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NON-DESTRUCTIVE LOAD TESTING OF A SINGLE-SPAN, CABLE-STAYED BRIDGE : TESTING DESIGN, INSTRUMENTATION & PRELIMINARY RESULTS

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Motivation & challenges

Key objectives:

- Perform a 'Structural Integrity Verification' study for a cable-stayed bridge
- Generate a library of "*reference datasets*" for research related to SHM of bridges:

  [a]: capture deformation information using heterogeneous, multi-sensor data

  [b]: attempt a complete as possible coverage of all structural elements (*deck, pylons, cables*)

  [c]: rely on various NDT scenarios (*static test, dynamic tests, ambient tests*)

"Umbrella" project:

- National Technical University of Athens:
  - *School of Rural and Surveying Engineering*
  - *School of Civil Engineering*
- University of Thessaly:
  - *Dept. of Mechanical Engineering*
- Attiki Odos SA

Project Specific Objectives & Present Status

Immediate goals:

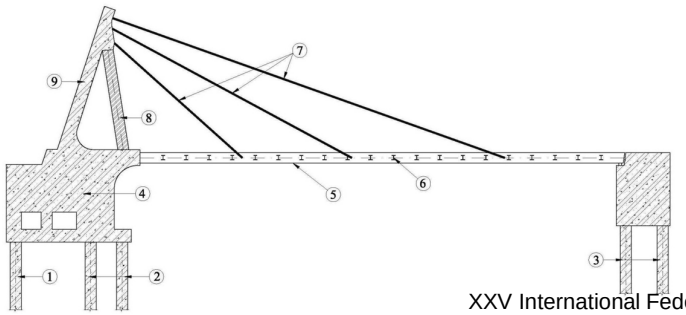
- Assess the structural integrity of the bridge:
  - undertake Operational Modal Analysis tests
    (*natural frequencies, mode shapes, damping factors, etc.*)
  - perform FEM update
    (*validate & calibrate existing FE models*)

At a next stage, the plan is:

- Create the opportunity to undertake research in various fields related to SHM, including:
  - an assessment of the potential sensors used for SHM (accuracy, reliability, etc.)
  - optimal sensor placement studies (cost / benefit studies)
  - an investigation of data fusion techniques for SHM
  - damage detection modeling studies

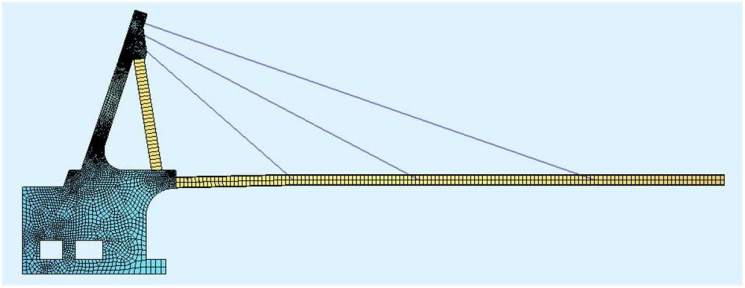
Description of test bridge: "Pallini" cable-stayed bridge, Greece

- roadway, cable-stayed bridge
- overpasses the highway connecting Athens to the int. airport
- consists of steel-composite deck, double-plane cables, two Λ-shaped pylons

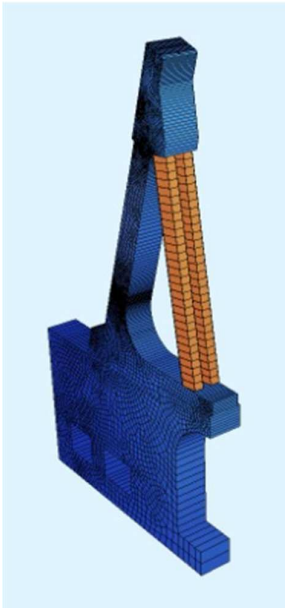


feature	*value*
suspended span	58.3 m
variable width	13.4 m - 16.5 m
pylons height	18.5 m
cables	3 on each side
traffic lanes	two
pedestrian walkways	in both sides

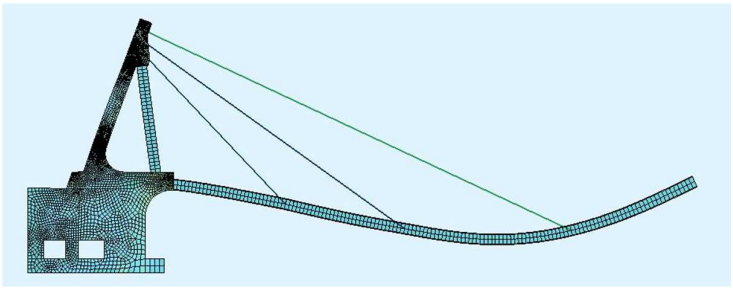
Preliminary analytical models of the bridge



finite element mesh model of bridge



finite element mesh of pylon



vertical displacements of deck under maximum static loads

Classification of NDT types

Static load tests:

- verify the structural integrity of the structure through FEM updating,
- estimate maximum “allowable” static loads
- monitoring observations are taken while a heavy vehicle stands at certain locations

Dynamic load tests:

- assess the actual behavior of bridge due to heavy vehicle passes through the bridge (*run at variable speeds / through obstacles, etc.*)
- estimate natural frequencies, damping factors, dynamic amplification factors, etc.

Ambient vibration tests:

- study the actual behavior of bridge under normal traffic conditions, wind, etc.
- estimate natural frequencies, mode shapes of bridge, etc.

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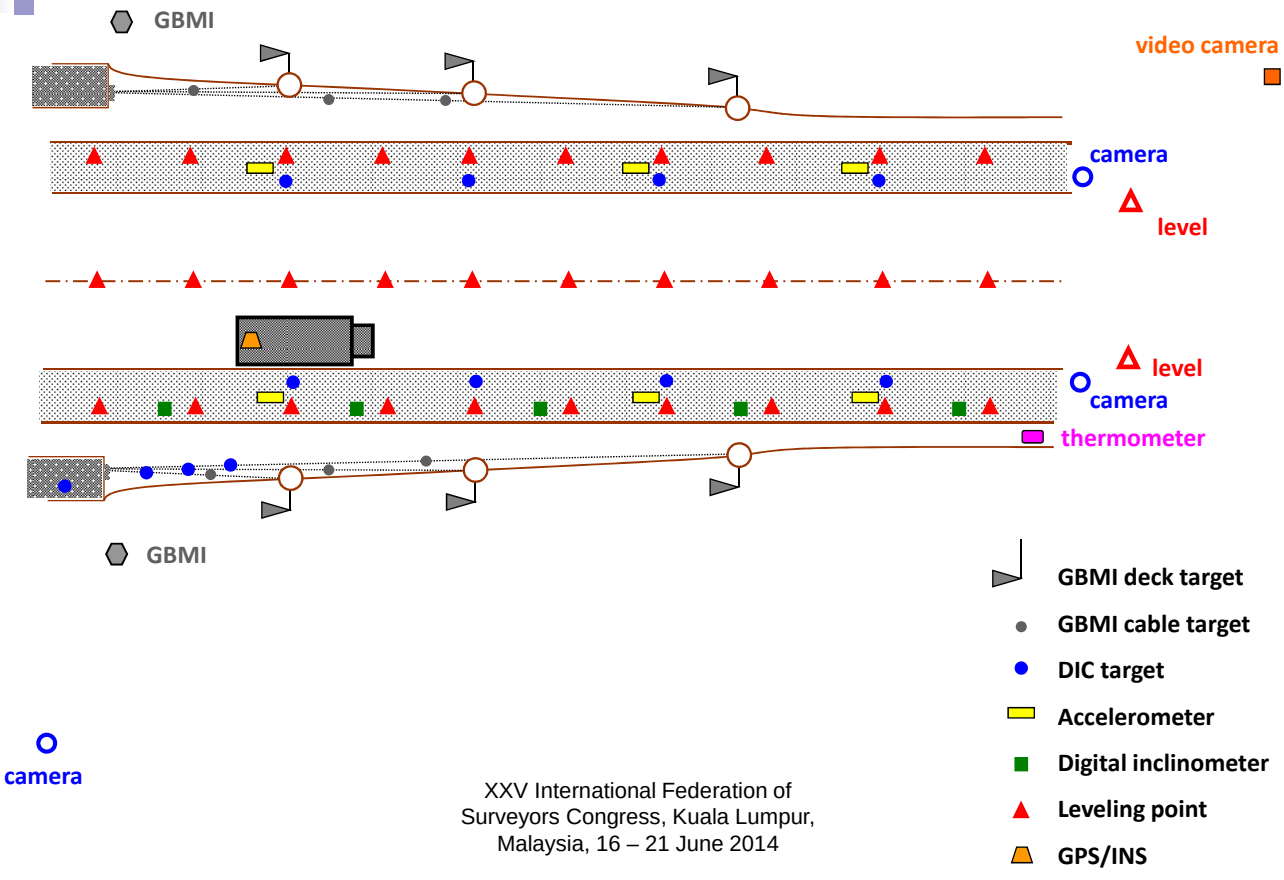
Observation methods, sensor types & sensor distribution



Observation scenarios classification & sensor types used

element → / ↓ mode	DECK					CABLES			PYLON		TRUCK	OTHER	
	PL	DIN	GBMI	ACC	DIC	GBMI	ACC	DIC	GBMI	DIC	GPS/INS	T	Video
STATIC	X	X	X		X	X		X	X	X	X	X	X
DYNAMIC			X	X	X	X	X	X	X	X	X	X	X
AMBIENT			X	X	X	X	X	X	X			X	X

Sensor types:

PL : precise leveling

DIN : digital inclinometers

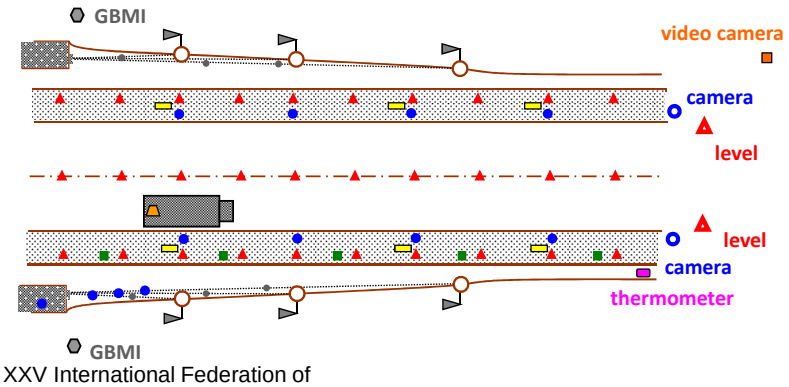
GBMI : ground-based microwave interferometry

ACC : accelerometer

DIC : digital image correlation

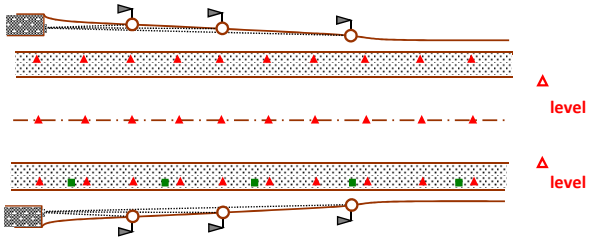
T : temperature

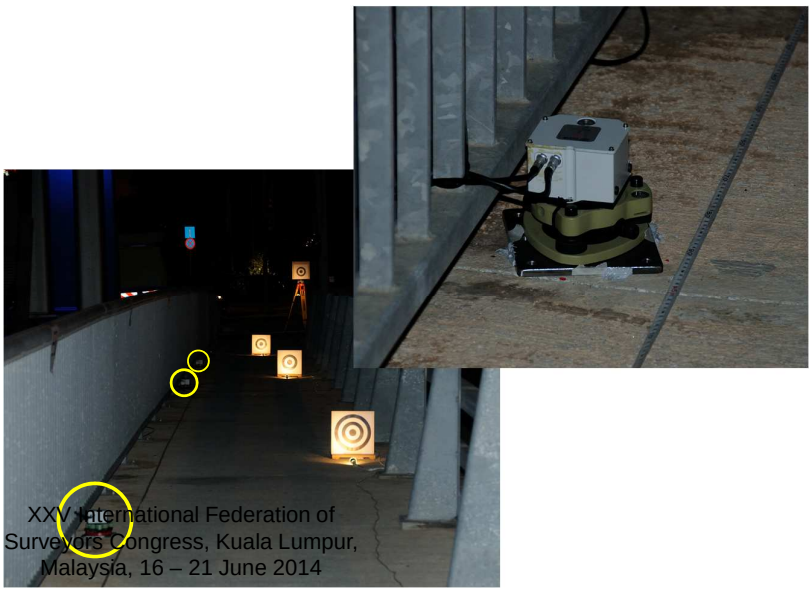
Video : video camera



Field data campaigns: precise leveling & digital inclinometers

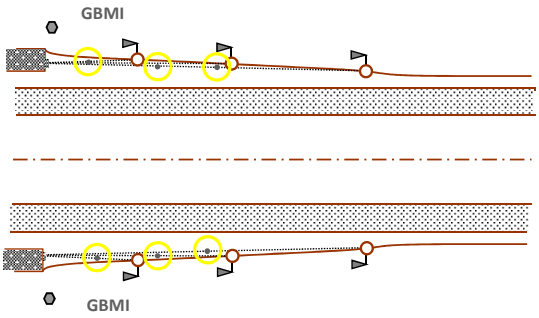
- 30 precise leveling points along three lines
- 5 digital inclinometers (*Leica Nivel 220*)
- all field campaigns at night time

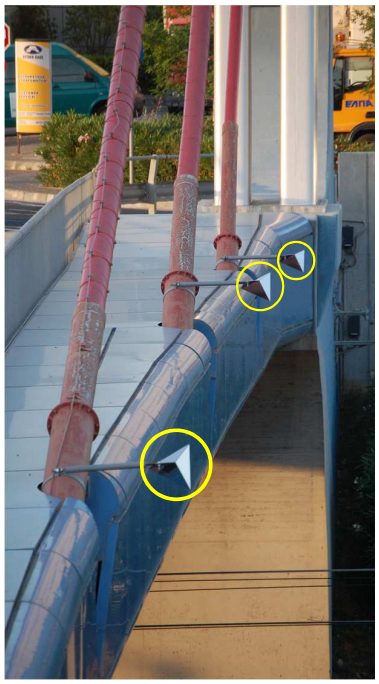




Field data campaigns: ground-based microwave interferometry

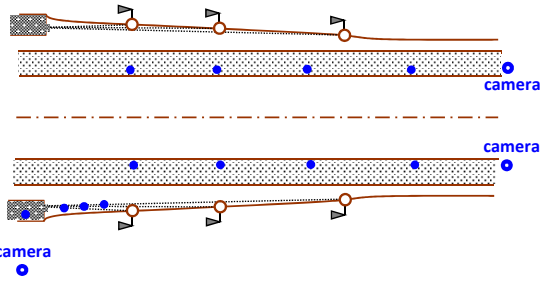
- GBMI (*IBIS-S*)
- corner reflectors at all cable anchor points
- single points of each of six cables

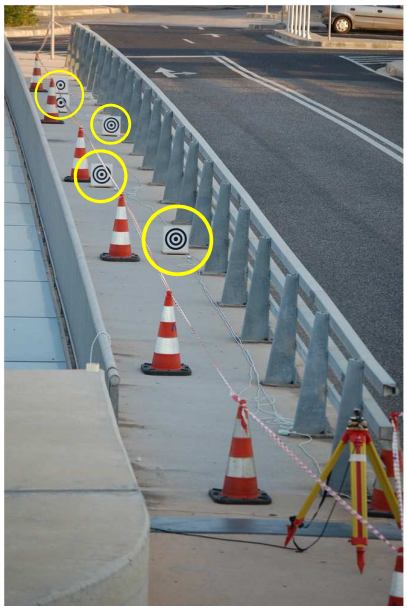


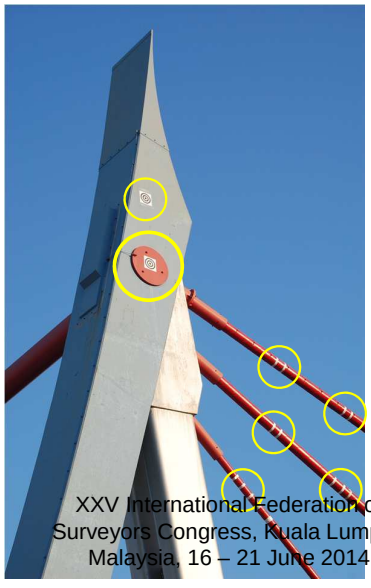


Field data campaigns: digital image correlation

- digital image correlation (*Video Gauge*)
- combines two cameras
- tested various types of ring targets
- put in place lighting system for night measurements

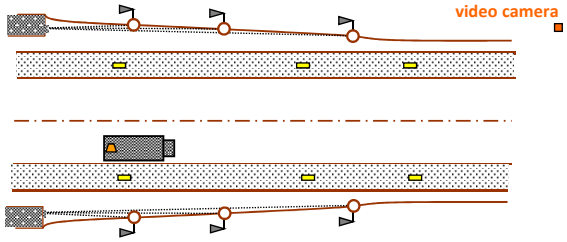


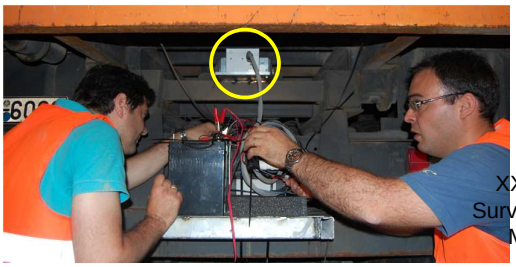




Field data campaigns: accelerometers & truck kinematics recording

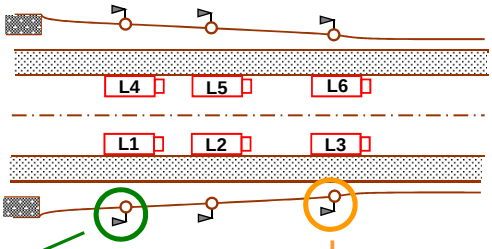
- truck vehicle kinematics (*NovAtel SPAN system*)
- apply several modifications on vehicle
- digital thermometer
- video camera recording

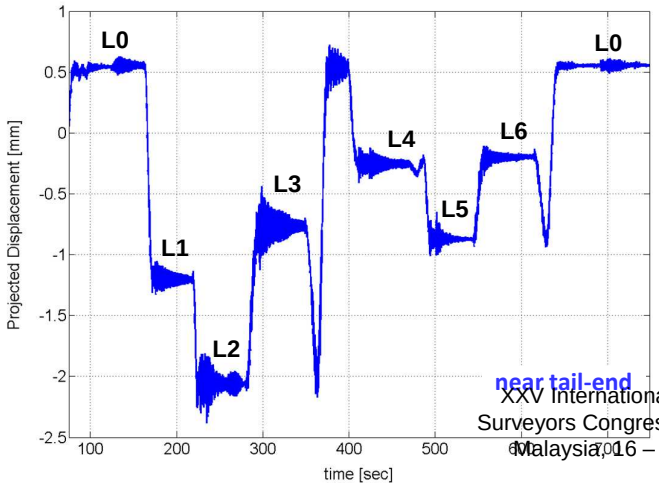


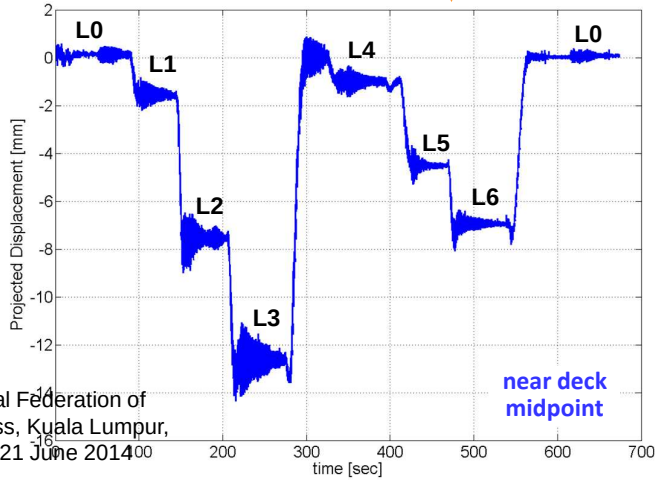


GBMI deck displacements – long & short cable anchor points

- the vertical displacements of the deck by the short & long cable anchor points using GBMI
- gradually increasing settlement pattern corresponds to truck location
- The deck midpoint deck (long cable anchor point) shows larger displacements
- dynamic part of static measurements

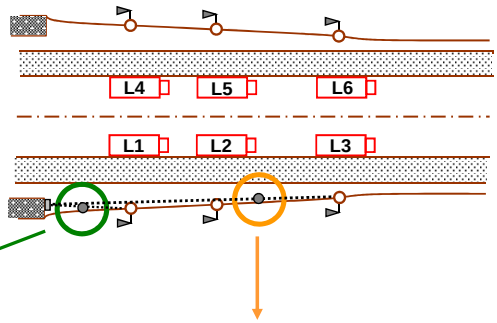


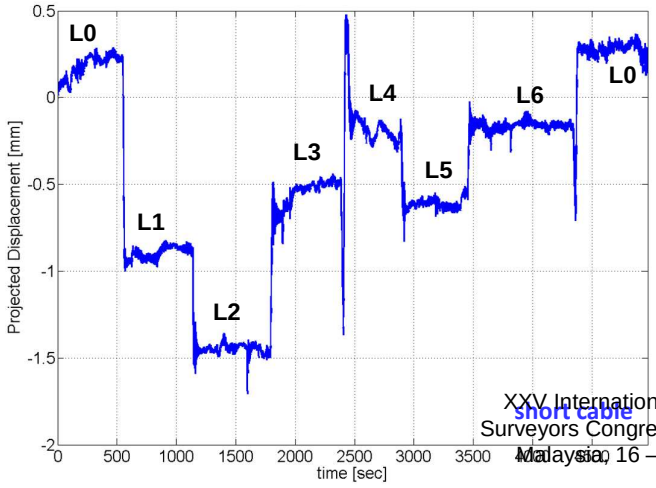


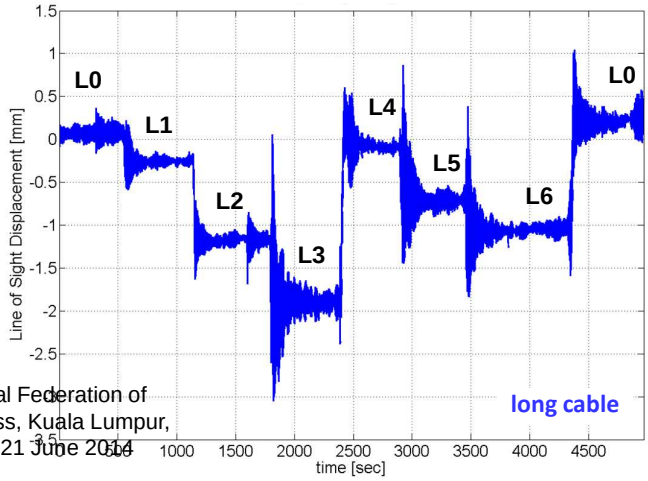


GBMI cable displacements – long & short cables

- midpoint displacements of the short and long cables derived using the GBMI system
- measured displacements follow the loading pattern
- the long cable produces larger displacements
- the long cable displacements contains a clear dynamic part

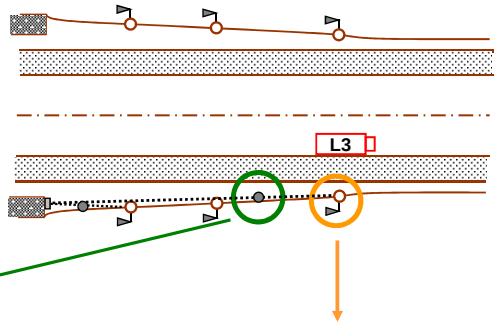


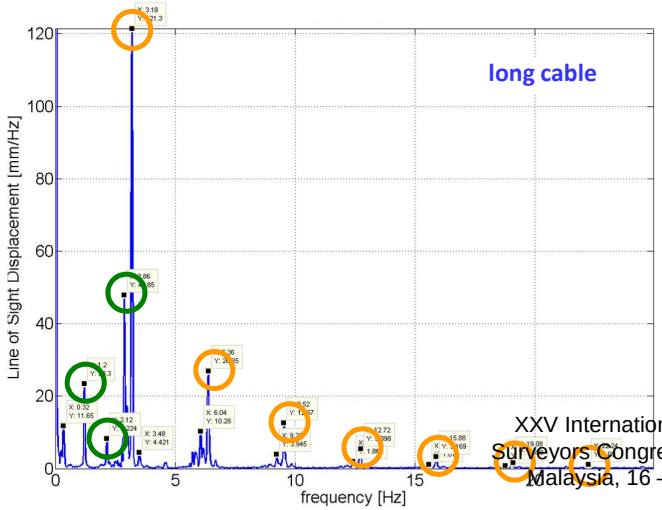


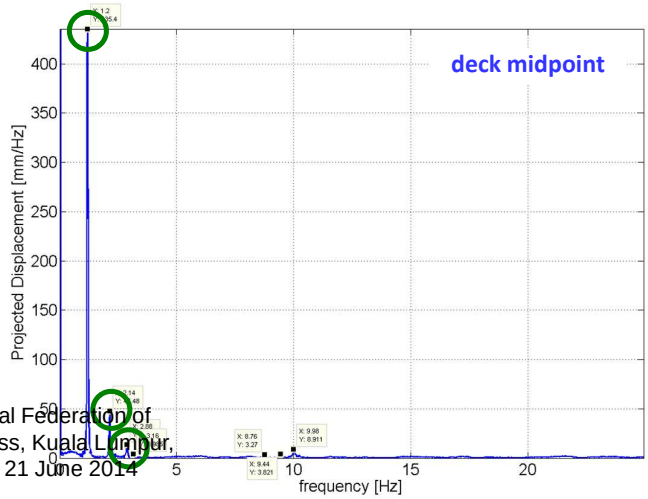


GBMI frequency response – deck & cable

- show the long cable and deck frequency spectra
- three dominant frequencies are found for the deck
- these also appear in the cable spectra
- higher frequencies refer to cable dominant frequencies with harmonics at regular intervals







Conclusions and future work

we are just at the beginning of this research effort …

immediate goals:

- undertake further processing of the static tests
- too many data in place from different sensors and test scenarios
- emphasis on comparisons between different sensor recordings
- construction of FEM update

at a next stage:

- start working on the design of the dynamic & ambient tests
- refine our research objectives
- combine this work with other research projects of civil & mechanical engineers