



Experimental Modal Analysis

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Experimental Modal Analysis

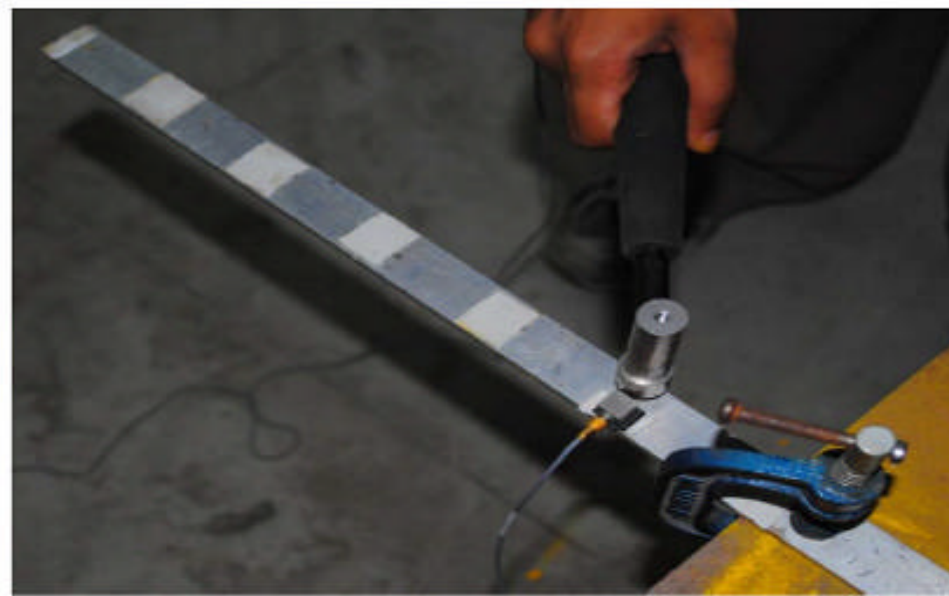
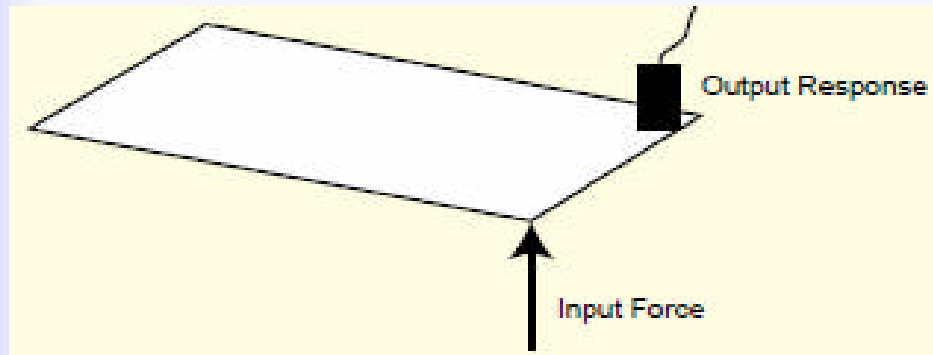
- describes the structure in terms of its *dynamic properties* :
 - natural frequencies
 - modal shapes
 - damping coefficients

Applications

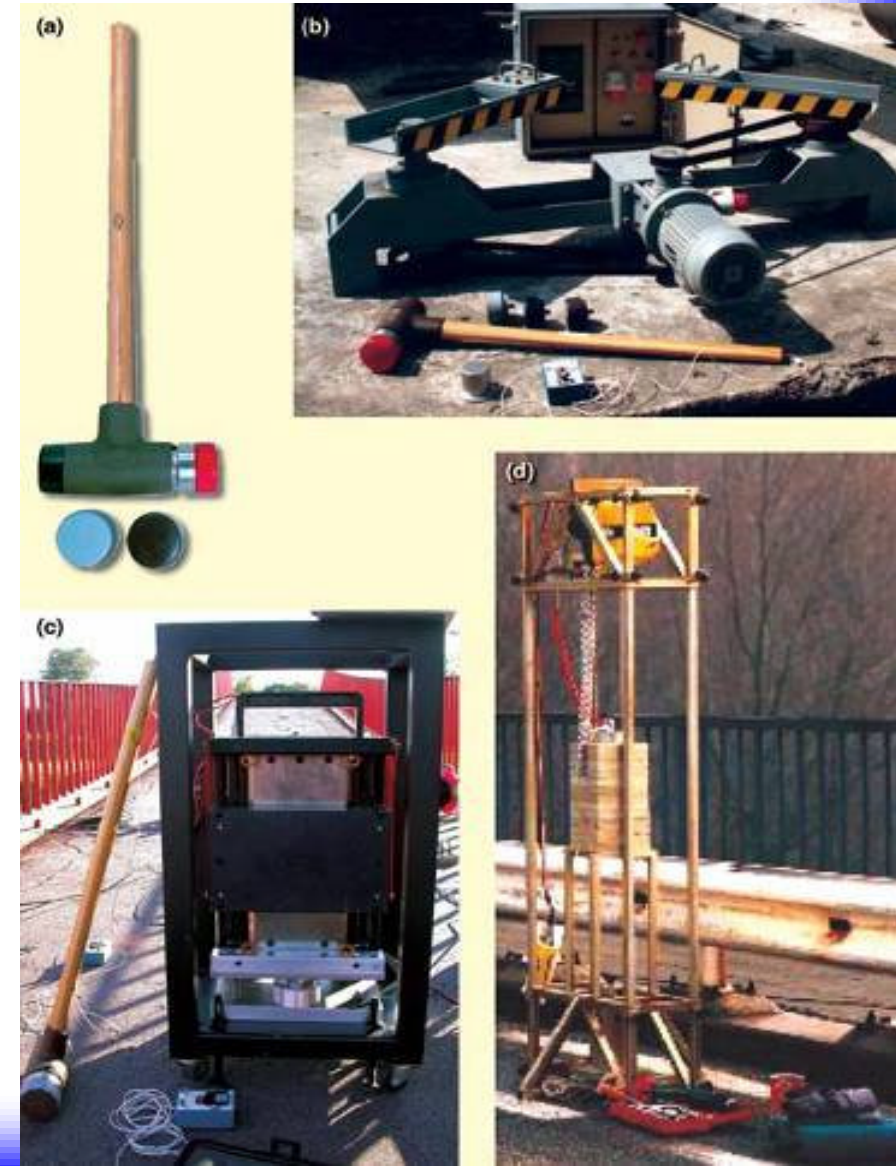
- ✓ Optimisation of structure's dynamic characteristics (mass, stiffness, damping)
- ✓ Risk assessment of having the resonance phenomenon
- ✓ Prediction of dynamic behaviour
- ✓ Evaluating the damping for inclusion in FE models
- ✓ Correlation of FE models with real structures
- ✓ Damage detection and assessment
- ✓ Long term building monitoring

Experimental Modal Analysis

- Classical (Input - Output)

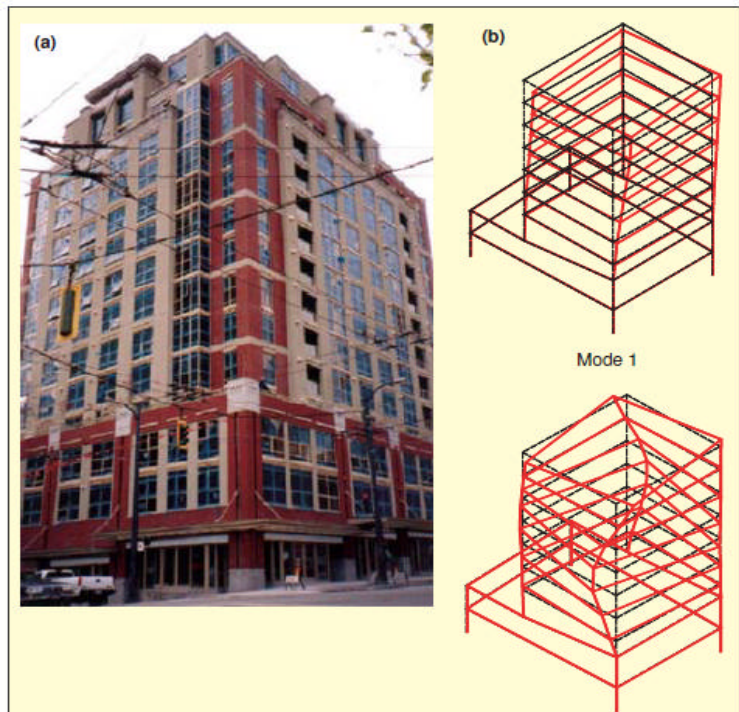
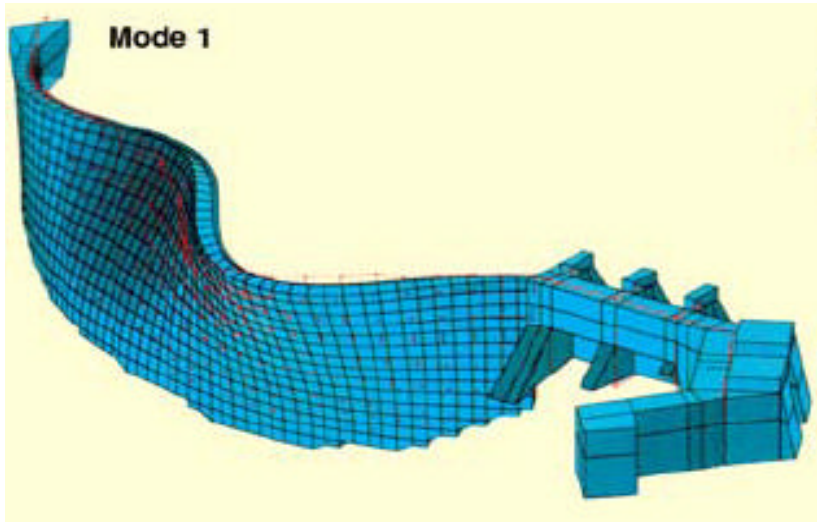
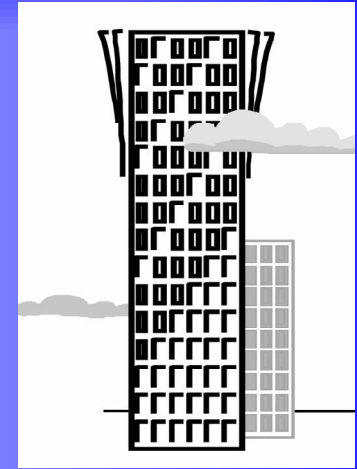


- a) Impulse hammer; b) eccentric mass vibrator;
- c) electrodynamic shaker over three load cells;
- d) impulse excitation device for bridges



Experimental Modal Analysis

- Operational (Output - only)



Laboratory equipment - Bruel&Kjaer

- **Portable Vibration Data Acquisition System**



- **Calibration system**



- **Piezoelectric and seismic accelerometers**



- **Cables**

- **Accessories**

- **Impact hammer**



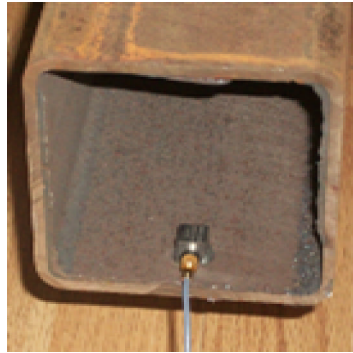
- **Software Pulse v.12**

Me'scope v.5

Classical Modal Analysis (Input - output)

Analysed element

- steel square pipe 100x5, L=2.2m, S235
- fixed accelerometer at one end
- 2 elastic supports



Classical Modal Analysis (Input - output)

Project definition

Brüel & Kjær - PULSE LabShop Version 12.0.0 - Impact hammer 06.03.2012

File Edit View Organiser Task Tools Window Help

MTC Hammer

Setup
Project Information
Hardware Setup
Geometry
Measurement DOFs
Measurement Sequence
Analysis Setup
Double Hit Detector
Hammer Trigger
Hammer Weighting
Response Weighting

Geometry Measurement Points

Select Insert Auto Fill

x-y-z x = 0.58, y = 0.81, z = 0.00, (Global)

Note for Measurement DOFs

Assign the sensors to their physically location by either drag-and-dropping from the **Transducer List**. For roving measurements, assign the roving transducer in the order in which it will be moved. The sequence can be edited in the

Transducer List

Family	Type	Name	Serial No.	Fram...	Slot N
Force	8210	8210	51349	1	2
Accelerometer	4507 B 2	4507 B 2-x	no data	1	2

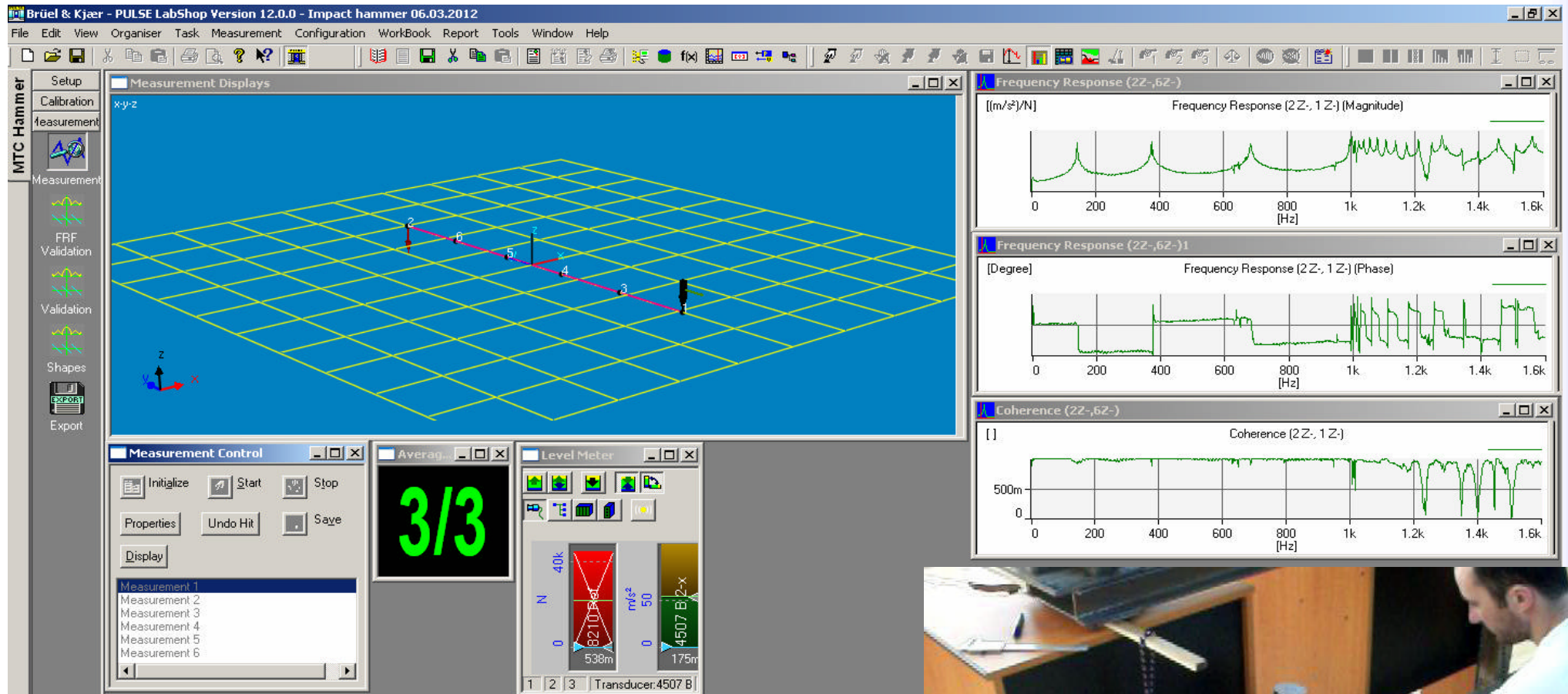
DOF Explorer

View: All

Label	Point	Xducer X	Xducer Y	Xducer Z	XducerType	Refere
4507 B 2-x	2	Z-	--	--	Accelerometer	no
8210	1	Z-	--	--	Impact Hammer	yes
8210	2	Z-	--	--	Impact Hammer	yes
8210	3	Z-	--	--	Impact Hammer	yes
8210	4	Z-	--	--	Impact Hammer	yes
8210	5	Z-	--	--	Impact Hammer	yes
8210	6	Z-	--	--	Impact Hammer	yes

DOFs Equations

Classical Modal Analysis (Input-output) *Measurements*

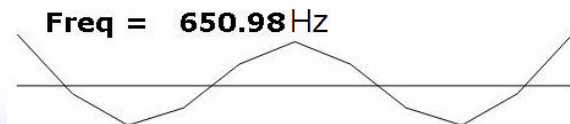
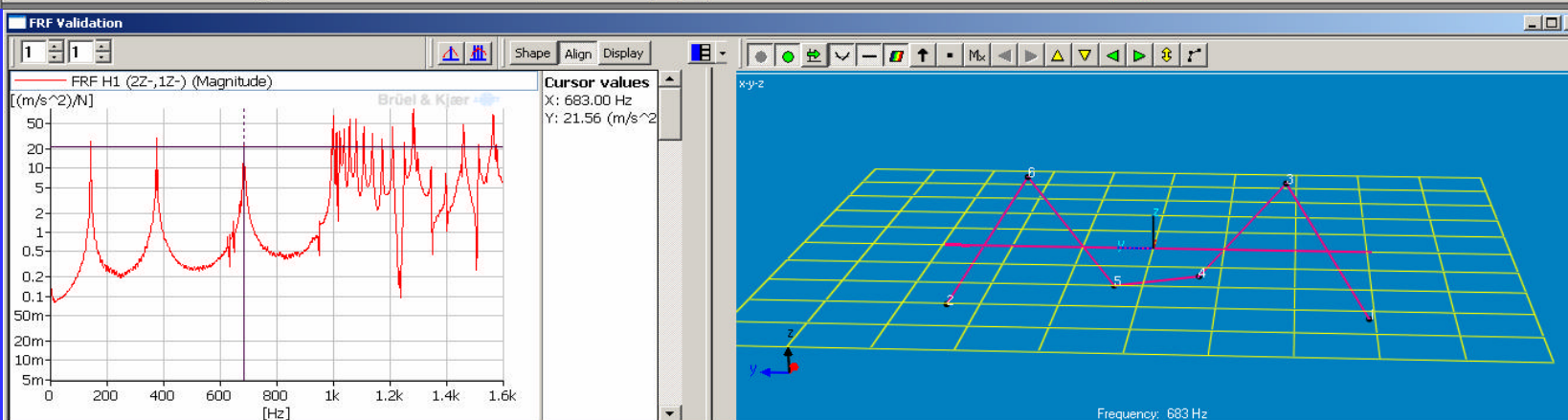
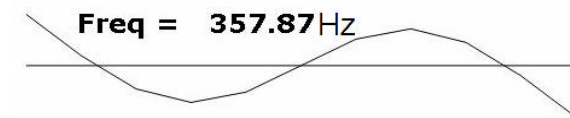
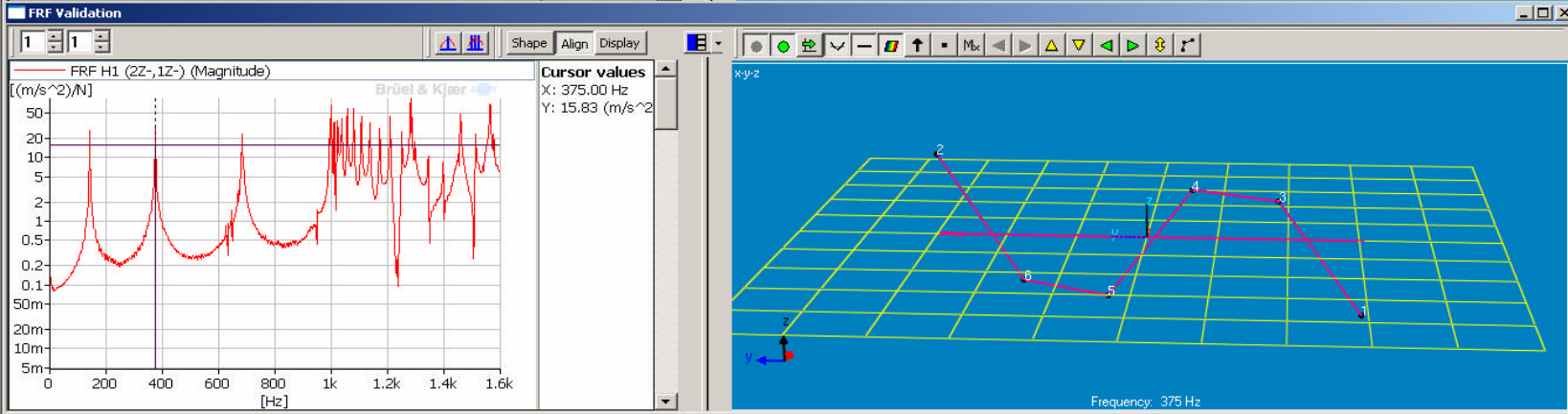
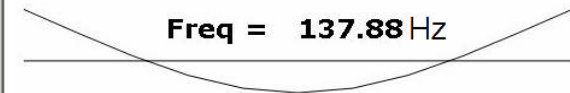
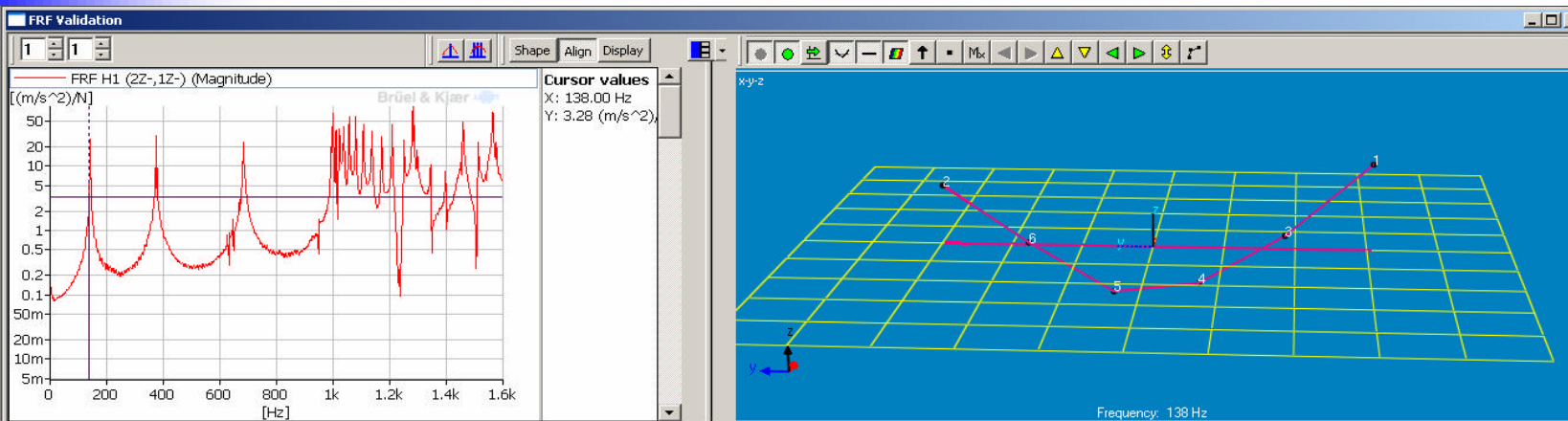


The excitation was introduced on a mesh of 6 points along the bar length. Three measurements were made for each point.



Classical Modal Analysis (Input - output)

Comparing Results (Experiment vs. FEA)



Classical Modal Analysis (Input - output)

Conclusions

- good agreement between the results of the two analyses (experimental and FE) in the frequency range 0-1kHz
- over 1kHz – poor identification of the vibration modes, the measurements displayed poor coherence, probably because of the too large impact hammer

Classical Modal Analysis (Input - output)

Future research directions

- Analysis of hollow core slabs



- Analysis of any flexible structure small enough to be excited with our impact hammer

Operational Modal Analysis (Output - only)

Analysed element

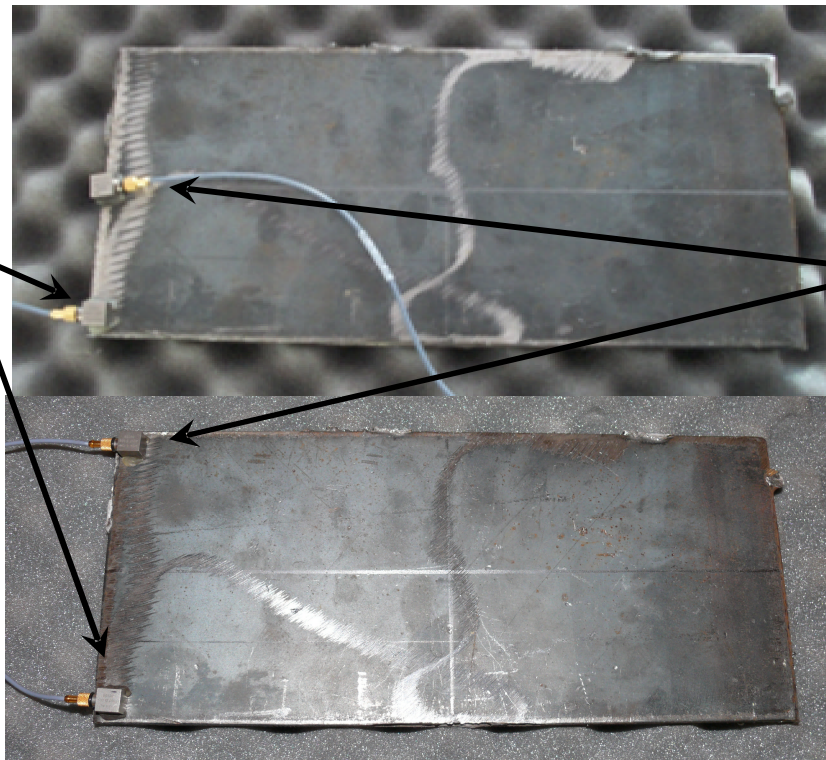
- steel plate 300x180x10, S235

- two accelerometers:

 - 1) reference - fixed

 - 2) roving

- elastic supports



Measurements were made on a rectangular grid of 9 points.

Operational Modal Analysis (Output - only)

Project definition

Brüel & Kjær - PULSE LabShop Version 12.0.0 - DMA Test Plate Data - 03.03.2012

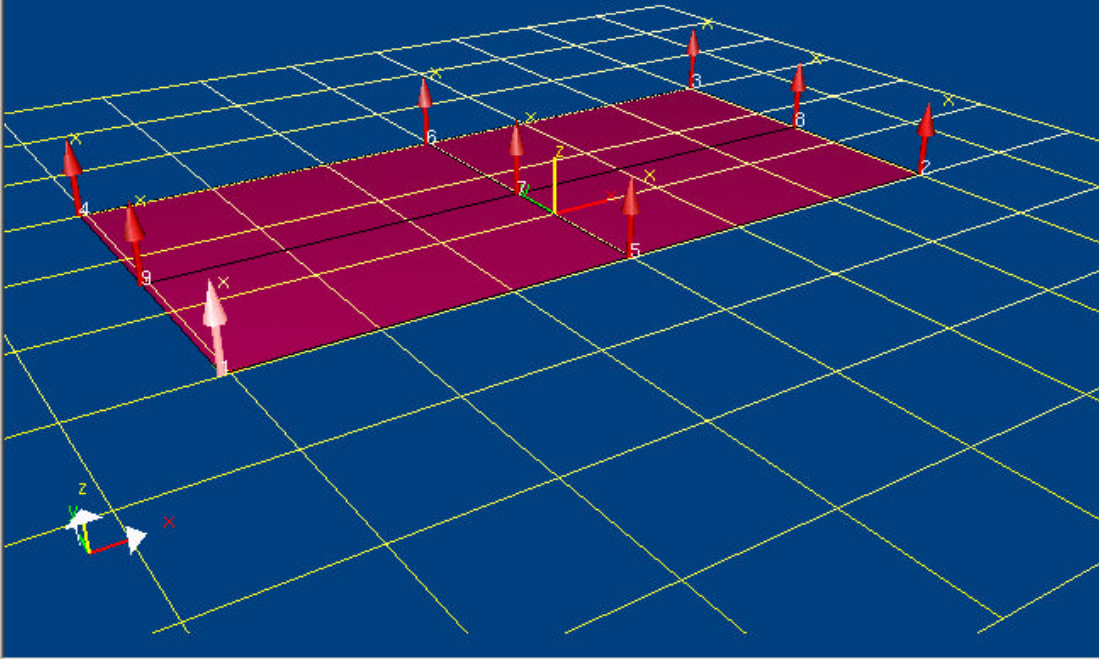
File Edit View Organiser Task Tools Window Help

Operational Modal using Data Recorder - Task - Measurement DOFs

Geometry for Measurement Points

Select Insert Auto Fill

x-y-z



Note for Measurement DOFs

Assign the sensors to their physically location by either drag-and-dropping from the **Transducer List**. Transducers can be set as a reference (fixed location) by right-clicking on the sensor in the Transducer List. For roving measurements, assign the roving transducer in the order in which it will be moved. The sequence can be edited in the next task, **Measurement Sequence Task**

Transducer List

Family	Type	Name	Serial
Accelerometer	4507	4507 B 2x	30158

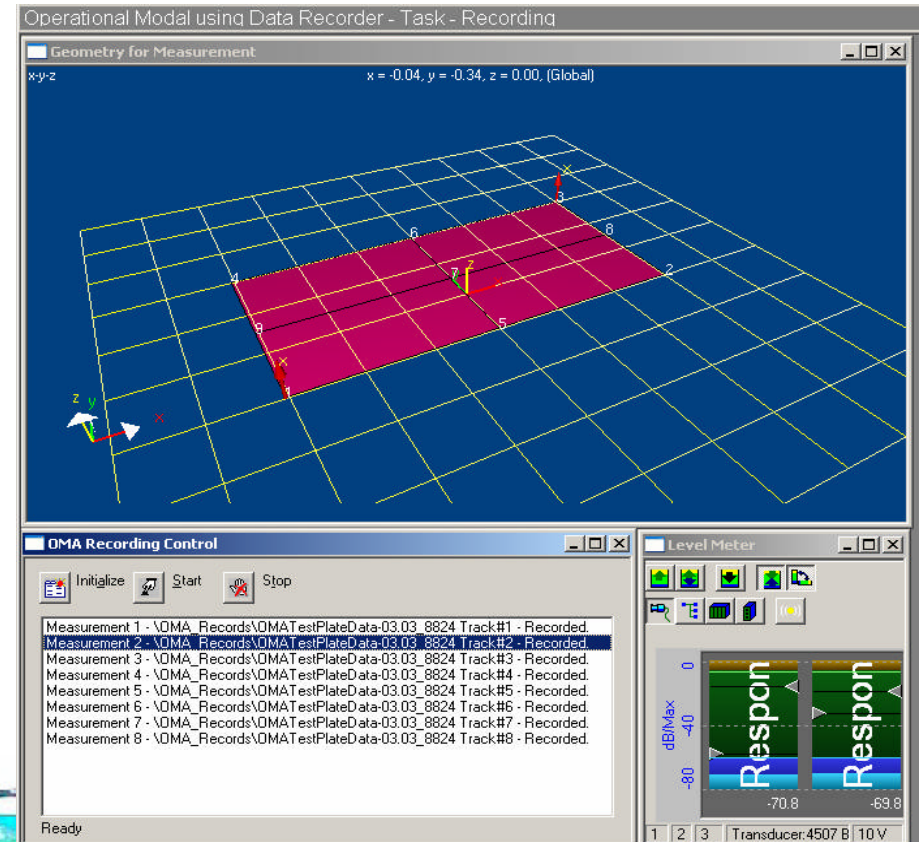
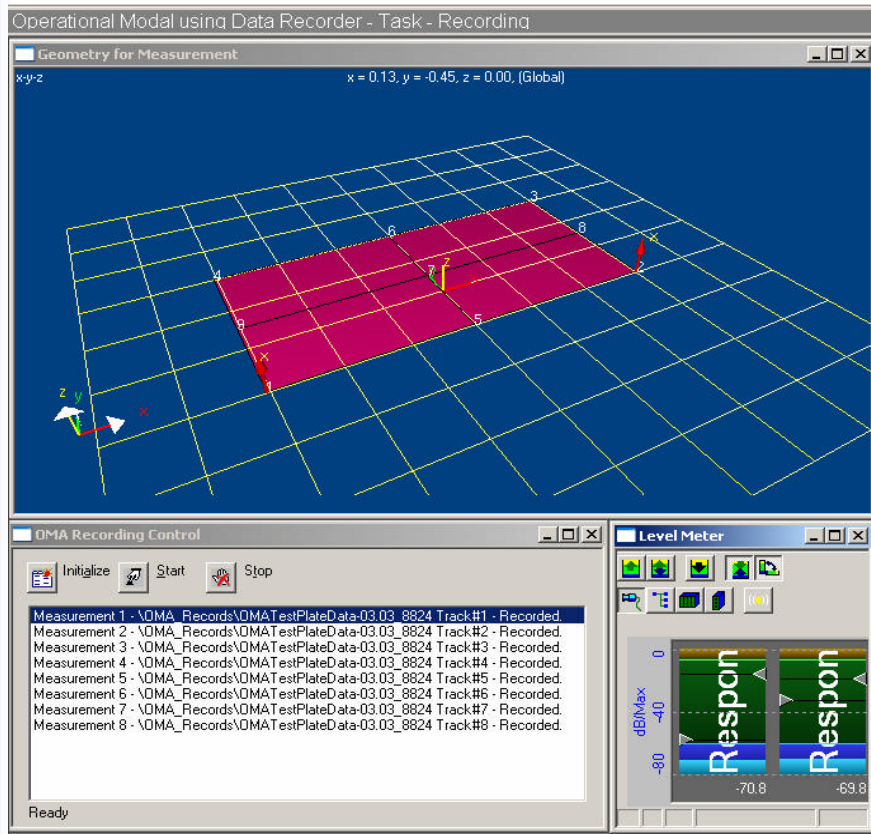
DOF List

Poi...	Transducer Type	Trans. Name	Component Nam
1	Monoax	4507 B 2x (1)	Rectangle (1)
2	Monoax	4507 B 2x (2)	Rectangle (1)
3	Monoax	4507 B 2x (2)	Rectangle (1)
4	Monoax	4507 B 2x (2)	Rectangle (1)
5	Monoax	4507 B 2x (2)	Rectangle (1)
6	Monoax	4507 B 2x (2)	Rectangle (1)
7	Monoax	4507 B 2x (2)	Rectangle (1)
8	Monoax	4507 B 2x (2)	Rectangle (1)
9	Monoax	4507 B 2x (2)	Rectangle (1)

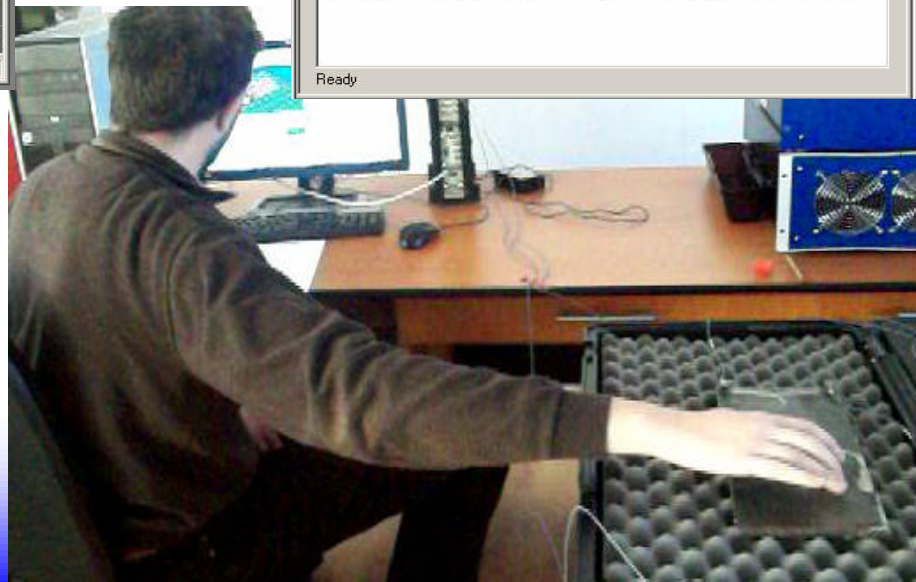
Operational Modal using Data Recorder

- Task
- Project Information
- Hardware Setup
- Geometry
- Measurement DOFs
- Measurement Sequence
- PreTest
- Accelerometer Calibration
- Acquisition Setup
- Recording

Operational Modal Analysis (Output - only) *Measurements*

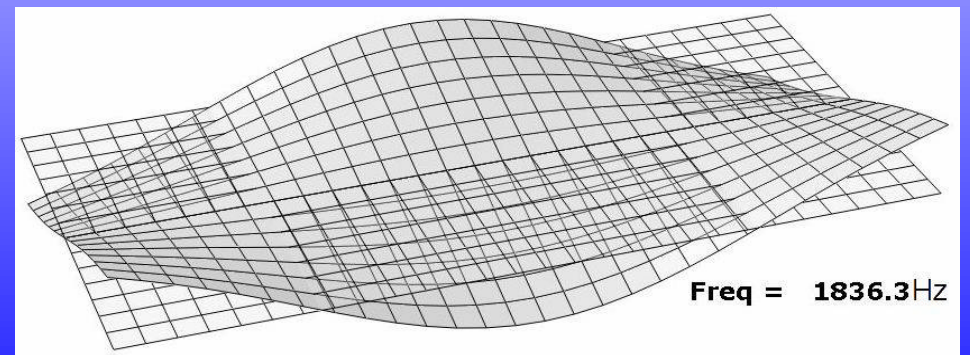
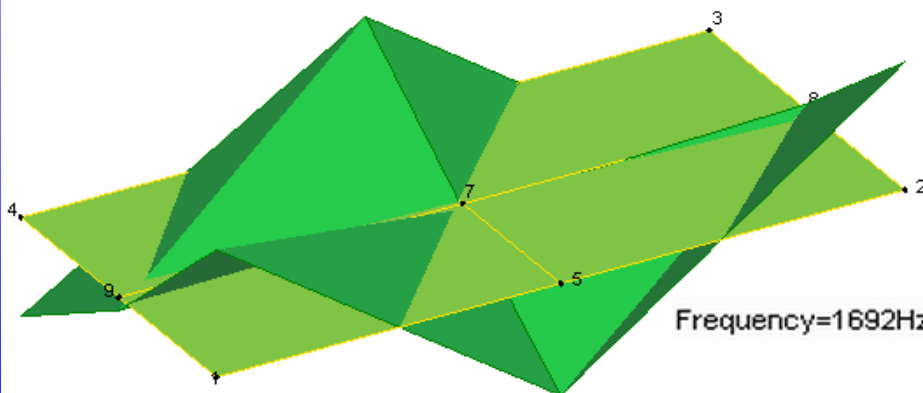
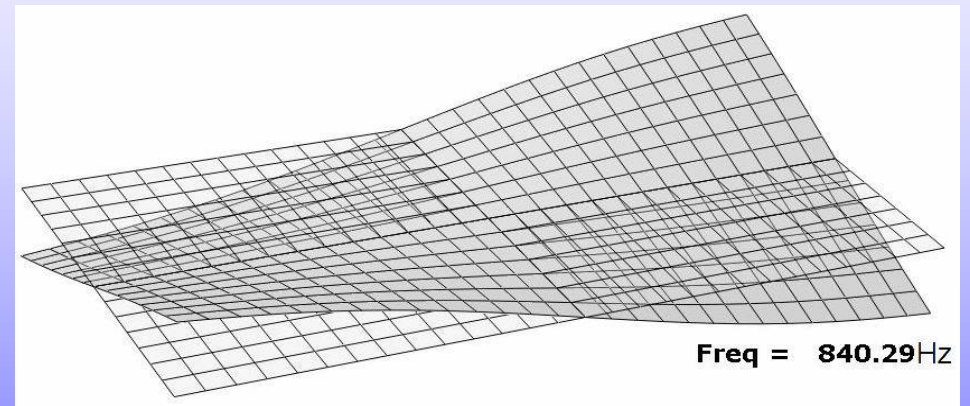
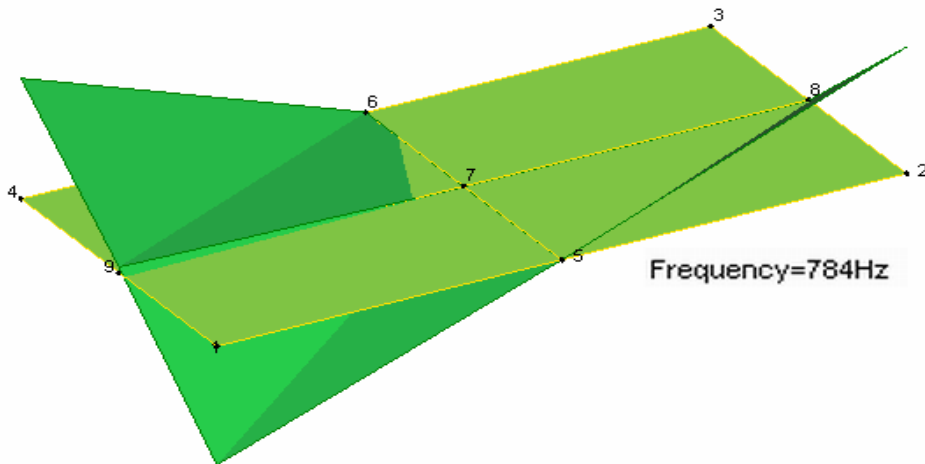
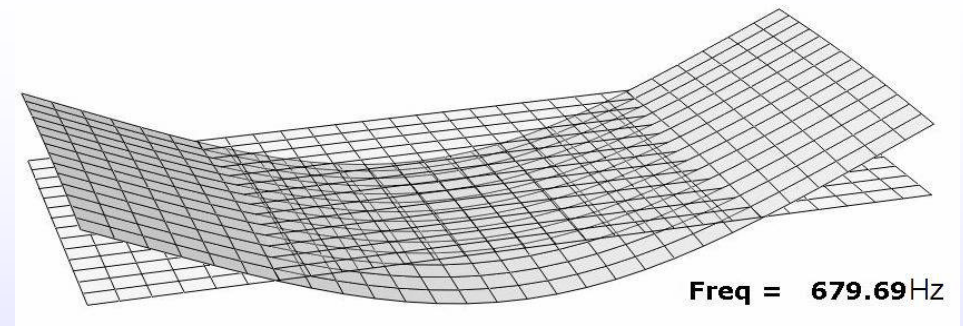
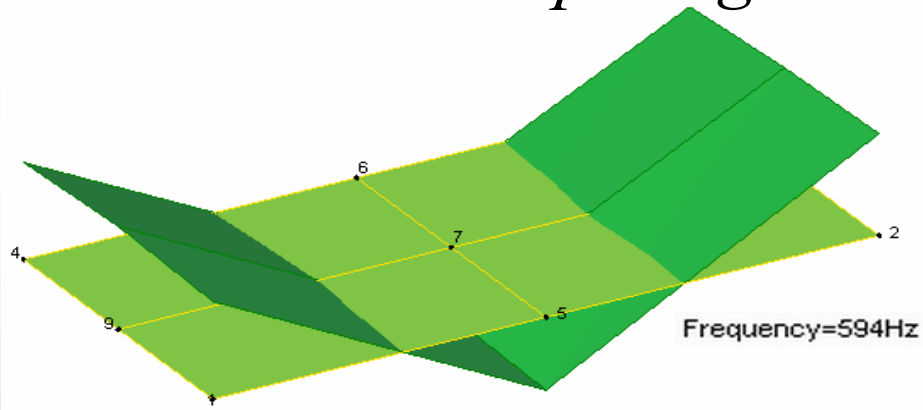


The plate was excited only
by random tapping.



Operational Modal Analysis (Output - only)

Comparing Results (Experiment vs. FEA)



Operational Modal Analysis (Output - only)

Conclusions

- Generally, good agreement between the results of the two analyses (experimental and FE). The differences are explained by the significant imperfections of the steel plate (weldings, cuts etc).
- *Experimental Analysis provides the real results!*

Future research directions

- Analysis of any flexible structure (buildings, bridges, railways, etc.)

Experimental Modal Analysis

Teaching/Research activity

- Experiments presentation on internet and at teaching courses
- Students can model and test small-scale structures
- Research activity for Ph.D. students
- Research activity for M.S. students

Experimental Modal Analysis

Technical studies and valuations

- analysis of dynamic properties of structural systems
 - experimental support for structural consolidation projects
 - experimental assessment of traffic induced vibrations
 - long term monitoring of dynamic structural behaviour
-

References:

1. Cunha, A. & Caetano, E. (2006) “Experimental Modal Analysis of Civil Engineering Structures”, Sound and Vibration, Vol. 6, No. 40, pp.12-20
2. Bruel&Kjaer - <http://www.bksv.com>
3. Shibabrat Naik, Wrik Mallik “Experimental modal testing for estimating the dynamic properties of a cantilever beam” - <http://fosetonline.org/Thought/CA-77.pdf>