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Editorial

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Risk, Fragility and Reliability Analyses in Structural Engineering

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Introduction and Definition of Risk

It has been for a long time that the structural systems' load and strength were considered in a deterministic manner by engineers and design codes. In this case, a safety factor was defined based on the ratio between the strength and the applied load on structure, which usually referred as the measure of the reliability of the considered structure. However, in the recent years, the researchers found that because of the uncertainties available in the strength, loadings and modeling of the structural system, the traditional deterministic approach cannot be considered accurate anymore. Hence, the probabilistic techniques have developed and are being used to evaluate the life-cycle performance and reliability of structures [1,2].

Here, we define risk as the expected consequences of a given activity. For an activity with n events, the total risk can be defined as:

$$R = \sum_{i=1}^{n} P_i \times C_i \qquad (1)$$

The schematic flow diagram of a risk analysis is presented in Figure 1.

Fragility Curves

The best way to evaluate the reliability index based on the probabilistic methods is by developing the fragility curves. These curves are functions which express the probability of occurring the undesirable events as a function of some measure of environmental excitation (typically a measure of force, deformation, or acceleration in an earthquake, hurricane, or other extreme loading condition). The second definition which is usually considered by the researchers represents fragility curves as the cumulative distribution function of the capacity of an asset to resist an undesirable limit state [3,4]. The common form of a fragility function considering Log-Normal distribution is given in Equation 2:

$$Fragility = Probablity\left[DS \geq d \middle| X = x\right] = \Phi\left(\frac{\ln(\frac{x}{C})}{\beta}\right) \qquad (2)$$

A sample fragility curves derived for the case of earthquake loading of a class of RC structures is illustrated in Figure 2.

Reliability Analysis

One of the most common methods for reliability analysis is to use the first order reliability method (FORM) which can be used for

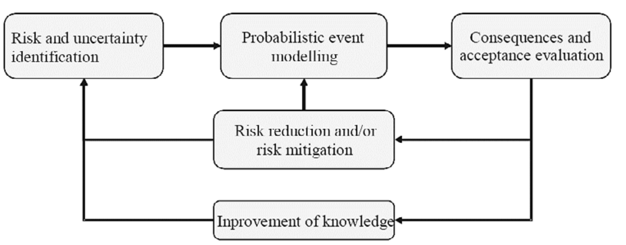

Figure 1: Principle flow diagram of a risk analysis.

complex case as well. The FORM approximation can be used to evaluate the reliability of a series system in which, individual limit states interact on each other and the overall systems reliability can be estimated when the individual failure modes are combined in a series system of failure elements [6]. A schematic representation of FORM approximation for a 2 dimensional case with 3 failure criteria is given in Figure 3.

As an example, for the case of earthquake loading on building structures, the structure reliability index; β proposed by [8] is calculated as follows:

$$\beta = \frac{E(z)}{\sigma_z} \qquad (3)$$

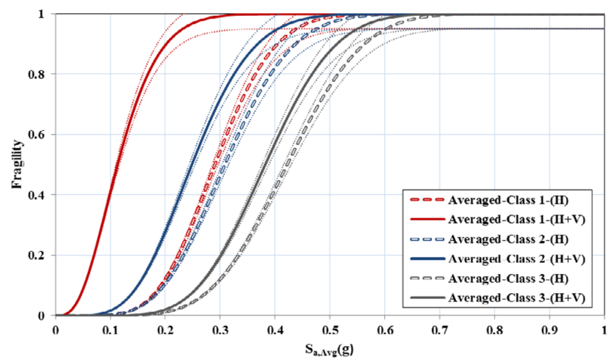

Figure 2: Seismic fragility curves for a wide range of RCMRFs in the moderate damage mode [5].

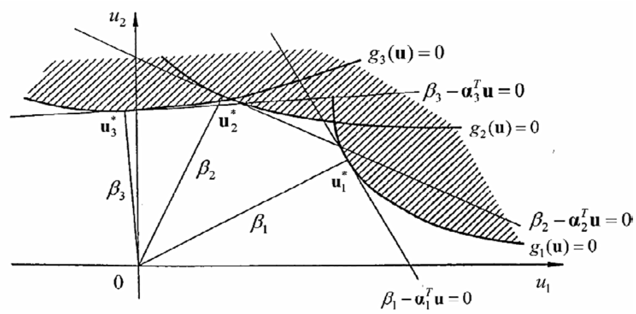

Figure 3: Illustration of the FORM-approximation [7].

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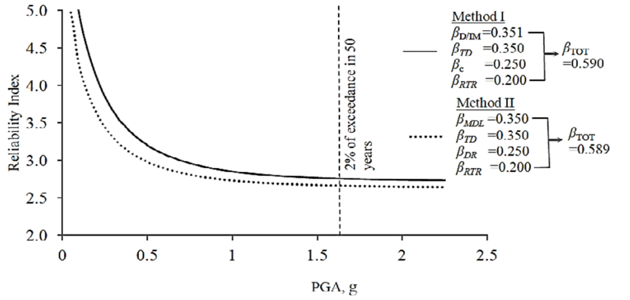

Figure 4: Comparison of Reliability Index for pre-collapse performance level [8].

Where, E(z) and σ_z are the mean and standard deviation of z. Monte Carlo simulation can be used to evaluate these parameters. The schematic seismic reliability indices for a given structure using two different fragility curves are presented in Figure 4.

Concluding Remarks

Reliability analysis and risk assessment research constitutes one of the important areas of existing and new Structures. Seismic reliability analysis of structures and infrastructures, help develop procedures to evaluate the seismic safety of them which includes limit states corresponding to serviceability and collapse. Based on these evaluations optimized retrofit procedures and restoration strategies can be suggested to engineers and consulting companies. Research projects concerned with reliability analysis and risk assessment should be carried out to provide practical tools for engineers to assess seismic risk to structures for the ultimate purpose of mitigating social impact.

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