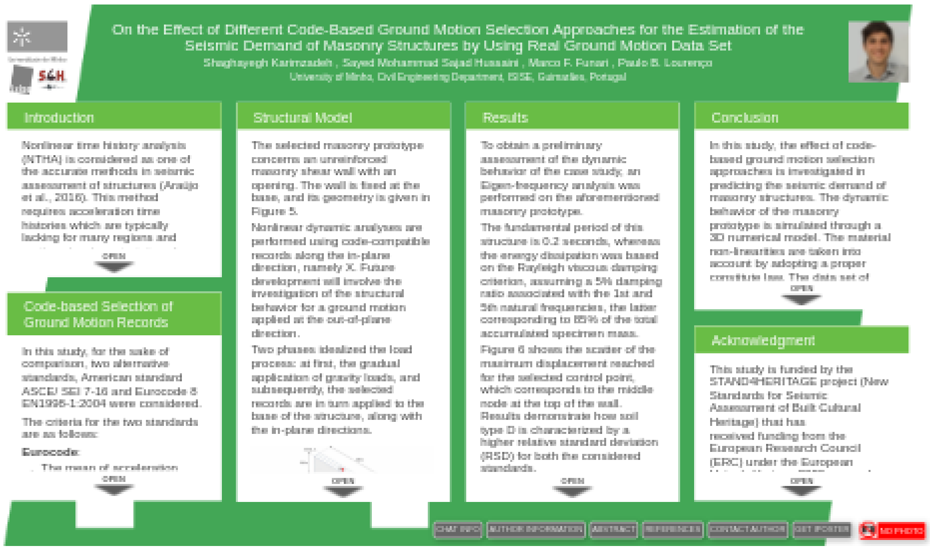
On the Effect of Different Code-Based Ground Motion Selection Approaches for the Estimation of the Seismic Demand of Masonry Structures by Using Real Ground Motion Data Set



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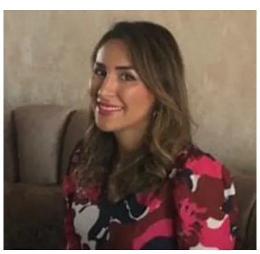   

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INTRODUCTION

Nonlinear time history analysis (NTHA) is considered as one of the accurate methods in seismic assessment of structures (Araújo et al., 2016). This method requires acceleration time histories which are typically lacking for many regions and earthquake characteristics of interest.

Alternative approaches are proposed by the codes to reach code-compatible ground motion record sets. However, the building codes prescribe a method of selection and scaling but usually address modern structures (e.g., steel, and reinforced structures).

Previous studies have shown that the response of reinforced concrete structures is dependent on the type of ground motion and corresponding methods of selection and scaling (Cantagallo et al., 2014; Grant et al., 2013).

This study compares the effect of current ground motion selection approaches prescribed in ASCE/ SEI 7-16 and Eurocode 8 EN 1998-1:2004 on the demand of masonry structures.

CODE-BASED SELECTION OF GROUND MOTION RECORDS

In this study, for the sake of comparison, two alternative standards, American standard ASCE/ SEI 7-16 and Eurocode 8 EN1998-1:2004 were considered.

The criteria for the two standards are as follows:

Eurocode:

- The mean of acceleration response spectra of the selected records within the period range of 0.2 T1- 2 T1, in which T1 is the fundamental period of the structure, should exceed 90% of the target spectrum.
- The mean spectra for the selected motions at T=0 seconds should not be smaller than the acceleration at the site of interest.
- Regarding the number of records, the minimum is considered as three accelerograms (Eurocode 8., 2004).

ASCE:

- The period range proposed by ASCE is similar to Eurocode which is between 0.2 T1 to 2 T1.
- In the case of amplitude scaling, ASCE uses the maximum direction spectrum which is evaluated for each pair of horizontal ground motions. The criterion is that the mean of maximum-direction spectra over the mentioned period range should exceed the target spectrum.
- For the other period ranges of interest, this mean spectrum should not be smaller than 90% of the target spectrum (ASCE 7., 2017).

In this study, to investigate the effect of alternative code-based ground motion selection standards on the seismic demand of masonry prototypes, the site of interest is assumed to be located at Reevesville, South Carolina 29471, USA. For this site, two hypothetic soil classes were considered.

The real records are selected from the PEER strong ground motion dataset (http://peer.berkeley.edu/nga/index.html (http://peer.berkeley.edu/nga/index.html)).

The seismological criteria in the selection process are restricted to:

- Mw: 5.5-9.0
- Fault mechanism: strike-slip
- RJB: 0-25 km
- Soil types: C (Vs30: 360-760) and D (Vs30: 180-360)

Note:

For Eurocode:

- ag=0.406 g

For ASCE (https://seismicmaps.org/ (https://seismicmaps.org/)):

- SS=0.664 and S1=0.198
- Soil class C: Fa= 1.234 and Fv= 1.5
- Soil class D: Fa= 1.268 and Fv= 2.203

In the selection process, real records are ordered according to their root mean square error (RMSE) between the mean and target spectra. Then, the top 11 records with minimum RMSE are considered as the final records for each standard. Figures 1-4 compare the target spectra with the individual and mean spectra of the selected records for the two standards and hypothetic soil types.

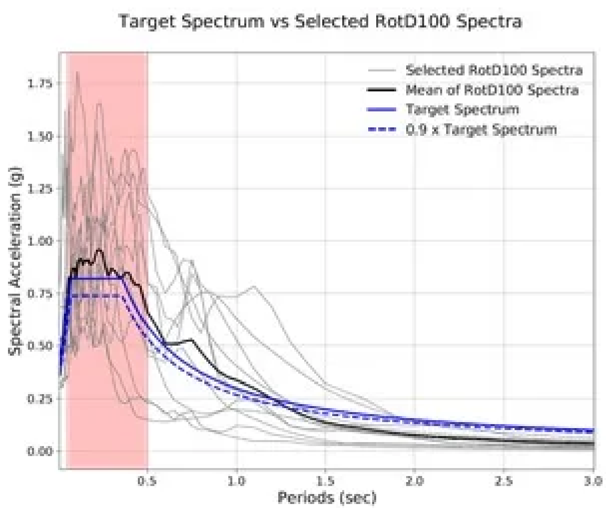

Figure 1 Comparison of response spectra for records selected based on ASCE (soil type C)

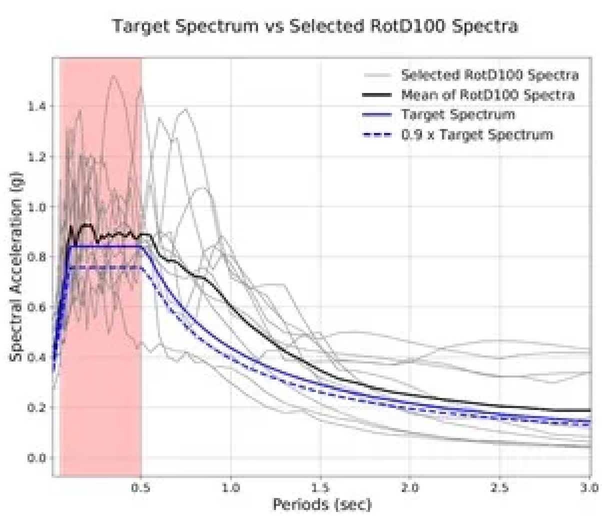

Figure 2 Comparison of response spectra for records selected based on ASCE (soil type D)

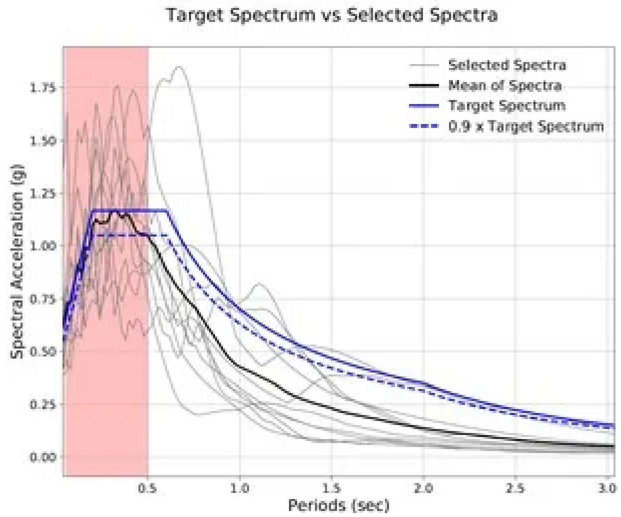

Figure 3 Comparison of response spectra for records selected based on EC8 (soil type C)

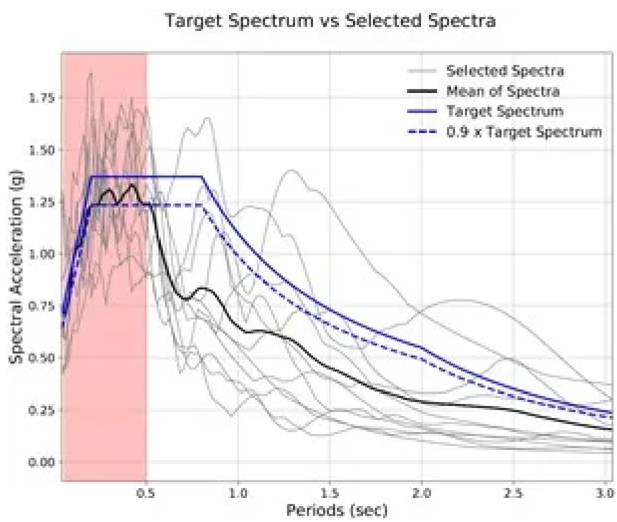

Figure 4 Comparison of response spectra for records selected based on EC8 (soil type D)

STRUCTURAL MODEL

The selected masonry prototype concerns an unreinforced masonry shear wall with an opening. The wall is fixed at the base, and its geometry is given in Figure 5.

Nonlinear dynamic analyses are performed using code-compatible records along the in-plane direction, namely X. Future development will involve the investigation of the structural behavior for a ground motion applied at the out-of-plane direction.

Two phases idealized the load process: at first, the gradual application of gravity loads, and subsequently, the selected records are in turn applied to the base of the structure, along with the in-plane directions.

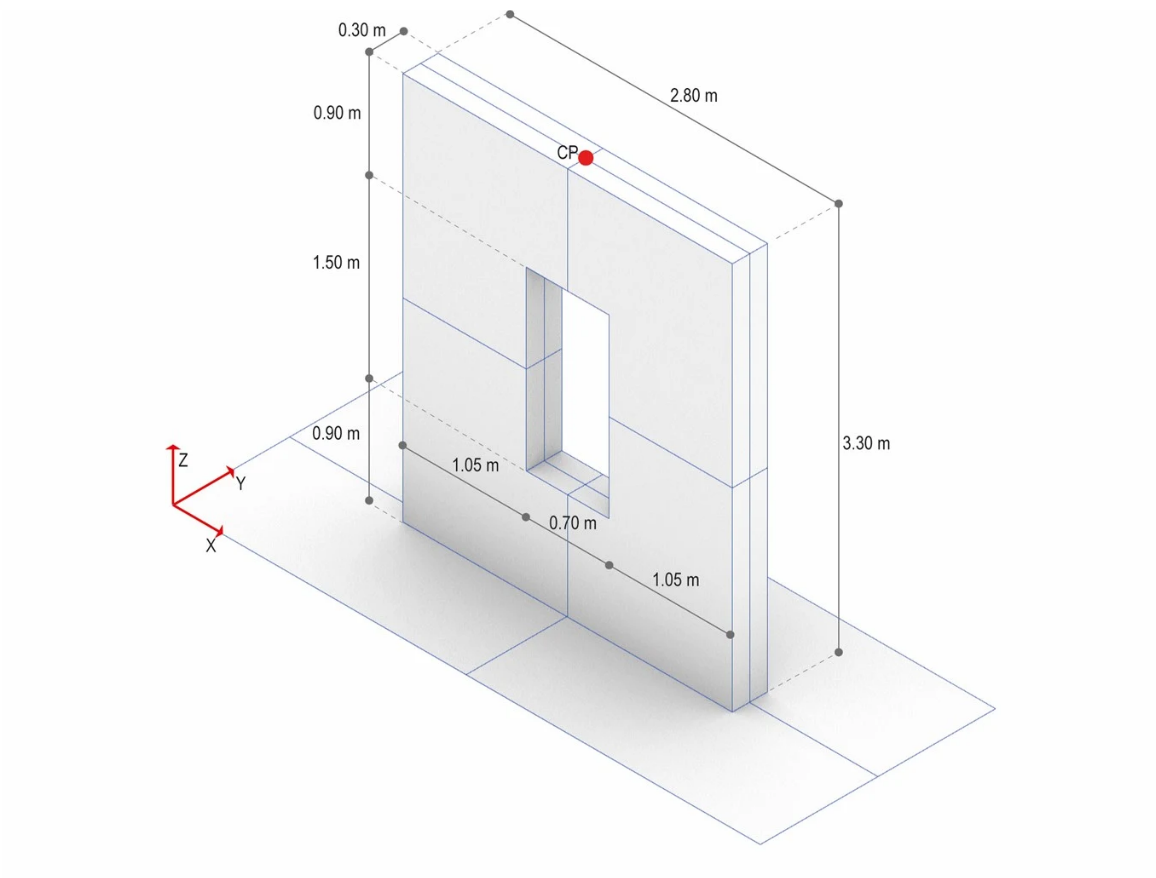

Figure 5 Geometry of the masonry prototype

The so-called macro-modeling approach was followed, meaning that the masonry arrangement is smeared out in a homogeneous material. This is especially convenient for the analysis of large-scale structures. ABAQUS offers the possibility to reproduce the macroscopic masonry mechanical behavior through several models, e.g., the smeared crack concrete, the brittle crack concrete, and the concrete damage plasticity (CDP) models (Abaqus, 2014).

Herein, the CDP model was used since it is suitable for quasi-brittle materials in general. It couples plasticity with a scalar-based damage model, and it was originally developed for concrete (Lubliner et al., 1989). CDP has been extensively used for studying large masonry structures, and the results indicate that it offers a good compromise between computational time and accuracy (Fortunato et al., 2017).

Material properties required to complete the proposed procedure are given in Tables 1 and 2.

Table 1 Mechanical properties of the masonry adopted in the simulations

Material properties	**Values**
Density	1850 Kg/m^3
Elastic Modulus	1500 N/mm^2
Poisson ratio	0.2
Dilation angle	10°
Eccentricity	0.1
f_{b0} / f_{c0}	1.16
K_c	0.667
Viscosity Parameter	0.002

Table 2 Compressive and tensile behavior of the masonry adopted in the simulations

Compressive behavior		**Tensile behavior**	
Stress [MPa]	Inelastic strain	Stress [MPa]	Inelastic strain
2.0	0	0.12	0
2.4	0.002	0.0012	0.001
0.2	0.007	0.0012	0.003

RESULTS

To obtain a preliminary assessment of the dynamic behavior of the case study, an Eigen-frequency analysis was performed on the aforementioned masonry prototype.

The fundamental period of this structure is 0.2 seconds, whereas the energy dissipation was based on the Rayleigh viscous damping criterion, assuming a 5% damping ratio associated with the 1st and 5th natural frequencies, the latter corresponding to 85% of the total accumulated specimen mass.

Figure 6 shows the scatter of the maximum displacement reached for the selected control point, which corresponds to the middle node at the top of the wall. Results demonstrate how soil type D is characterized by a higher relative standard deviation (RSD) for both the considered standards.

Finally, Figure 7 reports the representation of the most evident damage patterns obtained for each ground motion selection method.

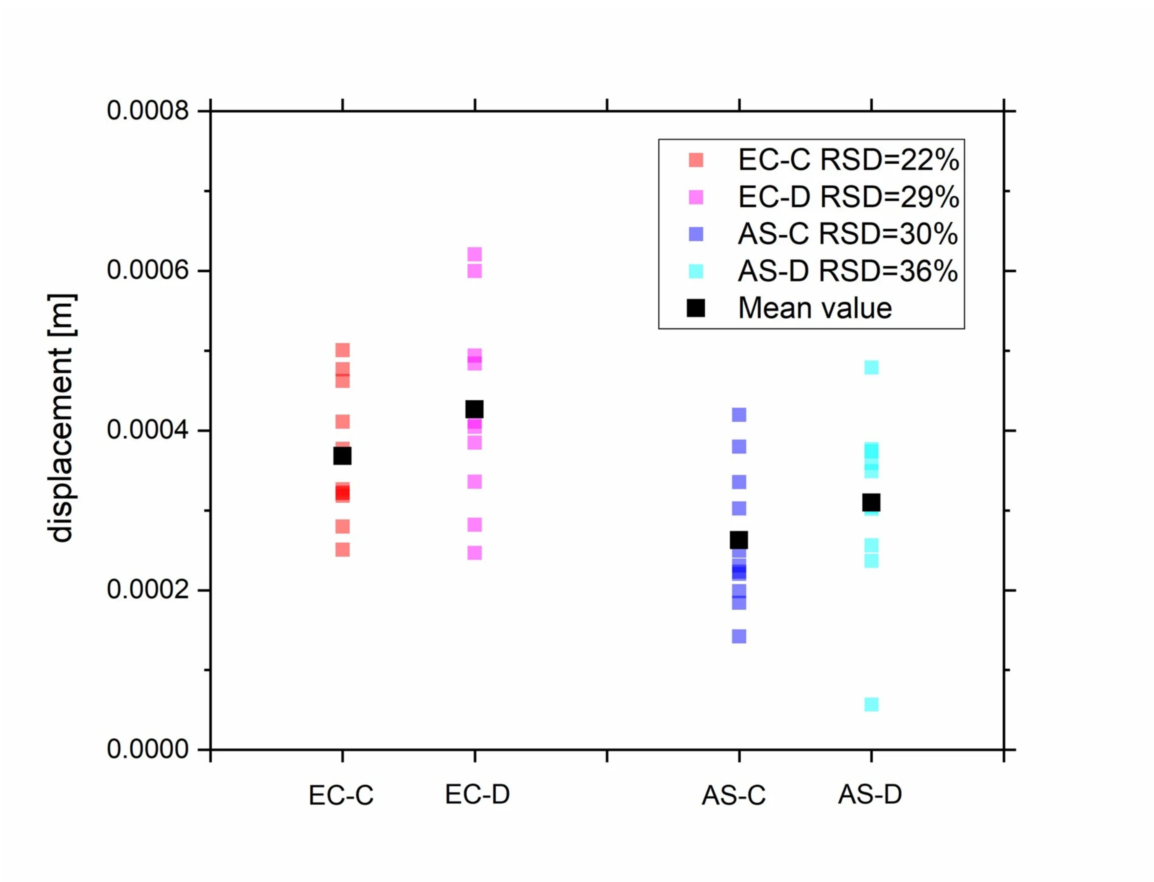

Figure 6 Comparison in terms of maximum displacement reached by the control point for each selection method

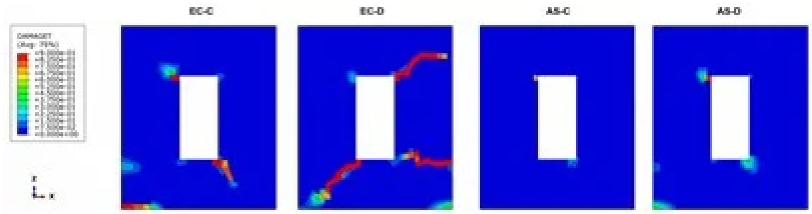

Figure 7 Most evident damage pattern obtained for each selection method

CONCLUSION

In this study, the effect of code-based ground motion selection approaches is investigated in predicting the seismic demand of masonry structures. The dynamic behavior of the masonry prototype is simulated through a 3D numerical model. The material non-linearities are taken into account by adopting a proper constitute law. The data set of PEER is used as the pool for selection and scaling based on various codes, including American standard and Eurocode. Results of this study are summarized as follows:

- In general, selected records based on the Eurocode standard provided higher demand in terms of displacement values for both soil types C and D.
- In both cases, results for soil type D are characterized by higher values of the RSD.
- As expected, soil type D provides higher mean displacement levels.
- Future study will involve investigation on different selection criteria in addition to a set of masonry prototypes with their response in the out-of-plane direction.

ACKNOWLEDGMENT

This study is funded by the STAND4HERITAGE project (New Standards for Seismic Assessment of Built Cultural Heritage) that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant No. 833123) as an Advanced Grant.

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ABSTRACT

Building design codes recommend using nonlinear dynamic analysis for an appropriate assessment of the seismic response of several types of structures. To perform nonlinear dynamic analysis, the recorded ground motion time histories of past events with a certain seismic intensity level compatible with the regional seismological characteristic are usually scarce. Therefore, alternative selection and scaling methods on the previously recorded ground motion data set are commonly employed to overcome this issue. However, the type of method and also the random characteristics of earthquake ground motion data induce variability in the estimation of structural response. In this paper, the effect of code-based ground motion selection approaches is investigated in predicting the seismic demand of masonry structures. The dynamic behavior of the masonry prototype is simulated through a 3D numerical model. The material non-linearities are taken into account by adopting a proper constitute law. The data set of PEER is used as the pool for selection and scaling based on alternative codes, including American standard and Eurocode. Results showed that alternative code-based selection approaches reach various seismic demand levels.

Keywords: Ground motion records, PEER data set, Scaling, Code-based selection, Masonry structures, Incremental dynamic analysis

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