National Technical University of Athens

42nd Risk, Hazard and Uncertainty Workshop
Ydra, Greece, 23–25 June 2016

SPO2FRAG V1.0: SOFTWARE FOR PUSHOVER-BASED DERIVATION OF SEISMIC FRAGILITY CURVES

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Ydra, 23/06/2016

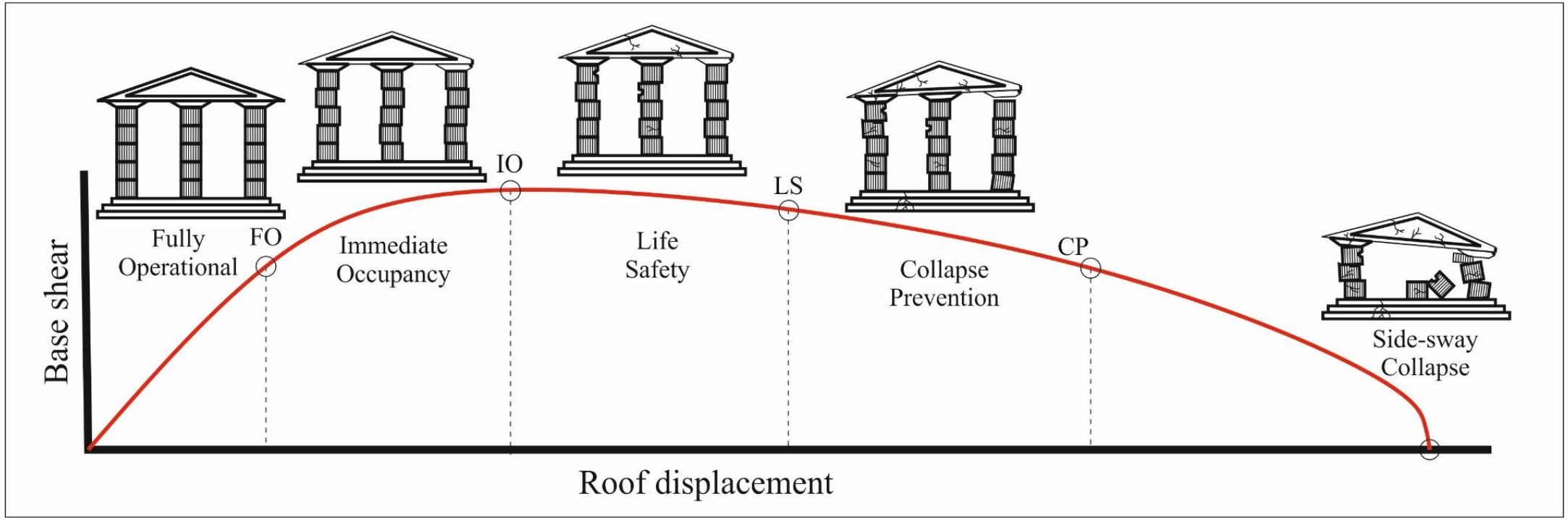
Università degli Studi di Napoli Federico II

PBEE – PROBABILISTIC SEISMIC RISK ANALYSIS

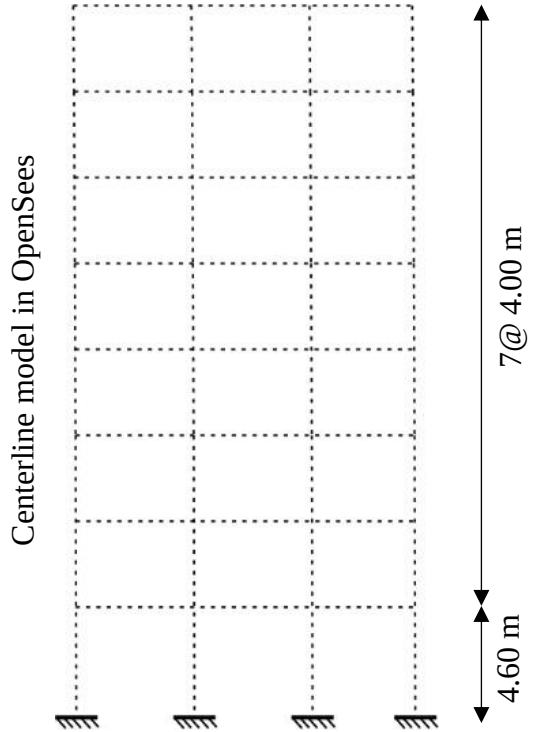
(Structure-specific) Seismic Risk: MAF of Limit State exceedance due to earthquakes

$$\lambda_{LS} = \int_{IM} P\left[IM_{C,LS} \le im\right] \cdot \left|d\lambda_{im}\right|$$

FRAGILITY **HAZARD**



ANALYTICAL DERIVATION OF FRAGILITY FUNCTIONS



⇨ Numerical modelling of inelastic behavior

⇨ Non-linear dynamic analysis using recorded accelerograms

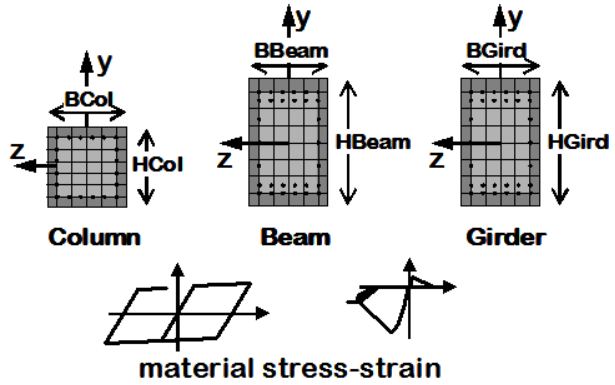


Image: opensees.berkley.edu

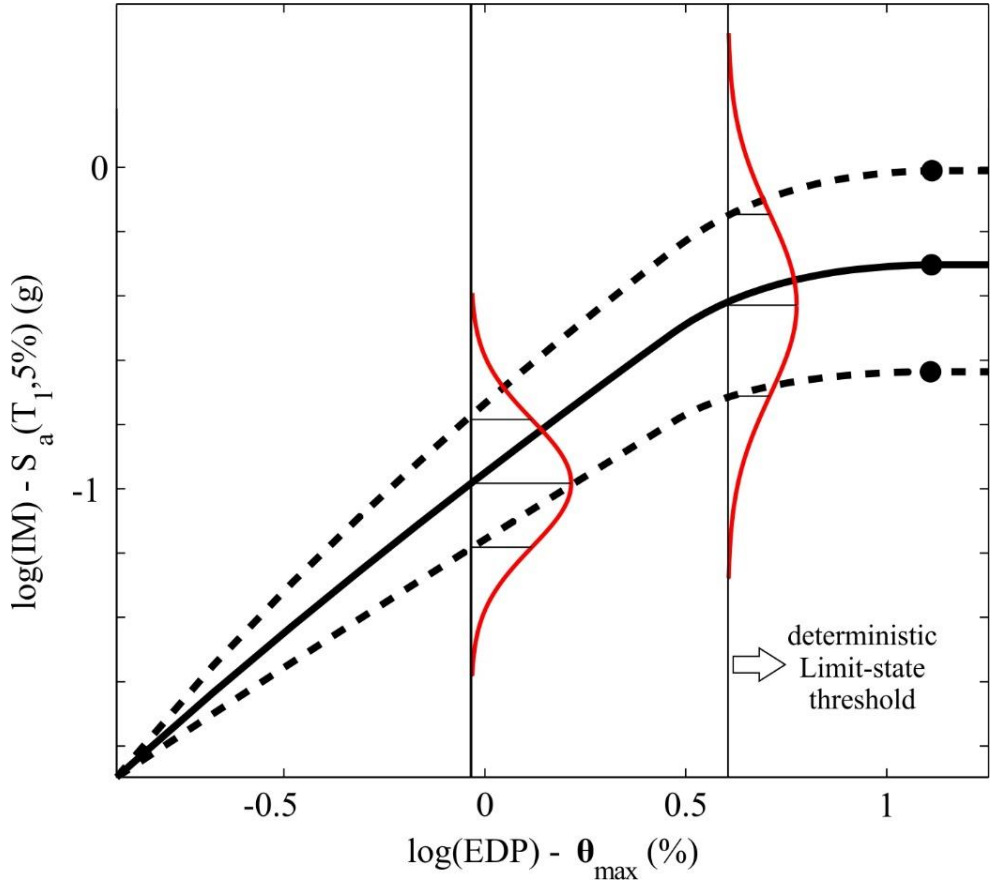
⇨ IM-based procedure

$$P\left[IM_{C,LS} \le im\right] = \Phi\left[\frac{\log(im) - \eta}{\beta}\right]$$

⇨ Computationally demanding method!

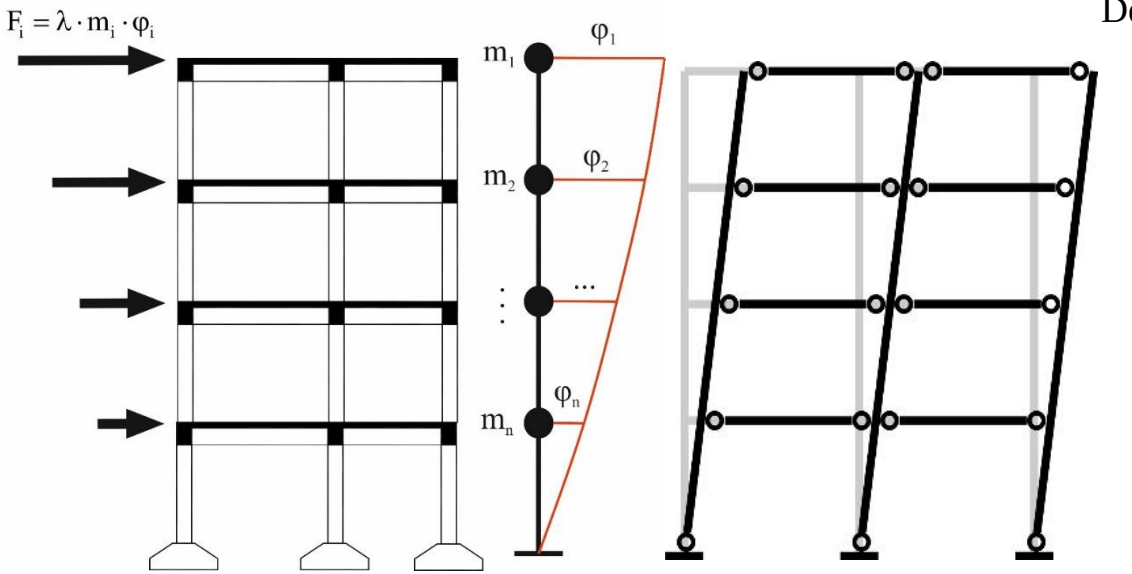
Incremental Dynamic Analysis

Vamvatsikos & Cornell, 2002

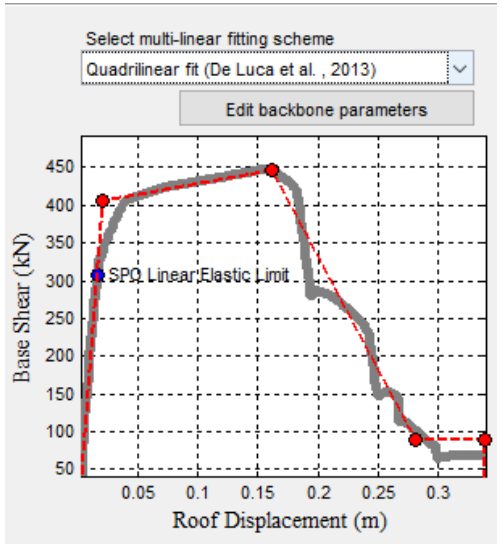


SPO2FRAG: OVERVIEW OF THE THEORETICAL ARSENAL

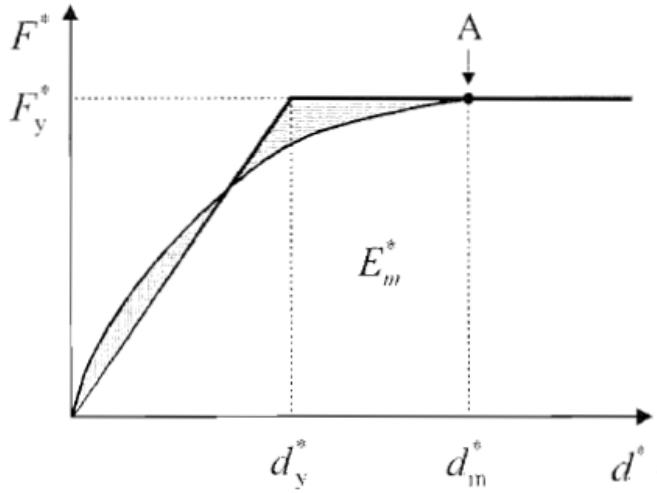
'Static Pushover Analysis' ⇨ Equivalent SDoF idealization of the structure based on SPO curve



De Luca, Vamvatsikos, Iervolino (2013)



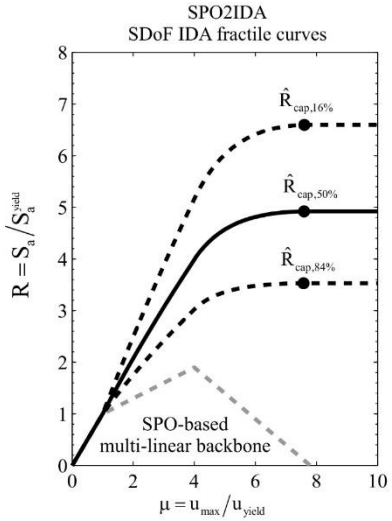
EN-1998-1 ANNEX B

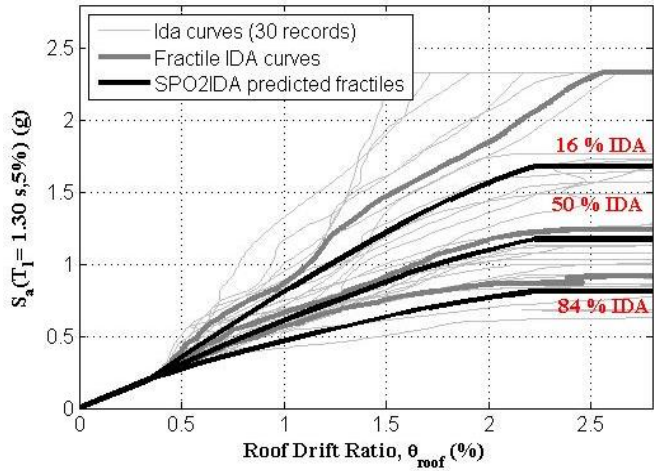


SPO2IDA

Simplified method for obtaining the distribution of seismic demand.

Vamvatsikos & Cornell, 2006

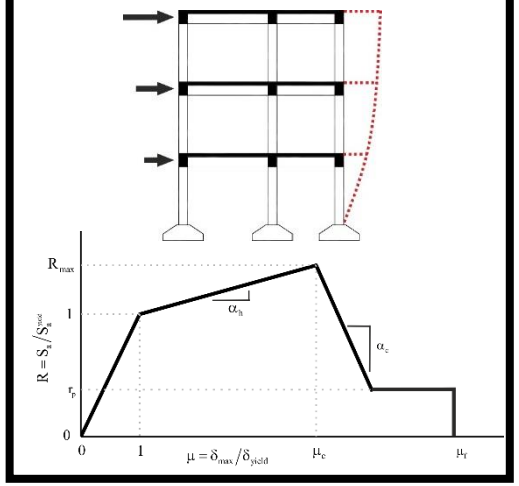




SPO2FRAG: OVERVIEW OF THE CONCEPTUAL FRAMEWORK

STEP 1

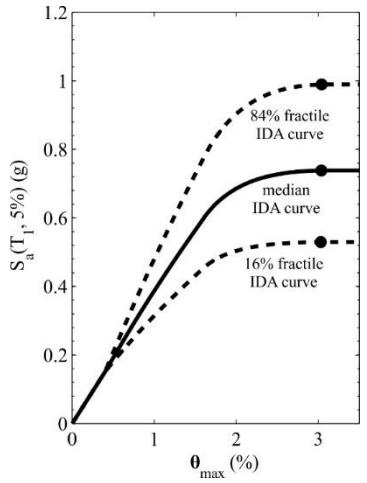
Static Pushover Analysis
Equivalent SDoF formulation



- Management of input SPO data
- Preliminary check of SPO curves
- Automatic definition of multi-linear backbone for equivalent SDoF system

STEP 2

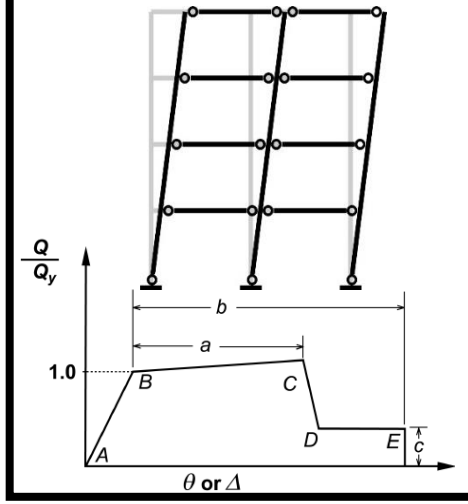
SPO2IDA Implementation to obtain fractile IDA curves



- Run SPO2IDA algorithm
- SDoF to MDoF transformations (EDP, IM)

STEP 3

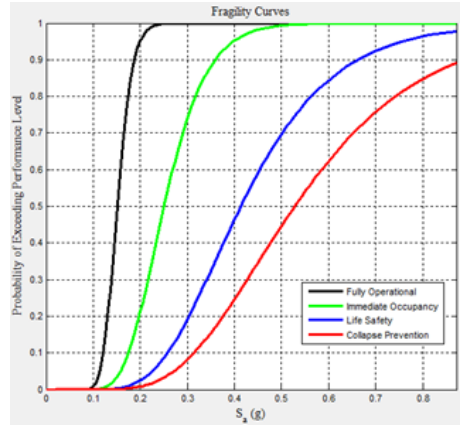
Definition of Limit-State thresholds and variability



- Basic Limit-State EDP threshold definition interface
- Account for variability of Limit-State thresholds.
- Incorporate additional variability due to MDoF effects
- Accomodate additional sources of variability (e.g., epistemic)

STEP 4

Calculation of Fragility Curves



- Log-normal distribution parametric fragility functions
- Manage/ export fragility functions

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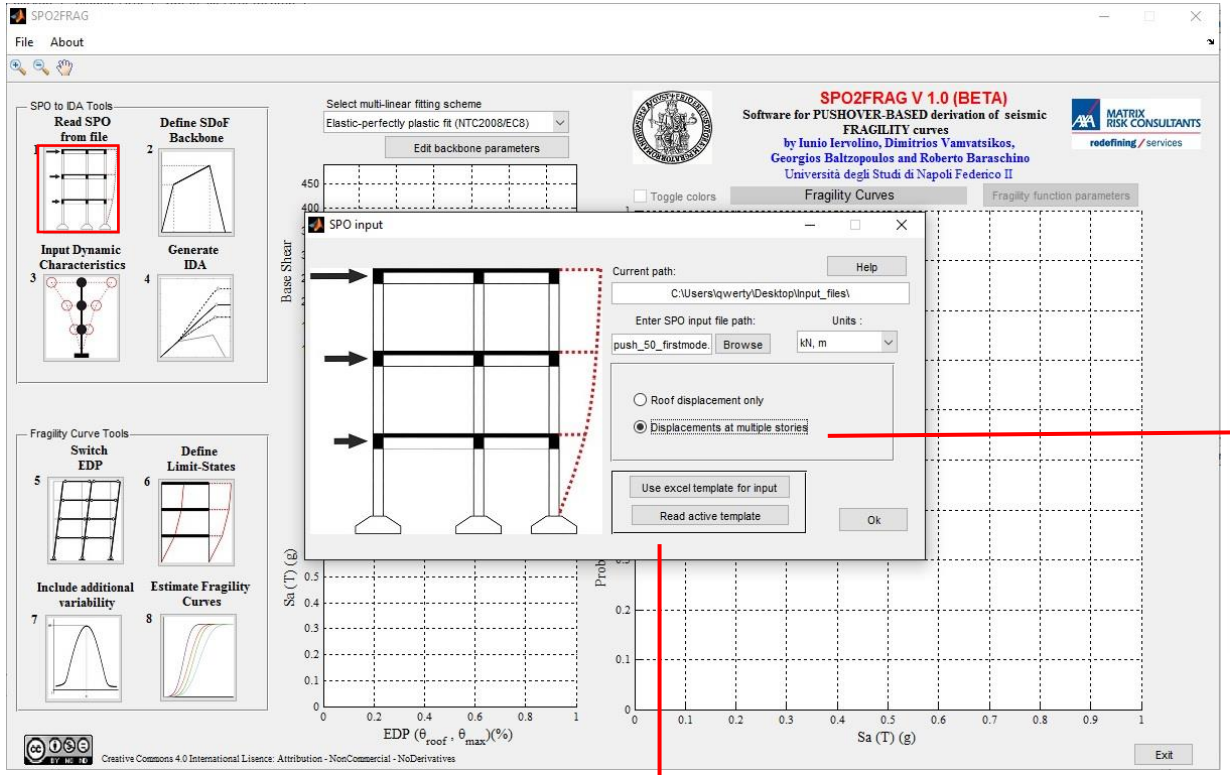
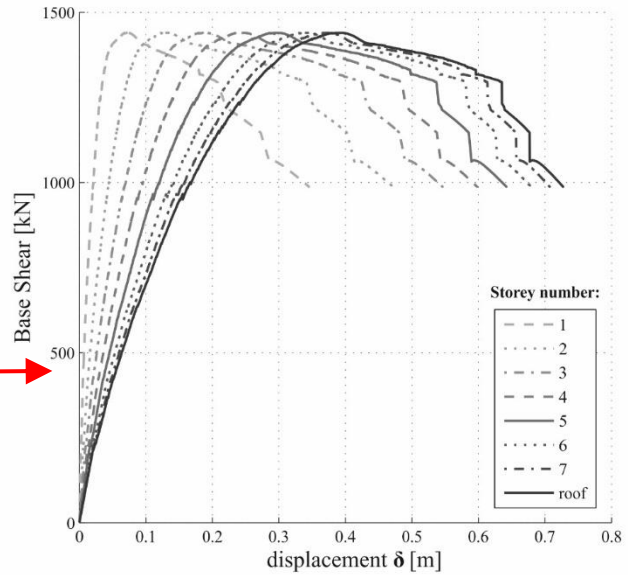
SPO2FRAG V1.0: Software for Pushover-based Derivation of Seismic Fragility Curves

INPUT INTERFACE

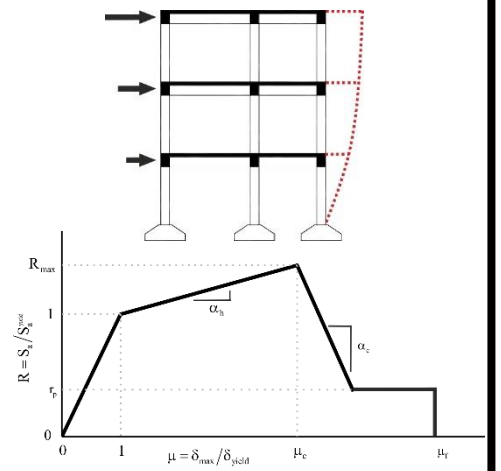




SPO curves for multiple storeys

STEP 1

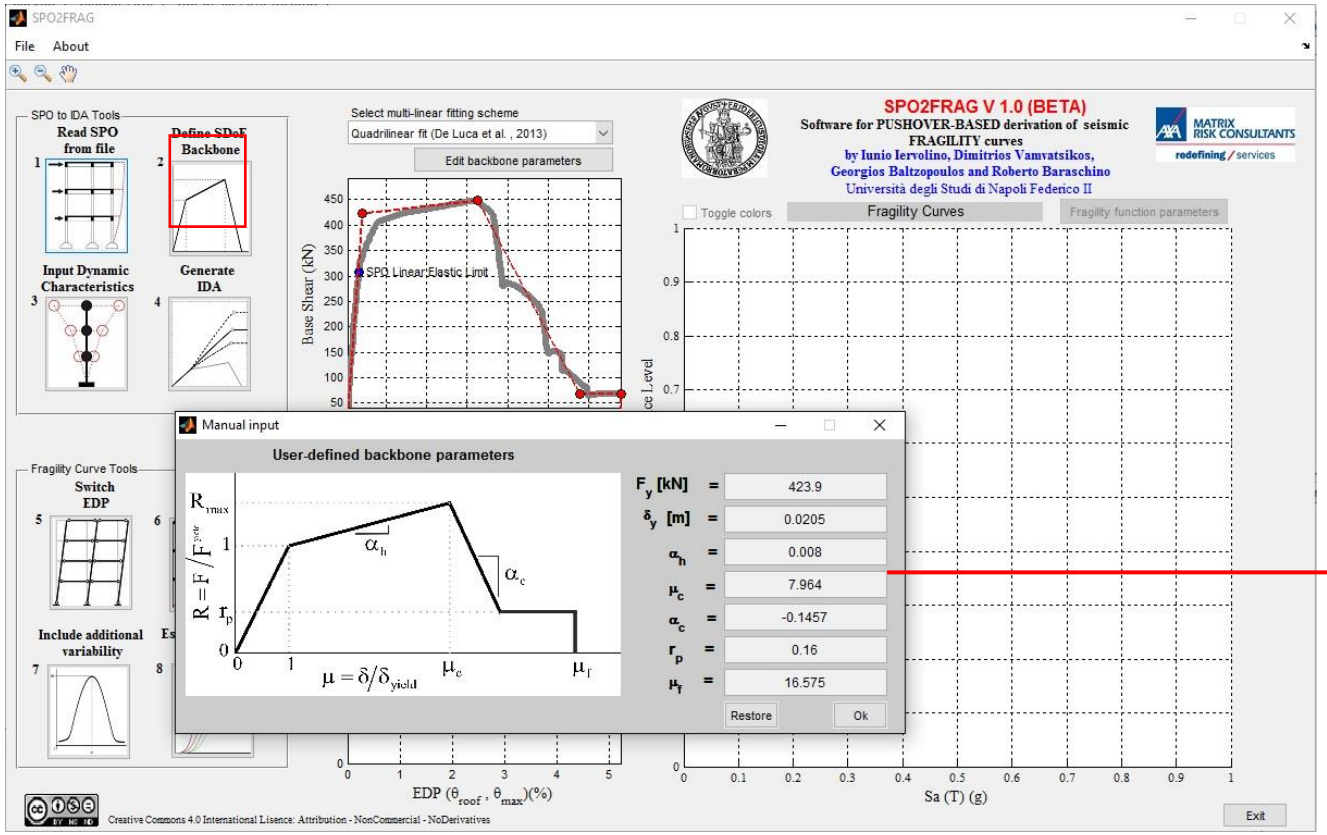
Static Pushover Analysis
Equivalent SDoF formulation



- ☑ Management of input SPO data
- ☑ Preliminary check of SPO curves
- ☑ Automatic definition of multi-linear backbone for equivalent SDoF system

⇨ Spreadsheet-based template for data input

AUTOMATIC MULTI-LINEAR FIT OF SPO CURVE



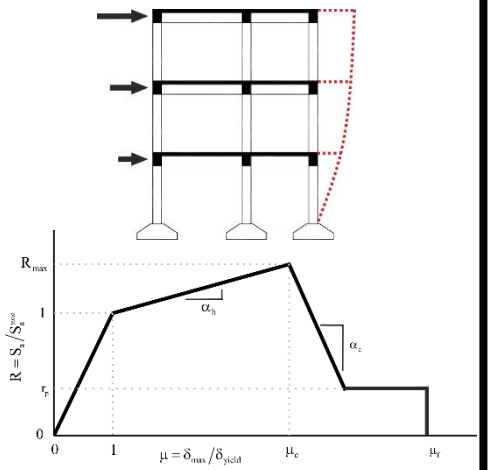
Type of multi-linear fit selection

- Elastic-perfectly plastic
- Bilinear fit
- Fully Quadrilinear fit
- User-defined parameters

SPO multi-linear fit algorithm output window

STEP 1

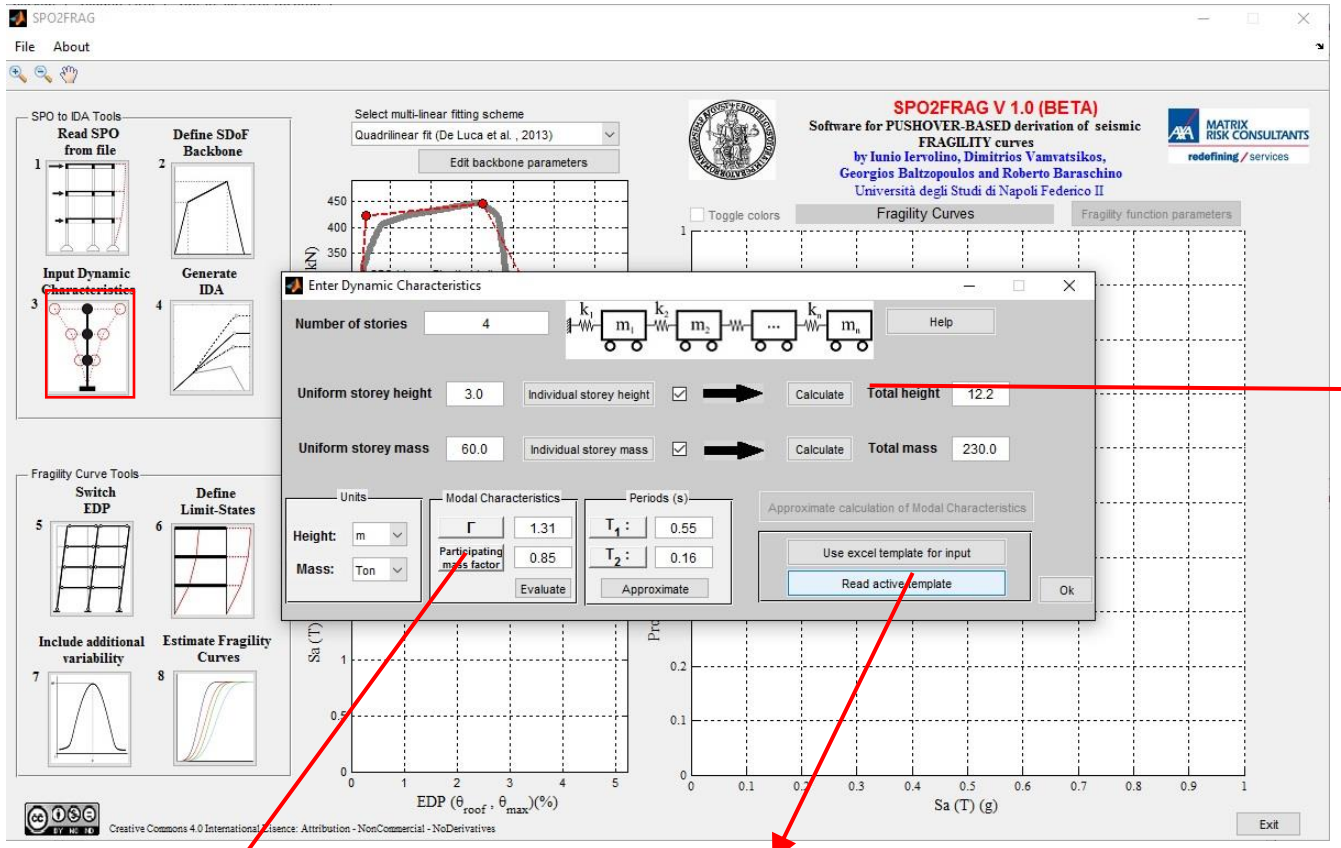
Static Pushover Analysis
Equivalent SDoF formulation



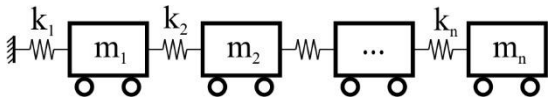
- ☑ Management of input SPO data
- ☑ Preliminary check of SPO curves
- ☑ Automatic definition of multi-linear backbone for equivalent SDoF system

⇨ Fit parameters are internally transferred to the SPO2IDA module.

INPUT OF DYNAMIC CHARACTERISTICS

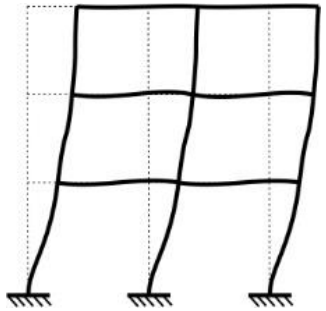


Storey height and floor mass input



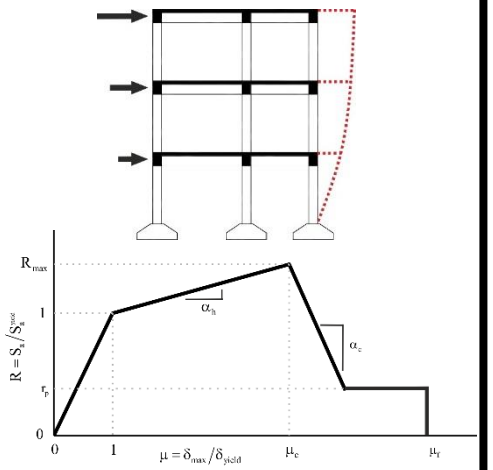
Spreadsheet-based template for data input.

Modal characteristics can be automatically extracted (approximated) from the input when SPO displacements at all stories are available.



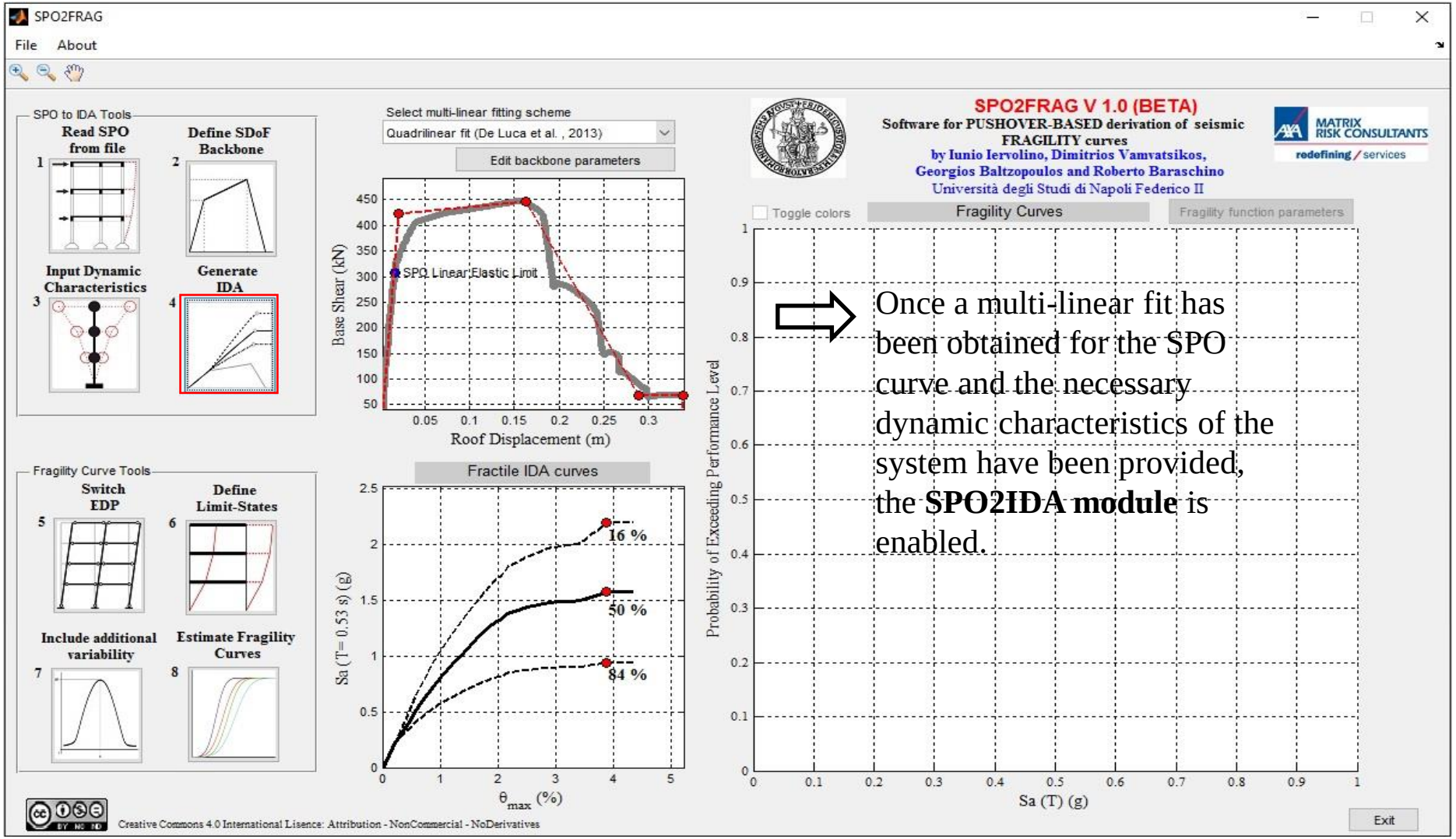
STEP 1

Static Pushover Analysis
Equivalent SDoF formulation



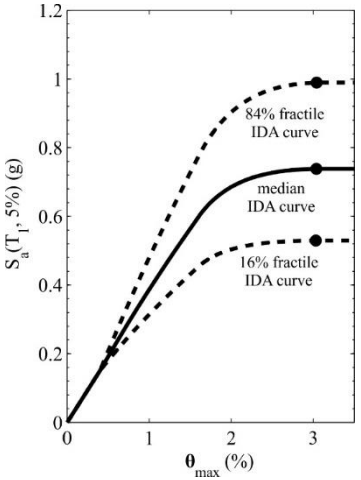
- ☑ Management of input SPO data
- ☑ Preliminary check of SPO curves
- ☑ Automatic definition of multi-linear backbone for equivalent SDoF system

GENERATE APPROXIMATE IDA FRACTILE CURVES THROUGH SPO2IDA



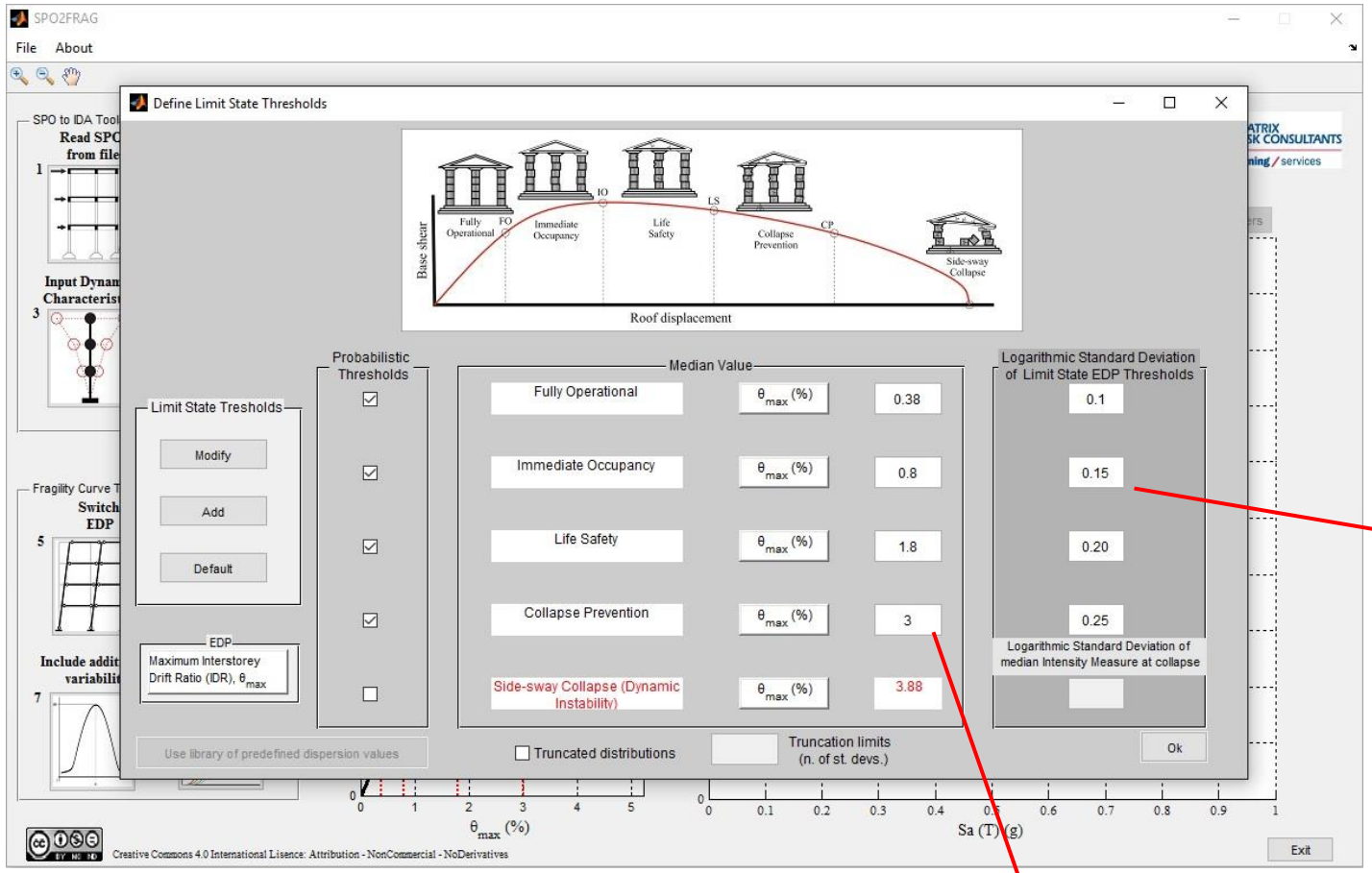
STEP 2

SPO2IDA Implementation to obtain fractile IDA curves



- [x] Run SPO2IDA algorithm
- [x] SDoF to MDoF transformations (EDP, IM)

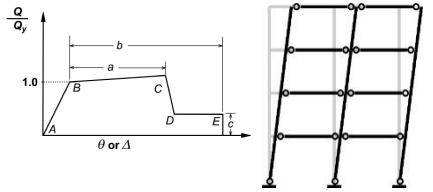
DEFINITION OF LIMIT-STATE THRESHOLDS



Definition of EDP thresholds per Limit State

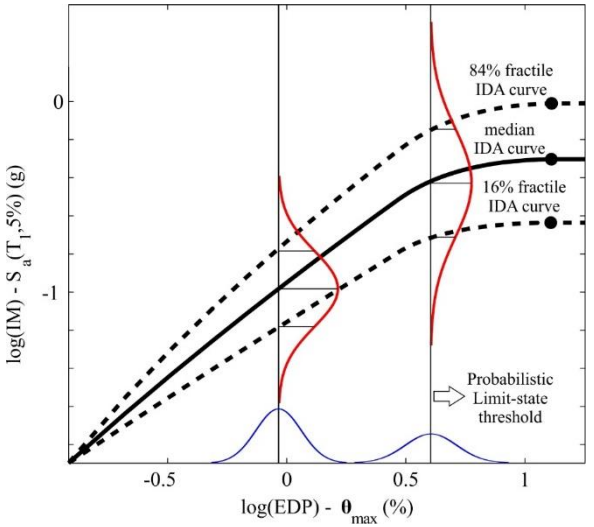
STEP 3

Definition of Limit-State thresholds and variability

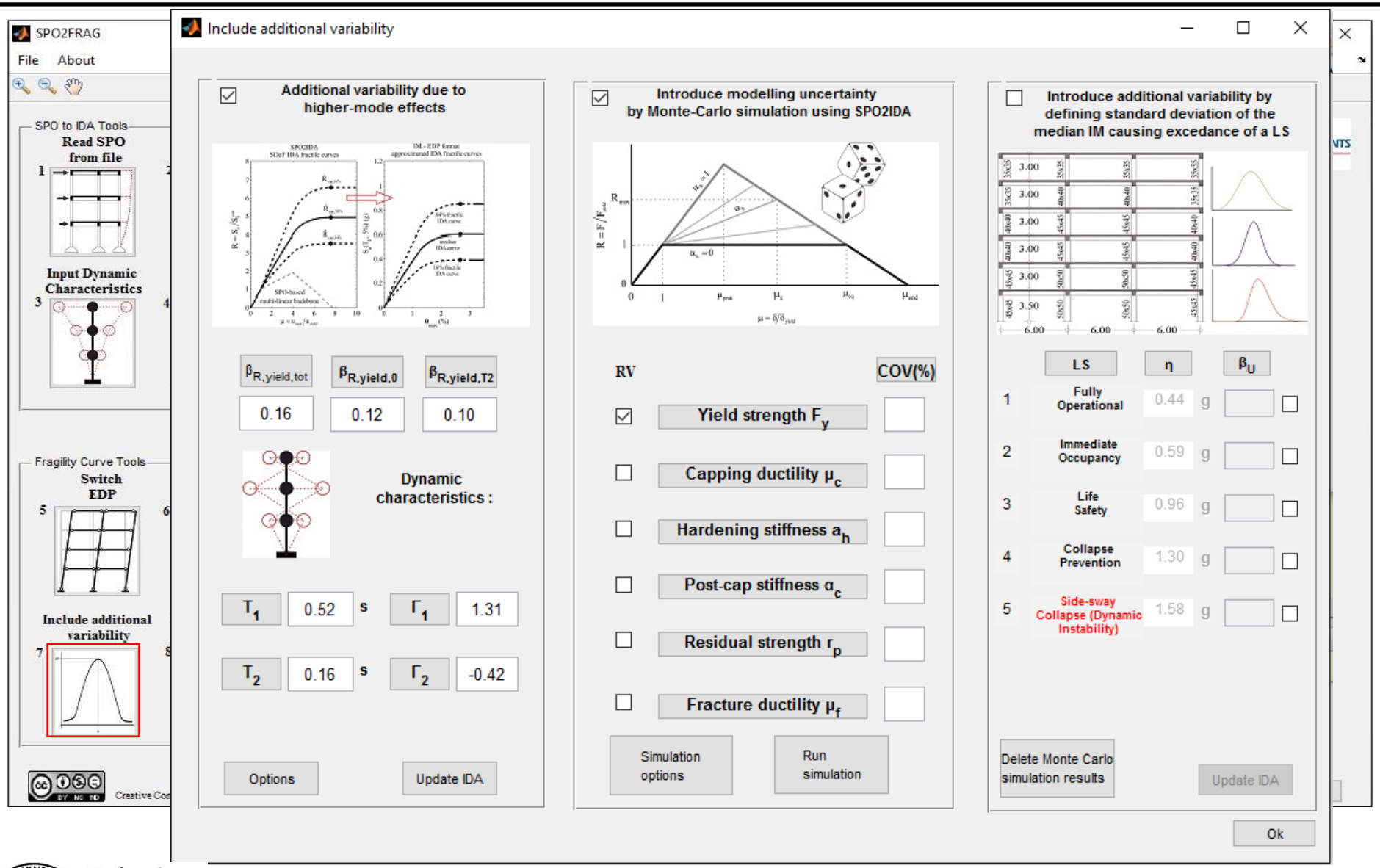


- ✓ Basic Limit-State EDP threshold definition interface
- ✓ Account for variability of Limit-State thresholds.

Define EDP threshold **variability** per Limit State

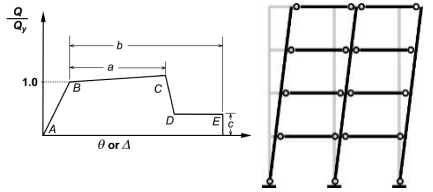


INCLUDE ADDITIONAL SOURCES OF RESPONSE VARIABILITY



STEP 3

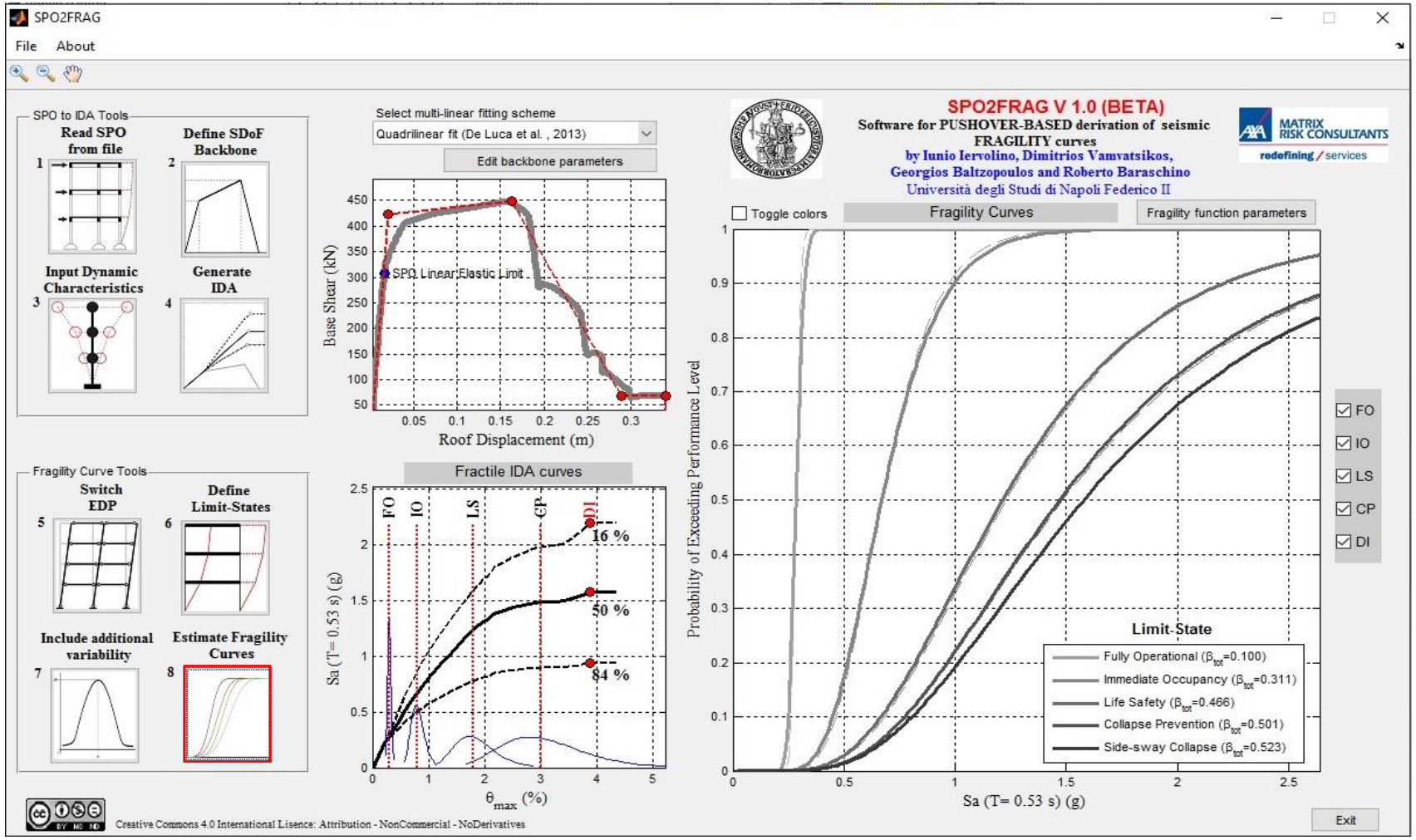
Definition of Limit-State thresholds and variability



- ☑ Incorporate additional variability due to MDoF effects
- ☑ Accomodate additional sources of variability (e.g., epistemic)

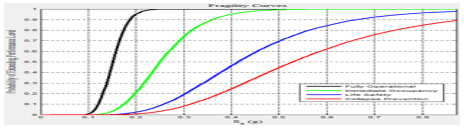
⇨ Direct assignment or estimation via MC simulation

CALCULATION OF FRAGILITY FUNCTIONS



STEP 4

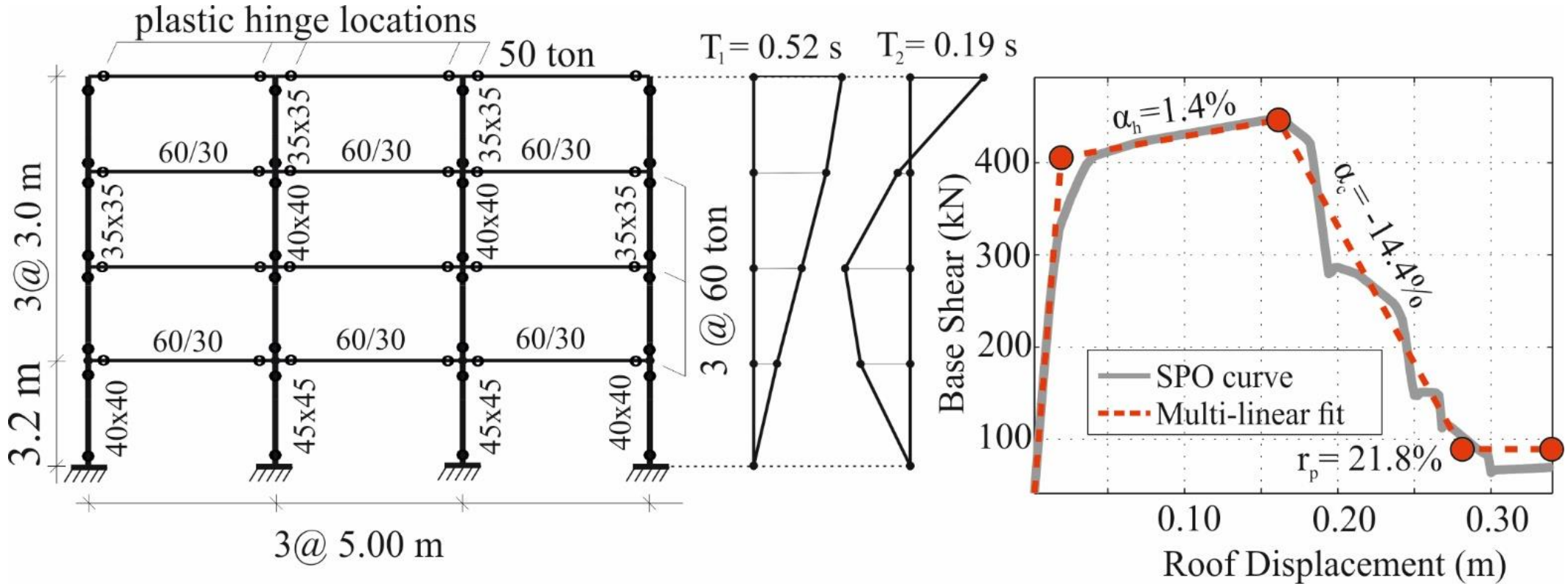
Calculation of Fragility Curves



☑ Lognormal parametric fragility functions

$$\begin{cases} \eta = \ln \mathrm{IM}_{C,LS}^{50\%} \\ \beta = \ln\left[\mathrm{IM}_{C,LS}^{50\%} \,/\, \mathrm{IM}_{C,LS}^{16\%}\right] \text{, or alternatively} \\ \beta = 1/2 \cdot \ln\left[\mathrm{IM}_{C,LS}^{84\%} \,/\, \mathrm{IM}_{C,LS}^{16\%}\right] \end{cases}$$

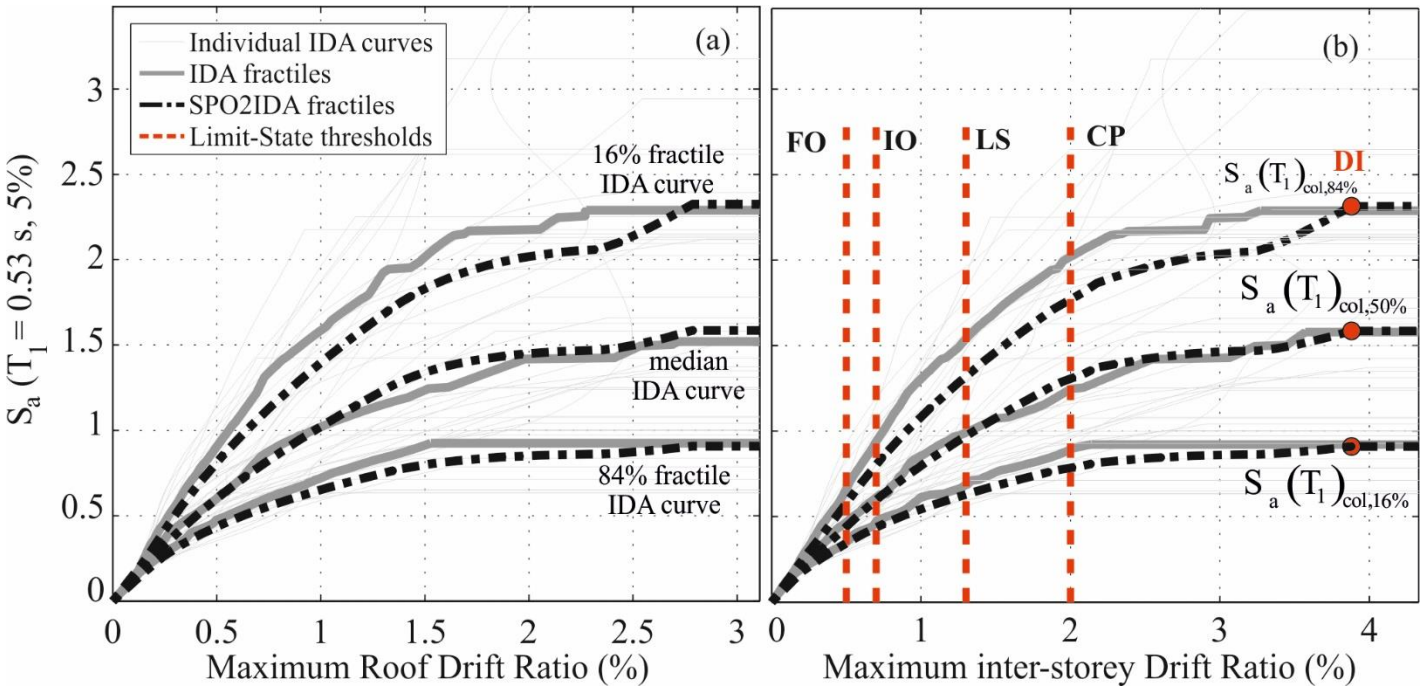
ILLUSTRATIVE APPLICATION

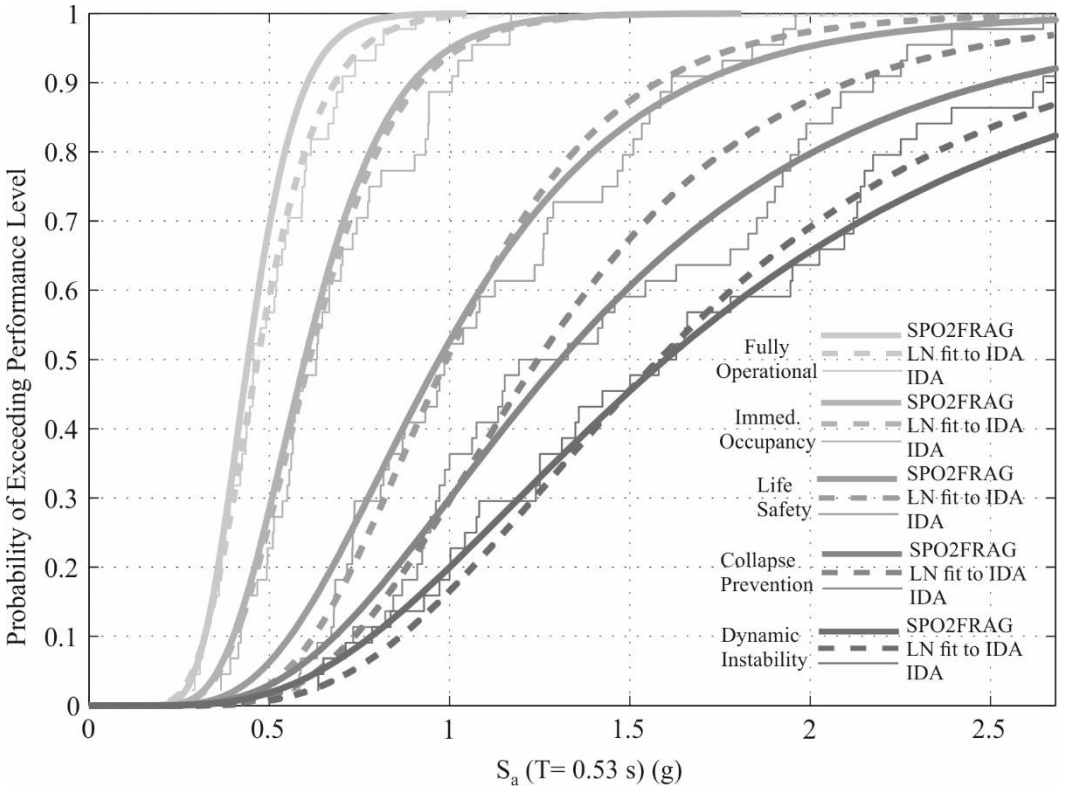


⇨ Four-storey, Bare, Plane, Moment-resisting RC frame, modelled in OPENSEES

⇨ Analytical validation of the program results using **Incremental Dynamic Analysis**.

ILLUSTRATIVE APPLICATION





⇨ Analytical validation of the program results using **Incremental Dynamic Analysis**.

SPO2FRAG: SUMMARY AND CONCLUSIONS

Software for approximate analytical derivation of seismic fragility functions for buildings

INPUT SPO RESULTS

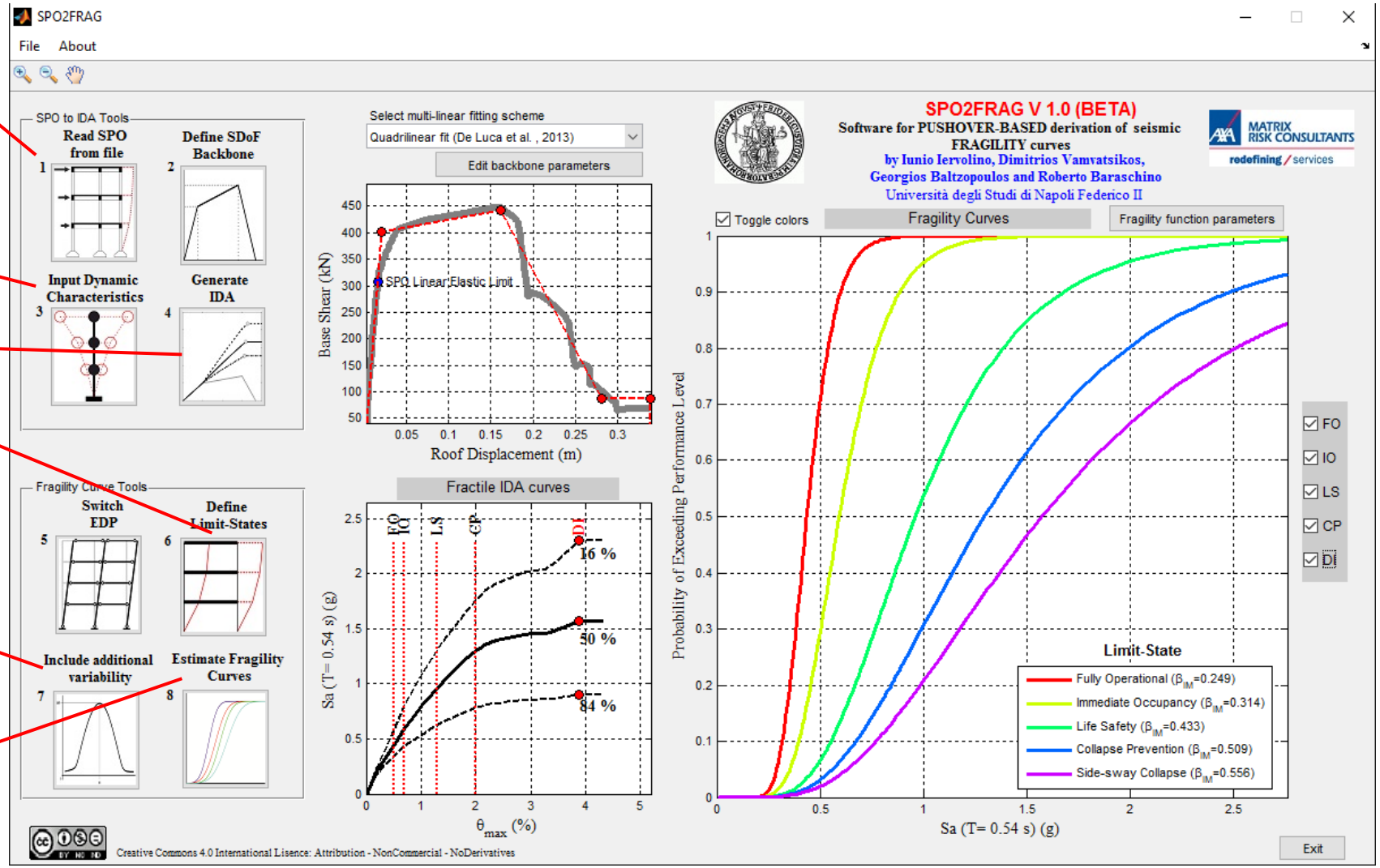
INPUT DYNAMIC CHARACTERISTICS OF THE STRUCTURE

ATTEMPT TO SIMULATE IDA

DEFINE APPROPRIATE EDP THRESHOLDS FOR EACH LIMIT STATE

CONSIDER ADDITIONAL SOURCES OF RESPONSE VARIABILITY

ESTIMATE FRAGILITY FUNCTION PARAMETERS (LOGNORMAL MODEL)



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If interested in participating in the BETA-testing of SPO2FRAG please visit: wpage.unina.it/iuniervo/

Thank you for your kind attention

SPO2FRAG was developed within the AXA-DiSt (*Dipartimento di Strutture per l'Ingegneria e l'Architettura, Università degli Studi di Napoli Federico II*) 2014-2017 research program, funded by AXA-Matrix Risk Consultants, Milan, Italy.

Ydra, 23/06/2016

MATRIX RISK CONSULTANTS
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