EXPERIMENTAL AND NUMERICAL ASSESSMENT OF HISTORICAL STEEL-CONCRETE COMPOSITE BRIDGE DECKS WITHOUT MECHANICAL CONNECTORS

Mauro Poliotti[1], Yuguang Yang[1] , Ane de Boer[2,3],
[1]Concrete Structures, Delft University of Technology, Delft, The Netherlands
[2] Ane de Boer Consultancy, Arnhem, The Netherlands
[3]Municipality of Amsterdam, Amsterdam, The Netherlands

DIANA USERS ASSOCIATION – 15/09/2022

TU Delft

1

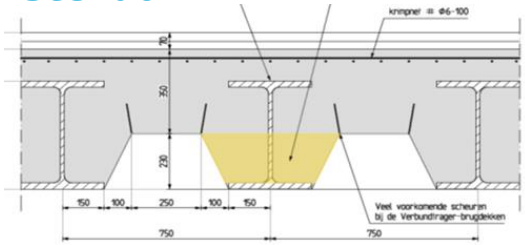
Content

- Introduction: Bridge70 Vijzelstraat, Amsterdam
- Challenges and goals
- Experimental Campaign
- Observed Failures
- Simulations Details
- Results
- Plain Model LB1
- Conclusions

TU Delft

2

Bridge70 Vijzelstraat, Amsterdam



TU Delft

Challenges

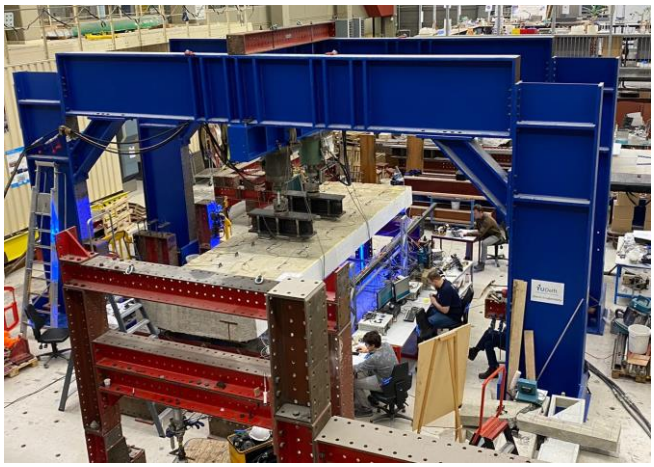
- 150 bridges in Amsterdam with similar designs constructed between 1880 and 1960
- ~ 30 of them without shear connectors in the interface
- Only shrinkage reinforcement (Φ6@100mm) on the top layer

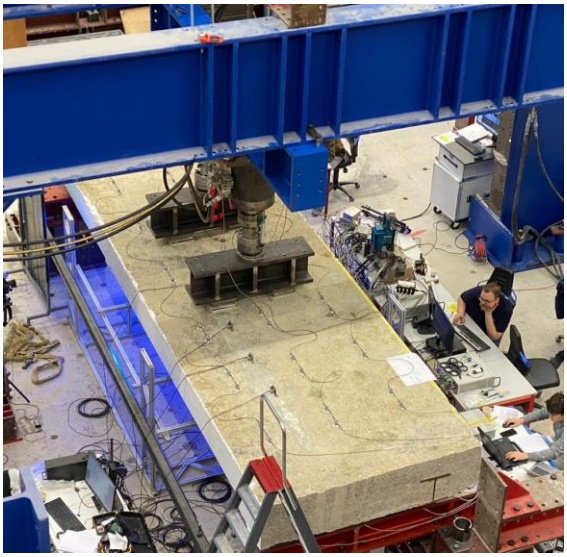
Goals

- Investigate the bearing capacity of this typology with emphasis on:
  - **Interface behavior**
  - **Transverse force distribution**

TU Delft

Experimental Campaign

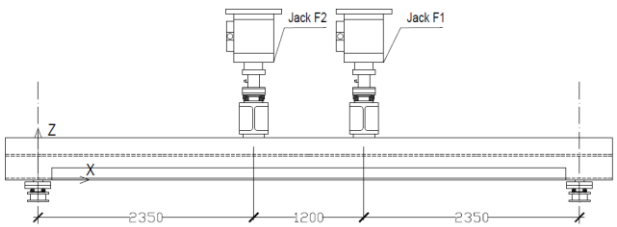


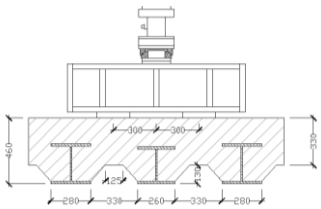


TUDelft

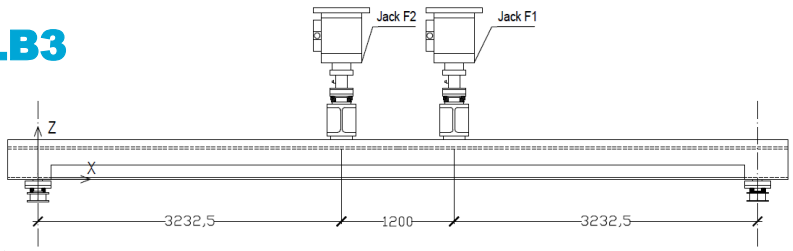
Specimens Description

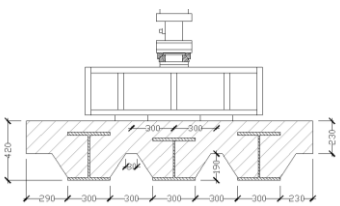
LB1





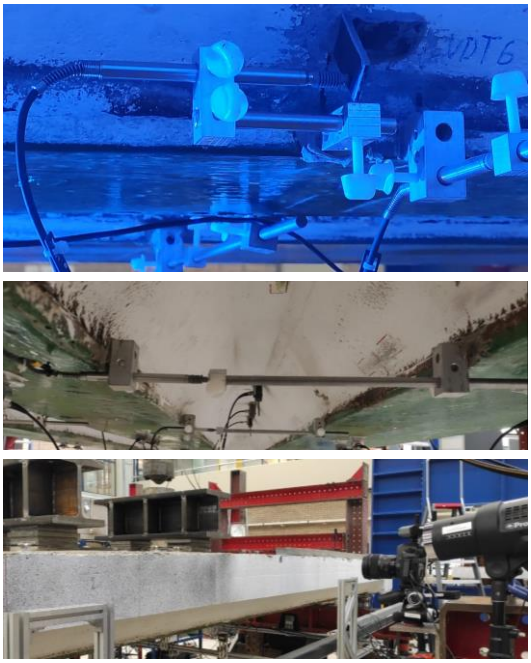
LB3

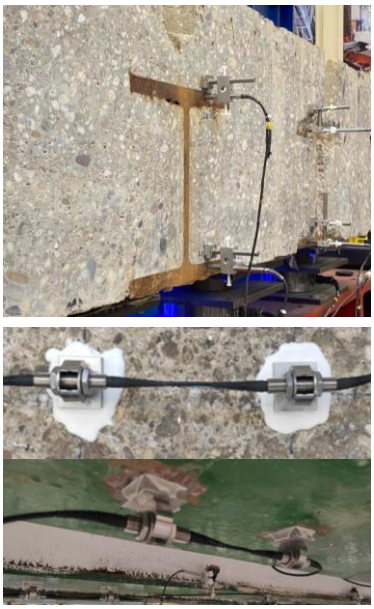




TUDelft

Measurement Plan



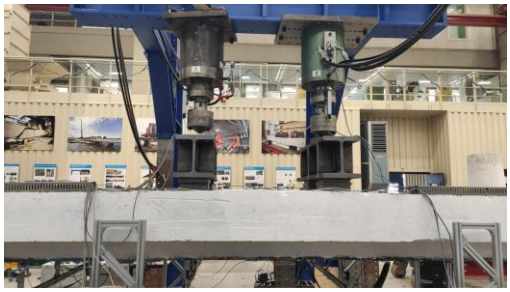


- 42 optic fibers
- 15 LVDTs
- 12 Lasers
- 6 reaction load cells
- 2D & 3D DIC

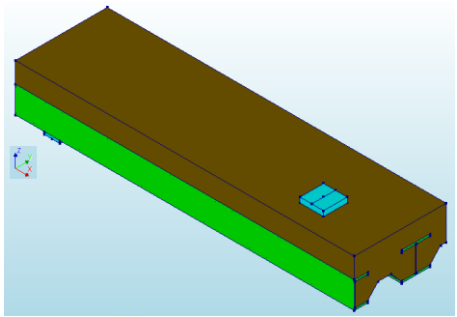
7

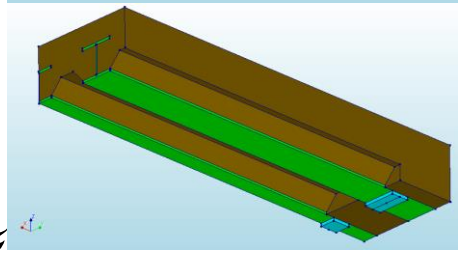
Observed Failures – LB1

Observed Failures – LB3



Simulation details





- 3D solid model with only ¼ of the specimen due to symmetry. (CHX60)
- The top reinforcement is neglected (Ø6@100)
- Mohr Coulomb Interface with c = 0.1MPa and φ = 26° (MC2010-6.4.2.3)
- Load is introduced as imposed displacement on the loading plate. Displacement increment Δ=0.5mm
- Total strain crack model for concrete (rotating)
- Von Mises Plasticity for steel with isotropic hardening
- Regular Newton Raphson
- Energy **or** Out-of-balance force convergence criteria (Energy 1E-4 and FORCE: 1E-2)
- Mesh size: 50mm

- Phased analysis; First steel beams + concrete self-weight
- Phase II Load till Failure

TUDelft

Material Properties. Based on material core-test

Concrete

Description	Value	
Aspect	[ ]	
Linear material properties		
Elasti		
Young's modulus	36984	N/mm²
Poisson's ratio	0.2	
Mass		
Mass density	2.45e-09	T/mm³
Total strain based crack model		
Crack orientation	**Rotating**	
Tensile behavior		
Tensile curve	**Hordijk**	
Tensile strength	3.68	N/mm²
Mode-I tensile fracture energy	0.148092	N/mm
Crack bandwidth specification	**Govindjee**	
Residual tensile strength	0	N/mm²
Poisson's ratio reduction		
Reduction model	**Damage based**	
Compressive behavior		
Compression curve	**Parabolic**	
Compressive strength	50.9	N/mm²
Compressive fracture energy	37.023	N/mm
Residual compressive strength	0	N/mm²
Reduction due to lateral crac...		
Reduction model	**Vecchio and Collins 1993**	
Lower bound reduction c...	**0.4**	
Stress confinement		
Confinement model	No increase	

Steel

Description	Value	
Aspect	[ ]	
Linear material properties		
Elasti		
Young's modulus	200000	N/mm²
Poisson's ratio	0.3	
Mass		
Mass density	7.85e-09	T/mm³
Von Mises and Tresca plasticity		
Plasticity model	Von Mises plasticity	
Hardening function	**Plastic strain-yield stress**	
Hardening hypothesis	Strain hardening	
plastic strain-Yield stress	[0, 235, 0.4, 318]	, N/mm²
Hardening type	Isotropic hardening	

TUDelft

Interface Properties

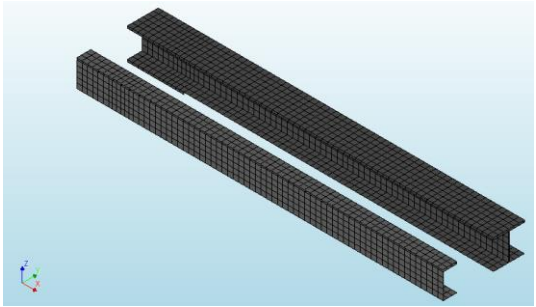
- Coulomb Friction

Coulomb Friction properties

Properties

Description	Value	
Aspect	[ ]	
Linear material properties		
Type	3D surface interface	
Elas6		
Normal stiffness modulus-z	36984	N/mm³
Shear stiffness modulus-x	18492	N/mm³
Shear stiffness modulus-y	18492	N/mm³
Coulomb friction		
Cohesion	0.1	N/mm²
Friction angle	26	°
Dilatancy angle	0	°
Hardening diagram		
Add...		
Interface opening model	**Tension cut-off**	
Tensile cut-off value	**0.67**	N/mm²

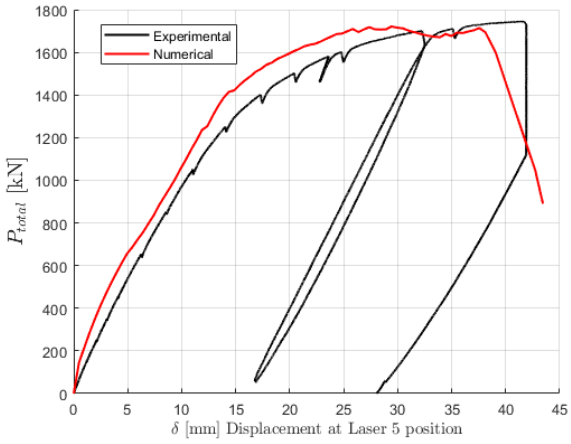
Interface Mesh elements (CQ48I)



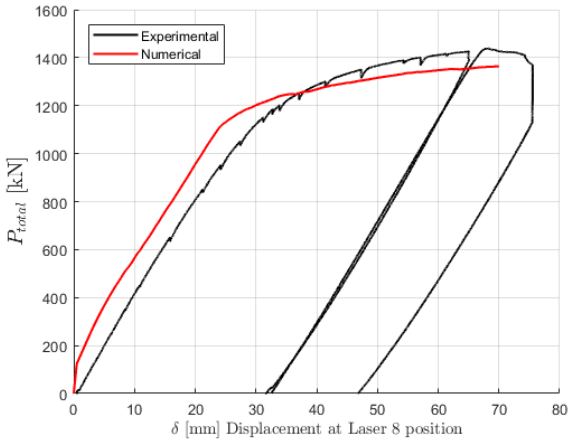
TUDelft

Load Deflection

LB1 – SHORT Specimen L=5900 mm

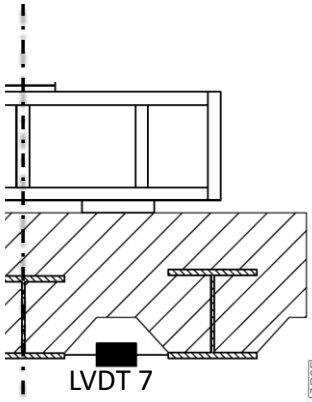


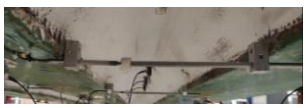
LB3 – LONG Specimen L = 7665 mm



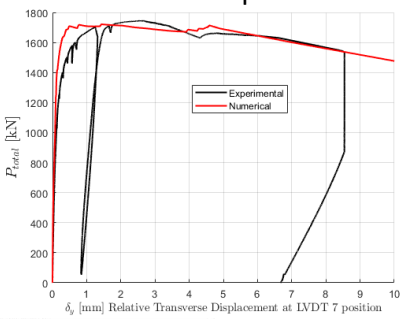
TUDelft

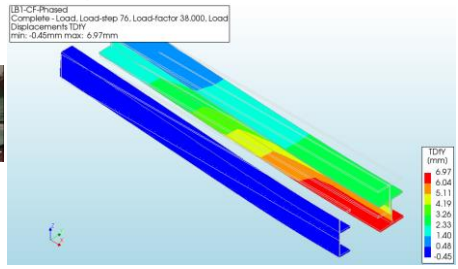
Transverse Displacement



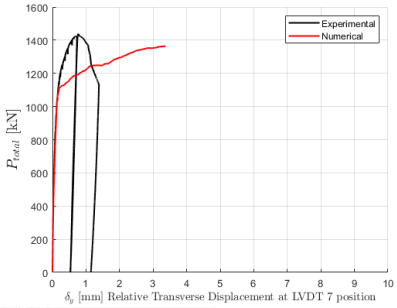


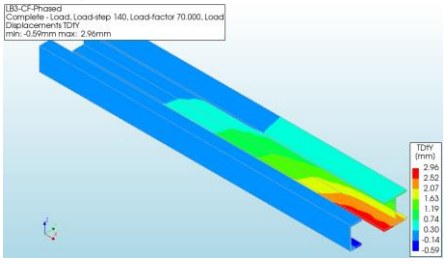
LB1 – SHORT Specimen





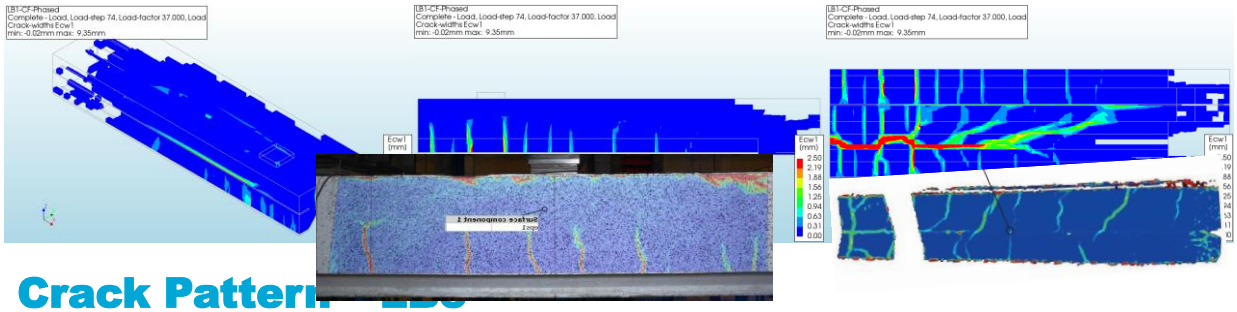
LB3 – LONG Specimen



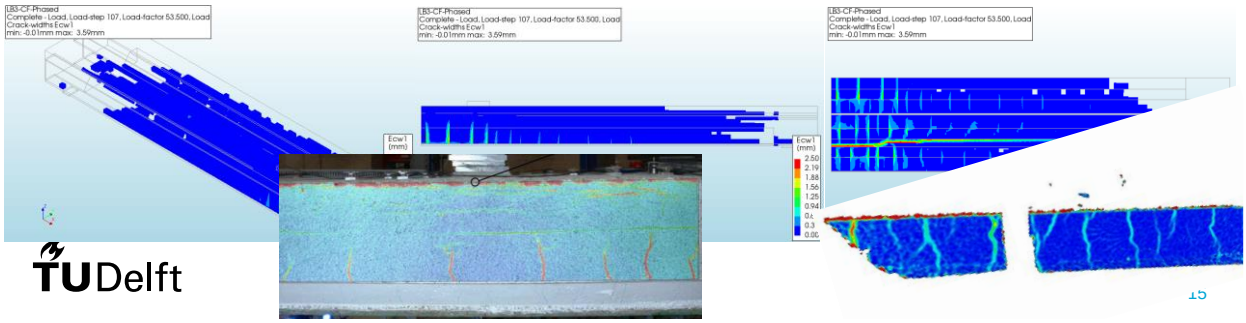


TUDelft

Crack Pattern – LB1

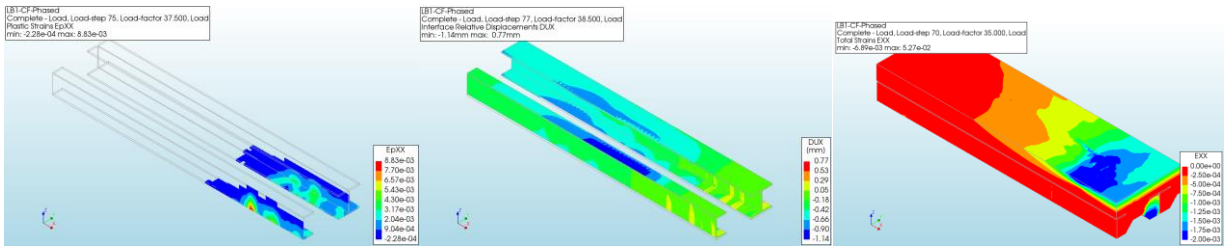


Crack Pattern – LB3

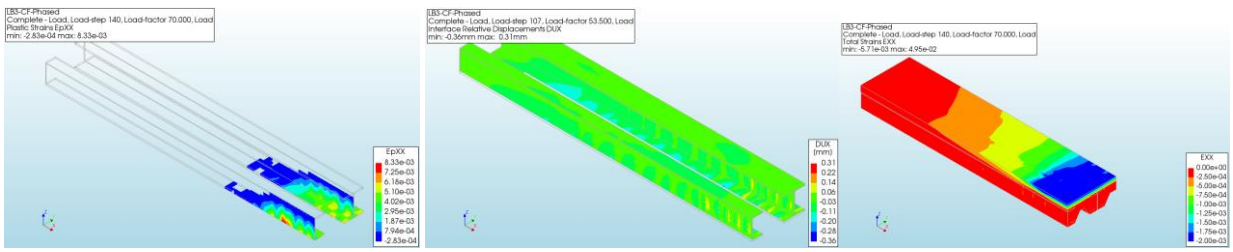


TUDelft

Other Results – LB1

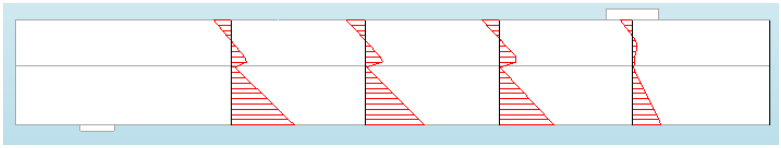


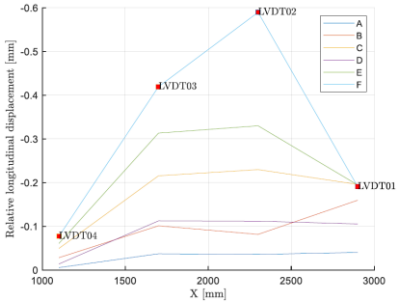
Other Results– LB3



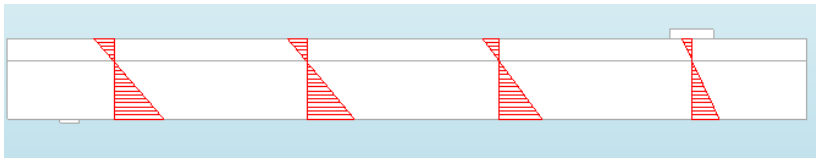
TUDelft

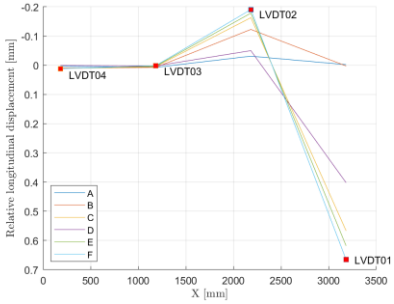
Interface – LB1





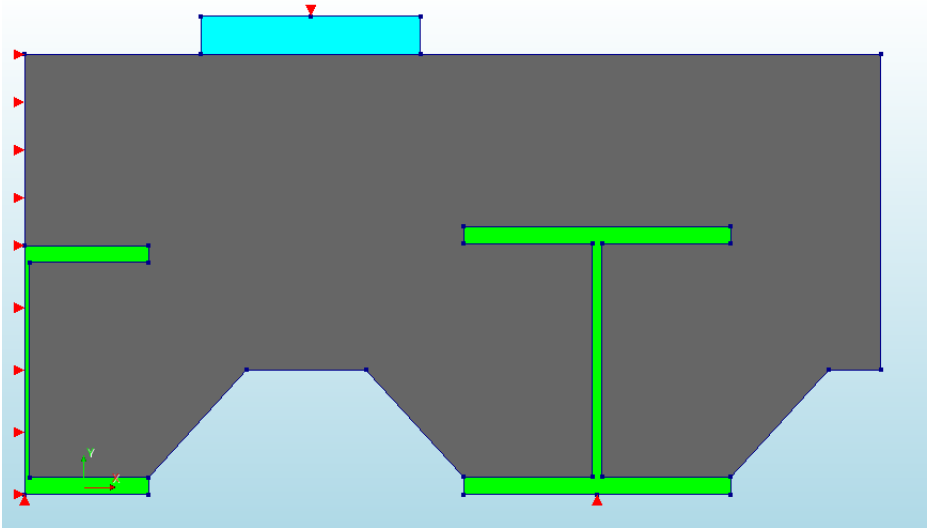
Interface – LB3





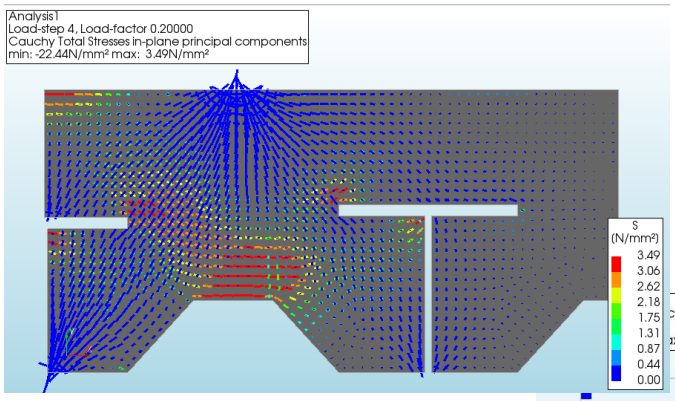
TUDelft

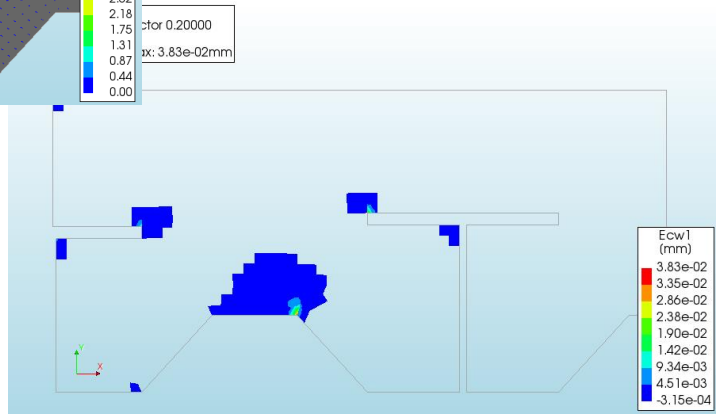
Plain Model – LB1



TUDelft

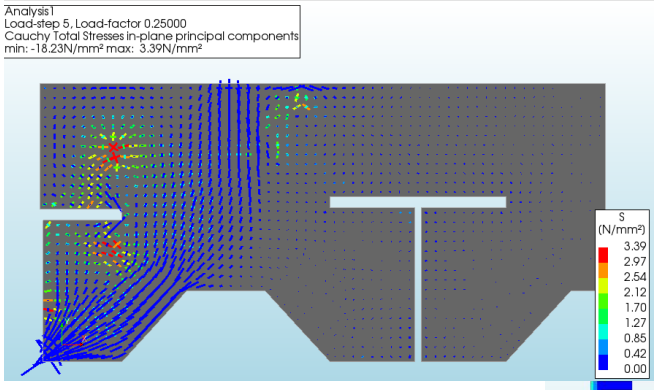
Plain Model – LB1 – Before Cracking

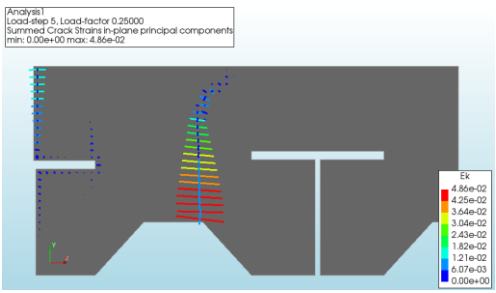


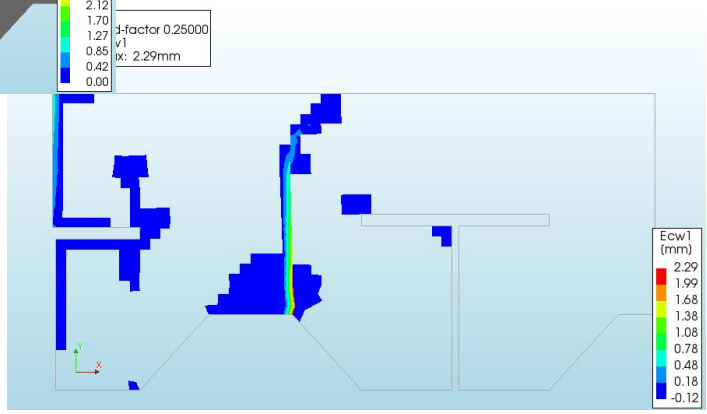


TU Delft

Plain Model – LB1 – Before Cracking







Conclusions

- Numerical models show good agreement with experimental observations (2 failure modes captured)
- Yielding of the steel elements is reached
- Lack of transverse reinforcement can lead to large transverse displacements and ductility of the element can be limited due to interface failure.
- Future work: Development of analytical model

TU Delft

21

Thanks for your attention

Questions ???

TU Delft

22