# Fragility Evaluation Methodology for Tsunami-borne Debris Impact

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## INTRODUCTION

In the safe design and risk assessment of structures in coastal area, it is important to consider tsunami-borne debris impact. Recently, probabilistic analysis has become the preferred form of analysis because of the large aleatory and epistemic uncertainties associated with tsunami effects, which are not captured in deterministic scenario-based assessments. By performing both a probabilistic tsunami hazard assessment (PTHA) and a tsunami fragility assessment (TFA) on structures, their annual failure frequency can be determined. The TFA involves evaluation of the response (e.g. debris impact force exerted on the structure) and the capacity of the structure to resist tsunami effects. Then, a fragility curve shows conditional damage probability of the structure for the tsunami magnitude (e.g., discrete tsunami height around the focused area). This study proposes a TFA methodology for tsunami-borne debris impact, as this has not yet been sufficiently established. Evaluation of the impact speed and impact probability of debris considering various uncertainties in the response evaluation are described in particular detail. Moreover, an assessment of a coastal industrial site was performed and fragility curves and the annual failure frequency of structures against debris impact were shown.

## METHODOLOGY

The TFA is performed for each tsunami bin which are segmentation of tsunami heights partitioned at intervals of several meters (Figure 1(b)). Prior to performing the TFA, tsunami scenarios for each bin are determined by analyzing the results of the PTHA (Kihara et al., 2018). For the TFA of tsunami-borne debris impact, it is necessary to evaluate the debris impact probability $P_C$ and the debris impact speed $V_C$. $P_C$ and $V_C$ are numerically evaluated by conducting Monte-Carlo simulations of debris tracking simulations. Items of epistemic and aleatory uncertainties that need to be considered in the TFA are summarized, because the debris tracking simulation needs to consider these uncertainties. The tracking simulations were conducted on various tsunami scenarios of each tsunami bin considering the epistemic and aleatory uncertainties. A set of $P_C$ and the histogram of $V_C$ is calculated considering aleatory uncertainties for each condition of a branch of epistemic uncertainties. Thus, we can obtain so many sets of $P_C$ and the histogram of $V_C$ as there are branches on epistemic uncertainties (Figure 1(b)). By using $P_C$ and the histogram of $V_C$, the conditional probabilistic density function (cPDF) of the response for a given tsunami bin is determined (Figure 1(c)).

The conditional damage probability of the structure for the tsunami bin is evaluated from cPDF of the response and PDF of the capacity, corresponding to the integrated value of the blue colored area shown in Figure 1(c). A fragility curve, as a function of tsunami height, is obtained by fitting the conditional damage probability to a logarithmic normal distribution (Figure 1(d)). The annual failure frequency of structures can be evaluated using the results of the PTHA and TFA (Figure 1(e)).

## APPLICATION OF THE PROPOSED METHODLOGY

The methodology proposed in this study was applied to a virtual coastal industrial site set on the northeastern coast of Japan where tsunami risk is high. In this study, tracking simulations of the tsunami-borne vehicle (4.5 m length, 2.0 m height and width, 2300 kg weight) are performed by a numerical model developed by our previous study (Kihara et al., 2019), considering the following epistemic uncertainties: drag coefficient, submersion time of the vehicle, roughness coefficient, and presence of the semi-empirical bore model. Aleatory uncertainty due to the turbulence is also considered. The total number of the simulation cases including these uncertainties was 24,000. The motion of 600 vehicles drifted by tsunami was simulated in each case. An example of the debris tracking simulation results is depicted in Figure 1(a).

By performing the TFA, fragility curves of some structures for debris impact were obtained as a function of the tsunami height in front of the seawall installed at the virtual site. The Annual failure frequency of the structure was also obtained by using the results of PTHA and TFA for the virtual site. Insights obtained from the application can aid in the future development of a simplified method of the TFA for tsunami-borne debris effects.

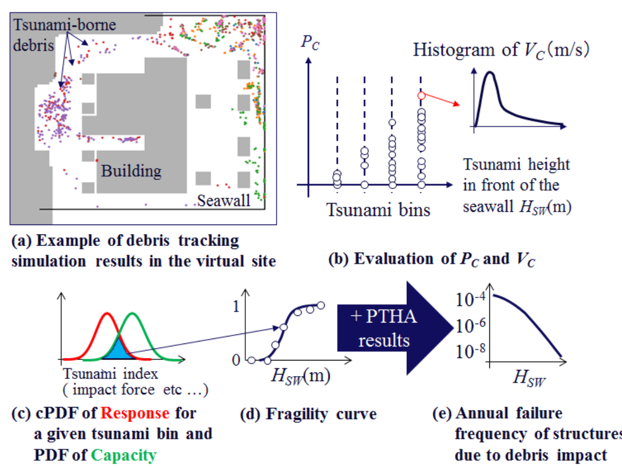


Figure 1 - Flowchart of the TFA against the debris impact.

## REFERENCES

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