Prof. Michael Oliva, University of Wisconsin

Construction and Design of a Reinforcement-Free Concrete Bridge Deck on Precast Girders

Discuss:

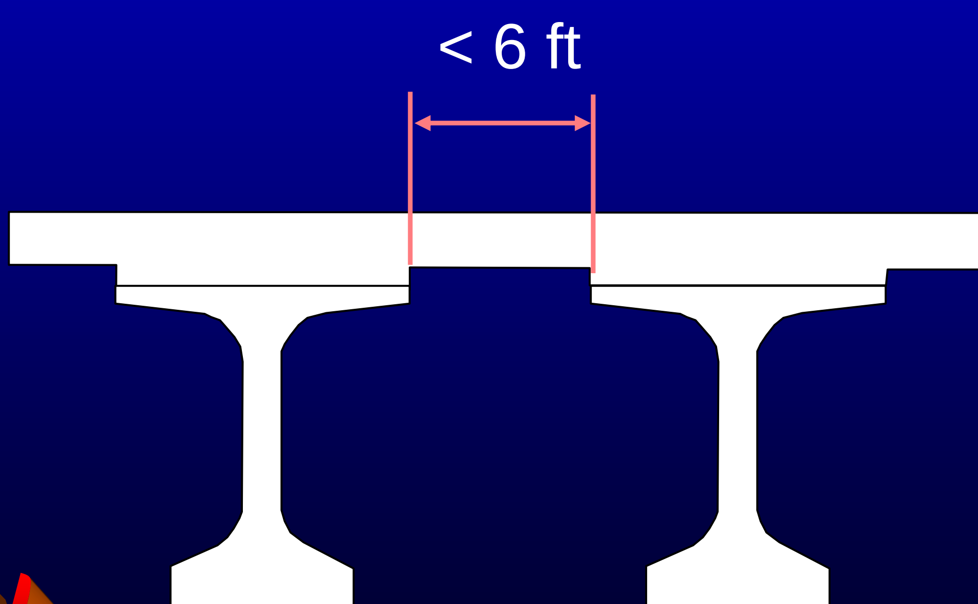
- **Development of steel-free deck idea**
- **Design for a prototype bridge**
- **Bridge construction & testing**

Authors: M. Oliva, H. Bae, L. Bank, J. Russell

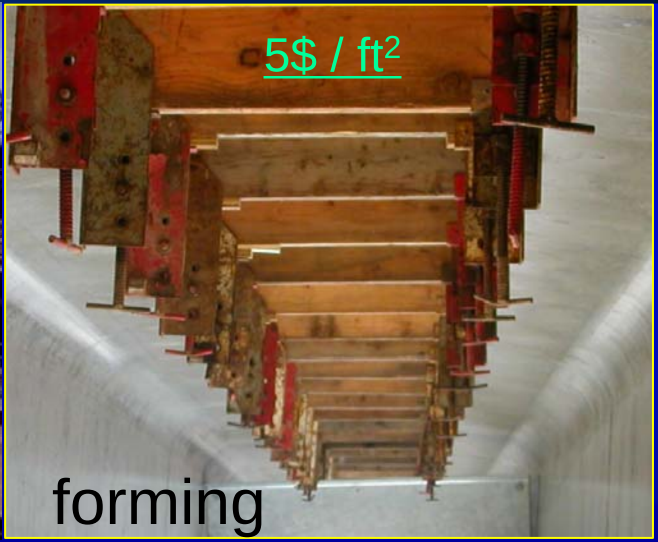
Idea:

New wide flanged precast girders are used at close spacings.

Bulb Tee girders



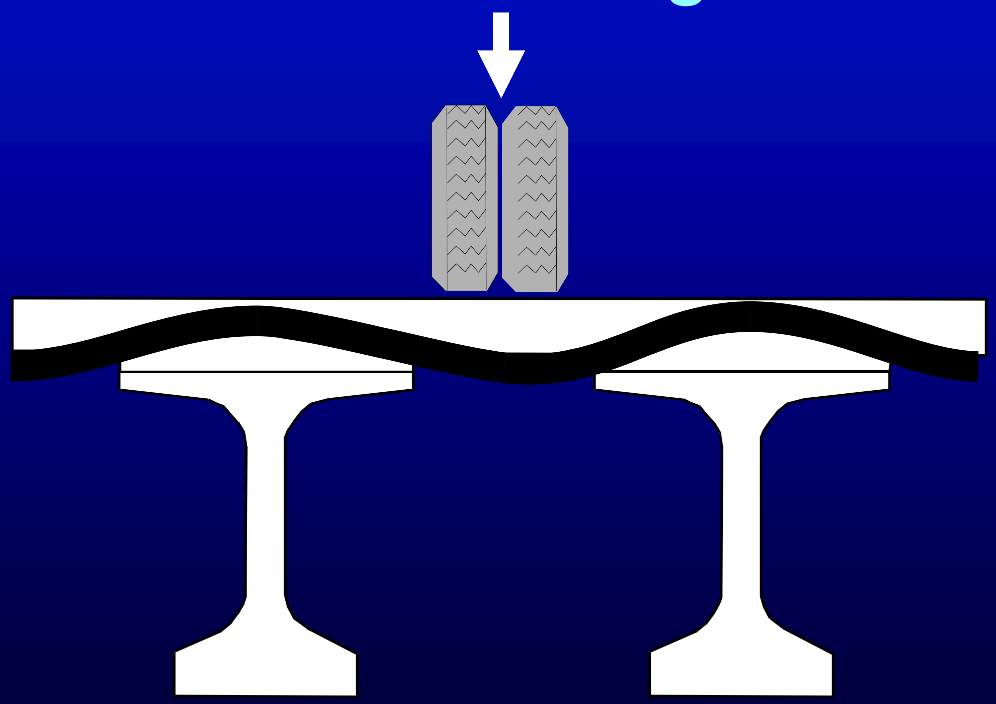
Contractors: **Can't we do something other than plywood forming?**



- short spans for forms,
- a lot of small pieces,
- significant safety hazard during removal;

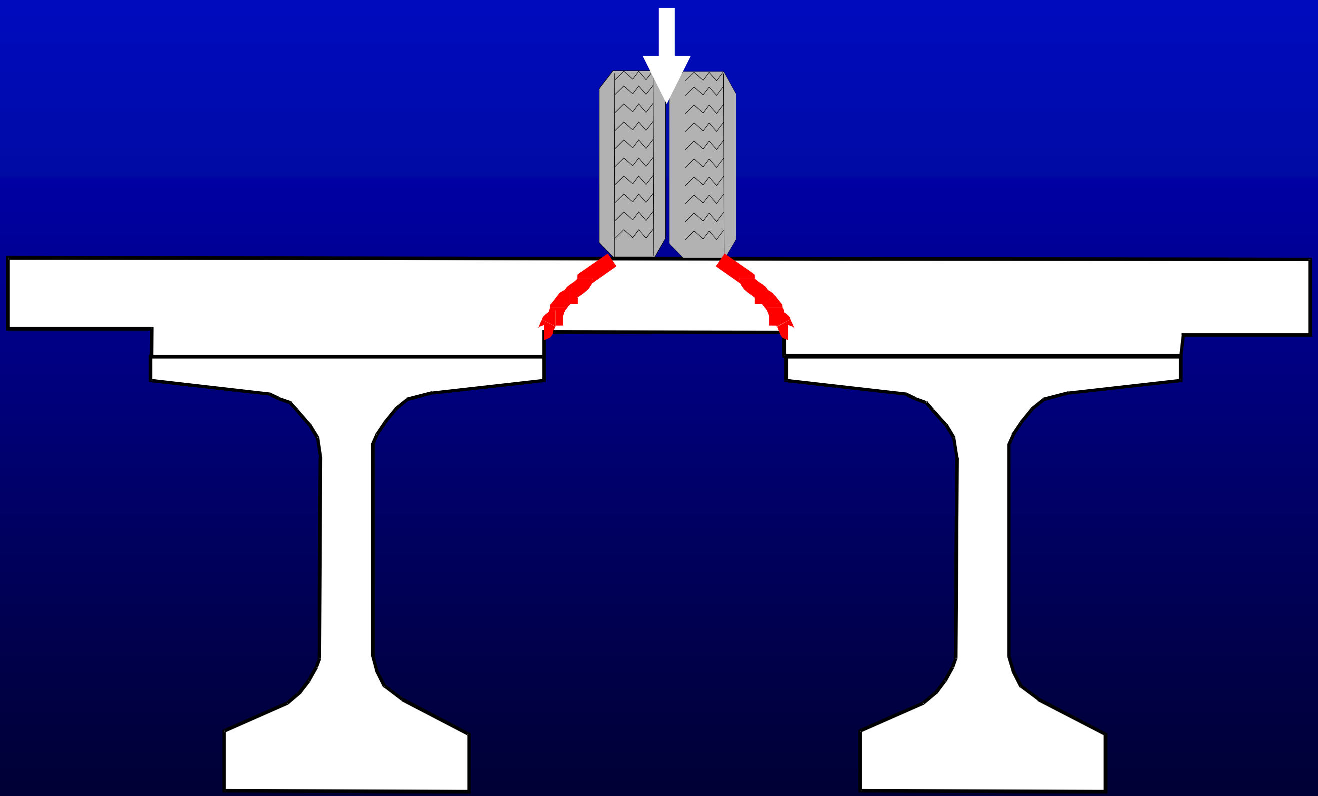
How does the short span deck work?

Conventional deck design is based on flexural strength



How does the short span deck work?

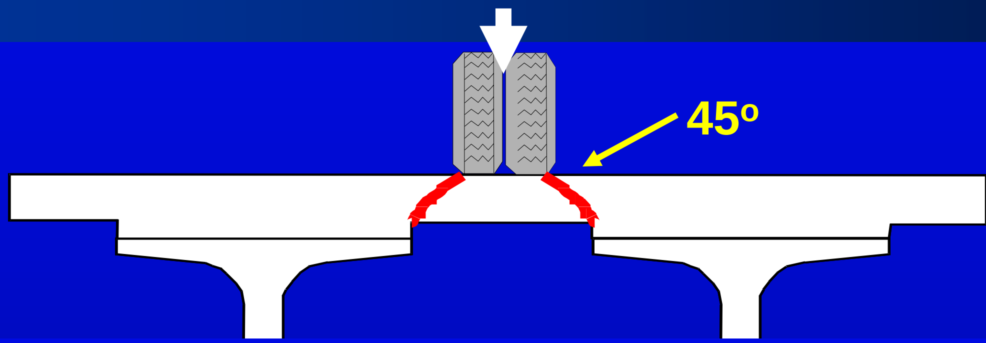
Actual failure
is in
shear - punching



Introduction: Problem

Need to develop a new bridge deck design method based on shear

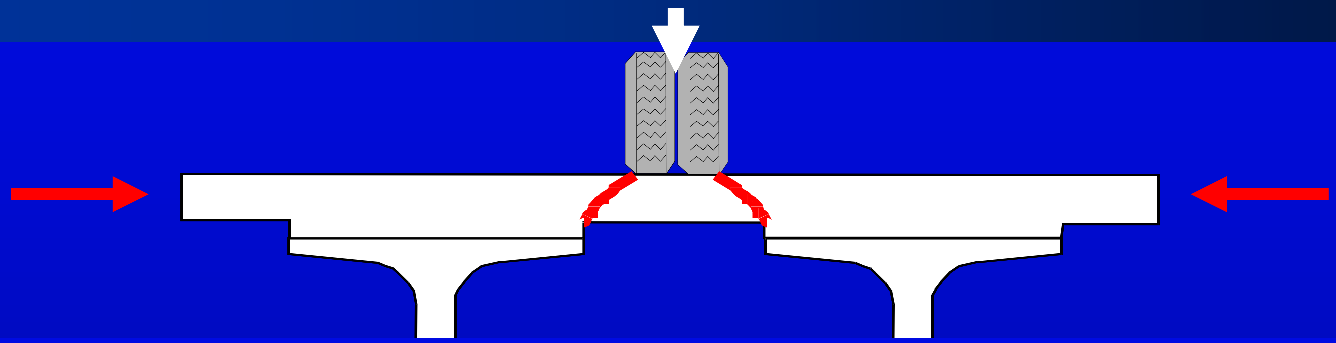
How does the short span deck work?



Normally: in unrestrained concrete we would expect to see a 45º shear cracking failure.

the failure plane size is defined by the 45º crack and combines with the strength of the concrete to provide the capacity

How does the short span deck work?



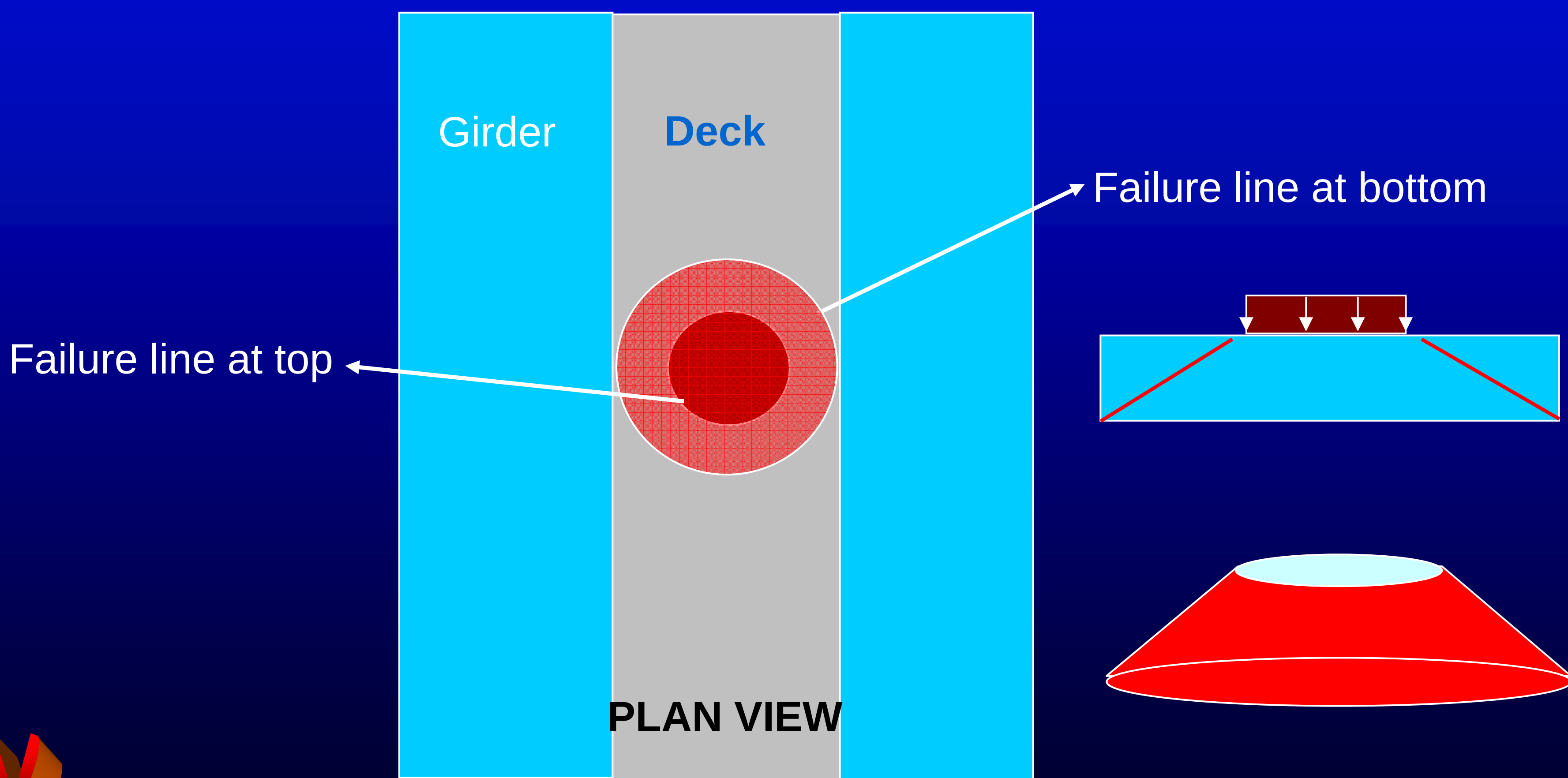
IF we can restrain the concrete deck,

(create compression inside the concrete)

then the shear crack angle becomes much less than 45º
and the capacity becomes larger

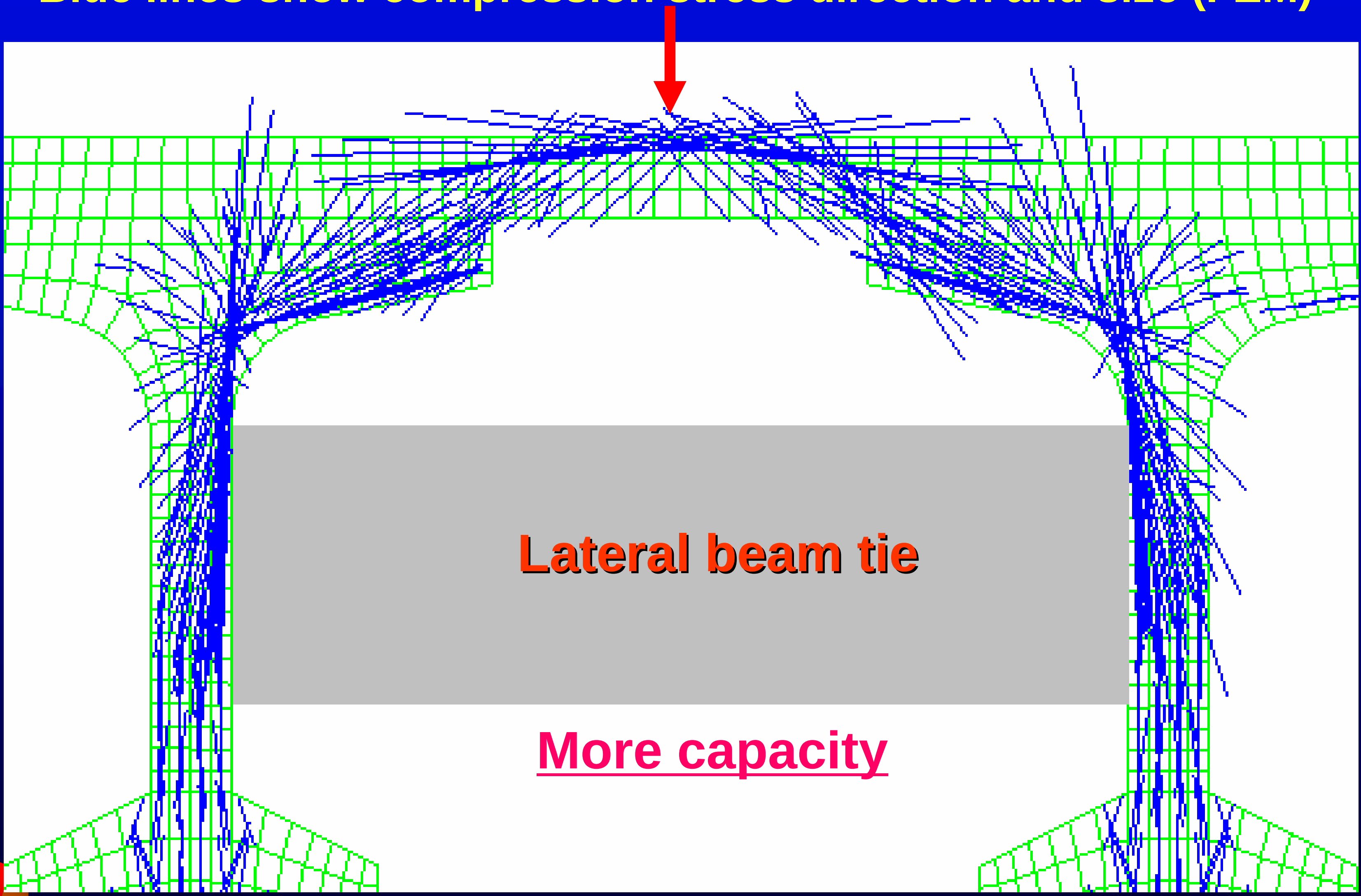
How does the short span deck work?

girders and deck surrounding the failure are providing "restraint" condition



How does the short span deck work?

Blue lines show compression stress direction and size (FEM)

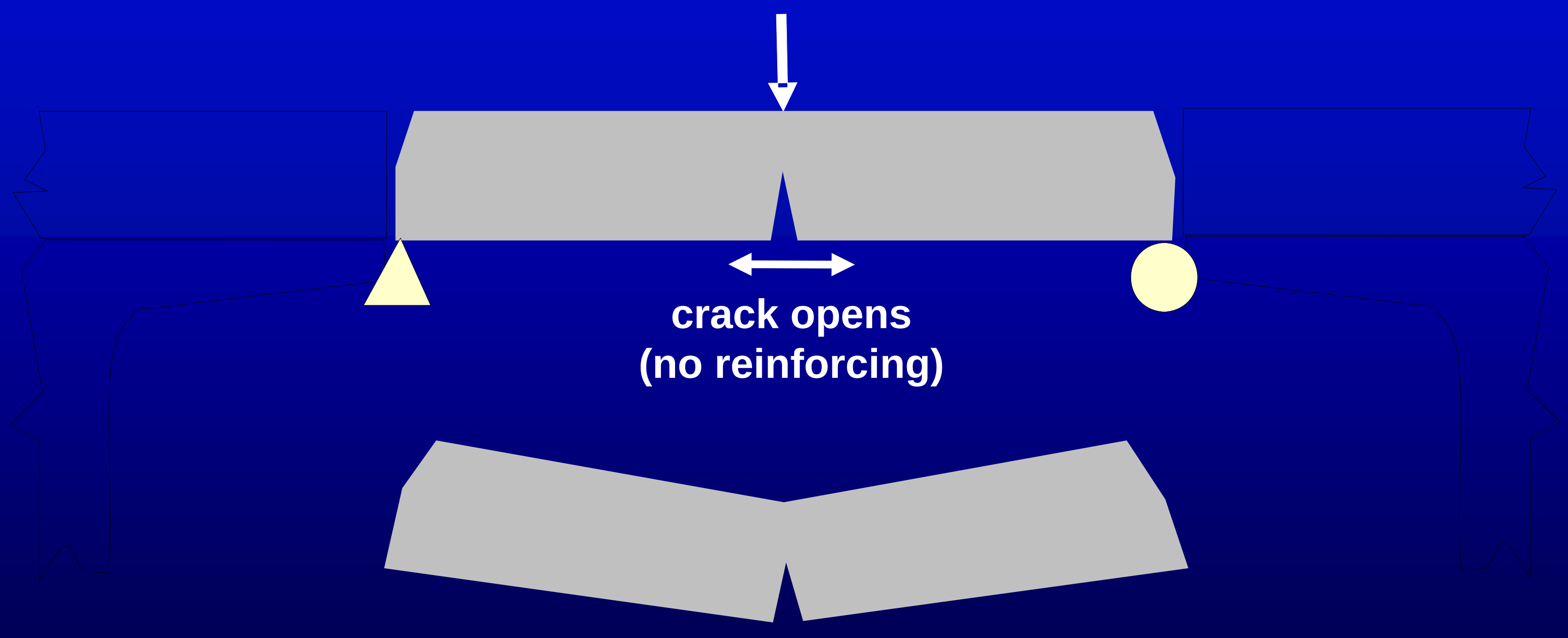


Making the deck system work?

Testing of ½ scale bridge deck system in laboratory:
3 span, different crack control in each span

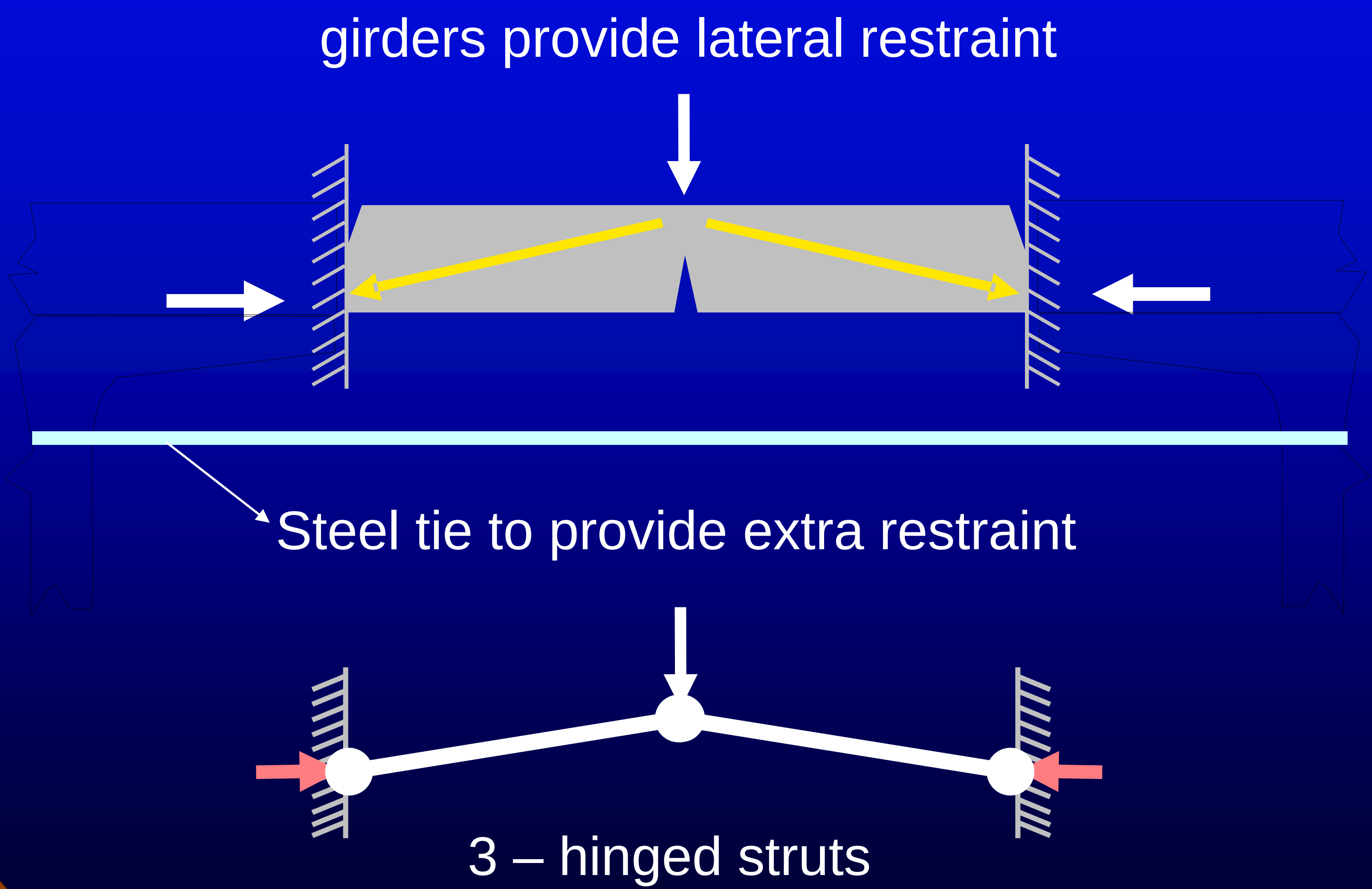
Actual behavior:

Without lateral restraint from girders:



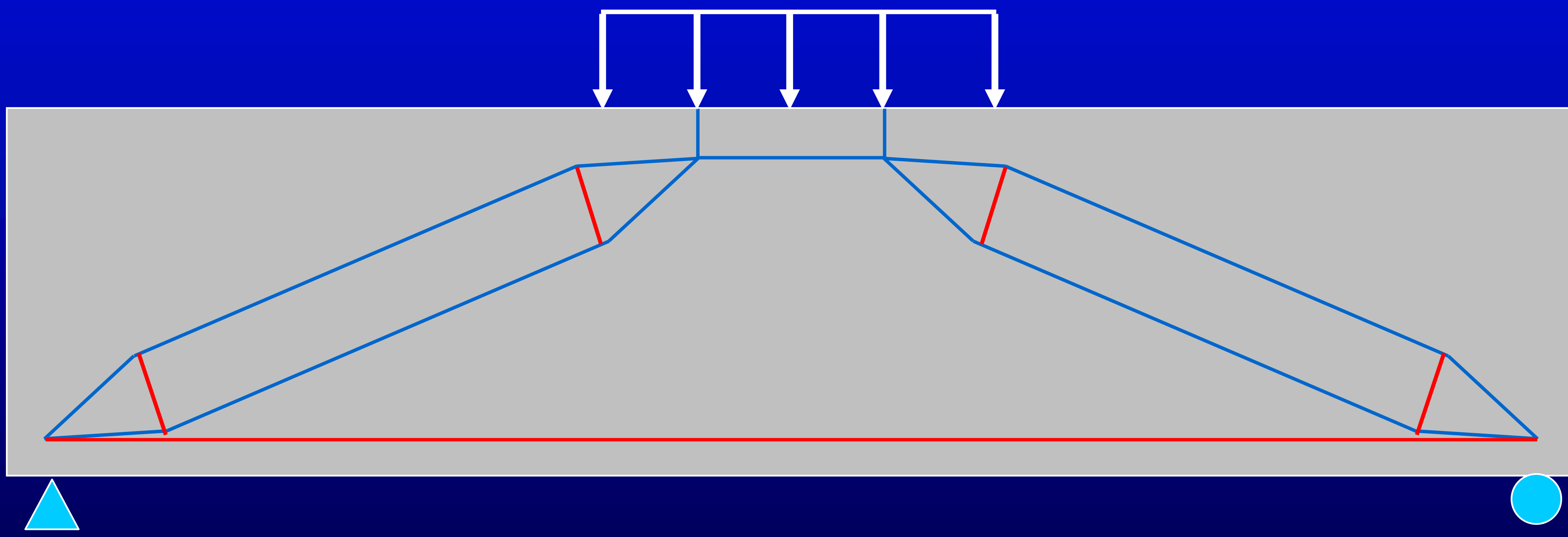
deck fails in flexure

Actual behavior:



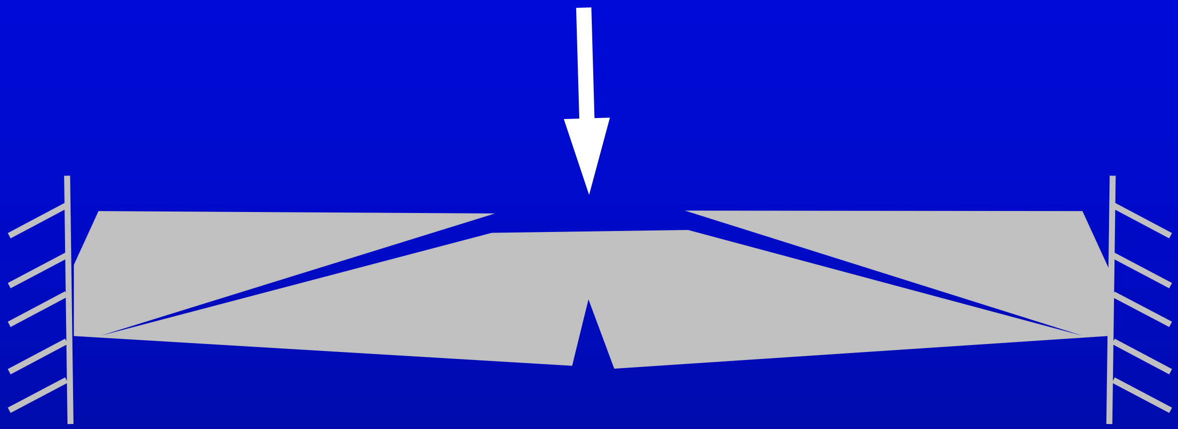
Modeling Example

struts = compression fields



University of Wisconsin

Design approach:

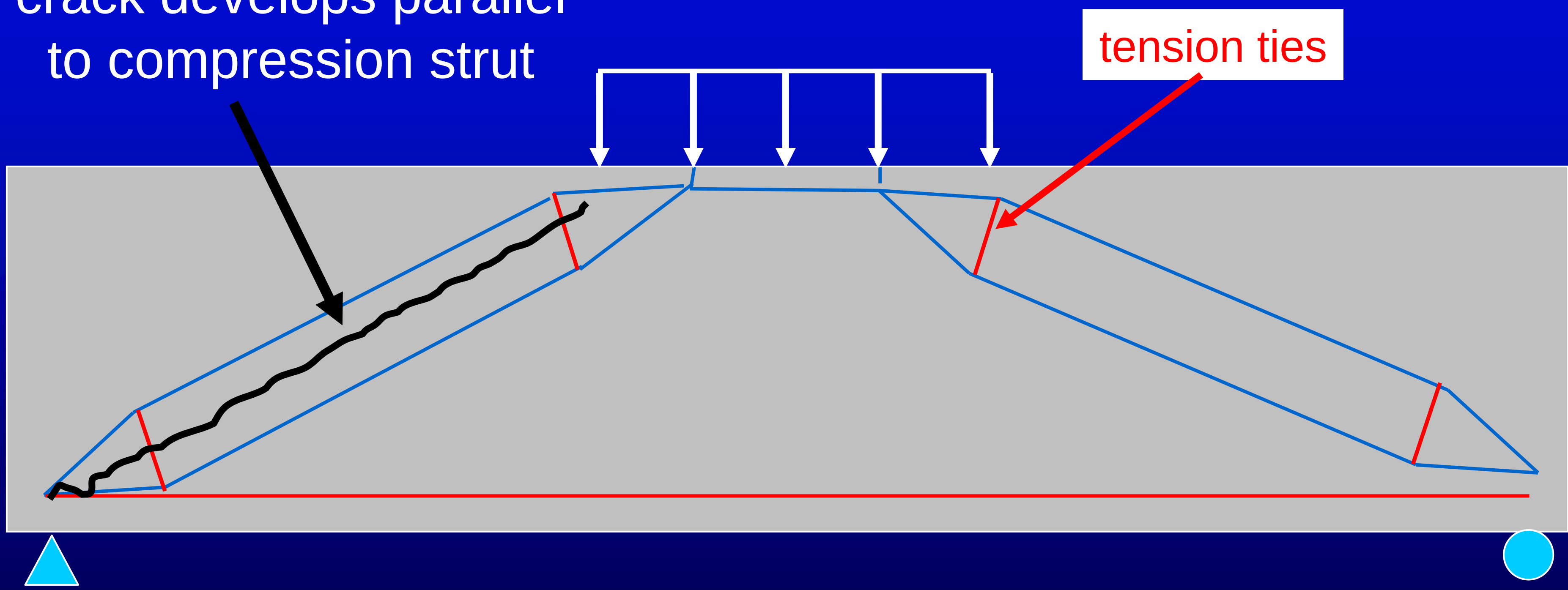


Design for shear-strut failure

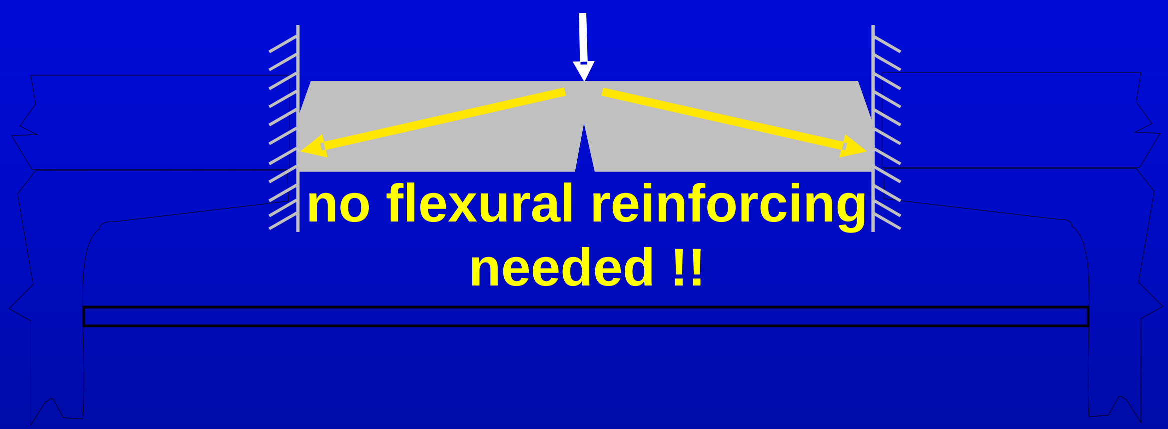
using compression membrane approach

Design approach:

Failure occurs when crack develops parallel to compression strut



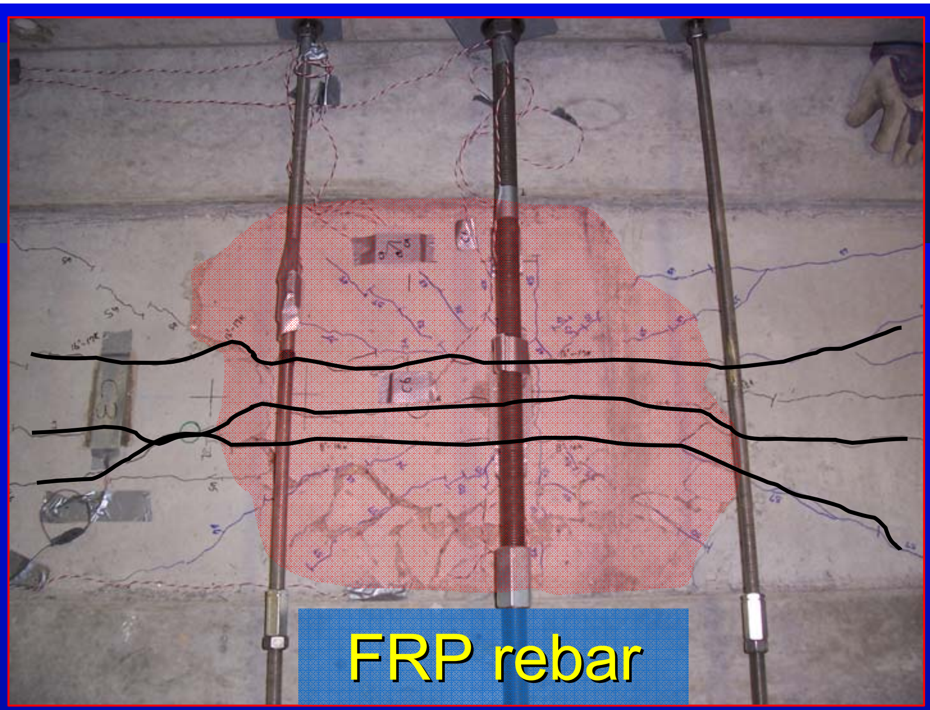
Introduction: New Problem



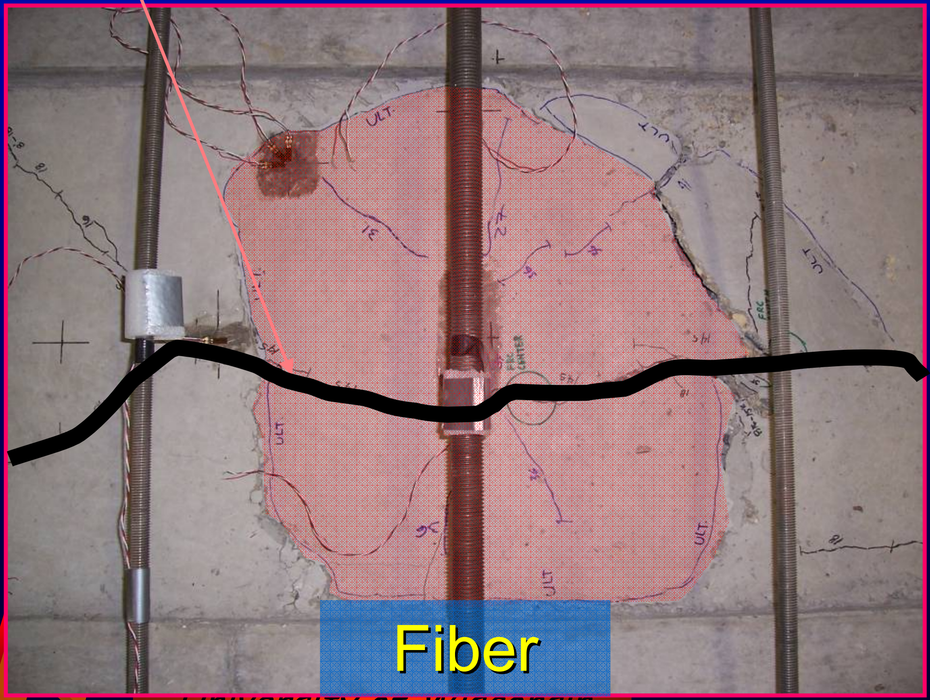
well before deck failure occurs –
a large flexural crack will develop

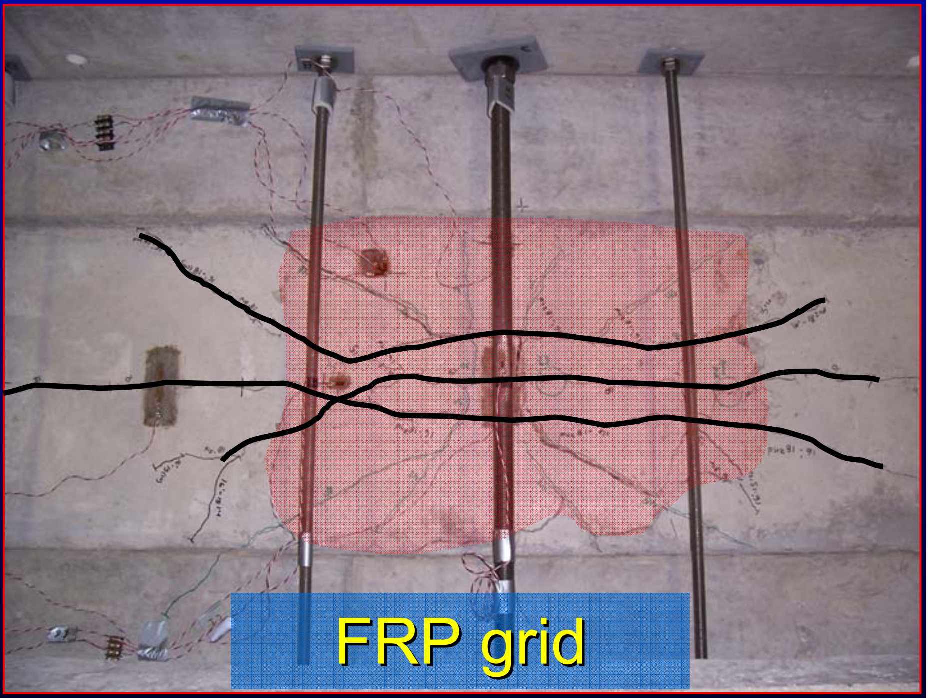
<u>unsightly</u>: need to control size of crack

3 span test results



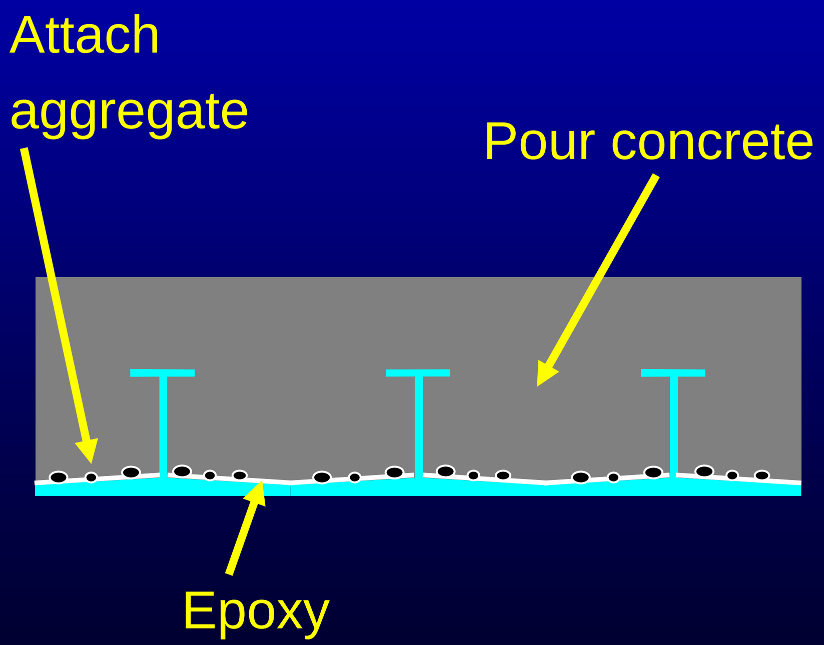
Crack needs to be controlled





*Introduction: **New Solution***

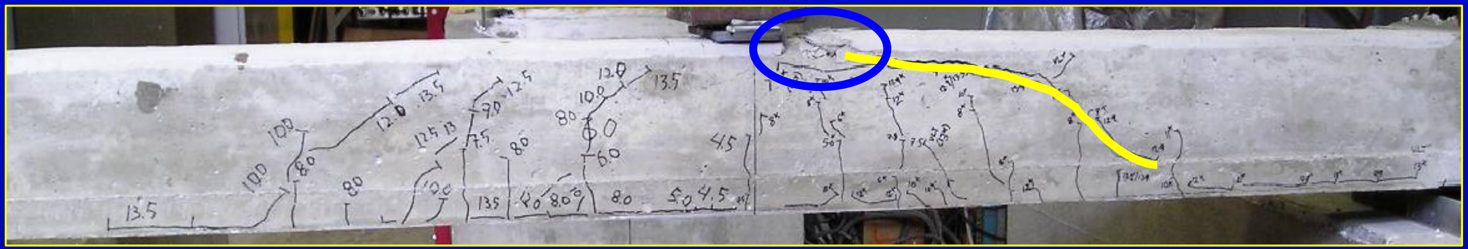
Use a lightweight pultruded FRP plank as stay-in-place formwork & secondary reinforcing



Experiments: crack control in beams

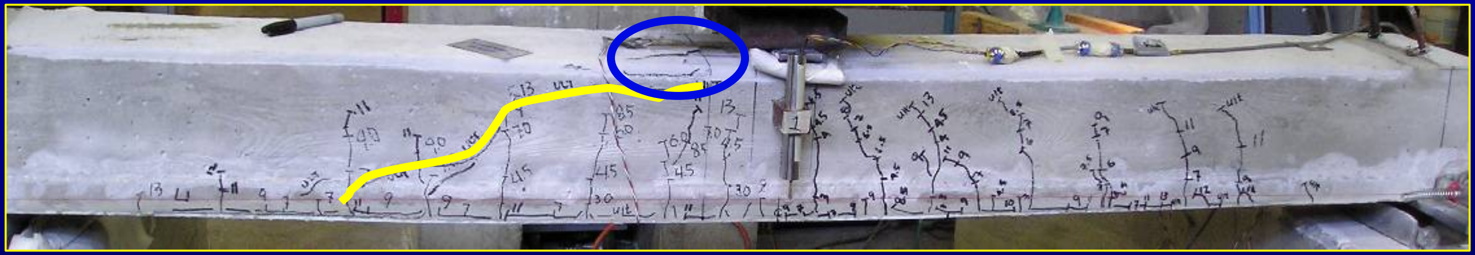
- 3 beams

FRP plank



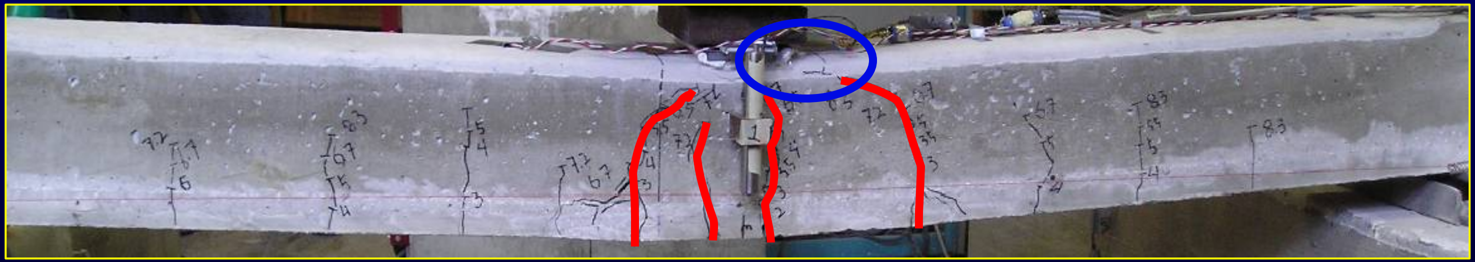
Hybrid crack

FRP plank



Hybrid crack

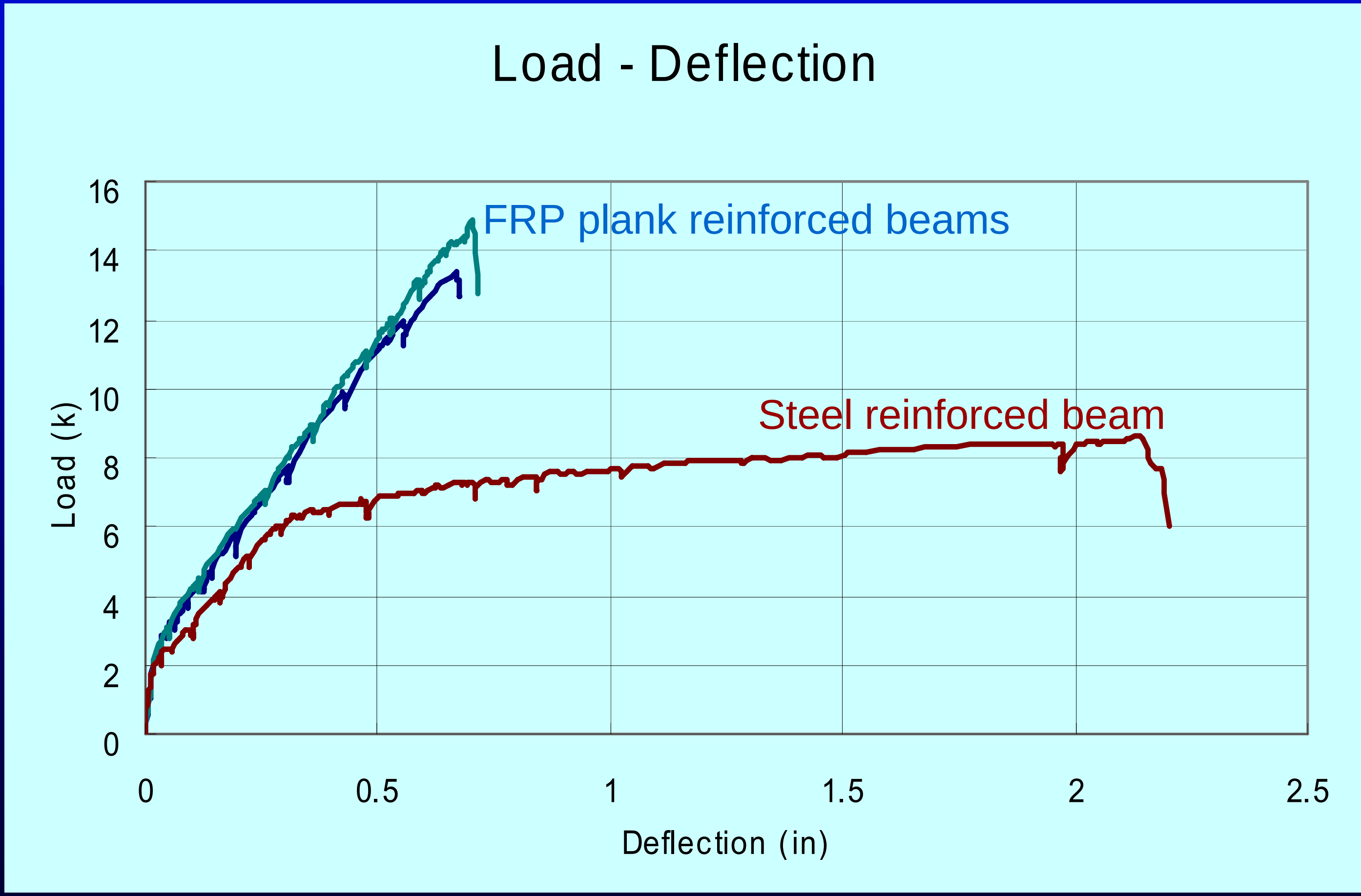
Steel reinf.



Flex. Failure

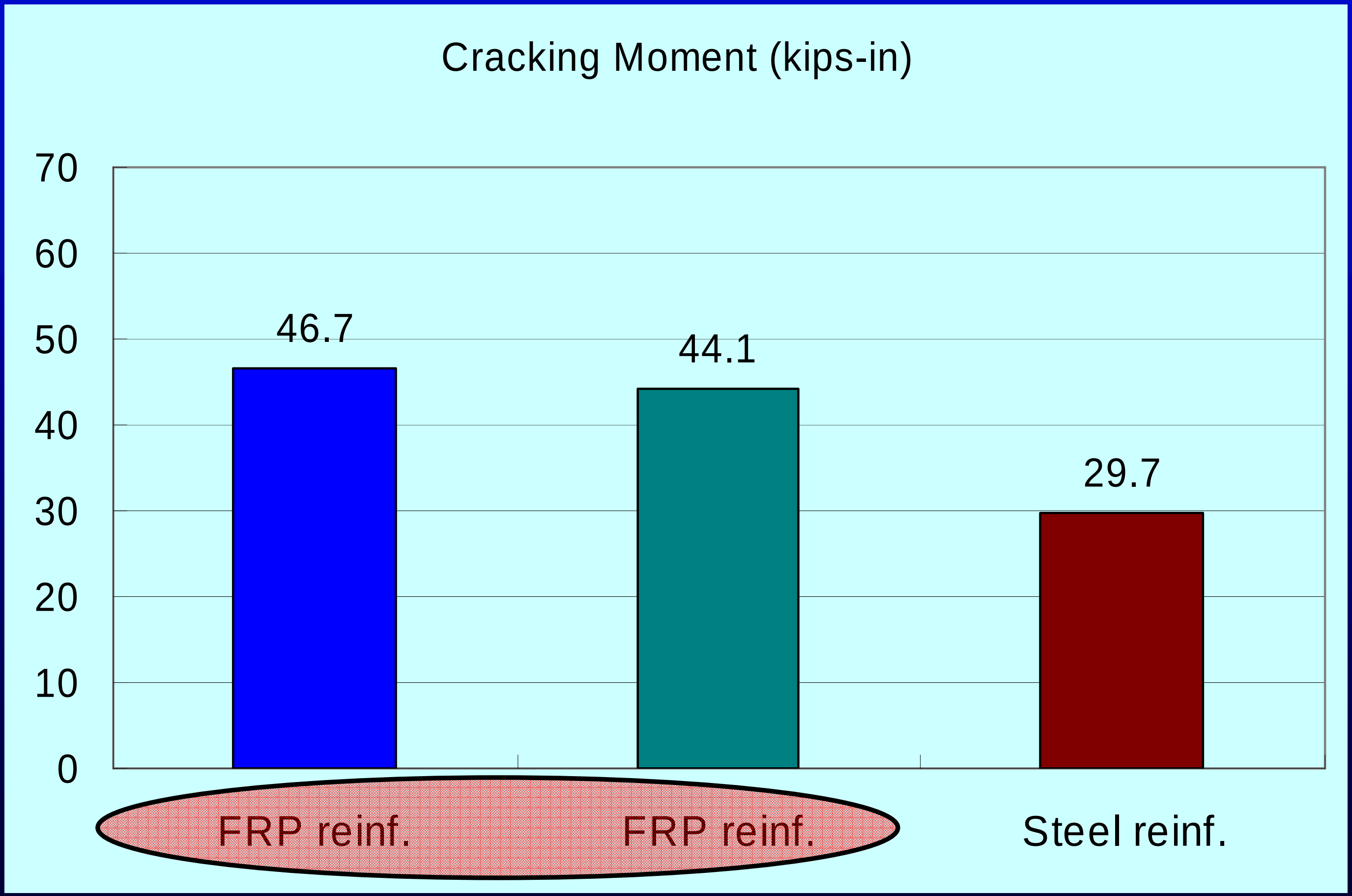
Experiments: crack control

- 3 beams



Experiments: crack control

- 3 beams

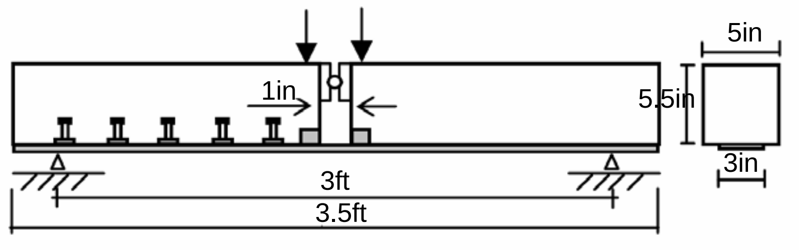


Crack control with FRP forms:

- Bonding is necessary to distribute cracking (many small cracks versus one big)
- Sand and gravel both appear effective in bonding
- Steel reinforced beam has greater ductility
- Beam with FRP bonded plank appears to perform better than a steel reinforced beam
  - In developing distributed cracking
  - In developing strength

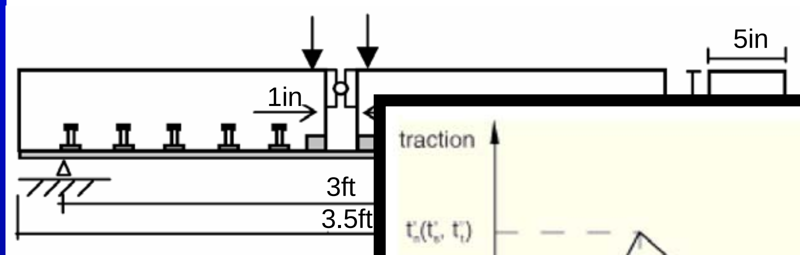
Modeling FRP bond:

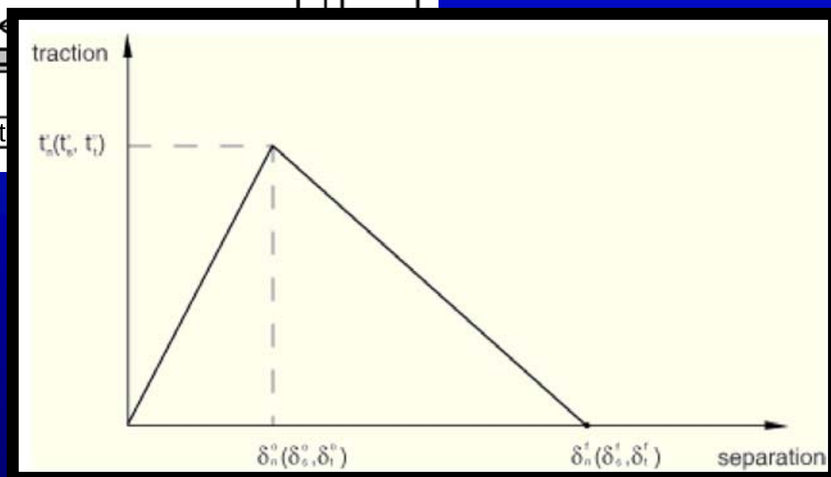
test beams and measure bond – slip behavior



Modeling FRP bond:

test beams and measure bond – slip behavior

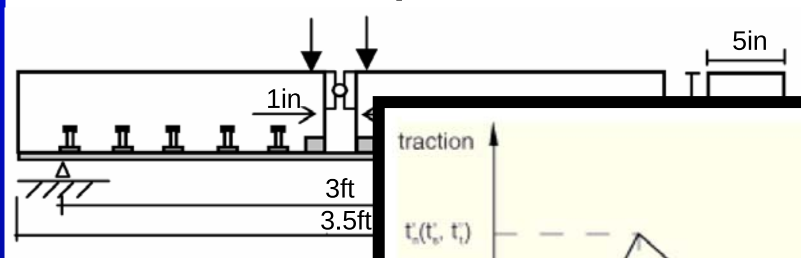


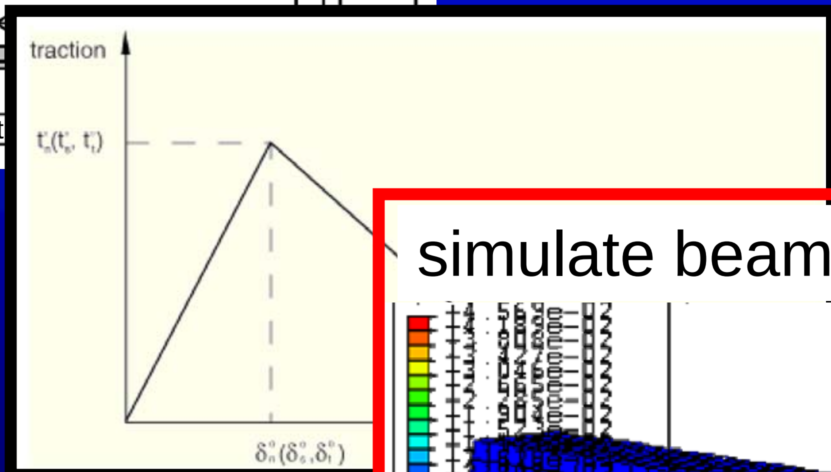


develop a bond-slip model

Modeling FRP bond:

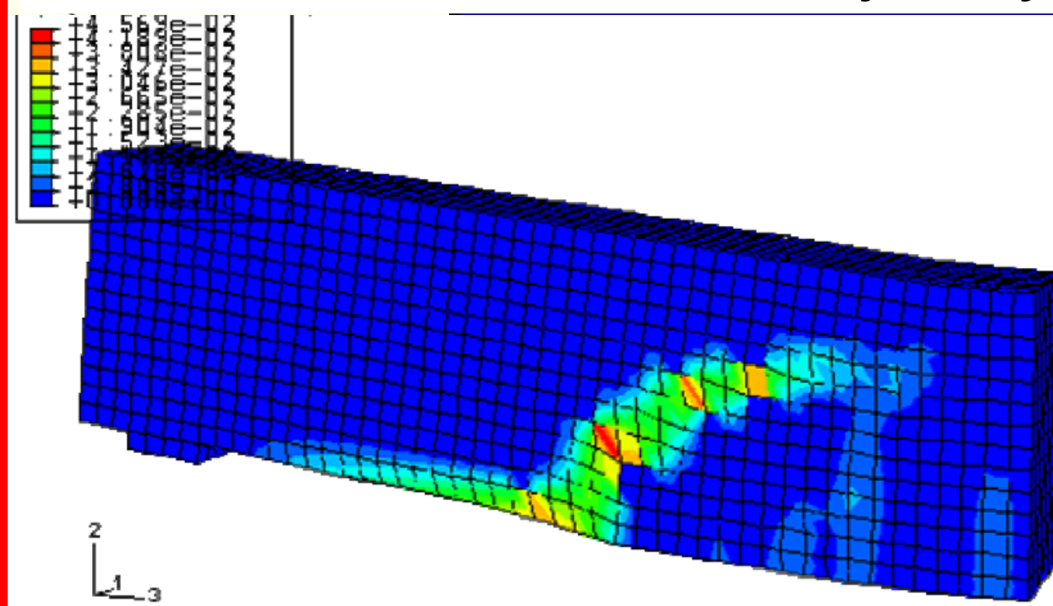
test beams and measure bond – slip behavior





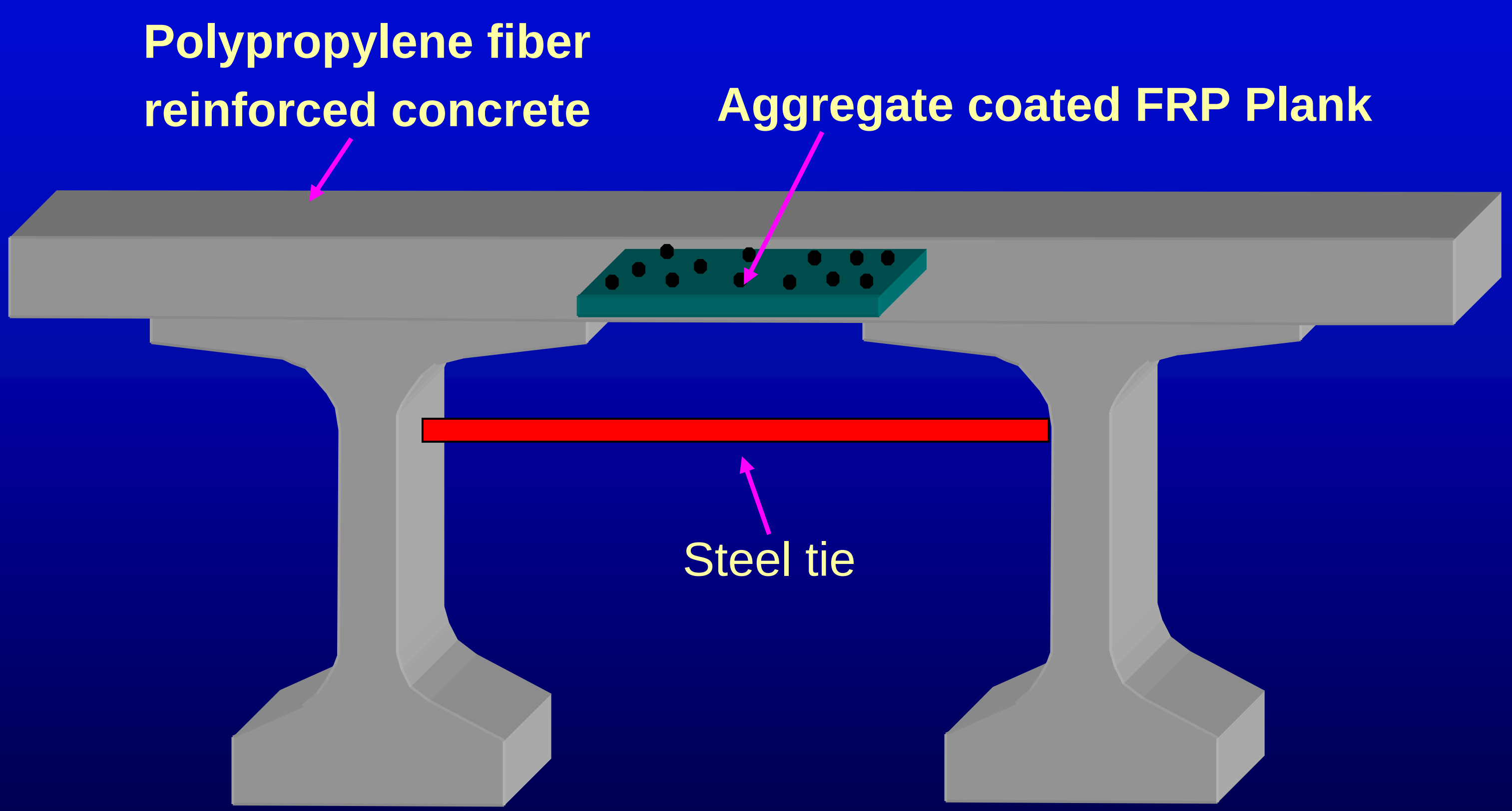
develop a b

simulate beam behavior analytically

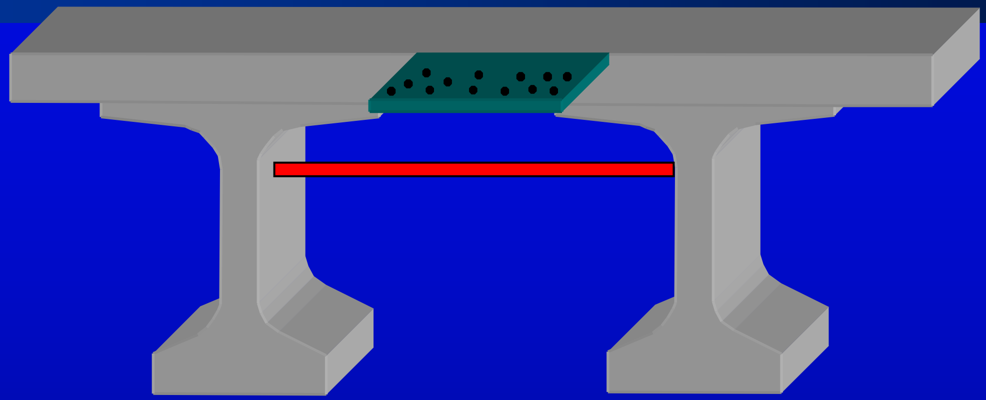


University of Wisconsin

New Design for Steel Free bridge Deck:



New Design for Steel Free bridge Deck:



AIM:

- simplified construction

  no forming, no deck steel

- safer construction procedure

  no form removal from below

- design is based on actual failure mechanism

  shear failure basis

Results to date:

• Stay-in-place forms are used for small deck spans with bulb tee girders

•A new approach is used for bridge deck design,

• FRP stay-in-place forms provide excellent crack control as a secondary reinforcing,

• Non-linear modeling of FRP to concrete bond can successfully predict behavior of the system

Bridge under construction:

Tie rods inserted into girders before

Bridge under construction:

sliding ties into place

Bridge under construction: ties all positioned

University of Wisconsin


PEPSI
Dairy Way
Ties: bearing plates and anchor nuts on girder webs.

Bridge under construction:

flange dapped to receive FRP form, prevents movement

Bridge under construction:

placing FRP deck forms

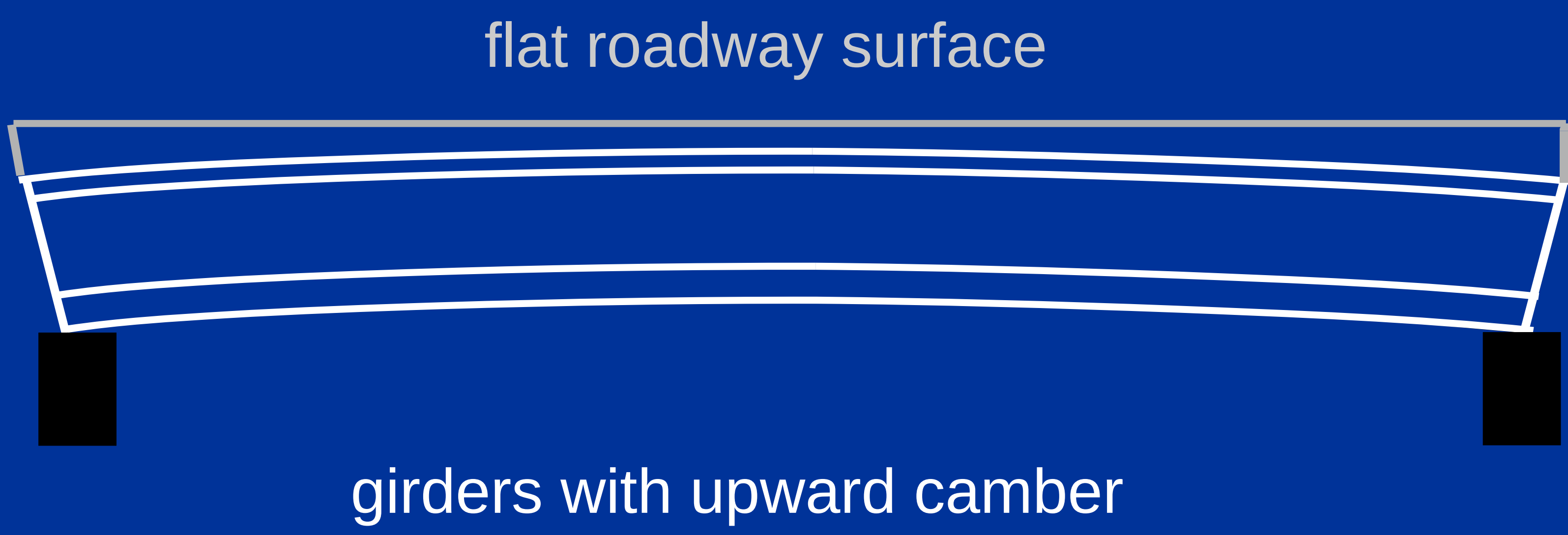
University of Wisconsin

Test bridge under construction:

placing FRP deck forms: adhesive

Bridge under construction:

Roadway profile usually achieved by building a varying depth haunch above the girder and keeping the deck constant thickness.



In this bridge – no haunch is used,
the deck thickens at the ends and is thinner at center,
eliminates the need for placing SIP forms on haunch.

ALSO:

- Load testing of test bridge
- Prepare code acceptable design approach

Summary:

- Compressive membrane approach was used to design a steel-free deck on wide flange girders.
- Aggregate coated FRP planks were used to control flexural cracks and as stay-in-place forms.
- Testing of FRP plank reinforced beams was conducted to investigate crack control ability.

Summary:

- Bond-slip behavior of coated FRP strip and concrete was investigated experimentally and used in finite element analysis.
- Test bridge has been constructed. Load testing and monitoring will continue.

Thank you!!