Numerical analysis of castellated beams with oval openings

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VALUES | INNOVATION | PERFECTION

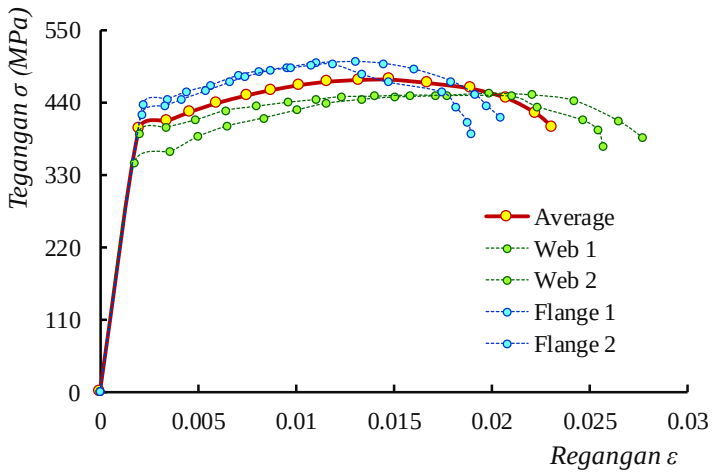
Introduction

- The main idea for the use of castellated beams is to reduce the self-weight by providing openings in the web of wide flange (WF), or I sections and re-arranging the cut section so that it result in an increase of height.
- Numerous research on castellated beams has been conducted, the majority of the studies aimed to optimize the opening size and the shape configuration of the openings.

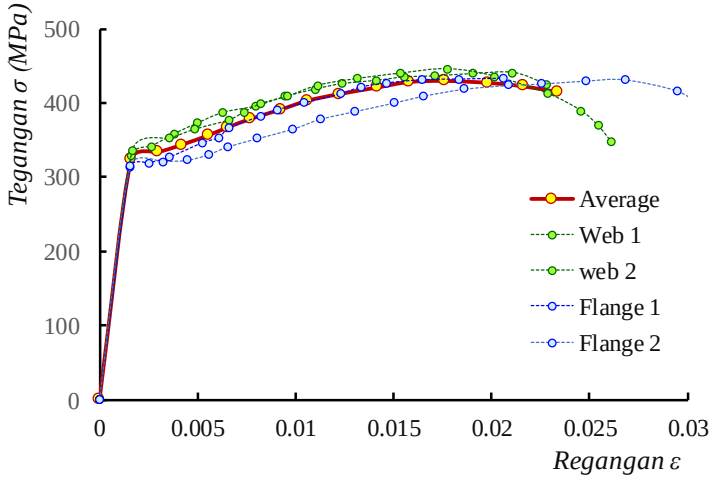
- The accomplished studies indicated that the stress concentration occurs in the corners of the openings leading to initial yielding in the section at the hexagonal opening.
- Previous research on oval openings indicate that this form provides a greater load capacity compared to the hexagonal forms.

Experimental test

- Steel properties test



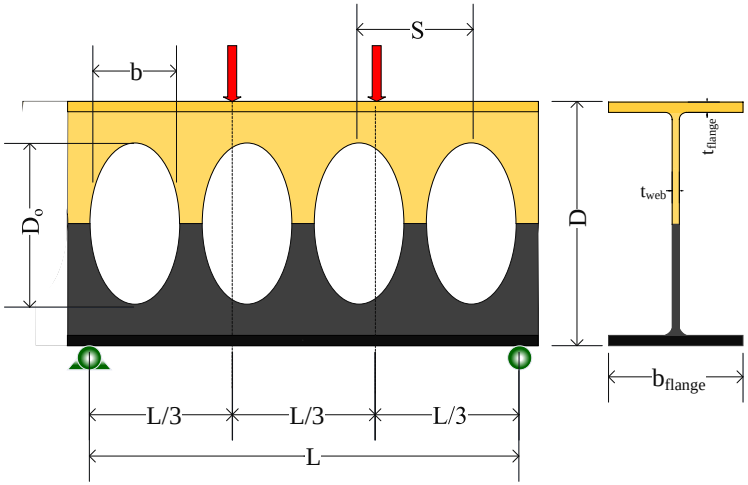
Stress-strain in tension of the WF 200x100



Stress-strain in tension of the WF 350x175

Experimental test

- Validation specimen



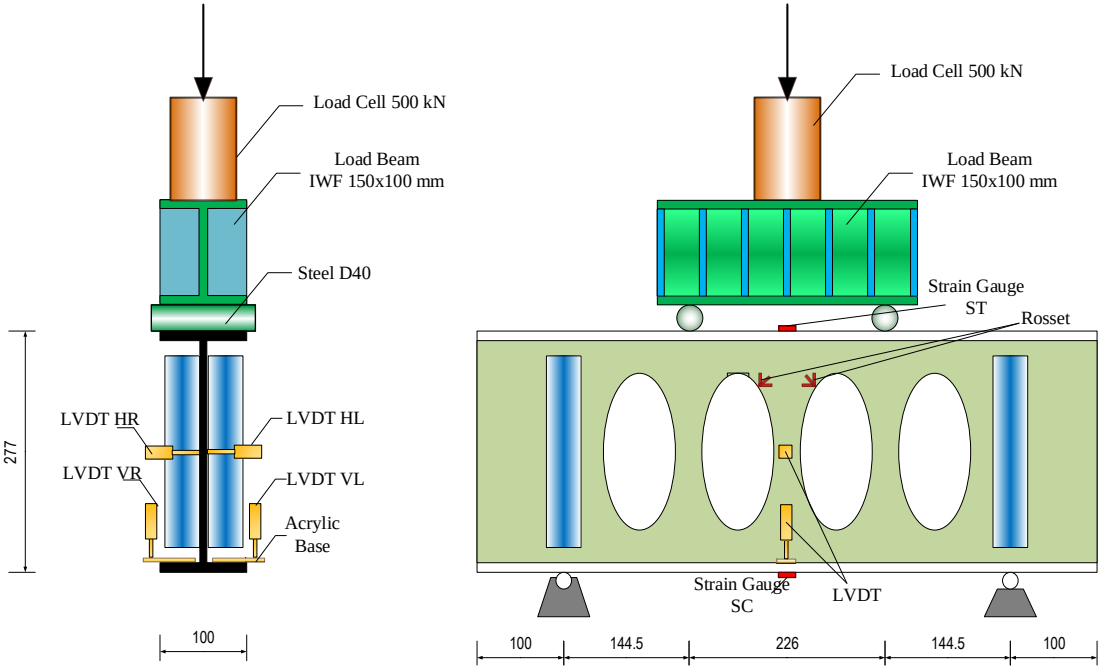
Specimen designation

Specification of specimen's geometric variations

Parameter	Dimension (mm)			
	CB - 1	CB - 2	CB - 3	CB - 4
Beamlength (L)	515	900	900	1600
Beam width (B)	100	100	175	175
Beam height (D)	277	277	485	485
Ratio D/L	0,54	0,30	0,54	0,30
Height of the opening (Do)	180	180	315	315
Ratio Do/D	0,65	0,65	0,65	0,65
Width of the opening (b)	83	83	145	145
Ratio b/Do	0,46	0,46	0,46	0,46
Distance between opening (S)	113	113	206	206

Experimental test

- Validation specimen



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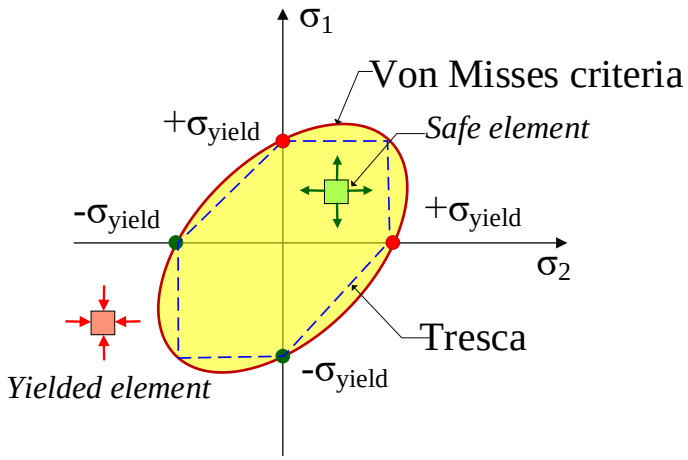
Numerical analysis

- Material behavior and failure criteria

The material of the castellated beams was assumed to be isotropic, and the stress-strain relationship obtained from the steel tensile test was used to accommodate the nonlinear steel material behavior. The steel material failure criteria used in the analyses were based on the Von Misses failure envelope.

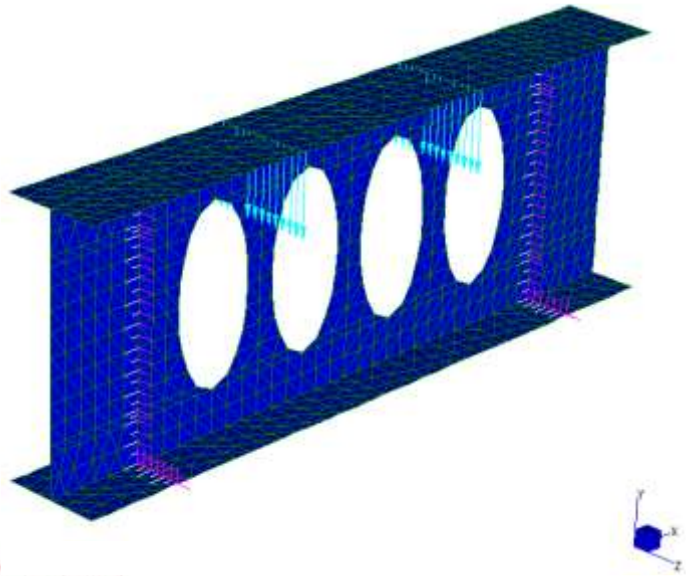


Von Misses failure criterion

Numerical analysis

- Finite element model

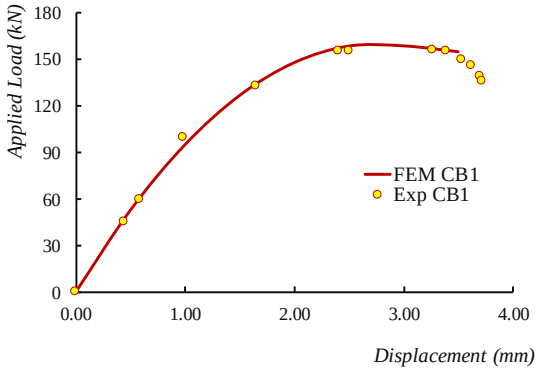
The plate element used in this work was a six-node triangular plate element. The elements have quadratic shape functions. The quadratic element has the ability to accommodate curved edges, as a quadratic curve is fitted through the three nodes along the edges. This element type is very suitable for modeling the castellated beam with oval-shaped openings [12, 13]. The mesh size was set at 10 mm to ensure a good meshing and enhance the convergence rate.

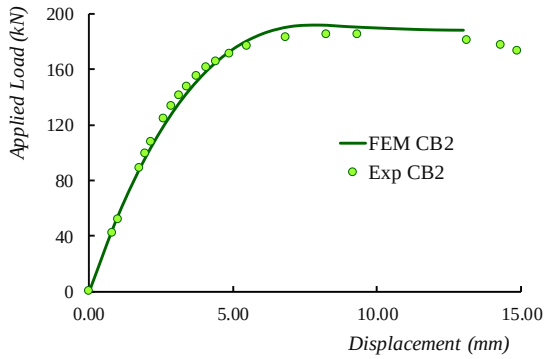


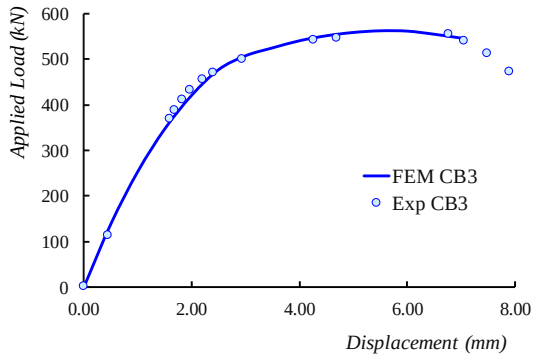
FEM of the castellated beam

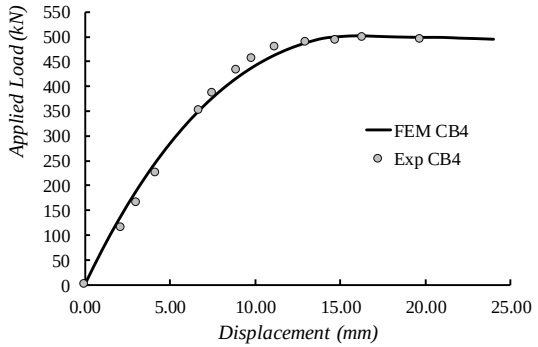
Test result and numerical model validation

- Validation of load-displacement response









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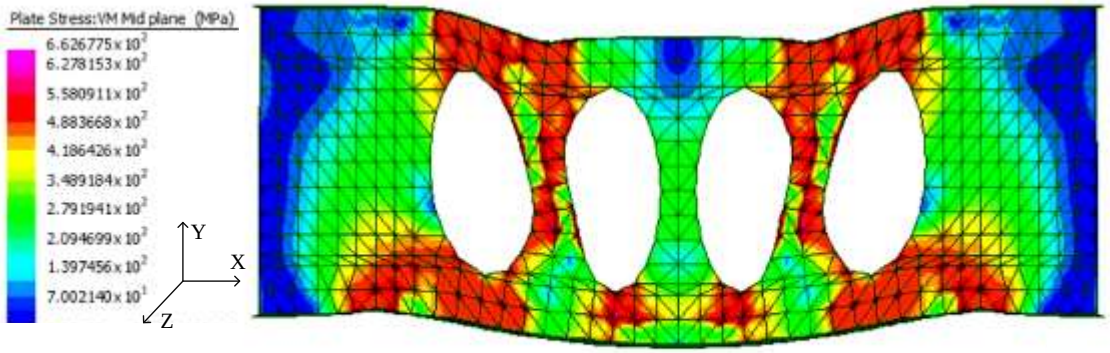
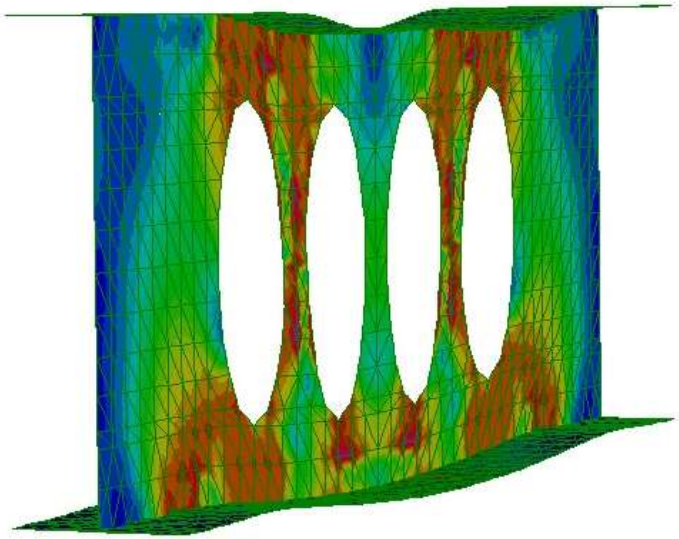
Test result and numerical model validation

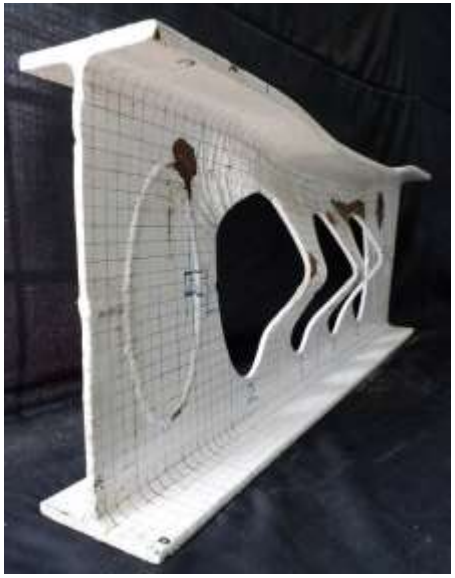
- Comparison deformation of finite element model with deformation of the tested specimen



Test result and numerical model validation

- Deviation in bottom flange behavior between the FEM and the experimental specimen





Conclusions

- The performed validation procedure to the load-displacement response of the Castellated steel beam, as well as the visual evaluation of the failure mechanism, showed that the constructed FEM could properly represent the specimen.
- A deviation between the FEM and the experimentally tested specimen was distinguished at the bottom flange.
- At further stages, this FEM will function to optimize the opening's configuration, size and distance as well as be used to evaluate the principal stress flow and strain responses at every loading stages. The model will also be used to evaluate stress concentrations in the web.

Thank You