CHARACTERIZATION OF WAVE SLAMMING FORCES FOR A TRUSS STRUCTURE WITHIN THE FRAMEWORK OF THE WAVESLAM PROJECT

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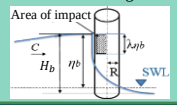
Motivation & Goal

- Focus on truss substructures, which are used predominantly in shallow waters from 5 to 40 m, typically called 'Jacket'.
- To characterize the wave slamming forces and determine the slamming coefficients C_s associated to them.
- A better understanding of these forces might lead to a structure optimization ➡ Offshore Wind Energy Costs ⇩

Front side of the prototype built up in Hannover, 2013.

The maximum response of these structures in shallow water is governed by slamming forces F_s, usually caused by plunging breaking waves:

➢ *Slamming forces:* $F_s = \rho_w R C_b^2 \lambda\eta_b C_s$



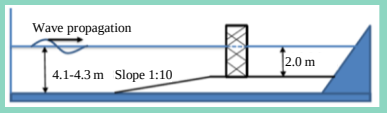
Uncertainties about some parameters [typical values]:
- ❖ $\lambda\eta_b$ [0.3 - 1]
- ❖ τ, time load
- ❖ C_s [$\pi - 2\pi$]

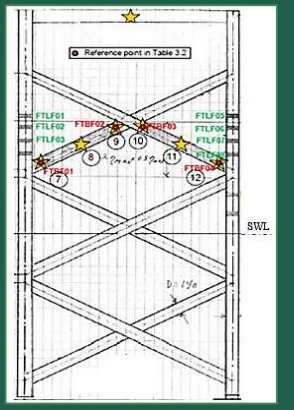
Project foundations

Wave Slam Project (Consortium headed by the University of Stavanger & Norwegian University of Science and Technology, Hannover 2013)

- Large scale prototype (1:8), subjected to thousands of wave impacts in the Large Wave Flume.
- The channel is 309 m long, 5 m wide. The structure is 2.25 m wide, 2.25 m long and 4.41 m high.
- Data measurements of the structure response along the bracings and columns.

Instrumentalization of the structure:
- ❖ 4 total force transducers (t.f.t)
- ❖ 12 XY f.t on the bracings
- ❖ 10 local f.t on the columns





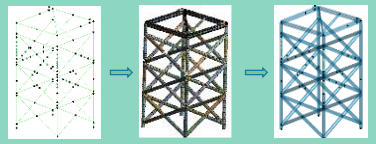
Details of the instrumented front bracings, FTBF01-02-03-04

Modelling and Validation process

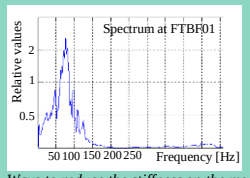
Modelled using ANSYS v14.5 as a line body (i)

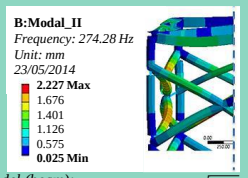
Materials:
- 94.7% is made of Steel St-37. 5.3 % is aluminum.
- The columns and bracings have a diameter of 0.14 m.
- Wall thickness: 5 mm.
- Young modulus: $2.1 \cdot 10^{11}\ Pa$. Density 7850 kg/m^3
- Partially submerged structured (d=2 m). Added mass coefficient is calculated.

Modelling scheme:



Uncertainties about connections of the bracings:
a) Frequency prototype: 70-90 Hz (spectrum analysis)
b) Frequency ANSYS: 250-270Hz (modal analysis) (ii)



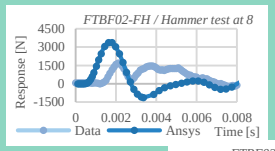


Ways to reduce the stiffness on the model (beam):
- ❖ Change boundary conditions ($\overline{W_N}$) ☹
- ❖ *Reduce Young Modulus, E* ☺
- ❖ Reduce Inertia, I ☹

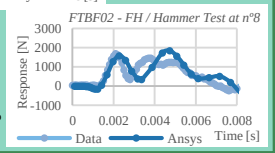
$$W_N = \overline{W_N}\sqrt{\frac{E\,I}{m\,l^4}}$$

W_N = Angular frequency beam (rad/s)

Throughout a validation process (hundreds of sensitivity analysis) some material properties have been modified ($E_i = 2.1 \cdot 10^{11}\ Pa \rightarrow E_{ii} = 2.1 \cdot 10^{10} Pa$) for the front bracings. (iii)



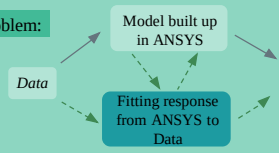
i) Initial Setup
Relative error:
- ❖ 1st. Peak force: 90%
- ❖ 1st. Timing: 70%



ii) Final Setup
Relative error:
- ❖ 1st. Peak force: 7%
- ❖ 1st. Timing: 9%

Characterization of wave slamming forces

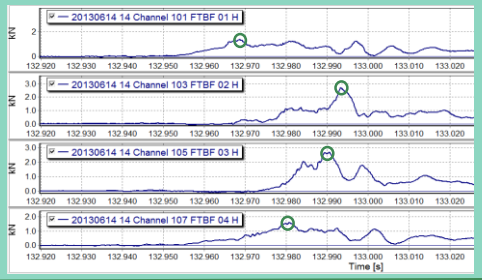
Inverse problem:



Characteristics of the process:
- ➢ Main focus on the front bracings.
- ➢ High and rapid wave forces.
- ➢ Calculation of the slamming coefficient at the beginning of the impact, C_s.

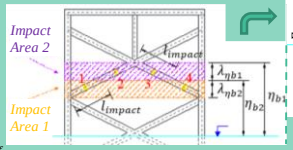
$$C_s = \frac{F_s}{\rho_w R C_b^2 \lambda\eta_b}$$

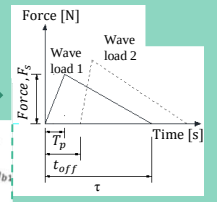
Study of the response on the front bracings for a specific wave:



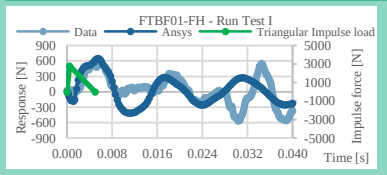
- ❖ Wave height when it breaks, H_{wave} : 1.97 m
- ❖ Sequence of impact:
  1 - FTBF 01 (+0.000 s)
  2 - FTBF 04 (+0.014 s)
  3 - FTBF 03 (+0.023 s)
  4 - FTBF 02 (+0.026 s)
- ❖ The wave hits asymmetrically.
- ❖ Two different impact areas are defined.
- ❖ Only focus on the impact forces. The morison forces are filtered down (quasi static forces).

Definition of the impact areas and wave loads:
- ➢ Four wave loads are defined in ANSYS within two impact areas:
  $\lambda_{\eta b1} = \lambda_{\eta b2} = 0{,}294\ m$
  $\eta_{b1} = 1{,}35\ m$, $\eta_{b2} = 1{,}06\ m$,
  $l_{impact} = 0.635\ m$
  $C_b = \sqrt{g \cdot h}$, where $h_{1,2} = d + \eta_{b1,2}$
- ➢ Wave actions are defined as triangular loads.
- ➢ A total of four parameters are calibrated:
  - ❖ Duration of the load, τ
  - ❖ Peak time, T_p
  - ❖ Max. force, F_s
  - ❖ Offset time (within the four loads), t_{off}

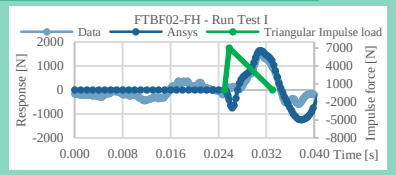




Comparison of the results between the response in ANSYS and the experiment (FTBF01-02) :



Relative Error for 1st peak Force = 7.01 % ; C_s= 2.09



Relative Error for 1st peak Force = 1.24 % ; C_s= 4.78

Conclusions

- ➢ Faithfully recreation of the initial response in the numerical model using a triangular time force history as a wave load.
- ➢ Largest slamming coefficient found C_s = *4.78*, smaller than recommended values (5.15 - 2π) for truss structures.
- ➢ Analysis of more wave tests are necessary.

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