The challenges posed by the experimental tests used in the inverse analysis for deriving the fracture parameters of the FRC in the design context

Joaquim Barros and Christoph Sousa

2021-05-05

Summry

1) Three point notched beam bending test executed according to the EN-14651
2) Round panel test executed according to the ASTM C1550-08

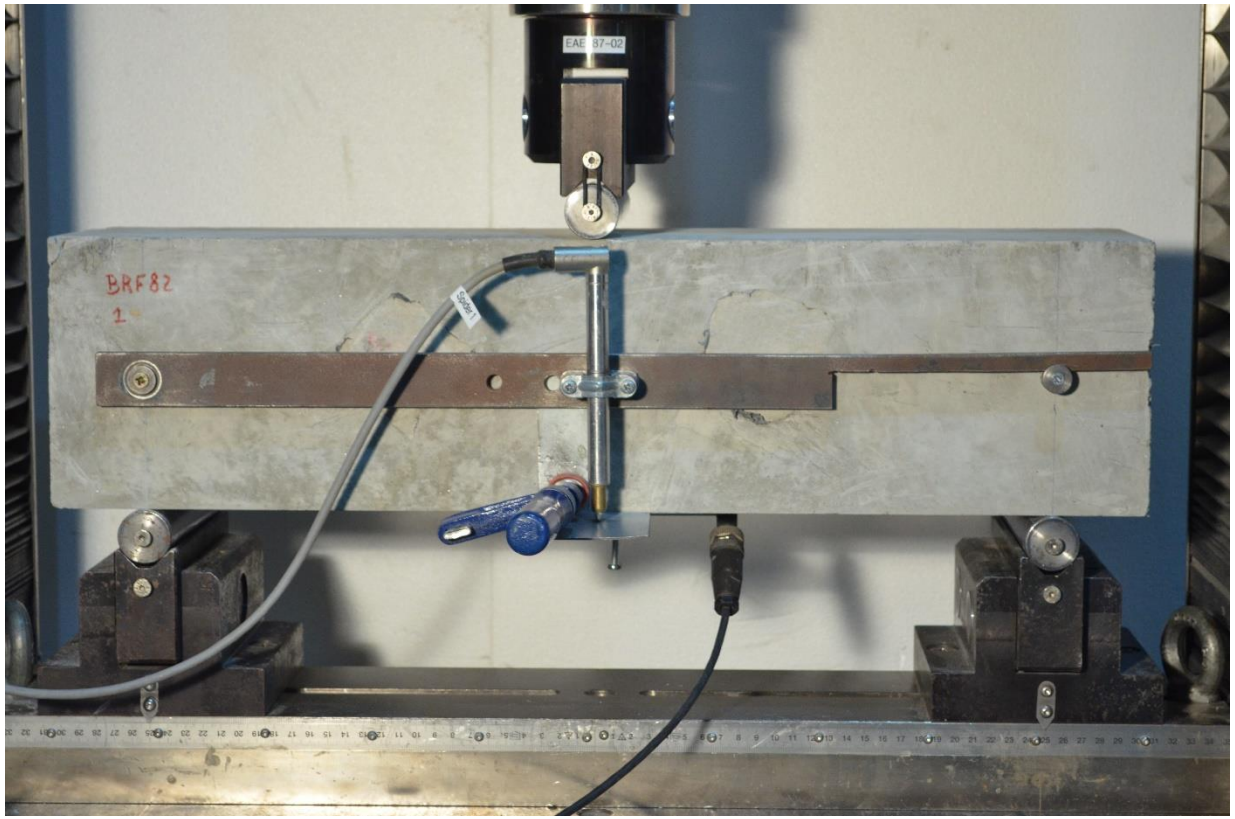


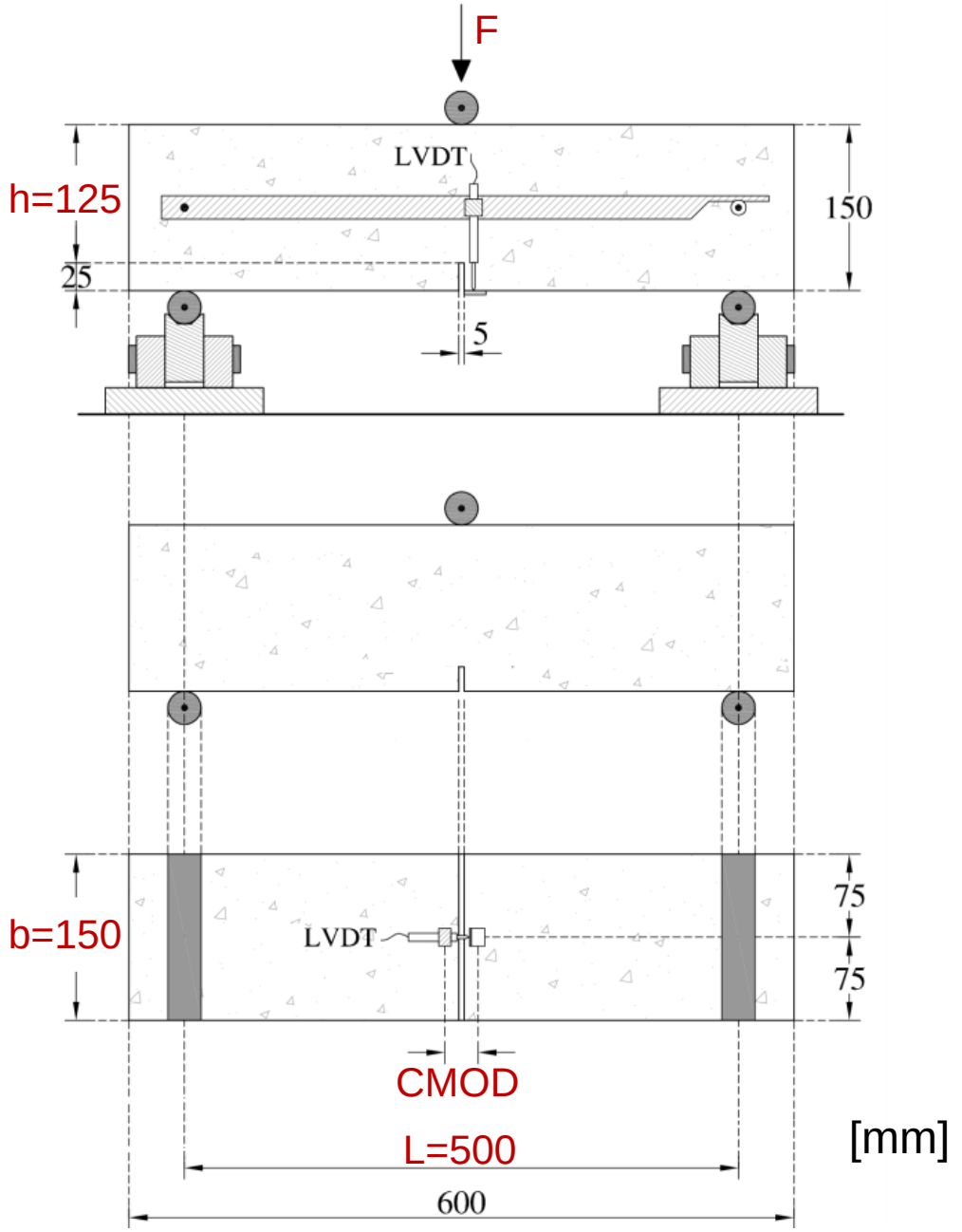
CIVITEST

PESQUISA DE NOVOS MATERIAIS
PARA A ENGENHARIA CIVIL

3-POINT BENDING TEST ON NOTCHED BEAM ACCORDING TO EN-14651

Three-point bending test





Three-point bending test

$$f_{R,j} = \frac{3FL}{2bh^2}$$

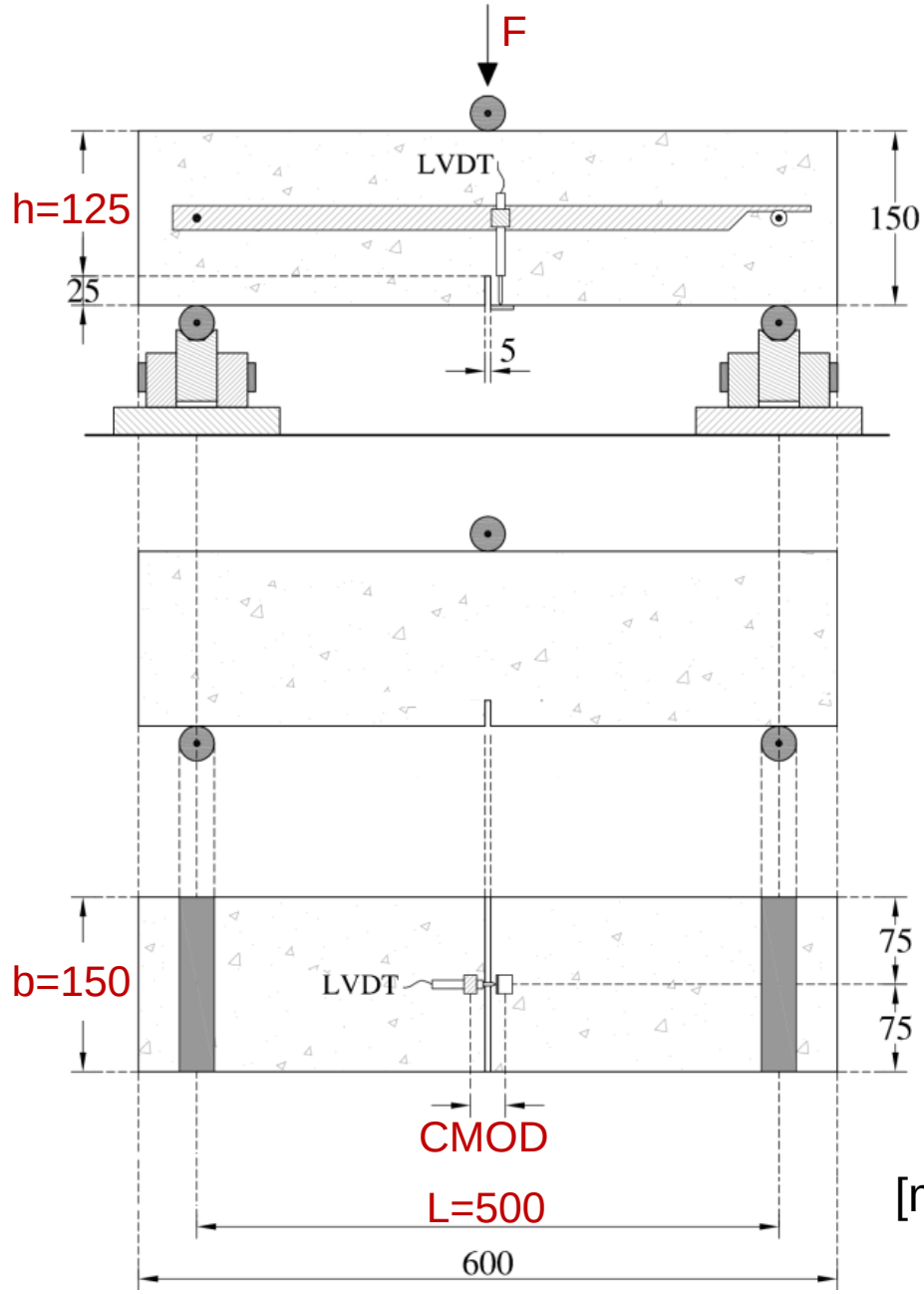
$f_{R,j}$ → Residual flexural tensile strength for corresponding Crack Mouth Opening Displacement (CMOD_j)

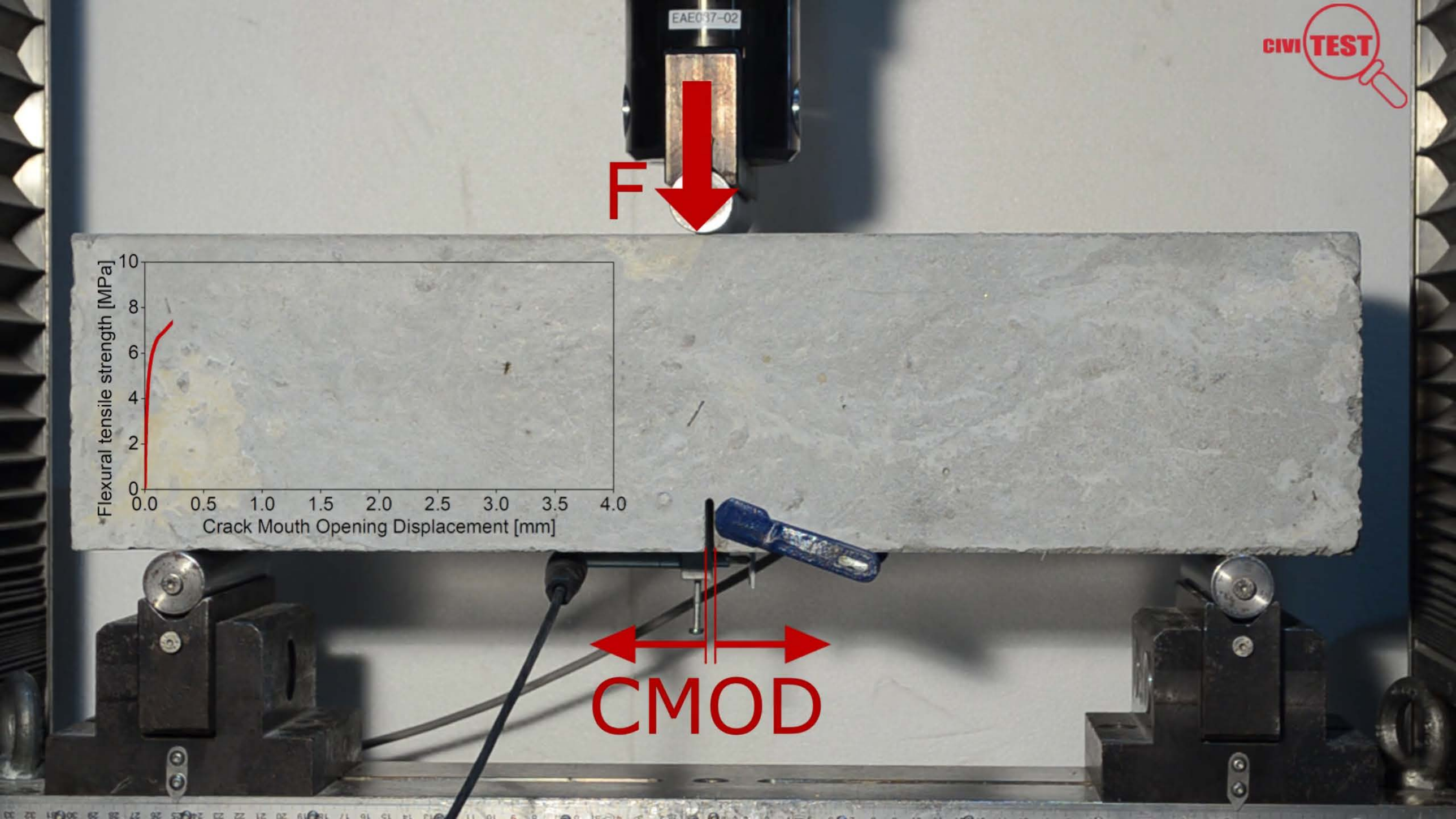
F_j → Applied load

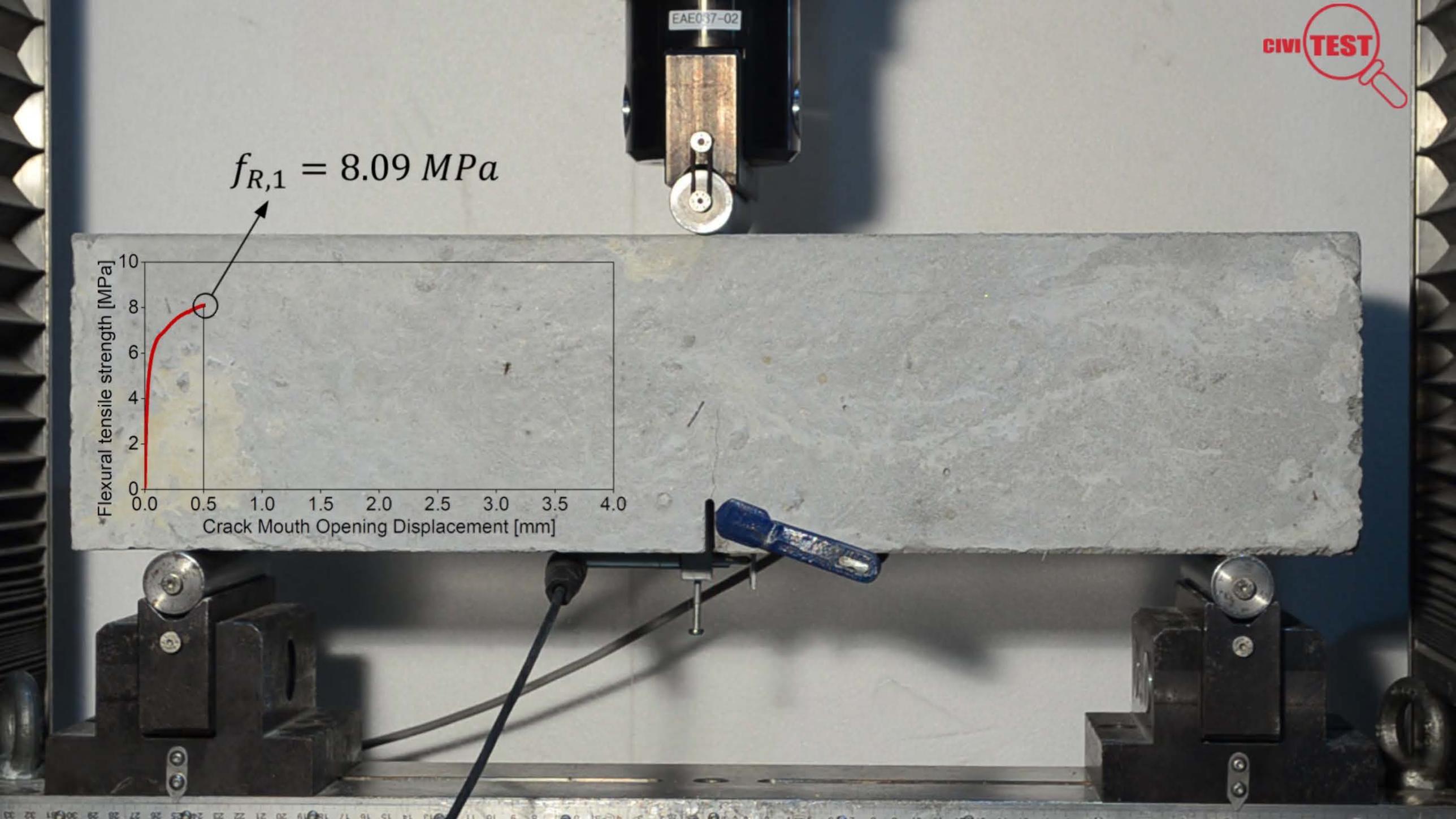
L → Span length

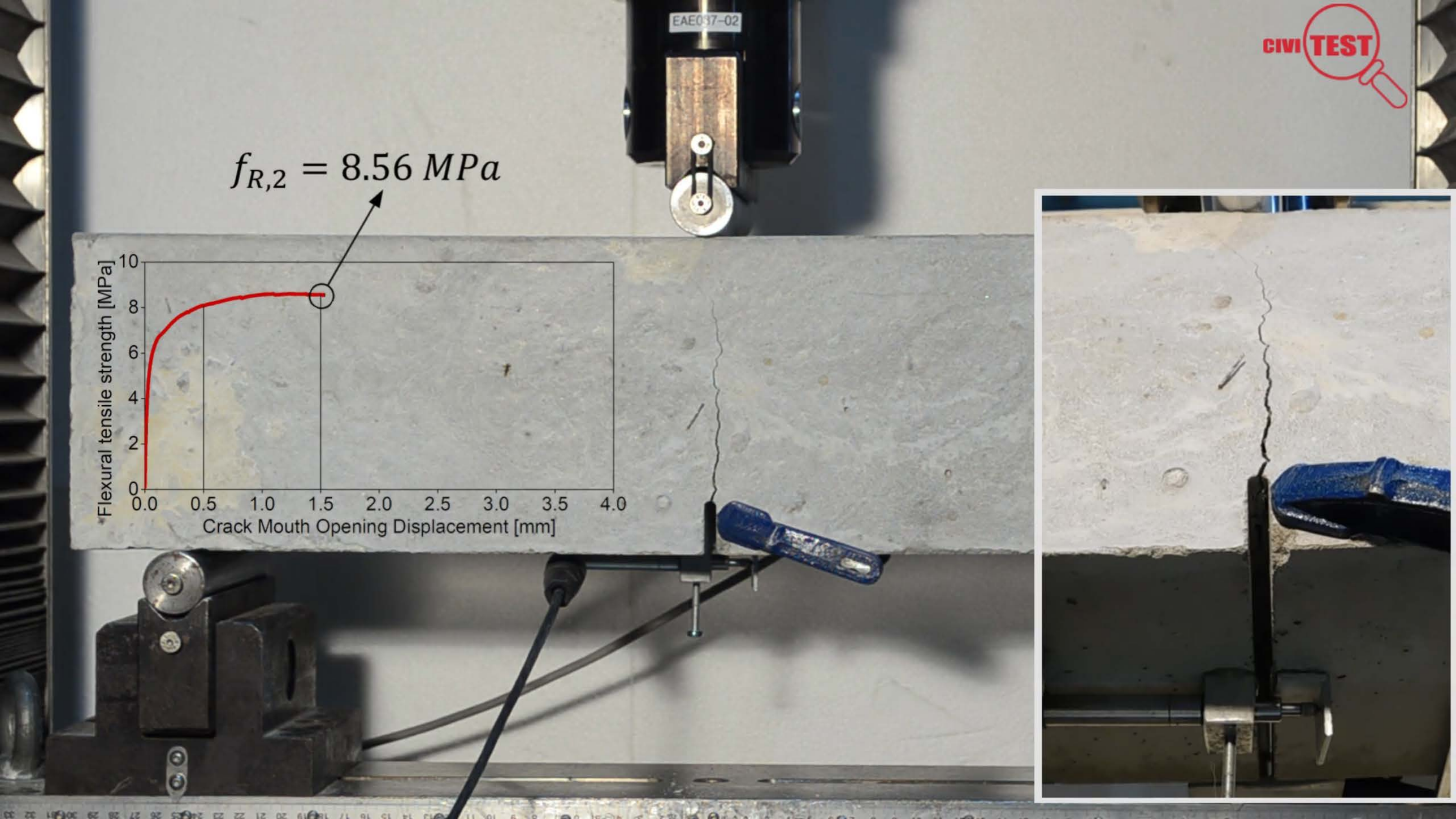
b → Specimen width

h → Distance between notch tip and top of the specimen

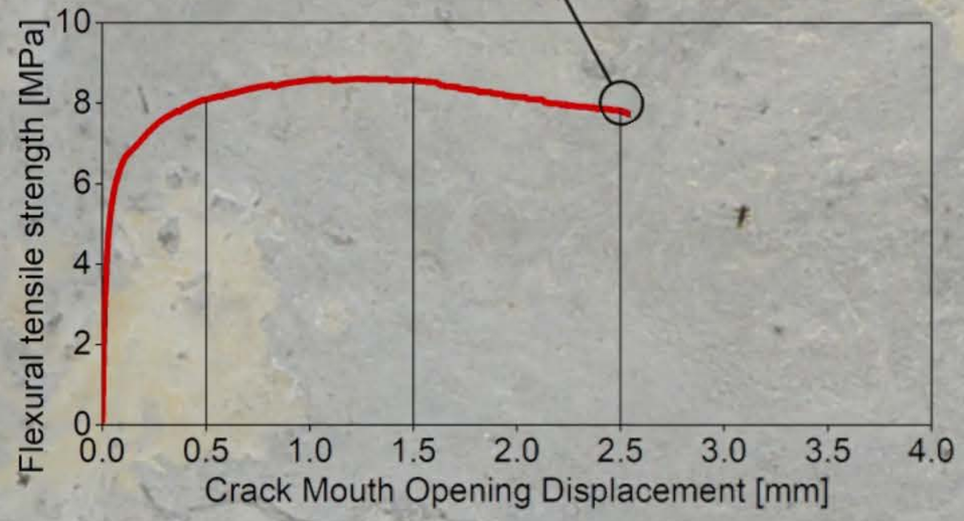



EAE037-02
F
Flexural tensile strength [MPa]
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Crack Mouth Opening Displacement [mm]
CMOD

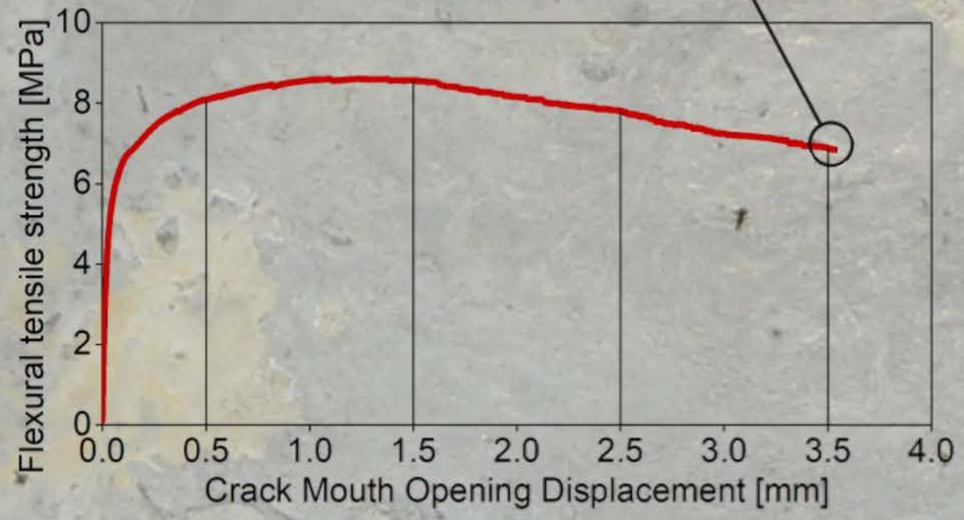

EAE037-02
CIVI TEST
$f_{R,1} = 8.09\ MPa$
Flexural tensile strength [MPa]
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Crack Mouth Opening Displacement [mm]


EAE037-02
CIVI TEST
$f_{R,2} = 8.56\ MPa$
Flexural tensile strength [MPa]
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Crack Mouth Opening Displacement [mm]

$$f_{R,3} = 7.81\ MPa$$

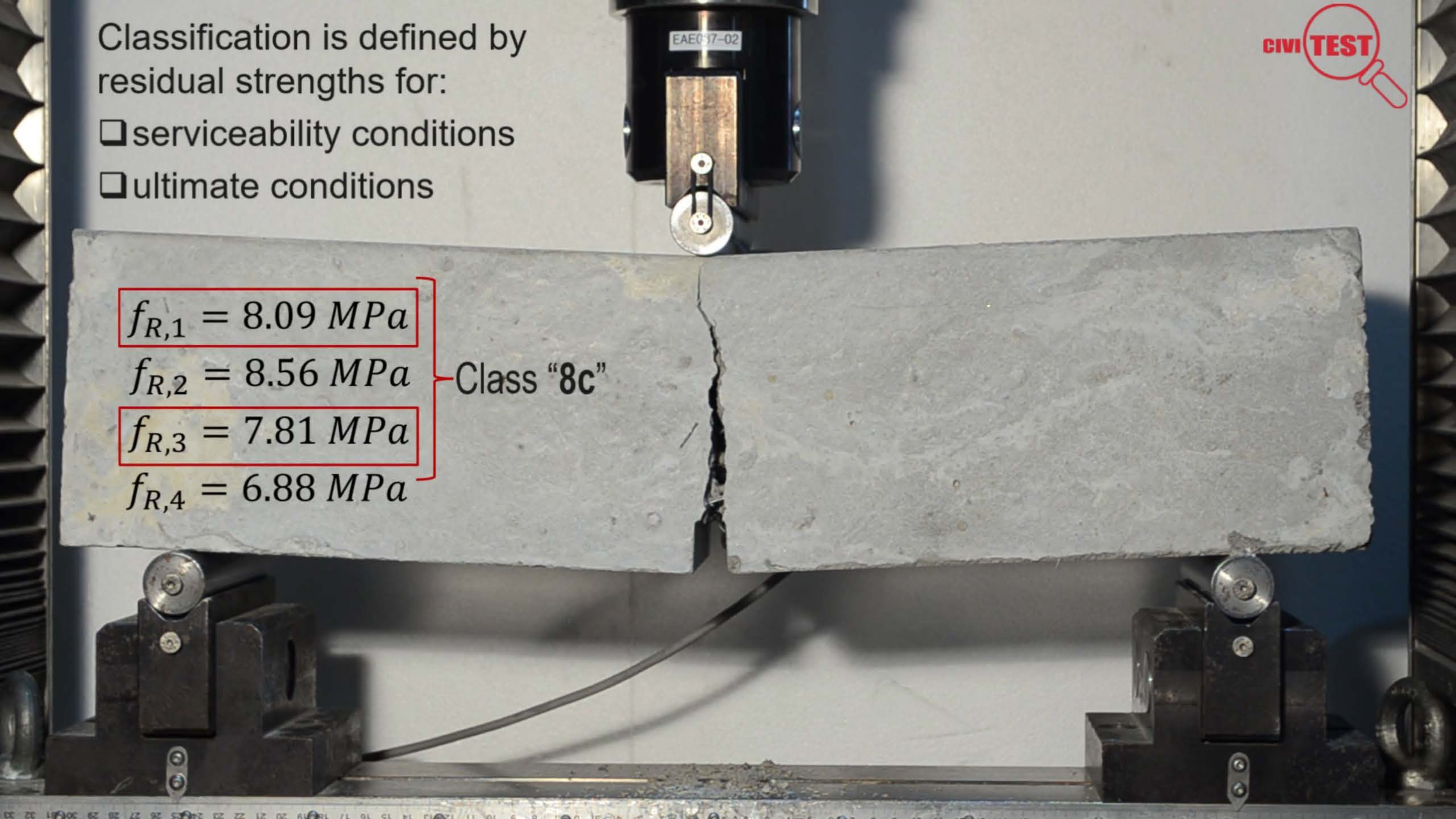

Flexural tensile strength [MPa]
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Crack Mouth Opening Displacement [mm]

$$f_{R,4} = 6.88\ MPa$$


Flexural tensile strength [MPa]
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Crack Mouth Opening Displacement [mm]

Classification is defined by residual strengths for:

- ❑ serviceability conditions
- ❑ ultimate conditions



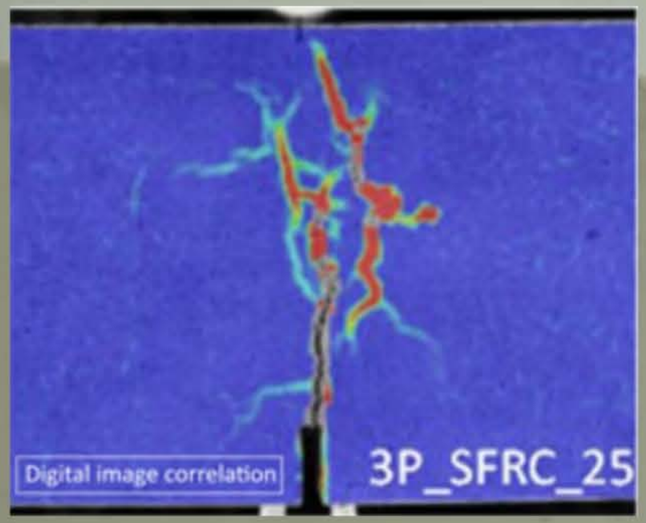
$f_{R,1} = 8.09\ MPa$

$f_{R,2} = 8.56\ MPa$

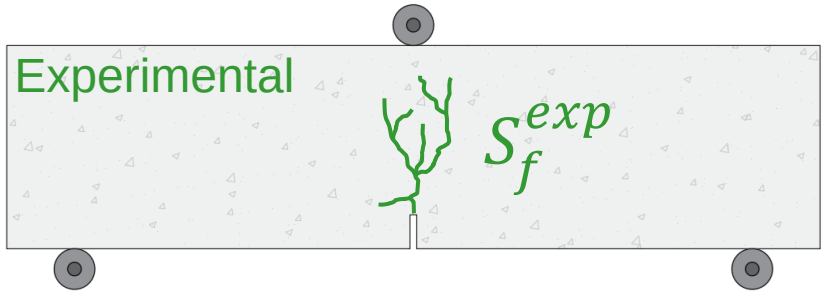
$f_{R,3} = 7.81\ MPa$

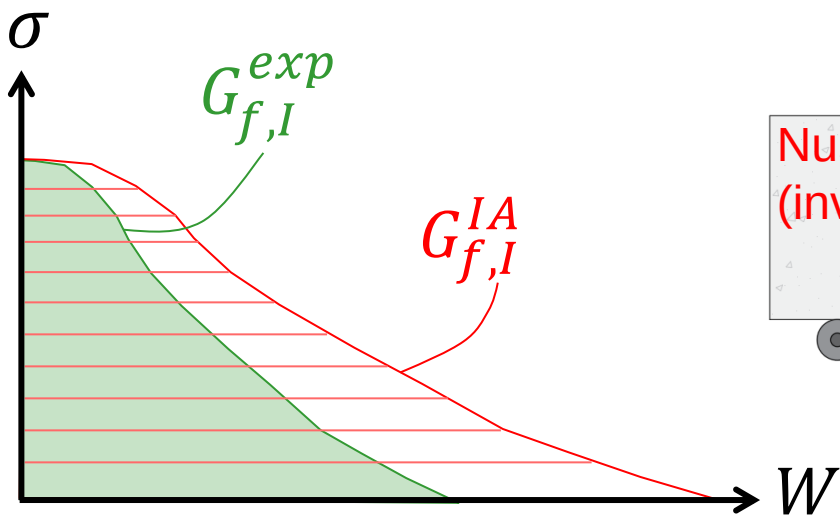
$f_{R,4} = 6.88\ MPa$

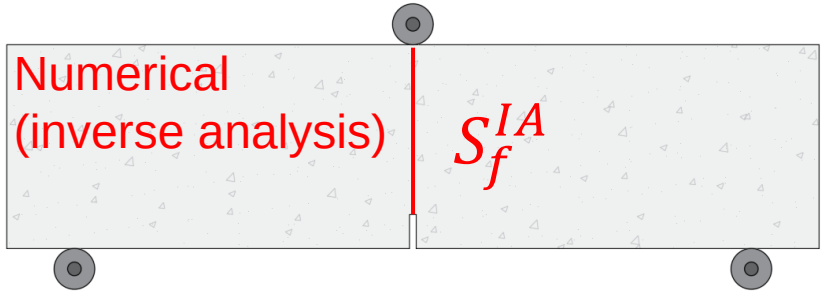
Class "**8c**"


Digital image correlation
3P_SFRC_25

Consequences of diffuse crack propagation







$$G_{f,I}^{exp} = \frac{W_{f,I}^{exp}}{S_f^{exp}} \; ; \; G_{f,I}^{IA} = \frac{W_{f,I}^{IA}}{S_f^{IA}}$$

$$S_f^{IA} < S_f^{exp} \quad \wedge \quad W_{f,I}^{IA} \cong W_{f,I}^{exp} \quad \Rightarrow \quad G_{f,I}^{IA} > G_{f,I}^{exp} \quad \rightarrow$$

Non-conservative predictions

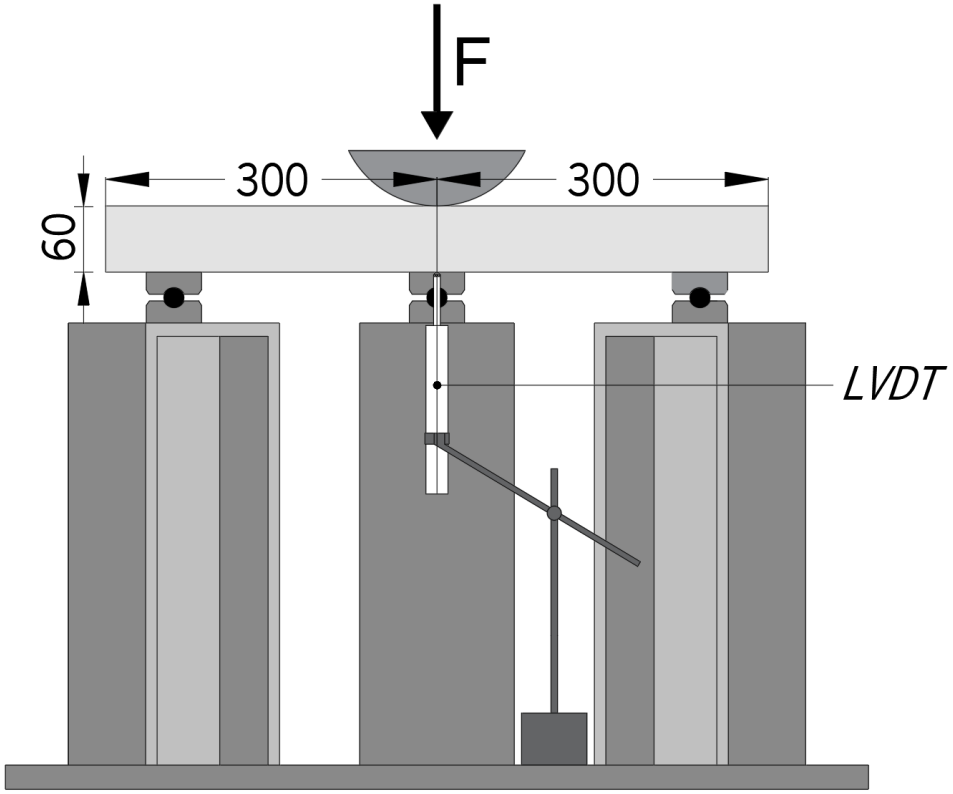
CIVITEST

PESQUISA DE NOVOS MATERIAIS
PARA A ENGENHARIA CIVIL

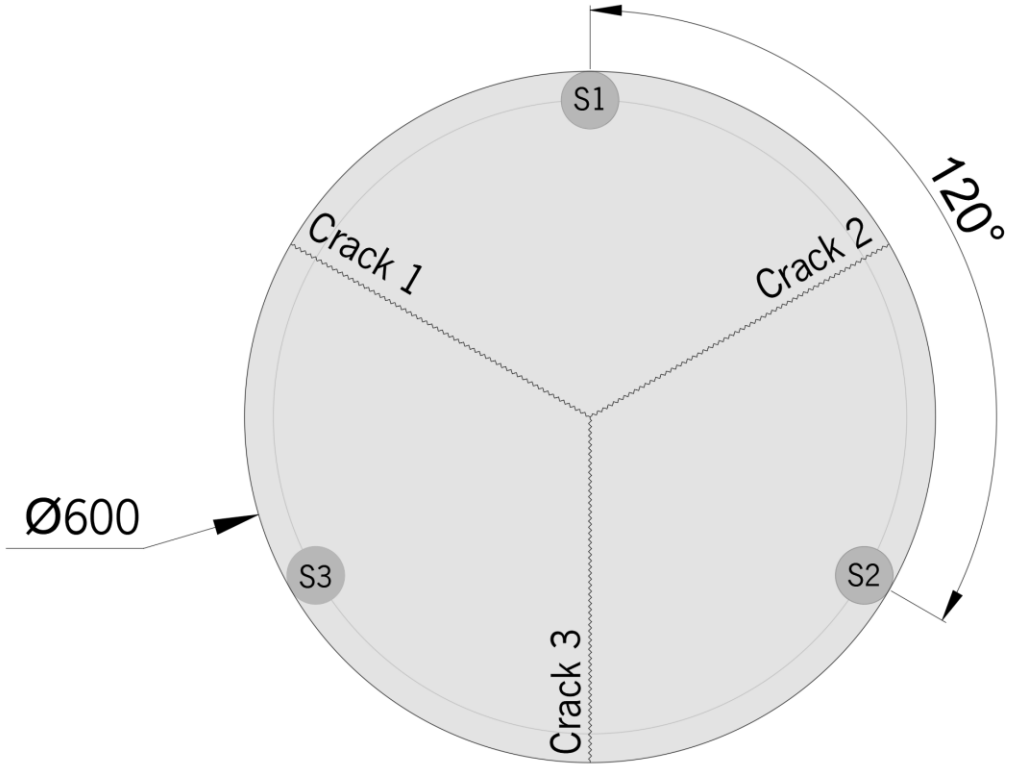
Evaluation of the post-cracking tensile performance of FRC through centrally loaded round panel test (ASTM C1550)

Centrally loaded round panel test

- Specimen dimensions [mm]



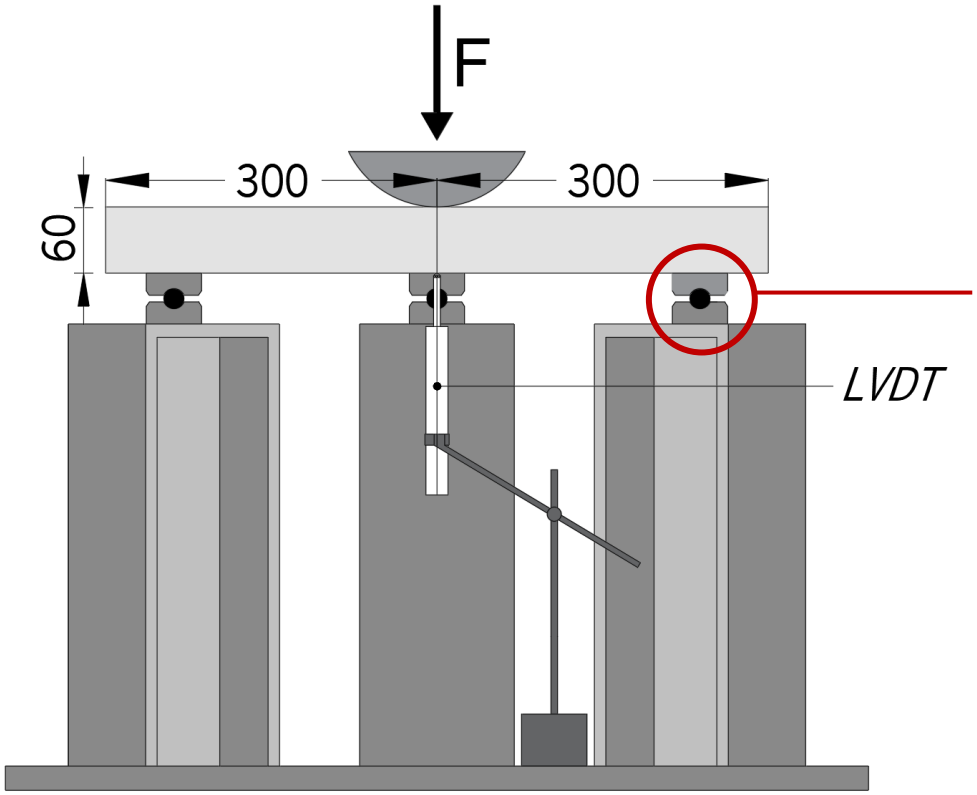
Front view



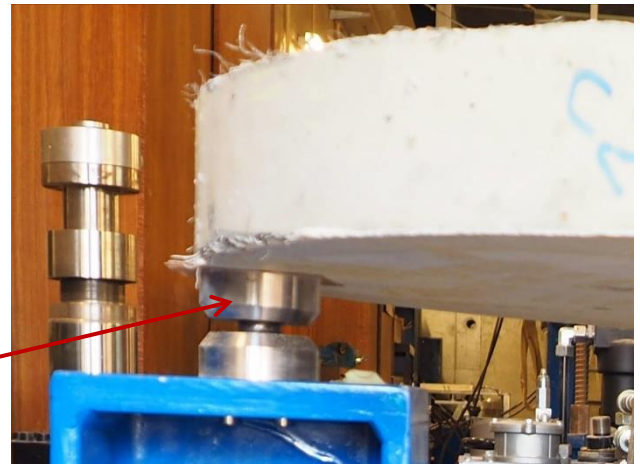
Bottom view

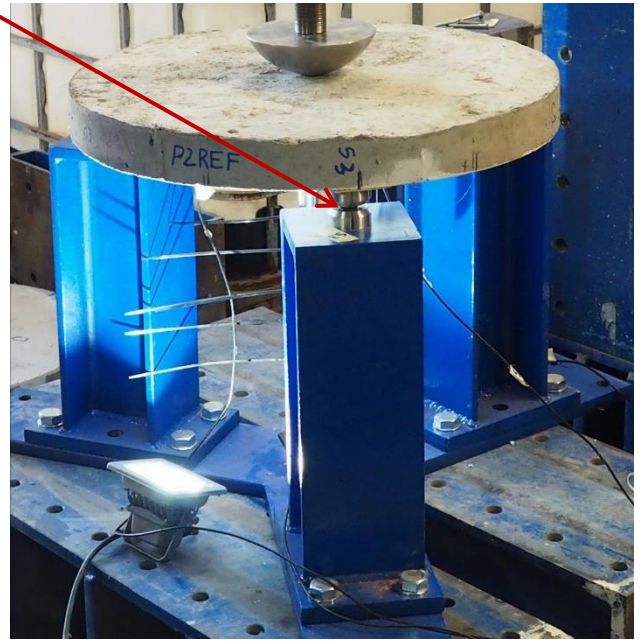
Centrally loaded round panel test

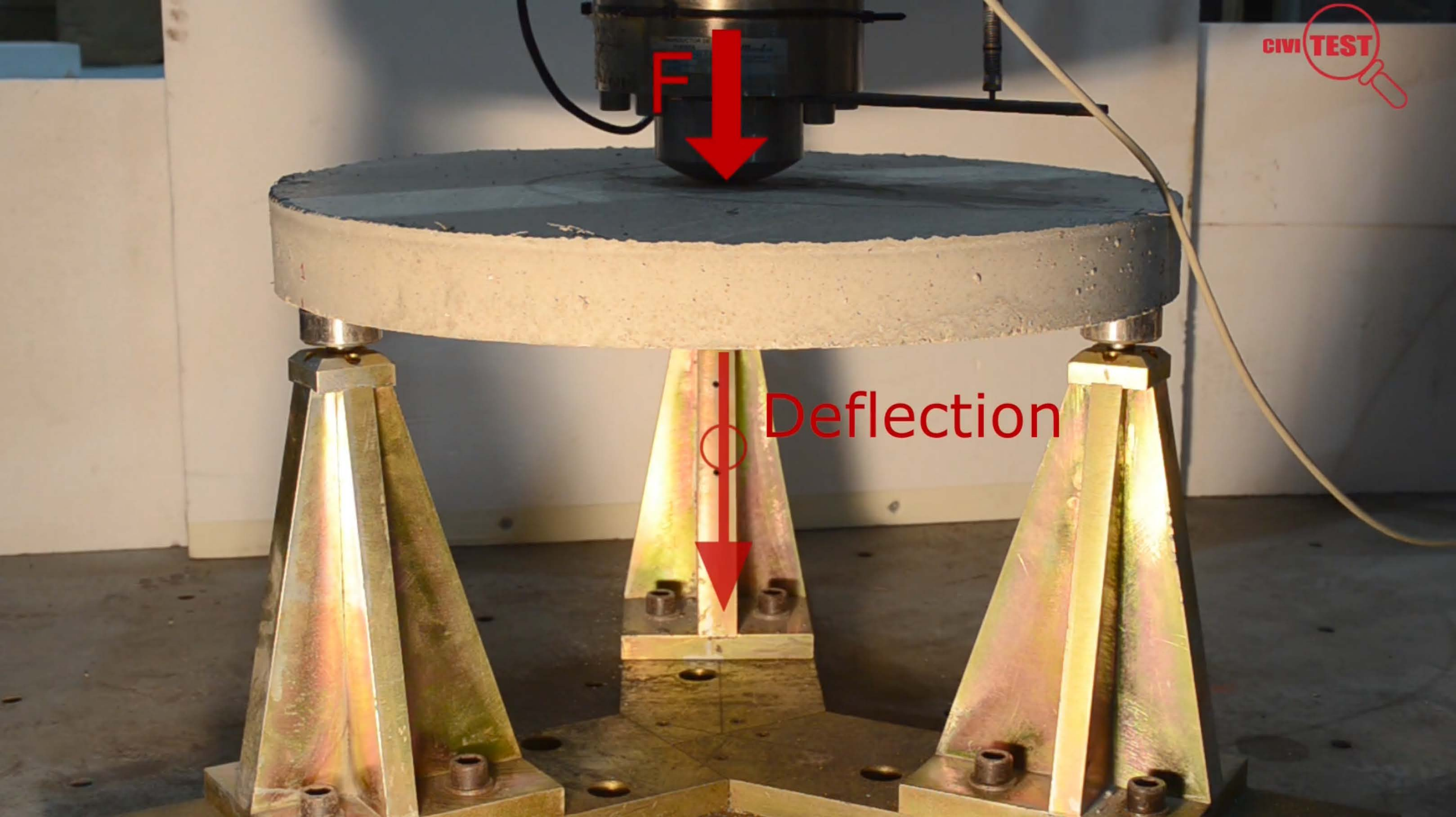
- Specimen dimensions [mm]

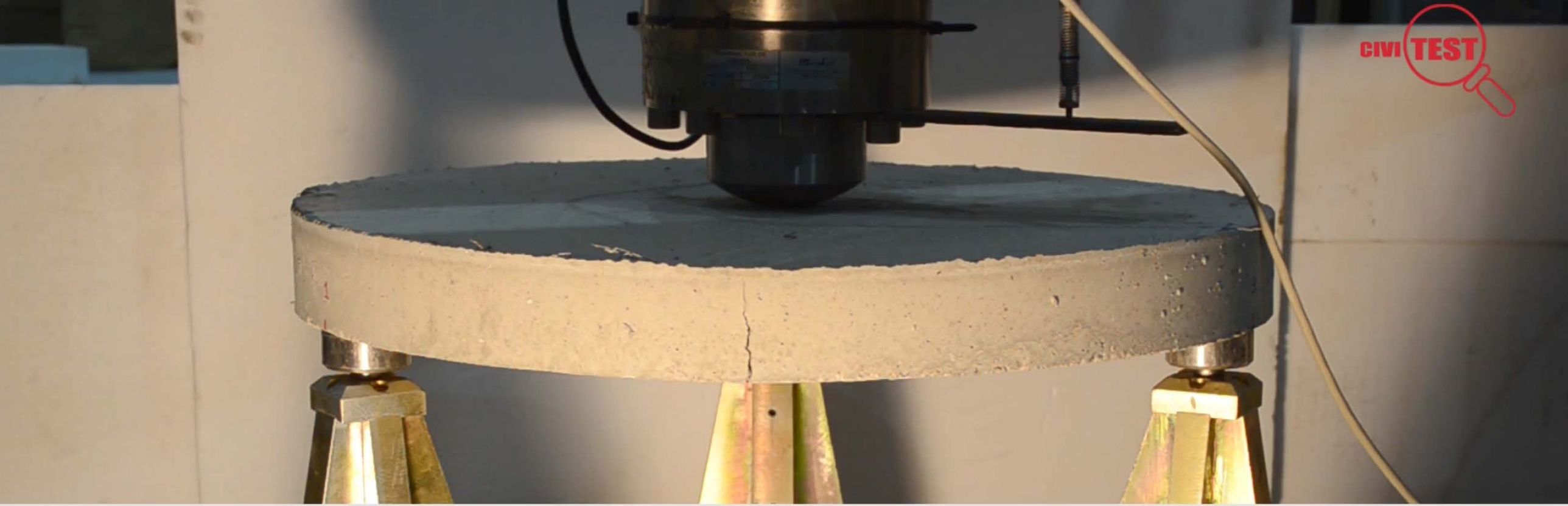


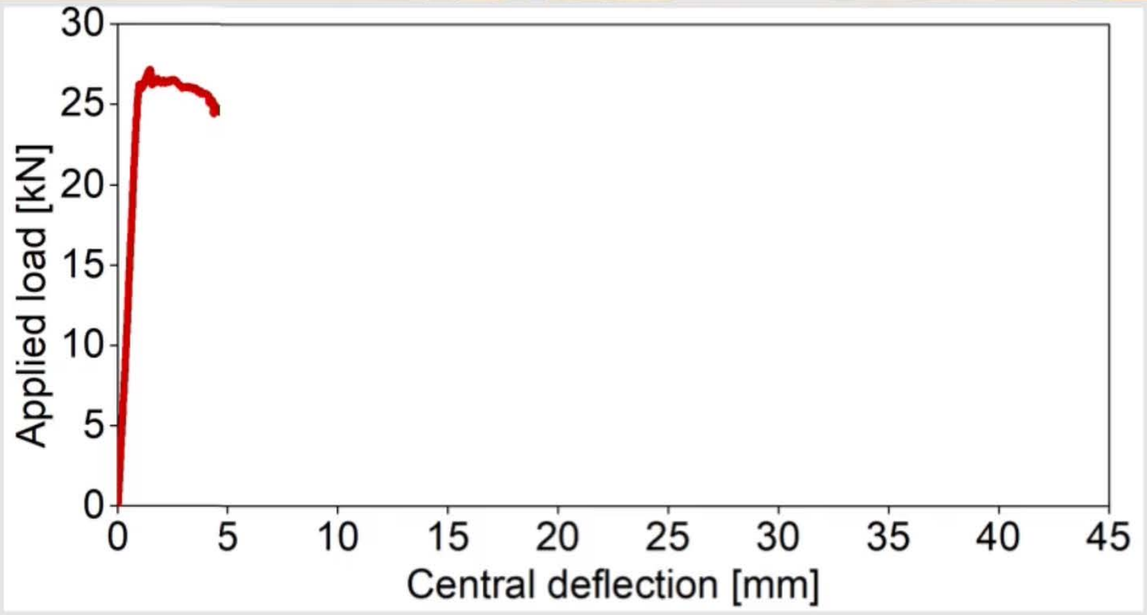
Special supports for eliminating friction

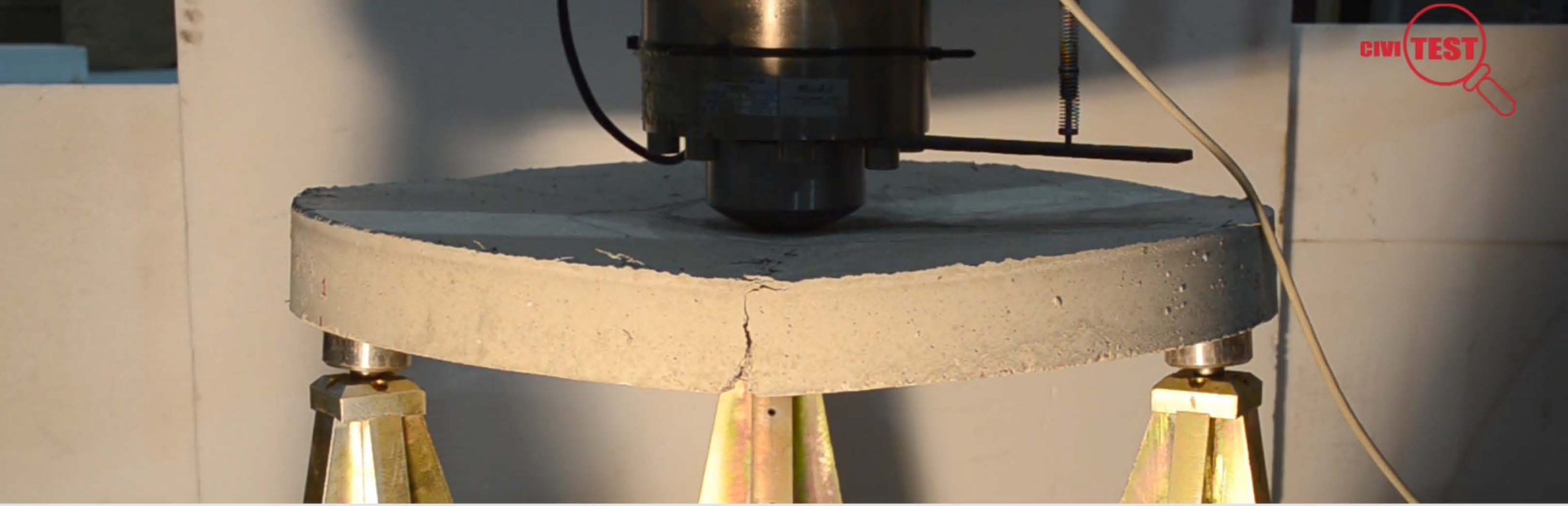


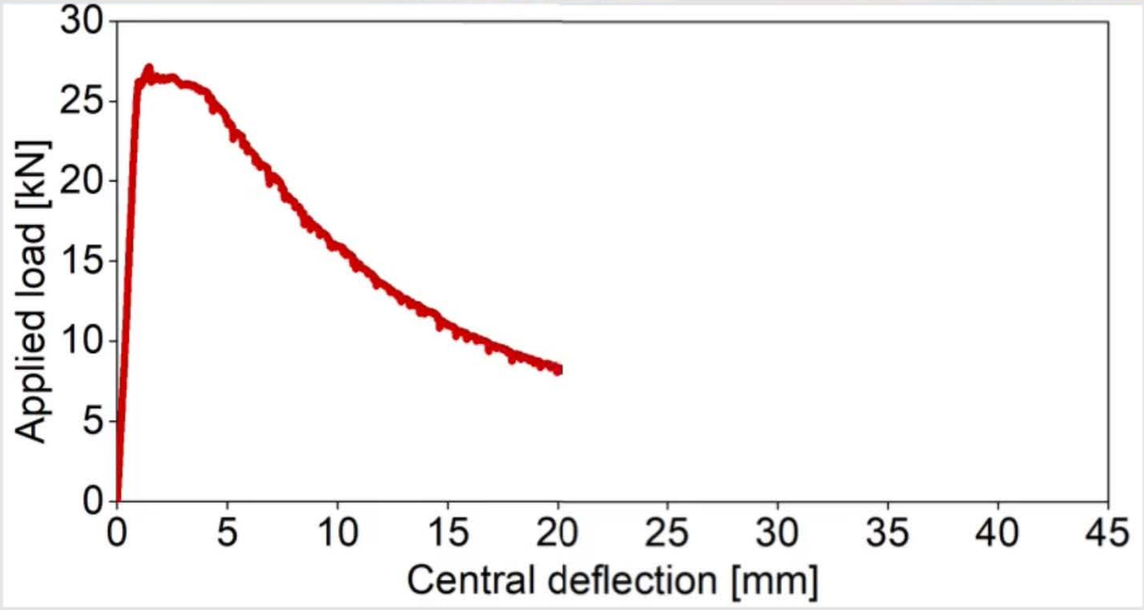


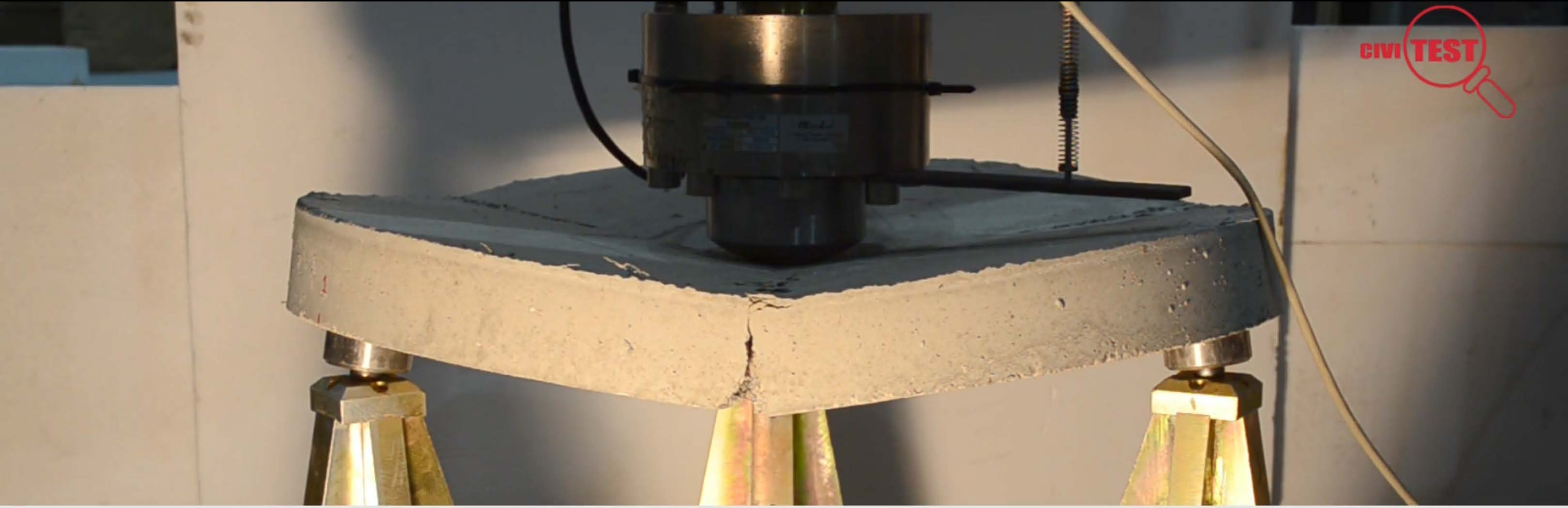

F
Deflection

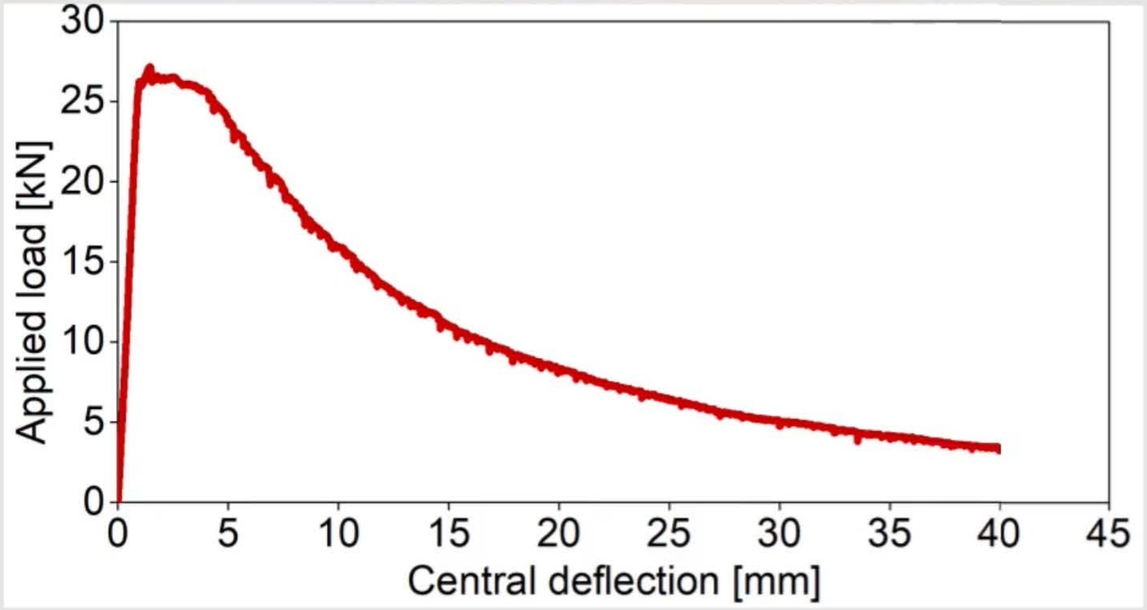


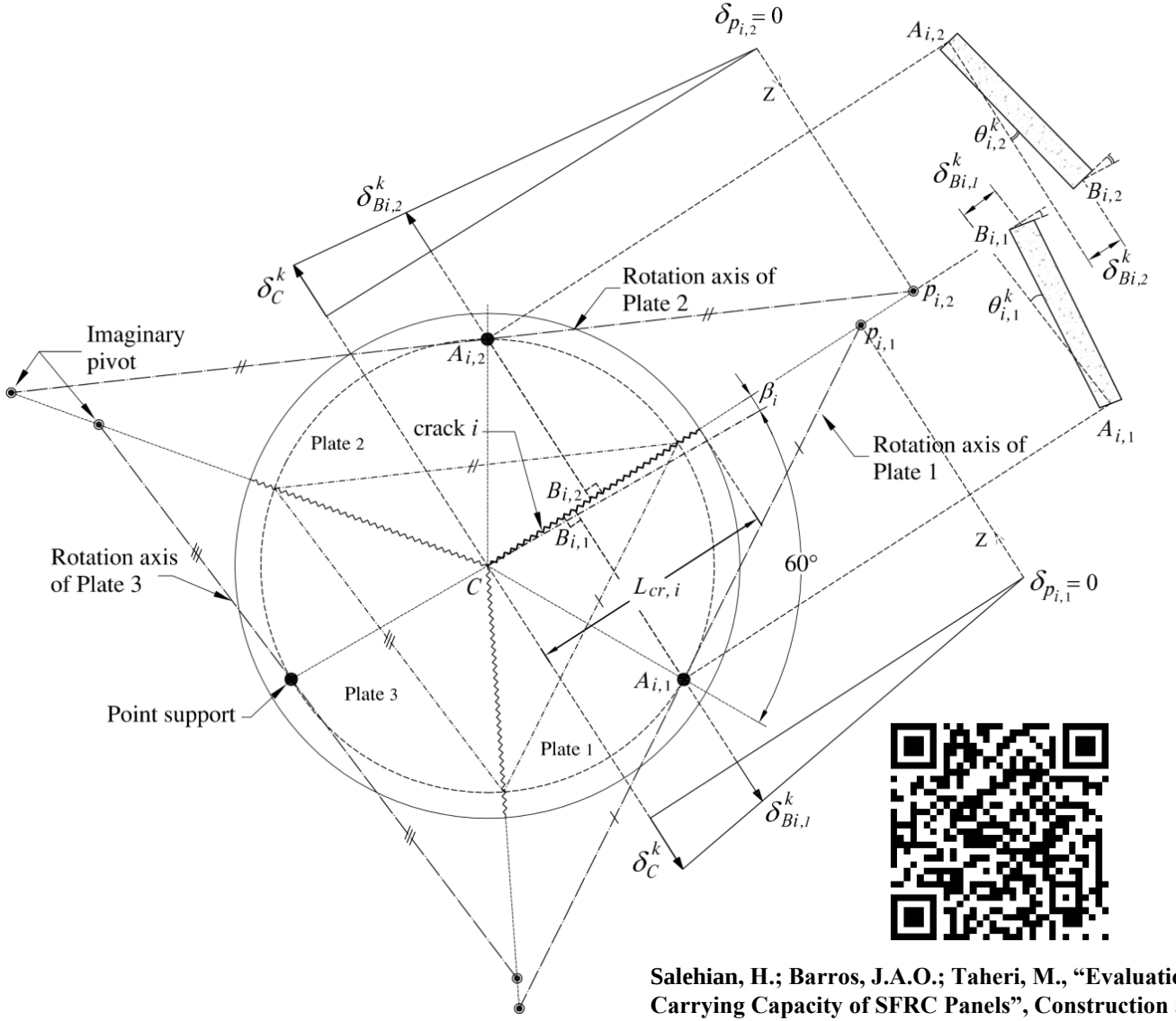

Applied load [kN]
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
45
Central deflection [mm]




Applied load [kN]
Central deflection [mm]
0
5
10
15
20
25
30
35
40
45




Applied load [kN]
0
5
10
15
20
25
30
0
5
10
15
20
25
30
35
40
45
Central deflection [mm]



$$\delta^{k}_{B_{i,1}} = \left(\frac{B_{i,1}\,p_i}{Cp_i}\right)\delta^{k}_{C} \qquad \delta^{k}_{B_{i,2}} = \left(\frac{B_{i,2}\,p_i}{Cp_i}\right)\delta^{k}_{C}$$

$$\theta^{k}_{i,1} = \frac{\delta^{k}_{B_{i,1}}}{A_{i,1}B_{i,1}} \qquad \theta^{k}_{i,2} = \frac{\delta^{k}_{B_{i,2}}}{A_{i,2}B_{i,2}}$$

$$\theta^{k}_{i} = \theta^{k}_{i,1} + \theta^{k}_{i,2}$$

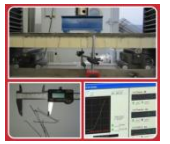
Principle of virtual work:

$$F^k = \frac{1}{\delta^k_c}\sum_{i=1}^{n_{cr}}\left(M^k_i \times L_{cr,i}\right)\theta^k_i$$

$M-\theta$

From a cross section layer model

Salehian, H.; Barros, J.A.O.; Taheri, M., "Evaluation of the Influence of Post-Cracking Response of Steel Fibre Reinforced Concrete (SFRC) on Load Carrying Capacity of SFRC Panels", Construction and Building Materials Journal, 73, 289-304, December 2014. DOI: 10.1016/j.conbuildmat.2014.09.043.


Conclusions

1) **Inverse analysis techniques** using 3PNBBT results have **tendency to provide upper bound values for the fracture parameters**; this tendency increases with the formation of more number of fracture surfaces and their tortuosity, which is related with the reinforcement performance of the fibres. **Using these values on the FEM-based analysis provide unsafe predictions**. A possible remedy is **using the characteristic minimum F-CMOD relationship** of the experimental tests in the IA.
2) In a **RPT 3 failure cracks are generally formed** of distinct orientation, therefore crossed by fibres of different orientation, providing **higher probability of mobilizing more representatively the fibres reinforcement mechanisms that occur in slabs and shells**; less tendency to the occurrence of diffuse cracking and cracks of high tortuosity.