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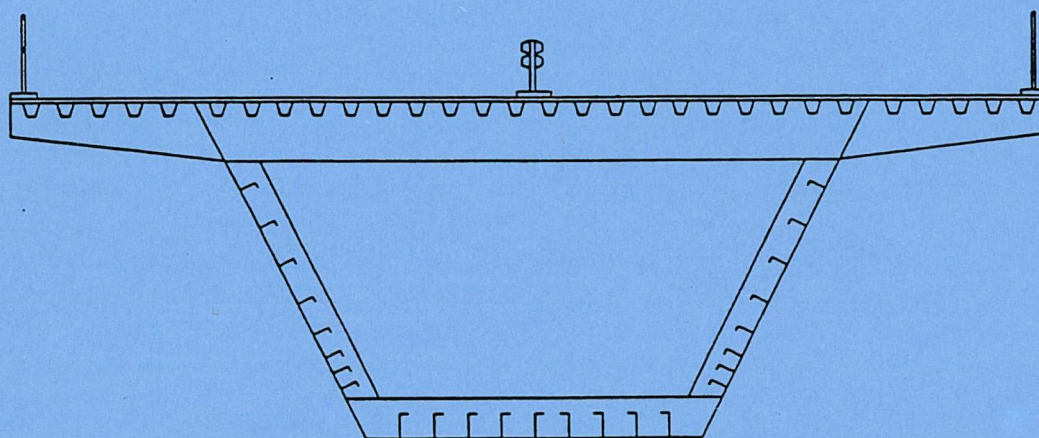
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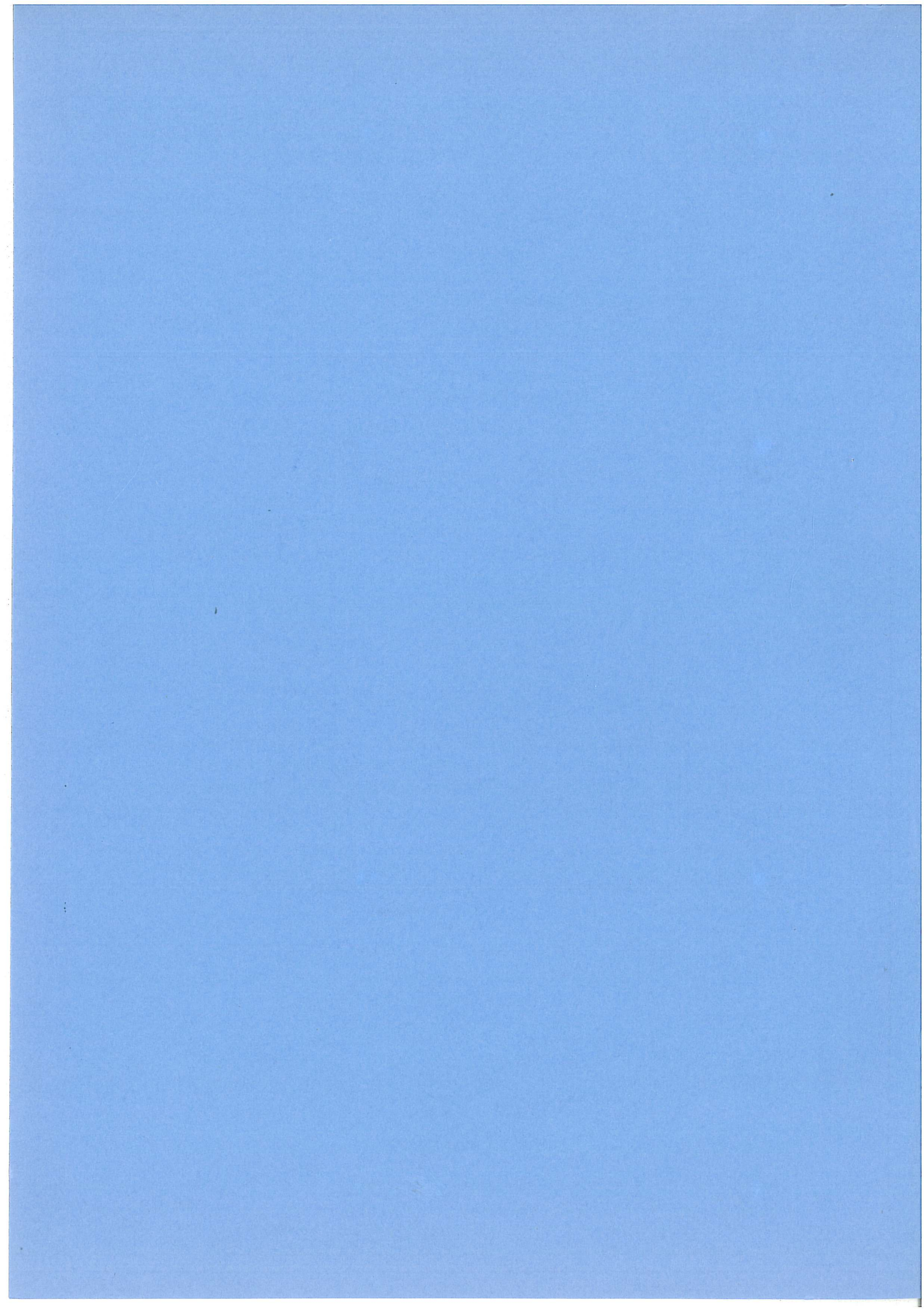
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FIGURHÆFTE

STORE STÅLBROER - Bjælkebroer samt skråstags- og hængebroer
ESDEP-UDDRAG v/A. ALBERTSEN
AUGUST 1994

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Dette hæfte knytter sig til NOTE U9407, der er et teksthæfte med samme titel.

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- 15B.2 Actions on Bridges
- 15B.3 Bridge Decks
- 15B.4 Plate Girder and Beam Design
- 15B.5 Truss Bridges
- 15B.6 Box Girder Bridges
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- 15B.9 Suspension Bridges
- 15B.10 Bridge Equipment

- 8.5.1 Design of Box Girder Bridges
- 8.5.2 Advanced Methods for Box Girder Bridges

LECTURE 15B.1

Conceptual Choice

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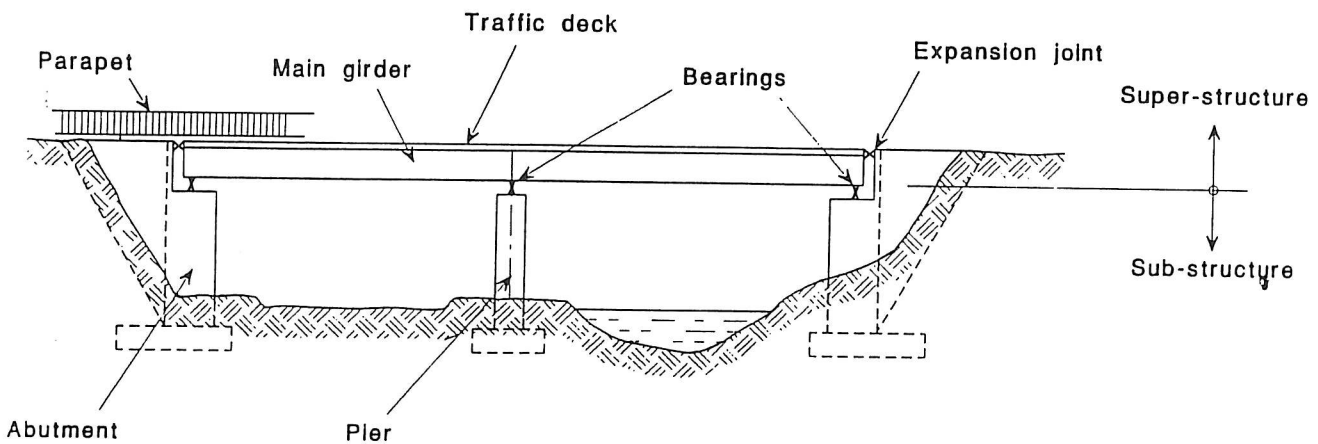
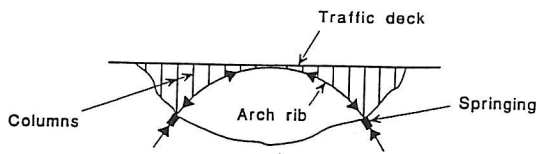
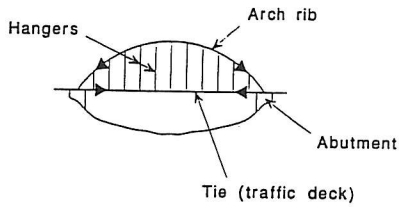


Figure 1 Elevation of typical girder bridge

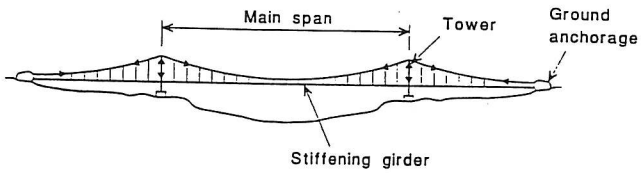




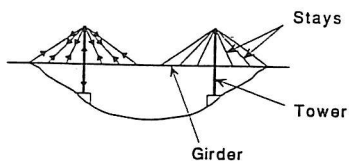
(a) Fixed arch bridge



(b) Tied arch bridge



(c) Suspension bridge



(d) Cable-stayed bridge

Figure 2 Types of bridge that carry load mainly by axial forces.



Lecture 15B.1



Lecture 15B.1

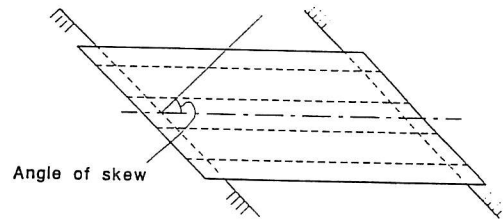


Figure 3 Typical plan view of skew bridge

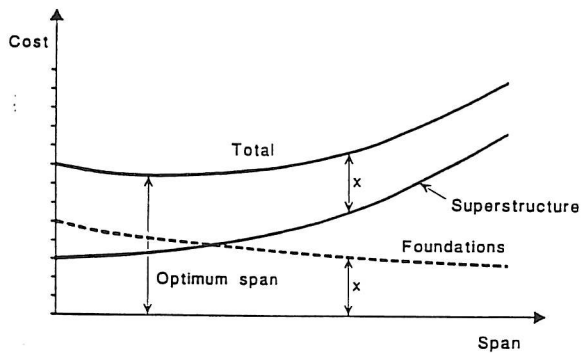


Figure 4 Bridge costs (diagrammatic)

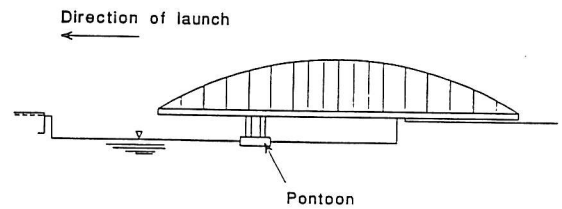


Figure 5 Typical launching arrangement using pontoon



Lecture 15B 1



Lecture 15B 1

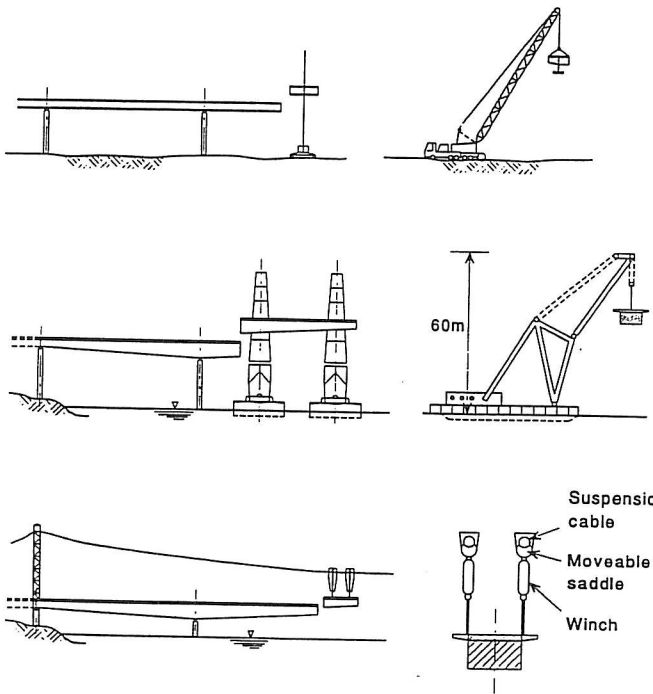
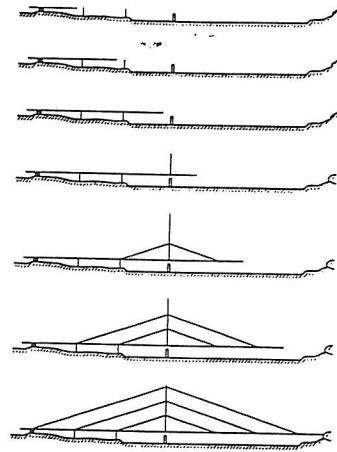


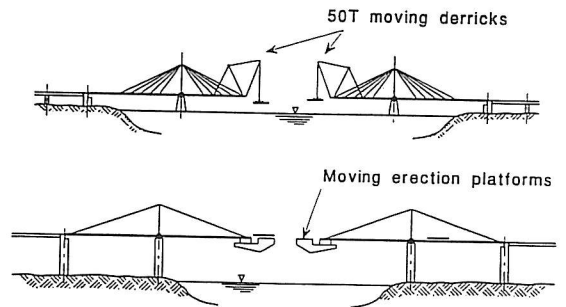
Figure 6 Typical methods of lifting bridge sections



Lecture 15B.1



(a) Overall scheme



(b) Options for positioning segments

Figure 7 Typical cantilever erection of a cable-stayed bridge.



Lecture 15B.1

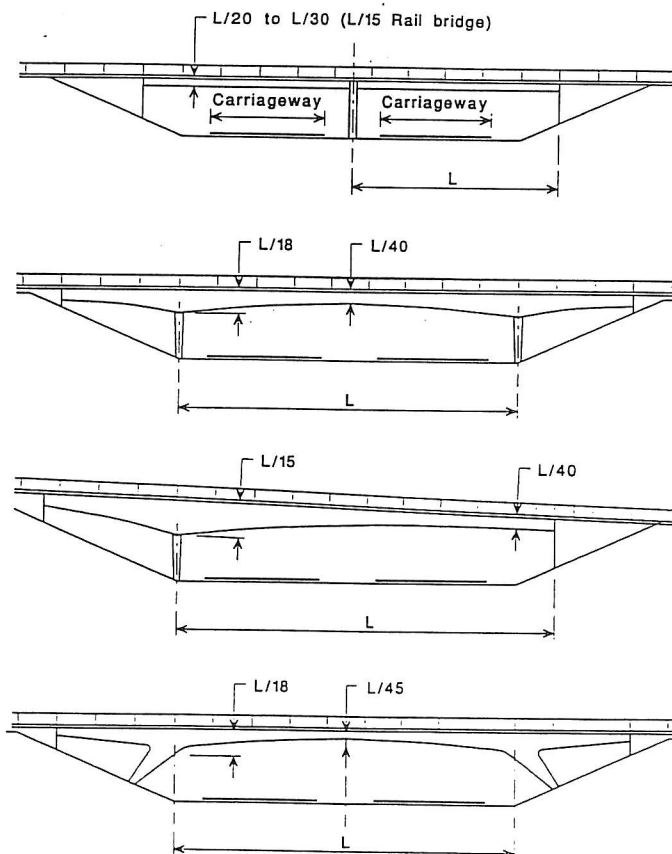


Figure 8 Typical elevations of highway overbridges.



Lecture 15B.1

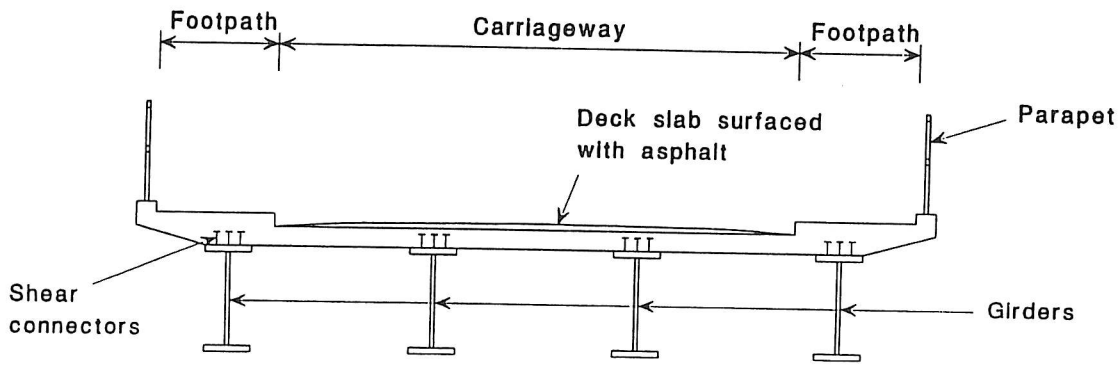


Figure 9 Typical cross-section of a single carriageway highway bridge



Lecture 15B.1

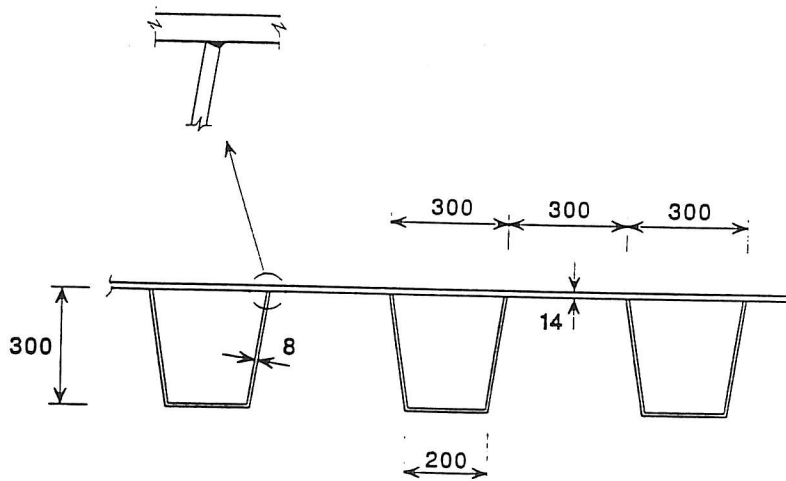
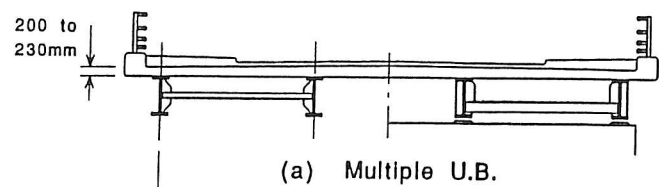


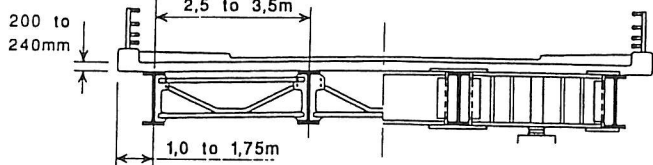
Figure 10 Orthotropic steel deck.



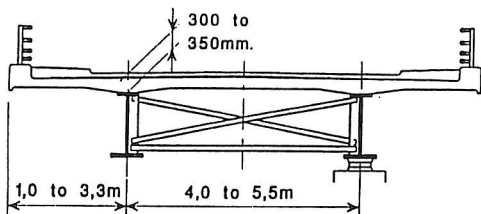
Lecture 15B.1



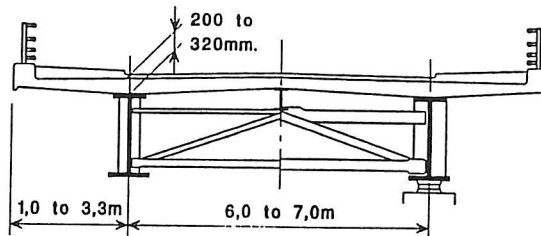
(a) Multiple U.B.



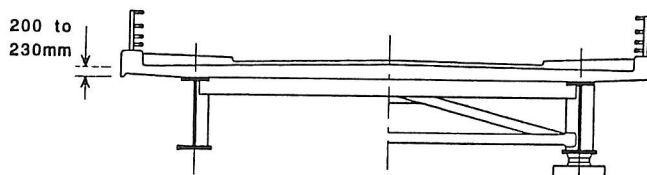
(b) Multiple plate girders



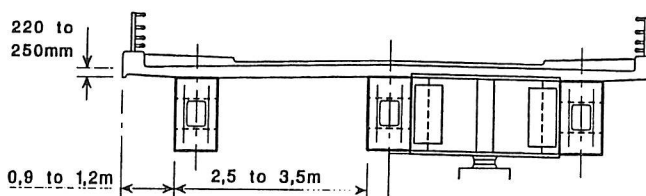
(c) Twin plate girders with haunched slab



(d) Twin plate girders and stringer



(e) Twin plate girders and cross girders



(f) Multiple box

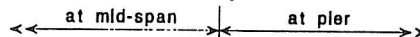


Figure 11 Typical cross-sections for highway bridges.

Lecture 15B.1

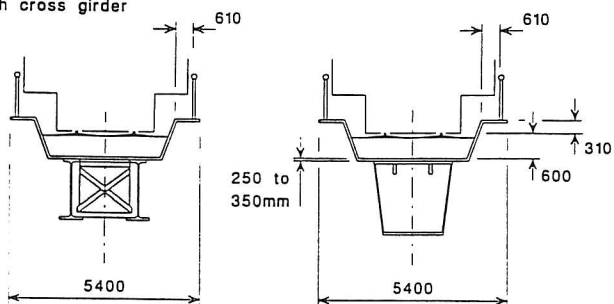
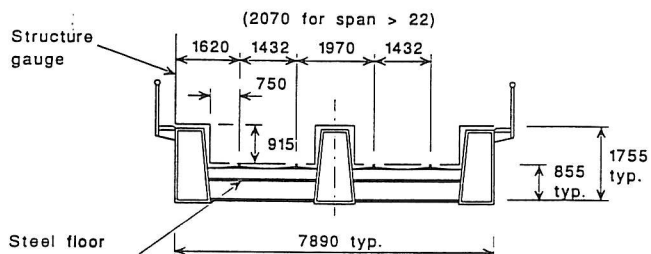
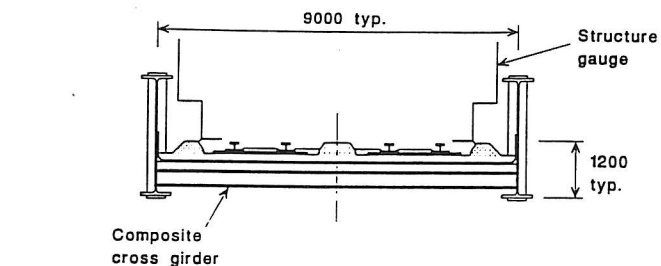


Figure 12 Typical cross-sections for railway bridges



Lecture 15B.1

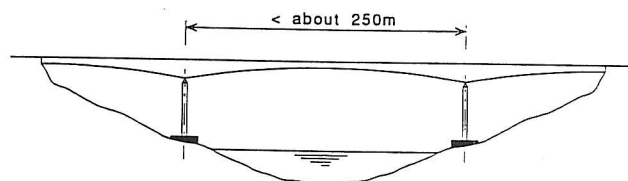


Figure 13 Typical elevation of long span girder bridge



Lecture 15B.1

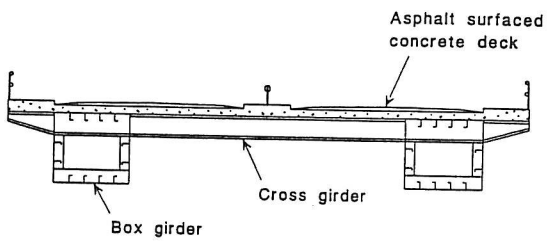


Figure 14 Typical cross-section of wide, long span, girder bridge.

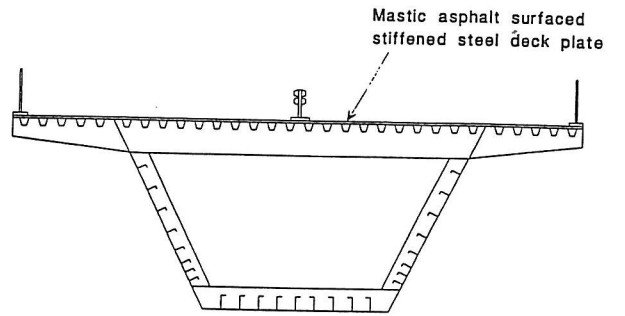


Figure 15 Typical cross-section of box girder long span bridge



Lecture 15B.1



Lecture 15B.1

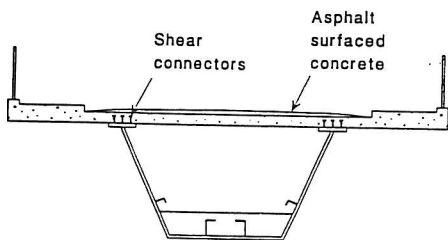
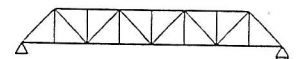
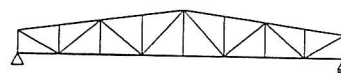
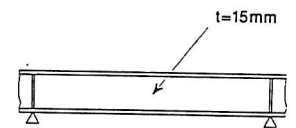
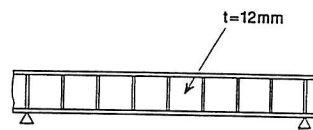


Figure 16 Typical open top composite box-girder bridge



(i) Traditional design with high fabrication content

(ii) Modern design with minimum fabrication content

Figure 17 Changes in economic design



Lecture 15B.1



Lecture 15B.1

LECTURE 15B.2

Actions on Bridges

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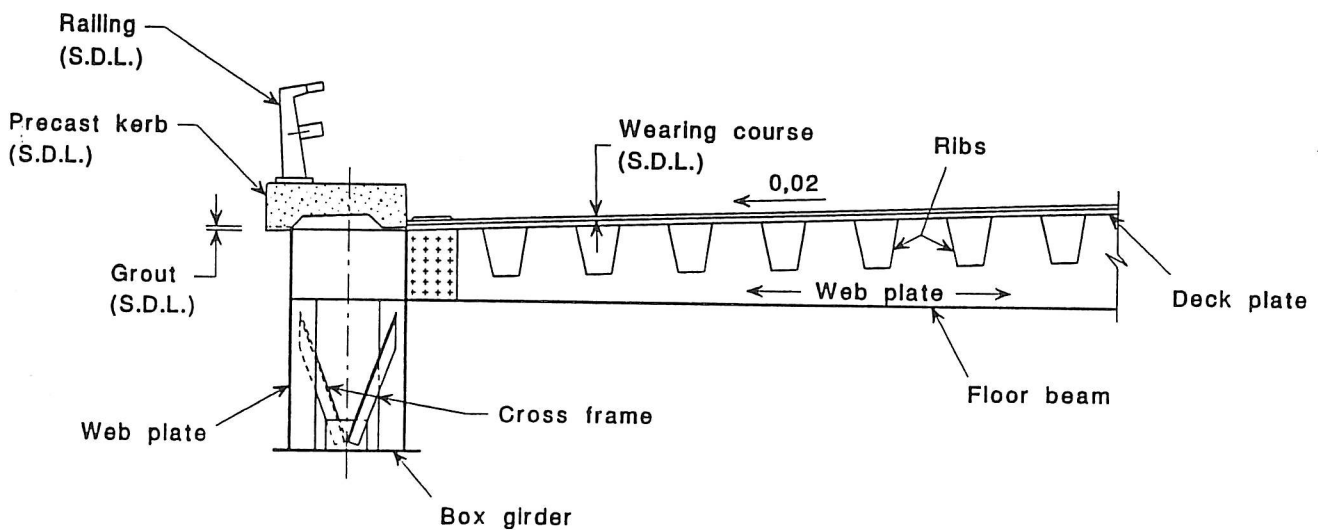


Figure 1 Dead load and superimposed dead load (S.D.L.)



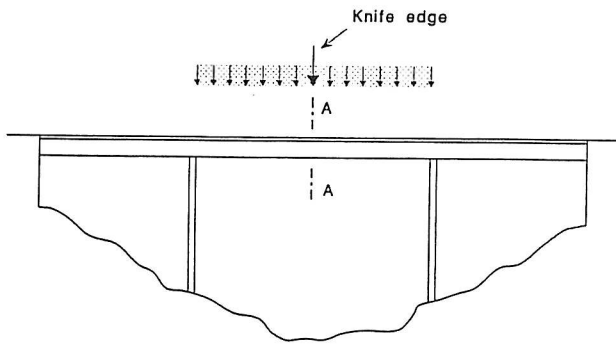


Figure 2 Location of distributed and knife edge loads to produce maximum mid-span moment.

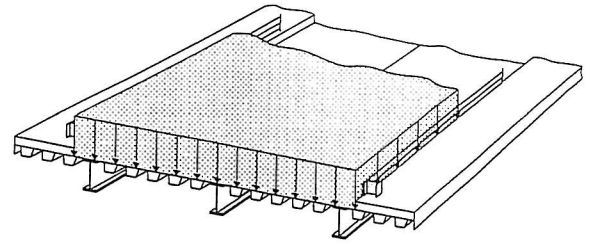


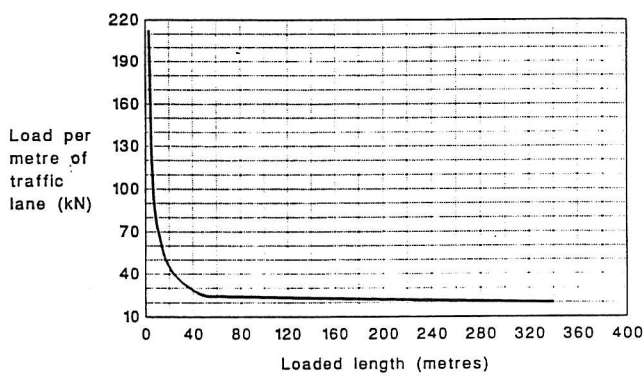
Figure 3 Uniformly distributed load on traffic lanes.



Lecture 15B.2



Lecture 15B.2



Note: HA loading consists of a uniformly distributed load, expressed in kN per linear metre of traffic lane and a knife edge load of 120kN applied across the width of the lane.

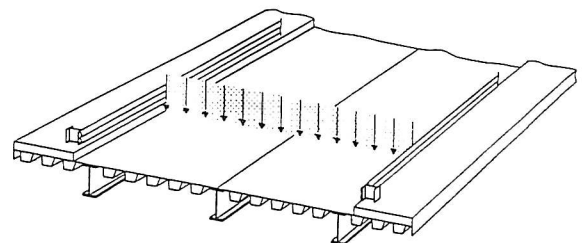


Figure 5 Knife-edge load.

Figure 4 Variation of type HA loading with loaded length (U.K. Department of Transport)



Lecture 15B.2



Lecture 15B.2

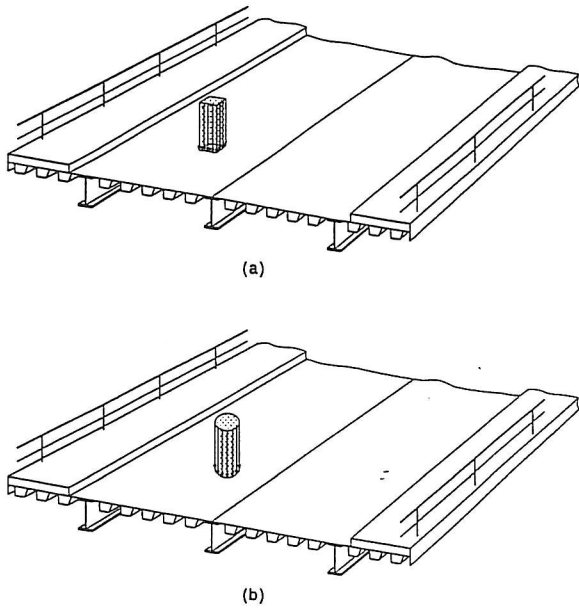


Figure 6 Single wheel loads



Lecture 15B.2

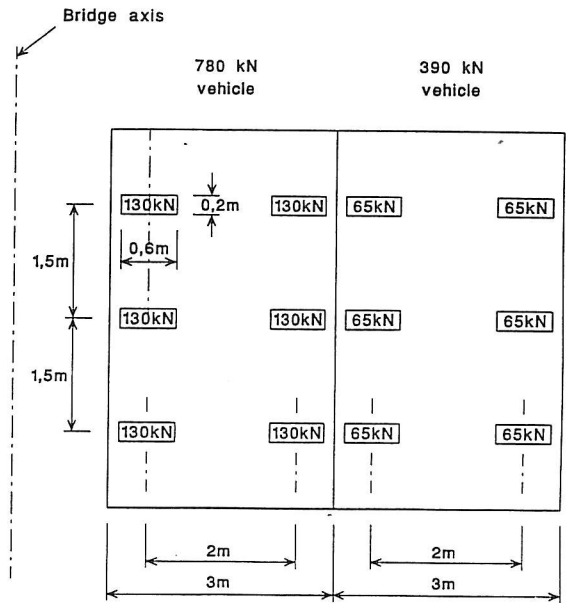


Figure 7 Concentrated wheel loads on bridge decks, according to load specifications by the Danish Road Directorate.



Lecture 15B.2

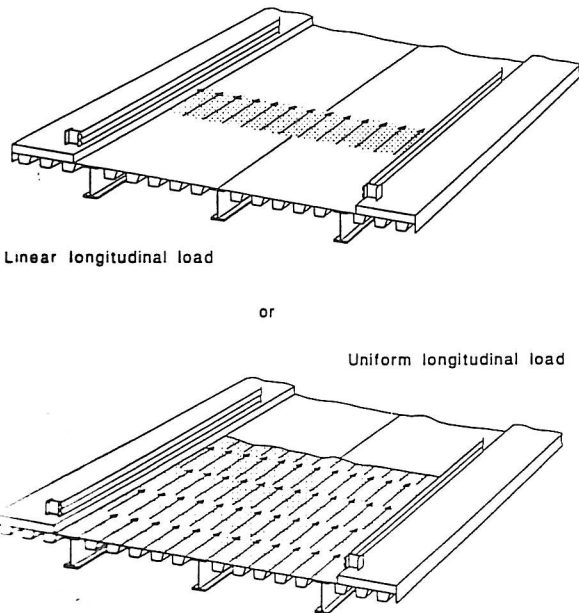


Figure 8 Longitudinal tractive forces.



Lecture 15B.2

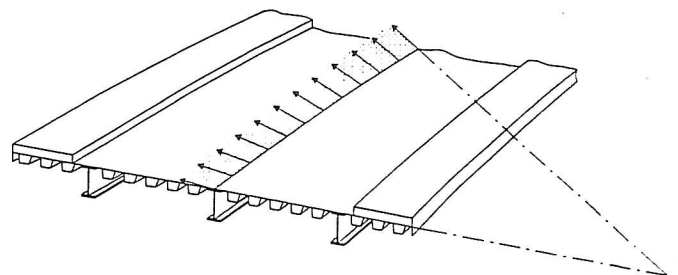


Figure 9 Centrifugal forces.



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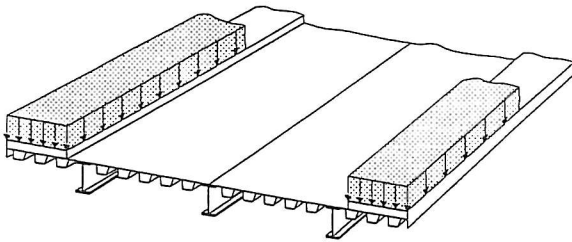


Figure 10 Sidewalk distributed load.

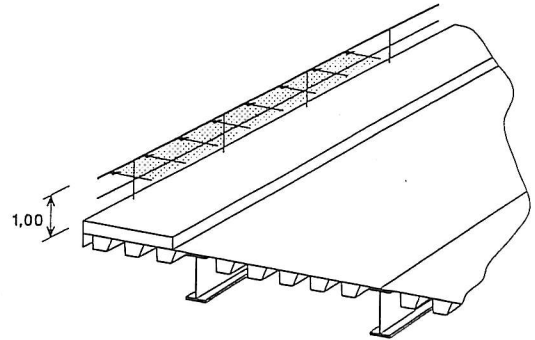
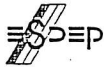


Figure 11 Distributed load on parapet.



Lecture 15B.2



Lecture 15B.2

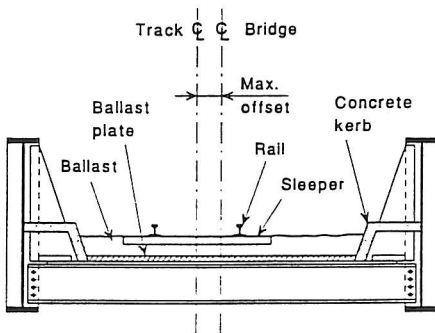


Figure 12 Typical section of a through-girder railroad bridge (curved track)

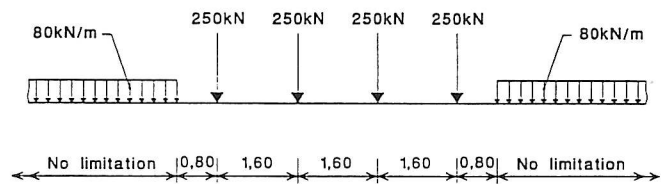


Figure 13 Typical train load.



Lecture 15B.2



Lecture 15B.2

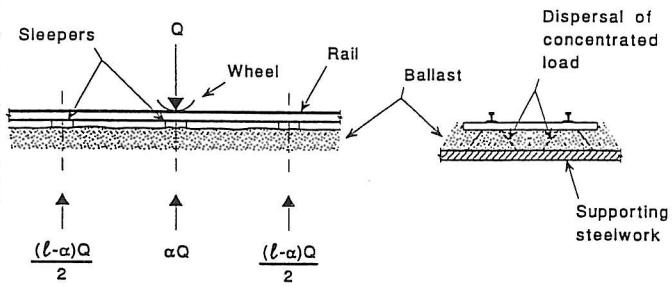


Figure 14 Dispersal of wheel loads.

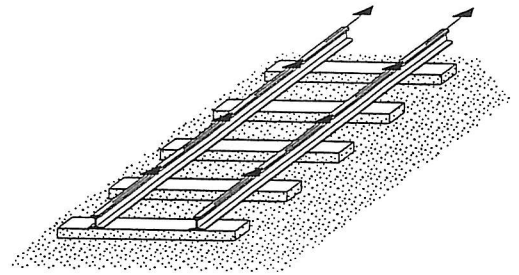


Figure 15 Longitudinal tractive forces.



Lecture 15B.2



Lecture 15B.2

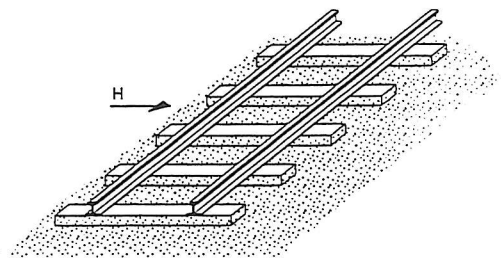


Figure 16 Horizontal force due to nosing

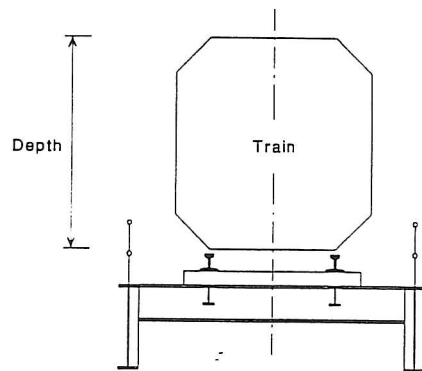
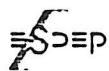


Figure 17 Depth of exposed area for wind actions.



Lecture 15B.2



Lecture 15B.2

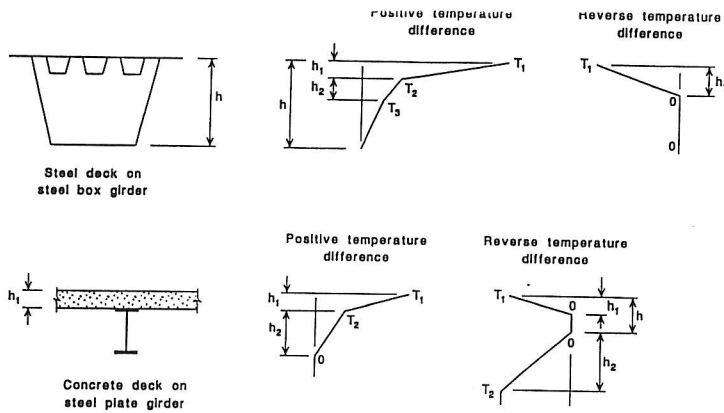
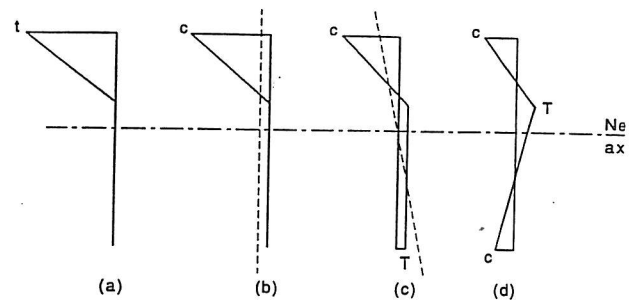
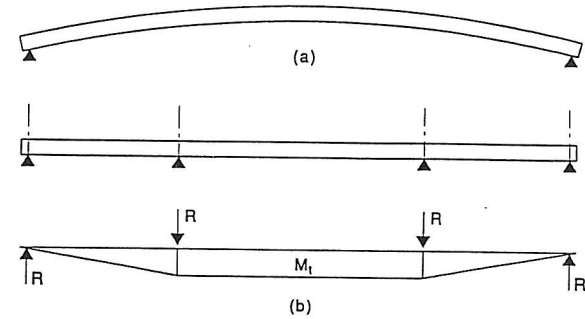


Figure 18 Examples of temperature differences.



- a) Non-linear temperature distribution.
- b) Equivalent "thermal" stresses if thermal effects fully restrained
- c) Thermal stress distribution if axial restraint removed.
- d) Thermal stress distribution if curvature restraint also removed

(i) Primary thermal stresses.



- a) Curved shape of simply supported beam.
- b) Secondary moments and reactions in beam continuous over four supports.

(ii) Secondary thermal effects.

Figure 19. Structural effects of non-linear temperature distributions.

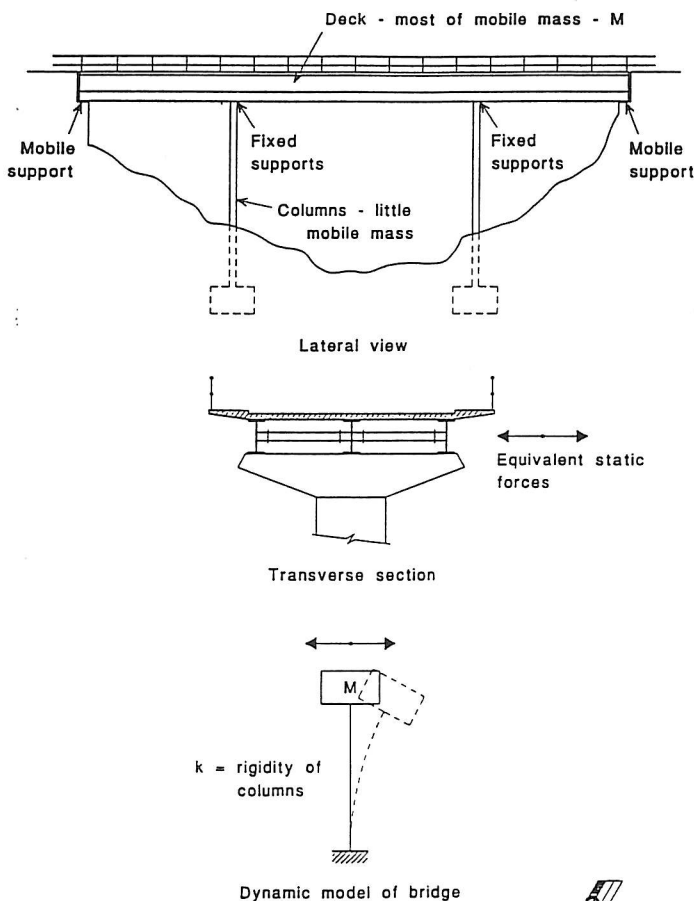


Figure 20 Example of bridge with simple dynamic behaviour.

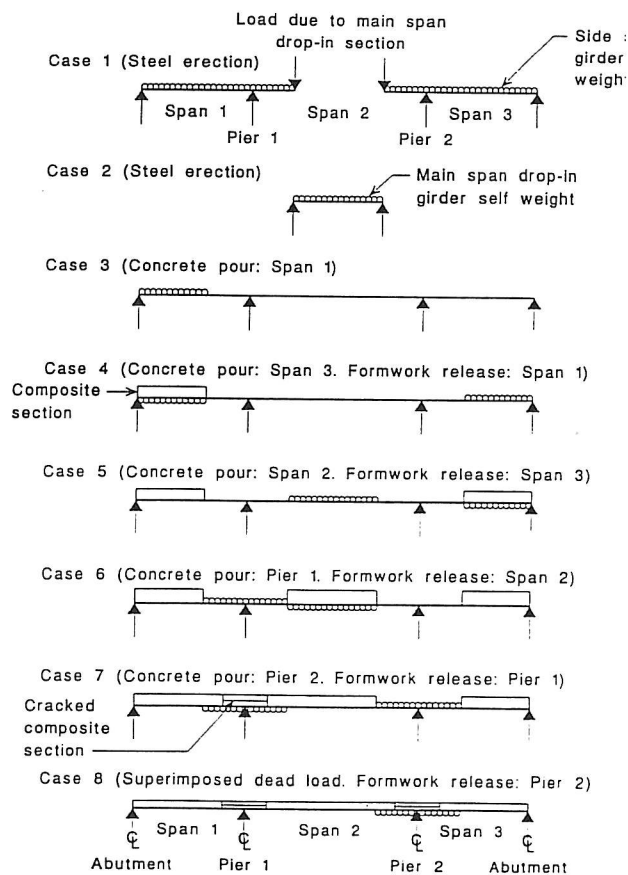


Figure 21 Construction load cases for a three-span composite highway bridge.

LECTURE 15B.3

Bridge Decks

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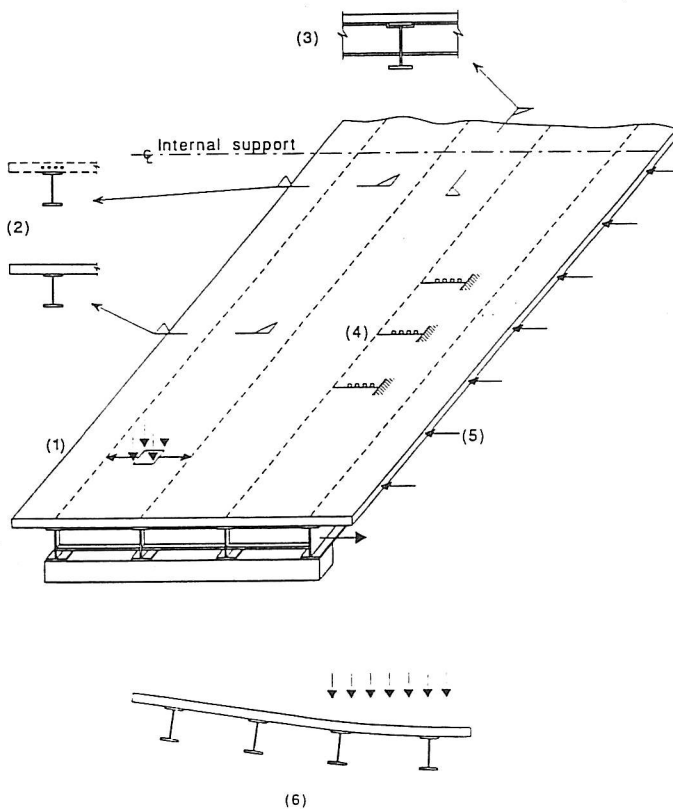
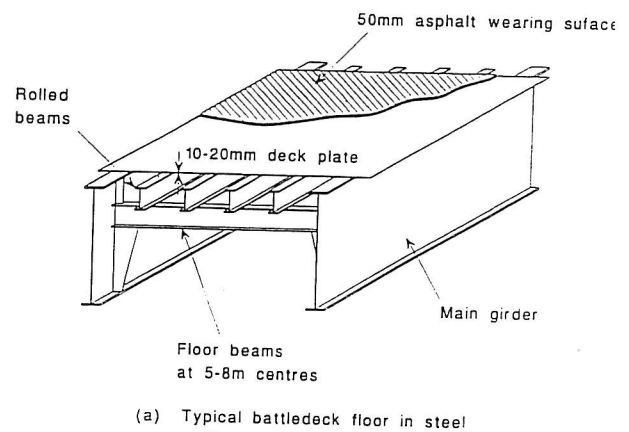
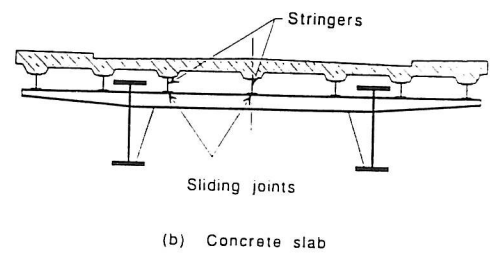


Figure 1 Structural actions of a highway bridge deck.

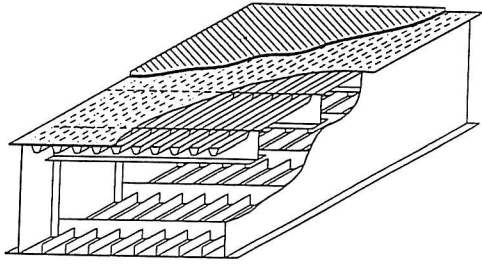


(a) Typical battledeck floor in steel

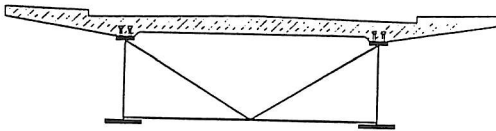


(b) Concrete slab

Figure 2 Early highway bridge decks.



(a) Orthotropic steel deck

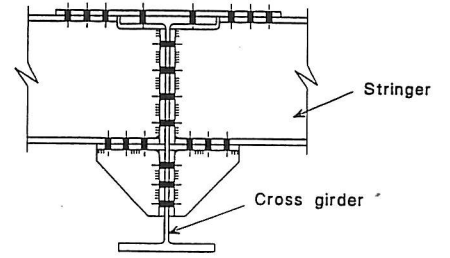


(b) Composite slab

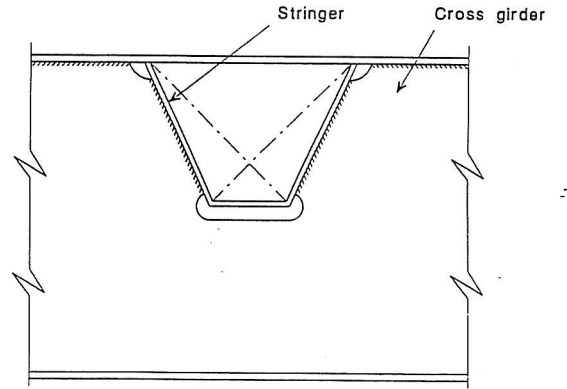
Figure 3 Modern highway bridge decks.



Lecture 15B.3



(a) Early bolted or riveted construction



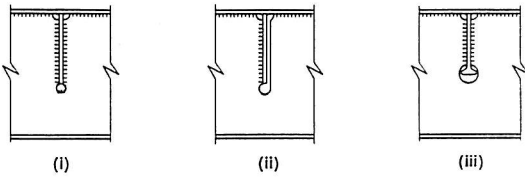
(b) Modern welded construction

Note:- Different orientation of diagrams to illustrate connections

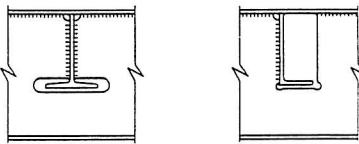
Figure 4 Stringer / Cross girder intersections



Lecture 15B.3

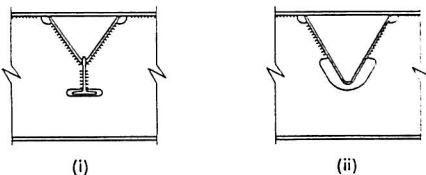


(i) (ii) (iii)

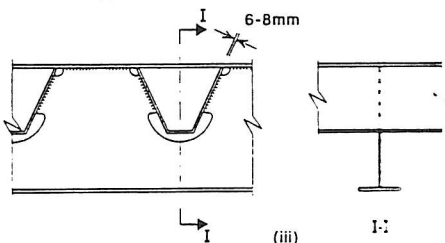


(iv) (v)

(a) Open, torsionally weak stiffeners



(i) (ii)



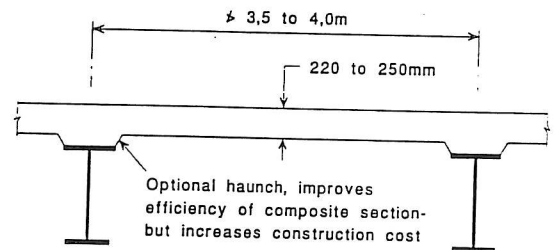
(iii) 1:1

(b) Closed, torsionally stiff stiffeners

Figure 5 Stiffeners (stringers) for orthotropic steel decks



Lecture 15B.3



(a) Multi girder or cross girder bridge



(b) Twin girder bridge without cross girders

Figure 6 Typical proportions for reinforced concrete highway bridge decks.



Lecture 15B.3

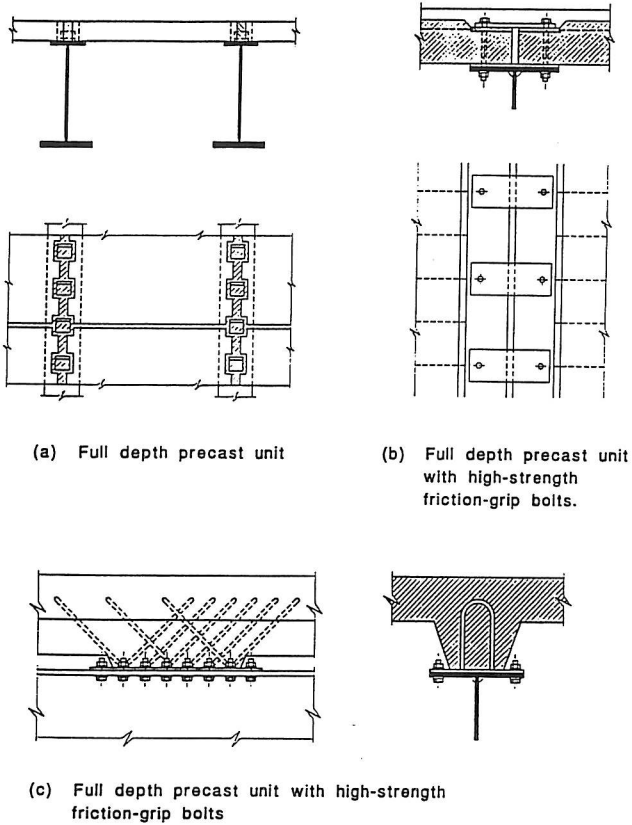


Figure 7 Means of eliminating conventional formwork for reinforced concrete decks.

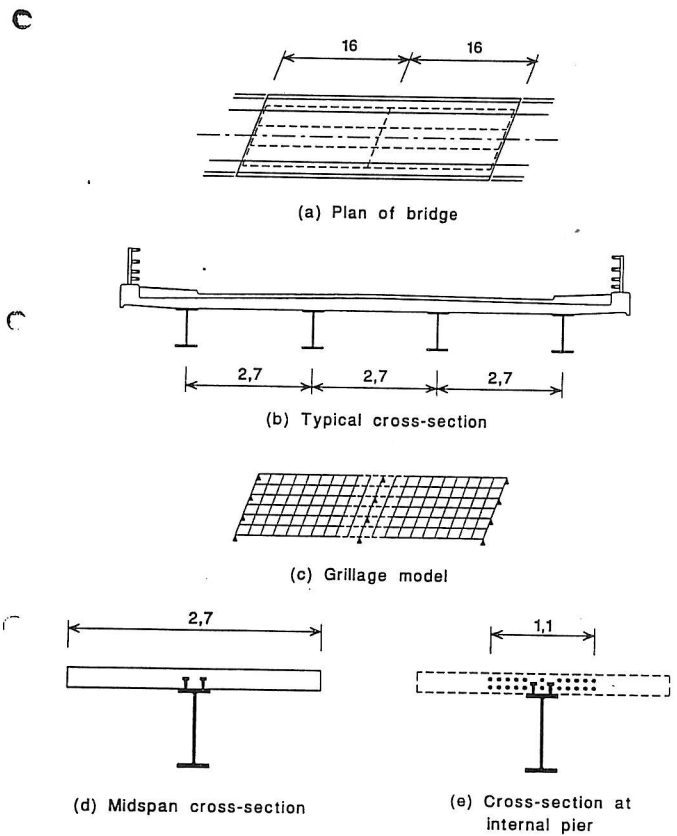
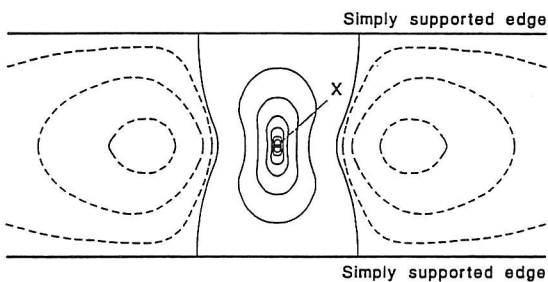


Figure 8 Typical grillage analysis for composite bridge, demonstrating the modelling of the slab as equivalent beam strips.

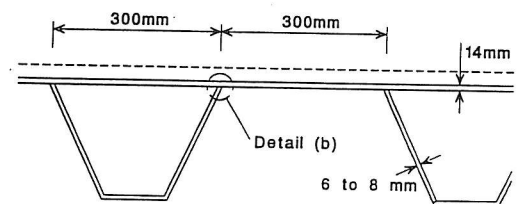


Influence surface for longitudinal moment at X

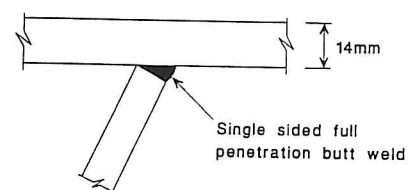
----- Negative contour

———— Positive contour

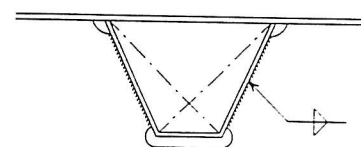
Figure 9 Example of Puchers charts for determining slab moments from local wheel loads.



(a) General arrangement



(b) Detail of stiffener/deck weld



(c) Detail of stiffener/cross girder connection

Figure 10 Standard orthotropic deck.

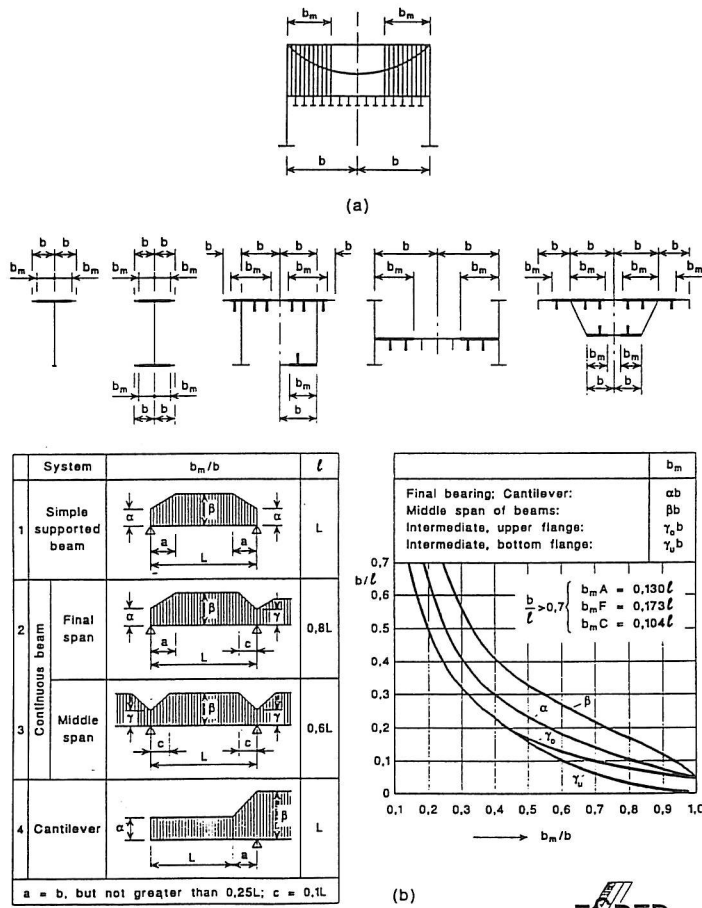


Figure 11 Definition of the effective width b_m



Lecture 15B.3

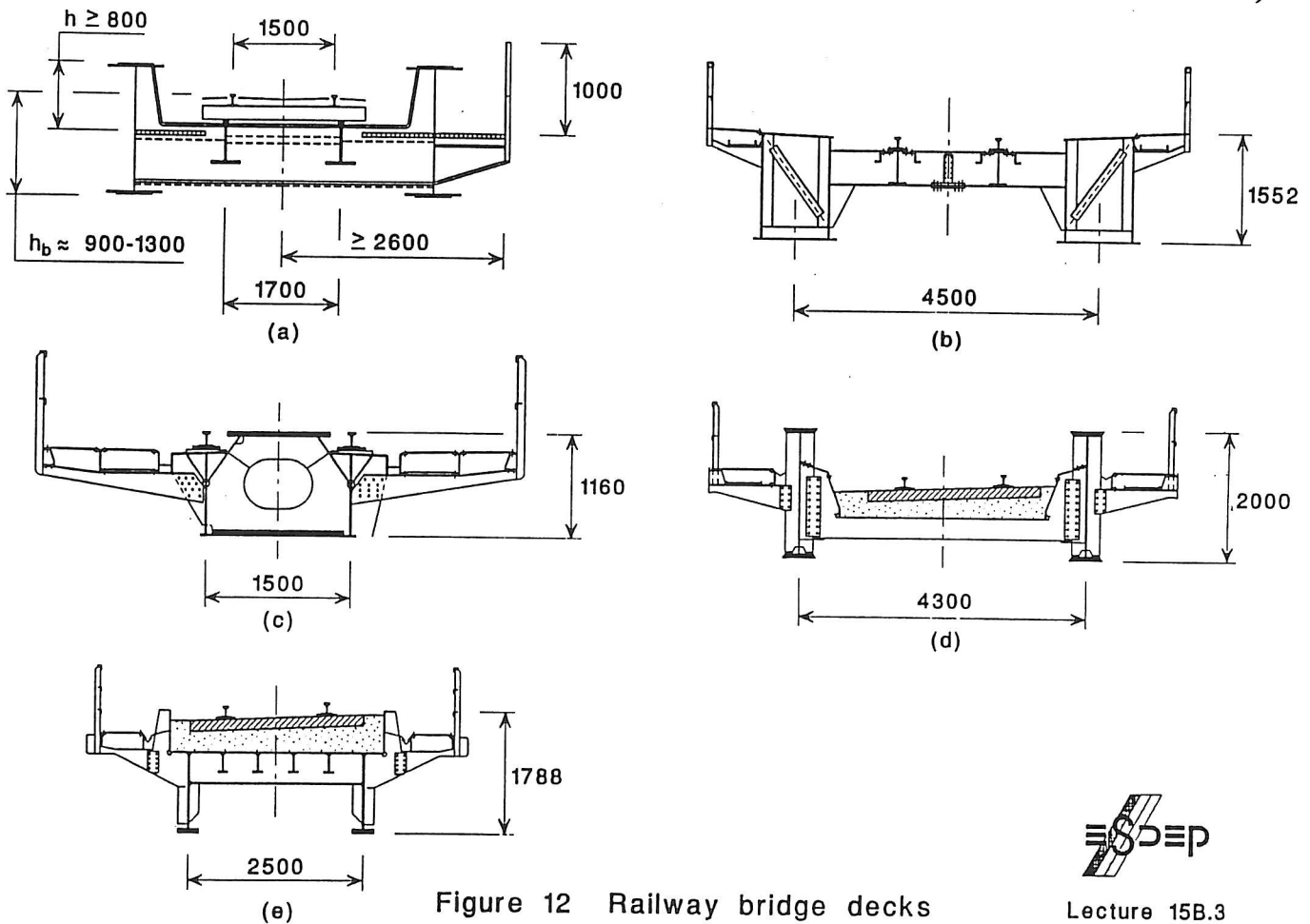


Figure 12 Railway bridge decks



Lecture 15B.3

LECTURE 15B.4

Plate Girder and Beam Bridges

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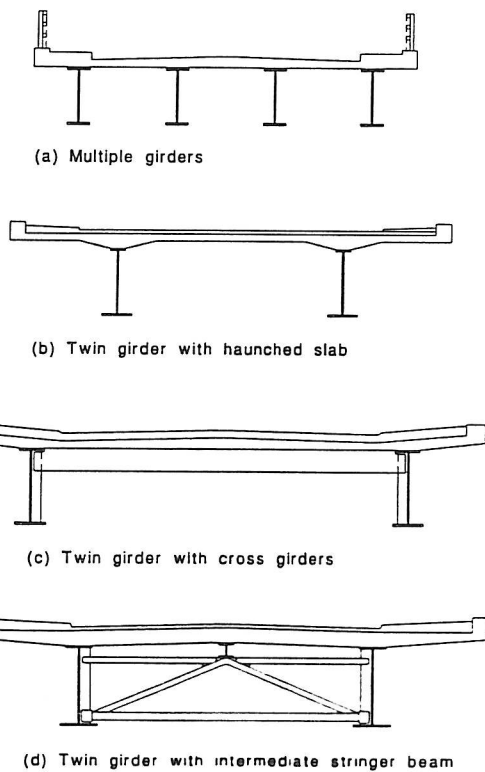


Figure 1 Types of composite plate girder and girder bridge

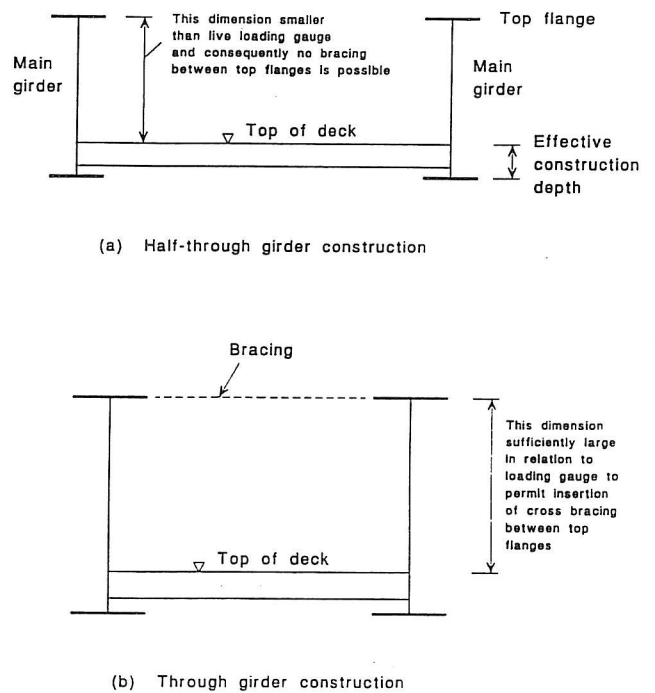


Figure 2 Half-through and through girder cross-sections.

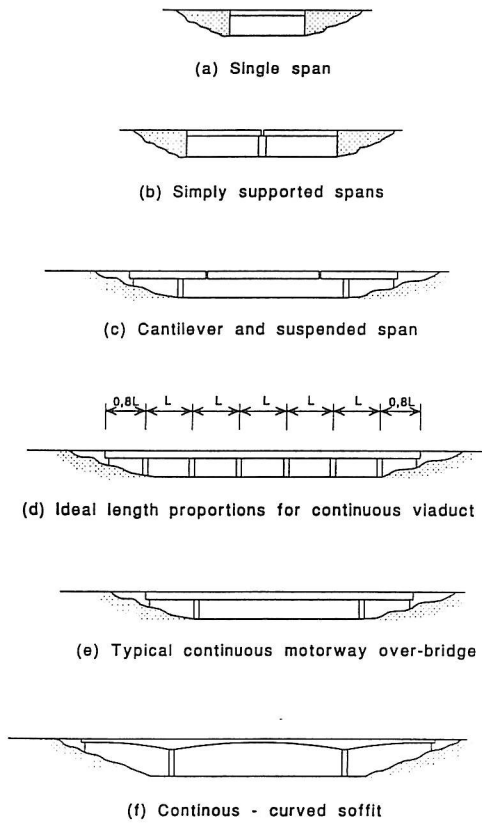


Figure 3 Arrangements for longitudinal girders



Lecture 15B.4

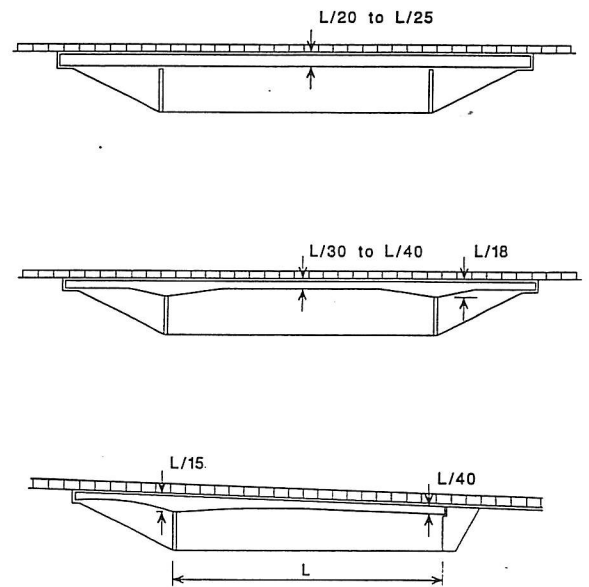


Figure 4 Typical span/depth proportions



Lecture 15B.4

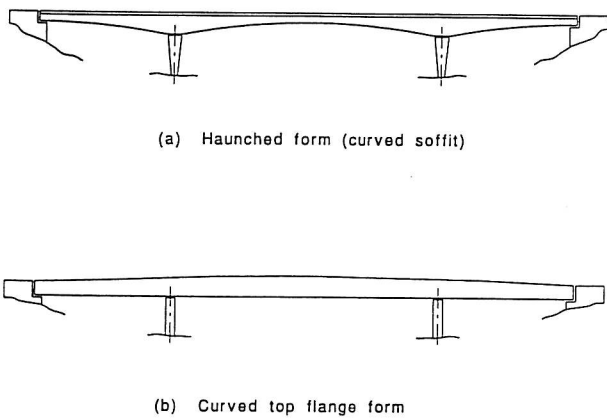


Figure 5 Alternative forms of variable depth plate girders

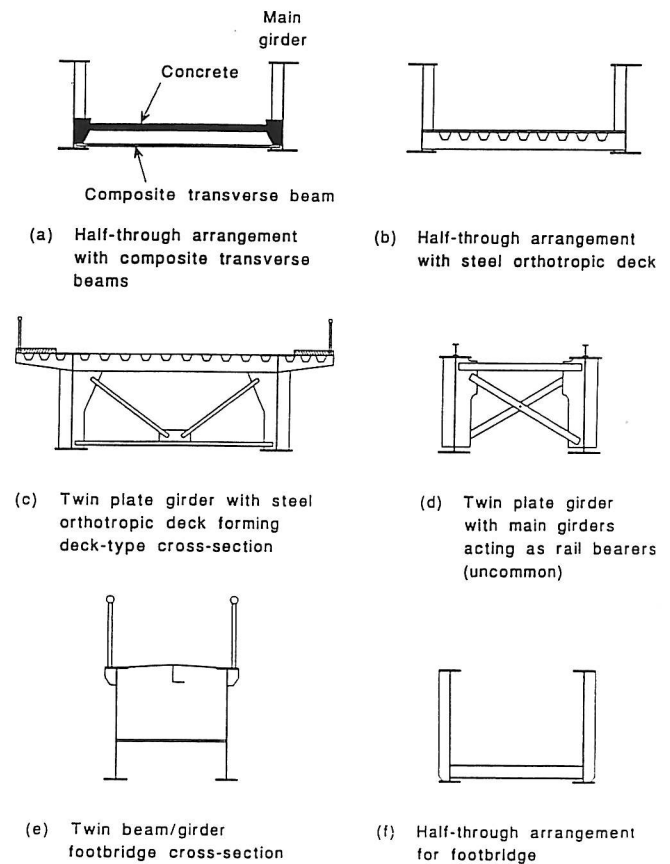


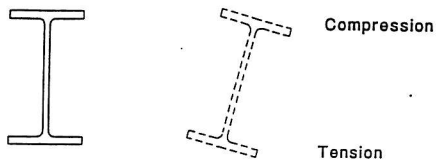
Figure 6 Selection of plate girder/beam bridge configurations



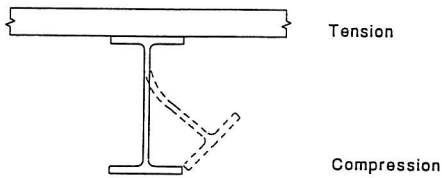
Lecture 15B.4



Lecture 15B.4



(a) Lateral-torsional buckling



(b) Distortional buckling

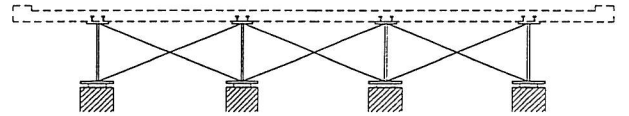
Figure 7 Modes of instability of plate girders



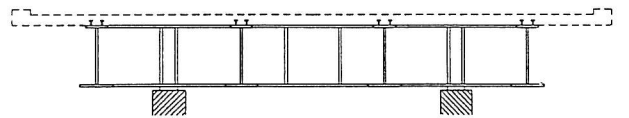
Lecture 15B.4



(a) Bracing within spans



(b) Bracing at abutment and piers

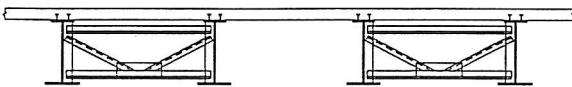


(c) Cross girder at piers

Figure 8 Types of transverse structure for composite plate girder bridges



Lecture 15B.4

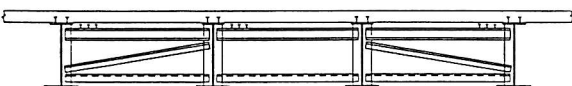


(a) K - bracing

The purpose of these links is to share wind load between all girders before concreting



(b) X - bracing

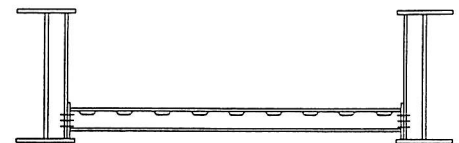


(c) Braced abutment trimmer

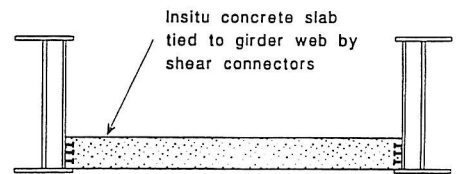
Figure 9 Commonly used bracing systems



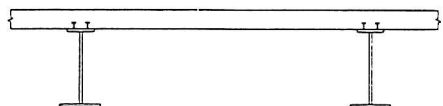
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(a) Discrete U - frame : positive moment



(b) Continuous U - frame : positive moment

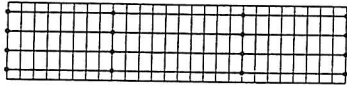


(c) Continuous U - frame : negative moment

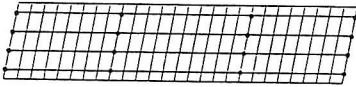
Figure 10 Types of U - frame restraint to compression flange



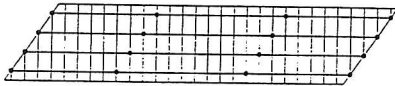
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(a) Orthogonal grillage



(b) Grillage for spans with small skew ($< 20^\circ$)



(c) Grillage for spans with large skew ($> 20^\circ$)

Figure 11 Typical grillages



Lecture 15B.4



Lecture 15B.4

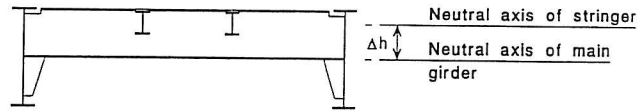
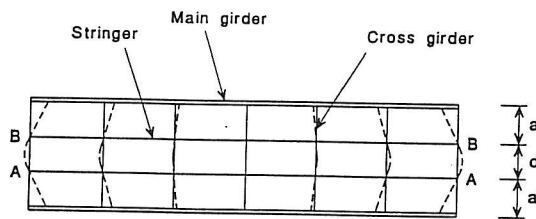
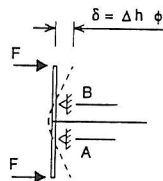


Figure 12 Open grid steel deck - difference in neutral axis levels between stringers and main girders



(a) Plan dimensions and deformed shape under uniformly distributed loading



(b) End cross girder deformation

Figure 13 Open grid steel deck - layout and deformations



Lecture 15B.4

LECTURE 15B.5 Truss Bridges

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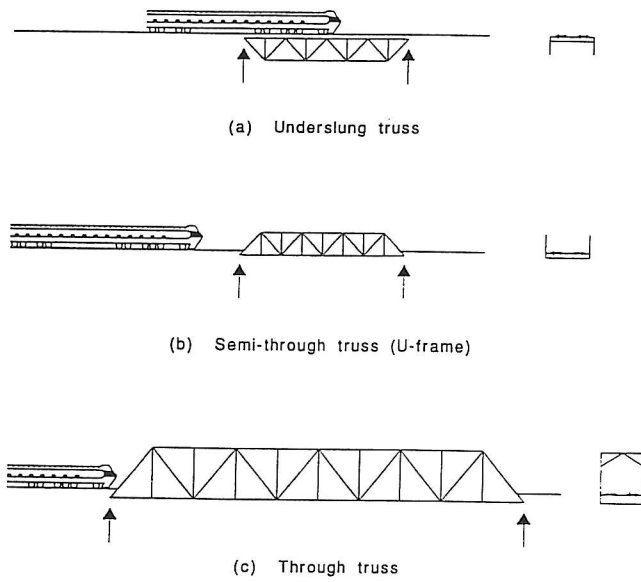
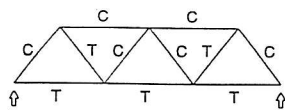


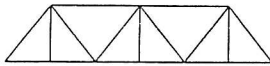
Figure 1 Truss configurations



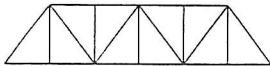
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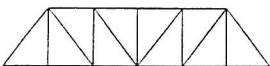
(a) Modern Warren truss:
spans 30-150m
T = Tension
C = Compression



(b)

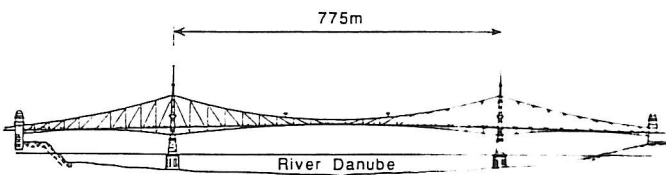


(c)



(d) Pratt truss
spans 30-100m

(b) and (c)
Modified Warren trusses:
spans 30-150m:
still used for railway
bridges

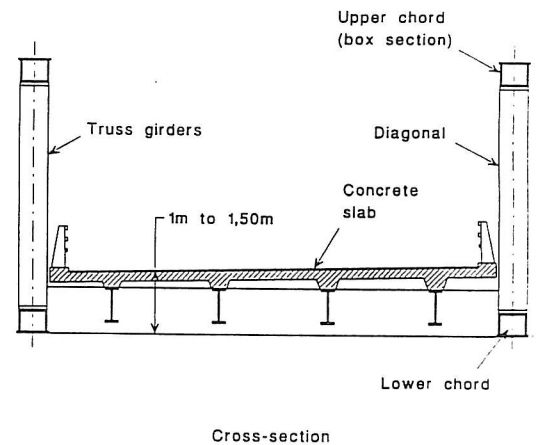


(e) Nagy truss in Budapest: 1892

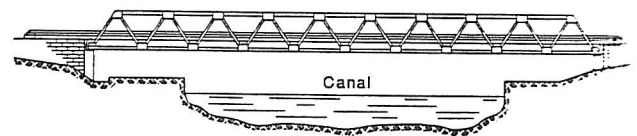


(f) Lattice truss
of historical
interest only

Figure 2 Principal types of truss



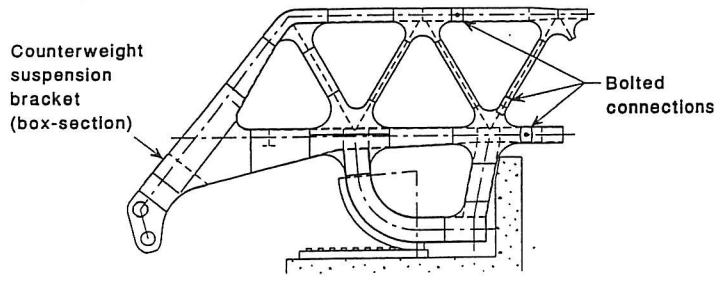
Cross-section



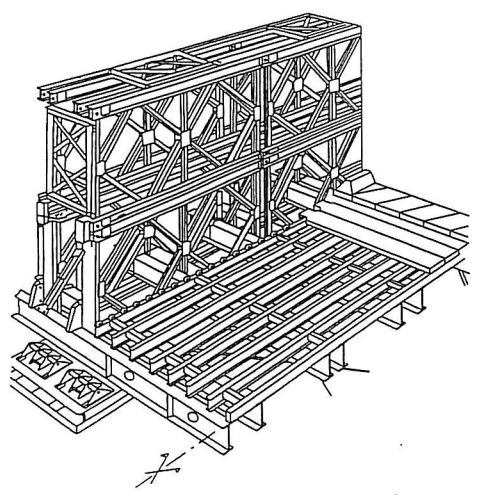
Elevation

Figure 3 A typical highway truss bridge.





(a) Example of movable truss bridge. Rear part of the bridge.

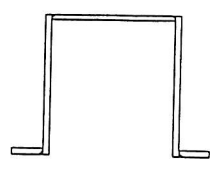


(b) Bailey temporary bridge for emergency uses.

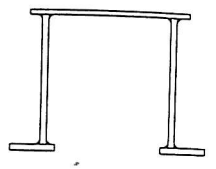
Figure 4 Particular applications of trusses in bridge construction



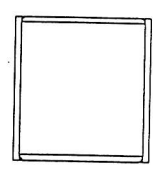
C



(a) Top hat (i)



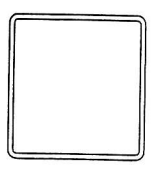
(b) Top hat (ii)



(c) Box

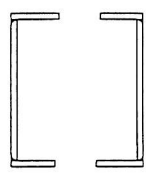


(d) Rolled section

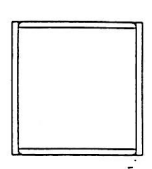


(f) Rolled hollow section

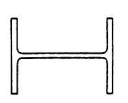
Figure 5 Compression chord members



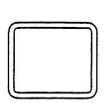
(a) Open box



(b) Box



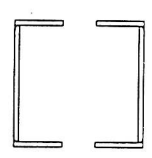
(c) Rolled section



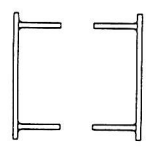
(d) Rolled hollow section

Figure 6 Tension chord members

C



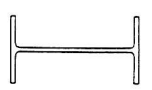
(a) Open box (i)



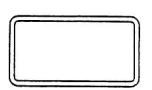
(b) Open box (ii)



(c) Made-up I



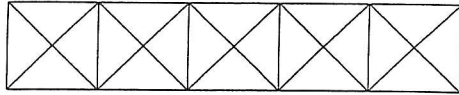
(d) Rolled section



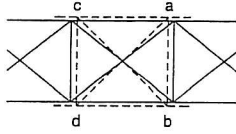
(e) Rolled hollow section

Figure 7 Diagonal and vertical members

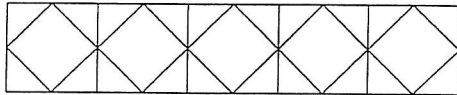




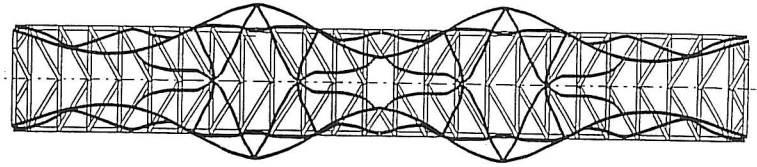
(a) St. Andrew's cross system



(b) Deformed shape of (a)



(c) Diamond system



Plan: upper chord
 Note: Truss webs, upper chord and its lateral bracing shown as solid lines for clarity

Figure 9 Buckling mode of a diamond system used as upper chord lateral bracing.

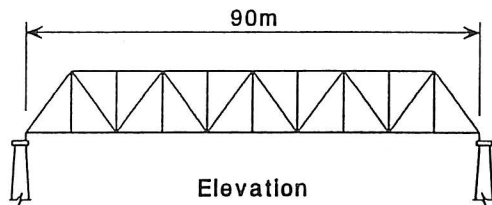
Figure 8 Upper chord lateral bracing



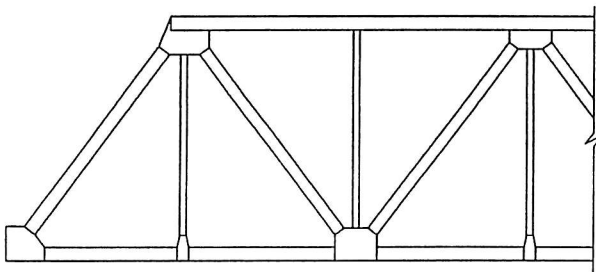
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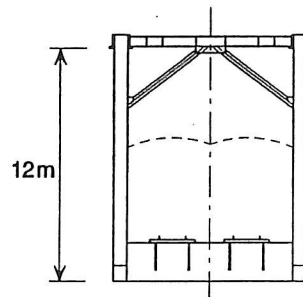
Lecture



Elevation

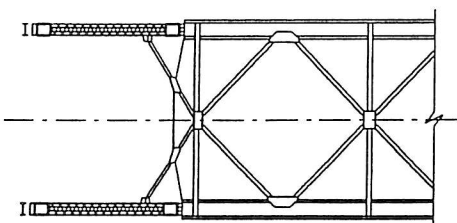


Elevation on part span

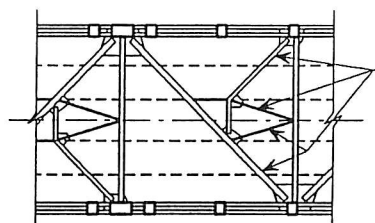


12m

Section



Plan on top laterals



Braking girder

Plan on bottom laterals



Figure 10 General arrangement of a through truss railway bridge.

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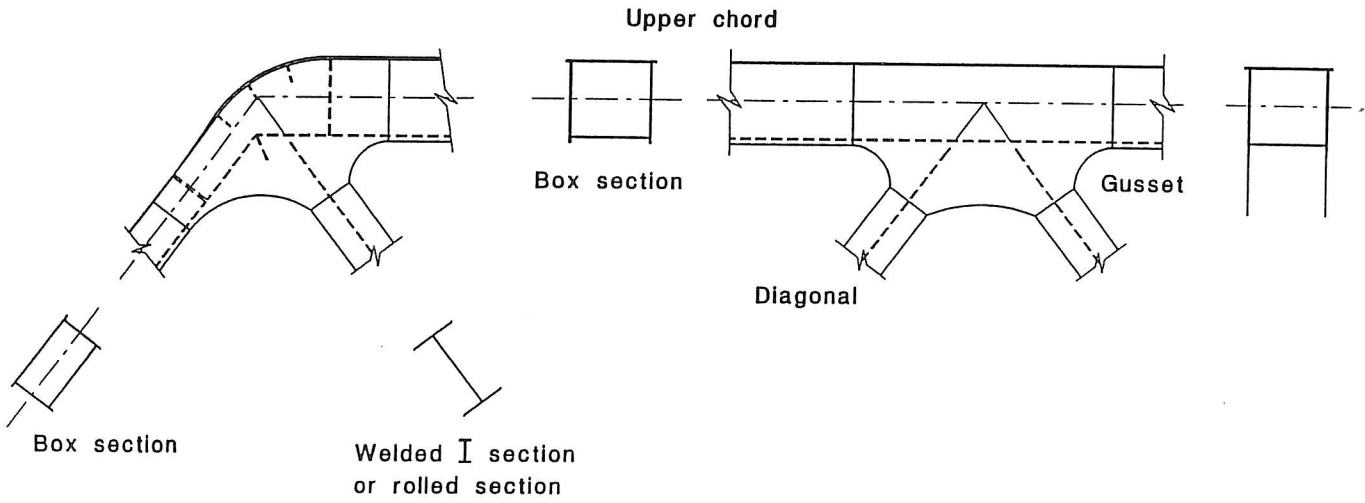


Figure 11 Butt-welded connections and gusset geometries used to avoid fatigue in the connection.



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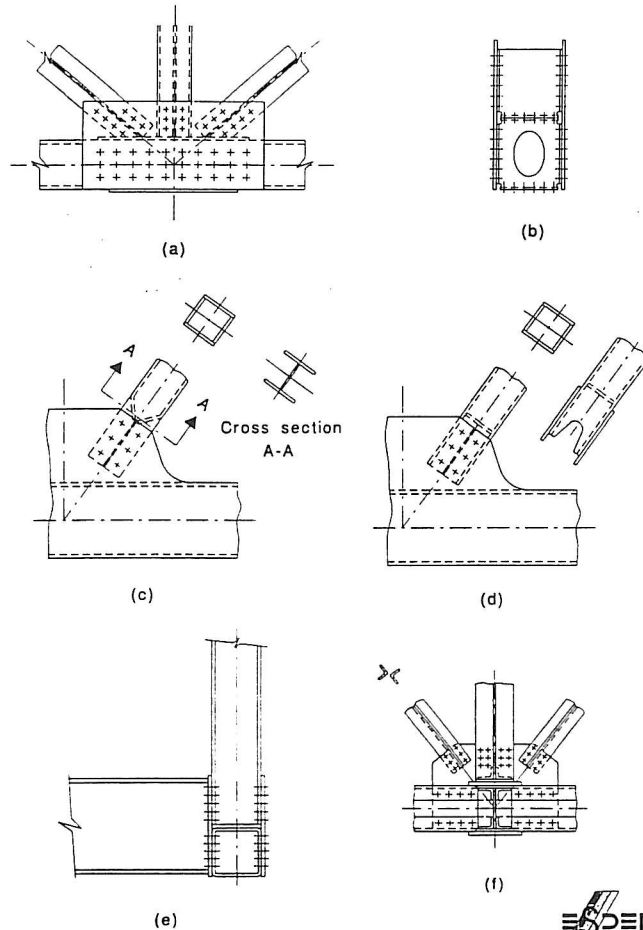


Figure 12 Bolted connections



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LECTURE 15B.6

Box Girder Bridges

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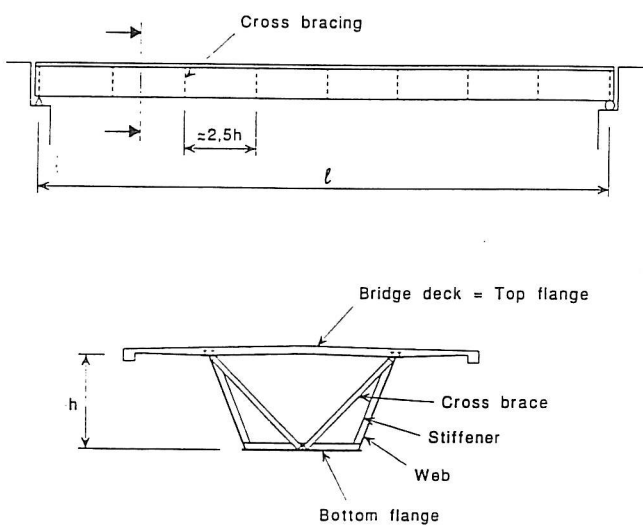


Figure 1 Box girder bridge with composite concrete deck: nomenclature

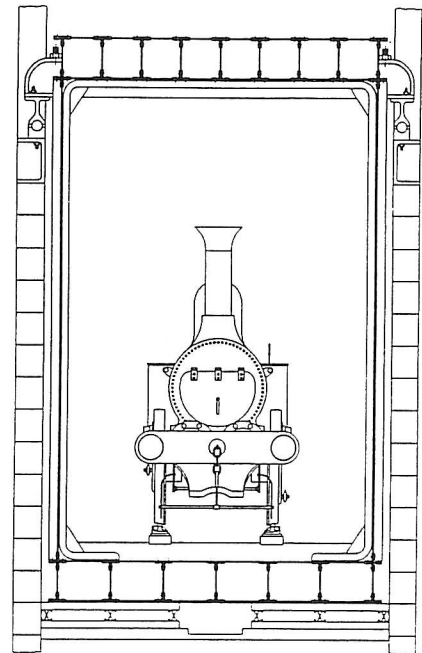


Figure 2 Britannia bridge, 1850.

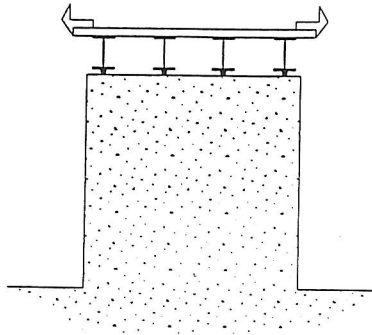
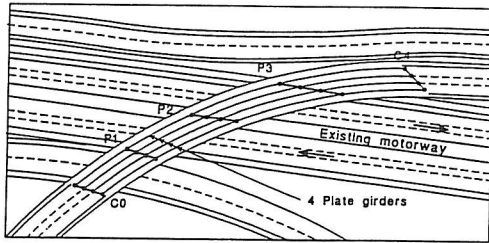
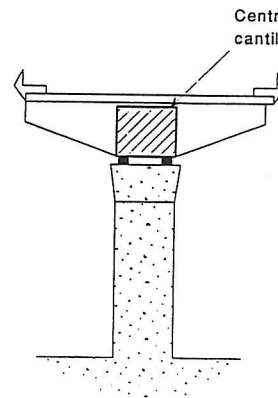
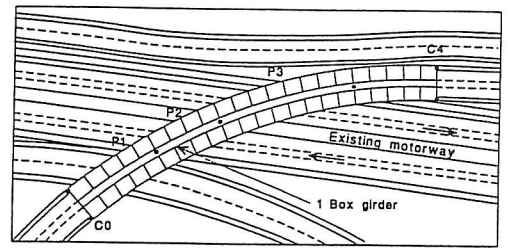


Figure 3a Plate girder bridge.



Lecture 15B.6



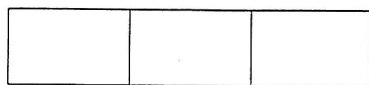
Central box girder with cantilever brackets.

Box girder bridge is in this case less expensive and more aesthetic in appearance than a plate girder bridge and skew alignments of bearings are avoided.

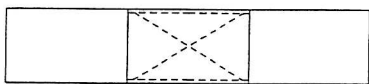
Figure 3b Box girder bridge.



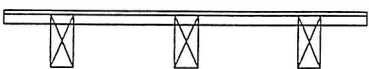
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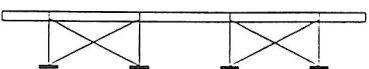
(a)



(b)



(c)

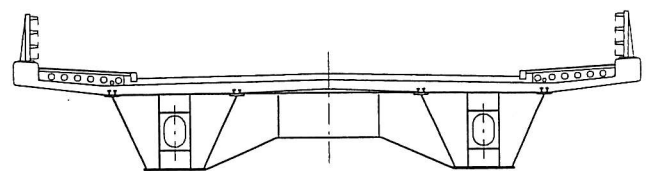


(d)

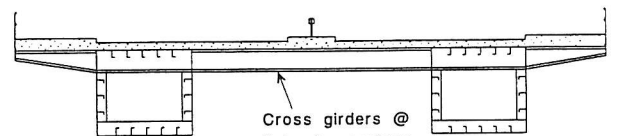
Figure 4 Types of cross-section.



Lecture 15B.6



(a) Example of diaphragm where distance between boxes is comparable with box width



Cross girders @ 3 to 4m centres

Box girder

(b) Cross girder for widely spaced boxes

Figure 5 Intermediate transverse elements between boxes.



Lecture 15B.6

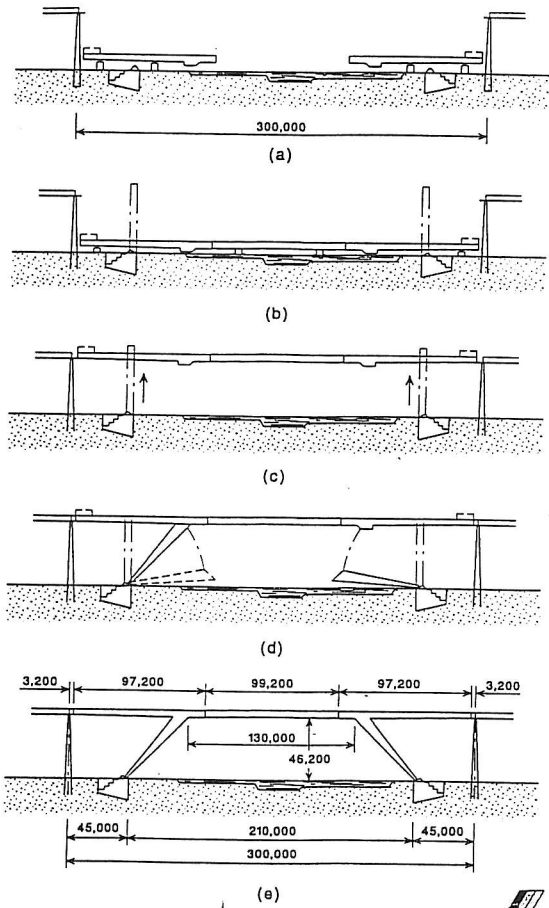
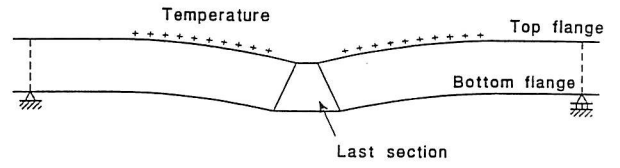


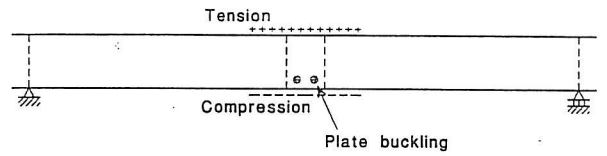
Figure 6 Erection of the Pont de Martique



Lecture 15B.6



(a) Closure in presence of temperature differential.



(b) Condition under uniform temperature.

Figure 7 Bridge across Danube, Vienna.



Lecture 15B.6

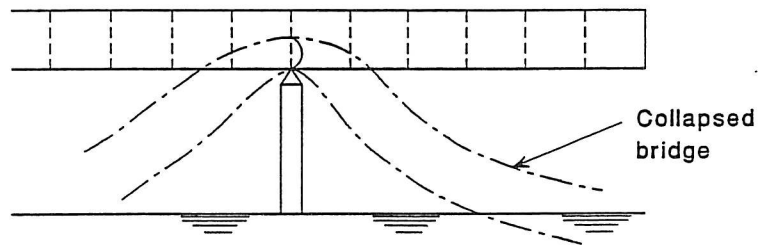


Figure 8 Milford Haven Bridge



Lecture 15B.6

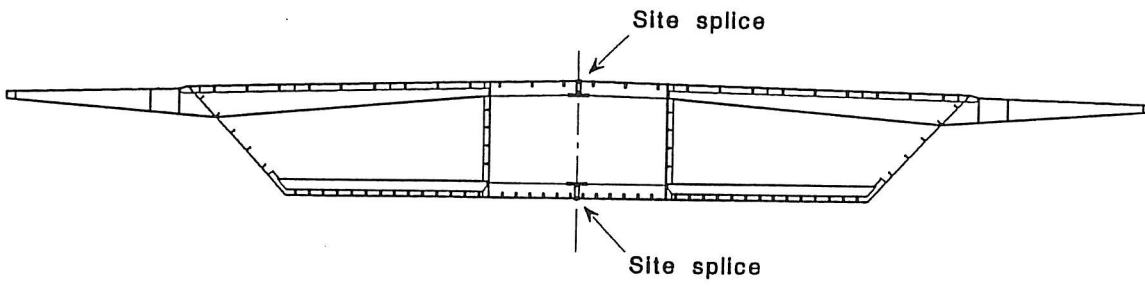


Figure 9 Typical cross-section of Melbourne bridge [2]



Lecture 15B.6

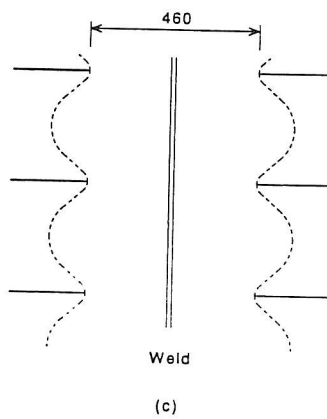
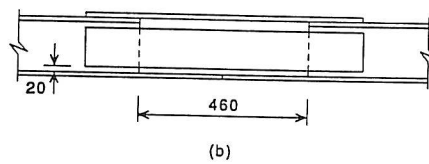
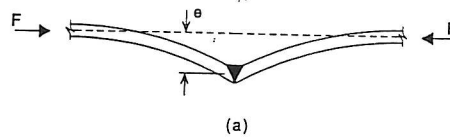


Figure 10 Detail of Koblenz bridge



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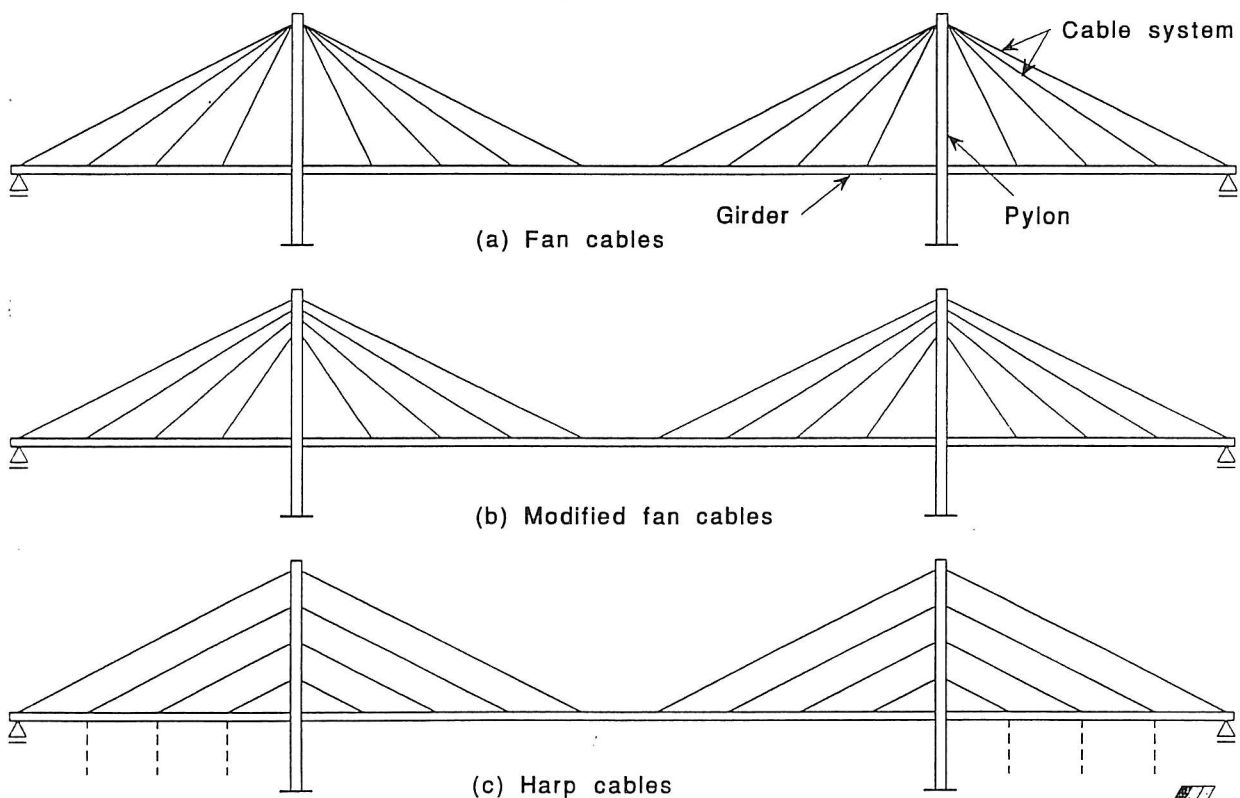
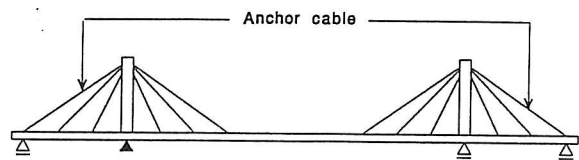
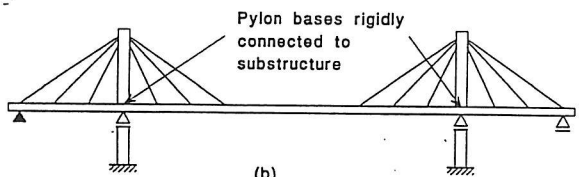


Figure 1 Types of cable stayed bridge

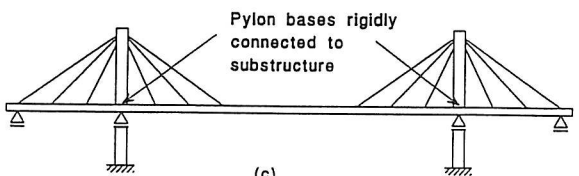




(a)



(b)



(c)

Figure 2 Support conditions for cable stayed bridges



Lecture 15B.8

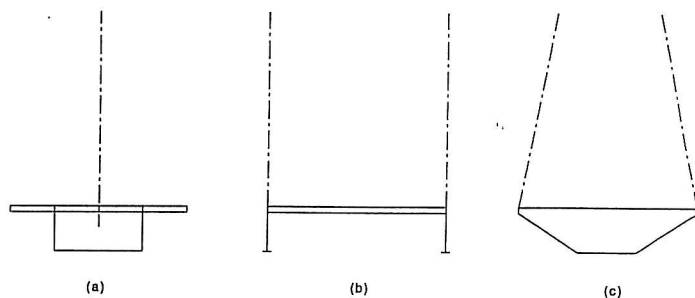


Figure 3 Alternative cable planes



Lecture 15B.1

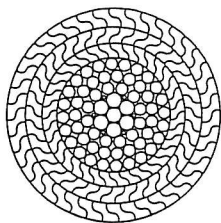


Figure 4 Lock coil cable

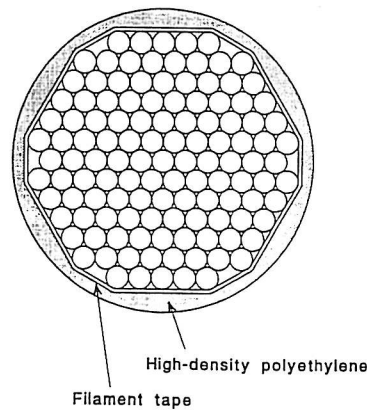


Figure 5 Parallel wire strand (PWS)



Lecture 15B.8



Lecture 15B.8

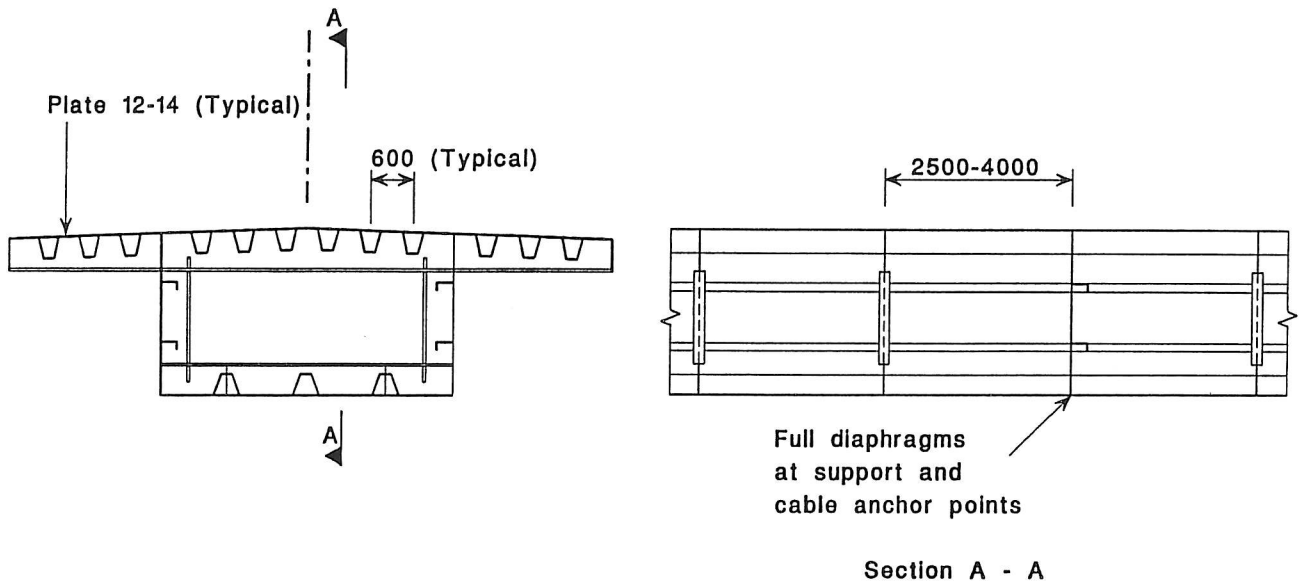


Figure 6 Typical box girder construction



Lecture 15B.8

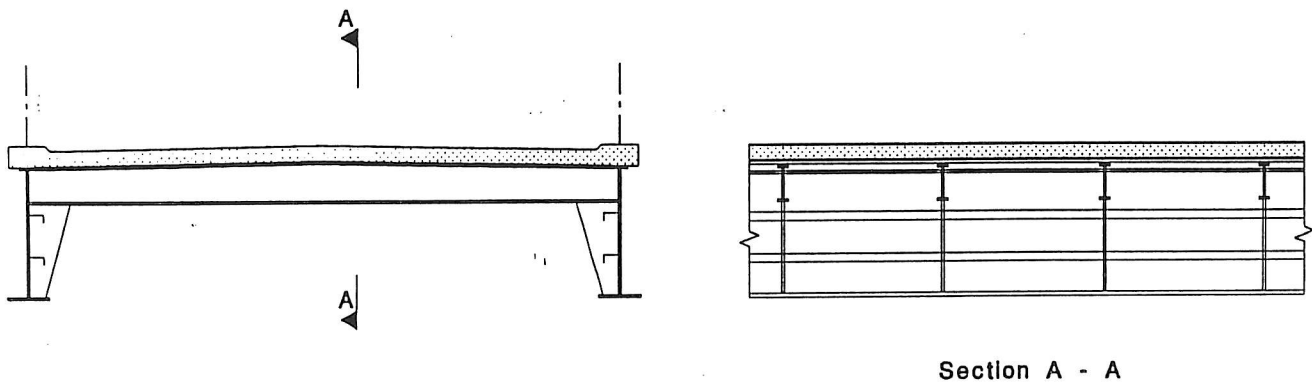
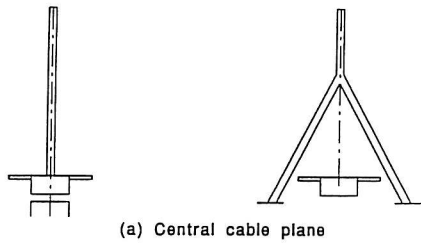


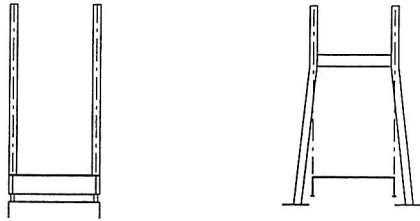
Figure 7 Typical plate girder construction



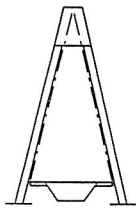
Lecture 15B.8



(a) Central cable plane



(b) Cables in parallel planes



(c) Cables in twin inclined planes

Figure 8 Pylon configurations

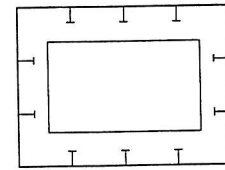
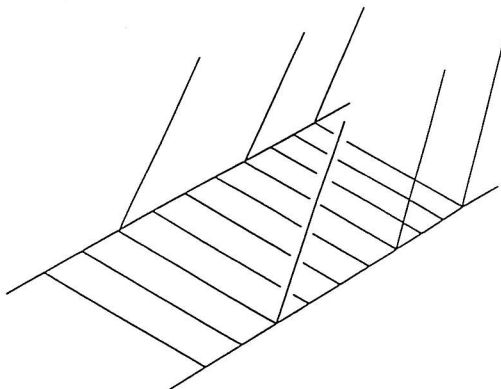
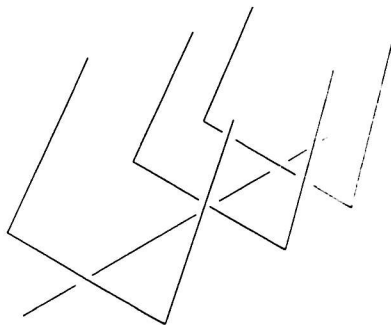


Figure 9 Typical pylon cross-section



(a) Twin cable planes and plate girder



(b) Inclined cable planes and a box girder

Figure 10 Analytical models for cable stayed bridges

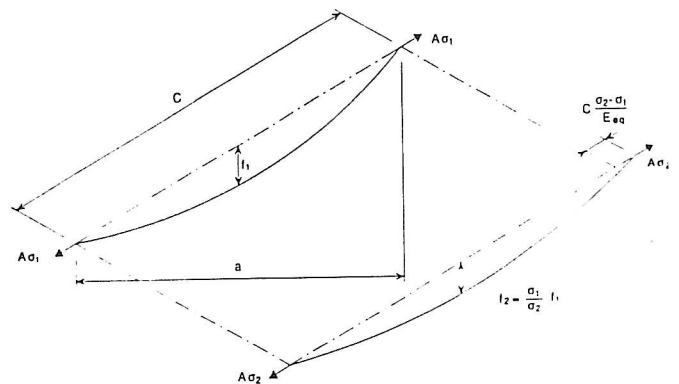


Figure 11 Influence of gravity on cable stiffness

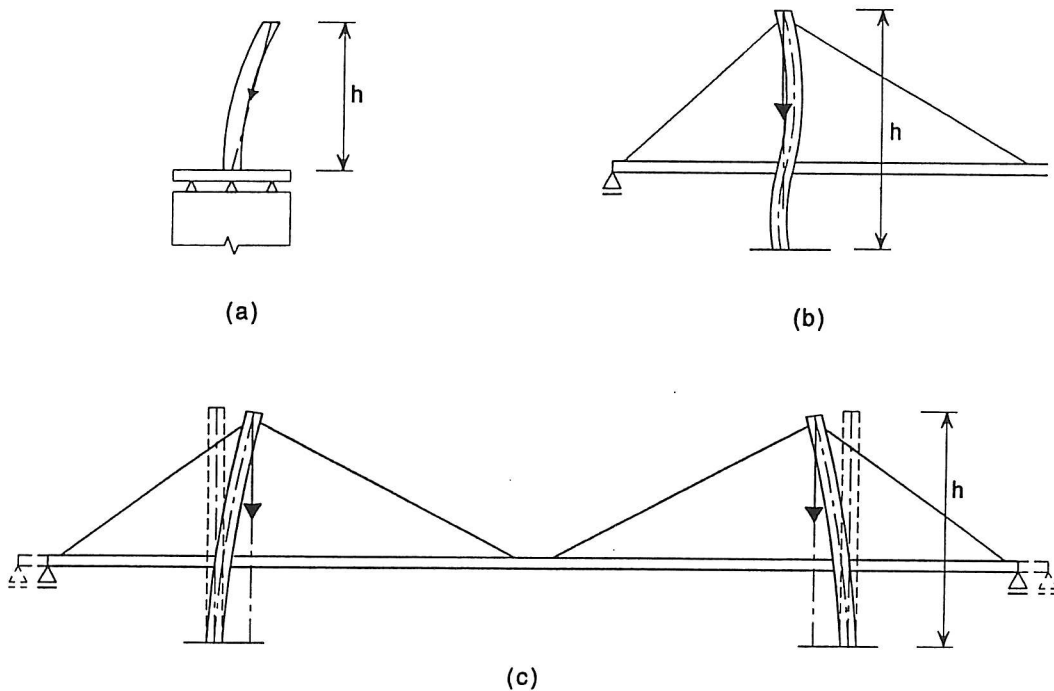


Figure 12 Stability of pylons



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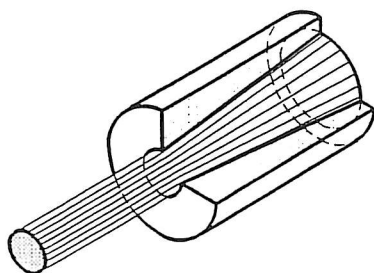


Figure 13 Typical cable anchorage

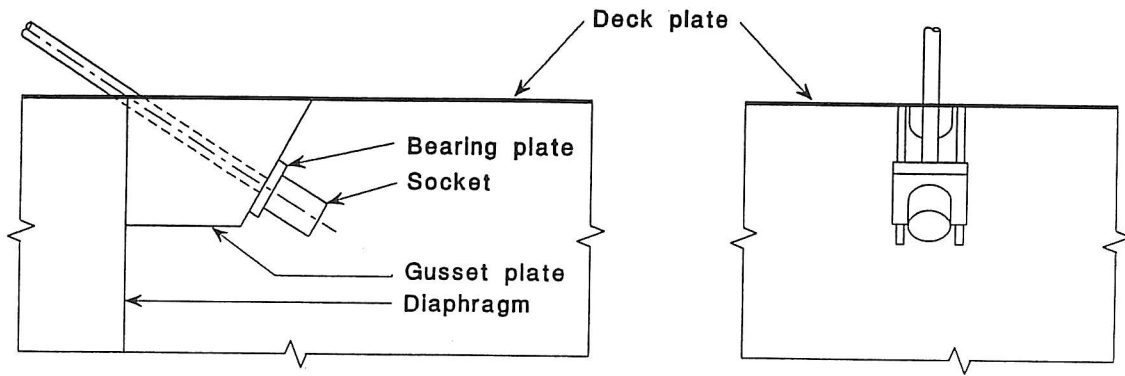


Figure 14 System for anchoring a central cable to a box girder



Lecture 15B.8

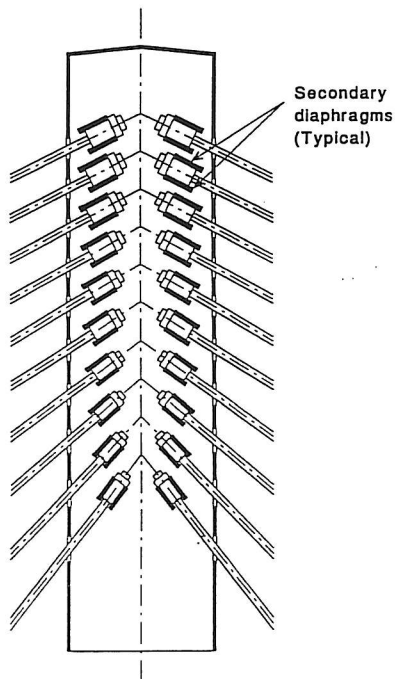


Figure 15 Anchorage system for cables at pylon in a modified fan bridge

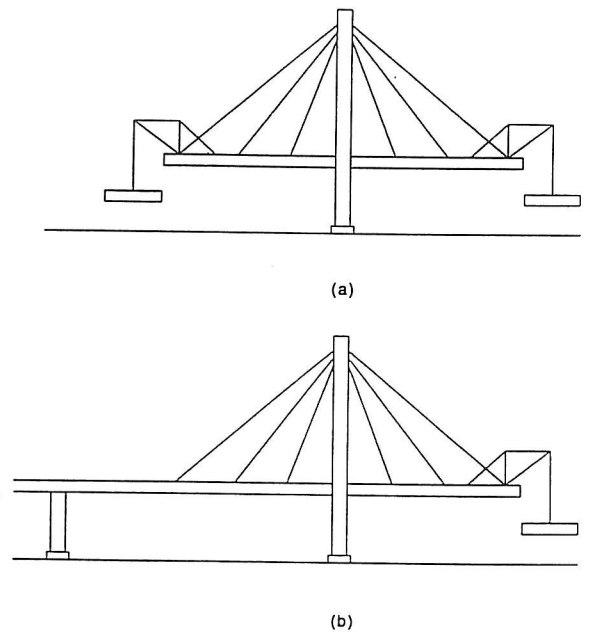


Figure 16 Methods of erection



Lecture 15B.8



Lecture 15B.8

LECTURE 15B.9

Suspension Bridges

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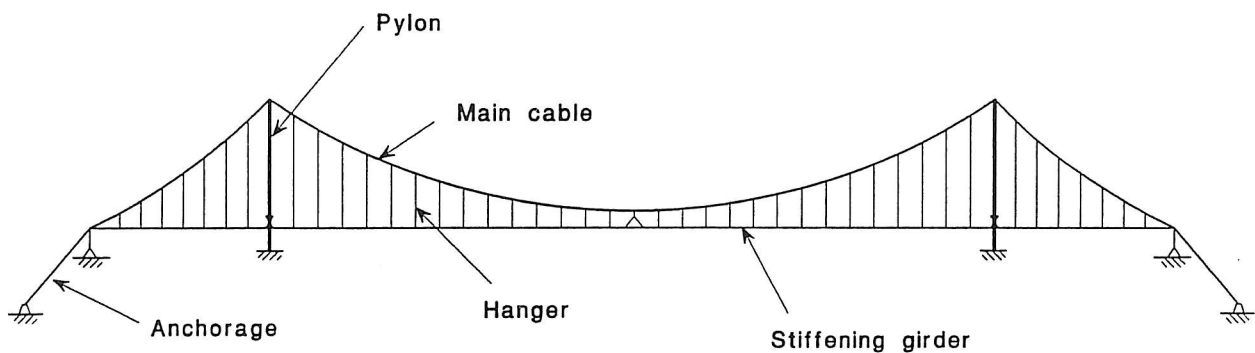


Figure 1 Principal components of a suspension bridge



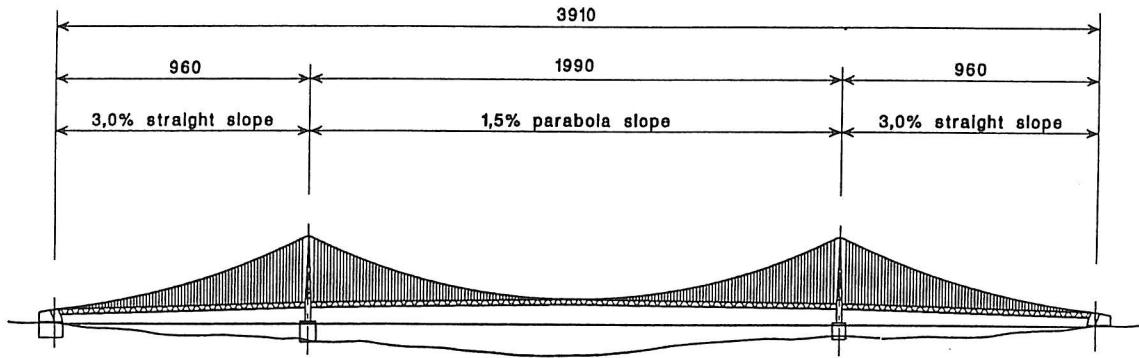


Figure 2 Akashi Kaikyo bridge



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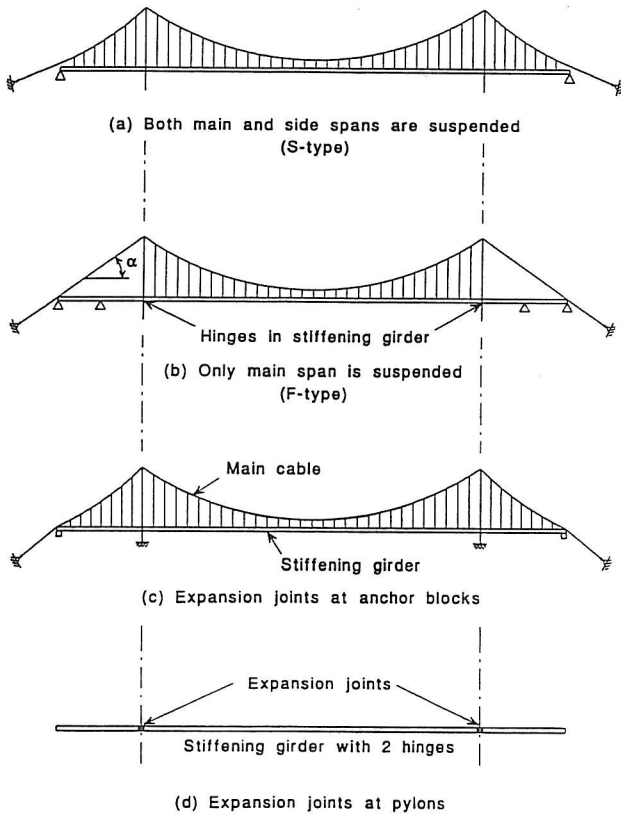


Figure 3 Classification of suspension bridges



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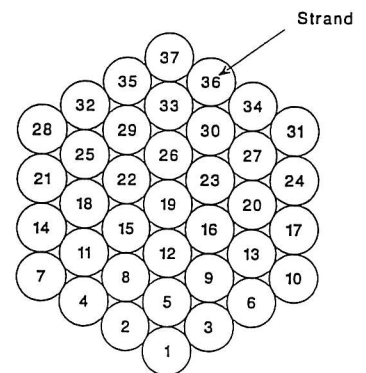


Figure 4 Pattern of strands in cable before compacting



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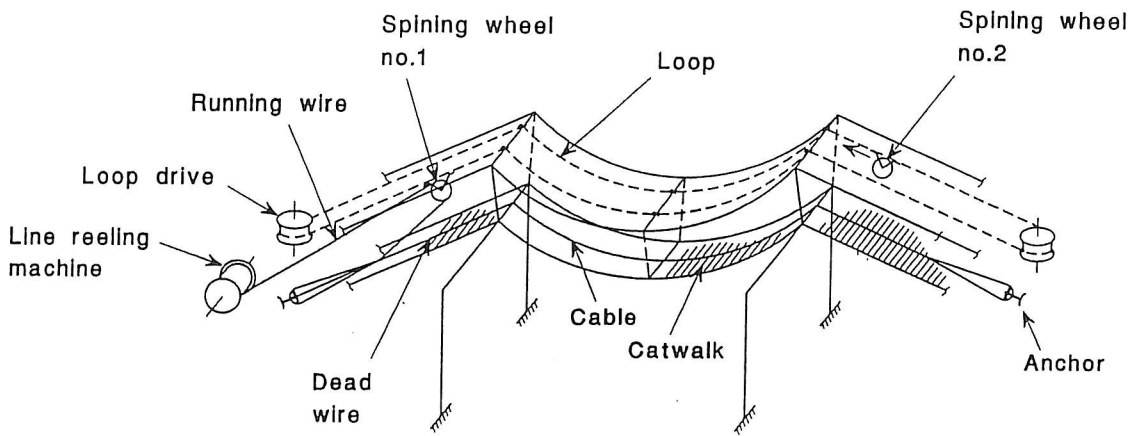


Figure 5 Cable spinning as developed by Roebling



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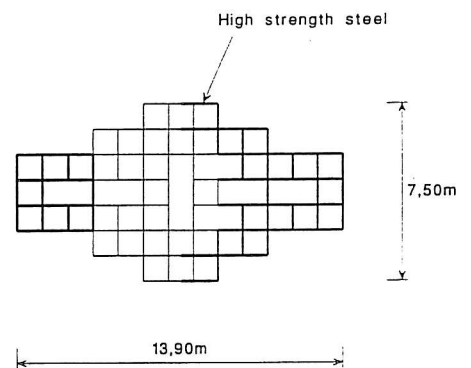
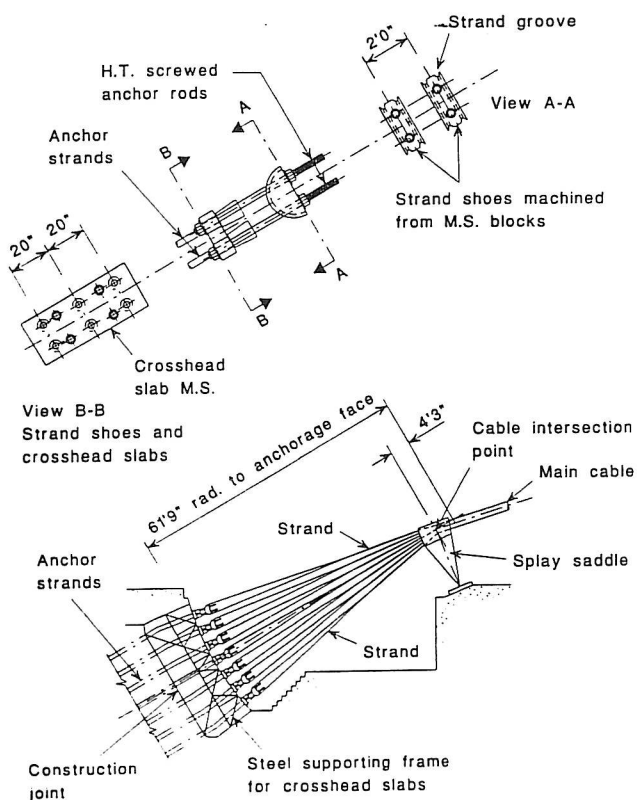


Figure 7 Cross-section of pylon: Golden gate bridge

Figure 6 Details of cable anchorage for the Severn bridge



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Lecture 15B.9

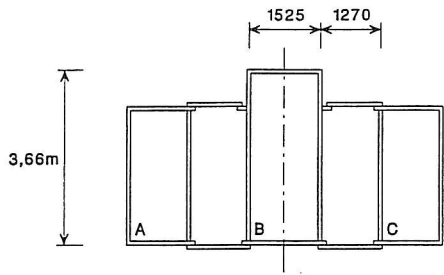


Figure 8 Cross-section of pylon:
Firth of Forth bridge

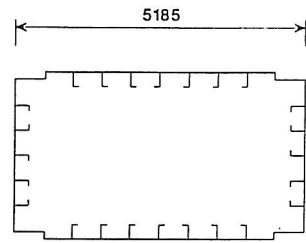


Figure 9 Cross-section of pylon:
Severn bridge



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Lecture 15B.9

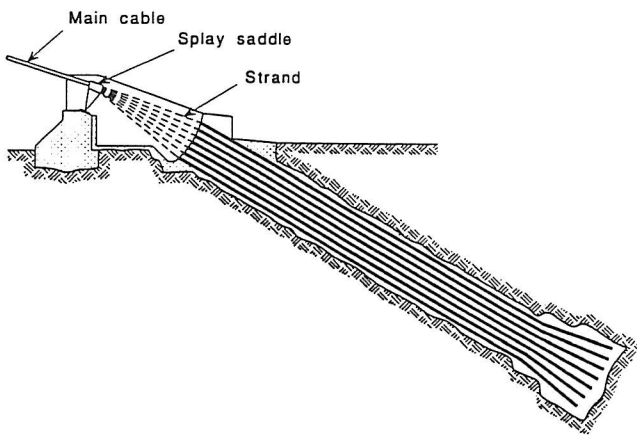


Figure 10 Firth of Forth bridge

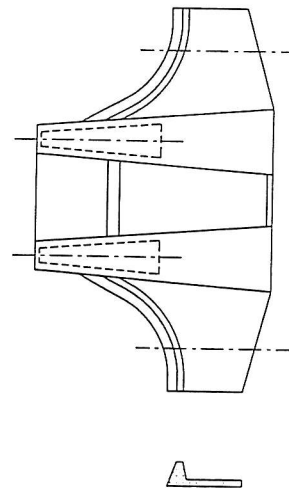


Figure 11 Concrete gravity anchorage:
Lillebelt bridge



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Lecture 15B.9

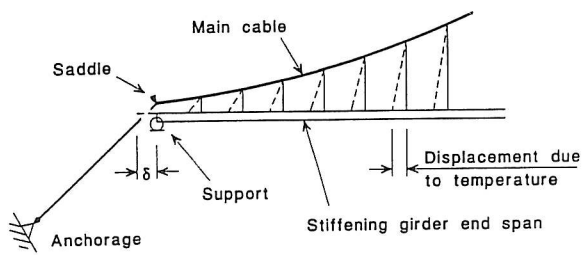


Figure 12 Influence of thermal expansion on hangers

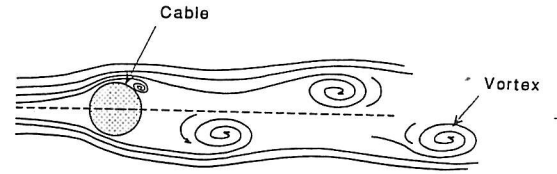


Figure 13 Vortex shedding



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Lecture 15B.9

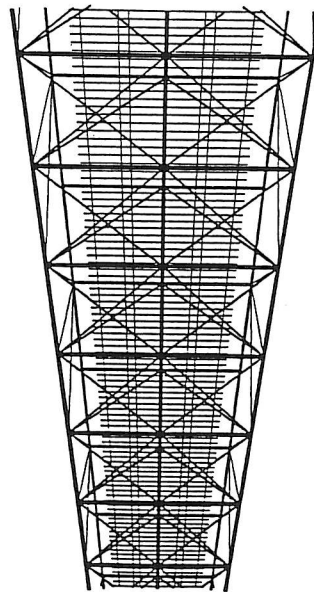


Figure 14 A view from underneath, showing the transparency of the Lisbon suspension bridge



Lecture 15B.9

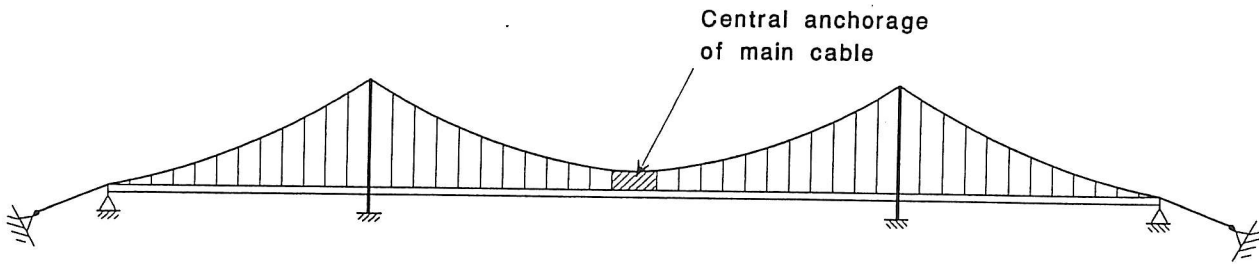


Figure 15 A technique for controlling flutter



Lecture 15B.9

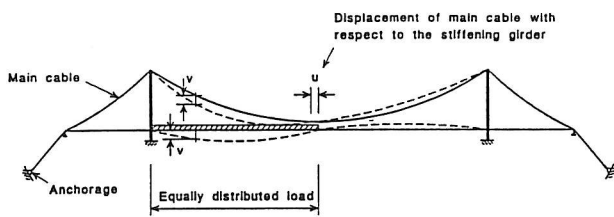


Figure 16 Deformation of the stiffening girder and displacement of the main cable due to a "half span" equally distributed load

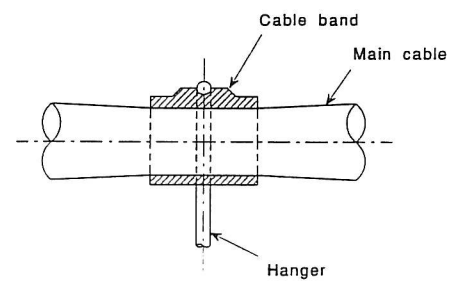


Figure 17 Cable band to main cable connection



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Lecture 15B.9

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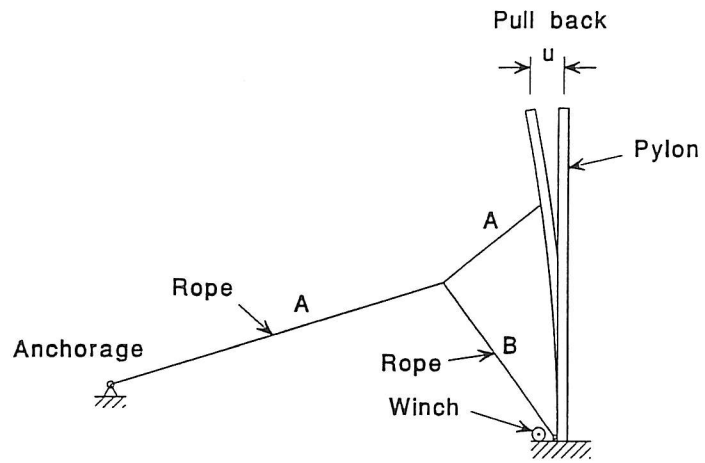


Figure 18 Prestetting pylons to prestress anchor portions of main cables

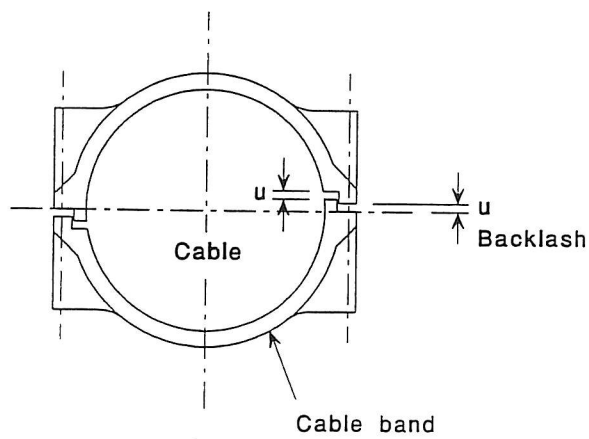


Figure 19 Backlash displacements in cable clamps

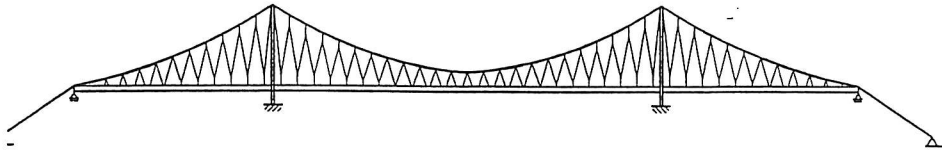


Figure 20 Hanger configuration:
Severn bridge

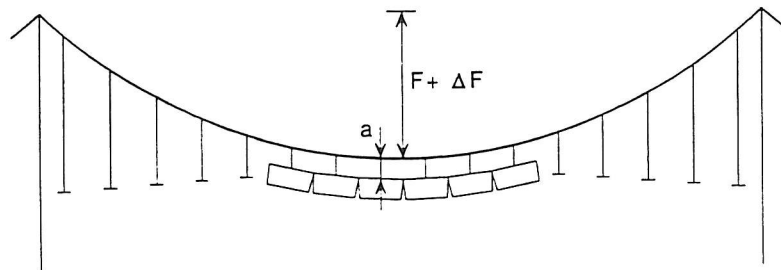


Figure 21 Cable distortion during erection
and to influence the on site
joints of stiffening girder

LECTURE 15B.10

Bridge Equipment

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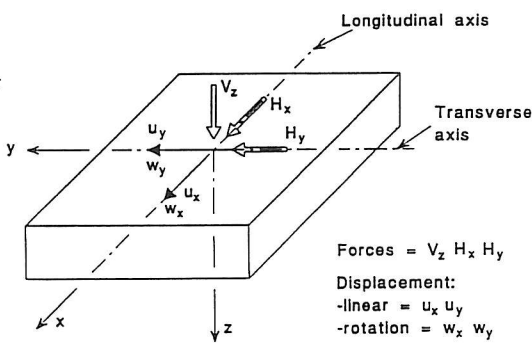
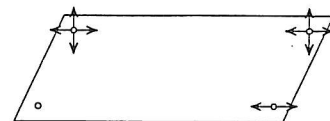
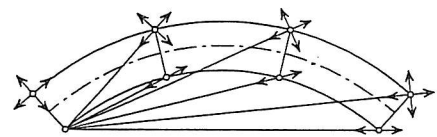


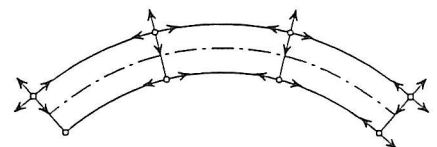
Figure 1 Forces and displacements on bearings



(a) Simple span.



(b) Long-span viaduct: bearings oriented in direction from the fixed point.



(c) Long-span viaduct: bearings oriented in tangential directions.

Key:

- Fixed bearing Unidirectional bearing
- Multidirectional bearing

Figure 2 Layout of bearing systems.



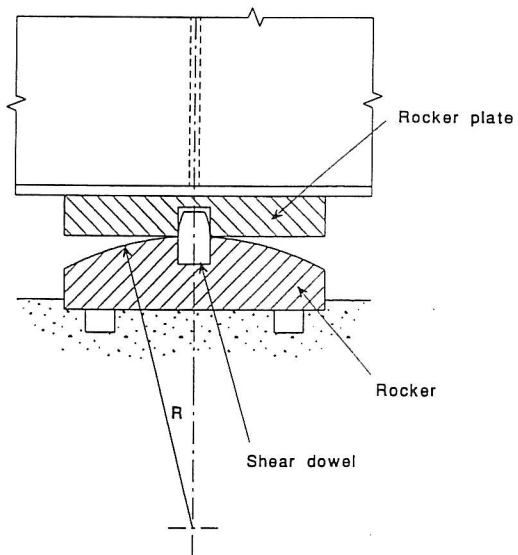


Figure 3 Elevation of line rocker bearing.



Lecture 15B.10

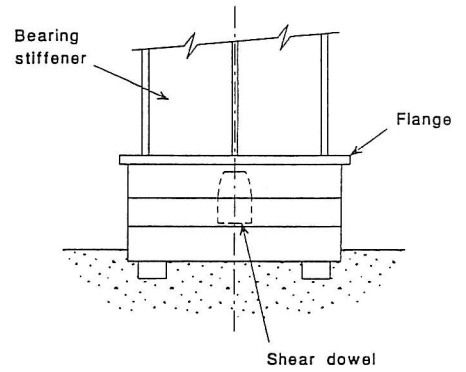


Figure 4 Section through line rocker bearing.



Lecture 15B.10

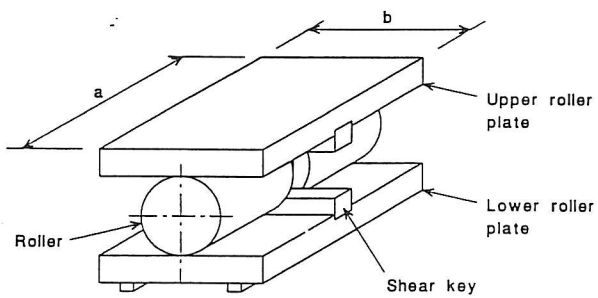


Figure 5 Roller bearing.



Lecture 15B.10

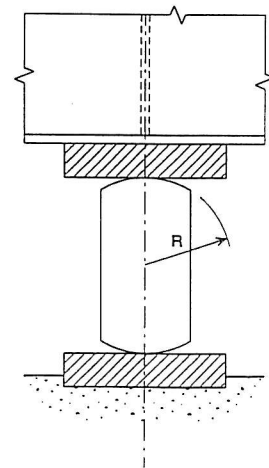


Figure 6 Flat-sided roller bearing.



Lecture 15B.10

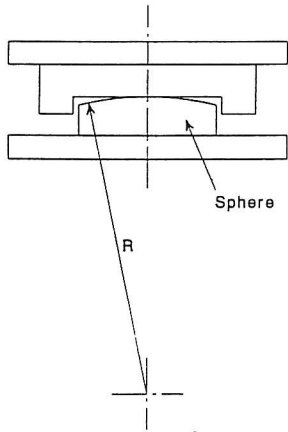


Figure 7 Plane/spherical point bearing.

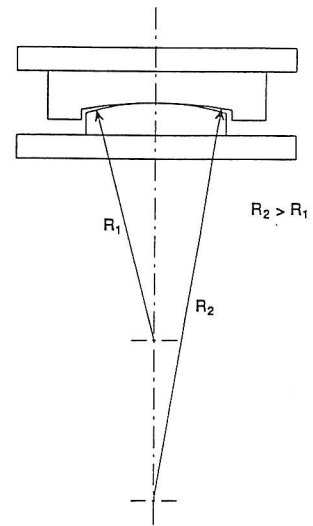


Figure 8 Double spherical point bearing.

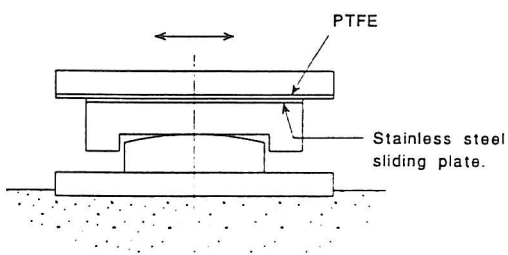


Figure 9 Sliding point bearing.

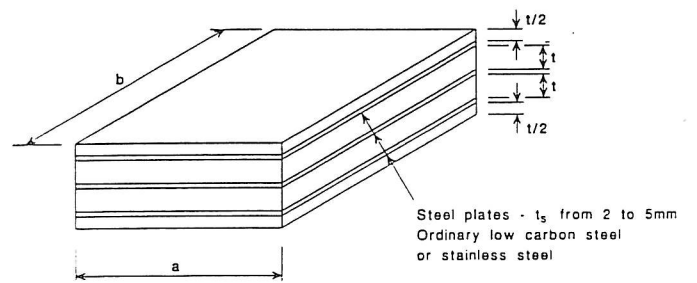


Figure 10 Reinforced elastomeric bearing system

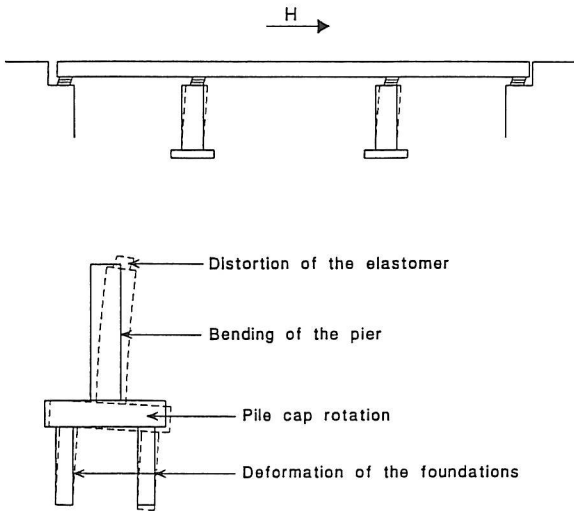


Figure 11 Location and action of the bearings.



Lecture 15B.10

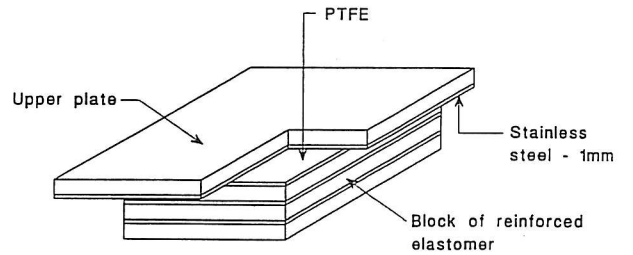


Figure 12 Sliding bearings in reinforced elastomer.



Lecture 15B.10

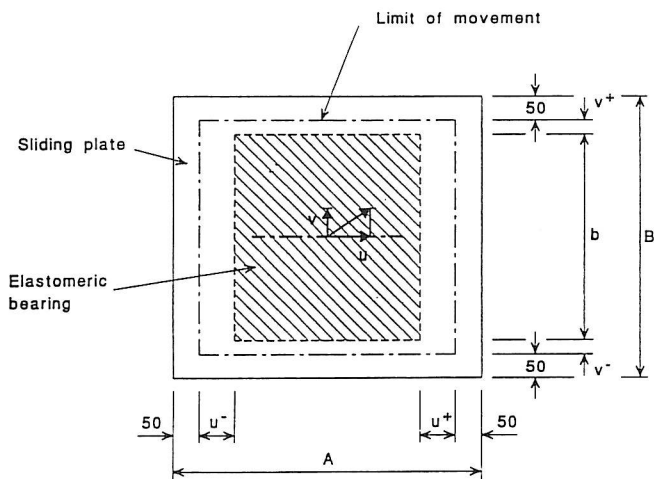


Figure 13 Layout of elastomeric sliding bearing



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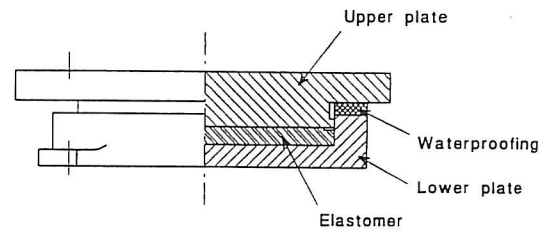


Figure 14 Fixed pot bearing.



Lecture 15I

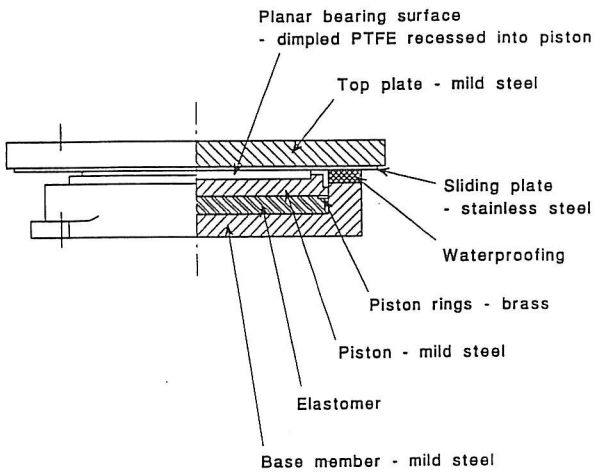


Figure 15 Multidirectional pot bearing.



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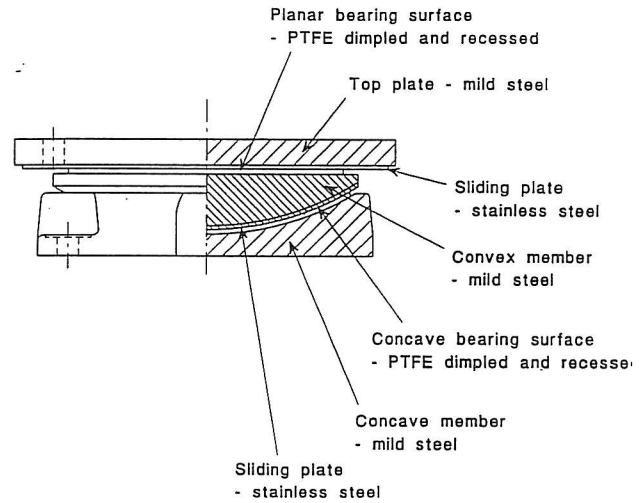


Figure 16 Bearings with spherical gap.



Lecture 15B.11

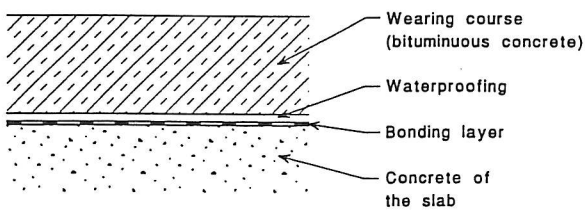


Figure 17 Finishing on concrete slab.

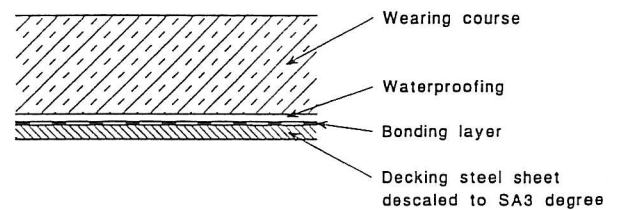


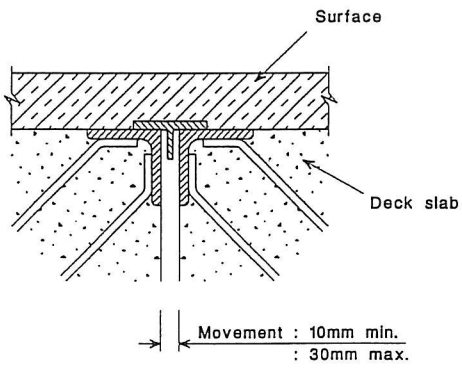
Figure 18 Finishing on orthotropic slab.



Lecture 15B.10



Lecture 15B.11



(a) Buried joint

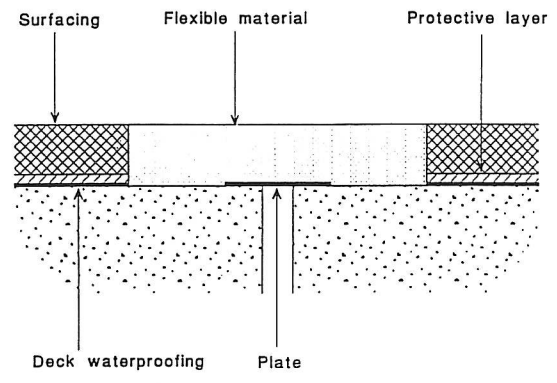


Figure 19b Asphaltic plug joint

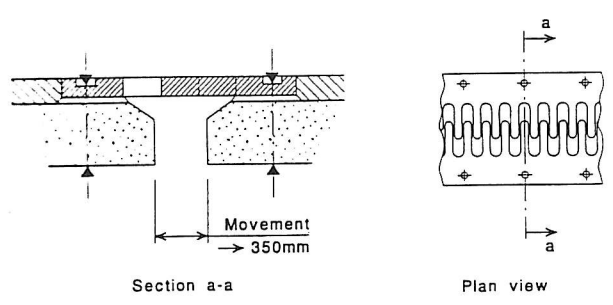
Figure 19a Types of covered expansion joint.



Lecture 15B.10



Lecture 15B.10



Section a-a

Plan view

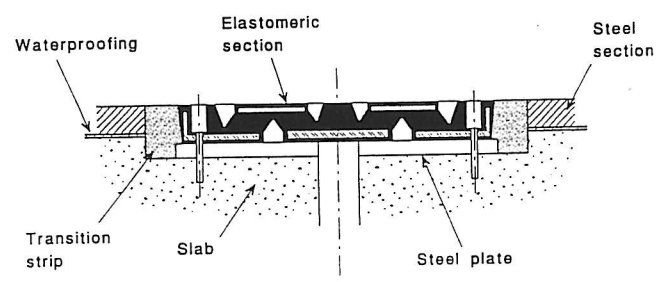


Figure 21 Joint with elastomeric extensions.

Figure 20 Toothed joint.



Lecture 15B.10



Lecture 15B.10

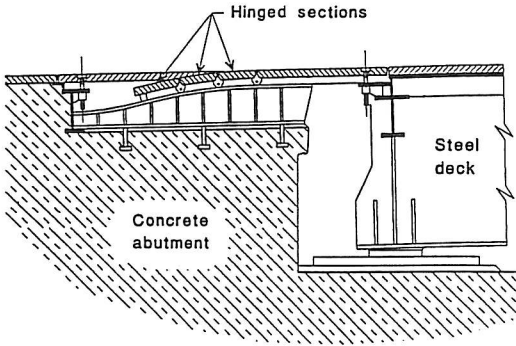


Figure 22 Roller shutter joint.

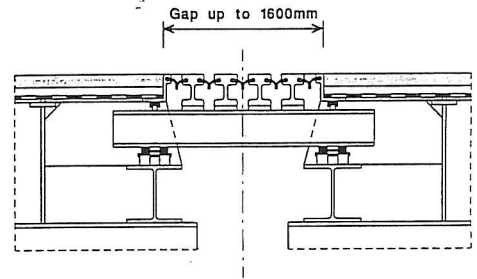


Figure 23 Bellows joints.



Lecture 15B.10



Lecture 15B.

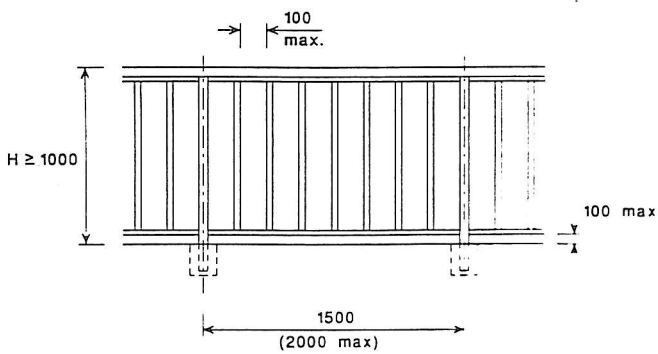


Figure 24 Pedestrian parapet.

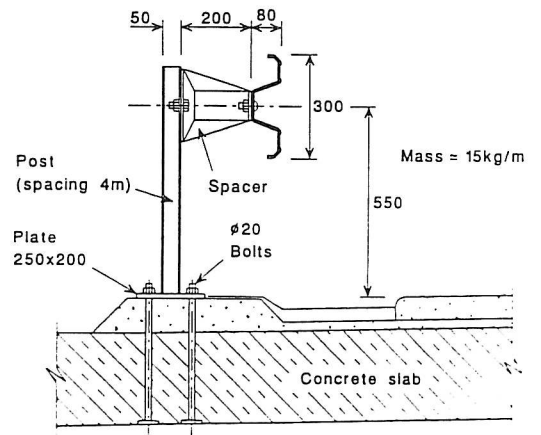
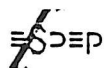


Figure 25 Crash barrier



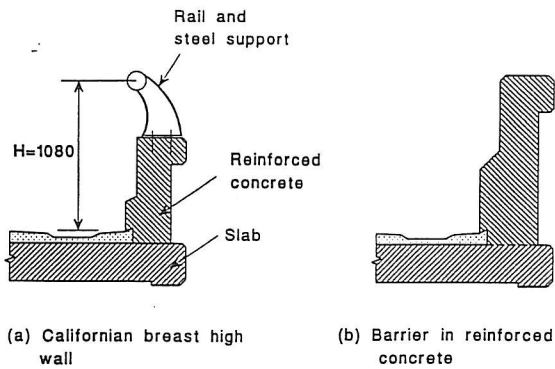


Figure 26 Examples of rigid safety fences

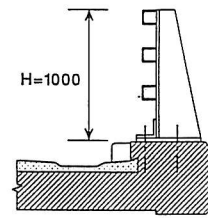


Figure 27 Typical flexible safety fence



Lecture 15B.10



Lecture 15B.

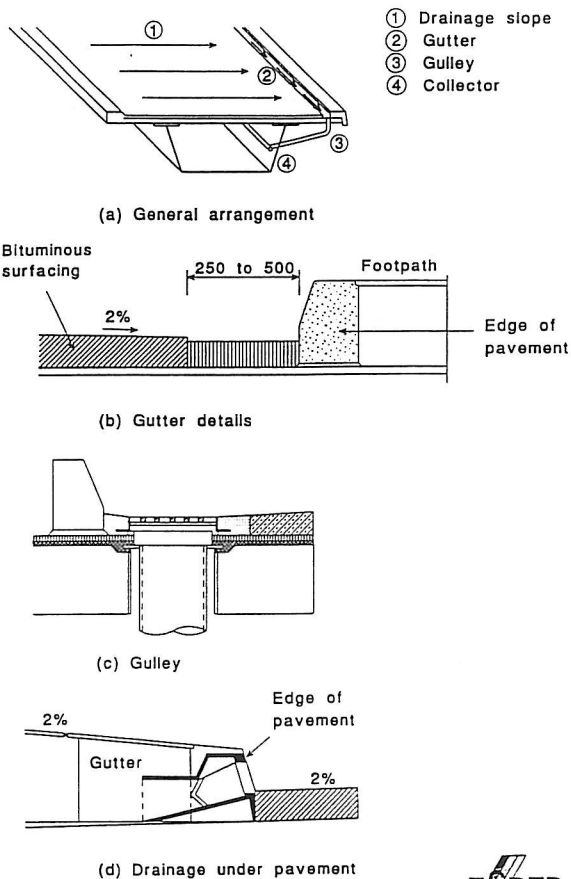


Figure 28 Drainage of rainwater



Lecture 15B.10

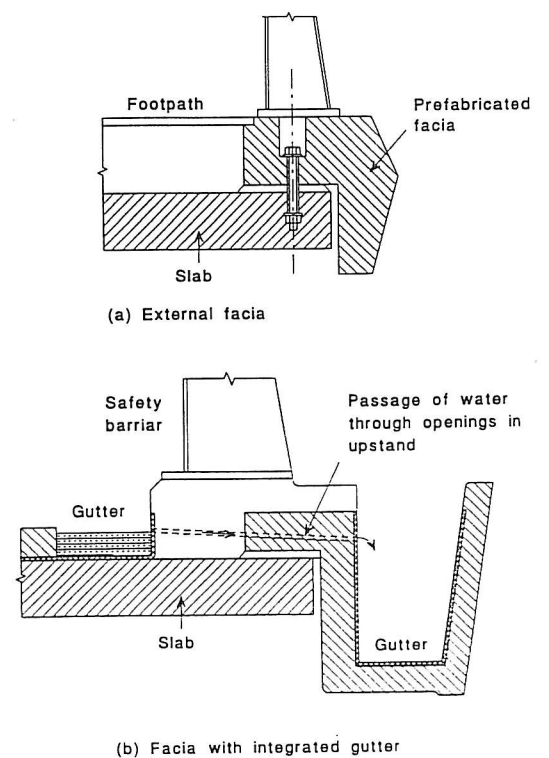


Figure 29 Fascias



Lecture 15B.

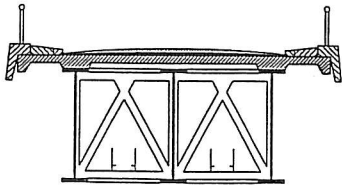


Figure 30 Fixed inspection walkways

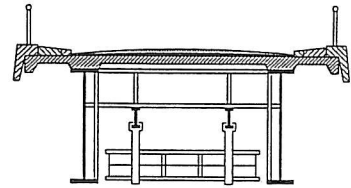


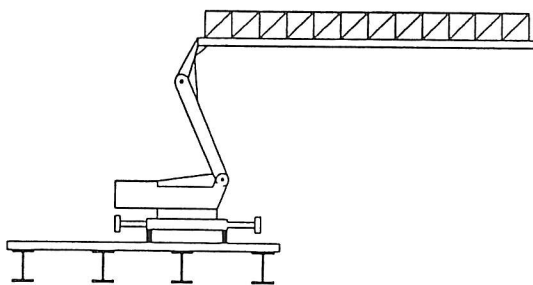
Figure 31 Moveable inspection gantry



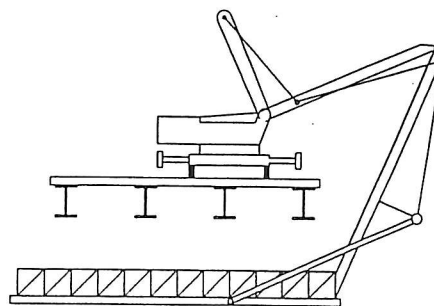
Lecture 15B.10



Lecture 15B.10



(a)



(b)

Figure 32 Special mobile inspection equipment



Lecture 15B.10

LECTURE 8.5.1

Design of Box Girders

LECTURES

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Figure 4:	Pages 3 & 9
Figure 5:	Pages 4 & 9
Figure 6:	Page 4
Figure 7:	Page 9
Figure 8:	Page 10
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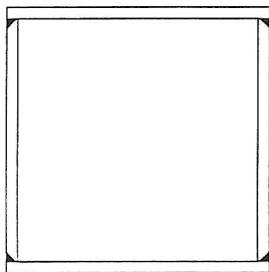


Figure 1 Cross-section of a box girder used in buildings

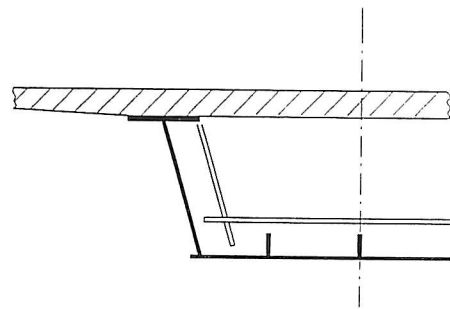


Figure 2 (a) Cross-section of a box beam with composite concrete top flange

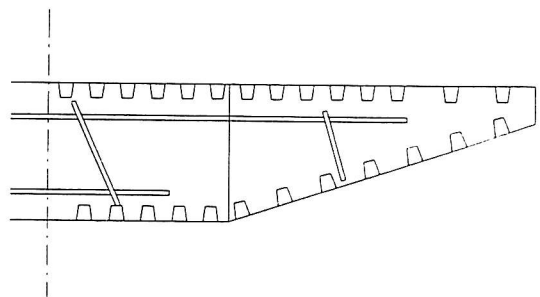


Figure 2 (b) Cross-section of an orthotropic box beam

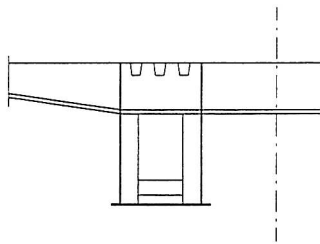


Figure 3 Composite slab with twin box beams

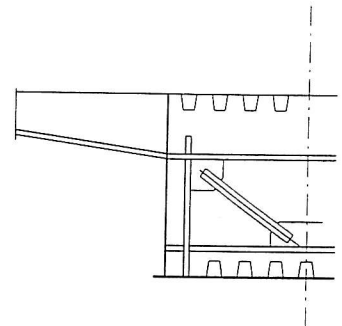


Figure 4 Reinforcement of the cross-section of an orthotropic box beam



Lecture 8.5.1



Lecture 8.5.1

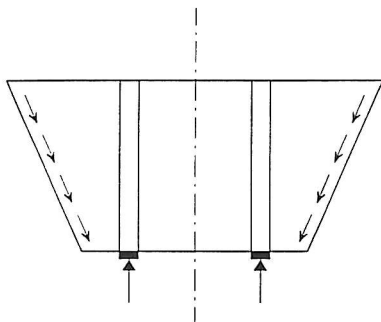


Figure 5 Transfer of reactions through support diaphragms

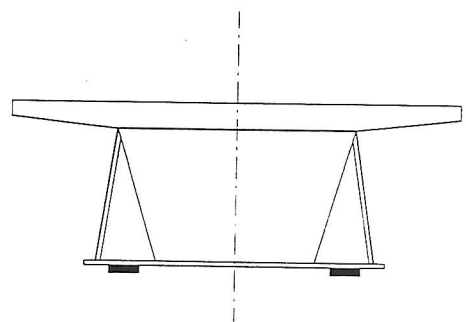


Figure 6 Load-bearing stiffeners external to a box girder



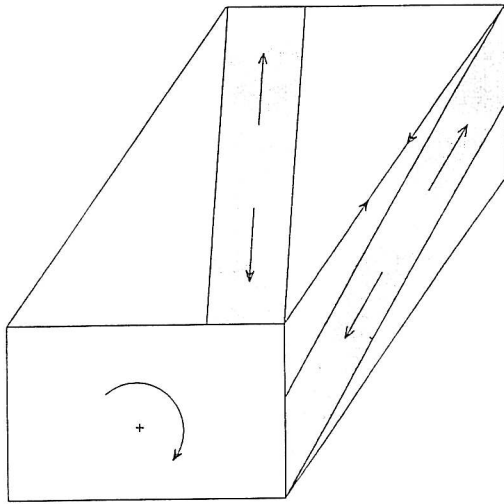


Figure 7 Tension fields developed under torsion

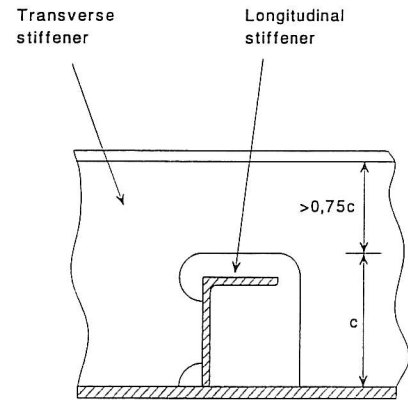


Figure 8 Longitudinal stiffener passing through transverse stiffener



Lecture 8.5.1



Lecture 8.5.1

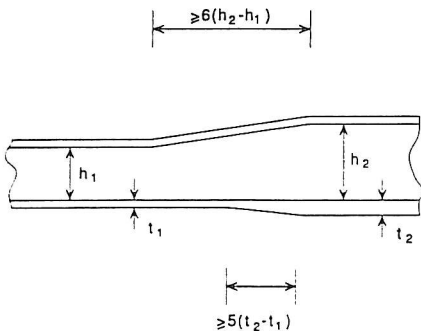


Figure 9 Tapering of longitudinal stiffener

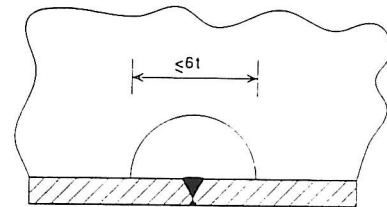


Figure 10 Cut-out to allow butt welding



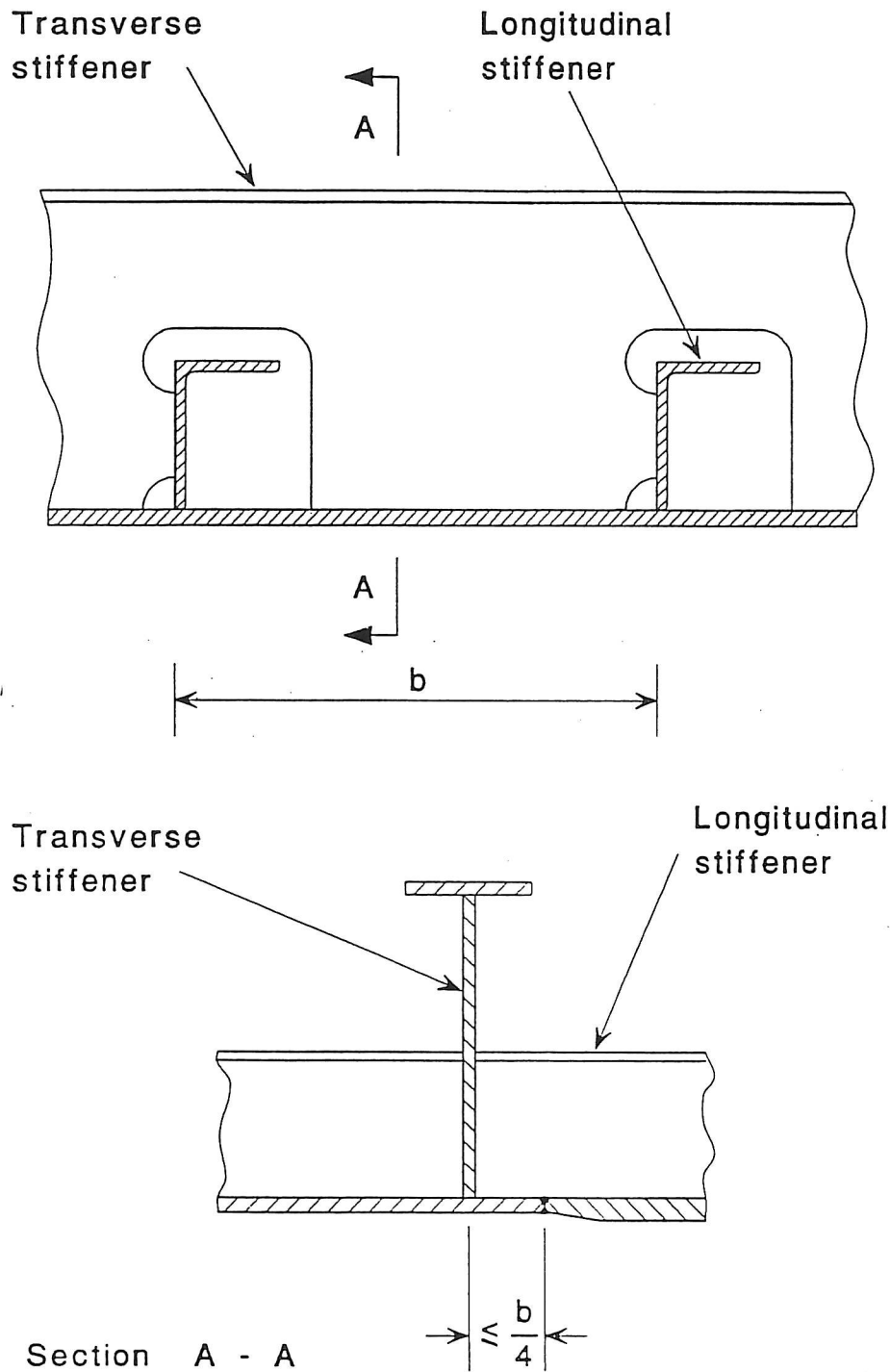


Figure 11 Transverse stiffener welded to thinner plate adjacent to transverse butt weld in the plate



LECTURE 8.5.2

Advanced Methods for Box Girder Bridges

FIGURES

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- Figure 9: Page 12

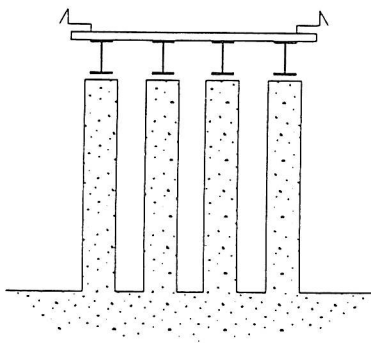
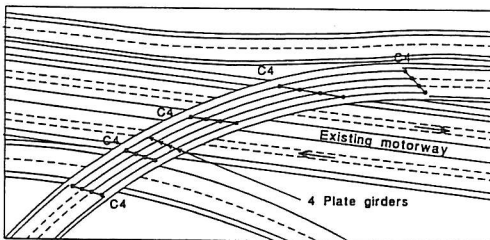
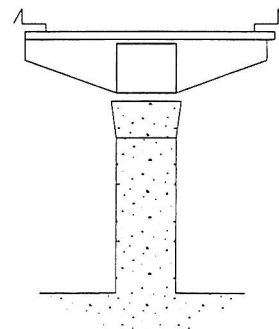
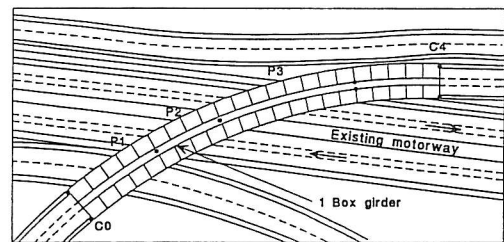


Figure 1 Plate girder bridge



Box girder bridges are less expensive and more aesthetic in appearance than plate girder bridges and skew alignments of bearings are avoided.

Figure 2 Box girder bridge



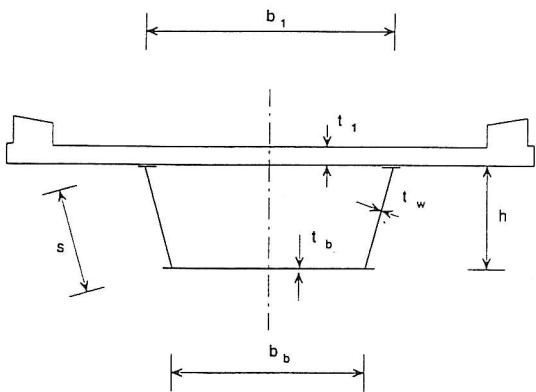


Figure 3 Composite box girder bridge with composite upper deck



Lecture 8.5.2

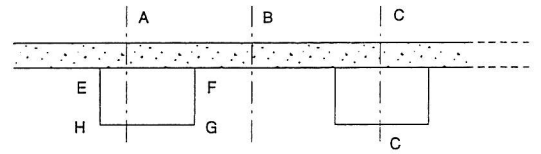


Figure 4 Interpretation of the output of a grillage analysis



Lecture 8.5.2

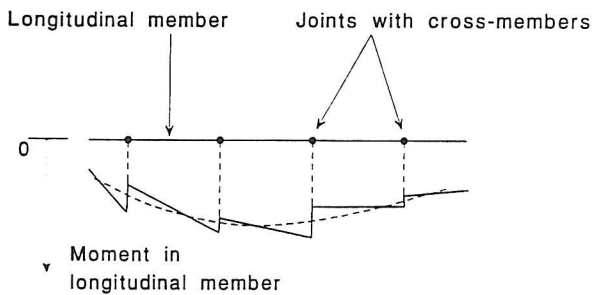


Figure 5 Typical bending or torsional moments given by a grillage analysis



Lecture 8.5.2

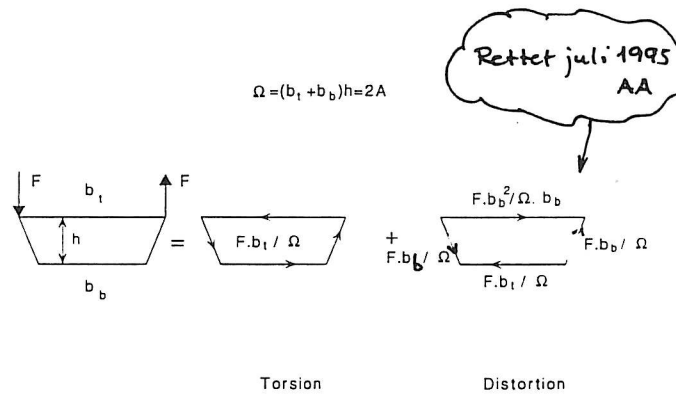
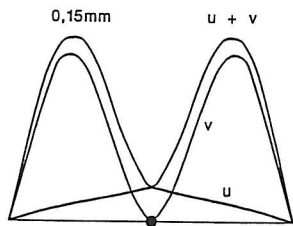
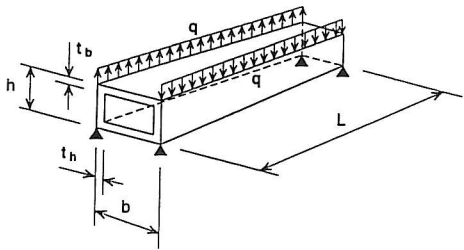


Figure 6 Computation of distortion force



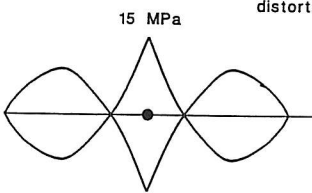
Lecture 8.5.2



Diaphragm $t = 5\text{mm}$

u : Top corner deflection due to torsion

v : Top corner deflection due to distortion



Warping stresses with one single diaphragm

Figure 7A Influence of diaphragm separation - one diaphragm

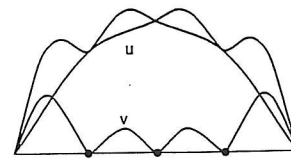


Lecture 8.5.2

Limit conditions on bearings:
 flexure rotation-free
 torsional rotation-blocked
 undeformable diaphragms at ends
 no warping stress at the ends

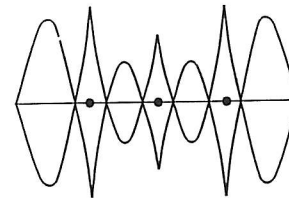
Numerically:
 $L = 2\text{m}$
 $b = 0,10\text{m}$ $t_b = 0,001\text{m}$
 $h = 0,05\text{m}$ $t_h = 0,003\text{m}$
 $E = 200.000\text{ N/mm}^2$ $\nu = 0,3$
 $q = 250\text{ N/ml}$

$$u + v < 0,030\text{mm}$$



Diaphragms $t = 2\text{mm}$

3 MPa



Warping stresses with three diaphragms

Figure 7B Influence of diaphragm separation - three diaphragms

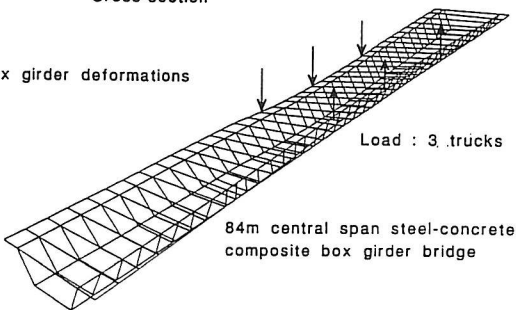


Lecture 8.5.2



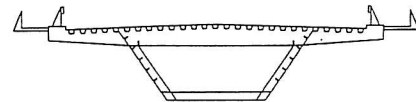
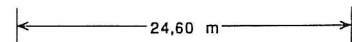
Cross-section

Box girder deformations



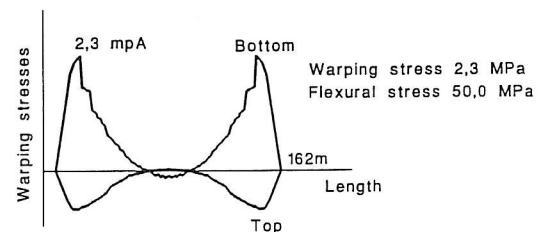
Load : 3 trucks

84m central span steel-concrete composite box girder bridge

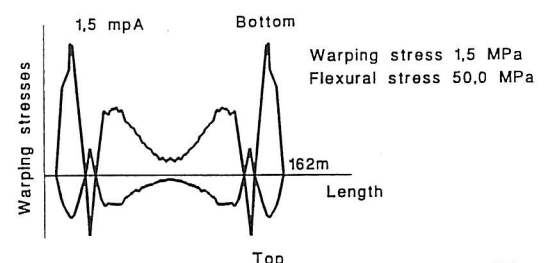


Cross-section

10,25 m



Folded plate analysis without additional bracings under uniform traffic torsion



Folded plate analysis with two additional bracings under uniform traffic torsion

Figure 9 The Cheviré bridge



Lecture 8.5.2

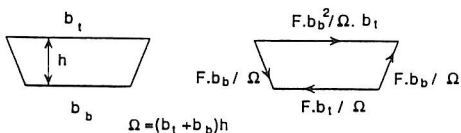
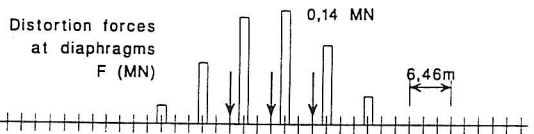


Figure 8 Distribution of the distortion forces between the cross-frames of a bridge



Lecture 8.5.2

