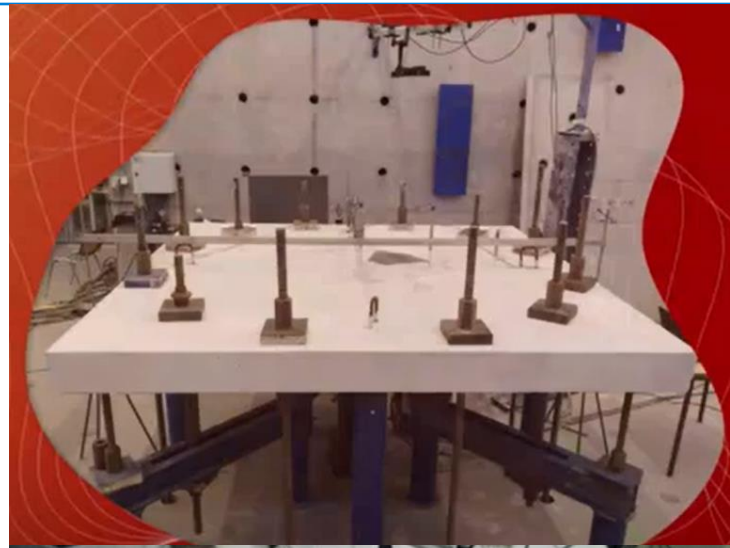
3rd Blind Simulation Competition

CEB-FIP workgroup WP 2.4.1

Simulation of slabs reinforced with conventional reinforcement and fibres subjected to punching loading configuration

Presentation on ABT submission
DOV lecture evening 7-2-2024



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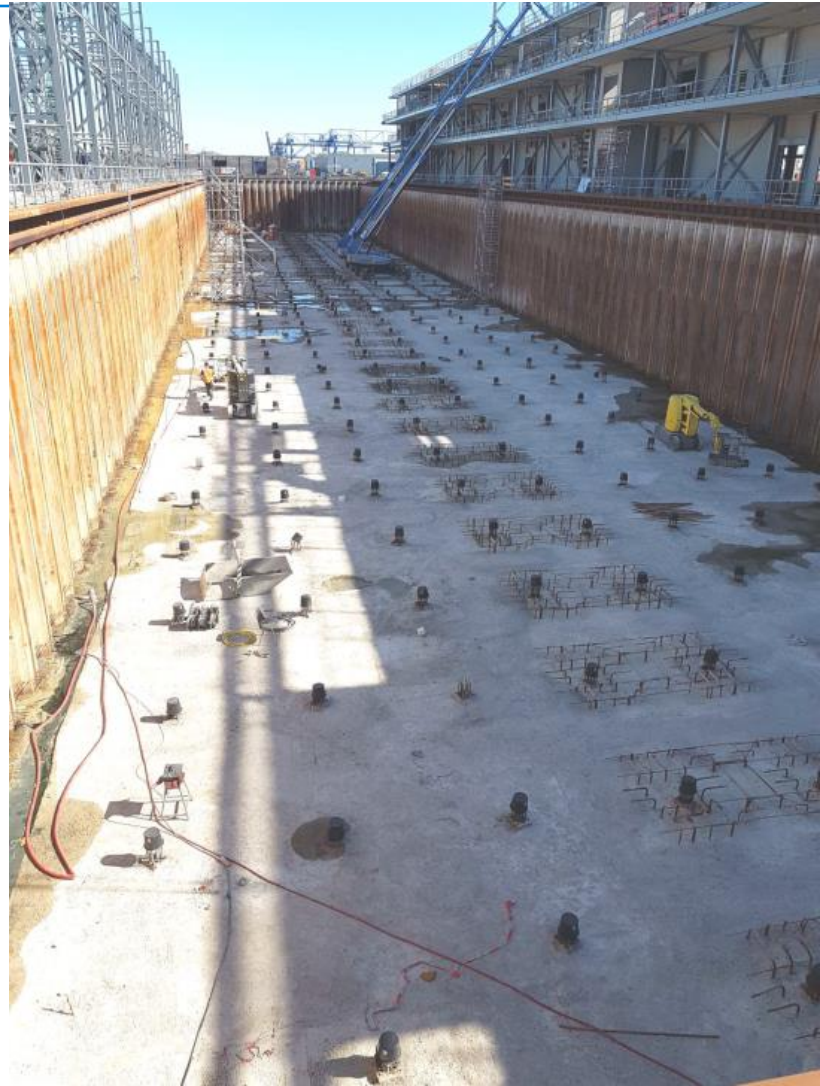
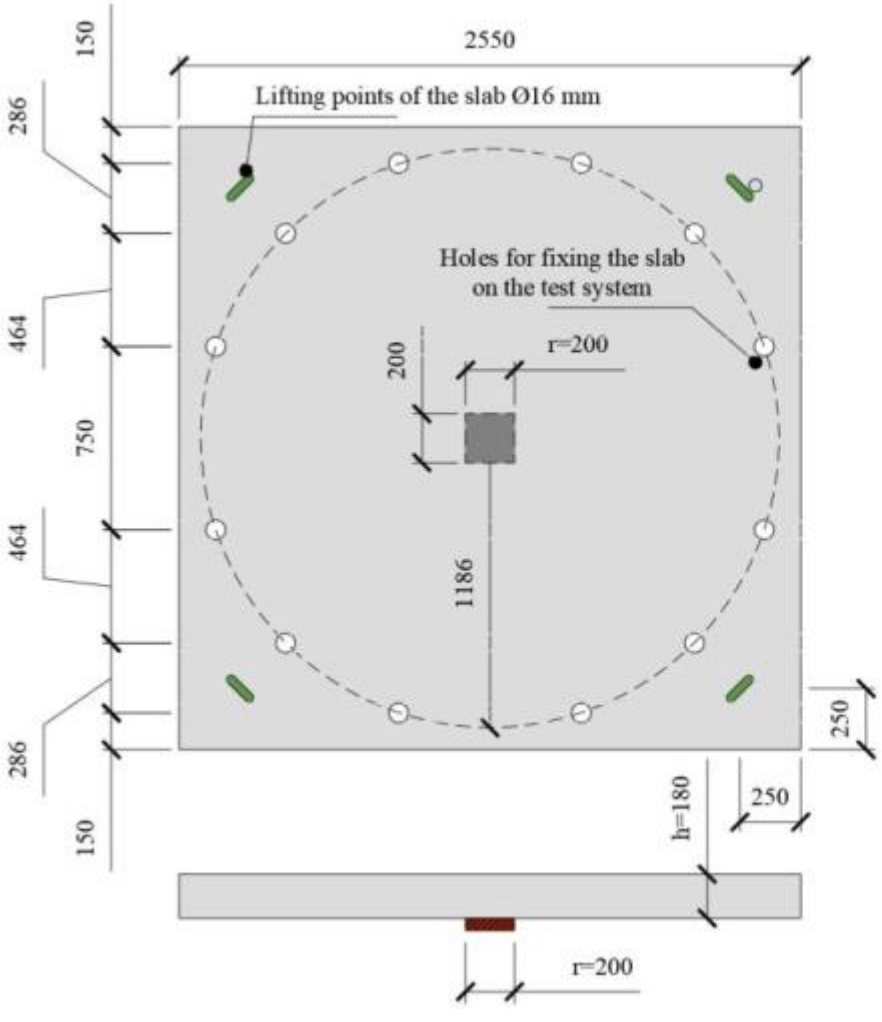
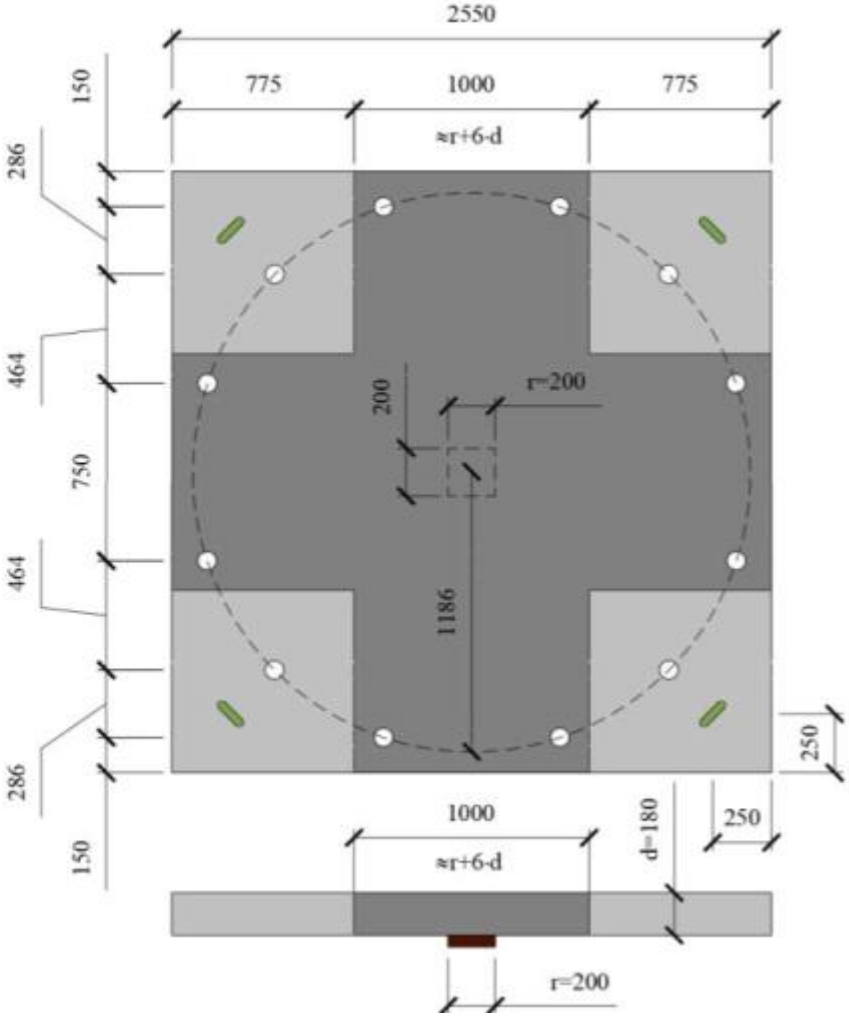
Krishna Ajithkumar Pillai

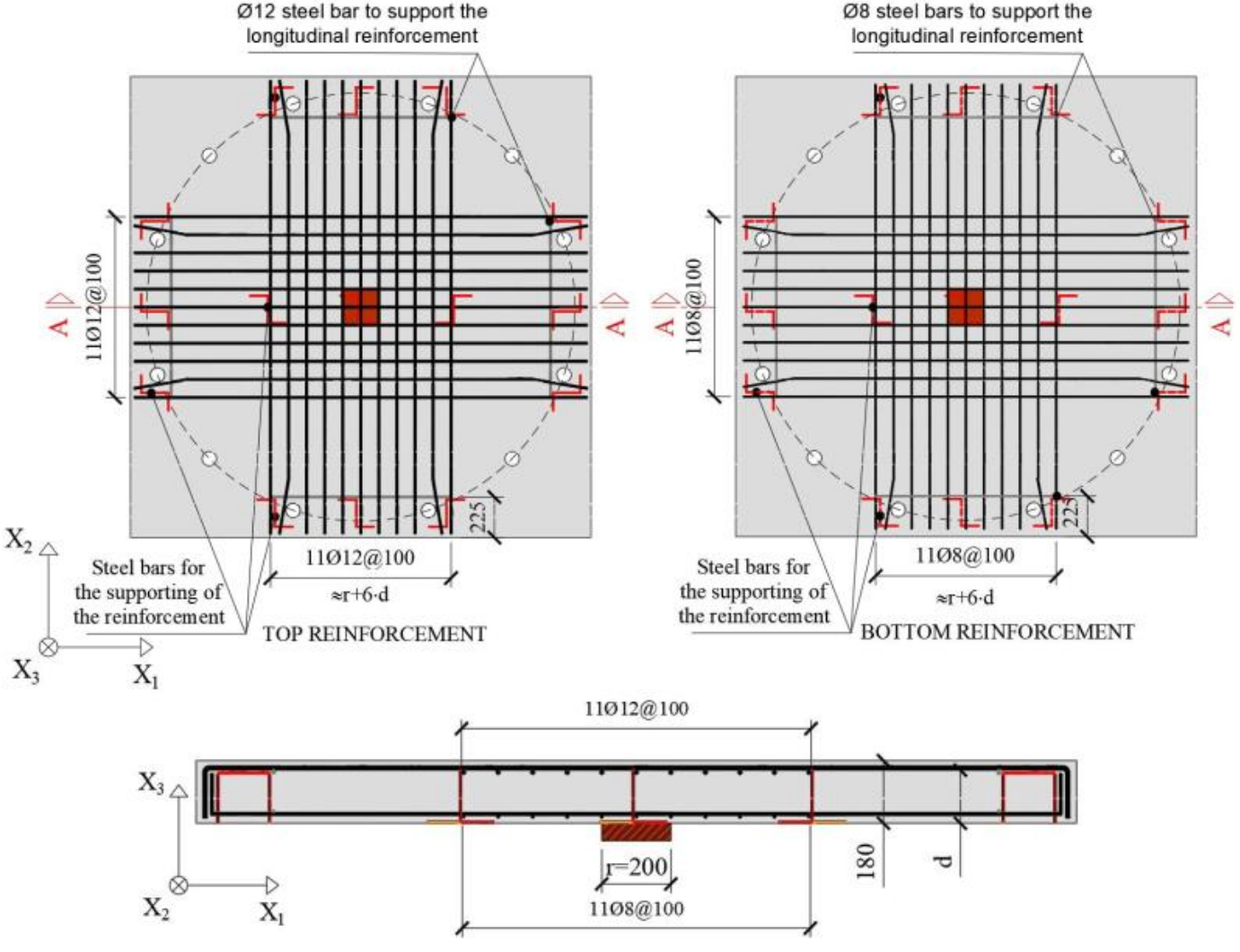
Projects SFRC

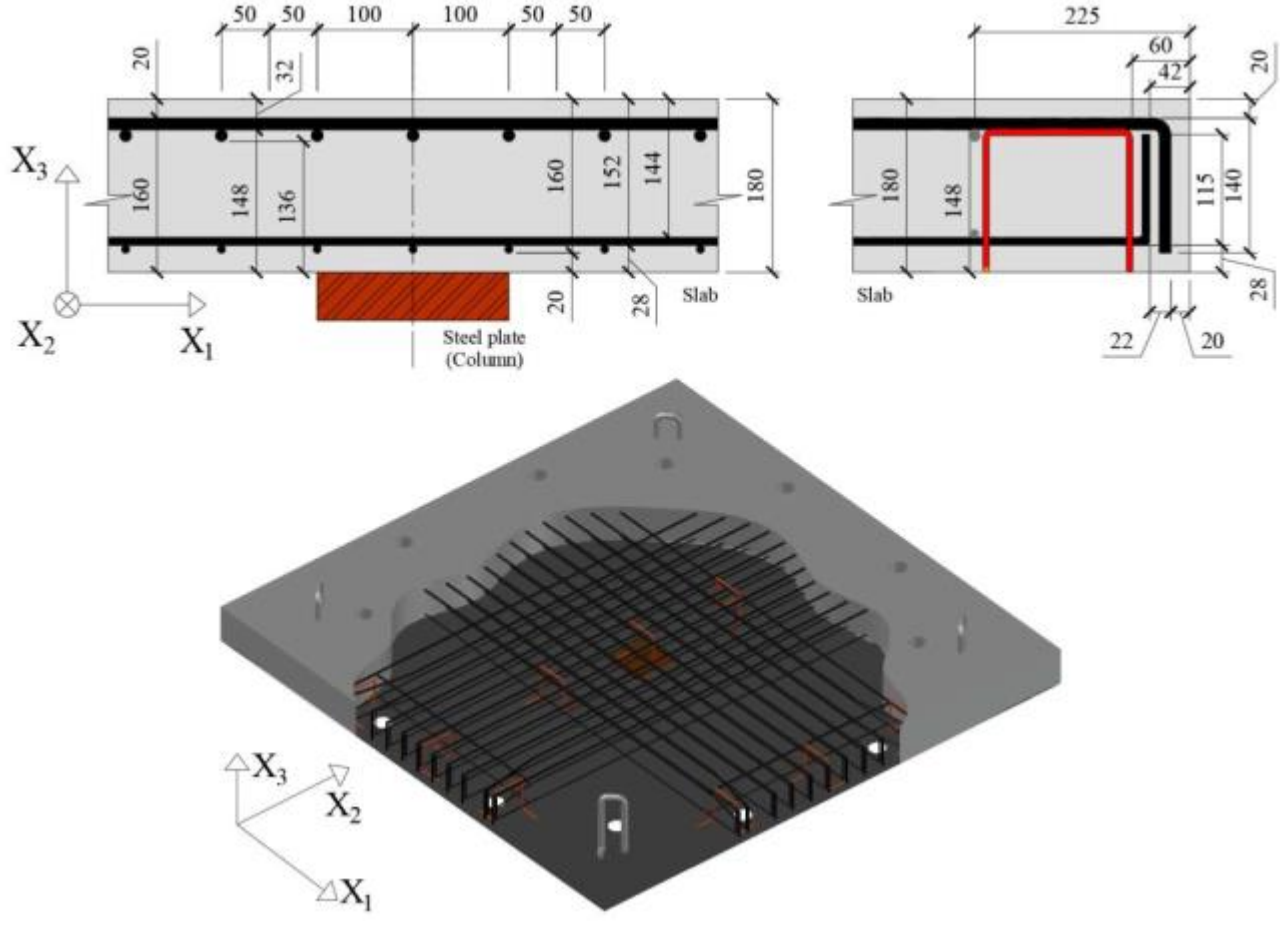
- Industrial floors
- Steel fibre under water concrete (CROW)
- Wind turbine foundations
- Precast concrete basements




2550
150
286
464
750
464
286
150
Lifting points of the slab Ø16 mm
Holes for fixing the slab
on the test system
200
r=200
1186
250
h=180
250
r=200


2550
775
1000
775
≈r+6-d
150
286
464
750
464
286
150
200
r=200
1186
250
1000
≈r+6-d
d=180
250
r=200


Ø12 steel bar to support the longitudinal reinforcement
11Ø12@100
A
A
225
11Ø12@100
≈r+6·d
Steel bars for the supporting of the reinforcement
TOP REINFORCEMENT
X2
X3
X1
Ø8 steel bars to support the longitudinal reinforcement
11Ø8@100
A
A
225
11Ø8@100
≈r+6·d
Steel bars for the supporting of the reinforcement
BOTTOM REINFORCEMENT
11Ø12@100
X3
X2
X1
r=200
11Ø8@100
180
d


50
50
100
100
50
50
20
32
160
148
136
160
152
144
180
20
28
Slab
Steel plate
(Column)
X3
X2
X1
225
60
42
20
180
148
115
140
28
Slab
22
20
X3
X2
X1

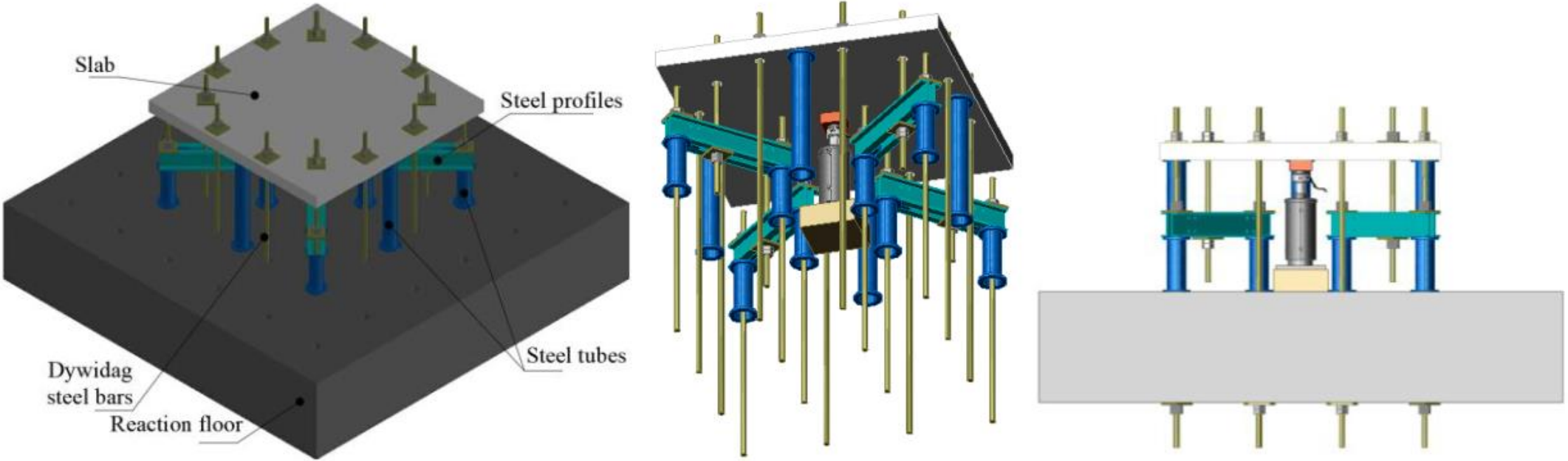
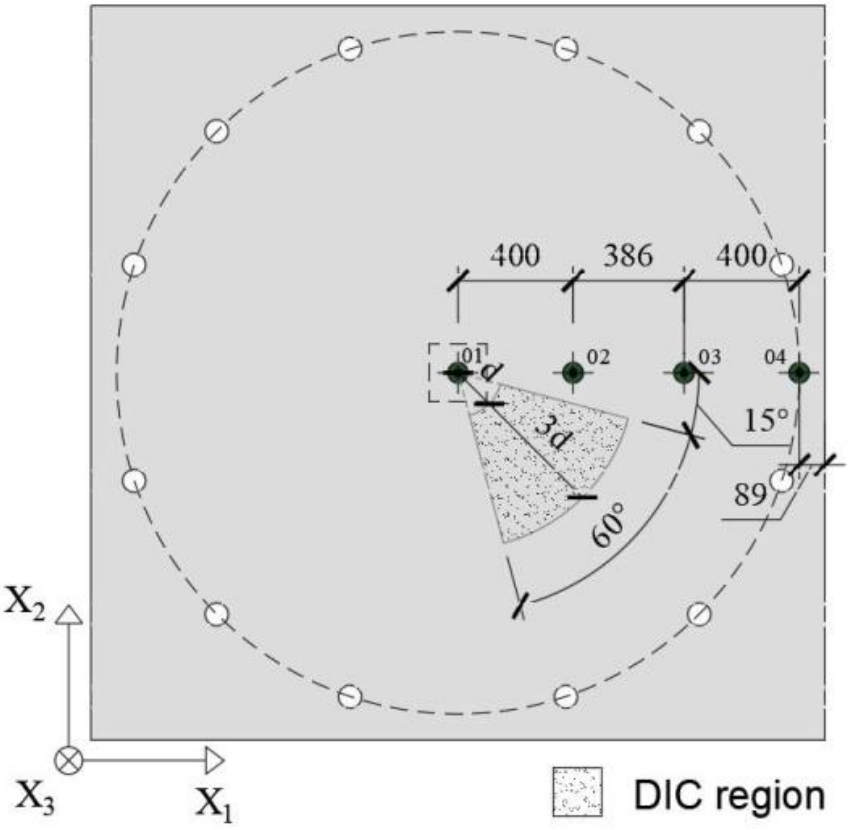
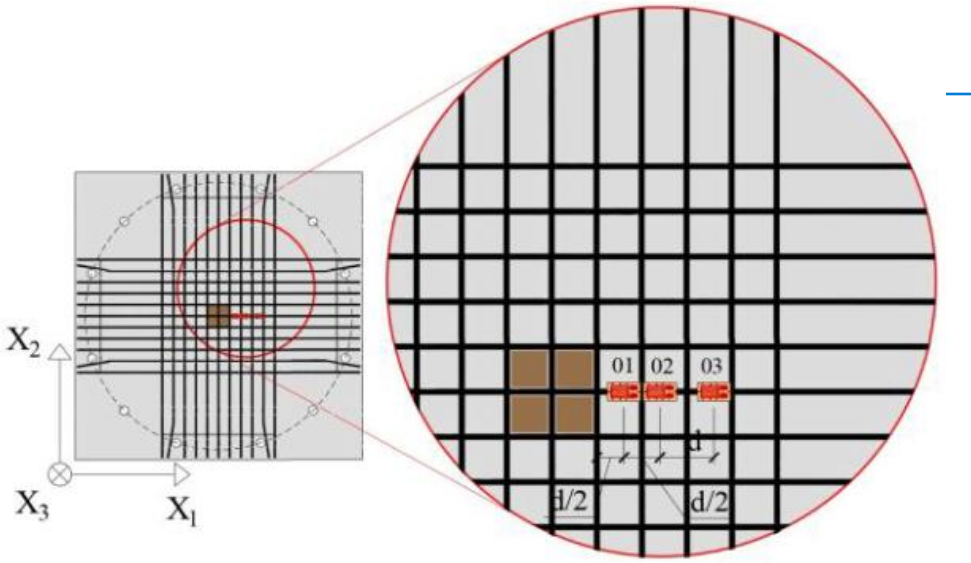
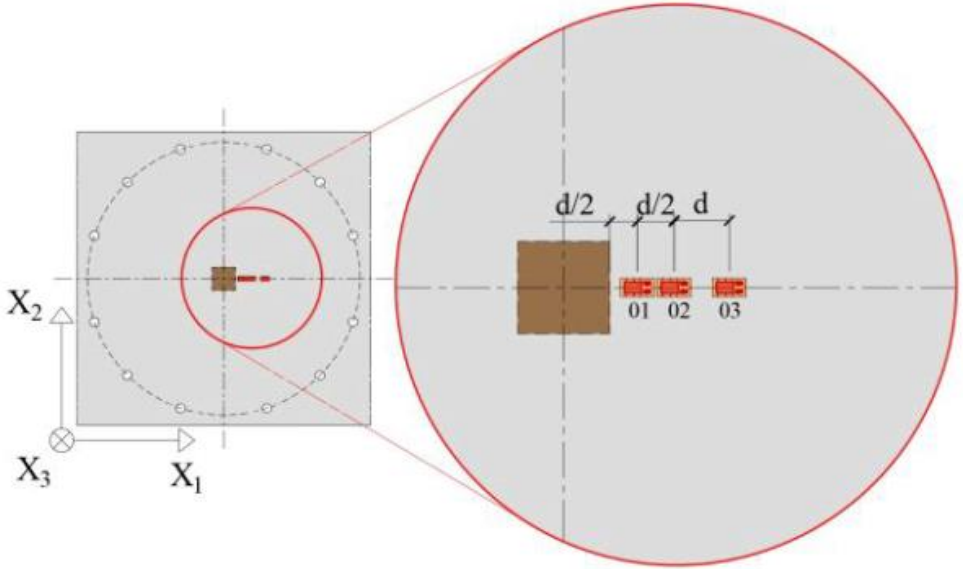
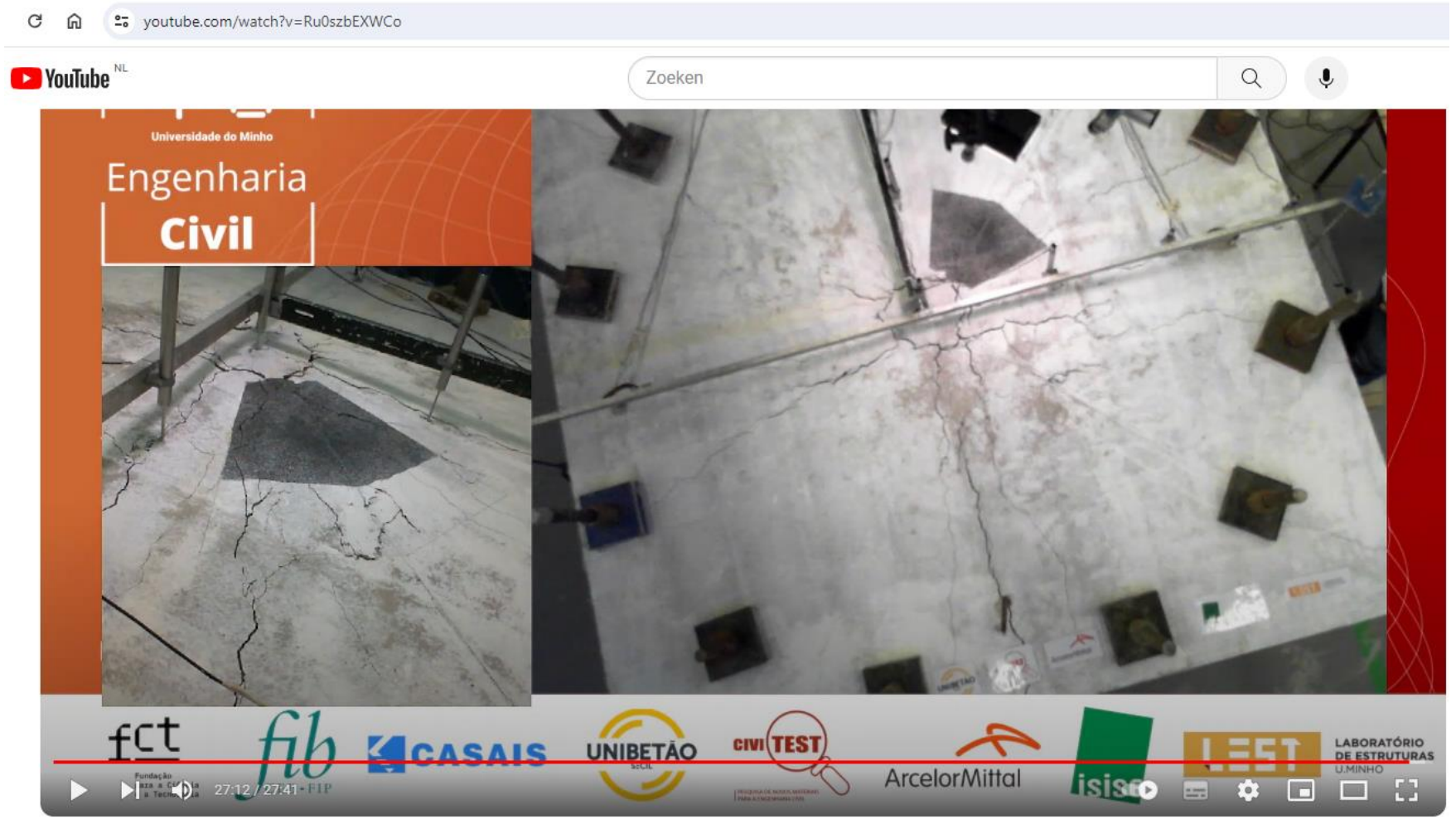


Figure 4. Test setup of the R/SFRC slab prototypes.

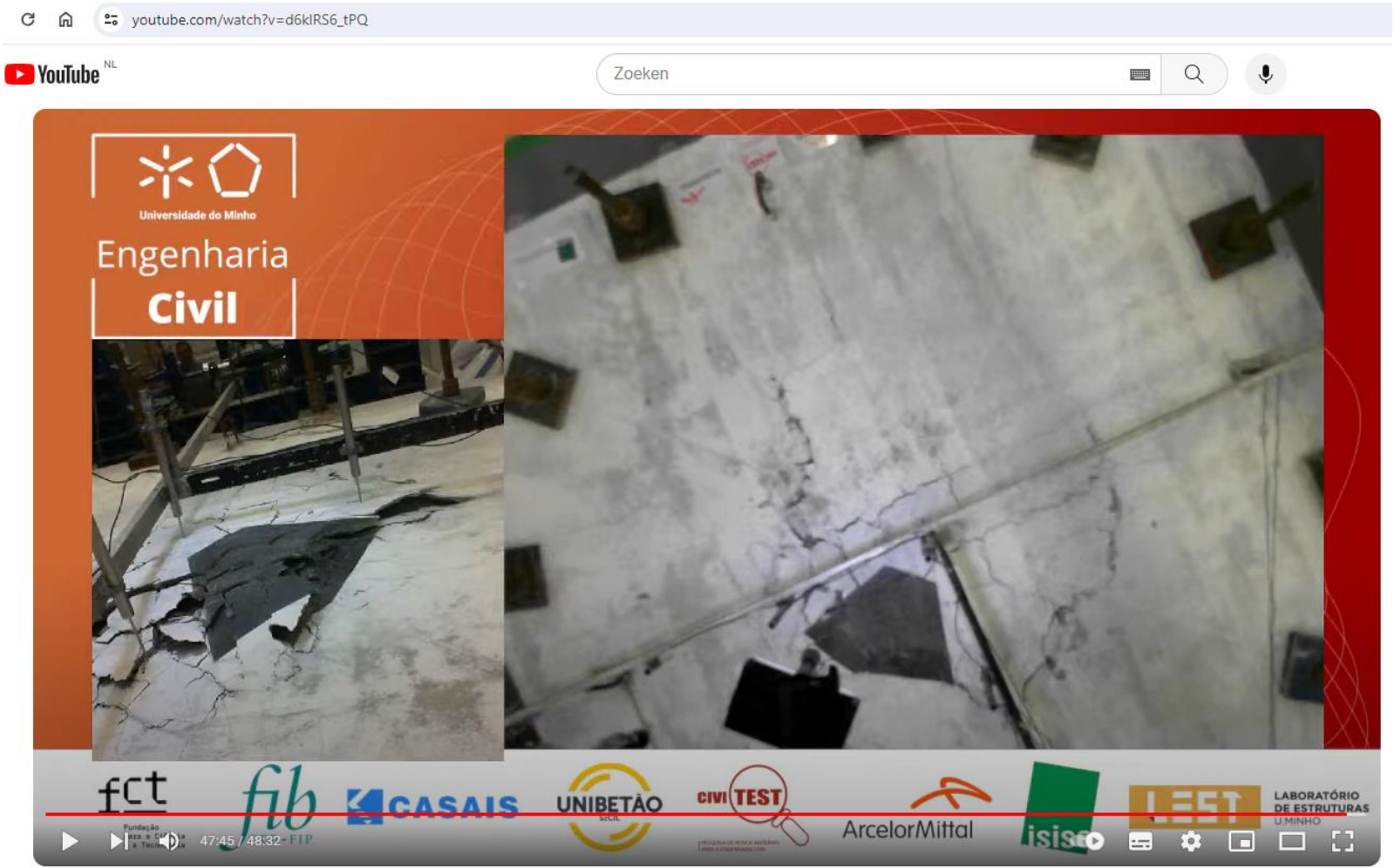

400
386
400
01
02
03
04
d
3d
15°
89
60°
X2
X3
X1
DIC region


X2
X3
X1
01
02
03
d
d/2
d/2


X2
X3
X1
d/2
d/2
d
01
02
03



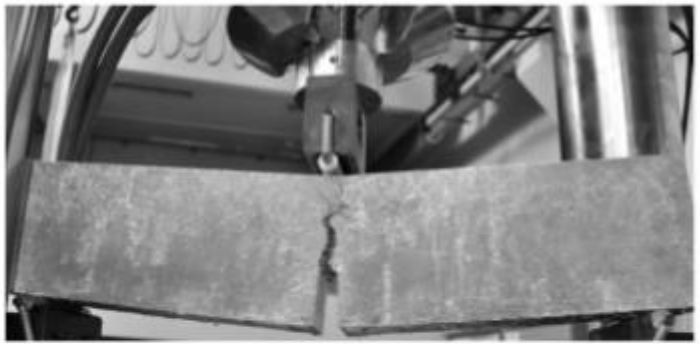
3rd Blind Simulation Competition - 18 July 2023

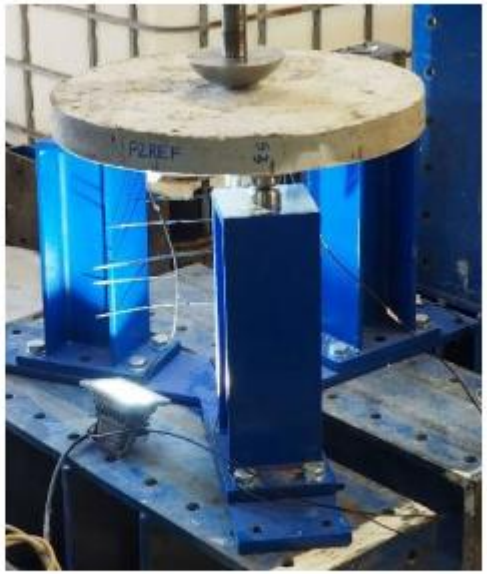


3rd Blind Simulation Competition - 27-07-2023

Material properties

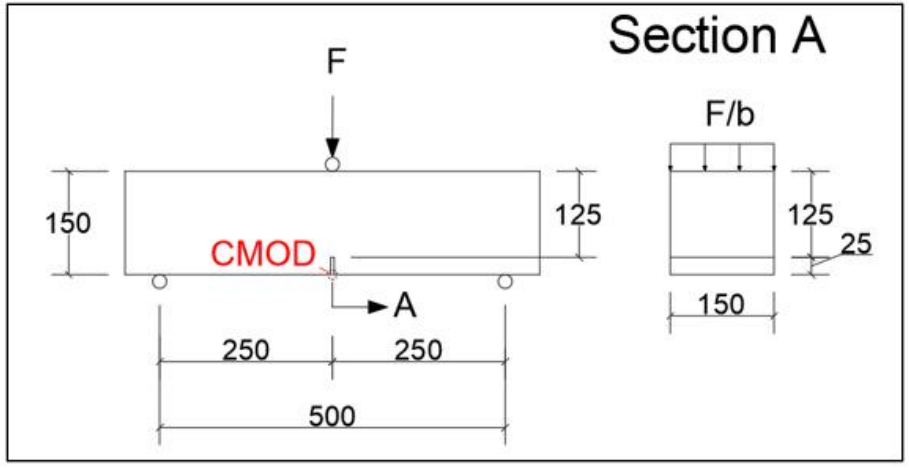
- Concrete mix composition
- 60 kg/m^3 steel fibres HE++ 90/60
- Secant modulus of elasticity in compression
- Compressive strength (~C50/60)
- Bending tensile strength results (EN 14651)
- Small round panel test results (SRDP)
- Reinforcement tensile test results (EN ISO 6982-1)

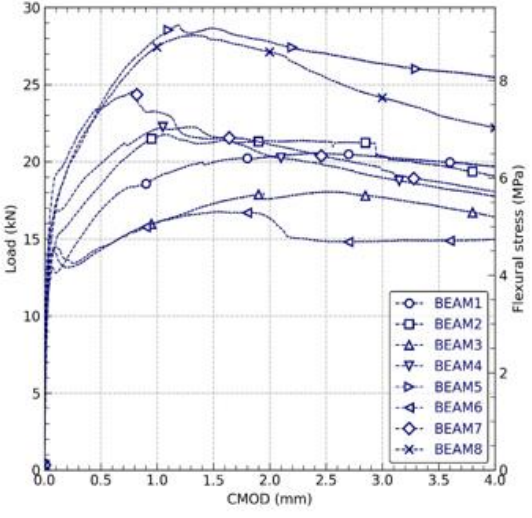


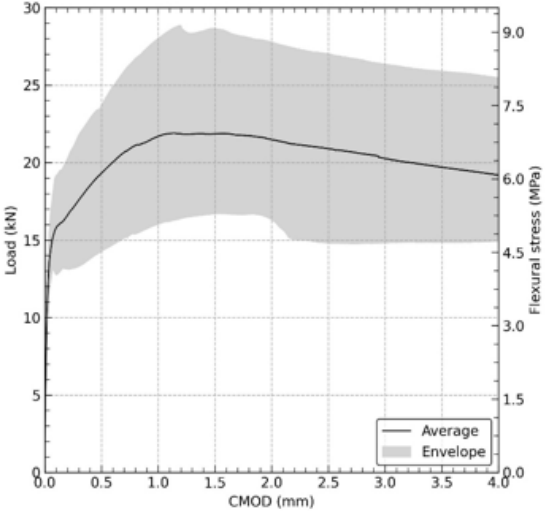


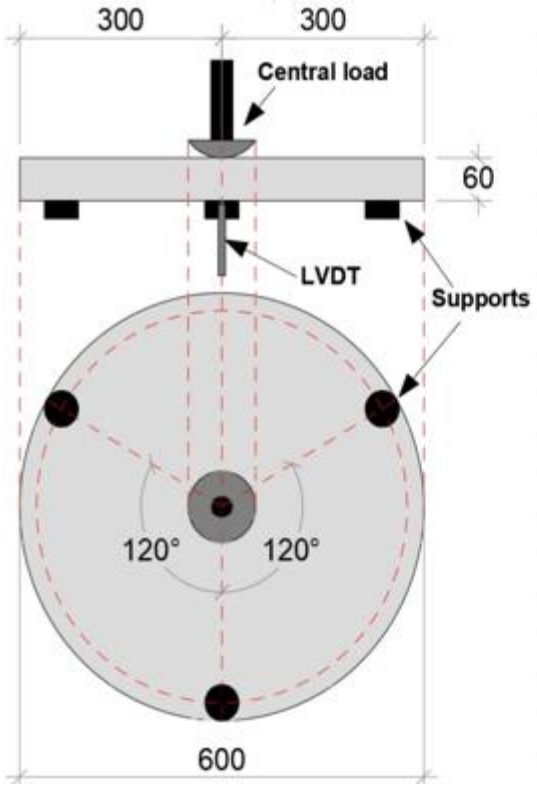
(a) (b)

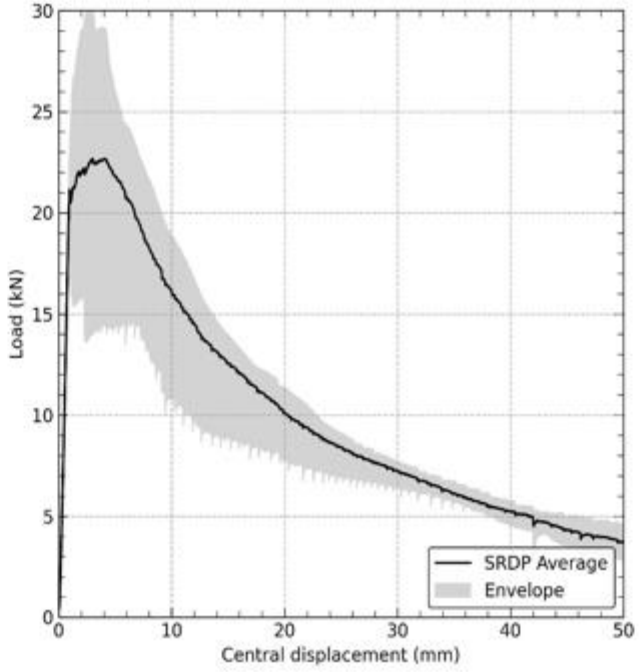
Figure 3. Test set up of (a) Three-point notched beam bending test, and (b) round panel test.

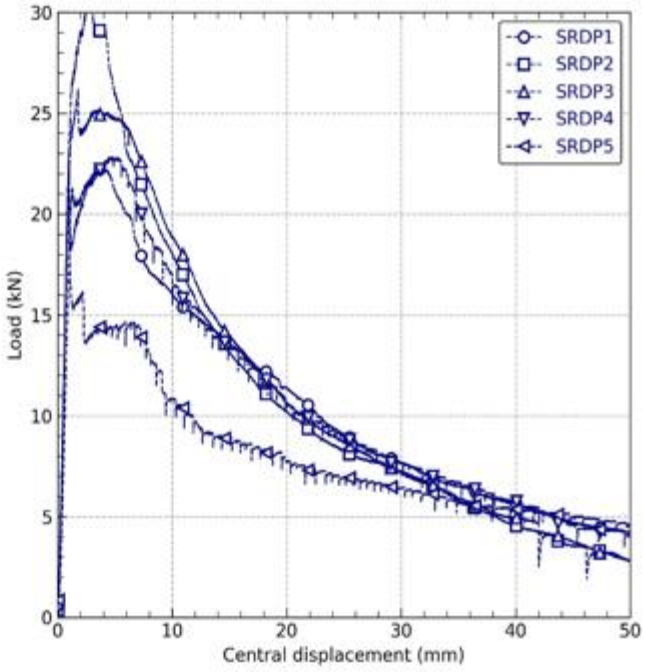

Section A
F
F/b
150
CMOD
125
125
25
A
250
250
500
150

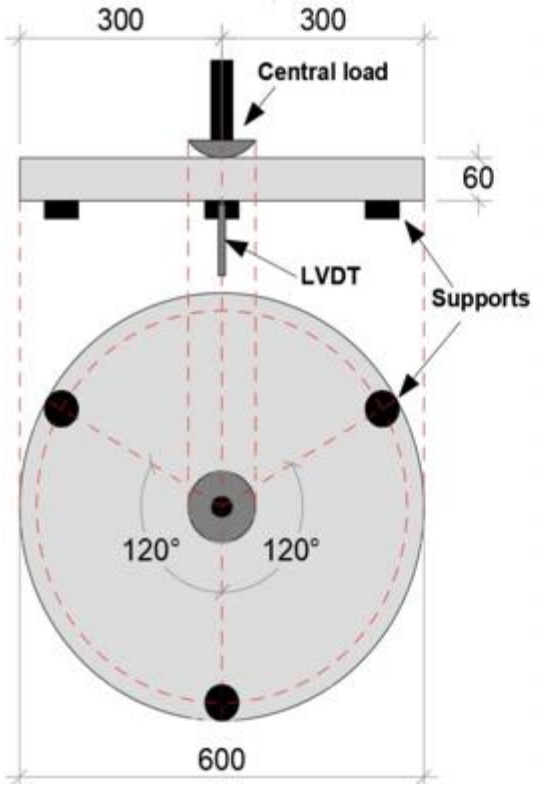

Load (kN)
Flexural stress (MPa)
CMOD (mm)
BEAM1
BEAM2
BEAM3
BEAM4
BEAM5
BEAM6
BEAM7
BEAM8

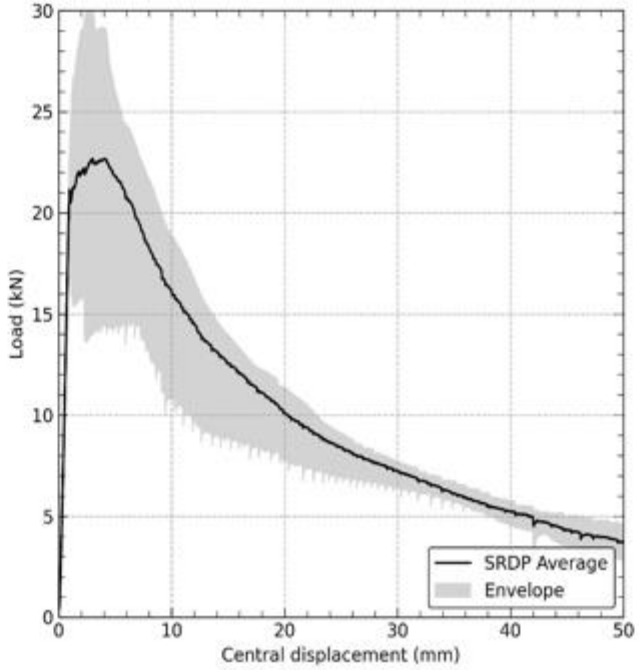

Load (kN)
Flexural stress (MPa)
CMOD (mm)
Average
Envelope

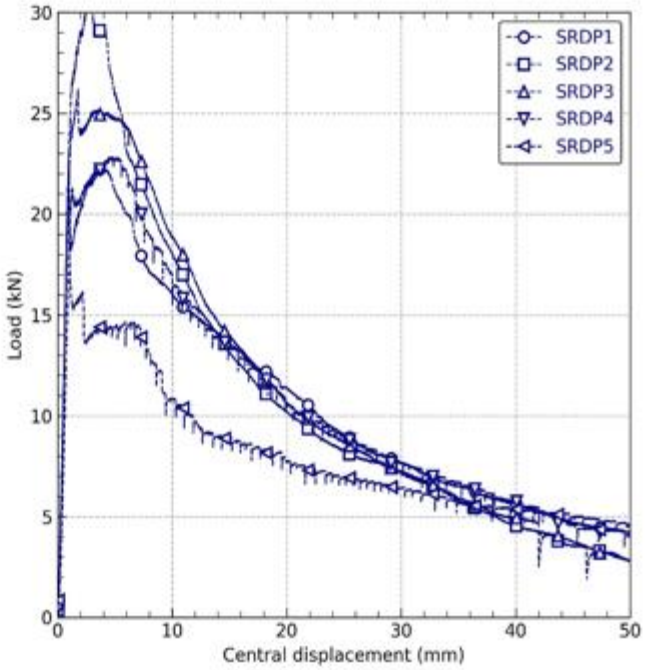

300
300
Central load
60
LVDT
Supports
120°
120°
600

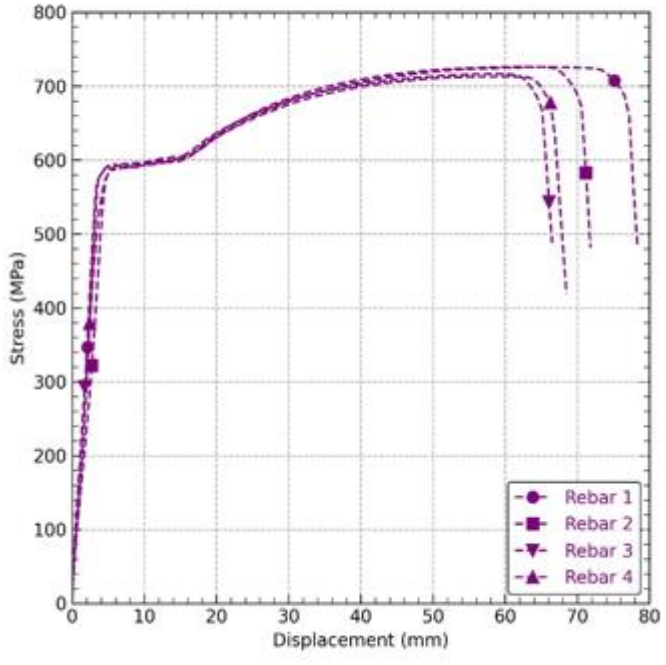
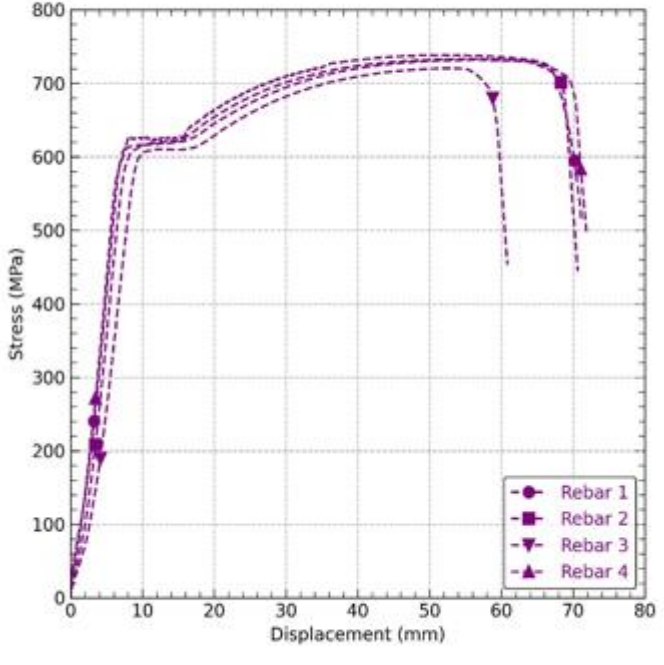

Load (kN)
Central displacement (mm)
SRDP Average
Envelope

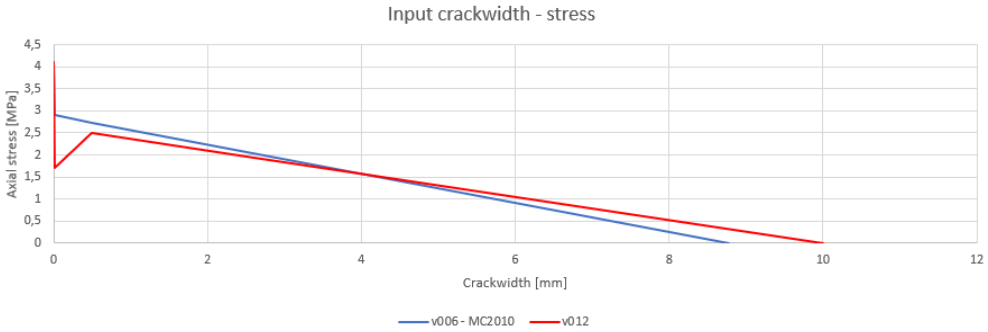

Load (kN)
Central displacement (mm)
SRDP1
SRDP2
SRDP3
SRDP4
SRDP5

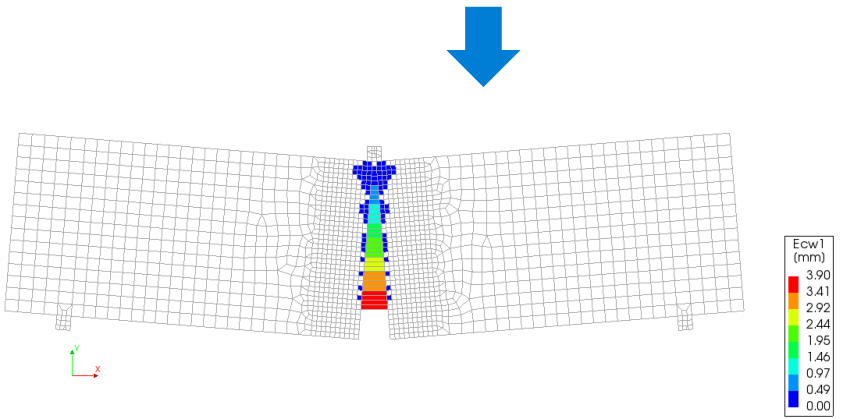

300
300
Central load
60
LVDT
Supports
120°
120°
600

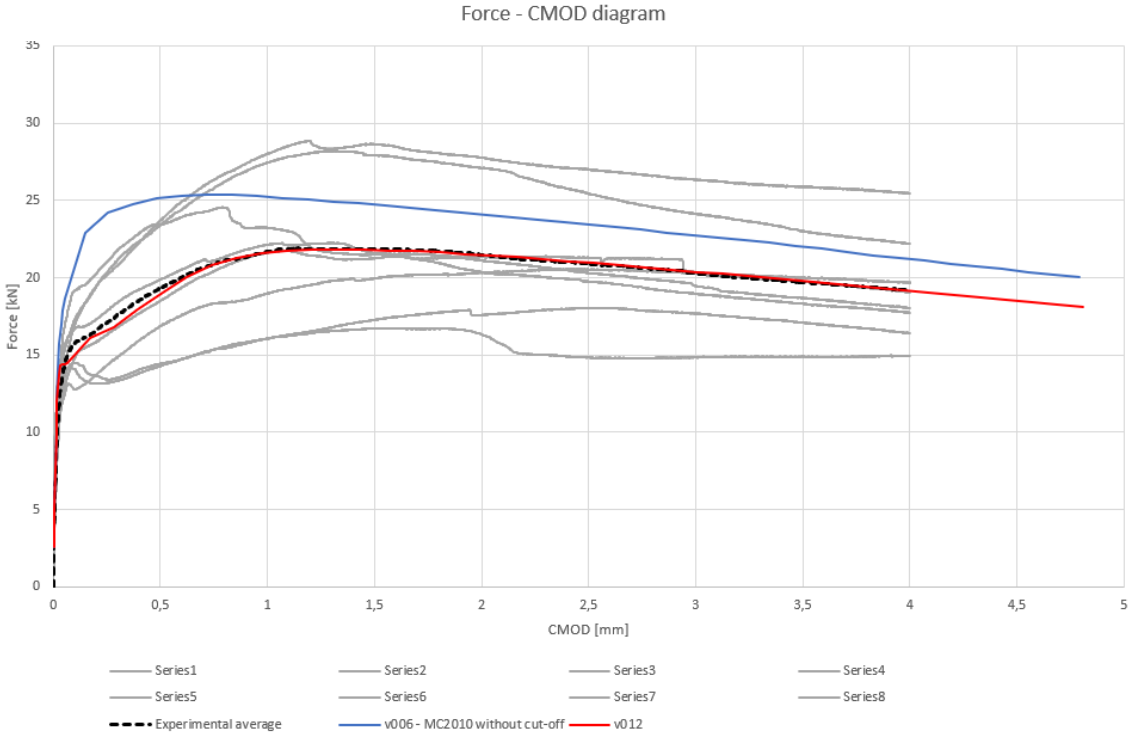

Load (kN)
Central displacement (mm)
SRDP Average
Envelope

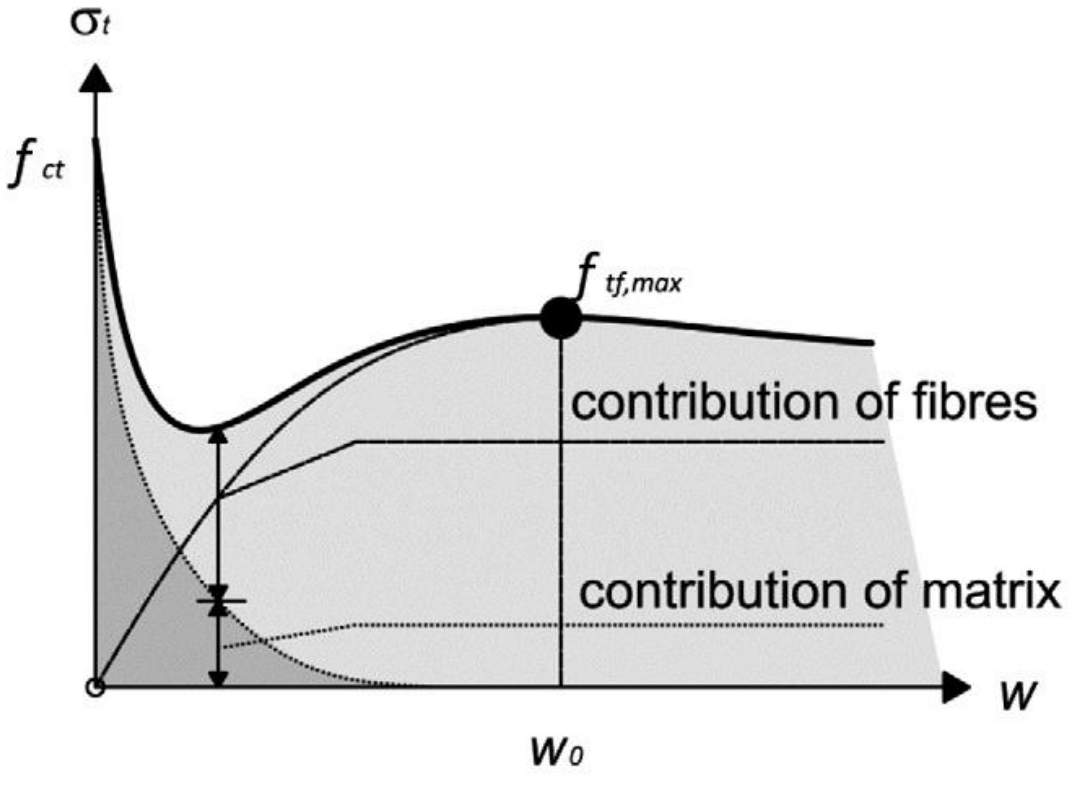

Load (kN)
Central displacement (mm)
SRDP1
SRDP2
SRDP3
SRDP4
SRDP5

8mm rebars graphic	12mm rebars graphic
	

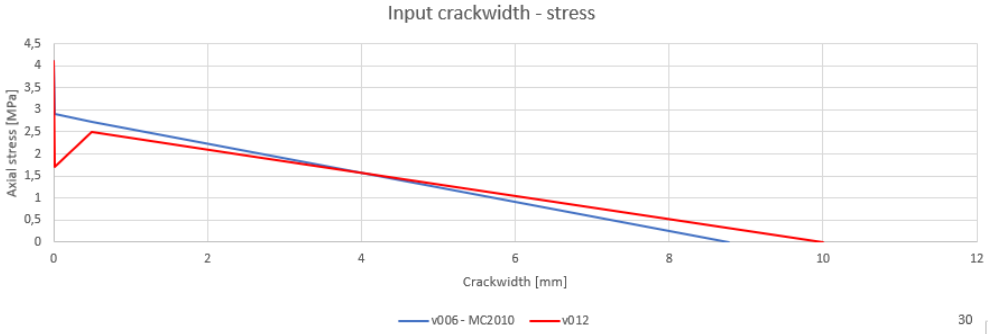

Input crackwidth - stress
Axial stress [MPa]
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
0
2
4
6
8
10
12
Crackwidth [mm]
v006 - MC2010
v012

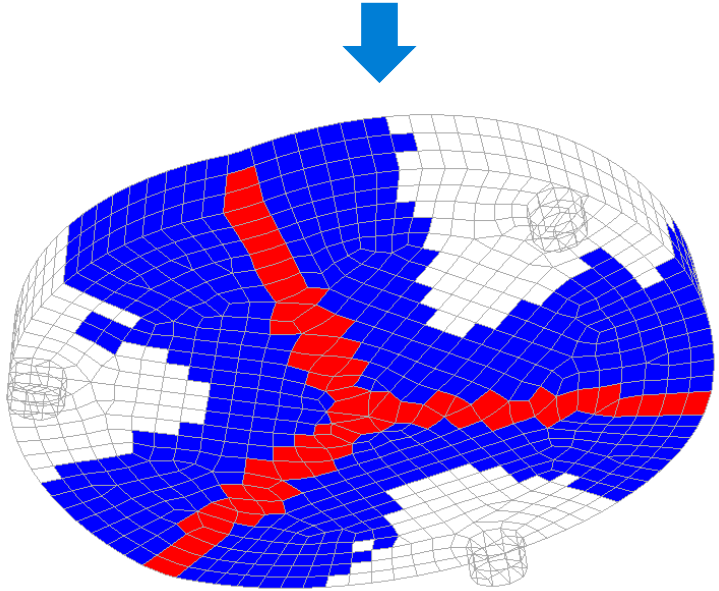

Ecw1 (mm)
3.90
3.41
2.92
2.44
1.95
1.46
0.97
0.49
0.00

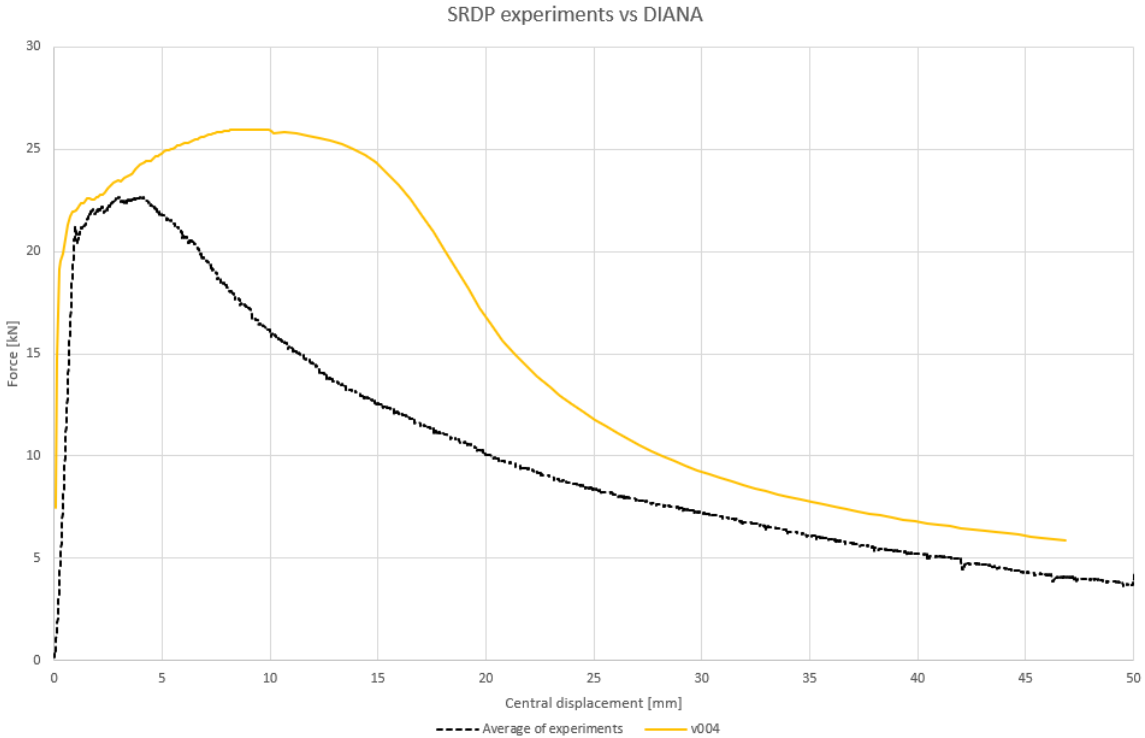

Force - CMOD diagram
Force [kN]
35
30
25
20
15
10
5
0
0
0,5
1
1,5
2
2,5
3
3,5
4
4,5
5
CMOD [mm]
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Experimental average
v006 - MC2010 without cut-off
v012

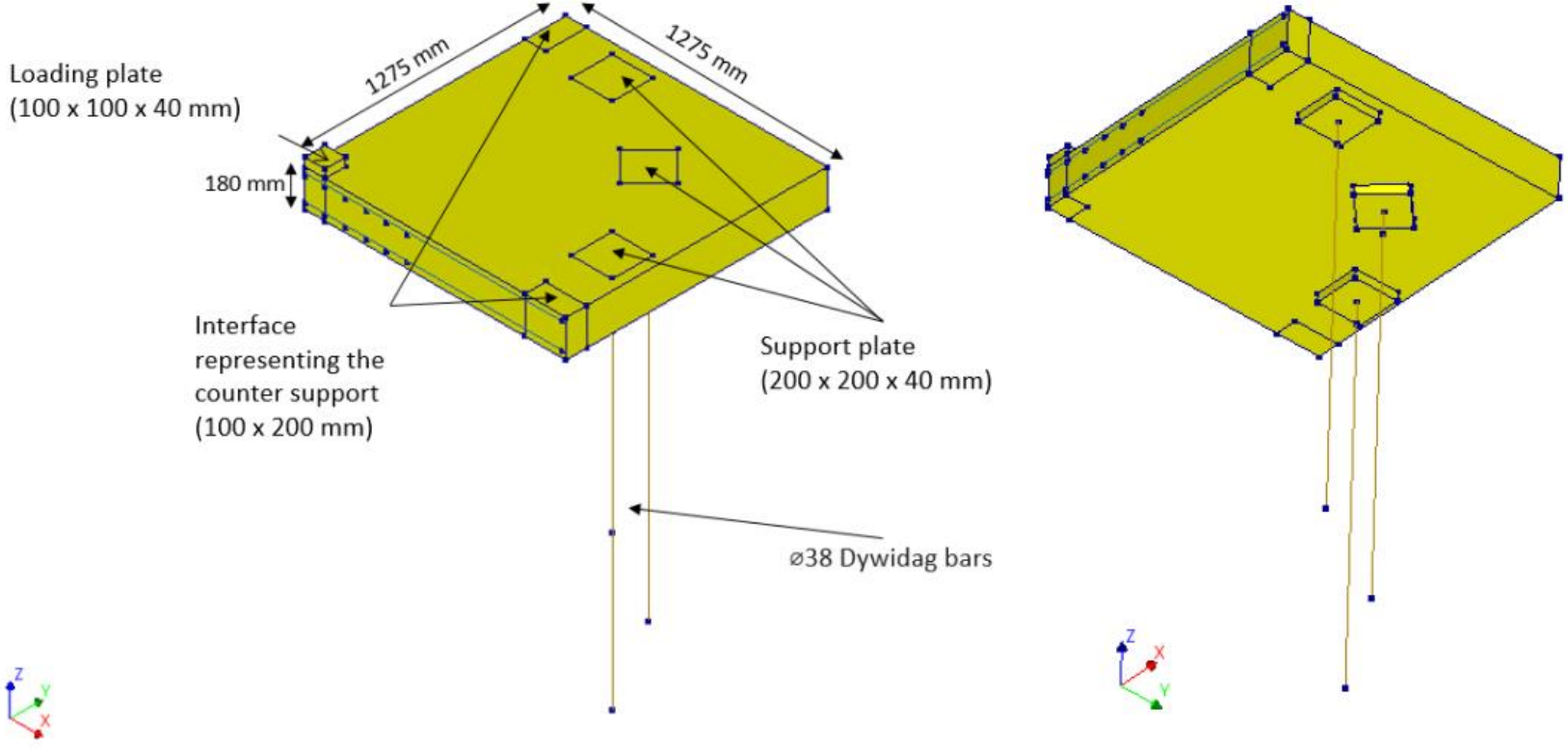


Source: Punching shear strength of steel fibre reinforced concrete slabs, Maya et al., Engineering Structures, 1 July 2012


Input crackwidth - stress
Axial stress [MPa]
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
0
2
4
6
8
10
12
Crackwidth [mm]
v006 - MC2010
v012




SRDP experiments vs DIANA
Force [kN]
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
40
45
50
Central displacement [mm]
Average of experiments
v004



(a) Top isometric view

(b) Bottom isometric view

Figure 1: Geometry of the numerical model of the test setup in DIANA FEA 10.5.

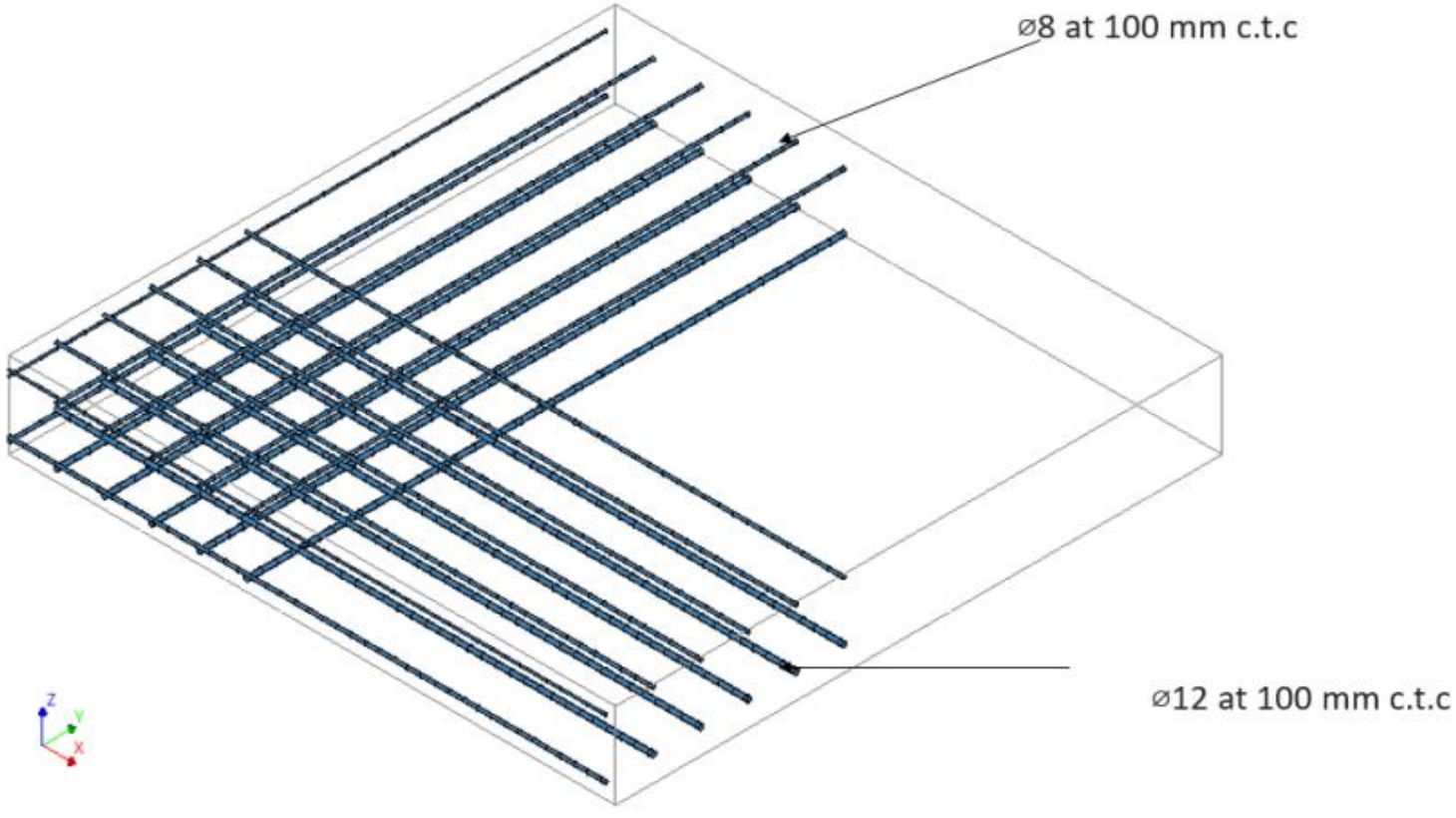
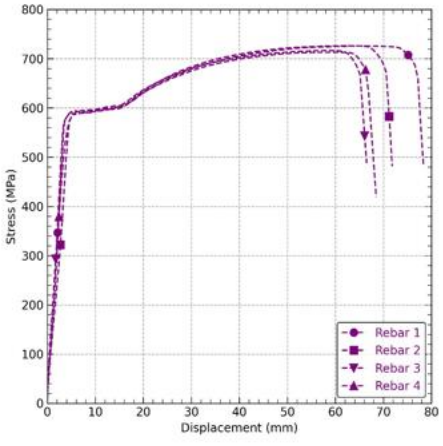
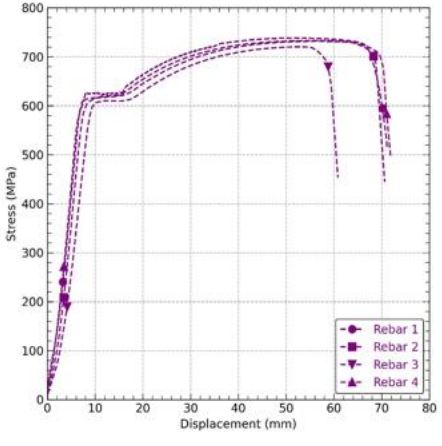
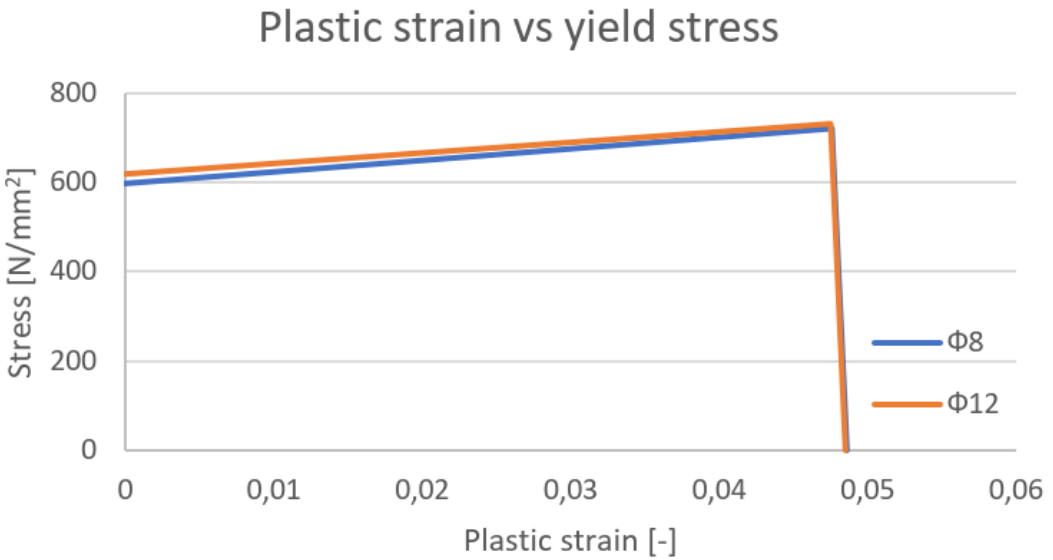
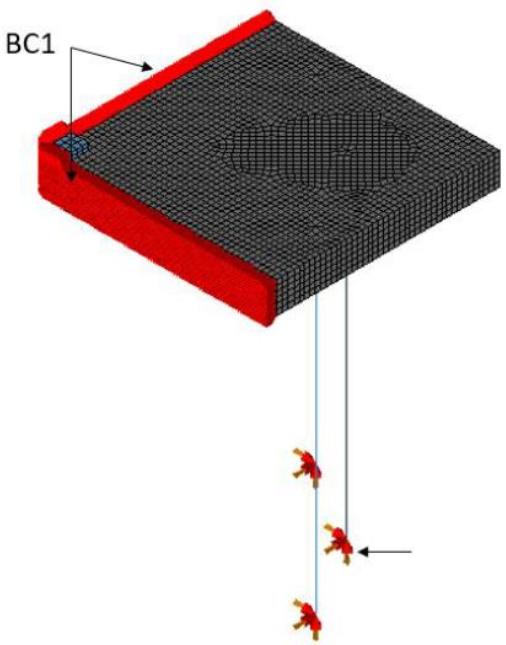
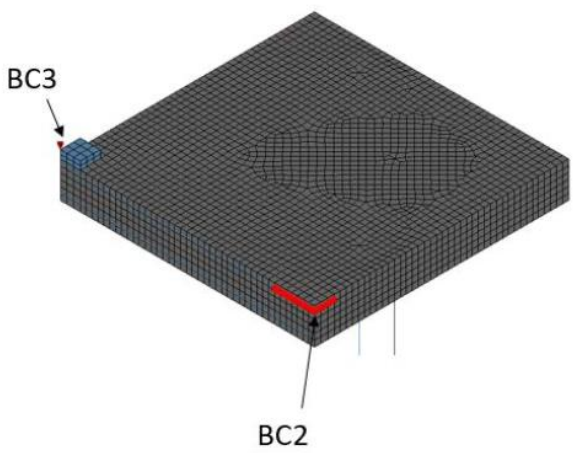


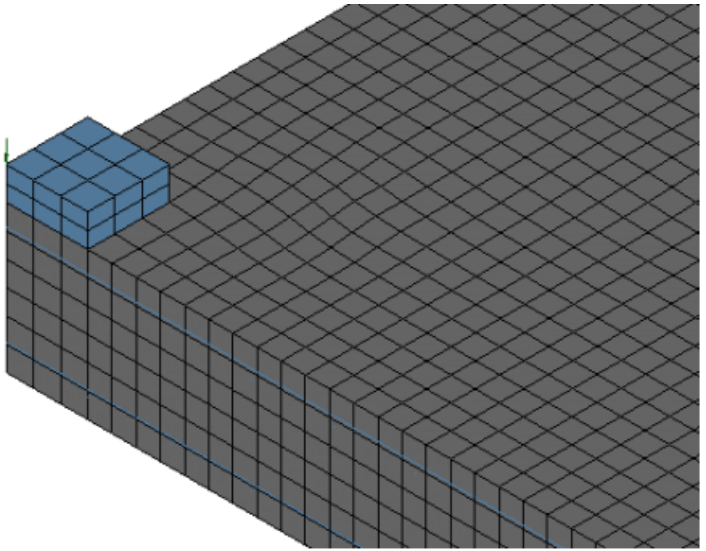
Figure 2: Flexural reinforcement

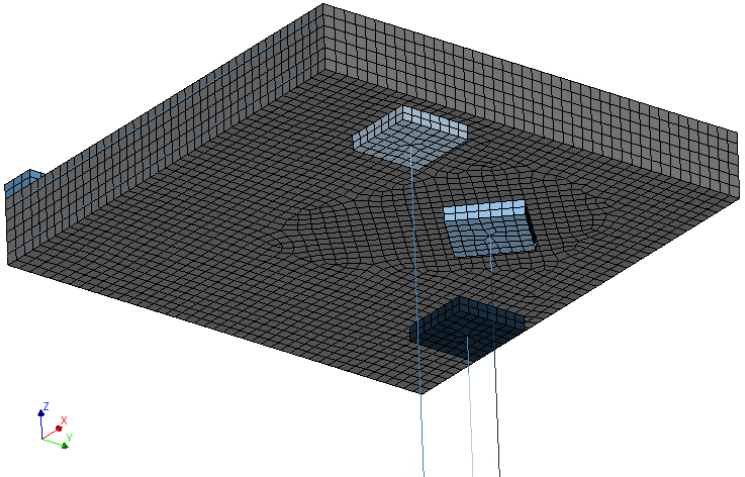
8mm rebars graphic	12mm rebars graphic
	




BC1


BC3
BC2

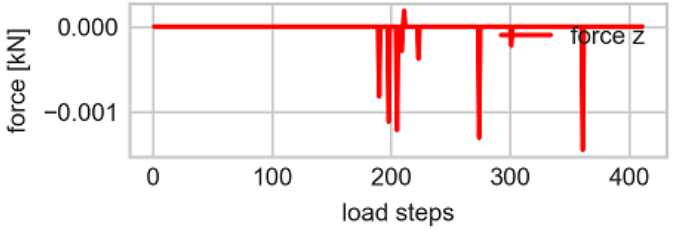


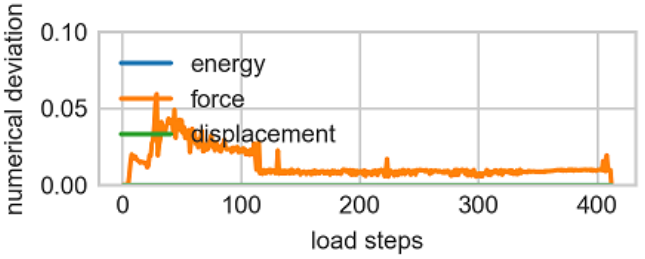


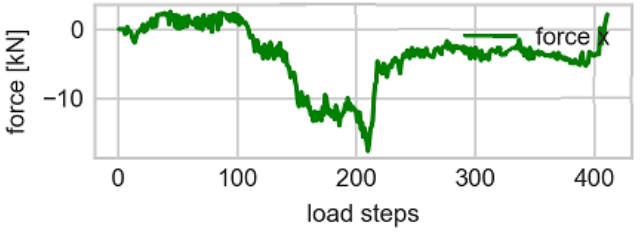
Analysis settings

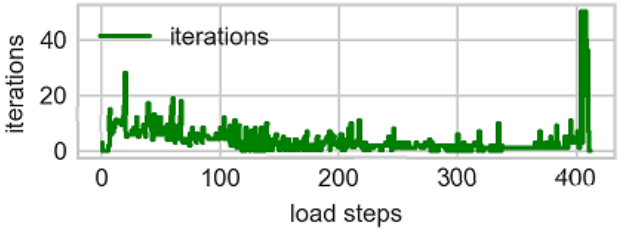
- Displacement control, 500 steps x 0.1 mm = 50 mm
- Regular Newton Raphson with line search
- Convergence on force tolerance 0.01
- Convergence on energy tolerance 0.001
- No simultaneous convergence required
- Max 50 iterations per step
- Continue when no convergence

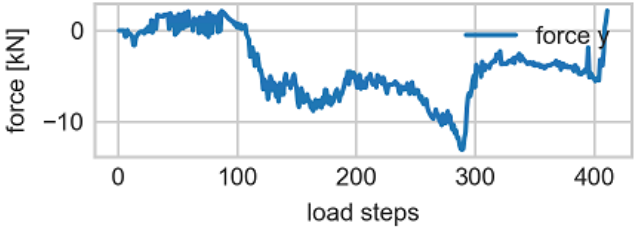
```
Elapsed time: 9 hours 9 minutes 31 seconds
```

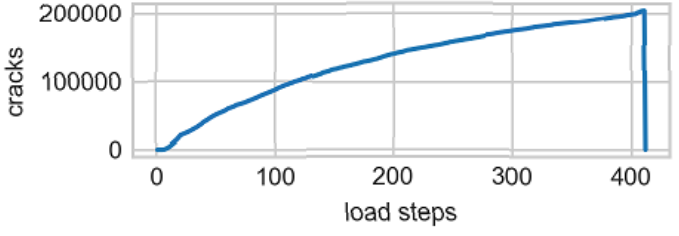


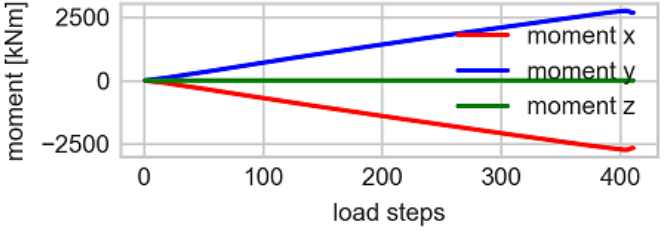


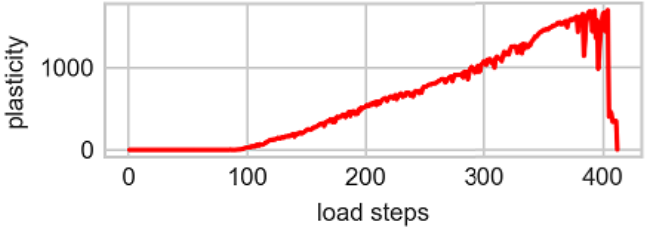


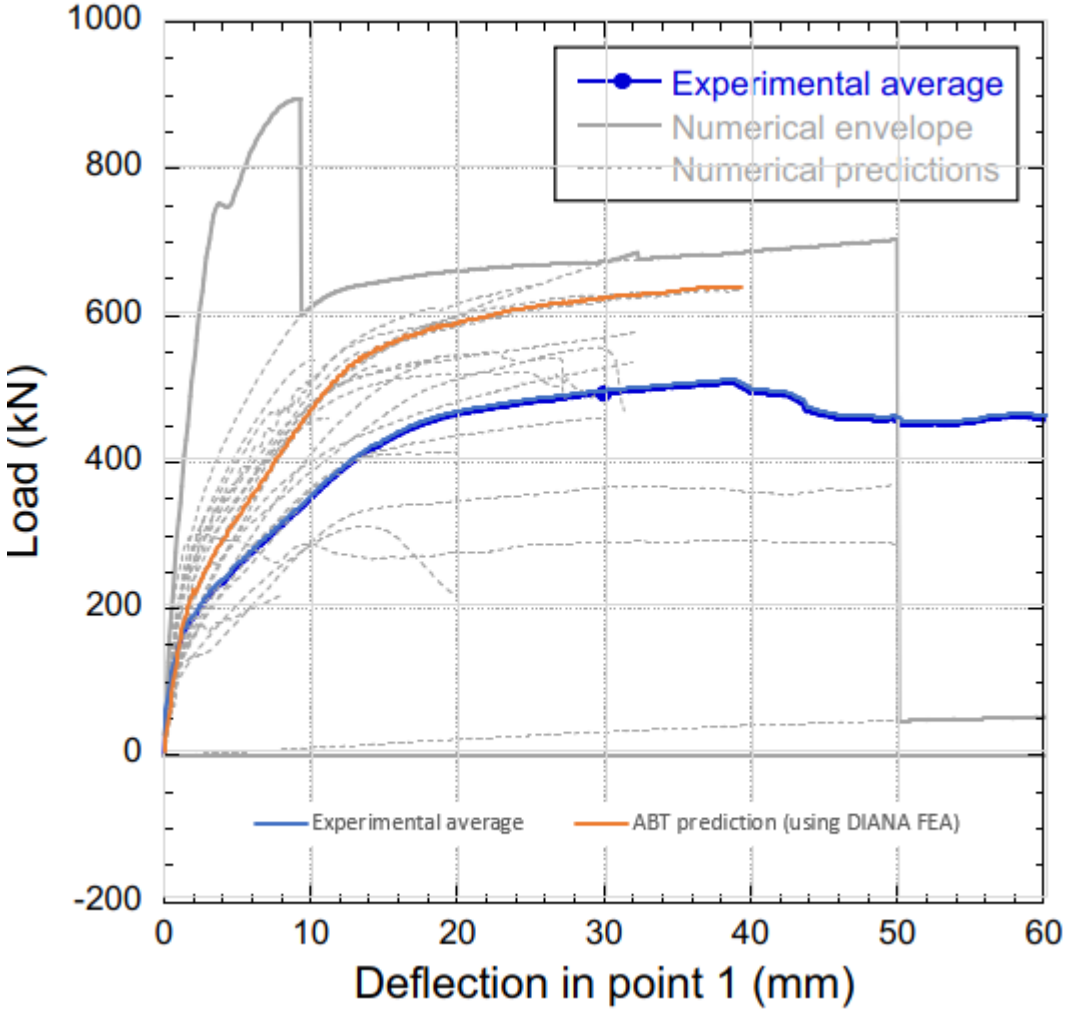




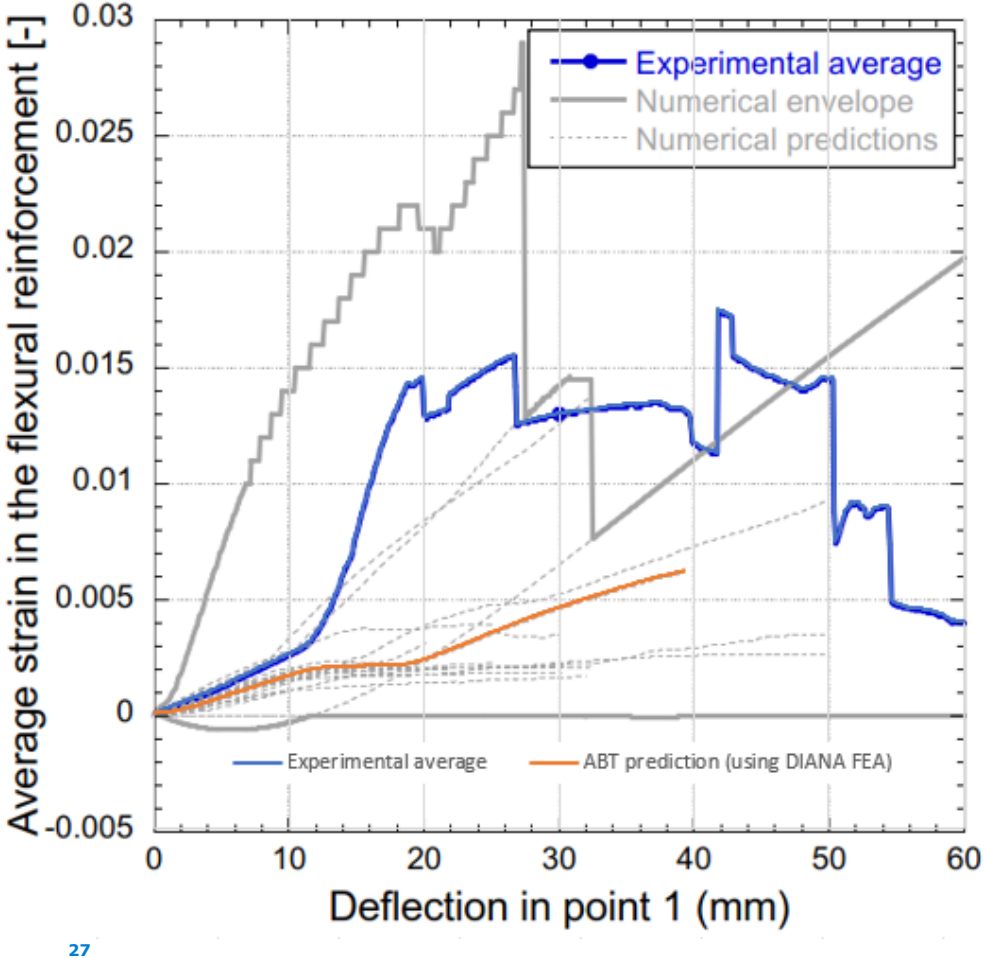


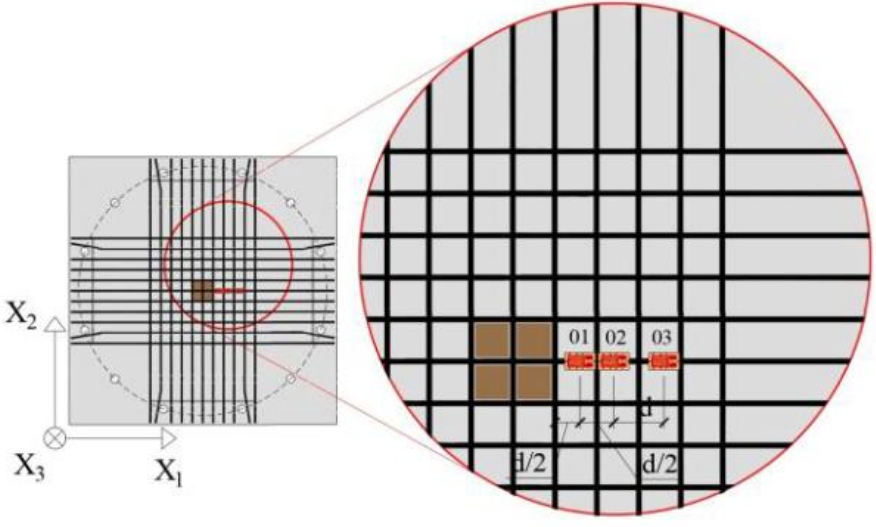






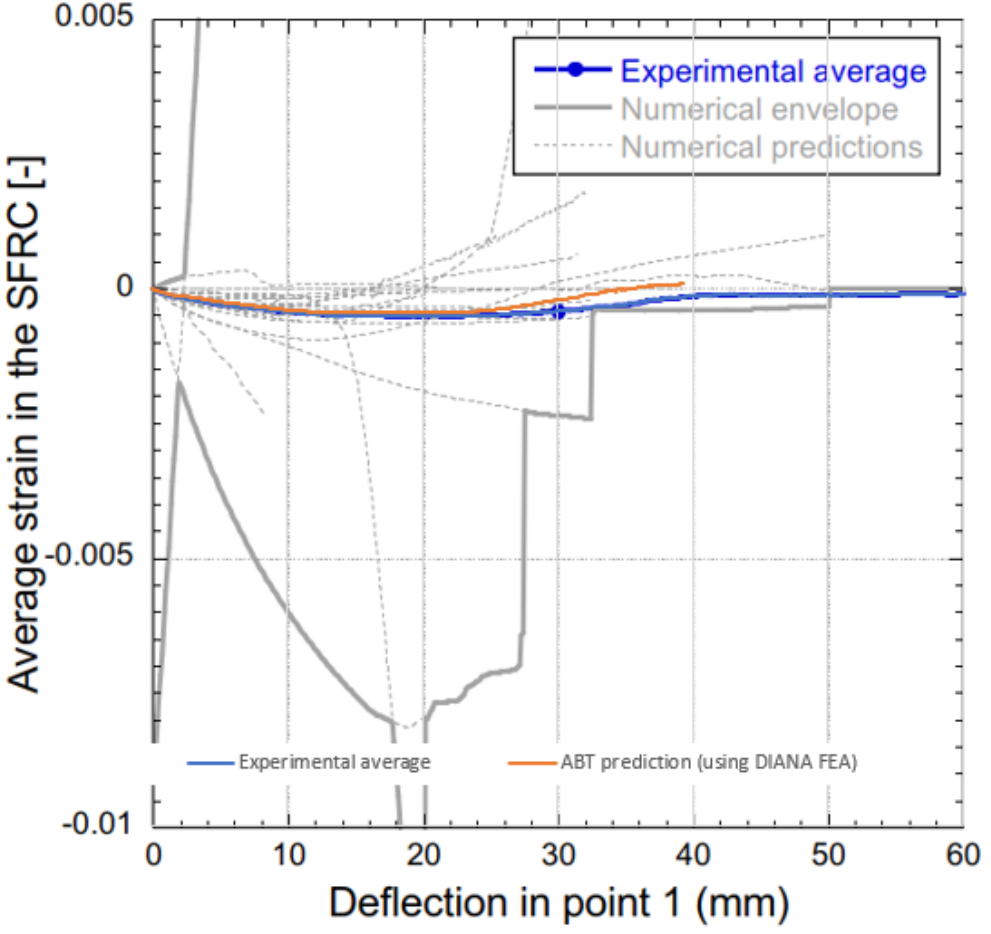
Contribution to score: 25%

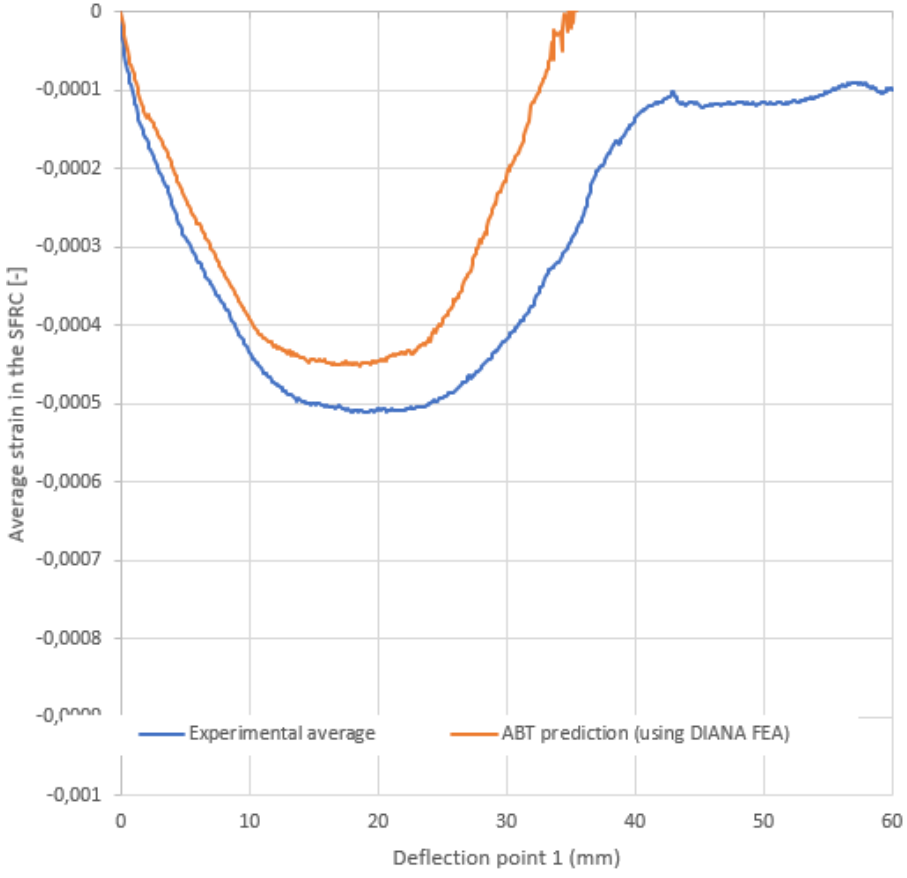




(a)

Contribution to score: 20%





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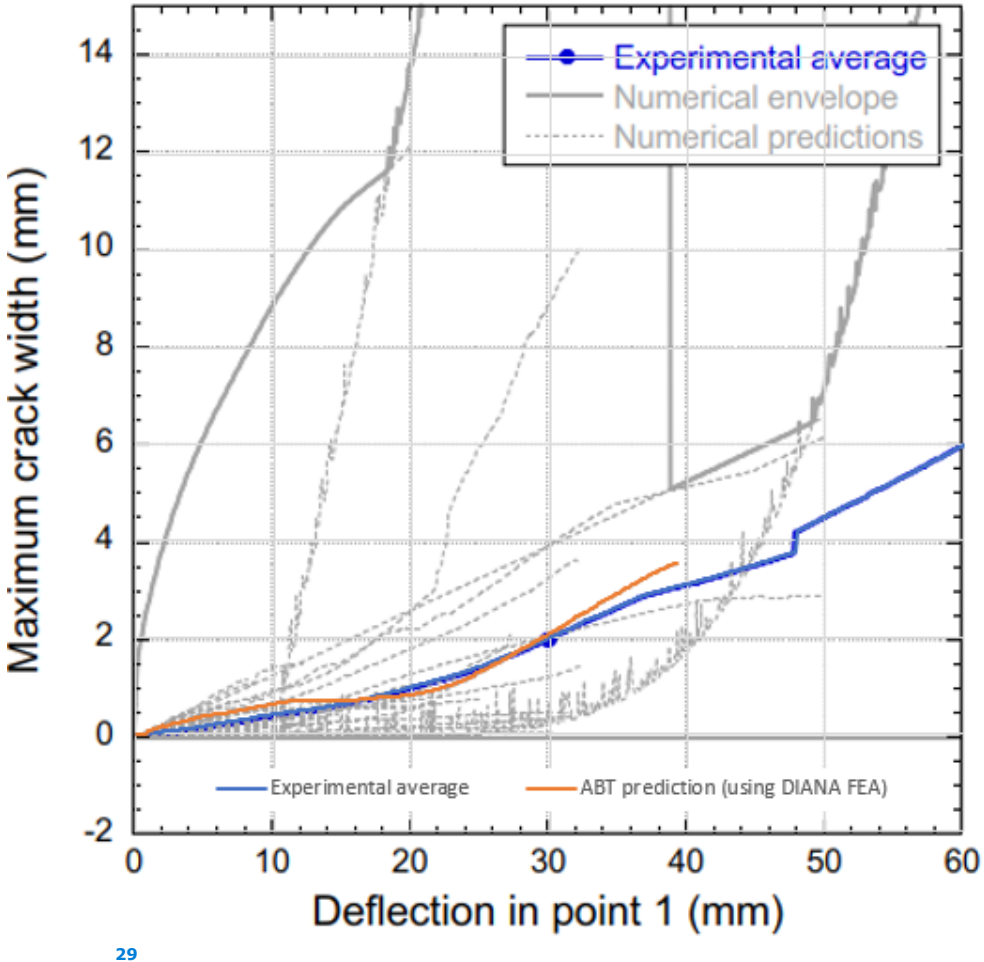

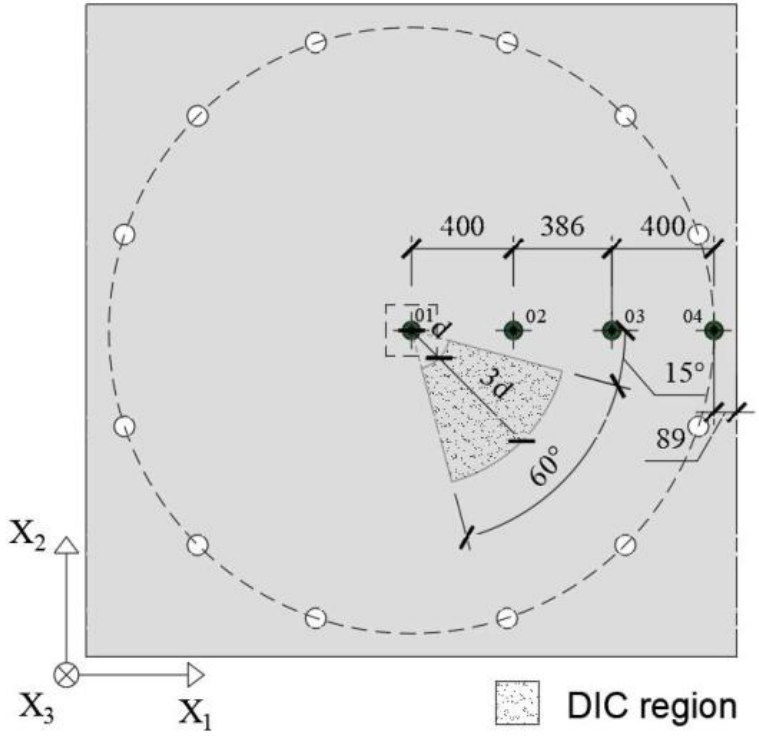

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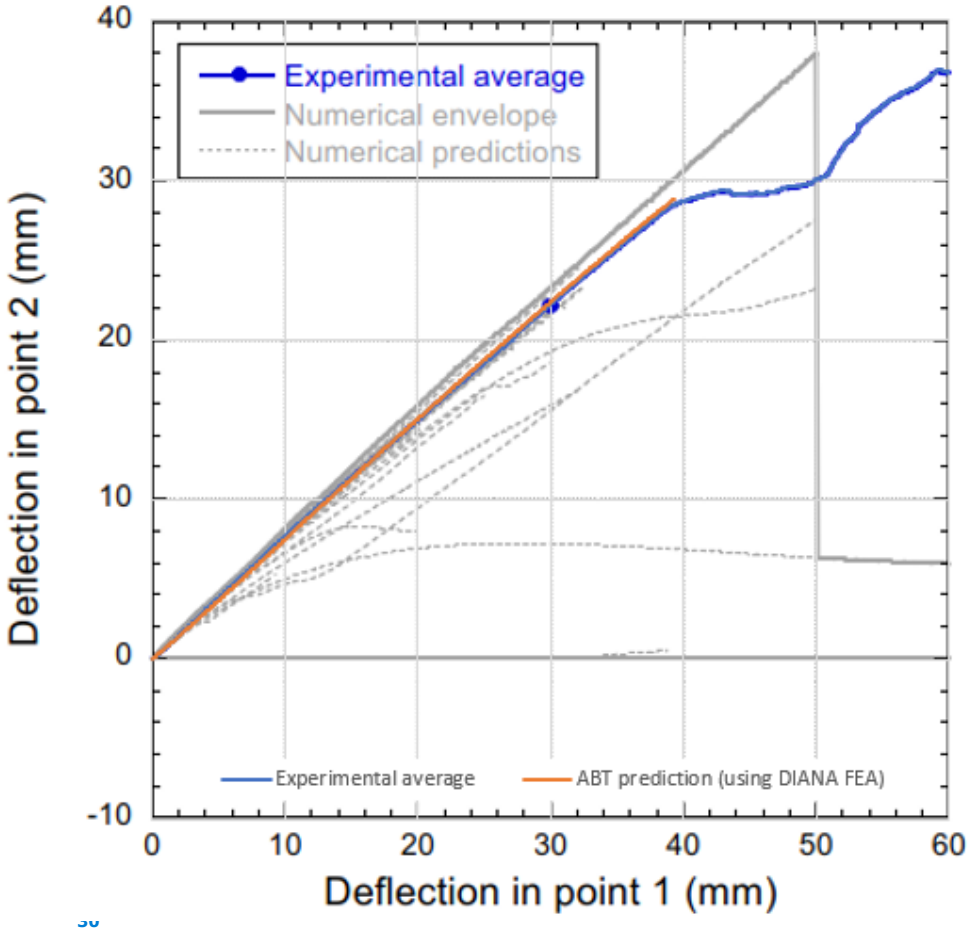

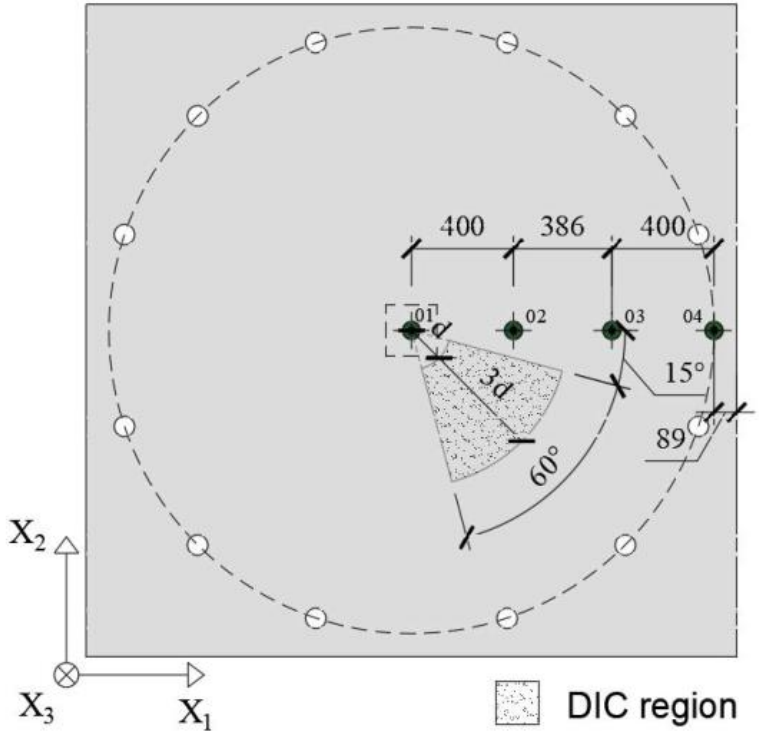

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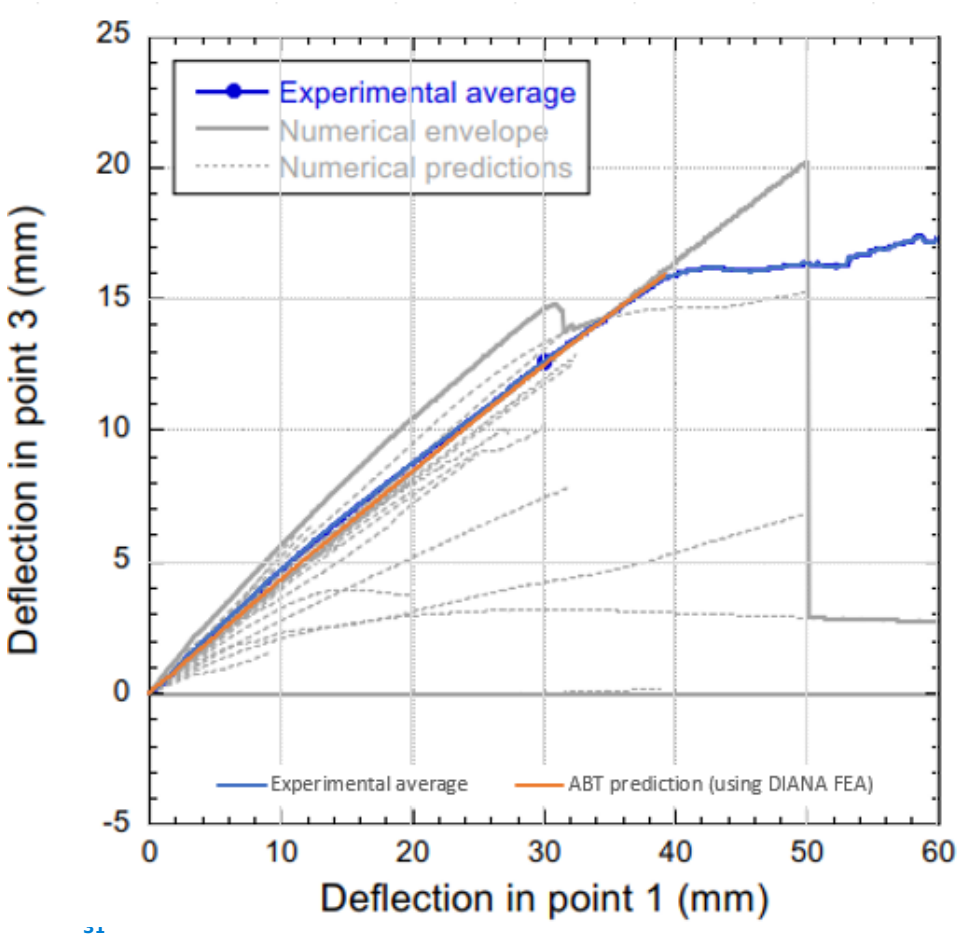

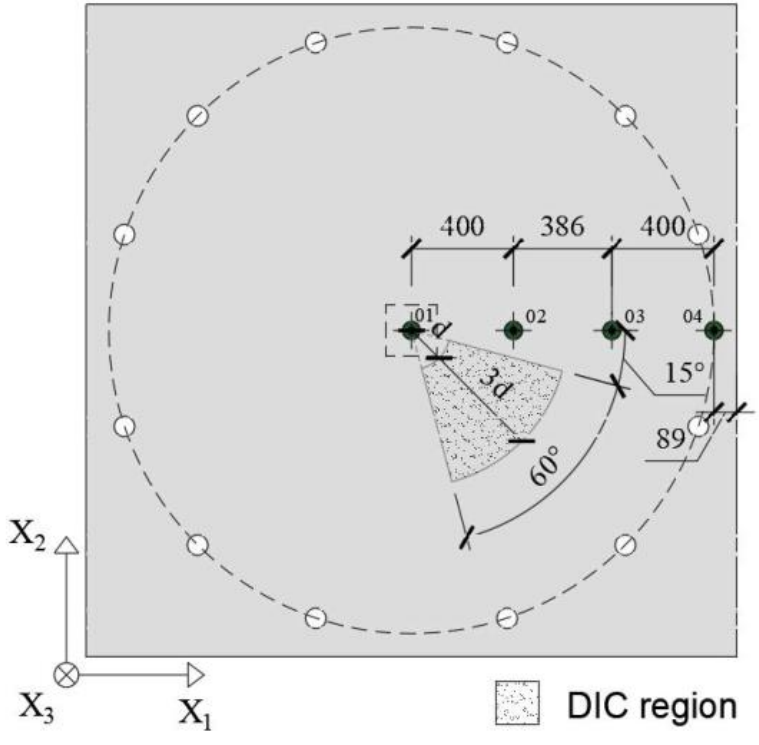

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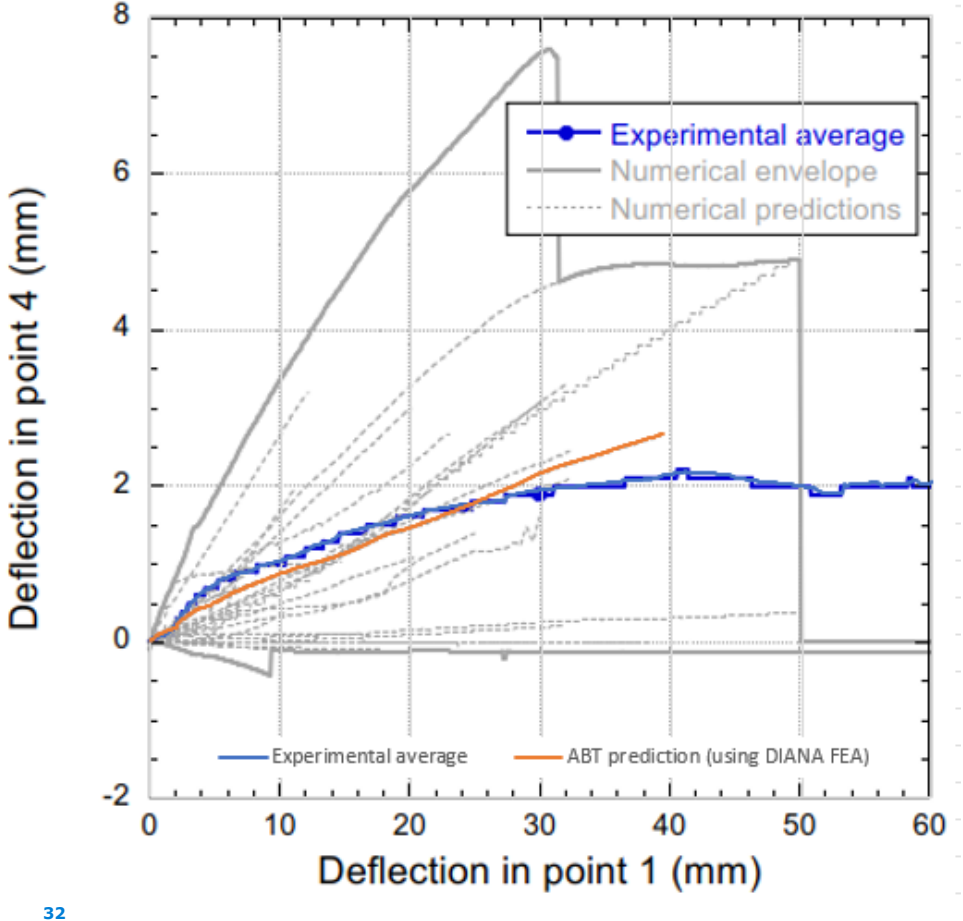
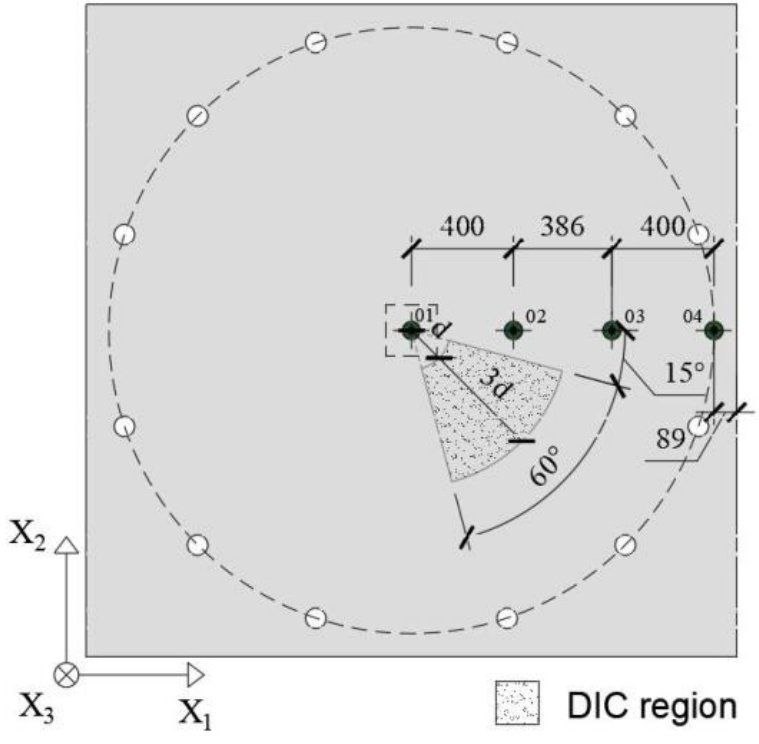
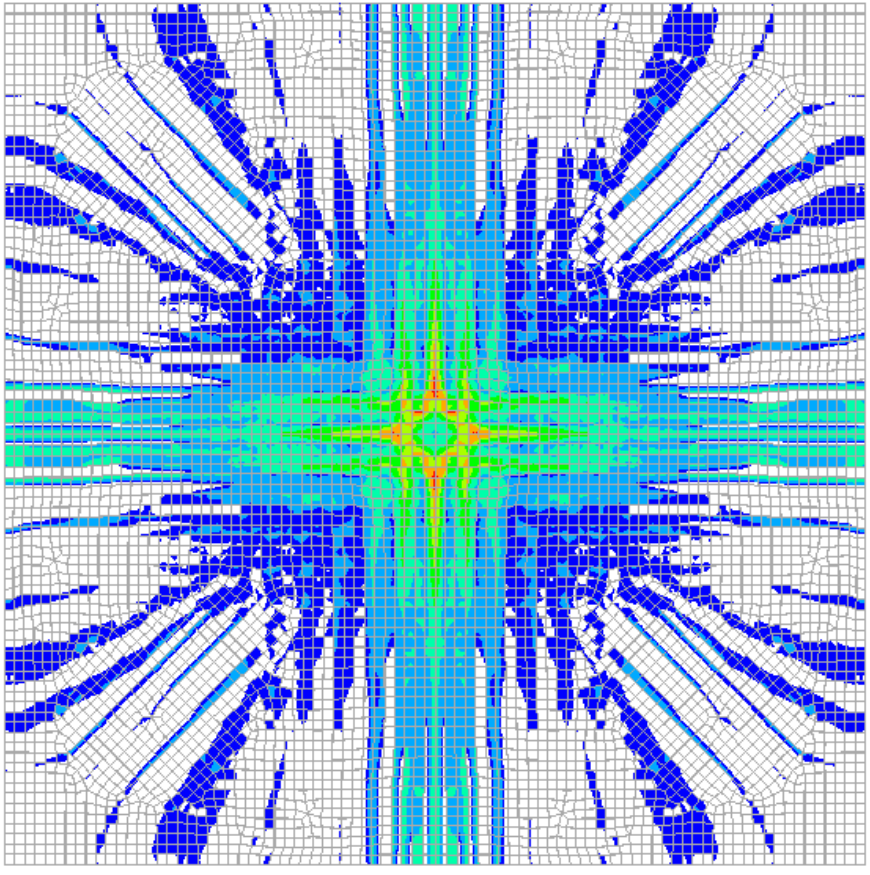




Contribution to score: 5%

Blind competition punching SFRC 2023 - ABT submission - v008 embedded
Load-step 393, Load-factor 39.300, test load
Crack-widths Ecw1
min: 0.00mm max: 5.13mm



Conclusions

- Excellent blind competition
  - Detailed input information
  - Detailed explanation of rules
  - Live stream of experiments
  - Detailed information about results
- ABT predicted displacements, crack width and concrete compressive strain very accurately
- ABT overestimated capacity by about 25% (!)
- Experimental results for steel strain are debatable

Questions?

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