Preliminary Study on the Recurrence Interval and Tsunami Heights for PTHA

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1. Introduction

An accident caused by the tsunami and Great East-Japan earthquake in 2011 occurred at the Fukushima Nuclear Power Plant (NPP) site. It is obvious that the NPP accident could be incurred by a tsunami. Therefore the Probabilistic Tsunami Hazard Analysis (PTHA) for an NPP should be required in Korea. The PTHA is a method that calculates the annual exceedance probability and height of a tsunami for a specific period, and based on the Probabilistic Seismic Hazard Analysis (PSHA). The major difference between a PSHA and PTHA are the parameters for the recurrence interval and tsunami height. Thus an analysis on the definition and determination method of these parameters is required. In this study, a basic analysis on the recurrence interval and tsunami height was performed.

2. Parameters

There are aleatory and epistemic uncertainties in the tsunami hazard analysis. Uncertainties in various model parameters and various alternatives about the PTHA model are treated as epistemic uncertainties, and the logic tree approach can be used for evaluating the uncertainty. Fig. 1 shows sample of the logic tree for a PTHA.

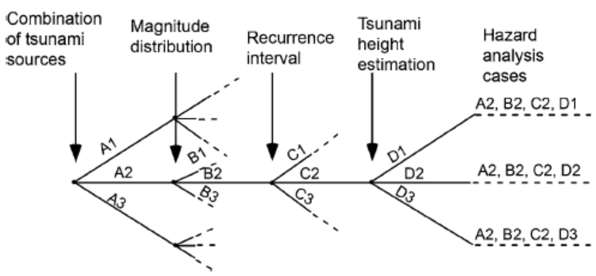

Fig. 1 A sample of a logic tree for a probabilistic tsunami hazard analysis [1]

2.1 The Recurrence Interval

In the PSHA, Gutenberg-Richter a- and b-values, which are related with seismic activity, were used in calculation of seismic hazards. To calculate the tsunami hazards, the recurrence, which is related to the rupture activity, should be determined. The BPT (Brownian Passage Time) model has been used for a PTHA as the recurrence interval model. This BPT distribution has the following noteworthy properties: the probability of immediate rerupture is zero; the hazard rate increases steadily from zero at t=0 to a finite maximum near the mean recurrence time, and then decreases asymptotically to a quasi-stationary level, in which the conditional probability of an event becomes time independent; and the quasi-stationary failure rate is greater than, equal to, or less than the mean failure rate because the coefficient of variations is less than, equal to, or greater than $1/\sqrt{2} \approx 0.707$ [2]. The BPT distribution is defined by two parameters, one is the mean time or period between events, μ, and the other is the aperiodicity of the mean time, α. The aperiodicity, α, is also called the coefficient of variation. The probability density for the BPT model is given by eq. (1).

$$f(t;\mu,\alpha)=\left(\frac{\mu}{2\pi\alpha^2 t^3}\right)^{1/2}\exp\left\{-\frac{(t-\mu)^2}{2\mu\alpha^2 t}\right\} \qquad (1)$$

The aperiodicity has an influence on the density and hazard in the probabilistic analysis.

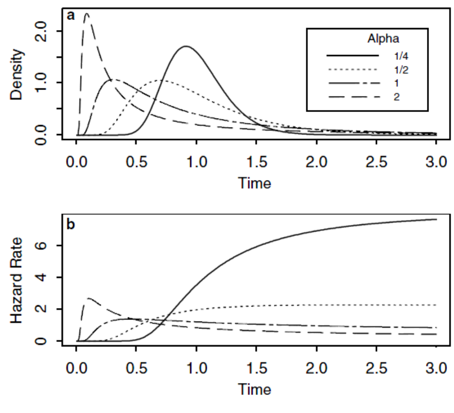

Fig. 2 Probability function for BPT (1,α), α=1/4. 1/2, 1 , 2 : probability densities (a) and hazard rates (b) [2]

Fig. 2 shows the densities and hazard (instaneous failure rate) function of BPT. It is clear that small values of α correspond to nearly symmetrical densities with a pronounced central tendency near the mean value. Larger values of α, on the other hand, produce densities highly skewed to the right, and sharply peaked at a value left of the mean. The BPT hazard rate functions increase to achieve their maximum value uniquely at some finite, to the right of the density's function, and from there decrease toward and asymptote [3].

To determine the mean time and aperiodicity, a chronological model should be suggested by a trench analysis and radiocarbon dating. It comes from the calculation of the timing of paleoearthquakes using the calibrated radiocarbon ages of the samples which was collected by field survey. The recurrence intervals were calculated by a distribution of the age of the sample and have considerable importance in understanding the long-term behavior of the fault. The aperiodicity is one standard deviation of the sample divided by the mean [4].

2.2 The Tsunami Wave Height

The theoretical model for the distribution function of tsunami wave height was suggested by Van Dorn [5]. Van Dorn investigated the cumulative distribution function of tsunami wave height on the basis of tsunami run-up observations in 1946 and 1967 on the coast of Hawaii. He found that the spatial distribution of tsunami wave heights is described by the log-normal distribution as eq. (2).

$$f(H)=\frac{1}{H\sigma\sqrt{2\pi}\ln 10}\exp\left(-\frac{(\log H-a)^2}{2\sigma^2}\right) \qquad (2)$$

Where, H is the maximum value of run-up height for each coastal point in meters, a is a mean value of log H, and σ is the standard deviation of log H. The parameter a and σ can be presented as eq. (3).

$$a=\frac{1}{N}\sum_{i=1}^{N}\log H_i\,,\ \sigma=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\log H_i-a)^2}\,, \qquad (3)$$

The distribution function obtained by integration can be presented in a universal form as eq. (4).

$$F(\zeta)=\frac{1}{\sqrt{2\pi}\ln 10\int_{\zeta}^{\infty}\exp\left(-\frac{1}{2}(\log\theta)^2\right)\frac{d\theta}{\theta}} \qquad (4)$$

where, ζ and $\overline{H}$ are presented by eq. (5).

$$\zeta=\left(\frac{H}{\overline{H}}\right)^{1/\sigma},\ \overline{H}=10^{a} \qquad (5)$$

Fig. 3 shows the distribution function for the 1983 tsunami obtained in the observed data [6]. The solid line is a theoretical curve (universal form), and the dots are obtained from the observed data. As can be seen, the agreement is good, and the log-normal curve is a good approximation of the real distribution [7].

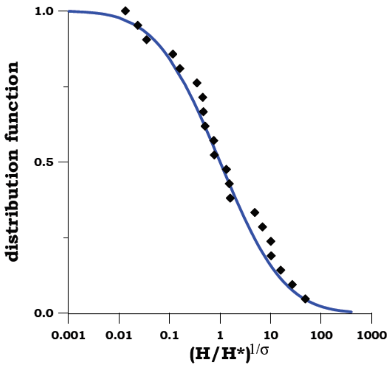

Fig. 3 Distribution function of tsunami height along the east Korean coast, (comparison with observed data) [6]

3. Summary

To perform the PTHA, this study analyzed the recurrence interval and tsunami height distribution, which would be used in the calculation of conditional probability for PTHA. This preliminary study can be used for the determination of parameters for PTHA. In the future, this basic analysis can be used in the determination of tsunami height distribution from tsunami simulation using the logic tree.

Acknowledgment

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