MODELLING A SKEW BRIDGE WITH SHELL ELEMENTS

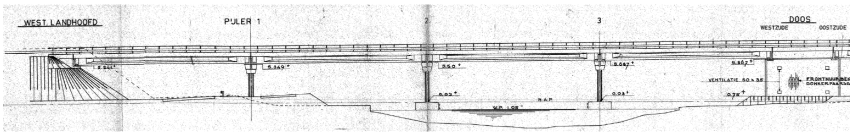
5 June 2018

Scope

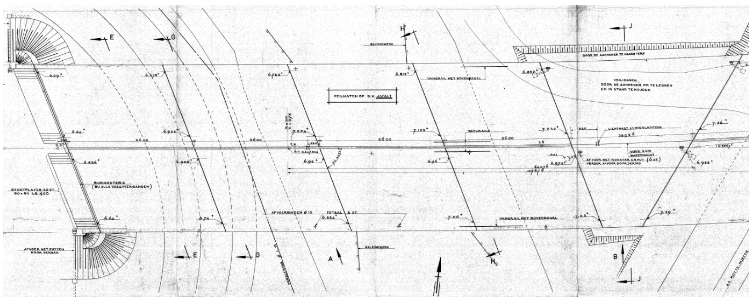
- ❑ Introduction to the assignment
- ❑ Applied solution
- ❑ Results
- ❑ Summary/conclusions

Introduction

Side view



Top view



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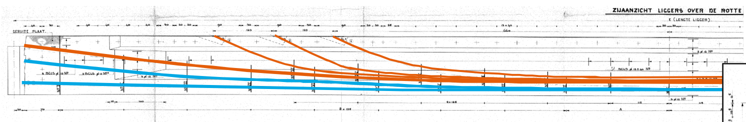
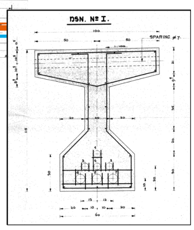
Introduction

- Skewness 68°53’
- 11 T-shapped prefabricated post-tensioned girders: 3 cables 100 ton and 4 cables 40 ton
- Span: 25.84 m; height 1.15 m
- Transverse prestressing in the bridge deck – dywidag bars
- Girder with stirrups
- C45/55





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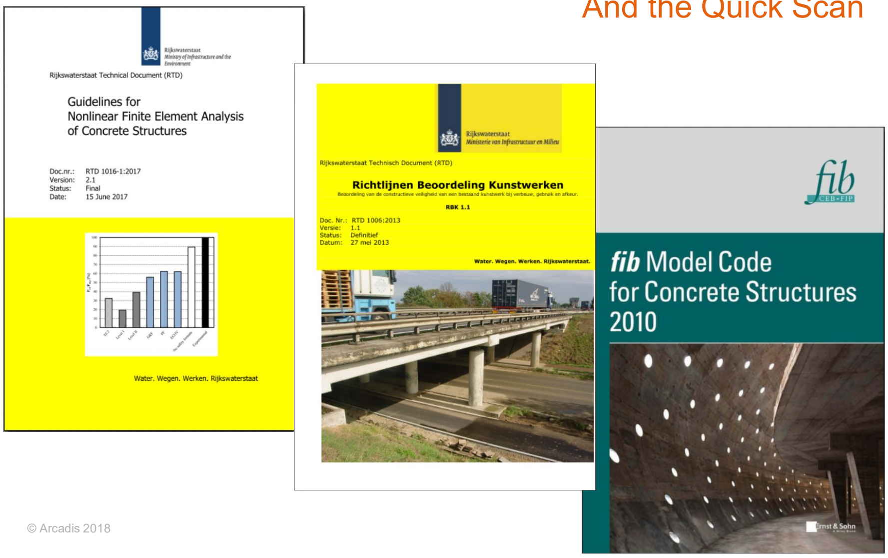
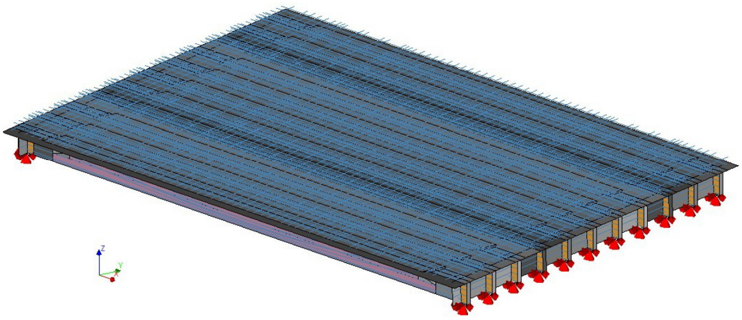
Design base

And the Quick Scan



“2.5 D” model



3D model with shell elements

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Modelling aspects – cross section

- ❑ Model built with vertical and horizontal shell elements
- ❑ Shape definition with function of:
  - ❑ Width over height – bottom flange and web
  - ❑ Height over width – top flange
  - ❑ Eccentricity of the top flange

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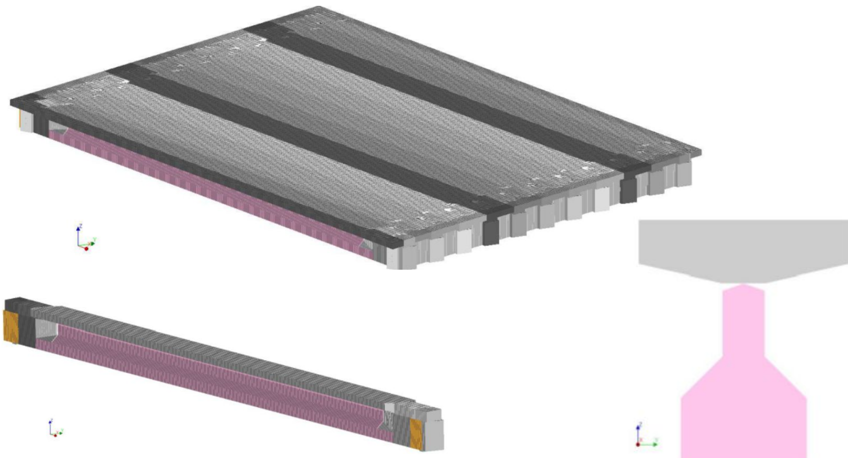
Modelling aspects cont.

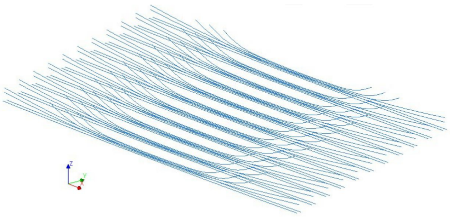
- ❑ True global geometry of the bridge and prestressing cables



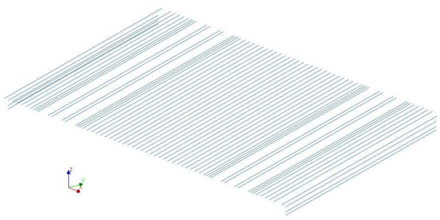
Modelling aspects – reinforcement, prestressing, phasing

- Prestressing applied to embedded reinforcement - DIANA POSTTENS functionality; drawback: elastic losses not taken into account, immediate transfer of bond-stresses
- Prestressing with bond-slip interfaces; unknown bond stress-slip relationship, problems with evaluation of reinforcement leaving or/and entering the shell elements' plane
- Importance of stirrups or "fictitious" stirrups for convergence behavior and the results
- Inclusion of actual construction phasing through phased analysis and activation of relevant shapes

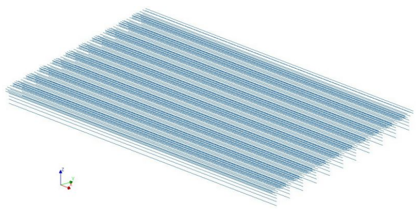
Reinforcement



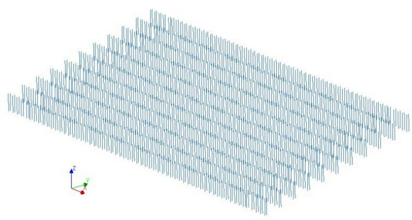
Prestressing 100 tons and 40 tons cables



Transverse prestressing Dywidag bars



Reinforcement in girders and concrete joints



Stirrups ϕ 12 applied in 2 rows

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Quick Scan

- Linear static calculations
- Based on the calculated resistances, 3 critical loading configurations were determined – the bridge is deemed to fail in diagonal tension shear (loading situation 1 and 3) and flexural shear (loading situation 2)
- The skewness of the bridge not taken into account in the Quick Scan!!!

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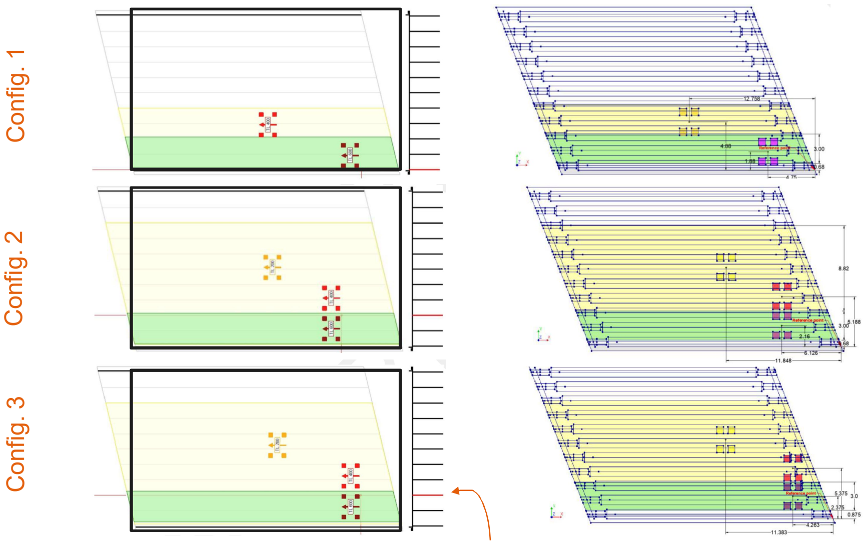
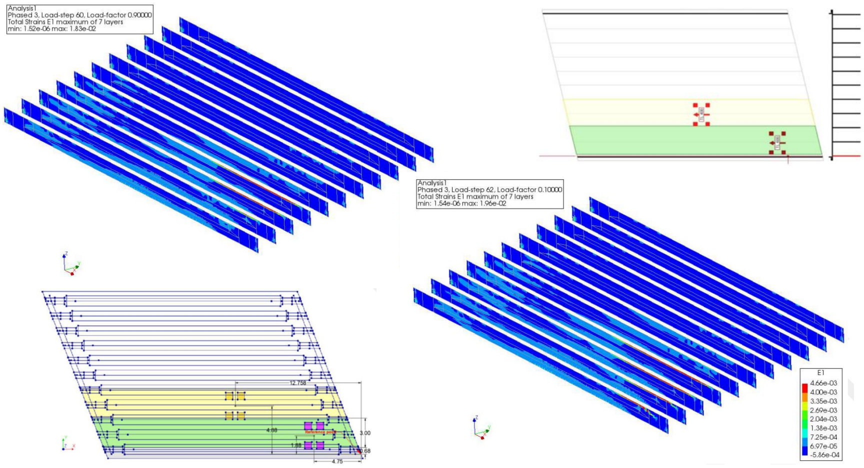
Loading configurations



Critical girders in red

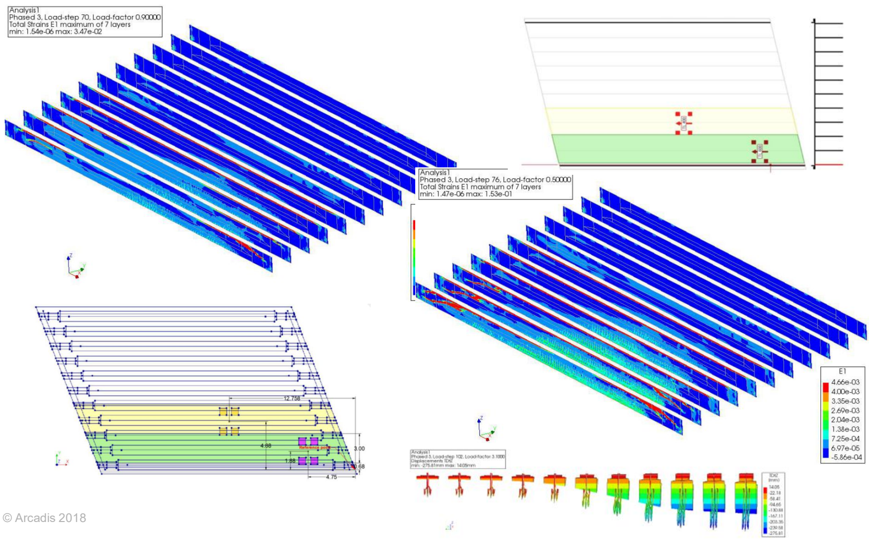
Results – model without stirrups

Course of crack formation – loading situation 1

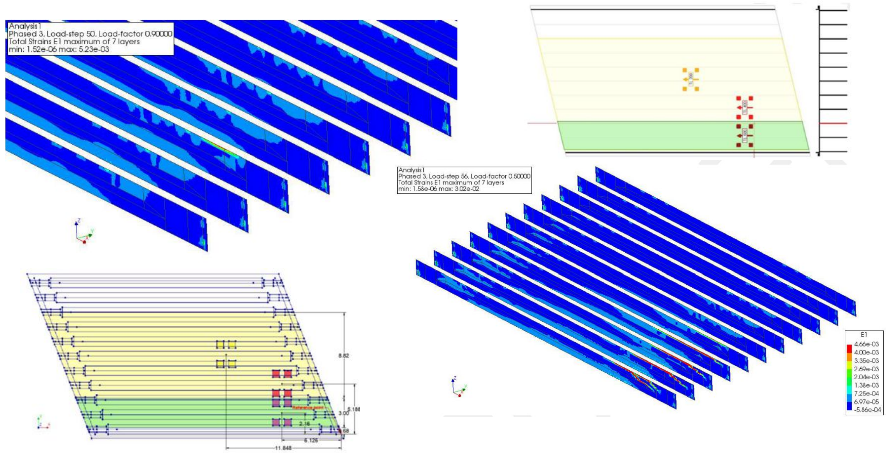


Results – model without stirrups

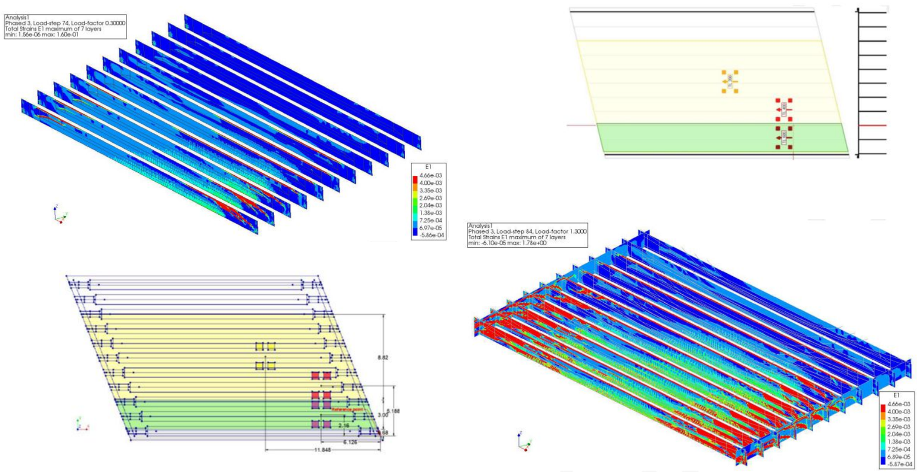
Course of crack formation – loading situation 1



Results – model without stirrups
Course of crack formation – loading situation 2

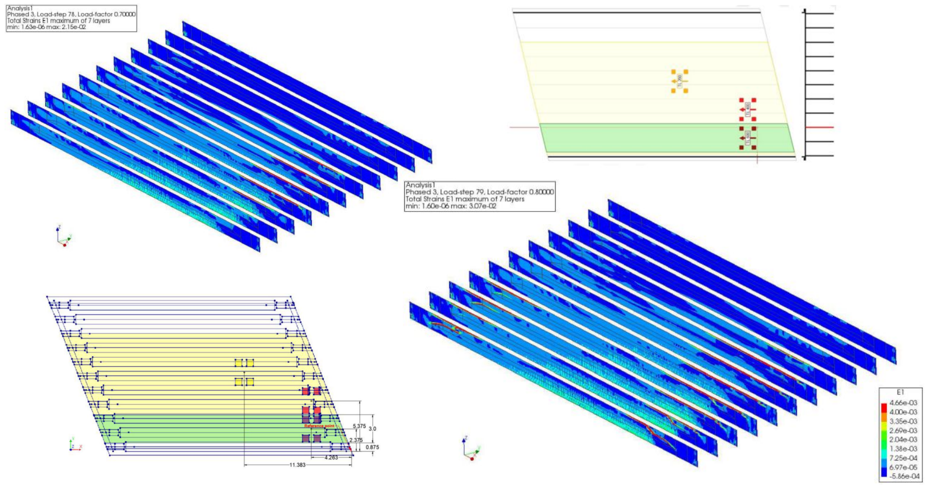


Results – model without stirrups
Course of crack formation – loading situation 2



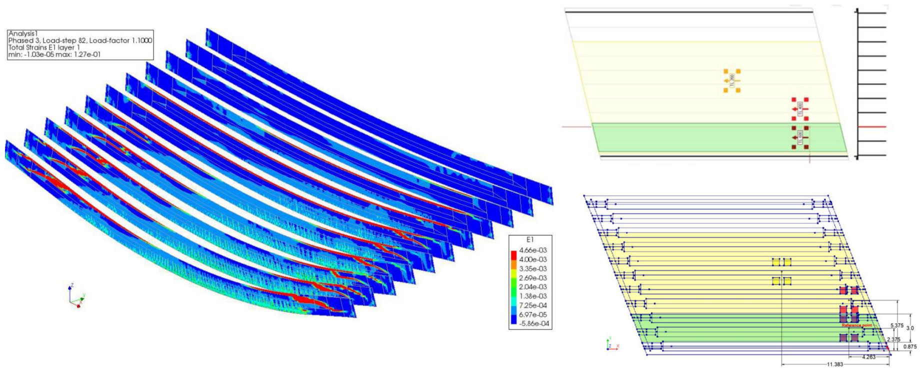
Results – model without stirrups

Course of crack formation – loading situation 3



Results – model without stirrups

Course of crack formation – loading situation 3



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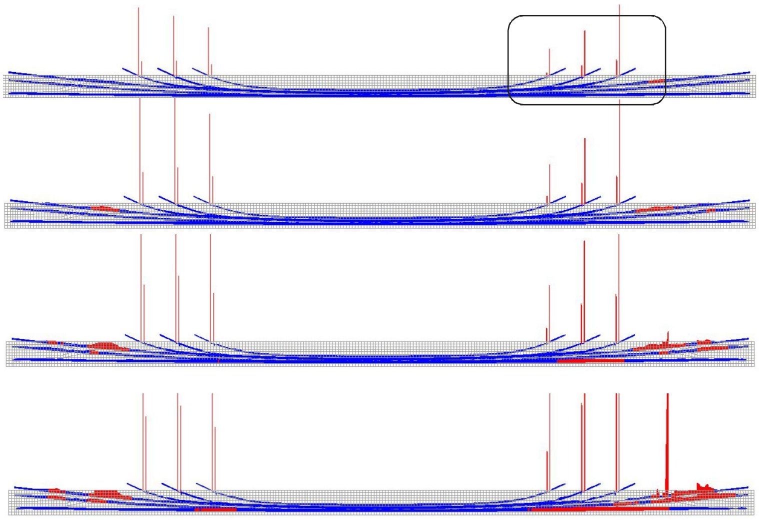
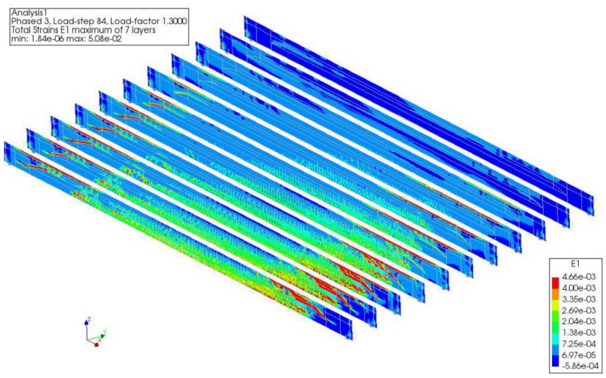
Failure mechanism



Results – influence of stirrups

- ❑ Increase of capacity
- ❑ Stirrups significantly reduce longitudinal cracks in the mid-span of the bridge; for a model without stirrup, application of stirrups as a function of height might be a solution
- ❑ Improved convergence behavior



Evaluation

- ❑ All cases meet GRF limit state
- ❑ The obtained failure mechanisms are different than anticipated based on the information from Quick Scan
- ❑ Complex nature of crack formation
- ❑ In the current loading configurations, the axle systems are too close to the skew edge of the bridge which leads to an additional capacity as the result of direct force transfer to the support
- ❑ An additional re-evaluation with different loading configuration e.g. applied to the other side of the bridge or at the current locations but taking into account the skewness of the bridge

Conclusions

- ❑ ‘2.5D’ model enables to analyze the global response of the structure failing in shear
- ❑ Gives more insight into the response of the structure
- ❑ Exposes the shortcomings of Quick Scan – influence of skewness and determination of the governing loading positions

Yet:

- ❑ Top flange cannot “crack” in shear
- ❑ Time consuming modelling
- ❑ 3D mode with solid elements might be a more efficient solution

Problems

- ❑ Assignment of mother elements
- ❑ Evaluation of reinforcement leaving or/and entering the shell elements' plane – relevant for prestressing cables with bond-slip

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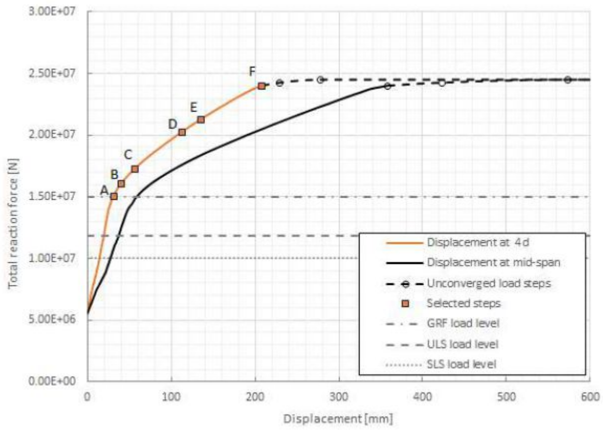

3.00E+07
2.50E+07
2.00E+07
1.50E+07
1.00E+07
5.00E+06
0.00E+00
Total reaction force [N]
0
100
200
300
400
500
600
Displacement [mm]
A
B
C
D
E
F
Displacement at 4d
Displacement at mid-span
Unconverged load steps
Selected steps
GRF load level
ULS load level
SLS load level