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Probabilistic Assessment of Collapse Limit- State in Steel Frames by Simulating Failure Modes Using Bayesian Probability Network

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ABSTRACT

Due to complex nature of the collapse phenomena, along with its important role in structural performance, collapse assessment has recently gained a great attention in performance based earthquake engineering. Furthermore, uncertain sensitive parameters on seismic collapse performance have intensified the complexity. In this paper, a novel probabilistic approach based on simulating failure modes within IDA framework with application of Bayesian Probability Network (BPN) is proposed to evaluate collapse of structures. Applying pushover analysis, likely Failure Modes (FMs) are recognized first, and then along with sensitive Random Variables (RVs), these FMs are incorporated in BPN. Conditional probability of these FMs related to the incorporated RVs, are calculated within IDA agendum, which directly considers record-to-record uncertainty.
Some of the results investigated in this research are: Comparing mean annual rate of collapse derived from the proposed method with the conventional limit-states considered in IDA approach, detection of structural response in a probabilistic framework and updating through BPN. Totally, it can be claimed that via the newly proposed methodology not only the safety index of structures are calculated in an effective way, but also structural response in the collapse limit state is detected probabilistically.

KEYWORDS
Failure Mechanisms, Bayesian Probability Network, IDA, Random Variables, Collapse Assessment, Mean Annual Rate of Collapse, Updating

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1- BRIEF INTRODUCTION

Due to the possibility of different seismic collapse scenarios as well as the complicated interaction of component ductility and redundancy in frame structures, system reliability has recently gained great attention. It is well known that sequential propagation of damage in steel moment frames in the form of plastic hinges (owing to several causes such as flange and web buckling and weld rupture), would reduce the degree of indeterminacy and become a cause for overall or local collapse. Due to a large amount of inherent uncertainty, known as Record to Record (RTR) variability, or epistemic uncertainty known as modeling variability, various types of collapse modes are likely to happen. A steel moment frame must be designed in a way to avoid undesirable brittle failure modes in order to maintain the structural stability when induced by a strong earthquake. A comprehensive and systematic representation of structural collapse using combined Incremental dynamic analysis (IDA) (Vamvatsikos and Cornell, 2002) and Bayesian Probability Network (BPN), in which all possible collapse scenarios at the presence of all sources of uncertainty can be concerned, is studied in this paper. The idea is originated from the works of Mahadevan et al. (Mahadevan et al, 2001).

The novel methodology presented in this paper is implemented on a one bay, two-story Special Steel Moment Resisting Frame (SSMRF), with utilization of suitable deteriorating models (Lignos, 2008). In general, the recommended approach is performed in two phases:

2- Recognizing sensitive sources of modeling uncertainty on structural collapse performance. Then, performing a series of pushover analyses with the detected Random variables (RV`s) so as to define probable Failure Modes (FM`s). The FM`s are extracted in terms of sequential component failure (plastic hinges) for the following IDA analyses. Through this stage, unlikely FM`s are eliminated which makes the methodology more feasible for large structures with numerous degrees of freedom. Investigations on the SSMRF depicted that the assumption in which collapse phenomena is initiated by a predominant failure mode (at least for the evaluated SSMRF), seems rational and its modeling, due to approximately accurate deteriorating hysteretic models, has become possible. As another interesting result, all probable FM`s contained the same plastic, however in diverse orders.

**3- Developing a BPN including probable FM`s (detected from the first phase)**, dependent upon the most influential RV`s, through a set of IDA analyses for each random state. By selecting proper damage indices as the criteria for recognition of hinge plasticization onset through the IDA process, conditional probabilities of FM chance nodes were calculated. Also, by assuming each FM as a cut set in the structural collapse phenomena, reliability of the whole system was represented by a single "system collapse" chance node. The developed BPN is graphically shown in figure 1.

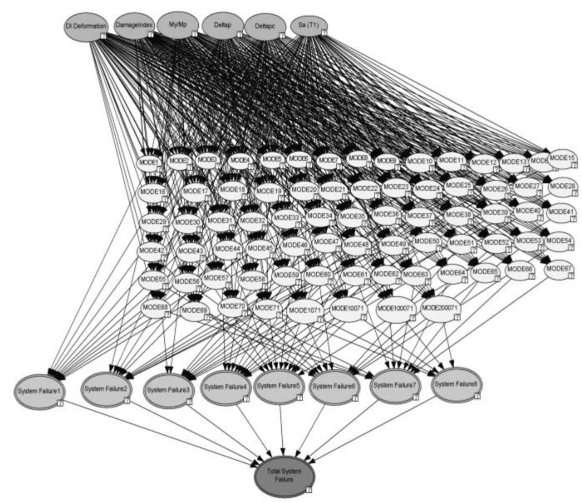

Figure 1. The developed BPN for the SSMRF.

4- CONCLUSION

In the following, through the developed BPN, systematic reliability assessment of the evaluated structure was performed. The mean annual rate of collapse (λcollapse) was computed and confirmed to have an acceptable consistency with the conventional IDA approach with the same RV`s (See table 1).

Proposed Method		Conventional Method	
$\lambda_{Collapse}$	$\beta_{Collapse}$	$\lambda_{Collapse}$	$\beta_{Collapse}$
5.76648E-05	*3.856*	*4.38086E-05*	*3.923*

Table 1. Comparison of system reliability index, derived from proposed and conventional methods.

Through investigating collapse mechanisms, it was shown for the SSMRF that by ignoring the order of plastic hinges formation in FM`s, pushover collapse modes contributed 99% of λcollapse. However, the efficiency of the proposed methodology should be investigated for buildings with more degrees of freedom.

In the following, the contribution of expected SMRF modes in λcollapse, proved that there may still be a long way to take control of the response of the SSMRF in near-collapse vicinity.

At the end, updating was exemplified via the developed BPN, with the observation of failure mode No. 11. All modeling RV`s were updated and influential parameters were recognized. As expected for a semi-rigid structure like the evaluating SSMRF, lower strength values were the most detrimental parameter among modeling RV`s. In summary, demonstrated on thebasis of Bayes rule (Bozorgnia and Bertero, 2004), probabilistic functions are updated based on the contribution of their states in causing the observation.

Overall, it can be claimed that via the newly proposed methodology, not only can the safety index of structures be calculated in an effective way, but structural response in the collapse limit state could also be detected probabilistically.

5- REFERENCES

[1] Bozorgnia, Y. and Bertero, V.V.; "Earthquake engineering: from Engineering Seismology to Performance-based Engineering", CRC Press, New York, 2004.

[2] Lignos D.G.; "Sideway collapse of deteriorating structural systems under seismic excitations", PhD.

[3] Dissertation, Department of Civil and Environmental Engineering and the Committee on the Graduate Studies of the Stanford University, 2008.

[4] Mahadevan S., Zhang R., and Smith N.; "Bayesian networks for system reliability reassessment", Journal of Structural Safety, September, 2001.

[5] Vamvatsikos D. and Cornell C.A.; "Incremental dynamic analysis", Journal of Earthquake Engineering and Structural Dynamics, 2002.