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Structural Investigation of the Log Accumulation Effect in a Debris Containment Grid Through Towing Tank Experiments

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Santo Antônio Hydropower Plant

- Madeira River, located in the Amazon Rainforest, North of Brazil
- Spillway flow rate of 84,000 m³/s
- 3.568 MW of installed power
- 45 million consumers
- 4th greatest hydropower plant in Brazil

Santo Antônio Hydropower Plant, North of Brazil

Santo Antônio Hydropower Plant, North of Brazil

Santo Antônio Hydropower Plant

- Logs flowing through the river and reaching the plant are a recurrent event, and represent a major concern
- Large volume of logs generates log accumulation
- In times of flood, it reaches 9,000 logs/day

Logs accumulation phenomena

Log Containment Proceedings

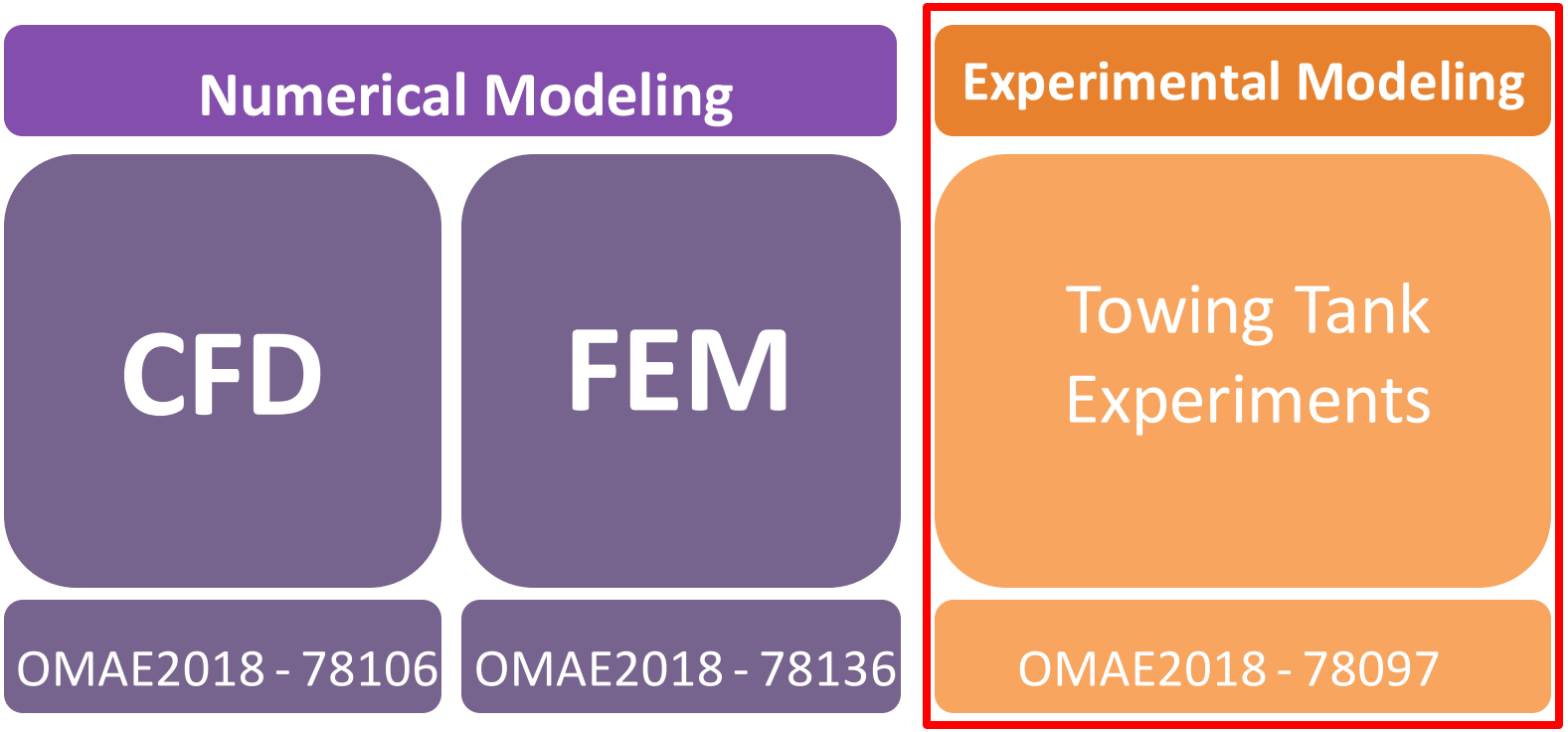
- In order to mitigate and protect effects caused by the debris, log booms were placed across the river and dam
- These structures are connected forming a line with a catenary-like shape line

Log boom line

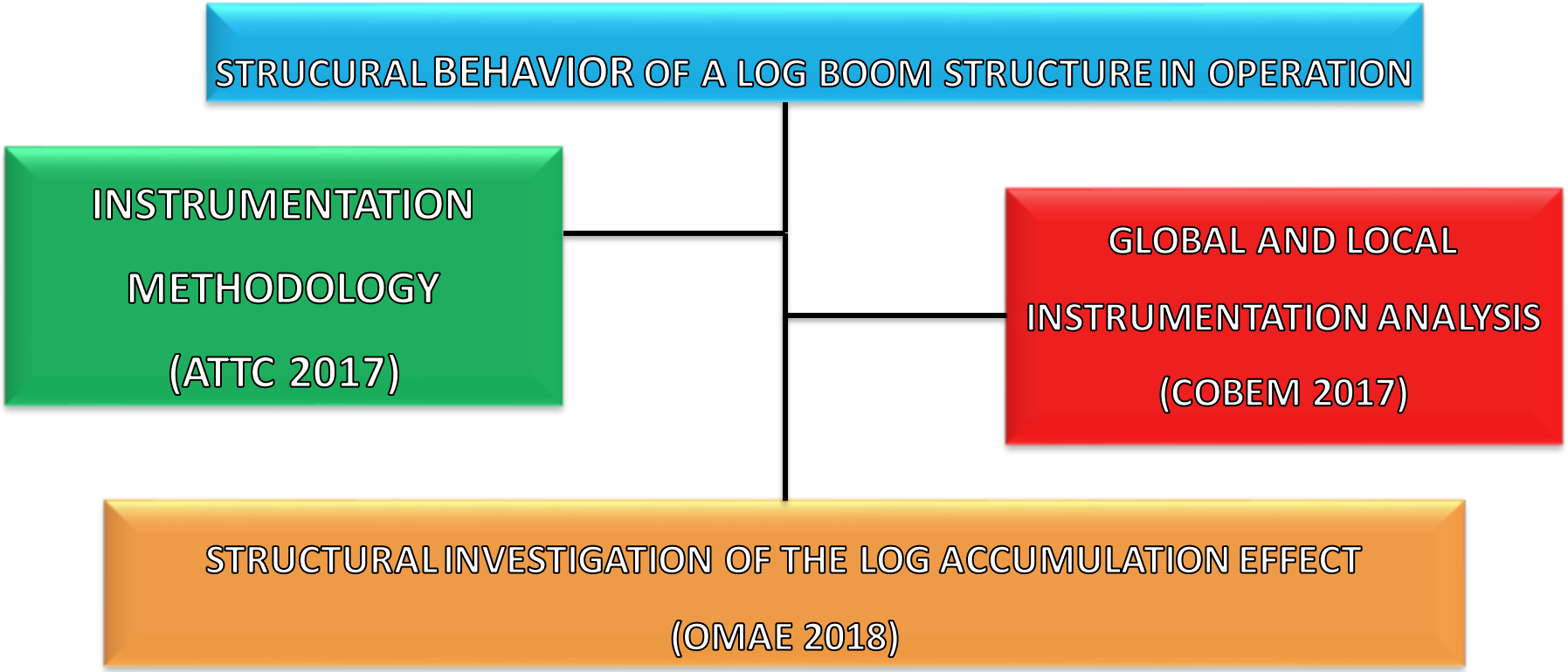
Objectives

- Determine how the **strain** and **load** are distributed along the model and anchorage system tested in a towing basin with the presence of debris
- Understand the movements and forces magnitude acting on the structure by development of a instrumentation methodology and further **structural analysis**

Log Boom R & D Project



So far...


STRUCURAL BEHAVIOR OF A LOG BOOM STRUCTURE IN OPERATION
INSTRUMENTATION METHODOLOGY (ATTC 2017)
GLOBAL AND LOCAL INSTRUMENTATION ANALYSIS (COBEM 2017)
STRUCTURAL INVESTIGATION OF THE LOG ACCUMULATION EFFECT (OMAE 2018)

Facilities

- Tests were set and conducted in the Laboratory of Naval and Ocean Engineering (NAVAL) of the Institute for Technological Research (IPT)
- IPT's Towing Tank is equipped with a dynamometer carriage, a Planar Motion Mechanism (PMM) and wave maker

IPT's Towing Tank

Dimensions	Section	
	Narrow	Wide
Length (m)	80	200
Depth (m)	4.0	6.6
Width (m)	2.2	3.5
Carriage Maximum Velocity (m/s)	3.5	

IPT's Towing Tank Main Particulars

Prototype

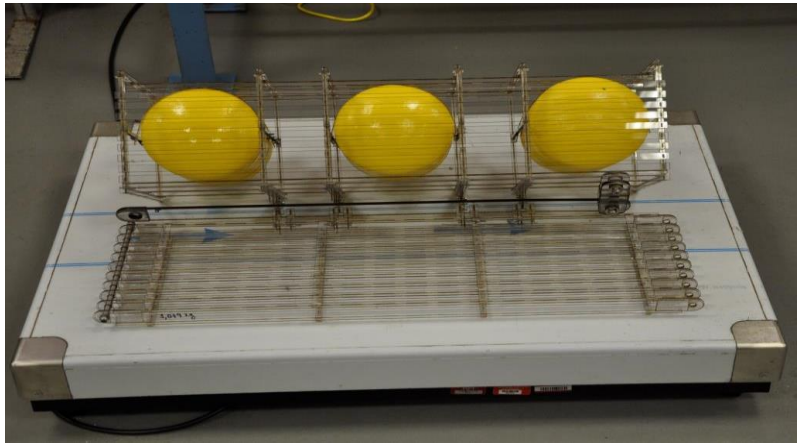
- Each module consists of **floaters** encaged on a **rigid frame structure** that is connected to a longitudinal **reinforced beam**, which in turn is connected to a **grid**
- Average water line is located at mid height of the upper structure, leaving around 3.5 m of hydrostatic submerged height

Log boom line during operation

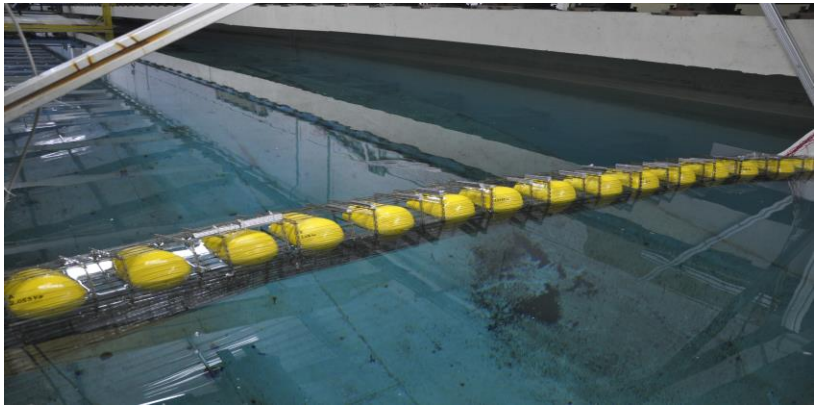
Installation of real size log boom module

Model

- 1:10 scale adopted
- Manufacturing proccess included laser cutting and 3D printing techniques
- The model length varies with the number of modules, reaching aroung 5 m



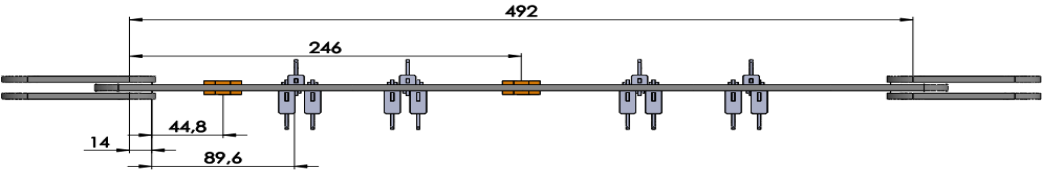
Log boom model module



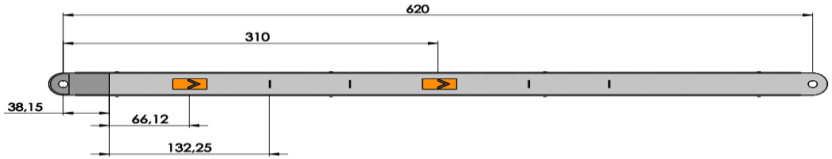
Log boom model line during tests

Instrumentation Methodology

- **Local** instrumentation aims to understand how the strain is transferred along the structure
- Water proof strain gages attached to **reinforced beam** and **girders of lower grid**
- Strain gages final locations were thought to avoid **stress concentration** and **high strain gradients** areas

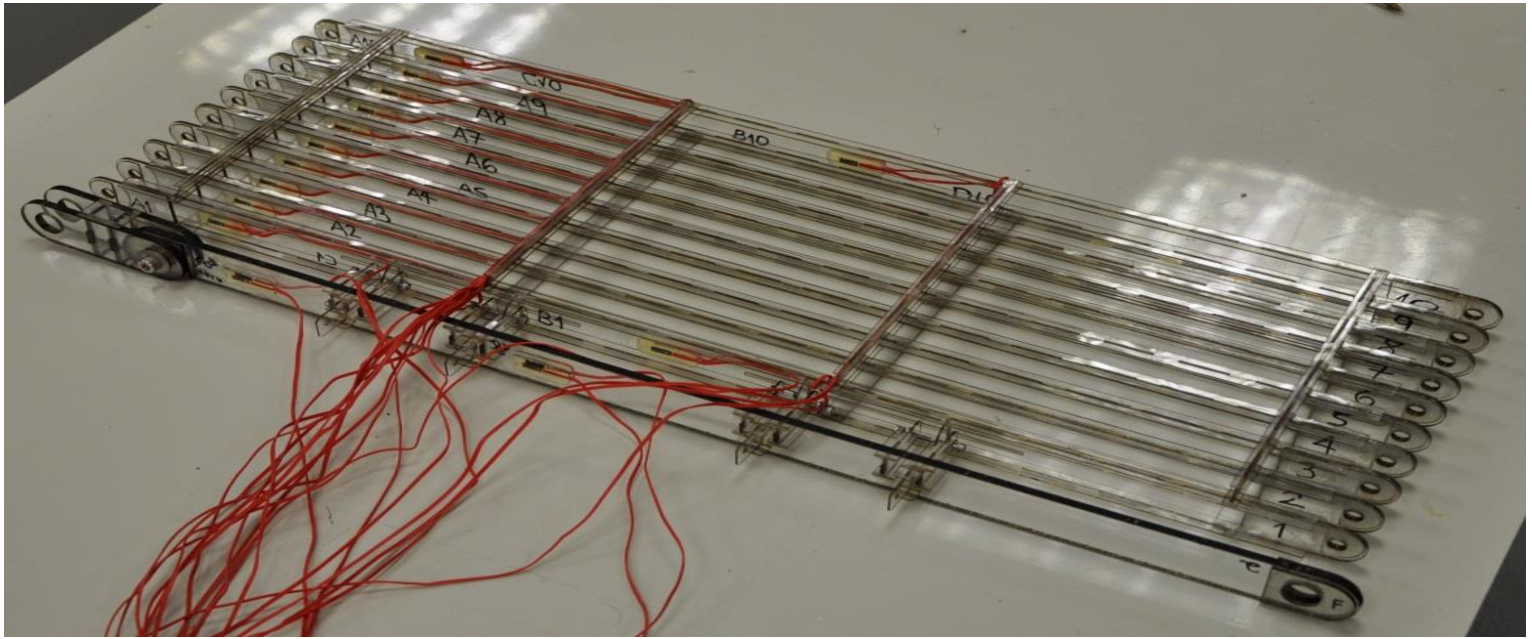


Reinforced beam strain gages arrangement sketch



Girder strain gages arrangement sketch

Instrumentation Methodology



Final assembly and connection

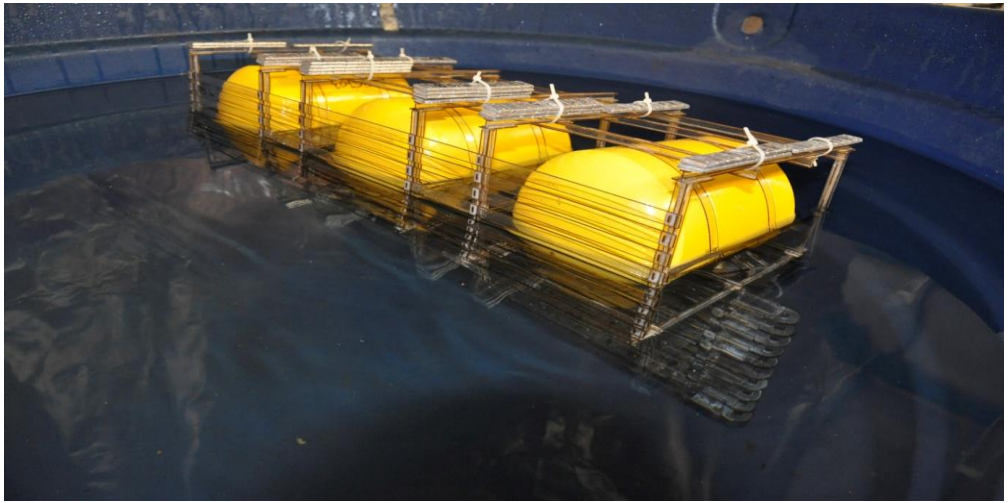
Instrumentation Methodology

- Global instrumentation was addressed to measure external forces at the anchorage regions of the truncated line
- Uniaxial water proof load cells installed

HBM S-Type S9M load cell

Model Balancing

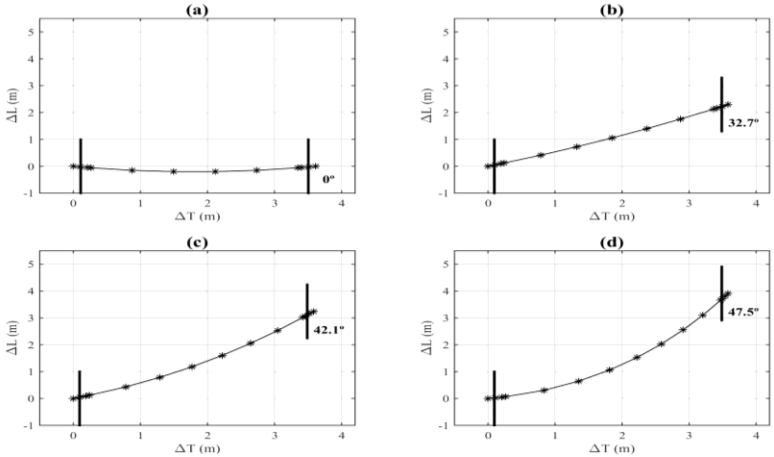
- Different weight distribution between model and real size structure
- Ballast performed distributing lead stripes over the grid and top of the model, without modification of frontal area, in order to minimize drag interference



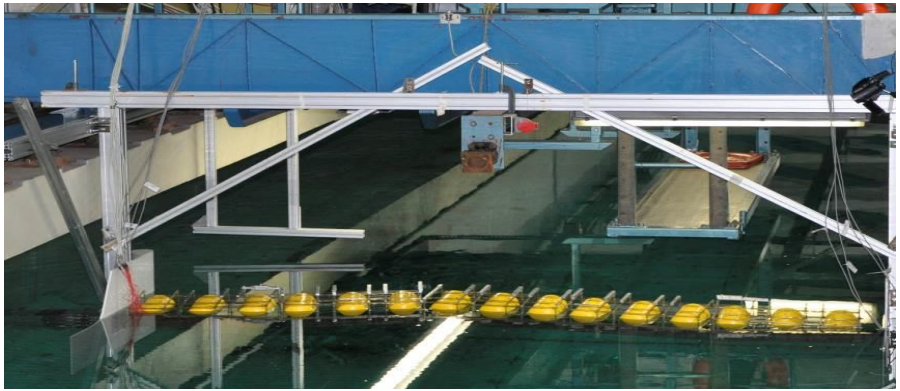
Log boom model ballast

Model Attachment

- Curvature catenary model line allows variation on flow incidence angle
- In order to vary the incidence flow, the experiment was designed to vary transversal and longitudinal distance between extremities



Model curvature variations

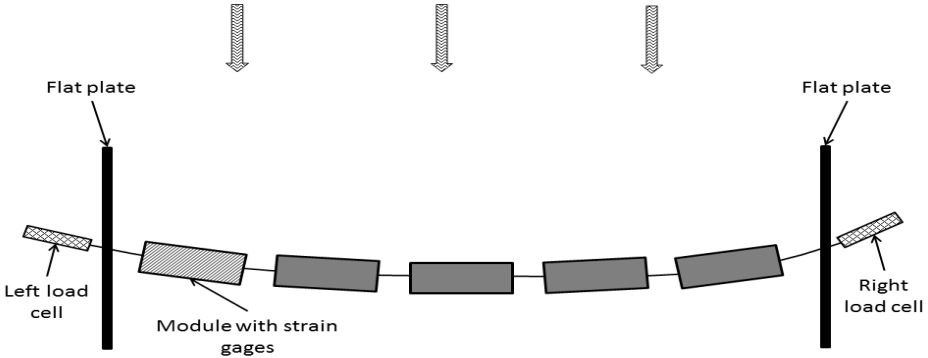


Log boom model and its anchorage structure at the towing carriage

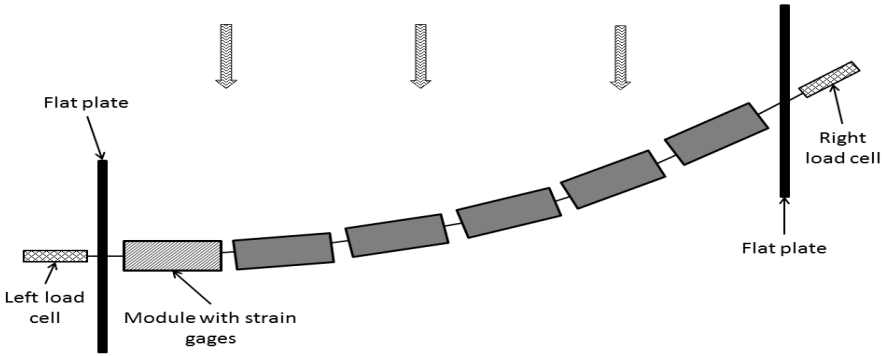
Test Methodology

- The log boom model was attached and set to the towing carriage
- The tests consist in towing the model along the tank to simulate a scale river stream velocity
- Vary parameters such as **log boom sets**, **carriage speed**, **curvature of model line**, and **log amount**, being purely hydrodynamic (**HYD**), having low density of logs (**T1**) or large density of logs (**T4**)

Test Methodology

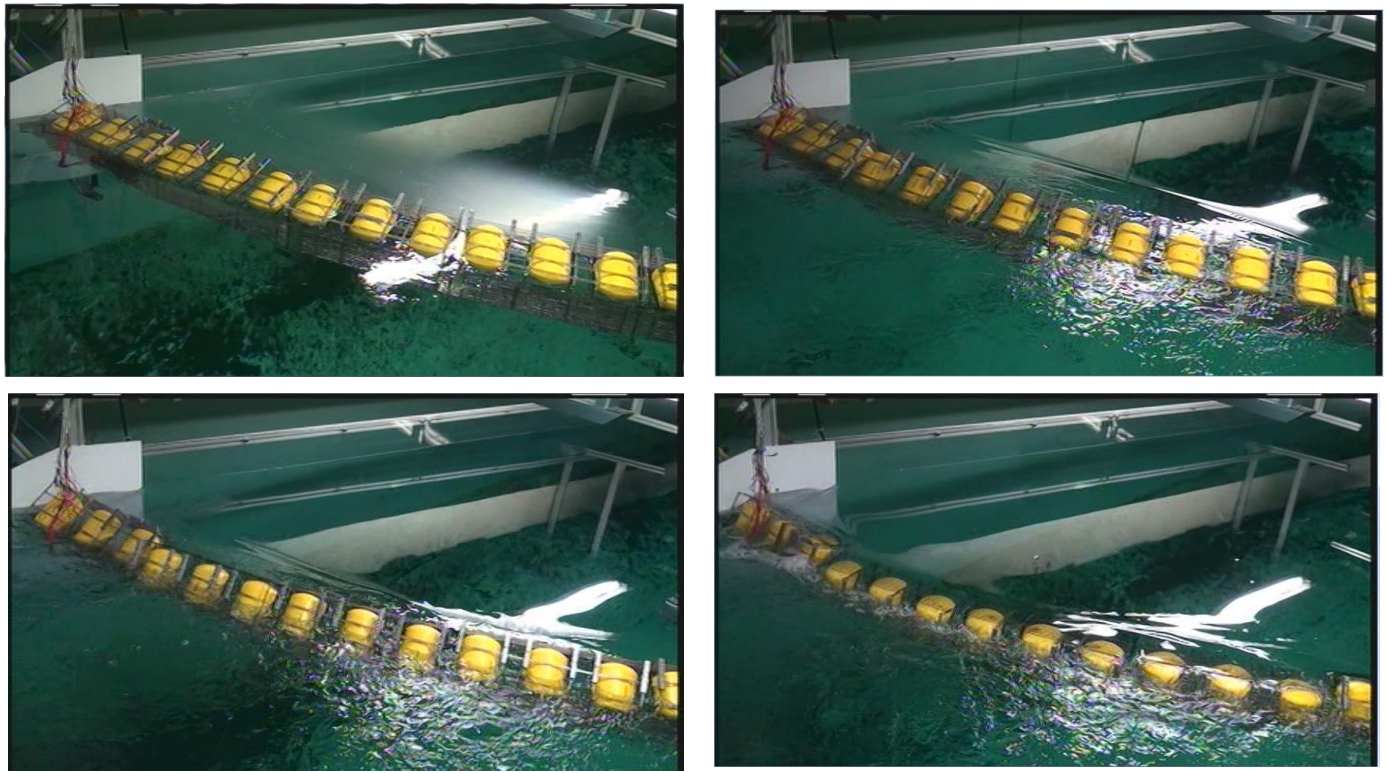


Symmetric configuration



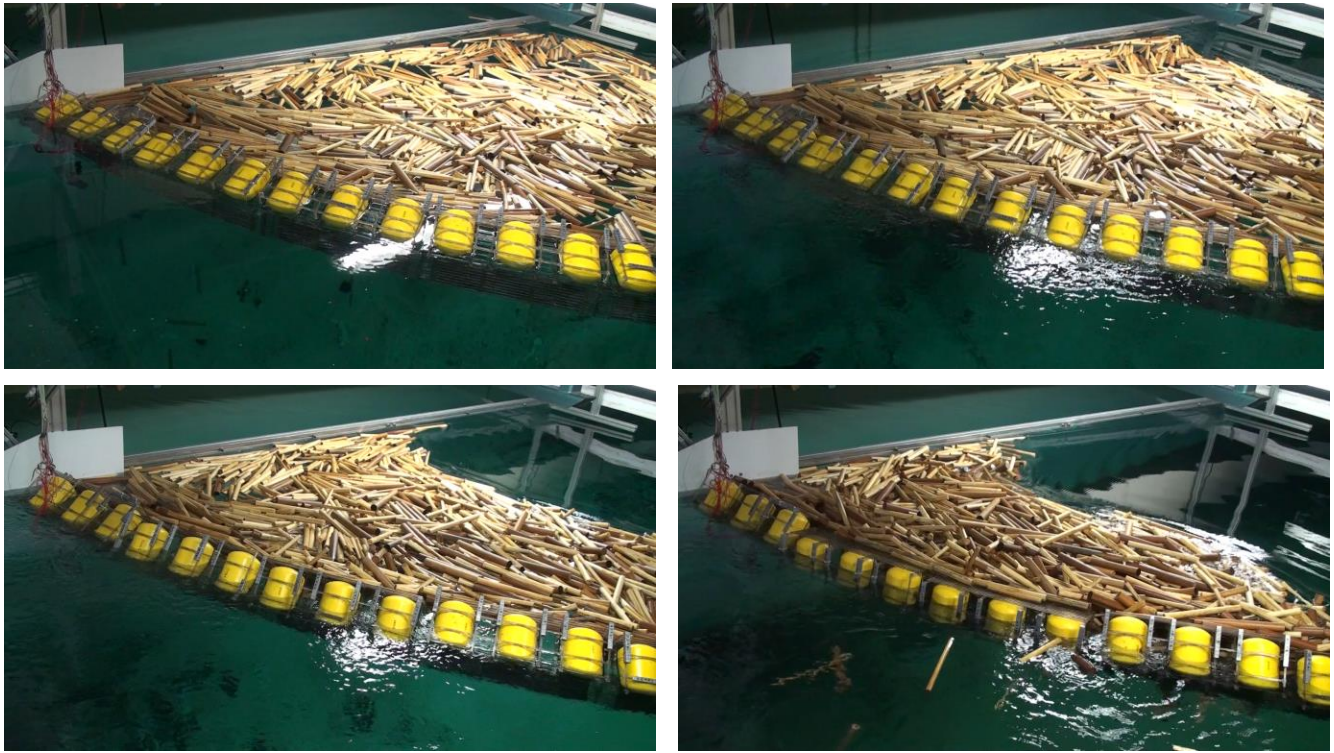
Non-symmetric configuration

Test Methodology



Log boom test with velocity variation and without logs

Test Methodology



Log boom test with velocity variation and logs

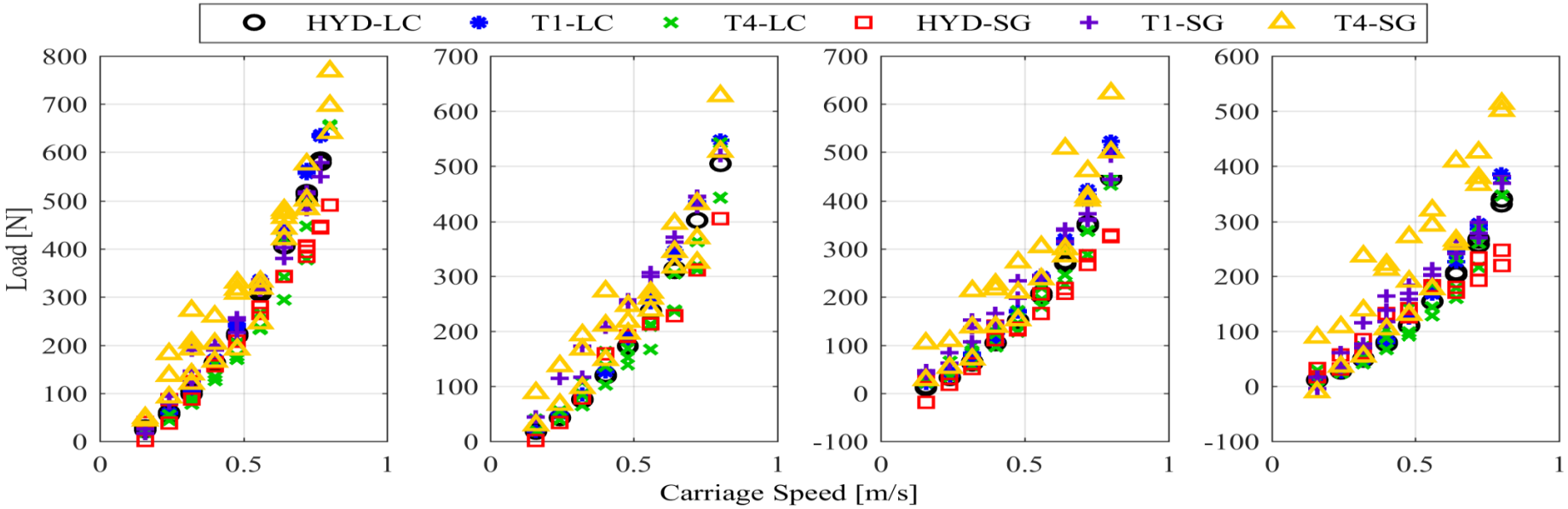
Experimental Matrix

Number of Modules	ΔT	ΔL	Angle	Prototype Velocity	Carriage Speed
5	3.66 m	0 m	0°	0.50 m/s	0.158 m/s
				0.75 m/s	0.237 m/s
6	3.58 m	2.3 m	32.7°	1.00 m/s	0.316 m/s
				1.25 m/s	0.395 m/s
7	3.58 m	3.24 m	42.1°	1.50 m/s	0.474 m/s
				1.75 m/s	0.553 m/s
8	3.58 m	3.9 m	47.5°	2.00 m/s	0.632 m/s
				2.25 m/s	0.711 m/s
				2.50 m/s	0.790 m/s

Experimental Matrix

Results

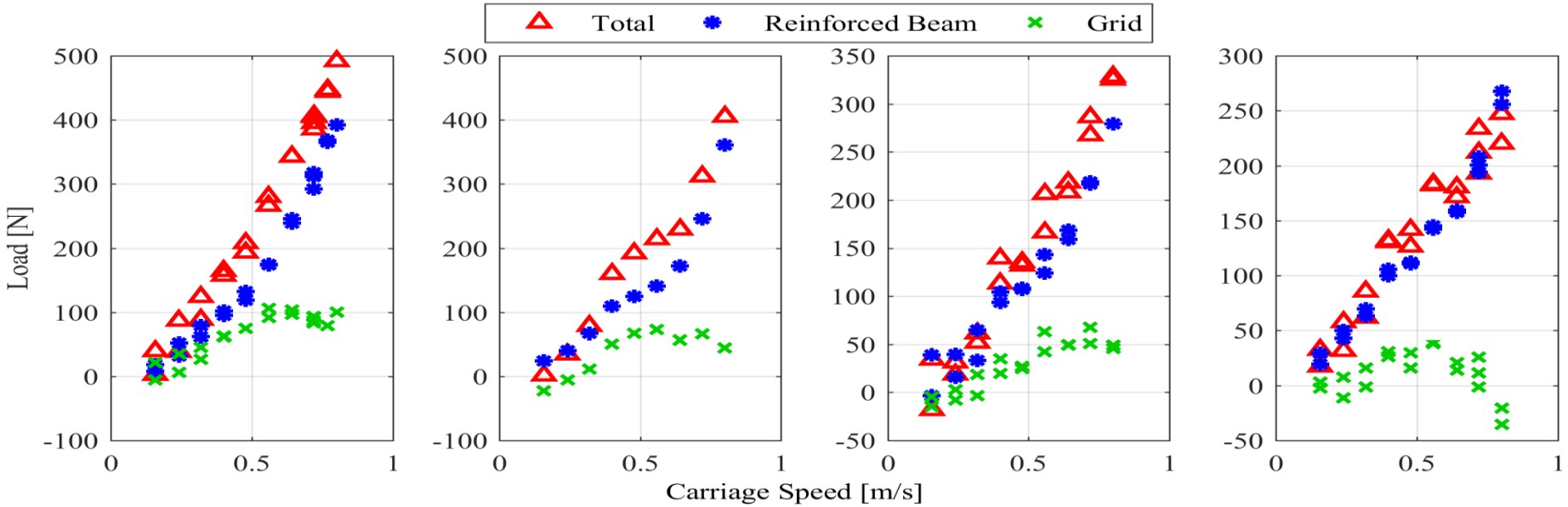
Load Cells (LC) and Strain Gages (SG)



Sum of load cell (LC) and strain gages (SG) forces measured at left side on three types of testes. From left to right: 5 modules, 6 modules, 7 modules, and 8 modules.

Results

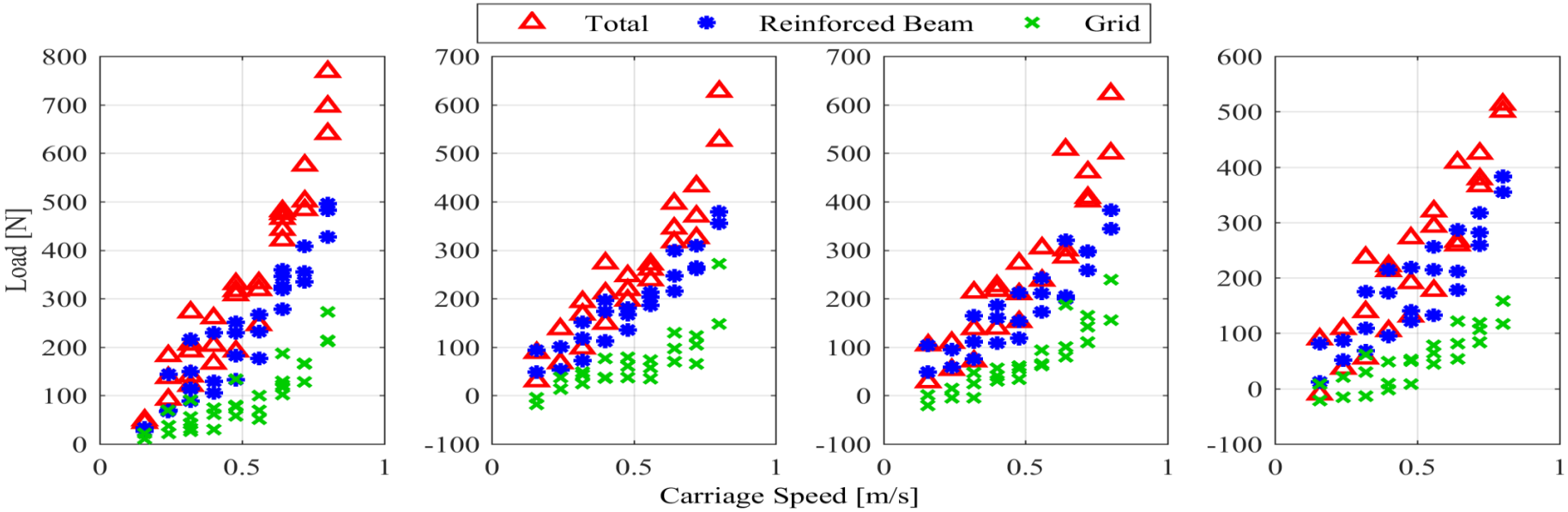
Reinforced Beam and Grid – HYD



Forces on reinforcement beam, grid, and total in the hydrodynamic tests. From left to right: 5 modules, 6 modules, 7 modules, and 8 modules.

Results

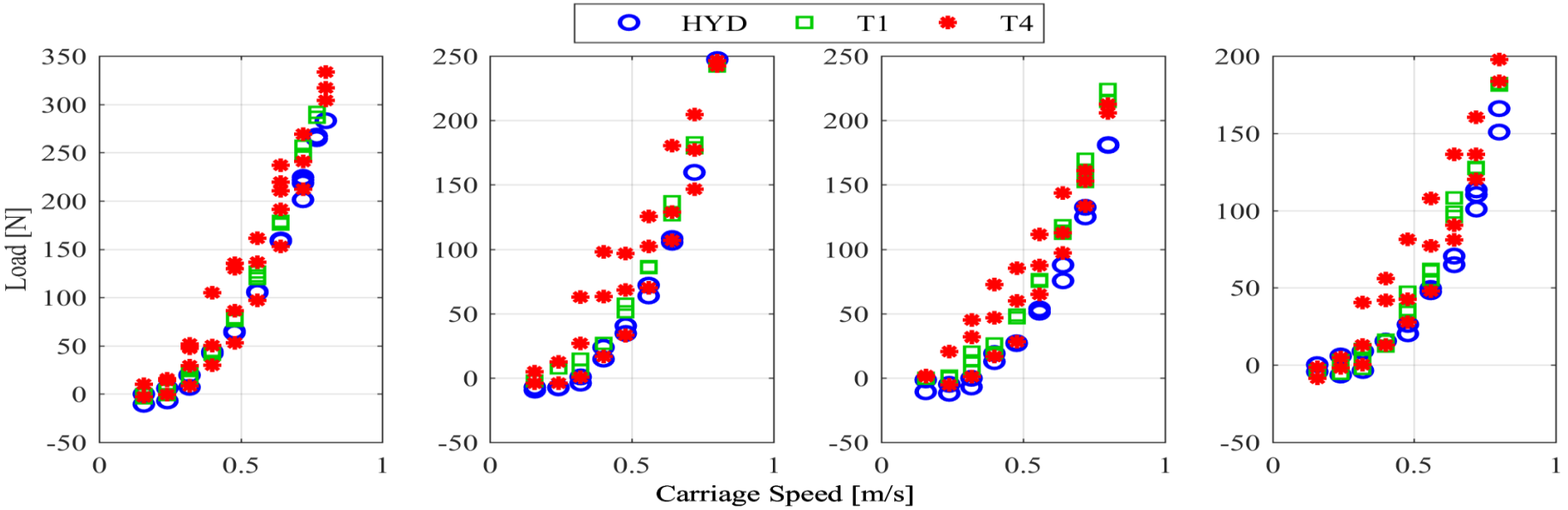
Reinforced Beam and Grid – T4



Forces on reinforcement beam, grid, and total in the log test T4. From left to right: 5 modules, 6 modules, 7 modules, and 8 modules.

Results

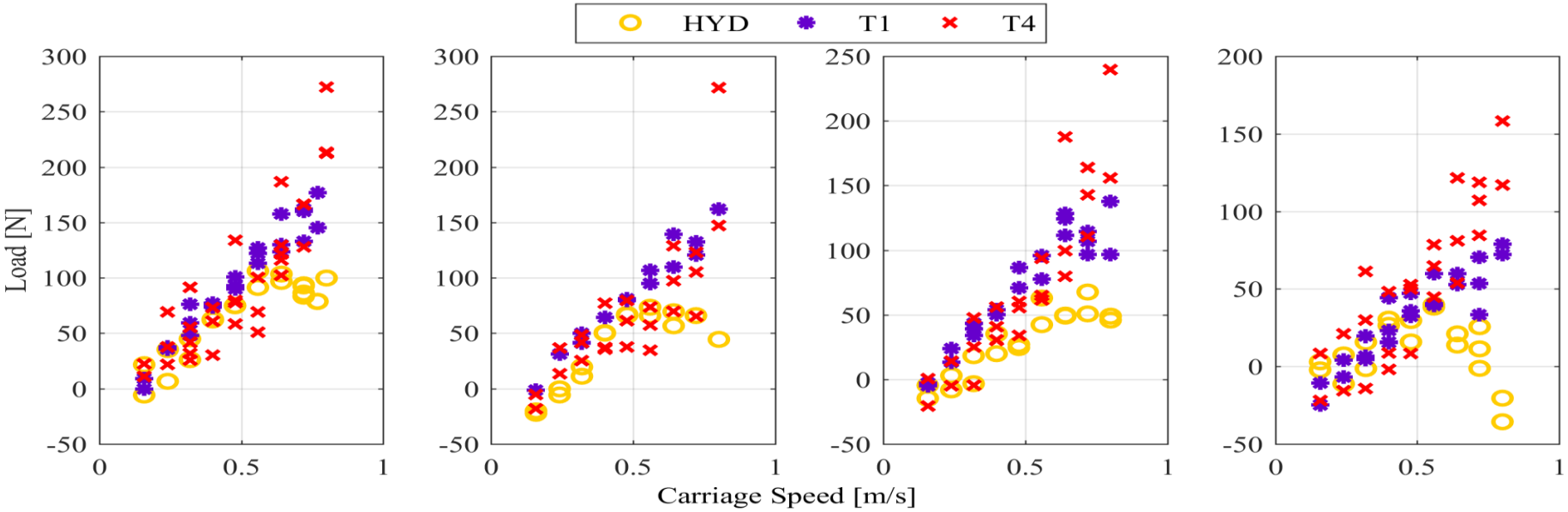
Reinforced beam



Mean forces on the reinforced beam. From left to right: 5 modules, 6 modules, 7 modules, and 8 modules.

Results

Grid



Strain gages loads in grid for different tests. From left to right: 5 modules, 6 modules, 7 modules, and 8 modules.

Conclusions

- Structural investigation for a reduced scale model of a hydropower plant debris containment grid **performed**
- Given the repeatability of the tests and the instrumentation process, the results demonstrated quite an **acceptable precision**
- A distinct load magnitude was shown with not only the increasing of the **towing speed** and **incident angle**, but also with the **log accumulation pattern**.
- The **reinforced beam** resisted to the majority of the load generated by the model interaction with the fluid stream, independently of the presence of logs in the flow.
- The log accumulation creates higher tension magnitudes felt by the **grid** as flow velocity increases.

Future Work

- Analogous analysis will be executed to the experiments with several conditions of log accumulation.
- Variation on the positioning of the instrumented module during the tests in order to improve the correlation analysis with the real prototype.
- Development of a measurement process using capture motion techniques and also to understand how the logs accumulate on the model with the increase of towing speed.

Acknowledgments

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CAPES

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SantoAntônio ENERGIA

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Thank you

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