

Structural Engineering Seminar
University of Liege
11 September 2015

Numerical crashworthiness analysis of an offshore wind turbine monopile impacted by a ship

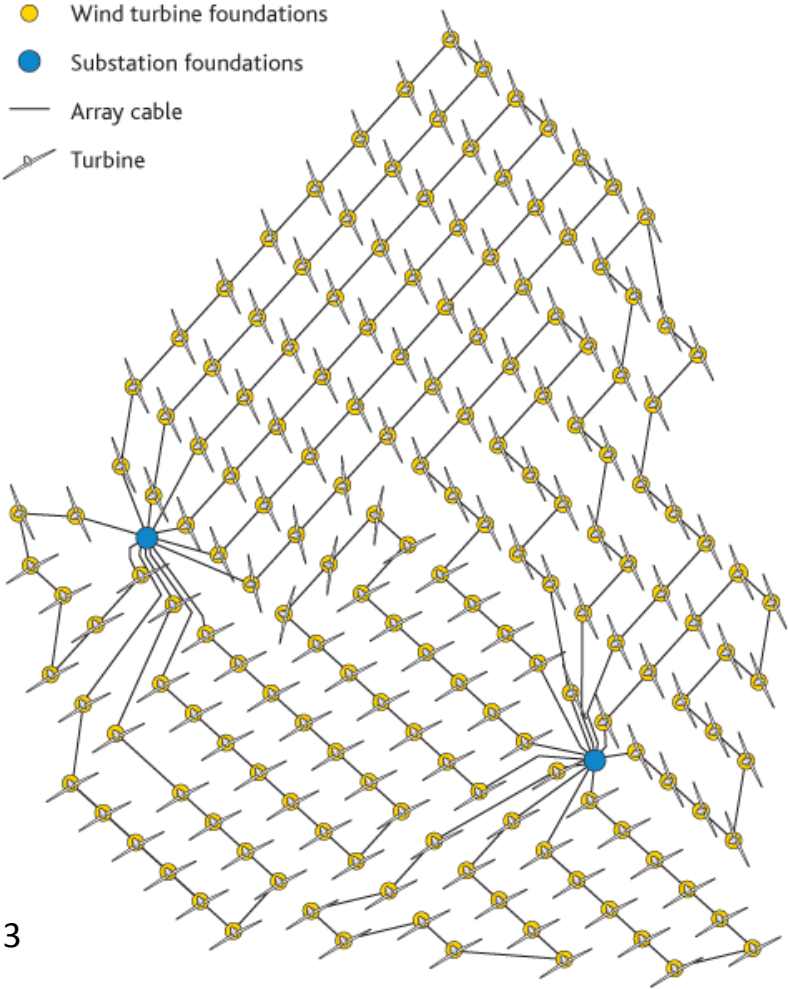
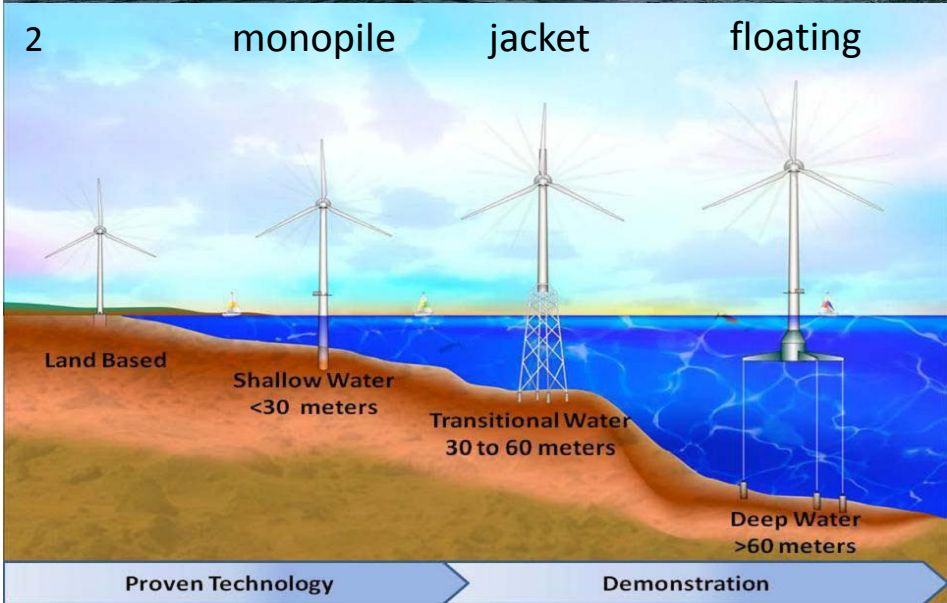
Andreea BELA

Promoter – Philippe RIGO

Co-promoter – Hervé LE SOURNE



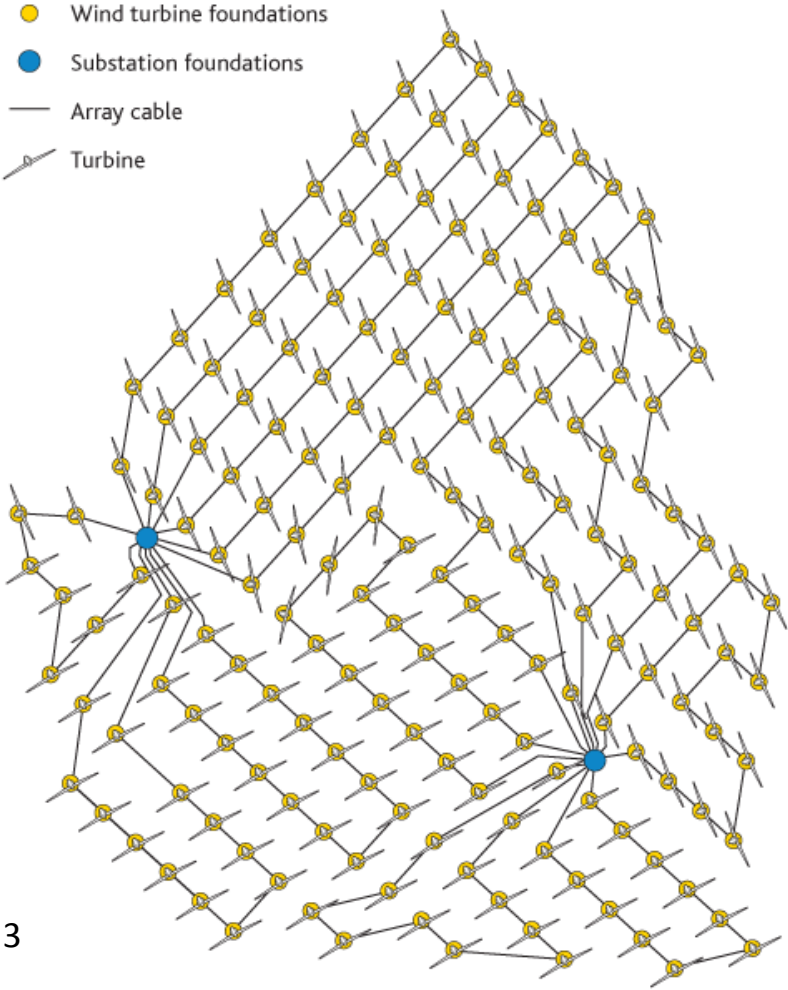
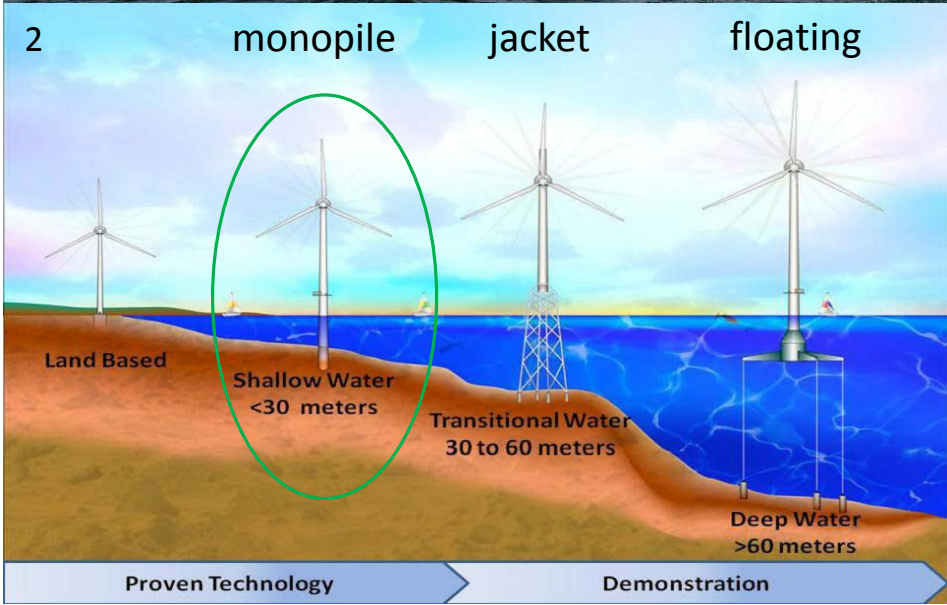
OFFSHORE WIND FARMS



London Array

1 - http://www.huffingtonpost.com/2013/12/12/wind-farms-provide-protection_n_4433948.html
 2 - <http://www.boem.gov/renewable-energy-program/renewable-energy-guide/offshore-wind-energy.aspx>
 3 - <http://www.eoi.es/blogs/pablosanchezsanchez/2014/03/30/london-array-where-amazing-happens/>

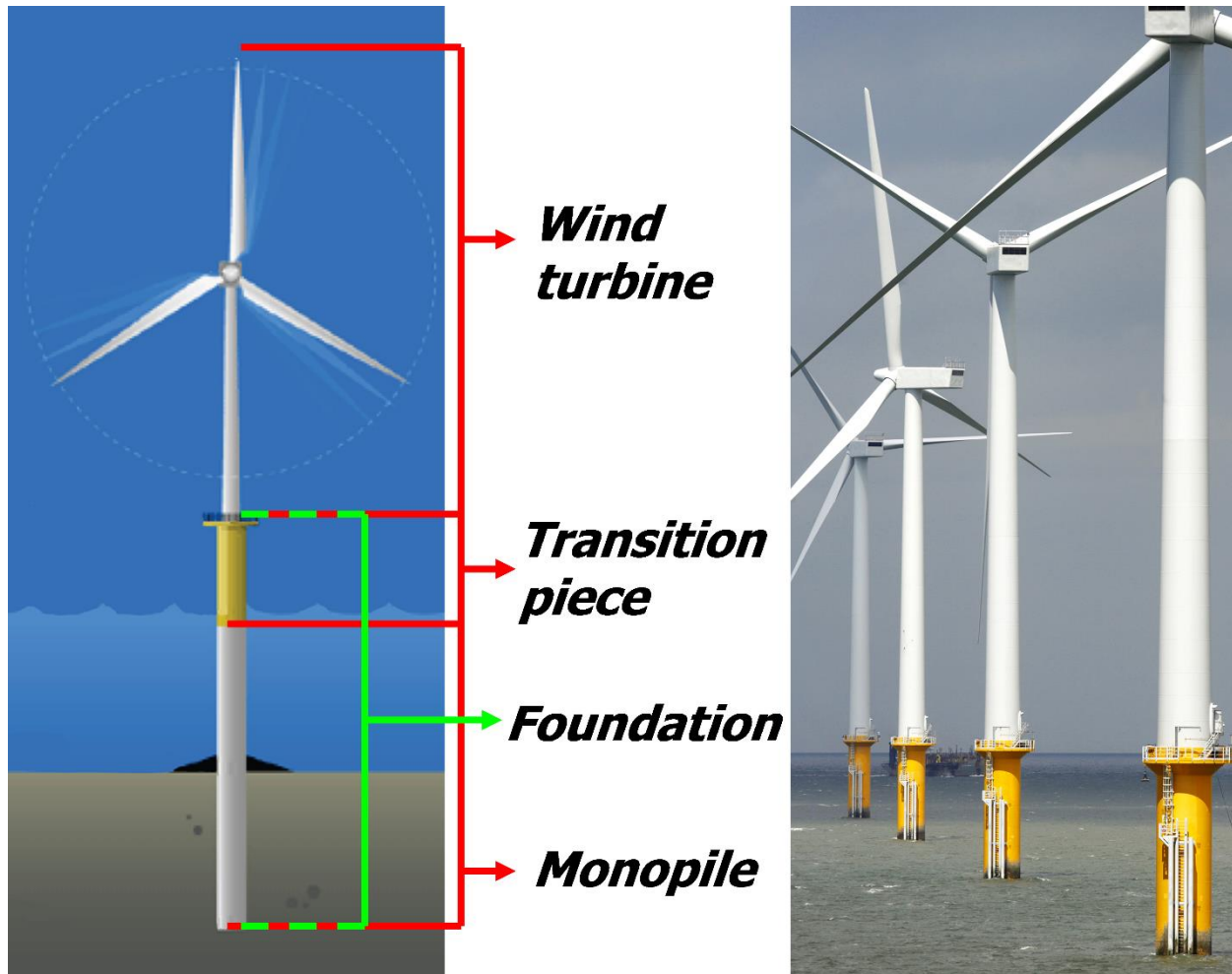
OFFSHORE WIND FARMS



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MONOPILE FOUNDATION



Source: <http://www.3me.tudelft.nl/en/about-the-faculty/departments/precision-and-microsystems-engineering/engineering-dynamics-ed/research-ed/numerical-methods/structural-dynamics-of-offshore-wind-turbine-foundations/>

SHIP COLLISION



Offshore Supply Vessel (OSV)

(Source:

<http://www.workboatbrokers.com/product/1356/130719-va>)



Passenger ship

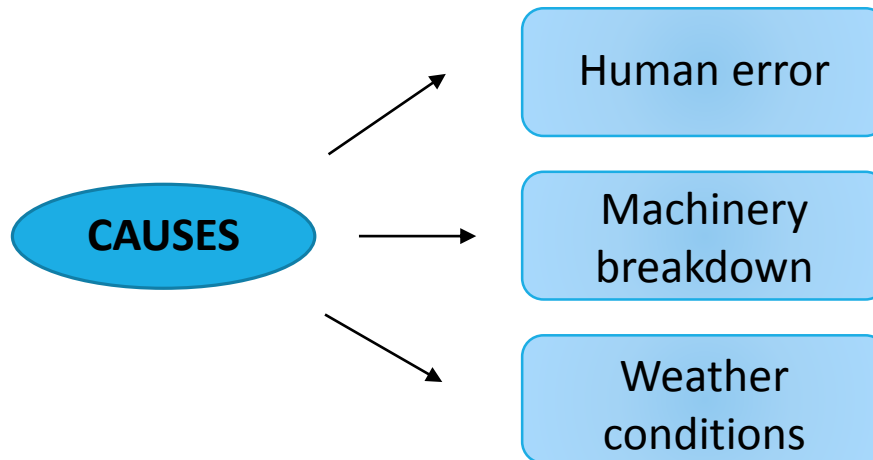
(Source: <http://www.cruiseselection.be/>)



Commercial ship

(Source:

<http://www.metcalfmoving.com/international-moves>)



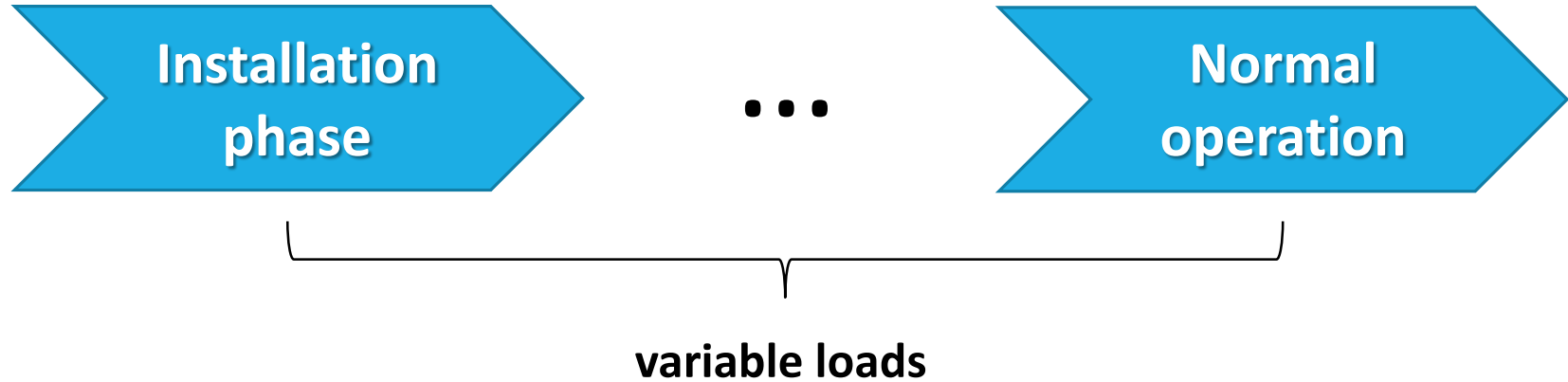
CONSEQUENCES OF COLLISION EVENTS



**CONSEQUENCES
OF COLLISION
EVENTS**

- ➔ **Structural damage**
- ➔ **Disruption in electricity production**
- ➔ **Collapse**
- ➔ **Ship sinking**
- ➔ **Pollution**
- ➔ **Loss of human lives**

NUMERICAL SIMULATIONS

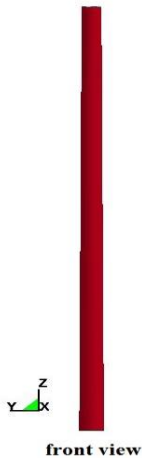


NUMERICAL SIMULATIONS	PARAMETERS
	impact velocity
	wall thickness
	nacelle mass
	wind
	impact point position
	soil stiffness

DESCRIPTION OF THE FE MODEL

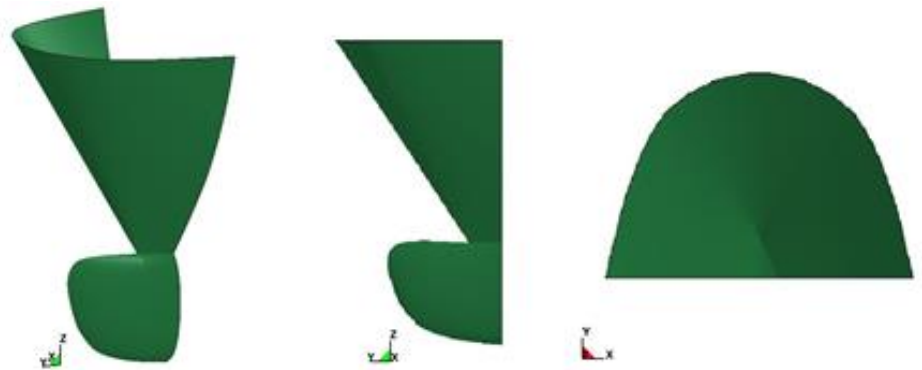
Wind turbine (monopile + tower):

- Height: 115 m;
- Top diameter: 4 m;
- Bottom diameter: 5 m;
- Wall thickness: 0,06 m;
- Nacelle mass: 350 t;
- Site water depth: 25 m



Striking ship (OSV): → Rigid body

- Type: bulbous bow;
- Length: 102,4 m;
- Breadth: 23,23 m;
- Depth: 25,89 m;
- Draft: 4,12 m;
- Displacement: 5000 t;
- Water (added mass): 250 t



IMPACT VELOCITY

Head on collisions

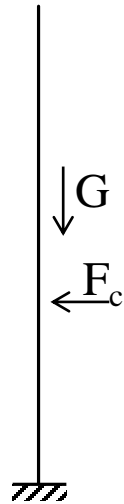


2 m/s
3,5 m/s
5 m/s

LS-DYNA user input
Time = 0

Hypothesis:

- Weight of the structure (without nacelle)
- Infinite soil stiffness



Impact velocity = 2 m/s

IMPACT VELOCITY

Head on collisions

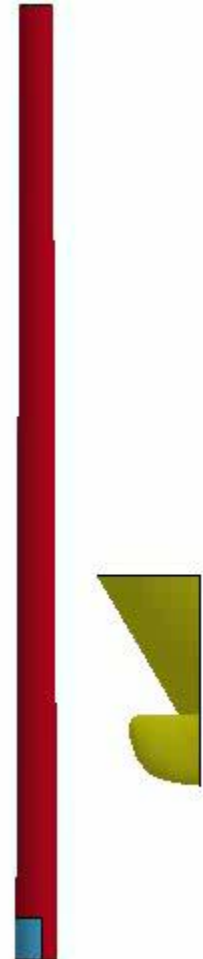
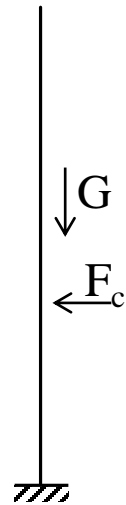


2 m/s
3,5 m/s
5 m/s

LS-DYNA user input
Time = 0

Hypothesis:

- Weight of the structure (without nacelle)
- Infinite soil stiffness



Impact velocity = 5 m/s

IMPACT VELOCITY

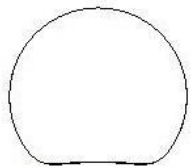
Head on collisions



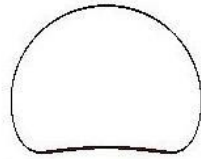
2 m/s
3,5 m/s
5 m/s

Hypothesis:

- Weight of the structure (without nacelle)
- Infinite soil stiffness



v = 2 m/s

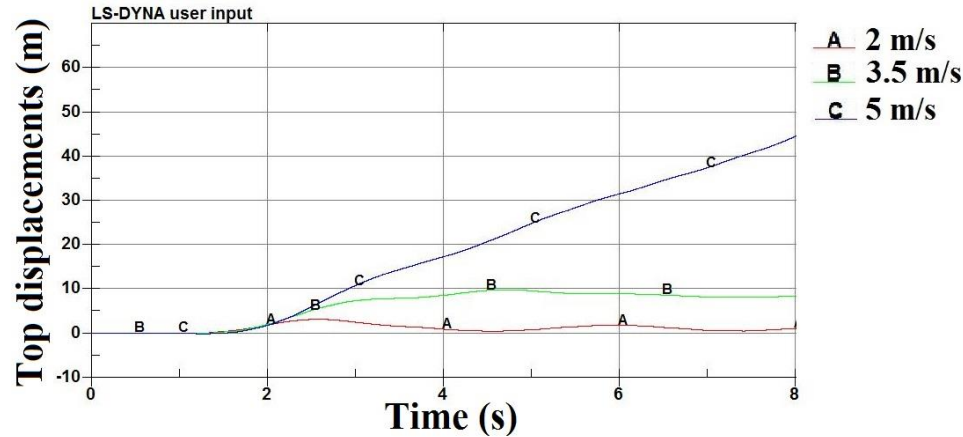
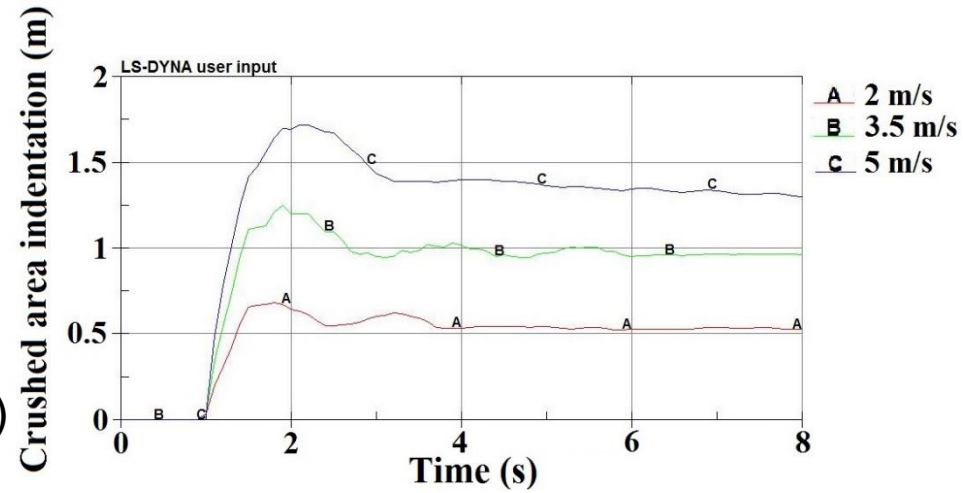


v = 3.5 m/s



v = 5 m/s

Crushed area

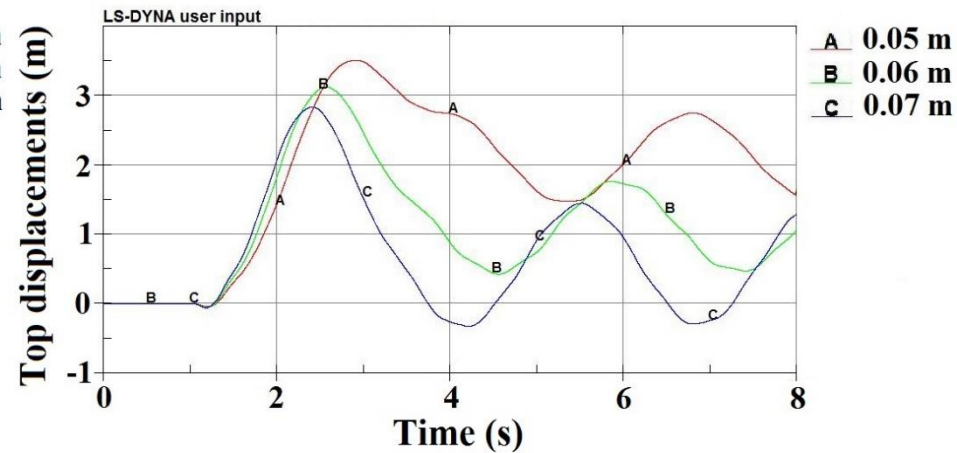
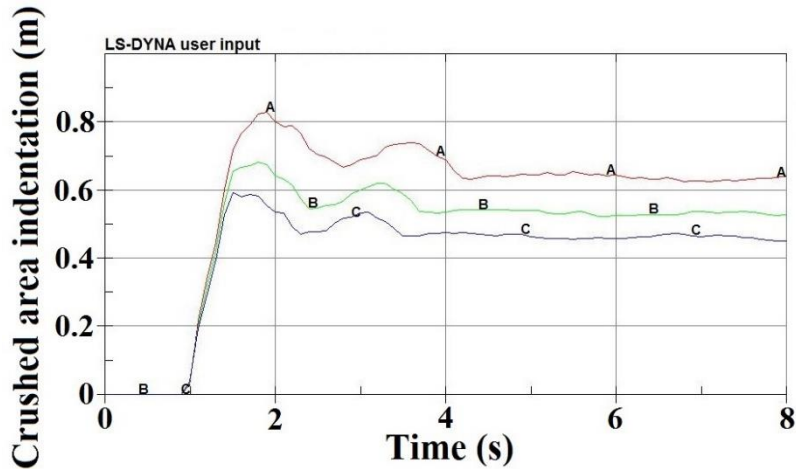
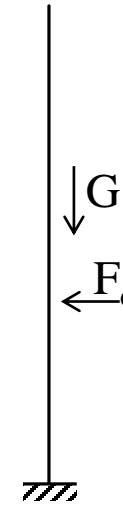


WALL THICKNESS

Wall thickness  **0,05 m**
0,06 m
0,07 m

Hypothesis:

- Impact velocity: 2 m/s
- Weight of the structure (without nacelle)
- Infinite soil stiffness

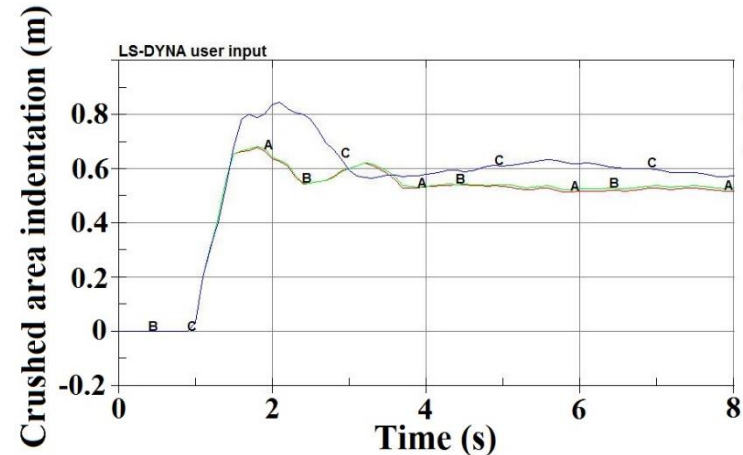
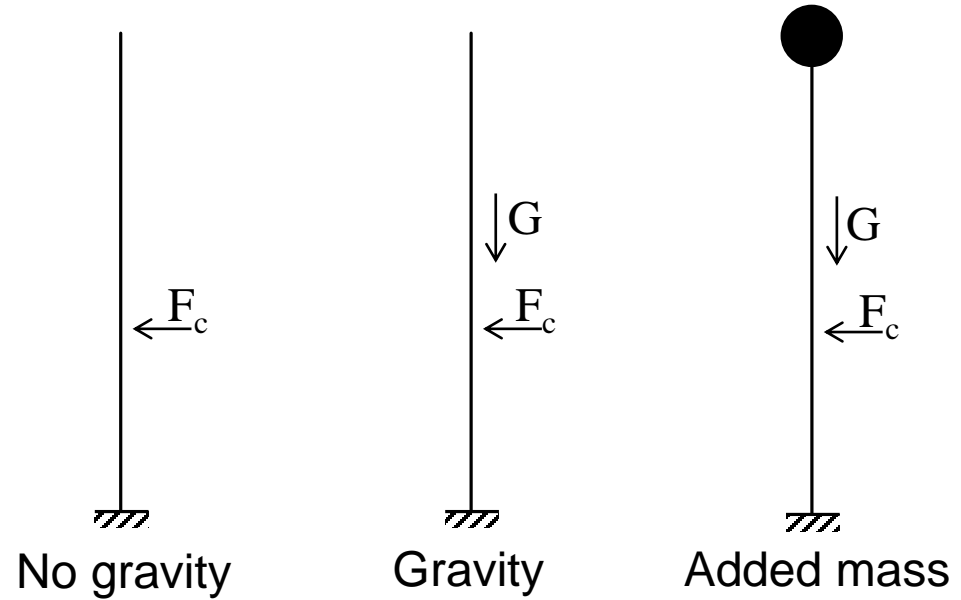


NACELLE MASS

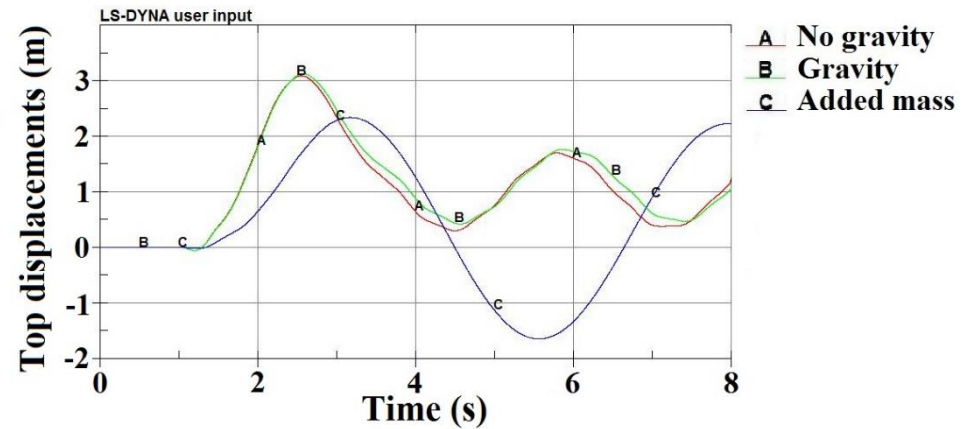
Cases:  **No gravity**
Gravity
Added mass

Hypothesis:

- Impact velocity: 2 m/s
- Infinite soil stiffness



A No gravity
 B Gravity
 C Added mass

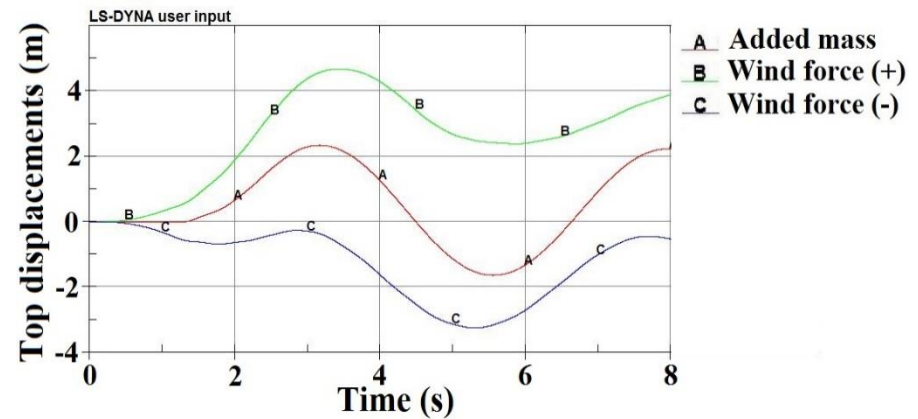
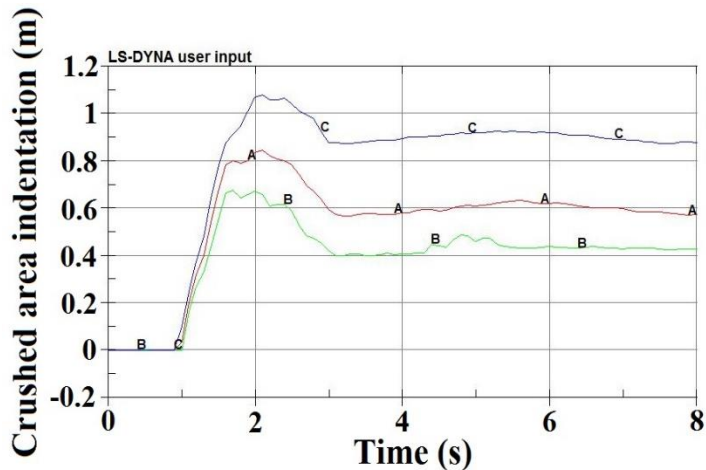
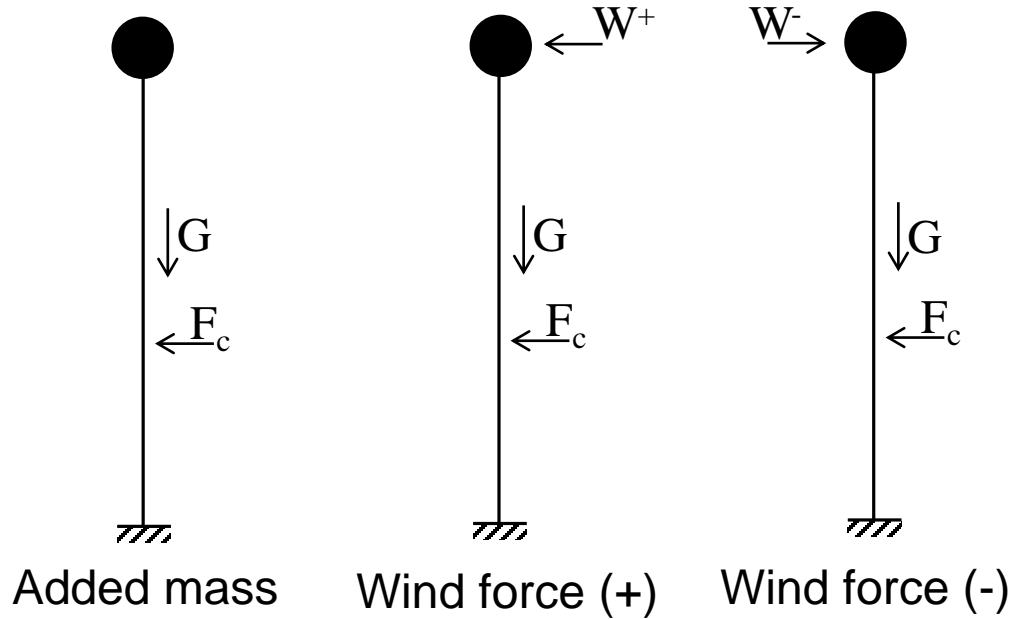


WIND LOADS

Cases:  **Added mass**
Wind force (+)
Wind force (-)

Hypothesis:

- Impact velocity: 2 m/s
- Infinite soil stiffness

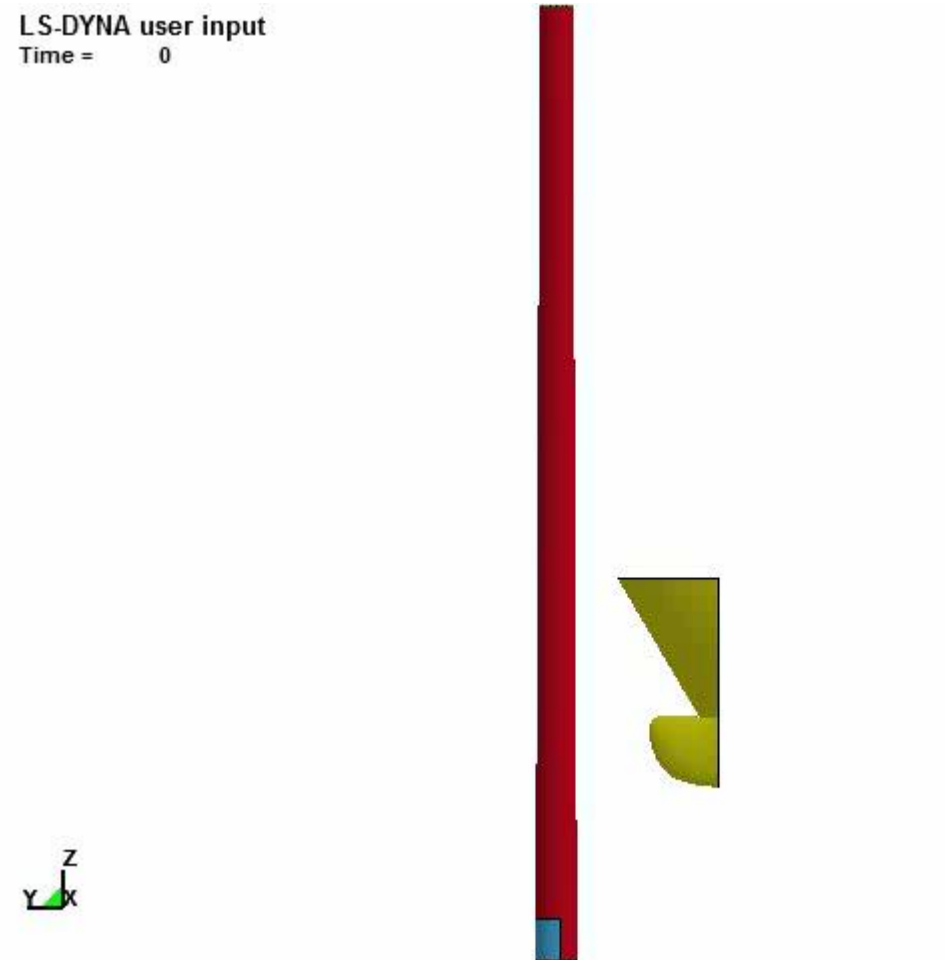


WIND LOADS

Cases:  **Added mass**
Wind force (+)
Wind force (-)

Hypothesis:

- Impact velocity: 5 m/s
- Infinite soil stiffness



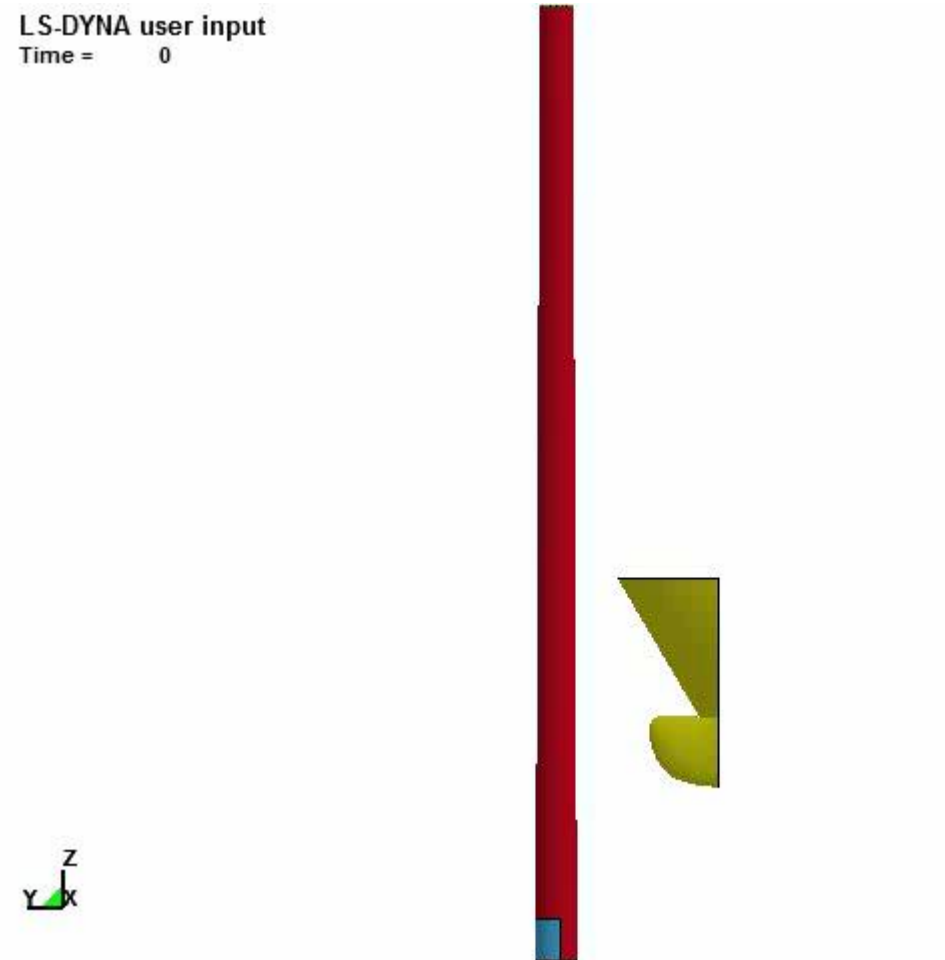
Wind force (+)

WIND LOADS

Cases:  **Added mass**
Wind force (+)
Wind force (-)

Hypothesis:

- Impact velocity: 5 m/s
- Infinite soil stiffness



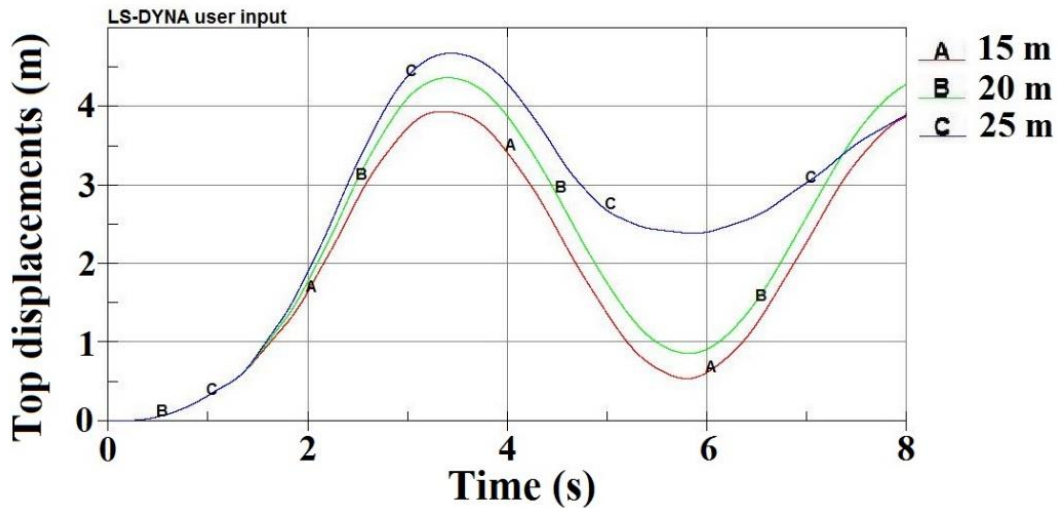
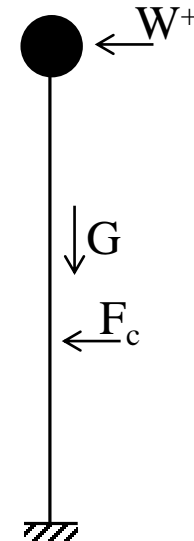
Wind force (-)

IMPACT POINT POSITION

Water depth → **15 m**
20 m
25 m

Hypothesis:

- Impact velocity: 2 m/s
- Weight of the structure + nacelle mass + wind force (+)
- Infinite soil stiffness

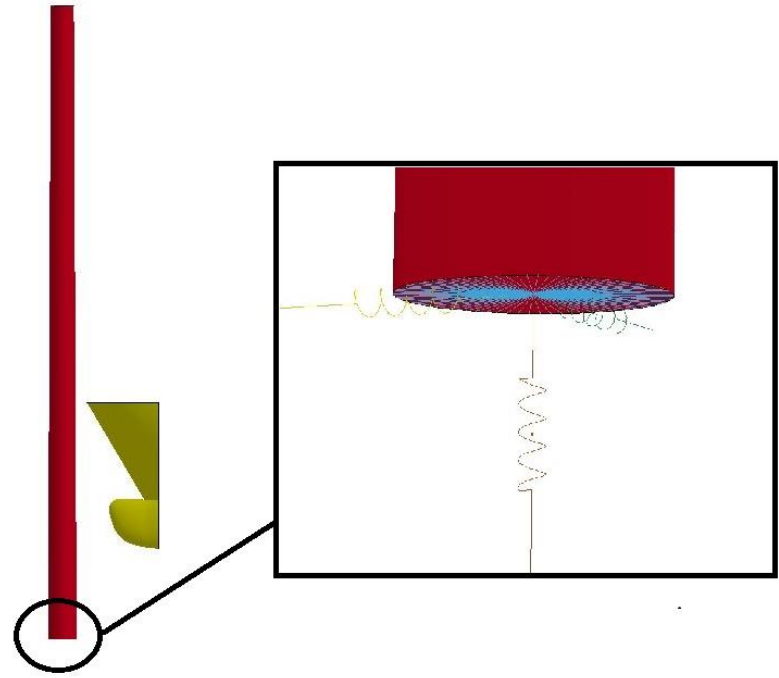
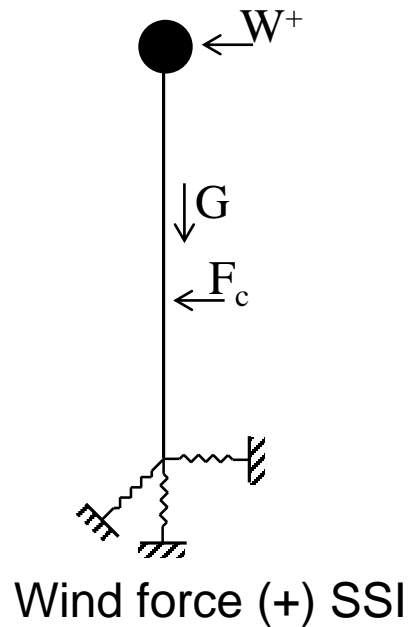
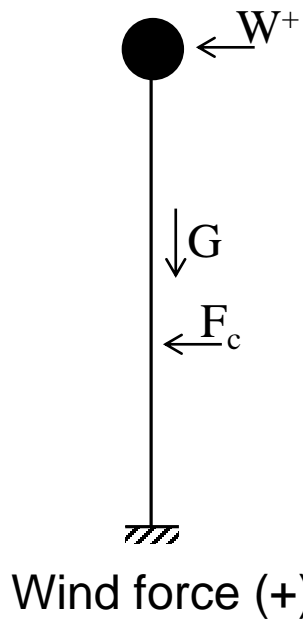


SOIL STIFFNESS

Cases:  **Wind force (+)**
Wind force (+) SSI

Hypothesis:

- Impact velocity: 2 m/s

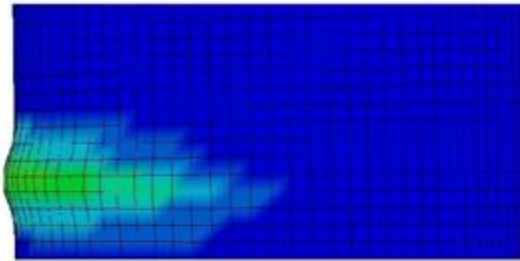


SOIL STIFFNESS

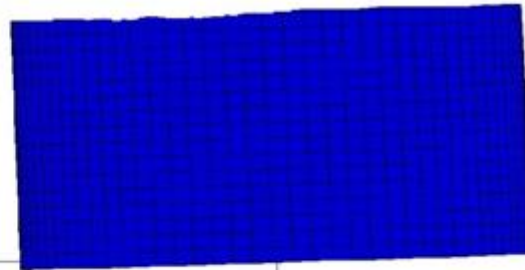
Cases:  **Wind force (+)**
Wind force (+) SSI

Hypothesis:

- Impact velocity: 2 m/s



Wind force (+)



Wind force (+) SSI

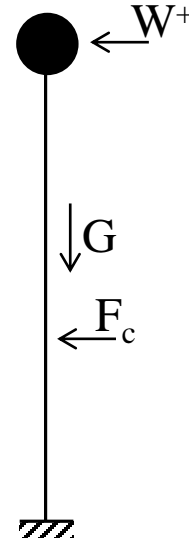


SOIL STIFFNESS

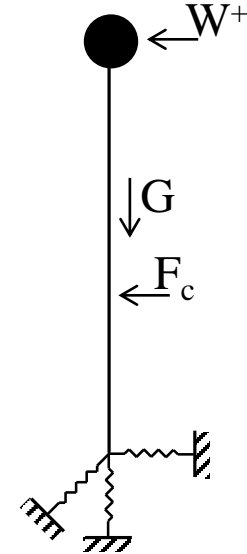
Cases:  **Wind force (+)**
Wind force (+) SSI

Hypothesis:

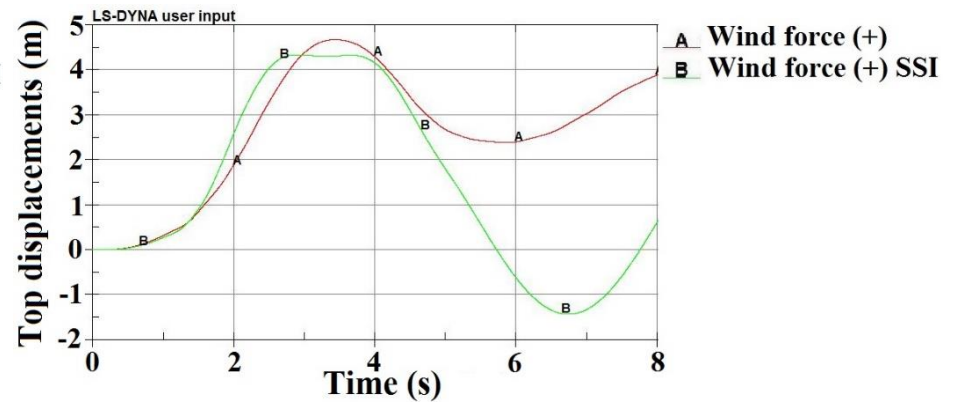
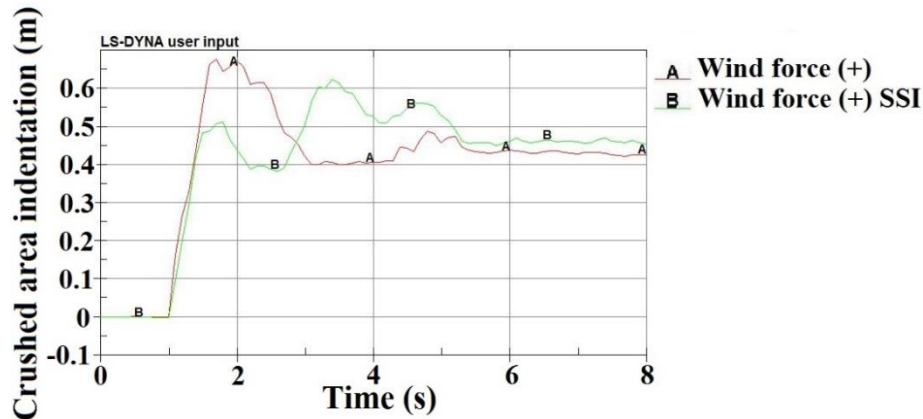
- Impact velocity: 2 m/s



Wind force (+)



Wind force (+) SSI



Thank you!

