UM WORKSHOP 2018
3-4 APRIL 2018, BRYANSK STATE TECHNICAL UNIVERSITY RUSSIA

Bridge-train dynamic interactions analysis using finite element and multi-body simulation:

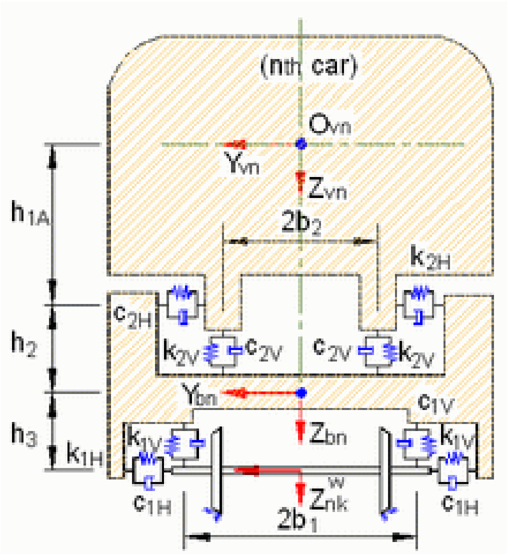
A CASE STUDY OF PORAMINTRA BRIDGE, THAILAND

SONGSAK SUTHASUPRADIT

Center of Excellence for Road and Railway Innovation

Faculty of Engineering, Naresuan University

Vibrations on Railway Vehicles

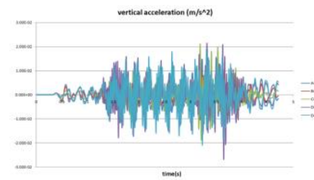


Car body

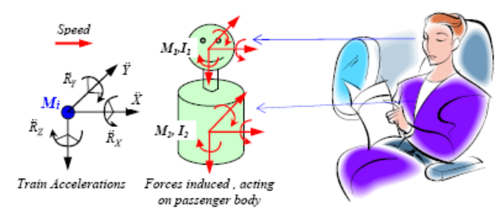
Bogie

Wheelset

Vibration

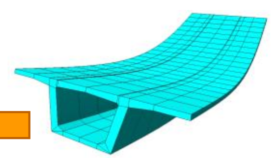


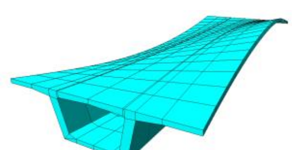
Safety & Running Quality



Track

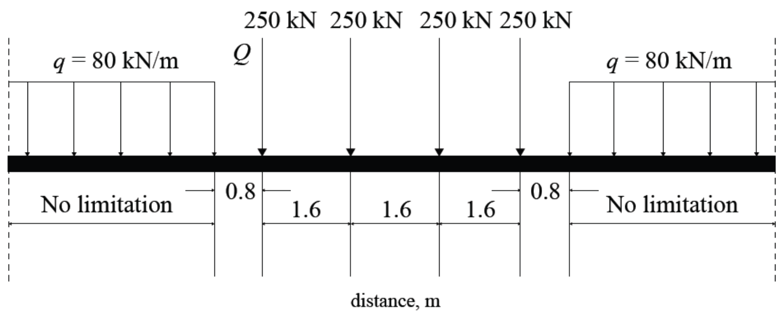
Structure



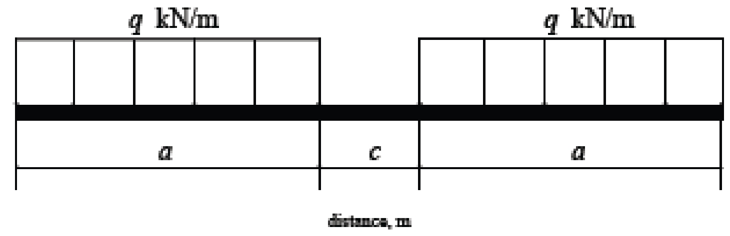


Bridge design load: Static Loads

Load Model 71 (EN 1991-2, EN 2003)

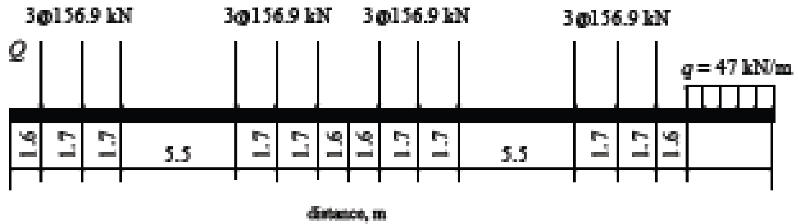


Load Model SW/2 (EN 1991-2, EN 2003)

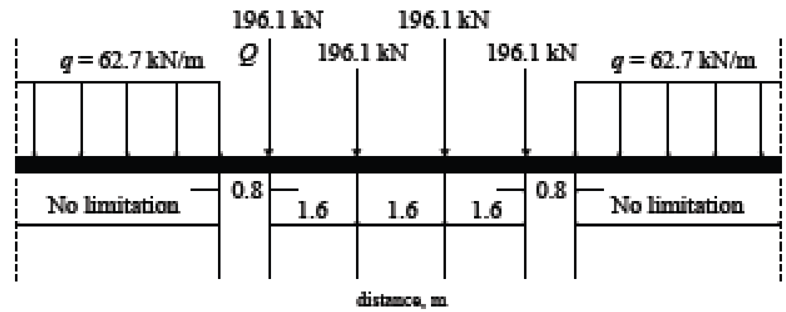


Load model	q, kN/m	a, m	c, m
SW/2	150	25	7

Load Model DL 16 (รฟท., 2001)

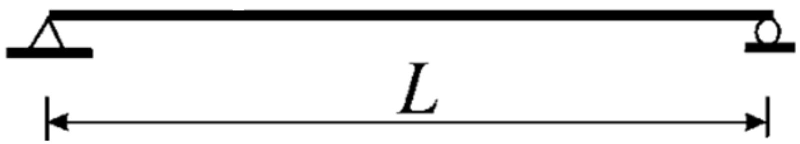


Load Model U 20 (รฟท., 2001)

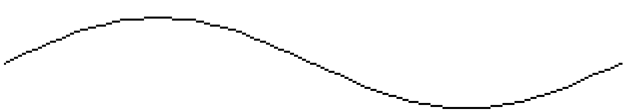


Bridge Dynamics

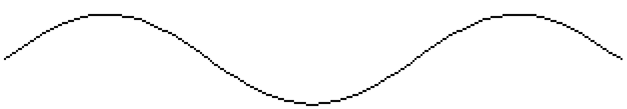
$$M\ddot{u} + C\dot{u} + Ku = F(x,t)$$



Fundamental: frequency f, tuned note of string

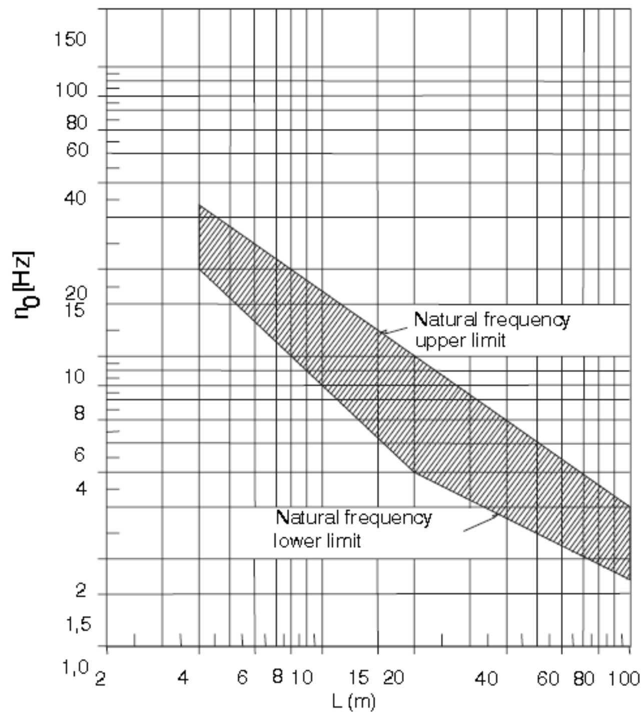


Second harmonic: frequency 2 f, one octave higher



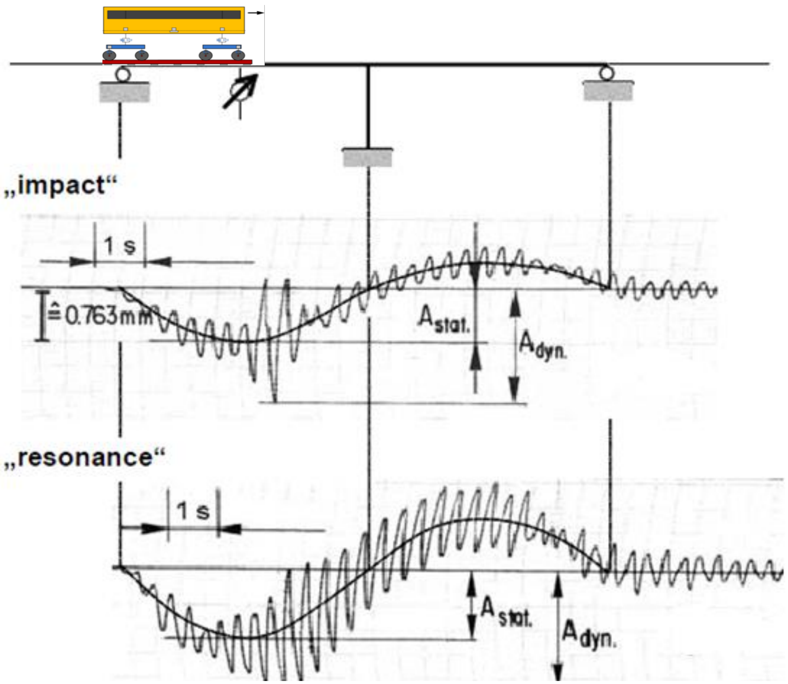
Third harmonic: frequency 3 f, one octave and a fifth higher

Frequency & Span length
(UIC 776-2R)

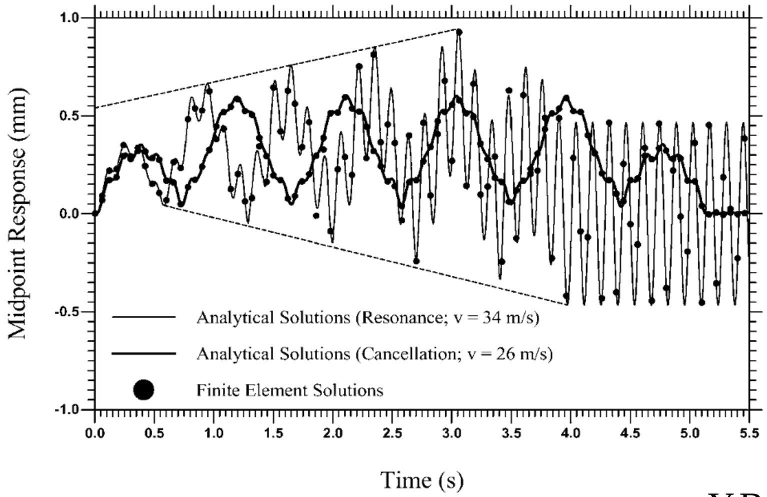


$$\omega_n = \frac{n^2\pi^2}{L^2}\sqrt{\frac{EI}{m}} \propto \sqrt{\frac{Stiffness}{Mass}}$$

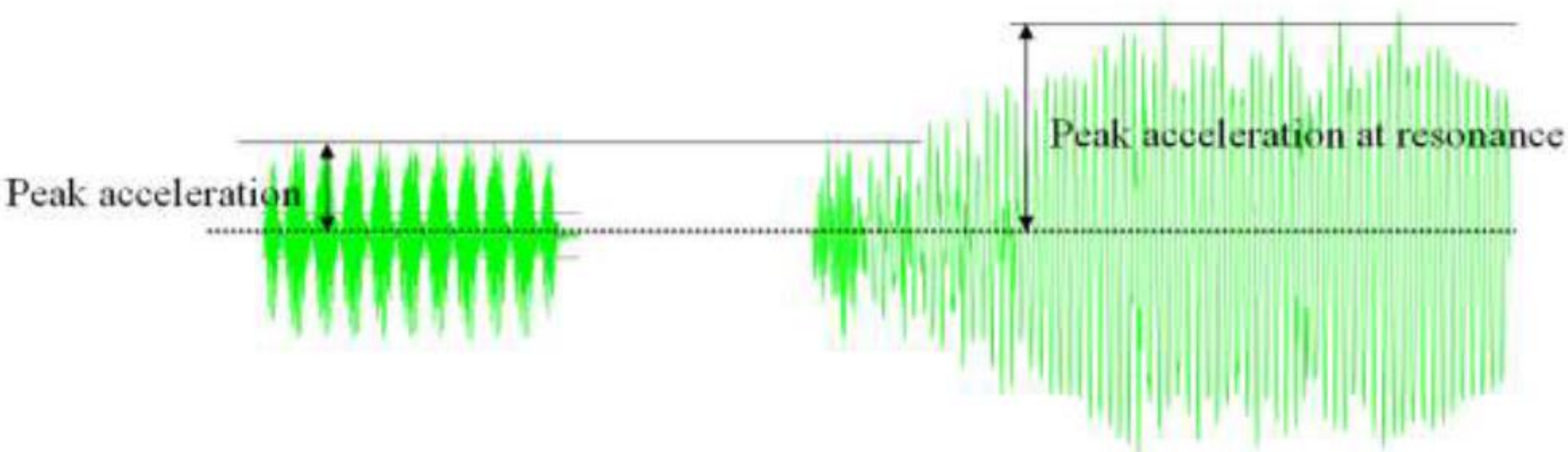
Bridge Resonance due to Series of Moving Load



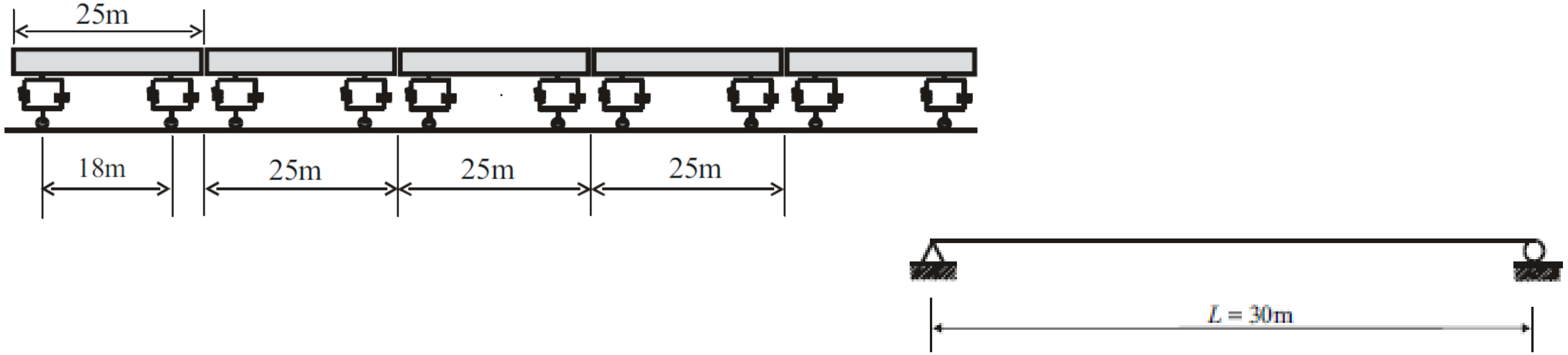
Time History Example of Bridge Deflection

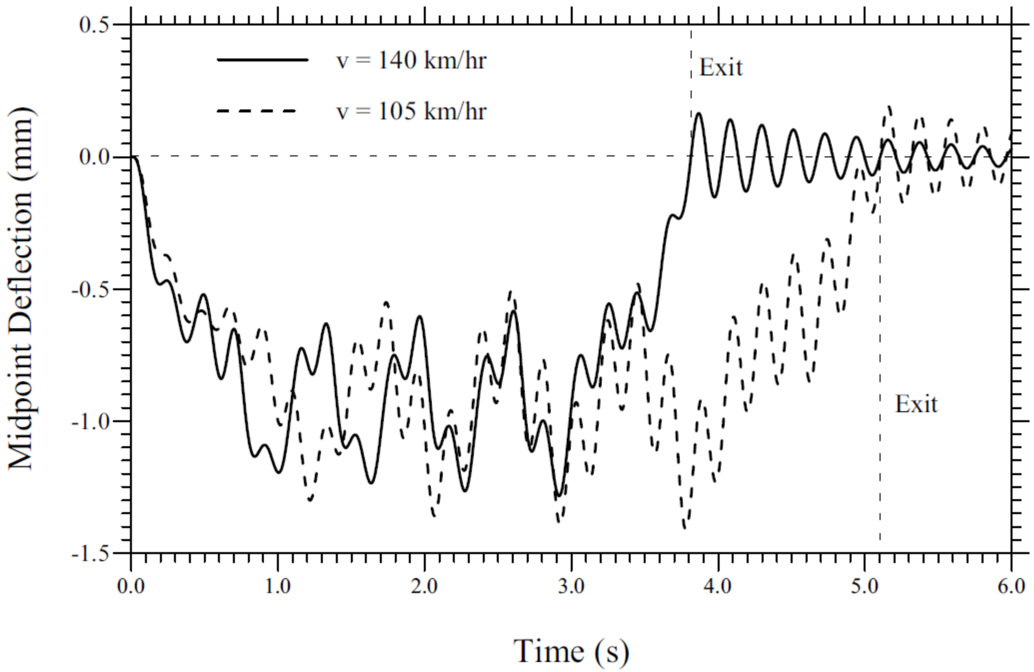


Y.B. Yang



Bridge resonance

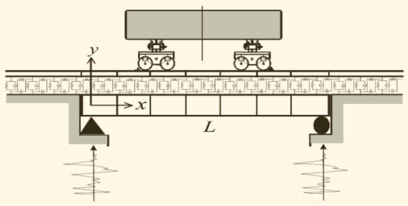


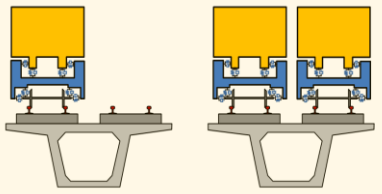


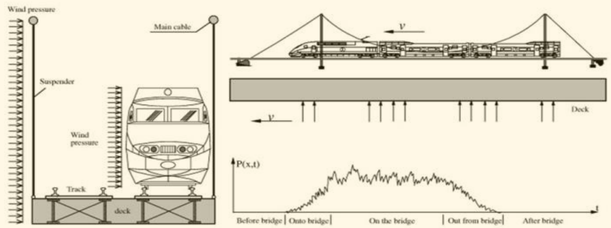
Resonance at Lower Speed

Y.B. Yang

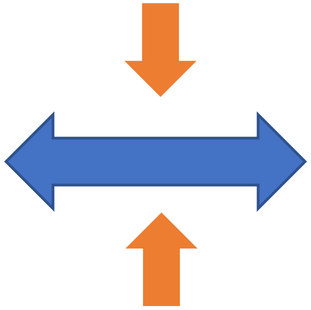
Bridge-Train Interaction



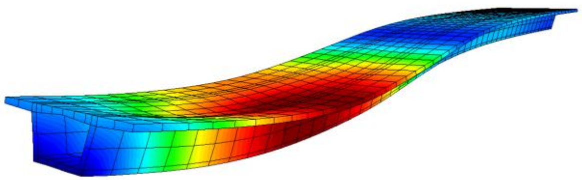




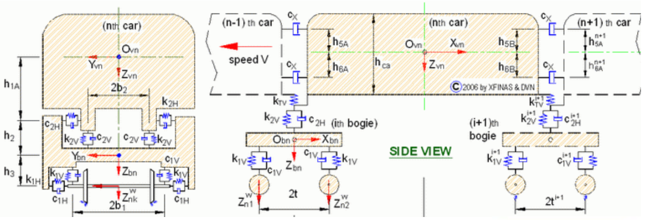
Operational Conditions

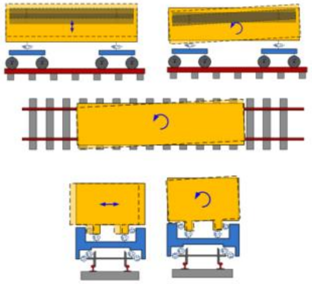


Bridge System



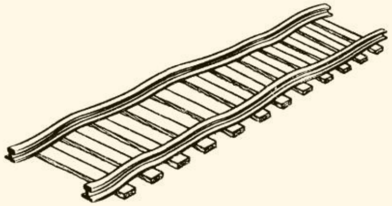
Train System





Train-Bridge Interface

Track Behavior & Track Irregularity



Wheel-Rail Interaction

SAFETY AND SERVICEABILITY EVALUATION OF RAILWAY BRIDGE VIA DYNAMIC ANALYSIS

Case Study : Thailand High Speed Railway Northern Line

Granted by Team Consultant Co. Ltd.

CASE STUDY: PORAMINTRA BRIDGE

Poramintra Bridge - Uttaradit, Thailand

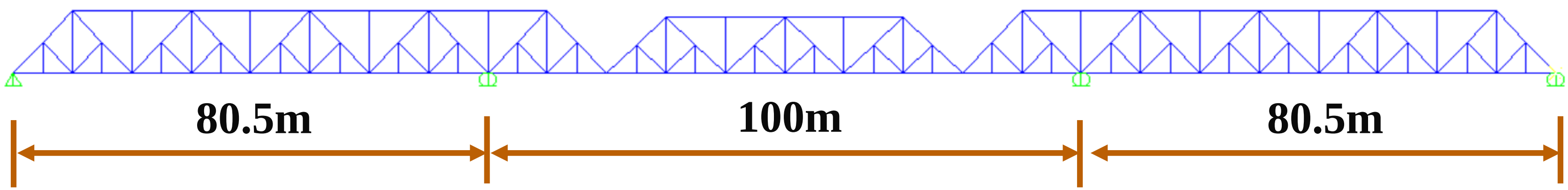
Poramintra Bridge - Uttaradit, Thailand

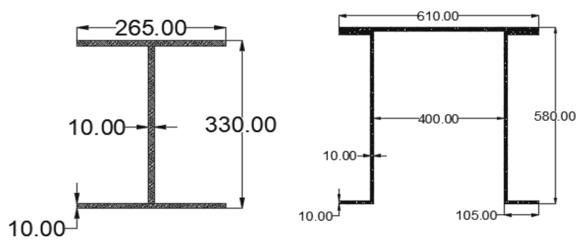
First build in 1906

WW2
1945

Rebuild in 1953

Bridge layout and member section





- Steel through truss
- Build-up section using rivet
- Overhanging span
- Single track on wood sleeper
- Average train speed 90km/h

Track condition

Present of track irregularities

White spot in approaching track

Track condition

Sleeper lift off

Loosen fastener

Traffic

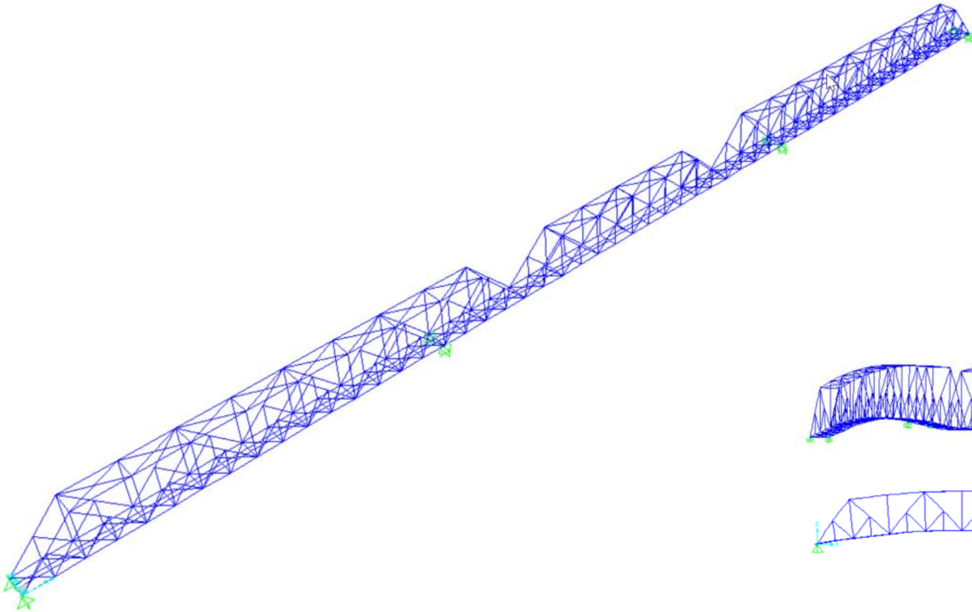
DMU

Diesel locomotive

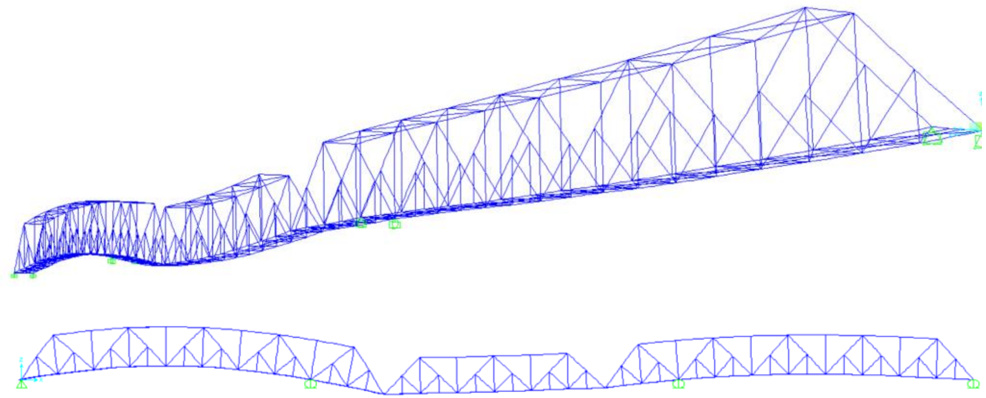
Passenger Car

Tanker

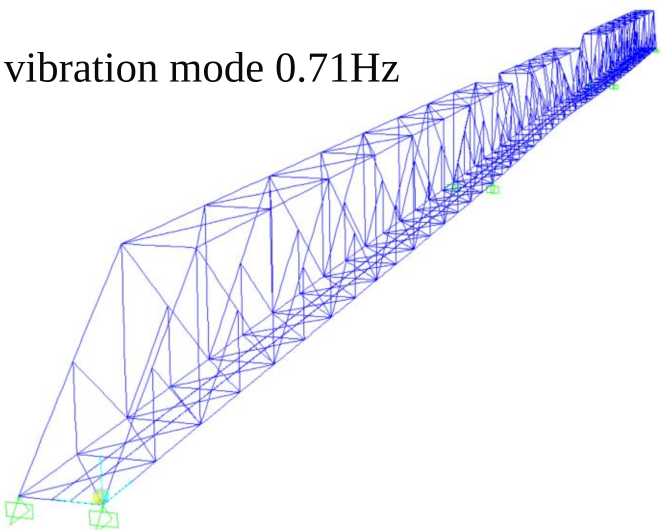
Finite element model



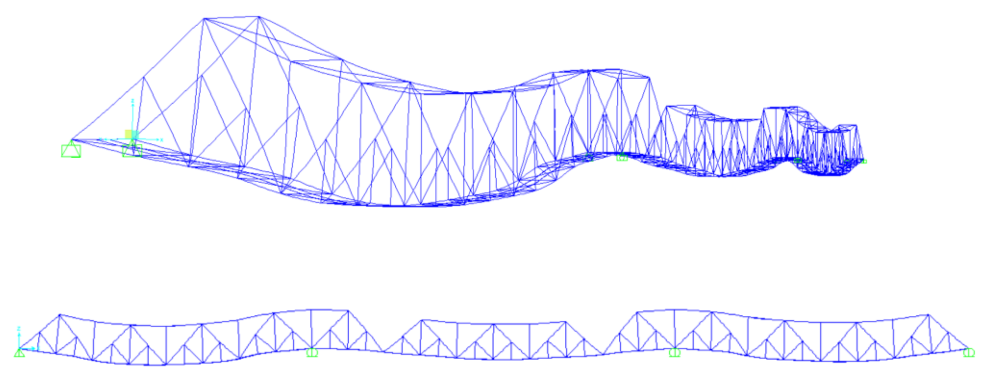
Vertical vibration mode 2.34Hz



Lateral vibration mode 0.71Hz

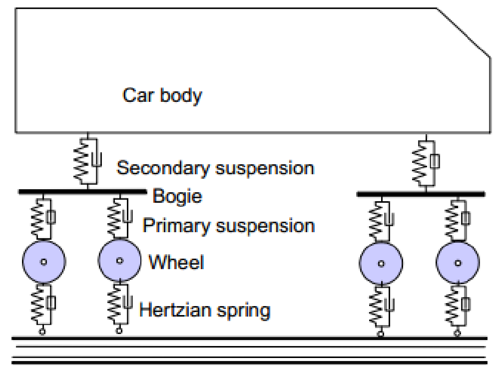


Vertical vibration mode 4.5Hz

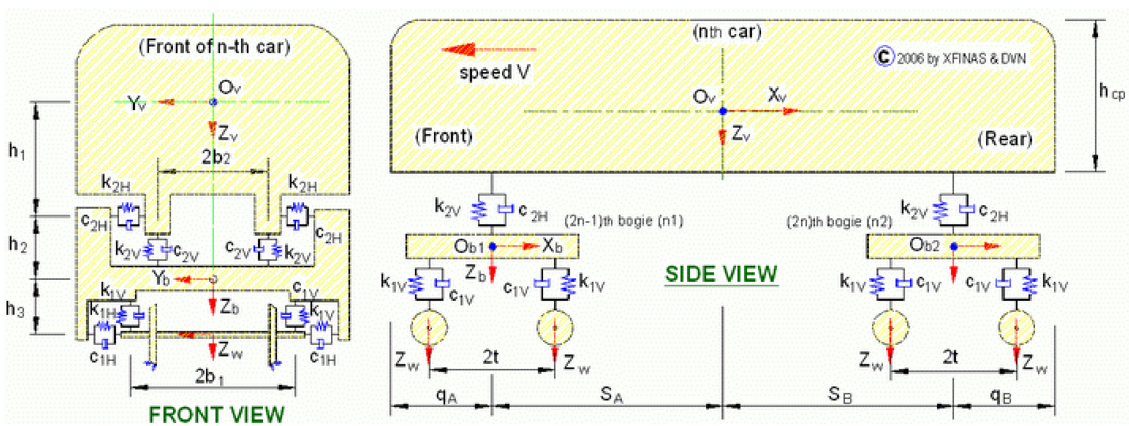


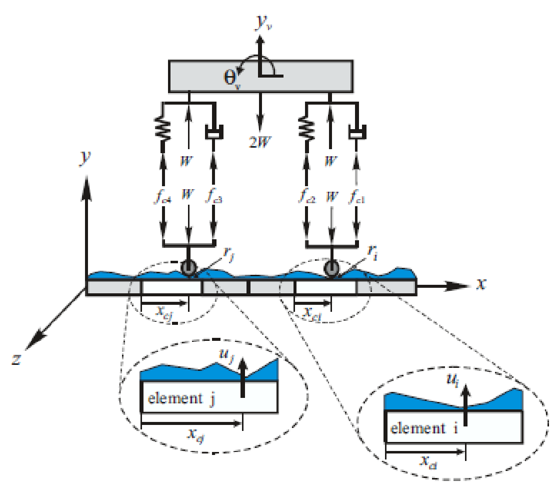
Modeling of Train Dynamic System

Sprung mass system with linear spring & damper



Linear Hertzizn spring for wheel/rail contact

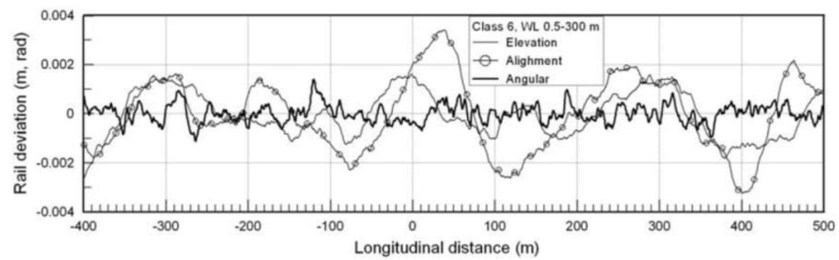




Modeling of Track Irregularities

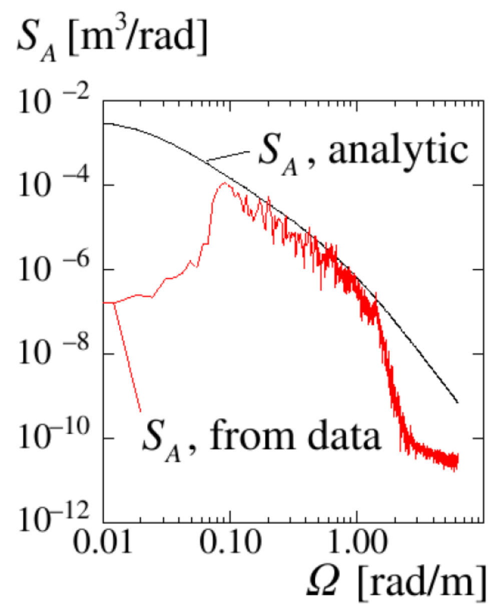
FRA Class 4

$$S_{e,a}(\Omega_n) = \frac{A\Omega_2^2\left(\Omega_n^2 + \Omega_1^2\right)}{\Omega_n^4\left(\Omega_n^2 + \Omega_2^2\right)} \quad (\mathrm{m}^3)$$

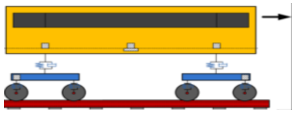


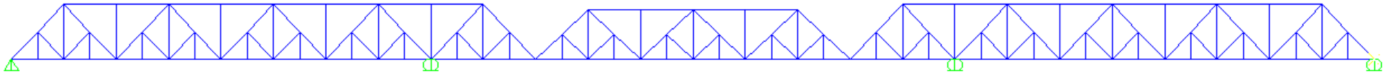
$$S_{c,g}(\Omega_n) = \frac{A\Omega_2^2}{\left(\Omega_n^2 + \Omega_1^2\right)\left(\Omega_n^2 + \Omega_2^2\right)} \quad (\mathrm{m}^3)$$

Irregularity	Constant		Constants for each rail class					
	Notation	Unit	1	2	3	4	5	6
Elevation	A	$10^8\,\mathrm{m}^3$	15.53	8.85	4.92	2.75	1.57	0.98
	Ω_1	$10^3\,\mathrm{m}^{-1}$	23.30	23.30	23.30	23.30	23.30	23.30
	Ω_2	$10^2\,\mathrm{m}^{-1}$	13.10	13.10	13.10	13.10	13.10	13.10
Alignment	A	$10^8\,\mathrm{m}^3$	9.83	5.51	3.15	1.77	0.98	0.59
	Ω_1	$10^3\,\mathrm{m}^{-1}$	32.80	32.80	32.80	32.80	32.80	32.80
	Ω_2	$10^2\,\mathrm{m}^{-1}$	18.40	18.40	18.40	18.40	18.40	18.40
Cross	A	$10^8\,\mathrm{m}^3$	4.52	3.15	2.16	1.38	0.98	0.59
	Ω_1	$10^3\,\mathrm{m}^{-1}$	23.30	23.30	23.30	23.30	23.30	23.30
	Ω_2	$10^2\,\mathrm{m}^{-1}$	13.10	13.10	13.10	13.10	13.10	13.10
Gauge	A	$10^8\,\mathrm{m}^3$	9.83	5.51	3.15	1.77	0.98	0.59
	Ω_1	$10^3\,\mathrm{m}^{-1}$	29.20	29.20	29.20	29.20	29.20	29.20
	Ω_2	$10^2\,\mathrm{m}^{-1}$	23.30	23.30	23.30	23.30	23.30	23.30



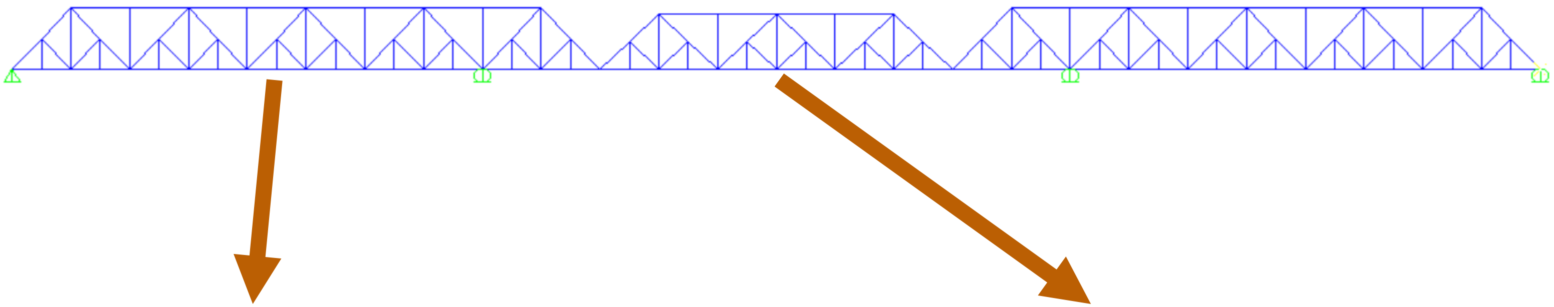
Dynamic analysis

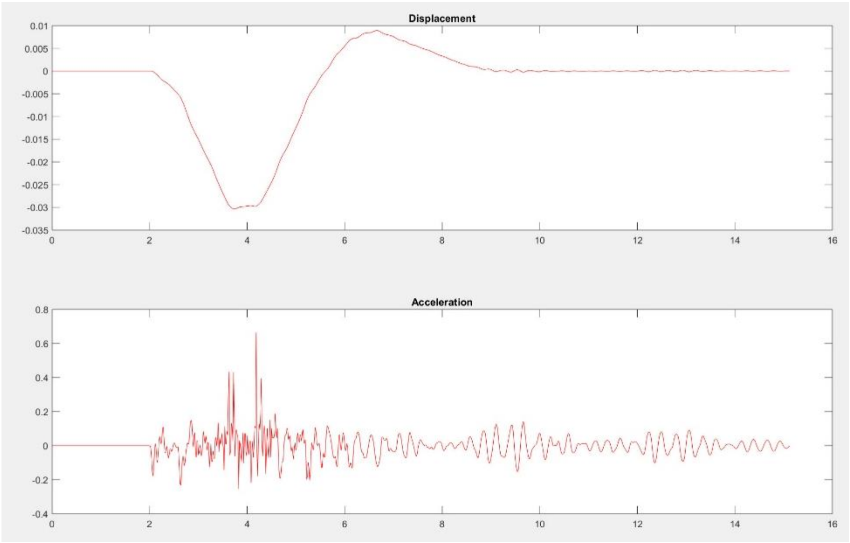


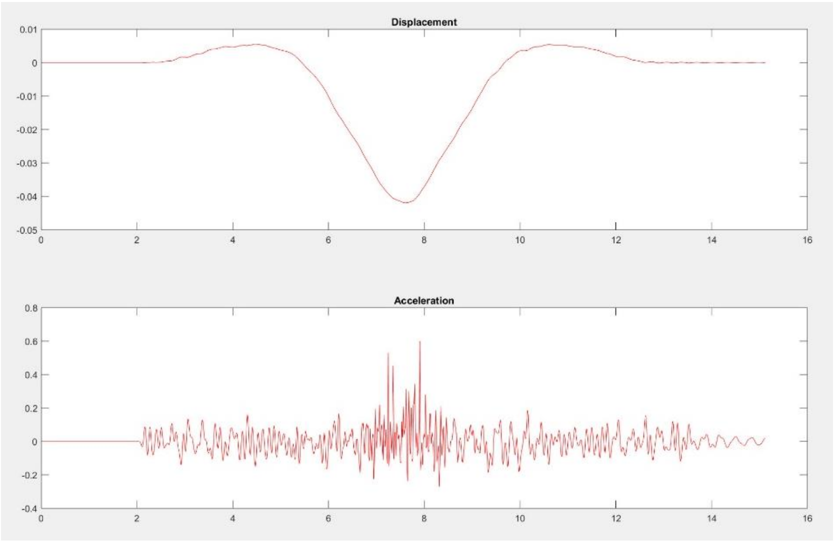


- 1 car train
- Axle load 14 ton
- Speed 40 – 120 km/h
- Track irregularity FRA-4

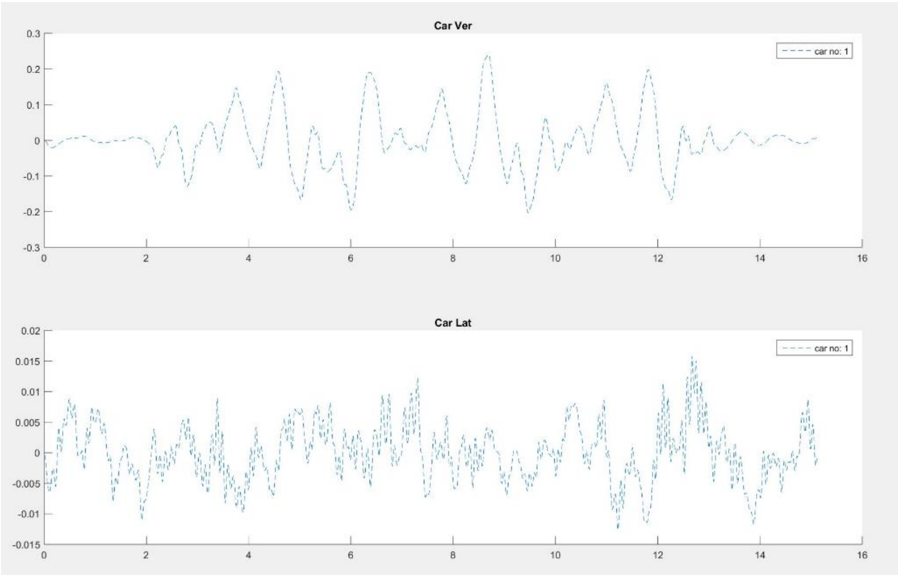
Bridge response @Speed 90 Km/h

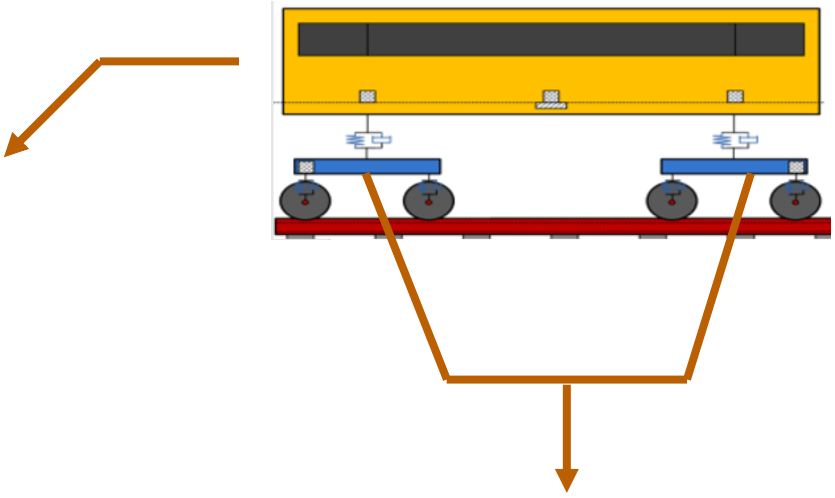


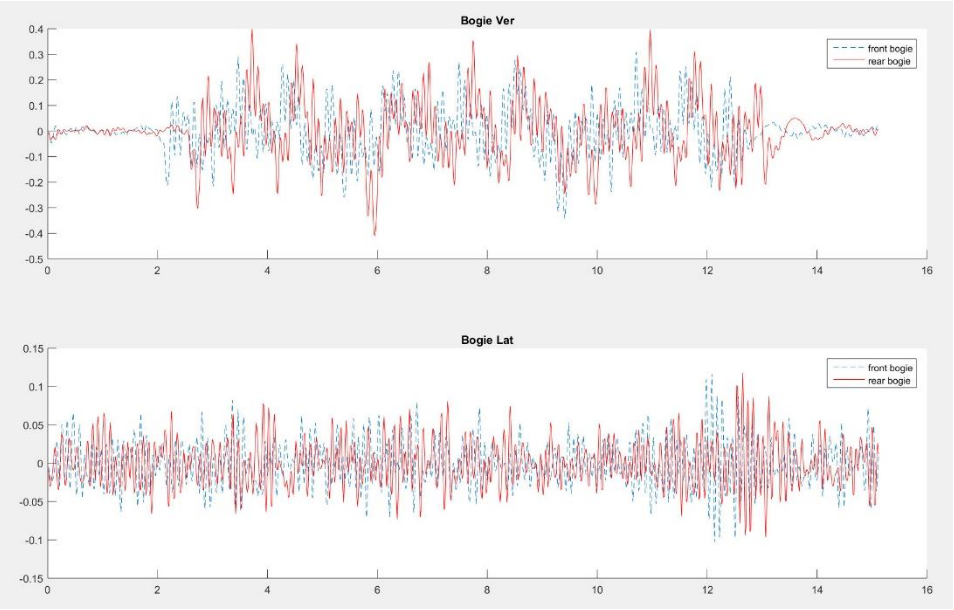




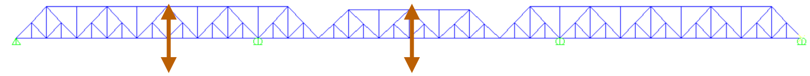
Train acceleration @Speed 90 Km/h

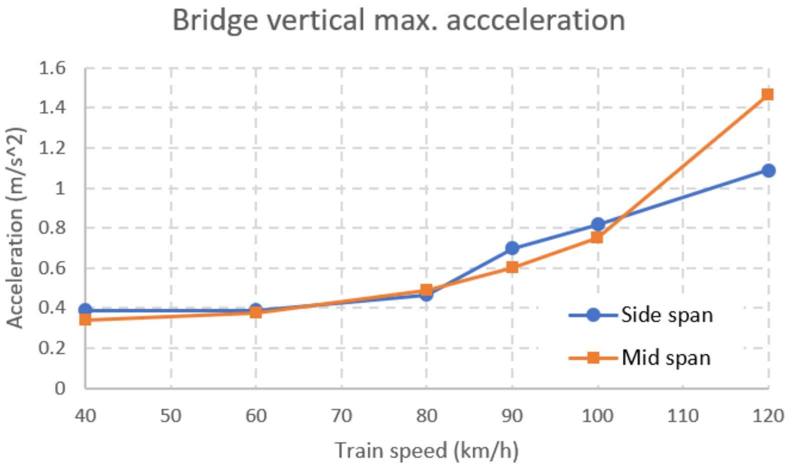


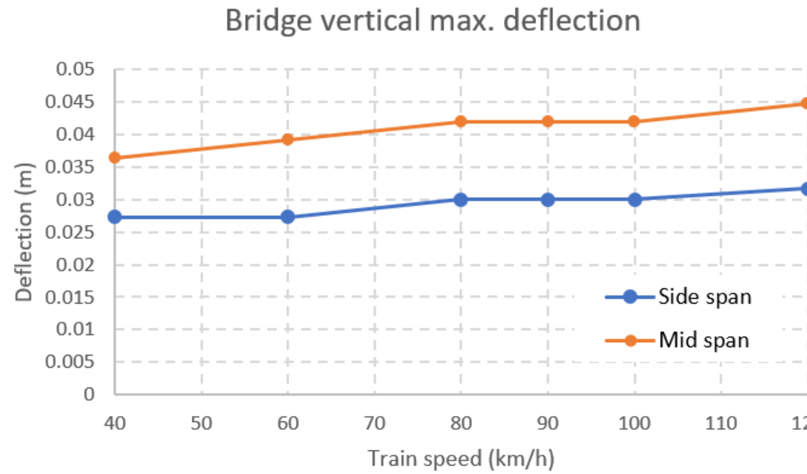


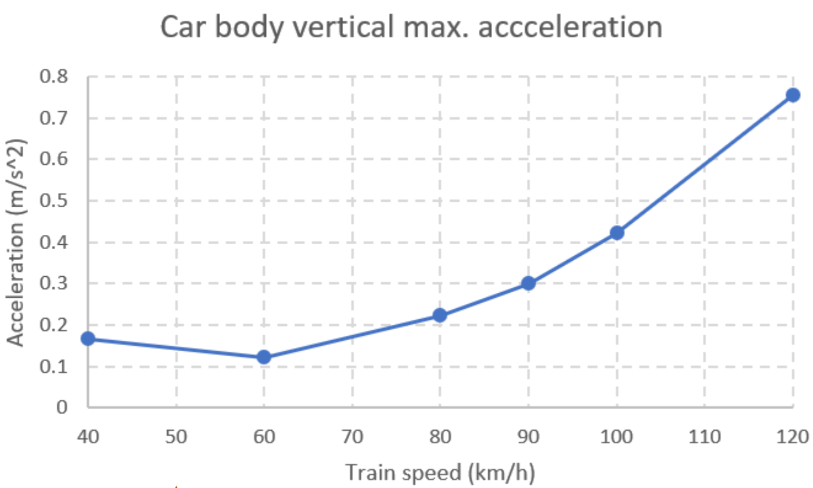


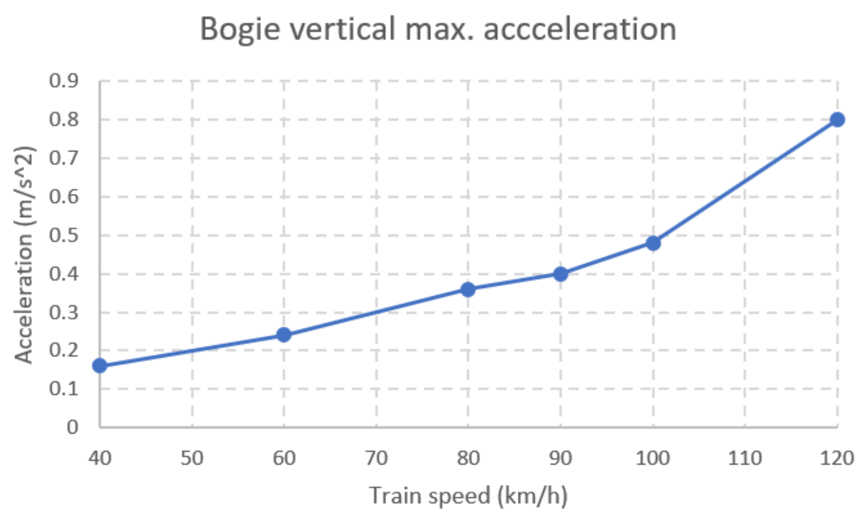
Maximum responses

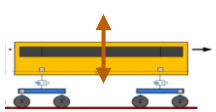


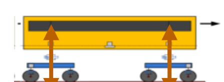






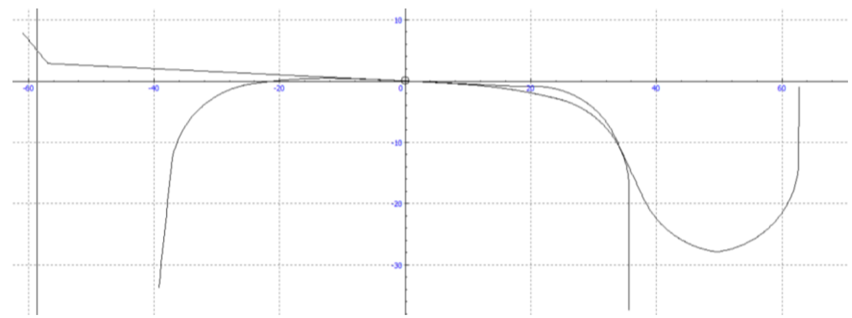


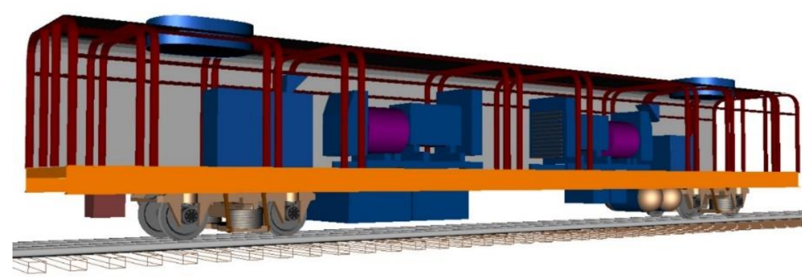




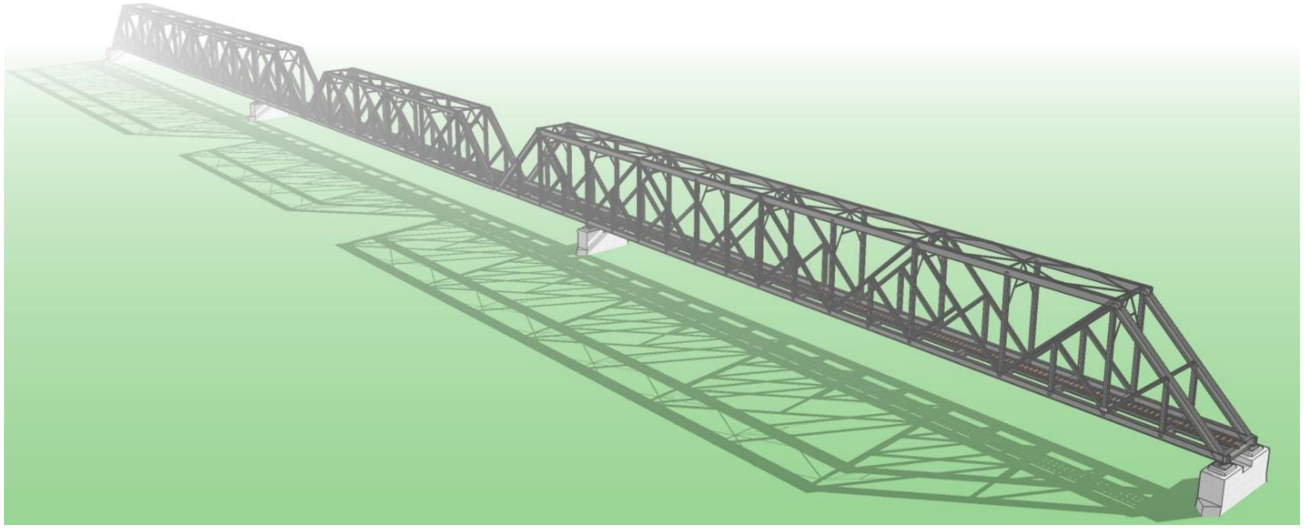
Further work:

- **Detailed track inspection**
- **Bridge vibration measurement**
- **Detail of SRT train**
- **Evaluation with UIC-776-2R, UIC-518, ISO-2631**
- **Using more sophisticate vehicle & wheel-rail contact model with UM software**





THANK YOU



Acknowledgement:

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