Tsunami Loading Characteristics on Power Poles

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Group: Civil Engineering

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Introduction

Natural disasters often have devastating impacts on a country's infrastructure, making it difficult to quickly establish and maintain support networks for affected communities immediately after an event. Electrical networks allow modern and developing societies to communicate, function and thrive and facilitates post disaster aid. Large scale natural disasters such as tsunamis have the potential to destroy power poles, vital components of the electricity network, delaying disaster relief often crippling communities. Power poles are an integral component within the electricity network, due to the significance that New Zealand puts on its electrical networks following a natural disaster it is important to investigate the vulnerability of the network, to establish potential damage states in post disaster scenarios.

Objective

To establish the resilience of various New Zealand utility pole designs and the potential damage states that may occur from varying tsunami bore heights. This is being performed in a tsunami flume with scale models, the key force outputs from the experiments will be put into an opensource structural modelling package called OPENSEES, this will allow us to model the fragility of the utility poles against a range of bore heights.

Method

Preparation → Laboratory Testing → Structural Modelling → Data Analysis

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Preparation

- In preparation for laboratory testing, we obtained New Zealand's ubiquitous power poles designs and scaled them suitably. The scale we selected was 1:24 such that the tsunami flume, of the Auckland University Fluid Mechanics Laboratory can produce tsunamis representative of those expected in Zealand Coastline. These models were constructed in aluminum so as to be able to withstand the forces during testing.
- While the models were under construction we calibrated the wave probes of the tsunami flume so that the bore heights could be measured with confidence in their accuracy .

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Laboratory Testing

- Prior to testing the models in the flume we first had to establish an appropriate range of waves and the flume settings that will allow for these. Settings that were experimented with were; the reservoir height, the rate at which the gate opens, the length of time the gate is open and the height it which it opens to.

3

Structural Modelling

- Model the chosen power poles in a structural model and input the forces found through lab testing in the tsunami flume.
- The structural model will give failure probabilities associated with each model, and each orientation, for the range of inundation depths tested.

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Data Analysis

- The failure probabilities developed by the structural model will be analysed by creating fragility curves for the three power poles.
- The fragility functions will display the correlation between inundation depth and failure probability, allowing for a greater understanding of the resilience of the electricity network to a different tsunami.

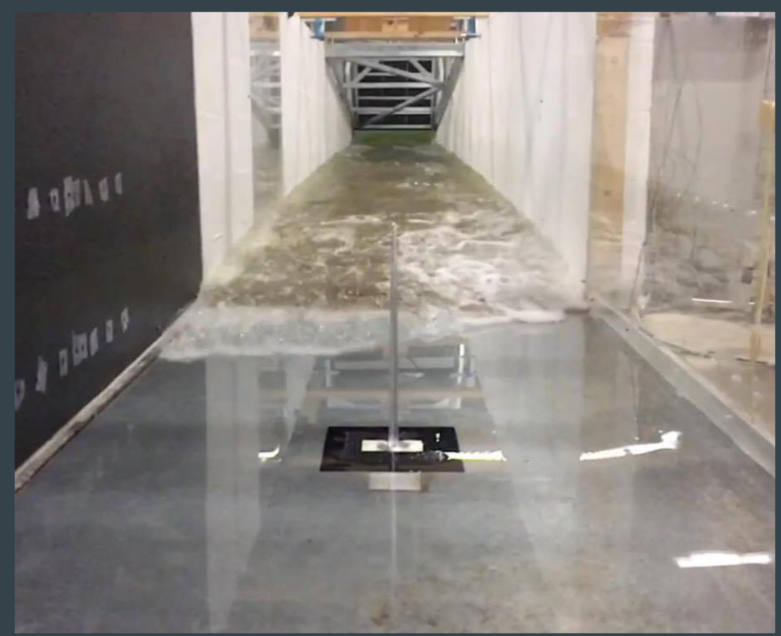
Scale Models

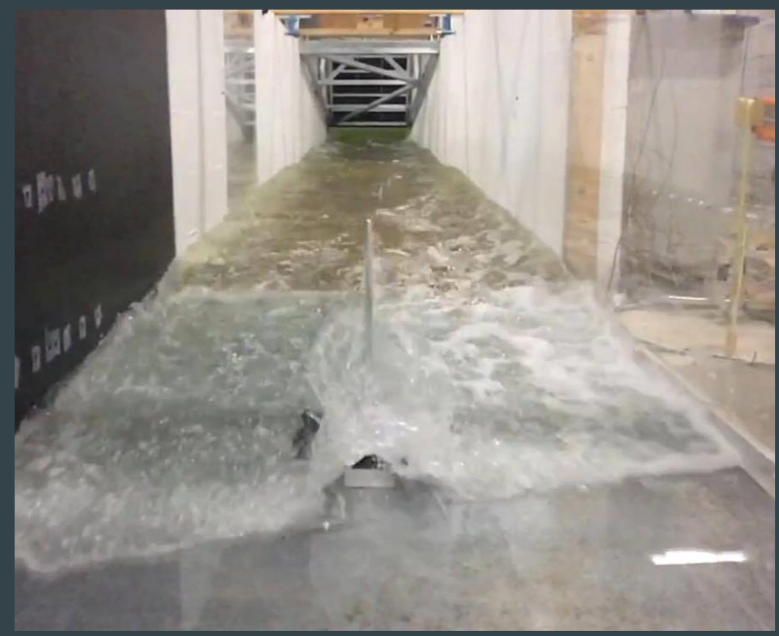
The following pictures show three typical utility poles found in New Zealand, two of which are concrete and one wooden, the concrete poles are newer and more prevalent. The Concrete poles are I-sections and as such were tested in two orientations (web facing down stream and flange facing downstream).

9m Wooden Utility Pole

11m Concrete Utility Pole

9.5m Concrete Utility Pole

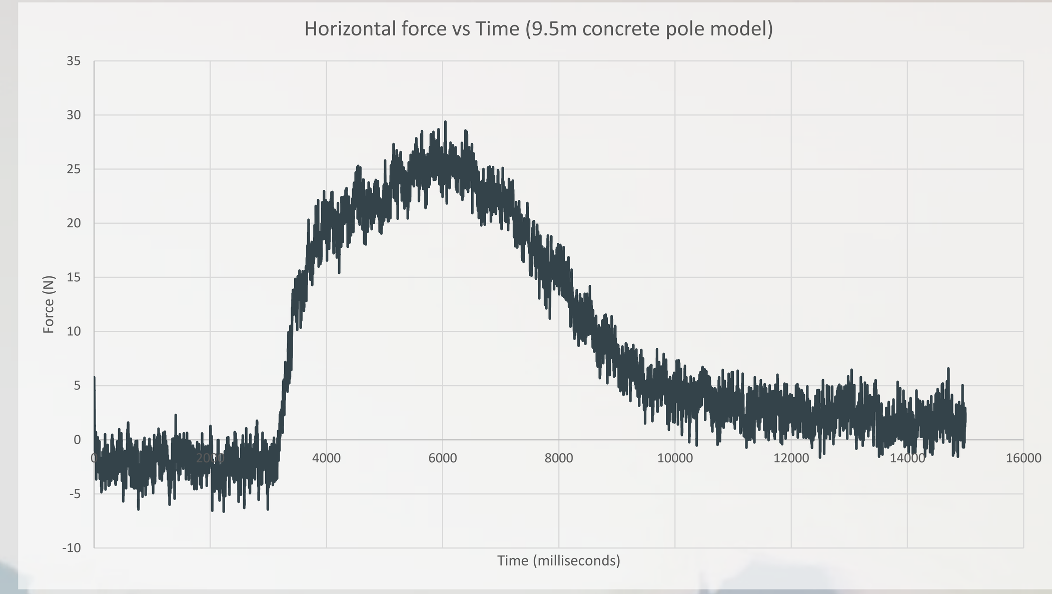




4m High Tsunami Vs 11.5m I-Section Concrete Utility Pole
Flume Properties: Reservoir height = 1000mm, Gate Opening = 500mm, Time to open/close gate = 1sec, Duration of gate opening = 3sec

Preliminary Results

This graph displays the results obtained from the load cell of the force on the smaller concrete model with respect to time. Despite the noise associated with the graph, there is a defined increase in Force after 3 seconds due to the impact of the tsunami bore on the model. This force increases to a peak value approximately three seconds afterwards, or around the time of maximum inundation flow depth, and then drops back down as the inundation depth decreases



Conclusion

To develop information on the resilience of New Zealand's electricity network research on the vulnerability of common power poles to tsunami damage must be done. Three designs of New Zealand's most common power poles were found and developed into scale models to be tested in laboratory conditions. The models, representing two concrete and one wooden power pole, were tested in a tsunami flume. A load cell was used to give detailed information on the hydrodynamic forces subject on the models. Data analysis, using the forces generated, will be implemented into a structural model to scale the forces up and provide failure probabilities for the real-sized power poles - combining to generate a series of fragility curves. These curves will display the relationship between the inundation depth and failure probability of the poles modelled. The fragility curves generated by this project will give greater information on the resilience of power poles in tsunami events, providing greater information on the requirements for electricity network restoration.

Further Testing

In the research conducted during the initial stages of the project, other potential failure modes were identified: including failure induced by debris impacts and scouring around the base of the structures. Research from the Great East Japan Tsunami of 2011 and the Chile Tsunami of 2010 indicated that there was a strong correlation between utility pole failure and the presence of debris, while other research has shown the potential for power pole collapse due to scour.

Further testing to investigate the effect of these parameters on the failure mechanisms of power poles under tsunami loading would need to be undertaken. Potential experiments could involve including debris in the tsunami flume experiments and comparing the differences in the forces on the models. Scour could be investigated by representing the imbedded bases of the power poles in a flume.

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