Bridge Construction Methods

By David TRAYNER

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Contents

A. Speaker

David Trayner

1. VSL - Special Projects – Operations Manager NSW
2. Graduated: UTS 1990 BEng; UNE 2001 MBA
3. 1989-91 Costain Australia Pty Ltd
4. 1991 – 2004 VSL Heavy Lift Operations Asia
    i. 1991-92 NS4 Bangkok
    ii. 1993 Tsing Mah Bridge HK
    iii. 1995 Skybridge Petronas Twin Towers KL
    iv. 1997 Burj Al Arab, Dubai
    v. 2002 –4 New Bangkok International Airport, BKK, Thailand
5. 2004 onwards VSL Australia, Projects: LHD, BRB, GDE, GUP

Precast Concrete Bridges

1. I Beams & Super Tee's
2. Segmental
3. Full Span

- Cast in-situ post tensioned concrete decks

Precast I Beams & Super Tee’s

1. Description
   - Standard Beams can be pre & or post tensioned.
   - Cast on site or in existing PC Yard
2. Advantages
   - Cheap
   - Simple to erect
3. Disadvantages
   - Limited in length (lat torsion buckling)
   - Less efficient
   - Logistics (police escort etc)
   - Aesthetics – banned in some countries

Cebu South Coastal Road - Philippines

Cebu South Coastal Road - Philippines

Cebu South Coastal Road - Philippines

Precast Segmental Techniques

1. Description
   - Complete deck cast, delivered & erected in unique cells
   - Segments are prestressed together using external and or internal tendons. Joints can be “dry” or “wet”.
   - Typically in Span by Span or Balanced Cantilever mode
2. Advantages
   - Structurally efficient and aesthetic
   - Complete with deck when erected I.e. rapid & safe
   - Cast during substructure works – overlap of activities
3. Disadvantages
   - Casting yard setup + logistics

PRECAST SEGMENTAL ERECTION TECHNIQUES

1. Erection on Falsework
2. Erection by Gantry
3. Erection by Crane
4. Erection by Lifting Frame
5. Full Span Erection Techniques

1. ERECTION ON FALSEWORK

M7 Crane Erection on Falsework

M7 Crane Erection on Falsework

2. ERECTION BY GANTRY

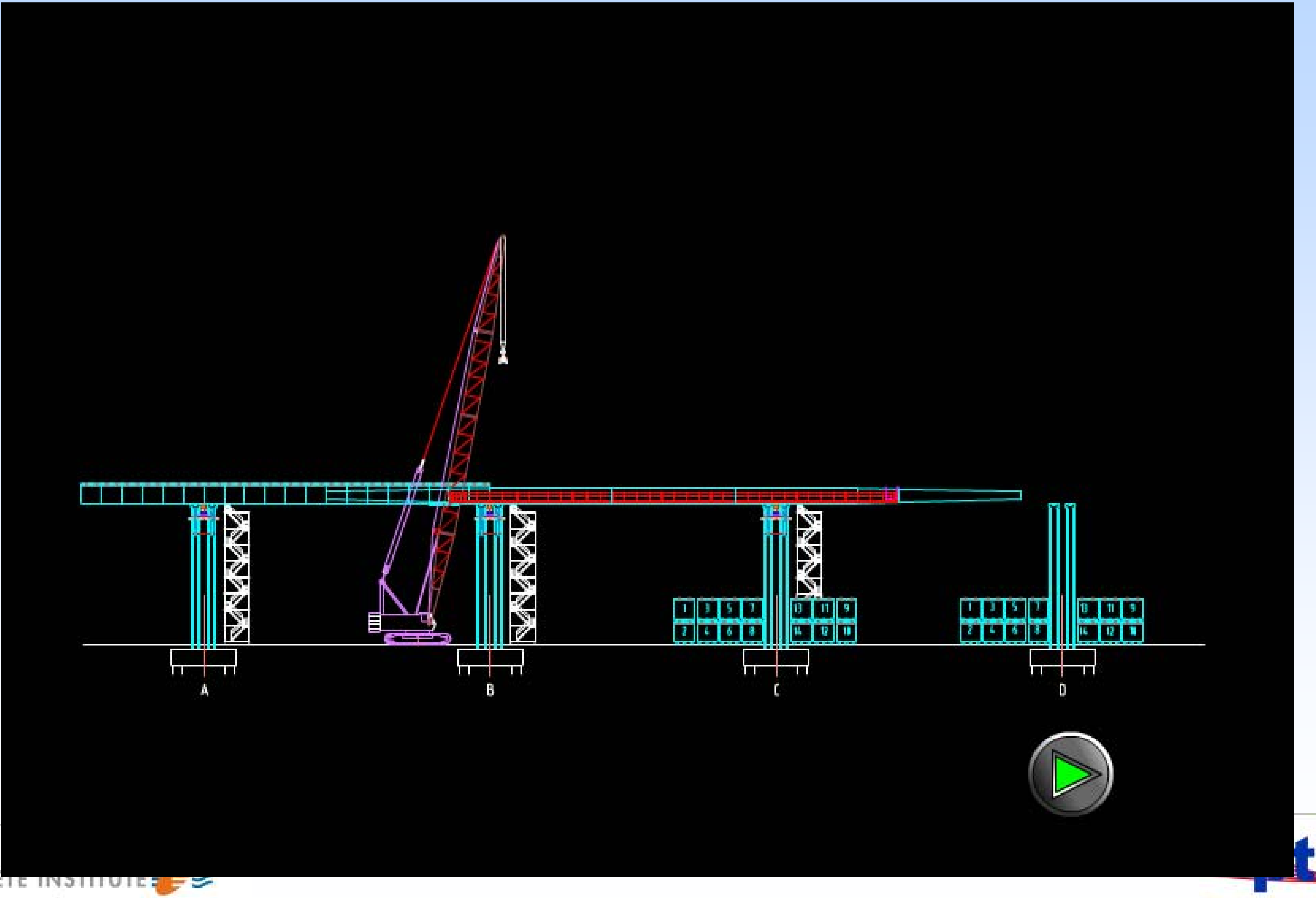
A. Span By Span – “Simply Supported”

B. Balanced Cantilever

Segmental Erection By Underslung Girder
KCRC West Rail - Hong Kong

M7 Span By Span by Underslung Gantry Over M4

KRCR WEST RAIL VIADUCT ERECTION TYPICAL ERECTION KINEMATICS FOR UNDERSLUNG GIRDER



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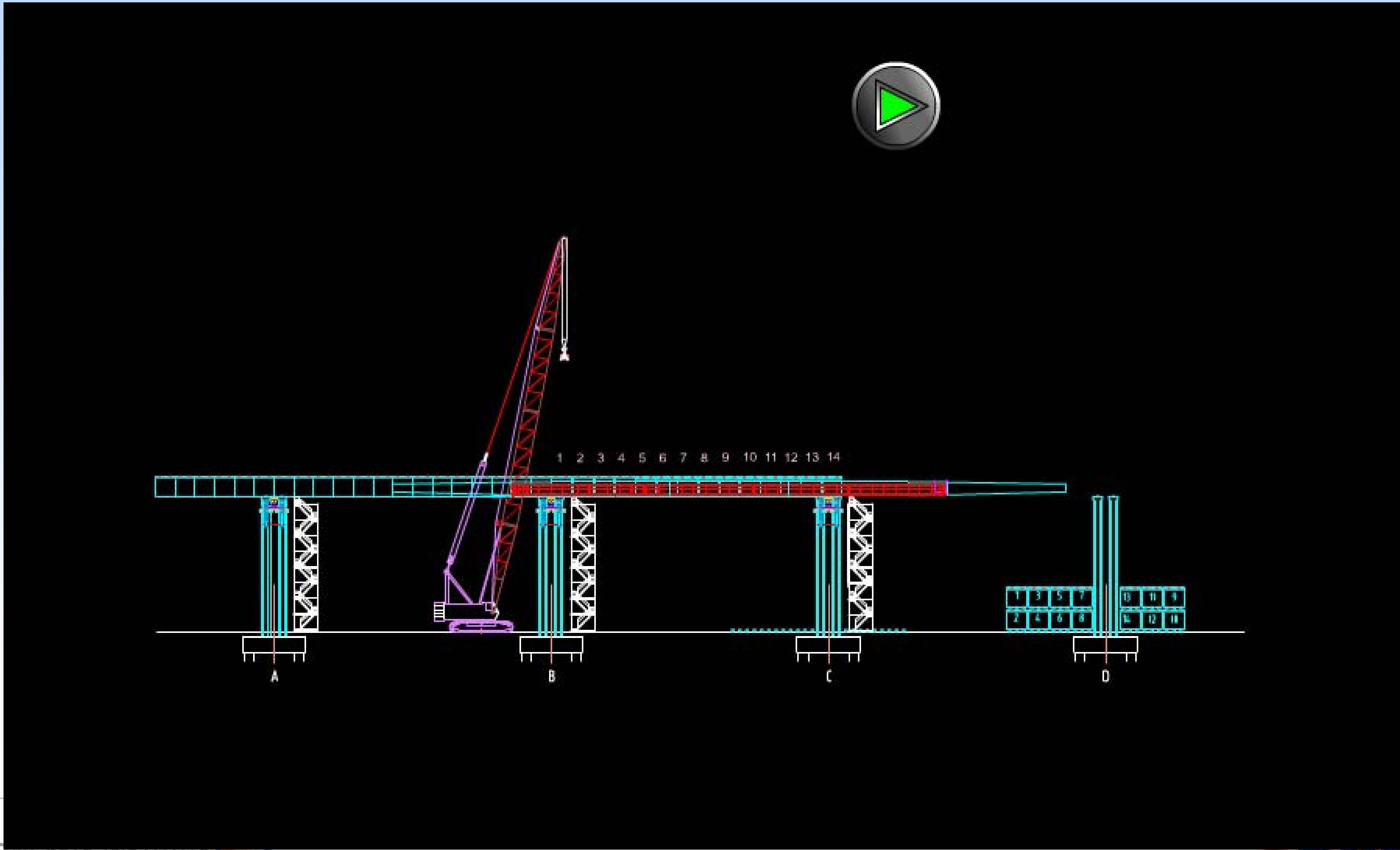

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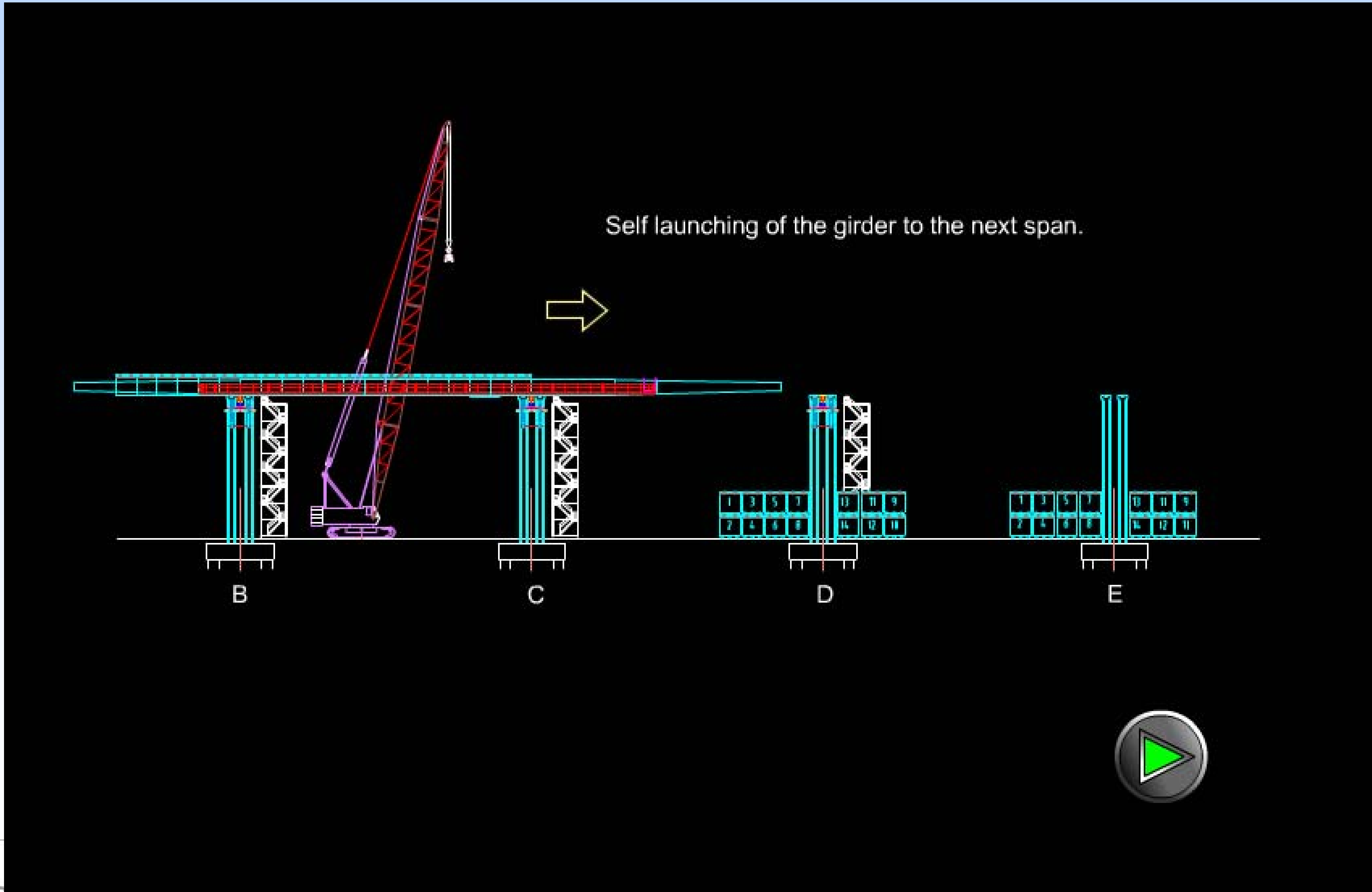

Segmental Erection By Underslung Launching Girder, Bangkok Second Stage Expressway

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Bridge Over Mekong River - Laos

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View of Launching Girder
Telok Blangah - Singapore

Northern Gateway Alliance – NZ, Waiwera Bridge

Shenzhen Western Corridor - HK

3. ERECTION BY CRANE

M7 BC Over Old Windsor Rd

M7 BC Over M4

Balanced Cantilever Segmental Erection by Crane
KCRC West Rail - Hong Kong

4. ERECTION BY LIFTING FRAME

Industrial Ring Road - Bangkok

Nanjing Second Bridge - China

Ibi River Bridge
Kisosansen Project - Japan

5. FULL SPAN PRECAST ERECTION TECHNIQUES

Singapore MRT Full Precast Span Erection

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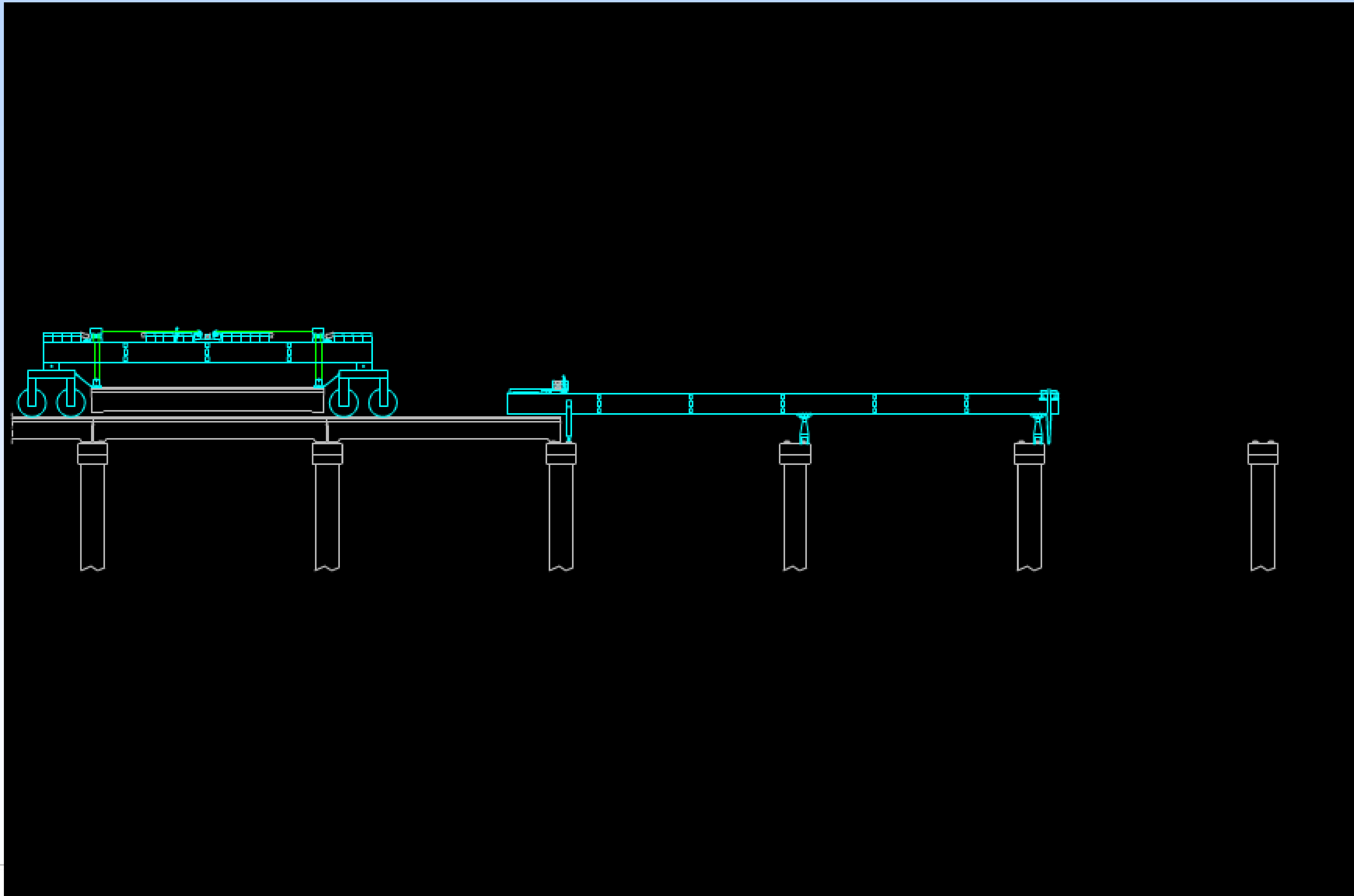
Singapore MRT Full Precast Span Erection

FULL SPAN PRECAST ERECTION
Taiwan High Speed Rail Contract C215

FULL SPAN PRECAST ERECTION
Taiwan High Speed Rail Contract C215

THSR TYPICAL ERECTION KINEMATICS FOR FULL SPAN PRECAST SEGMENT



IN-SITU CONCRETE BRIDGES CONSTRUCTION TECHNIQUES.

1. Cast in-situ Post Tensioned
2. Balanced Cantilever
3. Incrementally Launched

1. Cast in-situ Post tensioned

2. BALANCED CANTILEVER
Segmental Cast in -situ

Formwork Travellers
2nd Link Singapore / Malaysia

Seacliff Bridge - Formtraveller

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Gungahlin Drive Ext - Canberra

MFT on Taiwan High Speed Rail C215

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7. MFT application to THSR C215


16/06/2006

3. INCREMENTAL LAUNCHED

Cast In-situ


VSL

Incremental Launching Method

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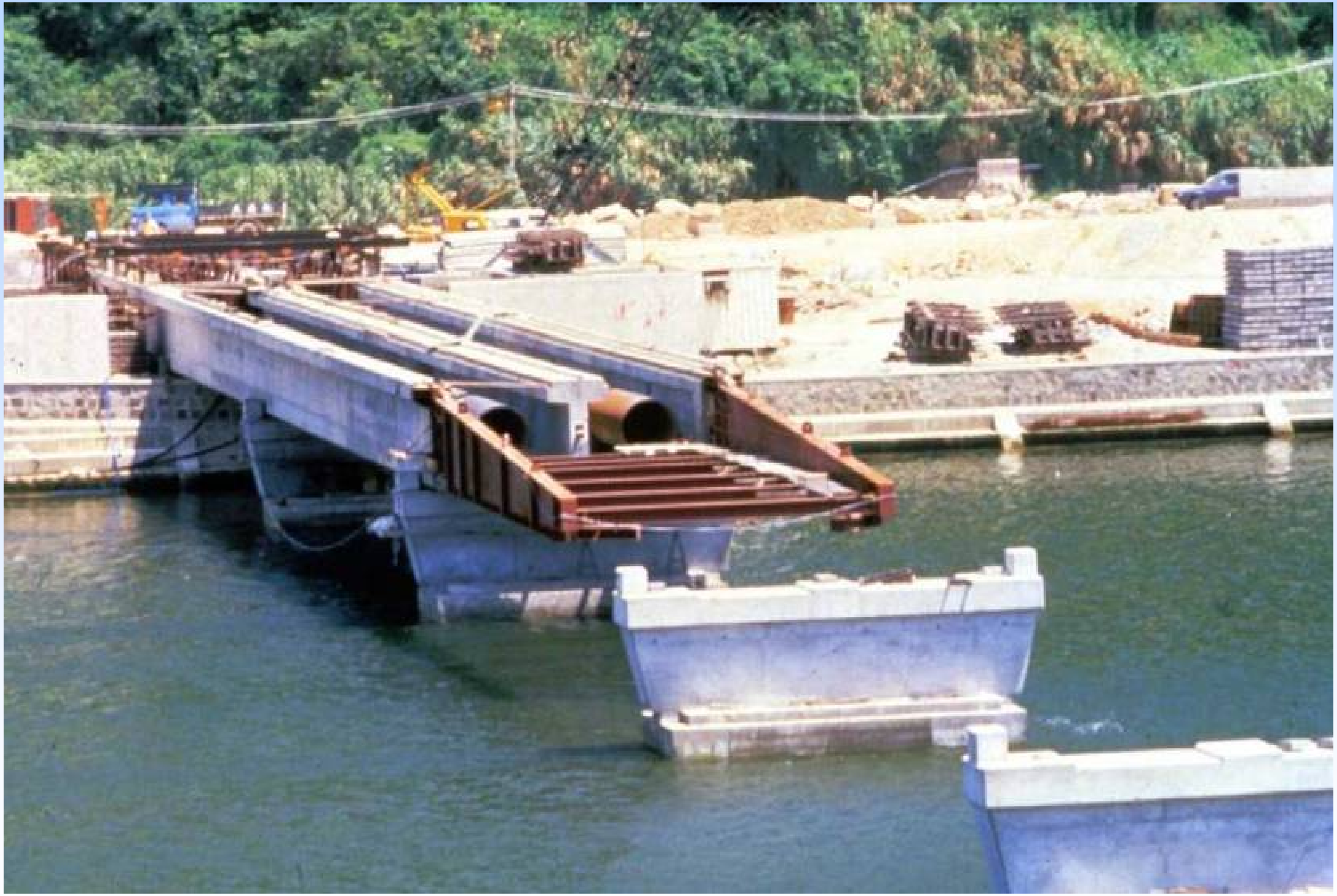
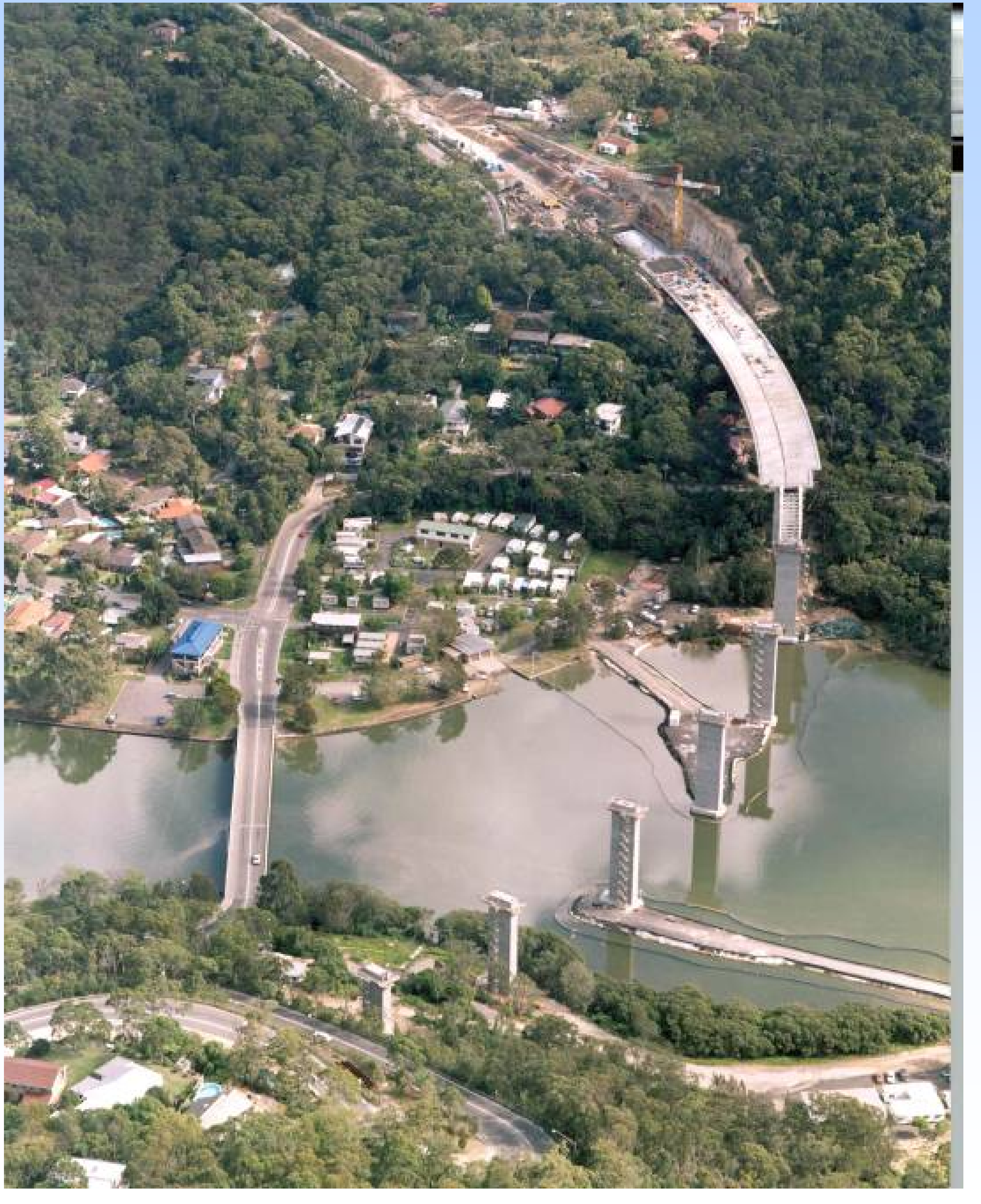
Incremental Launching Method





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Others

- Pier Head Rotation
- Arch Lowering
- Main Span Lifting
- Skybridge

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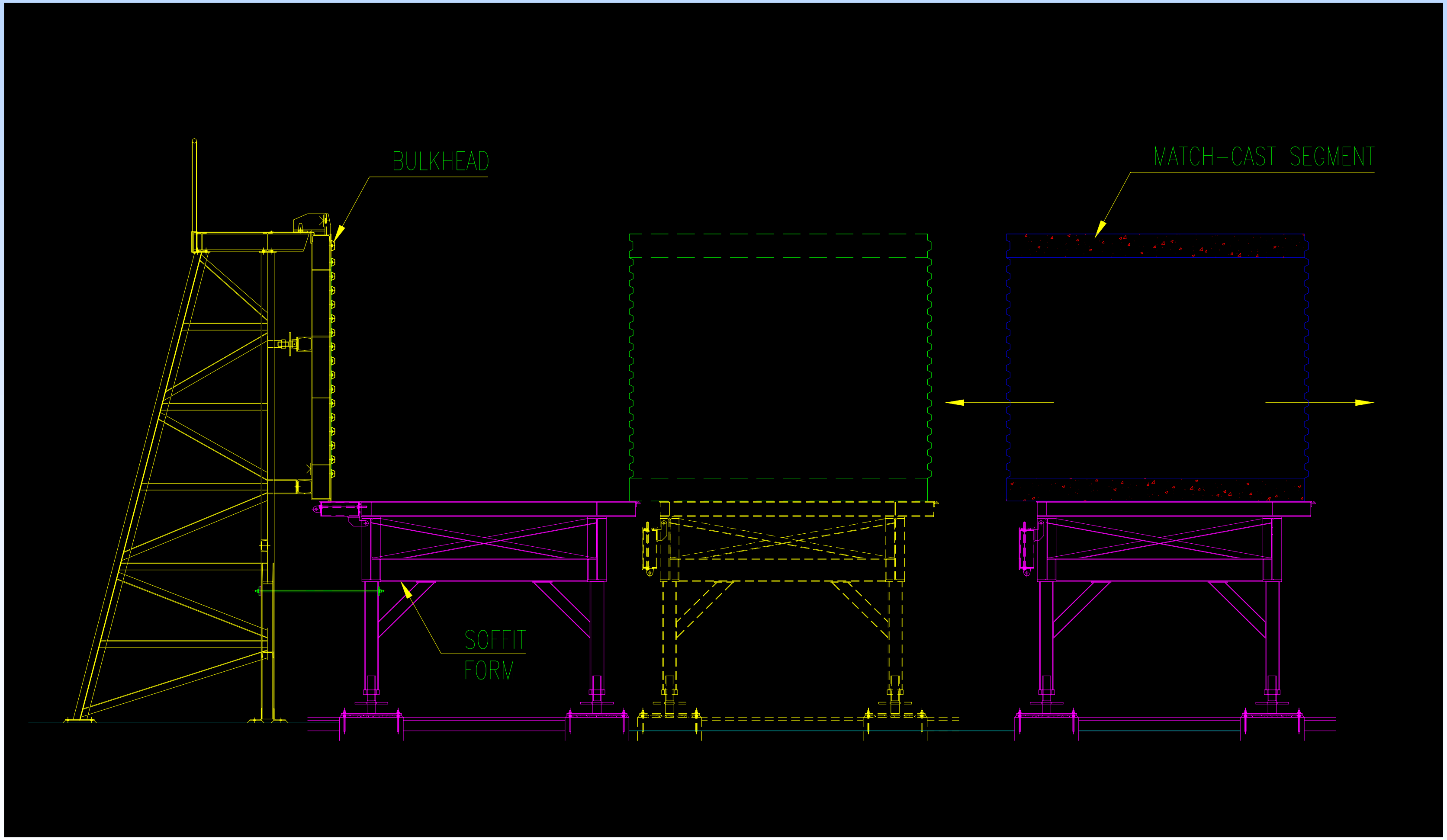
C.Precasting Techniques

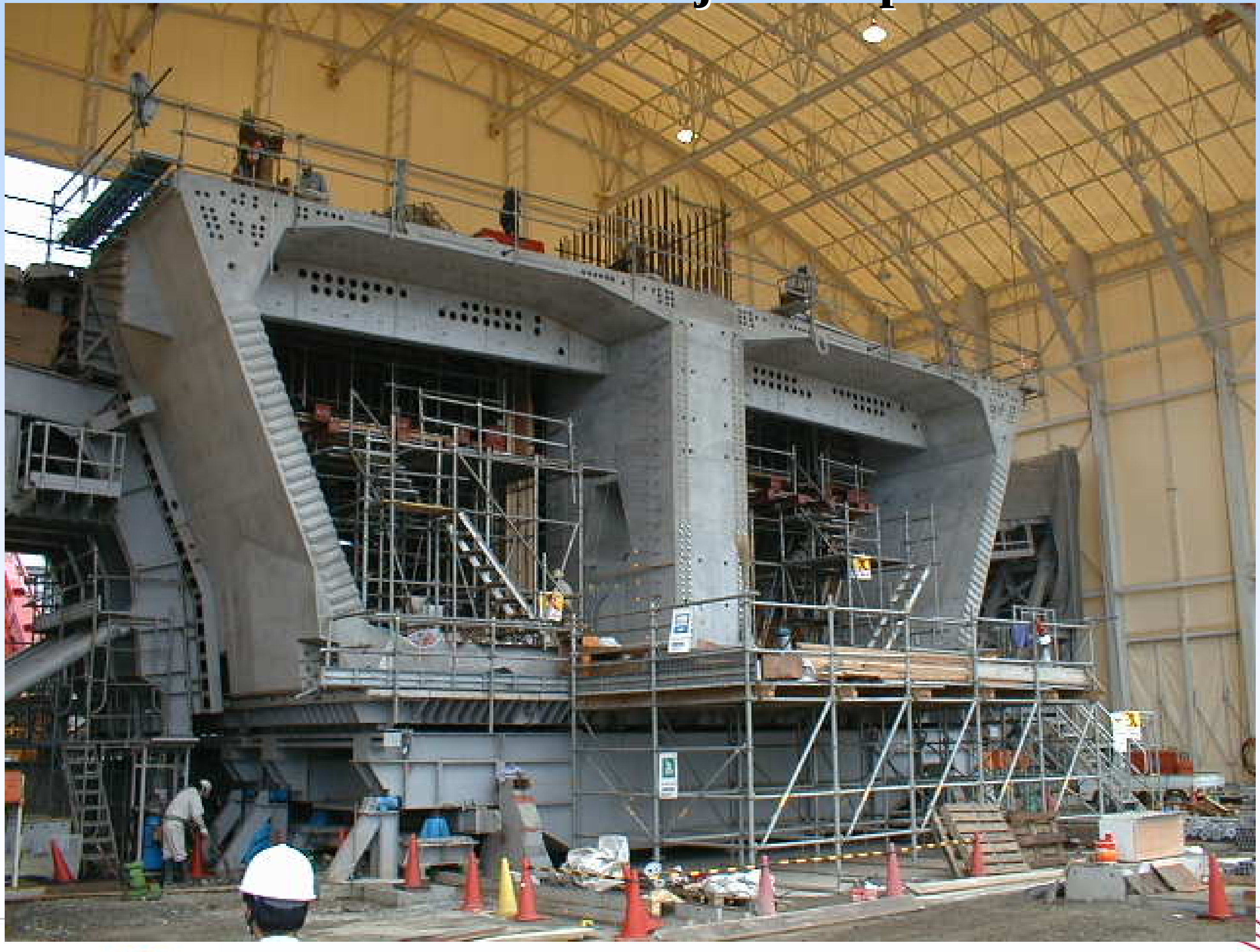
1. Segmental – shortline
2. Segmental – longline
3. Full Span
4. PC Girders

1. SHORT LINE PRECASTING CELLS

GEOMETRY CONTROL



Pier Segment in Match Casting Position.
Kisosansen Project - Japan



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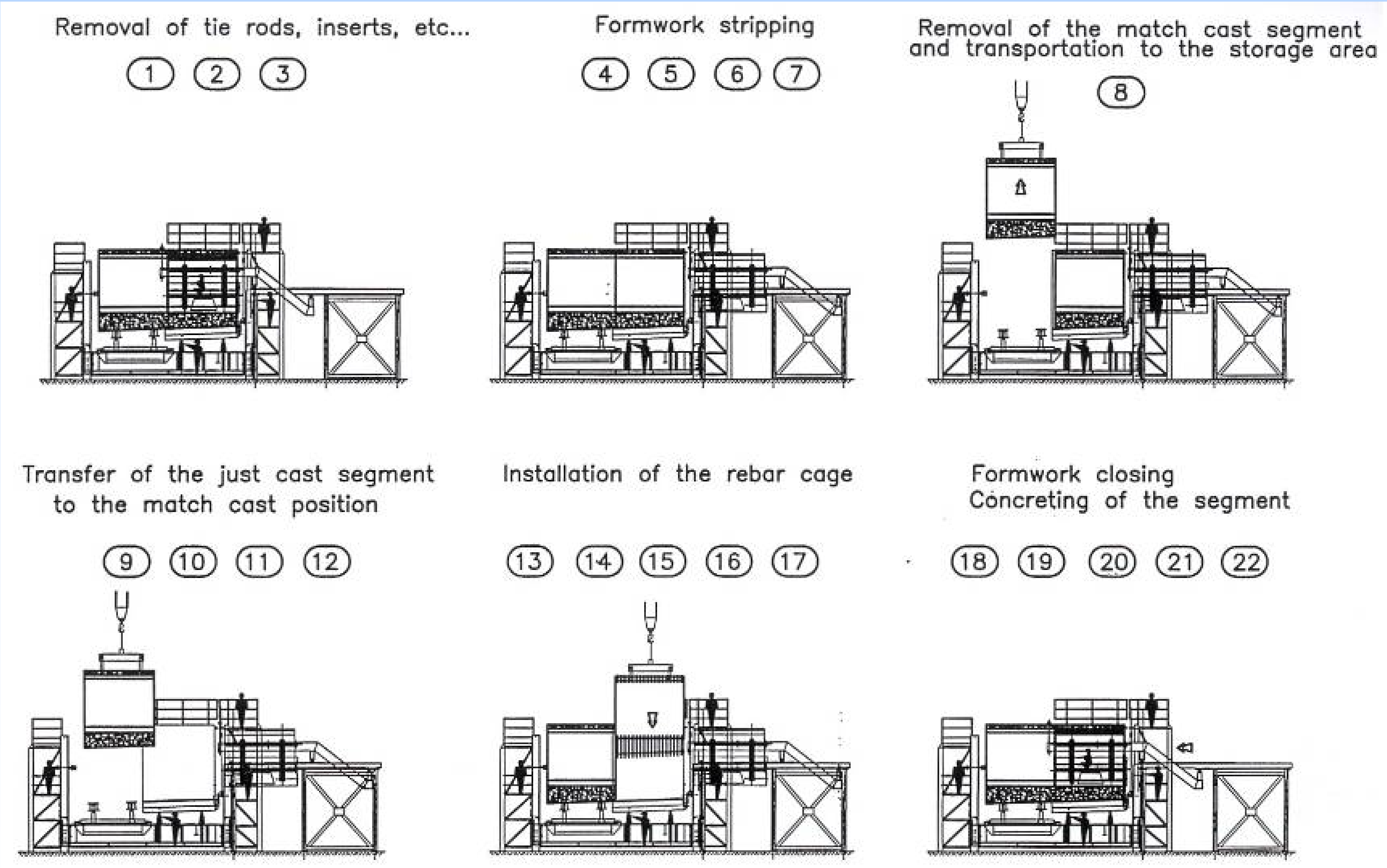
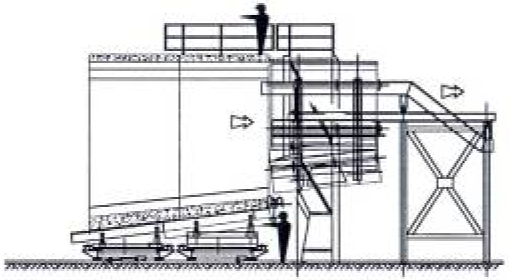
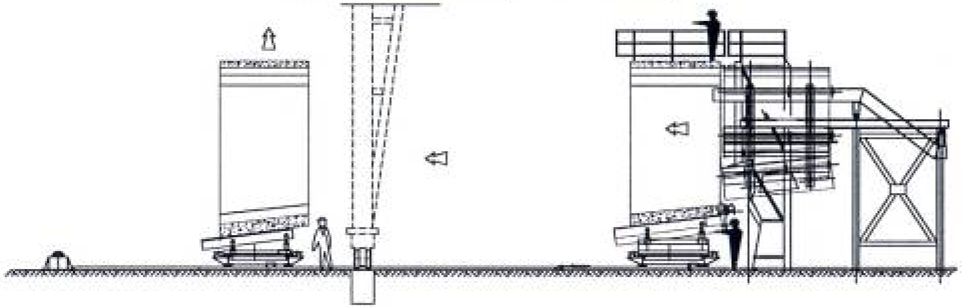
Soffit form
Support
frame
Soffit table


Removal of tie rods, inserts, etc...
1 2 3
Formwork stripping
4 5 6 7
Removal of the match cast segment and transportation to the storage area
8
Transfer of the just cast segment to the match cast position
9 10 11 12
Installation of the rebar cage
13 14 15 16 17
Formwork closing
Concreting of the segment
18 19 20 21 22

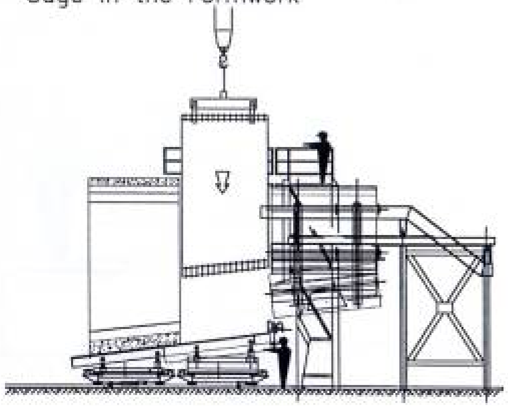
-Survey records
-Removal of Tie Rods, Inserts...
-Removal of Formwork



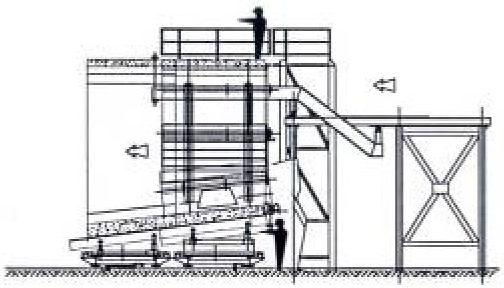
-Removal of Matching Segment
& Transport to Storage Area
-Removal of Casting Segment
& Displacement onto the matching position
-Adjusting with computer back up



-Reinstall the cart on new position
-Setting of the Reinforcement
Cage in the Formwork



-Formwork Installation
-Match Segment Pouring



2. LONG LINE PRECASTING BEDS

View of Precasting Formwork on Long Line.
Pakse Bridge - Laos

View of Precasting Yard.
Pakse Bridge - Laos

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Segment Transporter, Pakse Bridge - Laos

SPAN P+1

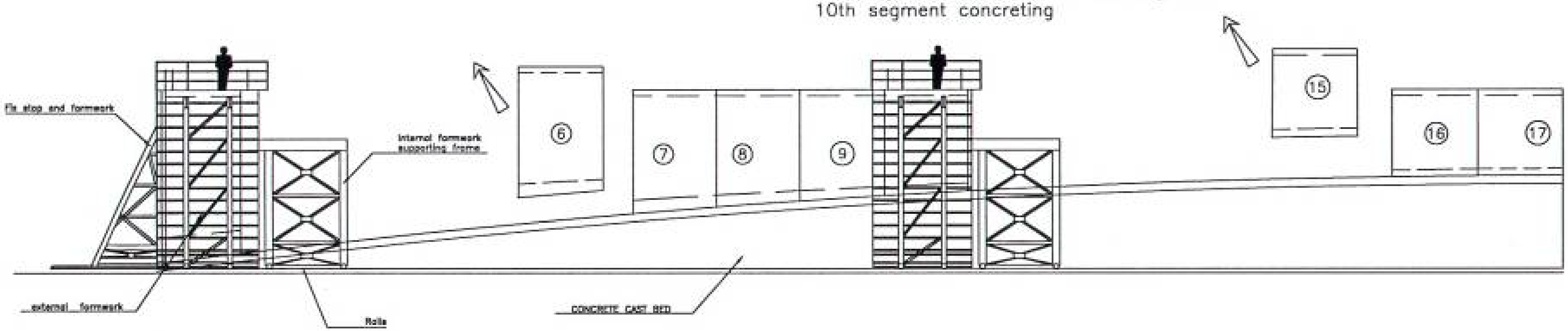
Stage N: 1st segment concreting

SPAN P

Stage N: Removal of segment 6
Stripping of formwork from 9th segment
10th segment concreting

SPAN P-1

Stage N: Removal of segment 15



SPAN P+1

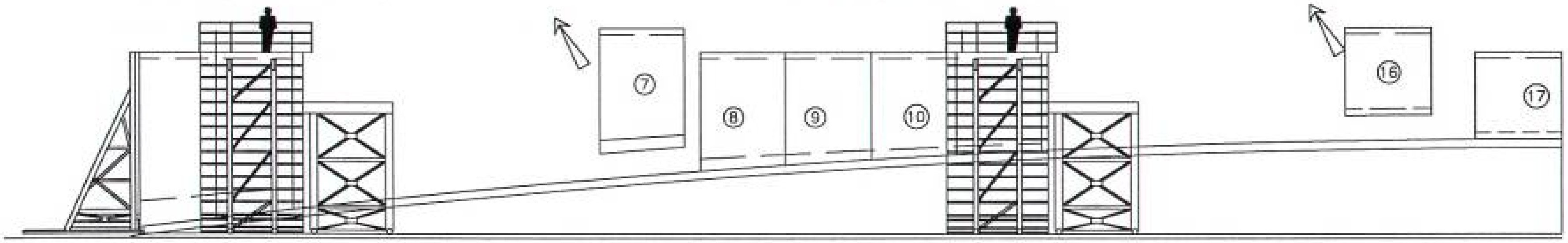
Stage N+1:
Stripping of formwork from 1st segment
2th segment concreting

SPAN P

Stage N+1: Removal of segment 7
Stripping of formwork from 10th segment
11th segment concreting

SPAN P-1

Stage N+1: Removal of segment 16



Repeat previous operations until completion of the precasting of the segments

3. FULL SPAN PRECASTING BEDS

TAIWAN HIGH SPEED RAIL - FULL SPAN PRECASTING

4. I BEAM
PRECASTING BEDS

View of Precasting Formwork.
Cebu South Coastal Road - Philippines

View of Precasting Formwork.
Cebu South Coastal Road - Philippines

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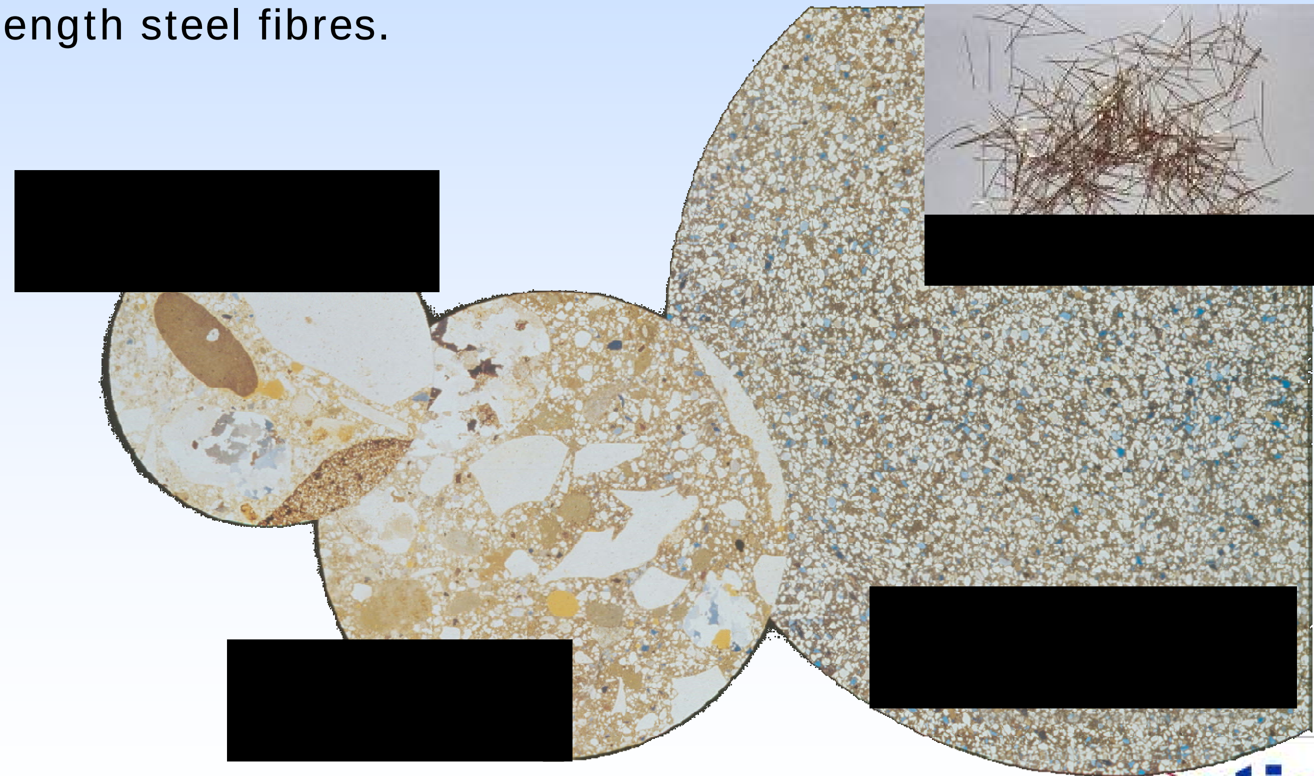
View of Prefabricated Rebar Cage.
Cebu South Coastal Road - Philippines

D. Ductal Reactive Powder Concrete


SEG

D. Ductal® a Reactive Powder Concrete

- RPC was initially developed by Lafarge, Rhodia and Bouygues the parent company of VSL, and is marketed under the name of Ductal®.
- Ductal (RPC) consists of cement, sand, silica fume, silica flour, superplasticiser, water and high strength steel fibres.



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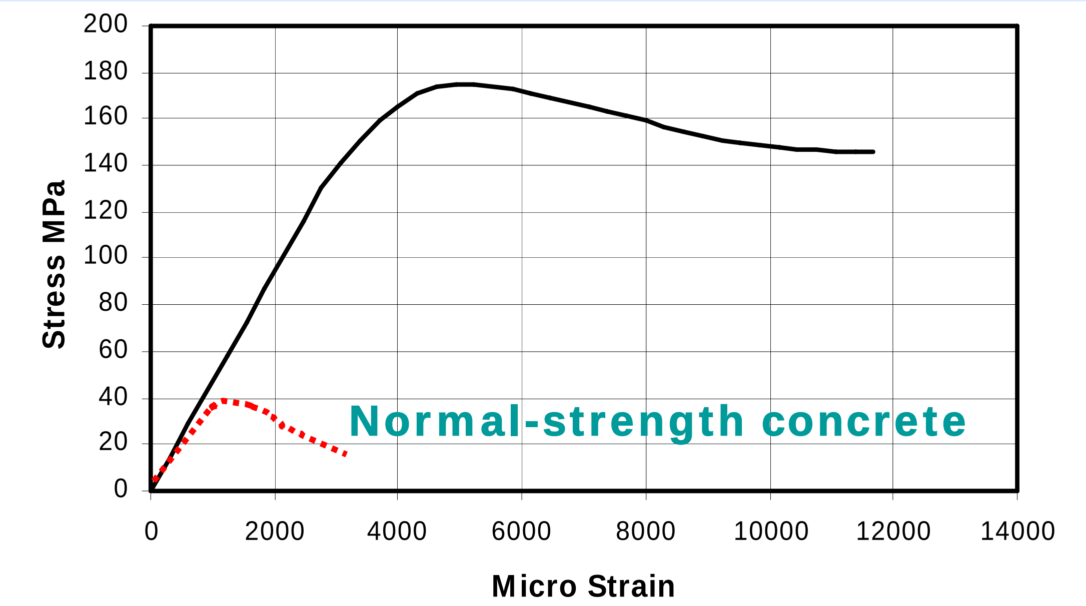
Behaviour of Ductal

Mechanical Behaviour

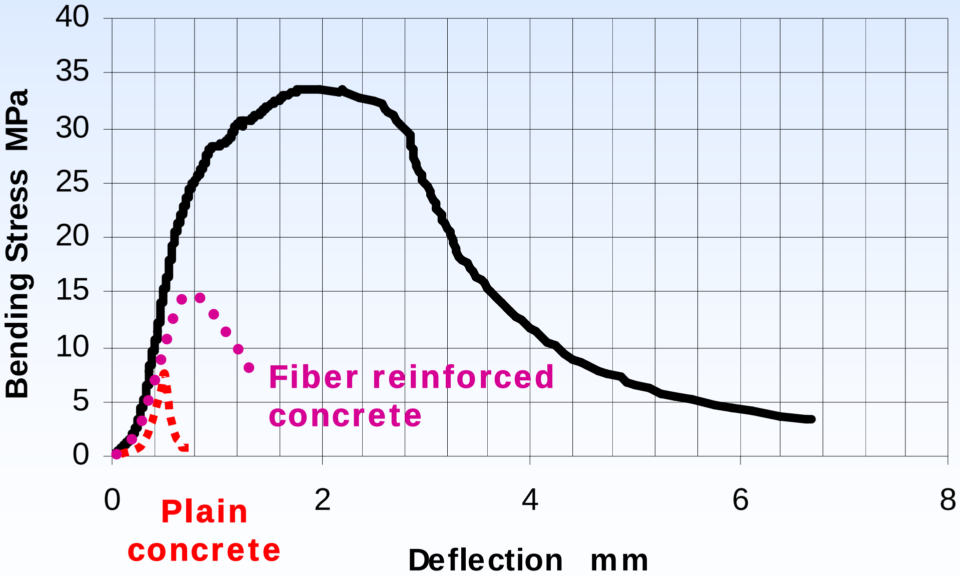
- In Compression
  - Mean test strength in compression: 175 - 185 MPa
  - Design (characteristic) strength: 140 – 160 MPa
  - Design Young's Modulus: 47 GPa
  - 'Ductile' softening behaviour unlike ordinary high-strength concretes

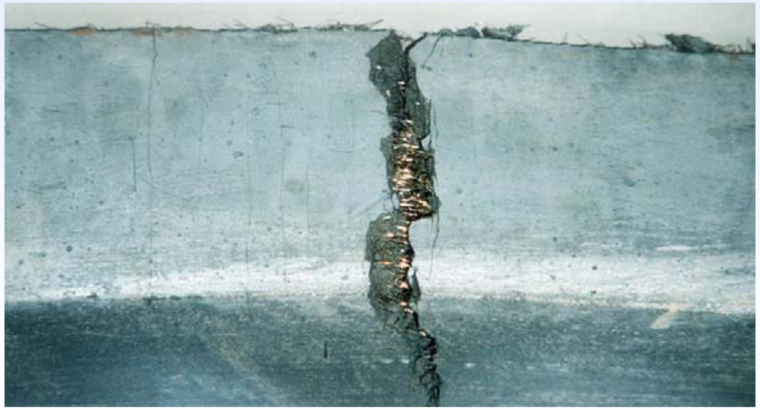


Behaviour of Ductal

Mechanical Behaviour

- In Tension:
  - Mean test results, Modulus of Rupture: 25 - 39 MPa
  - Design (characteristic), Modulus of Rupture: 15 MPa
  - Total fracture energy: 20,000 – 30,000 J/m





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Durability Properties of Ductal

- Ductal exhibits extremely high resistance to aggressive agents, due to the absence of capillary porosity.

DESIGN LIFE CALCULATION FOR DURABILITY
for exposure to marine environment

Assumptions
1. Non cracked section
2. Diffusion coefficient Dc constant (conservative, as Dc tends to decrease with time)

Cx = Cs[1-erf{x/(2(Dc.t)^0.5)}]

where

Cx =	concentration of chloride at depth x (%)	= maximum of 0.5%
Cs =	nominal concentration of chloride at the surface (%)	= 4%
Dc =	chloride ion diffusion coefficient (mm^2/s)	
x =	depth to reinforcement (mm)	
t =	time (seconds)	
erf[X] =	error function	

Design Life - Ductal			Design Life - Concrete		
f'c =	160	MPa	f'c =	50	MPa
x =	43	mm	x =	50	mm
Dc =	2.0 x 10^-8	mm^2/s	Dc =	1.0 x 10^-6	mm^2/s
Design life	**611**	**years**	**Design life**	**17**	**years**

- Durability properties of Ductal:
  - Total porosity: 2-6%
  - Micro porosity: <1%
  - Chloride ion diffusion: 2×10^{-8} mm^2/s
  - Abrasion coefficient: 1.3
  - Water absorption: 2.5 kg/m^2

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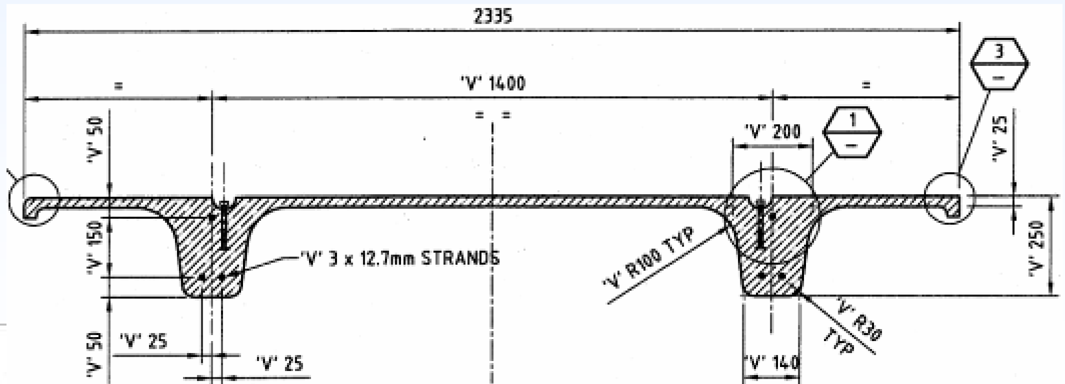
Ductal® Solution: Durability

Eraring Power Station Weir Covers, Australia

- Existing post-tensioned planks failed after 15 yrs of continuous salt water spray
- Durability the primary design requirements (design life 100 yrs)
- Ductal planks 11.1 x 2.33m, effective depth 68mm, 163 kg/m^2



Production of Ductal

Casting

- Ductal is almost self-placing.
- Batching requires a special shear mixer.
- Current Ductal solutions are precast.
- In-situ applications are being researched.

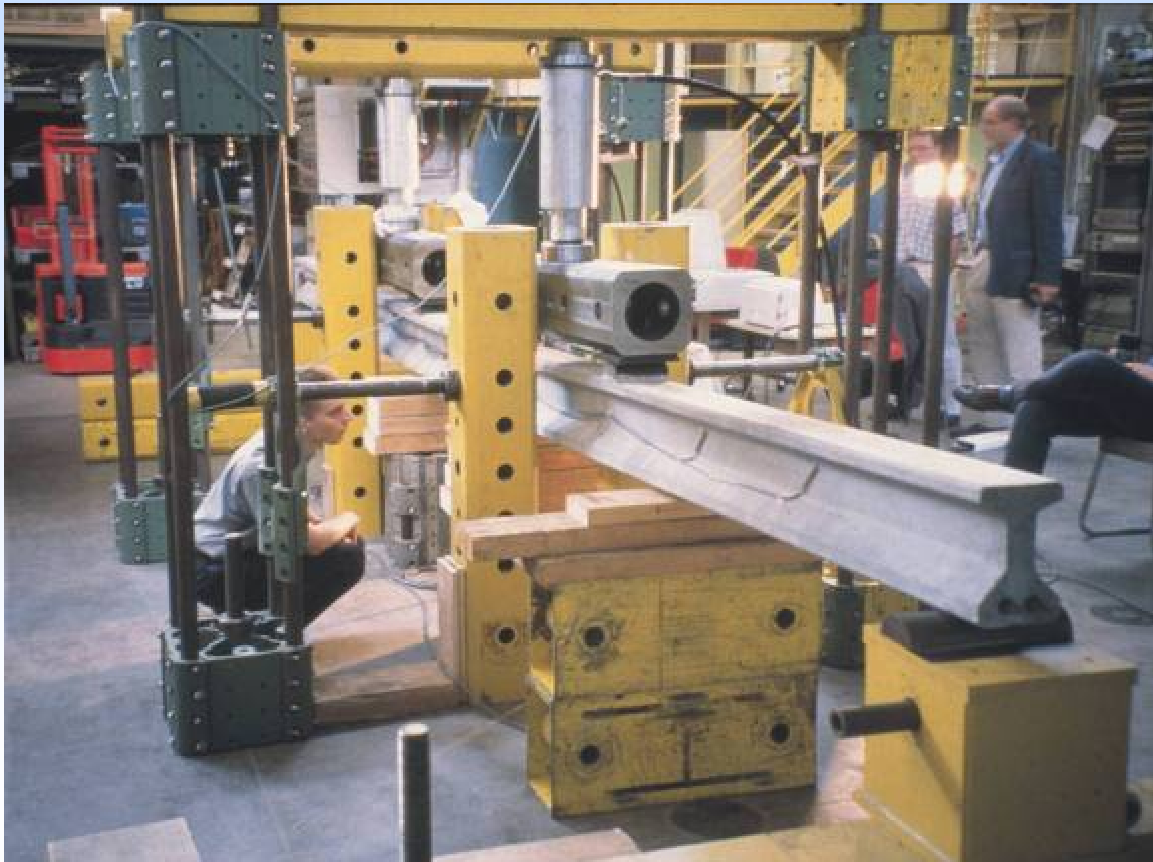
Production

- Production of Ductal (RPC) by VSL Australia commenced in early 2003.
- Heat treatment (90º for 48h) is optional and improves durability and mechanical behaviour.
- Primary Ductal facility located in Melbourne.
- Majority of Ductal production is exported.

Design using Ductal

- Design rules developed from extensive research by Bouygues (France), VSL and Australian Universities.

- Design guide in accordance with the intent of AS 3600 prepared by the University of New South Wales.



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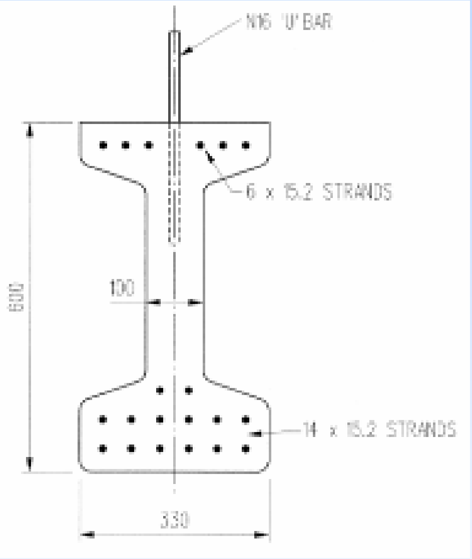
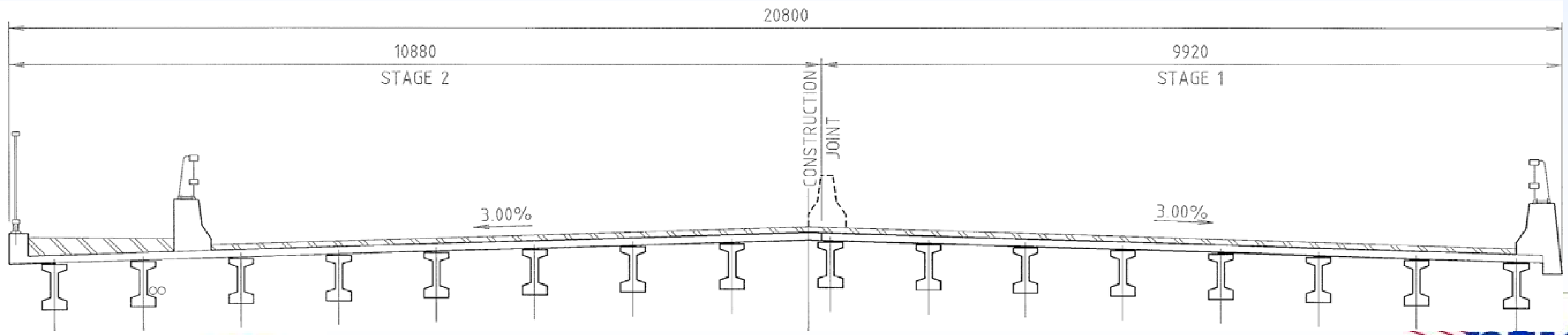
Shepherds Creek Road Bridge: Australia

From Research to Practice: Shepherds Creek Highway Bridge, Australia

- RTA evaluation trial of Ductal, design procedure and constructability
- <u>Ductal beams</u>: Precast and prestressed I-beams, no shear reinforcement, 1/3 weight of ordinary concrete beams (280kg/m)
- <u>Bridge</u>: Span 15.4m, 4 traffic lanes, 1.3m beam spacing
- <u>Construction</u>: Precast Ductal beams with ordinary RC in-situ concrete deck





Ductal® Solution: Design & Fabrication

From Research to Practice: Shepherds Creek Highway Bridge, Australia

- RTA load testing after completion of the first two lanes and again 1yr later
- Test load = 1.5 x T44 *Serviceability Load*

- **September 2005**: RTA issued a policy statement giving approval for Ductal to be used on RTA bridges and structures

Ductal beams in place

Load test

Australian Ductal Application

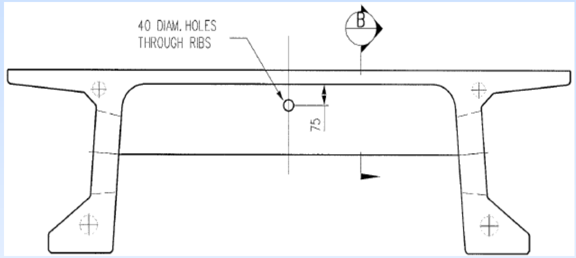
From Research to Practice: Shepherds Creek Highway Bridge, Australia

Completed: World's first Ductal bridge for highway traffic

Auckland Footbridges: New Zealand

Built in Australia and Shipped to New Zealand

- 650mm deep post-tensioned PI-beam section
- Section forms deck and beam; 2.2m wide, 50mm thick no reinforcement
- No anti-burst reinforcement in anchorage zones
- Match-cast in Australia using specialised formwork



Auckland Footbridges: New Zealand

Built in Australia and Shipped to New Zealand

- Segments shipped to Auckland on standard 40-foot flat-rack containers

Auckland Footbridges: New Zealand

- Papatoetoe Footbridge upgrade to give access to existing train stations
- Other bridges completed: Penrose, Middlemore, Papakura

Auckland Footbridges: New Zealand

Penrose Station: 265m total linear length

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Architectural Ductal Solutions

1. 20mm Ductal façade panels, France

2. Acoustic panels (1600 m^2); Monaco

3. 20mm Curved shell elements and supporting structure (white Ductal); Canada


1


2


3

Ductal Protective Solutions

- Realisation that Ductal has excellent **Impact and Blast Resistance**
- Group level investment into strategic R&D

Blast & Impact Resistance

Blast tests at Woomera, Australia (2004)

- 2 blasts of 5t of Hexolite (6t TNT equivalent)
- 2 types of Ductal panels tested at 3 distances
- Actual blast pressure and panel deflections measured

- **Panels Types:**

  - Size: 2m (span) x 1m x 100,75 and 50mm

  1 - pretensioned - at 30, 40 and 50m

  2 - plain - at 40 and 50m

- **Design reflective pressure for 10 msec:**

  5500 kPa at 20m

  1500 kPa at 30m

  650 kPa at 40m

  420 kPa at 50m

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Woomera Blast Tests, 2004

BLAST 1 - 100mm stressed at 30m; ready for blast test

Woomera Blast Tests, 2004

Panel 1 100mm stressed at 30m

Movement 50mm in from datum then to 37mm out from datum and then to final position on datum

Undamaged

Woomera Blast Tests, 2004

Panel 5 - 75mm stressed at 30m

Fractured, 150mm final deformation, no fragmentation

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Ductal Blast Resistant Panels

Installed Roof panels
Steel connections for redundancy
Rubber bearings for additional energy absorption
Drainage covers and tolerance panels

Concluding Remarks: Ductal Solutions

- Ductal is not a replacement for conventional concrete; instead it can create opportunities, and provide economical and innovative solutions in performance structures.

- Exceptional properties of RPC give engineers the ability to design enhanced bridge and other performance structures.

- Typical enhancements include:
  - Significant reduction of dead load
  - Excellent material ductility
  - Improved durability and longer service life with reduced maintenance
  - High flexural strength reducing the need for complex reo arrangements
  - Expanding the range and freedom of structural shapes and forms

Thank you for your kind attendance

Should you require any additional information please do not hesitate to contact:

E-Mail Address: Dtrayner@vsl-australia.com.au

Telephone: (02) 9484 5944