ING - IABSE

ING-IABSE Workshop on "Design, Construction and Maintenance of Steel Bridges", 19th & 20th October 2024

Erection of Steel & Composite Bridge Decks

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Presently he is Advisor- Technical in GECPL & a Director of GILCON Project Services Ltd. He is a member of various technical committees and co-convener of B-7 committee of IRC.

He has co-authored a book "Bridge Deck Erection Equipment" as a member of workgroup WG6 of IABSE. He was conferred the prestigious S.B. Joshi Award for excellence in Bridge & Structural Engineering in 2023.

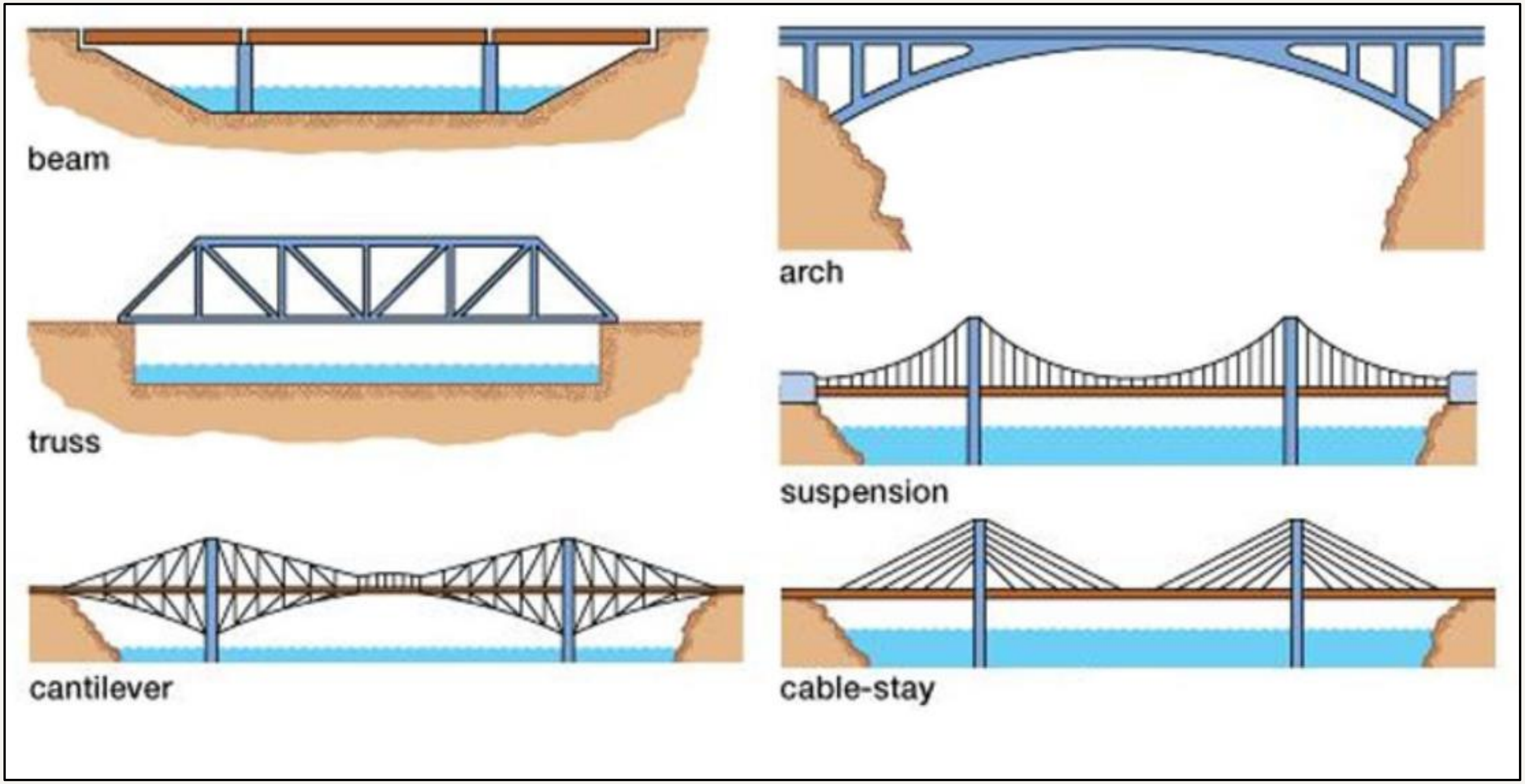
Presentation Structure

1. Introduction
2. Design Stage Considerations for Constructability
3. Construction Engineering Process
4. Various Methods of Steel Deck Erection
5. Some Critical Issues Related to Temporary Structures
6. Conclusion

Scope of Presentation:

- Construction engineering focuses on bringing increasingly sophisticated designs to life through the implementation of complex projects, overseeing the practical and operational aspects of construction.
- This presentation deals with construction engineering steel & composite bridge decks, viz. construction methods & associated temporary structures and erection equipment.
- Some critical aspects related to temporary structures are also covered briefly.

1. Introduction..contd.



Types of Steel Bridges as per structural system of the deck

- 1. Introduction
- **2. Design Stage Considerations**
- 3. Construction Engineering Process
- 4. Various Methods of Steel Deck Erection
- 5. Some critical issues related to Temporary Structures
- 6. Conclusion

Structural form selected for the bridge project has to ensure that erection is feasible and cost effective. Some important considerations at the design stage to ensure constructability are:

2.1 *Structural Form / configuration-* **Selection should consider**

- **Available access routes which may limit size and weight of fabricated components & heavy plant (like cranes) to be transported from work shop to the site. Presence of any weak bridges on the route also needs to be ascertained.**
- **Water bodies at site will pose a challenge (need for temporary bridges) or also provide a possibility of floating in the entire span.**

2. Design Stage Considerations… contd.

- Site topography & right of way for shifting components to the work front and placement of cranes
- Restrictions due to working season (floods/winter) or time blocks (railway lines) or working hours (urban zone)

• 2.2 *On site connections & trial assembly*

Trial assembly should be carried out at the fabrication shop to sort out any mis-fit issues. Sorting out such issues during final assembly at site is always time taking and difficult.

- Location of splices to suit transport limits and to suit erection methodology / capacity of erection equipment as well as structural efficiency (relatively less design forces at the locations of splices)
- Ease of access & space for tightening of bolts using power tools.

- **2.3 Stability of partially erected structure**
- **Deck structure which is stable in the completed form, may be unstable when partially erected. The designer has to ensure stability at each stage of erection by suitable means such as temporary bracings.**
- **Lateral torsional buckling of slender girders can be an issue after completion of fabrication during subsequent operations like protective treatment, transport, storage at site, exposure to wind after erection & loading during deck concreting.**

- Pairs of girders can be braced and can be lifted together to ensure stability
- Use of tub / box girders is advantageous for longer spans
- Access for workers inside the box has to be ensured by leaving openings at appropriate locations
- Detailing has to take care of constructability and health / safety risks during working in confined spaces.

1. Introduction
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3. **Construction Engineering Process**
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3. Construction Engineering Process

- Construction engineering identifies the construction means & methods & the resources necessary{ men, materials, temporary structures & equipment} consistent with quality, safety, environmental, cost effectiveness & project milestones.

Inputs for the process:

- Designer's envisaged method
- Site features- Location, topography, weather, flood season, working season, other constraints
- Location of fabrication facilities, delivery routes to site by rail / road or water
- Availability of suitable plant & equipment
- Safety , Quality, Cost effectiveness & Environmental factors

3. Construction Engineering Process… contd.

Sub-process	Output
How to construct the bridge	• Constructability review • Means & Methods: Method statements
Resource requirements	• Temporary Structures • Equipment incl. specifications- General purpose & tailer-made • Specialised manpower
Detailed sequence of construction	• Structural configuration of partially completed structures & forces acting during construction • Stability of partially completed structures & measures required if any
Controls during construction	Checklists In process inspection

3. Construction Engineering Process… contd.

IRC:87-2018 defines temporary structures as parts or the works those allow or enable construction to protect, support or provide access to the permanent works and which may or may not remain in place at the completion of works. They can also be used to support an item of plant or side slopes of excavation or provide access to work fronts during construction operations.

There are three basic types of temporary structures required:

- **Temporary fixtures to the bridge components such as lifting lugs, temporary bracings, local stiffening, etc.**
- **Civil works like temporary foundations, modifications to the substructure, etc.**
- **Supporting trestles, launching gear like spreader beam, etc.**

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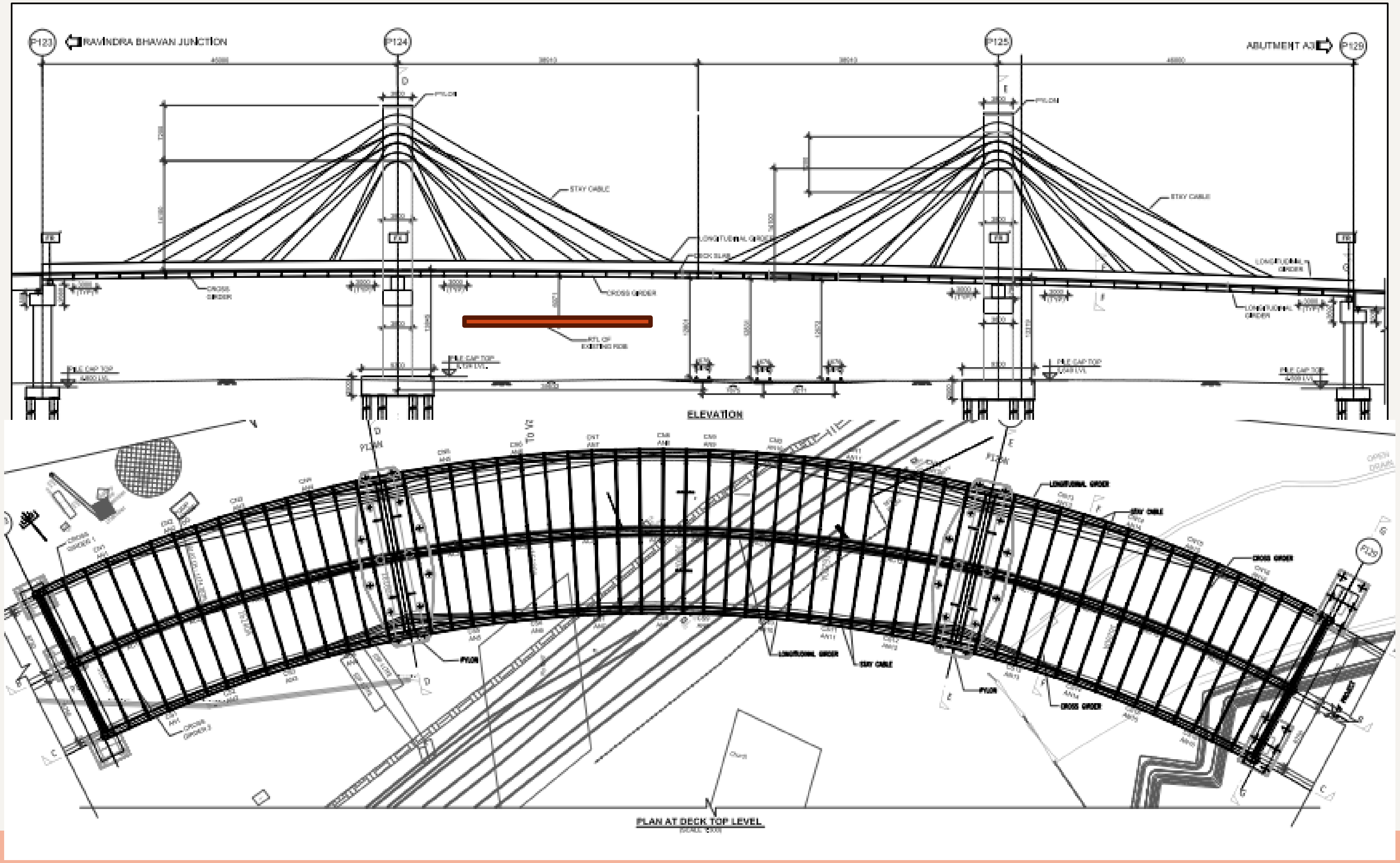
4. Various Methods of Steel Deck Erection

ASSEMBLY OF FABRICATED COMPONENTS

A	B	C
Part by Part Assembly In the Final Position	Complete Span Assembly Near its Final Position	Complete Span Assembly In Fabrication Shop
A.1 On temporary supports/ Full span beams with cranes/ gantries/ tower crane/ Cableway	B.1 Shifting longitudinally - Incremental launching	C.1 Transport & lift in one piece Possible only if fabrication is done very near the final location
A.2 By Cantilever method -With floating crane - With crane traveling on erected deck	B.2 Shifting longitudinally & transversely -SPMT	C.2 Float in

4.A.1 Part by Part Assembly In the Final Position- On temporary supports with crane, etc.



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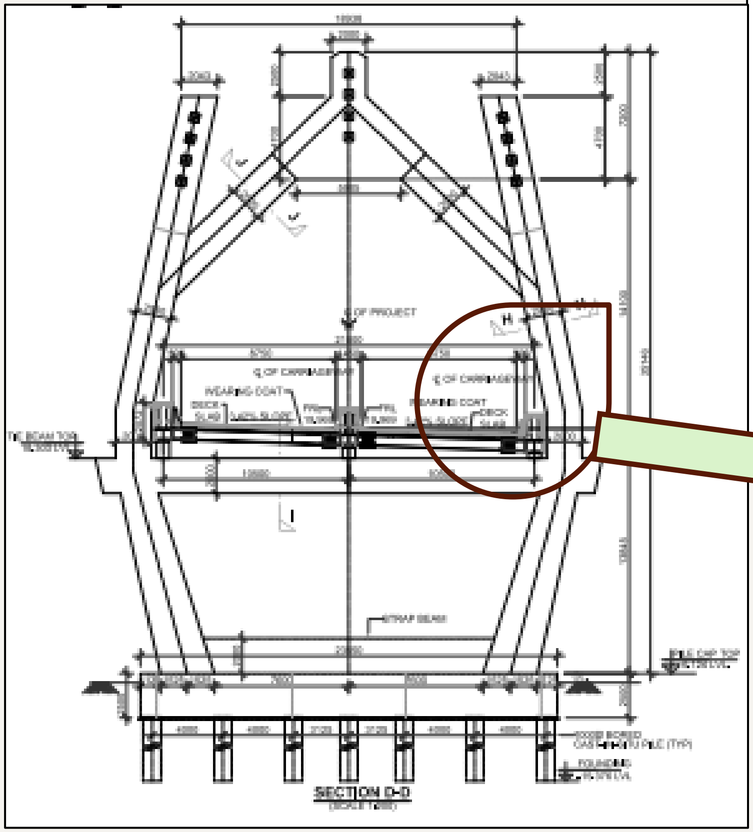
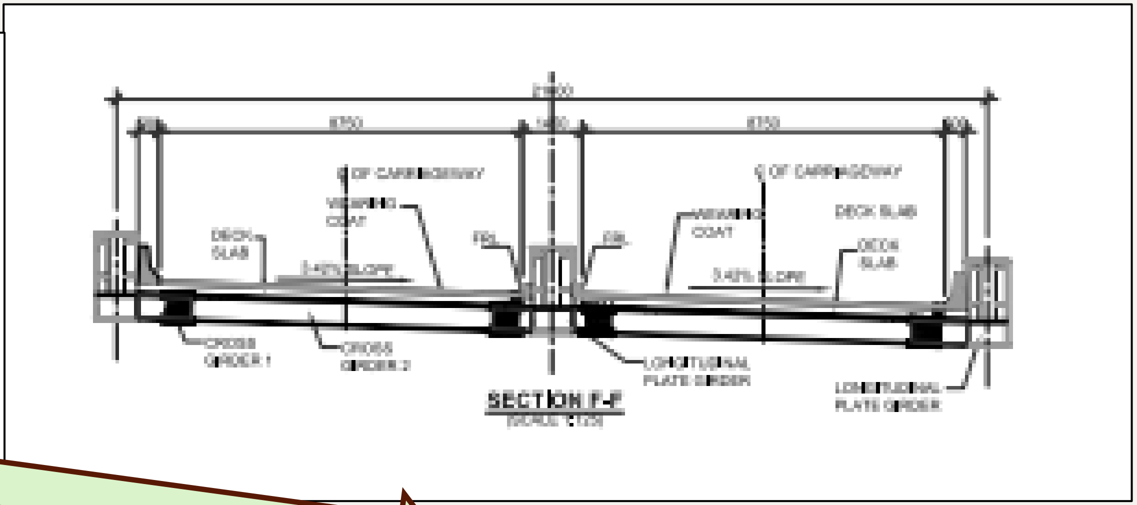
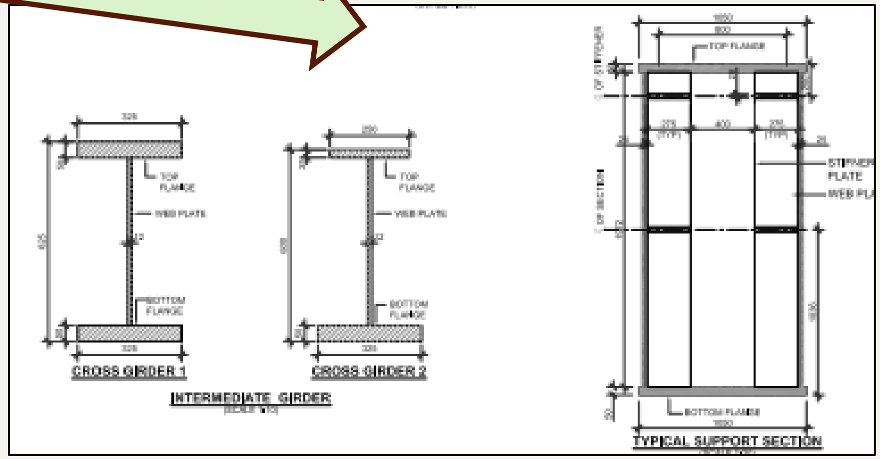
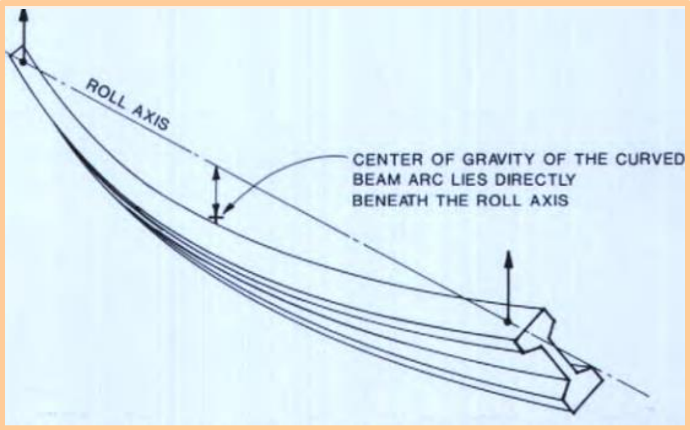






- One of the most critical stages during I-girder erection is when the first girder has been erected, but not yet connected to adjacent girders in the cross section.



When the supports have roll flexibility, the beam may roll sideways, producing lateral bending of the beam. This is the cause of most lateral stability problems of long , slender girders.

In the case of Goa-ROB2, cantilever erection of the deck was not possible as only one main girder would have to be erected at a time and it would not have been laterally stable. As such deck had to be erected on temporary trestles using a crane.

4.A.1 Part by Part Assembly In the Final Position- On temporary supports with crane, etc.

Detailed erection plans have to be prepared specially when erection with cranes are proposed.

"Erection Plans" describe and specify the erection (i.e., the field-installation and member-placement) of the structural steel. The Erection Plans include:

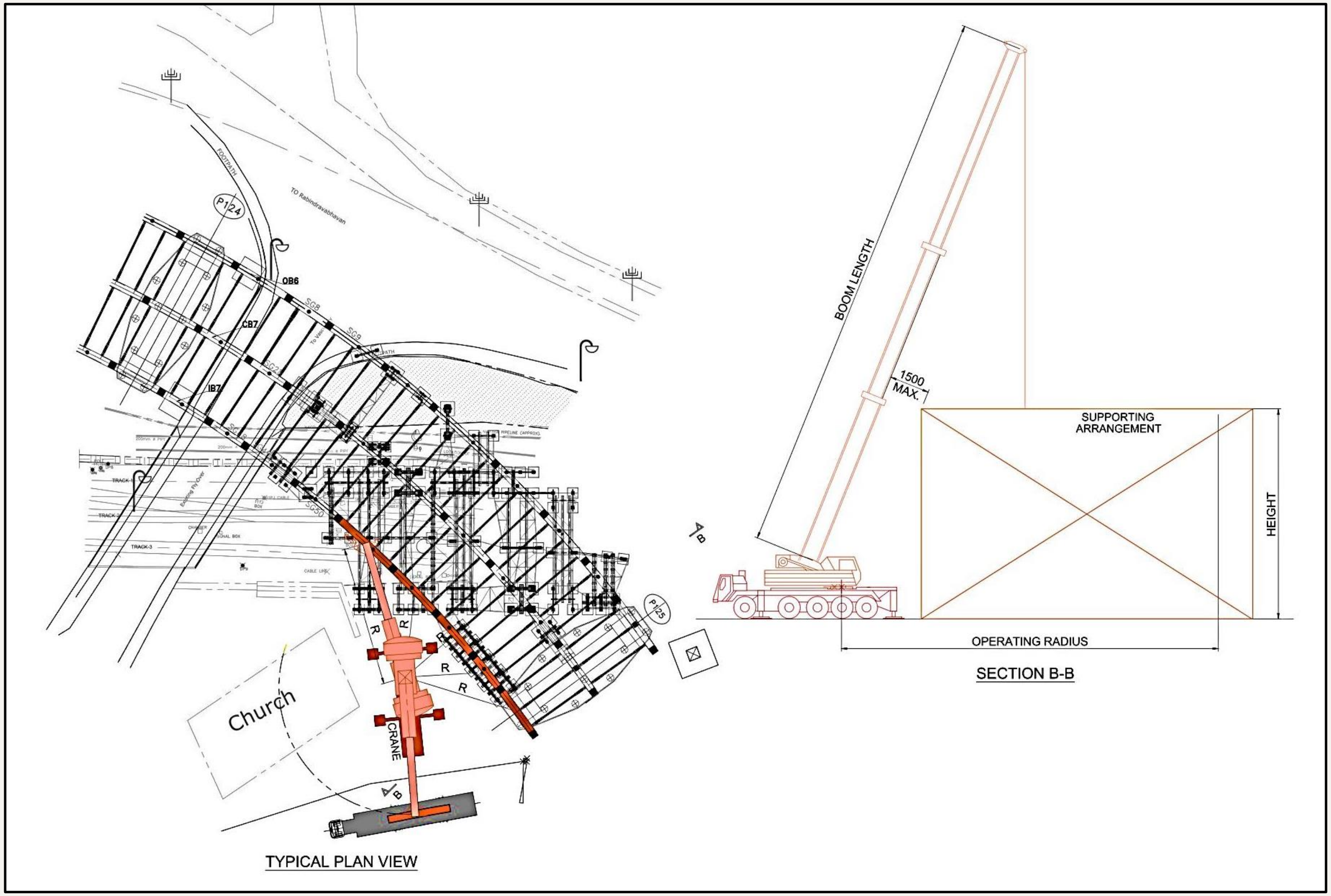
- A plan of the work area showing the proposed bridge,
- the permanent support structures (piers and abutments),
- roads, railroad tracks, waterways (including location and dimensions of any navigational channel & clearances
- overhead and underground utilities,
- structures and conditions that may limit access (consideration of clearance requirements over roadways or railroads),
- staging or material storage areas,
- right-of-way and property lines

4.A.1 Part by Part Assembly In the Final Position- On temporary supports with crane, etc.

- The Erection Plans include:
- information, plans, etc. regarding maintenance of traffic requirements, lane or road closures, restrictions, durations, etc. necessary to protect public safety for all erection operations over or adjacent to live traffic, and
- any other information that may be pertinent to the steel erection

The maximum crane lift radius is often controlled by the material delivery location, hence the need to indicate the delivery location on the Erection Plans and Procedures. Correct girder segment orientation at the delivery location is important since the ability to rotate long segments under the crane boom may be restricted

4.A.1 Part by Part Assembly In the Final Position- On temporary supports with crane, etc.



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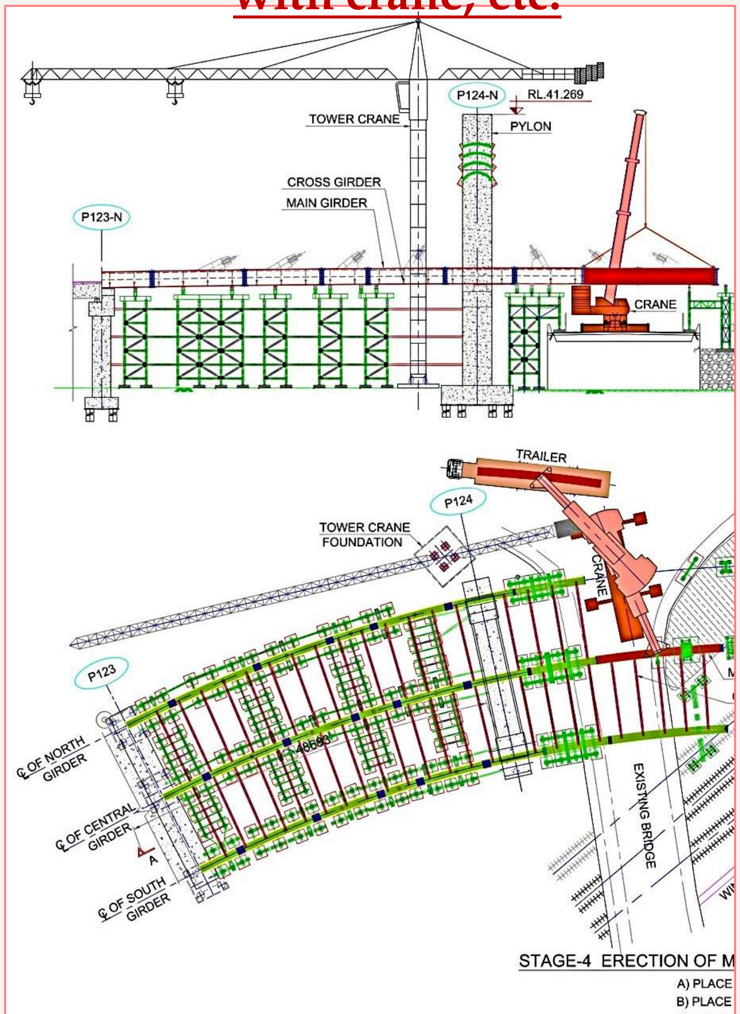

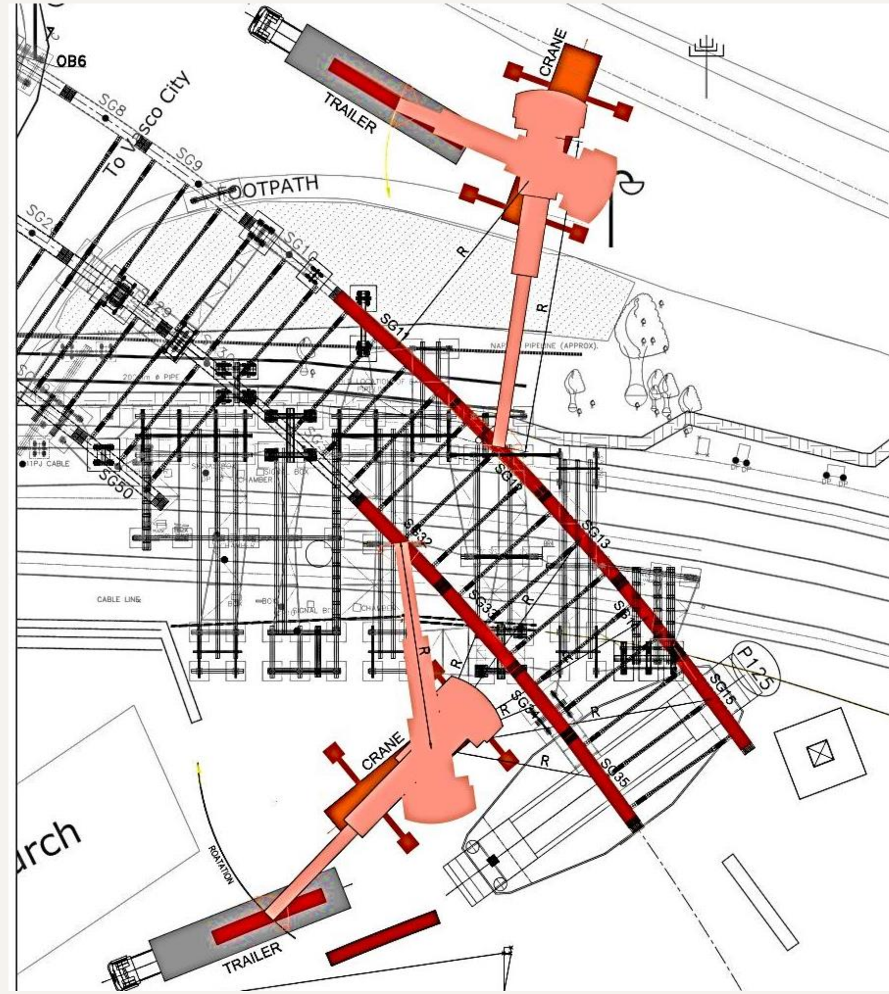

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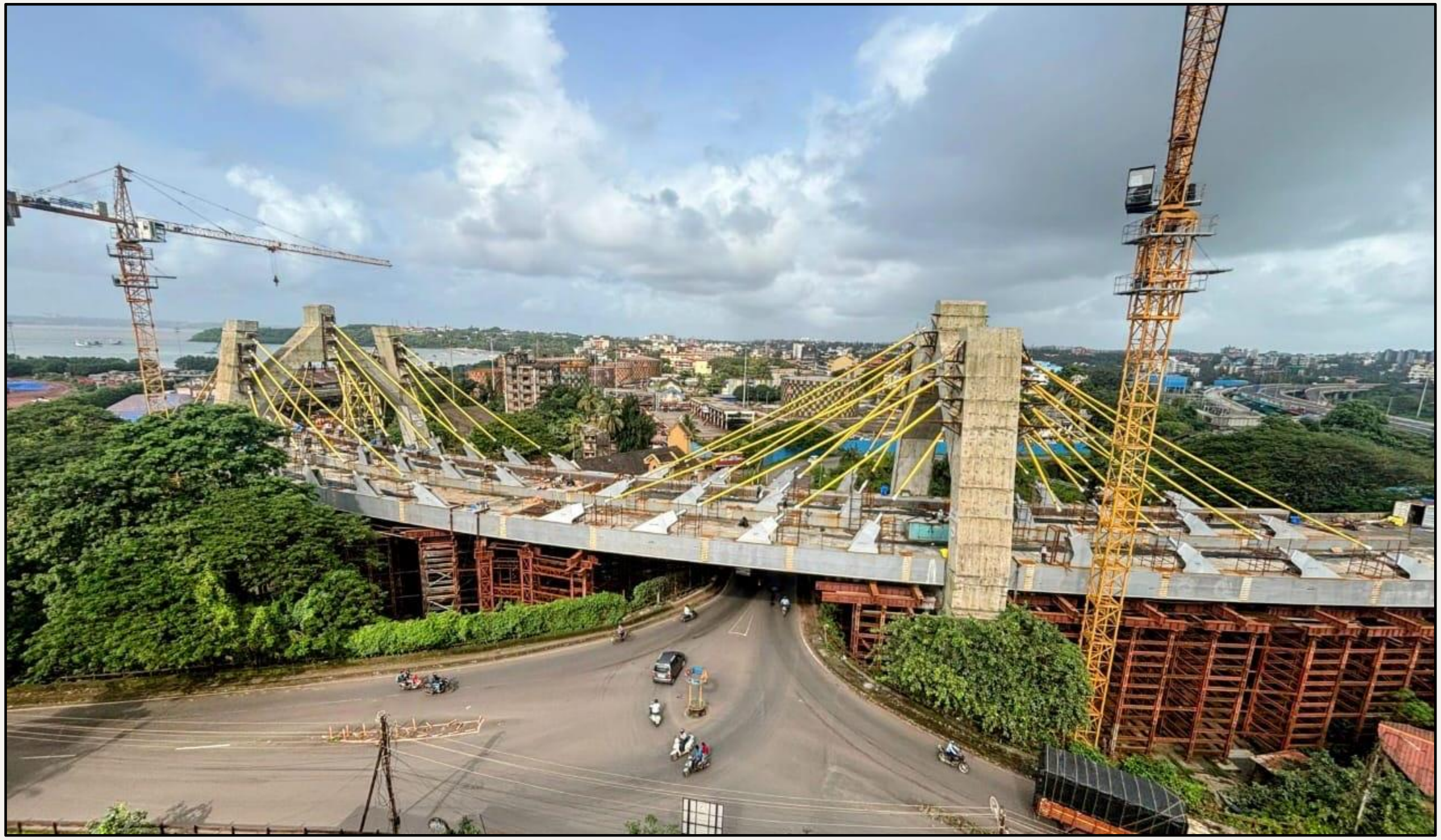
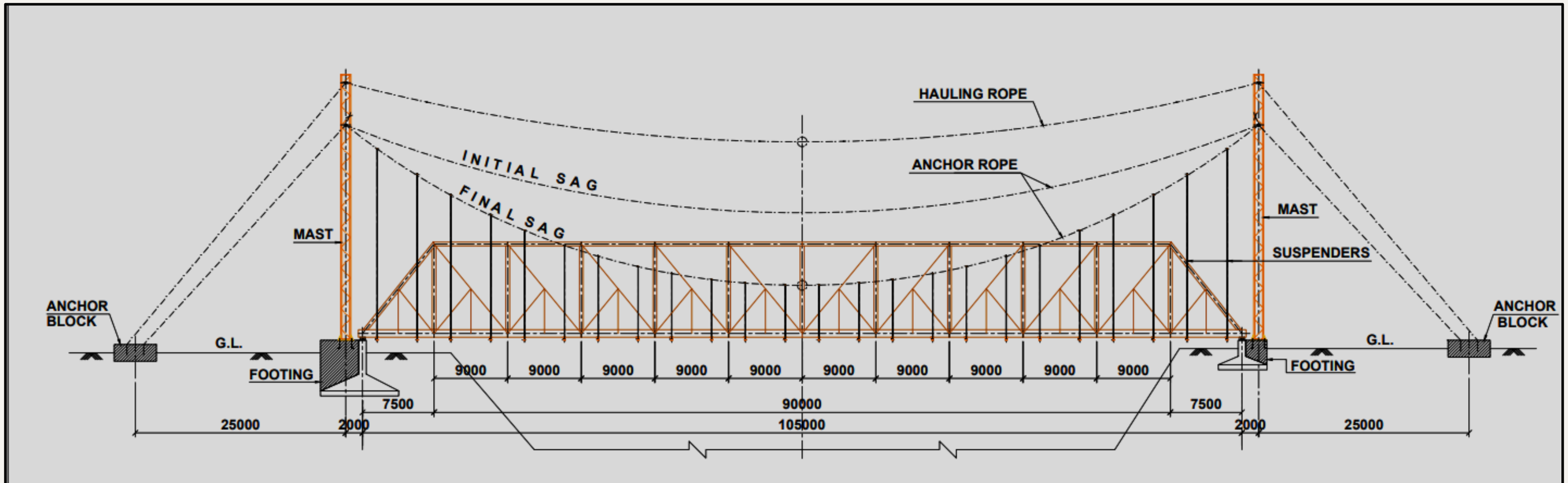


4.A.1 Part by Part Assembly In the Final Position- Truss Bridge Erection with Cableway

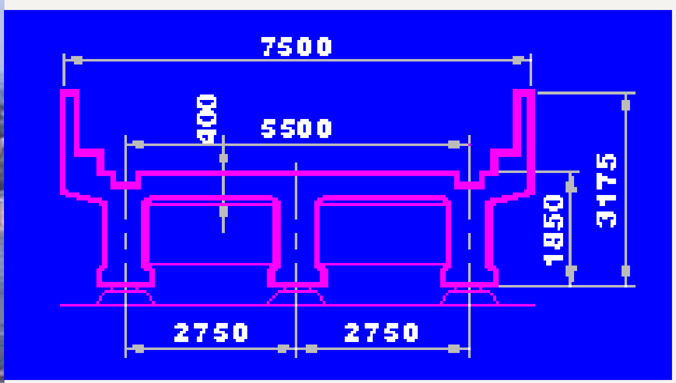


TRUSS BRIDGE ERECTION WITH CABLEWAY

- In this method individual members are supported from the anchor ropes at specific locations with suspenders prior to connecting. After a sufficient number of members are suspended, they are connected to each other and the remaining members are erected.

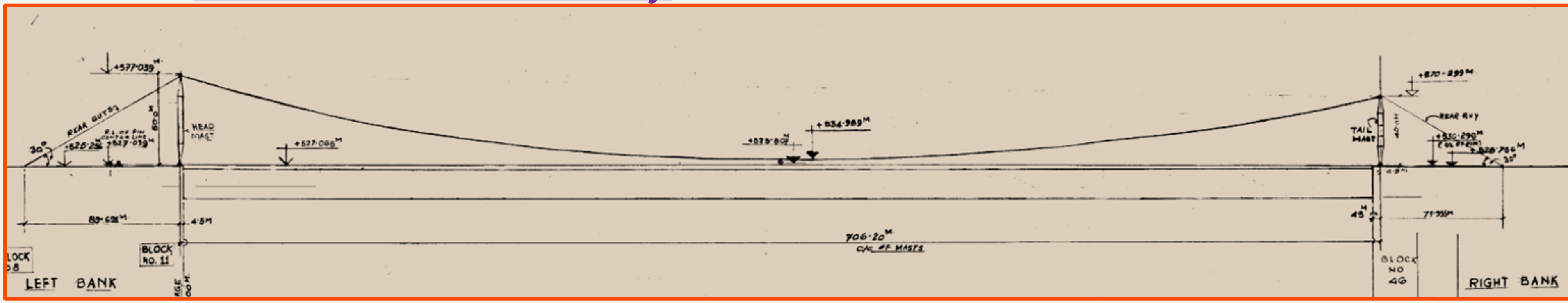
4. Various Methods of Steel Deck Erection… contd.

4.A.1 Part by Part Assembly In the Final Position- Girder Bridge Erection with Cableway



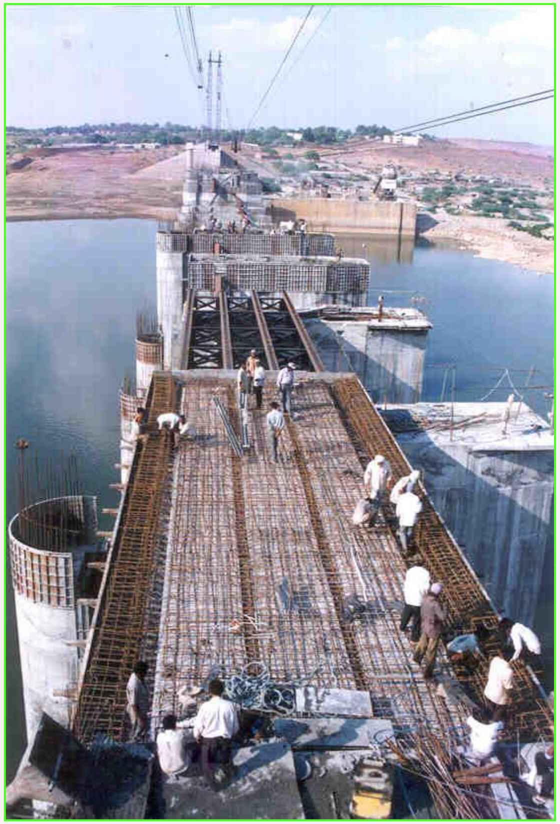
The spillway bridge having 26 nos. 18 m spans was originally designed as RCC beam & slab structure to be constructed in situ. As per time schedule it would have taken at-least two years to construct

4.A.1 Part by Part Assembly In the Final Position- Girder Bridge Erection with Cableway



- Composite decking was proposed considering availability of mechanical parts of two nos. five ton capacity cable ways.
- Cableway masts of 50 & 40 m height were designed & fabricated to suit the 706 m span required to cover the entire spillway bridge portion.

4.A.1 Part by Part Assembly In the Final Position- Girder Bridge Erection with Cableway



Rapid construction of the spillway bridge could be achieved by

- changing the design of the RCC decking to composite decking
- Utilising cableway for erection

4.A.2 Part by Part Assembly In the Final Position- Cantilever Construction

- The cantilever method of erection for continuous trusses starts with assembling the sections over an interior pier using temporary bents or pier brackets to stabilize the panels.
- Once the initial pier panels are erected, new panels are added to each end in an alternating fashion until mid-span or the abutment is reached

4.A.2 Part by Part Assembly In the Final Position- Cantilever Construction of Simply Supported Railway Truss Bridge at Munger

Rail-cum-road bridge over river Ganga at Munger, Bihar

Salient Features of superstructure

Span arrangement: 1x32m + 29x121.6m + 1x32m (3.685 km approx.)

Weight of steel per 121.6m span: 1915 MT

Weight of steel per 32m span: 350 MT

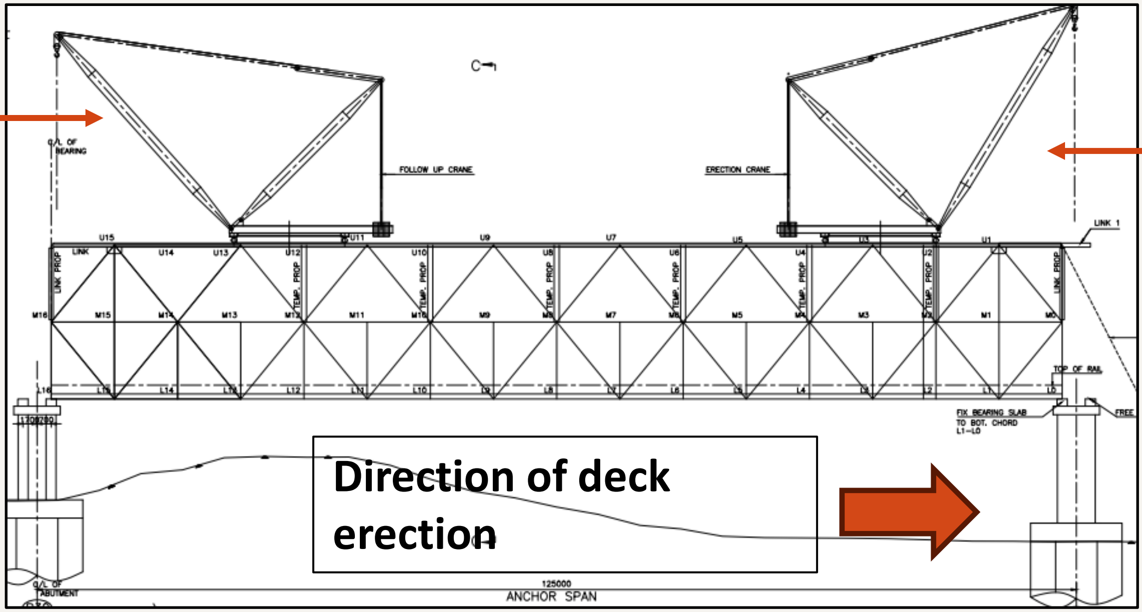
4.A.2 Part by Part Assembly In the Final Position- Cantilever Construction of Simply Supported Railway Truss Bridge at Munger

Erection was done from both ends
BBJ-Gammon JV

The first span was erected on trestles

4.A.2 Part by Part Assembly In the Final Position- Cantilever Construction of Simply Supported Railway Truss Bridge at Munger

Follow up crane



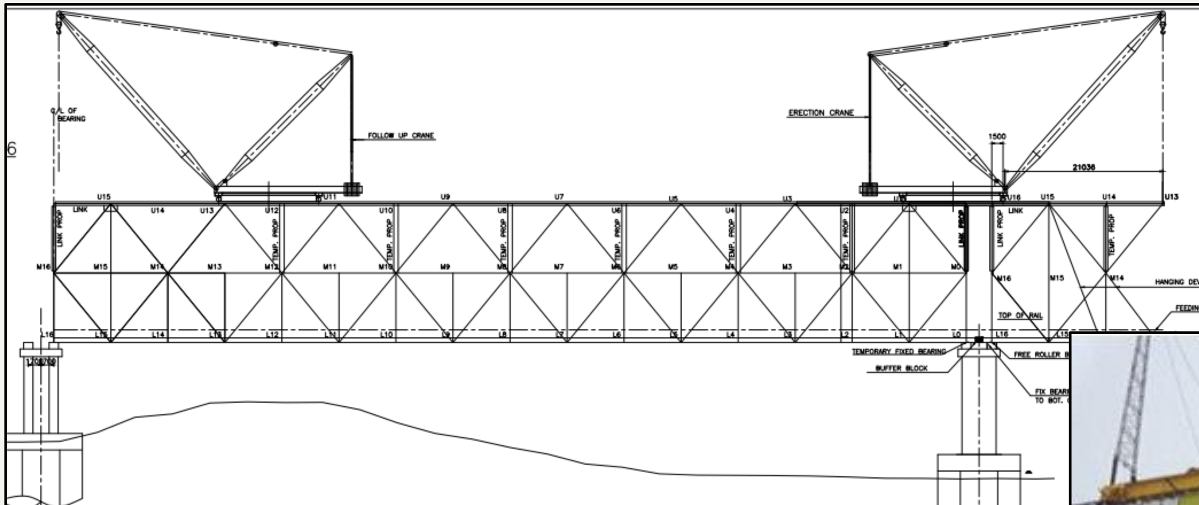
Deck Erection Crane

The deck erection crane and follow up crane were erected on the first span, which served as the anchor span for cantilever erection of the next span.

The deck erection crane erected the main truss elements, whereas the follow up crane erected the secondary elements, mainly to speed up the erection.

4. Various Methods of Steel Deck Erection… contd.

4.A.2 Part by Part Assembly In the Final Position- Cantilever Construction of Simply Supported Railway Truss Bridge at Munger

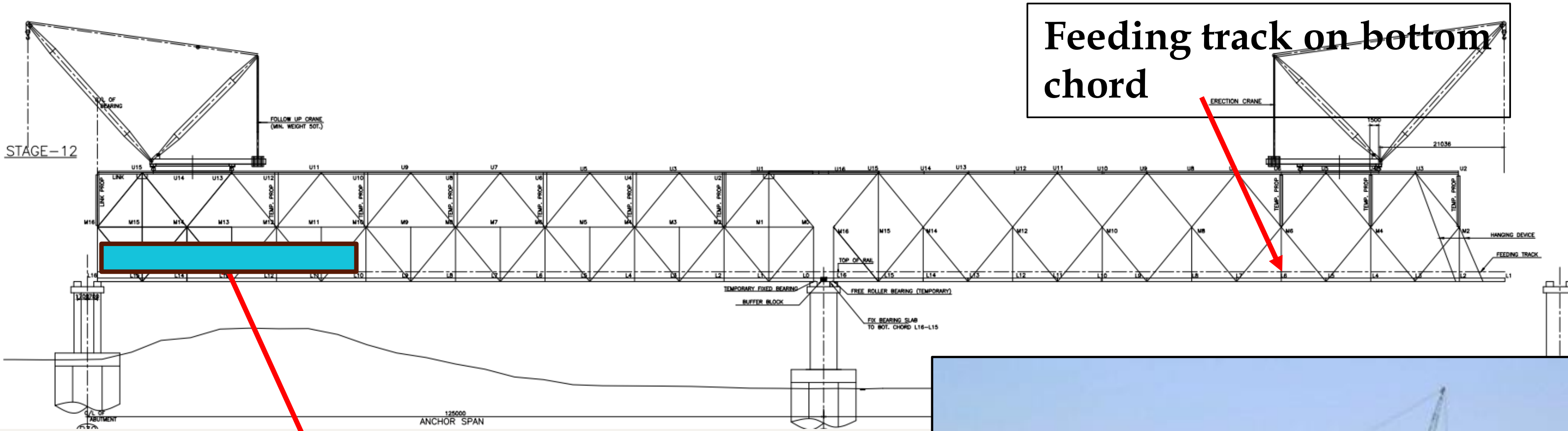


Link plates

Link plates & compression blocks provide continuity between the anchor span and the span being erected by cantilever construction there by providing stability.

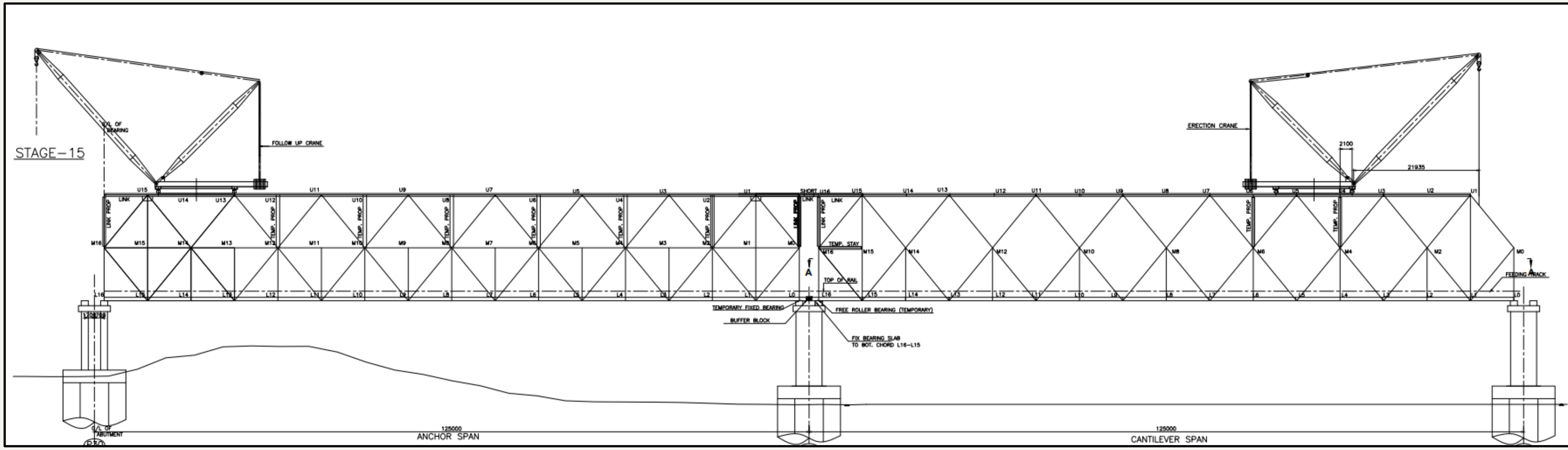
compression blocks

4.A.2 Part by Part Assembly In the Final Position- Cantilever Construction of Simply Supported Railway Truss Bridge at Munger



Feeding track on bottom chord

Kentledge (Rails) on end panels of anchor span



- After completing the erection activities on anchor & cantilever spans, the cantilever span is jacked up and secured on packs. The link plates and temporary props are removed with the follow up crane.
- Temporary bearings at both ends are removed and the span is lowered onto the permanent bearings.
- Buffer blocks, etc are removed and the span is fully aligned.

B.1 Complete Span Assembly Near its Final Position

Incremental Launching

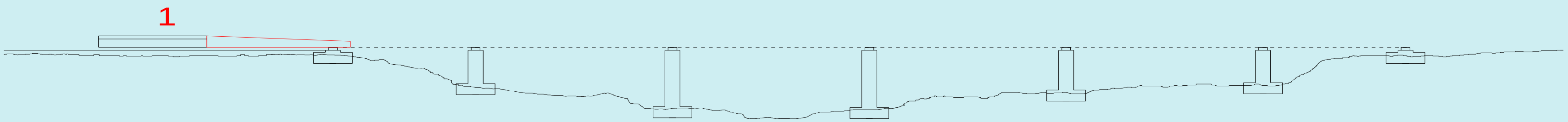
Used for difficult access sites

- **rivers, channels, wetlands, highways, railroads**
- **deep valleys, steep slopes**

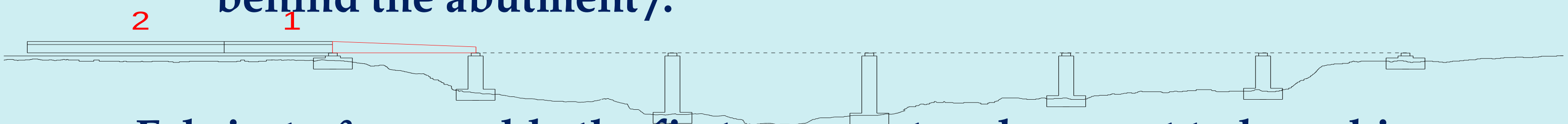
Fabrication / assembly yard on bank.

B.1 Complete Span Assembly Near its Final Position

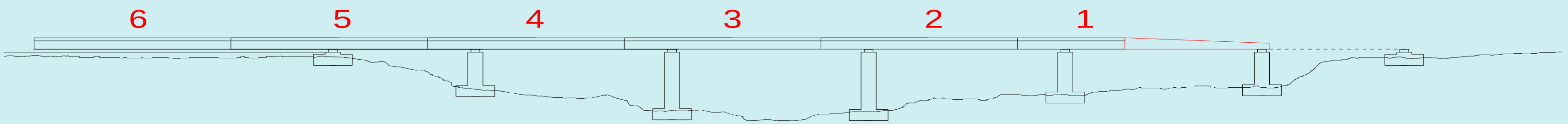
Incremental Launching

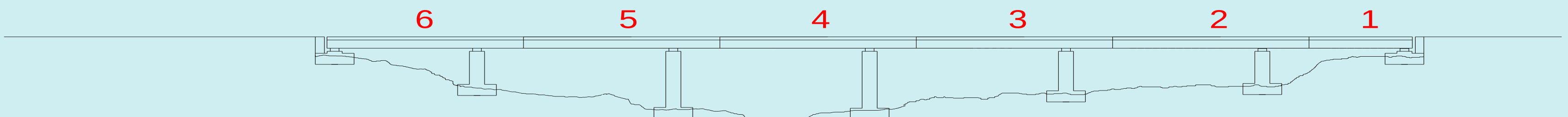


- Transport fabricated segments OR Set up fabrication yard behind the abutment /.



- Fabricate & assemble the first segment and connect to launching nose
- launch deck + nose forward





- repeat this sequence until deck completion

B.1 Complete Span Assembly Near its Final Position Incremental Launching

- The Beauharnois Bridge, Canada, has a total length of 2551 m, and it crosses (from east to west) the Beauharnois Canal (BHC) and the Saint Laurent Seaway canal (SLS) with a twin deck.
- Western approach, over land (25 typical spans of approximately 44.5 m continuous deck with 5 precast concrete beams)
- The main span of 150 m.
- Eastern approach over Beauharnois Canal waters (17 typical spans of 81.9 m and 63 m -steel composite box girder)

B.1 Complete Span Assembly Near its Final Position
Incremental Launching

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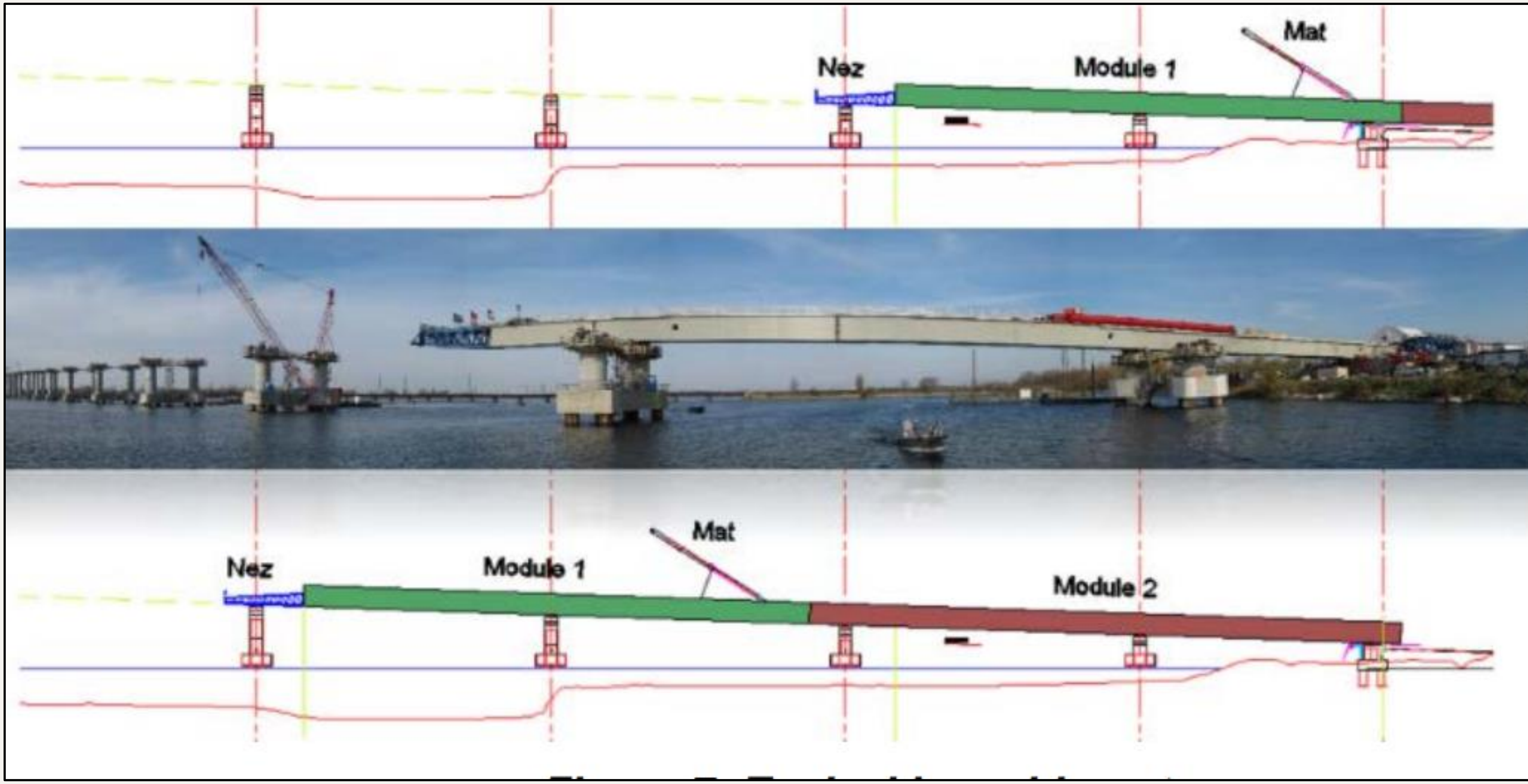
Incremental Launching



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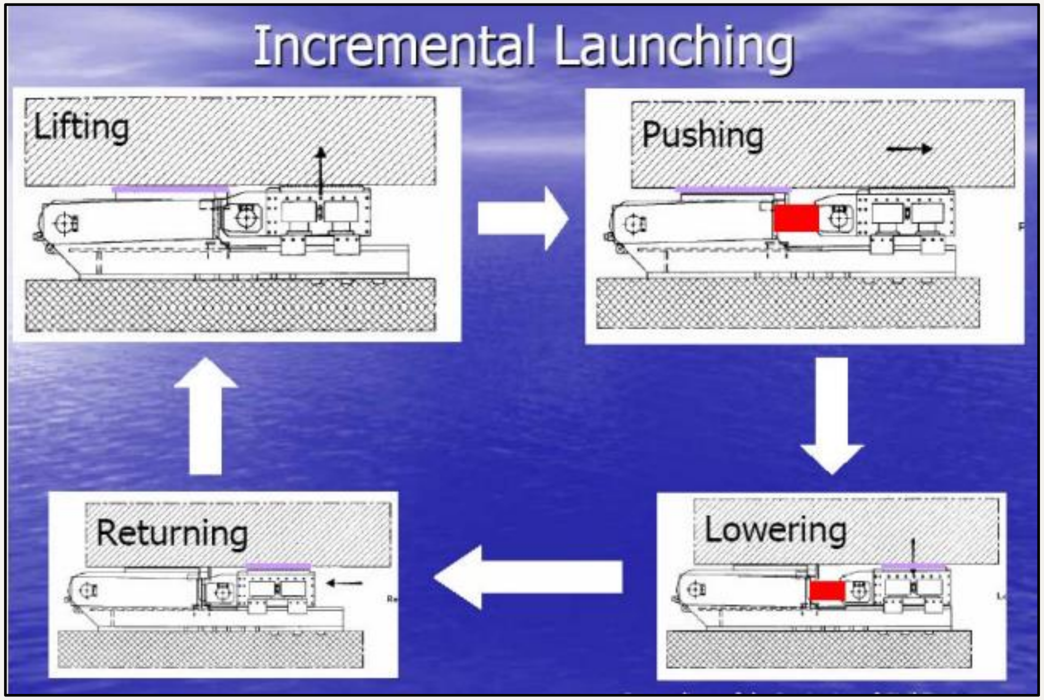
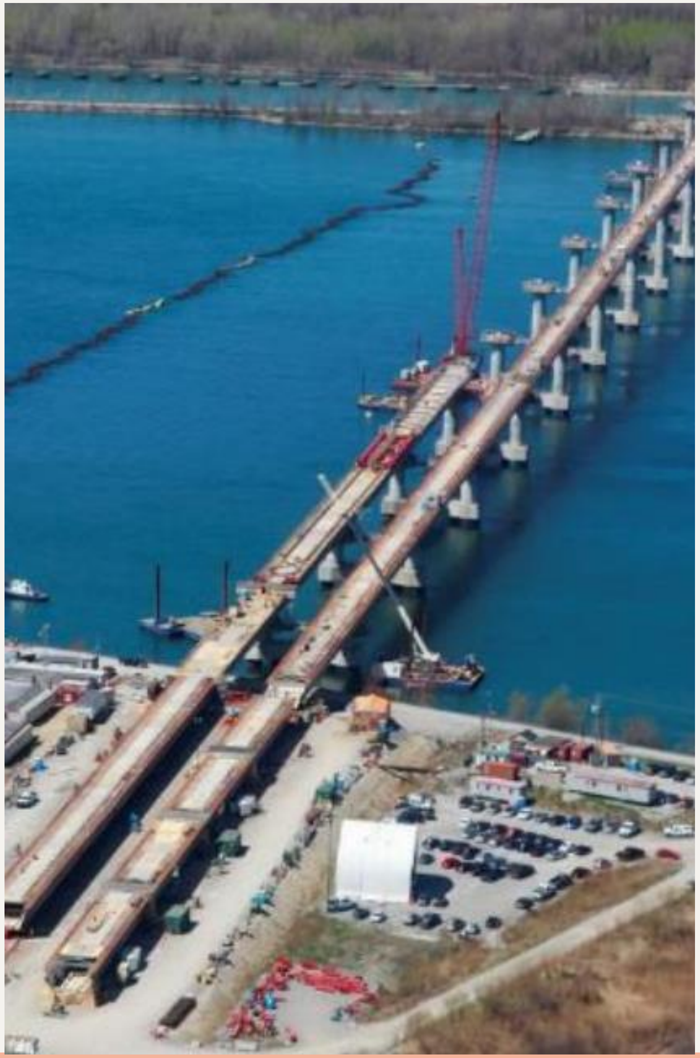
Incremental Launching





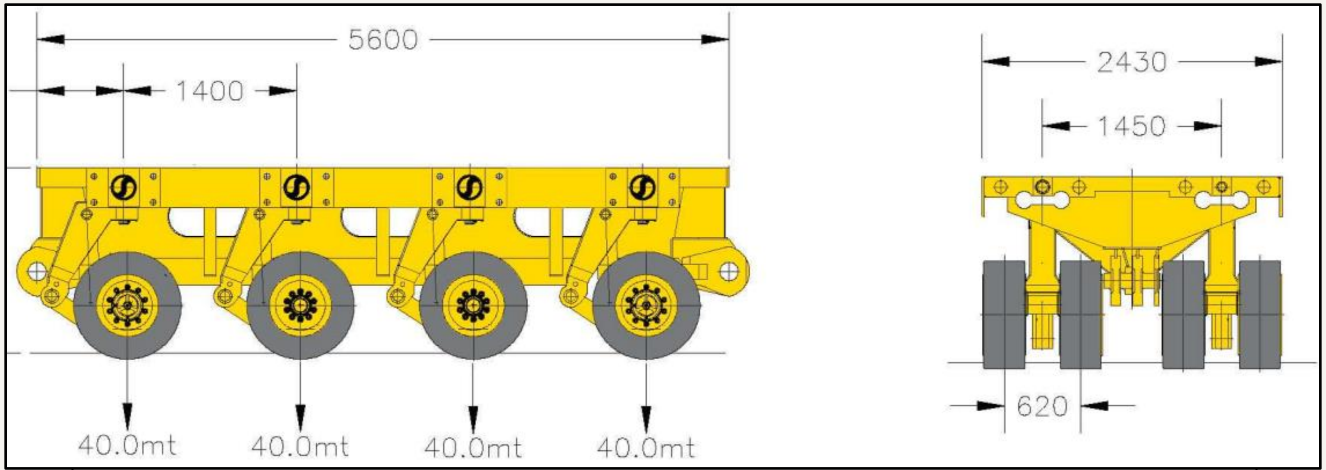
4. B.2 Complete Span Assembly Near its Final Position Shifting longitudinally & transversely

SPMT

(Self Propelled Modular Transporter)

4. B.2 Complete Span Assembly Near its Final Position Shifting longitudinally & transversely

Self Propelled Modular Transporter (SPMT): Specialized equipment used to move bridge superstructures, consisting of motorized load bearing multi-axle platforms with each axle having its own hydraulic lifting system to equalize loading pressures and maintain a level system and with turning capabilities that are linked and controlled through a computer



A typical 4 axle SPMT trailer unit- Max payload 144 MT

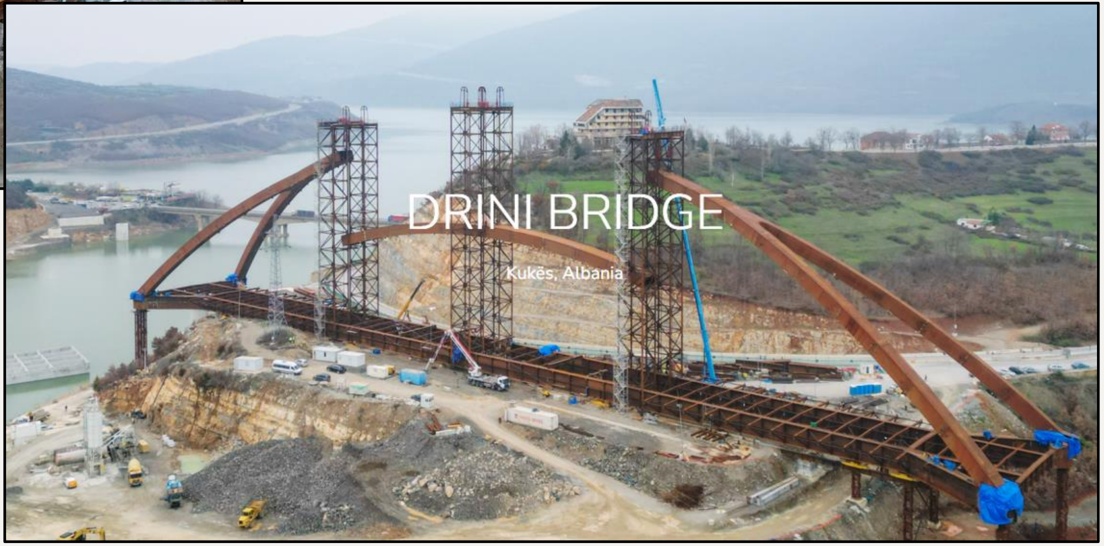
4.C.2 Complete Span Assembly In Fabrication Shop- Float In

SPMT

4.C.2 Complete Span Assembly In Fabrication Shop- Float In

- The Drini Bridge is built above the Black Drin Lake, Albania. The bridge is composed of three spans, the central one measuring 270 meters, 55 m tall and deck width of 23 m.
- The structure, weighing about 5000 MT is made of weathering steel and it is preassembled on the shore with the support of temporary towers, to be later launched in position using barges.

4.C.2 Complete Span Assembly In Fabrication Shop- Float In



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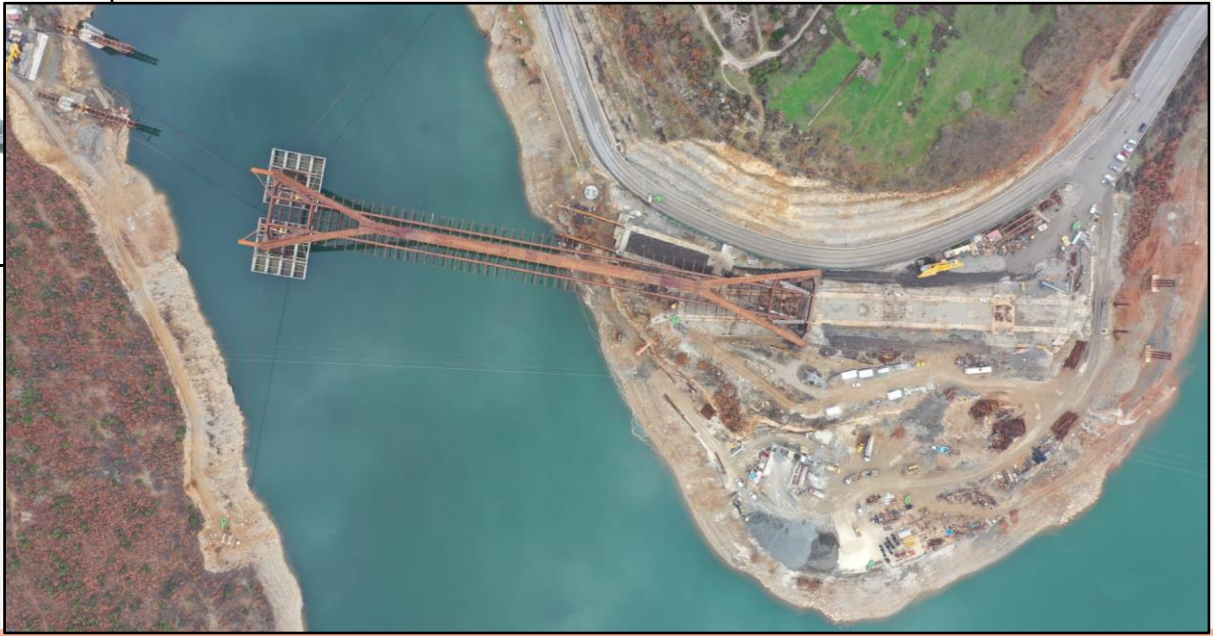

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5. Some Critical Issues Related to Temporary Structures

A large percentage of construction accidents is attributed to failure of temporary structures or some construction related issues.

Challenges in Implementation:

- After a spate of accidents related to falsework failure in the UK, the government appointed a committee headed by Professor Stephen Bragg to investigate. The final report (HSE 1976), known as the ‘Bragg Report’, had a large influence on the BS 5975: Code of practice for falsework first published in 1982.

- The committee analysed various falsework failures to determine direct technical reasons for failure and also the contributory procedural failures which allowed the technical faults to go undetected.

Challenges in Implementation… contd.

Reasons for failure of falsework, those can be directly attributed to technical issues, are:

1) **The design itself is inadequate for the specified loads**
2) **Loads coming on the structure at site are not the same as those considered in the design basis. This can happen when there are changes in methodology or sequence of work or changes in dimensions of the permanent structure itself.**

Challenges in Implementation… contd.

3) The falsework erected at site is not according to the design. There can be last minute changes in the structure as per the material available at site without consulting the designer.

- **The first and the third are more of coordination or procedural issues whereas the second is a purely a design matter.**

Principal Recommendation No. 17 of Bragg Report 1975

“ On all sites the Contractor must appoint a properly qualified Temporary Works Coordinator/ Structural Engineer Qualification whose duties are to ensure all procedures are followed, all checks and inspections carried out, and any changes authorised. Falsework may not be loaded or struck without the written permission of the Temporary Works Coordinator”

Procedural controls

Proper implementation of temporary works is largely dependent on management of various activities from concept to erection / dismantling as well as maintenance& storage.

The procedural controls can be categorized in three phases:

i) Design Phase

ii) Communication & Documentation

iii) Site operations phase

Procedural controls… Organisation

Designated Individual

Temporary Works Designer

Temporary Works Coordinator

Temporary Works Supervisors

Designated Individual is responsible for:

- Appointing the temporary works designer and the temporary works coordinator
- Procedures for control of temporary works
- Ensuring sub contractors have suitable procedures
- Responsibilities clearly defined & allocated
- All instructions clear & complete
- Documented records maintained from site minutes, drawings & calculations specific to the works.

Procedural controls… Site operation

Responsibilities of TWC are as follows:

1) Administrative

- Co-ordinate all temporary works activities
- Coordination and monitoring of interfaces between different organizations involved in the related activities
- Ensure that a documented safe system of work is in place and implemented for the erection and dismantling of any temporary works
- Ensure that during the use of temporary works all appropriate maintenance is carried out

2) Design Coordination

- point of contact between the designer of temporary structures and site office for all design issues

Procedural controls… Site operation.. Contd.

Responsibilities of TWC … contd.

2) Design Coordination…contd.

- point of contact between the designer of temporary structures and site office for all design issues
- Ensure that a design brief is prepared with full consultation, is adequate and is in accordance with the actual situation on site
- Ensure that any residual risks, identified at the design stage, assumed methods of construction, or loading constraints identified by the designer of the permanent works are included within the design brief

3) Procurement

- Ensure that the procured materials for temporary structures are in accordance with the designer's specifications

Procedural controls… Site operation…. Contd.

Responsibilities of TWC …. Contd

4) On site implementation

- Preparation of Method statements and Check lists for different activities
- The checking of erection, safe use, sequence of loading, dismantling in stages,
- maintenance and storage in stages where necessary, to ensure compliance with the design and any hold points.
- the issue of a formal "permit to load" and a "permit to dismantle" the temporary works.
- When it has been confirmed that the permanent structure has gained adequate strength and/or stability, ensure a permit to unload (take out of use) the temporary works is issued by either the TWC or TWS

Procedural controls… Site operation.. Contd.

Responsibilities of TWC are as follows:

5) Change management

- **Ensuring that any proposed changes in materials, method statements or sequence of construction are checked with the designer of temporary structures and appropriate action taken.**
- **Ensuring that the agreed changes or rectification of faults are correctly carried out at site.**

6) Maintenance of Records

- **Ensure a temporary works register is established and maintained;**
- **Register the drawings calculations and other relevant documents relating to the final design including revision control;**

Procedural controls- Design Phase:

A design brief needs to be prepared giving all data required for design of temporary works for the project to include:

- Drawings & specifications for permanent work,
- Codes &contractual specifications as per which design of temporary works is to be carried out ,
- Soil investigation & environmental data,
- Construction schedule & sequence of work,
- Proposed methods of construction, access requirements,
- Equipment & material available for temporary works and
- Any other relevant data.

Procedural controls- Design Phase… contd.

- If any deviations are proposed from the assumptions related to sequence or method of construction, loading or strength restrictions, etc. then the same have to be reviewed and approved by the designer of permanent works.

- Depending on the complexity, the design & drawings are to be reviewed to check the concept, structural adequacy & compliance with the design brief.

Communication & documentation:

Many agencies are involved in various stages of temporary works: designer, main contractor, subcontractors, system suppliers, clients engineer / project management team, etc.

After recording the design document & drawings, they are to be made available to all concerned.

Proper coordination and communication is required to ensure that necessary requirements are met at all stages and for each cycle of use.

Trained manpower

- **In spite of all documentation like stricter codes, procedures, check lists, etc , PROPER IMPLEMENTATION AT SITE IS IMPOSSIBLE without trained manpower !**

- **None of the surveys about accidents mention that there is an acute shortage of manpower and their training needs. All concerned need to pay attention to this requirement : Owners, contractors and so on.**

1. Introduction
2. Design Stage Considerations
3. Construction Engineering Process
4. Various Methods of Steel Deck Erection
5. Some Critical Issues Related to Temporary Structures
6. **Conclusion**

6. Conclusion

- ❑ Suitable type / configuration, design basis and performance specifications for temporary structures have to be derived from construction methodology
- ❑ Owners and prime consultants may consider project specific constructability review workshops which include engineers and contractors familiar with the requirements for successful lateral slides and incremental launches to assist with development of cost-effective and constructible designs.

6. Conclusion… contd.

- Success of temporary works is not just good design but depends on many aspects such as proper understanding of construction procedure, need to achieve target time cycles, following relevant procedures at site, safety, cost effectiveness and so on.
- Bridge construction is showing a worrying drop in safety and a consequent increase in the number of serious accidents.
- Serious attention needs to be given to training for developing manpower required for proper design to safe implementation at site

THANK YOU