Damage identification on stringers by modal analysis

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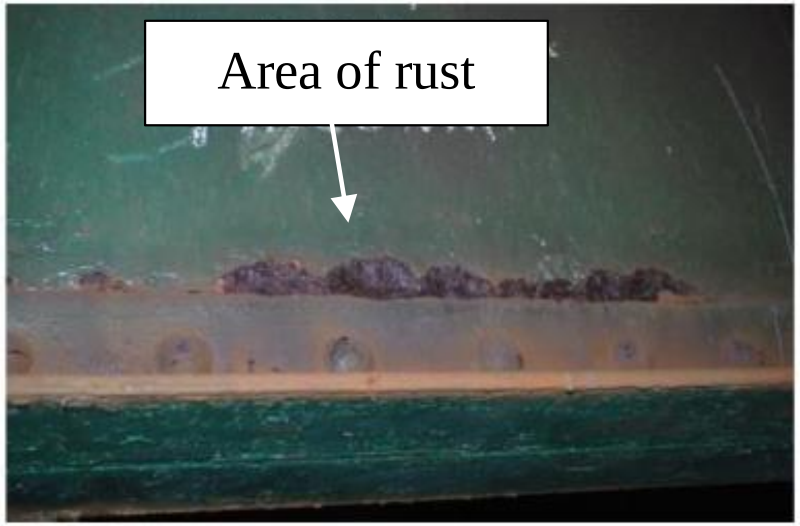
Introduction

- Many old railway bridges in Slovakia and Czech Republic are at the end of their lifespan
- We know many different types to identify of damage and failures on the structure.
- This article describes a method for detection of changing in stiffness of flange and web stringer connection using higher eigenfrequencies and mode shapes.
- The most common damage is rusting of some parts of stringer

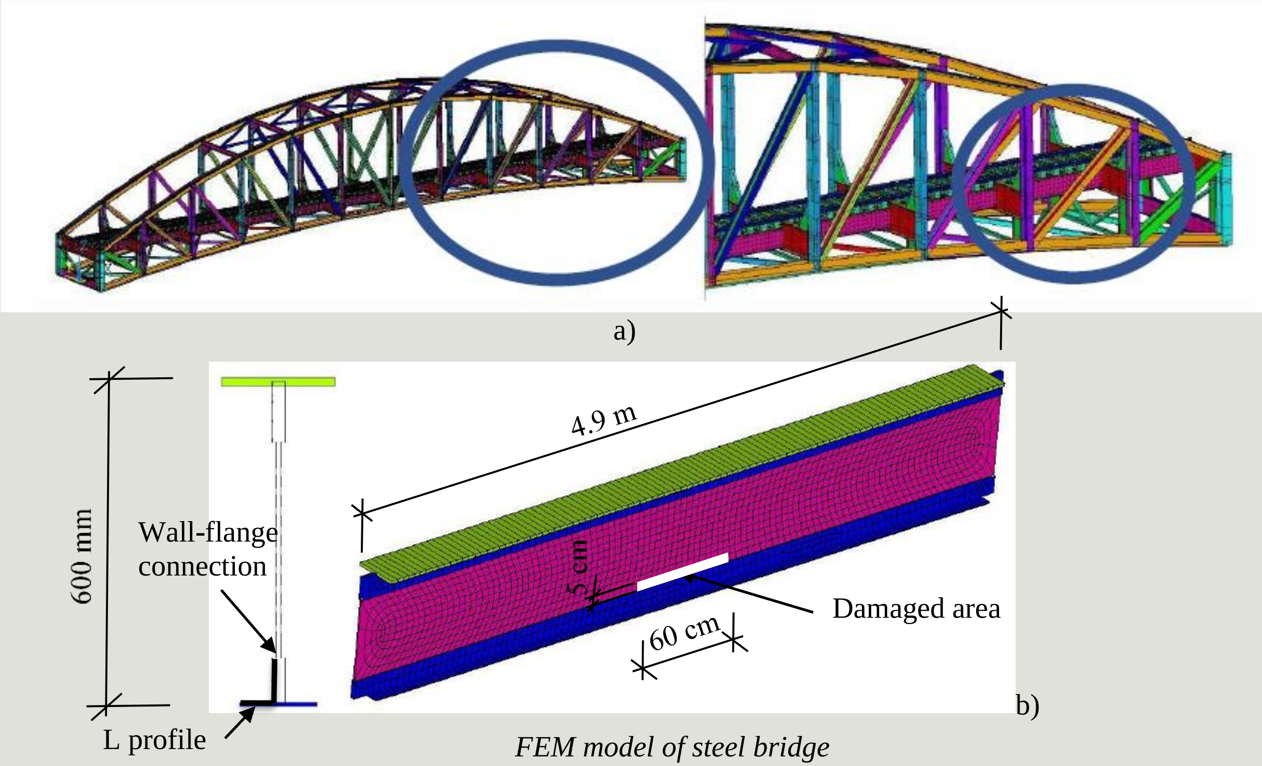


Introduction

- For this analysis, railroad bridge over the river Váh near Strečno has been investigated.
- The bridge consists of a truss arch bridge with a span of 57.4m
- The length of stringers is 4.9m and its height is 0,6m.

FEM model

- For this study was using FEM software (ANSYS)
- It was necessary to create the most accurate model of the bridge deck, especially stringers
- Damaged stringer - in the second field of the bridge
- The damage is located on the wall-flange connection above the L profile

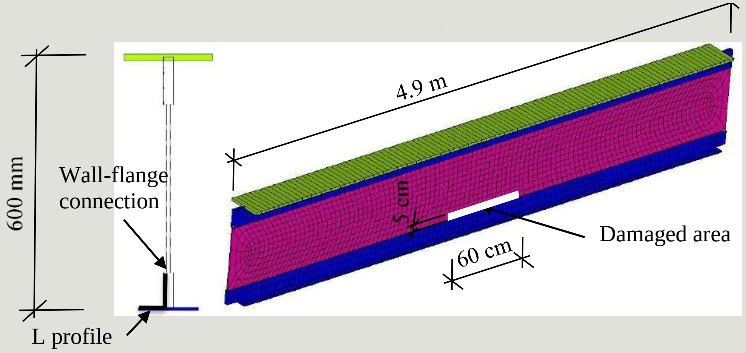


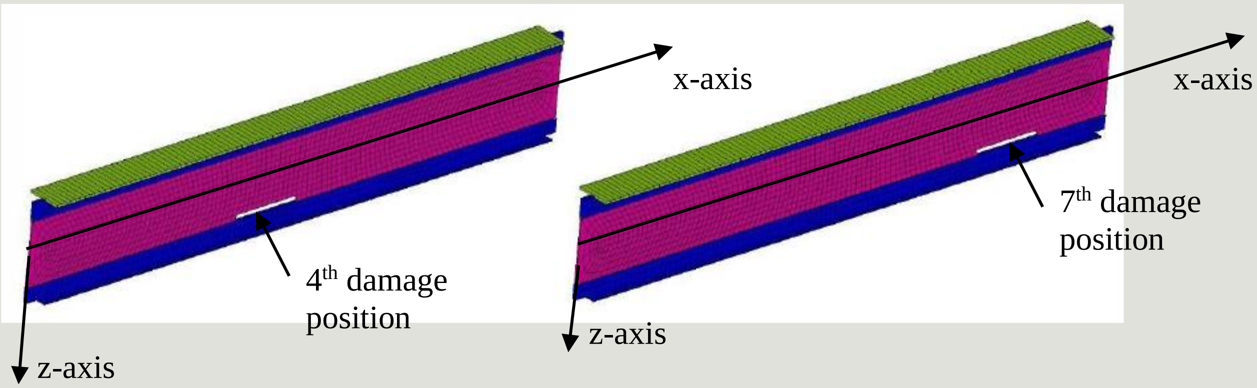
FEM model of steel bridge

FEM model

Damage

- Has been simulated by change the material properties – Young modulus.
- Was modelled as 60cm long and 5cm width damaged area with reduced material properties
- Was gradually shifted along the x-axis by 30cm overlap of previous position.
- Everything has been done in cycle automatically. This cycle resulted in nine position of damage. Each of these positions affected the local eigenfrequencies and modal shapes of the stinger.





Analysis of frequency and modal shapes

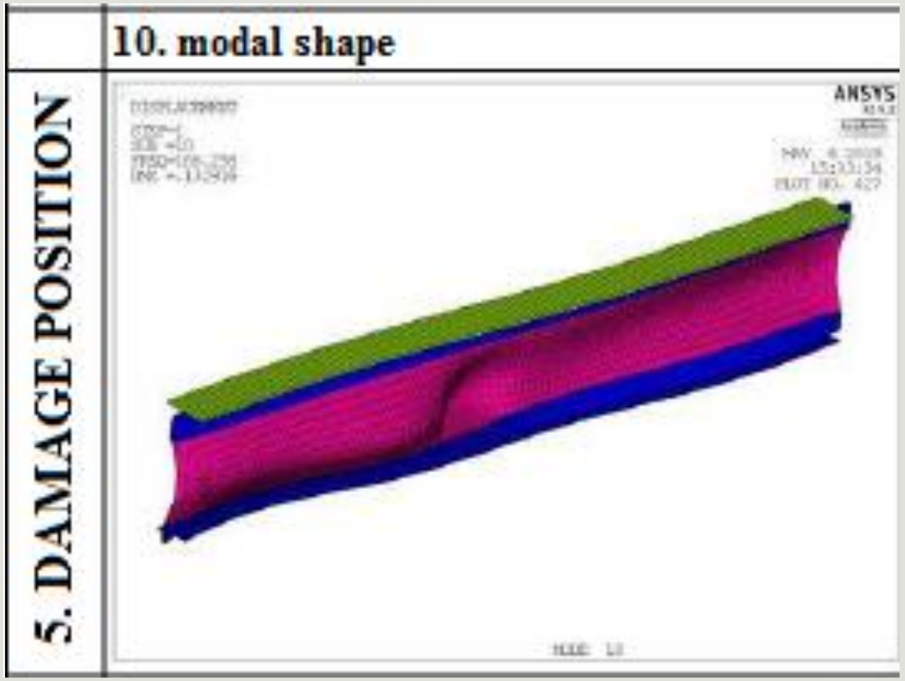
- Results in Tab. represent the changes of local mode shapes and eigenfrequencies of the stringer.
- These eigenvalues and mode shapes were at the beginning acquired assuming of rigid supports at connections between stringers and cross beams. However, this model doesn't consider the interaction of the stringer with the rest of the structure.
- For this reason the global bridge analysis was necessary, whereas in local conditions it is rather simple to reach higher frequencies, yet in case of the whole bridge it is necessary to evaluate the great number of the modes in order to find ones with frequency around 190Hz.

mode shape	1st damage position	2nd damage position	3rd damage position	4th damage position	5th damage position	6th damage position	7th damage position	8th damage position	eigenfrequency without damage
1st	1.000	0.998	0.997	0.999	1.000	0.997	0.997	1.000	41.26 Hz
2nd	1.000	0.998	0.999	0.999	0.998	0.998	0.998	0.999	53.80 Hz
3rd	0.999	0.992	0.992	0.998	0.999	0.992	0.991	0.998	69.65 Hz
4th	0.998	0.995	0.995	0.992	0.988	0.992	0.995	0.997	84.18 Hz
5th	0.958	0.976	0.991	0.998	1.001	1.000	0.994	0.987	108.68 Hz
6th	0.999	0.996	0.996	0.989	0.980	0.994	0.996	0.998	110.98 Hz
7th	0.975	0.977	0.996	0.994	0.994	0.985	0.986	0.971	128.60 Hz
8th	0.931	0.945	0.972	0.994	0.991	0.950	0.950	0.933	151.74 Hz
9th	0.976	0.953	0.960	0.970	0.940	0.957	0.938	0.979	164.05 Hz
10th	0.917	0.902	0.917	0.887	0.858	0.922	0.887	0.942	193.68 Hz
11th	0.974	0.967	0.972	0.969	0.968	0.963	0.967	0.973	198.50 Hz
12th	0.995	0.989	0.988	0.990	0.990	0.986	0.992	0.993	200.51 Hz
13th	0.989	0.976	0.994	0.970	0.975	0.974	0.977	0.994	207.76 Hz
14th	0.972	0.973	0.989	0.996	0.991	0.976	0.976	0.977	215.82 Hz
15th	0.977	0.956	0.916	0.957	0.952	0.922	0.970	0.987	235.24 Hz
16th	0.991	0.995	0.996	0.986	0.983	0.993	0.996	0.989	236.25 Hz
17th	0.983	0.996	0.998	0.999	0.995	0.992	0.988	0.969	247.99 Hz
18th	0.981	0.984	0.986	0.987	0.987	0.988	0.988	0.988	251.48 Hz
19th	0.975	0.991	0.994	0.991	0.984	0.985	0.989	0.978	256.10 Hz
20th	0.962	0.955	0.961	0.961	0.959	0.956	0.960	0.952	266.52 Hz

Ratio of corresponding eigen frequencies (damaged/undamaged)

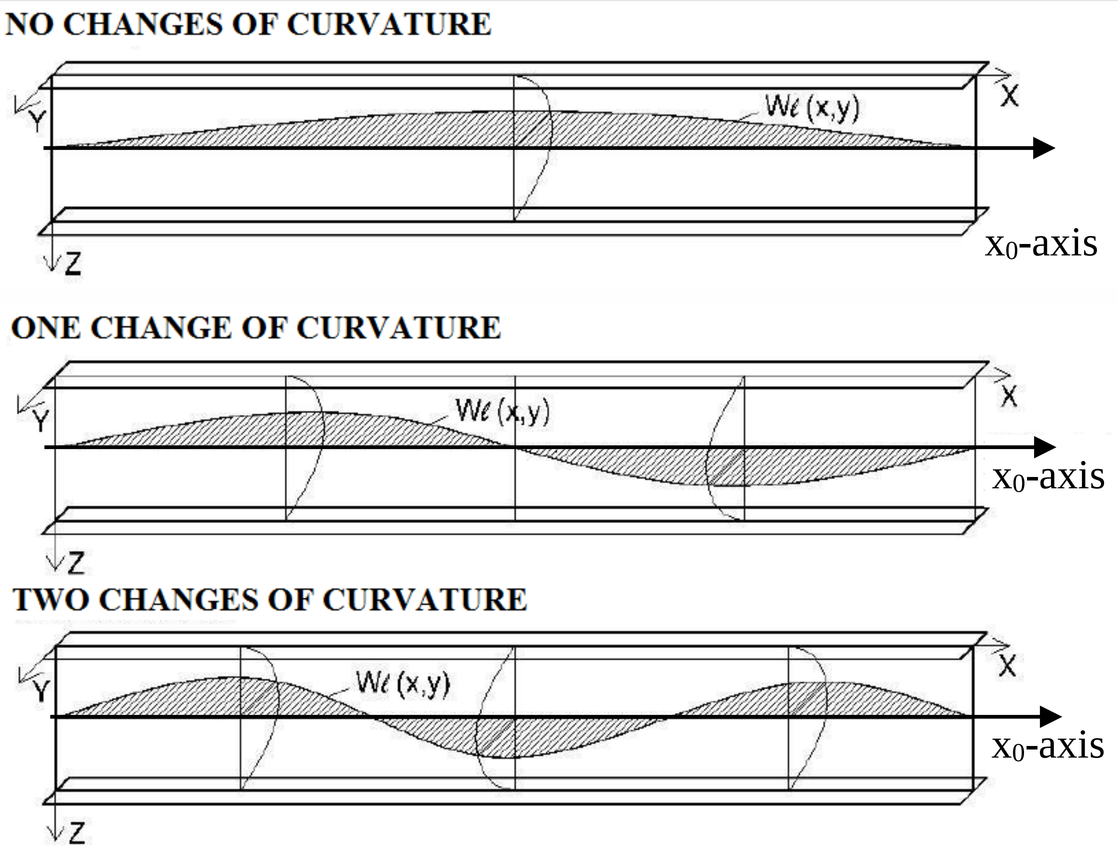
Analysis of frequency and modal shapes

- Big changes of eigenfrequencies were revealed at higher modes with frequencies around 160Hz-190Hz
- The biggest change has been found in the 10th mode shape at the 5th position of the damage. The undamaged stringer has a 10th frequency **193Hz**
- Assuming the damage on the 5th damage position, the frequency decreased by 14% to the value **166Hz.**
- The number of eigen mode was sometimes different from the original one so the difficulty was to find corresponding ones.
- The corresponding modes have been identified by comparing the numbers of changes in sign of curvature measured along the web of stringer by the special routine



Finding modal shapes by subroutine

- Searching for higher mode shapes in the global analysis of the whole bridge is time-consuming and difficult (because of changes the numbers of the modes)
- Subroutine was prepared for searching the corresponding shapes. This program can find changes in the curvature of the function $W_\ell(x, y)$.
- The function $W_\ell(x, y)$ represents the horizontal displacement of a certain line.
- The height of this line can be set as needed.
- The number of changes in curvature determines the mode shape.



Conclusions

- Paper is focused, on the damage identification on the steel bridge structure by modal analysis.
- This method is applicable for higher eigenfrequency. In this case the frequencies and around 190Hz have been evaluated.
- Higher modes can be affected by many factors. Due to this observation, it is not enough to compare only eigenfrequencies, but it is also necessary to follow the corresponding modal shapes.
- Original routine for identifying of local mode shapes based on changes in curvature has been developed. When searching for a change in the curvature of a mode section, the problem may occur when the height of the analysed axis x_0 is assumed too close to the bottom flange where a damage is located. This can lead to inaccurate results.
- Although the findings of the analysis were interesting there is a space for improvement of this method. But the first result seems to be promising.

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Thanks for your attention

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