

Special Session: Overview of the work done in the OECD SOCRAT benchmark dedicated to the beyond design seismic behavior assessment of crane bridges

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Safety context:

Probabilistic Safety Assessment (PSA)



Lessons

The **crane bridges** are significant contributors to the **Probability of core meltdown**.

Which objectives?

- to identify **best modelling practices** regarding the crane bridges;
- to identify **relevant failure criteria**;

How?

- **Benchmark** under umbrella of the **OECD/NEA**

Given

- Large Experimental database is available.



SOCRAT Benchmark General Presentation

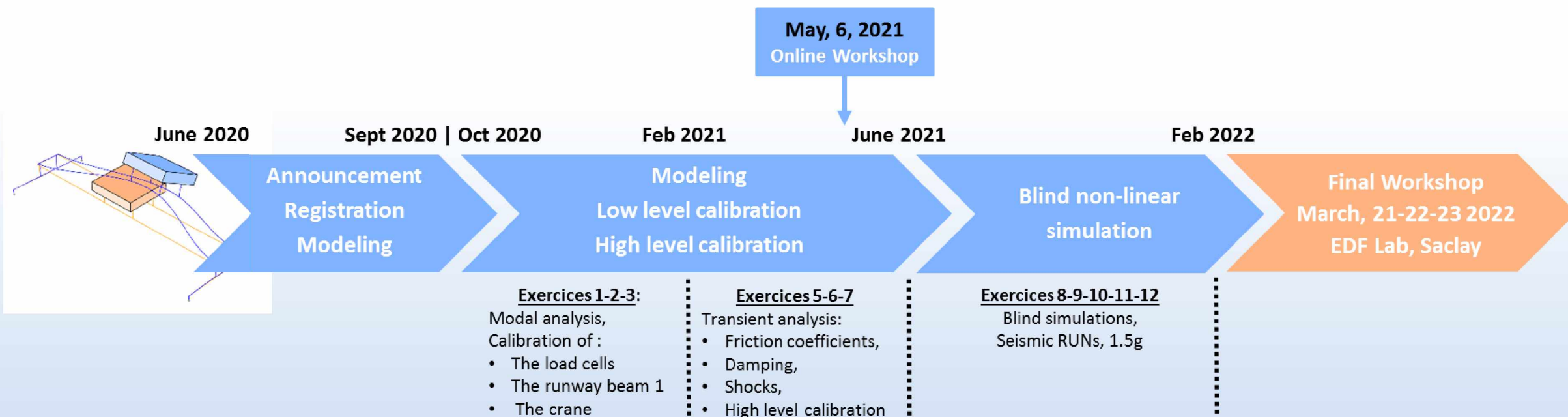
Presentation outline

- ❖ Agenda
- ❖ General statistics
- ❖ Content of the benchmark
 - Exercises of Stage 1
 - Exercises of Stage 2
- ❖ Some results of stage 1
- ❖ Some results of stage 2
- ❖ Some observations and concluding remarks

Steering Committee:

- ❖ IRSN (Institut de Radioprotection et de Sûreté Nucléaire, France)
 - Ibrahim BITAR
 - Benjamin RICHARD
- ❖ EDF (Electricité de France)
 - Fabien GRANGE
 - Adrien GUILLOUX
- ❖ GDS (Géodynamique & Structure, France)
 - Charles DROSZCZ
 - Jean-Mathieu RAMBACH

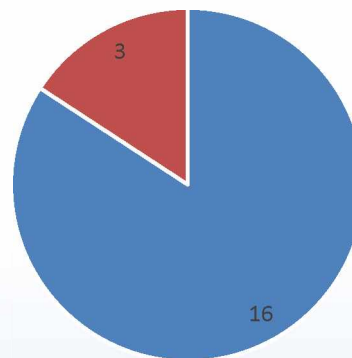
General agenda of the Benchmark



Overview of the participants

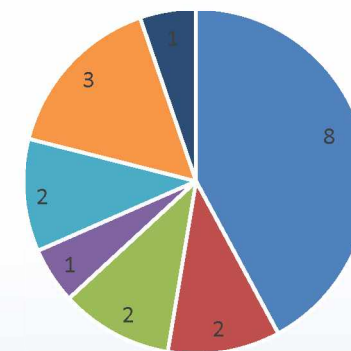
1. AERB - Atomic Energy Regulatory Board - Team 1 (India)
2. AERB - Atomic Energy Regulatory Board - Team 2 (India)
3. ATR (France)
4. CETIM Senlis (France)
5. CKTI - Vibroseism Ltd. (Russia)
6. CNAM - Conservatoire National des Arts et Métiers (France)
7. EGIS (France)
8. ENSI Team B&H - Basler & Hofmann AG (Switzerland)
9. ENSI Team Principia (Spain)
10. ENSI Team SPI - Stangenberg & Partners Consulting Engineers (Germany)
11. ESI (France)
12. ESTP - Ecole Spéciale des Travaux Publics (France)
13. F4E – ESTEYCO (Spain)
14. GRS - Gesellschaft für Anlagen und Reaktorsicherheit (Germany)
15. INSA Lyon / Laboratoire GEOMAS (France)
16. Nuclear Power Corporation of India Ltd. (India)
17. OKG Aktiebolag (Sweden)
18. ORANO (France)
19. TECHNIA (Sweden)

Continent



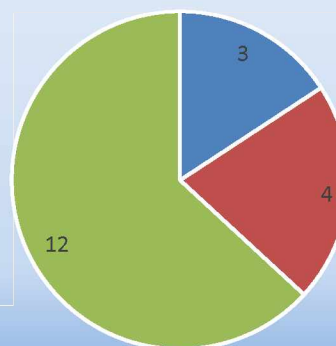
■ Europe ■ Asia

Country



■ France ■ Germany ■ Spain ■ Switzerland ■ Sweden ■ India ■ Russia

Field (1)



■ Academic ■ Industrial - General ■ Industrial - Nuclear

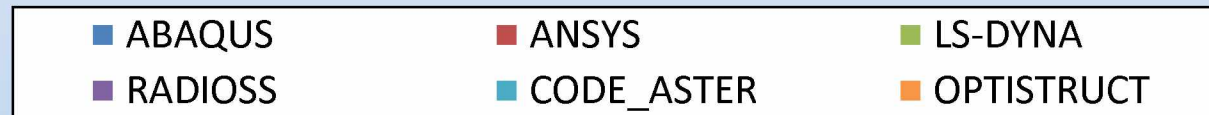
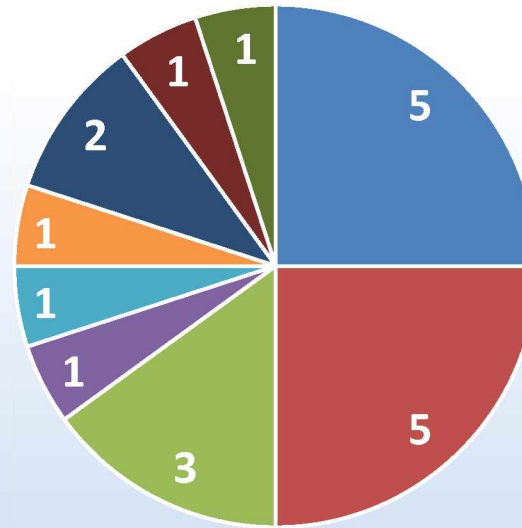
Field (2)



■ NPP Operator - Energy Producer ■ Engineering - Consulting company
■ Nuclear regulatory Authority ■ Software company

Overview of the participants - Software

Software



Overview of the participants - Models

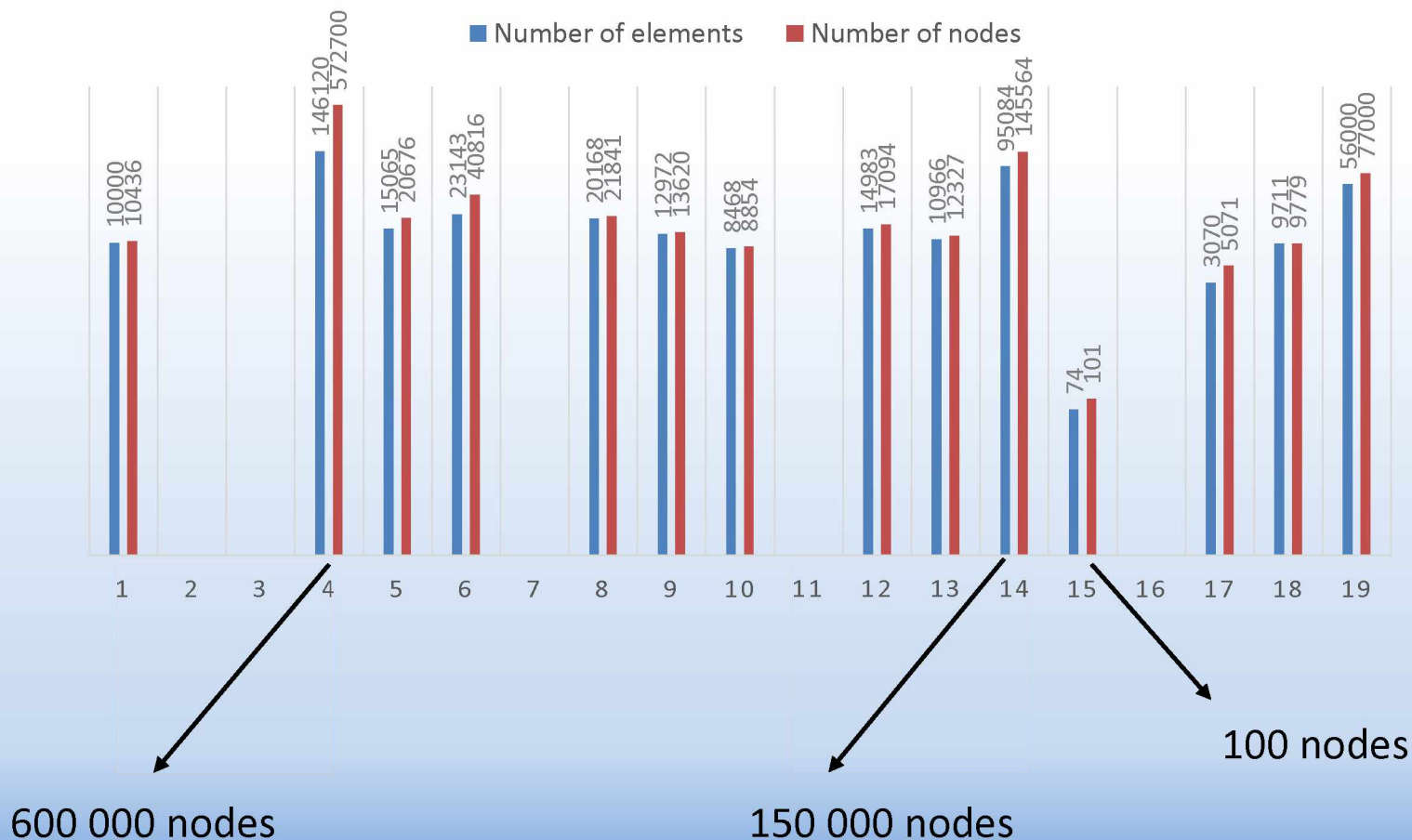
Numerical integration scheme:

- Implicit : 2/6
- Explicit : 3/6
- Implicit/Explicit: 1/6

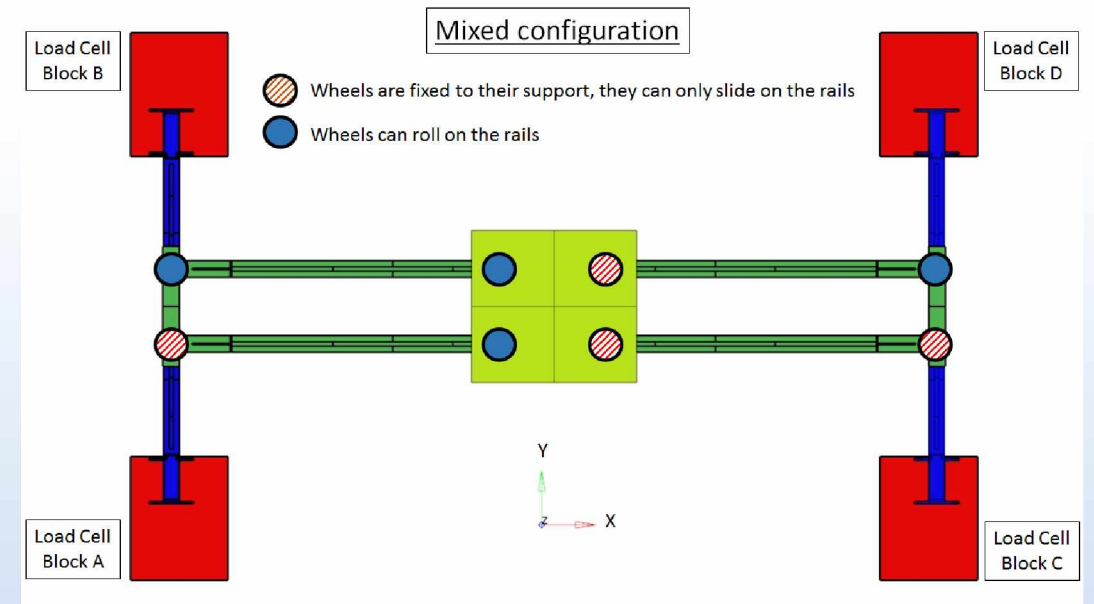
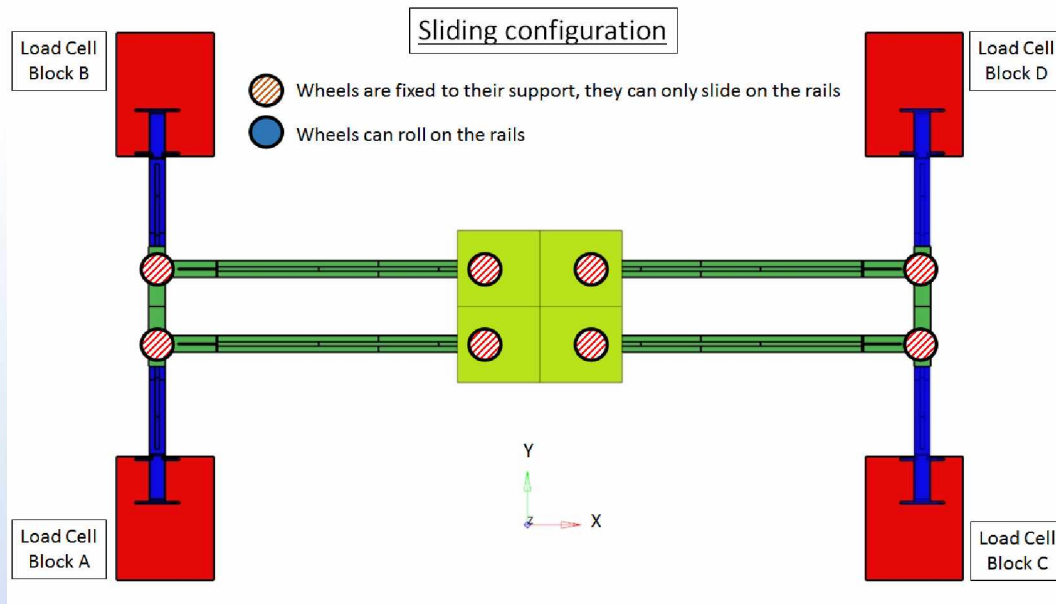
Type of Finite Elements:

- Full beam: 2
- Full shell: 2
- Full solid (except load cells): 3
- Shell and Solid: 6

NUMBER OF NODES AND ELEMENTS

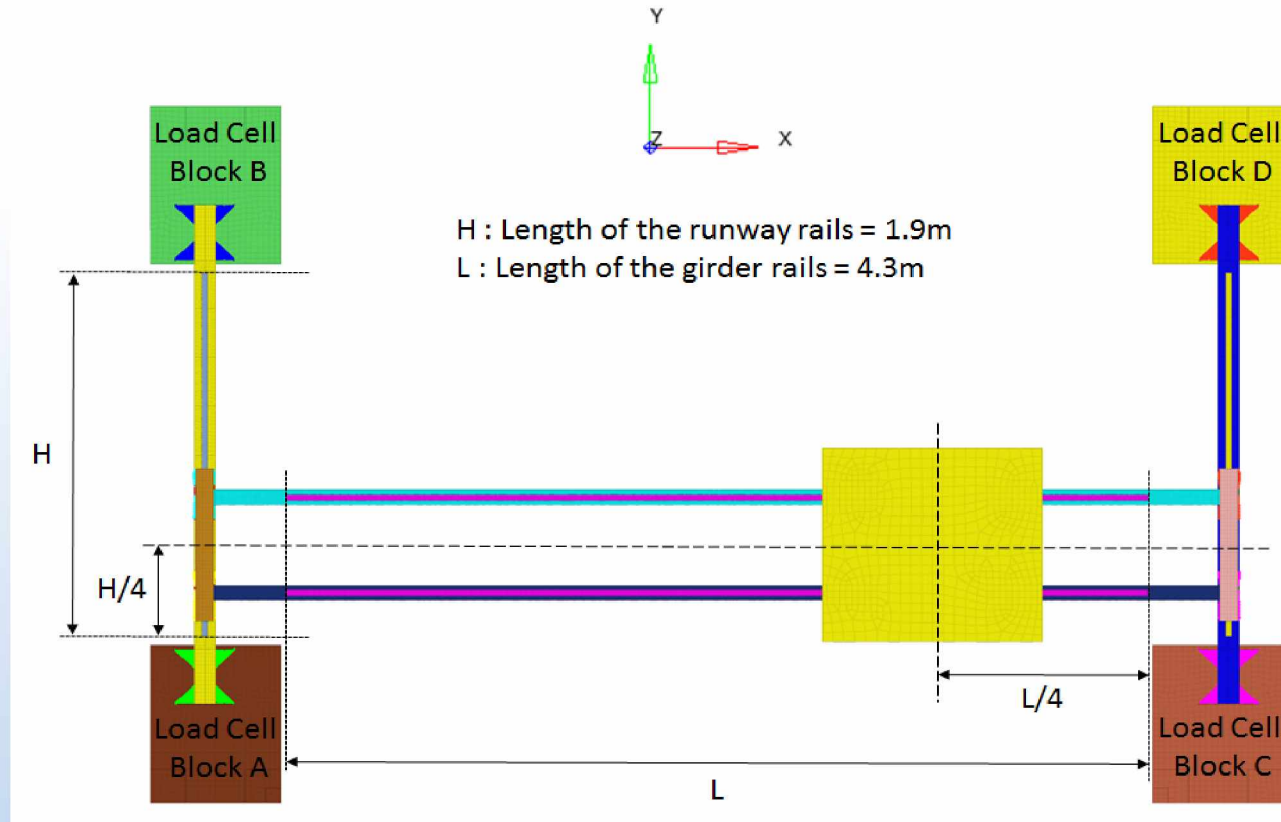


Exercises of the Benchmark – Wheels configurations



Exercises of the Benchmark – Crane configurations

Centered, and Decentered:



Exercises of the Benchmark – Stage 1

Exercise 1 - Modal calibration of the Load Cell Block A

Modal Analysis,
Transient Analysis, Hammer shocks

Exercise 2 - Modal calibration : Runway beam 1

Modal Analysis,
3 Transient Analysis – White Noises X, Y and Z

Exercise 3 - Modal calibration : Crane bridge mock-up

Modal Analysis,
Transient Analysis, White Noise XYZ

Exercise 5 - Friction coefficient and damping ratio

X Pulse, Sliding wheels, Centered configuration
Y Pulse, Sliding wheels, Centered configuration
Y Pulse, **Mixed** wheels, Centered configuration






Exercise 6 - Local shocks parameters

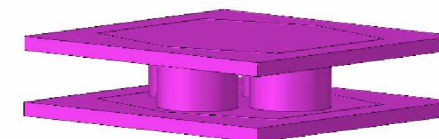
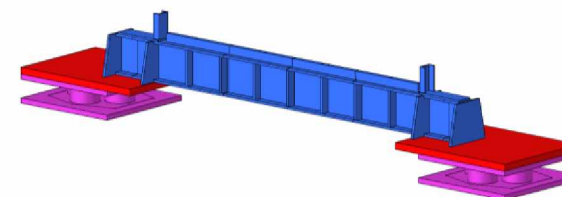
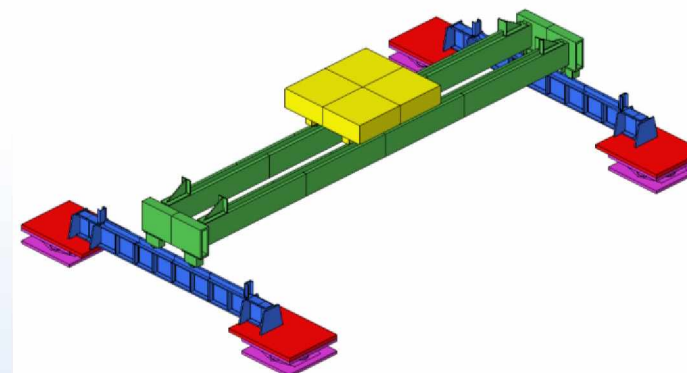
Seism XYZ 1.0g, Sliding wheels, **Decentered** configuration

Exercise 7 - High level calibration

Seism XYZ 0.5g, Sliding wheels, Centered configuration

Crane bridge components

-  Trolley
-  Girder beams and rails (x2) + End truck beams (x2)
-  Runway beams and rails (x2)
-  Plates (x4)
-  Load cell blocks (x4)

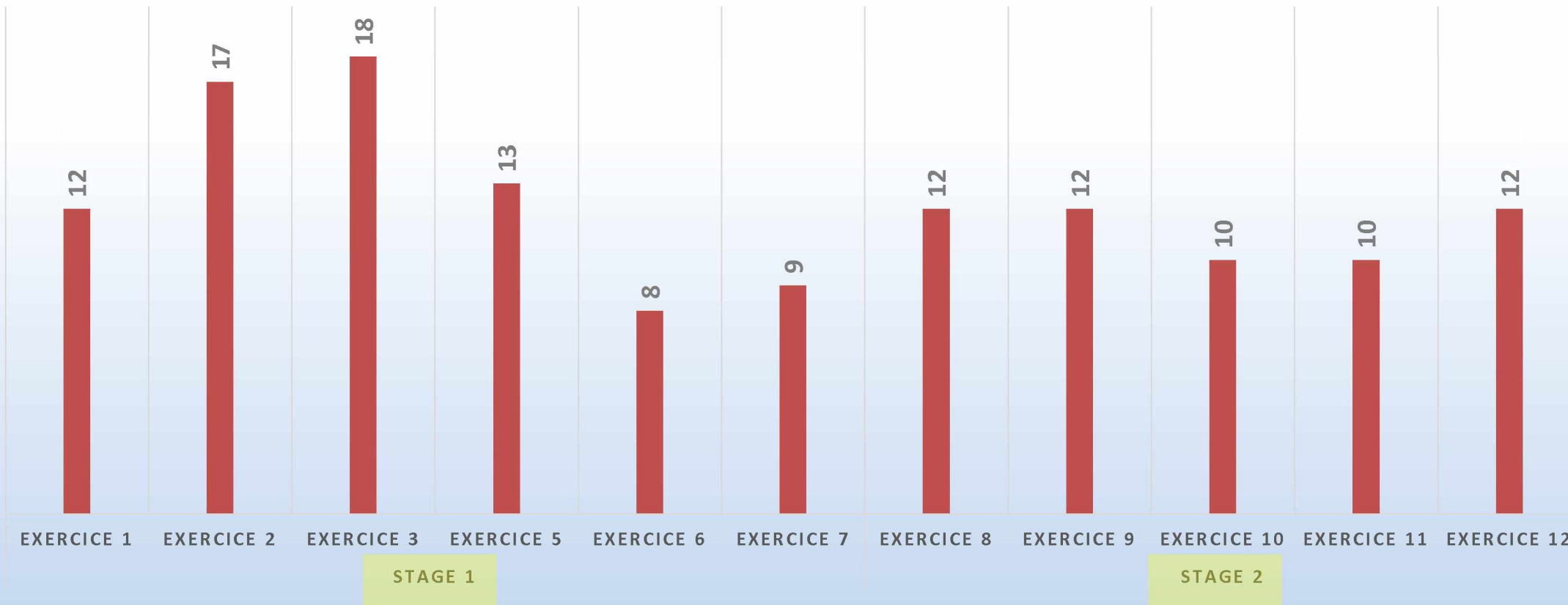


Exercises of the Benchmark – Stage 2 – Blind simulations

Blind simulations:

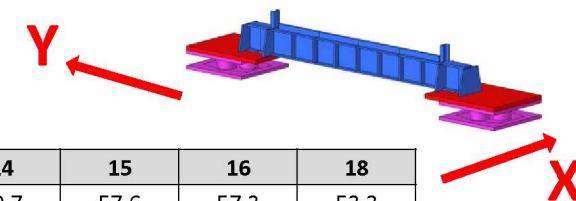
- Exercise 8 – RUN 80 – PGA=1.5g (XY) – Centered Configuration – **Mixed** Wheels
- Exercise 9 – RUN 42 – PGA=1.5g (XY) – Centered Configuration – Sliding Wheels
- Exercise 10 – RUN 112 – PGA=1.5g (XY) – **Decentered** Configuration – Sliding Wheels
- Exercise 11 – RUN 128 – PGA=1.5g (XY) – **Decentered** Configuration – **Mixed** Wheels
- Exercise 12 – RUN 100 – PGA=1.0g (XYZ) – Centered Configuration – **Mixed** Wheels

NUMBER OF RESPONSES



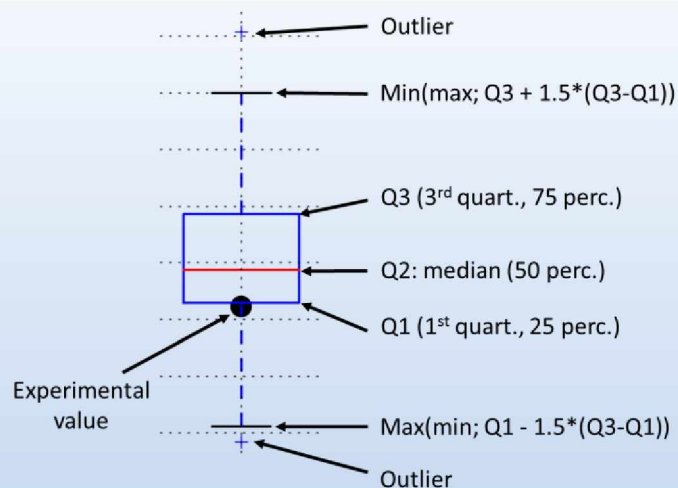
Exercise 2 – Modal Calibration – Runway beam

Participants modes

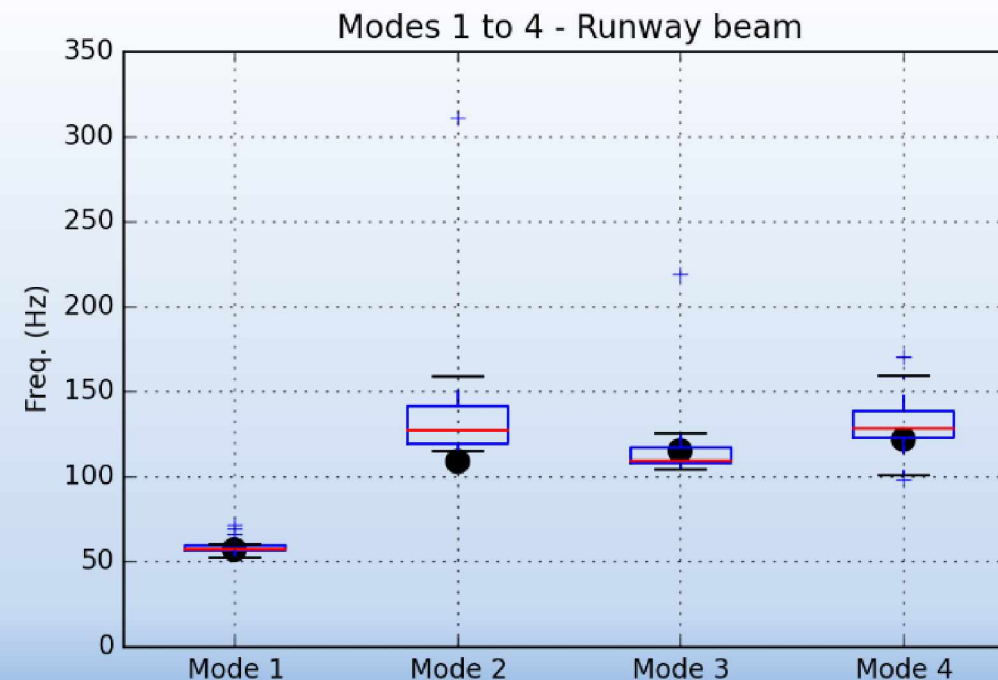


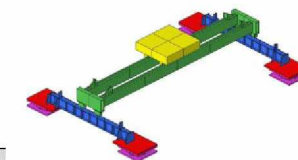
Mode	mock-up	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18
1-TX1	57.1	57.1	59.23	56.67	58	57.7	52.6	66.15	56.9	59.1	71.5	60.042	57.1	60.4	69.7	57.6	57.3	53.3
2-TX2	108.8	115.44	120.27	124.43	150.5	119.1	126.36	159.24	116.5	119.1	148.9		127.5		134.8	132.8	129.3	311.0
3-RY	115.2	108.94	106.38	108.69			107	123.3	108.6	116.8	125.9	116	104.6		118.0	110.1	108.9	219.0
4-TZ	122.2	151.8	126.85	123.31	141	98.4	128.9	160.01	122.2	106.6	137.9	101.2	123.3	170.7	132.5	128.5	133.6	

Box plot



- The half of the participants values are in this blue box
- A quarter of the participants values are under the blue box, and a quarter below
- The black lines show the limit between the considered values and the outliers



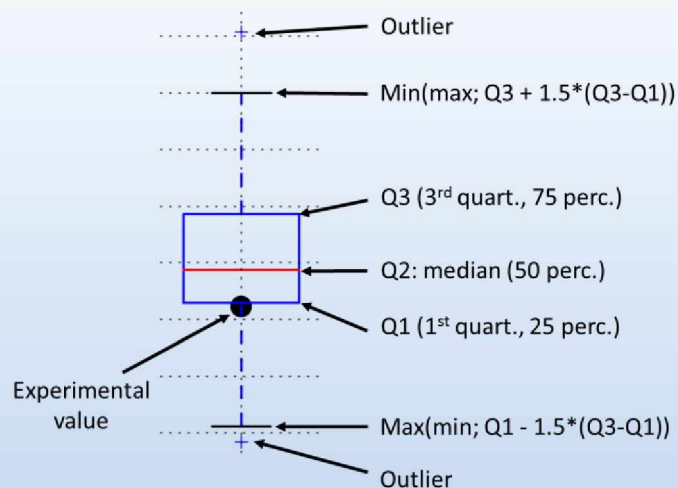


Exercise 3 – Modal Calibration – Crane

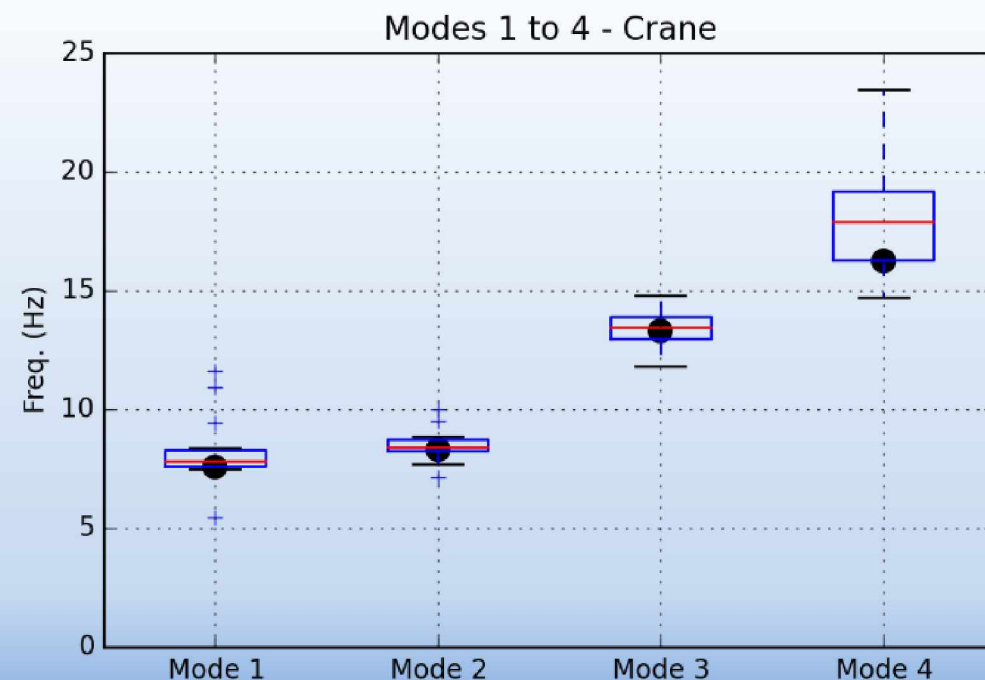
Participants modes

Mode	mock-up	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1-X	7.6	8.37	7.90	7.76	7.67	7.50	7.73	10.92	7.60	7.55	9.45	7.52	8.21	11.62	8.27	7.67	8.30	8.30	5.45
2-Y	8.3	8.29	8.61	7.71	8.28	8.70	8.21	9.51	8.30	8.46	8.86	8.32	8.58	8.77	8.42	8.86	7.90	10.00	7.12
3-Z	13.3	13.66	13.91	13.11	13.88	11.80	14.10	14.52	13.28	12.87	14.06	12.54	13.17	14.80	12.83	12.94	13.70	13.30	13.62
4	16.2	15.88	15.64	15.88	16.40	18.70	19.85	21.13	17.98	16.52	17.33	19.20	17.91	22.66	23.46	18.67	16.30		14.72

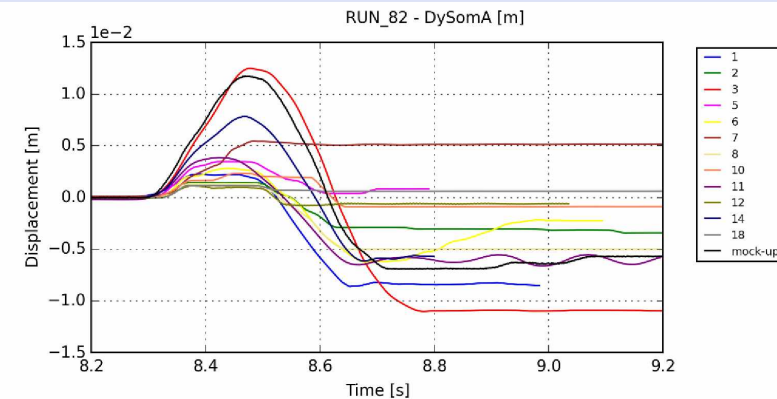
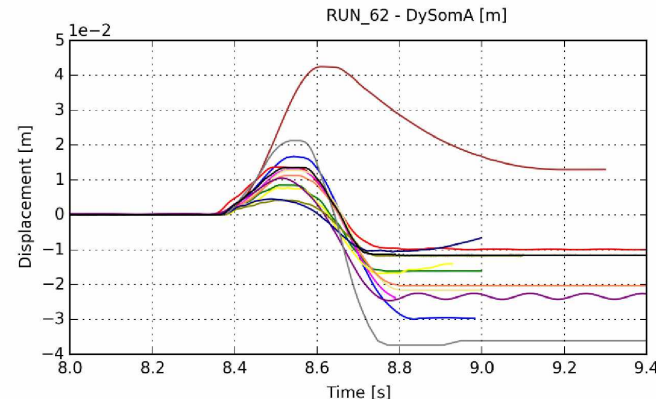
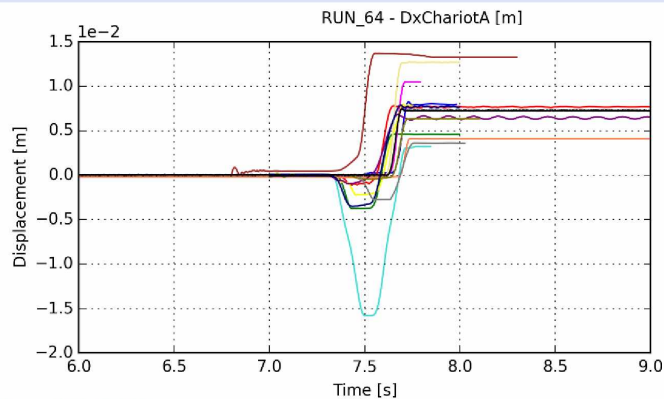
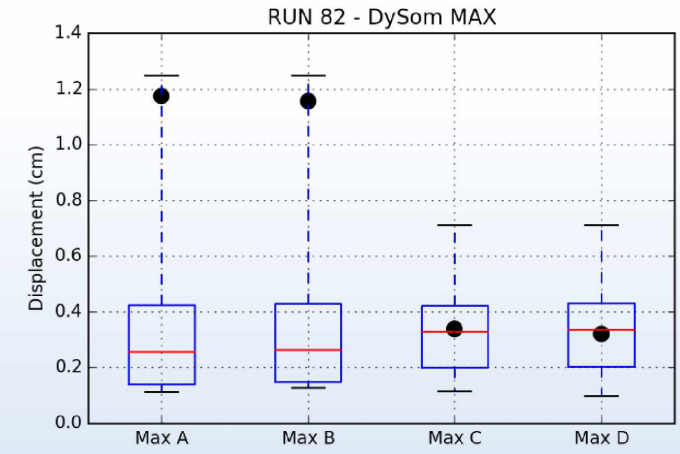
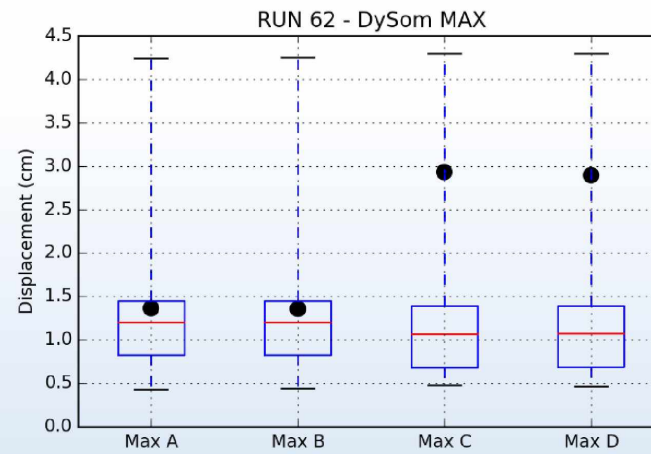
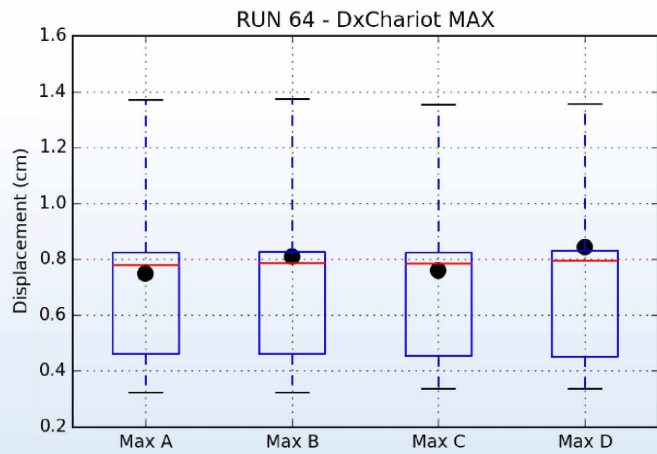
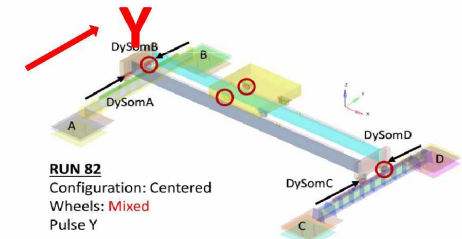
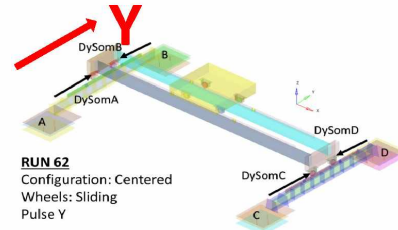
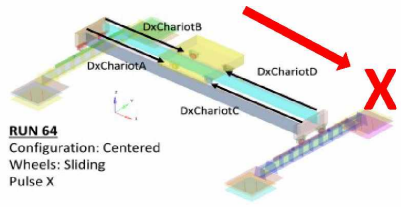
Box plot



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- The black lines show the limit between the considered values and the outliers

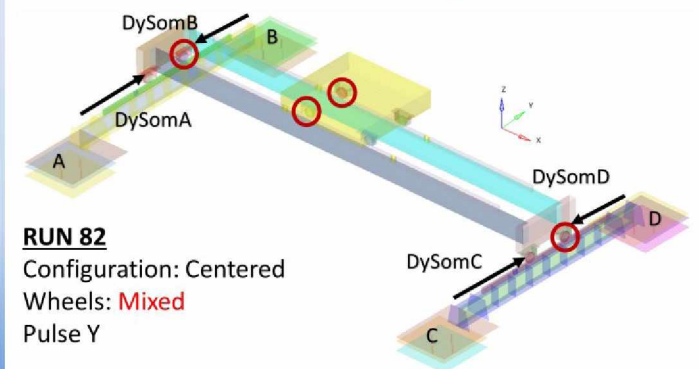
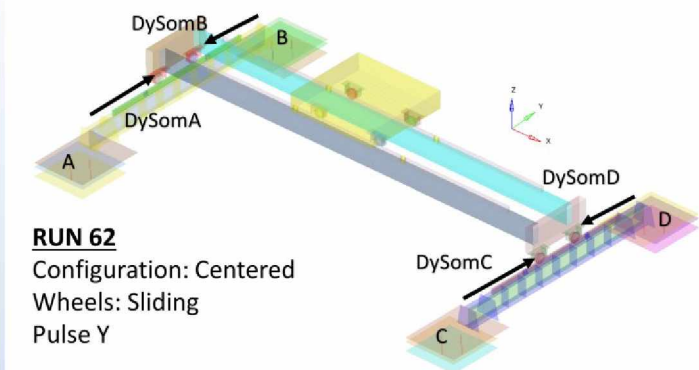
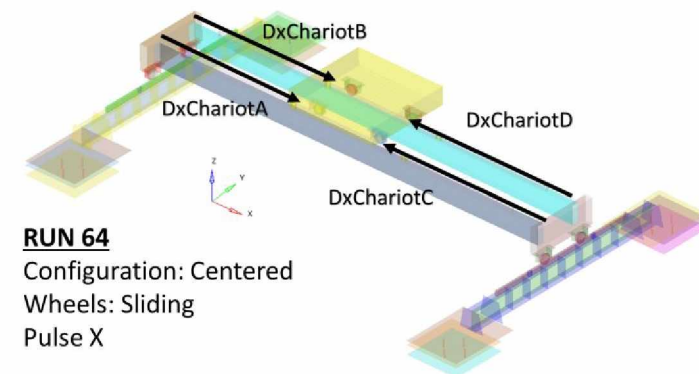
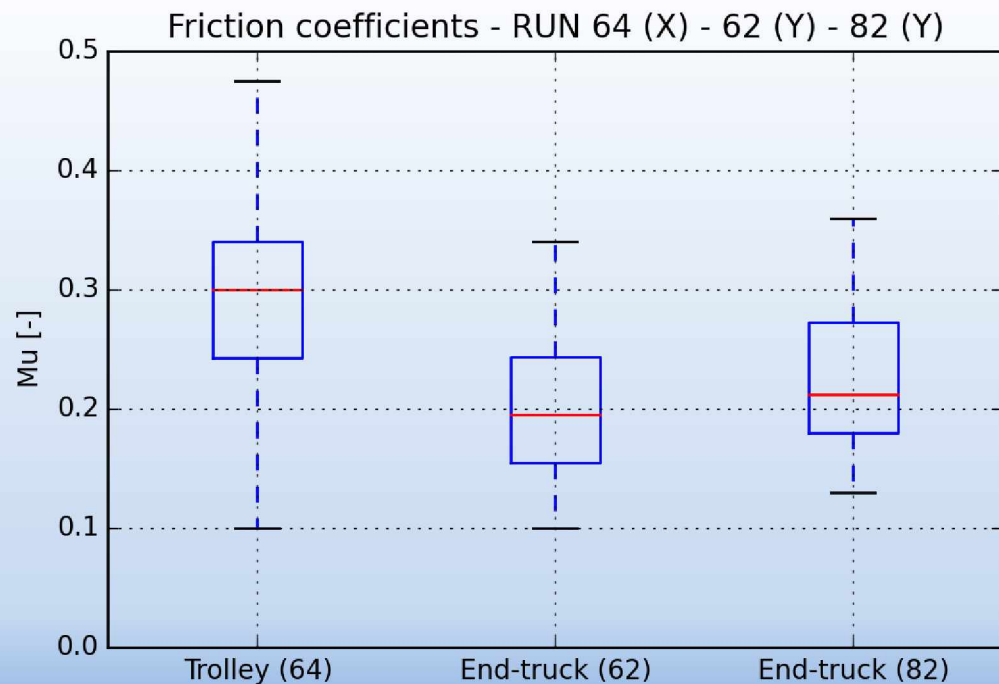


Exercise 5



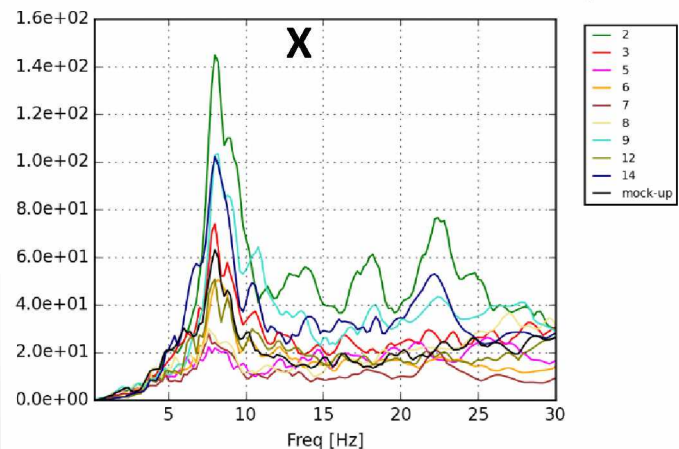
Friction coefficients

- Statistics on data provided by up to 13 participants
- 1 participant considers a dynamic coefficient (different from the static coefficient)
- 3 participants consider different friction coefficients for AB and CD end-truck beams (RUN 62 and 82)

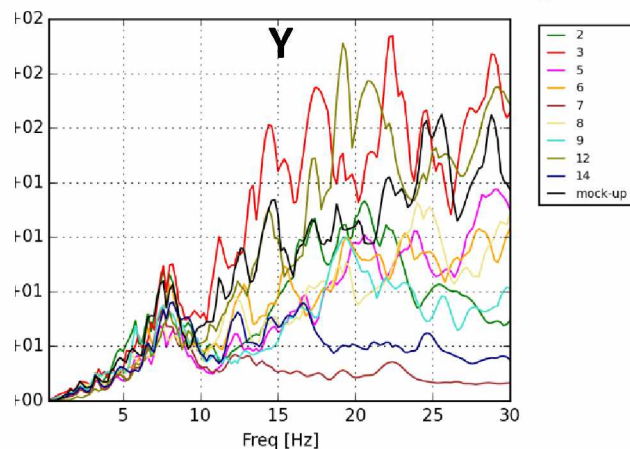


Exercise 7 – RUN 53 – Seism XYZ 0.5g

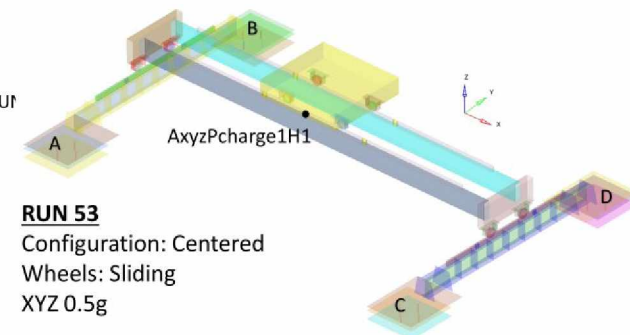
Response Spectrum - acceleration - AxPCharge - RUN_53



Response Spectrum - acceleration - AyPCharge - RUN_53

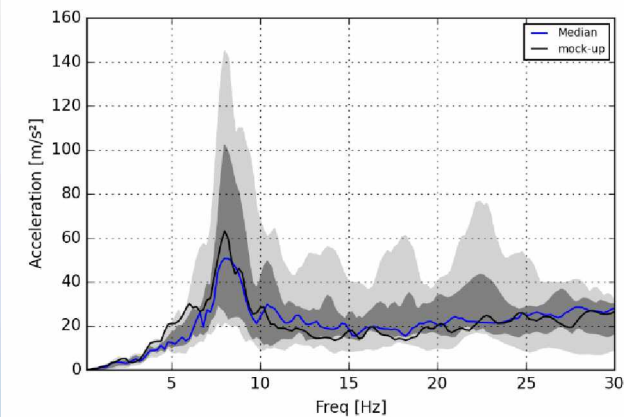


Response Spectrum - acceleration - AzPCharge - RUN_53

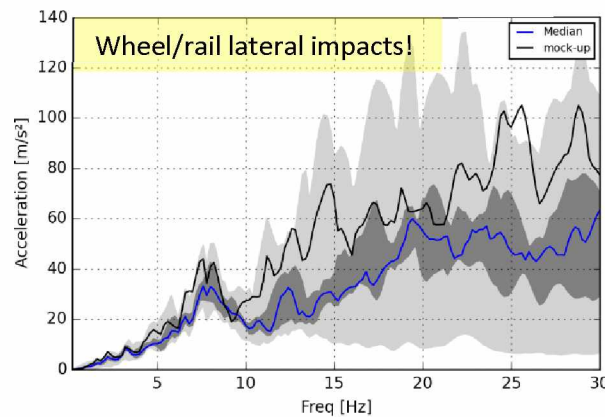


Girder Beam Spectra

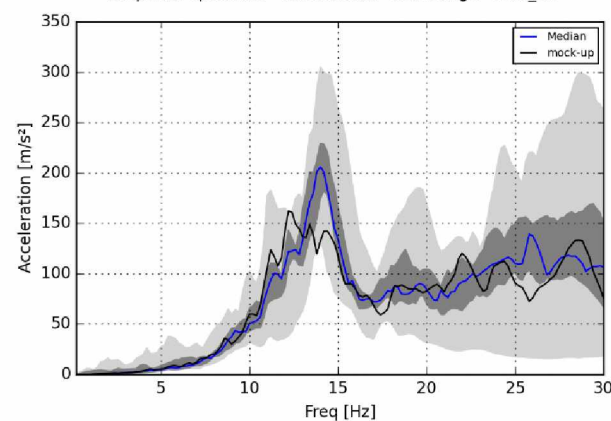
Response Spectrum - acceleration - AxPCharge - RUN_53



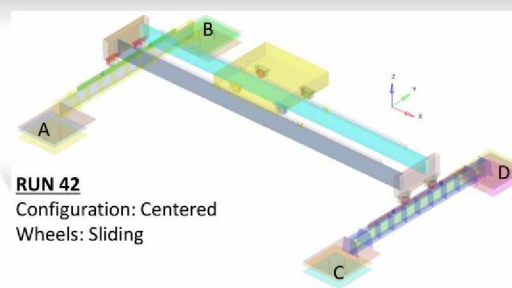
Response Spectrum - acceleration - AyPCharge - RUN_53



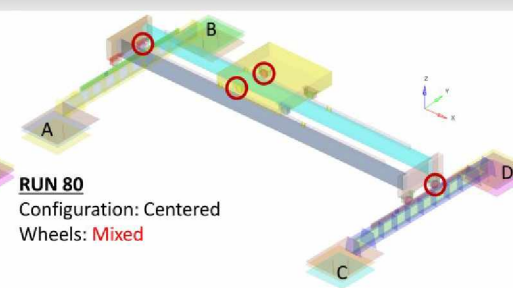
Response Spectrum - acceleration - AzPCharge - RUN_53



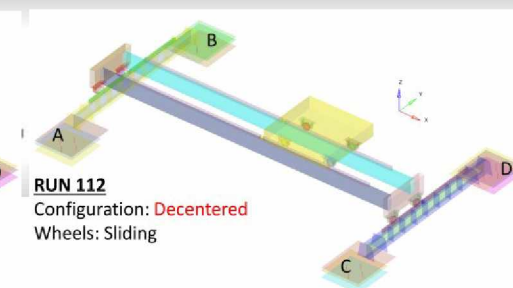
- Blue: contains for each frequency the median pseudo-acceleration among the participants' values
- Dark grey: The spectra of 1st quartile values and of the 3rd quartile values
- Light grey: The min and max spectra among participants' spectra



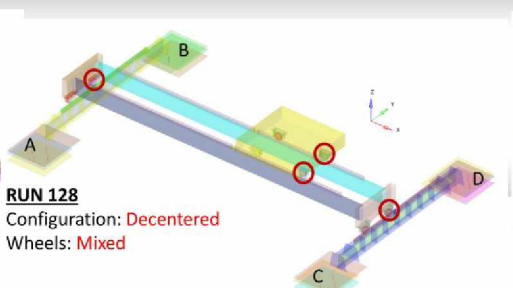
RUN 42
Configuration: Centered
Wheels: Sliding



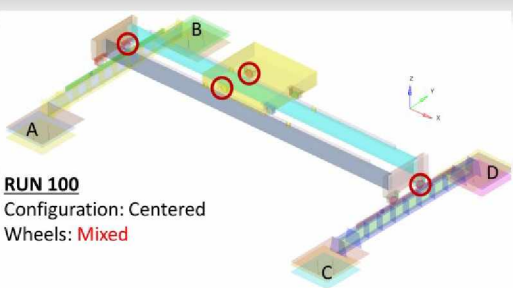
RUN 80
Configuration: Centered
Wheels: Mixed



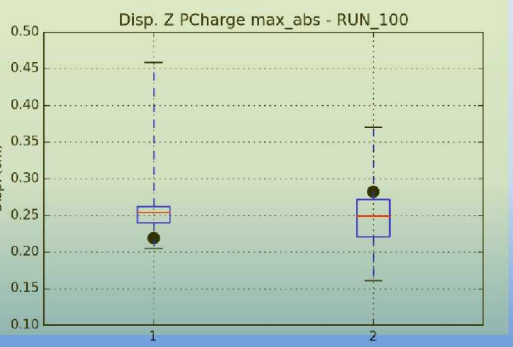
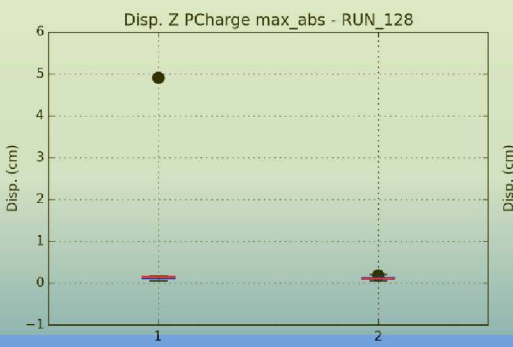
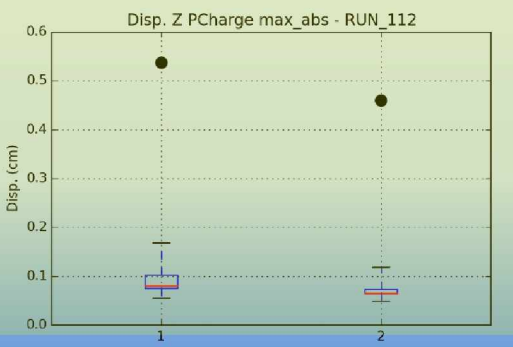
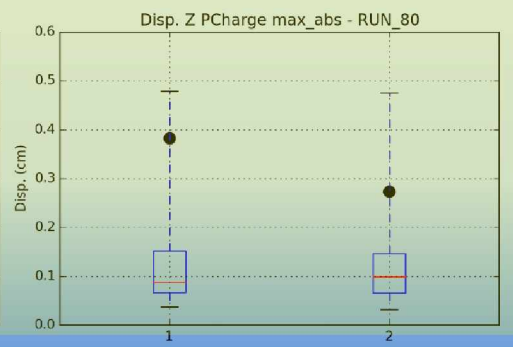
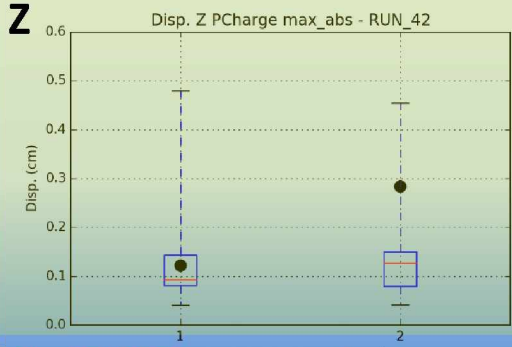
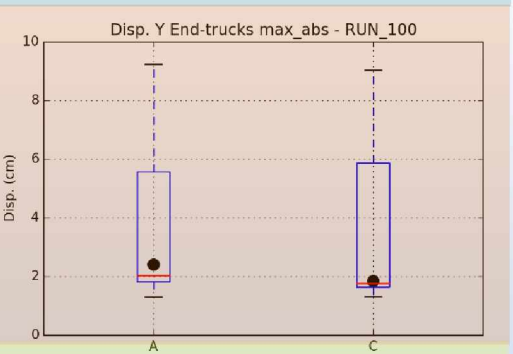
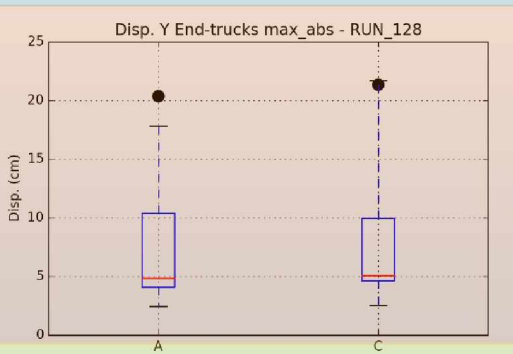
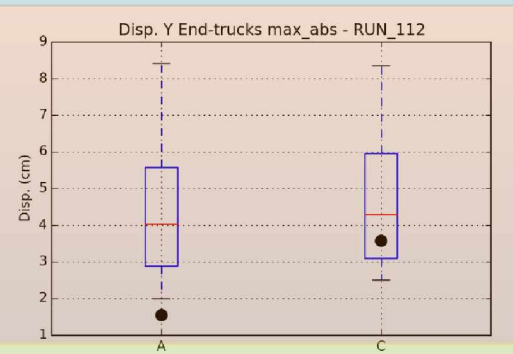
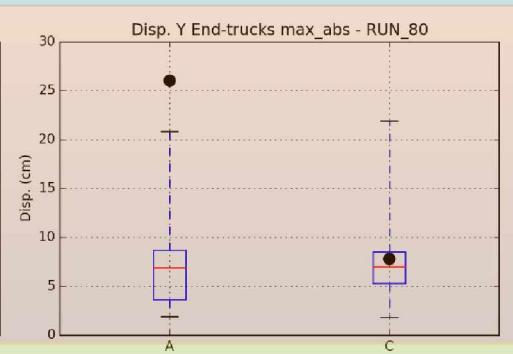
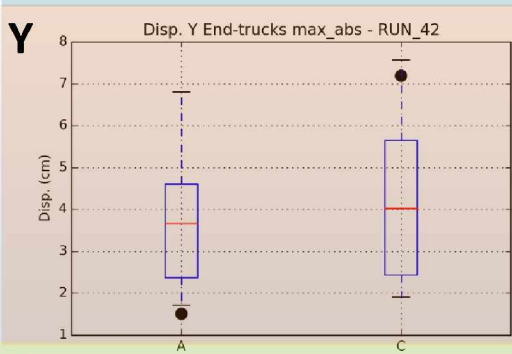
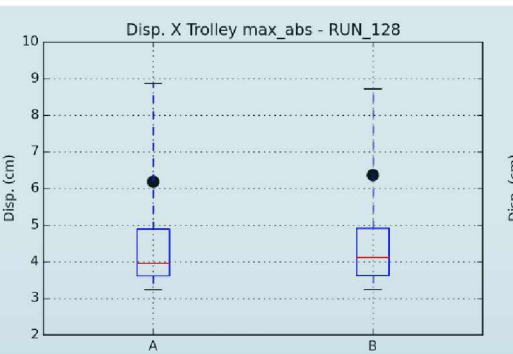
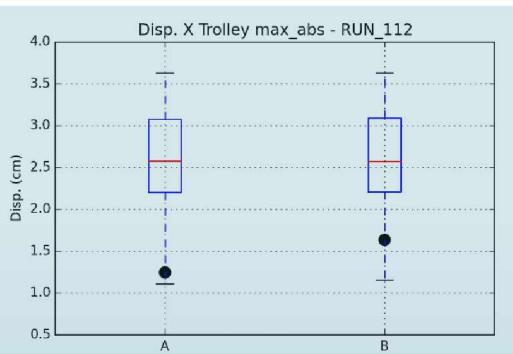
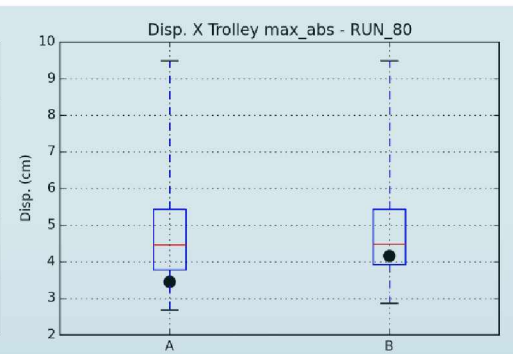
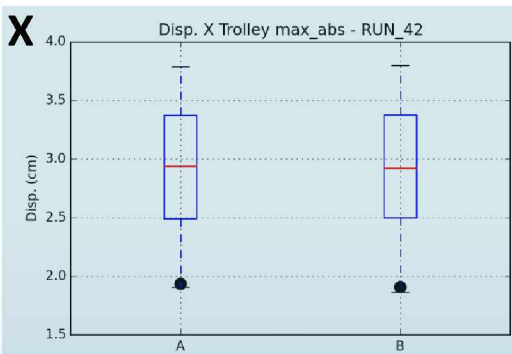
RUN 112
Configuration: Decentered
Wheels: Sliding



RUN 128
Configuration: Decentered
Wheels: Mixed

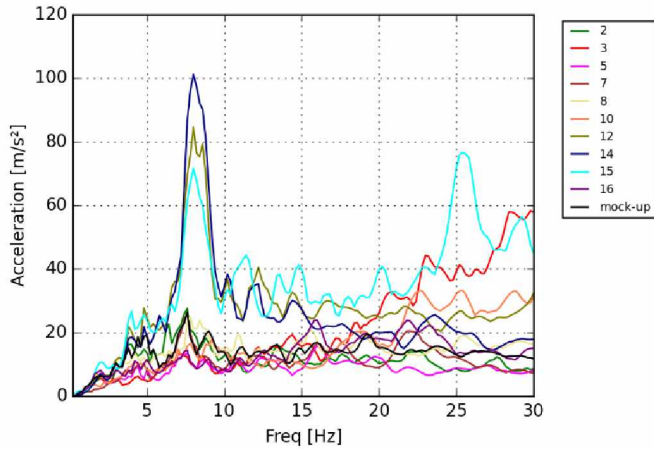


RUN 100
Configuration: Centered
Wheels: Mixed

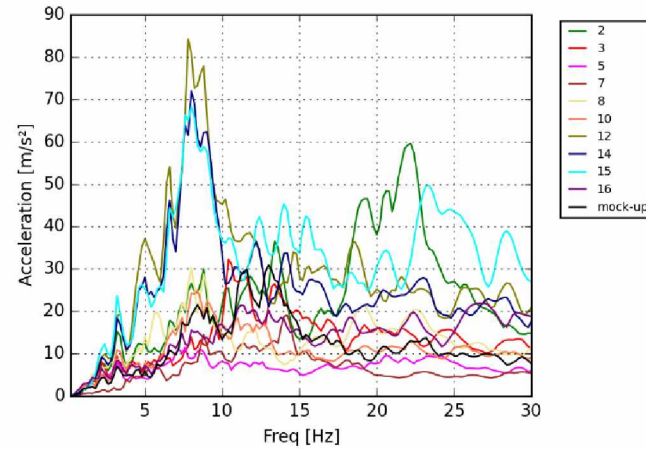


Spectrum – 2% – RUN 100 – Trolley (Chariot) – Seism XYZ 0.5g

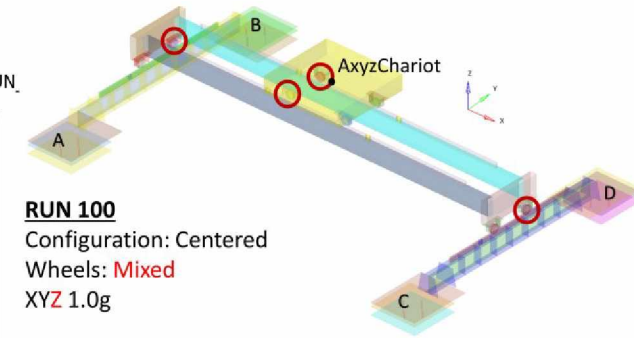
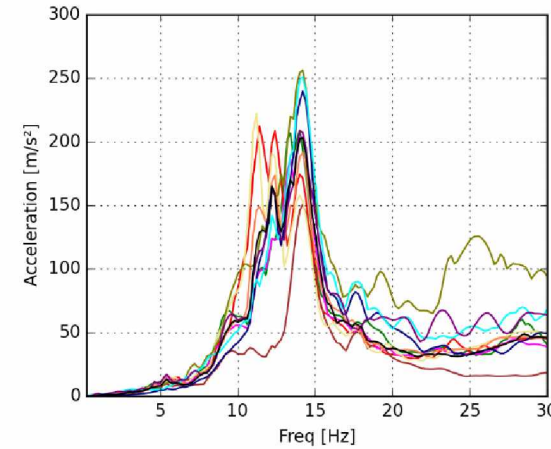
Response Spectrum - acceleration - AxChariot - RUN_100



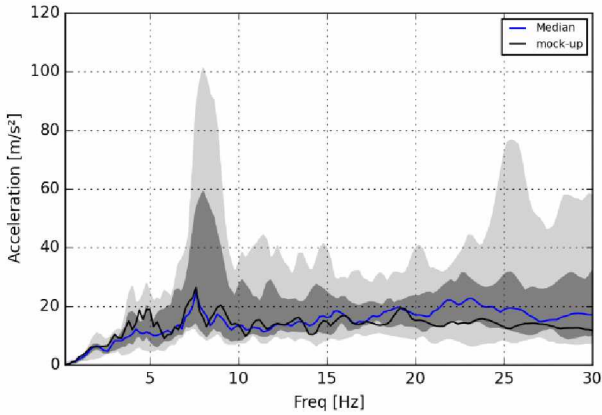
Response Spectrum - acceleration - AyChariot - RUN_100



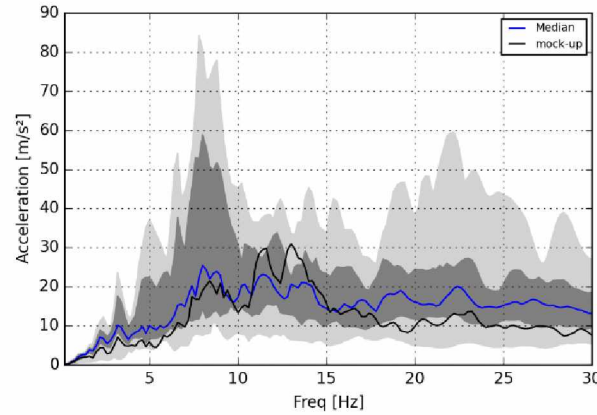
Response Spectrum - acceleration - AzChariot - RUN_100



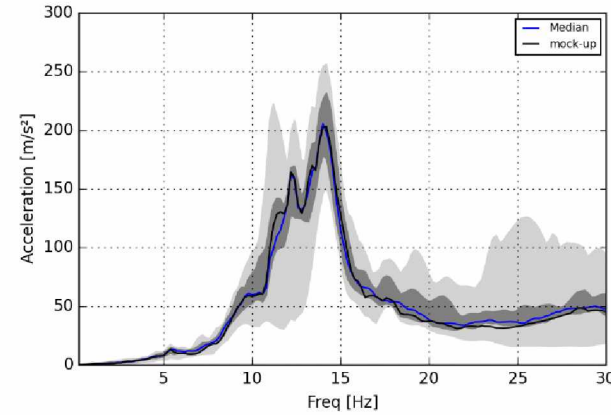
Response Spectrum - acceleration - AxChariot - RUN_100

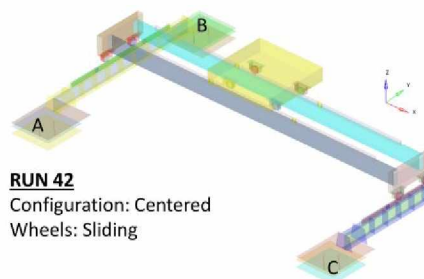


Response Spectrum - acceleration - AyChariot - RUN_100

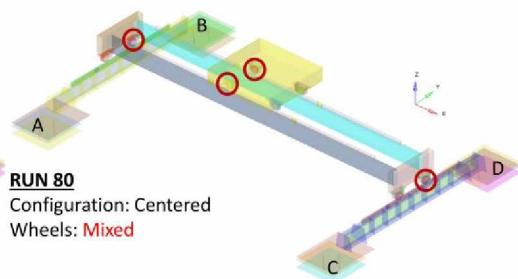


Response Spectrum - acceleration - AzChariot - RUN_100

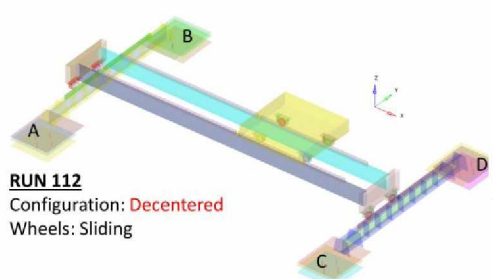




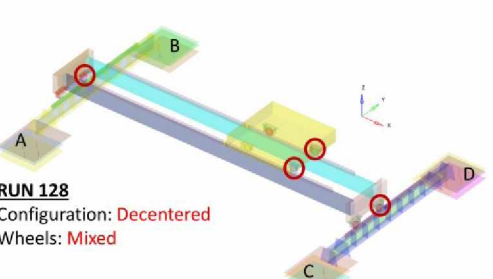
RUN 42
Configuration: Centered
Wheels: Sliding



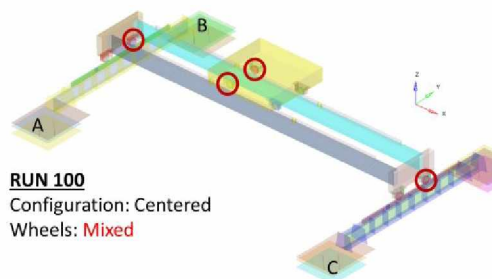
RUN 80
Configuration: Centered
Wheels: Mixed



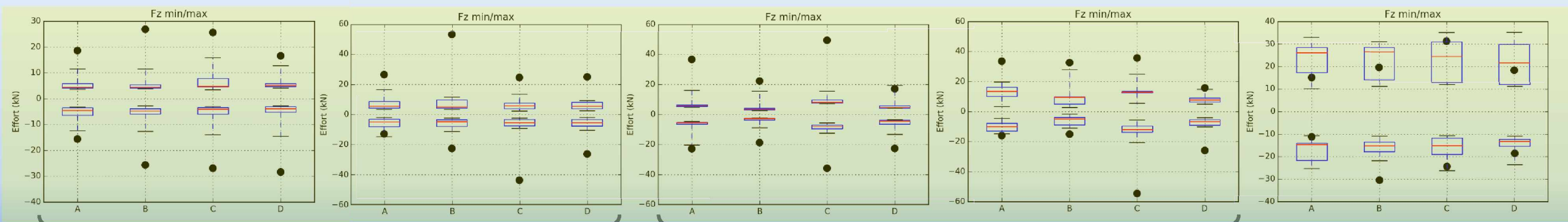
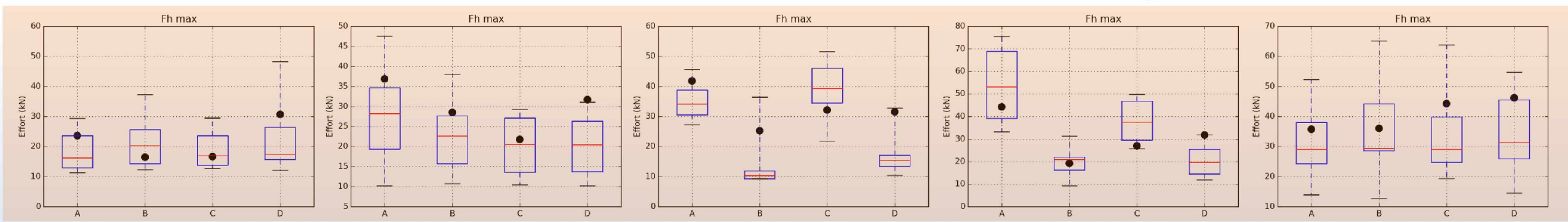
RUN 112
Configuration: Decentered
Wheels: Sliding



RUN 128
Configuration: Decentered
Wheels: Mixed



RUN 100
Configuration: Centered
Wheels: Mixed



Centered configurations

Decentered configurations

Centered configuration

Some observations and concluding remarks

- ✓ The objective was not to reproduce exactly the dynamic response of the crane in terms of displacement or acceleration of the rollers, but to make trends appear.
- ✓ The global dynamics of overhead cranes can be captured with different models, from the simplest to the most complex, and with different types of elements.
- ✓ The linear calculation for this type of equipment is very conservative since the main sources of energy dissipation are sliding and local shock phenomena.
- ✓ Friction between the wheels and the rail has a very significant influence on the seismic response of the crane
 - Statistical analysis in order to take into account the missknowledge of the exact initial position;
 - Taking into account bi-axial sliding.

Some observations and concluding remarks

- ✓ Vertical excitation and horizontal excitation observations
 - horizontal excitation can cause some uplifts on the trolley wheel due to the rocking behaviour;
 - vertical excitation can reduce sliding of the girder beams.

- ✓ Question of differential acceleration which is always the case in reality, since the supporting structure is not able to transfer the seismic signal in the same way for the two supporting rails.

- ✓ Damping question
 - It is necessary to take into account the eigenmodes related to the rigid body modes as well as those of the deformation modes.
 - However, it is important to cancel (reduce) the damping of the rigid body modes.

Some observations and concluding remarks

- ✔ It seems more interesting to have simplified models allowing to make parametric studies as well as statistical and probabilistic studies on the various parameters of influence (friction coefficient, gaps) than to have complex and heavy models in computation not really allowing to make a sensitivity study campaign.
 - Influence of input uncertainties:
 - the actual gap value may not be known with accuracy;
 - systematic asymmetric sliding behavior;
 - friction coefficients.

- ✔ Best practice suggestion: perform systematic sensitivity studies on the bridge crane to be studied since the input values, *which are uncertain*, will provide different outcomes and thus have a high influence.

Special Session at SMIRT 26, 10 - 15 July 2022, Berlin/Potsdam, Germany

Special Session: Overview of the work done in the OECD SOCRAT benchmark dedicated to the beyond design seismic behavior assessment of crane bridges organized by Ibrahim Bitar		
#	Title	Authors
1	Seismic simulation of Overhead CRANE on Shaking table: SOCRAT BENCHMARK 2021	Ibrahim Bitar (IRSN (Institut de Radioprotection et de Sûreté Nucléaire), Fontenay aux Roses), Charles Droszcz (Géodynamique & Structure, Montrouge), Benjamin Richard (IRSN (Institut de Radioprotection et de Sûreté Nucléaire), Fontenay aux Roses), Fabien Grange (Electricité de France, Paris), Emmanuel Viallet (Electricité de France, Paris)
2	SOCRAT Benchmark: Seismic Analyses of an Overhead Crane in LS-DYNA	Sara Ghadimi Khasraghy (Basler Hofmann AG, Forchstrasse 395), Jan Attinger (Basler Hofmann AG, Forchstrasse 395), Christian Schneeberger (Swiss Federal Nuclear Safety Inspectorate ENSI, Brugg), Peter Rangelow (Basler Hofmann AG, Forchstrasse 395)
3	Modelling of an Overhead Crane under Seismic Excitations (SOCRAT)	Javier Rodriguez (Principia Ingenieros Consultores, Madrid), Javier Reboul (Principia Ingenieros Consultores, Madrid), Pablo Gonzalez (Principia Ingenieros Consultores, Madrid), Maria Crespo (Principia Ingenieros Consultores, Madrid), Michael Borgerhoff (Stangenberg & Partners Consulting Engineers (SPI), Bochum), Christian Schneeberger (Swiss Federal Nuclear Safety Inspectorate (ENSI), Civil Engineering Section, Brugg)
4	Numerical Simulations of the Nonlinear Seismic Interaction of Bridge Crane Components in the SOCRAT Benchmark	Michael Borgerhoff (Stangenberg & Partners Consulting Engineers, Bochum), Matthias Stadler (Stangenberg & Partners Consulting Engineers, Bochum), Heiko Stangenberg (Stangenberg & Partners Consulting Engineers, Bochum), Christian Schneeberger (Swiss Federal Nuclear Safety Inspectorate ENSI, Brugg)
5	Seismic analysis of overhead crane bridges using friction-based sliding model	Johana Colomb, David Bouhjiti , Nikolay Anishchenko, Y. Shaparevich, Elias Bou Said (EGIS, Montreuil)
6	Simulation of a crane bridge mock-up under seismic loading within the SOCRAT benchmark	Ludwig Bahr (GRS, Cologne), Jens Arndt (GRS, Cologne), Jürgen Sievers (GRS, Cologne)
7	Explicit/Implicit co-simulation of bridge cranes under earthquake using Heterogeneous Asynchronous Time Integrator for frictional contact/impact problems	Michael Brun (Université de Lorraine, Arts et Métiers Paris Tech, CNRS, 7 Rue Félix Savart), Sijia Li (Structural Mechanics and Coupled Systems Laboratory, Conservatoire National des Arts et Métiers, 75003 Paris, France (sijia.li@lecnam.net), Paris), Anthony Gravouil (INSA-Lyon, CNRS UMR5259, LaMCoS, F-69621, France (anthony.gravouil@insa-lyon.fr), Lyon)

Special Session: Overview of the work done in the OECD SOCRAT benchmark dedicated to the beyond design seismic behavior assessment of crane bridges

14/07/2022

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THANK YOU

*Photo taken during Benchmark Closing Workshop
March 21 to 23, 2022
Saclay, France*

