Development of Probabilistic Vulnerability Functions for Damage Level Estimation of Refinery Facilities against Different Earthquake Scenarios

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Seismic design of petroleum facilities has been generally accomplished based on design codes such as API, ACI, ASME, and AISC. A sample design code is usually set in a deterministic perspective and therefore lacks the ability to predict the margin of safety of the structure or its probability against failure under a certain ground motion. Moreover, many of the facilities had been designed at a time when only some superficial regulations were on the table for seismic design. Unawareness of the safety margin provided by the design code along with existing uncertainties leads to the fact that vulnerability of the petroleum facilities against earthquakes is not readily known. Therefore, to estimate the extent of seismic vulnerability of mentioned facilities, use should be made of a systematic methodology that takes into account ideally all the sources of randomness and uncertainty in a probabilistic format.

Estimation of earthquake vulnerability of a structure is usually done in a three-step manner as: 1) determining the seismic hazard, 2) calculating the level of structural response, and, 3) vulnerability analysis of the structure for the response computed in step 2. To overcome the shortcomings of the existing procedures for estimating structural seismic vulnerability, in this thesis a new method is presented in which using the governing laws of behavior and capacity of structural elements based on strength and type of materials, loading history and also field observations of performance of structures, fragility curves are developed. These fragility are then used to estimate the vulnerability and to design based on reliability of equipments against earthquake.

Current deterministic capacity and demand models are not able to take into account the inherent uncertainties of structural assemblies. This fact is exactly what is needed in estimating seismic vulnerability and risk of a certain structure. In this research, based on the Bayesian probabilistic methodology and gathering the published experience with past earthquakes, some powerful vulnerability functions are developed that take into account randomness and uncertainty issues both in seismic capacity and seismic demand of facilities. Combining steps 2 and 3 above, an efficient procedure is presented to evaluate the seismic vulnerability of a sample petroleum facility.

The innovations of the work can be summarized as: 1) For different petroleum facilities fragility curves have used to be developed only based on PGA. But in the present work a special emphasis is given to structural behavior. 2) Different failure modes are considered separately. 3) An effective formulation is developed comparing directly demands with capacities to be used both in performance based design and in estimating seismic vulnerability. 4) Effects of uncertainty and randomness parameters are assessed comprehensively. 5) Efficiency of rehabilitation alternatives can be effectively evaluated. 6) As a basis for reliability based design, this method can be extended to different facilities in an industrial complex. 7) With applying this method to various refinery equipments and facilities, the seismic vulnerability of a petroleum complex can be estimated to a desired precision.