Design of the Canada Line Extradosed LRT Bridge

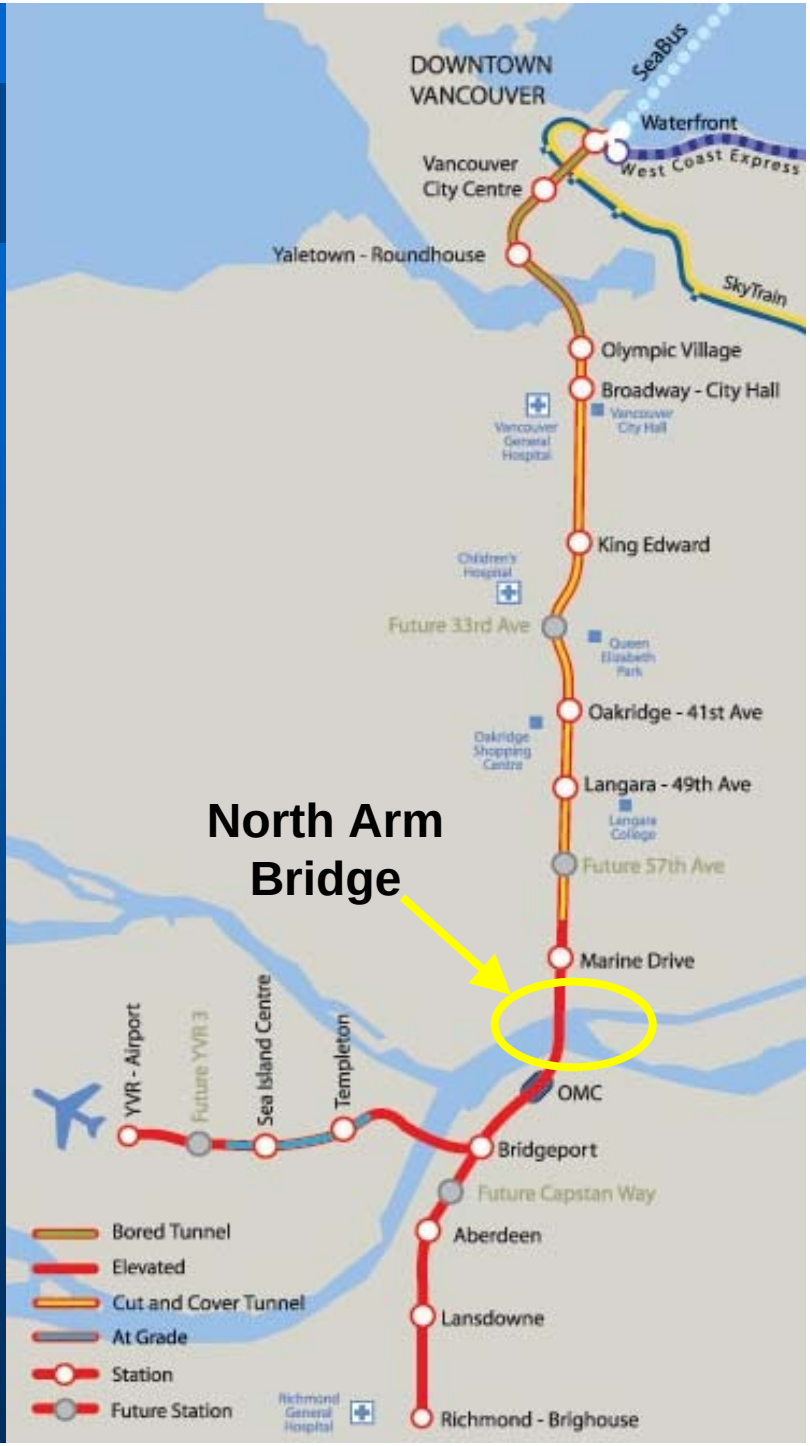
Christopher Scollard, P.Eng.

Andrew Griezic, P.E., P.Eng.

BUCKLAND & TAYLOR LTD.
Bridge Engineering

Canada Line

- 19 km Light Rapid Transit
- Connects Vancouver, YVR Airport and Richmond
- DBOT contract: SNC Lavalin
- Project value ~$1.9B
- Line in service Nov 2009



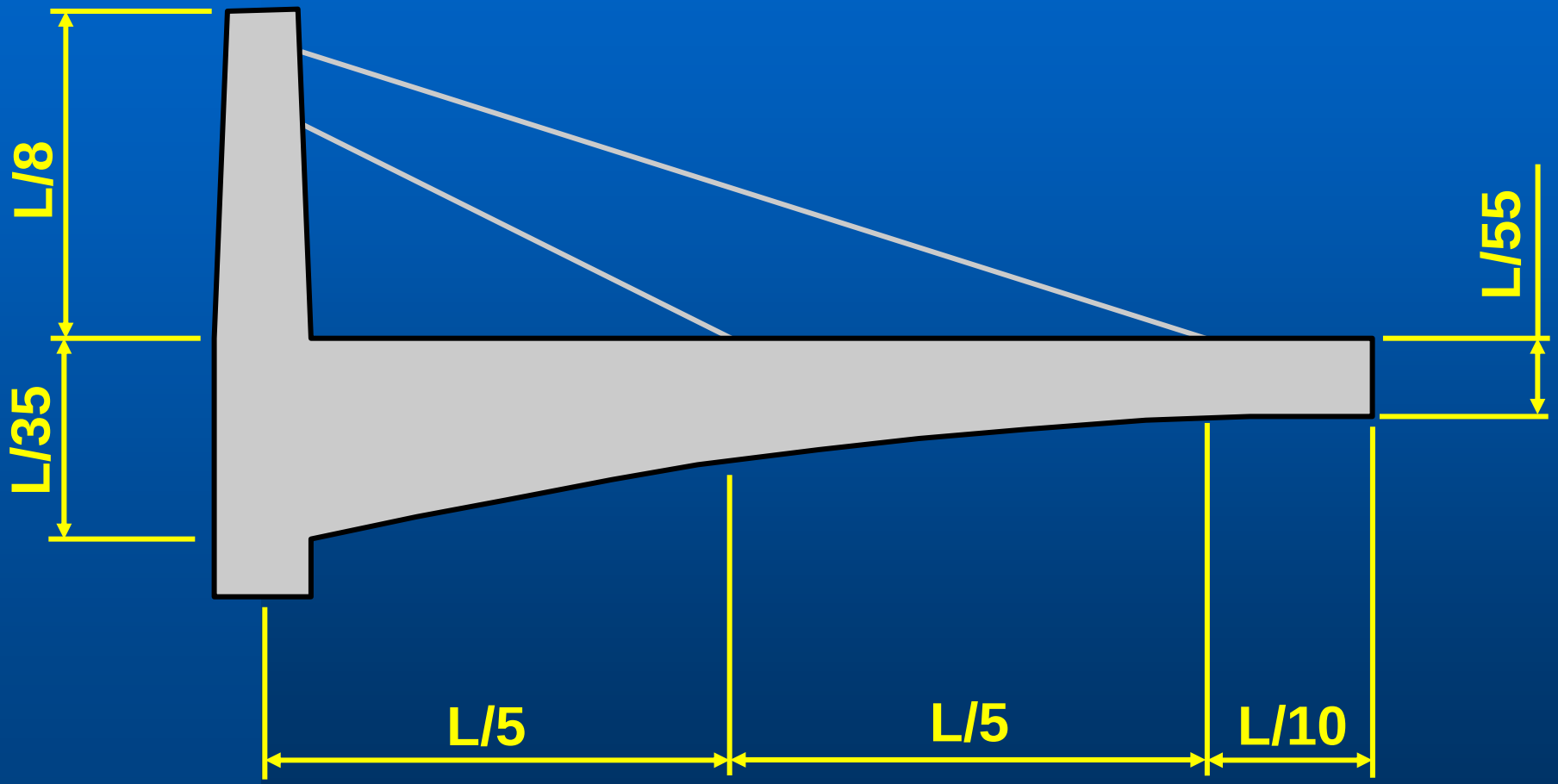
Outline

- Extradosed Bridges
- Geometric Constraints
- Constructability / Practical Constraints
- Structural Impacts
- Design Details
- Construction Photos
- Summary / Conclusions

Extradosed Bridges

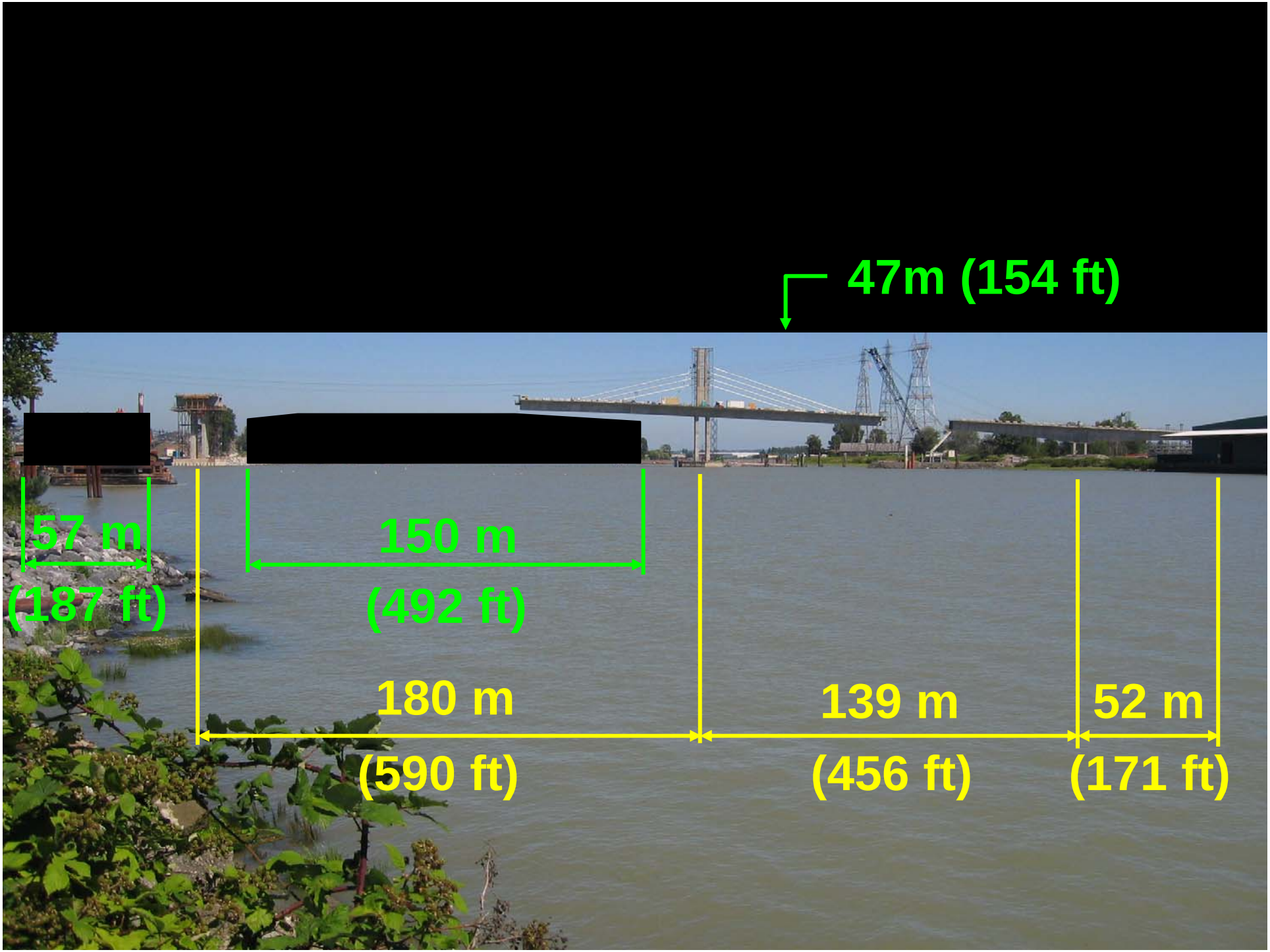
- Extend span range of box girder bridges.
- Optimize tendon profile for negative bending.
- Cost effective for medium spans up to 200m.
- Reduced tower heights over cable-stayed.
- Shallow cable angles → reduced fatigue stress range in stays.

Extradosed Bridges



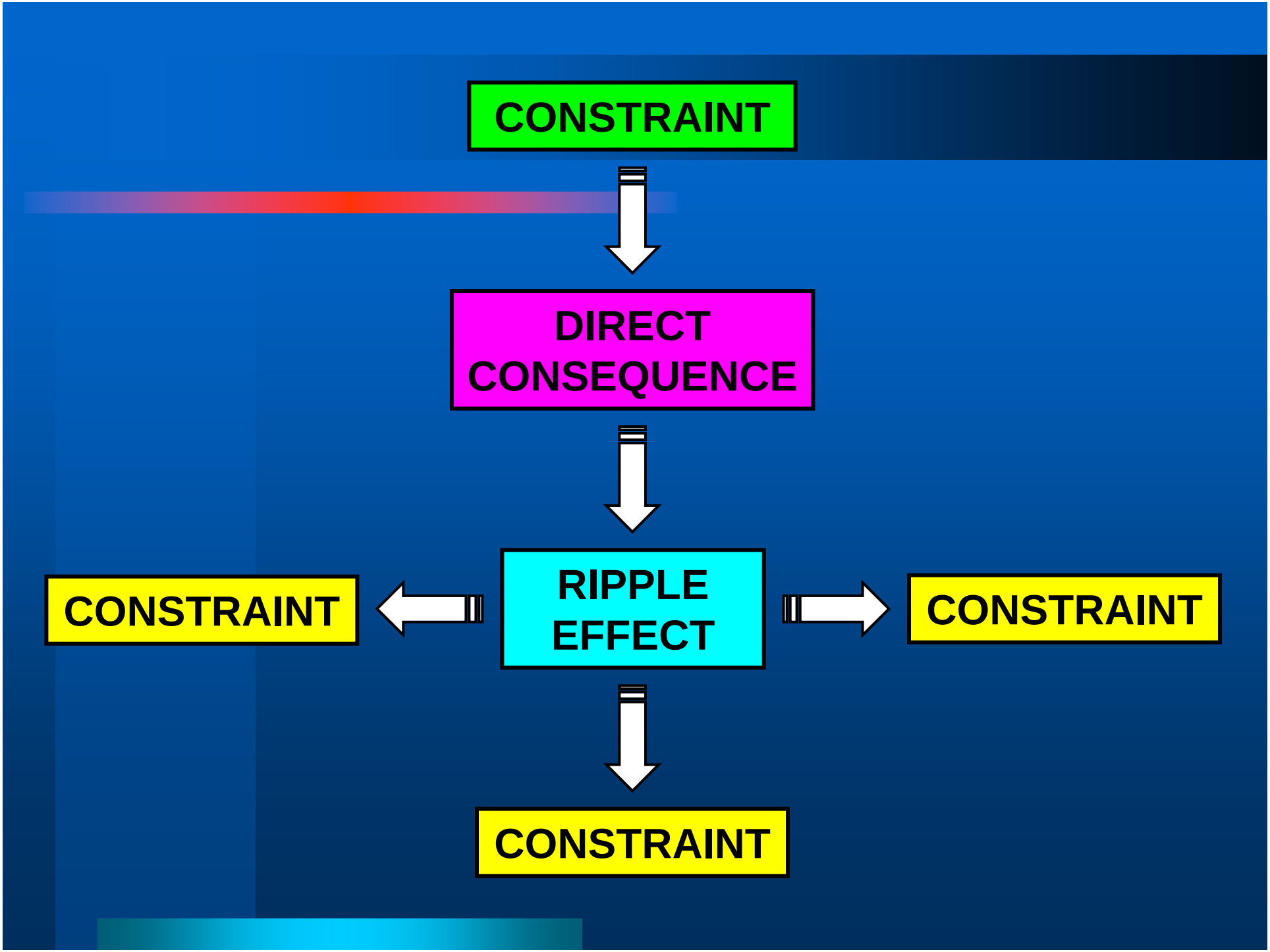
Geometric Constraints

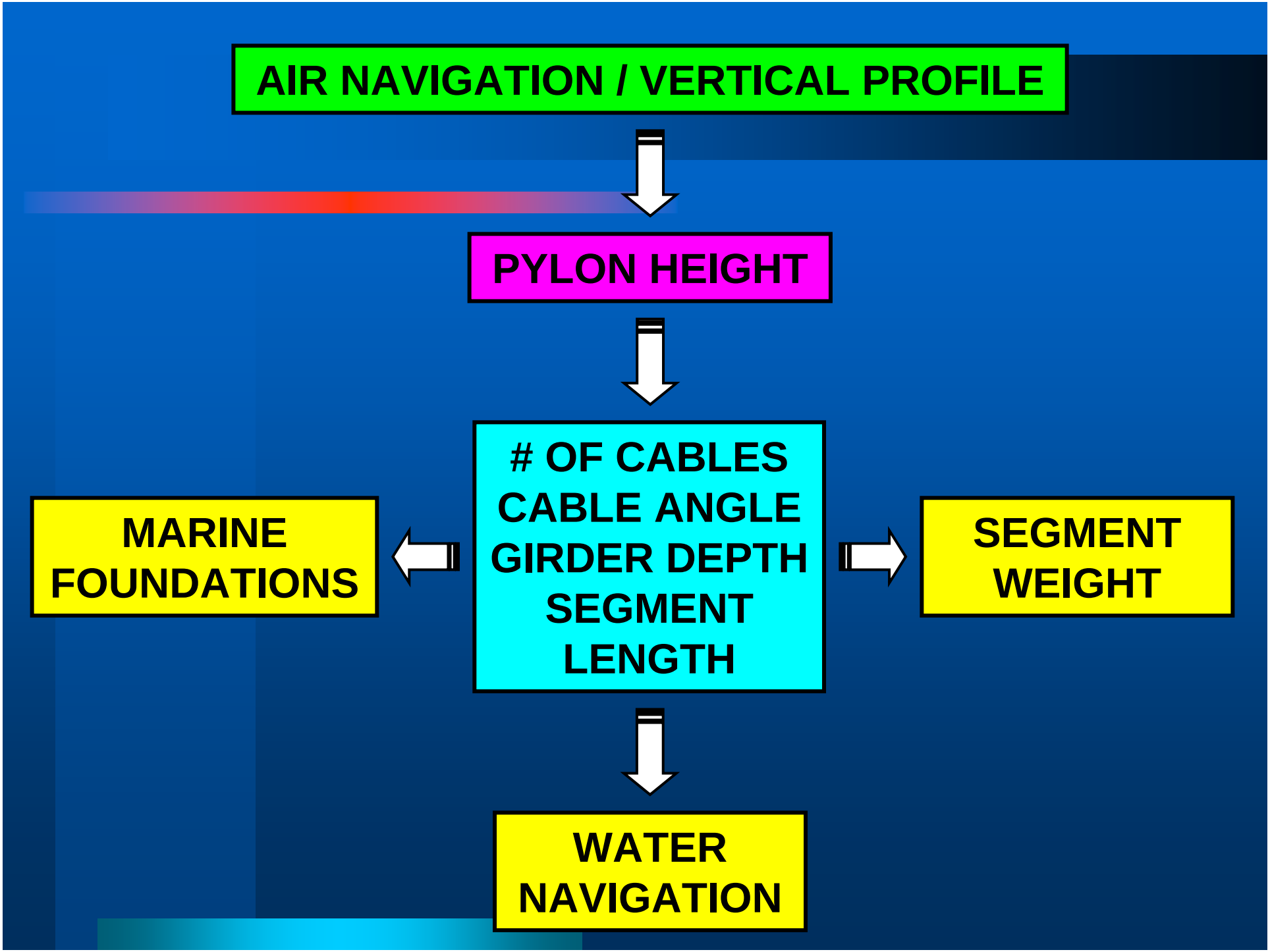
- **Water navigation – very busy river.**
- **Air navigation – < 5 km from major airport.**
- **Vertical profile – small part of big project.**


47m (154 ft)
57 m
(187 ft)
150 m
(492 ft)
180 m
(590 ft)
139 m
(456 ft)
52 m
(171 ft)

Constructability Constraints

- **Precast segmental.**
- **One marine foundation.**
- **Two mould types.**
  - **Adjustable depth, adjustable width.**
  - **Constant depth, constant width.**
- **~60 T maximum segment weight.**


CONSTRAINT
DIRECT CONSEQUENCE
CONSTRAINT
RIPPLE EFFECT
CONSTRAINT
CONSTRAINT


AIR NAVIGATION / VERTICAL PROFILE
PYLON HEIGHT
OF CABLES
CABLE ANGLE
GIRDER DEPTH
SEGMENT LENGTH
MARINE FOUNDATIONS
SEGMENT WEIGHT
WATER NAVIGATION

Girder

- **2.8 m to 5.8 m deep in approach span.**
  - **2.8 m long segments.**
- **3.4 m deep through main and side spans.**
  - **3.6 m long segments.**
- **Typical extradosed:**
  - **5.14 m at pylon**
  - **3.3 m at midspan**

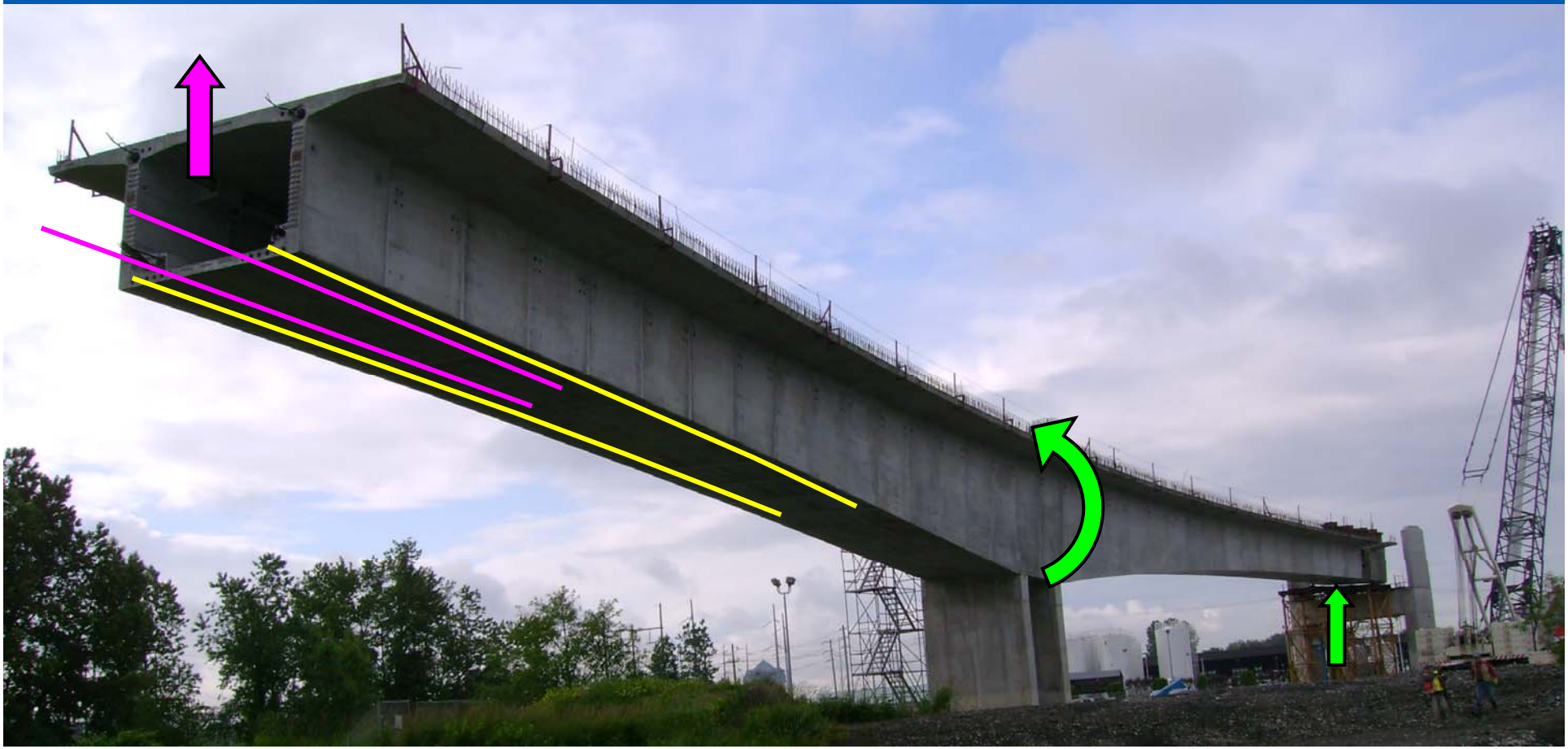
Post-Tensioning

- **Long unsupported girder lengths.**
- **No girder haunch at pylons.**
- **Many bottom continuity tendons.**

SPAN	TOP (PAIRS)	BOTTOM (PAIRS)
SIDE SPAN (139 m, 456 ft)	2 – 17-T15	6 – 19-T15
MAIN SPAN (180 m, 590 ft)	2 – 18-T15	7 – 19-T15 1 – 12-T15

Post-Tensioning cont'd

- **Bottom cantilever tendons.**



Cables

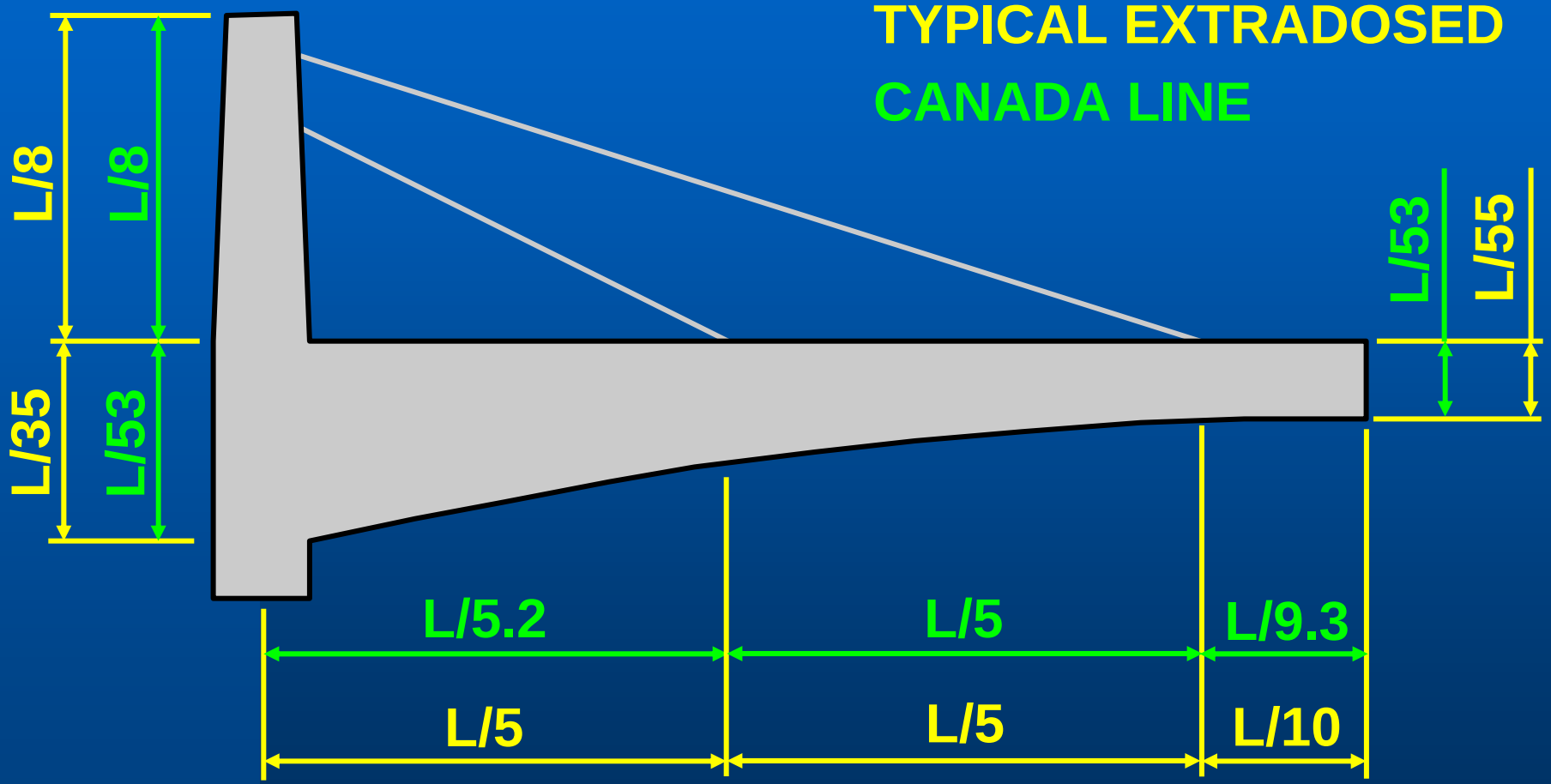
- **Conventional anchorages and saddles considered.**
- **Conventional anchorages required less strand → less expensive.**
- **24 – 58 strand cables.**
- **Maximum stress limit = 0.55 x GUTS.**
- **Monostrand stressing from girder.**


5 @ 7.2 m
(23.5 ft)
34.6 m
(113.5 ft)

Erection Sequence

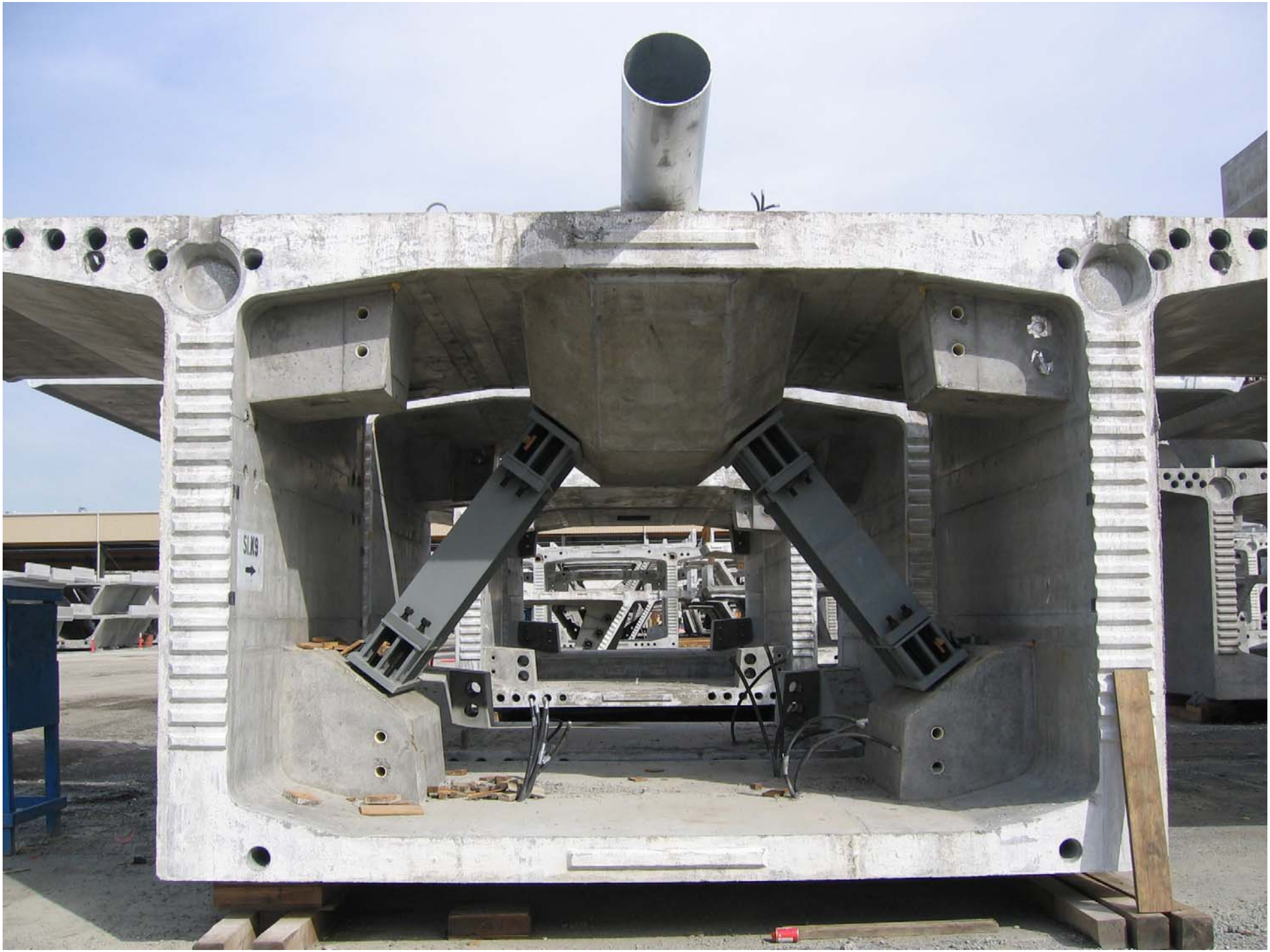
- **Balanced cantilever.**
- **Cycle: erect two segments, install cable…**
- **Place ballast, place closure pour.**
- **Stress continuity tendons.**
- **Remove ballast.**
- **Re-stress cables.**
- **Add SDL.**
- **Re-stress cables.**
- **Add remaining SDL.**

Extradosed Bridge?



Cable Anchor Segment

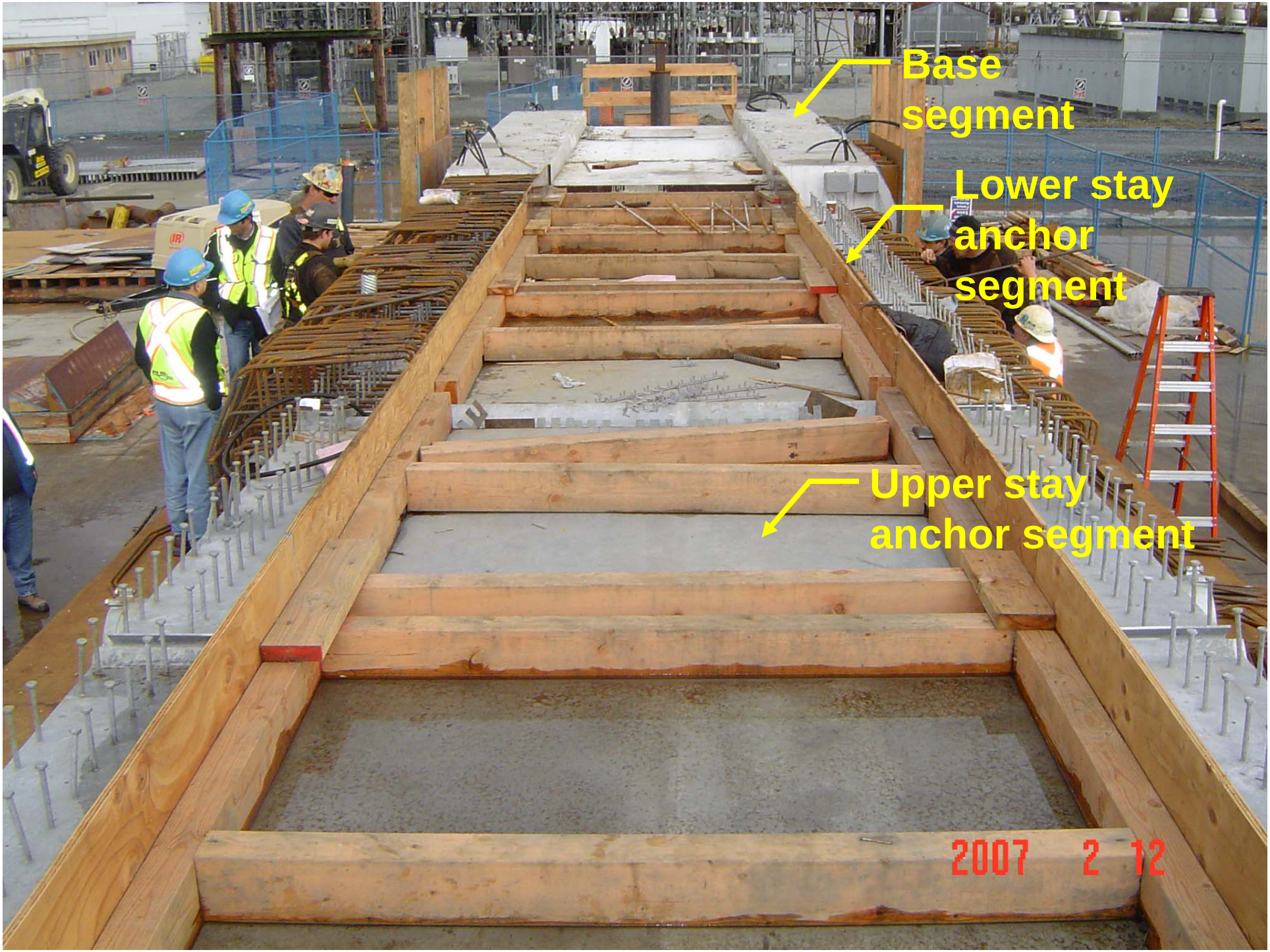
- **Transfers cable force into girder.**
  - **Horizontal component into top slab.**
  - **Vertical component into webs.**
- **Steel W610 (W24) anchored into concrete with threaded bars.**
  - **Tension member → steel.**
  - **Reduce weight.**
  - **Avoid ducts through cable anchorage.**


SLXS


SI.N9

Pylon

- **Precast, post-tensioned segmental.**
- **Composite steel-concrete.**
  - **Concrete flanges → axial load**
  - **Steel plate webs → tension and shear**
- **Compact cross-section – cable dead end.**


Base segment
Lower stay anchor segment
Upper stay anchor segment
2007 2 12

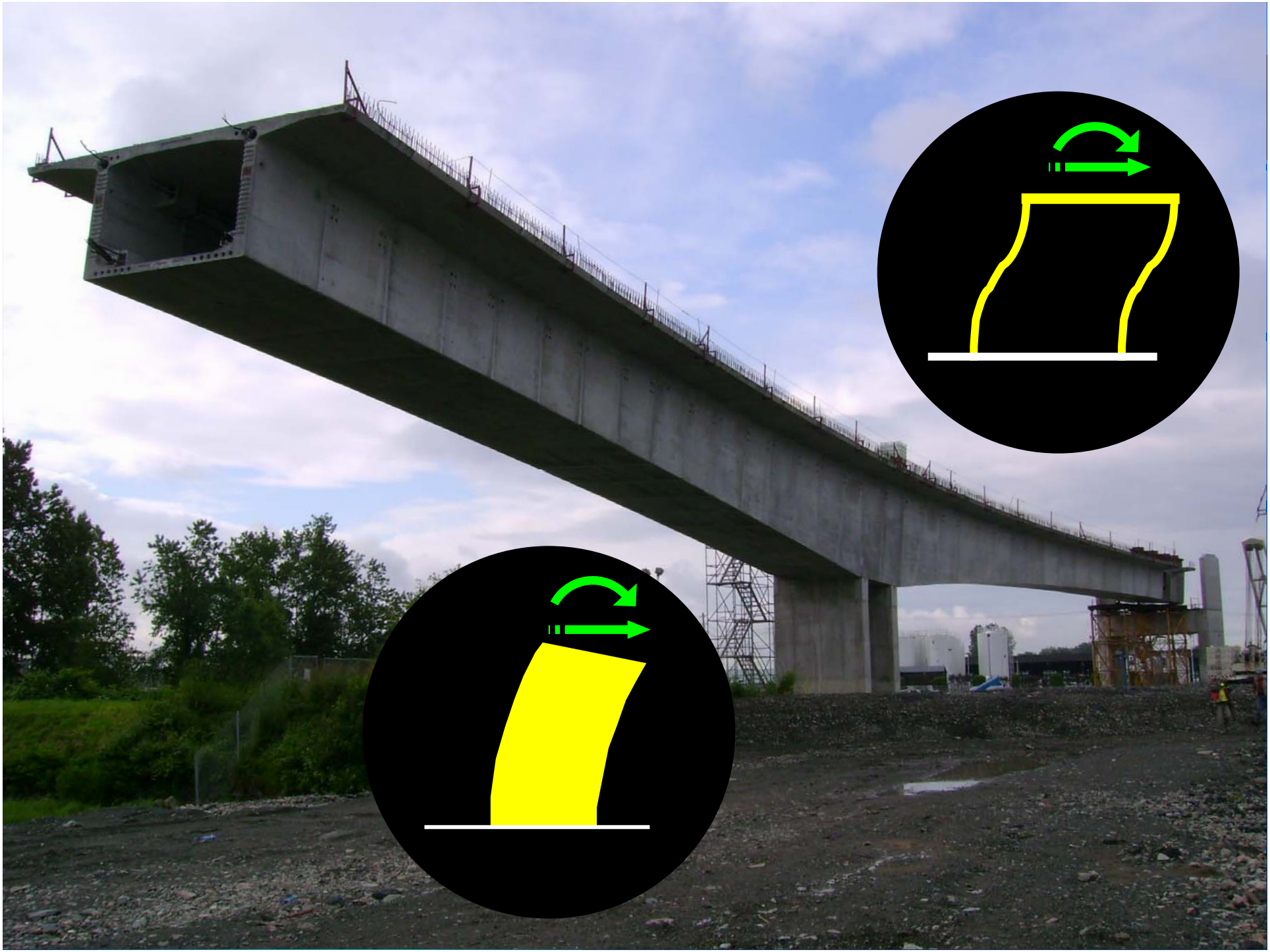

VOLVO
GAULTS

Flexible web plate connection

Flexible web plate connection

End Segments – 1st Iteration

- **Single bearing at end piers.**
- **Allow torsional rotation.**
- **Reduce / eliminate uplift demands.**
- **Reduce seismic girder torsion.**



End Segments - Final

- **Rail expansion joint movement tolerances:**
  - **1 mm transversely**
  - **3 mm vertically**
- **Torsional rotation must be prevented.**
- **Significant uplift.**
- **Required outrigger diaphragm.**
- **Too heavy to lift if completely precast.**

2007 May 01

2007 May 18


2007 May 28


2007 June 13

2007 June 25

2007 July 11


2007 July 26


2007 August 01

2007 August 14


2007 August 30

Summary / Conclusions

- **Extradosed form provided an effective solution given the many constraints.**
- **Presence of two potential vertical load paths provides designer with flexibility.**
- **Preliminary design work important.**