# TSUNAMI DESIGN FORCES FOR ABC RETROFIT

**Quarterly Progress Report**
**For the period ending May 31, 2020**

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# 1. Background and Introduction

The catastrophic damage that tsunamis cause to coastal communities is often exacerbated by the destruction of much of the transportation infrastructure (Fig. 1). This destruction delays critical rescue efforts and economic recovery.

Many components of the transportation infrastructure can be damaged by the incoming tsunami bore. Additional damage can be caused by the flow of water after the initial tsunami impact, at which time the water is often carrying debris from other structures from structures located nearer the coast (incoming flow) and structures further from the coast (outgoing flow).



*Figure 1. Ponulele Bridge Destroyed by 2018 Tsunami*

# 2. Problem Statement

The effects of the initial tsunami bore on bridges has been studied analytically and experimentally by a number of researchers. For example, with funding from FHWA and five state DOTs, PEER is currently coordinating a study in which the impact of a tsunami bore on a bridge superstructure was simulated experimentally at the NHERI wave flume at Oregon State University (OSU).

Our proposed research focuses on later, post-bore effects of tsunamis, which can be equally damaging but have rarely been studied. The post-bore effects are dominated by quasi-steady-state, debris-laden flows that cannot be simulated experimentally well in a flume with a transient, piston-generated wave. No data is available to calibrate design or simulation models for this condition. Such data is needed to develop ABC methods for the retrofit of bridges to resist tsunamis.

# 3. Objectives and Research Approach

UW and OSU researchers generated an initial set of data using the OSU wave flume. As shown in Fig. 2, the force history (shown for an elevated structure) generated by debris includes multiple impacts (sharp peaks in force history) and an accumulation of force as the debris increases the hydraulic area of the bridge. The forces decrease rapidly with time, because the transient wave lasted only a short time.
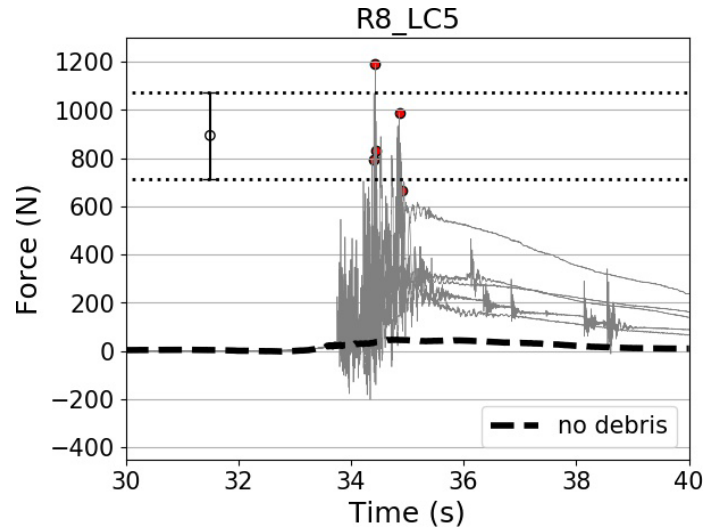


*Figure 2. Measured Forces on Elevated Structure*

Fig. 3 shows that the total measured force increased with the number of debris in the flow. For eight blocks, this figure also shows that the total force varied greatly among the repetitions, a behavior that is consistent with the semi-chaotic nature of debris interaction with the bridge. This dataset is available from the NHERI DesignSafe data repository (PRJ-1709: NHERI Debris Impact Experiments).
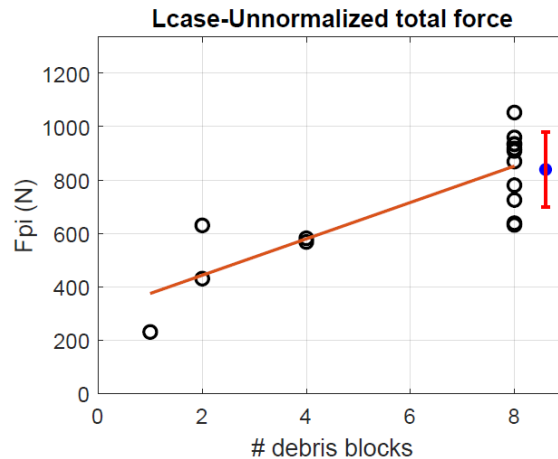


*Figure 3. Effects of # Debris on Measured Peak Force*

The ongoing research takes advantage of a new wind-wave-current interaction testing facility at the University of Washington. This 18-m long by 1.2-m high by 0.9-m wide facility generates currents with a centrifugal pump that enables quasi-steady flow conditions at a maximum velocity of 1.0 m/s for at maximum depth or 2.0 m at half depth. Many structures do not experience impact from the wave front of a tsunami; this facility can be used to model the accumulation of debris, and the effect of rising flows on bridges.

The experiments will create datasets that be used to develop and calibrate design and numerical models that account for flow-structure interaction, rising flow, and debris-induced forces.

# 4. Description of Research Project Tasks

The following is a description of tasks carried out to date.

### Task 1 – Prepare for Tests.

Establish forces for reference (no debris) flow conditions as a function of fluid velocity and depth, and design test structure, support frame and instrumentation.

The fabrication of the test structure is complete, and the components of the support frame and instrumentation system have been acquired and were delivered to the University of Washington during this past reporting period. Figure 3 shows an isometric view of the test structure, and Figure 4 shows a plan view of the overall test setup.
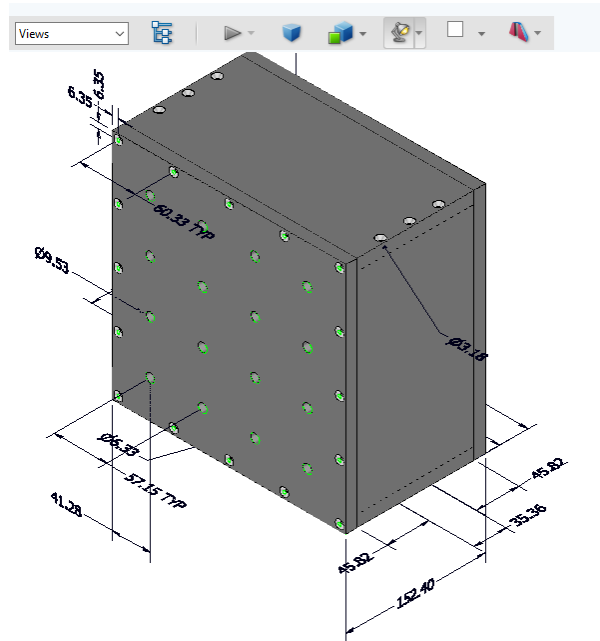


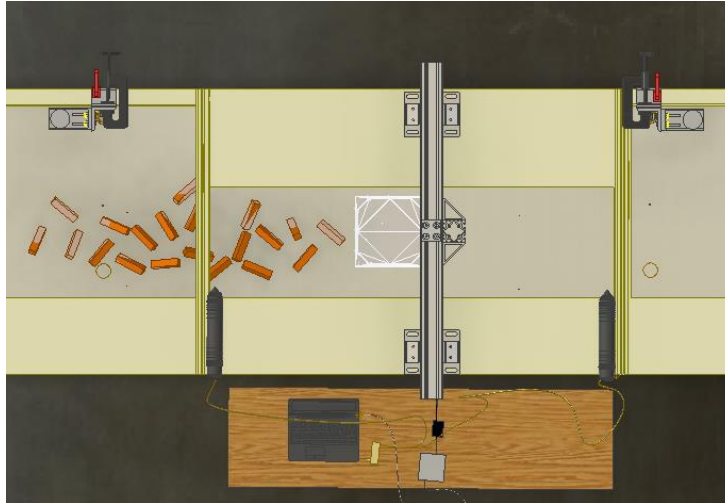*Figure 3. Drawing of Test Structure*

*Figure 4. Plan View of Test Setup*

**Task 2 – Conduct Tests**

Measure statistical distributions (at least 20 repetitions of each test) of impact and damming forces for numerous combinations of debris and flow characteristics.

Initially, we might guide the debris with wires, so that the debris orientation can be controlled. Later (and more numerous) tests will start debris fields with a particular configuration but then allow the debris to reconfigure themselves as they approach the bridge.  The main variables will be: (1) free-field flow depth, (2) free-field flow velocity, (3) # of debris/min., (4) debris shape, and (5) debris orientation.

Work has not yet begun on this task, because the laboratory has been closed as a result of COVID-19.  The laboratory has just reopened for limited use. We anticipate that the tests should start in the summer and fall of 2020.

**Task 3- Develop and Document Design Tools.**

Develop tools to estimate the statistical distributions of debris impact and damming forces as a function of the key test variables.

No work has yet been performed on this task.

# 5. Expected Results and Specific Deliverables

The main deliverables will be:

• data from numerous experiments with a closed-system flume facility to provide the statistical basis with which to estimate the forces generated by debris impacts and debris damming.

- statistical estimates of forces on bridges as a function of debris and flow characteristics.

# 6. Schedule

Progress of tasks in this project is shown in the tables below.

| Item | % Completed |
|---|---|
| Percentage of Completion of this project to Date | 20% |

Table 1. Schedule

| Research Task | 2019 | | | | | | | 2020 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S |
| 1. Prepare for Tests | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| 2. Conduct Tests | | | | | | | | | | | | | | ■ | ■ | |
| 3. Develop and Document Design Tools | | | | | | | | | | | | | | | | ■ |

| | Work Performed |
|---|---|
| (red) | Work Performed |
| (blue) | Work to be Performed |