Segmental Concrete
Box-Girder Bridges

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Outlines

• Bridge Characteristics
• Advantages and disadvantages
• Analysis of Segmental Bridge
• Design of Segmental Bridge
Segmental Concrete Box-Girder Bridge

External Prestressing System

(a) Without pressing blocks together

(b) With blocks pressed together
Structural Element of Segmental Box-Girder Bridge

Pier Segment

Typical Segment

Anchorage

Segment Joint

Longitudinal Tendon

Deviator Block

Deviation Segment

Pier Cap

The components

Sheaths and ducts

Prostressing steel and tendons

Threading equipment

Stressing equipment

Active anchorage

Transverse prestressing

Active anchorage for external prestressing

Dead end anchorage

Grouting equipment and auxiliary

Couplers

(page 4)

(page 5)

(page 8)

(page 12)

(pages 26)

(pages 9, 10, 11)
Structural Element of Segmental Box-Girder Bridge

1. Pier Segment
2. Typical Segment
3. Deviator Segment II
4. Deviator Segment I
Type of Segmental Concrete Box-Girder Bridge

SIMPLY SUPPORTED SPANS
SECOND STAGE EXPRESSWAY – BANGKOK

CONTINUOUS SPAN BY SPAN SCHEME – TYPICAL

CONTINUOUS SPAN BY SPAN SCHEME
WITH FIXED SUPERSTRUCTURE /PIER CONNECTIONS
Construction Method of Segmental Concrete Bridge

- Standard scaffolding
- Free cantilever
- Overslung truss
- Underslung truss
### Segmental Concrete Box-Girder Bridge

<table>
<thead>
<tr>
<th><strong>Disadvantages</strong></th>
<th><strong>Advantages</strong></th>
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| • safety (e.g. in case of fire)  
• extra cost (more prestressing required, single spans, truss) | • short construction time (segments are prefabricated while the substructure is being built)  
• no interruption of traffic  
• precast ‘mass’ production (cost efficient, good controlled quality shapes)  
• weather independent construction (dry joints)  
• small light segments  
• hollow box section  
• reduced dead load  
• cost (reduced reinforcement)  
• Recycling |
| • high construction loading (overslung truss)  
• new construction method – technology (e.g. geometry control of segments, design) | }
## External Prestressing

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Advantages</th>
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<tbody>
<tr>
<td>• additional mild reinforcement required ($\Delta \sigma_p$)</td>
<td>• replacement of tendons possible</td>
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<tr>
<td>• additional cost for ducts, anchorage, etc.</td>
<td>• inspection of tendons possible</td>
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<td>• only straight tendon layout</td>
<td>• easier Installation of longitudinal tendons</td>
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<td>• diffusion of post-tensioning forces</td>
<td>• good corrosion protection of p.t. cables</td>
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<td>• less dead load (thin webs)</td>
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<td>• less friction (no wobble losses)</td>
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<td>• prestress forces can be modified after construction (spare ducts)</td>
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Structural Action

- Simple beam action in the longitudinal direction causing longitudinal flexural stresses and shear stresses across the section.
- Shear lag effect in bending.

(a) Shear lag in bending

(b) Enlarged elevation of region of box beam near support showing shear lag in bending
Structural Action

- Torsion of the cross section due to eccentricity of loading. (St. Venant’s shear stress and warping shear stresses in the longitudinal direction)
- Distortion of the section due to eccentric loading. (Transverse bending stress, shear stress across the section, longitudinal warping stress (distortional), and corresponding (distortional) warping shear stresses)
Overall Structural Action of Box Girder

(a) Simple longitudinal flexure
(b) Rigid body rotation

(c) Distortion of section
(d) Local transverse flexure
Behavior of Segmental Box Girder

Precast segmental box girder bridges with external prestressing - design and construction - Prof. Dr.-Ing. G. Rombach, Technical University, Hamburg-Harburg, Germany
Behavior of Segmental Box Girder (Dry Joint)

- Whole structure is under compression at the beginning. (due to PT)
- The structure fails due to crushing of the concrete in the top
- A ductile behavior of the segmental bridge can be seen!!!
- The segments around mid-span are open.
- T. Takebayashi, et.al: A full-scale destructive test of a precast segmental box girder bridge with dry joints an external tendons
Critical sections

1. mid-span: greatest bending moment
2. first joint after support: greatest shear force but prestress force not uniformly distributed in cross-section
3. diaphragms: high concentrated loads due to anchorage of tendons
4. deviators: high concentrated loads due to tendons.
Design Codes

- AASHTO (Segment)  

- AASHTO (STD)  
  American Association of State Highway and Transportation Officials, Standard Specifications for Highway Bridges, 2002

- AASHTO (LRFD)  
  American Association of State Highway and Transportation Officials, LRFD Bridge Design Specifications, Interim 2005

- BS5400  
  British Standards Institution, British Standard 5400 (Steel, concrete and composite bridges)

- CEB-FIP  
  Euro-International Committee for Concrete and International Federation for Prestressing, CEB-FIB Model Code 1990 (Design Code), 1990
Loads – additional considerations-A5.14.2

- According to AASHTO (Segment), all loadings shall be in accordance with AASHO (STD) including temperature gradient, erection loads, and creep and shrinkage (ACI, CEB-FIP)
- LRFD-2005 includes some of loadings as specified above.
- For segmentally constructed bridges, the LC shall also be investigated at the service limit state:

  LRFD2005

  \[ DC + DW + EH + EV + ES + WA + CR + SH + TG + EL \]

  AASHTO(Segment)

  \[ DL + SDL + EL + \beta E + B + SF + R + S + TG \]

  \(< 100\% \text{ Allowable Stress}\)

- Additional three types of loading are listed below;
  - Construction
  - Creep and shrinkage
  - Temperature
Construction Loads

\[ DC = \text{weight of the supported structure (N)} \]

\[ DIFF = \text{differential load; applicable only to balanced cantilever construction taken as 2 percent of the dead load applied to one cantilever (N)} \]

\[ DW = \text{superimposed dead load (N) or (N/mm)} \]

\[ CLL = \text{distributed construction live load; an allowance for miscellaneous items of plant, machinery, and other equipment, apart from the major specialized erection equipment; taken as } 4.8 \times 10^{-4} \text{ MPa of deck area; in cantilever construction, this load is taken as } 4.8 \times 10^{-4} \text{ MPa on one cantilever and } 2.4 \times 10^{-4} \text{ MPa on the other; for bridges built by incremental launching, this load may be neglected (MPa)} \]

\[ CE = \text{specialized construction equipment; the load from segment delivery trucks and any special equipment, including a formtraveler launching gantry, beam and winch, truss, or similar major auxiliary structure and the maximum loads applied to the structure by the equipment during the lifting of segments (N)} \]

*Preliminary load from past experience:
  - formtraveler (2-lane, CIP, 4.5-5m segment: approx. 710 000 - 800 000 N)
  - formtraveler (double cell box section: approx. 1 250 000 N)
  - consult contractors for accurate weight!*

*Allows for possible variations in cross section weight due to construction irregularities*