Study of the seismic site effects at Lisbon metropolitan area

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Abstract

The main purpose of the present work is to study the local site effects on Lisbon metropolitan area and Algarve, because these are two of the most susceptible seismic risk zones in Continental Portugal. Using geotechnical profiles data from the two zones under study, a classification of the profiles was made applying the Eurocode 8 classification and a new classification proposed by Pitilakis *et al.* (2013). The shape of the average response spectrum computed by the linear equivalent method was compared with the shape of the elastic response spectra defined by the National Annex to Eurocode 8, for the two different types of seismic action established for Continental Portugal. For ground types A, B and E good agreement was observed, while for ground type C and type D, the spectral ordinates at longer periods are larger than defined by the National Annex.

Key-words: Elastic response spectra; seismic action; Eurocode 8 Portuguese National Annex

1. INTRODUCTION

The main purpose of this work is to study the local site effects at Lisbon metropolitan area and Algarve because these are two of the most susceptible seismic risk zones in Continental Portugal.

Initially, the ground profiles were classified according to Eurocode 8 (EC8) [1] and according to a new classification proposed by Pitilakis *et al*, (2013) [2].

Afterwards, the equivalent linear method was used to calculate elastic response spectra at ground profile surface. The shape of the average response spectrum was compared with the one from the National Annex the Eurocode 8 (NA8), for the two different types of seismic action established for Continental Portugal.

2. METHOD

In this study, the power spectral density at bedrock outcrop computed by Carvalho *et al*., 2007 [3], using the finite-failure stochastic method, was used to represent the two seismic scenarios representative of the two types of seismic actions established by the NA8.

The far source scenario includes simulations for magnitude between 5,1 and 8,7, in 0,2 intervals, and for 20 epicentral distances (from 50km to 700 km), resulting in a data base with a total of 45600 motions. For the near source scenario, only epicentral distances under 200 km and magnitudes between 4,1 and 7,5, in 0,2 intervals were considered, corresponding to a total of 45360 motions.

The elastic response spectra at the surface was determined through an existing program of seismic scenarios simulator (LNECLoss [4]) which applies the equivalent linear method to the shear wave’s propagation in the soil samples. The Darendeli (2001) [5] modulus reduction and material damping curves were used. The power density and acceleration response spectra at the surface was then calculated.

3. DATA

Within the framework of two national seismic risk evaluation projects for the Lisbon metropolitan area and the Algarve region, funded by ANPC (Civil Protection National Authority), multiples studies were realized and geotechnical data were collected by several teams of national entities, to construct geotechnical profiles used in this work.

For the Algarve region, the main source resulted from the work developed by an Algarve university team [6]. This study includes 280 profiles, but only 134 were used due to the incomplete information of the remaining 146. The data provided included the profile location, lithology, depth and shear wave velocity. However, due to the lack of data necessary for the samples classification, the estimated values for density (ρ [ton/m^3]) and plasticity index (IP [%]) indicated on the Table 1 were used.

Table 1. Density and plastic index values based on soil lithology

Lithology	ρ [ton/m^3]	IP [%]
Alluvium	1,6	40
Clay	1,7	40
Silty sand	1,9	10
Sand	1,8	0
Rock	2,2	0

The data for Lisbon metropolitan area includes in 38 profiles identified from B to AN [7]. The data for each profile included the depth from the top of the layer, density, shear waves medium velocity, number of layers and plasticity index.

4. SOIL CLASSIFICATION SYSTEM

4.1 Eurocode 8 soil classification

The Eurocode 8 (EC8) soil classification is synthetized in Table 2. The distribution of the 172 profiles by each class is presented in Figure 1.

Table 2. EC8 soil classification

Classification	**A**	**B**	**C**	**D**	**E**	**S1**
$V_{s,30}$ [m/s]	≥ 800	360 - 800	180 - 360	< 180	-	< 100
IP [%]	-	-	-	-	-	≥ 40
Superficial alluvial layer thickness [m]	-	-	-	-	5 - 20	≥ 10

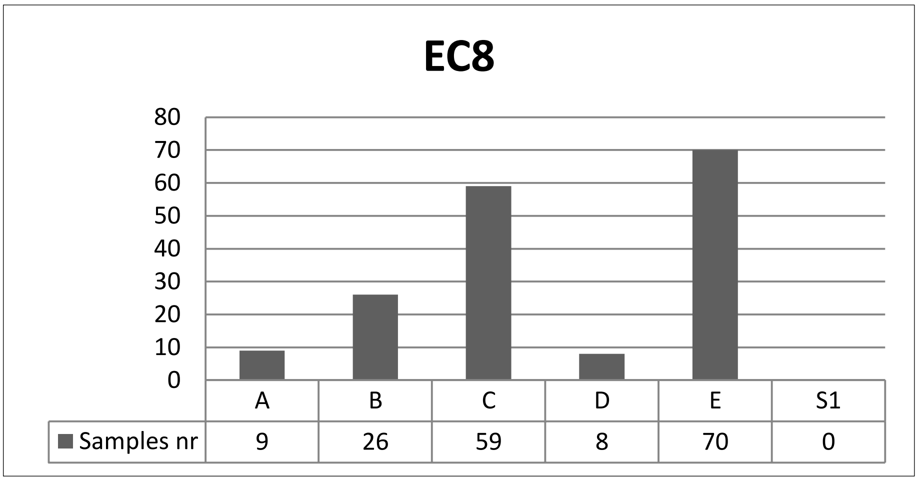

Figure 1. Samples distribution for the different EC8 classes

From Figure 1, it can be observed that most of the samples for the two study zones were classified as type E and none was classified as type S1. The type S2 was not included in this analysis because the soils liquefaction potential was not considered.

4.2 Pitilakis *et al.,* (2013) soil classification

Pitilakis *et al.,* (2013) [1] presented a new soil classification based on EC8 soil classification but using subdivided classes (Table 3). The samples were classified as previously with the EC8 classification and the samples distribution for each class was obtained, as shown in the Figure 2.

Table 3. Pitilakis et al., (2013) soil classification

Classificação	A1	A2	B1	B2	C1	C2	C3	D1	D2	D3	E
V_s [m/s]	≥ 1500	≥ 800	-	-	-	-	-	-	-	-	-
$V_{s,av}$ [m/s]	-	≥ 200	400 - 800			200 - 450	200 - 400	≤ 300		150 - 600	≤ 400
IP [%]	-	-	-	-	-	15 - 40	-	≥ 40	< 15	15 - 40	-
H [m]	0	0 - 5	5 - 30	30 - 60	≥ 60	20 - 60	≥ 60	20 - 60		≥ 60	5 - 20

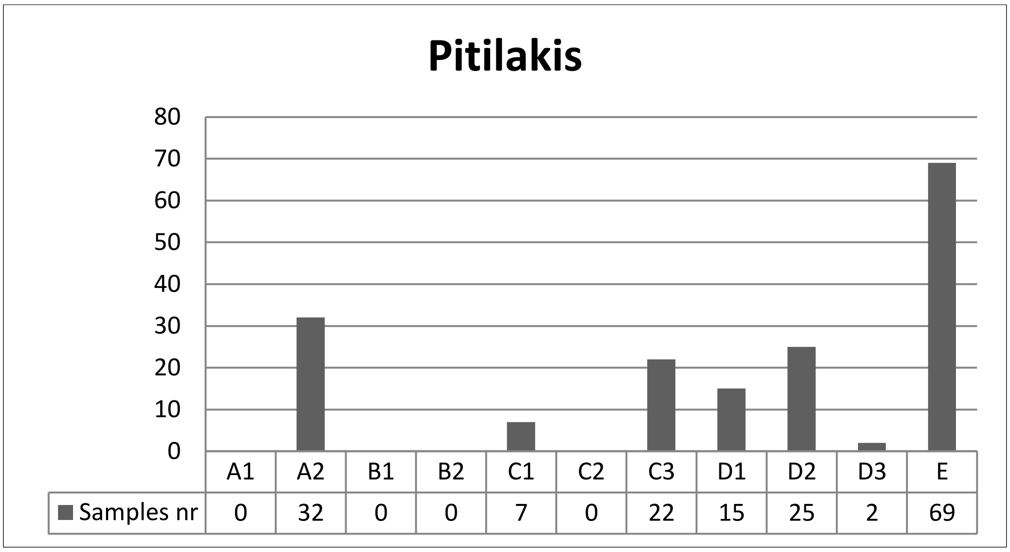

Figure 2. Samples distribution for the different Pitilakis et al., (2013) classes

Figure 2 shows that most of the samples continue to be classified as type E and that the EC8 second biggest class, type C, does not exist in this classification. The EC8 classification type C samples were distributed in several Pitilakis *et al*. (2013)' types C (type C1 and type C3) and in type D3. It is also important to refer that type B is missing because the EC8 type B samples were classified as Pitilakis *et al*. (2013)' type A2 or type E.

5. PORTUGUESE ANNEX NATIONAL TO EUROCODE 8 - ELASTIC RESPONSE SPECTRA ANALYSIS

5.1 Seismic action Type 1 – Far source scenario

This analysis was made for the surface response spectra resulting from the bedrock seismic action originated by earthquakes of magnitudes between 5,5 and 8,7. In order to better handle the data two groups were considered, one with magnitudes under 7,5 and another with magnitudes above 7,5.

Each magnitude corresponds to a different type of failure plan dimension and for each one, seismic actions with 500 different distances were generated. Since the earthquakes with higher magnitude produce effects at greater distances than the earthquakes with lower magnitude, the analysis considered the interval from 100km to 350km for lower magnitudes and the interval from 100km to 500km for higher magnitudes.

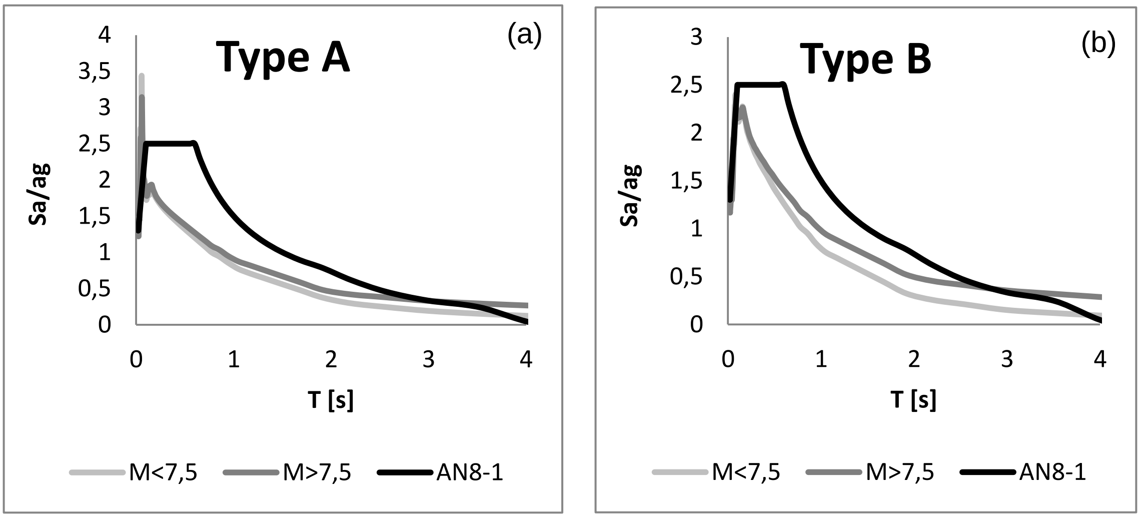

Figure 3. Comparison between AN8-1 response spectra and Type A (a) and Type B (b) response spectra for the type 1 seismic action

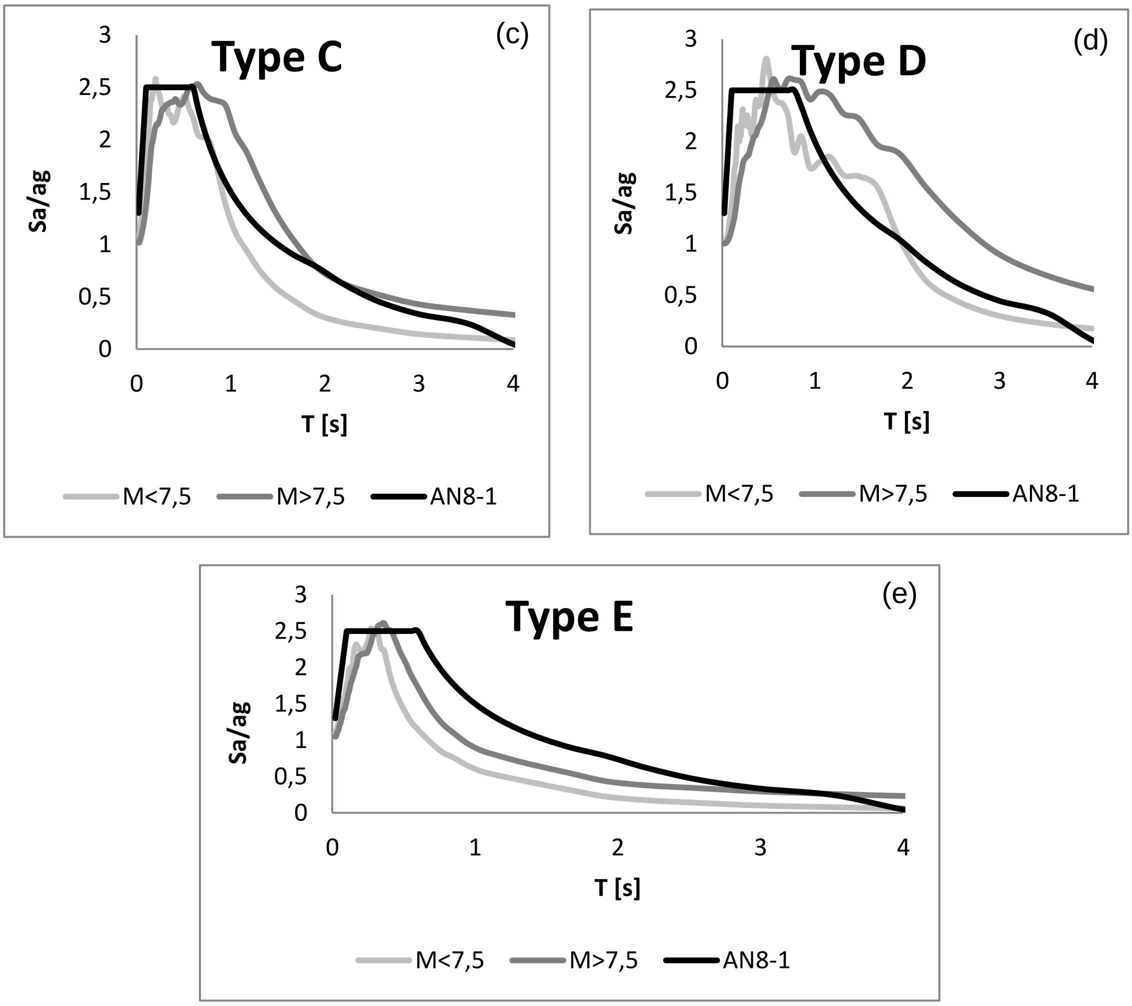

Figure 4. Comparison between AN8-1 response spectra and Type C (c), Type D (d) and Type E (e) response spectra for the type 1 seismic action

Figure 3 and Figure 4 compare AN8-1 elastic response spectra and the elastic response spectra of Algarve and Lisbon profiles. For type A (Figure 3 (a)), there is one spectral acceleration peak in the short period range that does not match the AN8-1 spectra form. The response spectra of type B (Figure 3 (b)) and of type E (Figure 4 (e)) are generally below the AN8-1 response spectra and do not present a baseline except for higher magnitudes than 7,5 and for larger periods than 3s. For the case of type C (Figure 4 (c)) and type D (Figure 4 (d)), for magnitudes higher than 7,5, the response spectra is always above AN8-1 response spectra. As the AN8-1 response spectra is a reference spectra that should not be overpassed, these results show the importance of parameters revision for these soil types, in order to expand the AN8-1 spectra form.

5.2 Seismic action Type 2 – Near source scenario

The magnitudes from 4,1 to 7,5 for this type of seismic action were considered, separated in two groups, one for magnitudes under 5,5 and another for magnitudes above 5,5.

For each magnitude 50 actions of different distances were generated. The analysis for earthquakes with lower magnitude considered distances until 50km and for higher magnitude distances until 100km were considered.

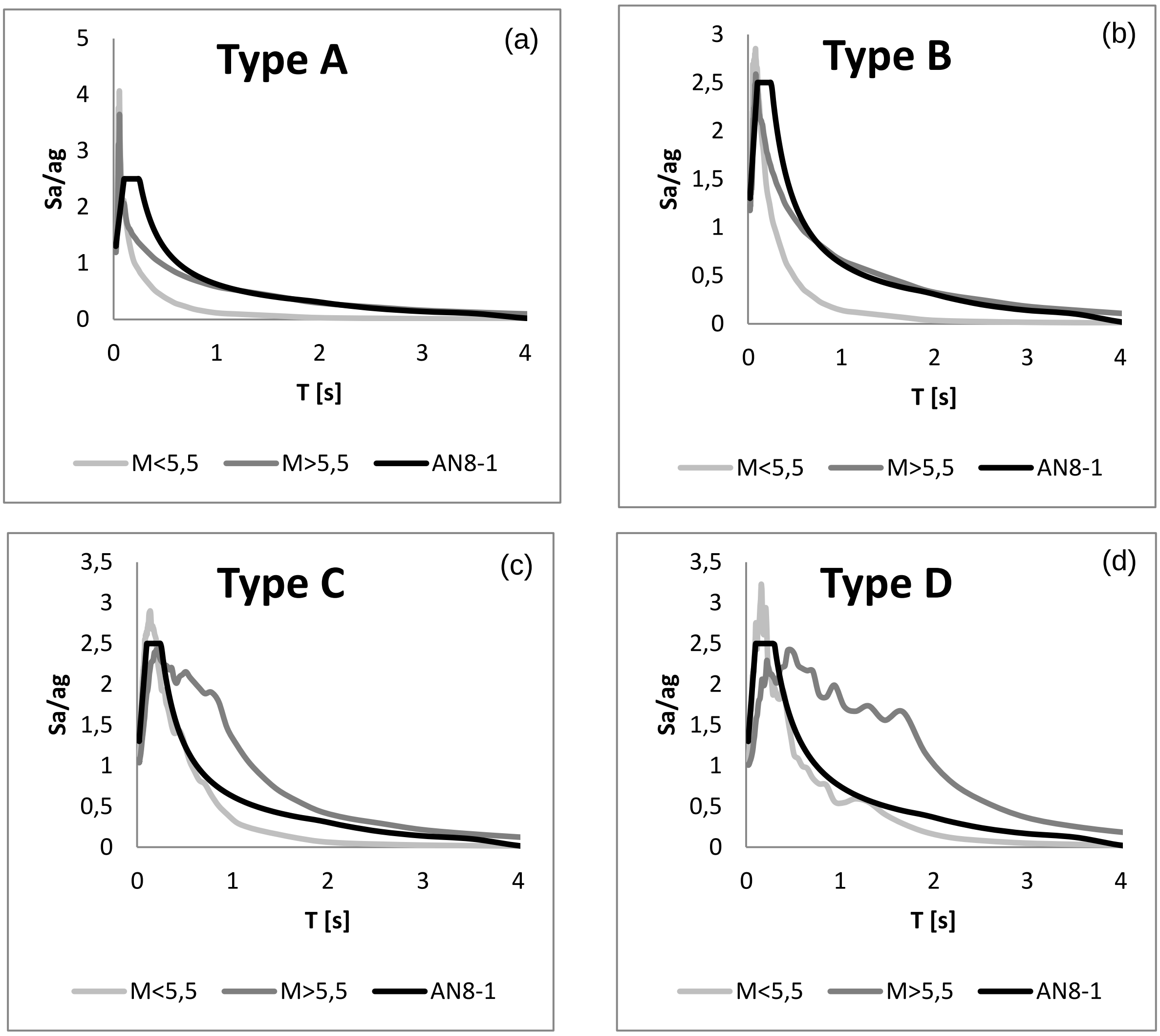

Figure 5. Comparison between AN8-1 response spectra and Type A (a), Type B (b), Type C (c) and Type D (d) response spectra for the type 2 seismic action

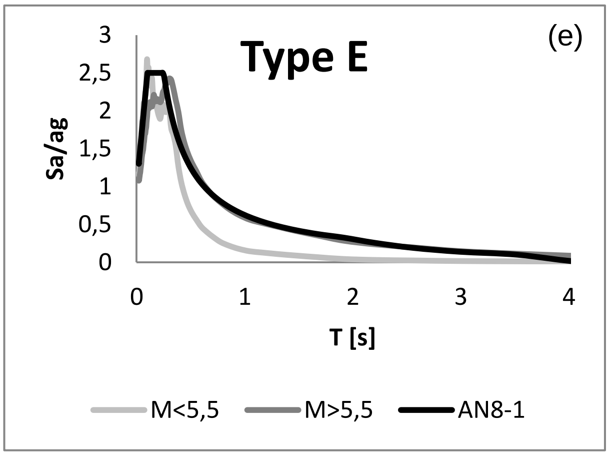

Figure 6. Comparison between AN8-1 response spectra and Type E (e) response spectra for the type 2 seismic action

The comparison between the AN8-1 elastic response spectra and the Algarve and Lisbon profiles elastic response spectra, for the type 2 seismic action, is shown in Figure 5 and Figure 6. From these figures it is possible to notice that, as observed in the previous section, the type A (Figure 5 (a)) spectra has a spectral acceleration peak for lower values of period and that, for magnitudes higher than 5,5, this spectra is coincident with the AN8-1 response spectra. For the other soil types the same is verified, as higher than 5,5 magnitude spectra overpasses or is coincident with the AN8-1 response spectra. However, lower than 5,5 magnitude response spectra for Type C (Figure 5 (c)) and Type D (Figure 5 (d)) and AN8-1 response spectra are coincident, which suggests, as in the previous section, that the AN8-1 spectra form should be more extended. For Type B (Figure 5 (b)) and Type E (Figure 6 (e)), besides what has already been referred, the AN8-1 response spectra for typical type 2 seismic action magnitude is adequate for the samples response spectra.

6. CONCLUSION

The application of two different classifications systems to the available ground profiles show that the differences between them were not significant. The Pitilakis *et al*. (2013) new classification system is more geotechnical detailed due to the new primary parameters not include in EC8 system classification.

The computed elastic response spectra when compared with the ones from AN8-1 exhibit differences, particularly for type C and type D soils, the response spectra form should be extended for long periods.

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