Simplified Performance Based Design/Assessment: Towards an Improved SAC-FEMA Approach

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INTRODUCTION

The objective of this research is to develop a simplified means of accounting for uncertainty in seismic assessment and design. The SAC/FEMA approach has been suggested by Cornell et al (2002) as a means of doing this. This approach proposes a simplified probabilistic performance assessment, however, the framework is based on a few significant assumptions.

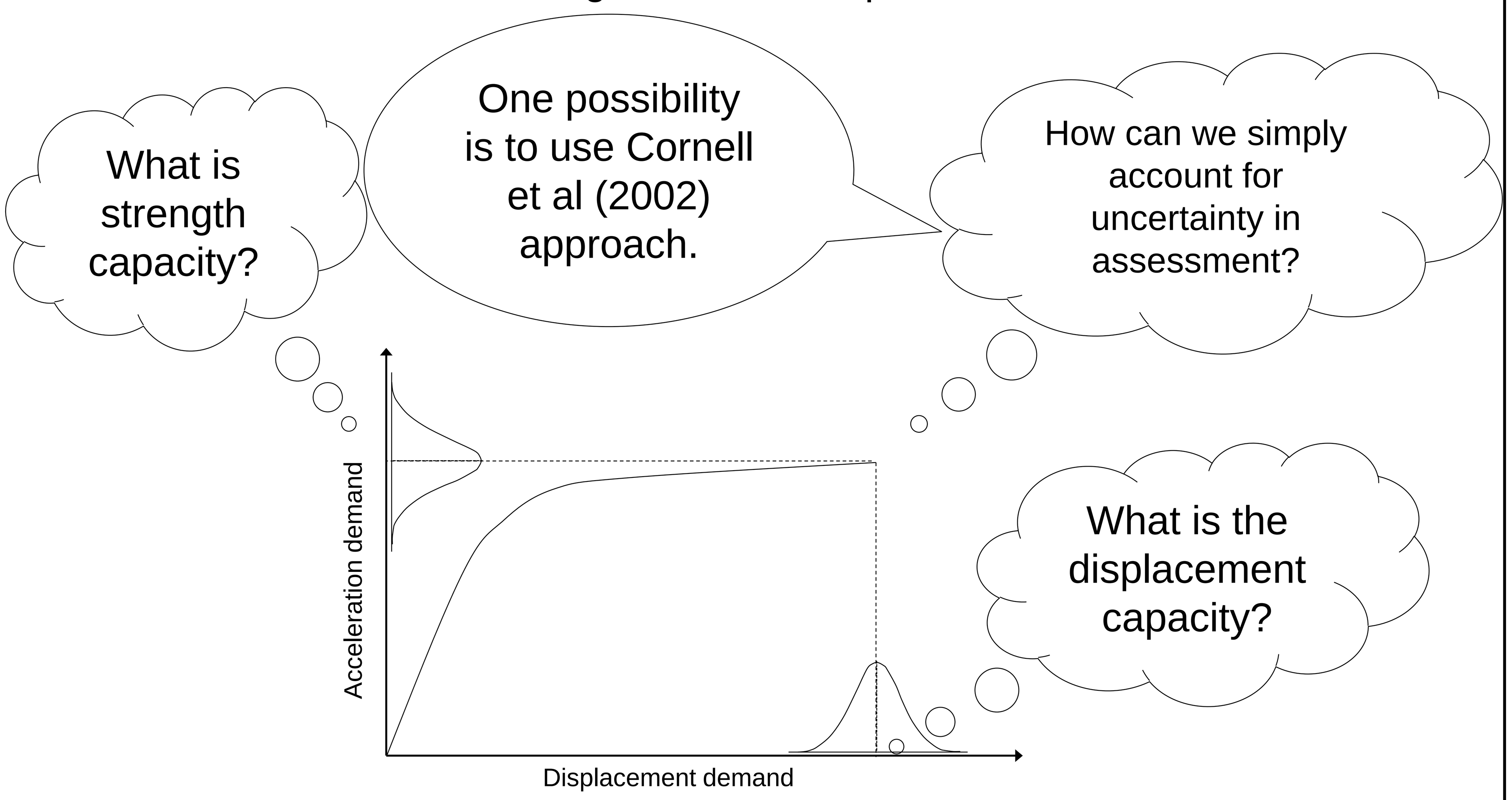


Figure 1. The simplified probabilistic performance assessment approach accounting for uncertainty demand and capacity

- SAC/FEMA approach assumptions:

  1- The displacement demand at each hazard level can be modelled with a lognormal distribution: $lognormal(\widehat{D}, \beta_{D|Sa})$

  2- The median value of displacement demand can be approximated adopting the power law function: $\widehat{D} = a(Sa)^b$

  3- According to the equal displacement rule (EDR), b is taken equal to 1.

LIMITATIONS WITH THE SAC/FEMA APPROACH (Cornell et al 2002)

1- The precision of the method is dependent on the accuracy of the estimated median and standard deviation.

2- 'a' and 'b' factors may vary based on the structural system, ductility demand, and period of vibration.

3- Previous research has shown that the Equal displacement rule may be valid only for a small number of structural systems, periods of vibration and ductility demands.

FRAMEWORK (HYSTERESIS MODEL)

In order to improve the SAC/FEMA approach, a robust campaign of nonlinear time history analysis can be used to examine how response varies with increasing intensity levels.

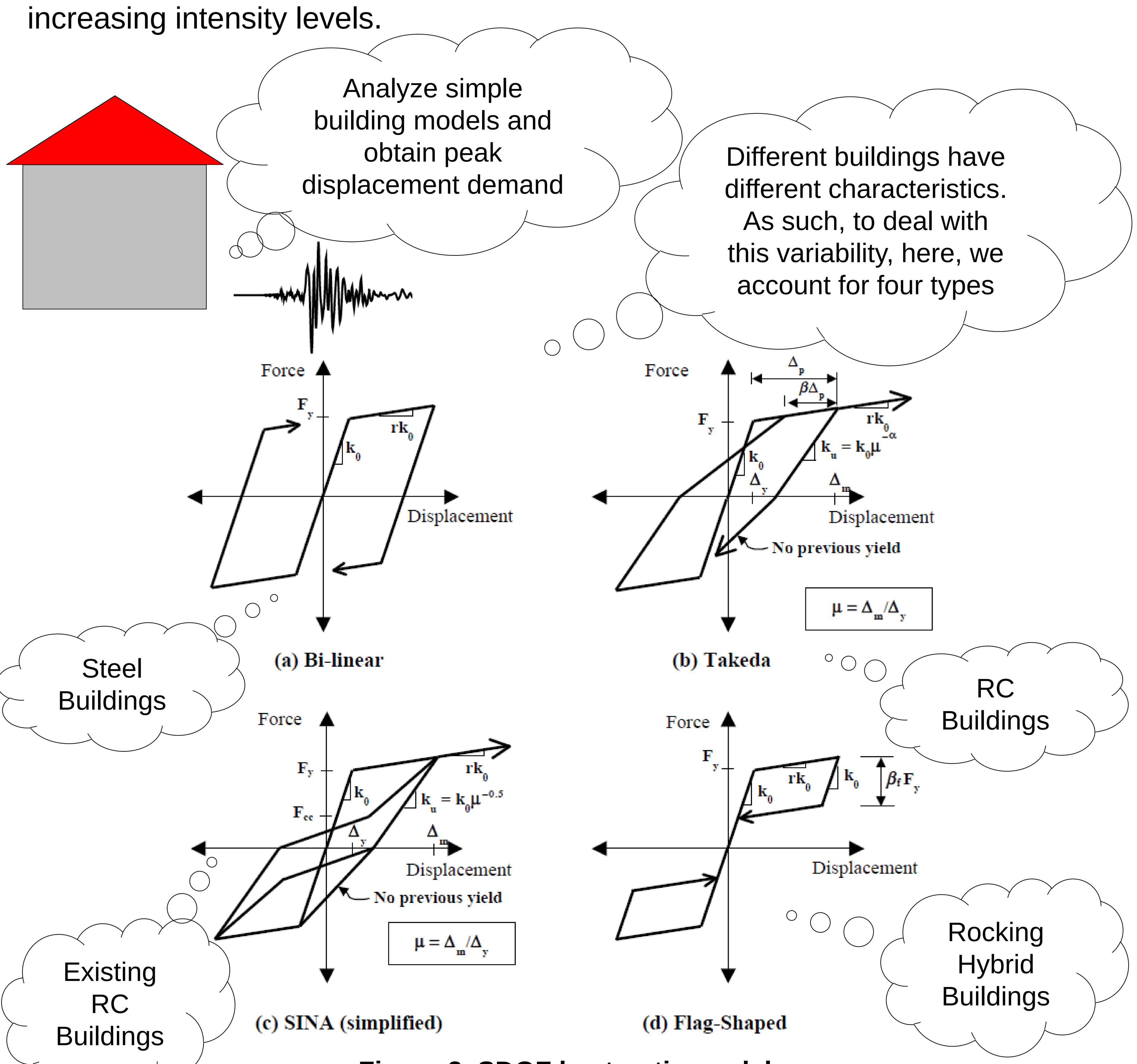


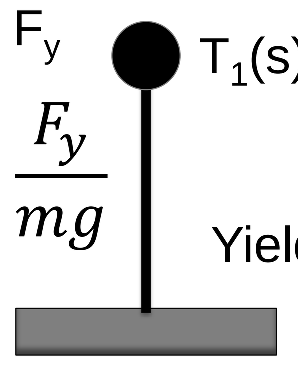
Figure 2. SDOF hysteretic models

FRAMEWORK -ANALYSIS

Each of the hysteresis models was considered in turn by Stafford et al. (2016) for SDOF models with specific period and yield strength, as shown below. Hence, 560 SDOFs were modelled and exposed to a set of 4812 ground motions. The results of these 48120 analyses are post-processed in this study to identify relationship for SAC/FEMA approach.

Periods of vibration representing buildings from 1 to 20_storey:

m, k, F_y



$$C_y = \frac{F_y}{mg}$$

T_1(s): 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

Short periods — Medium periods — Long periods

Yield strength representing buildings from 1 to 20_storey:

Cy: 0.025, 0.05, 0.075, 0.1, 0.125, 0.15, 0.2, 0.3, 0.4, 0.5.

CLOUD ANALYSIS RESULTS AND REGRESSION

The peak displacement demands for each analysis are plotted as a function of the seismic intensity. Binned analysis is adopted, and consequently nonlinear regression is used to estimate the b factor. If SAC/FEMA were accurate the b factor in Eq. (1) would be equal 1. The current recommendation in the SAC/FEMA method is for the b factor in Eq. (1) to be equal 1.

$$\widehat{D} = a[\hat{S}_a]^b \qquad \text{Eq. (1)}$$

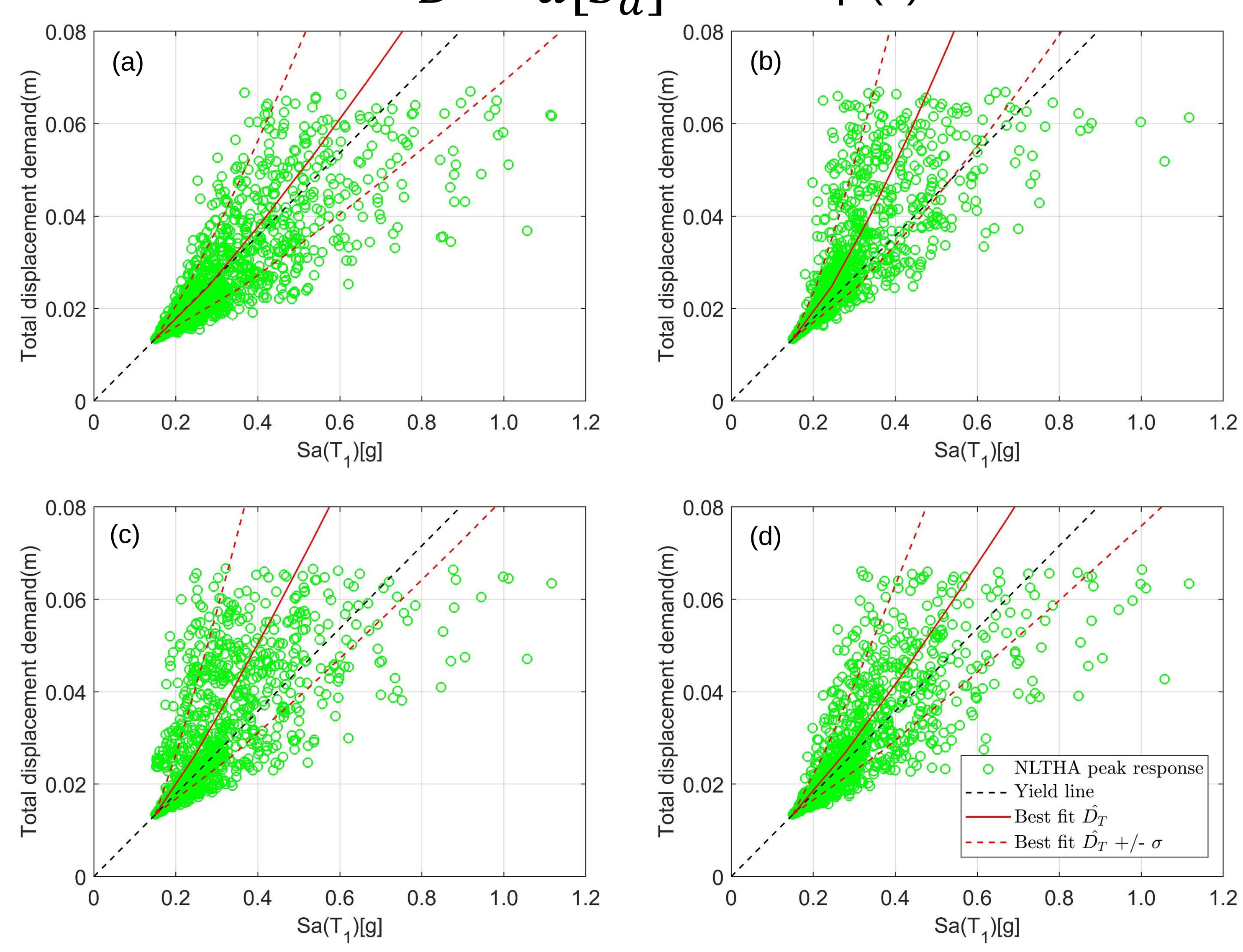


Figure 3. NLTHA analysis results associated with SDOF with C_y=0.125, T_1=0.6s and (a) Bilinear (b) Flag-shape (c) SINA (d) Takeda

b FACTOR-PERIOD (S) AND HYSTERETIC MODEL

From the results of regression analyses the b factor at different periods of vibration, yield strength, and hysteretic model have been found. Afterwards, the mean and standard deviation of the b factor is computed for short, medium, and long period structures (see period grouping above). Figure 4 displays the results for different hysteresis models.

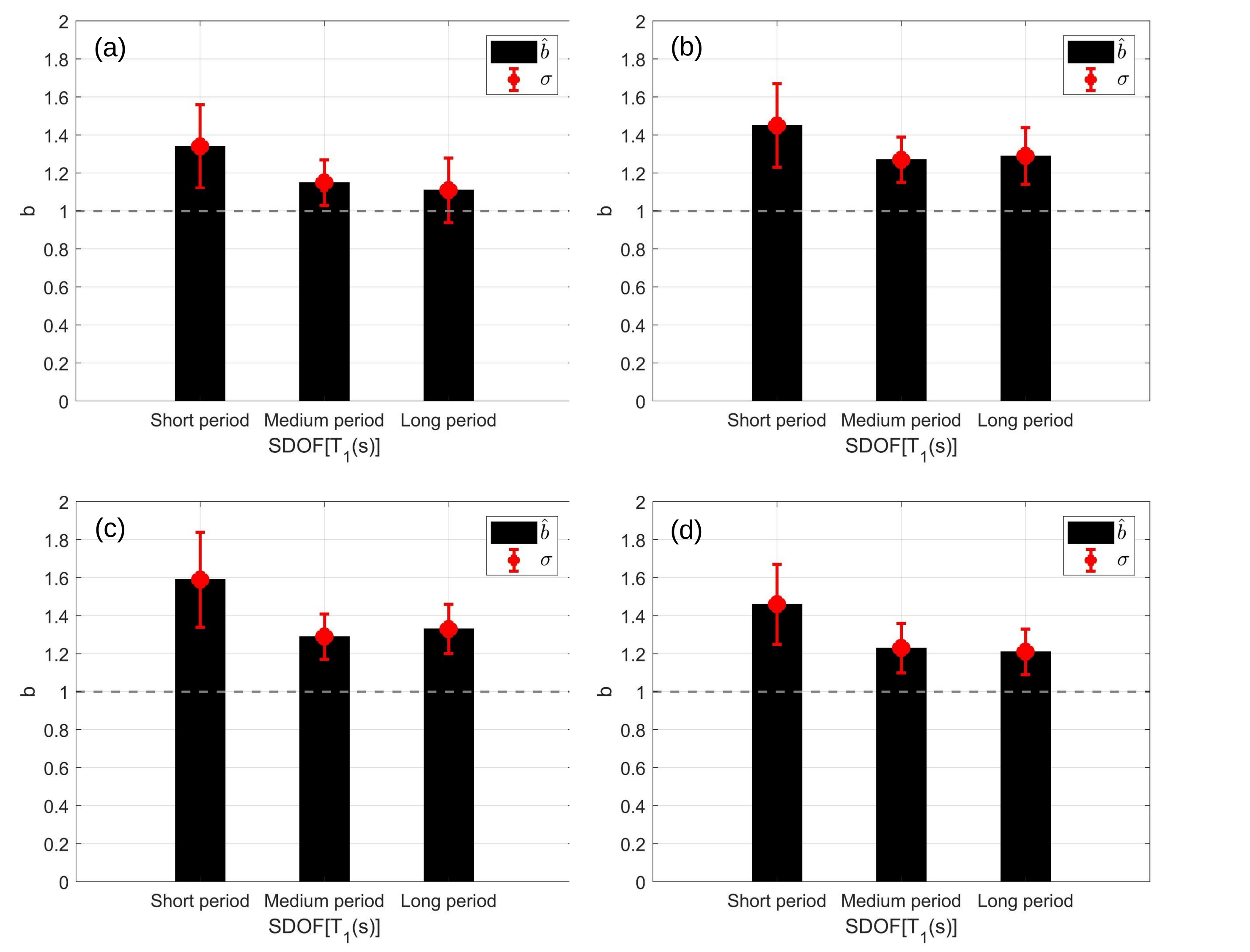


Figure 4. b factor mean value and standard deviation obtained for different period ranges and hysteretic models (a) Bilinear (b) Flag-Shaped (c) SINA (d) Takeda

CONCLUSIONS

This research has shown that the b factor for use in the SAC/FEMA method should be greater than 1.0 when demand exceeds the yield displacement and is a function of system period and hysteresis model. The new values obtained in this research could be useful as part of a simplified probabilistic assessment procedure that accounts for uncertainty.

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