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Multiple Impacts Of Debris On A Vertical Obstacle

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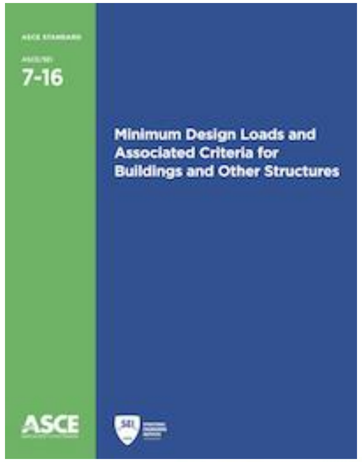
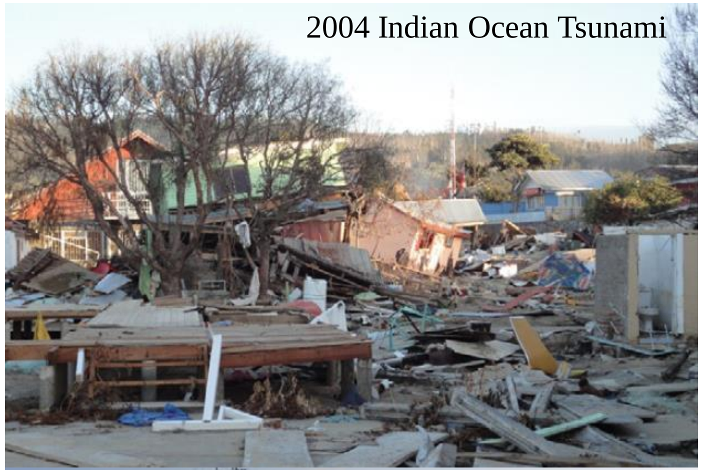
NHK (2011)

Motivation

- Critical infrastructure failed during recent major flooding events.
- A need to revaluate the current methods of addressing loading within these events (Nistor et al., 2009).
- Relying upon field surveys and video evidence, new load combinations have be considered in current standards (Chock, 2016).
- Within tsunami engineering:
  - SMBTR (2005)
  - FEMA P646 (2012)
  - **ASCE7 Chapter 6 (2016)**

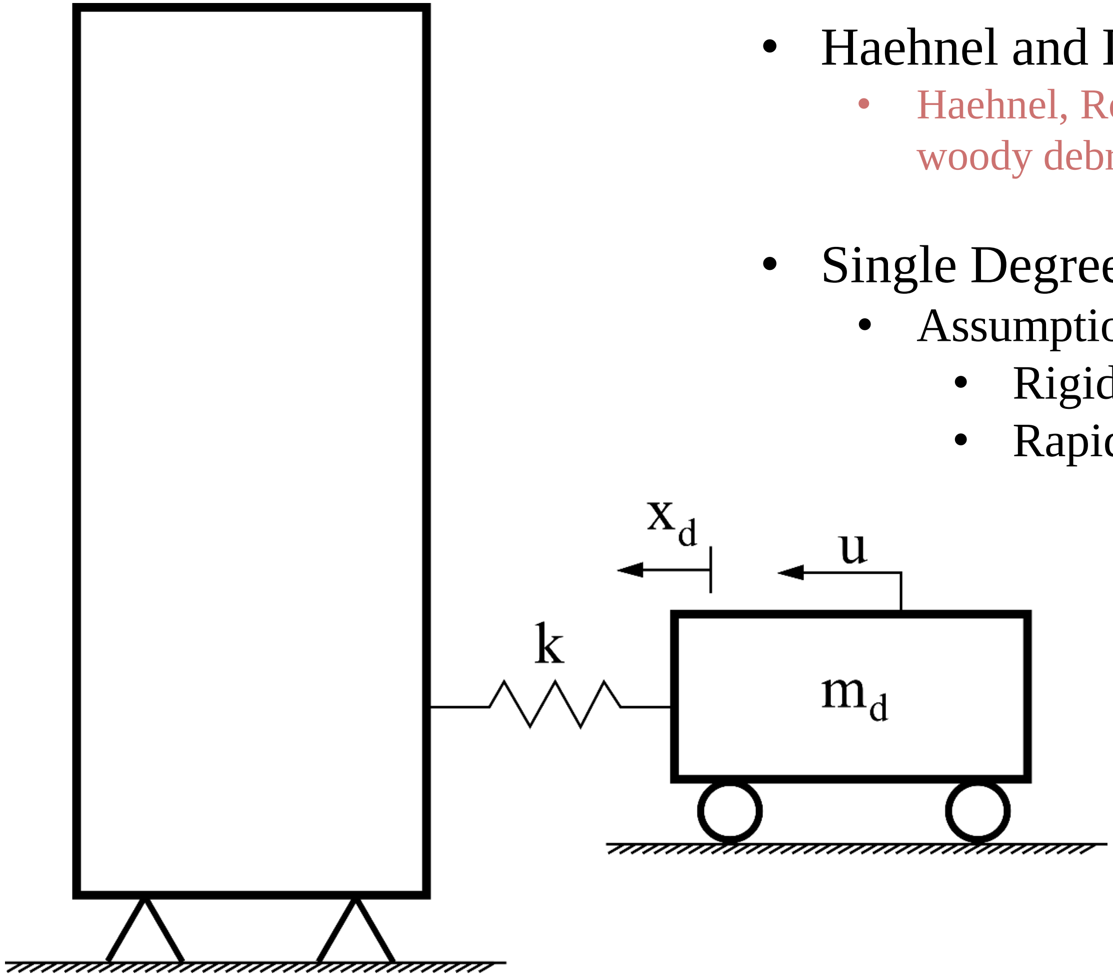



2004 Indian Ocean Tsunami


2011 Tohoku Tsunami


2017 Hurricane Maria

Debris Impact Loading



- Haehnel and Daly (2004)
  - Haehnel, Robert B., and Steven F. Daly. "Maximum impact force of woody debris on floodplain structures." *JHR* 130.2 (2004): 112-120.

- Single Degree-of-Freedom Impact Model
  - Assumptions:
    - Rigid Body Impact
    - Rapid Impulse

$$F_i = e\beta u\sqrt{km}$$

Limitations

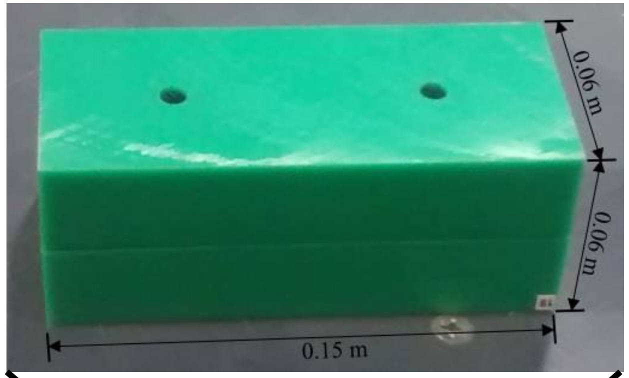
- Conservative Estimation
- 1D Model
- Single debris impact

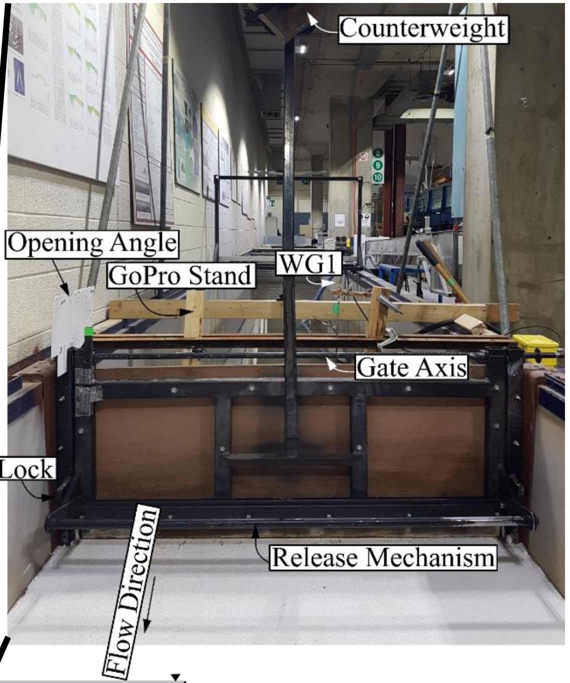
Objectives

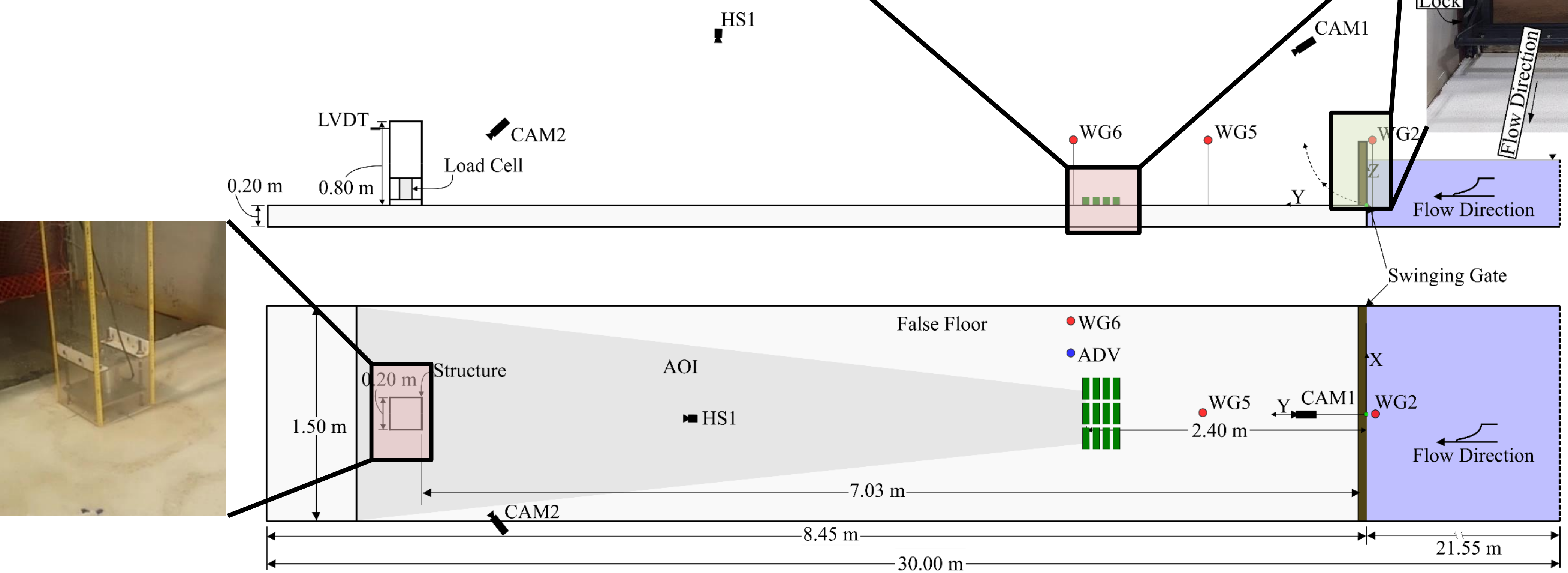
- Determine modes of impact
- Examine maximum forces from multiple impacts

Experimental Setup

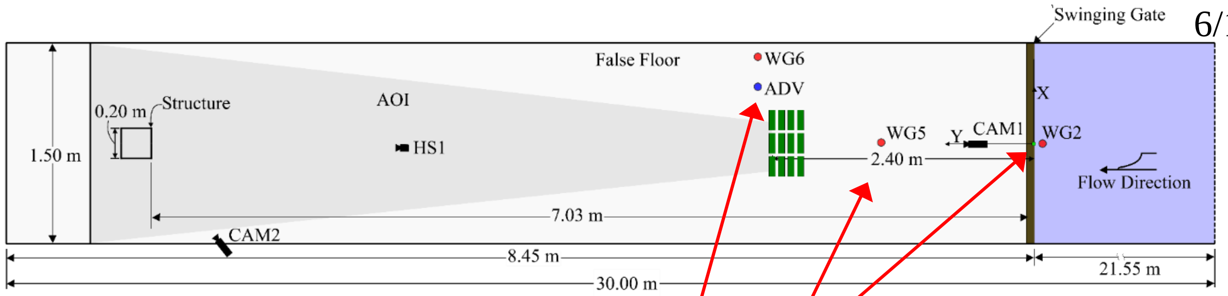
- The experiments were performed in the University of Ottawa dam-break flume.
  - 30 m × 1.5 m × 0.70 m

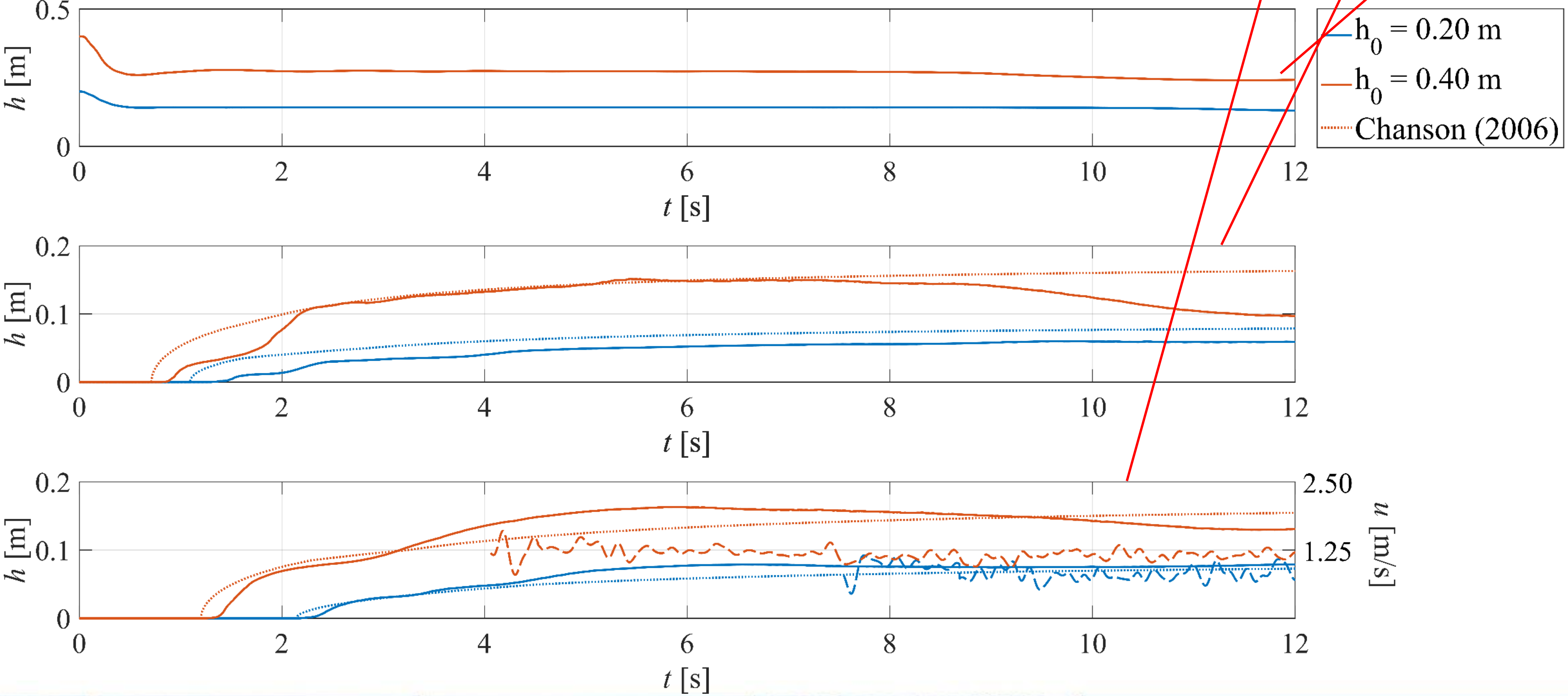






Dam-break Wave

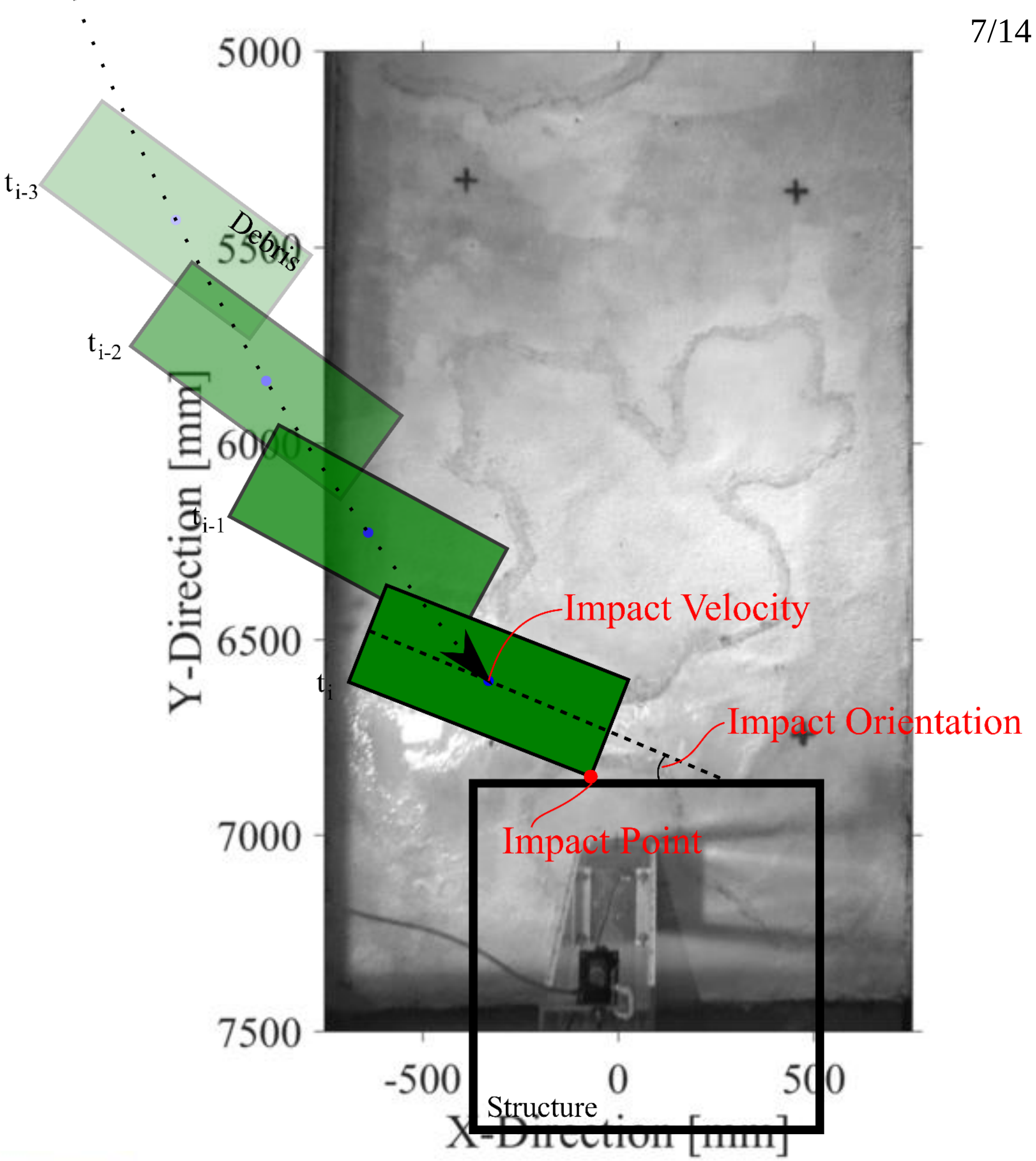




Experimental Protocol

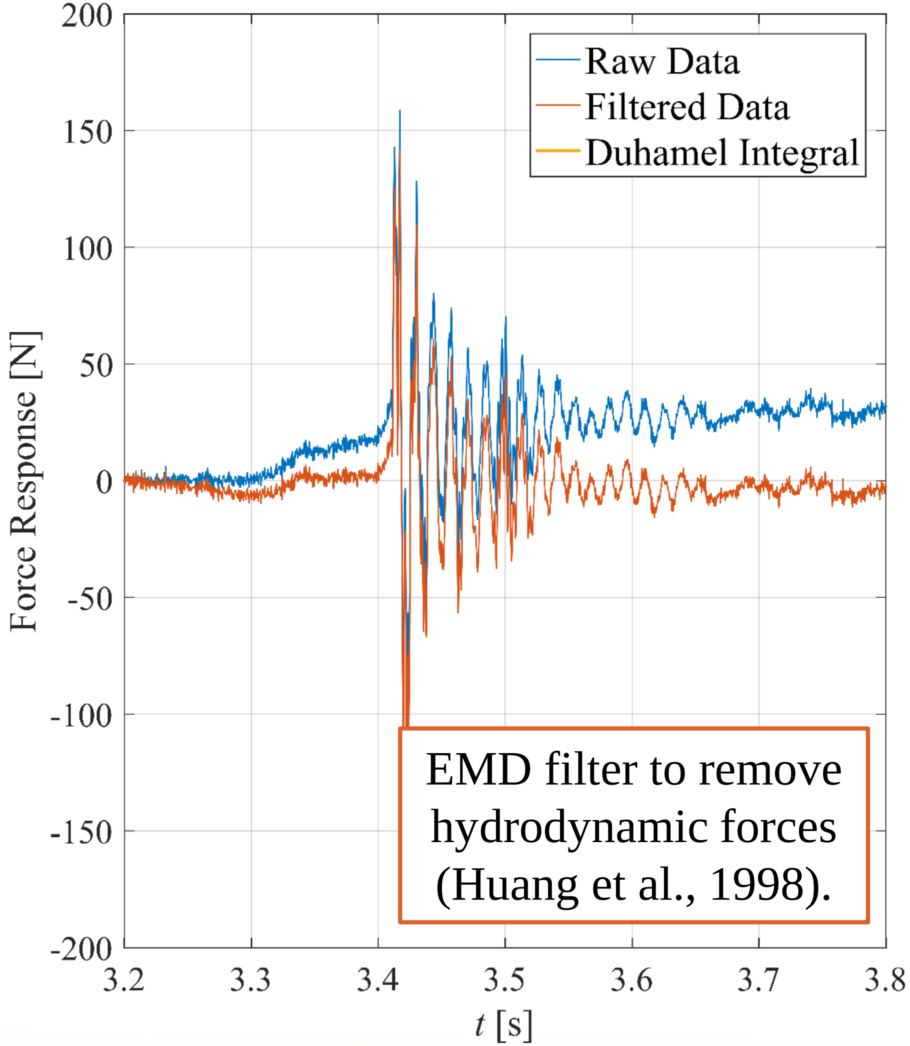
- Investigated several variables:
    - **Number of Debris**
    - **Impoundment Depth**
    - Initial Configuration
    - Debris Material
- Minimum of 10 repetitions per experimental condition (150 test total).

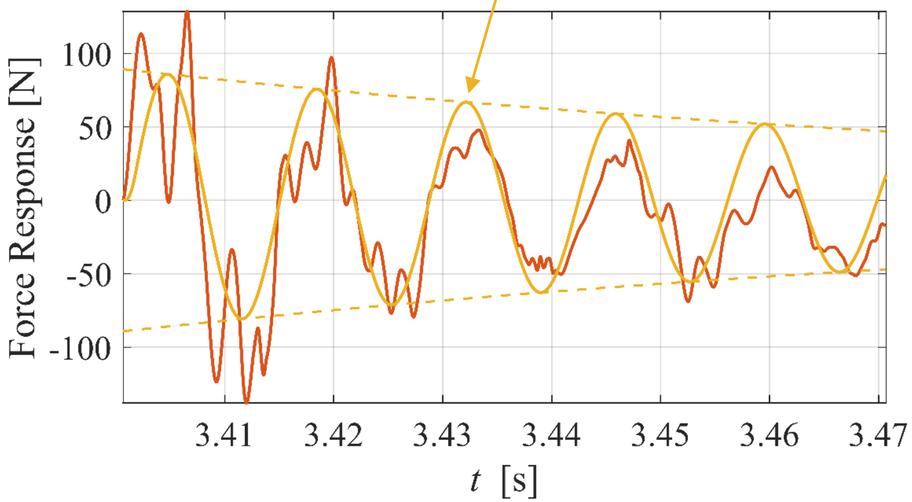
Impoundment Depth (h_0) [m]	Number of Debris (N) [-]	Debris Orientation (θ) [º]	Repetitions [#]
0.40	1	0	20
0.20	1	0	10
0.40	1	90	20
0.40	3	0	10
0.20	3	0	10
0.40	6	0	20
0.20	6	0	20
0.40	12	0	20
0.20	12	0	20

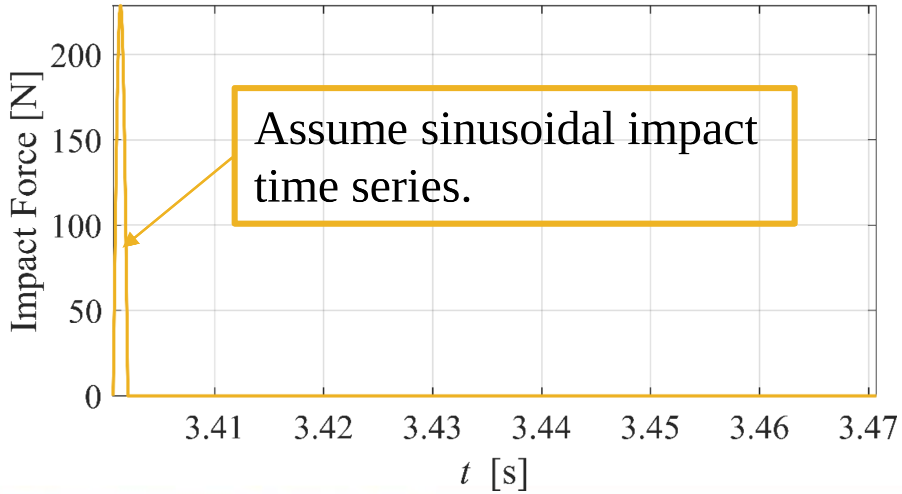


Impact Analysis

Duhamel Integral: $R(t) = \frac{k}{m_s \omega_d} \int_0^t p(\tau) \sin \omega_d (t-\tau) e^{-\xi \omega_d (t-\tau)} d\tau$

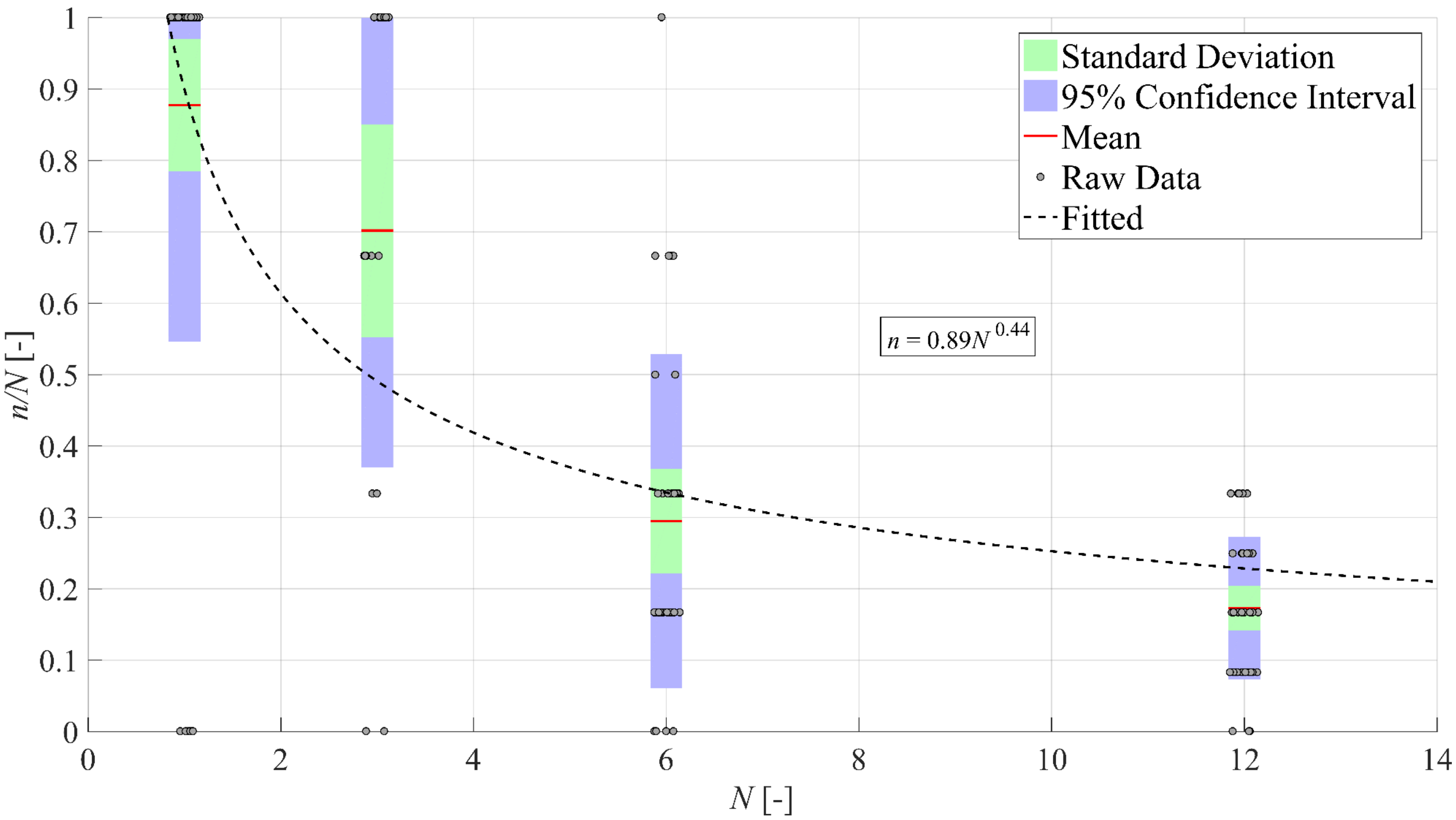






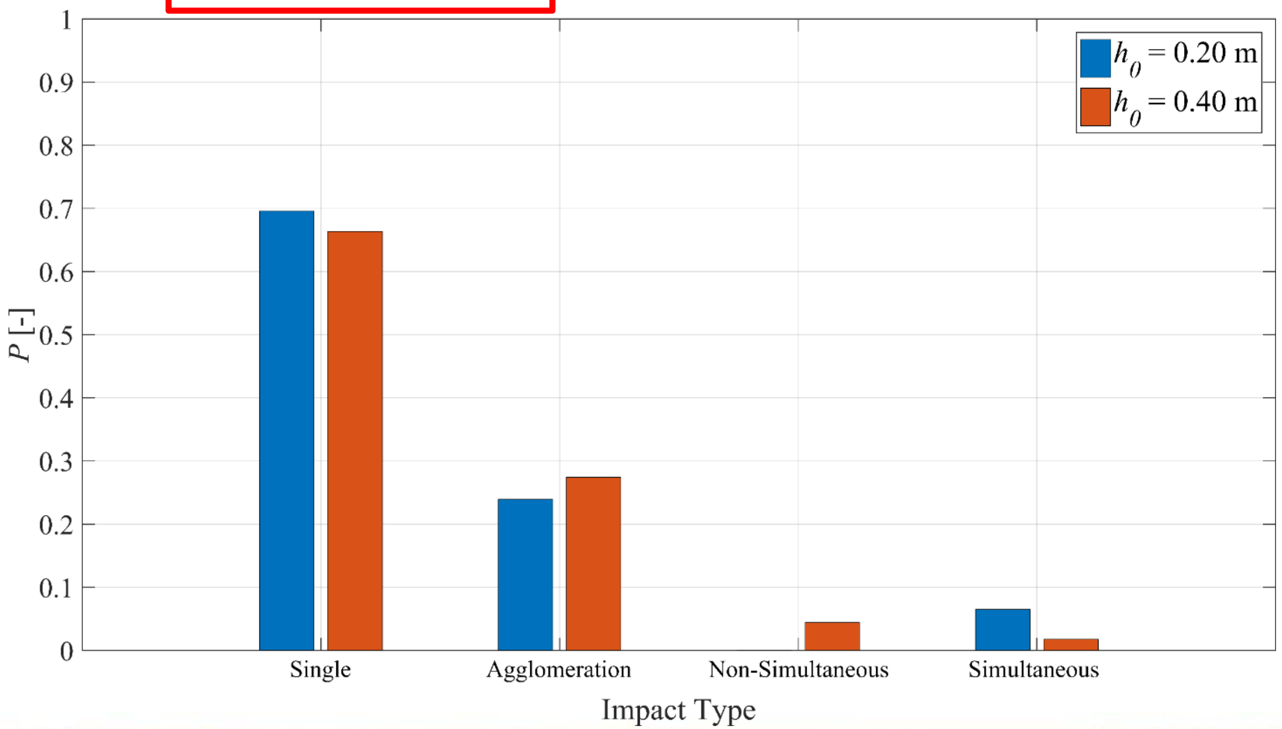
Debris Hazard

- The **number of impacts** (n, in aggl.) dependent on the **number of debris (N)** present.
- Presence of debris results in inter-collisions, causing increased spreading (Nistor et al., 2016).

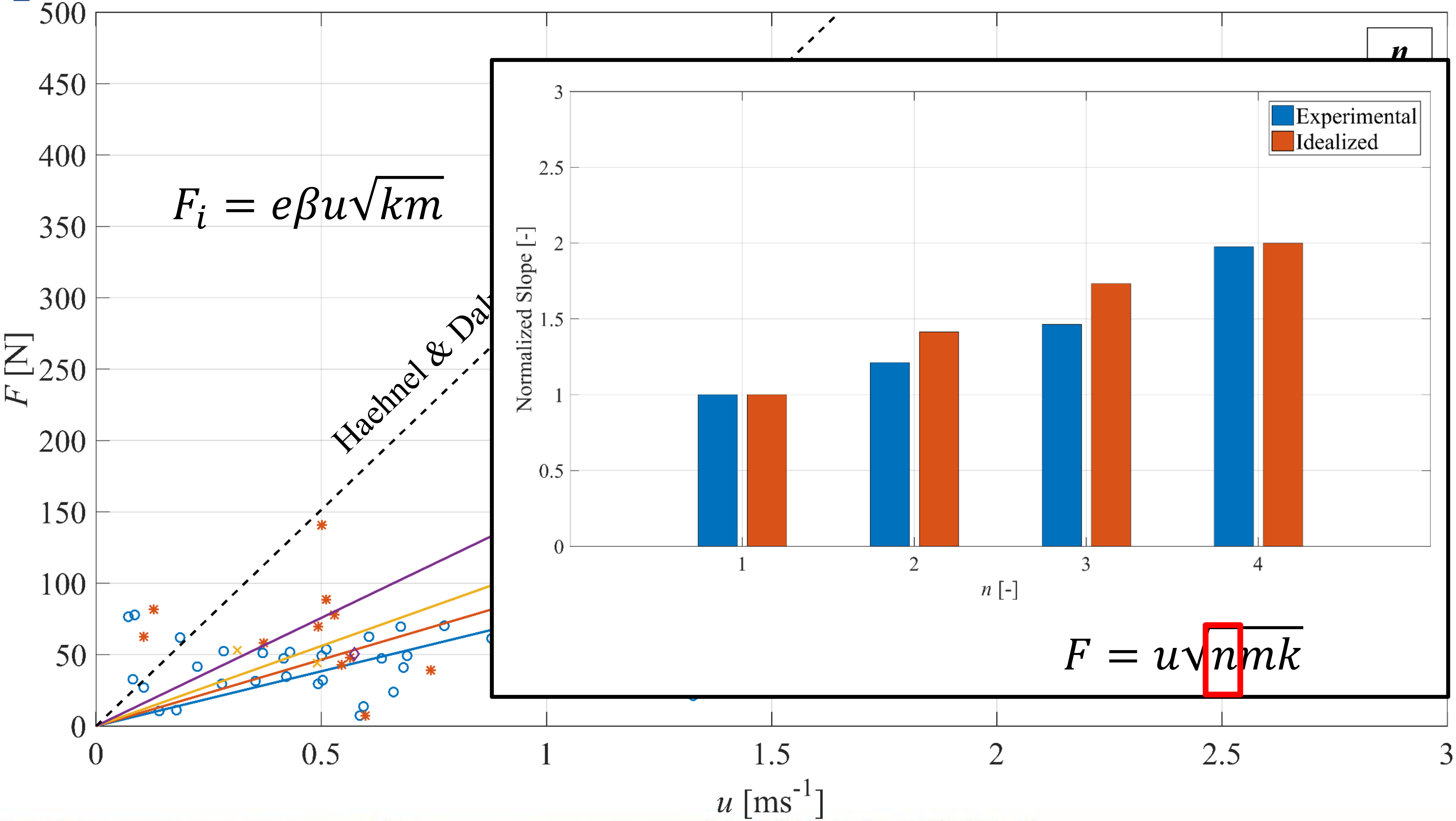


Impact Type

- The impact was classified into four categories:
  - **Single**
  - **Agglomeration**
  - Simultaneous
  - Non-Simultaneous



Impact Force



Conclusions

- The **number of debris** resulted in **more debris impacts**, though a lower percentage of debris impacts.
  - Due to increase in the spreading of the debris.
- **Hydrodynamic conditions** had no **apparent influence** on the type of impacts occurring.
- The **number of impacting debris** resulted in an **increase in the impact force**.
  - Not completely explained by the increased inertia of the projectile.

Next Steps

- Develop a method of addressing the **complex inertia of the impacting agglomerations**.
- Investigate **scale effects** related to solid body impact in extreme hydrodynamic conditions.

Thank you for your attention!

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