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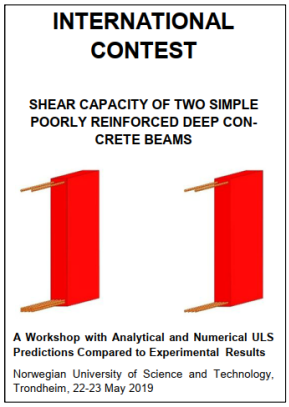
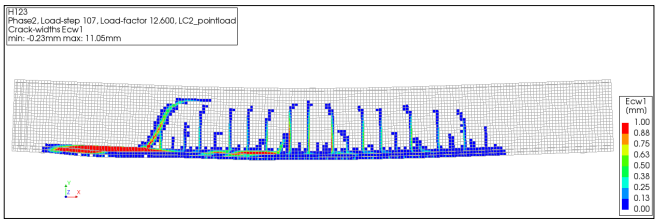
Beam contest 2019



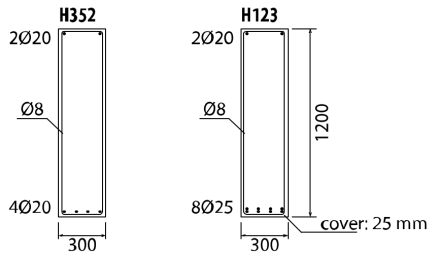


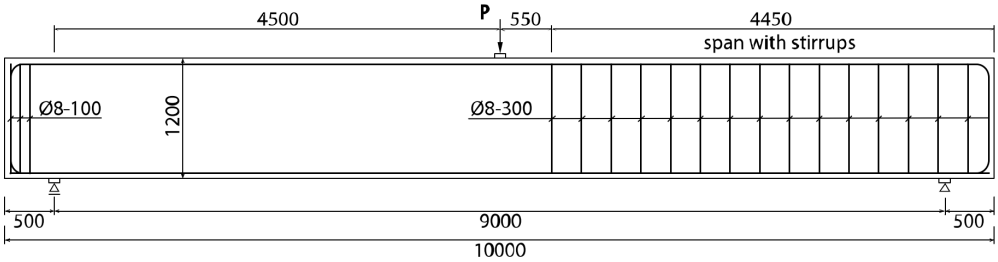
Contents

1. Introduction

Shear Prediction Workshop:

- Two poorly reinforced deep beams
- Same geometry but different reinforcement layout
- Three-point bending test
- Prediction of load capacity and failure mode using DIANA

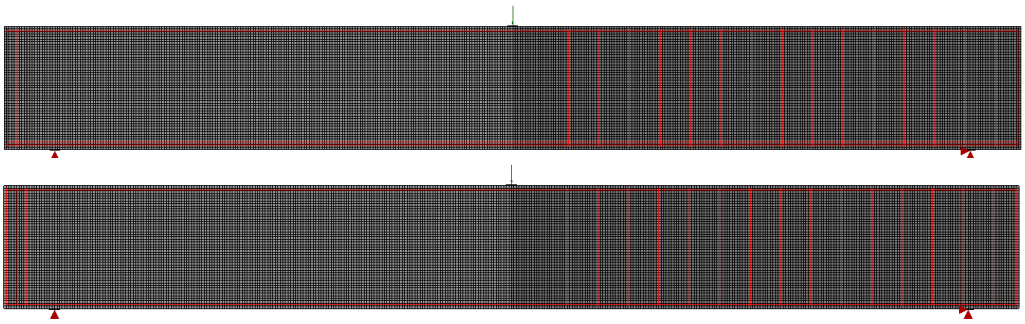




2. Initial DIANA models

Geometry and mesh:

- Concrete: Plane stress element
- Top longitudinal reinforcements: one embedded reinforcement with equivalent cross-section area
- Stirrups: one embedded reinforcement with equivalent cross-section area
- Bottom longitudinal reinforcements: multiple bond-slip circular beam reinforcements with actual cross-section area
- Mesh size: 25mm quadratic element



2. Initial DIANA models

Material input:
- Based on experimental results provided
- Calibrated using RWS guideline for NLFEA
- Mean values are selected as input

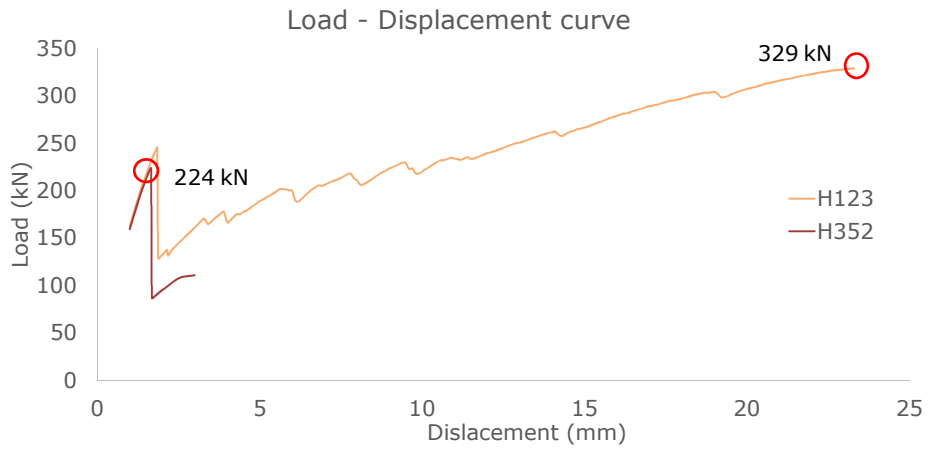
Concrete:
- Total strain based crack model
- Rotating crack orientation
- $E_{cm} = 41497\ N/mm^2$
- Hordijk tensile curve: $f_{tm} = 4{,}83\ N/mm^2$, $G_f^I = 0{,}158\ N/mm$
- Parabolic compression curve: $f_{cm} = 71{,}9\ N/mm^2$, $G_c = 39{,}4\ N/mm$

Reinforcement:
- $E_s = 200000\ N/mm^2$
- Von Mises plasticity
- Yield strength/Ultimate strength: $644{,}7$ / $755{,}1\ N/mm^2$
- Plastic yield strain/Plastic ultimate strain: $0{,}0467765$ / $0{,}0477765$

Bond-slip interface:
- $k_n = 100000\ N/mm^2$, $k_s = 10000\ N/mm^2$
- Bond-slip interface failure model: Shima bondslip function $t_t = 0.9 f_c'^{2/3} \left(1 - e^{\left(-40 \left(\frac{\Delta u_t}{D} \right)^{0.6} \right)} \right)$

2. Initial DIANA models

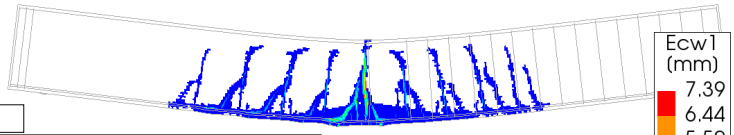
Load-displacement diagram:



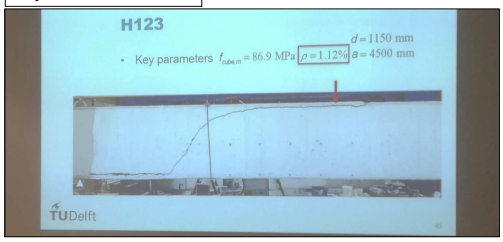
2. Initial DIANA models

Failure Mode Beam H123: spalling of concrete around the longitudinal reinforcement

Analysis1
Phased 1, Load-step 334, Load-factor 31.100, displacement
Crack-widths Ecw1
min: -1.70e-01mm max: 7.39e+00mm



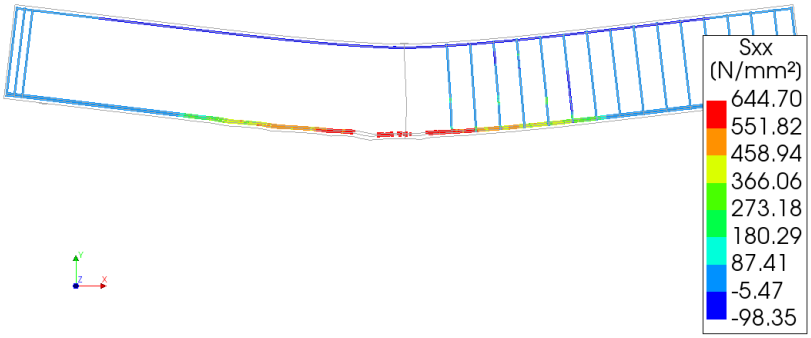
Experimental result



2. Initial DIANA models

Steel stresses of H123 beam

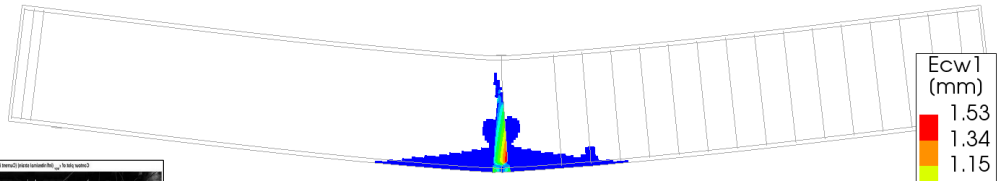
Analysis1
Phased 1, Load-step 334, Load-factor 31.100, displacement
Reinforcement Cauchy Total Stresses Sxx layer 1
min: -98.35N/mm² max: 684.44N/mm²

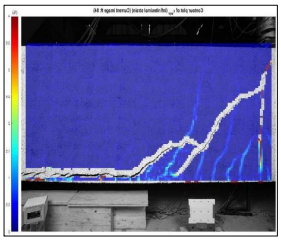


2. Initial DIANA models

Failure Mode Beam H352: flexural failure

Analysis1
Phased 1, Load-step 12, Load-factor 1.6800, displacement
Crack-widths Ecw1
min: -0.00mm max: 1.53mm



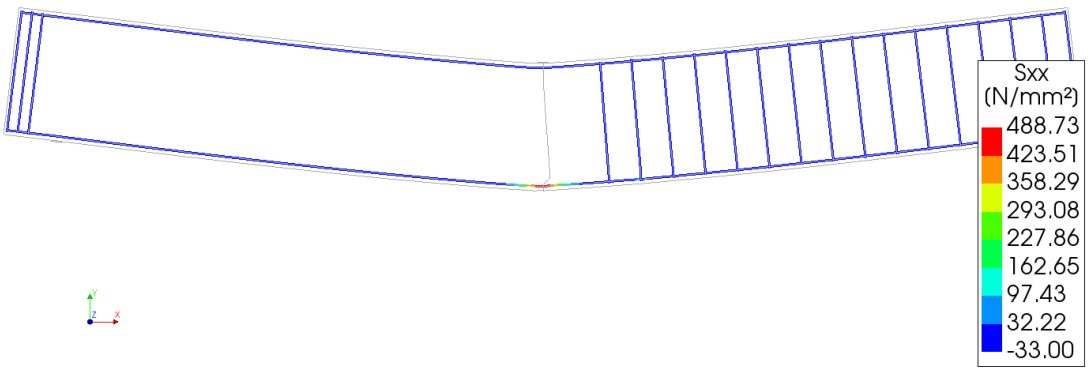


Experimental result

2. Initial DIANA models

Steel stresses of H352 beam

Analysis1
Phased 1, Load-step 12, Load-factor 1.6800, displacement
Reinforcement Cauchy Total Stresses Sxx layer 1
min: -33.00N/mm² max: 488.73N/mm²



3. Improved DIANA models

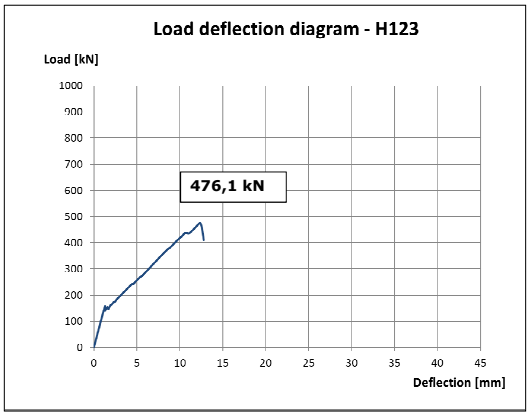
Changes made:

- Lowering tensile strength concrete to 4,0 Mpa
- Change yield stress reinforcement to 583,9 Mpa
- Tolerance setting for energy convergence criteria set from 0,001 to 0,0001
- Increase amount of iterations to 1000

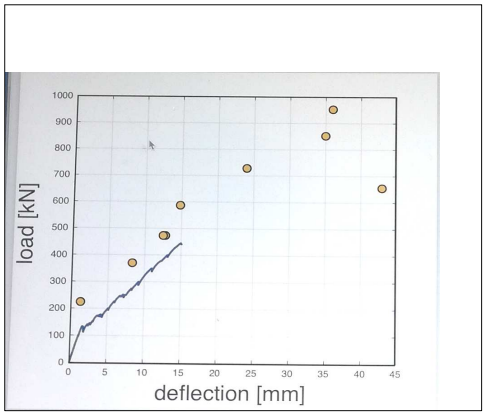
3. Improved DIANA models

Load-deflection diagram of H123 beam

Improved DIANA model

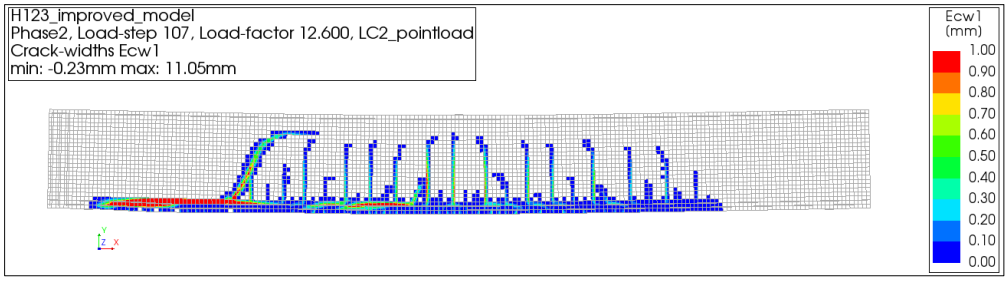


Experimental result

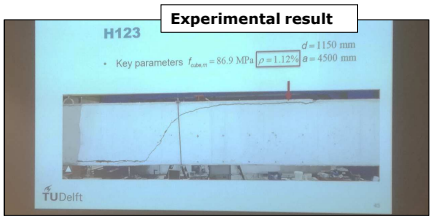


3. Improved DIANA models

Crack pattern of H123 beam

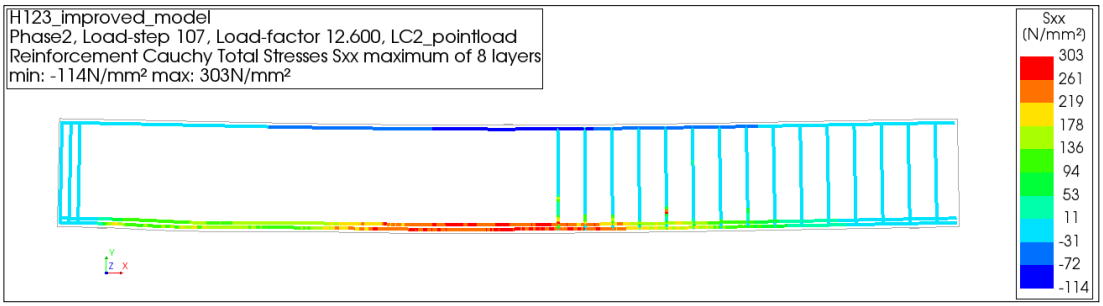


Experimental result



3. Improved DIANA models

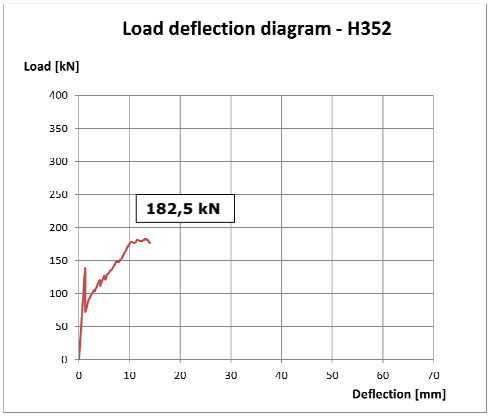
Steel stresses of H123 beam



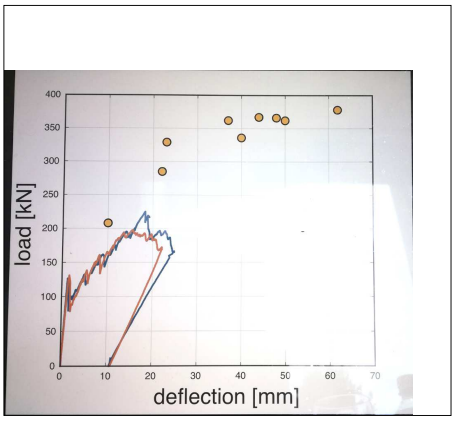
3. Improved DIANA models

Load-deflection diagram of H123 beam

Improved DIANA model

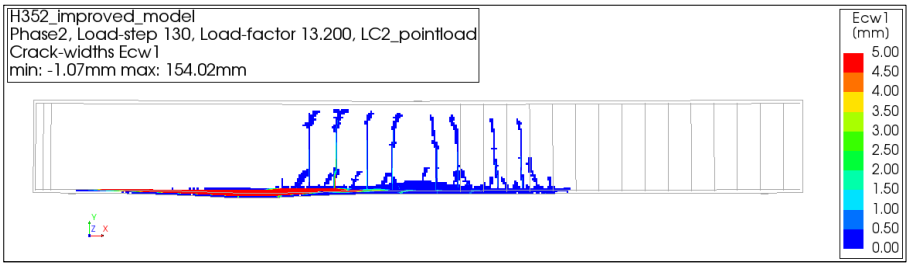


Experimental result

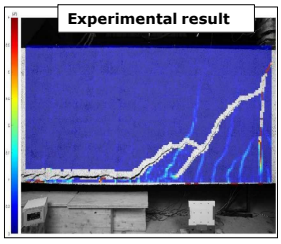


3. Improved DIANA models

Crack pattern of H352 beam



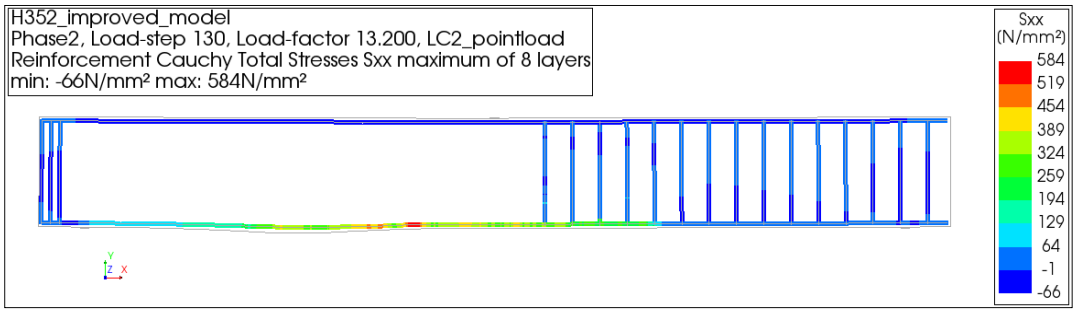
Experimental result



Dowel failure

3. Improved DIANA models

Steel stresses of H352 beam



4. Conclusions

- Improved models show better match with experimental results
- Concrete tensile strength is a very sensitive parameter
- Convergence criteria should be stricter for structural elements with mixed failure mechanism
- Conservative load capacity can be produced by following the RWS guideline
- Influence of using embedded reinforcement and bond-slip reinforcement should be further investigated