PCN Study Report

SHEAR CAPACITY EVALUATION OF HOLLOW CORE SLABS

Eurocode EN 1992.1.1 EN 1168 Annex J Tests and test results

UAP Proposal for modifications to EN 1168

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IPHA Seminar Delft, 7th- 8th November 2005

Normative Documents

A) Eurocode 1992.1.1

6.2.2 Members not requiring design shear reinforcement

1) Formula 6.2a

$VRdc = [C_{Rd,c} \cdot k \cdot (100 \cdot \rho_1 \cdot f_{ck})^{1/3} + k_1 \cdot \sigma_{cp}] \cdot b_w \cdot d$

- with minimum of $VRdc = (\upsilon_{min} + k_1 \sigma_{cp}) \cdot b_w \cdot d$
- not to be checked for $x < d$, as per point 6.2.1 (8)

2) Formula 6.4

$$VRdc = \frac{J \cdot b_w}{S} \sqrt{(f_{ctd})^2 + \alpha_l \cdot \sigma_{cp} \cdot f_{ctd}}$$

- in regions uncracked in bending where tensile stress $\leq f_{ctk0.05}/\gamma c$
- not to be checked for $x < d/2$ as per point 6.2.2 (3)

B) EN 1168 "Hollow core slabs"

1) Point 4.3.3 makes reference to Common Rules EN 13369, which refer again to EN 1992.1.1
2) Specific formulas only for shear/torsion, shear capacity of longitudinal joint, punching shear capacity

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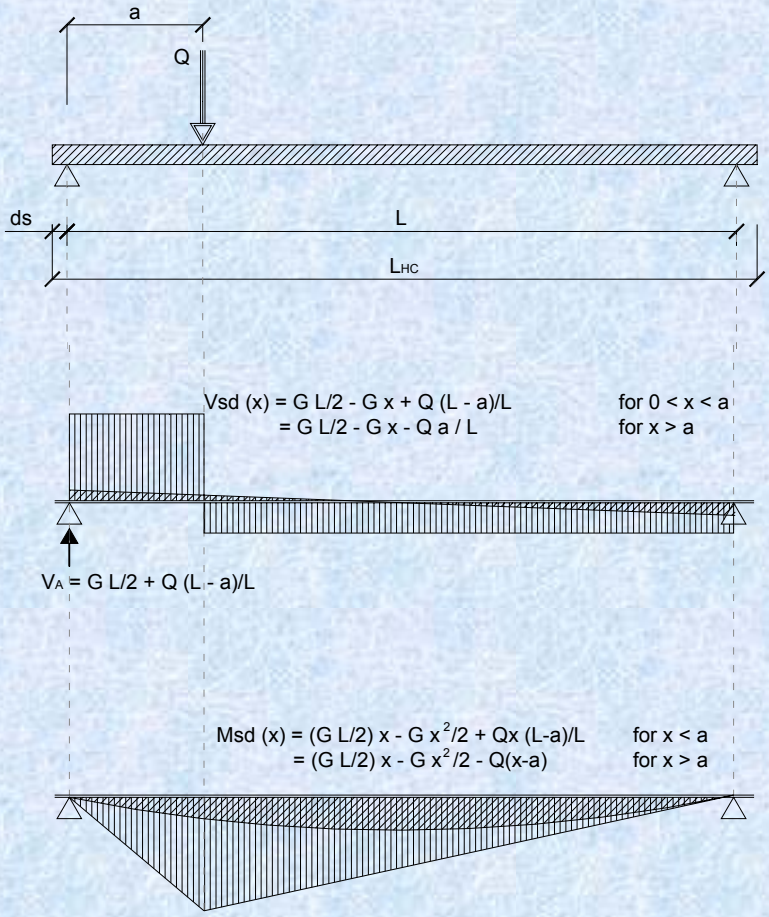
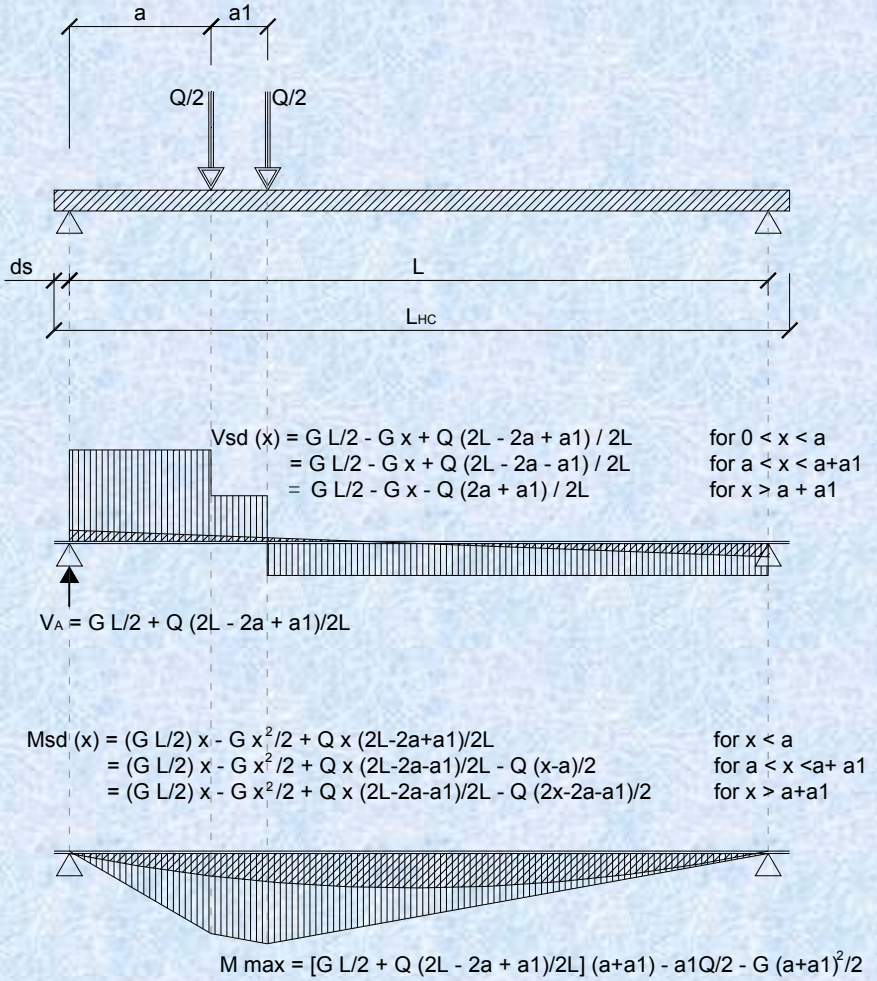
Annex J Full scale test

1) Test schemes

A) Annex J Fig. a), and VTT report 4÷6



B) Annex J Fig. b), and VTT report type 5



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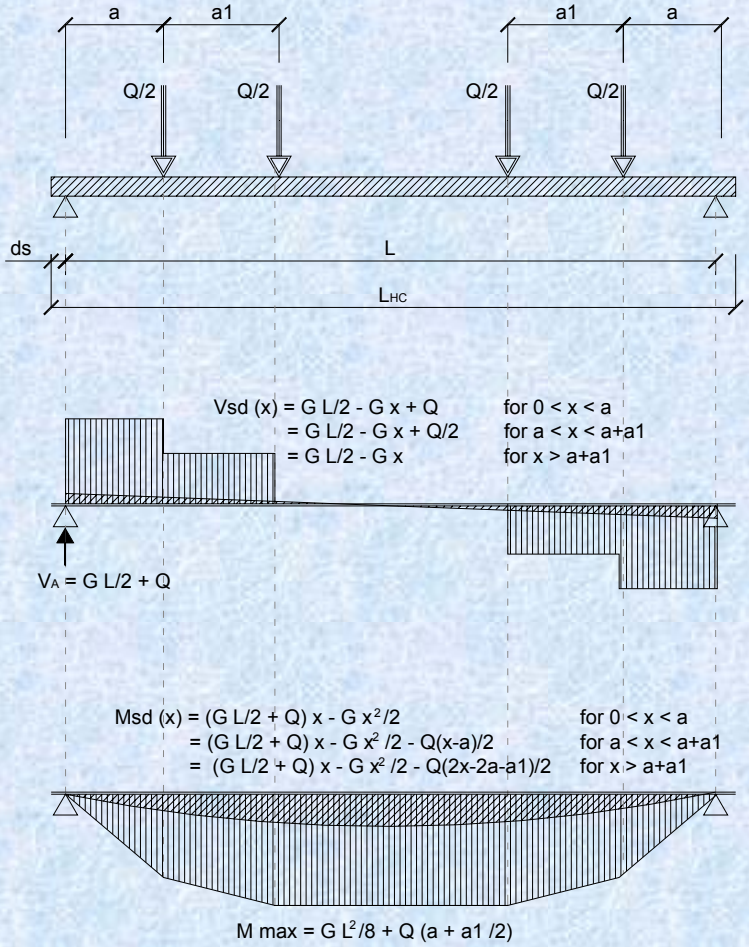
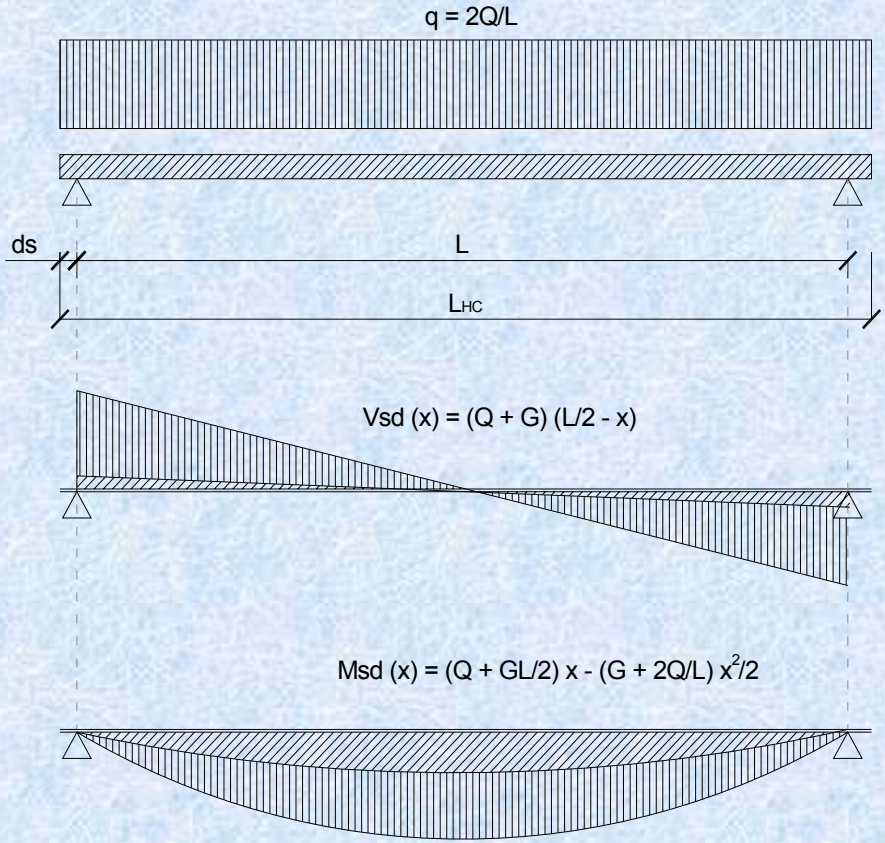
Annex J Full scale test

1) Test schemes

C) VTT report type 1/2/3



D) Standard uniform load



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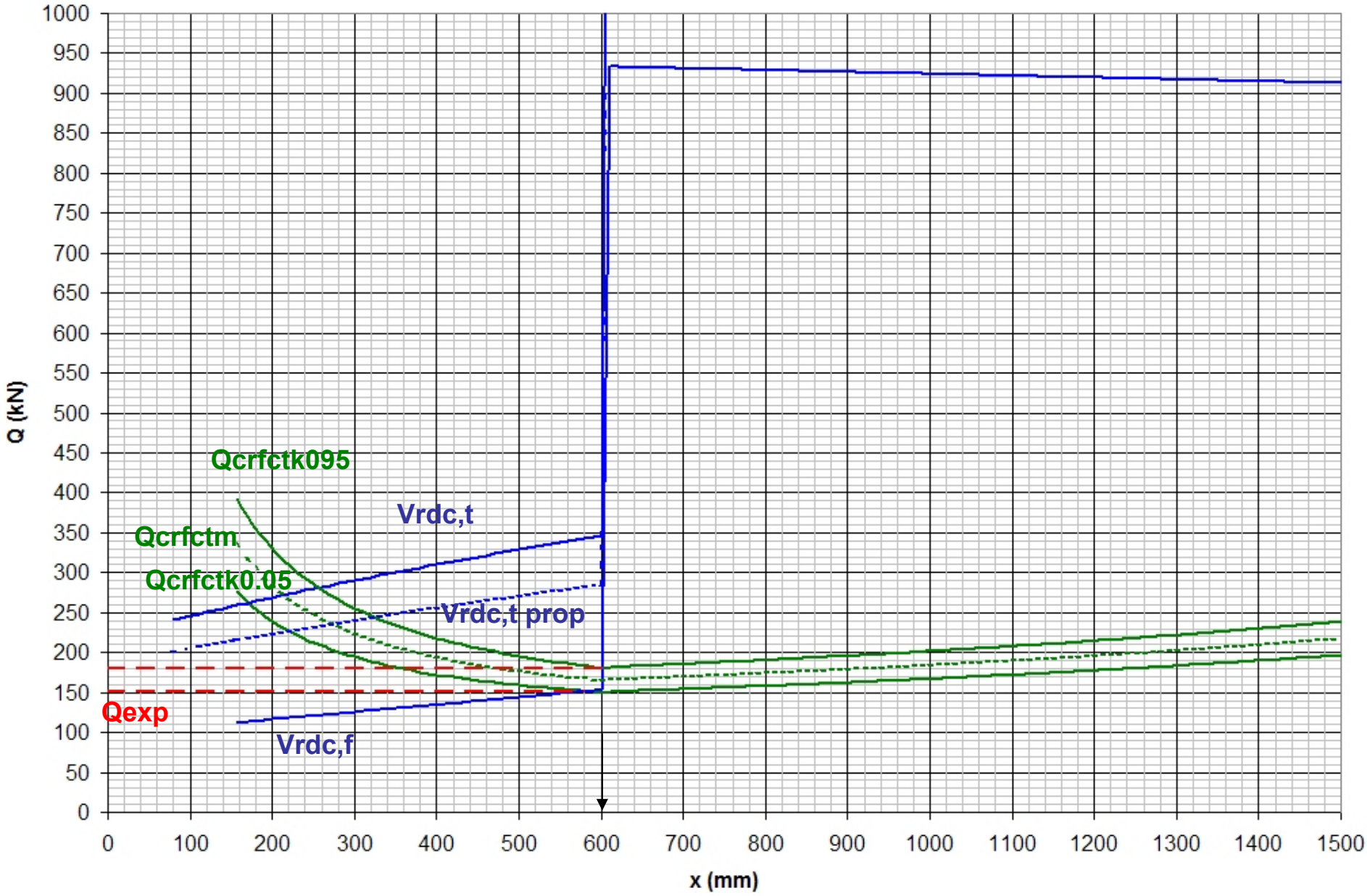

when $\varphi_{HC} \leq 0.2$ or ≥ 0.4

4) Plot Q(Vrdc,t)prop = QRdc,t(x) with
Vrdc,t prop = proposed formula for shear tension

Tests results

PCN H 200 n° 3 test (slip-form H.C. with $\varphi_{H.C.} \leq 0.2$)

PCN H 420 n° 3 test (slip-form H.C.with $\varphi_{H.C.} \leq 0.2$)

} Load scheme A

VTT Test 31.200 n° 1 test (extr. H.C. with $\varphi_{H.C.} \geq 0.4$)

VTT Test 178.400 n° 1 test (extr. H.C., with $\varphi_{H.C.} \leq 0.2$)

VTT Test 191.500 n° 1 test (extr. H.C. with $\varphi_{H.C.} \leq 0.2$)

} Load scheme C

- The $Q_{failure}$ of test is plotted at an "x" position corresponding to the average value of intersection of failure crack with centroidal axis.
- When available also the Q_{crack}, corresponding to the first flexural crack, is reported

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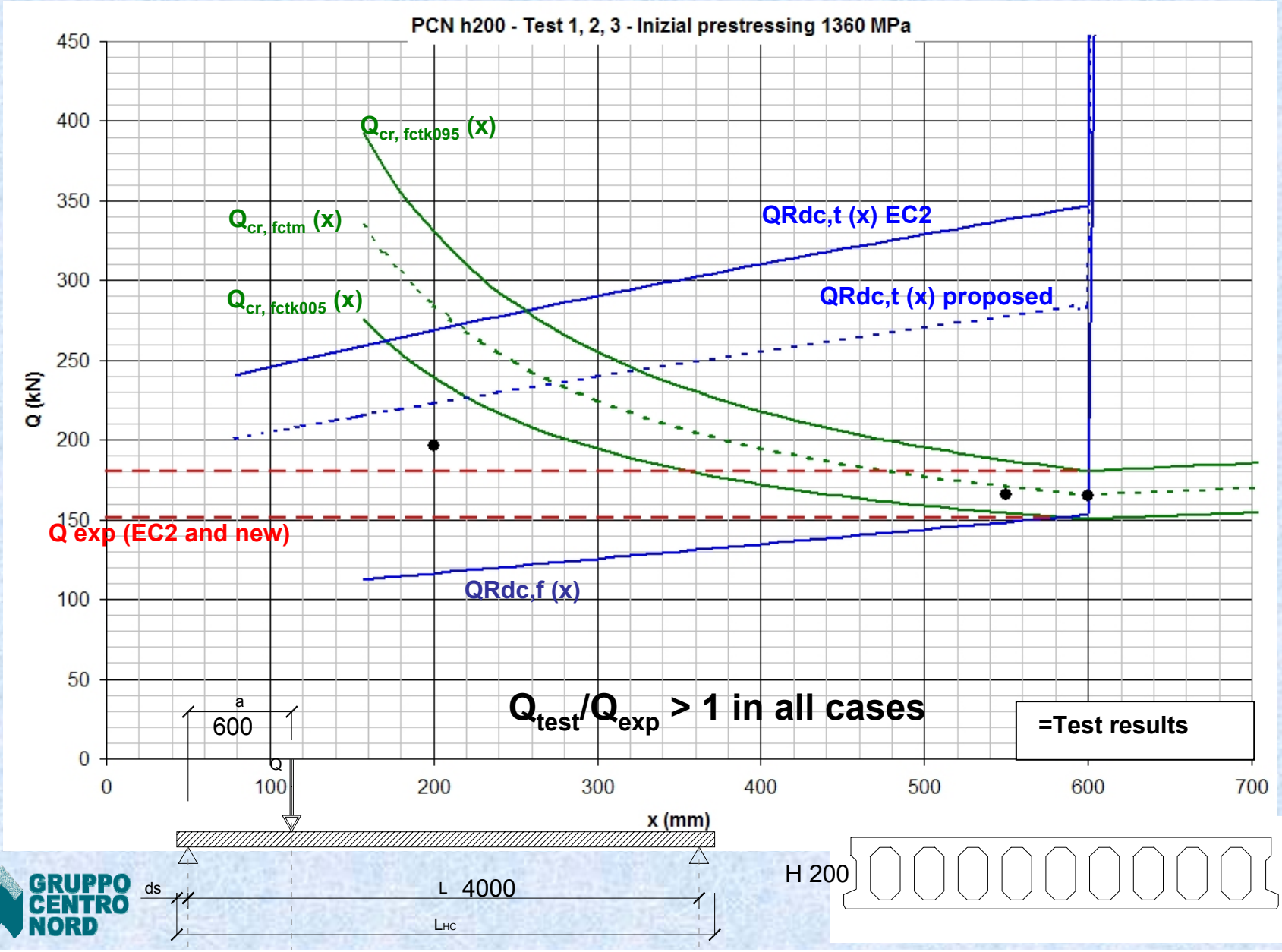
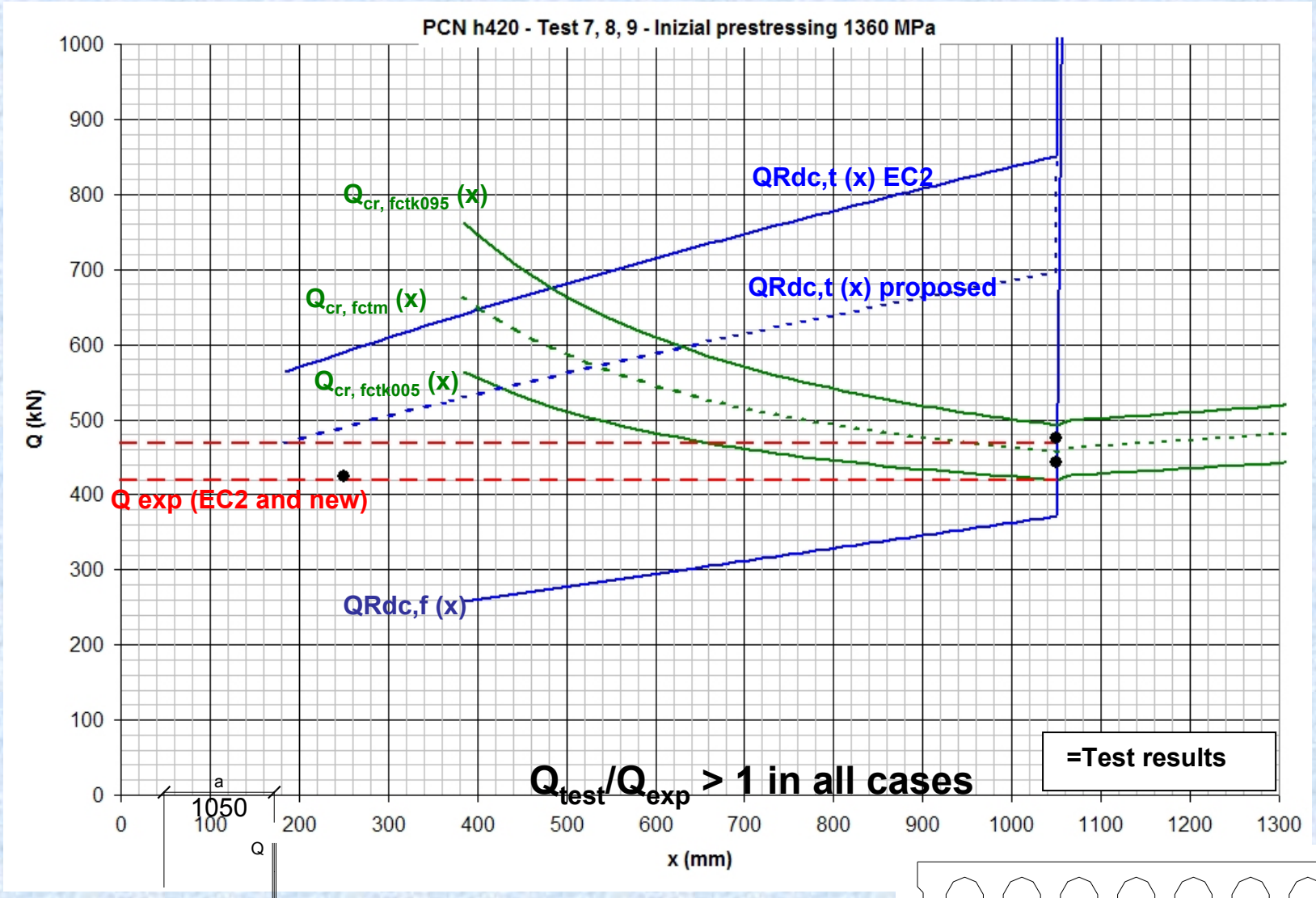
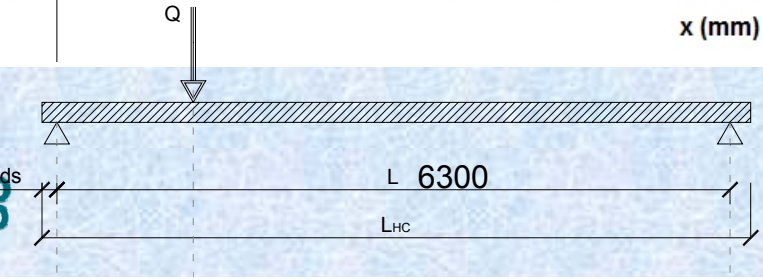
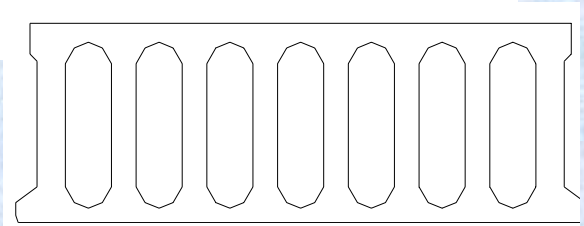
PCN Tests results



PCN Tests results







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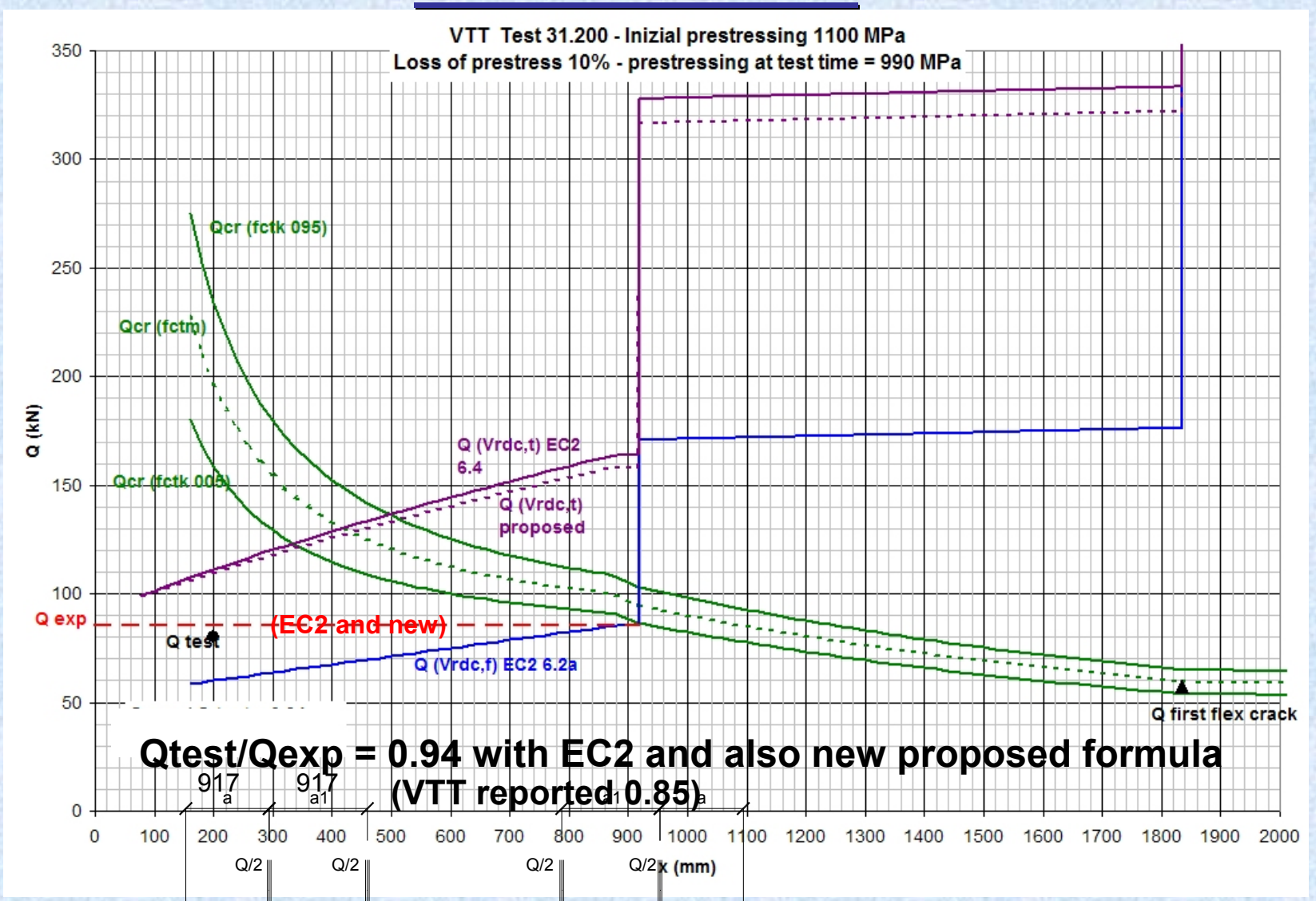
VTT Tests results



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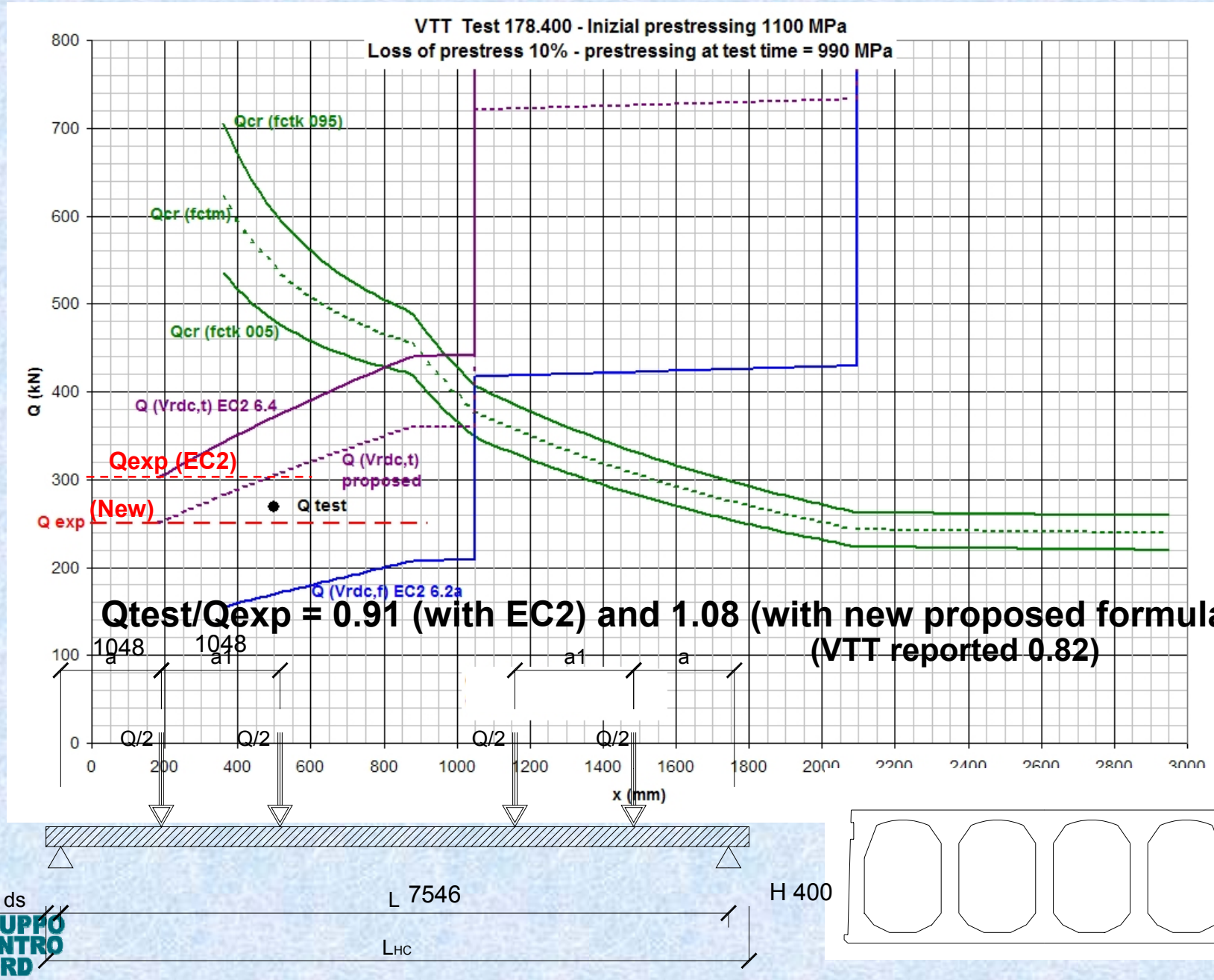
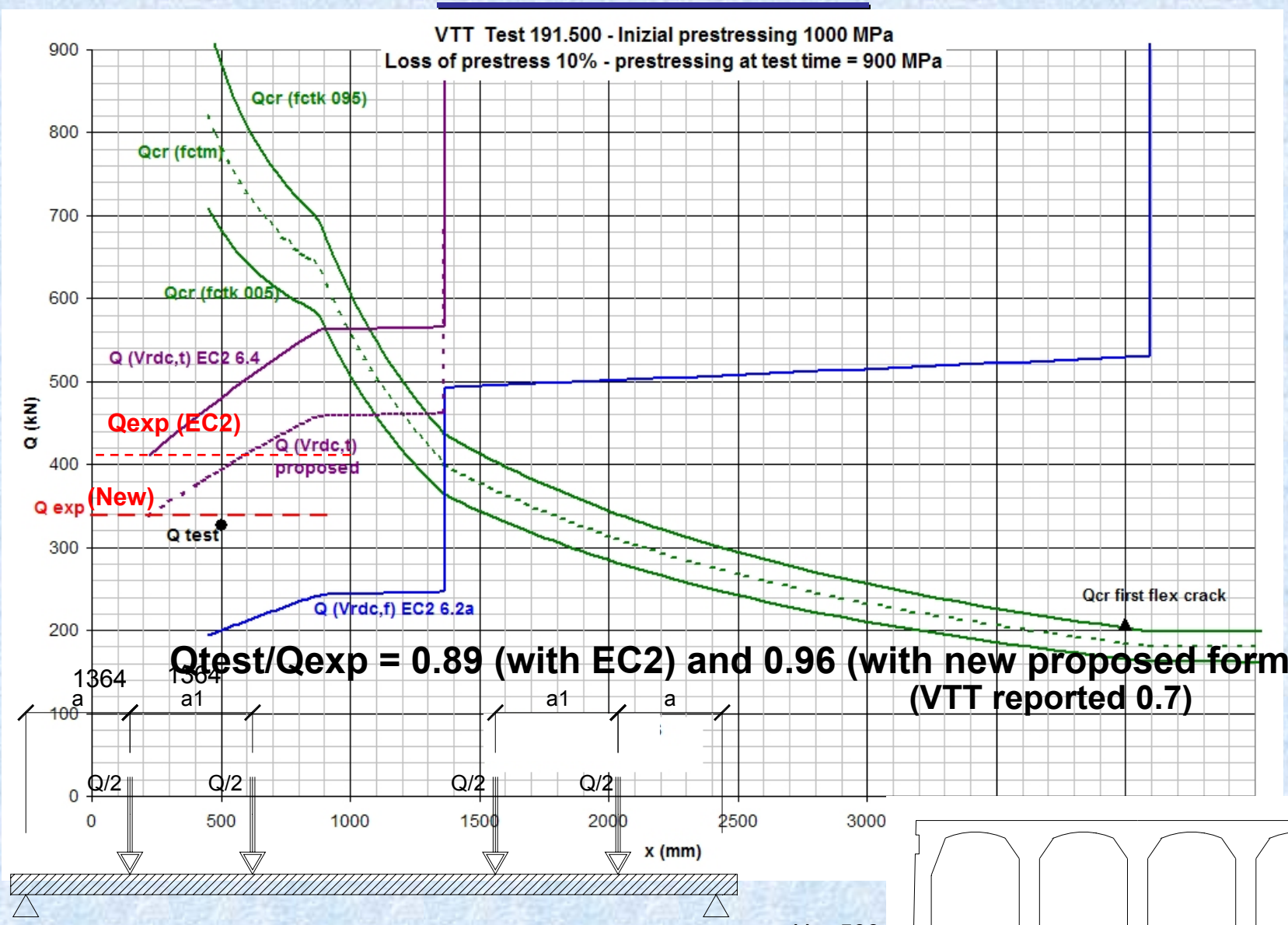
VTT Tests results



VTT Tests results



Qtest/Qexp = 0.89 (with EC2) and 0.96 (with new proposed formula)
(VTT reported 0.7)

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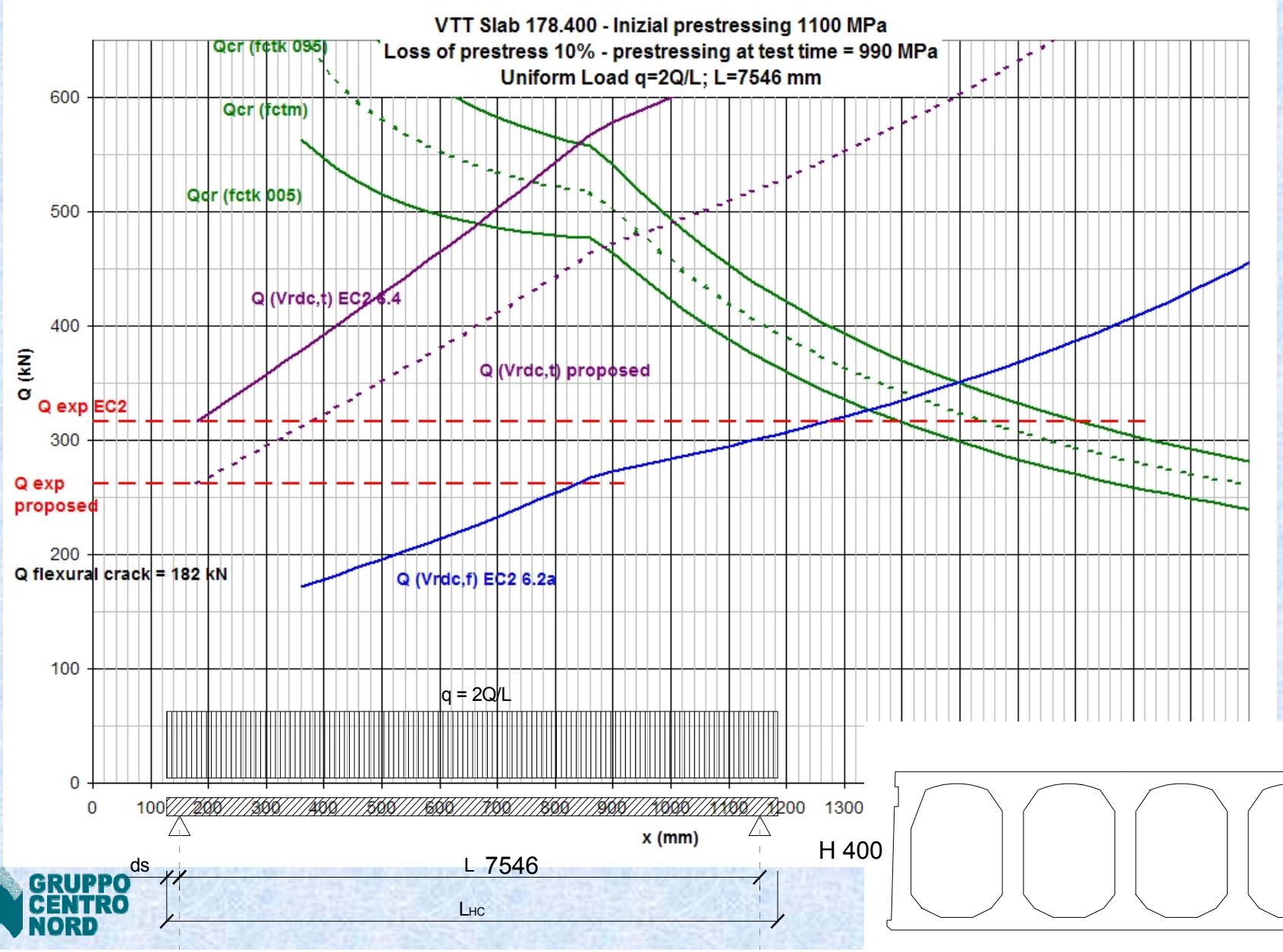
VTT slab with uniform load test simulation



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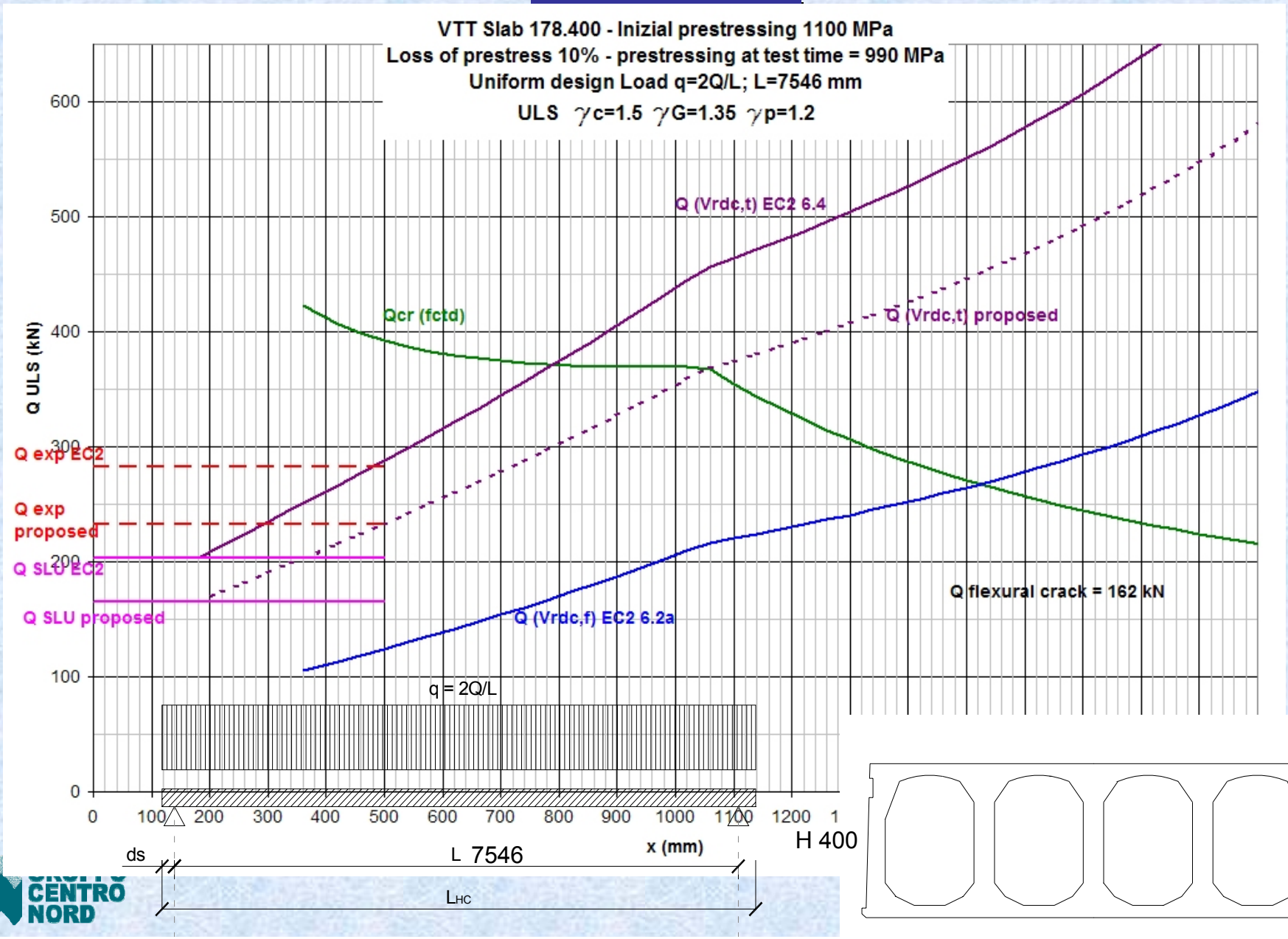
VTT slab with uniform load
ULS design



UAP Proposal for modification to EN 1168

1) Extend the Scope to hollow core slabs up to 500 mm depth

Modify the 6th paragraph of point 1. Scope as follow:
"The application of the standard is limited for prestressed elements to a maximum depth of ~~450~~ 500 mm and ....."

2) Apply reduction factor $\alpha_{H.C.}$ and β to EC2 formula 6.4 to take into account the shape of the webs and relevant spalling stresses

Add, after the 3rd paragraph of point 4.3.3.1 the following:
"In region uncracked in bending (where the flexural tensile stress is smaller than fctk0,05/γc), the shear resistance of hollow-core slabs should be limited by the tensile strength of concrete, taking into account the splitting stresses generated by prestressing transfer, which depend on the shape and section of the webs and cores.

Unless more rigorous evaluations at finite element are performed, to be confirmed by adequate experimental tests, to take into account these factors in the formula (6.4) of EN 1992.1.1, the reduction factors $\alpha_{H.C} = 0.9$ and $\beta = 0.85 \div 1.0$ according to the shape of the webs and cores of hollow core section, shall be included, as follows:

$$V_{Rd,c} = \beta \frac{I \cdot bw_{n\text{-}n}}{S_{n\text{-}n}} \sqrt{(f_{ctd})^2 + \alpha_{H.C.} \cdot \sigma_{cp} \cdot f_{ctd}}$$

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New formula for shear tension capacity

$$V_{Rd,c} = \beta \frac{I \cdot bw_{n-n}}{S_{n-n}} \sqrt{(f_{ctd})^2 + \alpha_{H.C.} \cdot \sigma_{cp} \cdot f_{ctd}}$$

where

I is the second moment of area.

∑bw n-n is the width of the cross-section at the centroidal axis.

S in the first moment of area above and about the centroidal axis.

$\alpha_{H.C.}$ **0.9** for hollow-core slabs with depth H ≤ 500 mm

$\alpha 1$ lx/lpt2 ≤ 1

lx is the distance of section considered from the end of slabs

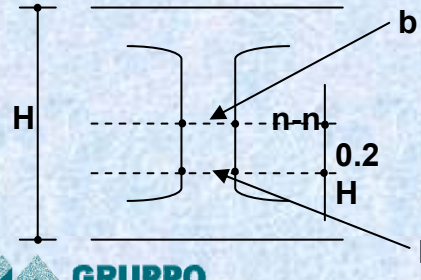
N.B. the first cross section to be checked is at the intersection of the elastic centroidal axis and a line inclined from the inner edge of the support at an angle of 45°.

lpt2 is the upper bound value of the transmission length of the element

σcp is the concrete compressive stress at the centroidal axis due to prestressing

N.B. for the purpose of this calculation the prestressing development shall be linear

β **0.85÷1.0** according to the shape of cross section as follows:



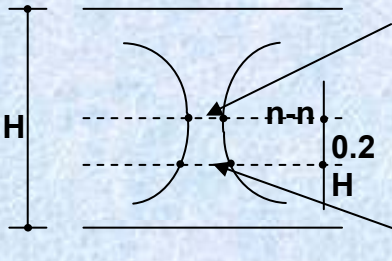
b w_{n-n}

$\varphi_{H.C} = \frac{b w_{inf} - b w_{n-n}}{b w_{inf}} \leq 0.2$

(quasi rectangular cores)

β = 0.85 for φbw ≤ 0.2

b $w_{inf.}$



b w_{n-n}

$\varphi_{H.C.} = \frac{b w_{inf} - b w_{n-n}}{b w_{inf}} \geq 0.4$

(quasi circular cores)

β = 1.0 for φbw ≥ 0.4

b $w_{inf.}$

The value of β in between may be interpolated.

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THANK YOU FOR ATTENTION

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