Shear and Torsion in Hollow Core Slabs

Holcitors

A European research project

Financiers and collaboration partners

- European Commission
- International Prestressed Hollow Core Association
- Bundesverband Spannbeton-Hohlplatten
- Castelo
- Consolis
- Echo
- A. Van Acker
- Strängbetong
- VTT
- Chalmers
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Project started January 1, 2002 and ended December 31, 2004
Aim of the project

• To use the capacity of the hollow core slabs better
• To develop methods to design for combined shear and torsion in hollow core slabs
  – Single units
  – Whole floors
Practical cases where torsion appears

- Alternating position of columns at slab ends.
- Large openings
- Trimmer beam
- Support on three edges
- Skew ends.
Shear

Web shear tension failure

Torsion

Torsion failure
Combined shear and torsion in a hollow core unit

Design method used today (EN 1168):
- Cracking means failure
- Only crack in web is considered
- One critical point
- Stresses are added linearly

\[ \text{Torsional moment } T = \text{Shear } V \]
Tests on hollow core units loaded in shear and torsion
FE model of hollow core unit

Concrete in compression

Concrete in tension

Steel in tension

Bond-slip relationship
Comparison of results

- Maximum load
- Load versus deflection
- Failure mode
- Crack pattern

Maximum load in test [kN] vs. Maximum load in analysis [kN]

- ST400
- ST200
Comparison of results

Test Q = 100.0 kN
FEA Q = 86.3 kN
Test b Q = 98.1 kN
Comparison of results

- Neoprene
- Mortar bed
- Thin plastic sheet

Graphs showing comparison of forces (Q) and displacements (δ) between tests E1M and E1, with FEA results for comparison. The graphs depict the force-displacement behavior for different materials and configurations.
Effect of neoprene

- Strain
- Concrete
- Neoprene

Graphs showing load vs. microstrain and load vs. displacement for ST400E1-Web 5 and ST400E1-Web 4 with different values of El.
Critical section for shear tension crack in 400 mm unit

Analytical model

FE-analysis, pure shear
Conclusions FE-analyses of HC-units

- FE-analyses of tests are able to capture the overall behaviour:
  - Failure mode
  - Maximum obtained load
  - Crack pattern
  - Vertical deflections (until first crack)
- Large difference in capacity due to support condition
FE analyses to establish interaction diagram

\[
\begin{align*}
\delta^A_y &= \delta^A_y \\
\delta^B_y &= \delta^B_y \\
\delta^C_y &= \delta^C_y 
\end{align*}
\]
Interaction diagram for 400 mm unit

EN 1168
Interaction diagram for 200 mm unit

EN 1168
FE model of hollow core floor

Beam elements to model single hollow core units

Interface elements to model joints

Tie beam modelled by tyings

Reduced torsional moment
Design of hollow core slabs

FE-model for floor integrated with FE-model for hollow core unit

Load capacity

FE-model for floor

M, V and T

V-T capacity

Improved design

FE-model for floor integrated with FE-model for hollow core unit

Load capacity

FE-model for floor

M, V and T

V-T capacity

Analytical method in EN1168

Traditional design

Distribution diagram (α-factors) in EN 1168

Structural analyses

Resistance analyses

IV

III

II

I

Load capacity

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Structural analyses

Resistance analyses
Test on hollow core floor
Designing a floor – Design level III and II
Simulation of a floor test – Design level I

Test: $Q_{\text{max}} = 521$ kN

FE: $Q_{\text{max}} = 480$ kN
Floor, design example

$Q_{max}$ [kN]

Experiment 521 kN

357 kN

EN 1168

449 kN

480 kN

Design level
Conclusions

• Modelling methods for hollow core slabs were developed
  – Hollow core floor ⇒ Sectional forces M, V and T
    • Reduced torsional moment
    • Arbitrary geometries and loadings
  – Hollow core unit ⇒ Shear-torsion capacity
    • Higher resistance
• The capacity of the hollow core units can be used better
Thanks!