Precast, Pre-stressed Concrete Panels(PCP) as Stay in Place (SIP) Bridge Deck System

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PCP as SIP –initiated in the1950s

- In the early 1950s the Illinois Department of Transportation (DOT) developed precast prestressed concrete panels (PCP) to act as stay-in-place (SIP) deck forms, topped over by cast-in-place (CIP) concrete for an alternative and economic bridge system.

Used in the 1950s for a series of underpasses for the Illinois Toll Highway Authority on the Northwest Toll way near Chicago, Illinois, U.S.A.

ADVANTAGES OF THE SYSTEM

Concrete SIP panels provide:

- Economic, quick, improved deck construction
- Enhanced durability of deck
- Reduced on-site construction time and costs

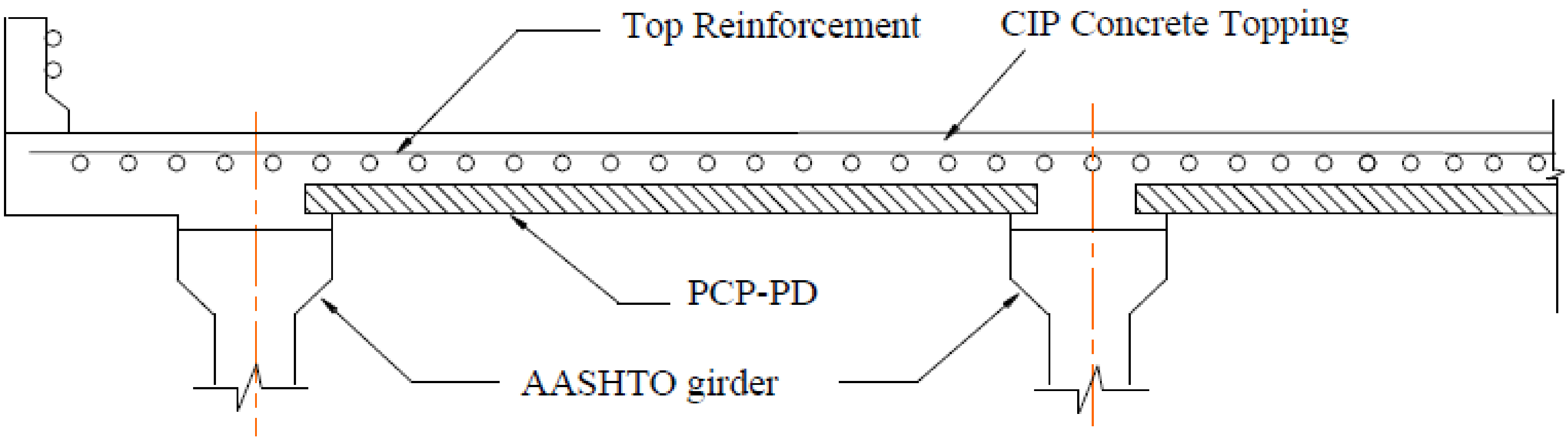
DIFFERENT PCP BRIDGE DECK SYSTEMS

- PCP bridge deck system can be of the following types:
- **1. A precast prestressed concrete panels-partial depth (PCP-PD), which act as SIP deck forms,**
- **2. A precast prestressed concrete panels-full depth (PCP-FD), which act as the entire deck thickness,**
- **3. PCP-PD-full span- used to span from abutment to abutment, and**
- **4. PCP-PD-post tensioned-where panels are post tensioned in both directions.**

PCP-PD

- PCP-PD panels are:
- •Precast and concentrically prestressed
- •Topped over by cast-in-place (CIP) concrete
- •Roughened at the top surface to achieve composite action

Typical transverse section of a PCP-PD bridge deck system



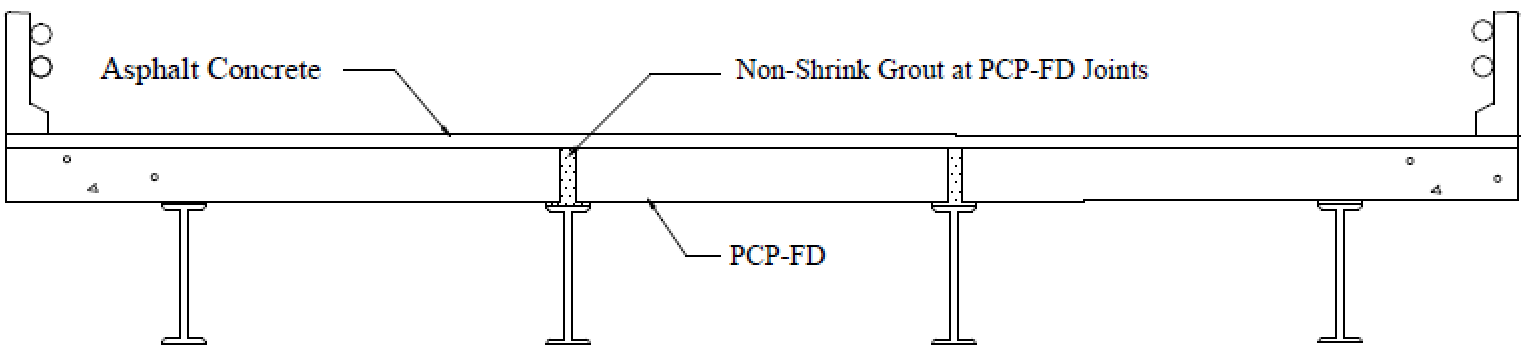
PCP-PD deck preparation at New Hampshire, U.S.A.

Courtesy: Prof. Cook, UNH

PCP-FD

- PCP-FD panels:
- •Provide the full depth of the bridge deck,
- •Have prestressing strands or mild steel commonly used in two layers, and
- •Employ non-shrink grout at panel-to-panel connections.

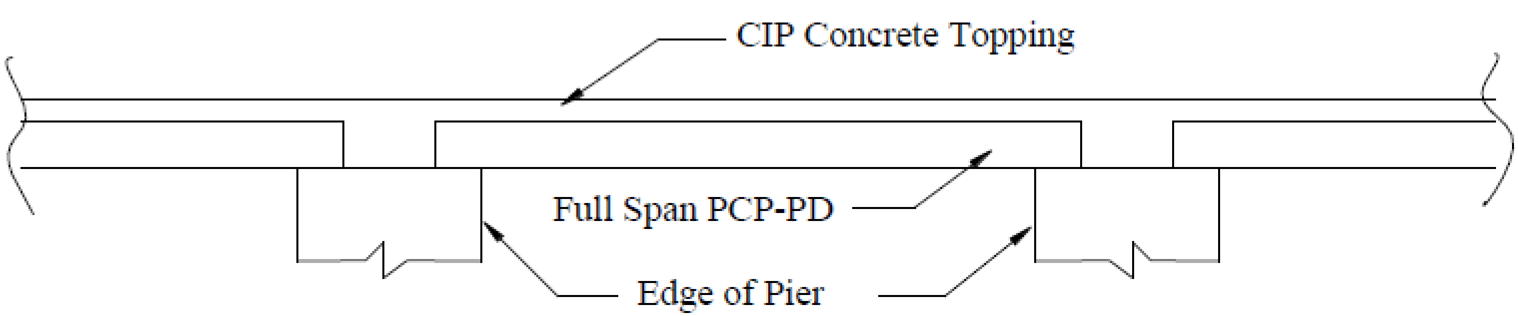
Typical transverse section of PCP-FD bridge deck system



PCP-PD-full span

- PCP as SIP panels have also been used to span longitudinally from supporting abutment to supporting abutment instead of the more common use of spanning laterally from bridge girder to bridge girder,
- normally spanning less than 12 meters (39.4 ft).

Typical full span PCP-PD spanning longitudinal direction



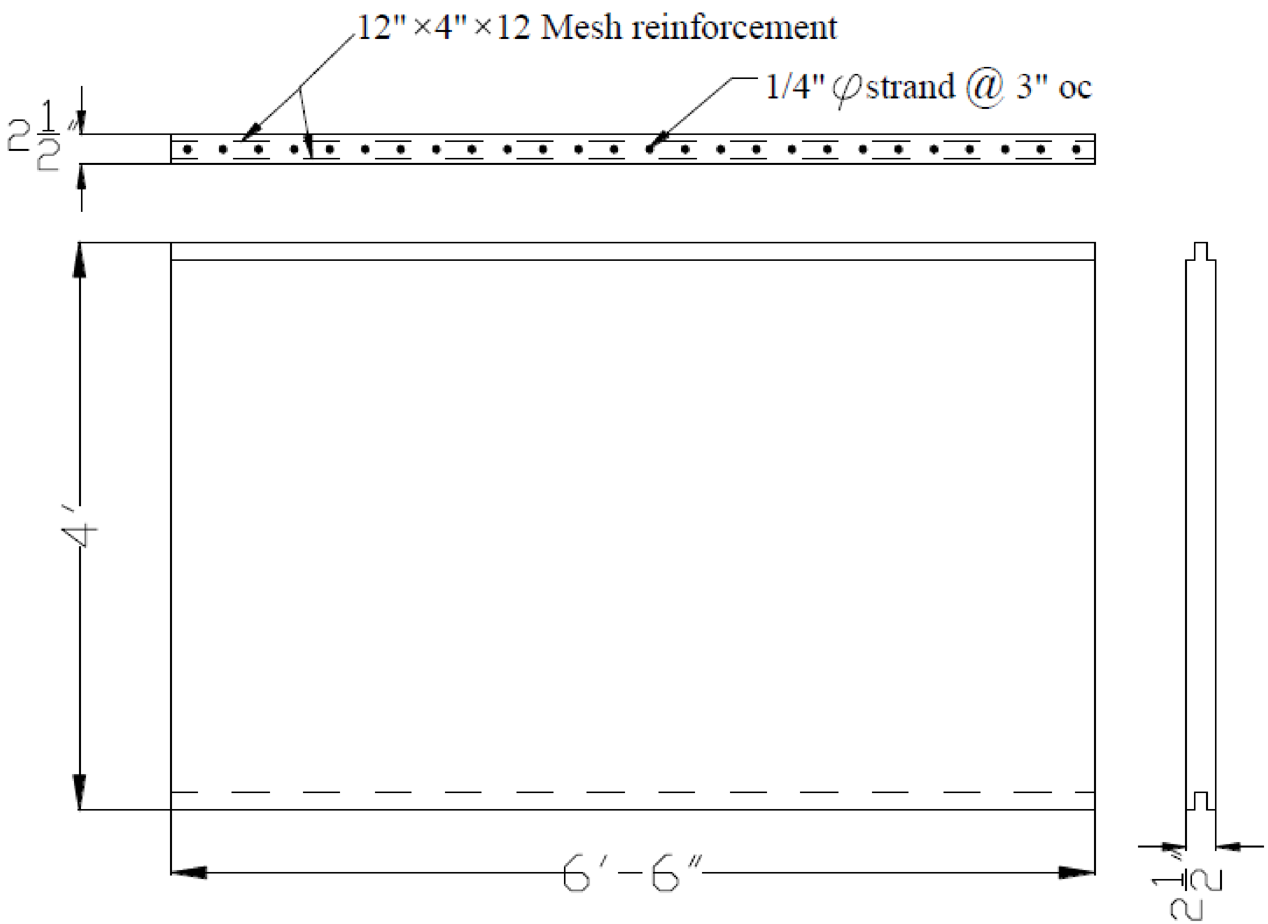
PCP-PD-post tensioned:

- There is another type of PCP slab reported in Texas on a large elevated highway project on IH 345 in Dallas, Texas, constructed in the late 1960s.
- The deck slab was post-tensioned in both directions. The prestressed slab is still in good condition but the design has not been used since.

Early History

- first proposed in the early 1950s for a series of underpasses for the Illinois Toll Highway Authority on the Northwest Tollway near Chicago.
- The first such full-scale prototype bridge was load tested in Illinois in 1956 and was the Beverly Road Bridge located at the intersection of Northern Illinois Toll Highway and Beverly Road in Cook County

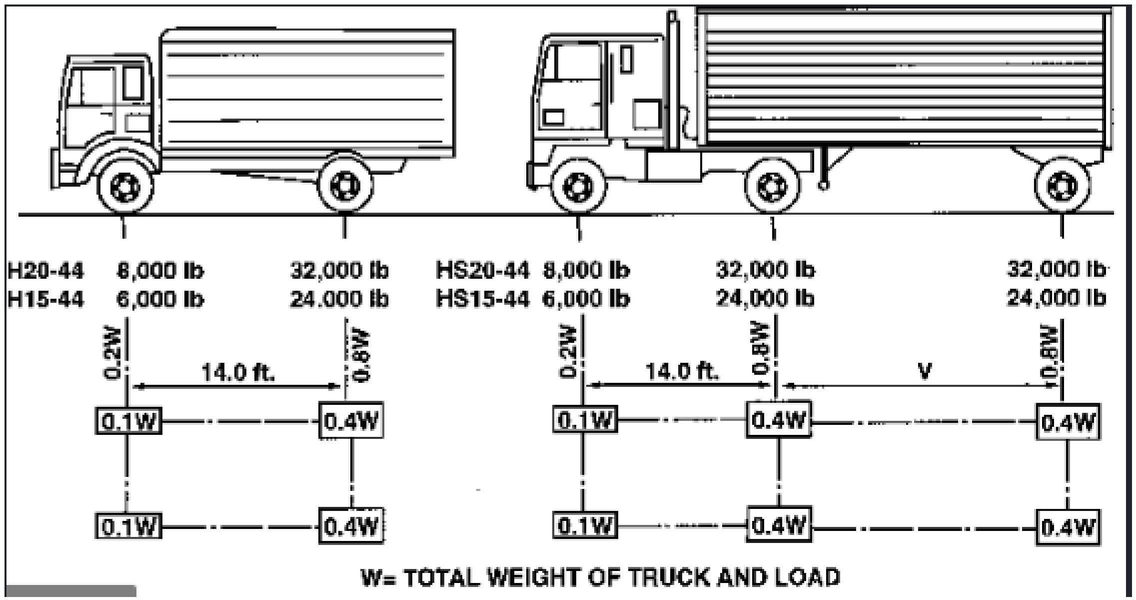
Details of Illinois PCP, 1956

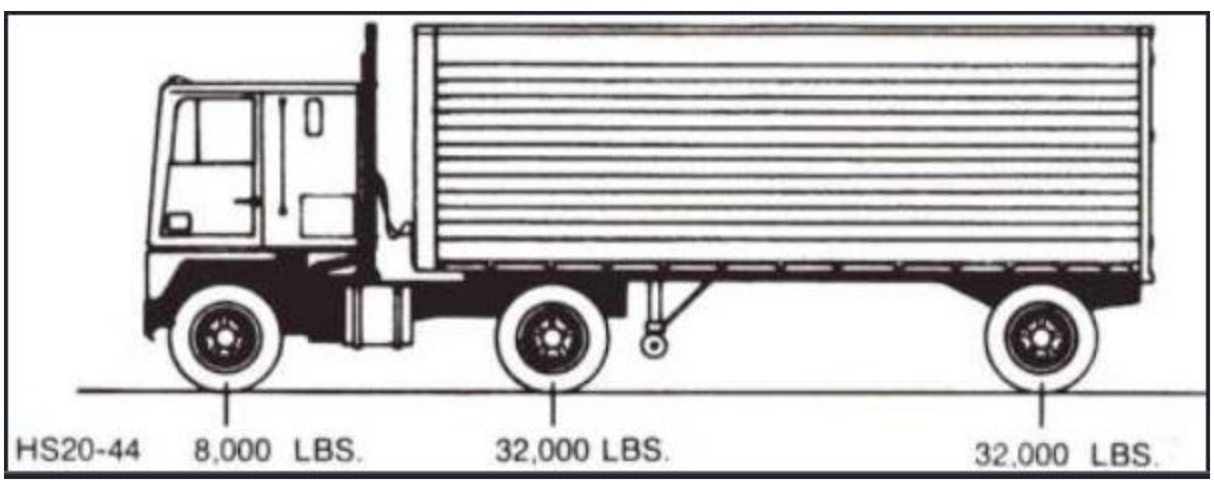


Complete and positive composite action between the precast girders; precast slabs and CIP slab

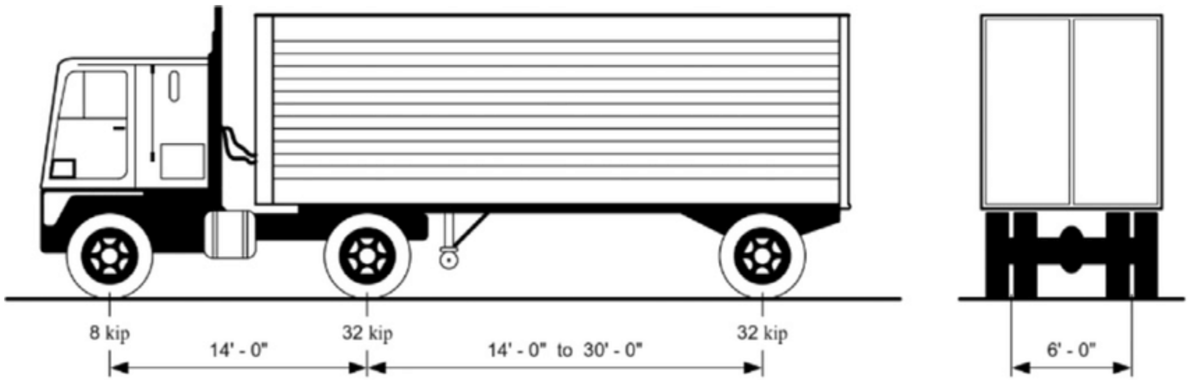
- tests were performed on the bridge that included piles, girders and slabs.
- Additional tests were conducted at Lehigh University on portions of composite deck slab.
- The resulting girder and slab moments were, in most instances, far in excess (even 7 times) of design moments based on AASHO H-20 truckloads plus impact.

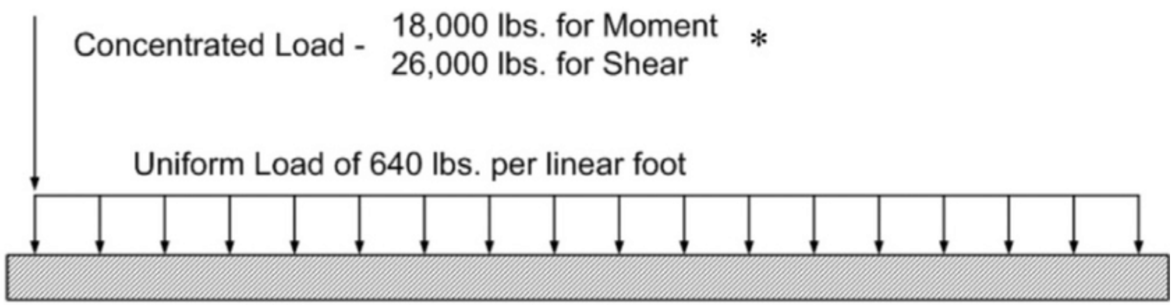
AASHTO Trucks





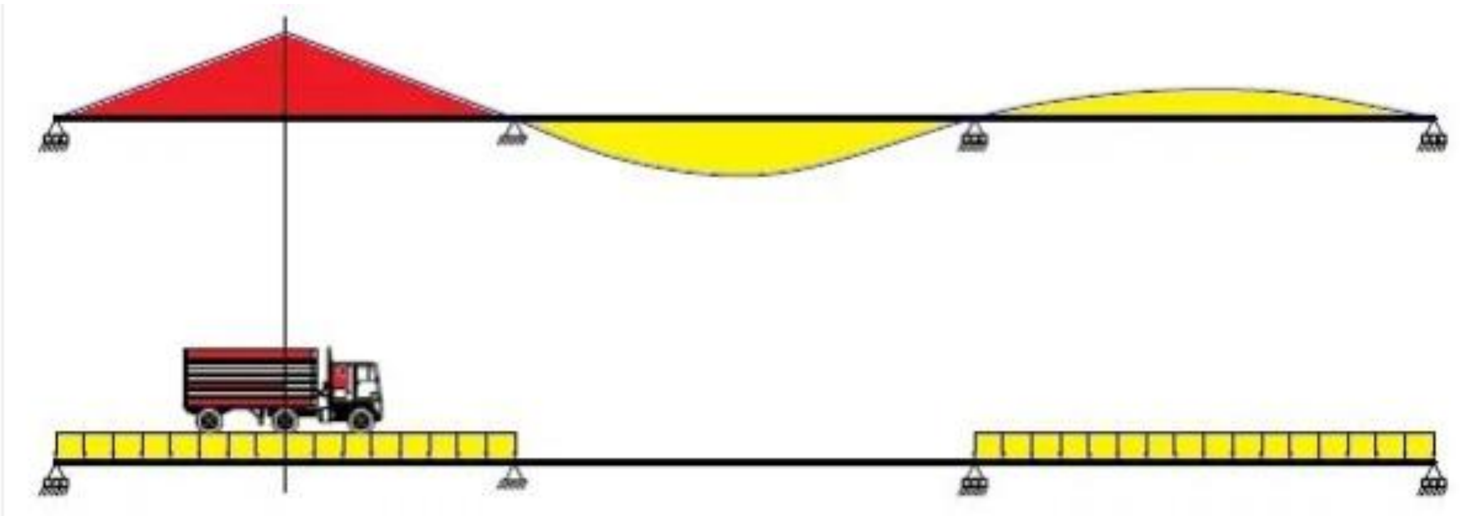
For H20-44 and HS20-44:
Concentrated load 18 kips for moment
26 kips for shear
Uniform loading 640 lb/ft of load lane





H20-44 Loading
HS20-44 Loading

Design vehicle and lane loads should be applied in such a way that extreme force effect is obtained for design.



impact factor to increase the live load to account for the bounce and sway of vehicles.

$$I = \frac{50}{L + 125} \leq 0.3$$

where L is the length of the span in feet

Joint Detail Problem

- In the 1980's Florida DOT abandoned PCP deck
 systems as a result of cracking problems
- Joint detail identified as problem in the mid 1980's by Florida and Texas
- Precast panels supported on flexible fiberboard,
 experienced severe cracking and spalling

Joint Detail Problem

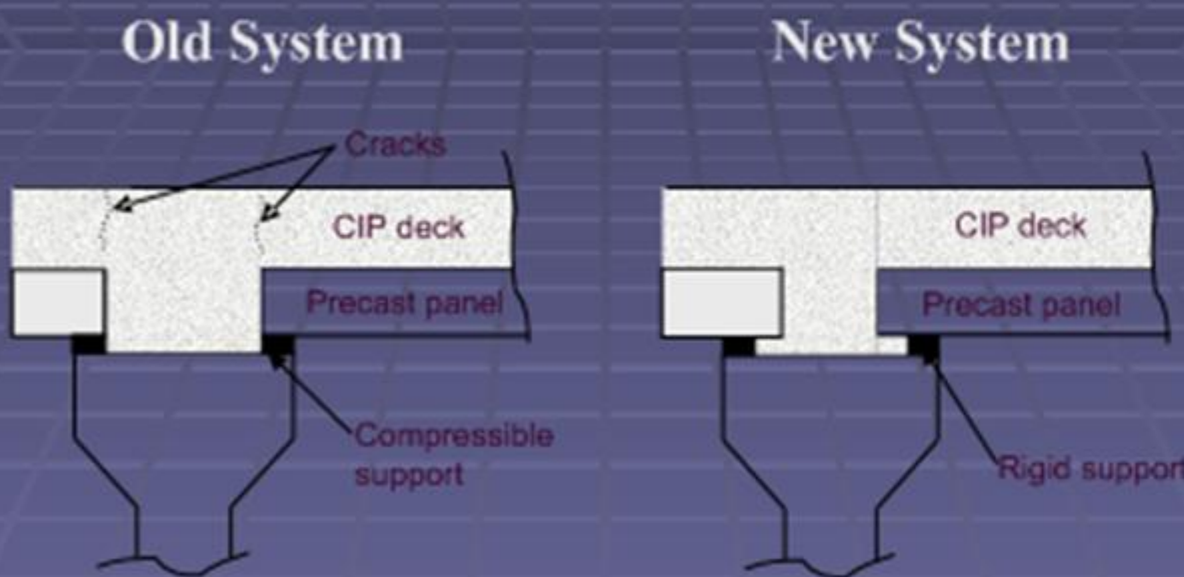
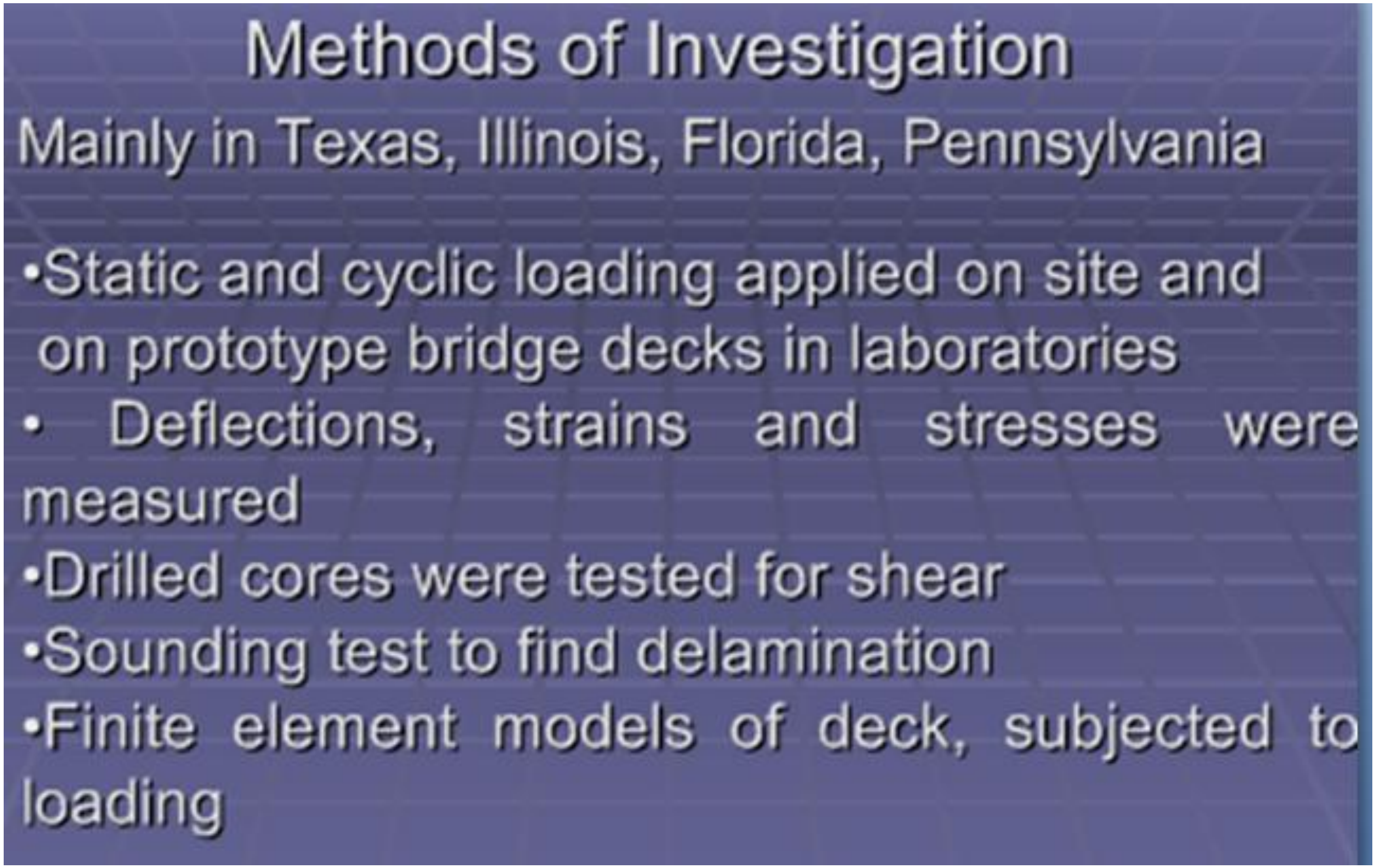


Fig. Courtesy: Prof. Ronald A. Cook, UFL

Research-Focus for PCP as SIP System

- Composite behavior of PCP Deck
- Significance of Shear Ties at interface
- Fatigue Capacity and Nature of Failure


Methods of Investigation
Mainly in Texas, Illinois, Florida, Pennsylvania
•Static and cyclic loading applied on site and on prototype bridge decks in laboratories
• Deflections, strains and stresses were measured
•Drilled cores were tested for shear
•Sounding test to find delamination
•Finite element models of deck, subjected to loading

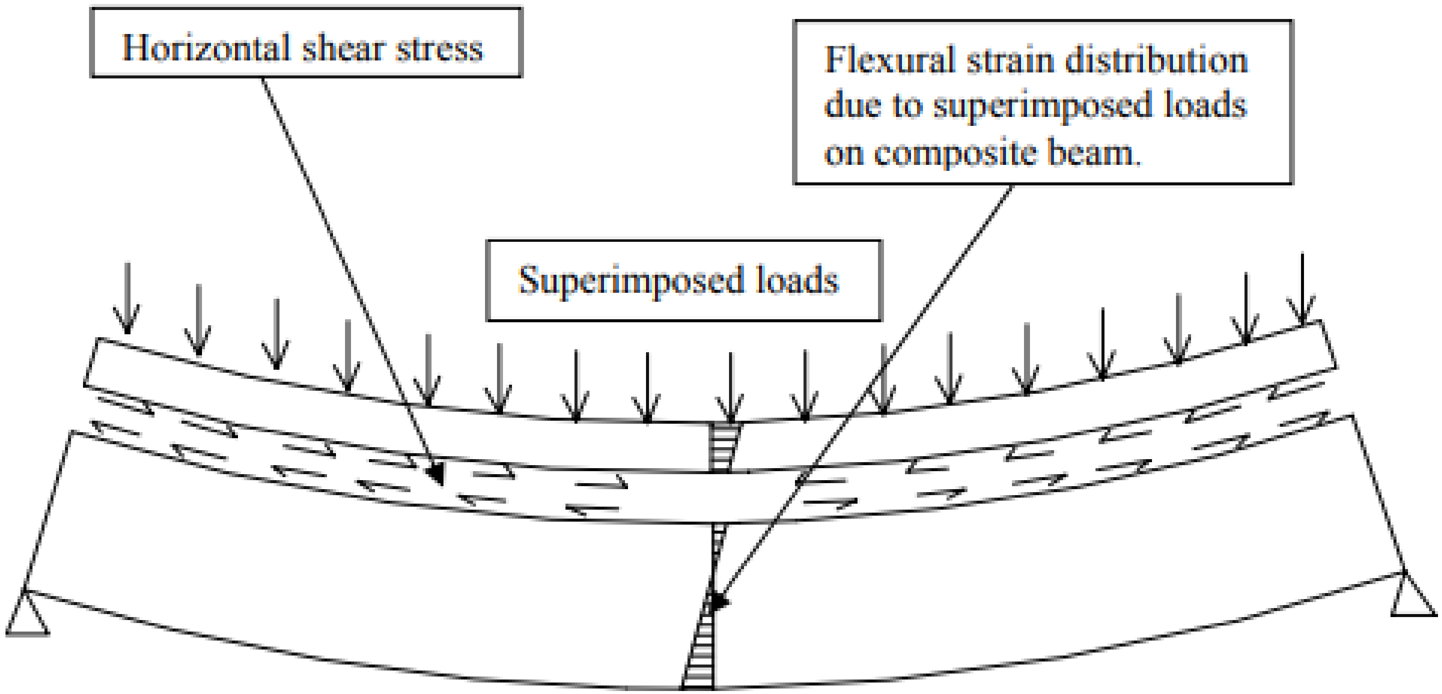
Conclusions from researches

- Complete and positive composite action between SIP panels and CIP topping prevailed
- No need for shear ties in the panels as long as the top surface is roughened
- Current AASHTO code is too conservative as evidenced from static and fatigue loading tests

Bridge Deck Replacement by PCP-PD at NH in 2002

Photo Courtesy: Prof. Raymond A. Cook, UNH

Development of shear forces during composite action



horizontal shear stresses, V_h

$$v_h = \frac{VQ}{Ib}$$

where V_h = horizontal shear stress
V = vertical shear force at the section considered
Q = static moment of area of the slab or flange about the neutral axis of the composite section
I = moment of inertia of the composite section
b = width of the section considered

Spread Sheet for Shear Flow Calculation at the PCP-CIP Interface
Calculated for Typical NHDOT PCP as SIP Bridge Deck

Thickness of Deck (inches)		8.5		
Spacing between Girders (ft)		8		
Panel Width (ft)		4		
Panel Thickness (inches)		3.5		
Description of Live Load				
Worst Possible Loading:				
Military Vehicle-25kip Axle Load at 4 ft apart with 6 ft between the wheels				
and the distance between the nearest wheel and girder is 0.75of the slab thickness				
Load Factors				
Multiple presence factor			1.2	
Overload factor for vehicular Live Load			1.75	
Impact			1.33	
Loading			REACTIONS	
Right Wheel (kips)	34.9		Right support (kips)	39.0
Left Wheel (kips)	34.9		Left Support (kips)	30.8
			Design Shear (kips)	39.0
Area for CIP Concrete (in^2)		240		
Q (in^3)		420		
Moment of Inertia (in^4)		2456.5		
Shear Stress Flow (VQ/It) (psi)		138.9		

Note that, here, t=Panel width and Inertia, I =(t)(h)^3/12

Test Results From Prototype PCP-PD Deck At NHDOT

Property	Remark	Avg.
Shear Stress	Tested at interface parallel to roughened panel surface	241 psi
Shear Stress	Tested at interface perpendicular to roughened surface	108.3 psi
Tensile	Failed at interface between SIP and CIP	190.0 psi

Typical NH Panel System

Photo Courtesy: Prof. Raymond A. Cook, UNH

Panel End Support Detail at NH

Photo Courtesy: Prof. Raymond A. Cook, UNH

Panel End Support Detail at Texas

Photo Courtesy: Prof. Ronald A. Cook, UFL

System Used Extensively in Texas

Photo Courtesy: Prof. Ronald A. Cook, UFL

Typical Texas Panel System

Photo Courtesy: Prof. Ronald A. Cook, UFL

1986-87 PCI Survey Status

Number of States that were using the system	24
Number of States that abandoned the system (FL, WV)	02
Number of States that never used the system	21
Number of states that did not use it before but considering future use – Oklahoma*, Maine*, Arkansas	03
Total states	50

* Currently use the system

2002-03 UNH Survey Status

Number of States that currently use the system	25
Number of States that discontinued the system	11*
Number of States that never used the system	13
Number of states that did not use it but considering future use -(Vermont)	01
Total states	50

*Most of them do not have well documented & sound explanation

Major concerns of PCP system

1. Cracking - both Longitudinal & Transverse cracking
2. For continuous bridges at the negative moment regions
3. In areas with severely skewed joints, severely tapered spans or in curved girder spans

Tackling the longitudinal cracking

"Illinois DOT eliminated most of the longitudinal cracking by requiring the planks to be 60 days old. at the time the deck is poured. The cracks are due to the shrinkage, creep and elastic shortening of the prestressed planks. 90% of these take place in the first 60 days since the casting of the planks With 90% reduction the tensile stresses that are transferred to the cast portion of the deck are reduced to below the cracking stress of the concrete." –Salah Y. Khayyat, P.E., Illinois DOT

RESPONSE TO OTHER CONCERNS

- Transverse cracking is a durability issue, most of the full depth cast-in-place decks have the same problem
- Most of the PCP bridges have continuous spans & there is no problem in the negative moment region
- Missouri DOT is using steel SIP form in case of curved bridges

Concrete vs. Steel SIP forms

- Some states use steel SIP for most of their bridges(AL) while some states employed probation(MS) and some use both (MO) of them.
- Problems with steel SIP pointed out as
  - Inspection problem
  - Possibility of becoming a pan to gather water
  - Rusting out of the metal panels in areas of heavy salt use

Proposed BD DECK 1

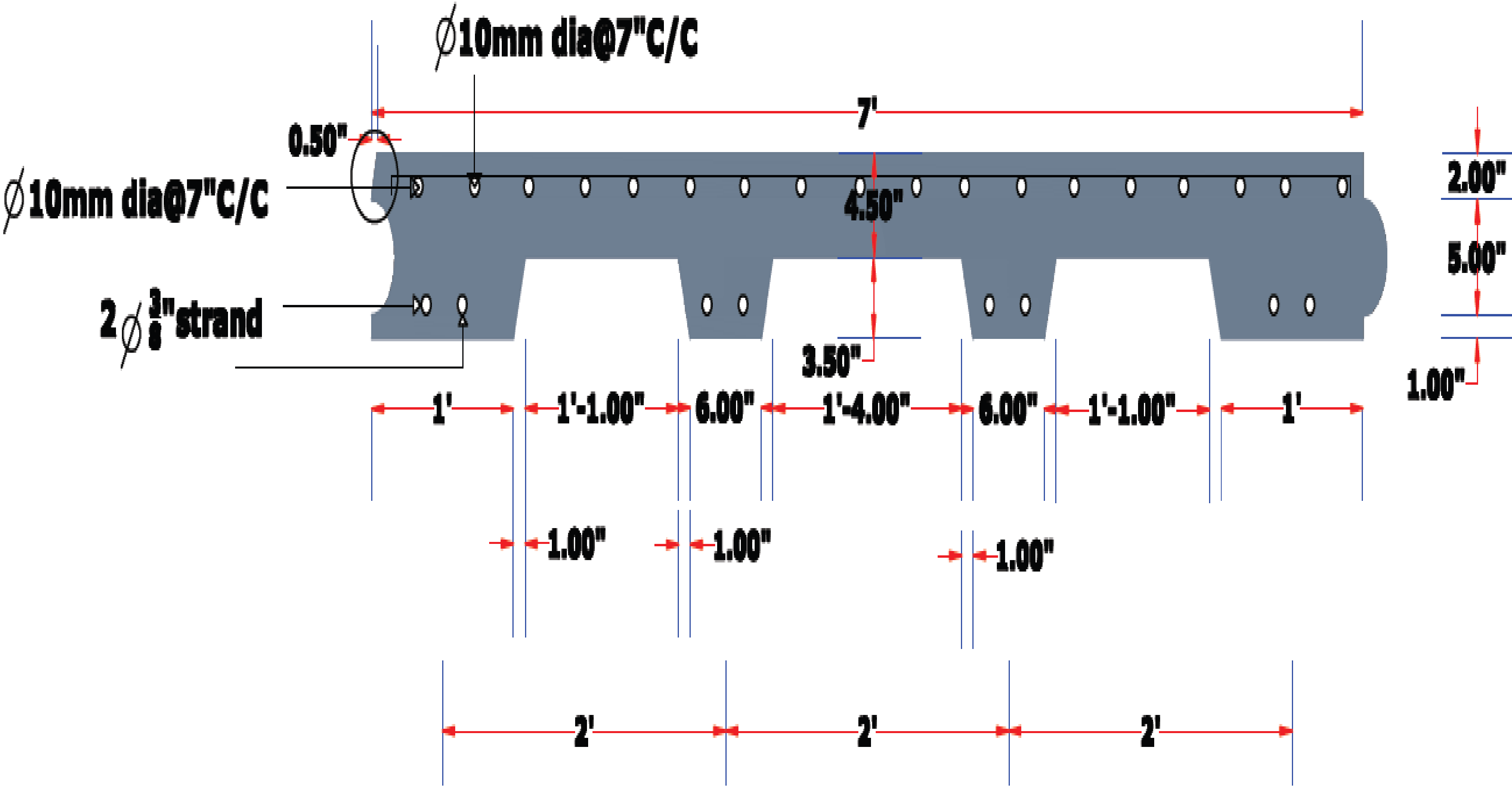


Fig: Typical cross section of BD Deck 1

Proposed BD DECK 1

- The crown can be achieved by the base support under the panels.

- At the top, a **0.5 inch gap** is provided between two panels, which is filled with **bitumen filler**. This will prevent concrete expansion and contraction **cracking**.

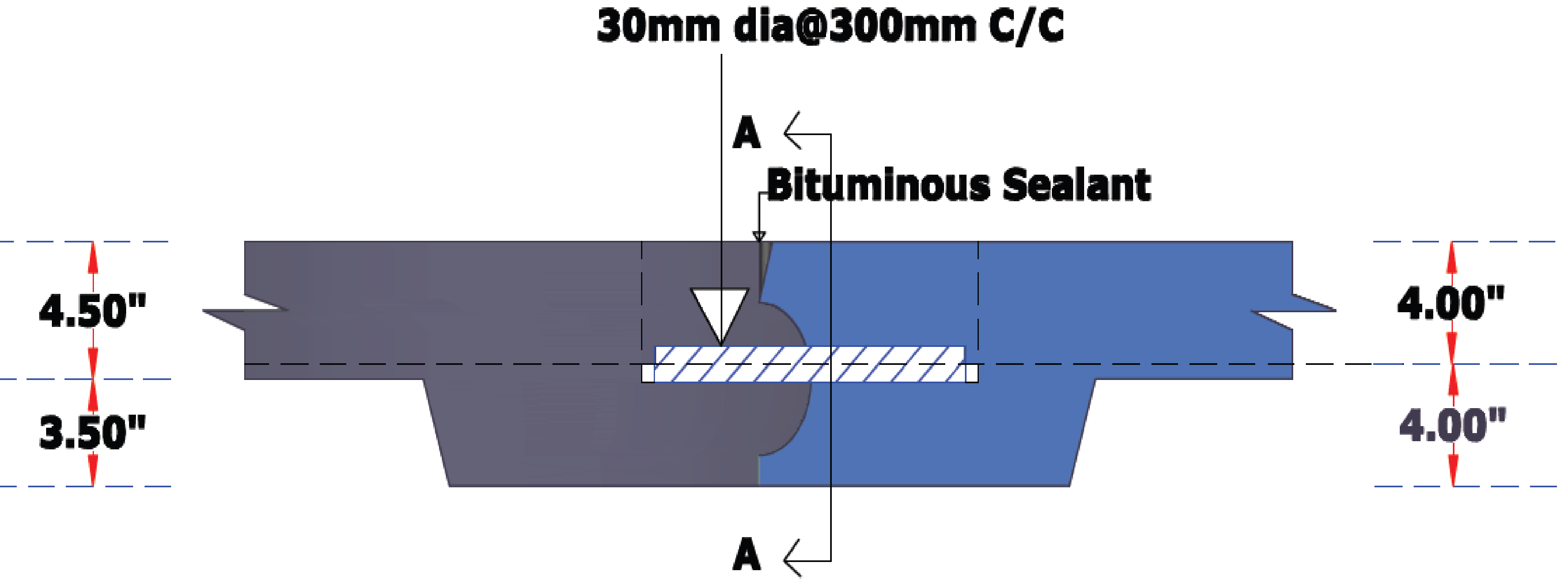


Fig : Contraction Joint with Dowel Bar

Proposed BD DECK 1

- The deck panels will be **joined** by using **dowel bars**. These dowel bars will be placed within the **shear pockets** and then filled by **non-shrink grout**.

- If needed, a **bitumen overlay** for a smoother surface, with approximately **3 inches** at the crown and **1 inch** near the curbs can be provided.

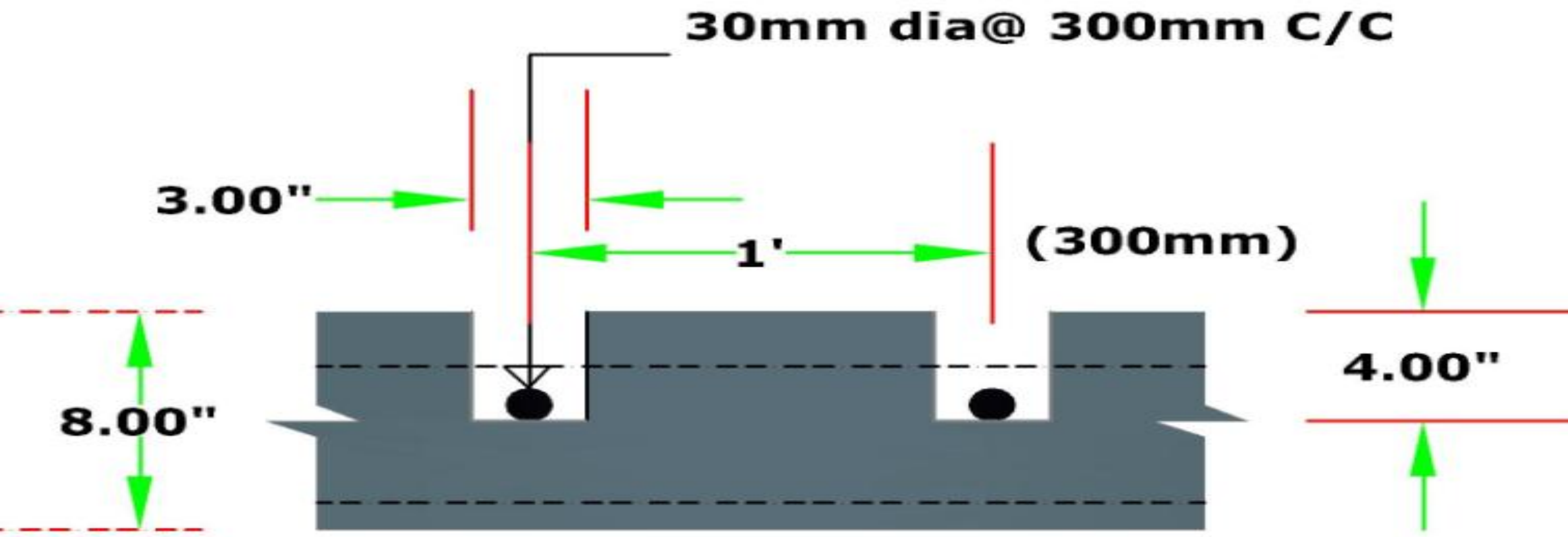


Fig : Section A-A

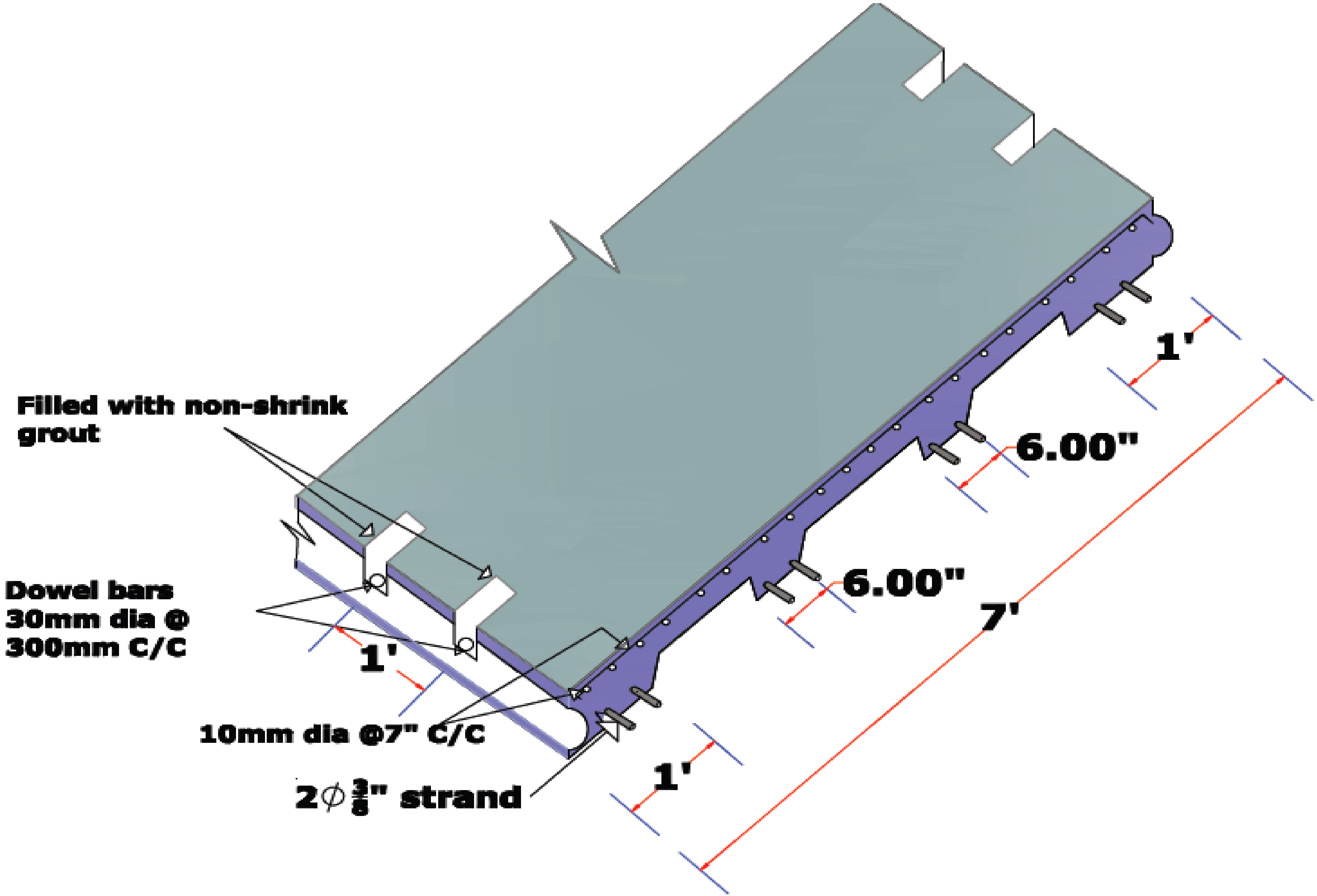
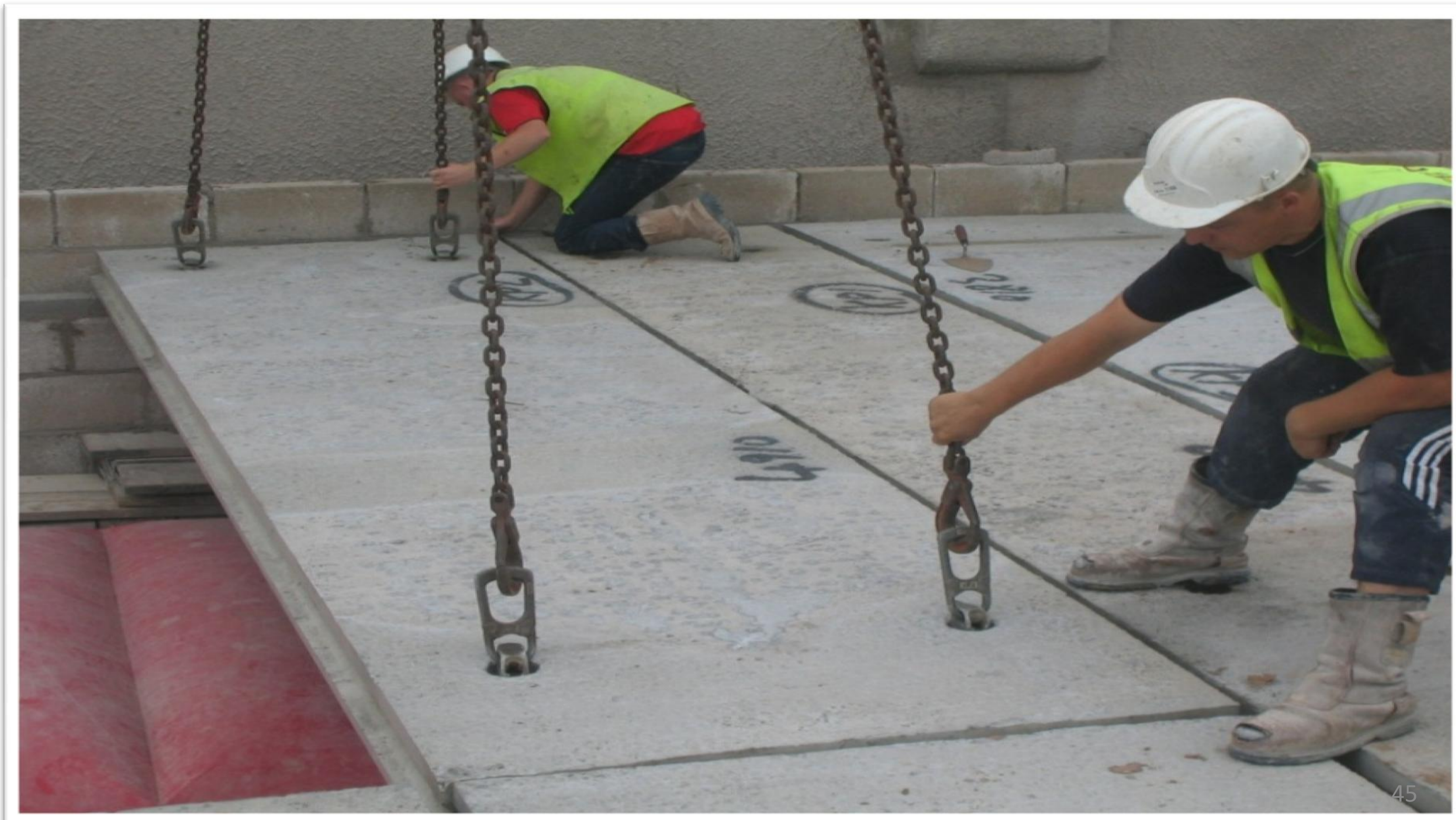
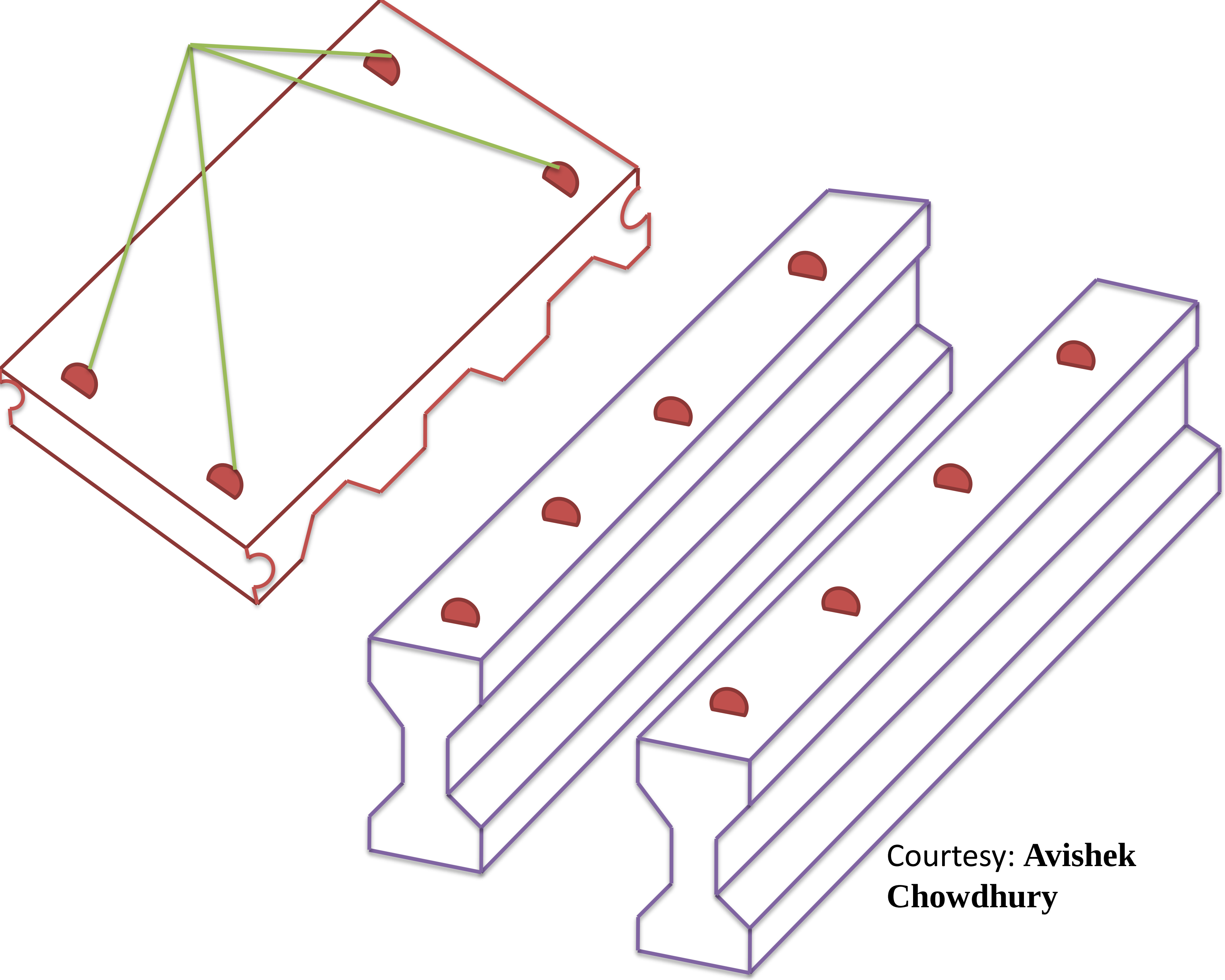


Figure : BD Deck 1

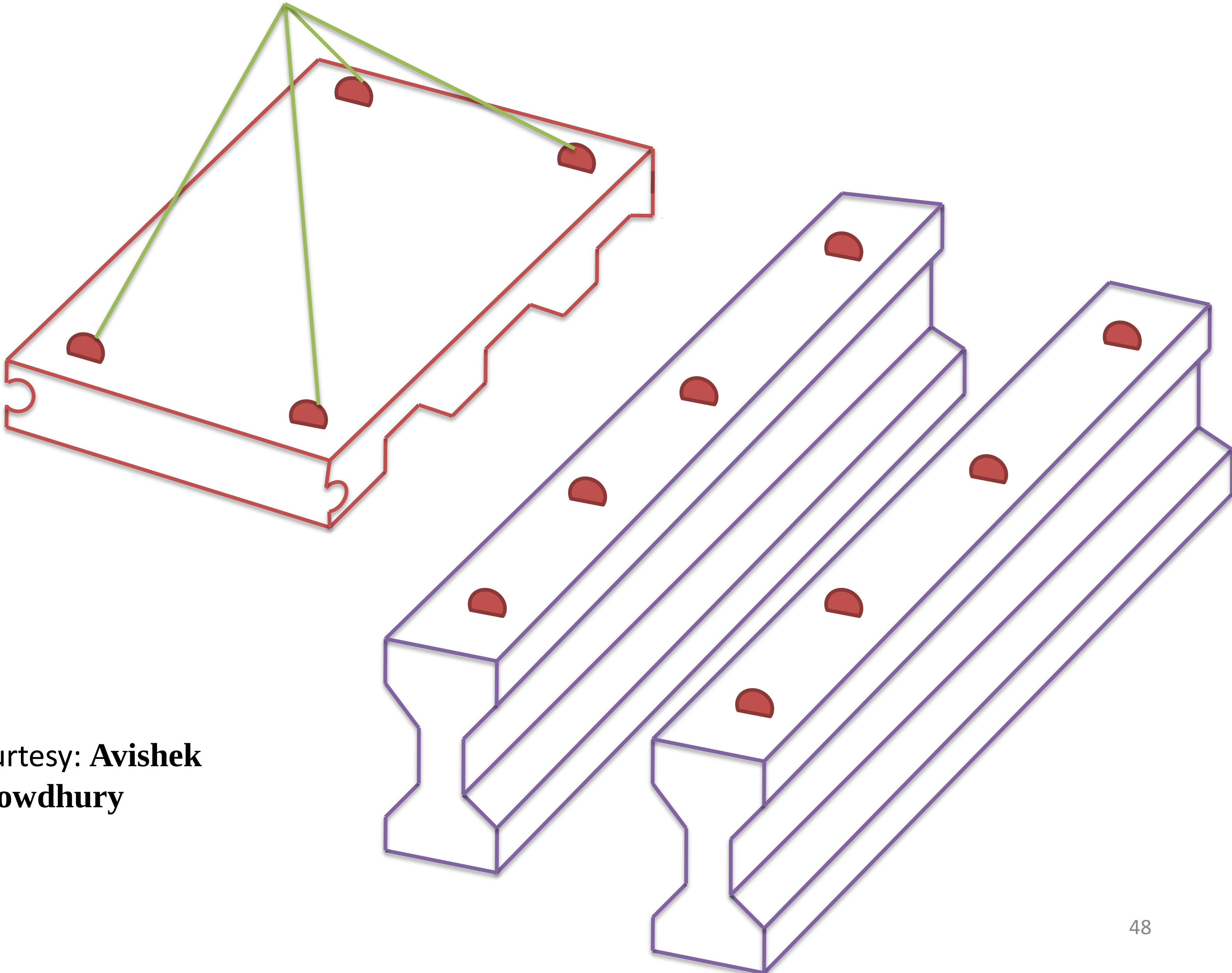
Lifting of the Deck Slab



Lifting of the Deck Slab



Courtesy: **Avishek Chowdhury**



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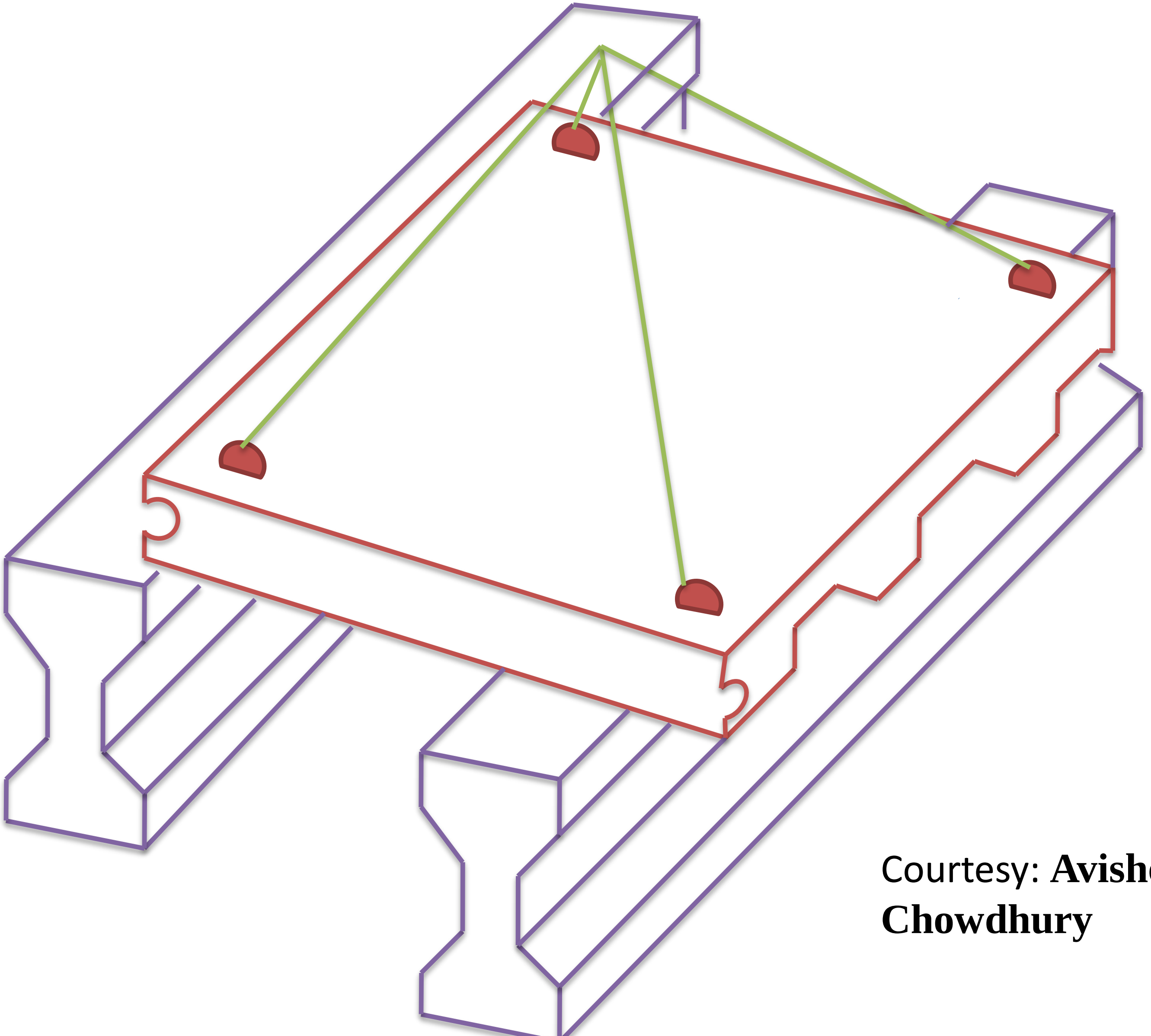

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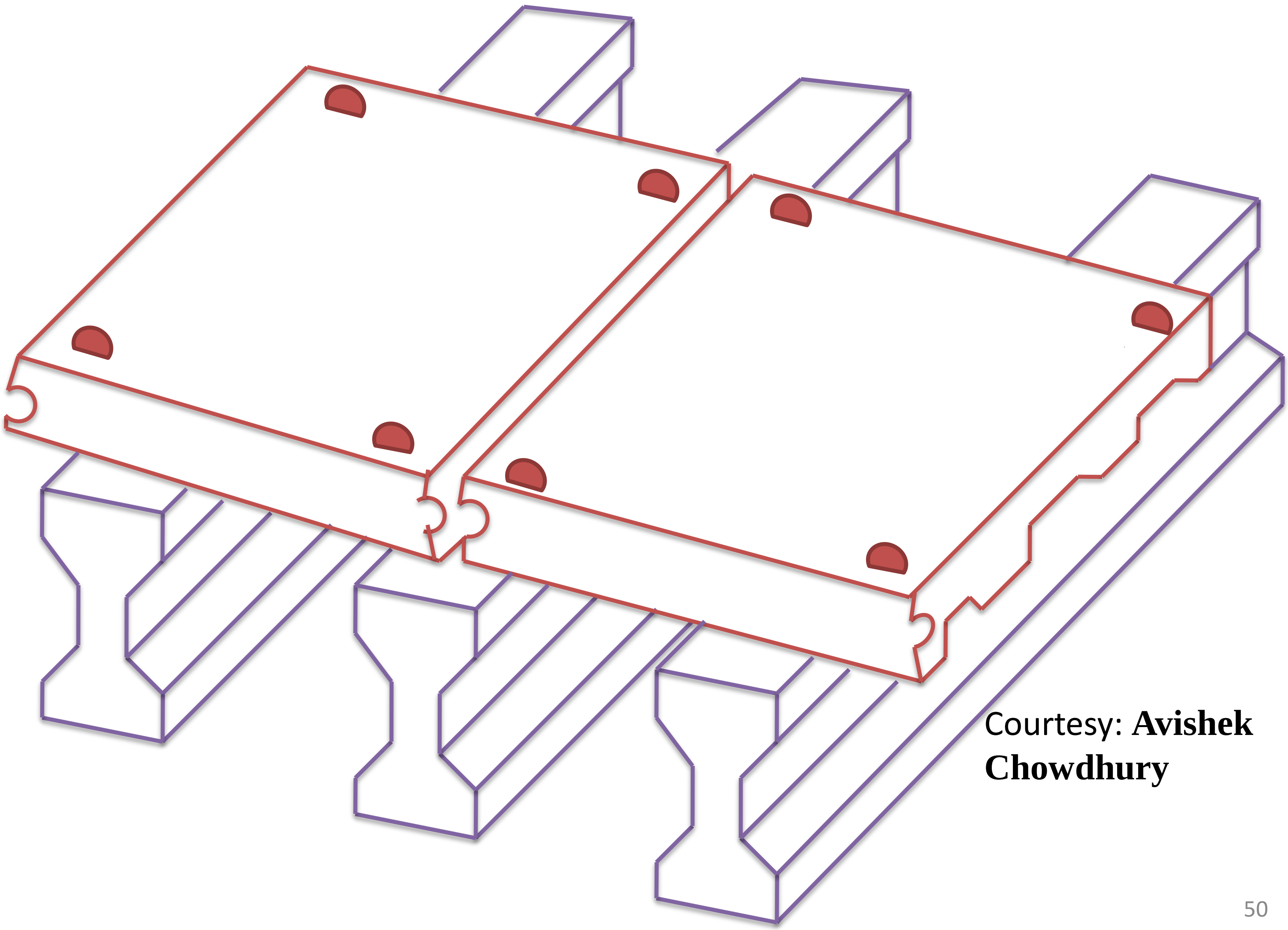

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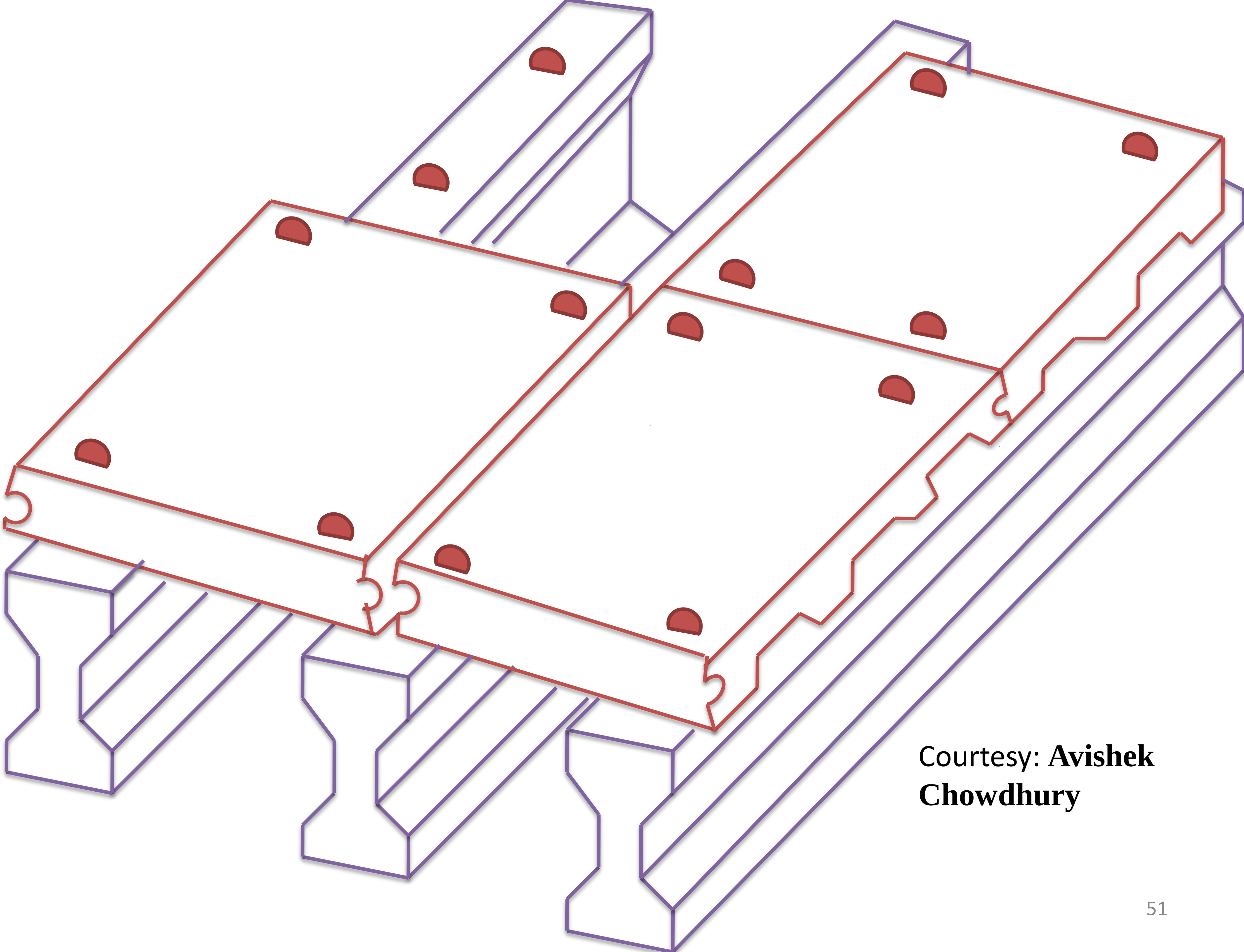

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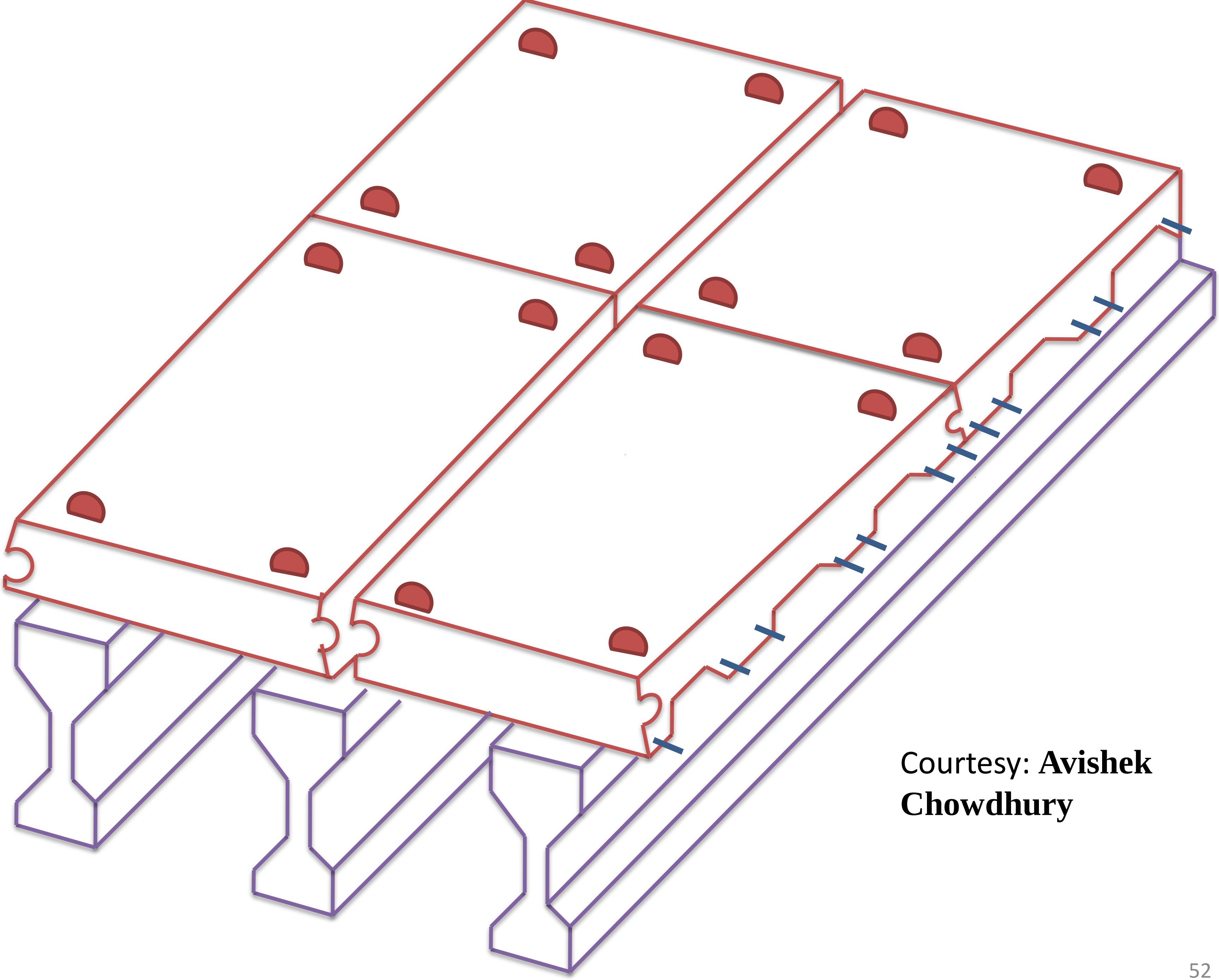

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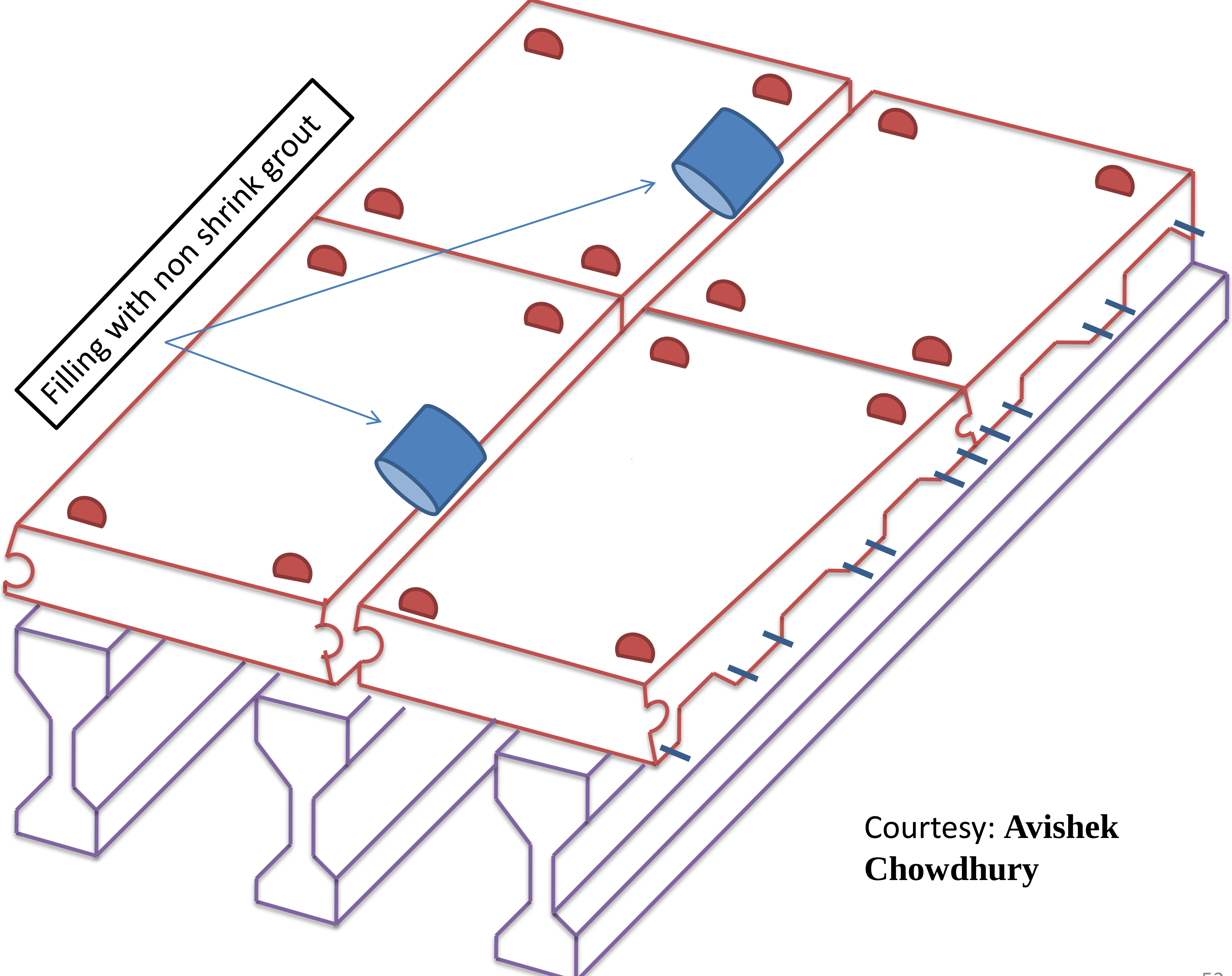

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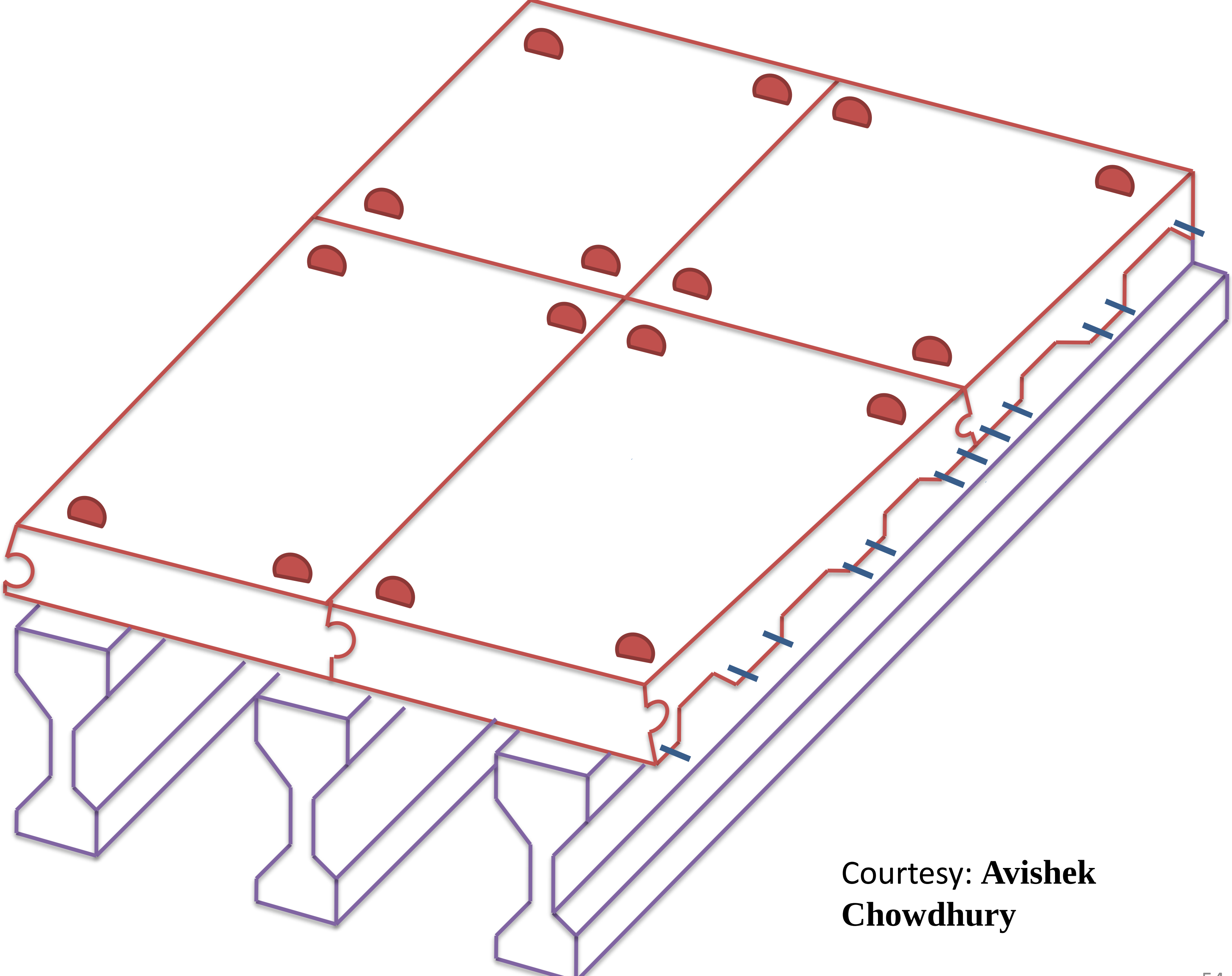

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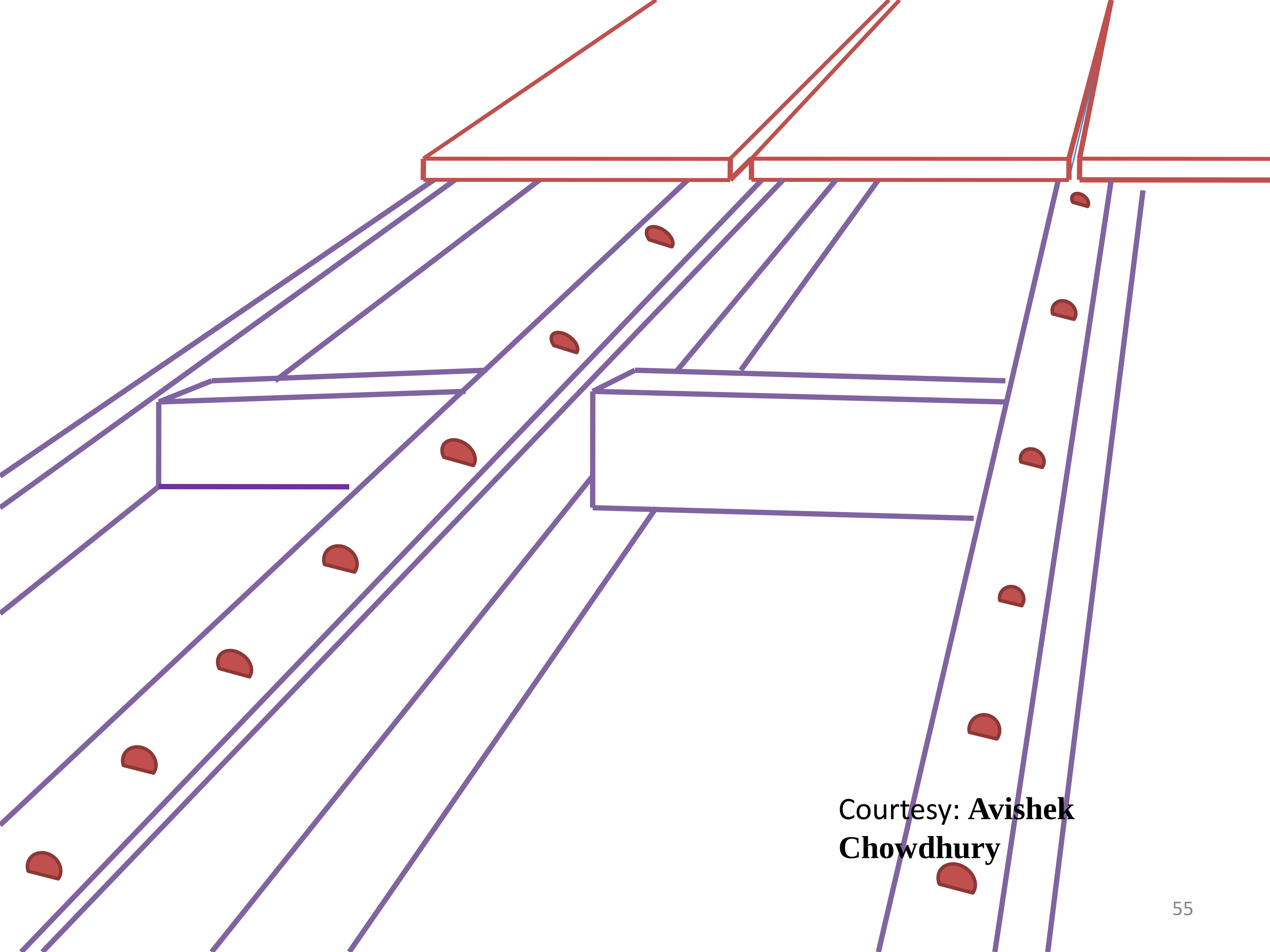

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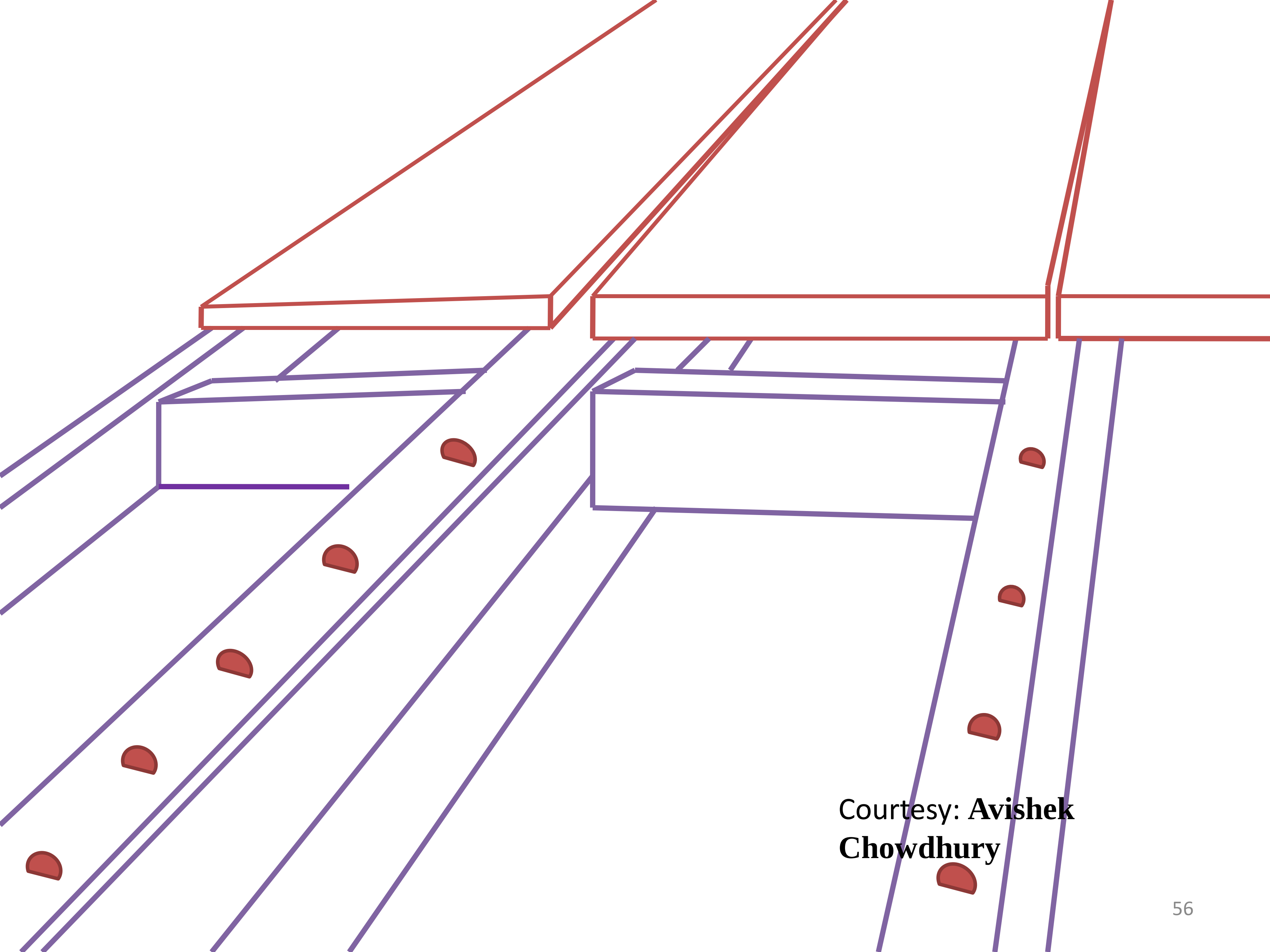

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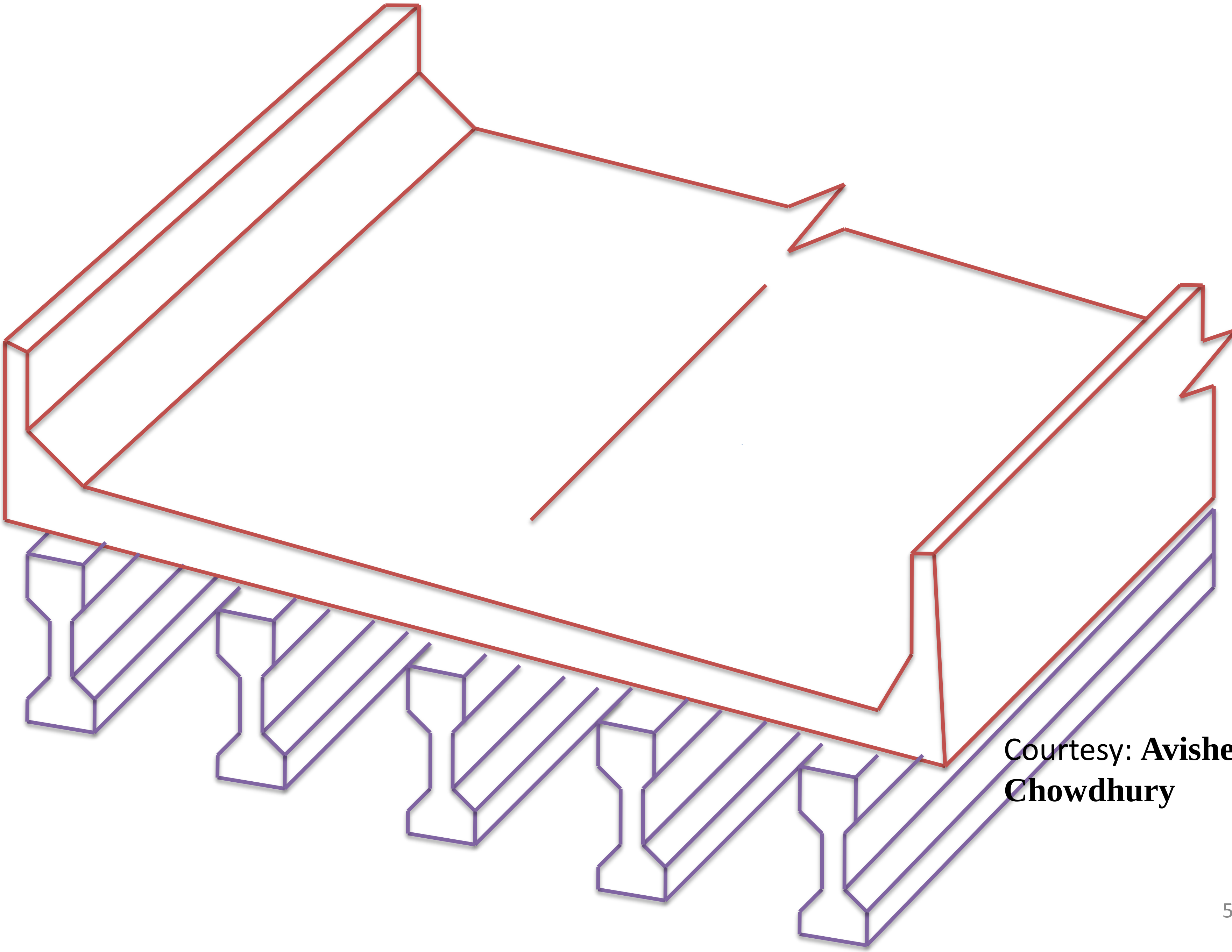
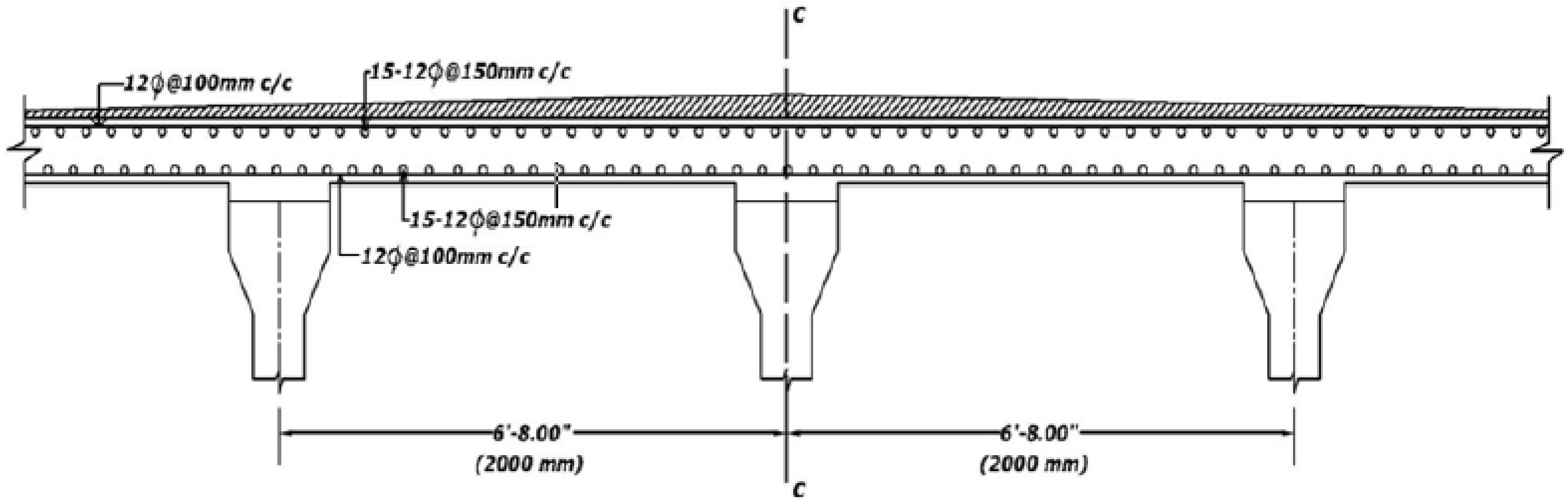


Courtesy: **Avishek Chowdhury**


Transportation of the deck slabs is
easy
cost effective
reduces time
Courtesy: **Avishek Chowdhury**

Case Study



Reinforcement details of a typical bridge deck of a span of 27m

Cost Economy

If we use BD deck 1 instead of the regular deck then due to ribbed panels, the self-weight will be reduced by 24%,

Life Cycle Cost =

Initial Construction Cost

+

Total Operating Costs

+

Maintenance

Contact: drlatifee@gmail.com