A new method for deriving analytical seismic fragility curves

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Outline

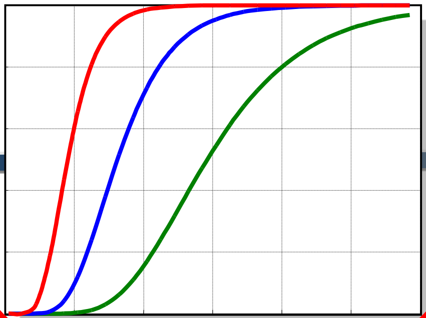
1. Introduction
2. Objective
3. Proposed Method
4. Application Example
5. Conclusion and Future Research

Background

- Fundamental Objectives of Earthquake Engineering Field are Seismic Loss Estimation and Mitigation.
- Seismic Risk Assessment

Hazard
EQ

Fragility
(Vulnerability)



Inventory
Structures

Effective Risk Assessment requires Accurate and Reliable Fragility Curves.

Motivation

- Analytical Fragility Curves

$$P_f\,(\,LS \mid R_D\!=\!d\,) = P_f\,(\,S\text{-}D \le 0 \mid R_D\!=\!d\,)$$

- Analytical-function-based method
  - explicitly expressed in analytical functions
  - $P_f\,(\,S\text{-}D \le 0 \mid R_D\!=\!d\,)$
  - Shortcomings: limited to SDOF, static, linear structural analyses
- Simulation-based method
  - evaluated from random samplings
  - $P_f\,(\,S\text{-}D \le 0 \mid R_D\!=\!d\,) = n_f \,/\, n_s$
  - Shortcomings: computational cost and convergence issue

Objective

Develop a new method for deriving analytical seismic fragility curves, which can overcome shortcomings of existing methods

Proposed Method

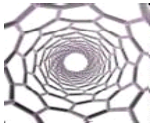
- Analytical Fragility Curves

$$P_f\ (\ LS\ |\ R_D{=}d\ ) = P_f\ (\ S{-}D \leq 0\ |\ R_D{=}d\ )$$

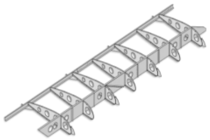
- Evaluate without deriving analytical functions
- Utilize FORM (First Order Reliability Method)
- Integrated framework approach
- Merit
  - More accurate results
  - Less computational cost
  - Sophisticated structural analysis techniques

Proposed Structural Reliability Analysis (SRA)

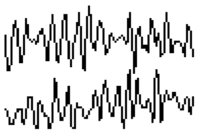
Uncertainties



Materials

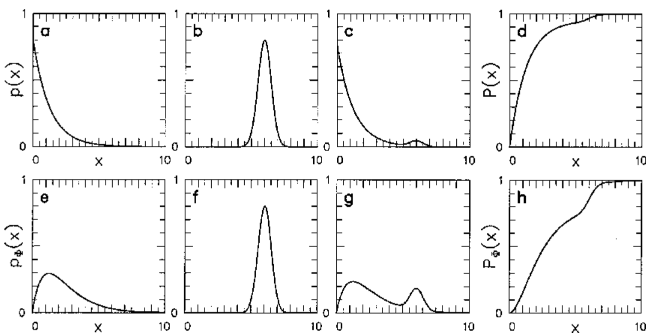


Structure

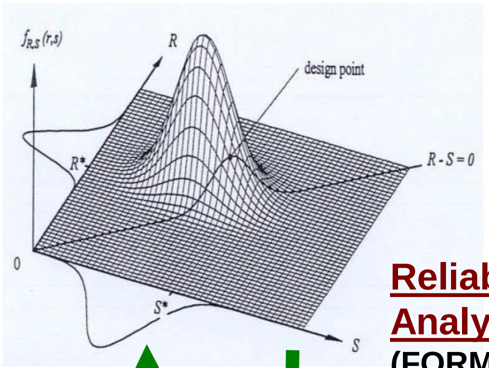


Loads

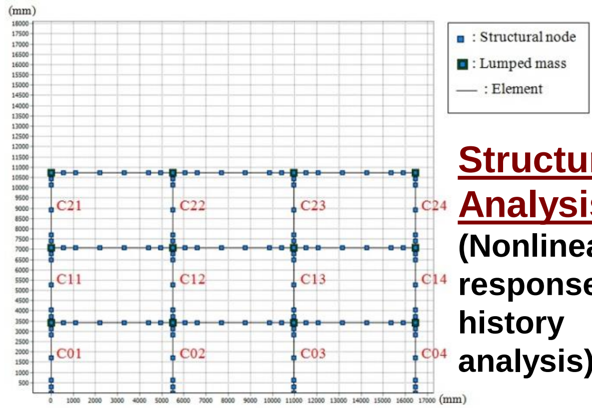
Statistical Properties



Identification of Input Uncertainties



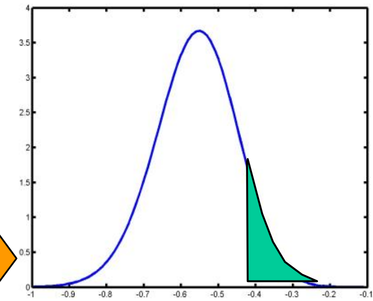
Reliability Analysis (FORM)



Structural Analysis (Nonlinear response history analysis)

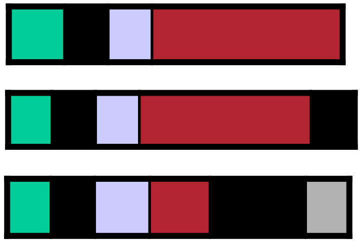
Structural Reliability Analysis

Failure Probability



Byproducts

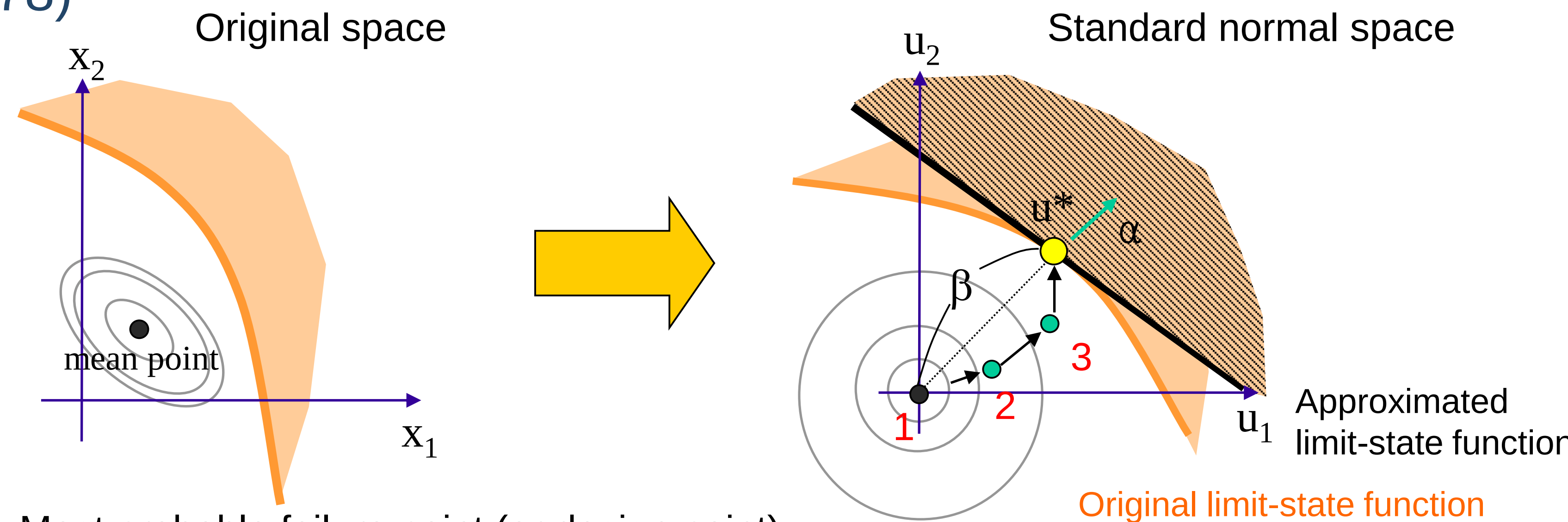
(e.g. Sensitivity, MPP)



Uncertainty/Risk Quantification

SRA Employing FORM

- First Order Reliability Method (FORM, Rackwitz & Fiessler 1978)



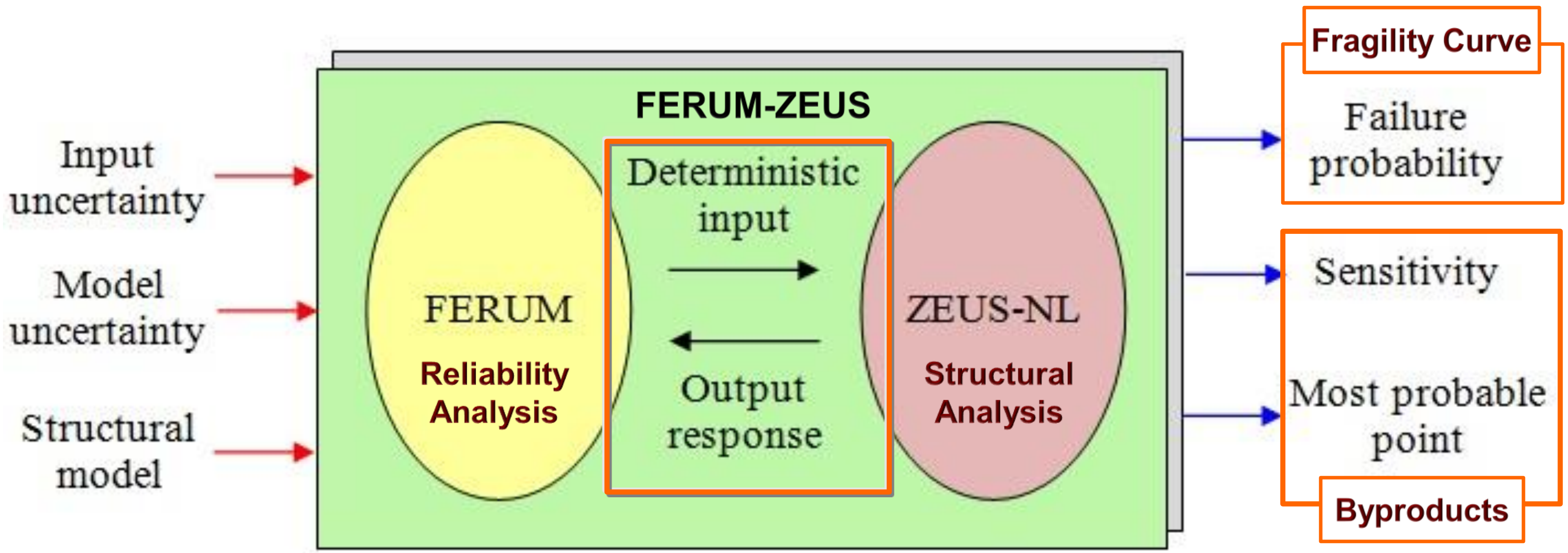
u^* Most probable failure point (or design point)

β Reliability index

$P(E_i) \cong \Phi(-\beta)$ Component failure probability

$$\alpha = -\frac{\nabla G(\mathbf{u}^*)}{\left\|\nabla G(\mathbf{u}^*)\right\|}$$ Normalized gradient vector

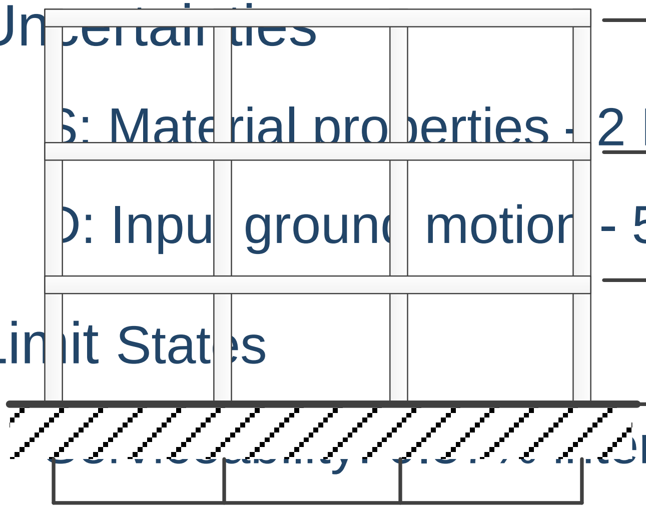
Computational Framework

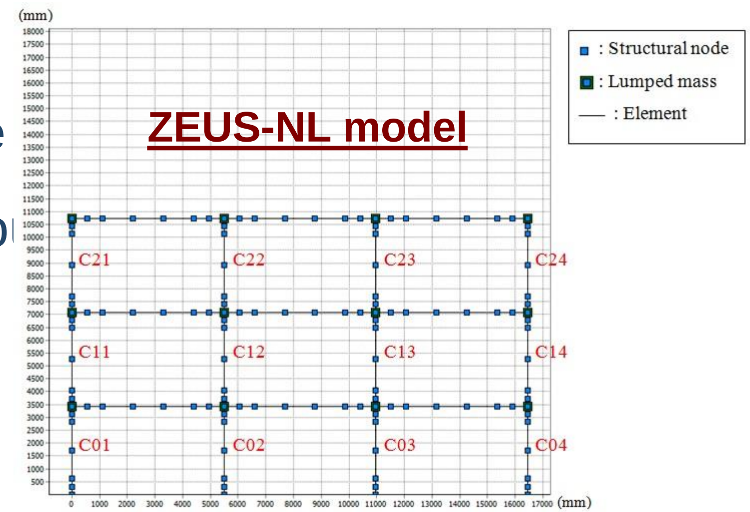


- FERUM (Finite Element Reliability Using MATLAB)
- ZEUS-NL
- FERUM-ZEUS

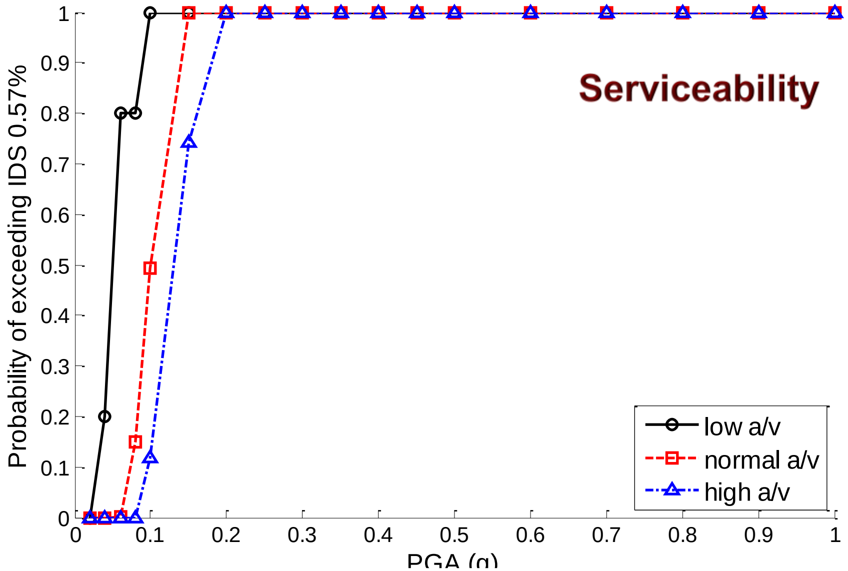
Numerical Example: 2D Frame Structure

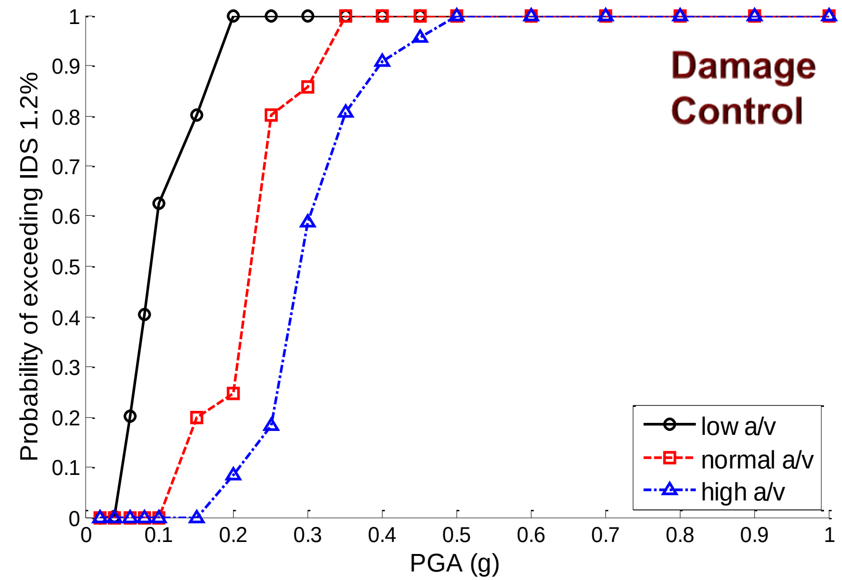
- Benchmark Problem from Kwon and Elnashai (2006)
- Three-story RC moment frame structures
- Uncertainties
  - S: Material properties - 2 RVs (Concrete
  - D: Input ground motion - 5 sets of 3 grou
- Limit States
  - Serviceability: ... inter-story drift
  - Damage control: 1.2% inter-story drift
  - Collapse prevention: 2.3% inter-story drift

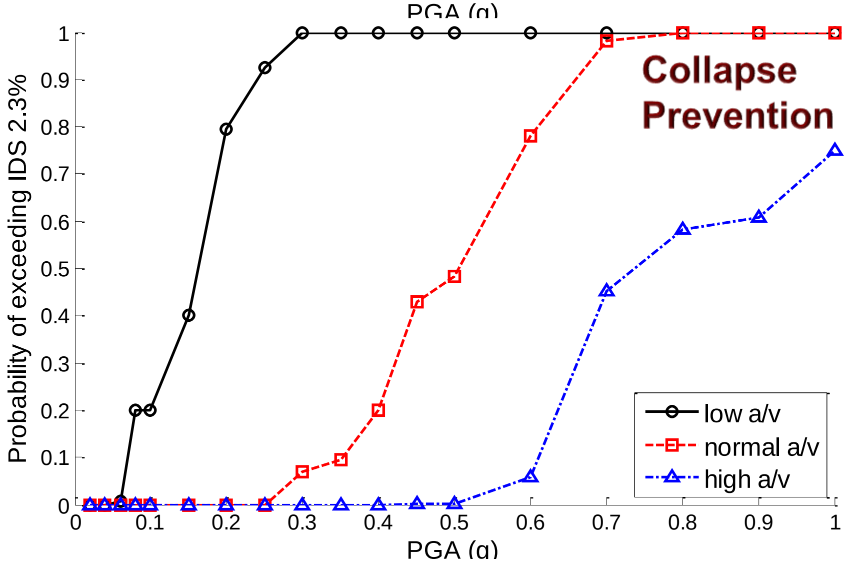




Seismic Fragility Curves (from the proposed method)







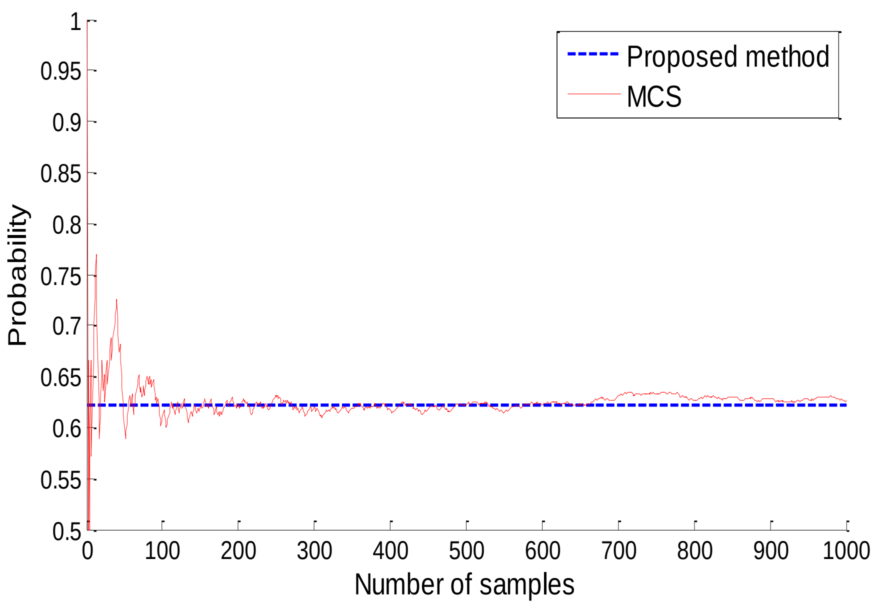
- Results match with those in Kwon and Elnashai (2006)

Comparison with Monte Carlo Simulation

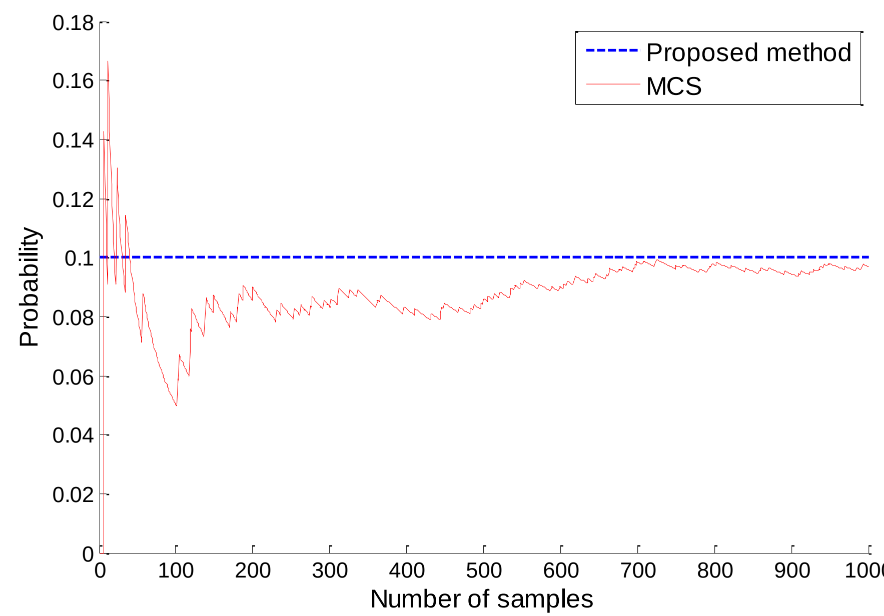
Three Selected Cases

Case Name	Input Ground Motion	PGA (*g*)	Limit State	Failure Probability from the Proposed Method	Number of Structural Analyses
Case1	Set02-01	0.08	Serviceability	2.32×10^{-2}	21
Case2	Set03-04	0.35	Damage Control	$\mathbf{1.00\times10^{-1}}$	**18**
Case3	Set01-05	0.25	Collapse Prevention	$\mathbf{6.22\times10^{-1}}$	**12**

Case 3



Case 2



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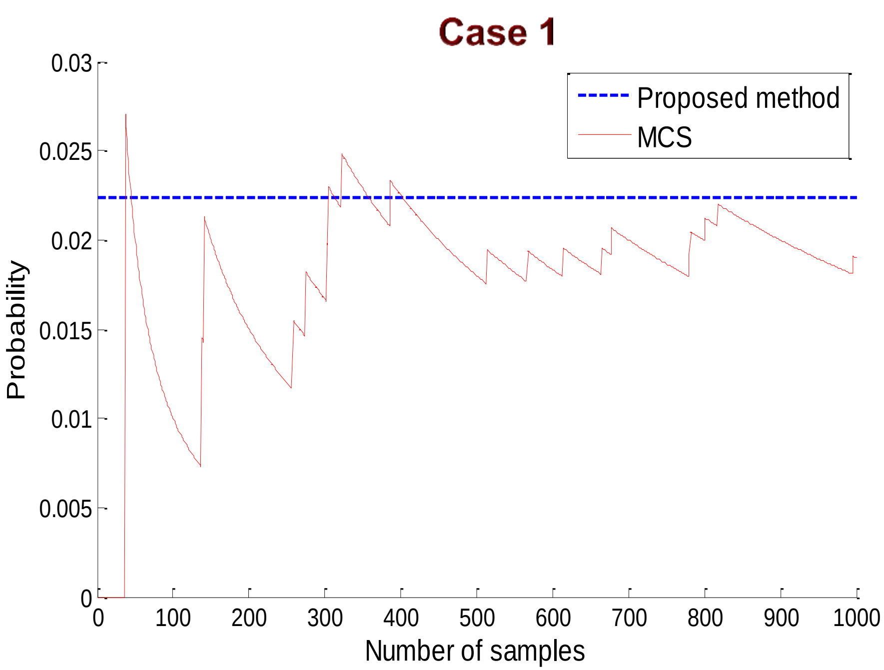

- More Effective
- More Accurate

Conclusions & Future Research

- A new method for deriving analytical seismic fragility curves is proposed.
- Seismic fragility curves are successfully derived with the proposed method.
- The proposed method can derive seismic fragility curves more accurately and efficiently than the simulation-based methods.
- More effective risk assessment is expected with the proposed method.
- Future Research
  - Apply to more complex structures such as 3D moment frames
  - Utilize useful byproducts

Thank You !!!

Questions and Comments?