EXCHANGE-RISK WORKSHOP

HOCHTIEF ENGINEERING

INTERACTION EFFECTS BETWEEN BUILDINGS AND UNDERGROUND LIFELINE STRUCTURES UNDER SEISMIC EXCITATION

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Secondments at HOCHTIEF

- **Xenia Karatzia, University of Bristol**

  8 months (August 2017- April 2018)

  Topic: *Interaction effects between buildings and underground lifeline structures under seismic excitation*

- **???, University of Patras**

  6 months (tbd 2018/2019)

  Topic: tbd, continuation of topic above?

RESEARCH OBJECTIVE

To investigate the effect of massive rigid structures on relatively soft underground structures (pipelines / channels) under seismic excitation

Assumptions

- ❑Linear elastic analysis
- ❑No change at the stress field close to the lifeline e.g. due to large excavation of soil
- ❑The construction method may do not affect substantially the stress field (bored pile walls – less disruption to the adjacent soil, no vibration)

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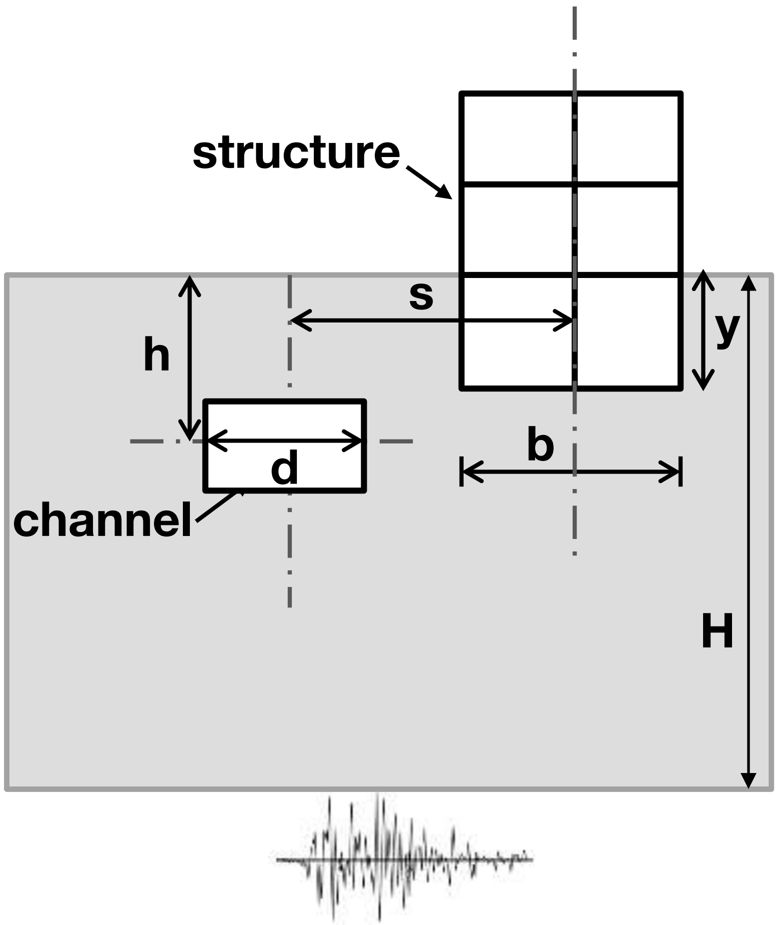
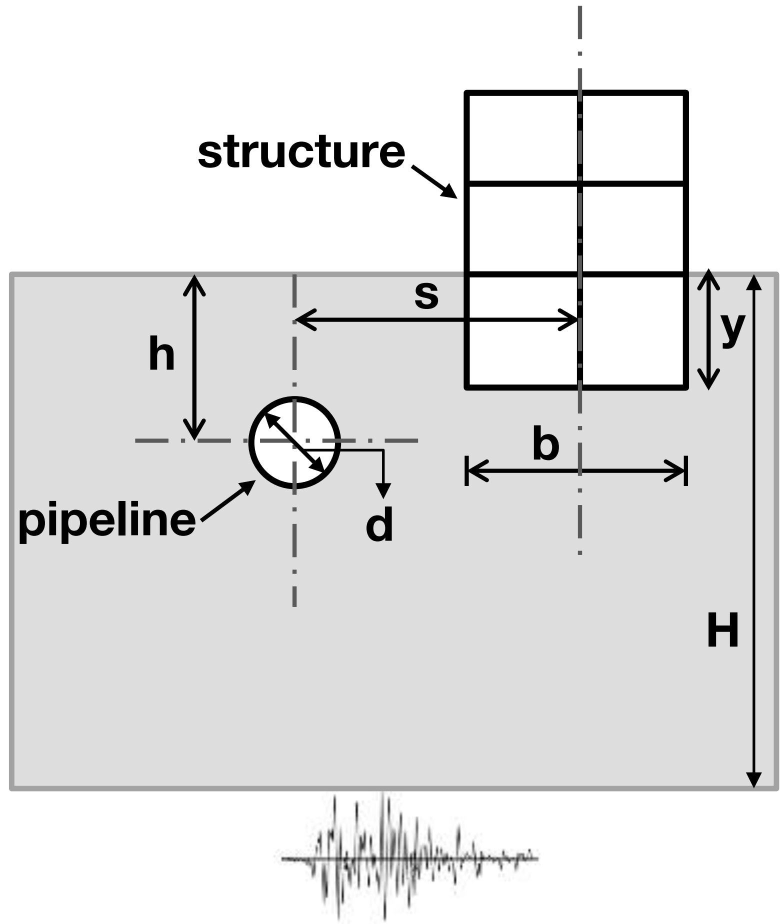
PROBLEM DEFINITION

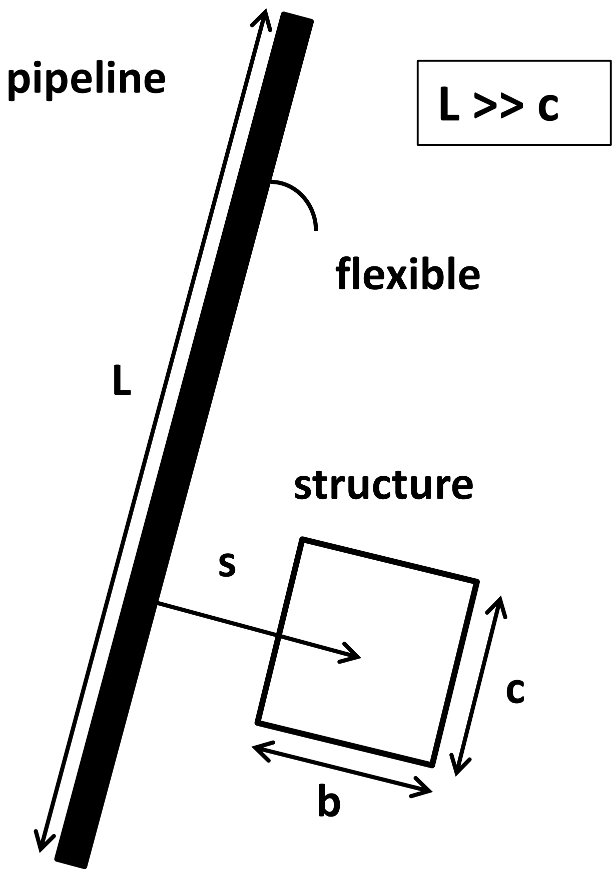
Configuration 1

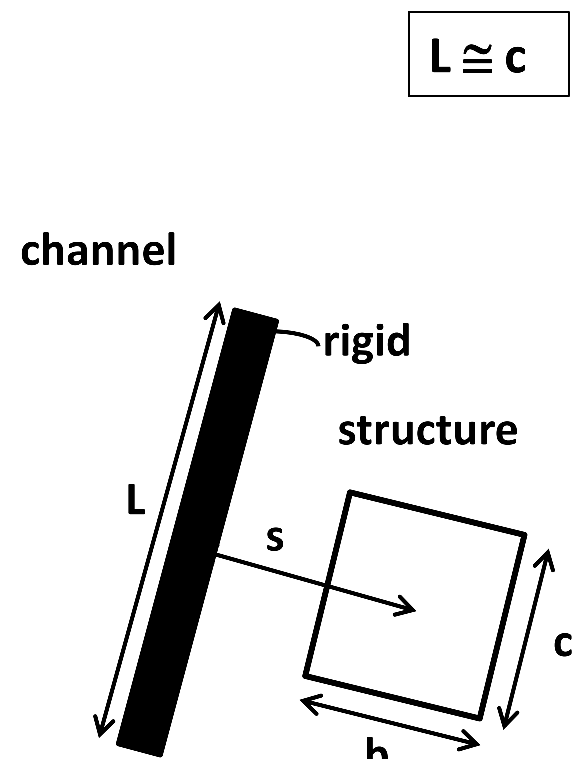


Configuration 2



PROBLEM DEFINITION





PROBLEM DEFINITION

PARAMETERS INVESTIGATED:

- Dimensionless length of lifeline (L / d)
- Dimensionless distance between the two structures (s / d)
- Burial depth of lifeline (h / d)
- Embedment depth of the building (y / d)
- Geometry of the foundation of the building (b / d and b / c)
- Eccentricity between the two structures (e / d) (in case of channel)
- Resonance effect between structure and soil (T_1 / T_{str})
- Normalized excitation frequency (ω / ω_1)

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PROPOSED METHODOLOGY

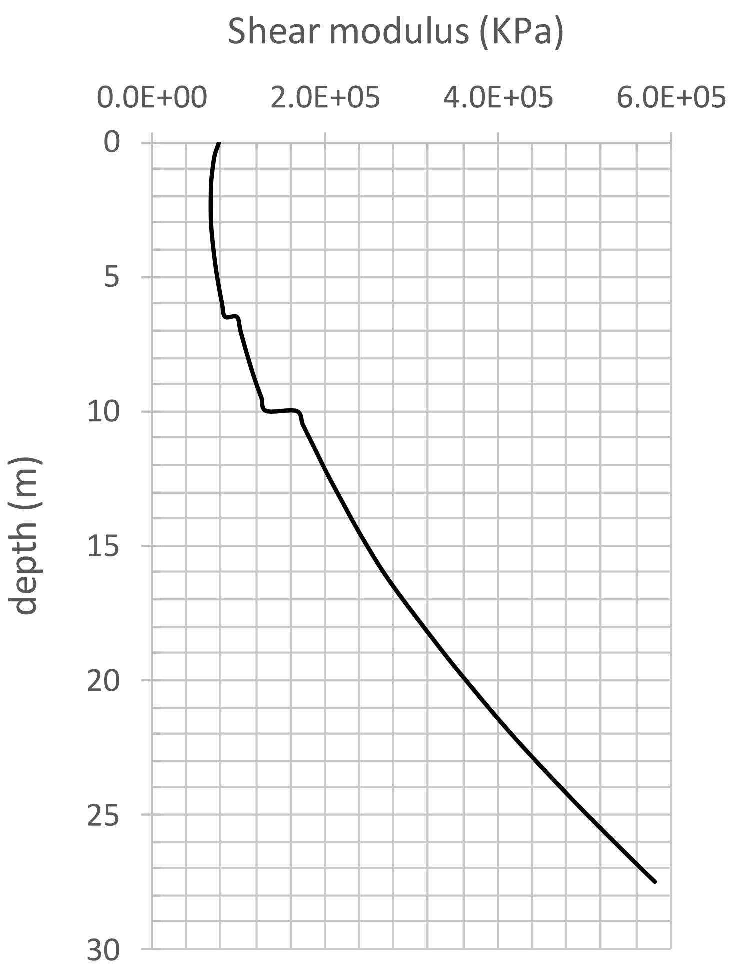
Thin-layer Method (implemented in code BAUBOW) coupled with Finite Element Method

BAUBOW	SAPC	
▪ Kinematic interaction: Determination of Foundation Input Motion ▪ Determination of impedance (stiffness & damping) functions	▪ Dynamic analysis (in frequency domain) considering soil-structure-interaction (FIM & impedance functions) ▪ Determination of transfer functions	▪ From acceleration time-histories Fourier spectra are obtained (FFT). ▪ Multiplication of transfer functions with Fourier spectra and transformation back into the time domain

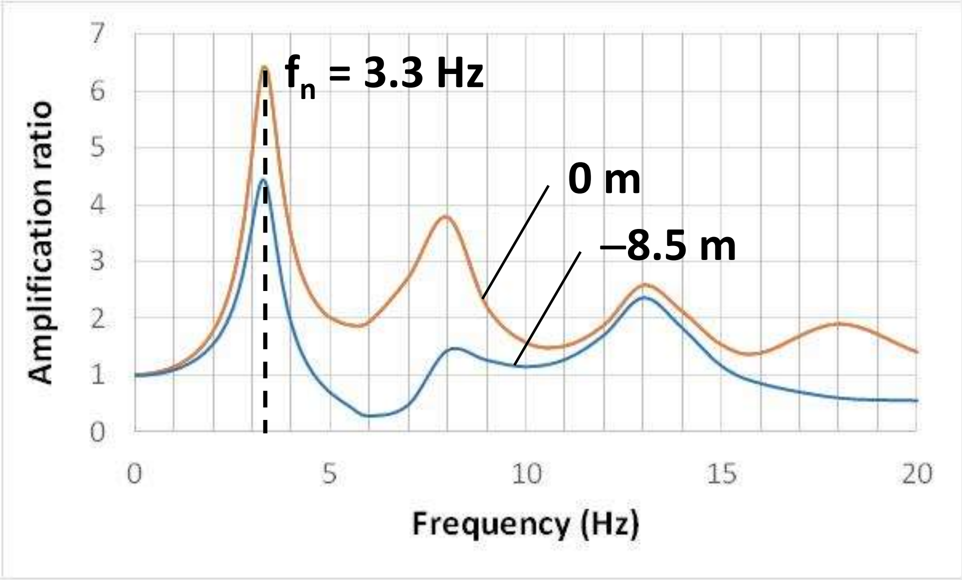
Results in terms of:

- **Amplification ratios**
- **Acceleration time-histories**
- **Response spectra**

SOIL PROFILE



- Actual soft soil profile
- Bedrock at ~ 27.5 m



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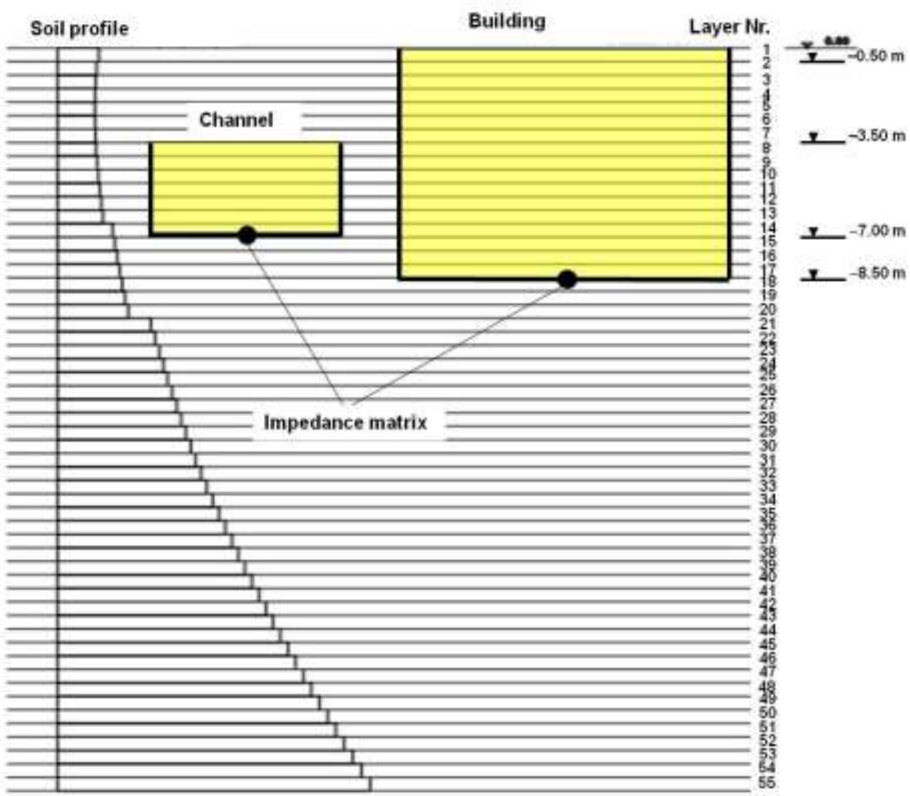
FOUNDATION MODEL (1)



*Schematic representation of the two foundations

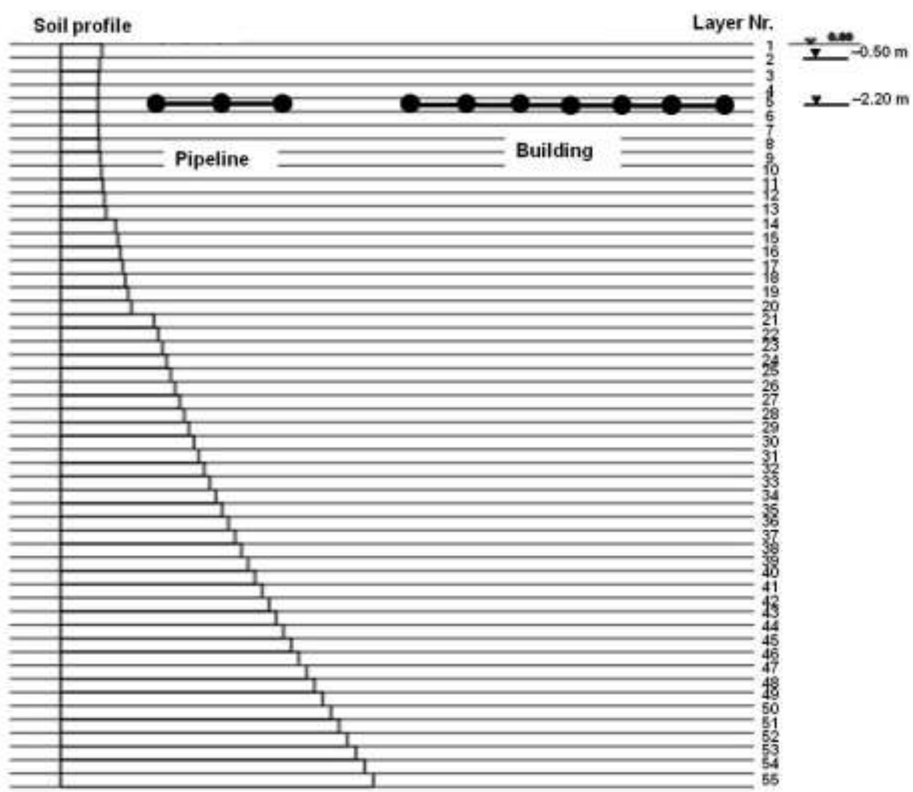
- Both foundations are rigid

<u>Buried channel:</u>
Foundation 30 m x 6 m
Height: 3.5 m
Mass ≅ 800 tn

<u>Building (reference case):</u>
Foundation: 18 m x 18 m
Center of mass at –1m
Mass ≅ 10000 tn

- **Dynamic impedance matrix**
- **Seismic forces due to unit horizontal and vertical oscillation**

FOUNDATION MODEL (2)



*Schematic representation of the two foundations

- Both foundations are flexible

<u>Buried pipeline:</u>
Foundation 0.3 m x 9 m
Mass ≅ 178 kg/m

<u>Structure (reference case):</u>
Foundation: 4 m x 4 m
Center of mass at –1m
Mass ≅ 240 tn

- Dynamic flexibility matrix
- Seismic forces at each foundation node due to unit horizontal and vertical oscillation

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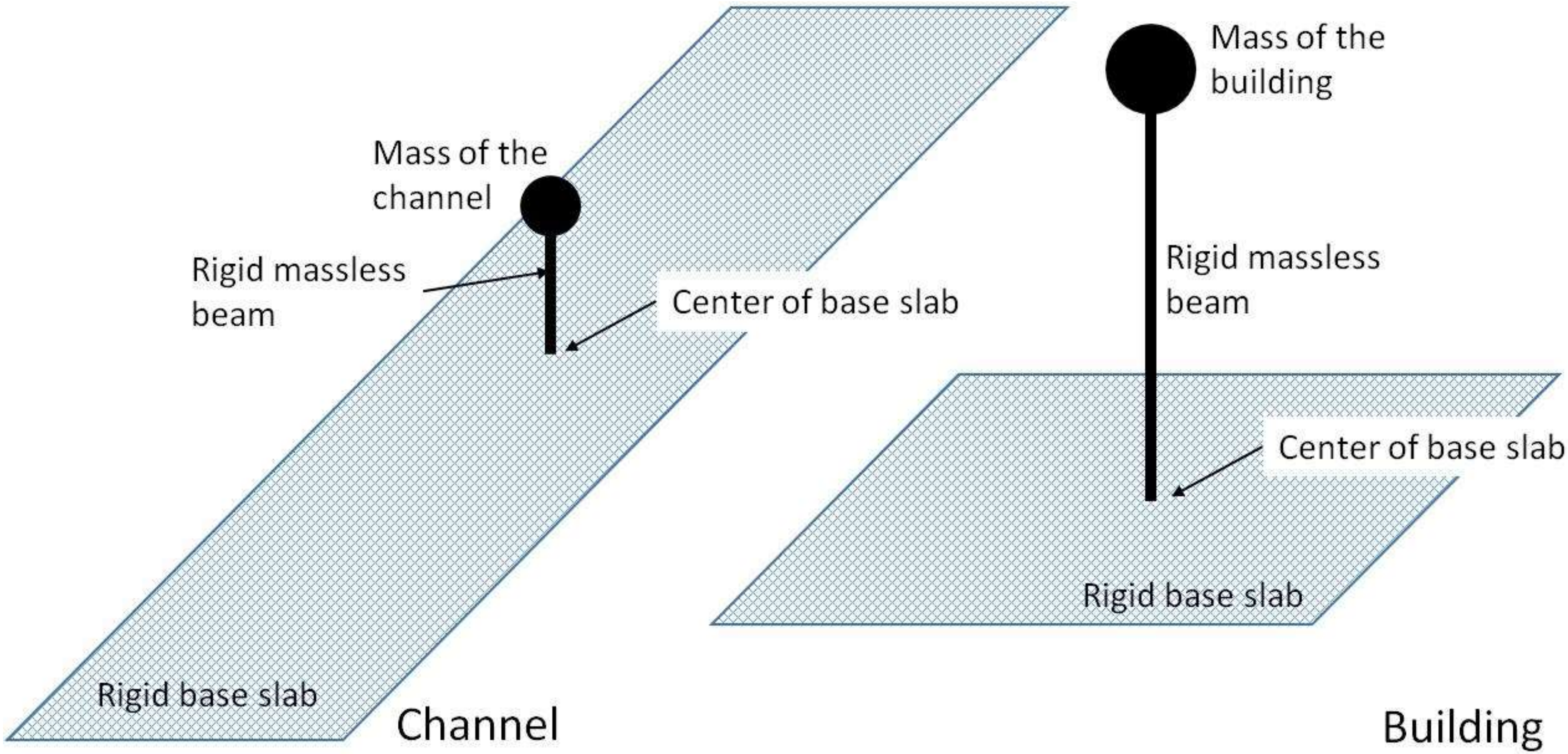
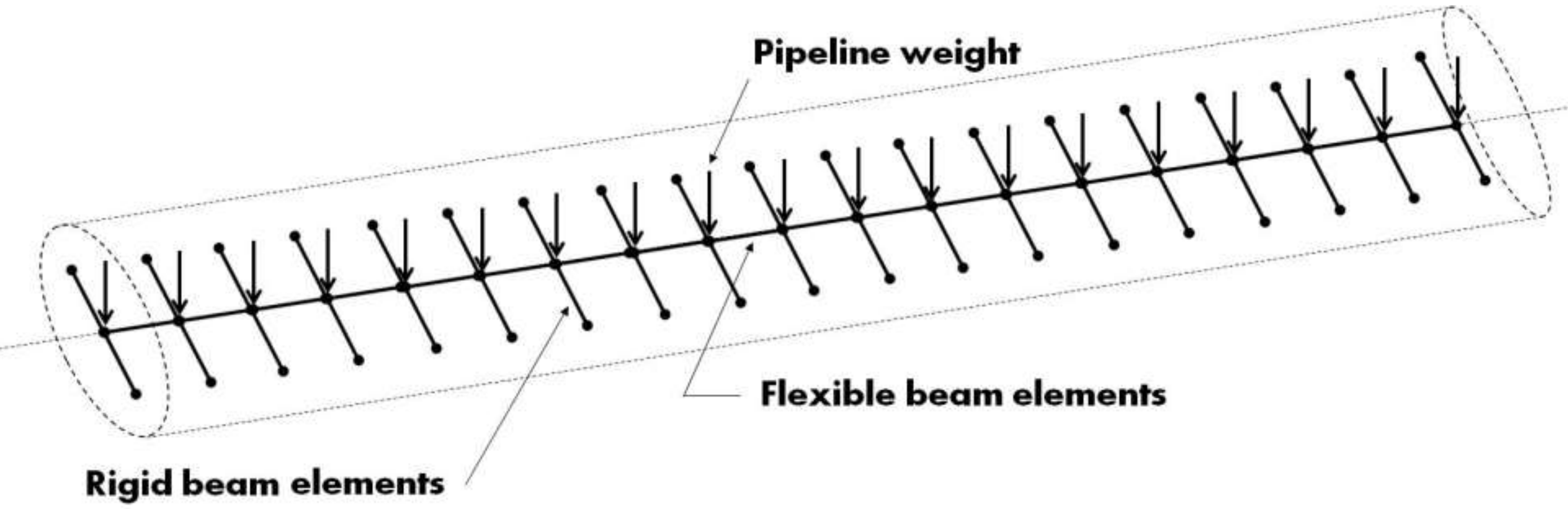
FEM MODEL (1)

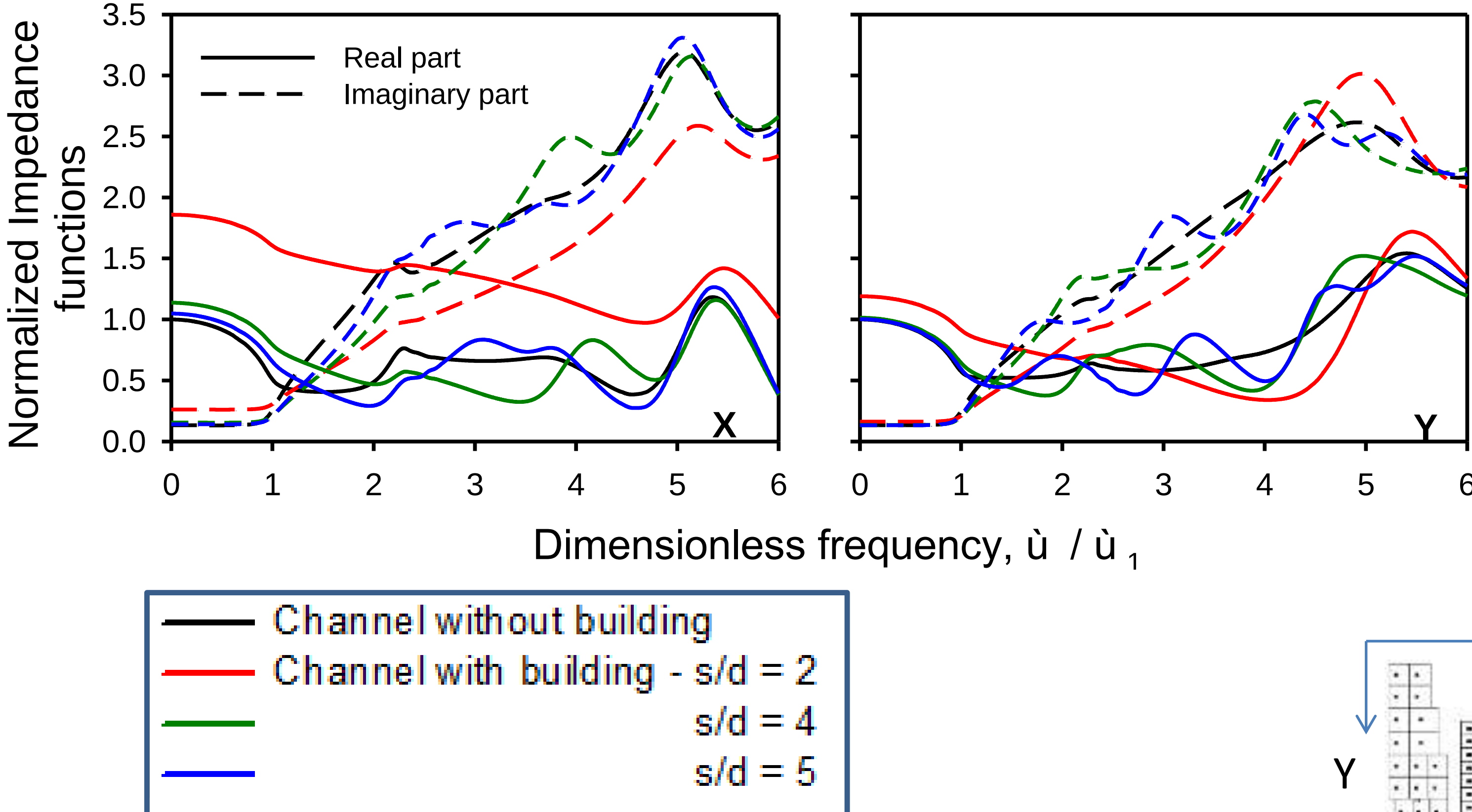


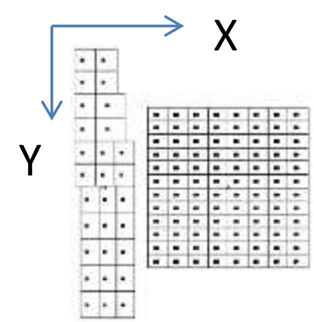
FEM MODEL (2)


Pipeline weight
Flexible beam elements
Rigid beam elements

RESULTS - IMPEDANCE FUNCTIONS

➢ **Influence of s/d ratio**

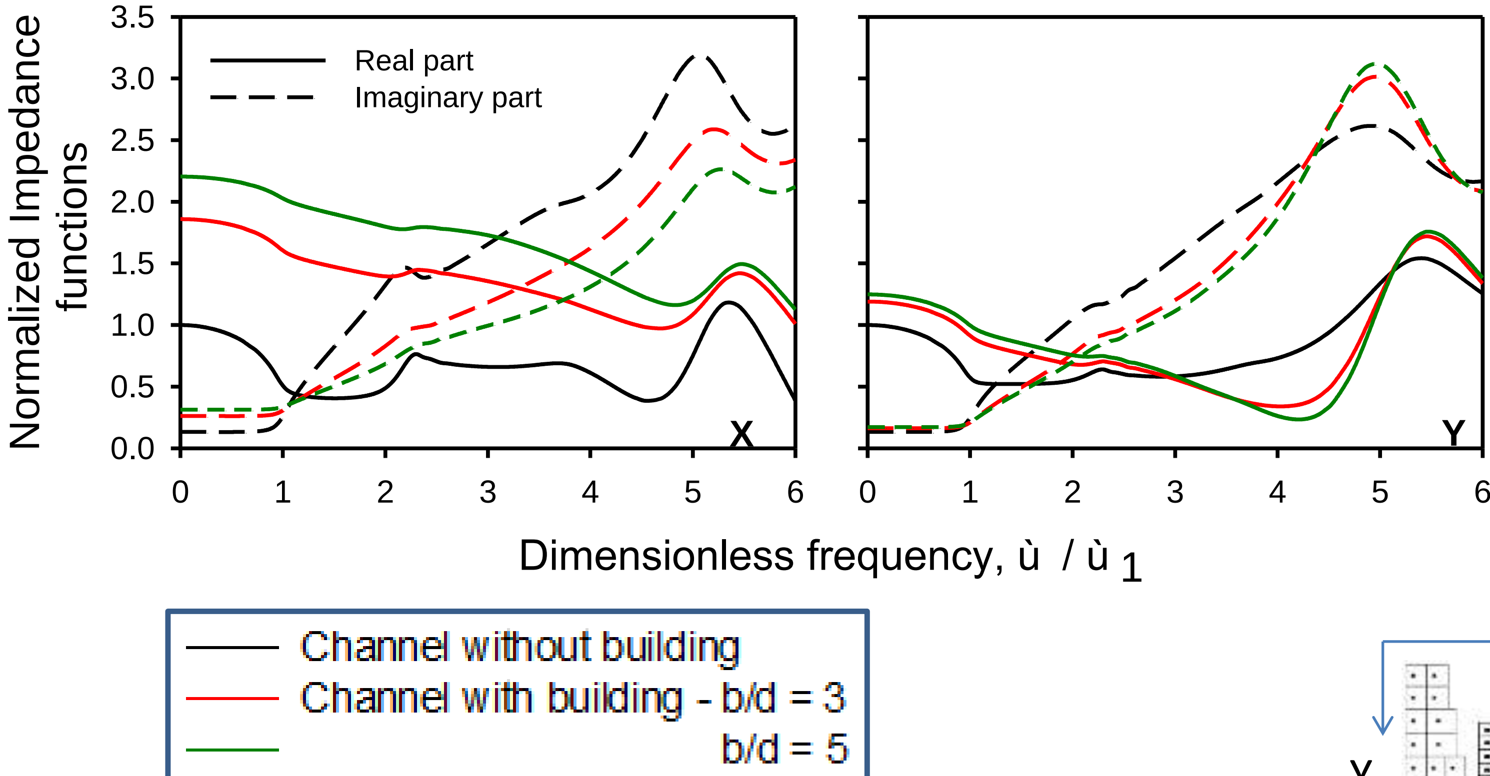


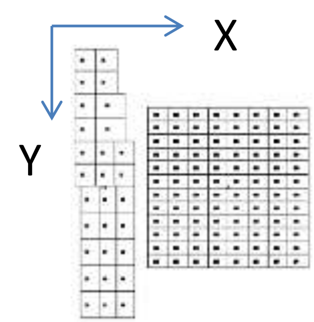


*real (stiffness) and imaginary part (damping) normalized with static stiffness of channel without the presence of the building

RESULTS - IMPEDANCE FUNCTIONS

➢Influence of b/d ratio

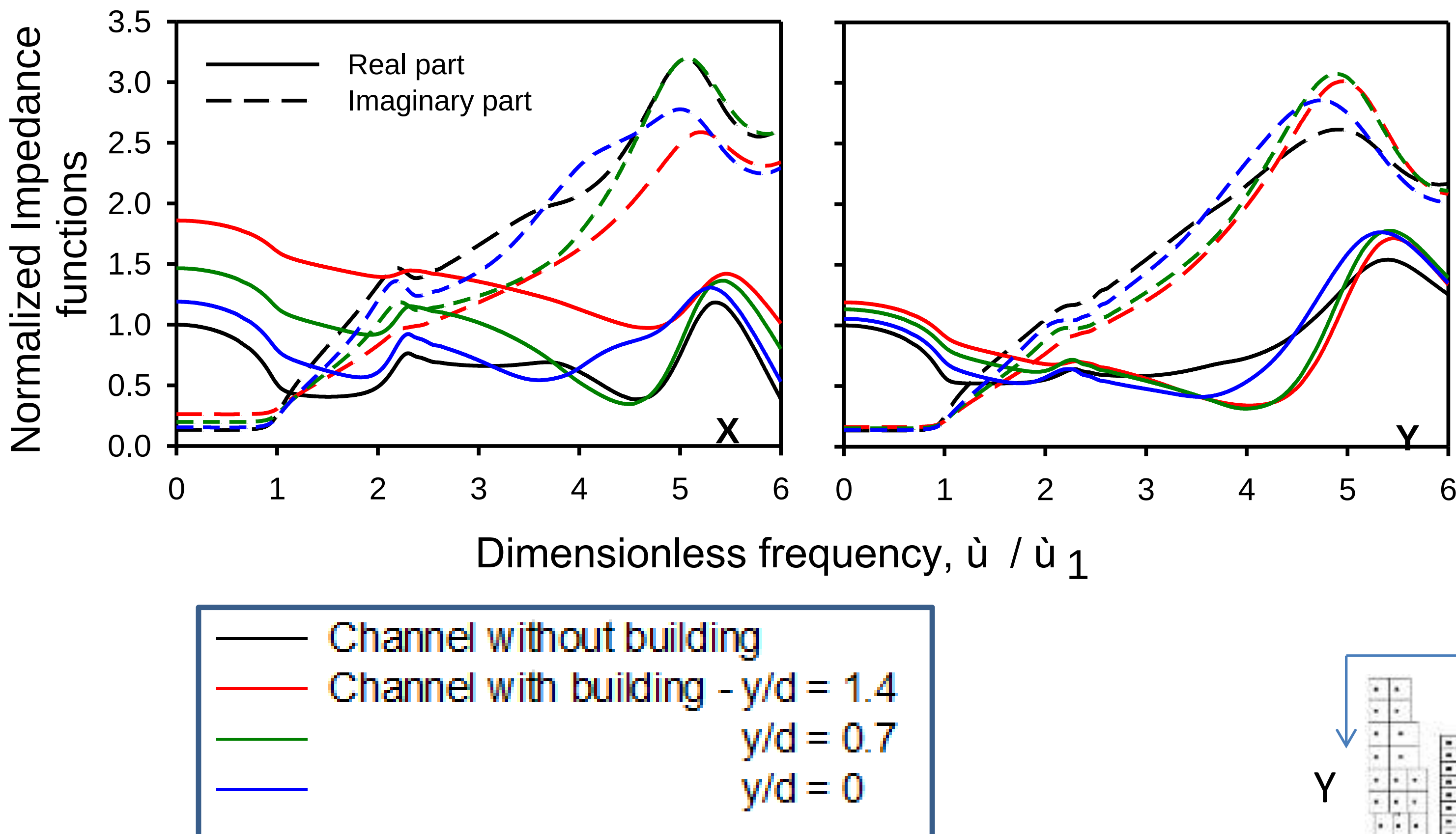


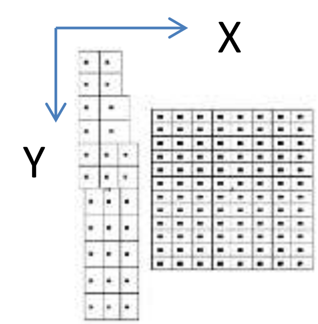


*real (stiffness) and imaginary part (damping) normalized with static stiffness of channel without the presence of the building

RESULTS - IMPEDANCE FUNCTIONS

➢ **Influence of y/d ratio**





*real (stiffness) and imaginary part (damping) normalized with static stiffness of channel without the presence of the building

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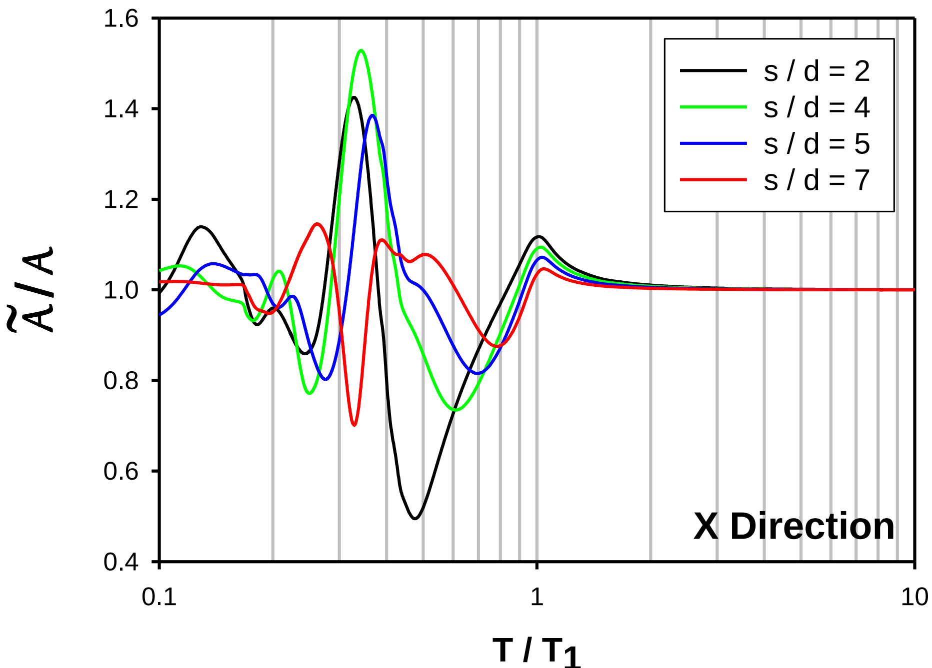
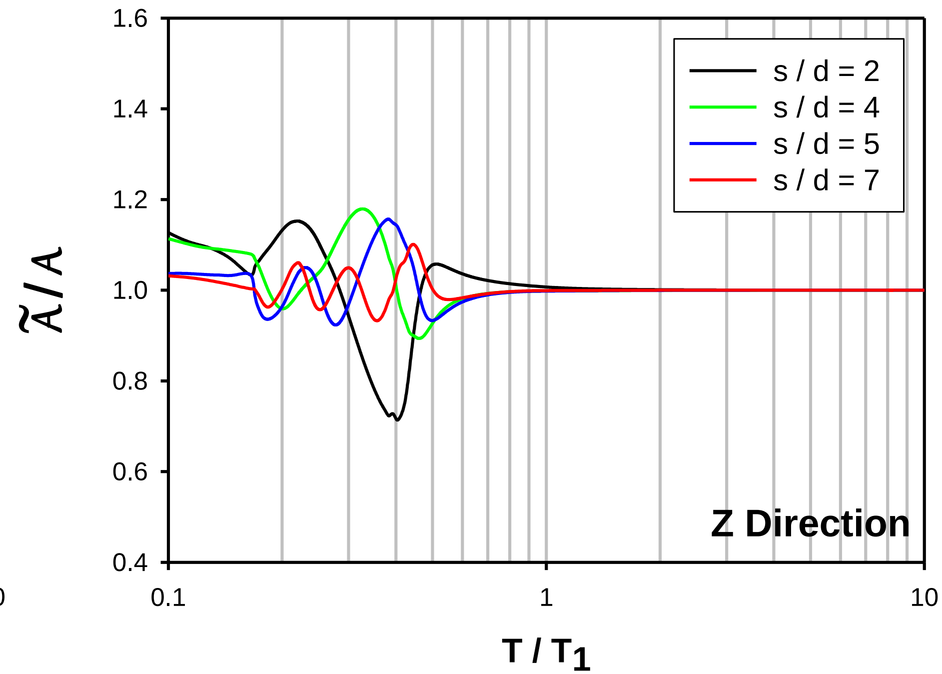
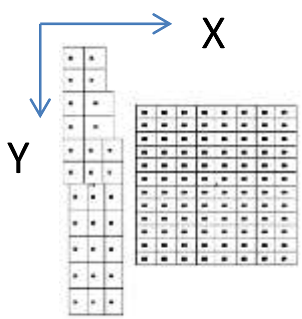
RESULTS – RATIO OF TRANSFER FUNCTIONS

- **Influence of s/d ratio**



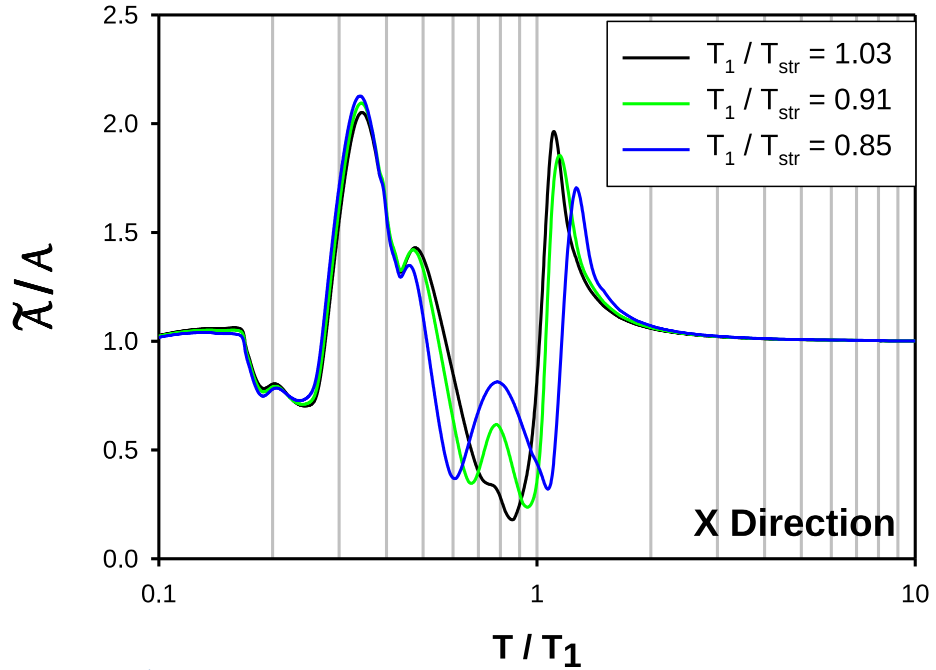


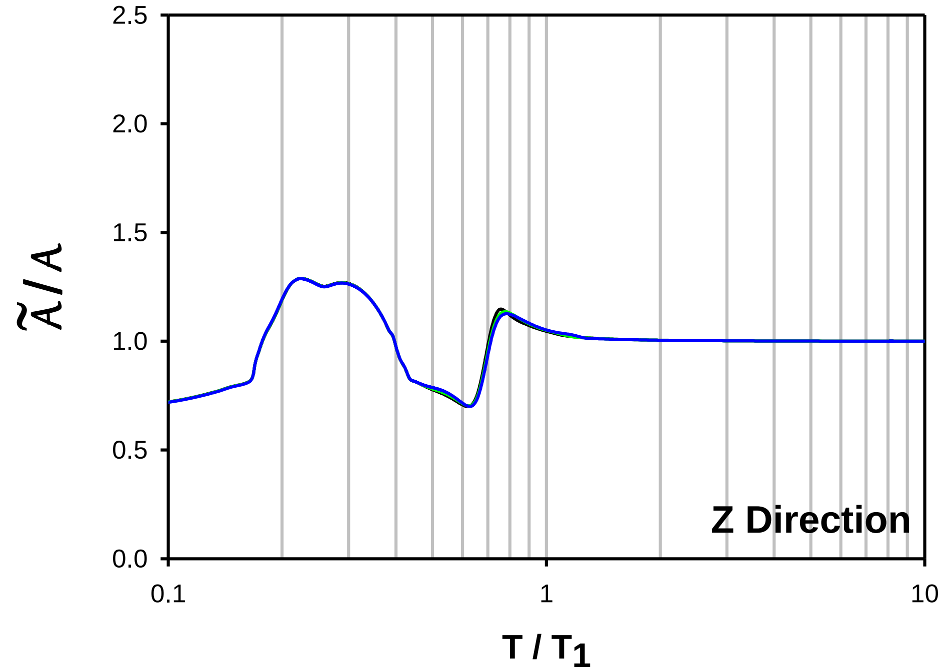


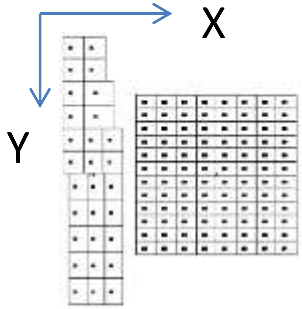
$T_1/T_{str} = 1$

RESULTS – RATIO OF TRANSFER FUNCTIONS

➢ Influence of T_1 / T_{str} ratio







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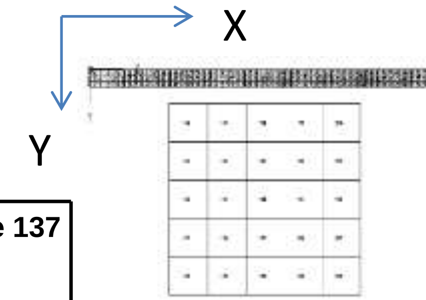
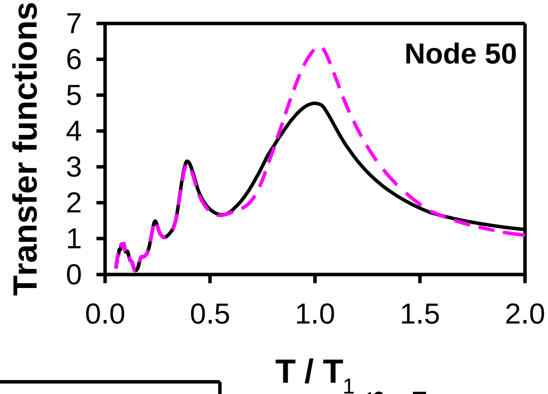
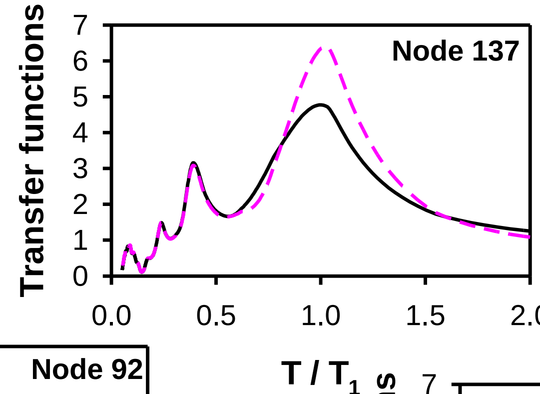
RESULTS TRANSFER FUNCTIONS

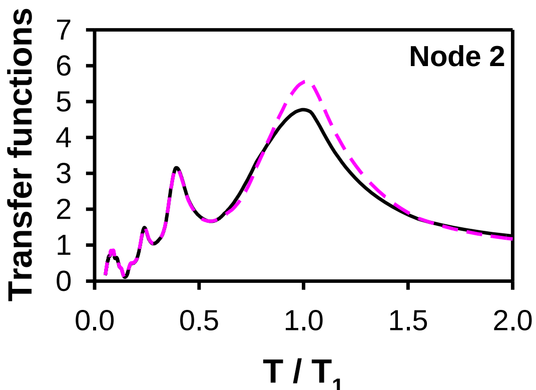


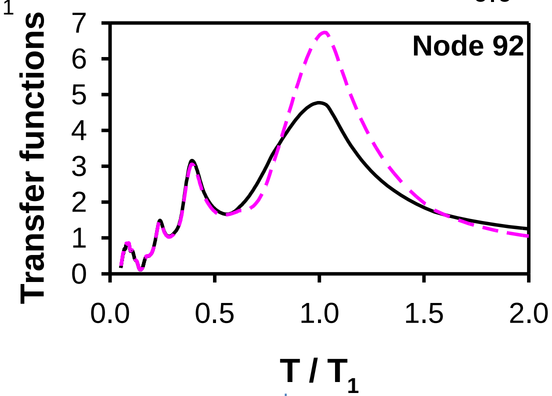
Horizontal Y

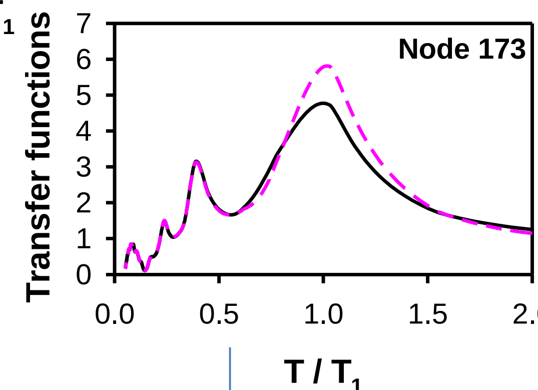
$T_1/T_{str} = 1$

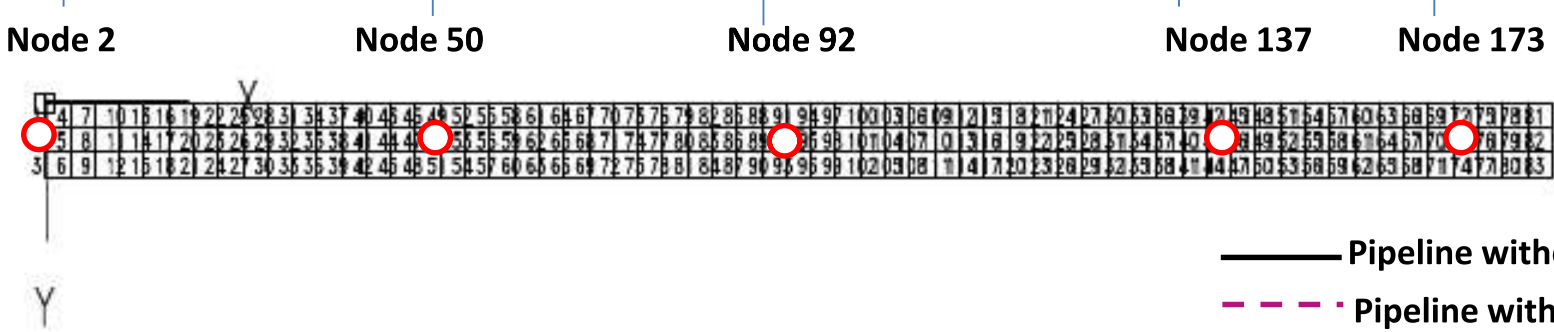












Pipeline without building

Pipeline with building

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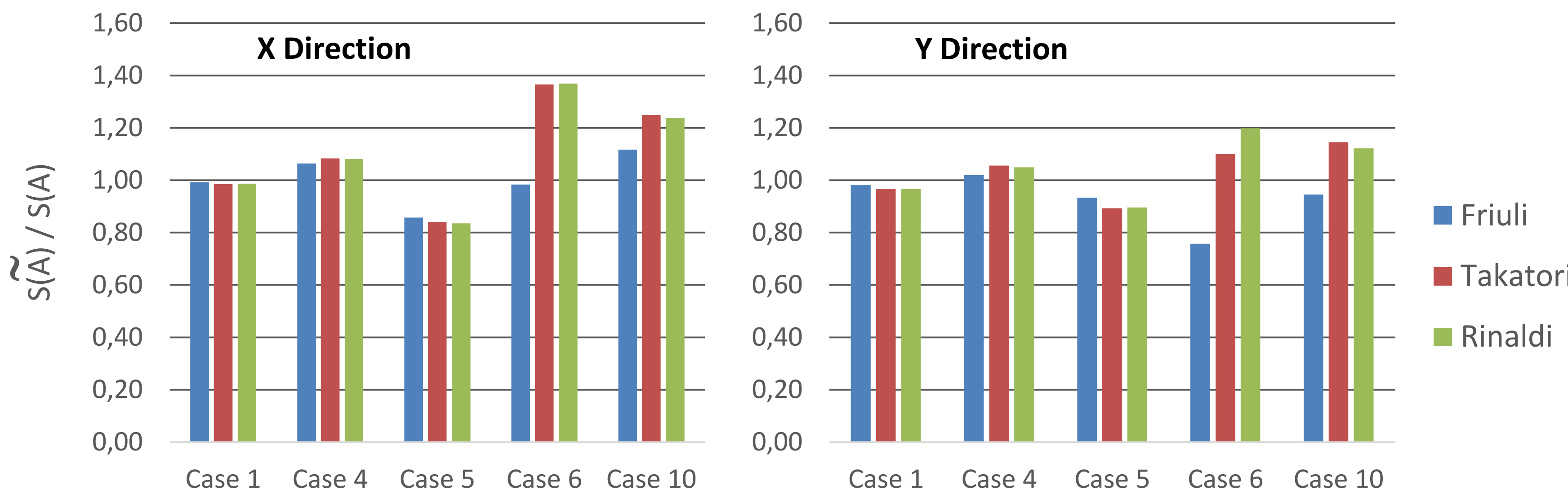
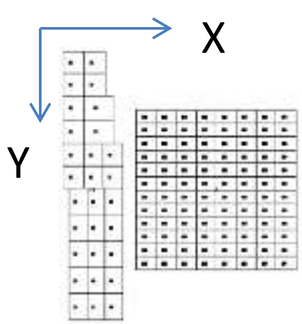
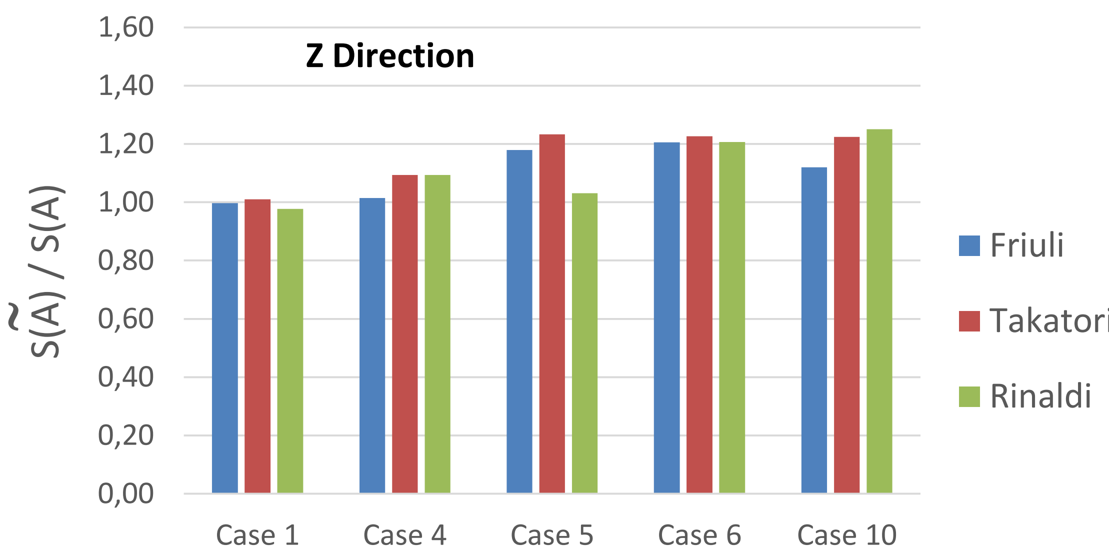
RESULTS – RATIO OF MAXIMUM SPECTRAL ACCELERATION

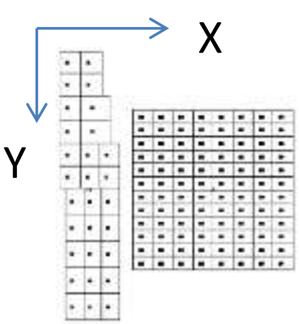




Case1 (s/d = 3.5, b/d = 5, b/c=1.7, h/d = 0.9, y/d = 1.4), e/d = 1.5
Case4 (s/d = 2, b/d = 3, b/c=1, h/d = 0.9, y/d = 1.4, e/d = 0)
Case5 (s/d = 3.5, b/d = 5, b/c=1, h/d = 0.9, y/d = 1.4, e/d = 0)
Case6 (s/d = 2, b/d = 3, b/c=1, h/d = 0.9, y/d = 0, e/d = 0)
Case10 (s/d = 2, b/d = 3, b/c=1, h/d = 0.9, y/d = 0.7, e/d = 0)

RESULTS – RATIO OF MAXIMUM SPECTRAL ACCELERATION





Case1 (s/d = 3.5, b/d = 5, b/c=1.7, h/d = 0.9, y/d = 1.4), e/d = 1.5
Case4 (s/d = 2, b/d = 3, b/c=1, h/d = 0.9, y/d = 1.4, e/d = 0)
Case5 (s/d = 3.5, b/d = 5, b/c=1, h/d = 0.9, y/d = 1.4, e/d = 0)
Case6 (s/d = 2, b/d = 3, b/c=1, h/d = 0.9, y/d = 0, e/d = 0)
Case10 (s/d = 2, b/d = 3, b/c=1, h/d = 0.9, y/d = 0.7, e/d = 0)

CONCLUSIONS

- It is observed increase in stiffness and decrease in damping (at the frequency range 0 – 10 Hz).
- As the distance (s/d) between channel and structure increases, the interaction decreases. For *s/d* = 7, the impedance functions of channel are almost unaffected.
- As the embedment depth of the structure decreases the dynamic impedance functions of the buried channel are slightly affected.
- A rigid heavy structure close to the channel may have positive, negative or no effect at all on the transfer functions of the buried lifeline.
- The increasing distance between two adjacent structures yields no change in transfer functions of the lifeline with the critical distance being s/d = 5 ~ 7.

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CONCLUSIONS

- The arrangement of the structures and the direction of the seismic motion are the most important parameters (greater effect is observed in the direction where the two structures are arranged in parallel).
- Parameters s/d, b/d, y/d and T_1/T_{str} seem to be crucial for the response.
- A significant increase or decrease in spectral acceleration is observed when the adjacent structure has an eigenfrequency close to that of the soil deposit.
- In most cases studied, it is observed an increase in the vertical spectral acceleration.
- The outcome that the lifeline is heavily affected when the adjacent structure has eigenfrequency close to that of free-field has been observed by researchers (Wang et al 2017).

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Thank you!