MONASH University

MONASH
Civil Engineering
Department

Research in SHM and damage detection for civil structures at Monash University

Dr Colin Caprani
Ehsan Ahmadi
Ruiqi Guan

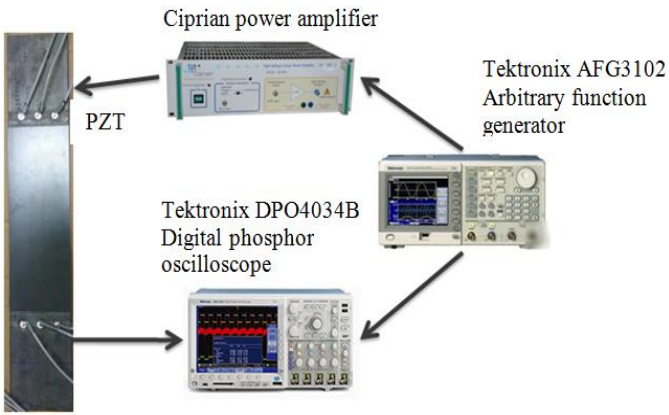
20 November 2016

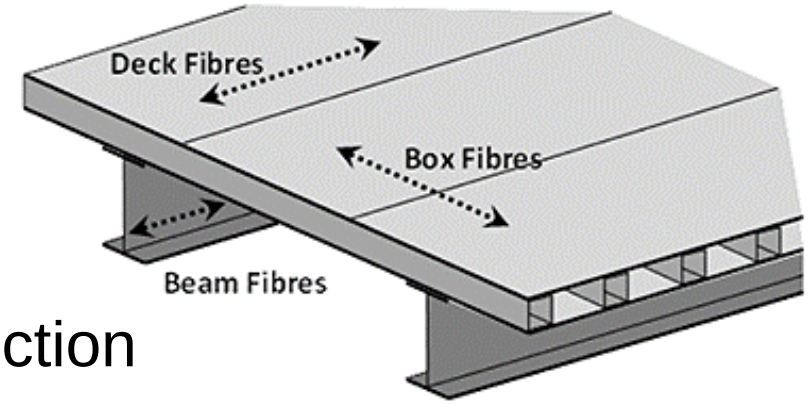
GROUP OF EIGHT AUSTRALIA

SHM Capabilities

Facilities

- Vibration excitation and monitoring
- Laser Doppler Vibrometer
- Human loading measurement
- Biomechanical measurements
- Guided Lamb waves
- Bridge sensor networks
- Nonlinear ultrasonics
- Weigh-In-Motion
- ARAMIS strain measurement
- Pipe burst monitoring and prediction





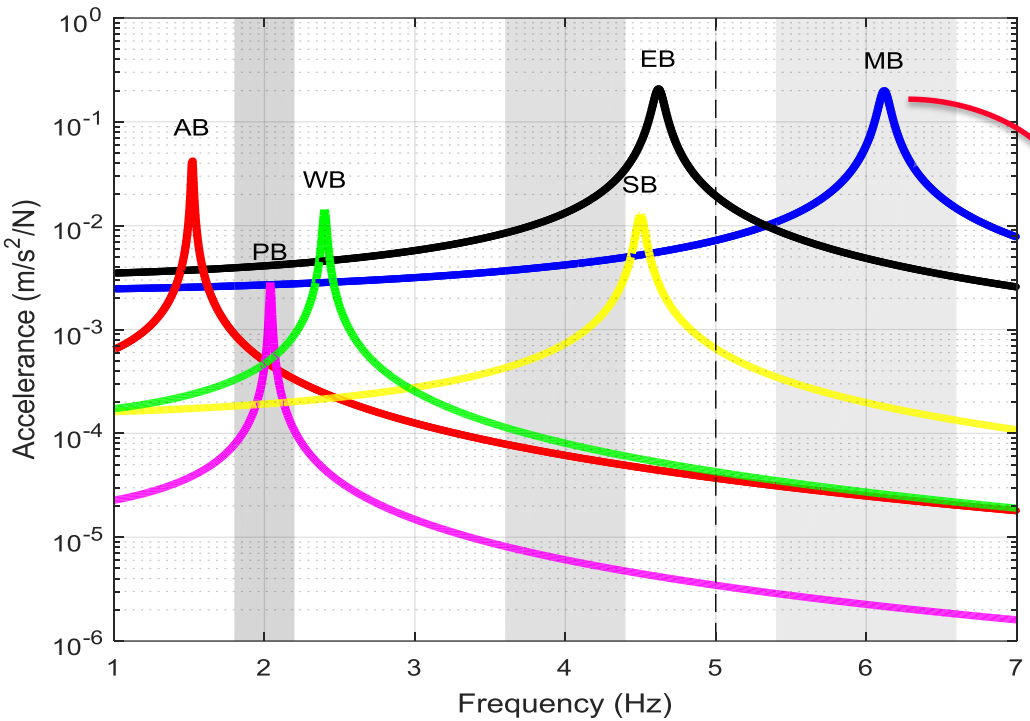
SHM for Human-Induced Vibration

Motivation and the Monash Footbridge

GFRP structures have:

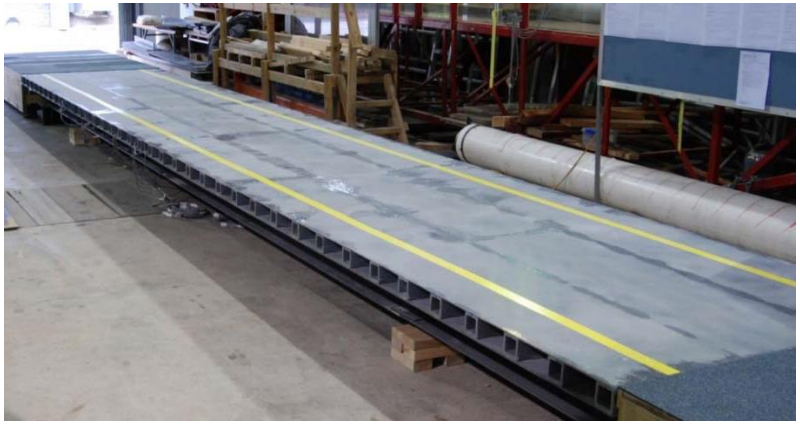
- Low mass density
- High stiffness
- Low damping

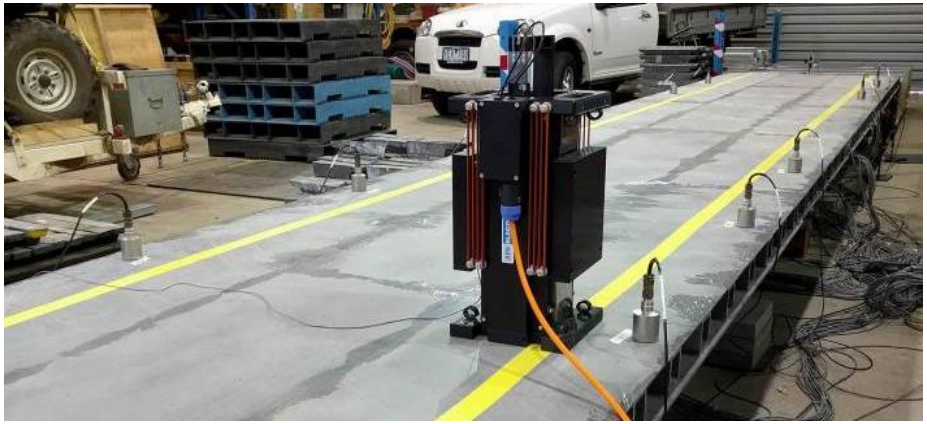
Susceptible to human-induced vibration



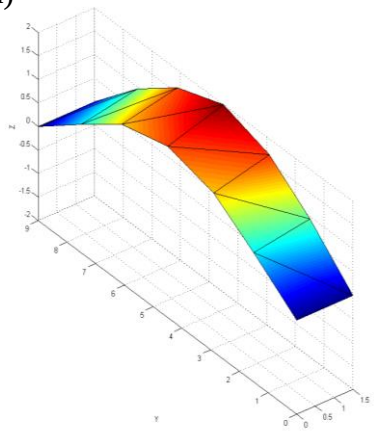
Monash GFRP footbridge

Experimental Modal Analysis (EMA) of the Monash Footbridge

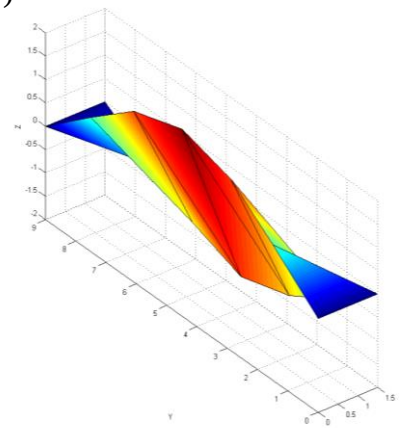




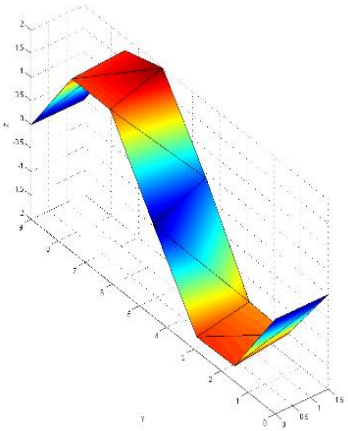
a)



b)

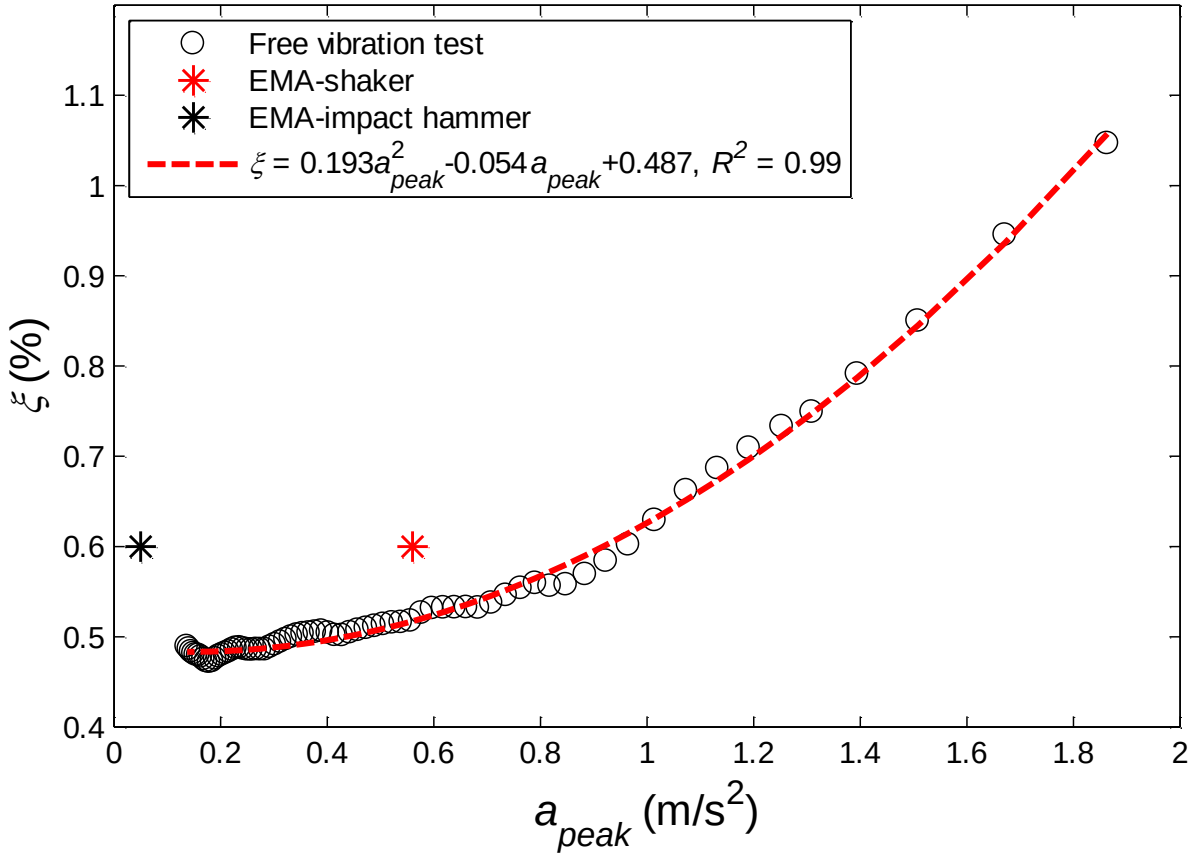


c)

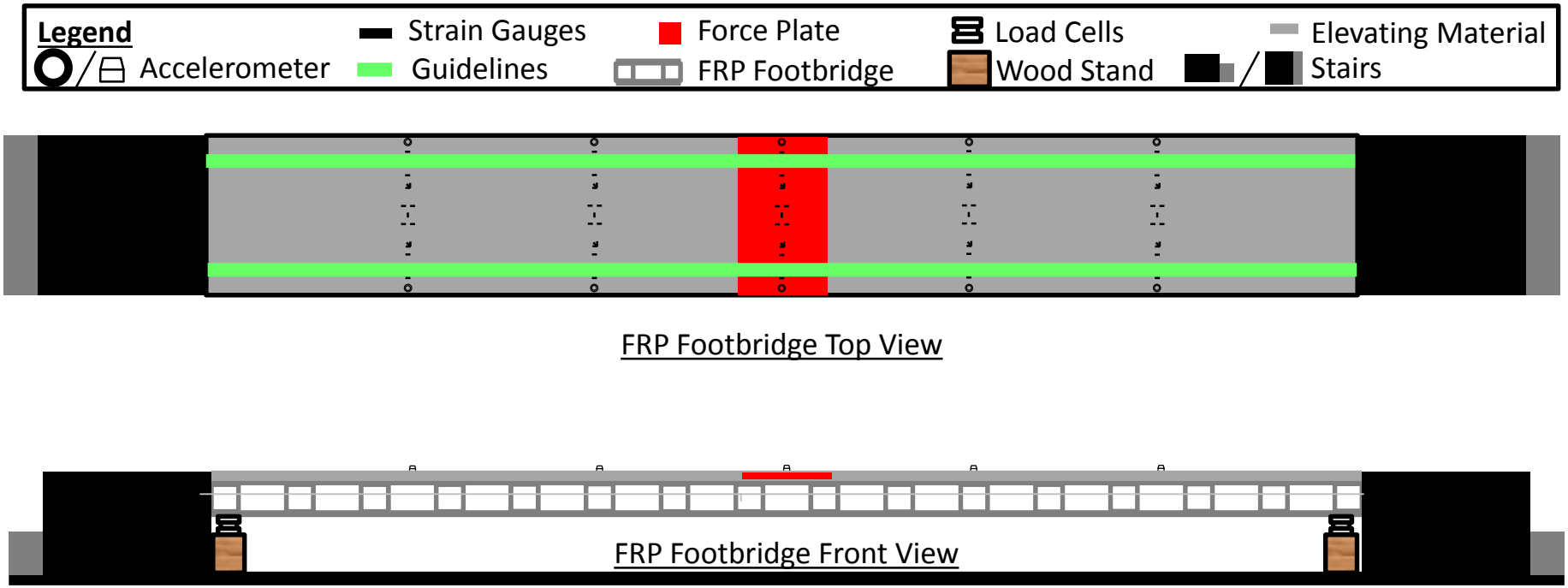


(a) f_1 = 5.86 Hz, ξ_1=0.62 (b) f_2 = 10.02, ξ_2=0.97 (c) f_3 = 18.14 Hz, ξ_1=0.71

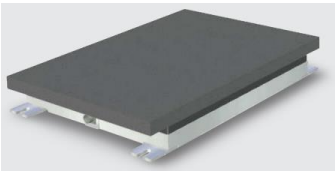
EMA and Free vibration test



Footbridge instrumentation



Dynamic test setup



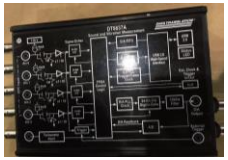
Force Plate

Accelerometer

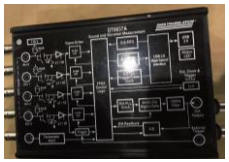
Tekscan Sensor

F-Scan DAQ

Load Cells

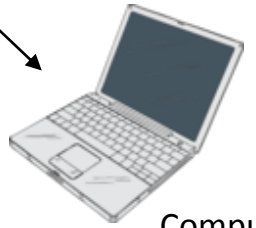


DAQ device 1



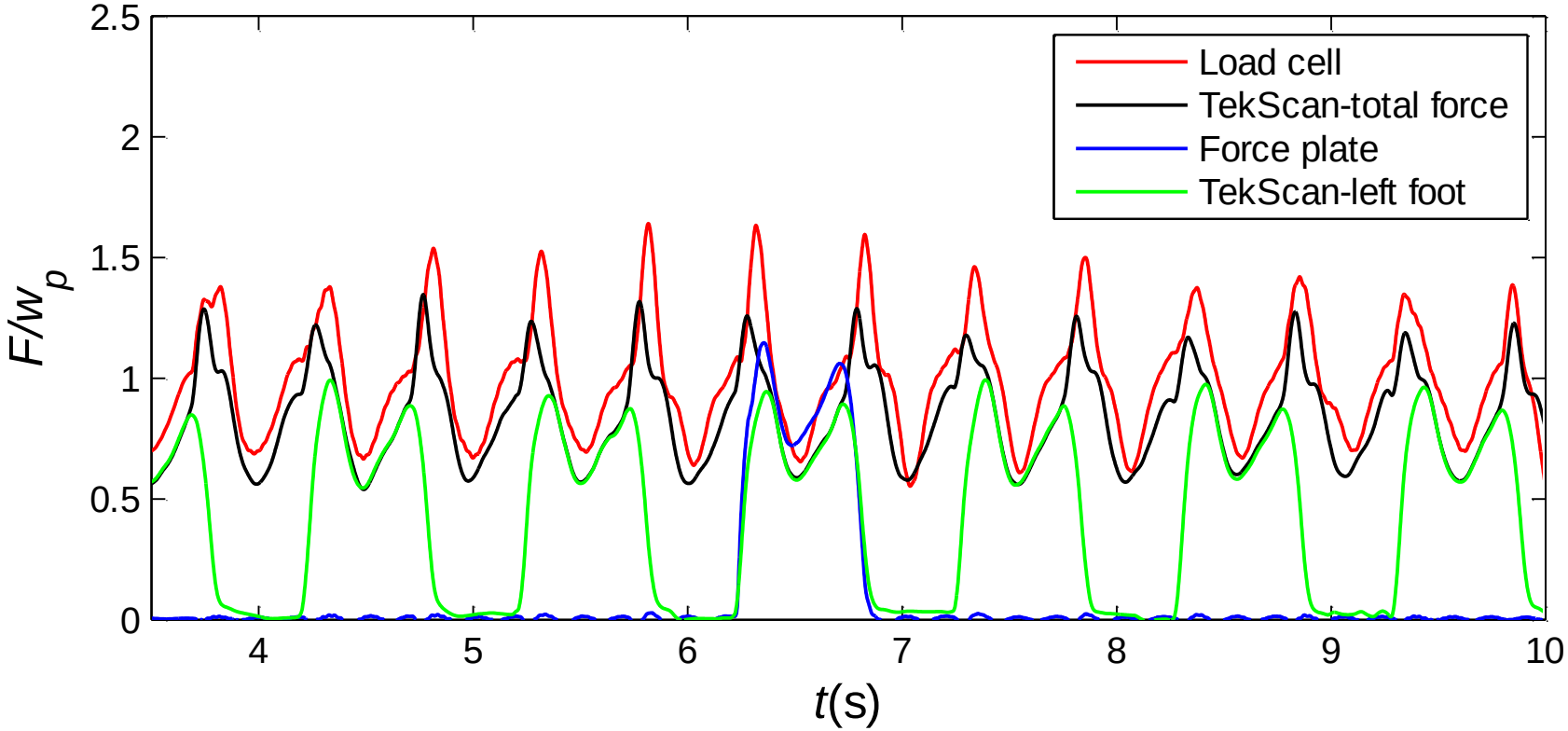
DAQ device 2

Wireless Master Trigger

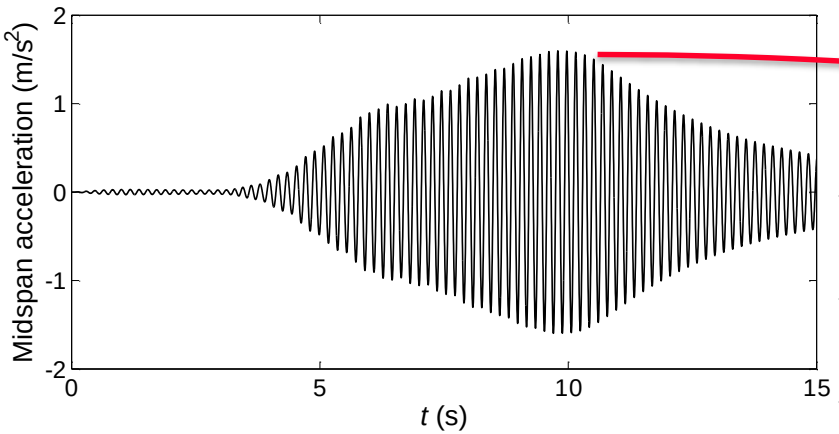


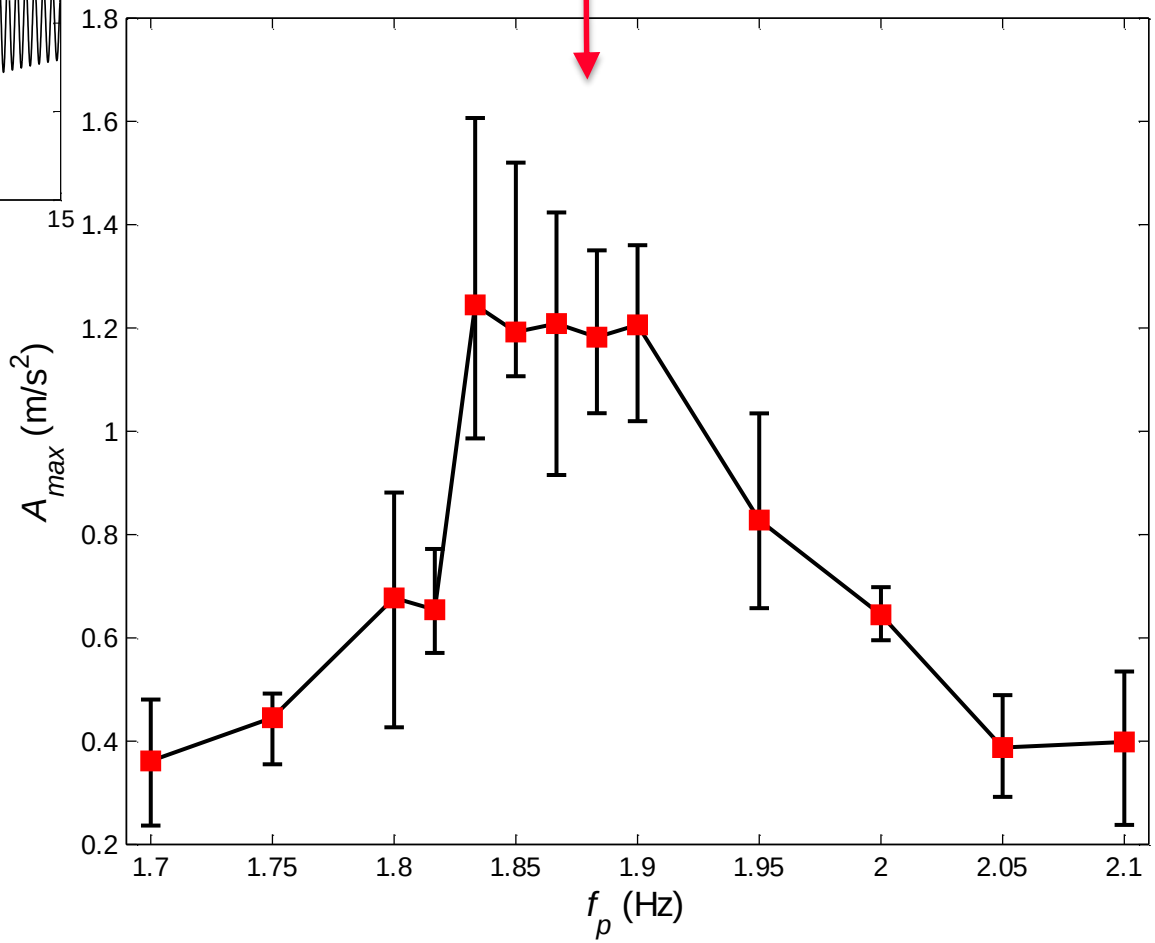
Computer

Measured force signals



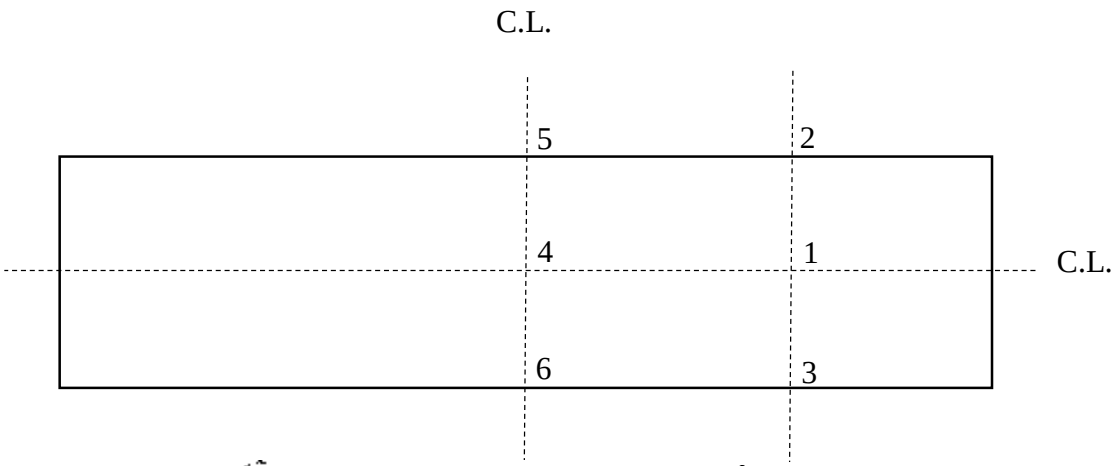
Measured acceleration signal





Interestingly…

Experimental Modal Analysis (Electrodynamic Shaker)

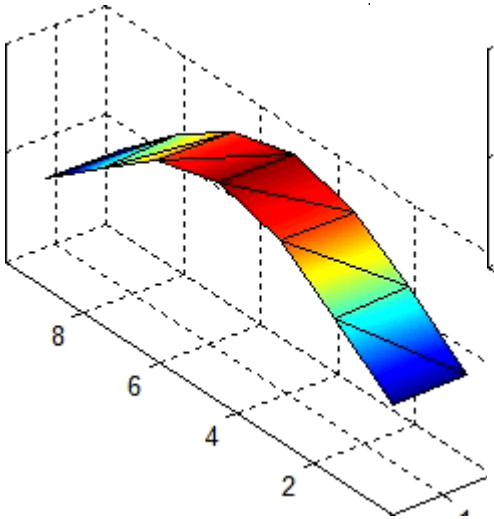


Structural Health Problem

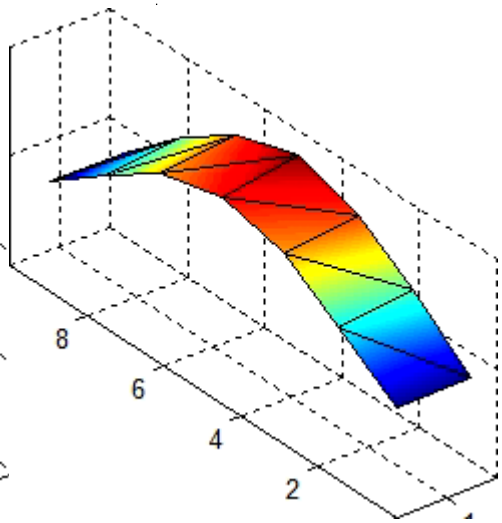
Asymmetric Mode Shape

Possible causes:

- Adhesive Bond quality
- Support stiffness
- I-beam girder stiffness



Shaker @ *6*



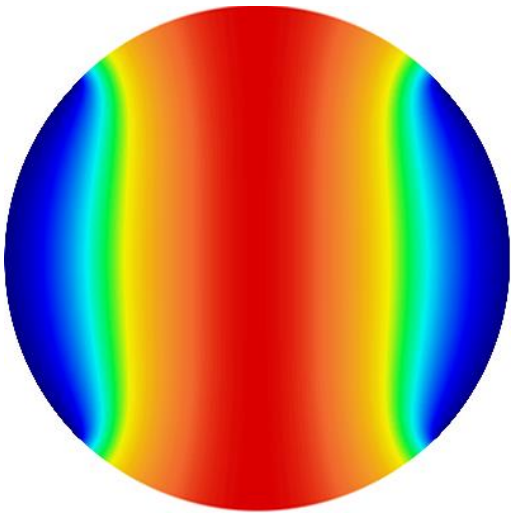
Shaker @ *4*

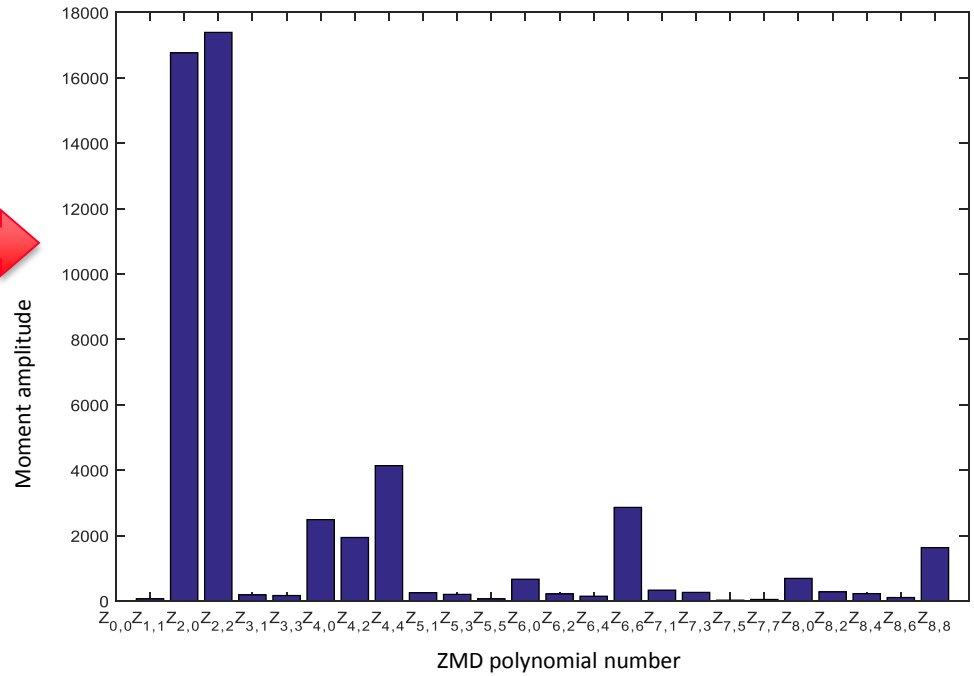
Zernike Moment Descriptors

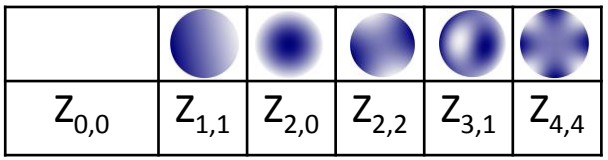
Orthogonal functions, defined on the unit circle

- $Z_{nm} = \iint_{0 \le x^2+y^2 \le 1} I(x,y) V^*_{n,m}(x,y)\,dx\,dy$

Features of Mode shape 1



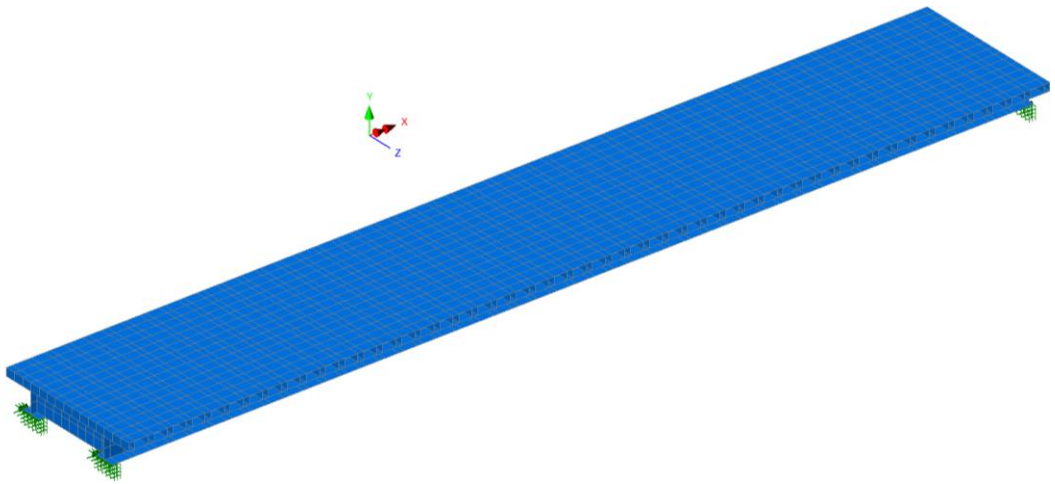




ZMD + FE Model Updating Example

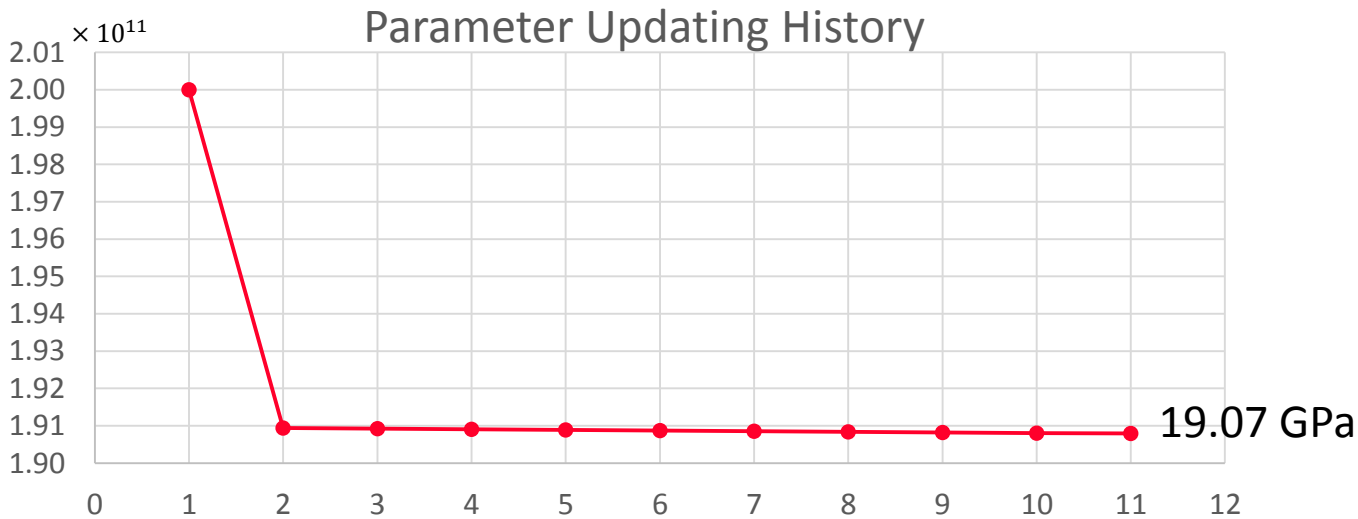
Parameter selection

- Beam stiffness E_1 = 20 GPa
- Spring support stiffness, k_s



Target responses

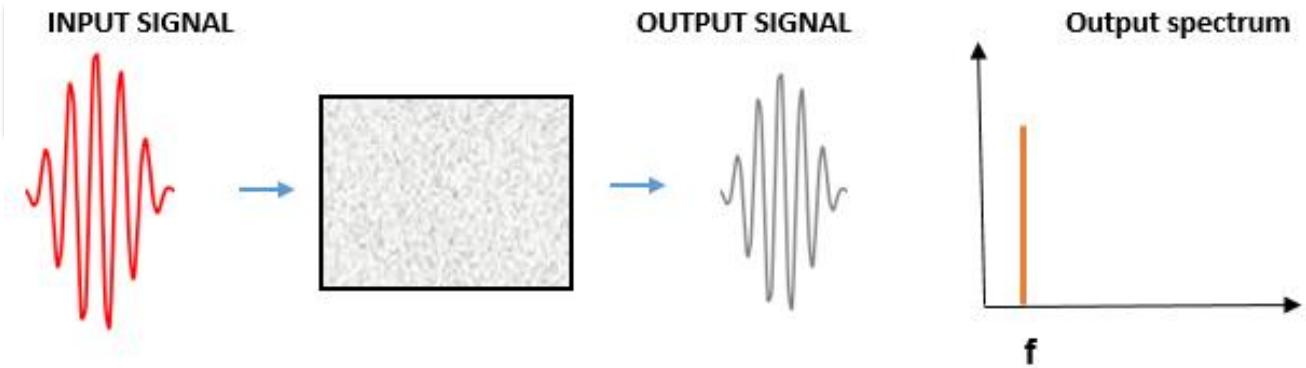
- Mode shapes → **ZMD**
- Natural Frequencies

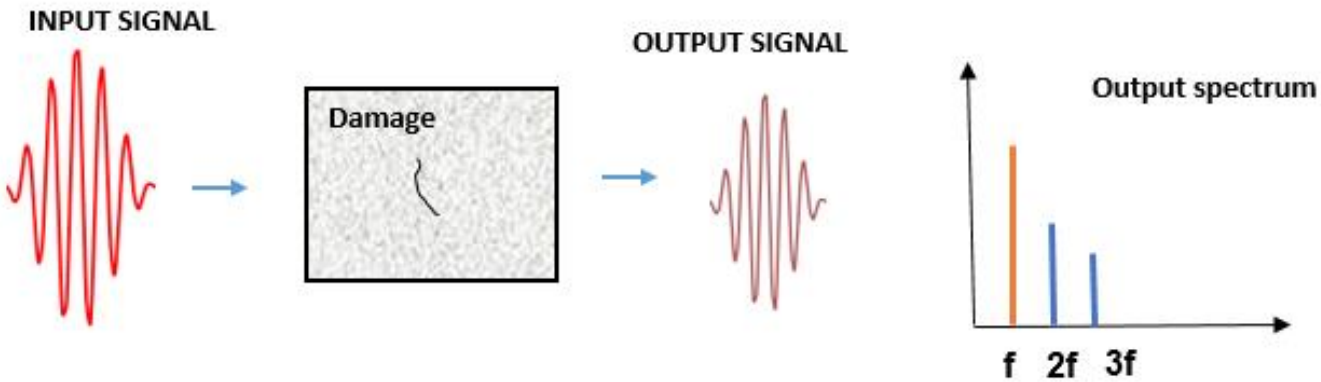


MONASH University

Damage Detection Using Guided Waves

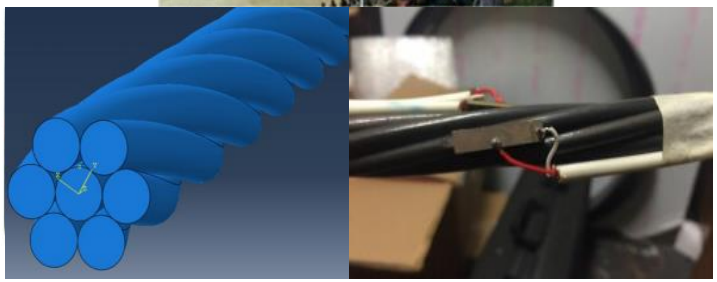
Background of nonlinear guided waves



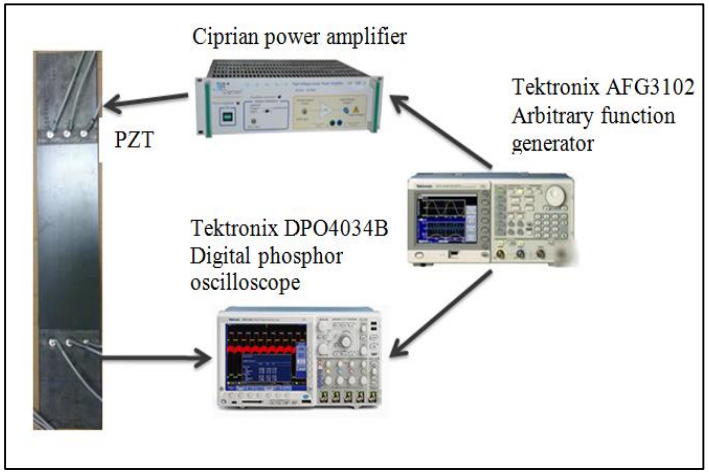


$$\beta = \frac{A_2}{{A_1}^2}$$

Nonlinear guided waves detection in metal structures



- Detect Loss of cable load in multi-wire cables

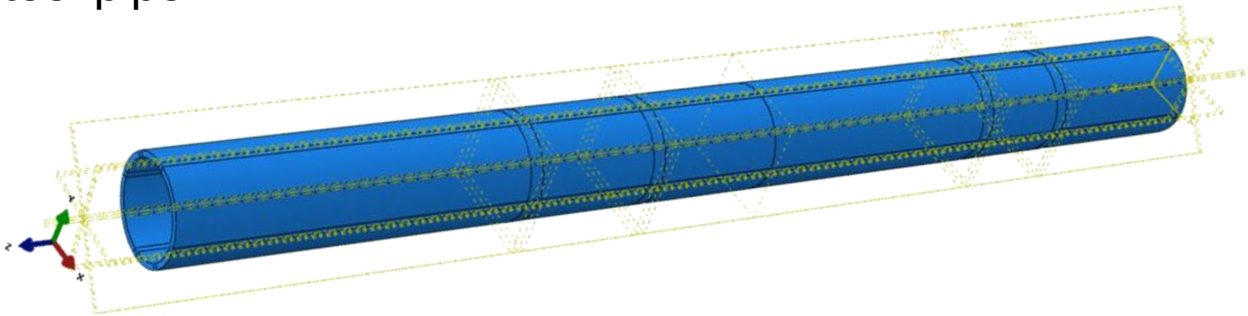


- Detect fatigue cracks in CFRP-reinforced steel plates

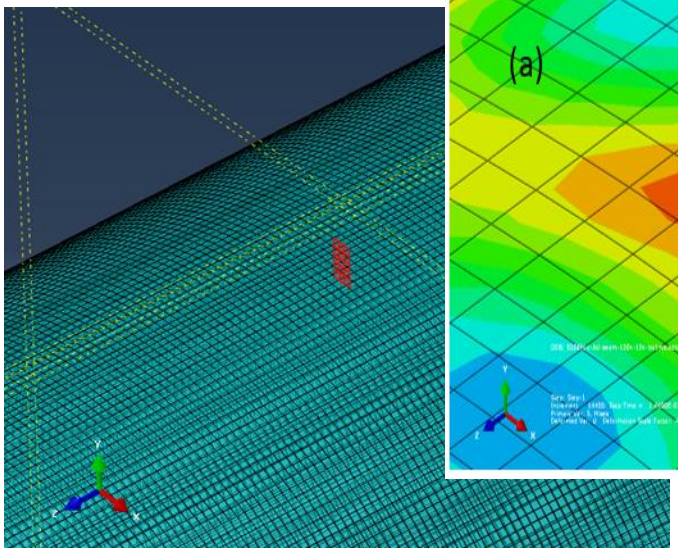
- Detect fatigue cracks in steel pipes

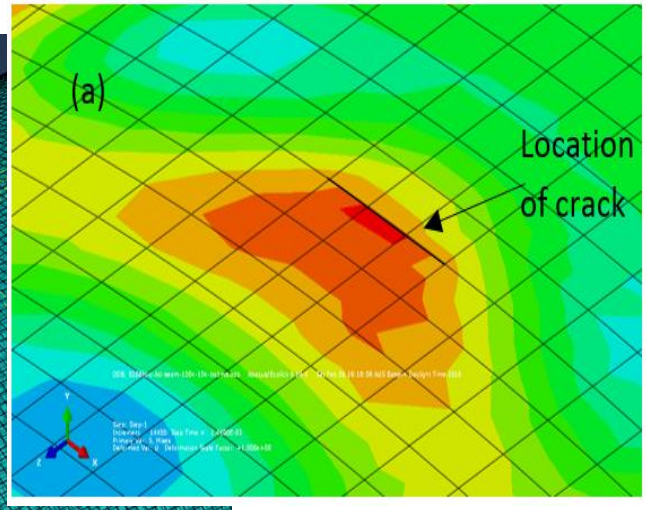
Nonlinear guided waves in steel pipe

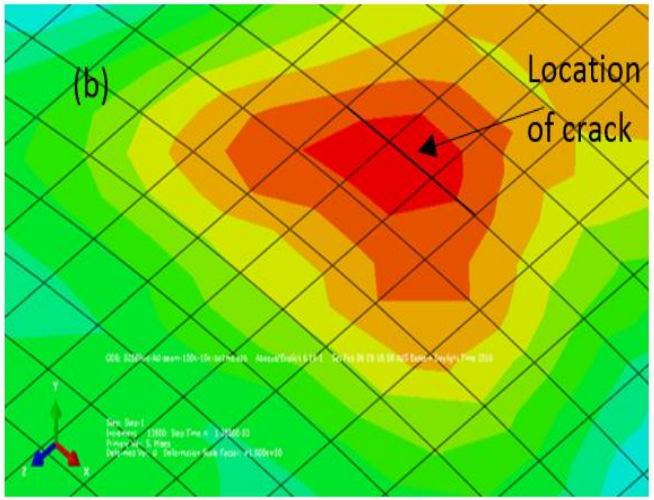
Simulation work in steel pipe



- Fatigue crack



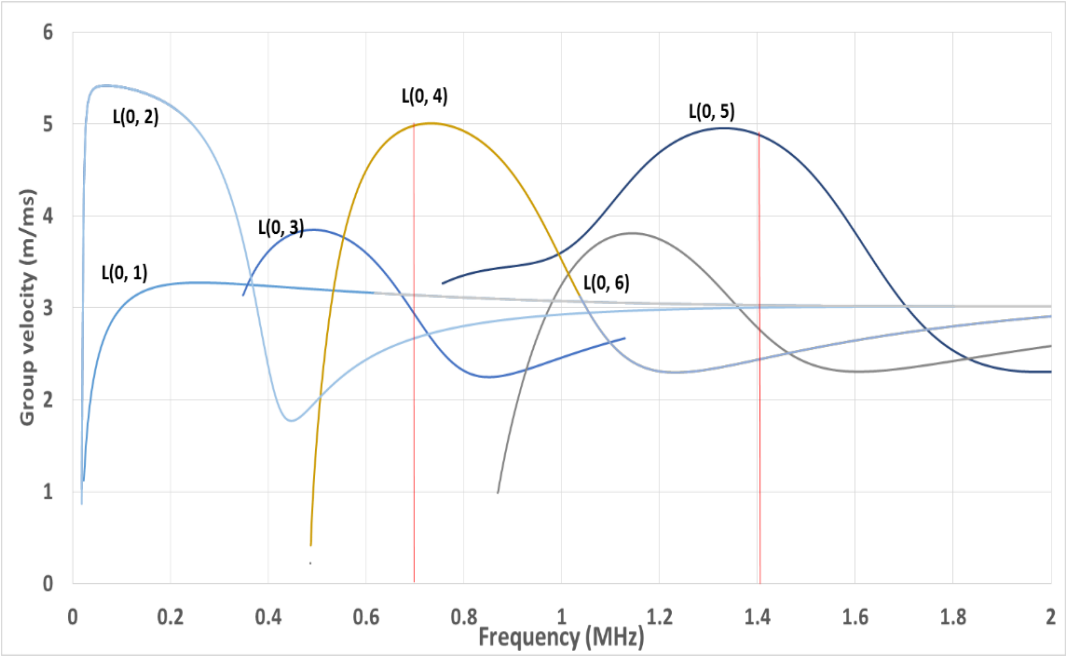


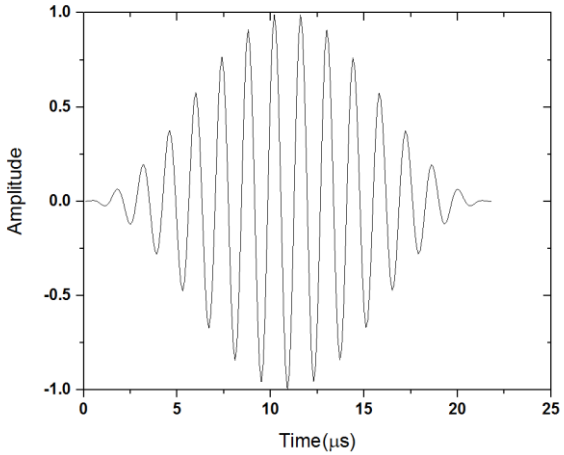


Nonlinear guided waves in steel pipe

- Mode selection and input signal

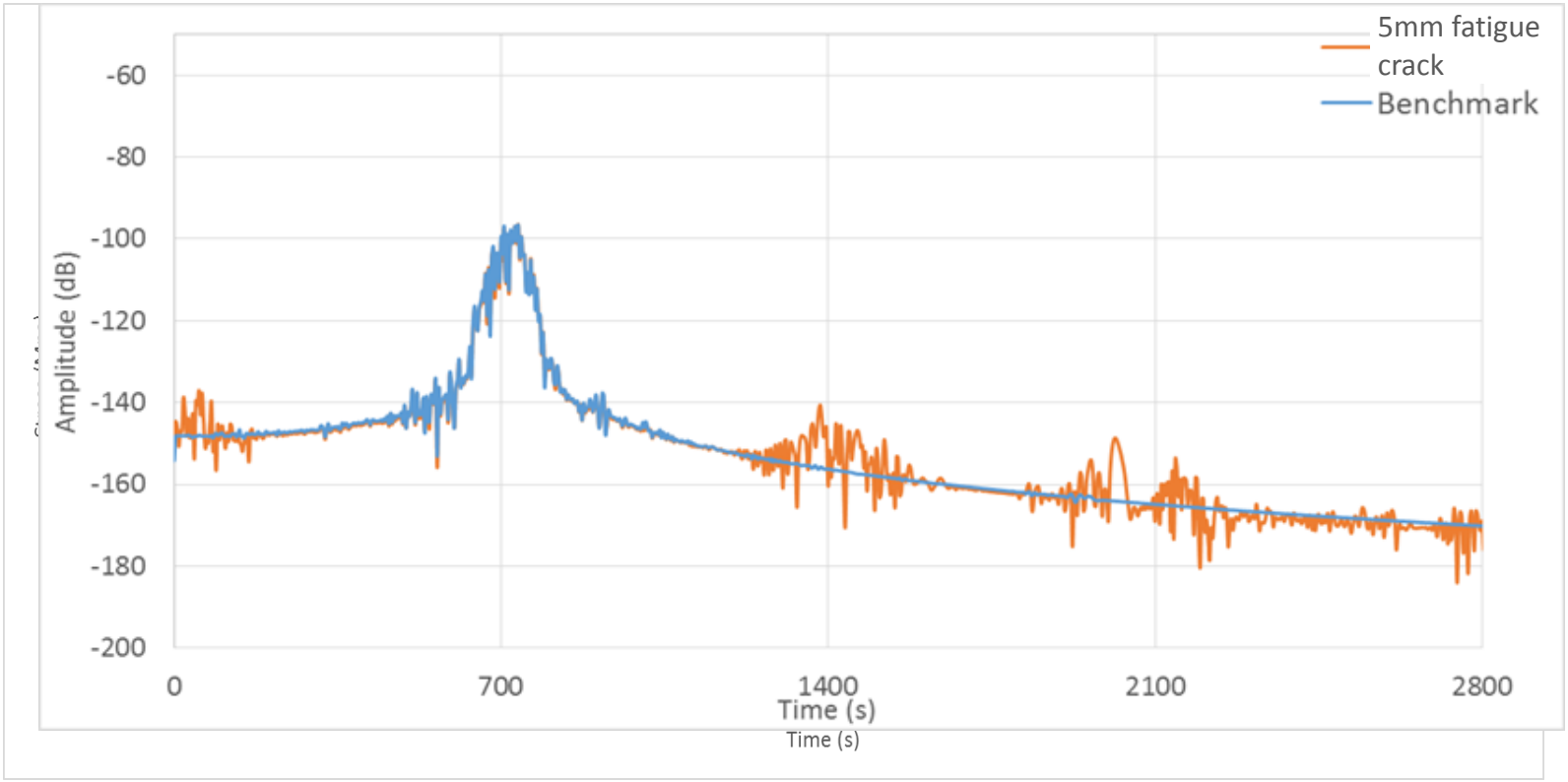
  L(0,4) and L(0,5); 15.5cs tone burst signal at 0.71MHz





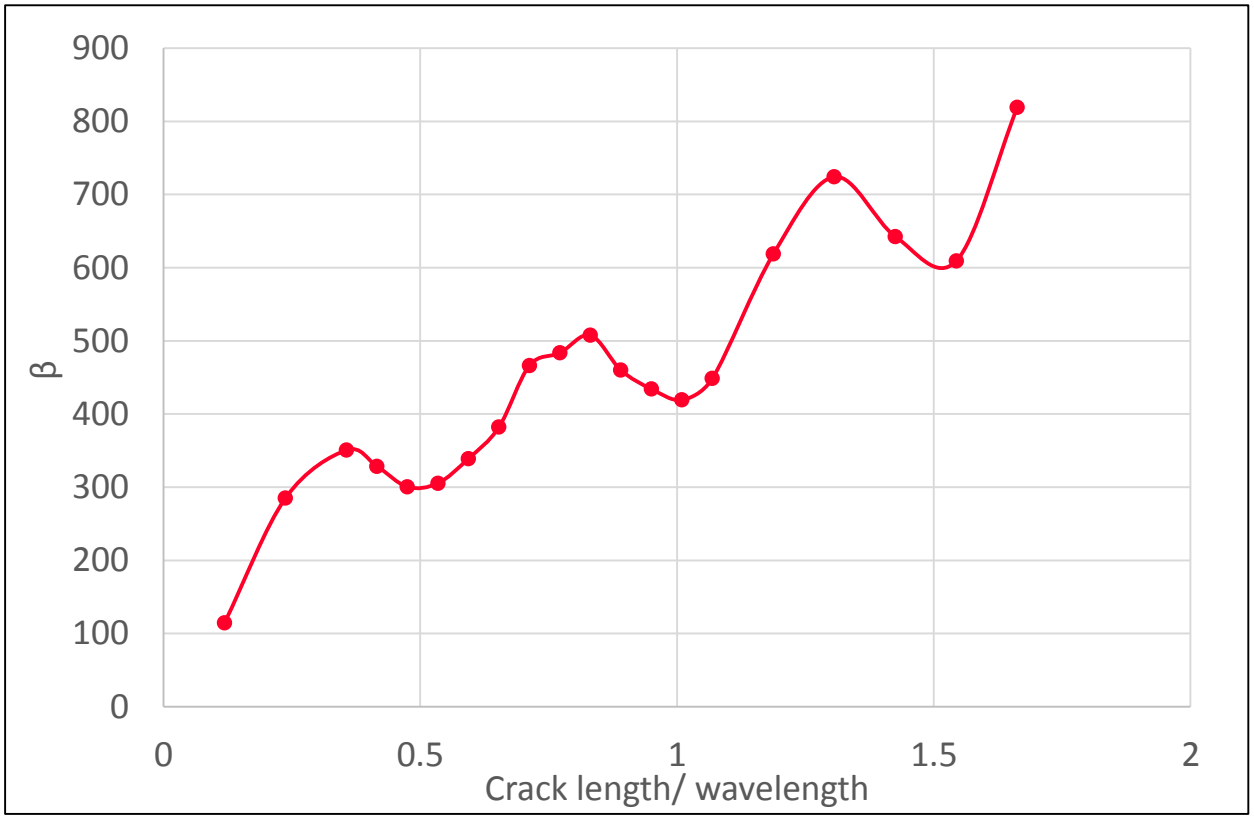
Nonlinear guided waves in steel pipe

Simulation result



Nonlinear guided waves in steel pipe

Simulation result



MONASH University

Thank you for your attention!