Drafting and Design Presentation Standards
Volume 3: Structural Drafting Standards

Chapter 10: Bridge Geometry

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Queensland Government

Feedback: Please send your feedback regarding this document to: tmr.techdocs@tmr.qld.gov.au

Chapter 10 Amendments

Revision register

Issue/Rev No.	Reference Section	Description of Revision	Authorised by	Date
1	-	First Issue	Manager (Structural Drafting)	Apr 2011
2	-	Document name change	Manager (Structural Drafting)	Nov 2011
	10.10	Add section Road Design Considerations with Respect to Low-Level Frequently Flooded Bridges		
	10.11	Edit section Road Design Considerations with Respect to Rarely Flooded Bridges		
3	10.9	Reference to section 7.7.3 added for ease of use.	Team Leader (Structural Drafting)	Feb 2016
	10.10	Grammatical changes. Recommend skew to 30° to suit published standards.		
	10.12	New section - Summary of geometric layout.		
	10.13	Section number changed from 10.12 to 10.13. Outdated reference to Road Planning Updates removed		

Contents

10 Bridge Geometry

10.1 Glossary of terms

For a complete glossary of terms refer Chapter 1 - *Introduction*.

10.2 Figures and examples shown in this volume

The figures and examples shown in this volume are for presentation purposes only, and may contain some details that are now superseded. These details have been included for ease of reference, to illustrate typical solutions, and to show the required standard of drafting presentation. The details are not to be used without an engineering check and certification by a Structural RPEQ to confirm that the details are appropriate for the specific project.

10.3 General

Bridge geometry can be divided into two broad areas, horizontal alignment and vertical alignment.

Horizontal Alignment

Layout of the bridge as viewed in plan. It provides a corridor or laneway that covers the full pavement width of the road.

Vertical Alignment

Profile of the bridge as viewed in elevation. It conforms to the grading and the cross sectional profile of the road.

10.4 Orientation of bridge control to horizontal alignment

The Bridge Control line is the principal line of reference used throughout bridge drawings. The procedure for fitting a bridge to a horizontal curve should consider how best to orientate the Bridge Control to the Road Control.

This is achieved by applying the following guidelines:

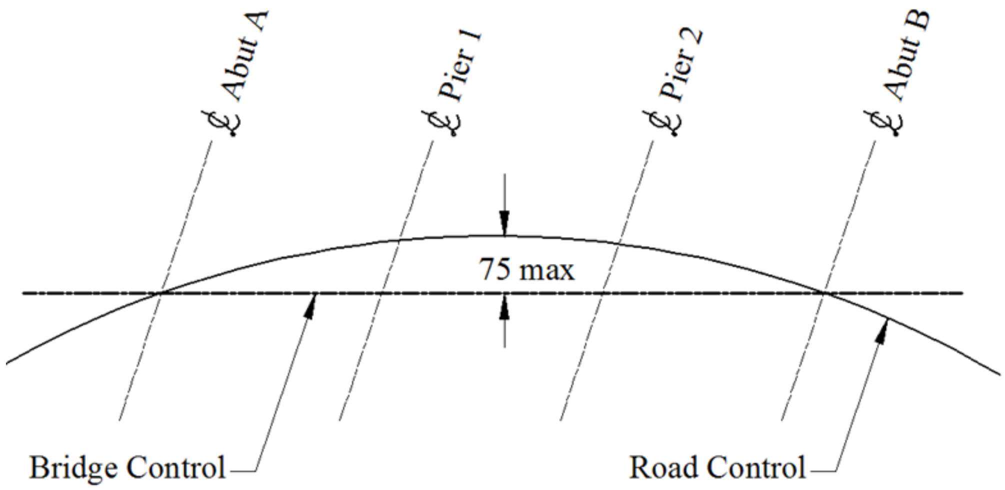
STEP 1 - Consider if it is possible to locate the bridge on a straight line, even though the Road Control is curved. This approach simplifies the laying out of the bridge

The limiting factor in being able to apply this approach is the maximum permissible offset from the straight Bridge Control to the curved Road Control which is 75 mm.

There are two ways of applying this 75 mm offset and they are shown in Figure 10.4-1 - Bridge Offset 75 mm Maximum and Figure 10.4-2 - Bridge Offset 150 mm Maximum.

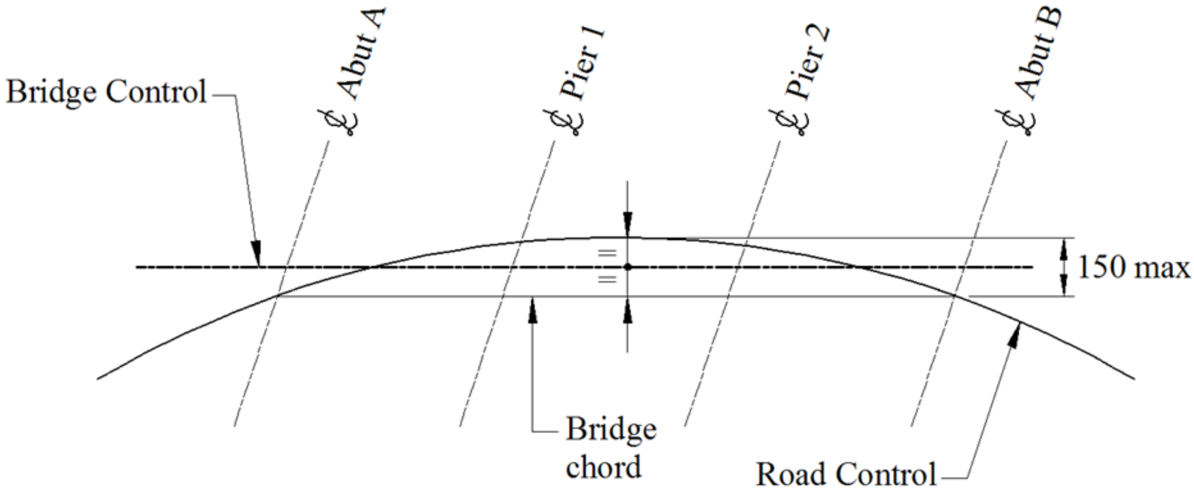
Figure 10.4-1 - Bridge Offset 75 mm Maximum

Bridge offset is less than or equals 75 mm



Bridge offset from the chord to the Road Control is greater than 75 mm but less than 150 mm

Figure 10.4-2 - Bridge Offset 150 mm Maximum



STEP 2 - If the combination of small radius curve and length of bridge makes it impossible to maintain a straight bridge alignment, then it is necessary to locate the bridge around the curve with each span set out as a parallelogram. Refer Figure 10.4-3 - Span Offset 75 mm Maximum and Figure 10.4-4 - Span Offset 150 mm Maximum.

Figure 10.4-3 - Span Offset 75 mm Maximum

Bridge offset is greater than 150 mm and span offset is less than 75 mm

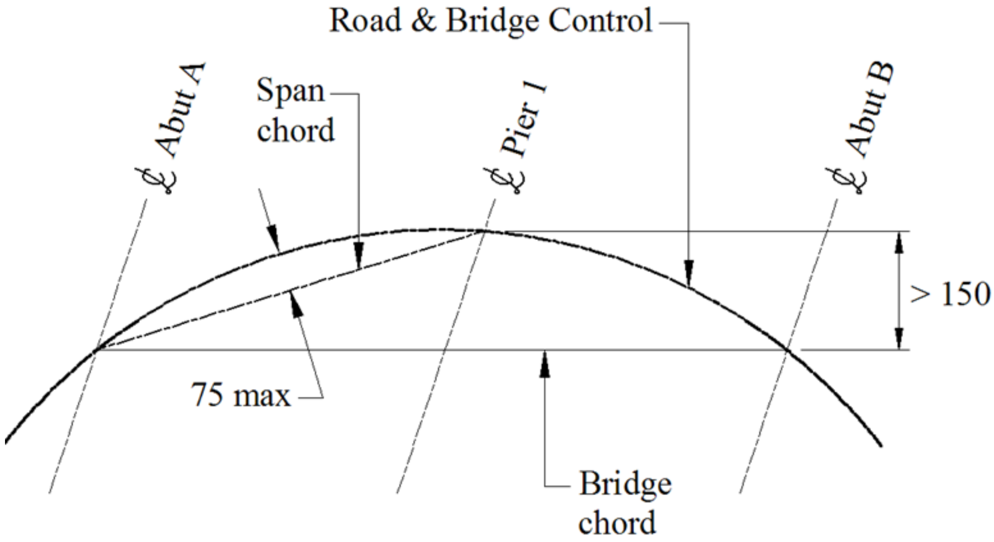
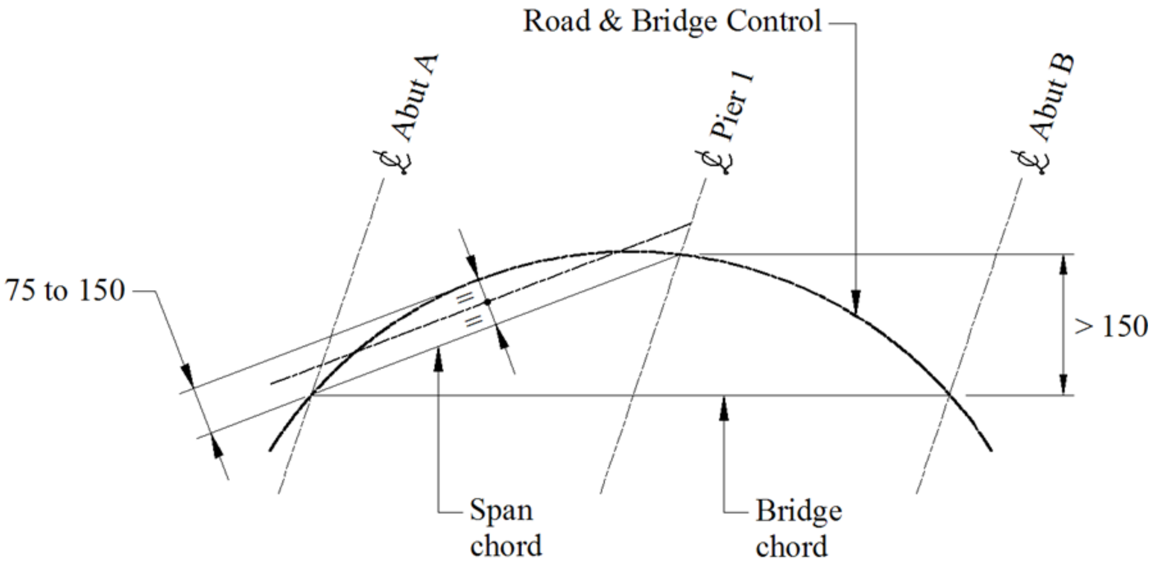


Figure 10.4-4 - Span Offset 150 mm Maximum

If the span offset from the span chord to Road Control is greater than 75 mm and less than 150 mm



10.5 PSC deck units on small radius curves

General setting out

The general setting out of deck unit bridges on curves has been covered in Section 10.4 – *Orientation of Bridge Control to Horizontal Alignment*. This section deals with deck unit bridges around small radius curves where a combination of factors such as the amount of skew, tightness of curve, or length of bridge precludes the use of simple parallelograms.

Special geometry required for bridges around small radius curves is dependent on several criteria, but basically a bridge can be set out in a series of parallelograms from the chords until the gaps between the units exceed 30 mm in width.

Every endeavour should be made to use parallelograms, but in the event of that system not working then the following system should be used.

When looking at a curved bridge, it will be noticed that, if parallelograms where used, the bridge would increase in width in a particular direction depending on the orientation of the curve and direction of the skew. Therefore the geometric calculations must commence from the narrowest end.

After setting the span lengths along the Road Control, the commencing span is set up as a parallelogram. For the next span, two parallel lines are set either side of the chord for that span, representing the inside face of the cast insitu kerb or the outer edge of the outer deck unit. These lines are then intersected by an arc (with a radius equal to the span length) centred at the intersection of the pier centreline and the edge line for the preceding spans. The connection of these points creates the centreline of the next pier. Figure 10.5-1 - PSC Deck Unit Bridges on Small Radius Curves and the procedure explained below assists with the previous explanation.

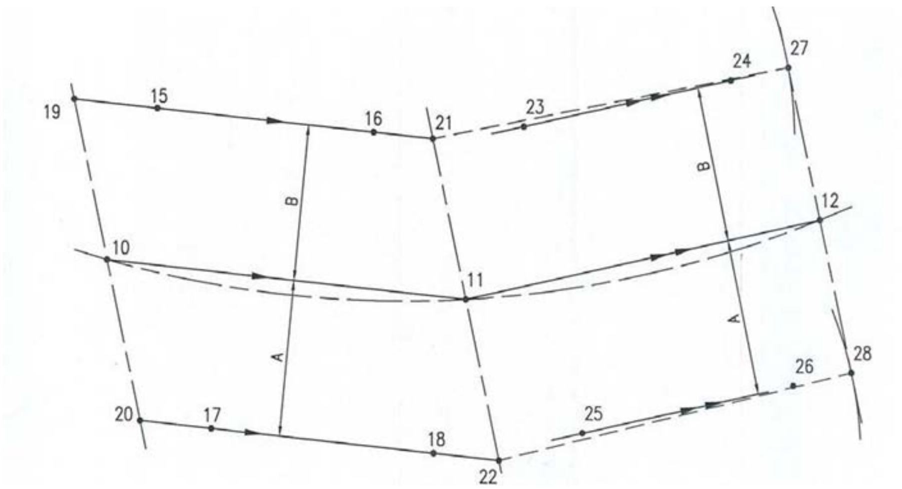
It will be noted that this pier centreline is no longer parallel to the previous pier or abutment centreline as the skew is slightly increased. Due to this effect the commencing skew angle must allow the designed bridge skew to be correct (±1º) at the heaviest flow section of the waterway. The same procedure is then repeated for each successive span.

Procedure

Refer Figure 10.5-1 - PSC Deck Unit Bridges on Small Radius Curves.

- set up both the horizontal alignment and vertical alignment
- locate the abutment and pier positions along the alignment (points 10 to 12)
- at the commencement end, set up parallel lines, either side of the chord, representing the bridge edge (inside face of the cast insitu kerb or the outer edge of the outer deck unit) (points 15 to 18)
- find the intersection of these lines with the centrelines of the abutments and piers (points 19 to 22)
- set up parallel lines in the second span to the same width as before (points 23 to 26)
- intersect these lines with arcs (with a radius equal to the span length) centred at points on the pier (points 21 and 22)
- join these points (27 and 28). Thus determining the bearing of the next pier
- repeat steps five, six and seven for the remainder of the bridge.

Figure 10.5-1 - PSC Deck Unit Bridges on Small Radius Curves



10.6 Layout of reinforced concrete deck bridges

PSC deck unit bridges

As skew angles increase, span lengths increase, and the number of spans increase, it becomes increasingly difficult to achieve a layout which accommodates the use of transverse stressing bars in deck unit bridges on a horizontal curve. When slotted holes longer than 100 mm x 70 mm are required for the passage of stressing bars due to saw toothing of the deck units, the option of using a reinforced concrete deck on deck unit design should be investigated.

The advantage of this system is that there is no requirement for allowance of stressing bars, no mortar between the deck units, and the layout of the deck units is not tied to the line of each span (to create the line of the kerb).

The maximum overhang from the outside of the outer deck unit to the outside face of the kerb should be approximately 500 mm. Refer Chapter 17 – *Cast Insitu Kerbs and Decks*, Section 17.6 – *Deck Overhang*.

Girder bridges (Super T-girders)

When detailing a reinforced concrete deck bridge on a horizontal curve, first preference should be given to locating girders parallel in each span. This will simplify detailing and subsequent construction of the cross girders and the PSC girders.

Care should be exercised in locating the intersection of girder centre lines and abutment and pier centre lines in order that:

- A maximum cantilever of 1.25 m from centre line of girder to outside face of the girder flange is maintained. Refer Chapter 14 – *Prestressed Concrete Girders,* Section 14.5 – *Girder Profiles*.
- If deck drainage is required, enough width must be provided in the outer most girder flange to fit scuppers and a drainage pipe.
- When factors of skew, span length and tightness of horizontal curve make the above parameters unattainable, then girders should be splayed, i.e. spacing of girders would vary from one end of span to the other end.

- Maintain constant length of girders where possible.

10.7 Encroachment of wing tip into traffic lane

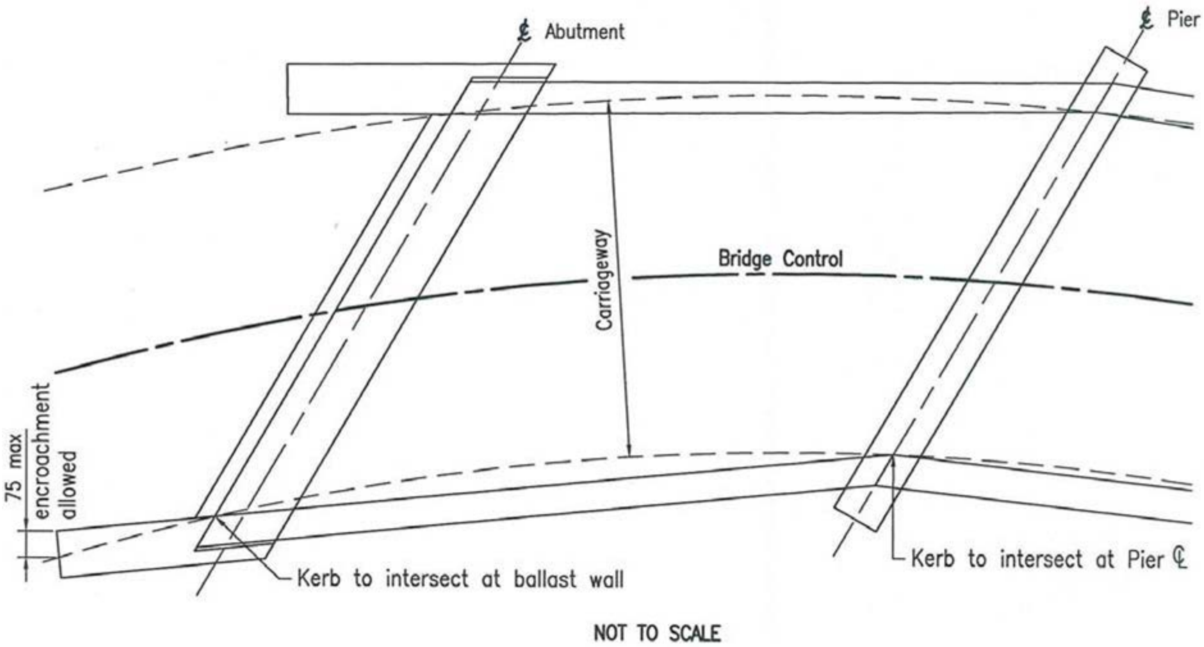
PSC deck unit bridges – without a reinforced concrete deck

On small radius curves and when spans are located around the curve, a check should be made to ensure that the end of the wing walls, which usually assume the line of the kerbs on the adjacent span, do not project more than 75 mm into the traffic lane.

If this is the case, the wingwalls are to be set parallel to a chord line running from the start of the abutment wing (at the ballast wall) to the end of the wingwall.

It should be noted that the bridge traffic rails will need to be kinked at the abutments and piers to accommodate this change. Refer Figure 10.7-1-Wing Encroachment.

Figure 10.7-1 - Wing Encroachment



10.8 Vertical alignment

Vertical Curves

Vertical curves come in two forms:

- Crest VC - the grade decreases in the direction of progressive chainage.
  Refer Figure 10.8-1 – Crest VC Details.
- Sag VC - the grade increases in the direction of progressive chainage.

Refer Figure 10.8 – Sag VC Details.

It is important to note that vertical curves as applied to TMR vertical geometry are parabolic curves and not pure circular curves. The fact that vertical curves are denoted on working drawings as having a particular radius, can create some confusion to designers. It should be noted that, in fact, a radius calculated for a vertical curve is only a nominal radius which applies at that part of the parabola which very closely resembles a pure circular curve.

Vertical Alignment

With regard to positioning a bridge in a longitudinal vertical plane, it can be accepted that the bridge will follow the vertical alignment of the Road Control. This may result in the bridge being on a straight or curved grade, or in some cases a combination of both.

Figure 10.8-1 – Crest VC Details

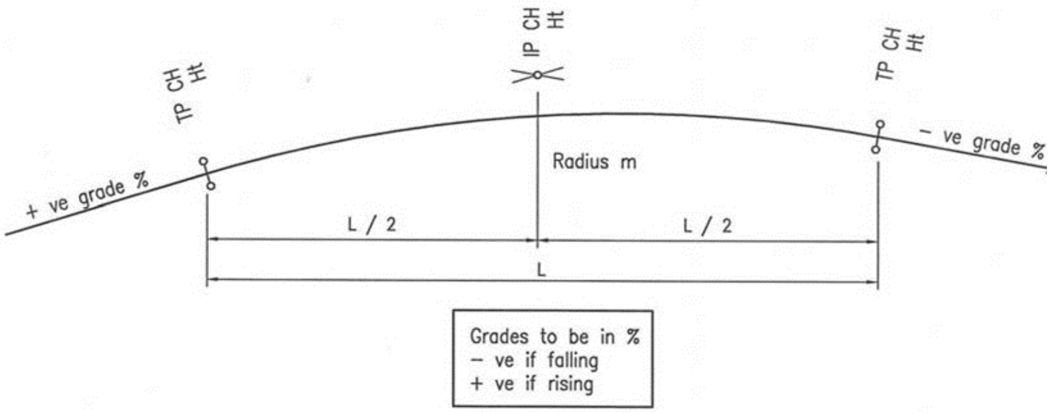
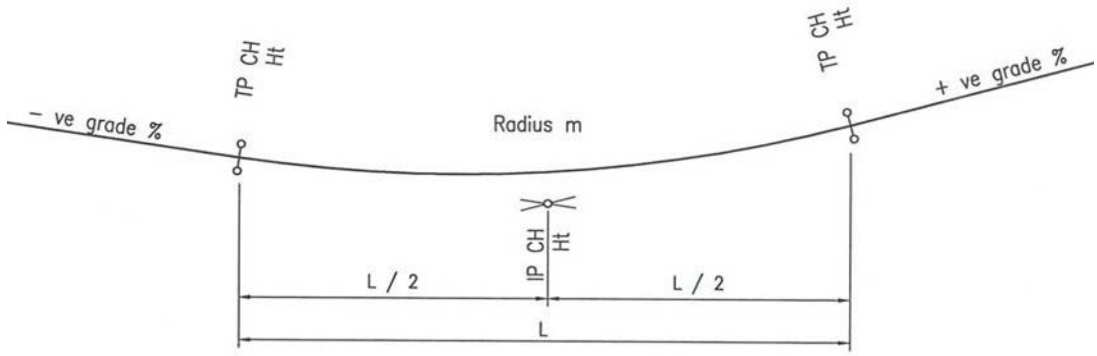


Figure 10.8-2 – Sag VC Details



10.9 Bridge crossfall

The crossfall / superelevation and alignment of a bridge is usually provided by a road designer. It should comply with *Road Planning and Design Manual*, Table 7.16 (in section 7.7.3) as duplicated in Table 10.9-1 - Typical Pavement Crossfalls.

Table 10.9-1 - Typical Pavement Crossfalls

Road Surface	Traffic Lane (%)	Shoulder (%)
Cement Concrete	2.0-3.0	2.0-4.0
Asphalt Concrete	2.5-3.0	2.5-4.0
Sprayed Seal	3.0-4.0	3.0-4.0
Unsealed	3.5-4.0	4.0-5.0
Within Floodway's	1.0-2.0	1.0-2.0

There are many controls in urban areas which force departures from the above values. For further explanation refer to the *TMR Road Planning and Design Manual*, 7.7.3 – *Road Crossfall*.

There may be good reasons why there is a deviation from the values, such as the following example:

- The bridge surface of a widened bridge may also need to be flatter than the TMR *Road Planning and Design Manual* specifies to reduce the amount of dead load caused by the additional DWS. Older bridges were not designed to carry the same loads that modern bridges are.

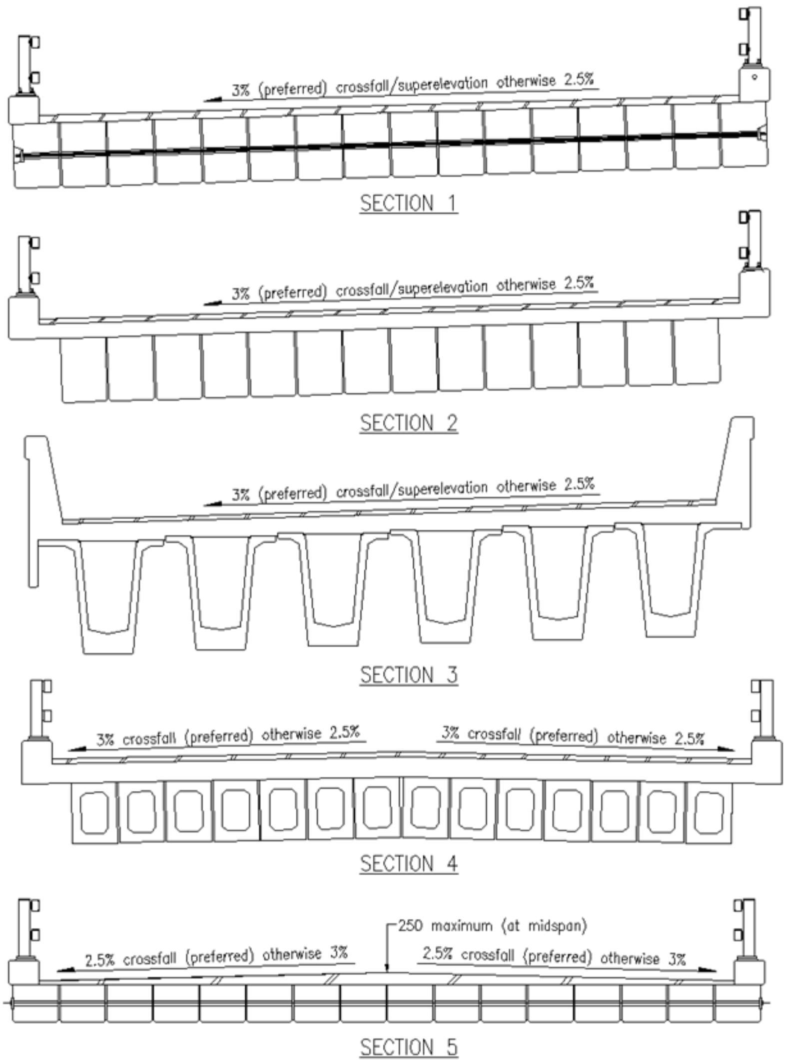
The maximum crossfall for a footpath is 2.5%, though two per cent is preferred.

Three per cent is the preferred bridge crossfall so that water runs off the road surface as quickly as possible. Refer to Sections 1 to 4 in Figure 10.9-2 - Bridge Crossfall / Superelevation.

Three per cent crossfall suits bridges where the DWS is a constant thickness, for example, bridges with a deck or bridges that are superelevated.

2.5% is the preferred crossfall for bridges with a crown and without a deck. Refer to Section 5 in Figure 10.9-2 - Bridge Crossfall / Superelevation. 2.5% crossfall is used to reduce the depth of DWS at the crown. This will reduce dead load and rutting in the road surface. The depth of DWS must not exceed 250 mm anywhere along the span. For very wide bridges a deck may be needed to prevent the DWS being too deep. Refer to Section 4 in Figure 10.9-2 - Bridge Crossfall / Superelevation.

Figure 10.9-2 - Bridge Crossfall / Superelevation



Deck wearing surface

On deck unit bridges the thickness of DWS is varied to achieve the nominated profile of the road and to account for the hog of the deck units.

On bridges with a reinforced concrete deck, the DWS is a constant thickness because the deck accounts for the hog of the deck units and any changes in crossfall / superelevation. Refer Chapter 7 – *Deck Wearing Surface*.

10.10 Road design considerations with respect to low-level frequently flooded bridges

For the purpose of this document, a bridge is considered to be low-level and frequently flooded when its superstructure may be partially or fully submerged by a flood smaller in magnitude than a 20 year average recurrence interval (ARI).

When planning a road alignment, the road designer should work closely with hydraulic and structural engineers to determine the best design. Every bridge shall be accessed individually, however the following general guidelines may assist in reducing construction costs and simplify the design, drafting, and construction of a bridge:

Crossfall/Superelevation:

- The bridge deck should be designed with a two way crossfall. There are advantages and disadvantages when the deck is superelevated (see below), and therefore a two way crossfall is the best compromise.
- A superelevated deck falling to the upstream side will tend to be covered in debris and silt after the flood water subsides. It will however, be safer to drive on, as there is less chance of the vehicle being pushed downstream by the force of the water.
- A superelevated deck falling to the downstream side may trap debris underneath the deck. It will also be subjected to greater uplift forces. The deck however, should be relatively clean after the flood water subsides.
- Constant crossfall / superelevation is preferred.
- Varying crossfall / superelevation can be accommodated but should be avoided.

Vertical alignment:

- The deck should be level so that the deck acts as a weir when flood water over-tops it. If the bridge is on a grade or a VC, the flood water will be directed to the low end of the bridge. This may drastically alter the pattern and turbulence of flow and lead to scour and erosion problems at the low end of the bridge.
- Additionally, the deck should be level so that motorists crossing a flooded bridge do not encounter an unexpected increase in water depth.
- If extenuating circumstances prevent a level bridge, a small constant grade is preferred.
- Generally a VC is not preferred on bridge, however sometimes they can assist with draining the deck when stormwater is not allowed to drain directly from the bridge deck into the stream. This is achieved by putting the crest of the VC near the middle of the bridge, and draining the water towards each abutment. Doing this may mean that a drainage system is not required.
- A combination of any of the above can be accommodated but should be avoided.

Horizontal alignment and skew:

- Where possible, the alignment should be designed to minimise the length and skew of the bridge. This may be achieved by traversing the watercourse as square as possible to the direction of the flood flow. A bridge on a HC, or a bridge not square to the flow, may direct water towards the downstream abutment. This may drastically alter the pattern and turbulence of flow and lead to scour and erosion problems around this embankment.
- A bridge crossing a stream is usually skewed so that the abutments and piers are parallel to the flood-water flow.
- Skews should be minimised where possible to be 30° or less to simplify girder and unit design. (published PSC Deck Units are limited to 30°)
- Varying skew can be accommodated to suit horizontal curves but should be avoided where possible.

10.11 Road design considerations with respect to rarely flooded bridges

For the purpose of this document, a bridge is considered to be rarely flooded when its superstructure is not submerged by a flood smaller in magnitude than a 20 year average recurrence interval (ARI).

When planning a road alignment, the road designer should work closely with hydraulic and structural engineers to determine the best design. Every bridge shall be assessed individually, however the following general guidelines may assist in reducing construction costs and simplify the design, drafting, and construction of a bridge:

Crossfall / Superelevation:

- Constant crossfall / superelevation is preferred.
- Varying crossfall / superelevation can be accommodated but should be avoided.

Vertical alignment:

- A bridge with a level deck is the easiest to draw, however a bridge on a slight grade improves the drainage of the bridge deck. Therefore, all bridges should be on a minimum grade of 0.3% if this can be easily accommodated by the approach road works at both ends of the bridge.
- Generally a VC is not preferred on bridge, however sometimes a VC can assist with draining the deck when stormwater is not allowed to drain directly from the bridge deck into the stream. This is achieved by putting the crest of the VC near the middle of the bridge, and draining the water towards each abutment. Doing this may mean that a drainage system is not required.
- A combination of any of the above can be accommodated but should be avoided.

Horizontal alignment and skew:

- The bridge should be straight and aligned as square as possible to the direction of the flood-water flow. This will reduce skew and length of the bridge.
- A HC is the next preferred option.
- A combination of any of these can be accommodated but should be avoided.
- A bridge crossing a stream is usually skewed so that the abutments and piers are parallel to the flood-water flow.

- If the bridge needs to be skewed, try and limit it to 30° to suit standard precast beams
- Varying skew can be accommodated but should be avoided.

10.12 Summary of alignment design and bridge layout aims

Road alignment design should consider the impacts of the alignment on the bridge structures. The combined effects of horizontal curve / vertical curve / skew / grade / superelevation can complicate the geometric layout of a structure significantly especially when considering bearing and unit / girder geometry and placement – where possible design alignments should seek to eliminate at least one or two or if practical most of these of these alignment features.

The desired outcomes of an optimised alignment and bridge layout are:

- First pass when deciding on the bridge layout is to attempt to use a straight bridge for a curved design alignment, the constraints being no part of the bridge kerbs and wings is to deviate from curved alignment by more than 75 mm
- Simplify the design alignment where available to reduce skew, horizontal and vertical curves, superelevation and grade
- Skews on structures at 30° or less – this allows use of TMR standard drawings as a basis for RPEQ certified project specific PSC unit drawings
- Minimised curves allowing the use of transverse stressing units which may negate the need for cast insitu decks (span lengths or durability may mandate cast insitu deck)
- For curved bridges a cast insitu deck may be required to overcome fitment issues with transverse stressing bars – designer to check using a layout diagram
- Rationalisation of precast products such as deck units (length and skew)
  - Attempt to use average skew across neighbouring spans to minimise variation in girders / units on multiple span bridges with curves (for example, a 6 span bridge may utilise 3 distinct skews averaged across spans 1&2, 3&4, 5&6 to reduce unit variations)
  - Use standard length units to match published standard drawings
  - Rationalise unit lengths around curves where practical (geometry may require units to be fanned so that gaps increase to accommodate same length units)
- Overhang of cast insitu deck on curved decks to be managed to meet identified design limitations (for example, 500 max 100 min overhang – design engineer to inform)
- Vertical geometry needs to be assessed for effects on girder and unit ends. Ends of precast products need to be calculated to be vertical when placed on the grade (sloped when cast). (Nominal end clearance of 50 mm is required between girders / units / ballast walls at abutments and piers – it is recommended the designer draft a scaled elevation of the superstructure and substructure to ensure clearance is achieved)
- Consideration of the location of the top and bottom faces of units on grade / crossfall / superelevation needs to be addressed to ensure correct placement of formed holes and adequate clearances to end walls and ballast walls at the abutments. It is recommended a layout drawing be drafted to validate formed hole locations and clearances, unit lengths, stressing bar fitment etc. For complex geometry a 3d drawing may be required.

10.13 Bridge width

For minimum design requirements regarding bridge widths, refer TMR *Bridge Design Criteria for Bridges and other Structures*. These requirements override AS 5100 - *Bridge Design* and the TMR *Road Planning and Design Manual*.