing would be unacceptable. To avoid the slip, fitted bolts, in close tolerance holes, or High Strength Friction Grip (HSFG) bolts are required. Generally HSFG bolts are used, since this avoids the need to match and ream the holes. The pretensioning of the bolts also improves their fatigue life and prevents the nuts working loose due to vibration.

DESIGN OF BOLTED SPLICES

The most straightforward procedure for the design of a splice is to consider the load paths by which the forces are transmitted through the splice. The load paths must be sufficient to carry all the applied forces, moments and shears. The load paths must be complete and in equilibrium, i.e., there must be no weak or missing links. They should be as direct as possible. Splices should be designed to carry the maximum bending resistance of the girder section and the actual shear force at the splice location.

DESIGN OF SPLICES

The following points must be considered in the design and detailing of splices:

1- Care is required to ensure that the worst combinations of moments and forces that can occur at the splices are used for their design. They are not necessarily the moment and forces used for the design of the members. It follows that the moments and forces supplied by a computer program for the design of the members may not be sufficient for the design of the connections.

DESIGN OF SPLICES

2- The centroidal axes of members (and elements of members) should intersect wherever possible. If it is not possible, the effects of any eccentricity should be taken into account in the design.

3- Wherever practicable, the centroidal axis of the splice material should coincide with the centroidal axis of the elements joined. If this is not possible, the effect of any eccentricity should be considered in the design.

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DESIGN OF SPLICES

4- When a section changes at a splice location, the smaller section should be used in calculations.

5- Avoid severe stress concentrations. This is particularly important where fatigue could be a problem.

6- When friction type bolts are to be used, adequate clearances must be provided to allow the use of suitable tightening tools.

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DESIGN OF SPLICES

7- When shims or packs are needed, for example, where there is a change of flange plate thickness, it is essential that the surfaces of the packs or shims comply with the requirements assumed for the faying surfaces in the design.

DESIGN OF SPLICES

8- When the bridge girder is continuous, the splices are usually positioned near to where the inflection point (zero moment) would be if the bridge were subjected to uniform loading. The maximum moment (and shear) that the splice can be subjected to under the possible loading patterns must be determined.

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DESIGN OF BOLTED SPLICES

The girder web transmits primarily shearing stresses, and web splices are most efficiently located at points of small shear, although practical requirements may dictate otherwise. In general, the shear force to be spliced in the web is much smaller than the shear capacity of the web. Most bolted web splices, except those for very heavy girders, are controlled by minimum dimension requirements rather than stress computations.

DESIGN OF BOLTED SPLICES

For example, two splice plates are usually employed one on each side of the web; the splice plates must have not less than the minimum thickness; and must be extended. the entire depth of the girder from flange to flange. In all cases the net section through the splice plates must provide the required area to resist the shear and the required section modulus to resist the bending moment safely.

BOLTED WEB SPLICES

When a web splice is to transmit a pure shear **Q** (without any moment at the splice location), the bolts should be designed to resist a force **Q** applied at the centroid of the bolt group. This means that the bolts should be designed to transmit load **Q**, with an eccentricity ***e***. When the depth d of the web is much greater than the eccentricity ***e***, the design is often made for a direct shear **Q**, neglecting the eccentricity. In this case for a given bolt diameter, the bolt resistance ***R*** is known, and the required number of bolts is simply **Q/*R***.

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BOLTED WEB SPLICES

If, In addition to shear **Q**, there is a moment ***M*** at the splice section, then the portion of the total moment carried by the web must be transmitted by the web splice. This moment, M_w, is obtained as: $M_w = M I_w / I_g$, where I_w and I_g = net moments of inertia of web and girder, respectively.
The splice is then designed to resist a shear force **Q** plus a bending moment $M_s = Q * e + M_w$. A check is then made of the resulting force in the extreme bolt and the bending stress in the splice plate.

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BOLTED FLANGE SPLICES

Bolt Design:

Flange splice moment =

M_f **= M – M_w**

Flange couple C **= T = M_f /d**

Number of splice bolts = **T** / **R_{least}**

where **R_{least}** is the bolt resistance.

Splice Plate Design:

The net section of the splice plates is designed to carry the flange force T.

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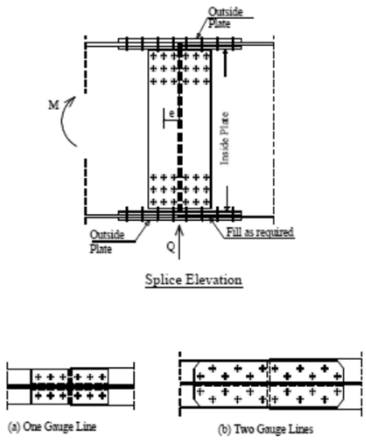
BOLTED FLANGE SPLICES



Splice Elevation

Flange Splice

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BRIDGE BRACING

A bridge is actually a ***space structure*** that not only carries the vertical gravity loads to the supporting piers and abutments, but also resists:

a) Transversal loads caused by wind, seismic and centrifugal loads,
b) Longitudinal loads caused by braking and thermal effects.

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BRIDGE BRACING

The analysis and design of the bridge is usually simplified by breaking it down into planar and linear components, such as stringers, cross girders, main girders and bracing systems. The effect of vertical loads on bridge elements has been presented in the preceding sections. In this section, the effect of transversal loads due to wind on bridge elements is presented.

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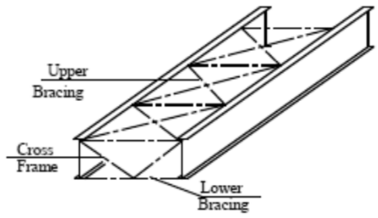
WIND LOAD TRANSFER

The horizontal wind pressure on the bridge is assumed to be transmitted to the bridge supports using suitable systems of bracings. In general it may consist of Upper, Lower, and Transversal bracing. The wind load is assumed to be carried to the bridge supports as follows:



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DECK BRIDGES

a) The wind load on the upper half of the web of the exterior girder as well as that on the live load on the bridge is assumed to be carried by a horizontal bracing truss in the plane of the top flange to the span ends. The flanges serve as the chords of the lateral bracing truss, and are connected together by the cross girders plus a system of diagonal members. The diagonal members may be single or double diagonals, or may be of the K- type.

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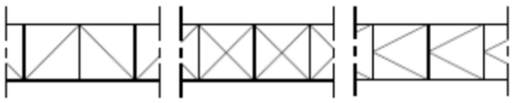
DECK BRIDGES

In a deck bridge provided with a deck slab, the slab may be assumed to act as a horizontal diaphragm transmitting wind loads to the span ends. In this case the bracing truss is needed only temporarily during erection before the slab hardens.



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DECK BRIDGES

b) The wind load on the lower half of the web of the exterior girder of a deck bridge is usually much smaller in value than that on the top flange (being the unloaded chord) and thus may not need a complete lateral truss. Instead, wind load on the bottom flange may be transmitted to the upper plane using:

a) intermediate cross frames,

b) intermediate inverted U-frames, or

c) intermediate diaphragms.

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DECK BRIDGES

Fig. 5.41 Cross Bracing for Deck Bridges - Intermediate Cross frames

Fig. 5.42 Cross Bracing for Deck Bridges - Intermediate U- frames

Fig. 5.43 Cross Bracing for Deck Bridges - Intermediate Diaphragms

DECK BRIDGES

In addition, these intermediate systems facilitate erection and serve also to brace the compression flange of the girder. According to ECP 2001, lateral bracing of the compression flange of deck girders should be designed for a transverse shear in any panel equal to 2.0 % of the total axial stress in the flange in that panel, in addition to the shear from specified lateral forces.

DECK BRIDGES

Intermediate cross frames and diaphragms should be spaced at intervals up to 8 meters. They should be placed in all bays. Cross frames should be as deep as practicable. The angle of cross frame diagonals with the vertical should not exceed 60 degrees.
In order to transmit the end reactions of upper bracings to the bridge supports, end cross frames are provided at the bridge ends and over interior supports.

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THROUGH BRIDGES

Neither cross bracings nor top lateral bracing can be used in most cases of through plate girder bridges. Furthermore, the top flange is subjected to compression in regions of positive moments and therefore must be braced to prevent its lateral buckling. Lateral bracings are normally located near the bottom flanges. These flanges thus also serve as the chords of the lateral bracing truss, and are connected together by the floor beams plus a system of diagonals.

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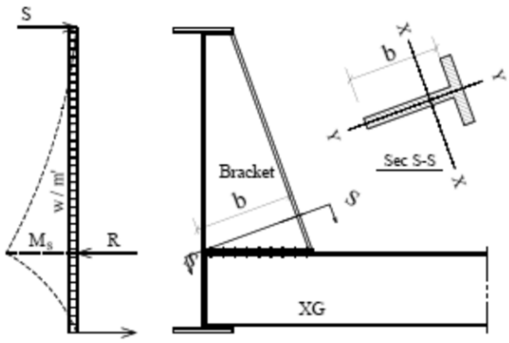
THROUGH BRIDGES

In such regions, the top compression flange should be stiffened against lateral deformation with solid web ***knee brackets.*** The brackets should be attached securely to the top flanges of the bridge cross girders and to stiffeners on the main girders. They should be as wide as clearance permits and should be extended to the top flange of the main girder.

DECK BRIDGES

These knee brackets are designed to carry the share of wind loads on the bridge main girder and the moving live load (truck or train). When the bracket is also used to support the compression flange against lateral torsional buckling, it should be designed to carry additionally a stability force that is equal to 2 % of the flange compression force

DECK BRIDGES



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Summary

- Spilces.
  – Welded.
  – Bolted.
- Bracing.
  - Deck Bridges.
  - Through Bridges.

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