EXPERIMENTAL INVESTIGATIONS ON BUILT-UP COLD-FORMED STEEL CORRUGATED WEB BEAMS ASSEMBLED WITH WELDING

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Objectives

To present new research developments on cold-formed steel beams of corrugated web (CWB)
ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

Exemplification by Zeman & Co (http://www.zeman-stahl.com/)
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ACTUAL TECHNICAL SOLUTIONS FOR CORRUGATED WEB GIRDERS

The main benefits:
• the corrugated webs increase the beam’s stability against buckling;
• the use of thinner webs results in lower material cost (an estimated cost savings of 10-30% in comparison with conventional fabricated sections and more than 30% compared with standard hot-rolled beams);
• the buckling resistance of used sinusoidal corrugated sheeting used for webs is comparable with plane webs of 12 mm thickness or more.

DESIGN \Rightarrow adapted to EN 1993-1-5 Annex D
IDEA

CEMSIG Research Centre of PU Timisoara

- is 100% composed of cold-formed steel elements, avoiding the combination of two types of products;
- high protection to corrosion due to the fact that all components are galvanized;
- to develop a structural system able to enable easy and/or automated prefabrication, reduced erection time, mass production and possibility of high-precision quality control.
- flanges: – 2xC120/2.0
- corrugated web: -A45/0.7
- supplementary shear panels of 1mm thickness
- self-drilling screws for flange-to-web connections – 6.3x25
- self-drilling screws as seam fasteners – 4.8 x20
- M12 class 8.8 bolts for end connections of back-to-back lipped channels to the supports

Actual solution : SCREWED!
## EXPERIMENTAL PROGRAM

<table>
<thead>
<tr>
<th>CWB - 1</th>
<th>Standard solution: flange-to-web connection in every corrugations and uniformly distributed seam fasteners</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWB - 2</td>
<td>Standard solution + supplementary lipped channel sections C under the load application points</td>
</tr>
<tr>
<td>CWB - 3</td>
<td>Optimized solution by adapting the flange-to-web connections according to the distribution of shear stresses (connections at each second corrugations where the shear force decreases)</td>
</tr>
<tr>
<td>CWB - 4</td>
<td>Optimized solution by eliminating shear panels and doubling of corrugated webs in the zones with high shear forces</td>
</tr>
<tr>
<td>CWB - 5</td>
<td>Optimized solution by adapting both the flange-to-web connections and seam fasteners to the distribution of shear stresses</td>
</tr>
</tbody>
</table>

**Monotonic load -** \( v_{test} = 2\text{mm/min} \)

**6 points bending test**
EXPERIMENTAL PROGRAM

Beam CWB-5

- First deformation – distortion of corrugated web near support – 21mm
- $K_{0-\text{Exp}} = 5516.23 \text{ N/mm}$
- $F_{\text{max}} = 214.575 \text{ kN}$
- Collapse at 88mm displacement
EXPERIMENTAL PROGRAM

Beam CWB-5
EXPERIMENTAL PROGRAM

Beams CWB 1...5

Force [kN] vs. Displacement [mm]

- CWB - 1
- CWB - 2
- CWB - 3
- CWB - 4
- CWB - 5

Design level
SLEN
SLS
ULS
Numerical model calibration and validation

ABAQUS/CAE 6.7.1

-dynamic explicit
Numerical model calibration and validation

- **SHELL Element – S4R type**
  - 4 nodes, reduced integration

- **CONECTOR Element – CONN3D2 type**
  - for self-drilling screws and bolts
  - 2 nodes, 6 DOF per node
  - Non-linear deformation according to imposed load

- **BEAM Element – RB3D2**
  - rigid body, for load transfer

- **BEAM Element – MPC-BEAM type**
  - Multi-point constrain beam for DOF coupling
Numerical model

- General contact
  - Normal direction – HARD CONTACT
  - Transversal direction with a friction coefficient of $\mu=0.1$

- Material behavior – curves obtained from tests on materials cut from specimens

- Initial imperfections – according to first 3 eigenmodes from a LBA
Numerical model

Self-drilling screws and bolts were introduced using CONN3D2 element type according to the mean values recorded from tests of each type of connection.
Numerical model

FEM vs. Experimental

CWB - 1 - EXP
CWB - 1 - FEM

FEM vs. Experimental

CWB - 2 - EXP
CWB - 2 - FEM

FEM vs. Experimental

CWB - 3 - EXP
CWB - 3 - FEM

FEM vs. Experimental

CWB - 4 - EXP
CWB - 4 - FEM

FEM vs. Experimental

CWB - 5 - EXP
CWB - 5 - FEM
INITIAL STIFFNESS AND ULTIMATE LOAD: FEM VS. EXPERIMENTAL RESULTS

<table>
<thead>
<tr>
<th>Beam type</th>
<th>$K_{0-Exp}$ (N/mm)</th>
<th>$K_{0-FEM}$ (N/mm)</th>
<th>$F_{max-Exp}$ (kN)</th>
<th>$F_{max-FEM}$ (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWB-1</td>
<td>6862.2</td>
<td>7721.1</td>
<td>218.9</td>
<td>225.9</td>
</tr>
<tr>
<td>CWB-2</td>
<td>7831.5</td>
<td>7834.6</td>
<td>231.3</td>
<td>229.5</td>
</tr>
<tr>
<td>CWB-3</td>
<td>7184.9</td>
<td>6819.3</td>
<td>209.5</td>
<td>205.8</td>
</tr>
<tr>
<td>CWB-4</td>
<td>3985.0</td>
<td>4932.0</td>
<td>181.9</td>
<td>223.5</td>
</tr>
<tr>
<td>CWB-5</td>
<td>5516.2</td>
<td>6594.9</td>
<td>214.6</td>
<td>216.0</td>
</tr>
</tbody>
</table>

- it can be noted that the behaviour and maximum load accurately replicate the experimental tests
- in case of CWB-4 beam the numerical results are 23% higher than experimental one. The reason could be the higher degree of flexibility (no shear plates to stiffen the beam).
Fast welding cold-formed steel beams of corrugated sheet web

WELLFORMED

The main objectives of the project:

• to validate a new technological solution, CWB where the connections made of intermittent SW and MIG/MAG W;

• to validate it by a parametric study via numerical models using ABAQUS FEM tool;

• to adapt/extend the rules of the EN 1993-1-5, Annex D to this new type of beams;

• to develop a structural system able to satisfy easy prefabrication, automation and mass production.
Laser welding
Spot welding
Spot welding
Spot welding – preliminary investigations
MIG/MAG welding equipment impulse welding
MIG/MAG welding equipment impulse welding - preliminary investigations

$v_s = 300 \text{ cm/min}$

$w_f0 = 12 \text{ m/min}$

$Stuckout = 14 \text{ mm}$

$\alpha = 1/4$

$\Delta f = 3 \text{ MHz}$

$I = 185 \text{ A}$

$U_a = 14,3 \text{ V}$
(a), (b), (c) one spot

(d), (e), (f) two spots

Seria T1-1.4
WPs:

WP 1: Design of testing program
WP 2: Tests of welded connections and optimisation of fastening technology
WP 3: Tests on full scale CWB beams
WP 4: Numerical testing of beams and parametric investigations
WP 5: Exploitation and dissemination of results
WP 2: Tests of welded connections and optimisation of fastening technology

670 specimens for welded connections (SW and CMT)
95 specimens for tensile tests
WP 3: Tests on full scale CWB beams

4 full scale beam specimens two using SW and two using CMT
CONCLUSIONS

- several types of beams with corrugated webs and different arrangements for self-drilling screws and shear panels were experimentally tested;

- very good agreement between numerical models and experimental ones, both in failure modes and load-displacement curves;

- a new experimental program on connecting details (using SW and MIG/MAG W) and full-scale beams has started at the PU Timisoara, on the purpose to demonstrate and evaluate the performances of proposed solutions;

- the results are encouraging and prove the potential of this solution to standardized beams and industrialized fabrication.
Thank you for your attention!

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