Third Karnaphuli Bridge
the first major cable supported bridge in Bangladesh

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St Hugh’s College, Oxford
Third Karnaphuli Bridge
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Fast Track Procurement

2001 Study concluded replacement bridge required

Decision to progress project on a D&B basis, funded by KFAED and Government of Bangladesh

Early 2005 Contractor Consortium Pre-Qualified

August 2005 D&B Tenders Invited

July 2006, Tender awarded to MBEC-ACL-COPRI JV

July 2007 Construction Start

July 2009 final stitch

Construction complete early 2010
Location of the new bridge is 50m upstream of the existing Shah Amanat Bridge.
Functional Requirements

- Concrete structure with low maintenance
- Design to AASHTO LRFD 2004/2006
- Two full lanes + one narrow lane of traffic each carriageway (AASHTO 6 lanes for design)
- 200m spans with navigation clearance (4m depth at midspan)
- Resistant to seismic and ship impact forces
- Cantilever deck construction (minimise works in river)
- Large diameter bored piles
Main Bridge Layout - Elevation
Main Bridge Layout - Pier

FOOTWAY 1.65m 7.3m 2.96m 7.3m 1.65m FOOTWAY
SLOW CARRIAGeway
LANE
CARRIAGewaysSLOW LANe
6No. STAY CABLES
REINFORCED CONCRETE TOWER
25750 24.47m
2.5% 2.5%
6.75m
Main Bridge Layout - Midspan

BRIDGE

24.47m

4m

DIAGONAL REINFORCED CONCRETE STRUTS
Extradosed Bridge - Definition

- **Girder Bridge**
- **Extradosed Bridge**
- **Cable-Stayed Bridge**

- **Extradosed**: Tower height = 1/15 to 1/10 of span
- **Cable-stayed**: Tower height = 1/5 to 1/4 of span
- **Karnaphuli**: Tower height = 1/8 of span

- **Extradosed**: <30% total vertical load carried by stays
- **Cable-stayed**: >40% total vertical load carried by stays
- **Karnaphuli**: 45% total (dead+live) carried by stays
Main Bridge Articulation

(1) Construction (temporary erection loads); (2) Normal (traction, wind); (3) Seismic
Main Bridge Piers

- 1200x1200x231 Thick Elastomeric Buffer
- OUTLINE OF DECK SHEAR KEY 2950 x 2135 x 2225 DEEP.
- SHOCK TRANSMISSION UNIT.

PLAN ON TYPICAL PIER HEAD

- 2.25m diameter Columns
- Pile Cap
- 3m diameter piles

SECTION

Tabletop
Shock Transmission Units

- Velocity Sensitive
- Allows “Slow” movements (e.g. creep, shrinkage, temperature)
- Locks under impulse loading (e.g. seismic and ship impact)
RM2000 Model (Detail)

Permanent load Stresses
(No Tension)
Deck Fibre Stresses
(Permanent loads only at end of construction)

45MPa (cylinder)
Concrete
(cf 50MPa Specified)

LIMIT 1
(Construction 35MPa)
21 MPa Comp
2.97 MPa Tens

LIMIT 2
(Final 45 MPa)
19.8 MPa Comp
1.67 MPa Tens

Includes reduction for slenderness
Deck Fibre Stresses
(Live load only envelopes)

ONLY 2-3Mpa!
Tower Top Displacement due to Creep
(10,000 days)

110mm transversely due to deck curvature!
Deck Transverse Design

Features:
- Single cell RC
- Central longitudinal beam with struts @ 8m c/c
- Top slab transversely prestressed over “stayed” length
- Stay forces balanced by strut prestress
- 3D LUSAS analysis
Substructure Design

- **PIERS 8, 9 AND 10**
  - Compliant structure for seismic
  - 3D Framework modelled in RM2000
  - Section design using SAM software
  - 3.0m diameter piles

- **PIER 7**
  - Insufficient height to fit “legs”
  - “Stiffer” so attracts more seismic load particularly when unscoured
  - 3.0m diameter piles

- **PIER 6**
  - Transition between main bridge and approach viaduct
  - Expansion joint
  - 1.5m diameter piles

- **SOUTH ABUTMENT**
  - Expansion joint

Transverse No Scour  Longitudinal No Scour
THEORETICAL PILE CAPACITY

- 1.5m or 3.0m diameter bored concrete piles
- AASHTO LRFD Method with “Service” (unfactored), “Strength” (factored), and “Extreme” (seismic) capacities.
- Scoured and unscoured ground profiles
- Capacities calculated using $N_q$ and $\delta$ (using lower bound friction angle) NOT LRFD empirical method (based on uncorrected $N$)
- Pile toe founded in very dense sand ($N_{160}>50$) but Service loads mainly carried in friction
Pile Testing
Pile Load Test Method

- “O-Cell” test on 1.5m diameter piles
- Cell is located 1m above toe to measure end bearing resistance and friction above toe
- Shaft stresses measured with strain gauges to show distribution of friction (no need for two-level “O-Cell”)
- Plot graphs:
  - Frictional resistance against Displacement
  - End bearing resistance against Displacement
- Calculate Total resistance against Displacement and check (See Table opposite for Pier 3)
- Results from Pier 3 confirm that Service Loads carried by shaft friction alone with 3mm settlement!

<table>
<thead>
<tr>
<th>LIMIT STATE</th>
<th>DESIGN LOAD</th>
<th>PILE SETTLEMENT CRITERIA</th>
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</thead>
<tbody>
<tr>
<td>SERVICE</td>
<td>4.2MN</td>
<td>10mm differential settlement = 20mm total say</td>
</tr>
<tr>
<td>STRENGTH</td>
<td>5.6MN</td>
<td>5% diameter=75mm total</td>
</tr>
<tr>
<td>EXTREME</td>
<td>6.1MN</td>
<td>5%-10% diameter=150mm (Damage Criteria)</td>
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Stay Cable Design

SUMMARY

- 91No 15mm strand system individual encapsulated
- Continuous across tower saddle anchored in deck
- Stress limited to 45% to 50% UTS (conservative to permit replacement)
- Single stage stressing (but can be re-stressed) at deck level
Stay Cable System

Cable system for
Karnaphuli Bridge

OVM250AT-91

Wedge hole layout

A - A

R - R
Multi-Pipe Saddle
Tower Top Under Construction
Stay Cable Installation
Stay Cable Stressing
Concrete Supply

Deck 50MPa Cylinder

CEM I 42.5 OPC with superplasticiser

Local aggregates:

‘Sylhet’ sand
‘Pakur’ stone

Two batch plants:
50-80 cu m/hr from each river bank

Access via temporary trestle bridge to piers 7, 8, and 9
Deck Cantilever Construction
Deck Cantilever Construction
Design and Construction of Third Karnaphuli Bridge, Bangladesh.

Astin, Xie and Gillarduzzi

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FACTS & FIGURES

BRIDGE SPAN: 830m (950m with viaduct)
BRIDGE WIDTH: 24.4m
EACH MAIN-SPAN OF MAIN BRIDGE: 200m
EACH SIDE-SPAN OF MAIN BRIDGE: 115m
CARRIAGEWAY: 2 x 7.30m
SLOW MOVING VEHICLE LANE: 2 x 1.65m
FOOTPATH: 2 x 1.5m
PILING: 40 x 1.5m dia. and 16 x 3.0m dia.