

Store stålbroer (ESDEP-uddrag)

bjælkebroer samt skråtags- og hængebroer : figurhæfte

Albertsen, A.

Publication date:
1994

Document Version
Også kaldet Forlagets PDF

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Albertsen, A. (1994). *Store stålbroer (ESDEP-uddrag): bjælkebroer samt skråtags- og hængebroer : figurhæfte*. Institut for Bygningsteknik, Aalborg Universitet. U / Nr. U9408

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

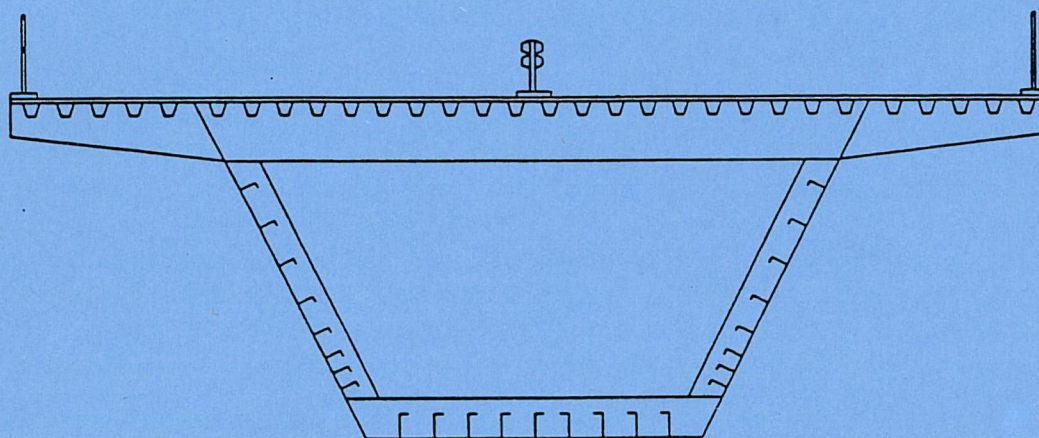
Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

INSTITUTTET FOR BYGNINGSTEKNIK

DEPT. OF BUILDING TECHNOLOGY AND STRUCTURAL ENGINEERING
AALBORG UNIVERSITET • AUC • AALBORG • DANMARK

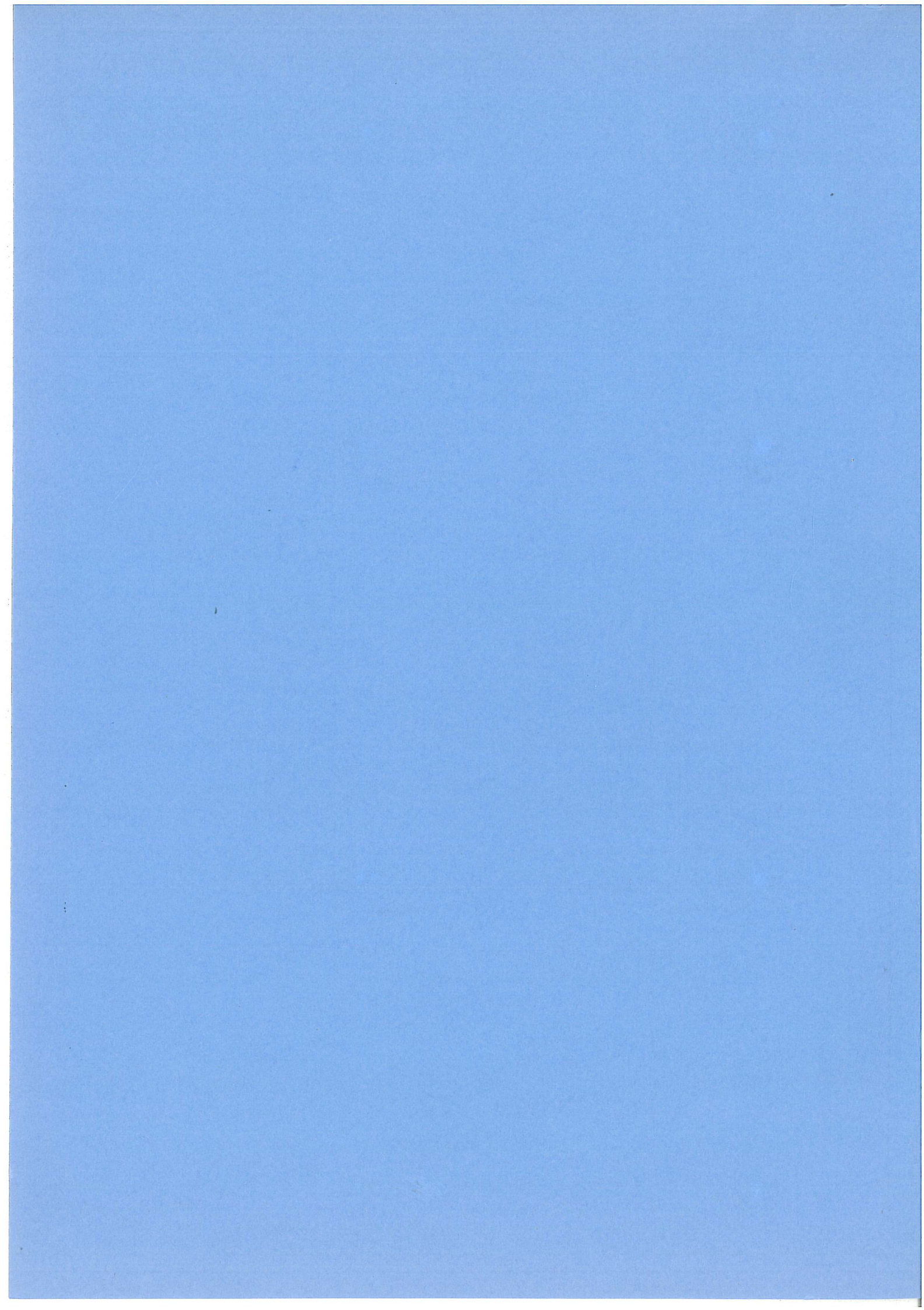
41.25



FIGURHÆFTE

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

ISSN 0902-8005 U9408



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

INDHOLDSFORTEGNELSE

- 15B.1 Conceptual Choice
- 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
- 15B.8 Cable Stayed Bridges
- 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

LECTURES

Lecture 1B.6.1:	Page 4
Lectures 15B:	Page 4
Lecture 15B.2:	Page 7

FIGURES

Figure 1:	Page 4
Figure 2:	Page 4
Figure 3:	Page 8
Figure 4:	Page 8
Figure 5:	Pages 10 & 14
Figure 6:	Page 10
Figure 7:	Page 10
Figure 8:	Pages 12, 13 & 14
Figure 9:	Page 13
Figure 10:	Page 13
Figure 11:	Pages 13, 14 & 15
Figure 12:	Pages 13 & 14
Figure 13:	Page 16
Figure 14:	Page 16
Figure 15:	Page 16
Figure 16:	Page 16
Figure 17:	Page 17

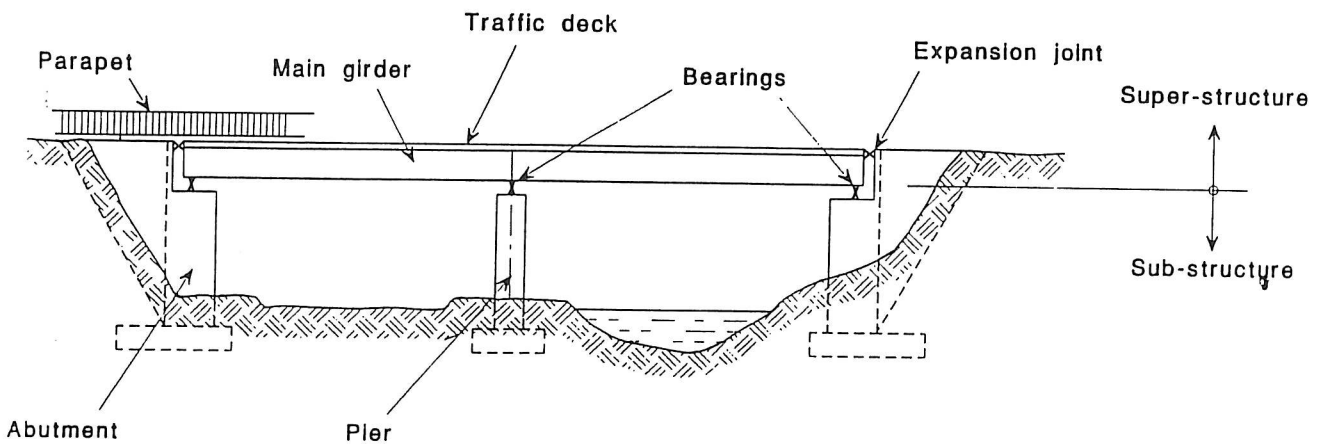
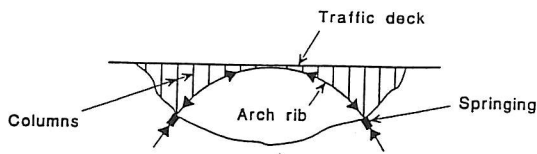
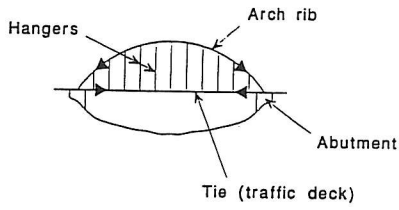


Figure 1 Elevation of typical girder bridge

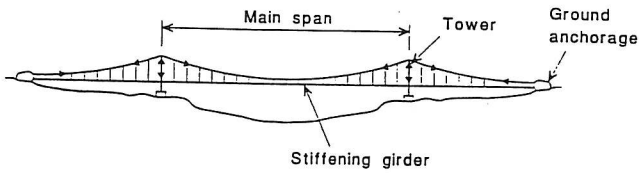




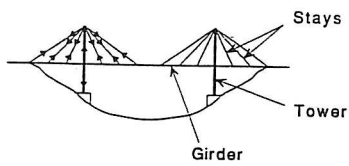
(a) Fixed arch bridge



(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

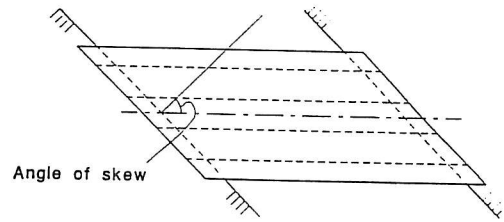


Figure 3 Typical plan view of skew bridge

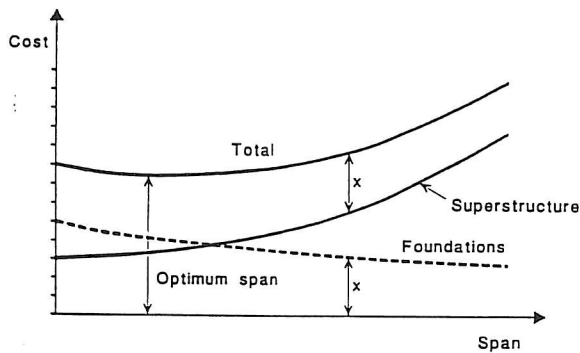


Figure 4 Bridge costs (diagrammatic)

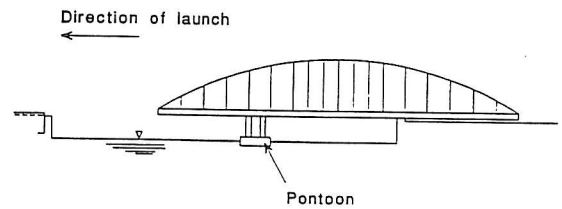


Figure 5 Typical launching arrangement using pontoon



Lecture 15B 1



Lecture 15B 1

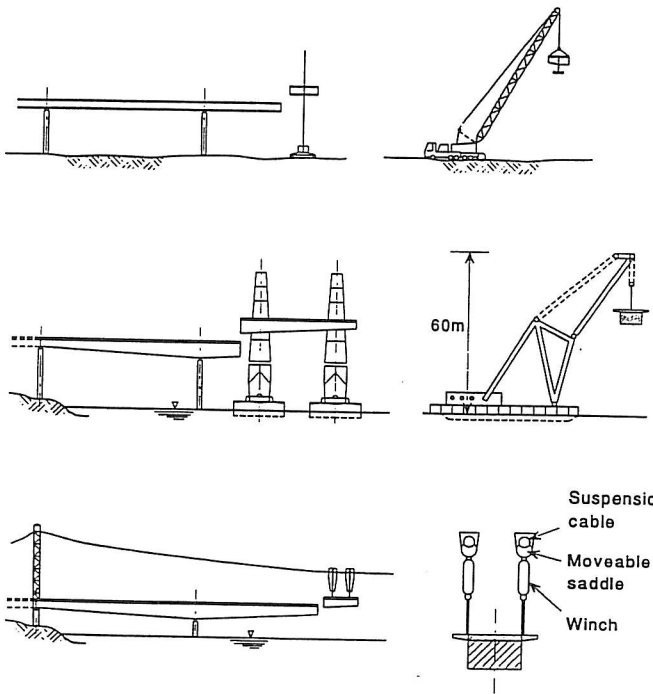
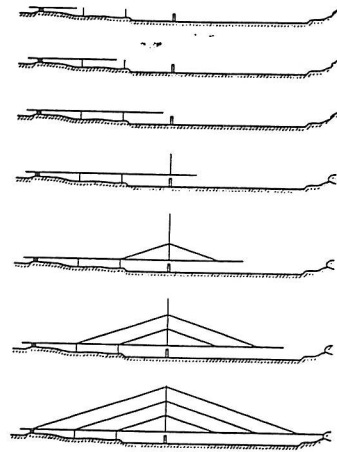


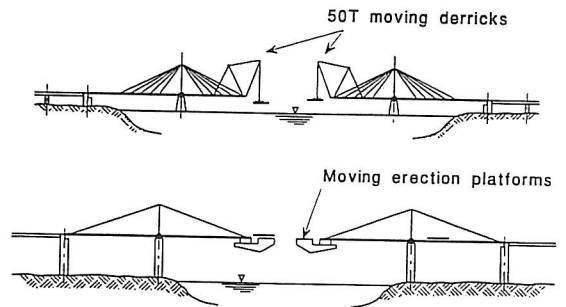
Figure 6 Typical methods of lifting bridge sections



Lecture 15B.1



(a) Overall scheme



(b) Options for positioning segments

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



Lecture 15B.1

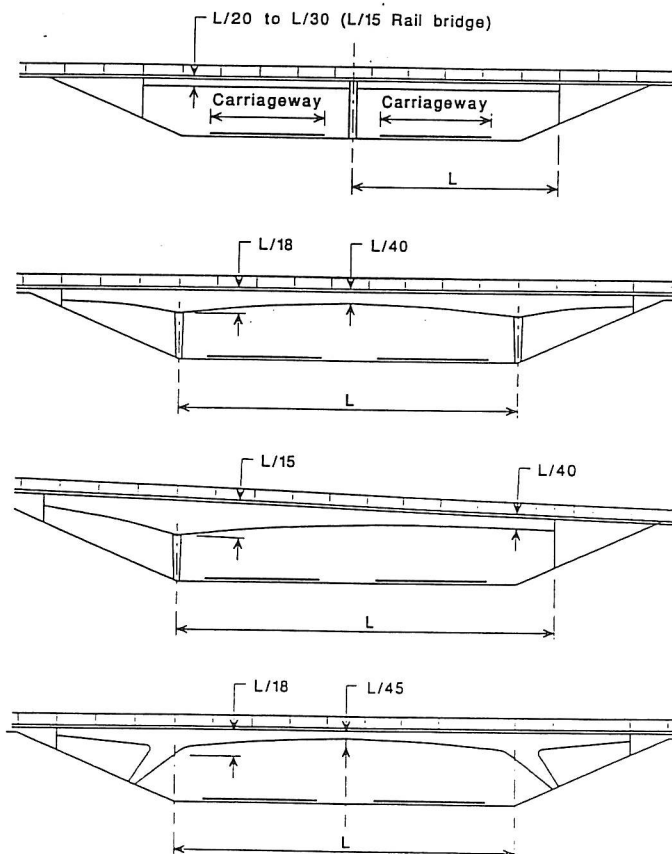


Figure 8 Typical elevations of highway overbridges.



Lecture 15B.1

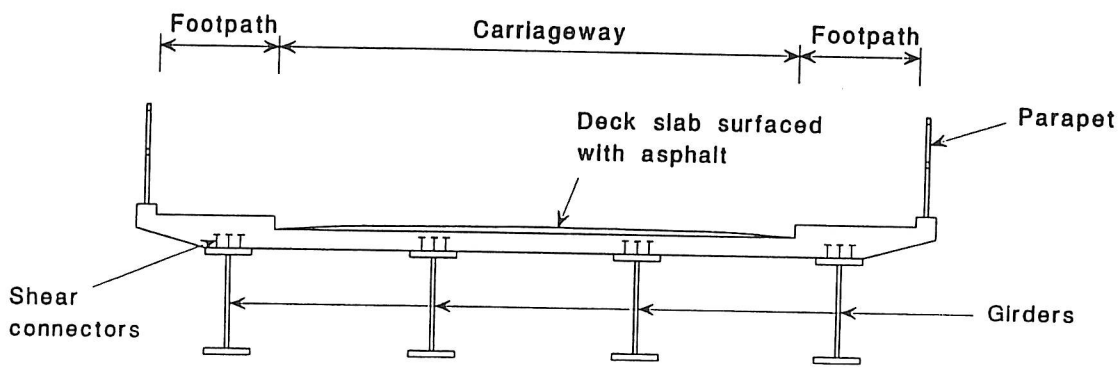


Figure 9 Typical cross-section of a single carriageway highway bridge



Lecture 15B.1

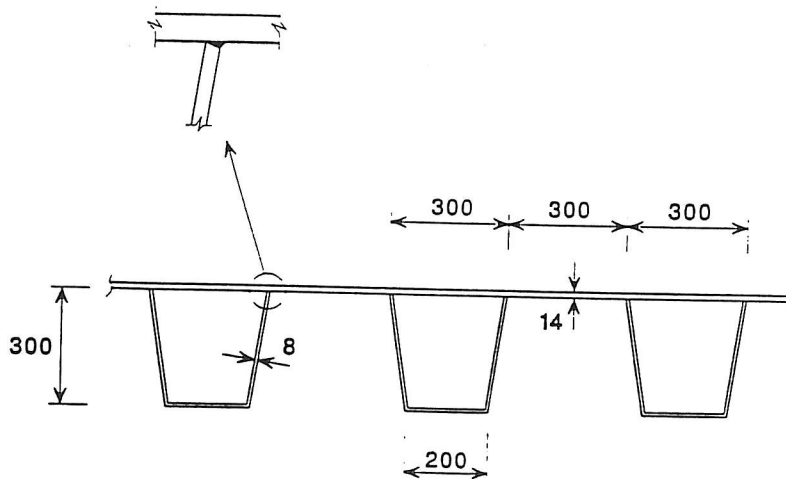
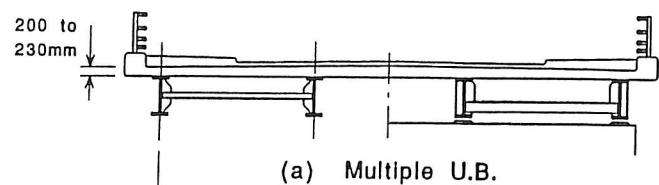


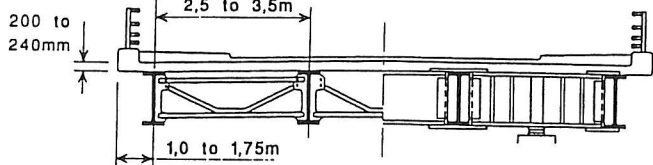
Figure 10 Orthotropic steel deck.



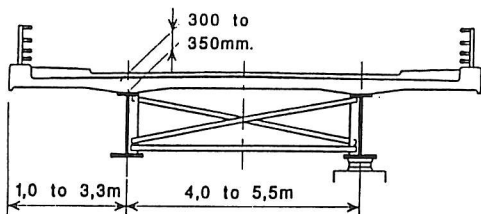
Lecture 15B.1



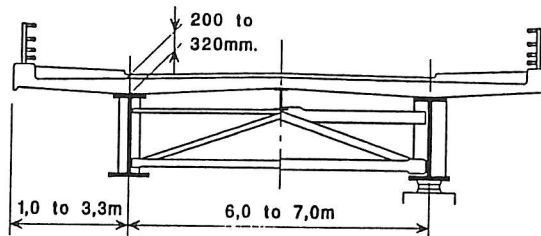
(a) Multiple U.B.



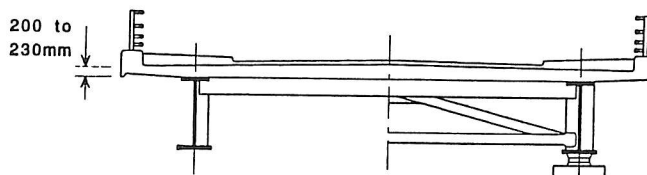
(b) Multiple plate girders



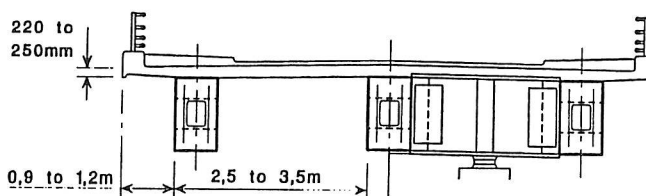
(c) Twin plate girders with haunched slab



(d) Twin plate girders and stringer



(e) Twin plate girders and cross girders



(f) Multiple box

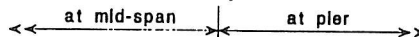


Figure 11 Typical cross-sections for highway bridges.

Lecture 15B.1

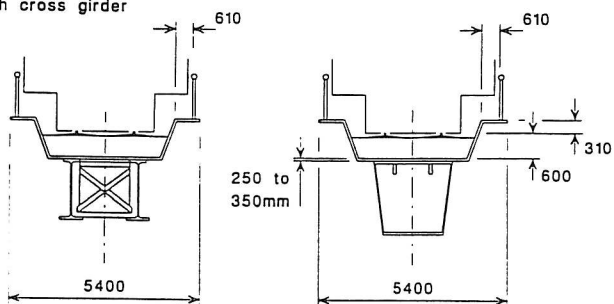
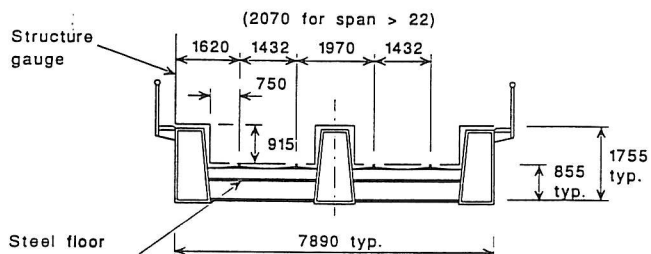
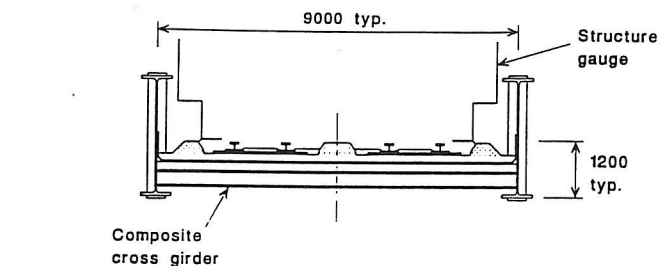


Figure 12 Typical cross-sections for railway bridges



Lecture 15B.1

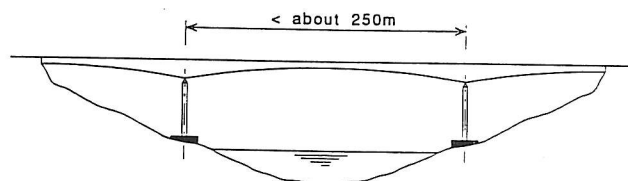


Figure 13 Typical elevation of long span girder bridge



Lecture 15B.1

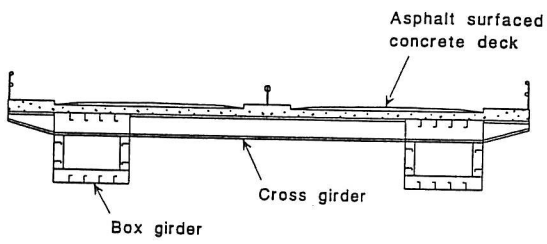


Figure 14 Typical cross-section of wide, long span, girder bridge.

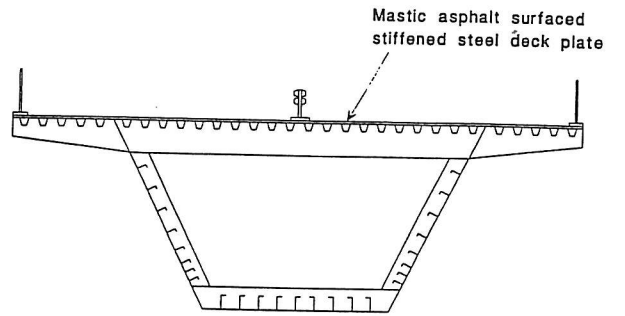
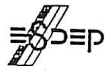


Figure 15 Typical cross-section of box girder long span bridge



Lecture 15B.1



Lecture 15B.1

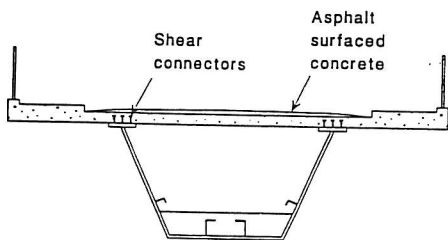
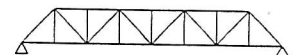
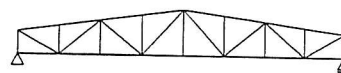
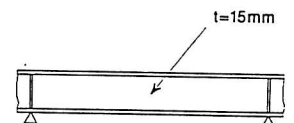
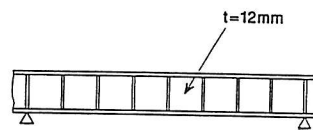


Figure 16 Typical open top composite box-girder bridge



(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

LECTURES

Lecture 15.3: Page 15

FIGURES

Figure 1:	Page 4
Figure 2:	Page 4
Figure 3:	Page 4
Figure 4:	Page 4
Figure 5:	Page 4
Figure 6:	Page 5
Figure 7:	Page 5
Figure 8:	Page 5
Figure 9:	Page 5
Figure 10:	Page 5
Figure 11:	Page 5
Figure 12:	Page 7
Figure 13:	Page 7
Figure 14:	Page 7
Figure 15:	Page 7
Figure 16:	Page 8
Figure 17:	Page 9
Figure 18:	Page 10
Figure 19:	Page 10
Figure 20:	Page 11
Figure 21:	Page 13

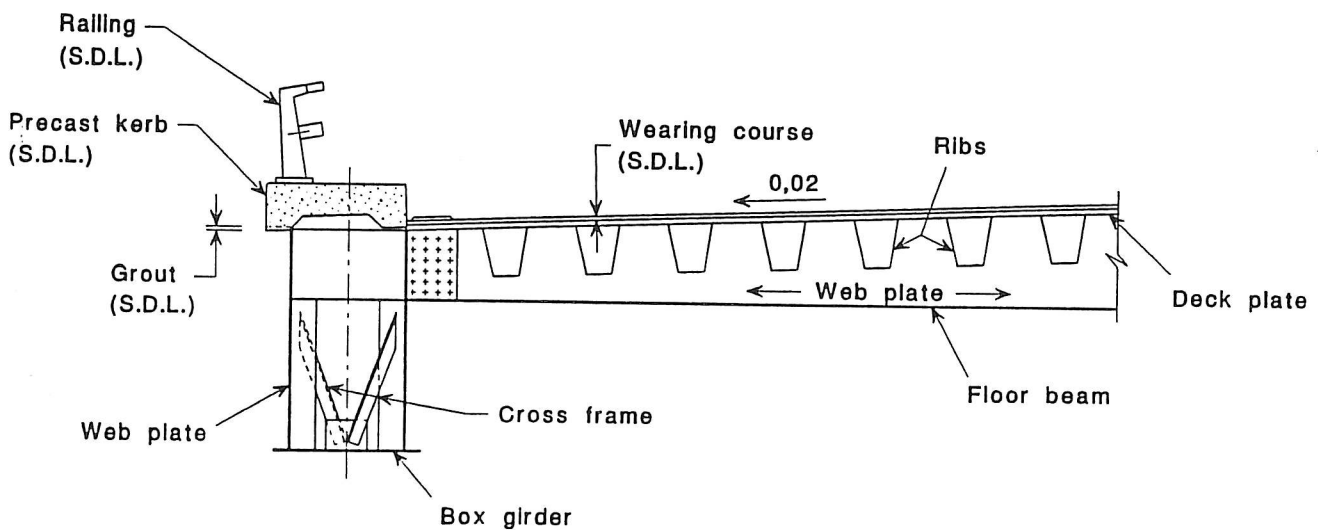


Figure 1 Dead load and superimposed dead load (S.D.L.)



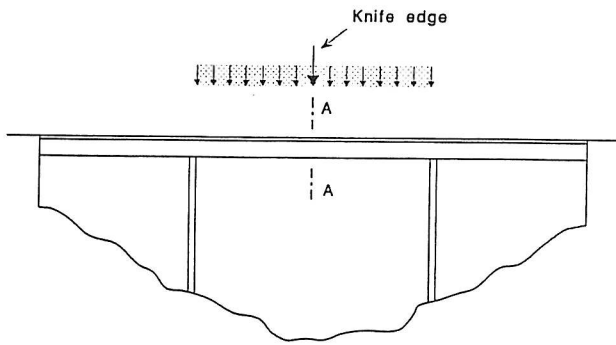


Figure 2 Location of distributed and knife edge loads to produce maximum mid-span moment.

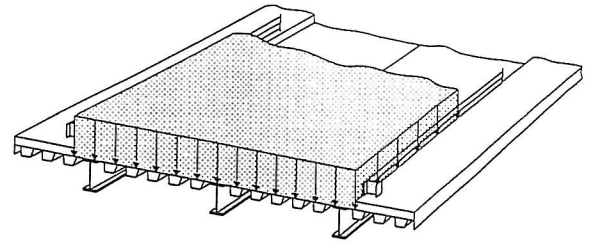


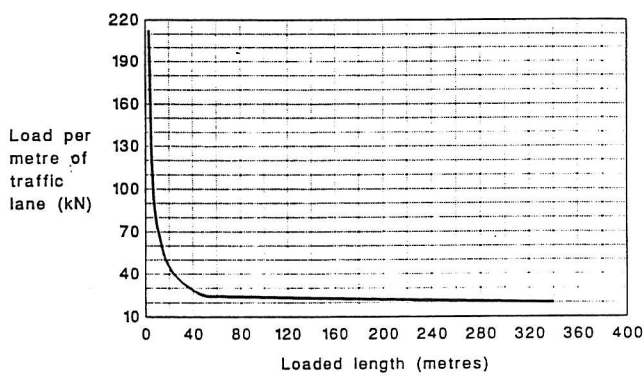
Figure 3 Uniformly distributed load on traffic lanes.



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.

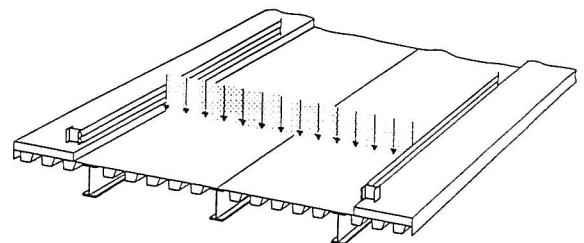


Figure 5 Knife-edge load.

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



Lecture 15B.2



Lecture 15B.2

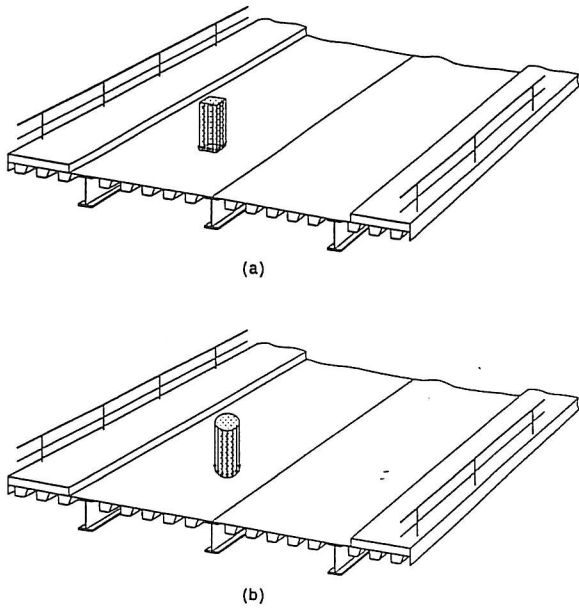


Figure 6 Single wheel loads



Lecture 15B.2

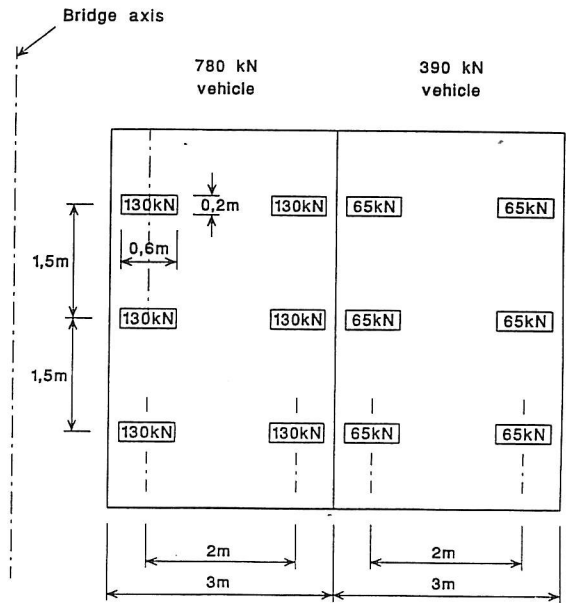


Figure 7 Concentrated wheel loads on bridge decks, according to load specifications by the Danish Road Directorate.



Lecture 15B.2

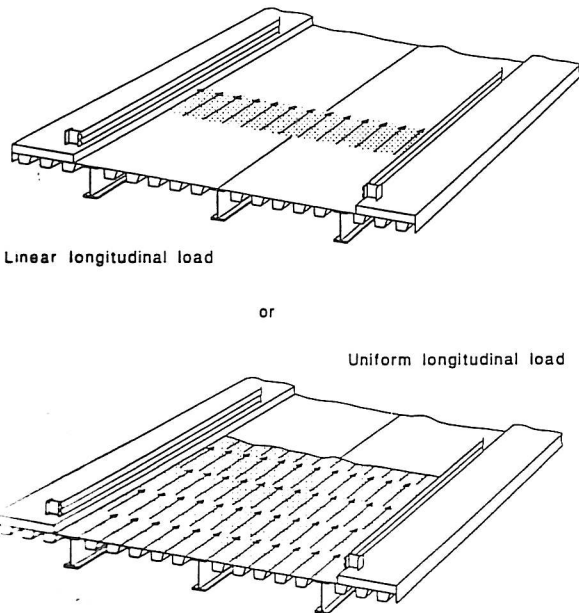


Figure 8 Longitudinal tractive forces.



Lecture 15B.2

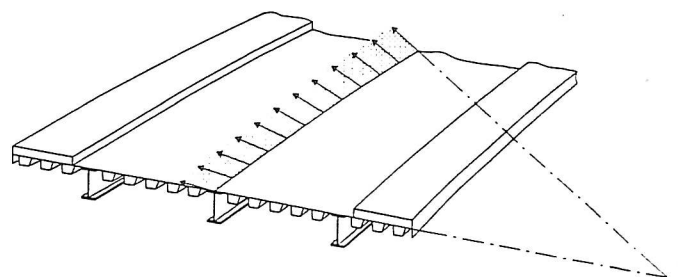


Figure 9 Centrifugal forces.



Lecture 15B.2

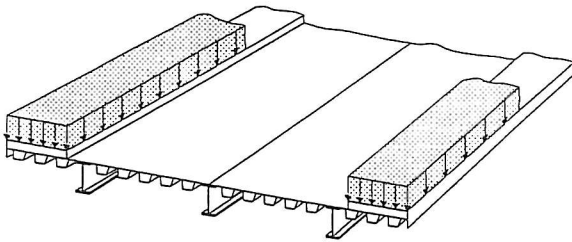


Figure 10 Sidewalk distributed load.

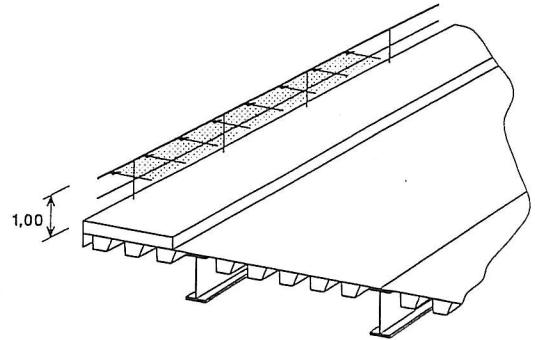


Figure 11 Distributed load on parapet.



Lecture 15B.2



Lecture 15B.2

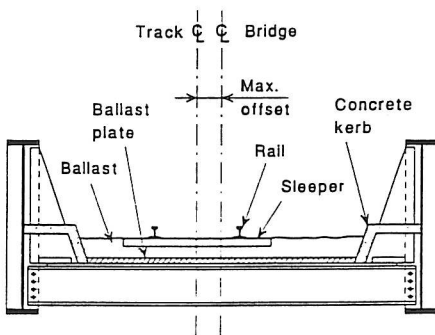


Figure 12 Typical section of a through-girder railroad bridge (curved track)

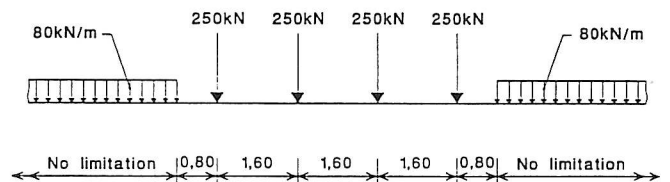


Figure 13 Typical train load.



Lecture 15B.2



Lecture 15B.2

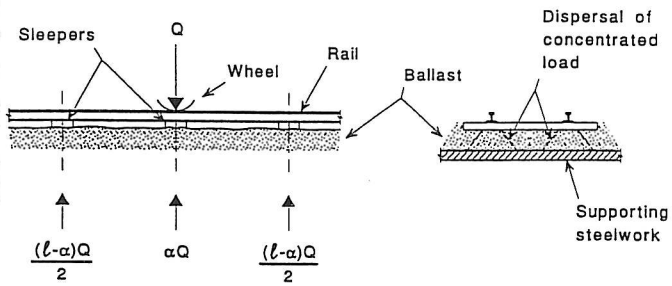


Figure 14 Dispersal of wheel loads.

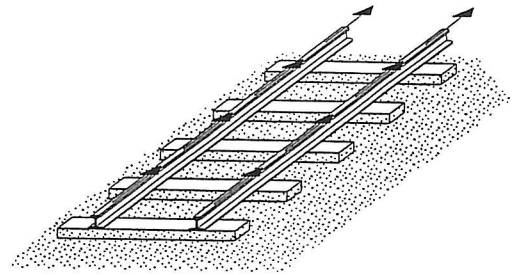


Figure 15 Longitudinal tractive forces.



Lecture 15B.2



Lecture 15B.2

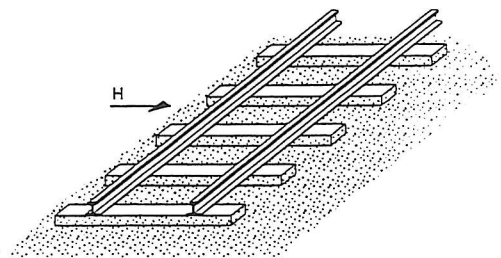


Figure 16 Horizontal force due to nosing

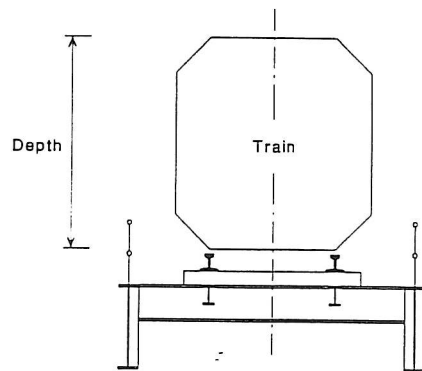
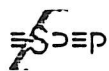


Figure 17 Depth of exposed area for wind actions.



Lecture 15B.2



Lecture 15B.2

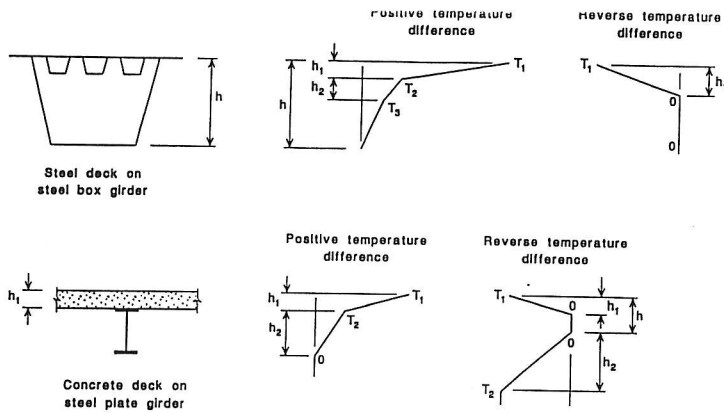
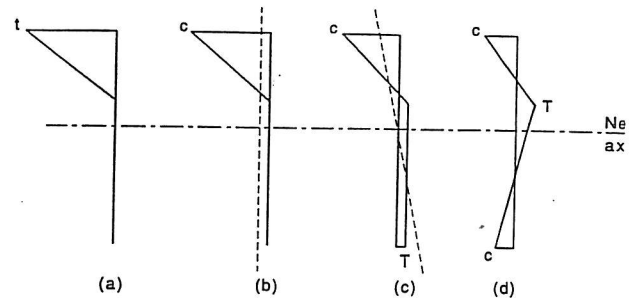
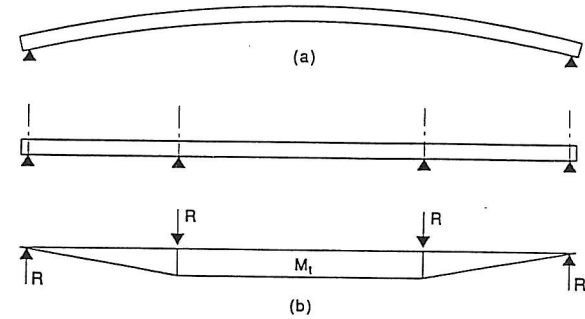


Figure 18 Examples of temperature differences.



- 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.

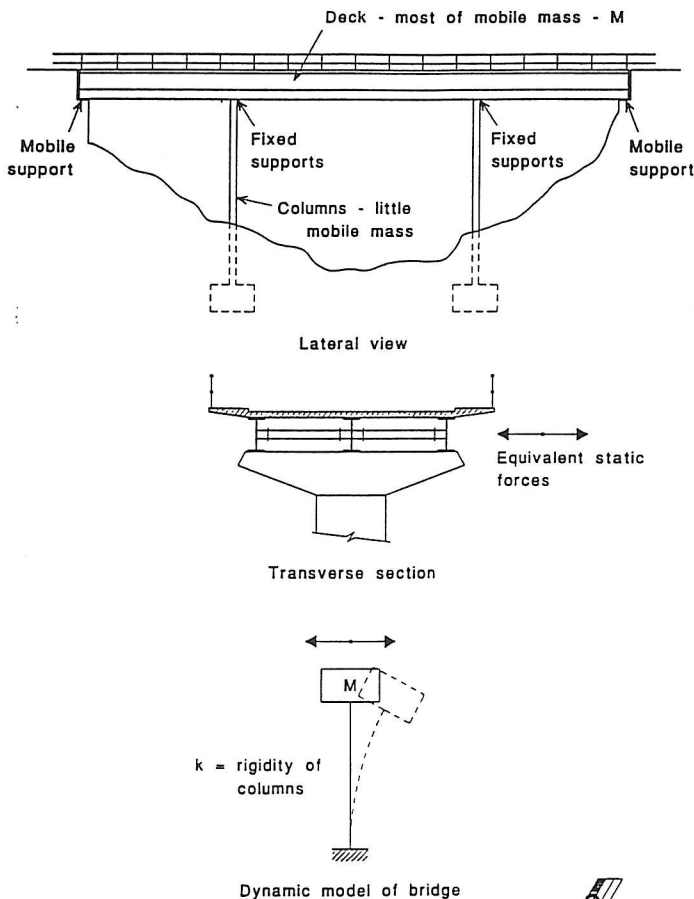


Figure 20 Example of bridge with simple dynamic behaviour.

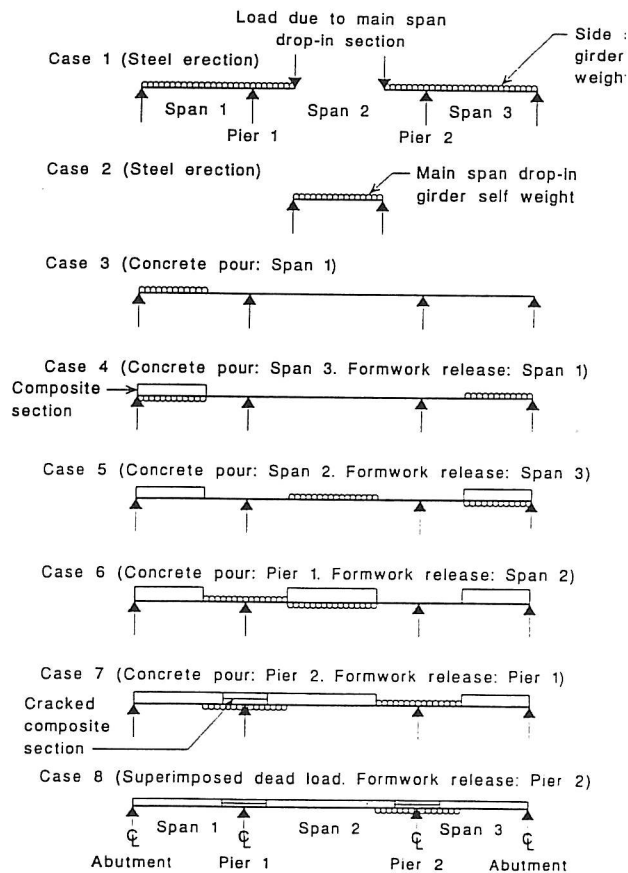


Figure 21 Construction load cases for a three-span composite highway bridge.

LECTURE 15B.3

Bridge Decks

FIGURES

Figure 1:	Page 3
Figure 2:	Page 4
Figure 3:	Page 4
Figure 4:	Page 4
Figure 5:	Page 5
Figure 6:	Page 6
Figure 7:	Page 6
Figure 8:	Page 7
Figure 9:	Page 7
Figure 10:	Page 8
Figure 11:	Page 10
Figure 12:	Page 11

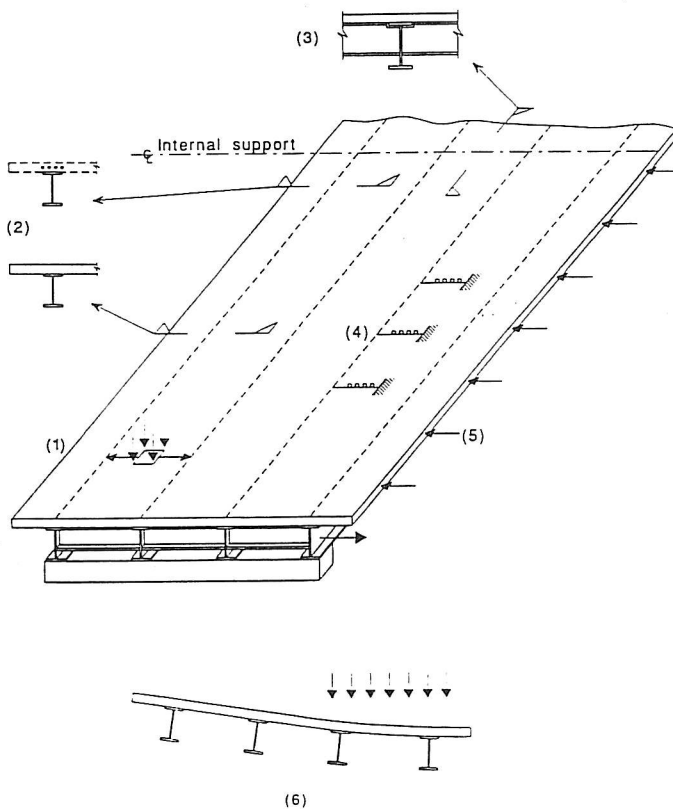
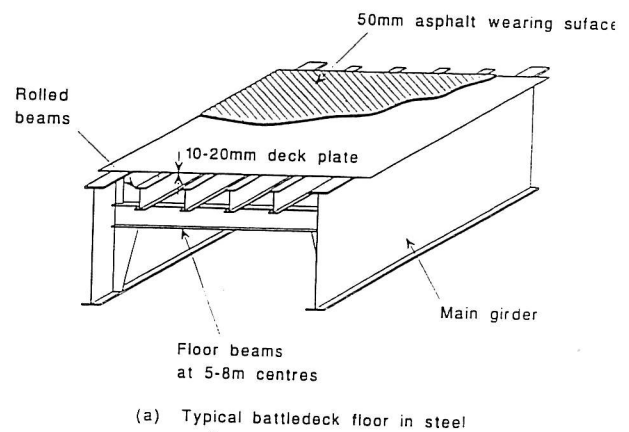
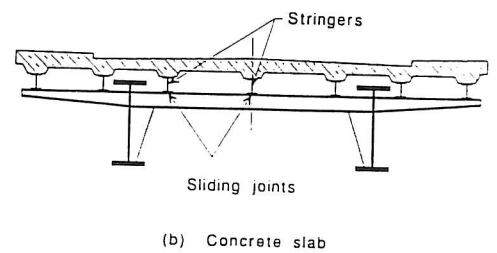


Figure 1 Structural actions of a highway bridge deck.

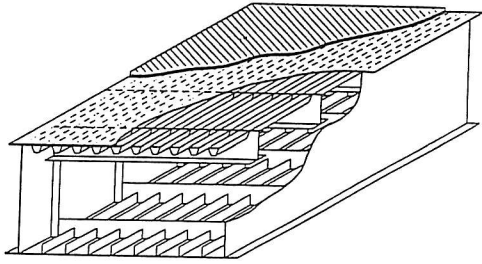


(a) Typical battledeck floor in steel

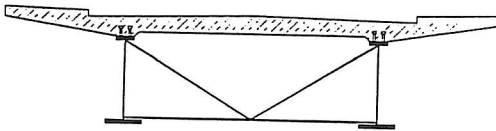


(b) Concrete slab

Figure 2 Early highway bridge decks.



(a) Orthotropic steel deck

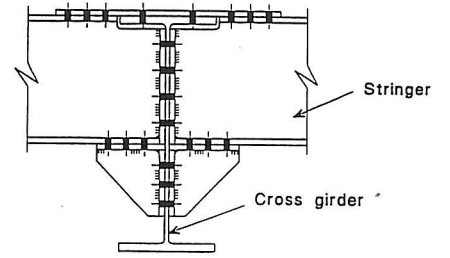


(b) Composite slab

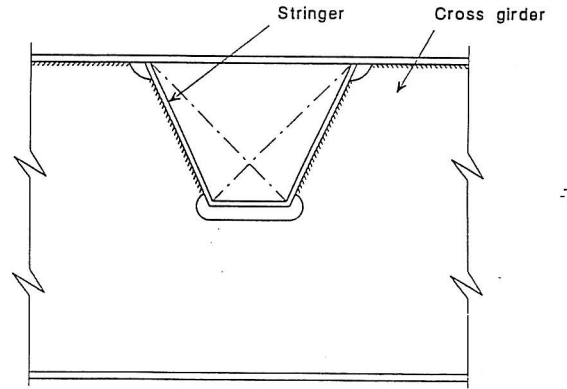
Figure 3 Modern highway bridge decks.



Lecture 15B.3



(a) Early bolted or riveted construction



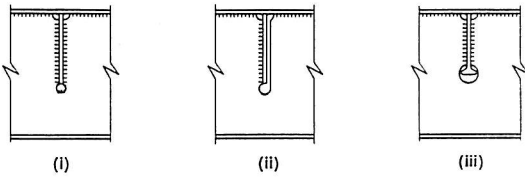
(b) Modern welded construction

Note:- Different orientation of diagrams to illustrate connections

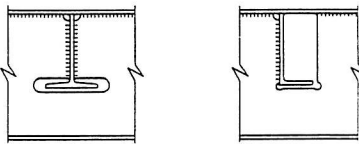
Figure 4 Stringer / Cross girder intersections



Lecture 15B.3

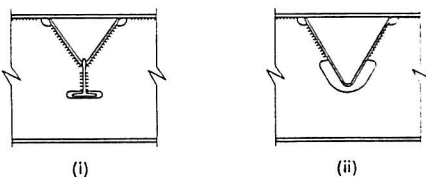


(i) (ii) (iii)

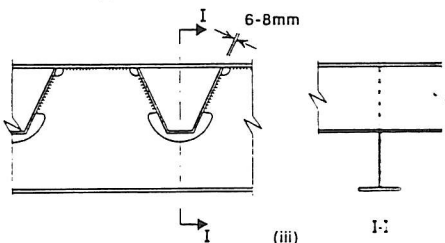


(iv) (v)

(a) Open, torsionally weak stiffeners



(i) (ii)

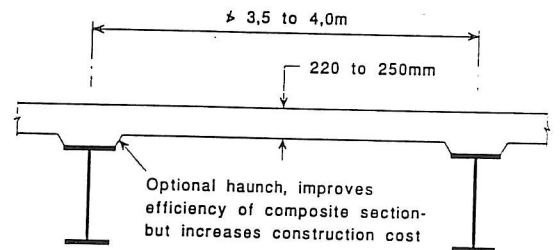


(b) Closed, torsionally stiff stiffeners

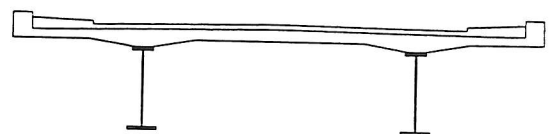
Figure 5 Stiffeners (stringers) for orthotropic steel decks



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

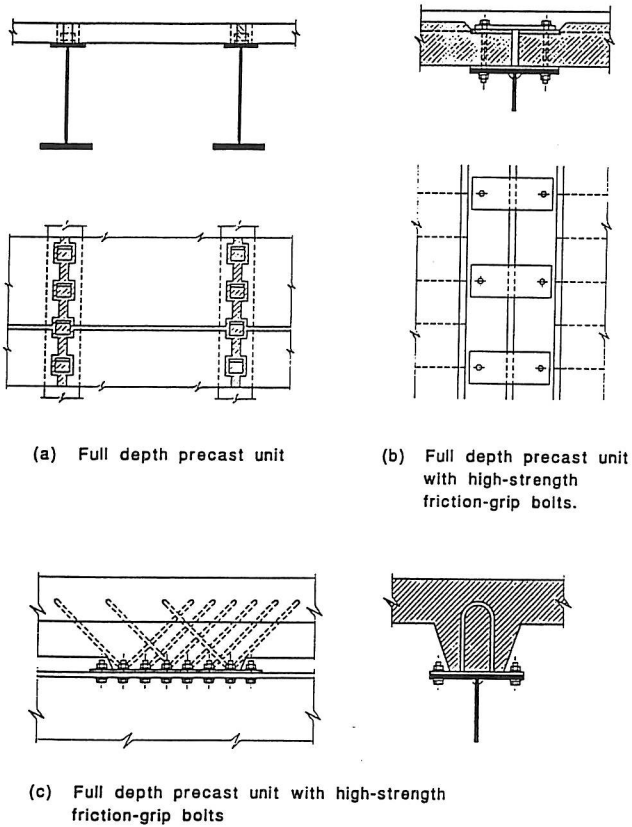


Figure 7 Means of eliminating conventional formwork for reinforced concrete decks.

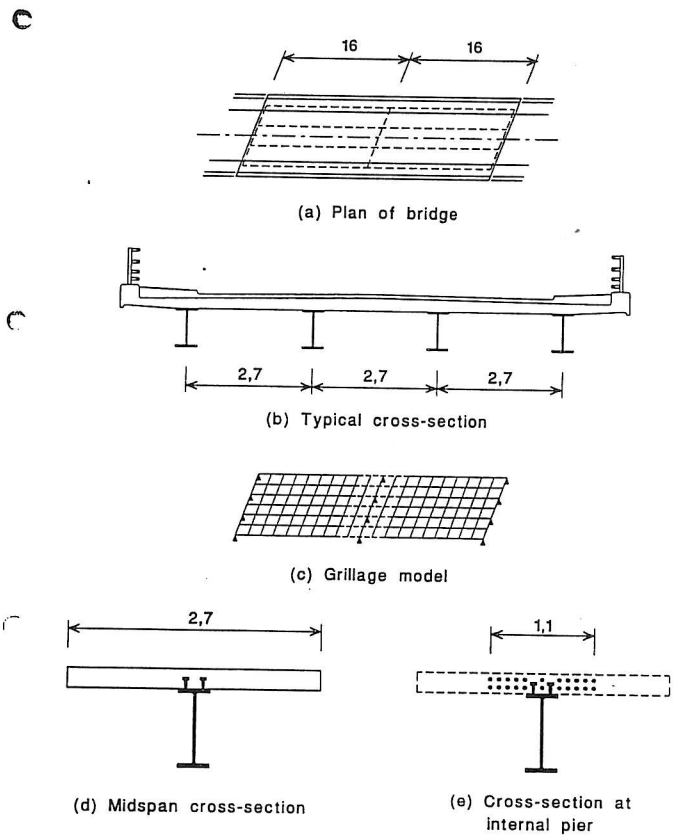


Figure 8 Typical grillage analysis for composite bridge, demonstrating the modelling of the slab as equivalent beam strips.

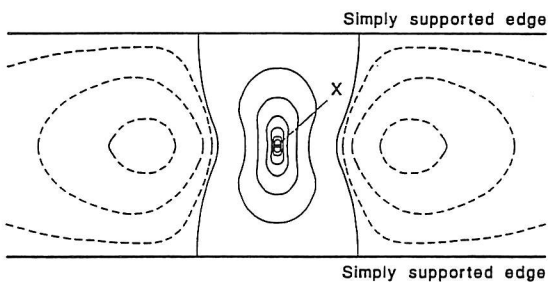


Figure 9 Example of Puchers charts for determining slab moments from local wheel loads.

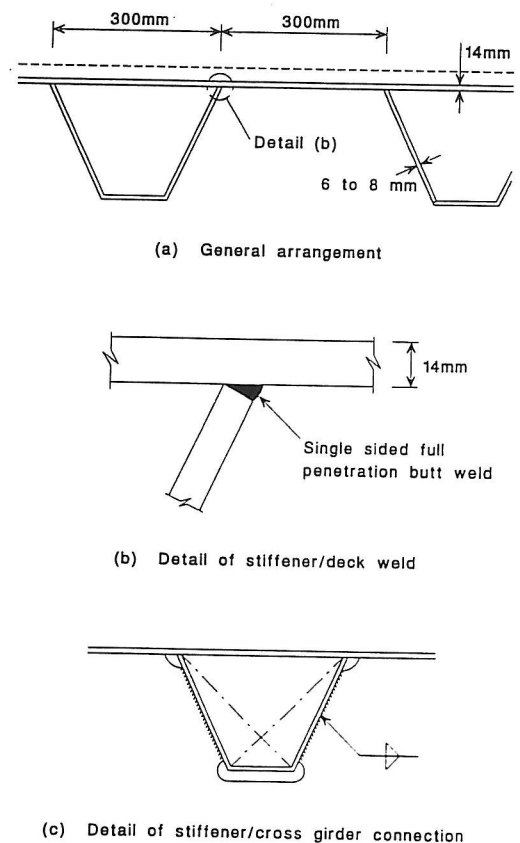


Figure 10 Standard orthotropic deck.

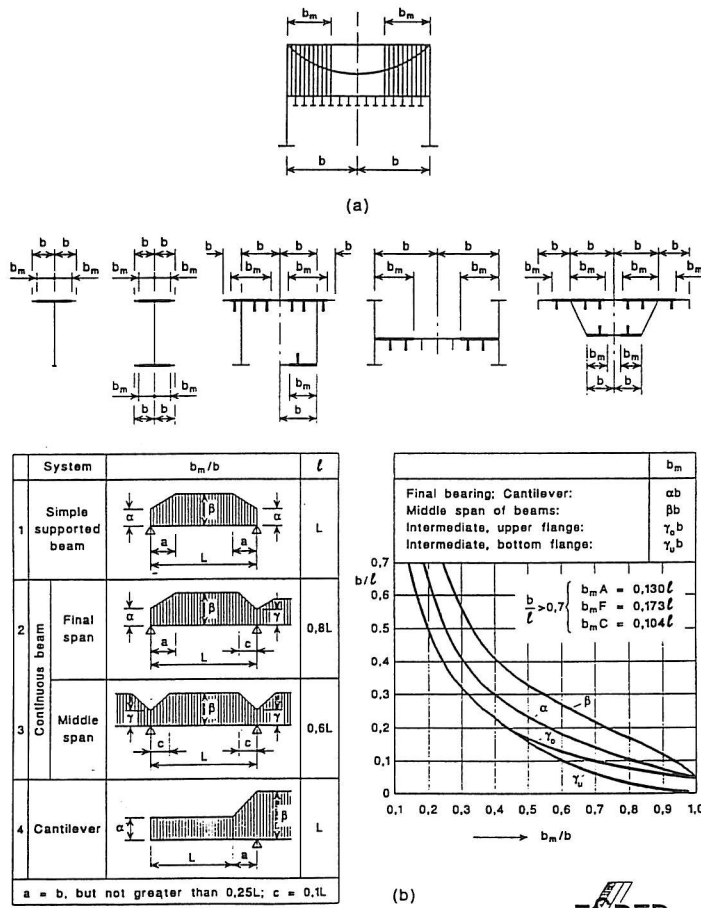


Figure 11 Definition of the effective width b_m



Lecture 15B.3

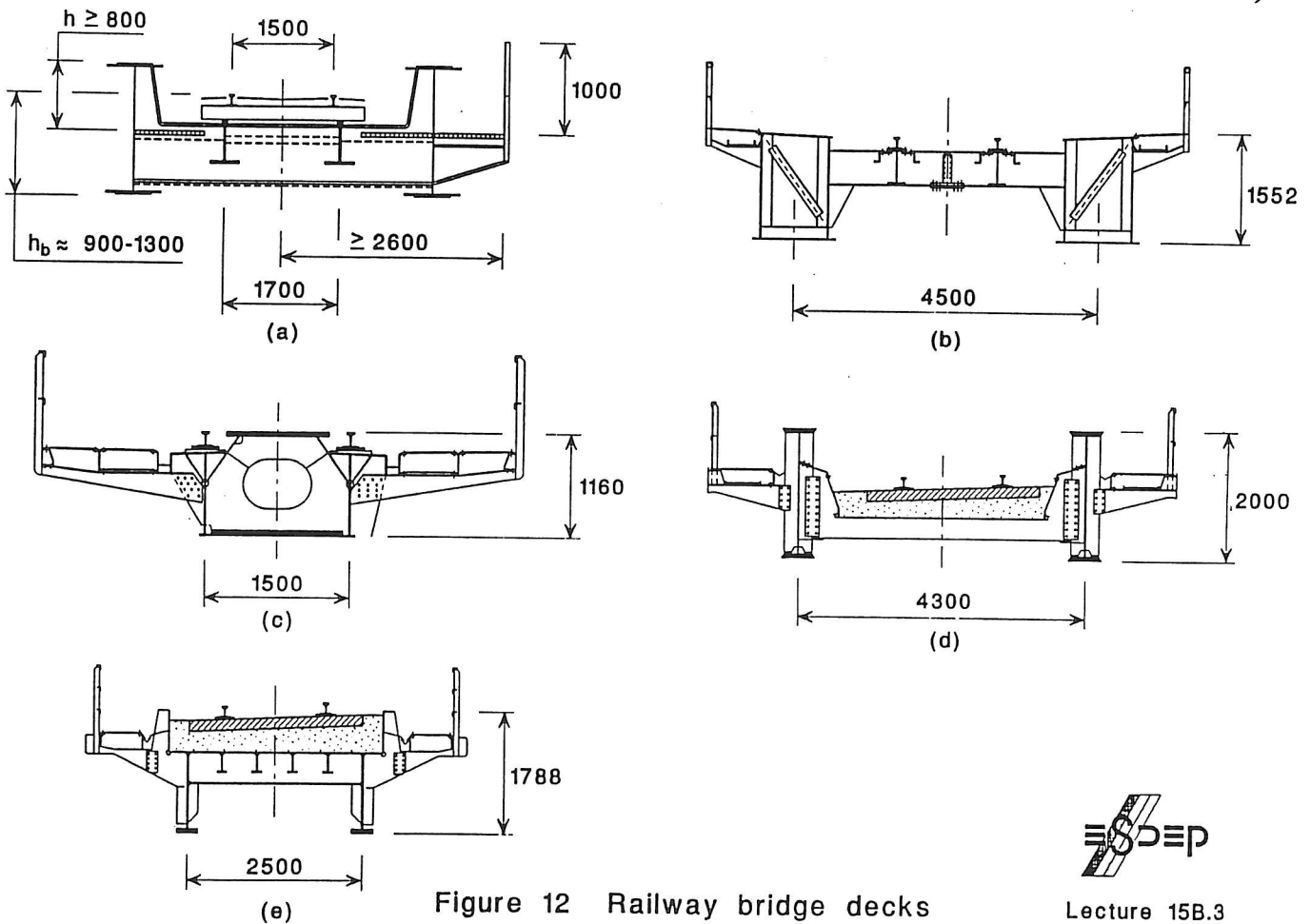


Figure 12 Railway bridge decks



Lecture 15B.3

LECTURE 15B.4

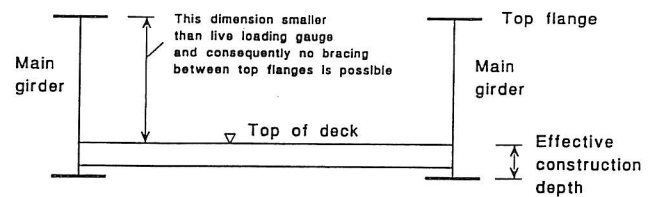
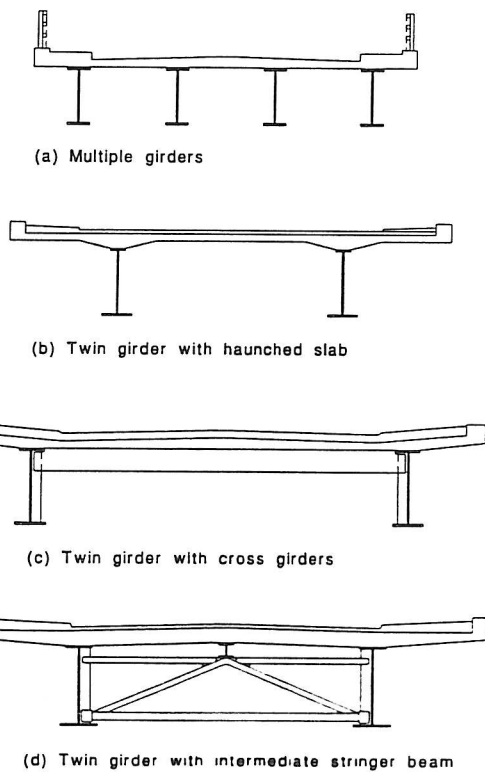
Plate Girder and Beam Bridges

LECTURES

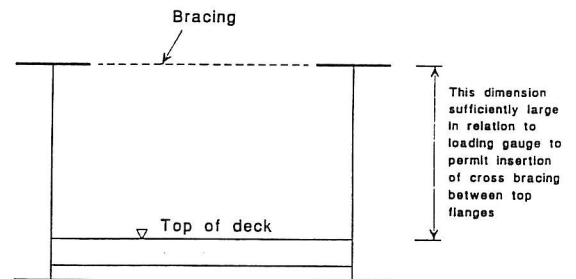
Lectures 8.4:	Page 16
Lecture 8.4.1:	Page 12
Lecture 8.4.3:	Page 11
Lectures 11:	Page 16
Lecture 15B.3	Pages 12 & 15
Lecture 15B.11:	Page 16

FIGURES

Figure 1:	Pages 3 & 6
Figure 2:	Pages 3, 4 & 10
Figure 3:	Page 5
Figure 4:	Page 5
Figure 5:	Pages 5 & 11
Figure 6:	Pages 10, 11 & 14
Figure 7:	Pages 13 & 14
Figure 8:	Pages 13 & 14
Figure 9:	Page 13
Figure 10:	Page 14
Figure 11:	Page 15
Figure 12:	Page 17
Figure 13:	Pages 17 & 18



(a) Half-through girder construction



(b) Through girder construction

Figure 1 Types of composite plate girder and girder bridge

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



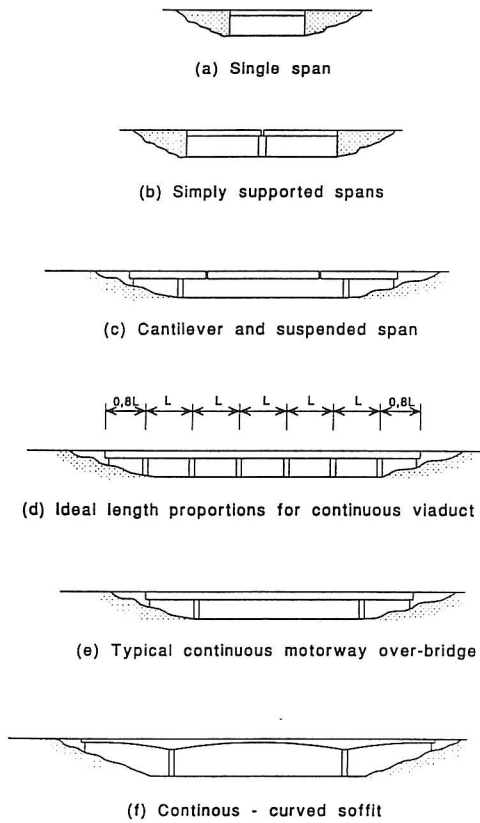


Figure 3 Arrangements for longitudinal girders



Lecture 15B.4

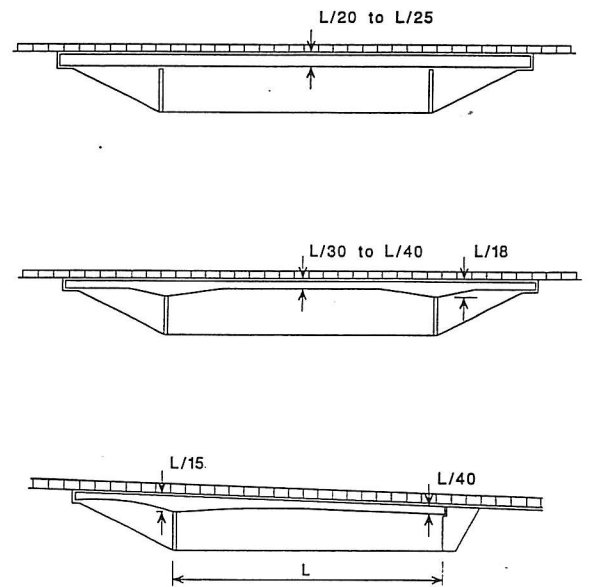


Figure 4 Typical span/depth proportions



Lecture 15B.4

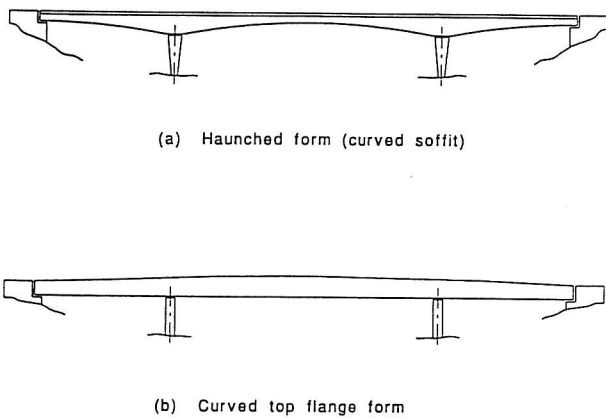


Figure 5 Alternative forms of variable depth plate girders

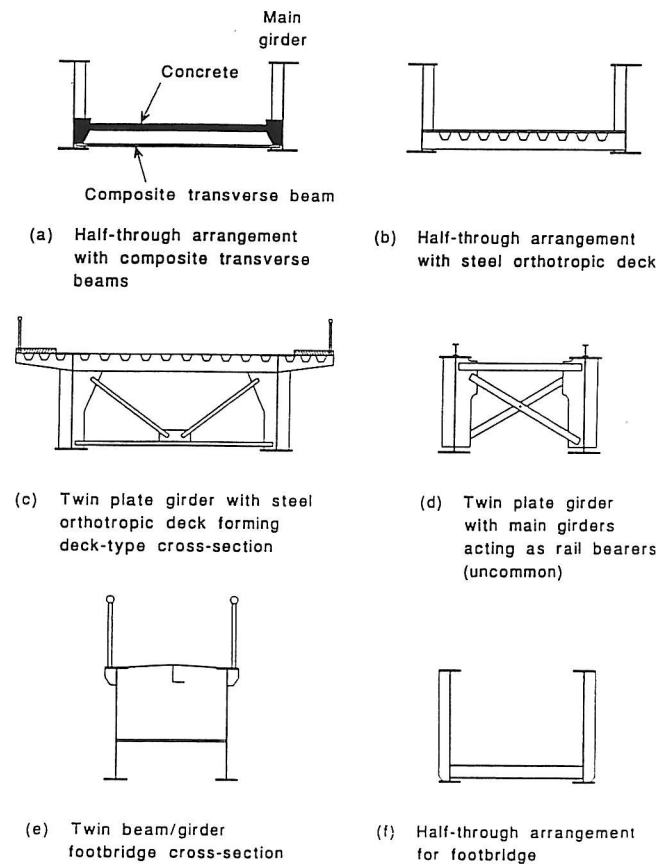


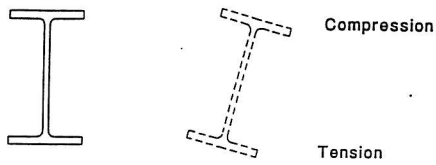
Figure 6 Selection of plate girder/beam bridge configurations



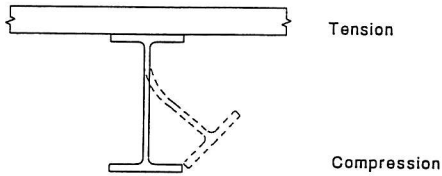
Lecture 15B.4



Lecture 15B.4



(a) Lateral-torsional buckling

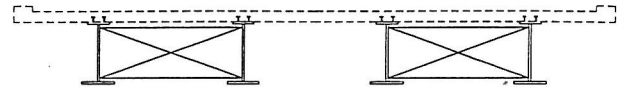


(b) Distortional buckling

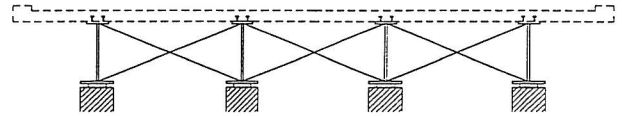
Figure 7 Modes of instability of plate girders



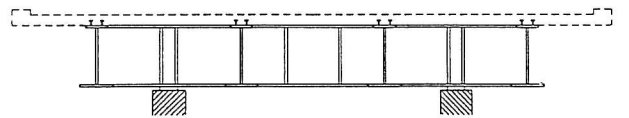
Lecture 15B.4



(a) Bracing within spans



(b) Bracing at abutment and piers

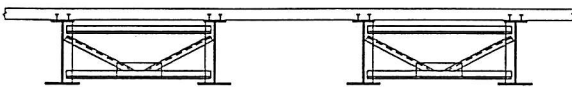


(c) Cross girder at piers

Figure 8 Types of transverse structure for composite plate girder bridges



Lecture 15B.4

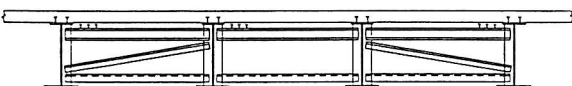


(a) K - bracing

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



(b) X - bracing

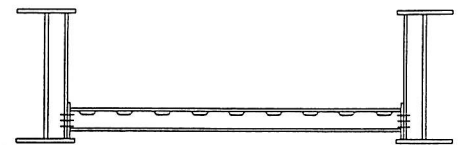


(c) Braced abutment trimmer

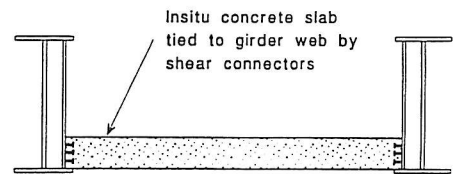
Figure 9 Commonly used bracing systems



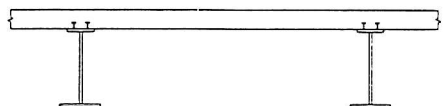
Lecture 15B.4



(a) Discrete U - frame : positive moment



(b) Continuous U - frame : positive moment

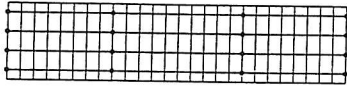


(c) Continuous U - frame : negative moment

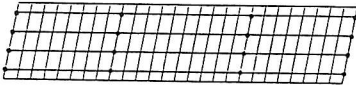
Figure 10 Types of U - frame restraint to compression flange



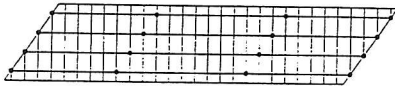
Lecture 15B.4



(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

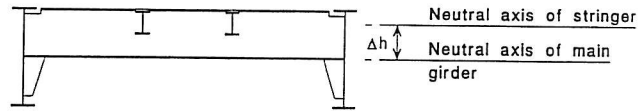
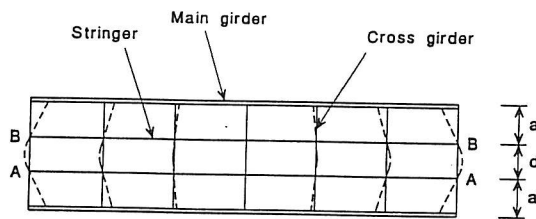
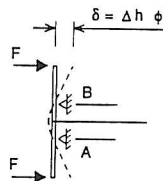


Figure 12 Open grid steel deck - difference in neutral axis levels between stringers and main girders



(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

LECTURES

Lecture 1B.6.2: Page 6

FIGURES

Figure 1:	Pages 3, 4
Figure 2	Page 4
Figure 2a:	Page 3
Figure 2e:	Pages 4, 7
Figure 2f:	Page 4
Figure 3:	Page 4
Figure 4a:	Page 6
Figure 4b:	Page 6
Figure 5:	Page 8
Figure 6:	Page 10
Figure 7:	Page 10
Figure 8a:	Page 12
Figure 8b:	Page 12
Figure 8c:	Page 12
Figure 9:	Page 12
Figure 10:	Pages 10, 15
Figure 11:	Page 15
Figure 12a:	Pages 15, 16
Figure 12b:	Page 15
Figure 12c:	Page 16
Figure 12d:	Page 16
Figure 12e:	Page 16
Figure 12f:	Page 16

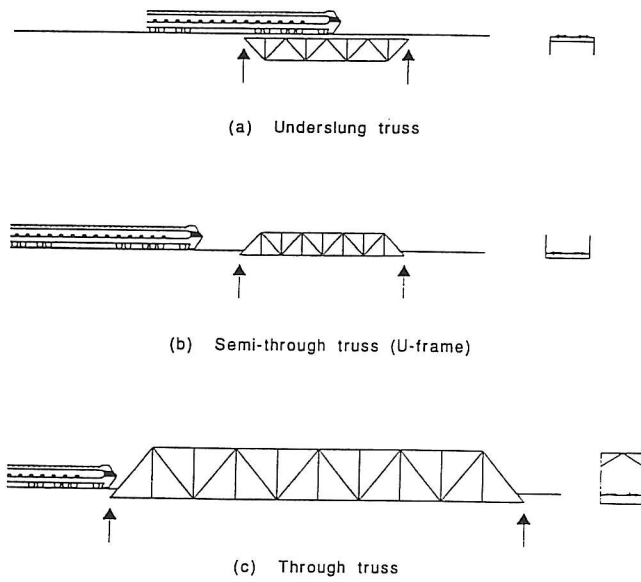
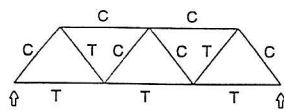


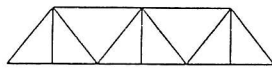
Figure 1 Truss configurations



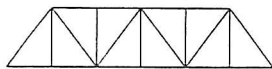
Lecture 15B.5



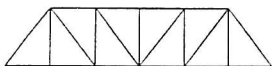
(a) Modern Warren truss:
spans 30-150m
T = Tension
C = Compression



(b)

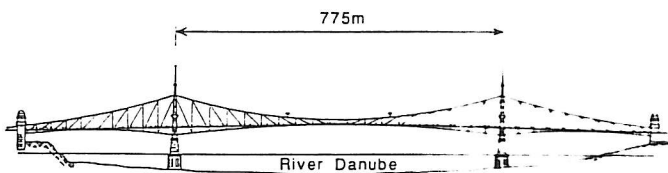


(c)



(d) Pratt truss
spans 30-100m

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

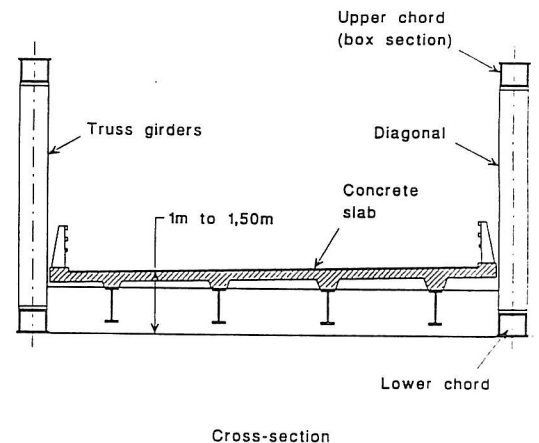


(e) Nagy truss in Budapest: 1892

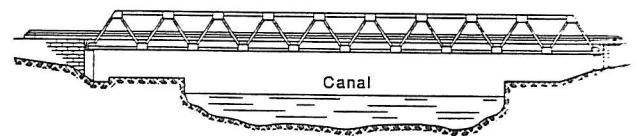


(f) Lattice truss
of historical
interest only

Figure 2 Principal types of truss



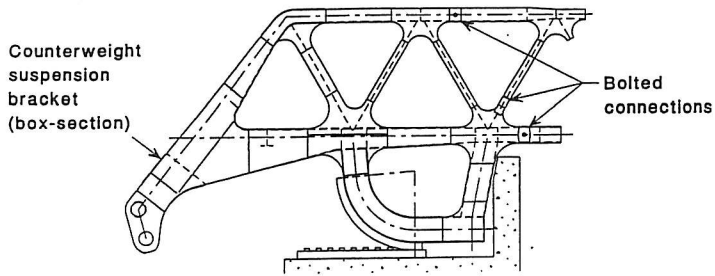
Cross-section



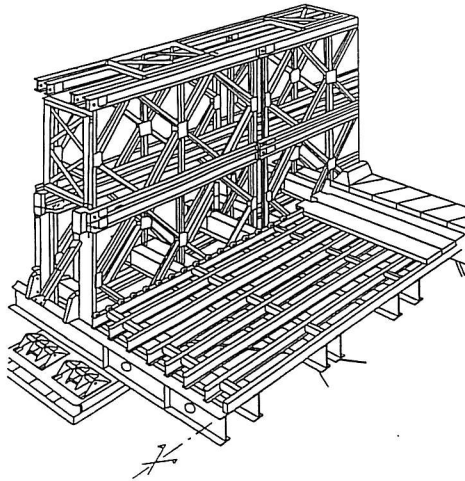
Elevation

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

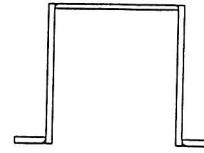


Lecture 15B.5

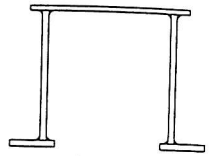


Lecture 15

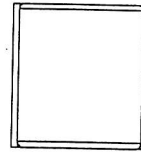
C



(a) Top hat (i)



(b) Top hat (ii)



(c) Box



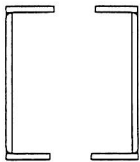
(d) Rolled section



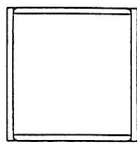
(f) Rolled hollow section

Figure 5 Compression chord members

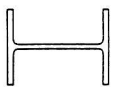
C



(a) Open box



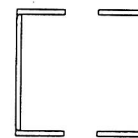
(b) Box



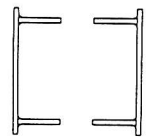
(c) Rolled section



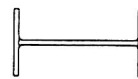
(d) Rolled hollow section



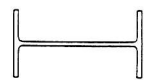
(a) Open box (i)



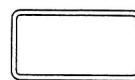
(b) Open box (ii)



(c) Made-up I



(d) Rolled section

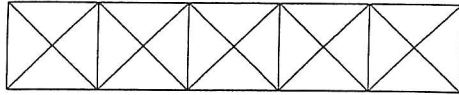


(e) Rolled hollow section

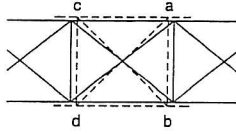
Figure 6 Tension chord members

Figure 7 Diagonal and vertical members

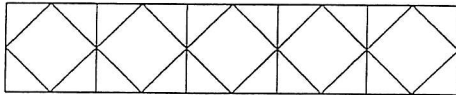




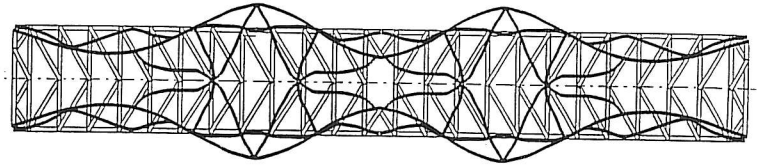
(a) St. Andrew's cross system



(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.

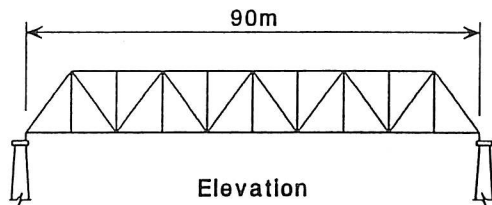
Figure 8 Upper chord lateral bracing



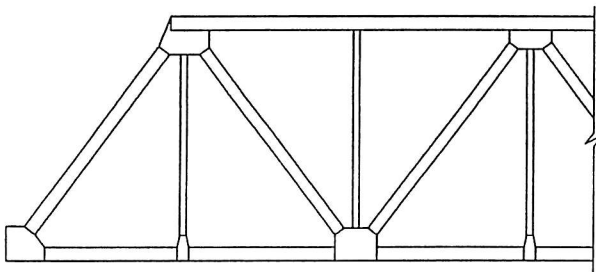
Lecture 15B.



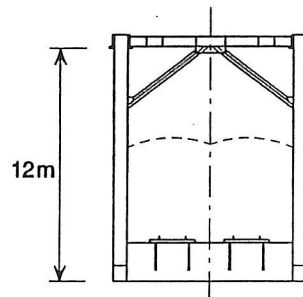
Lecture



Elevation

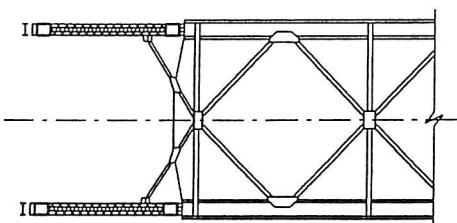


Elevation on part span

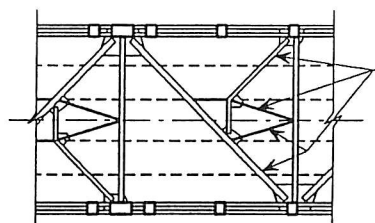


12m

Section



Plan on top laterals



Plan on bottom laterals

Braking girder



Figure 10 General arrangement of a through truss railway bridge.

Lecture 15B.5

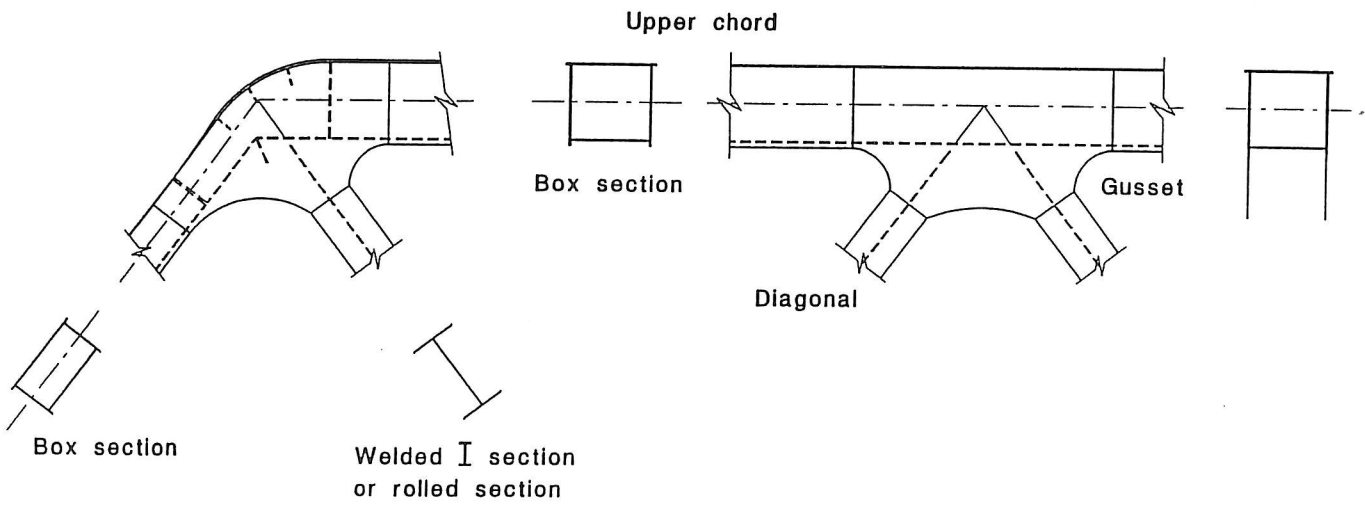


Figure 11 Butt-welded connections and gusset geometries used to avoid fatigue in the connection.



Lecture 15B.5

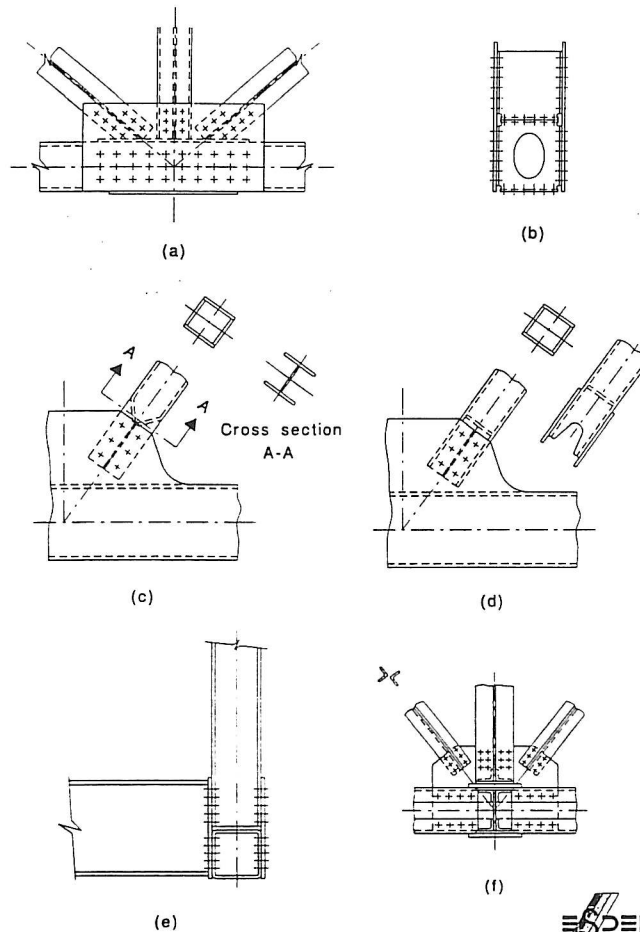


Figure 12 Bolted connections



Lecture 15B 5

LECTURE 15B.6

Box Girder Bridges

LECTURES

Lecture 8.5.1:	Page 10
Lecture 8.5.2:	Pages 8 & 10
Lecture 15B.3:	Page 8

FIGURES

Figure 1:	Page 3, 6 & 8
Figure 2:	Page 3
Figure 3:	Pages 4, 5, 6
Figure 4:	Page 4
Figure 5:	Pages 8 & 9
Figure 6:	Page 11
Figure 7:	Page 12
Figure 8:	Page 12
Figure 9:	Page 12
Figure 10:	Page 13

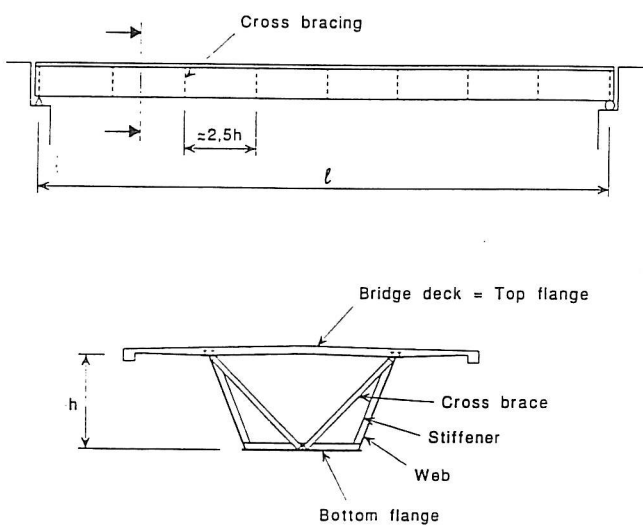


Figure 1 Box girder bridge with composite concrete deck: nomenclature

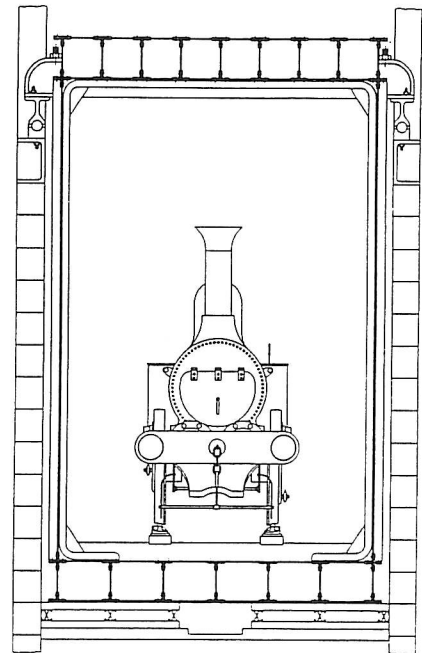


Figure 2 Britannia bridge, 1850.

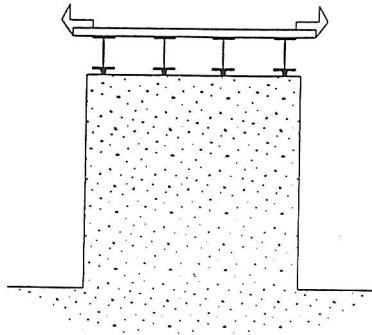
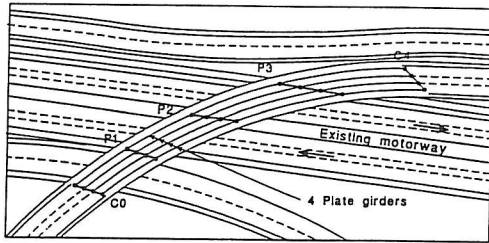
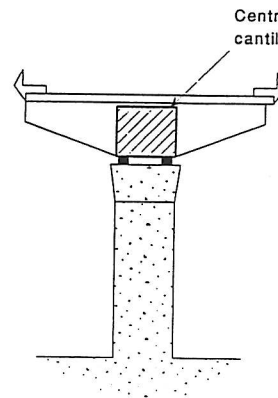
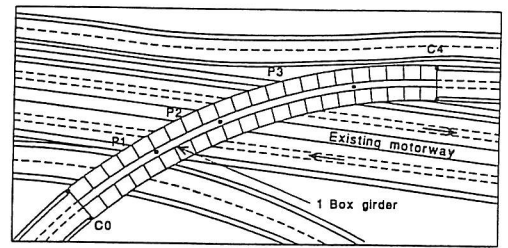


Figure 3a Plate girder bridge.



Lecture 15B.6



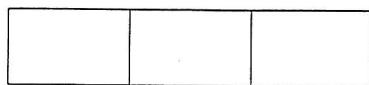
Central box girder with cantilever brackets.

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.

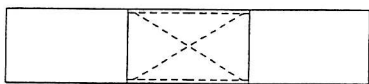
Figure 3b Box girder bridge.



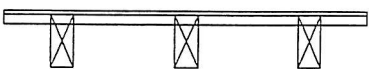
Lecture 15B.6



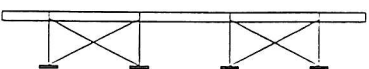
(a)



(b)



(c)

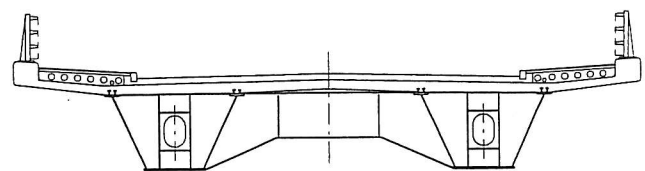


(d)

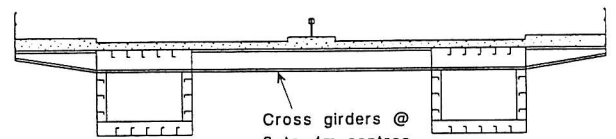
Figure 4 Types of cross-section.



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

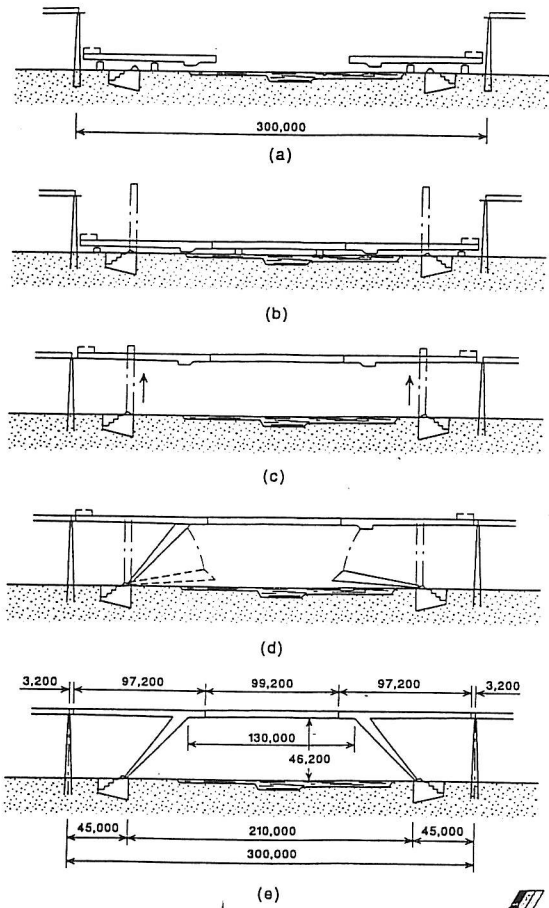
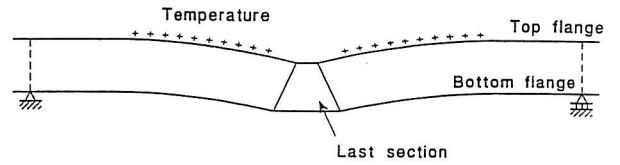


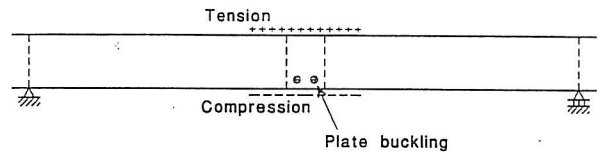
Figure 6 Erection of the Pont de Martique



Lecture 15B.6



(a) Closure in presence of temperature differential.



(b) Condition under uniform temperature.

Figure 7 Bridge across Danube, Vienna.



Lecture 15B.6

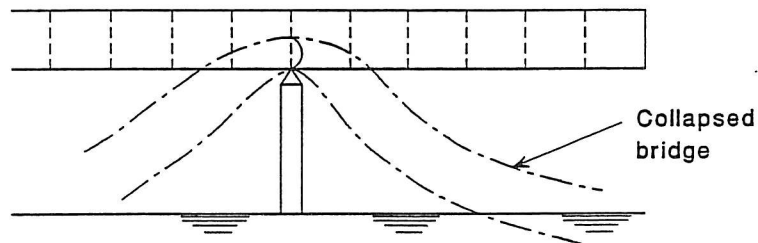


Figure 8 Milford Haven Bridge



Lecture 15B.6

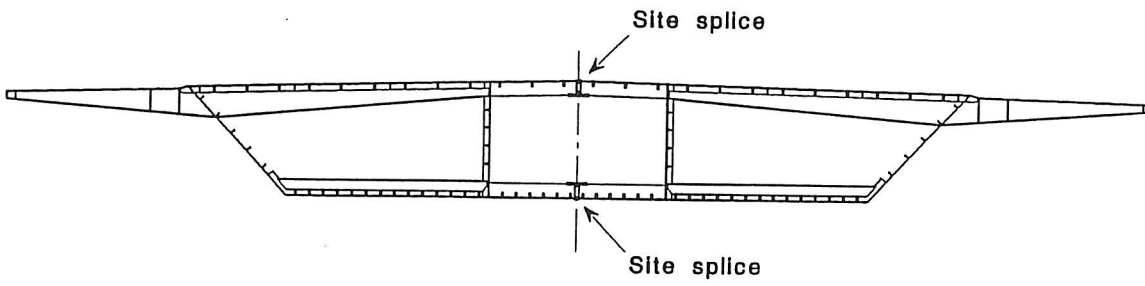


Figure 9 Typical cross-section of Melbourne bridge [2]



Lecture 15B.6

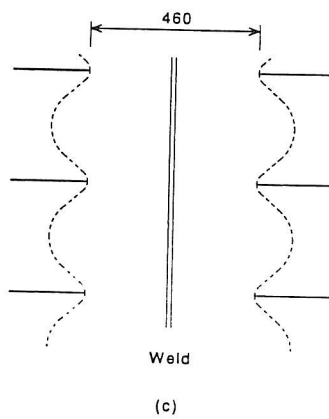
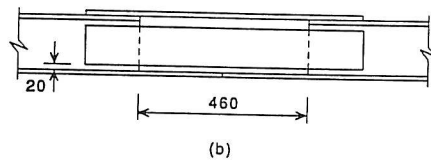
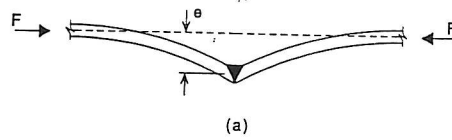


Figure 10 Detail of Koblenz bridge



Lecture 15B.6

FIGURES

Figure 1:	Page 4
Figure 2:	Pages 4 & 5
Figure 3:	Pages 5, 6 & 10
Figure 4:	Page 7
Figure 5:	Page 8
Figure 6:	Page 8
Figure 7:	Page 8
Figure 8:	Page 9
Figure 9:	Page 9
Figure 10:	Page 10
Figure 11:	Page 10
Figure 12:	Pages 11 & 12
Figure 13:	Page 13
Figure 14:	Page 13
Figure 15:	Page 14
Figure 16:	Page 15

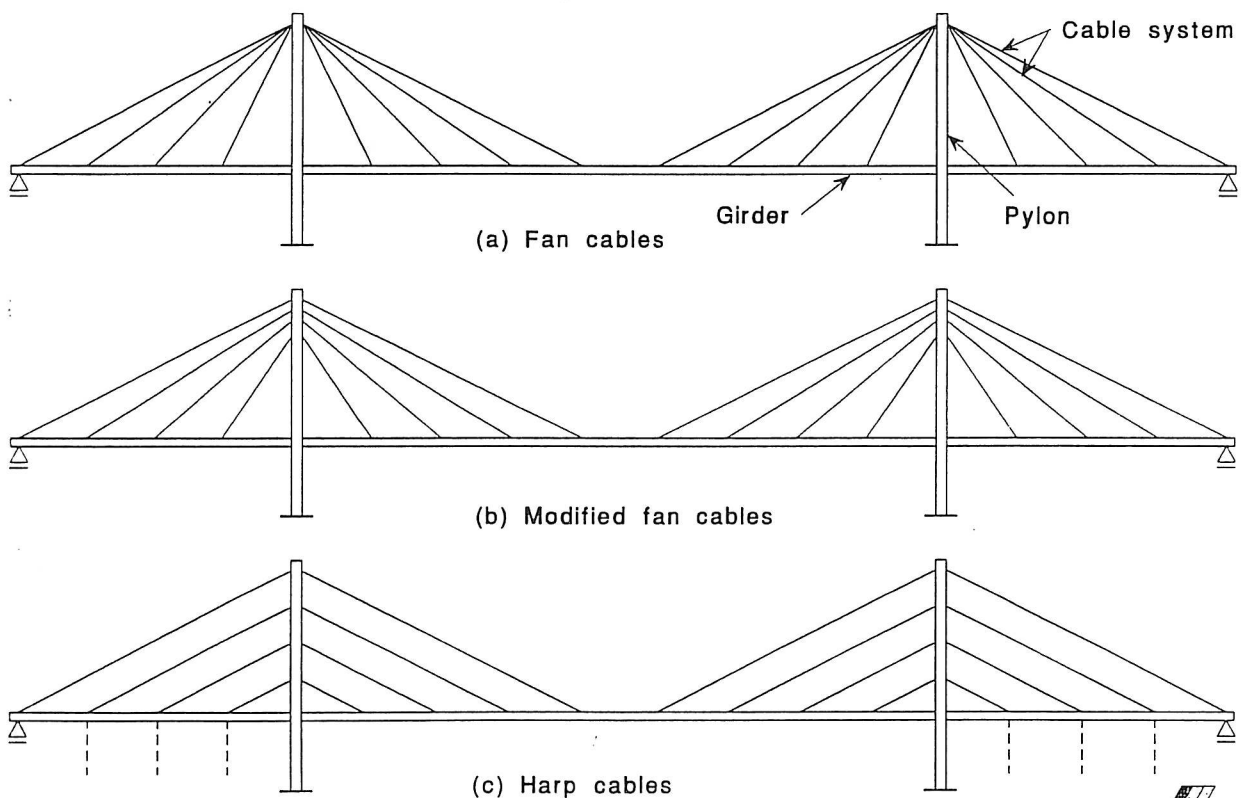
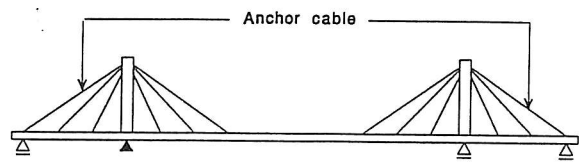
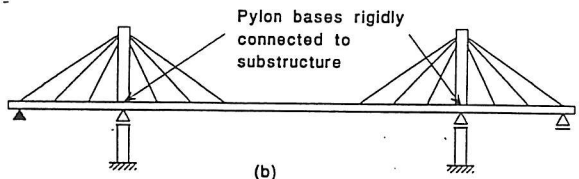


Figure 1 Types of cable stayed bridge

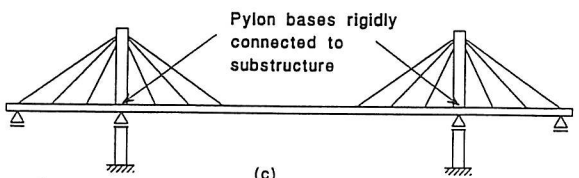




(a)



(b)



(c)

Figure 2 Support conditions for cable stayed bridges



Lecture 15B.8

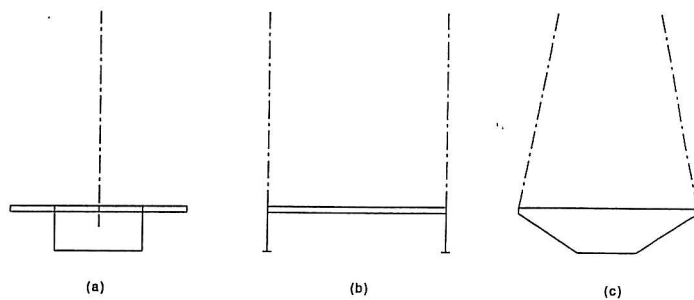


Figure 3 Alternative cable planes



Lecture 15B.1

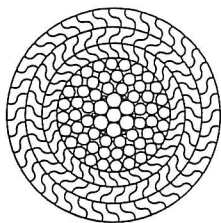


Figure 4 Lock coil cable

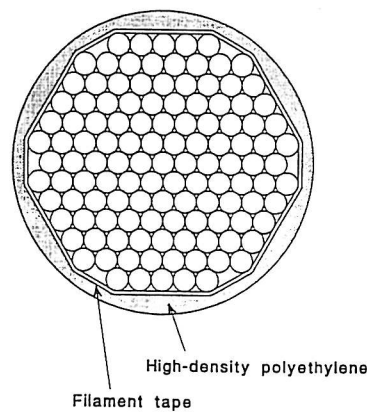


Figure 5 Parallel wire strand (PWS)



Lecture 15B.8



Lecture 15B.8

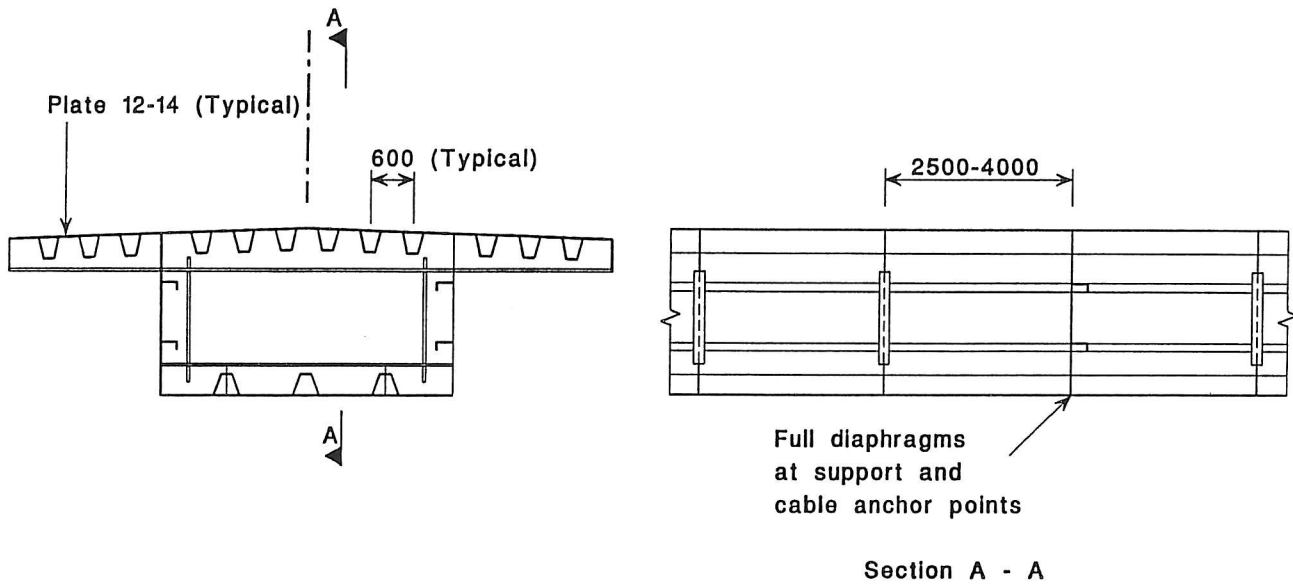


Figure 6 Typical box girder construction



Lecture 15B.8

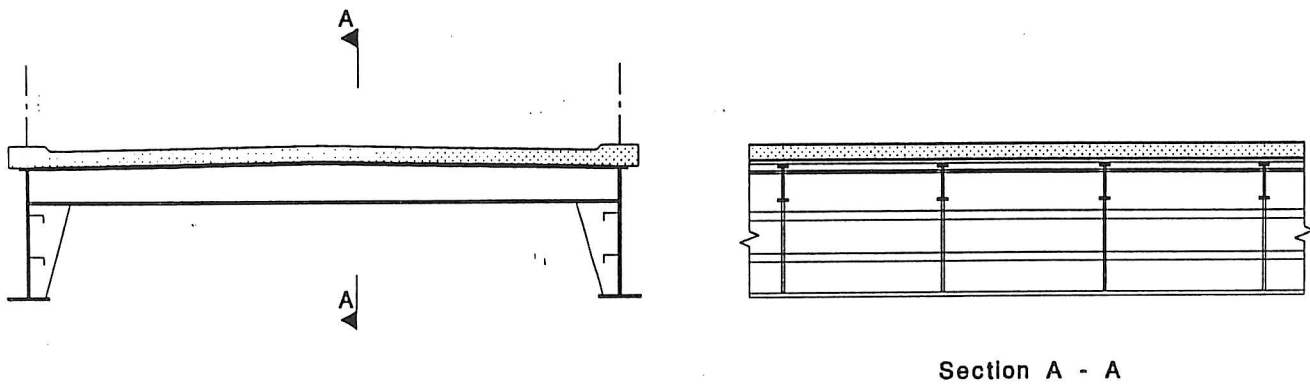
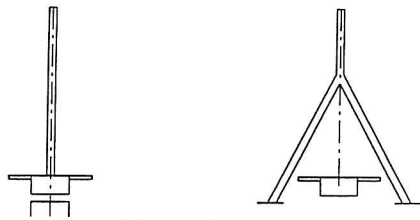


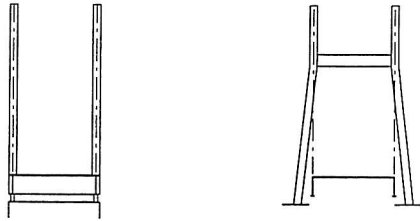
Figure 7 Typical plate girder construction



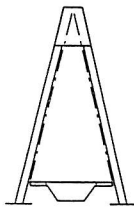
Lecture 15B.8



(a) Central cable plane



(b) Cables in parallel planes



(c) Cables in twin inclined planes

Figure 8 Pylon configurations



Lecture 15B.8

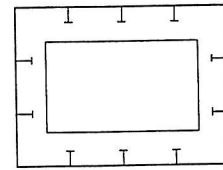
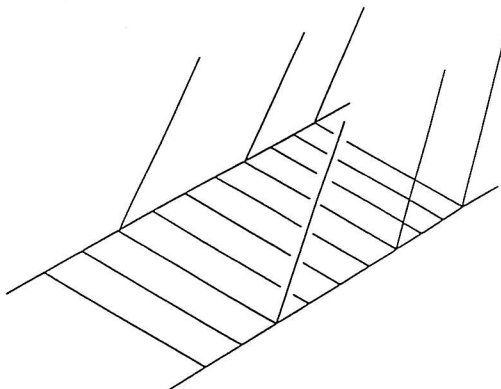


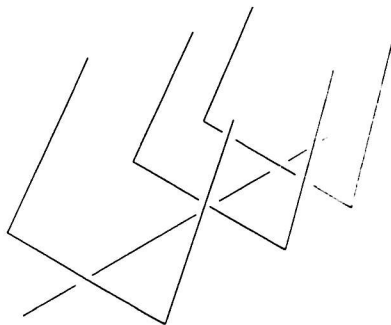
Figure 9 Typical pylon cross-section



Lecture 15B.8

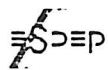


(a) Twin cable planes and plate girder



(b) Inclined cable planes and a box girder

Figure 10 Analytical models for cable stayed bridges



Lecture 15B.8

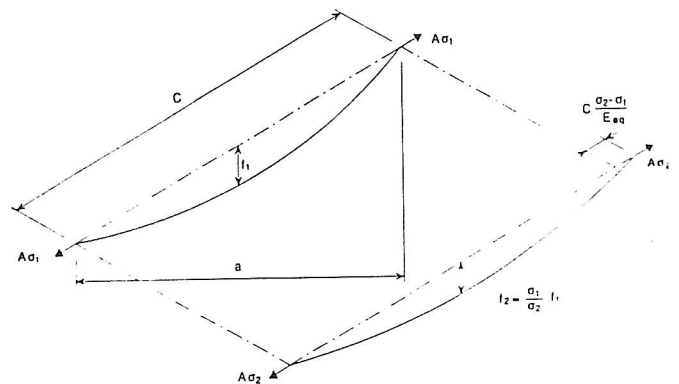


Figure 11 Influence of gravity on cable stiffness



Lecture 15B.8

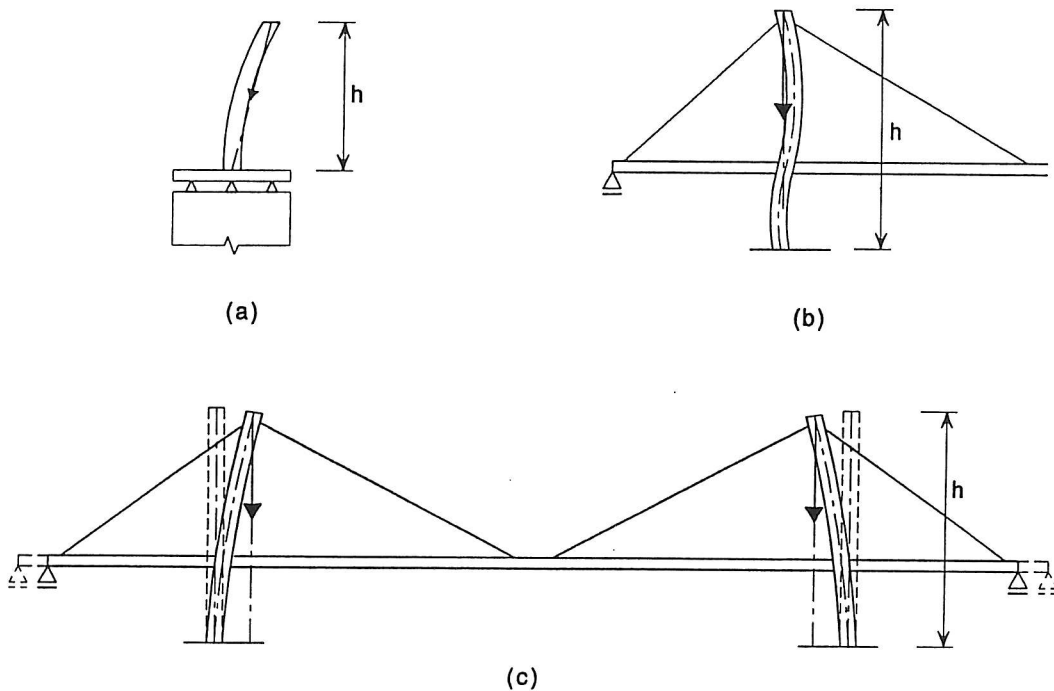


Figure 12 Stability of pylons



Lecture 15B.8

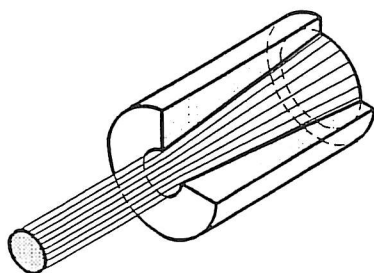


Figure 13 Typical cable anchorage

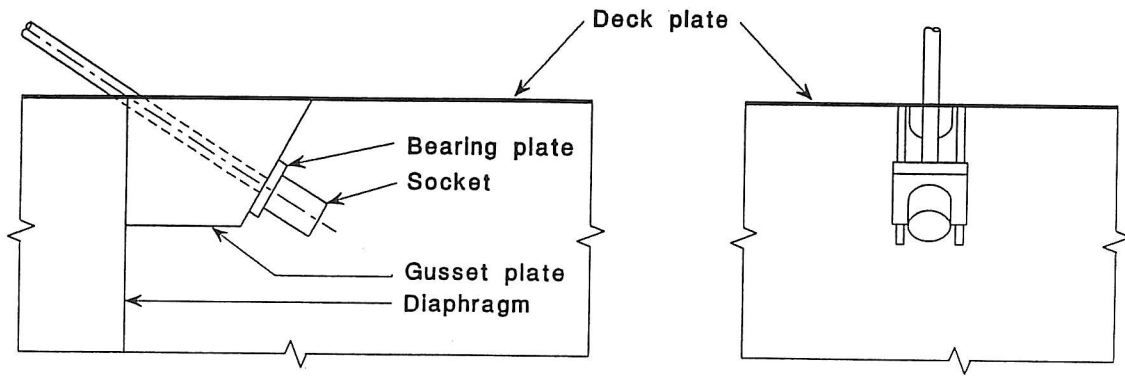


Figure 14 System for anchoring a central cable to a box girder



Lecture 15B.8

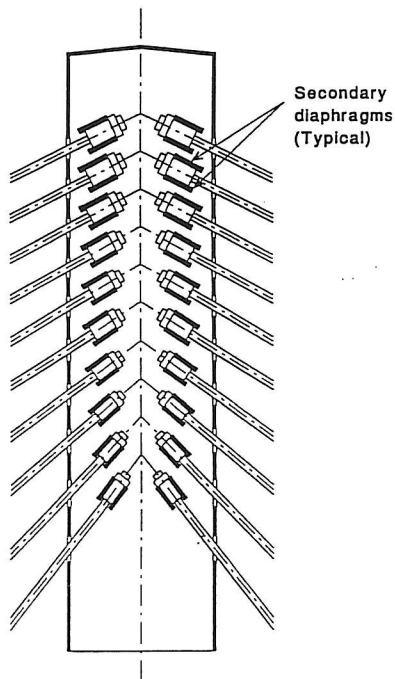


Figure 15 Anchorage system for cables at pylon in a modified fan bridge

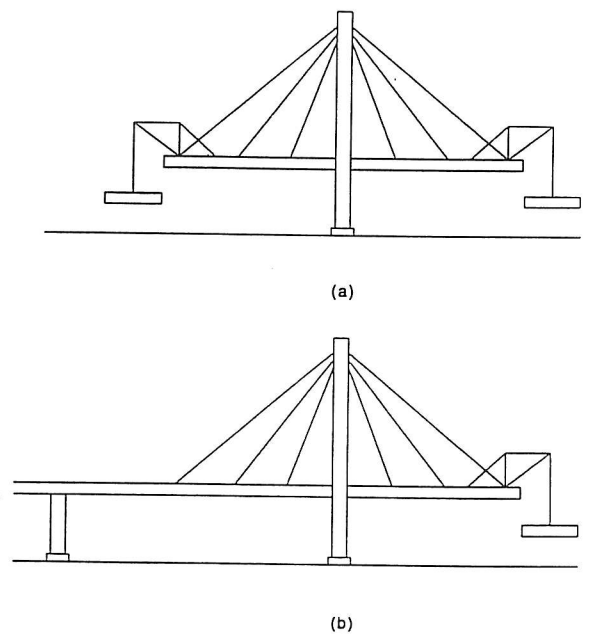


Figure 16 Methods of erection



Lecture 15B.8



Lecture 15B.8

LECTURE 15B.9

Suspension Bridges

LECTURES

Lecture 15.3: Page 7
Lecture 15.6: Page 7
Lecture 15.7: Page 3

FIGURES

Figure 1: Page 3
Figure 2: Page 3
Figure 3: Page 5
Figure 4: Page 6
Figure 5: Page 6
Figure 6: Page 6
Figure 7: Pages 6 & 7
Figure 8: Page 7
Figure 9: Page 7
Figure 10: Page 8
Figure 11: Page 8
Figure 12: Page 9
Figure 13: Page 10
Figure 14: Page 11
Figure 15: Page 11
Figure 16: Page 11
Figure 17: Page 13
Figure 18: Page 13
Figure 19: Page 13
Figure 20: Page 13
Figure 21: Page 14

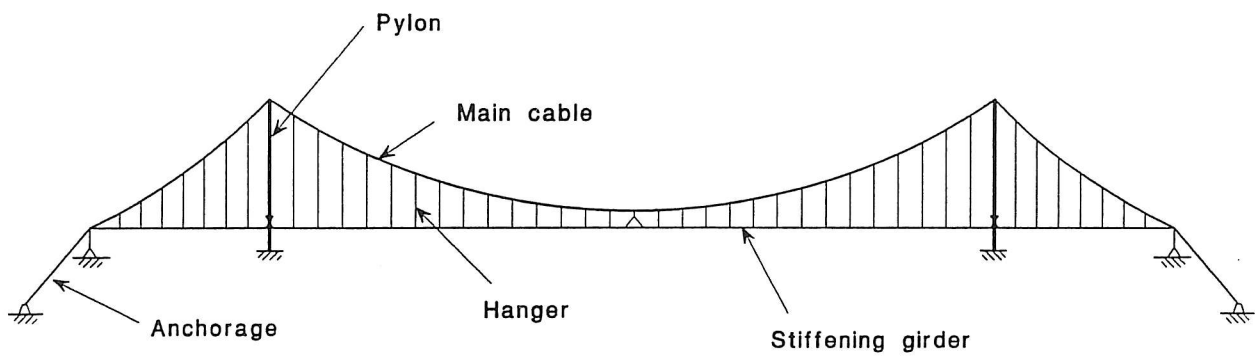


Figure 1 Principal components of a suspension bridge



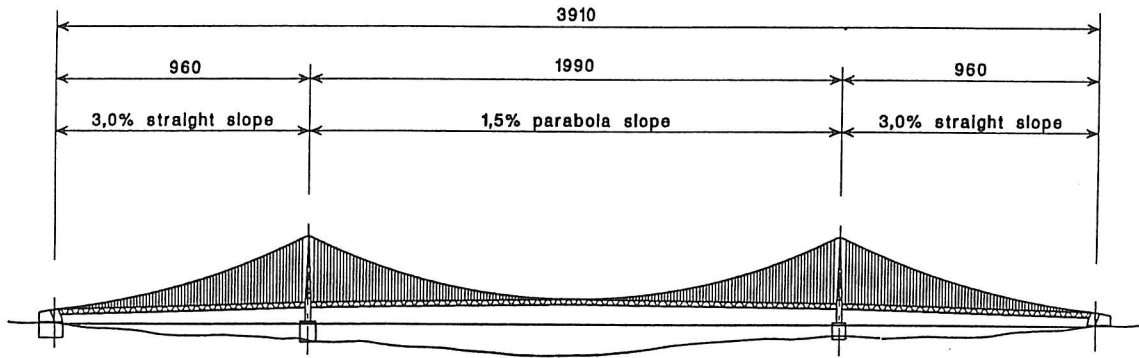


Figure 2 Akashi Kaikyo bridge



Lecture 15B.9

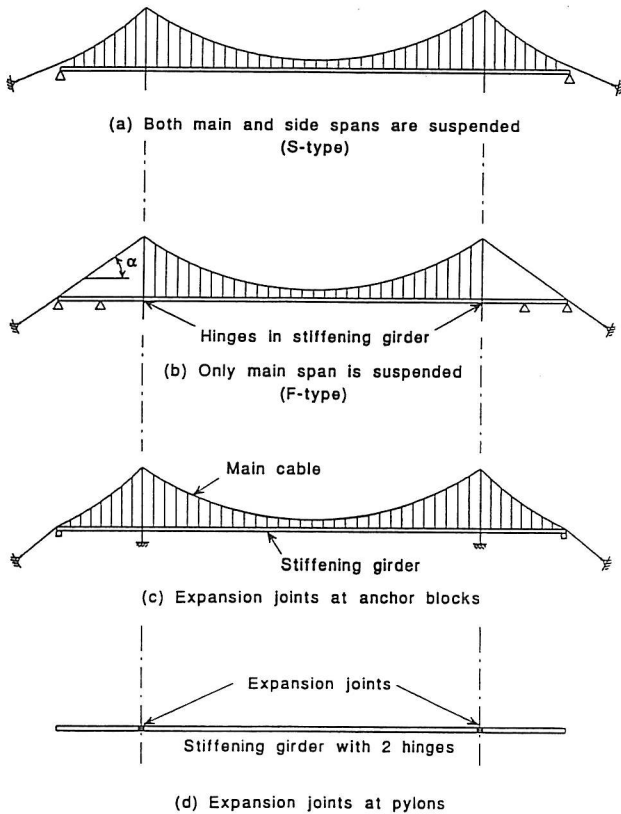


Figure 3 Classification of suspension bridges

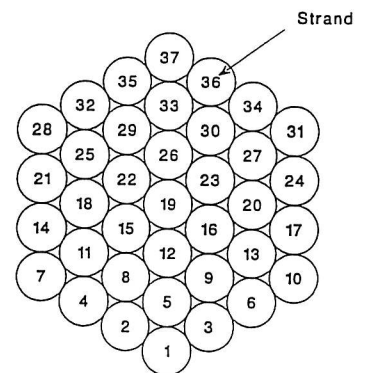


Figure 4 Pattern of strands in cable before compacting



Lecture 15B.9



Lecture 15B.9

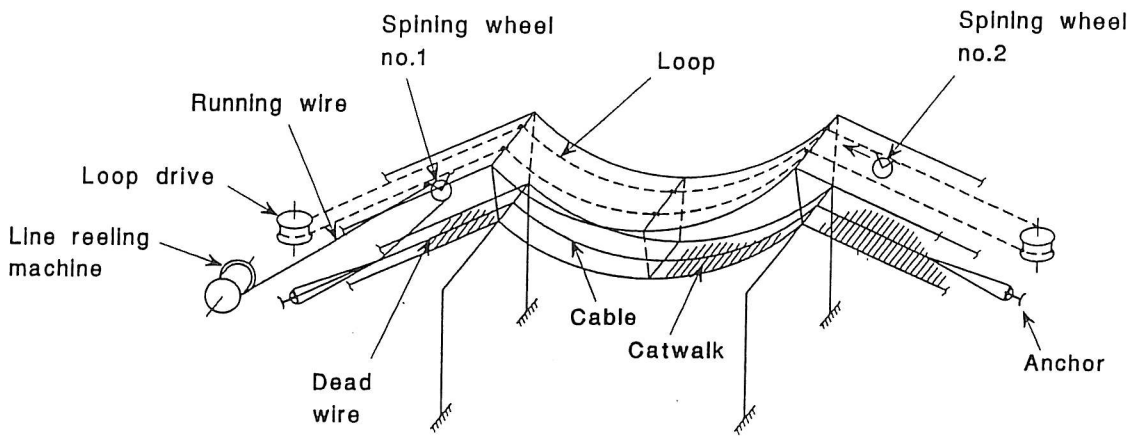


Figure 5 Cable spinning as developed by Roebling



Lecture 15B.9

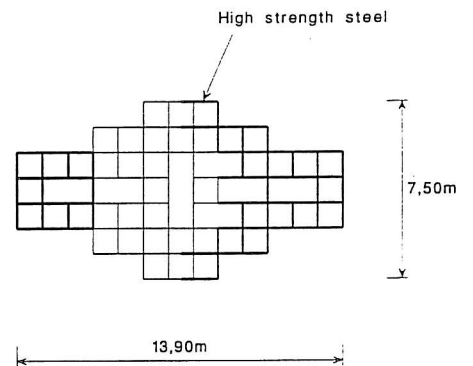
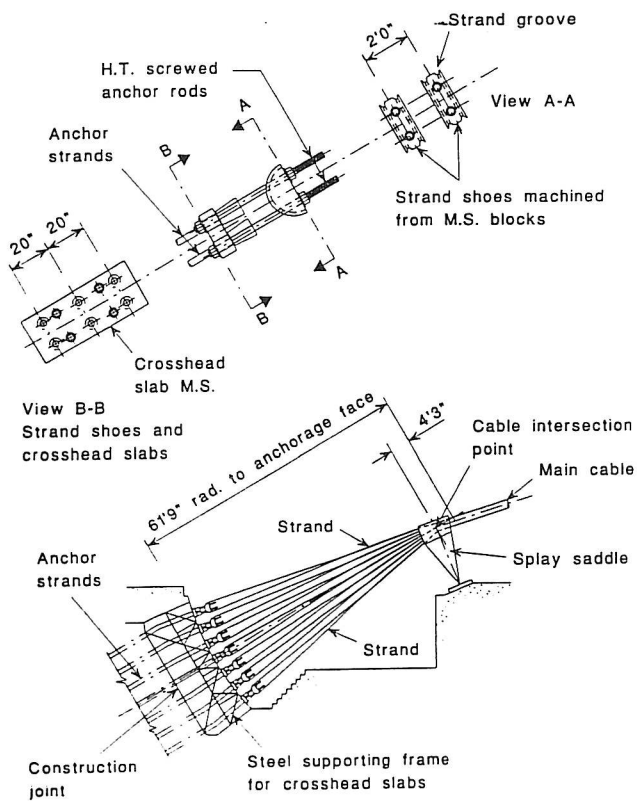


Figure 7 Cross-section of pylon: Golden gate bridge

Figure 6 Details of cable anchorage for the Severn bridge



Lecture 15B.9



Lecture 15B.9

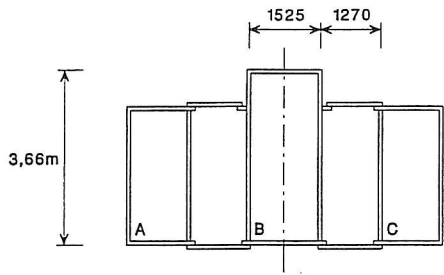


Figure 8 Cross-section of pylon:
Firth of Forth bridge

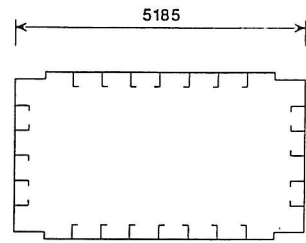


Figure 9 Cross-section of pylon:
Severn bridge



Lecture 15B.9



Lecture 15B.9

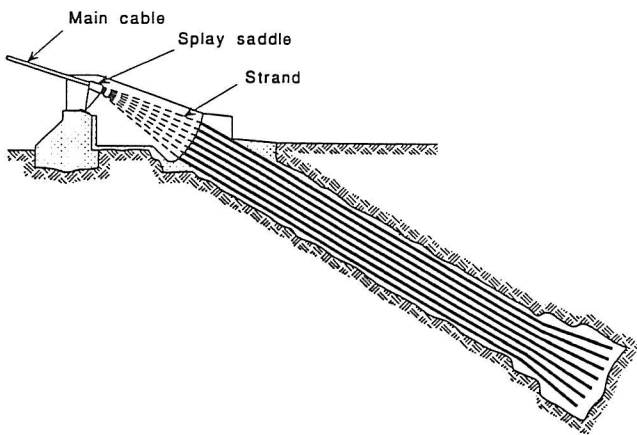


Figure 10 Firth of Forth bridge

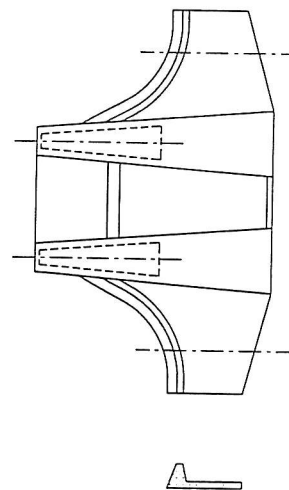


Figure 11 Concrete gravity anchorage:
Lillebelt bridge



Lecture 15B.9



Lecture 15B.9

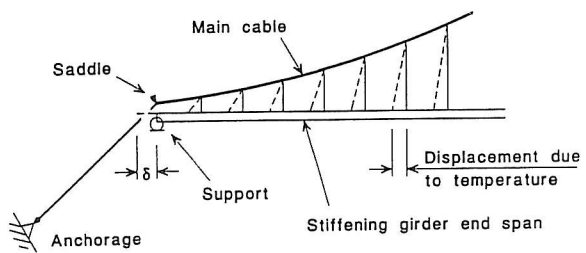


Figure 12 Influence of thermal expansion on hangers

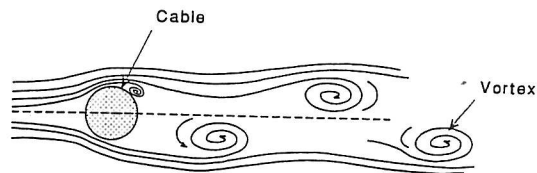


Figure 13 Vortex shedding



Lecture 15B.9



Lecture 15B.9

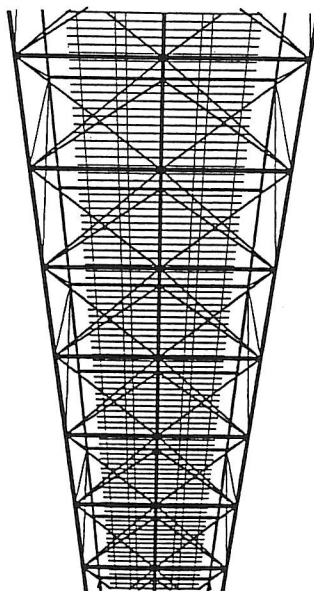


Figure 14 A view from underneath, showing the transparency of the Lisbon suspension bridge



Lecture 15B.9

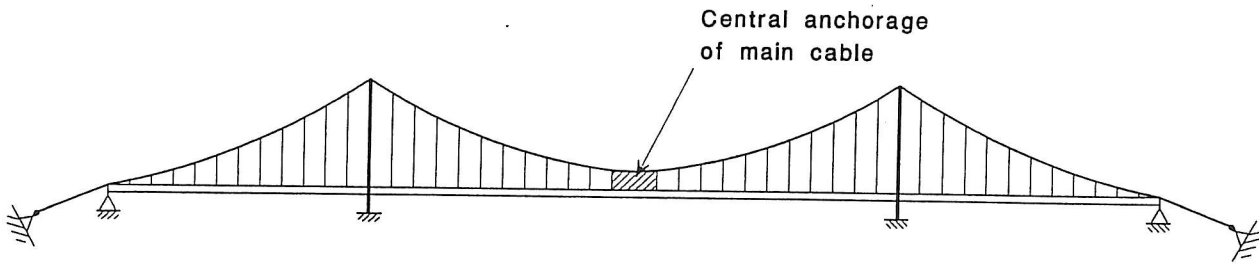


Figure 15 A technique for controlling flutter



Lecture 15B.9

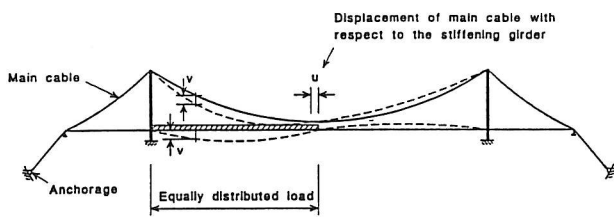


Figure 16 Deformation of the stiffening girder and displacement of the main cable due to a "half span" equally distributed load

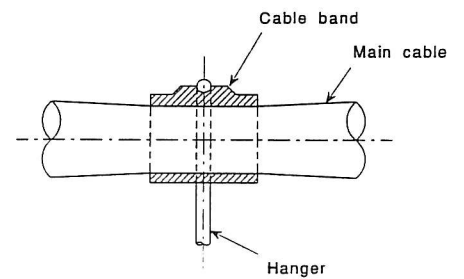


Figure 17 Cable band to main cable connection



Lecture 15B.9



Lecture 15B.9

15B.9

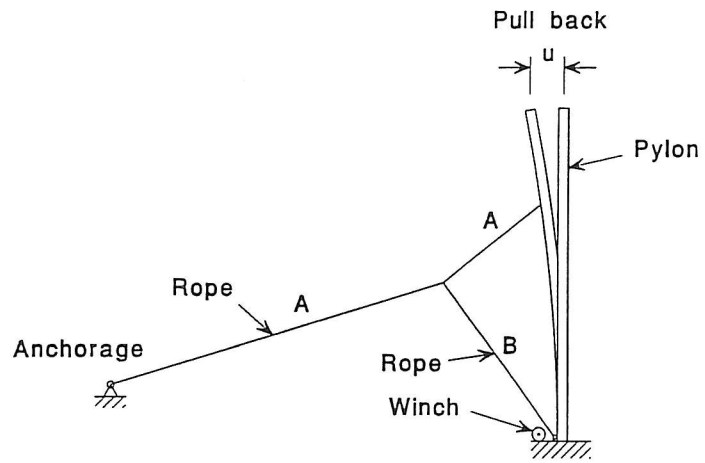


Figure 18 Prestetting pylons to prestress anchor portions of main cables

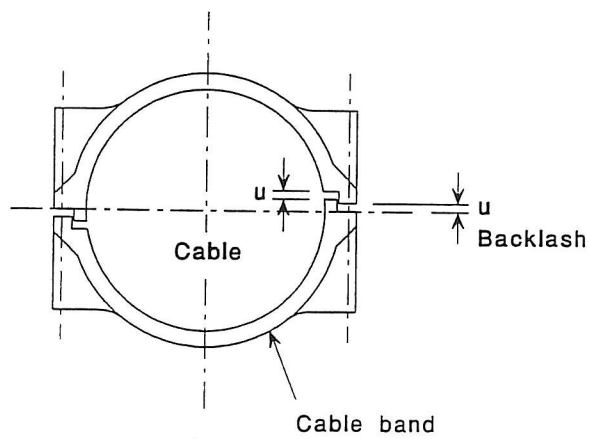


Figure 19 Backlash displacements in cable clamps

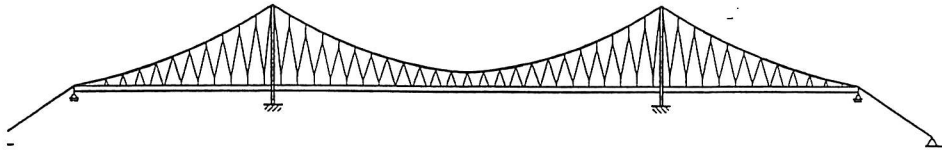


Figure 20 Hanger configuration:
Severn bridge

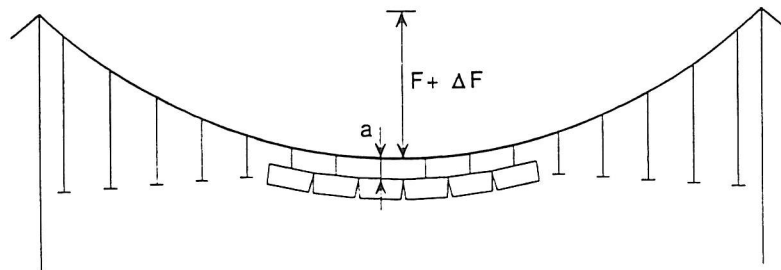


Figure 21 Cable distortion during erection
and to influence the on site
joints of stiffening girder

LECTURE 15B.10

Bridge Equipment

LECTURES

Lectures 4A: Page 13

FIGURES

Figure 1:	Page 3
Figure 2:	Page 3
Figure 3:	Pages 4 & 16
Figure 4:	Page 4
Figure 5:	Page 4
Figure 6:	Page 5
Figure 7:	Page 5
Figure 8:	Page 5
Figure 9:	Page 5
Figure 10:	Page 5
Figure 11:	Page 6
Figure 12:	Page 6
Figure 13:	Page 6
Figure 14:	Page 6
Figure 15:	Page 6
Figure 16:	Page 6
Figure 17:	Page 8
Figure 18:	Page 8
Figure 19:	Page 11
Figure 20:	Page 11
Figure 21:	Page 11
Figure 22:	Page 11
Figure 23:	Pages 11 & 12
Figure 24:	Page 12
Figure 25:	Page 12
Figure 26:	Page 12
Figure 27:	Page 12
Figure 28:	Page 14
Figure 29:	Page 15
Figure 30:	Page 16
Figure 31:	Page 16
Figure 32:	Page 16

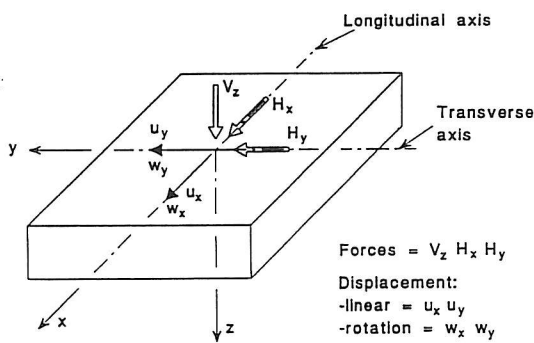
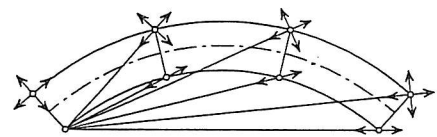


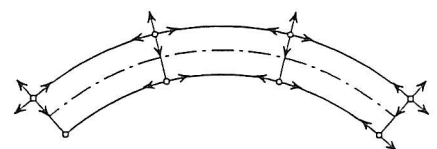
Figure 1 Forces and displacements on bearings



(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.



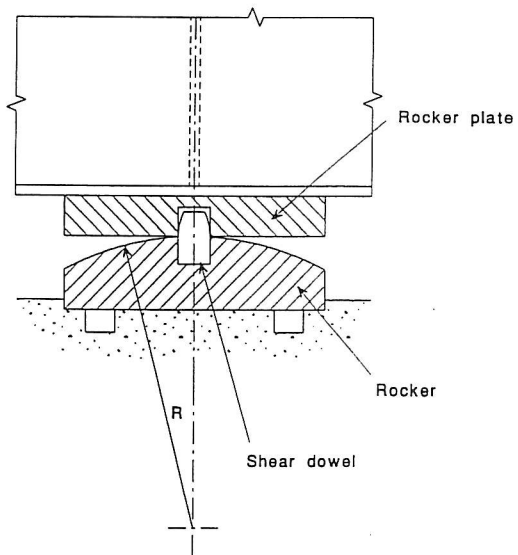


Figure 3 Elevation of line rocker bearing.



Lecture 15B.10

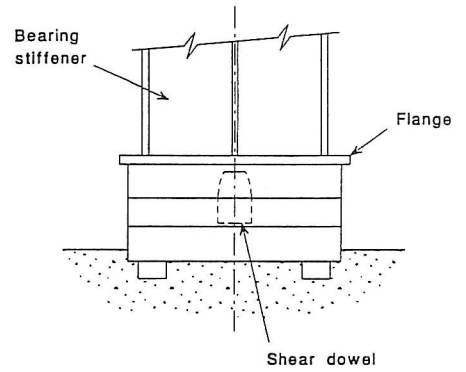


Figure 4 Section through line rocker bearing.



Lecture 15B.10

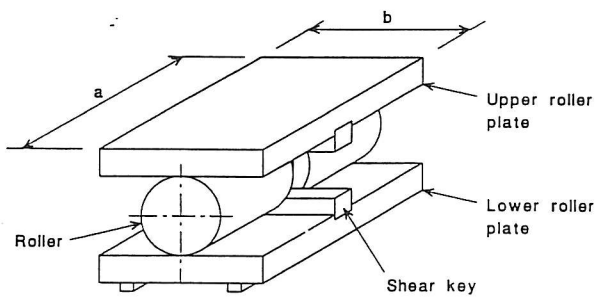


Figure 5 Roller bearing.



Lecture 15B.10

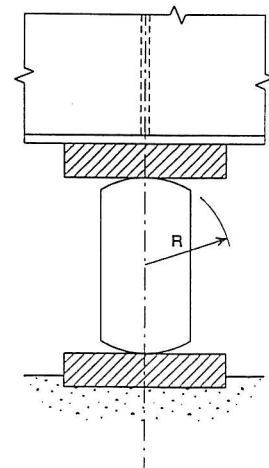


Figure 6 Flat-sided roller bearing.



Lecture 15B.10

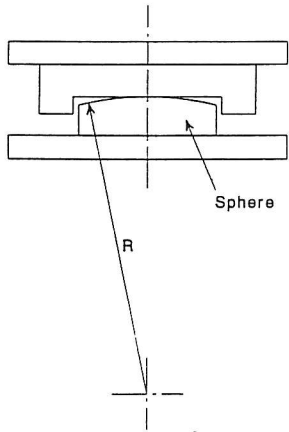


Figure 7 Plane/spherical point bearing.

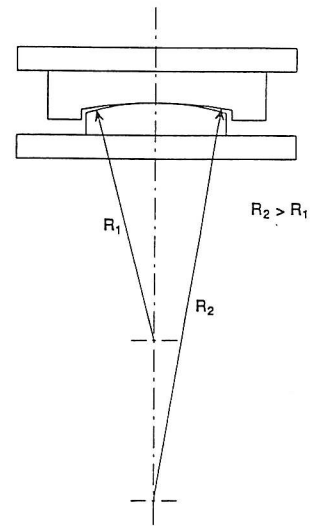


Figure 8 Double spherical point bearing.

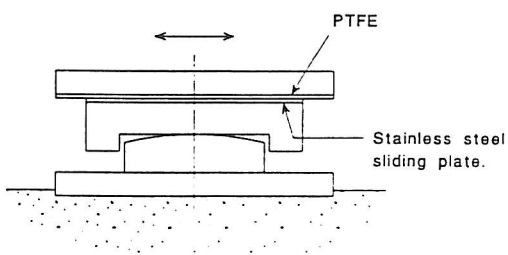


Figure 9 Sliding point bearing.

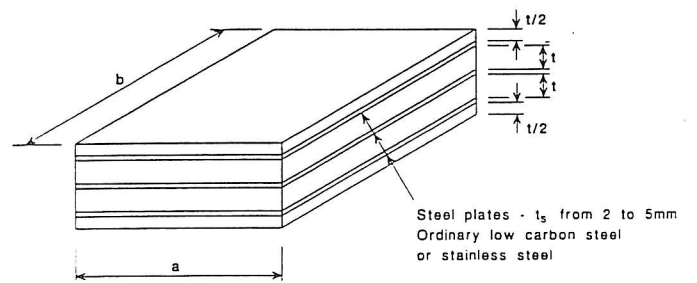


Figure 10 Reinforced elastomeric bearing system

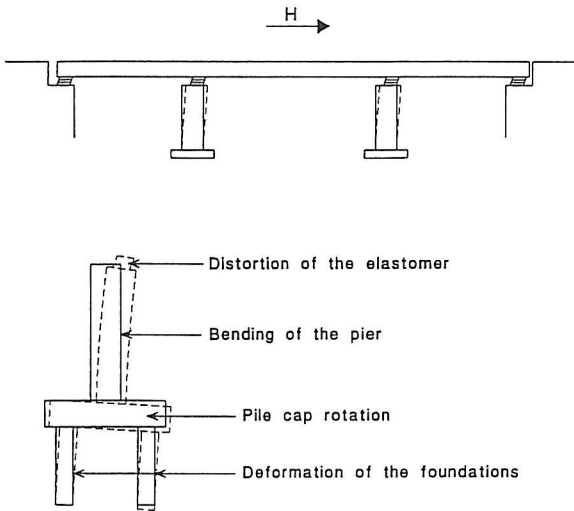


Figure 11 Location and action of the bearings.



Lecture 15B.10

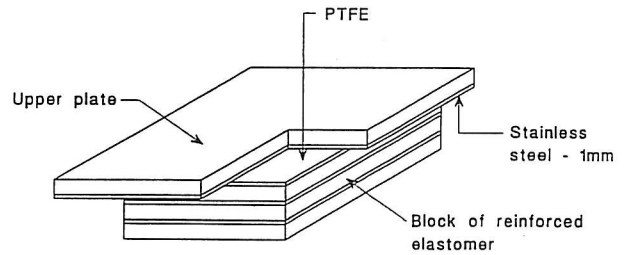


Figure 12 Sliding bearings in reinforced elastomer.



Lecture 15B.10

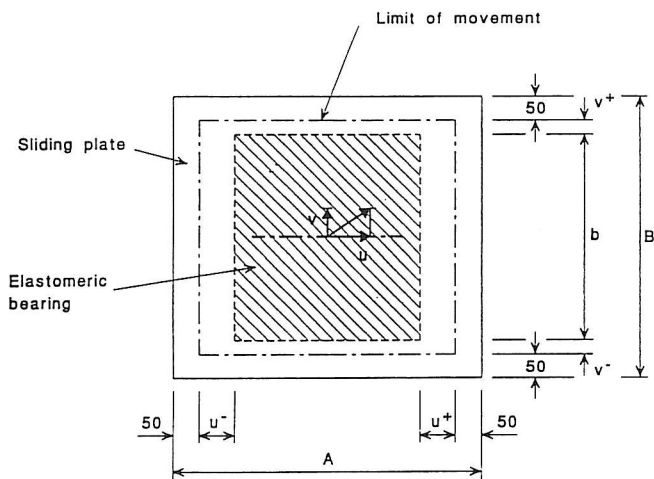


Figure 13 Layout of elastomeric sliding bearing



Lecture 15B.10

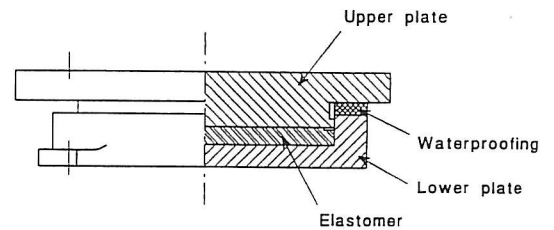


Figure 14 Fixed pot bearing.



Lecture 15I

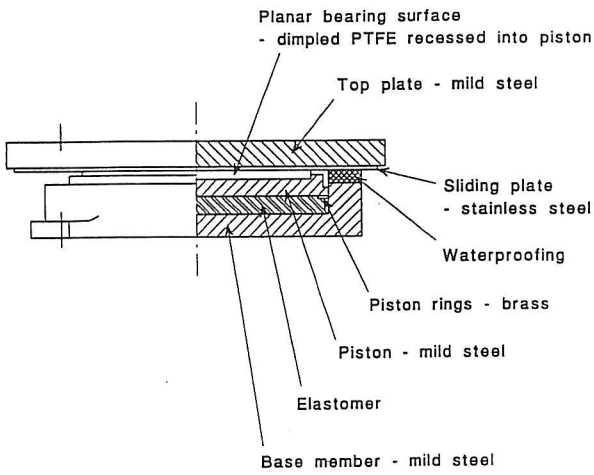


Figure 15 Multidirectional pot bearing.



Lecture 15B.10

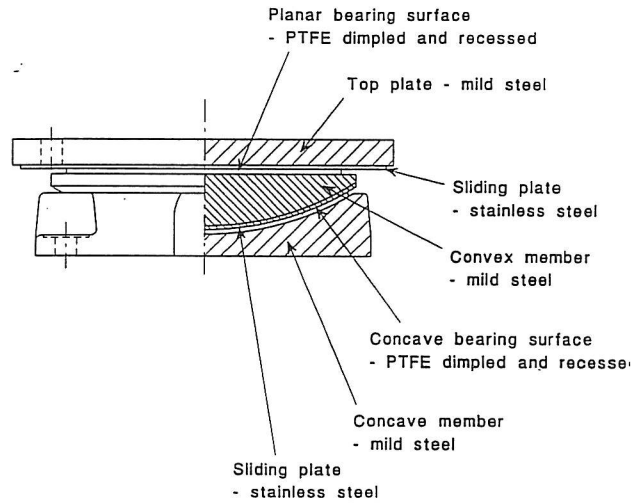


Figure 16 Bearings with spherical gap.



Lecture 15B.11

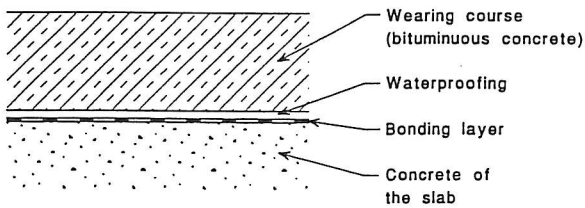


Figure 17 Finishing on concrete slab.

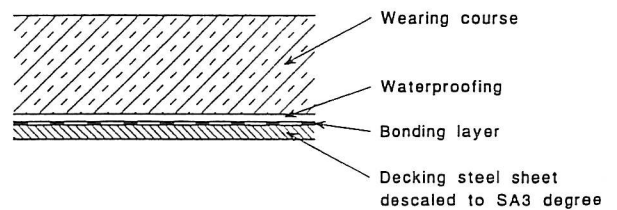


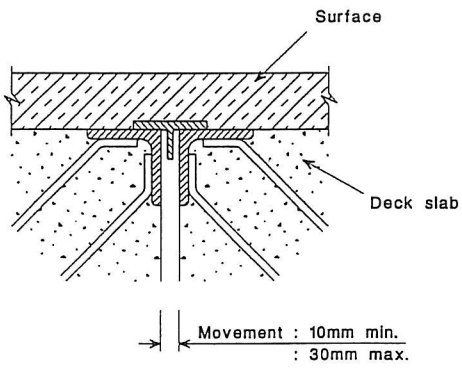
Figure 18 Finishing on orthotropic slab.



Lecture 15B.10



Lecture 15B.11



(a) Buried joint

Figure 19a Types of covered expansion joint.

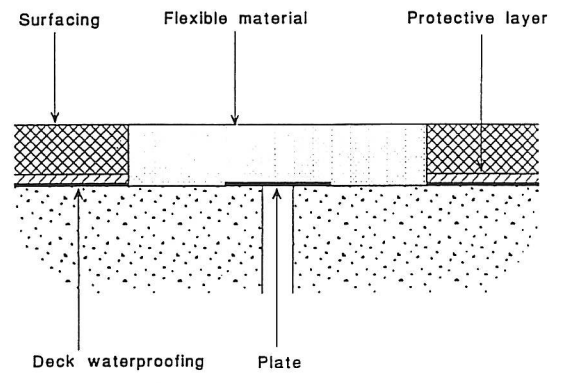
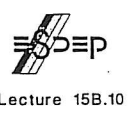


Figure 19b Asphaltic plug joint

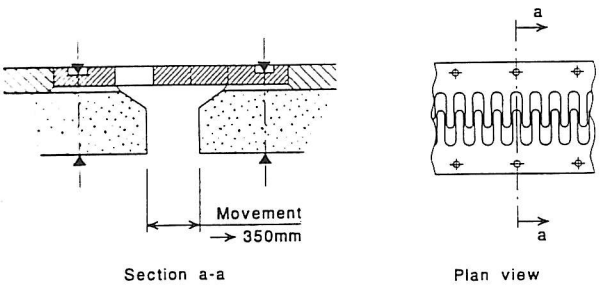


Figure 20 Toothed joint.

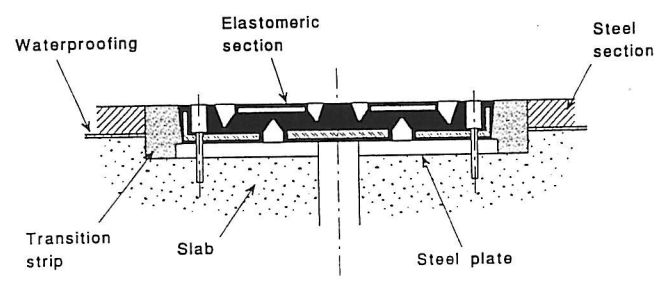


Figure 21 Joint with elastomeric extensions.



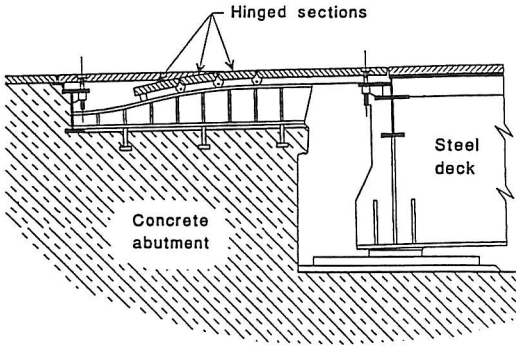


Figure 22 Roller shutter joint.

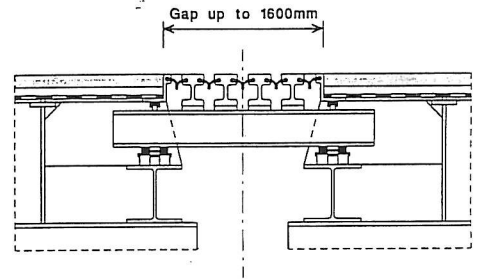


Figure 23 Bellows joints.



Lecture 15B.10



Lecture 15B.

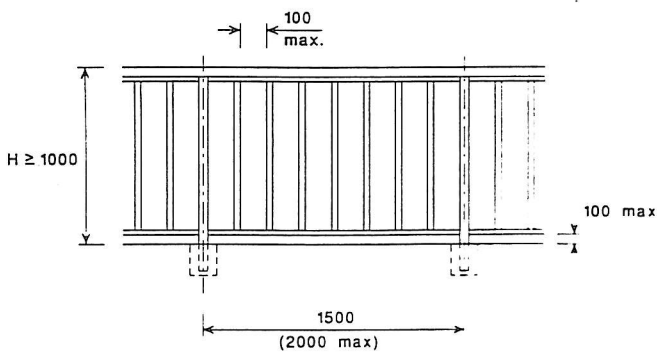


Figure 24 Pedestrian parapet.

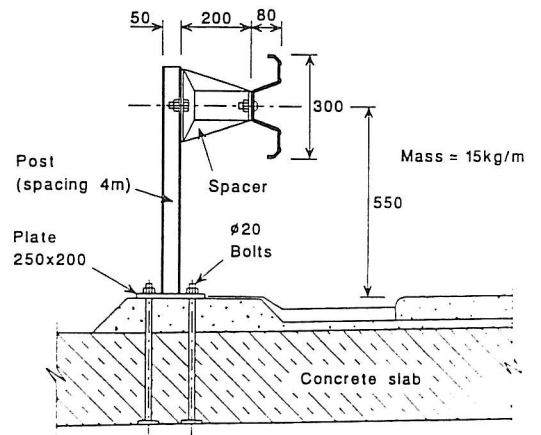


Figure 25 Crash barrier



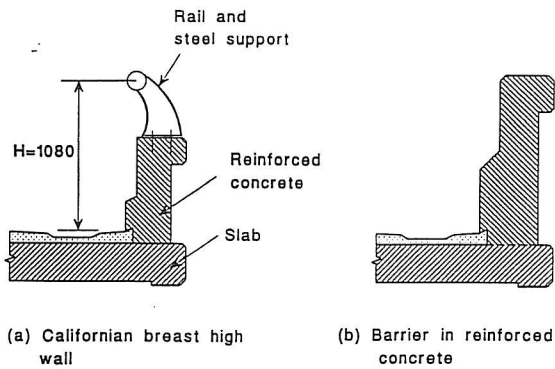


Figure 26 Examples of rigid safety fences

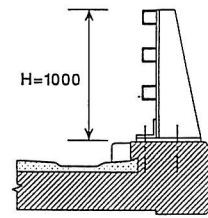


Figure 27 Typical flexible safety fence



Lecture 15B.10



Lecture 15B.

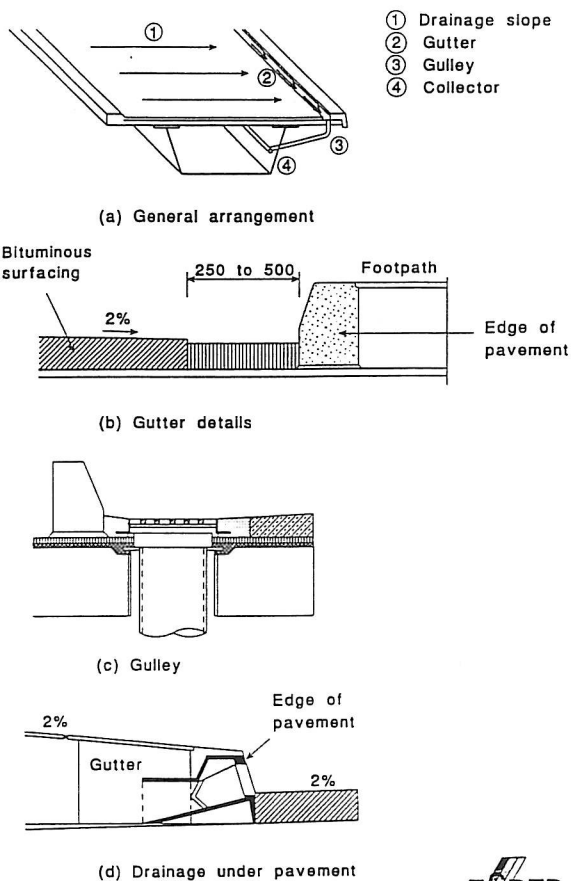


Figure 28 Drainage of rainwater



Lecture 15B.10

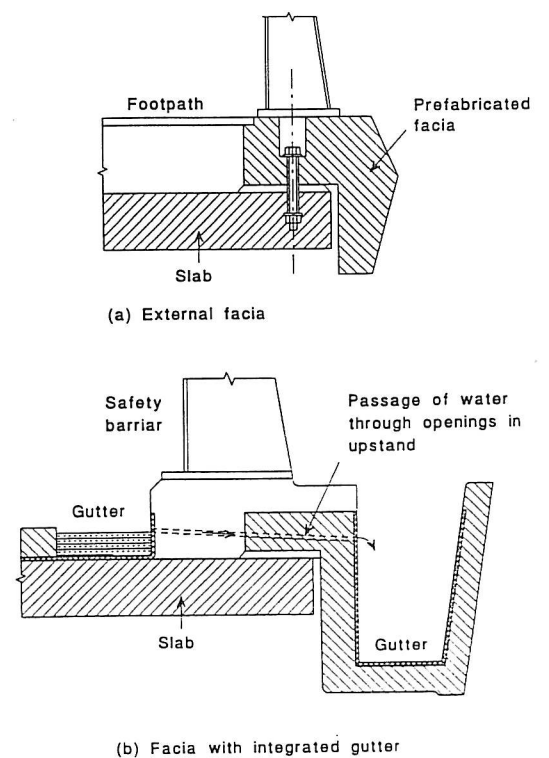


Figure 29 Fascias



Lecture 15B.

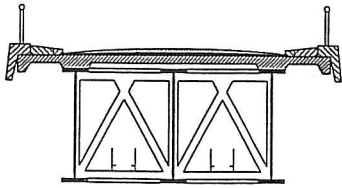


Figure 30 Fixed inspection walkways

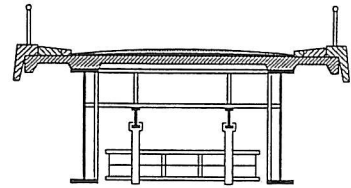


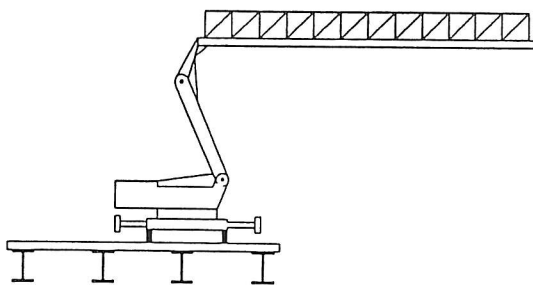
Figure 31 Moveable inspection gantry



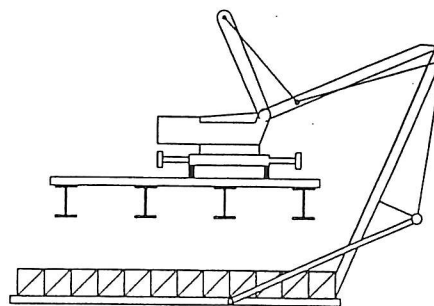
Lecture 15B.10



Lecture 15B.10



(a)



(b)

Figure 32 Special mobile inspection equipment



Lecture 15B.10

LECTURE 8.5.1

Design of Box Girders

LECTURES

Lecture 8.5.2: Page 8

FIGURES

Figure 1:	Page 3
Figure 2:	Pages 3 & 10
Figure 2a:	Page 3
Figure 2b:	Page 3
Figure 3:	Pages 3 & 9
Figure 4:	Pages 3 & 9
Figure 5:	Pages 4 & 9
Figure 6:	Page 4
Figure 7:	Page 9
Figure 8:	Page 10
Figure 9:	Page 10
Figure 10:	Page 10
Figure 11:	Page 10

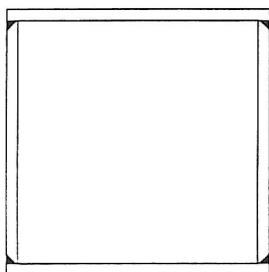


Figure 1 Cross-section of a box girder used in buildings

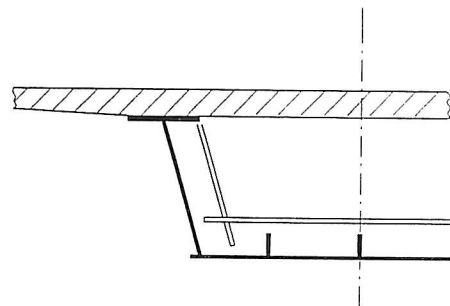


Figure 2 (a) Cross-section of a box beam with composite concrete top flange

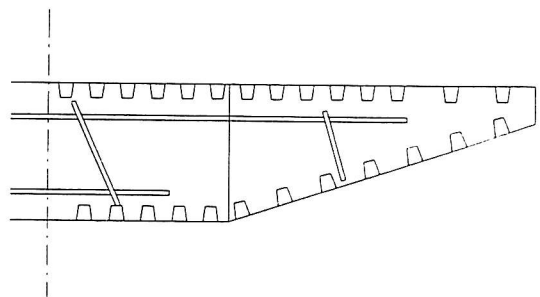


Figure 2 (b) Cross-section of an orthotropic box beam

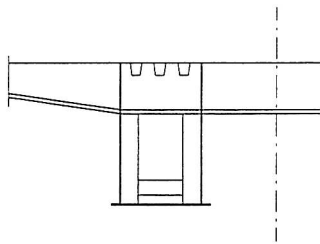


Figure 3 Composite slab with twin box beams

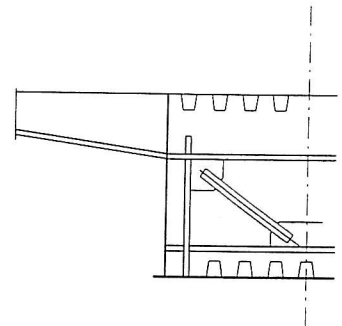


Figure 4 Reinforcement of the cross-section of an orthotropic box beam



Lecture 8.5.1



Lecture 8.5.1

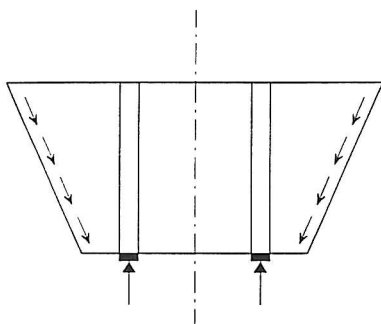


Figure 5 Transfer of reactions through support diaphragms

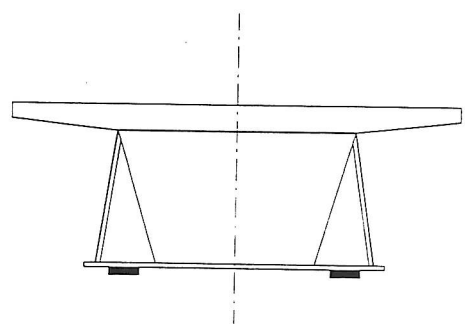


Figure 6 Load-bearing stiffeners external to a box girder



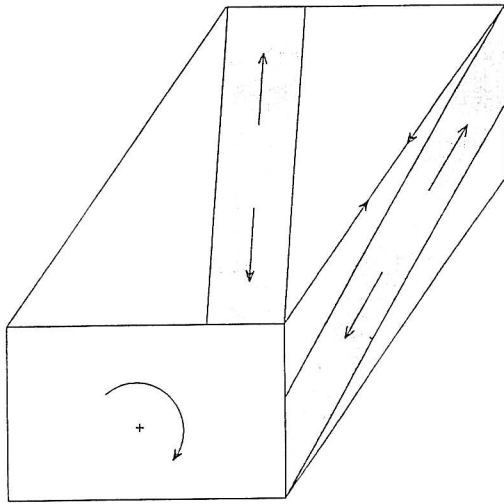


Figure 7 Tension fields developed under torsion

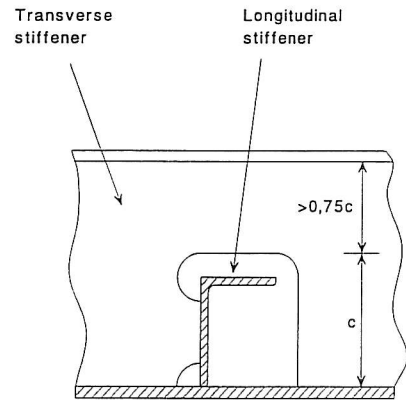


Figure 8 Longitudinal stiffener passing through transverse stiffener



Lecture 8.5.1



Lecture 8.5.1

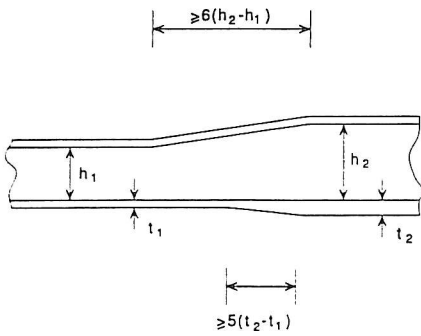


Figure 9 Tapering of longitudinal stiffener

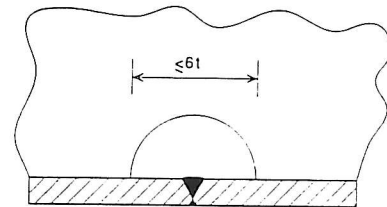


Figure 10 Cut-out to allow butt welding



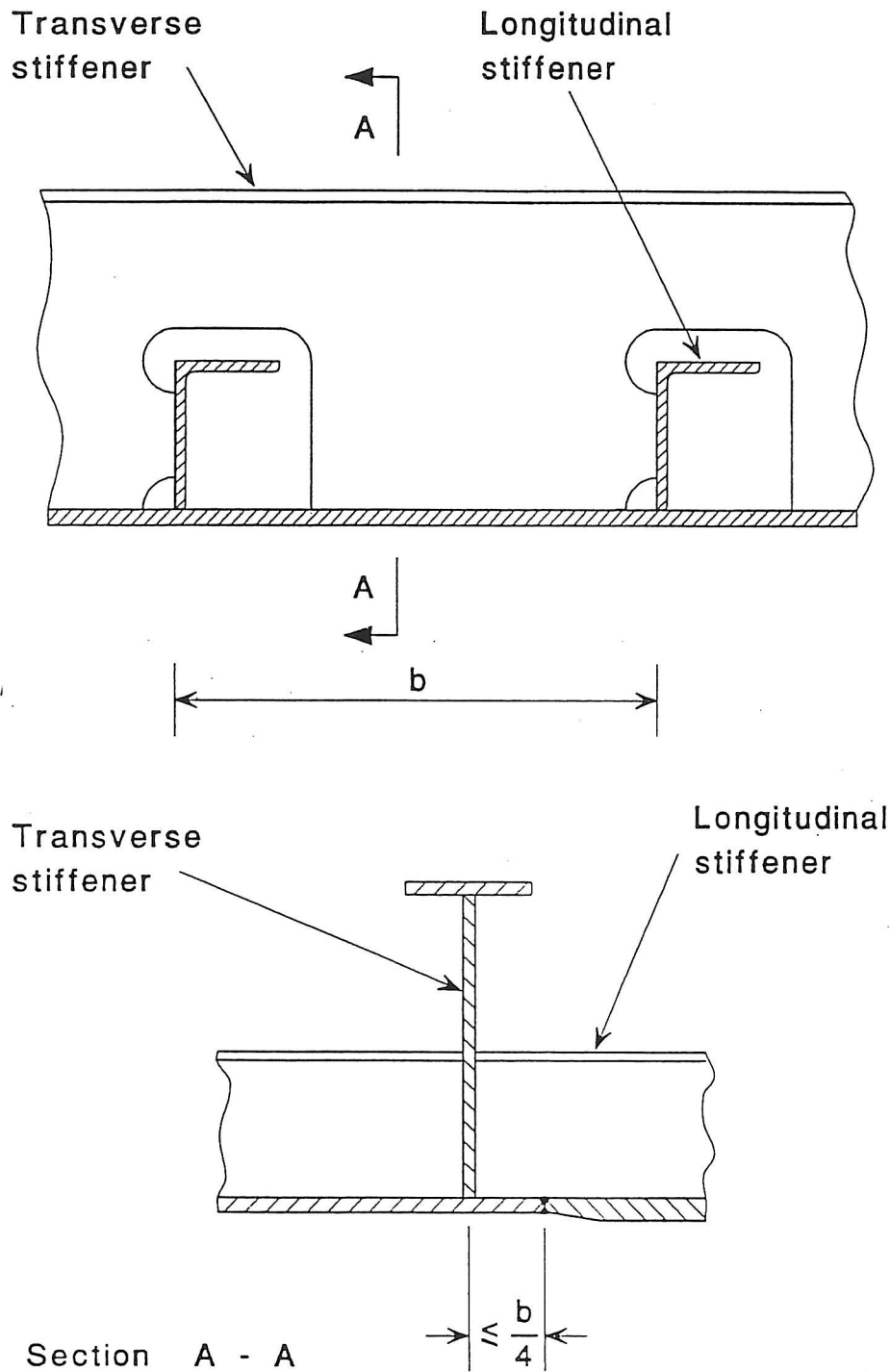


Figure 11 Transverse stiffener welded to thinner plate adjacent to transverse butt weld in the plate



LECTURE 8.5.2

Advanced Methods for Box Girder Bridges

FIGURES

- Figure 1: Page 3
- Figure 2: Page 3
- Figure 3: Pages 6 & 12
- Figure 4: Page 7
- Figure 5: Page 7
- Figure 6: Page 11
- Figure 7: Page 11
- Figure 8: Page 12
- Figure 9: Page 12

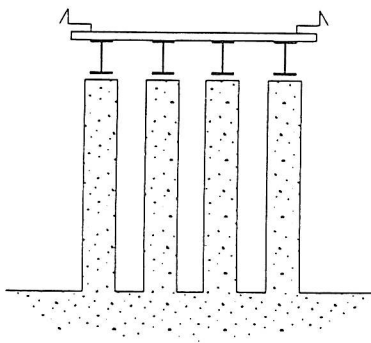
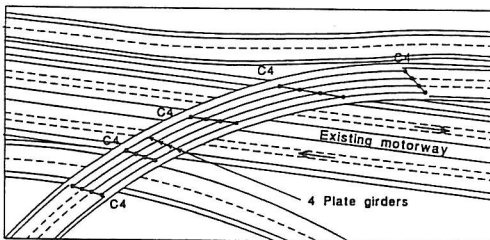
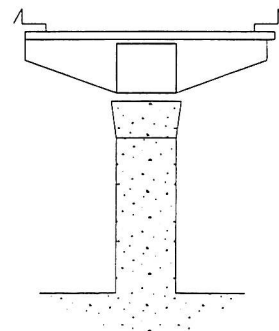
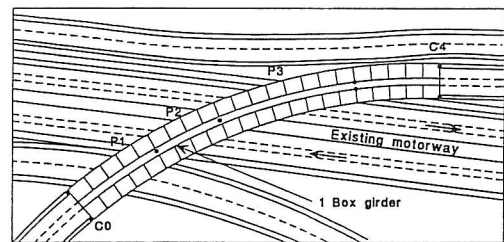


Figure 1 Plate girder bridge



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



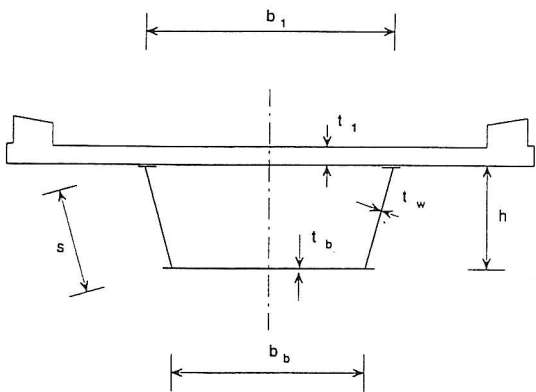


Figure 3 Composite box girder bridge with composite upper deck

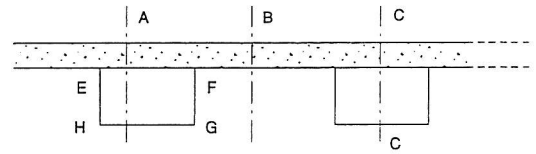


Figure 4 Interpretation of the output of a grillage analysis

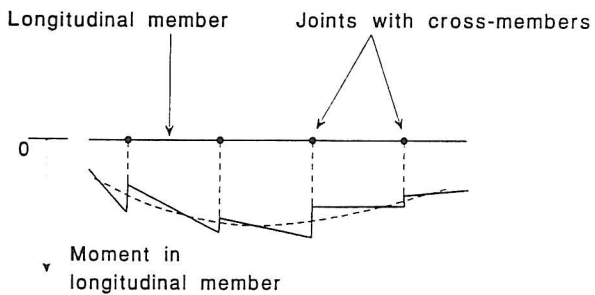


Figure 5 Typical bending or torsional moments given by a grillage analysis

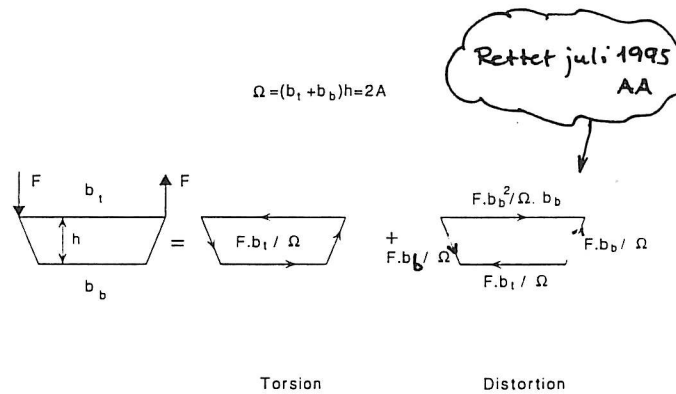
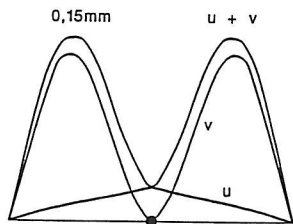
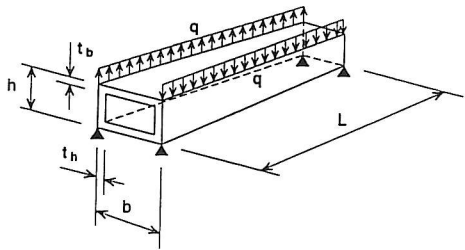


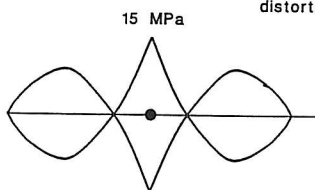
Figure 6 Computation of distortion force



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

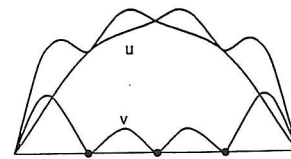


Lecture 8.5.2

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

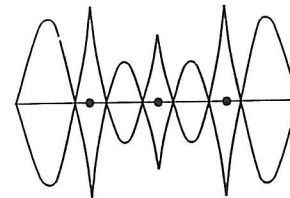
Numerically:
 $L = 2\text{m}$
 $b = 0,10\text{m}$ $t_b = 0,001\text{m}$
 $h = 0,05\text{m}$ $t_h = 0,003\text{m}$
 $E = 200.000\text{ N/mm}^2$ $\nu = 0,3$
 $q = 250\text{ N/m}$

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



Diaphragms $t = 2\text{mm}$

3 MPa

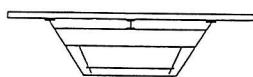


Warping stresses with three diaphragms

Figure 7B Influence of diaphragm separation - three diaphragms

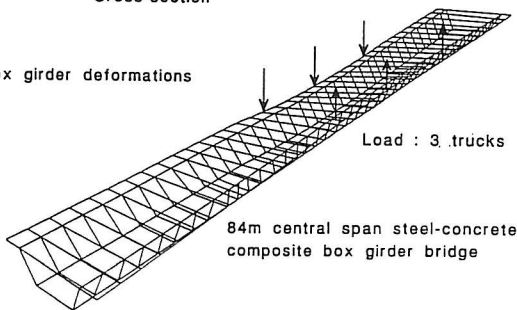


Lecture 8.5.2



Cross-section

Box girder deformations



Load : 3 trucks

84m central span steel-concrete composite box girder bridge

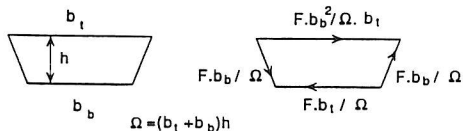
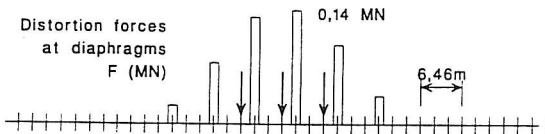
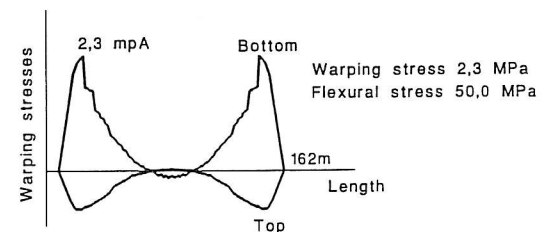
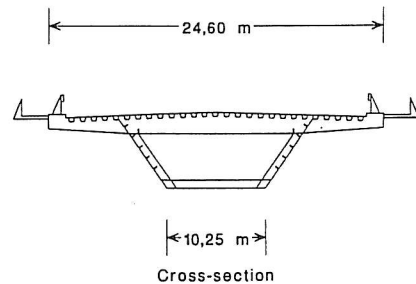


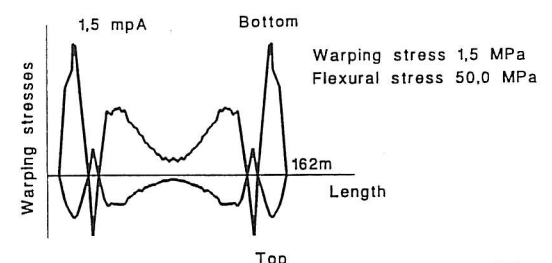
Figure 8 Distribution of the distortion forces between the cross-frames of a bridge



Lecture 8.5.2



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

