Master's Thesis Engineering Technology

2020-2021

Geometrical imperfections in numerical models of steel bridges

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Master of Civil Engineering Technology

Situating

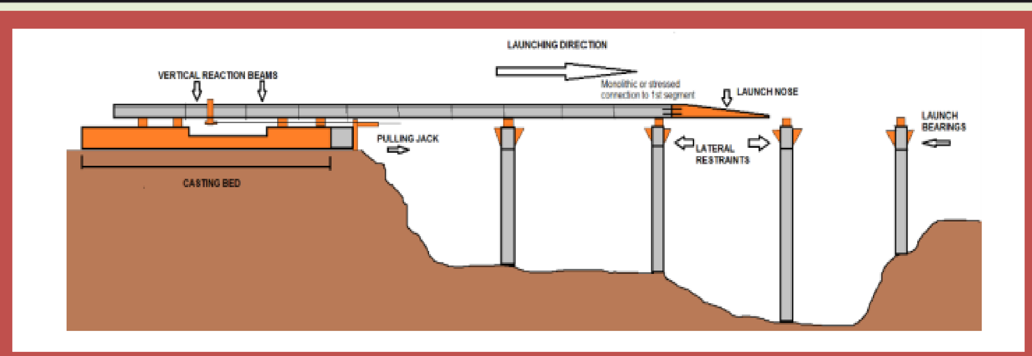

Fig. 1: Incremental launch method [1, p.19]

I. History

- ✓ A popular way to construct Hungarian bridges is the **incremental launch method,** inducing **buckling problems in the girder web** because of transversal forces and bending forces
- ✓ Very limited research regarding **bending moments**
- ✓ **Weak open-section longitudinal stiffener**s prove to have a stimulating effect on the ultimate resistance

II. Problem statement

- ✓ Conservative imperfection amplitudes proposed by **EN 1993-1-5** prove to **underestimate** the patch loading resistance
- ✓ It is **unknown** whether imperfection amplitudes proposed by EN 1993-1-5 provide accurate results for **girders subjected to bending** forces
- ✓ EN 1993-1-5 is **not fit** for girders with **more than one stiffener**

III. Goal

- ✓ Provide design recommendations on a) **imperfection shapes** and b) **magnitudes** of the analyzed failure modes of different structure types
- ✓ Determine **patch loading & bending resistances** using a FE analysis based on a **GMNIA**

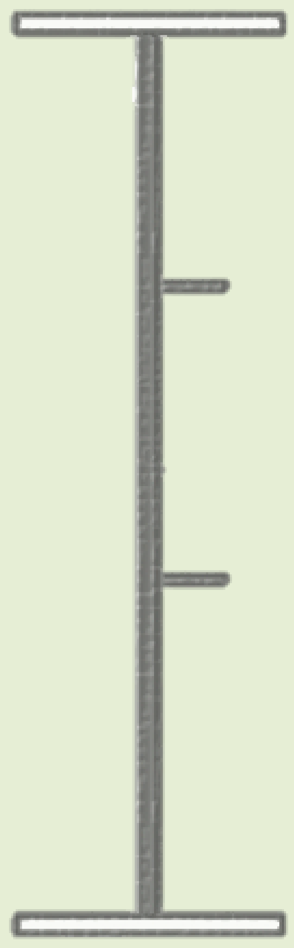

Fig. 2: Girder with two weak open-section longitudinal stiffeners

Method

I. Model verification

- ✓ Numerical model created using **ANSYS**, based on Kövesdi
- ✓ Four configurations: 1 unstiffened, 3 stiffened specimens
- ✓ Including material **nonlinearities** and geometrical **imperfections**
- ✓ Defining global and local imperfections
- ✓ Recalculate numerical results → proving model's accuracy → apply on bending cases

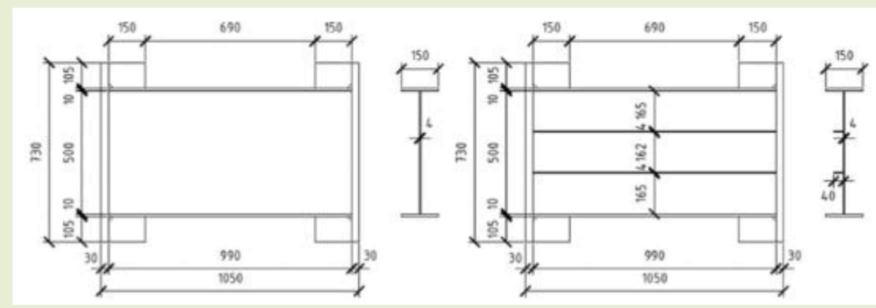

Fig. 3: Unstiffened (left) and stiffened (right) girders

II. Optimal imperfection amplitudes

- ✓ Identify the **necessary amplitudes** → equaling numerical and experimental lab resistances
- ✓ **Parametric analysis:**
  - ○ web thickness (t_w)
  - ○ web height (h_w)
  - ○ loaded length (s_s)
  - ○ panel length (L)
- ✓ **Comparison** between adequate imperfection amplitudes / shapes of:
  - ✓ Patch loading
  - ✓ Bending

  → Comparing to EN 1993-1-5

Patch loading

- ✓ **Two methods**: first eigenmode shape & hand-defining
- ✓ **Optimal amplitude**: unstiffed ($h_w/540$), stiffened ($b_1/865$)

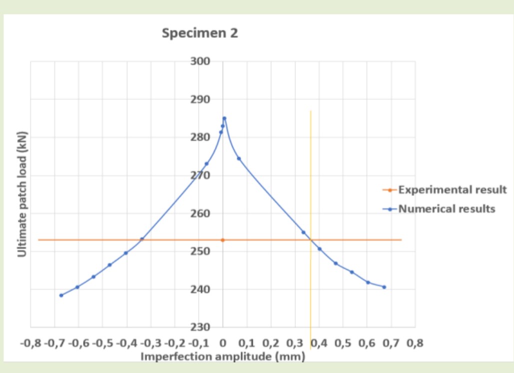

Fig. 4: Ultimate load – imperfection amplitude

For girder with two stiffeners

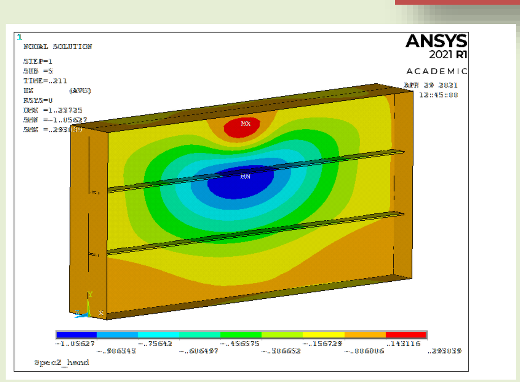

Fig. 5: GMNIA representation

- ✓ **Parameter with largest influence**: $\mathbf{t_w}$ > s_s > h_w > L
- ✓ **Web thickness:**

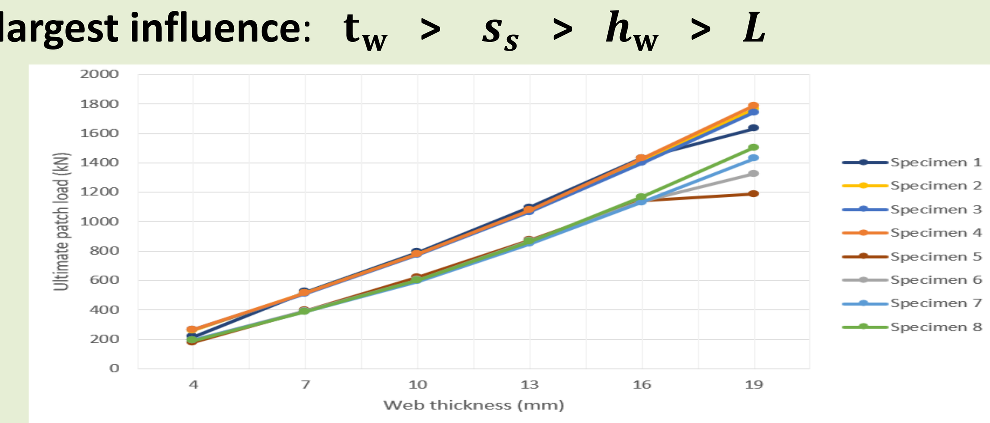

Fig. 6: Ultimate load – web thickness (tw)

- ✓ **Conclusions:**
  - ○ Sensitivity of girder biggest for small imperfections
  - ○ Smaller imperfection amplitudes than EN 19933-1-5 may be applied

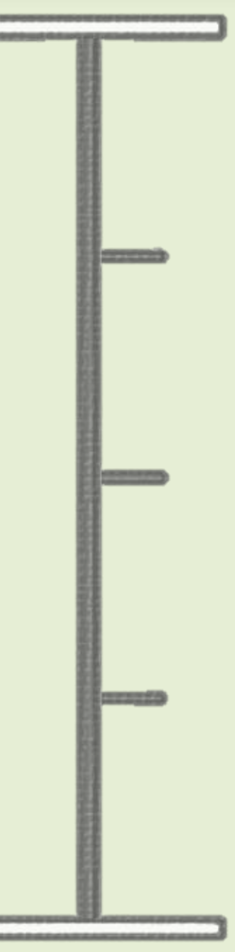

Fig. 7: Girder with three weak open-section longitudinal stiffeners

Bending

- ✓ **Method**: first eigenmode shape
- ✓ **Optimal amplitude**: unstiffed ($h_w/1230$)

Experimental

Fig. 8: Unstiffened damaged girder

vs

Numerical

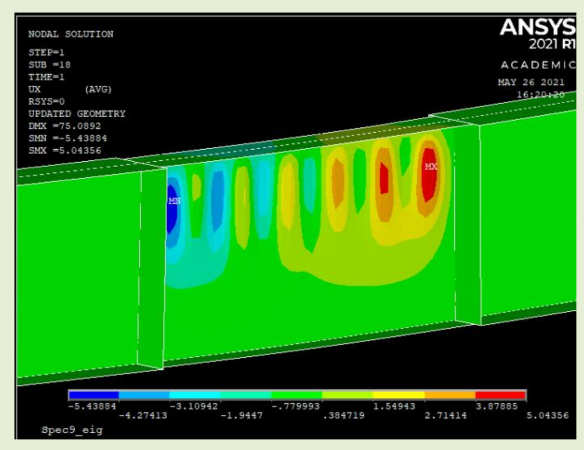

Fig. 9: Unstiffened damaged girder (numerical result)

✓ **Parametric analysis**

- ✓ Parameter with largest influence: $\mathbf{h_w}$ > $\mathbf{t_w}$ > L > t_s
  - ✓ Web thickness (t_w): linear relation → local buckling eliminated to global buckling
  - ✓ Web depth (h_w): linear relation → global buckling eliminated to local buckling
  - ✓ Stiffener size (h_w): linear relation → small influence on ultimate bending resistance
  - ✓ Panel length (L): irregular relation → local buckling eliminated to global buckling
- ✓ **Conclusions:** ○ Sensitivity of girder biggest for small imperfections

Supervisors / Co-supervisors / Advisors

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[1] S. Janssens, "A comparative study of the patch loading resistance of longitudinally stiffened girders

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