

V_{s30} Mapping and Soil Classification in Tiznit Region Based On H/V Spectral Ration Method

Fadoua Cherki^{1*}, Mehdi Tadili², Benaissa Tadili² and Nadia Mhammdi¹

¹Mohammed V University in Rabat, Institut Scientifique, GEOPAC Research Center, Geophysics and Natural Hazards Laboratory, Av. Ibn Batouta, B.P 703 Agdal, Rabat, Morocco.

²Engineering Office IservicePro, Morocco.

Abstract. The average shear wave velocity measured to a depth of 30 meters (VS30) is an important parameter for determining soil characteristics. As part of the seismic risk assessment in the Tiznit region, ambient noise recordings were made during the geophysical investigation campaign using the (H/V) method. The spectral analysis of these recordings enabled the determination of dominant frequencies and the estimation of VS30 values for each site. The aim of this study is to map the spatial variation of VS30 and classify soil types in the Tiznit region. The results show that the soil in the study area is divided into two classes according to the National Earthquake Hazards Reduction Program (NEHRP) classification: Class C refers to soft rock and very dense soils with VS30 greater than 360 m/s, while Class D represents stiff soils with VS30 values between 180 m/s and 360 m/s.

Keywords: Seismic risk assessment, HVSR, VS30 mapping, Tiznit, soil classification.

1. Introduction

The Pan-African evolution of the Anti-Atlas range is marked by a sequence of extensional and collisional events, analogous to those observed in other Pan-African orogenic belts surrounding the West African craton [1]. However, the Anti-Atlas exhibits distinct features, including limited deformation and the absence of significant crustal thickening. Its formations are primarily composed of superficial terrains characterized by low-grade metamorphism, ranging from greenschist to amphibolite facies. Additionally, the post-orogenic extensional phase played a pivotal role in shaping the region, which is crosscut by a network of predominantly strike-slip faults-oriented E-W to NE-SW.

At the eastern end of the Anti-Atlas, the focal mechanism solutions for the two Rissani earthquakes in 1992 correspond to strike-slip faults with a normal component, featuring E-W dextral and N-S sinistral fault planes [2]. The E-W planes are considered the main fault planes due to the presence of numerous Paleozoic normal faults oriented in this direction.

* Corresponding author: fadouacherki1@gmail.com

Seismic activity in the Anti-Atlas is generally lower than that observed in the High and Middle Atlas [3]. Analysis of macroseismic data from historical and instrumental records seismicity indicates that the Tiznit region has been affected by only two significant earthquakes, likely in 1755 during the Lisbon earthquake and in 1960 during the Agadir earthquake. However, this does not guarantee the city's safety from future seismic events. The effort that can be undertaken is to study the characteristics of local site effects. Recently, the H/V spectral ratio method, based on continuous ambient noise recordings, has been considered the most effective method for assessing local site effects.

Average shear wave velocity for 30m depth (V_{S30}) is an important parameter for determining soil characteristics using ambient noise measurements.

Ambient noise refers to low-amplitude vibrations resulting from hydrographic conditions, wind interactions with trees and structures, industrial activity, and road traffic [4]. The aim of this study is to map the shear wave velocity calculated over the first 30 meters of depth (V_{S30}) and classify soil types in the Tiznit region using the H/V spectral ratio method. The results of this mapping can be utilized to enhance disaster preparedness.

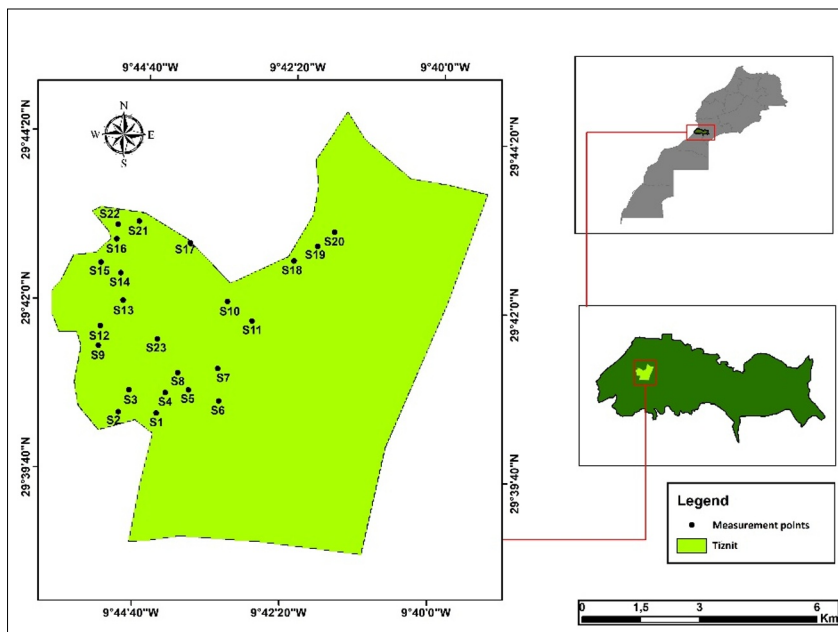


Fig. 1. The study area.

2. Soil Classification of Tiznit

2.1. Approach

The H/V ambient noise method, known as the Nakamura method, is based on the recording of low-amplitude mechanical vibrations ($<10^{-3} \text{ m/s}^2$) generated by local sources related to everyday activities [5] [6]. Ambient noise creates stress on the soil, and with appropriate equipment, the response can be measured. Based on ambient noise recording, the spectral ratio between the horizontal and vertical components (H/V ratio) of microtremors is calculated [7]. This ratio provides a pseudo transfer function at the measurement point and offers a reliable estimate of the fundamental soil frequency. In this sense, it is a useful geophysical technique for assessing the fundamental frequency of soft soils, which have a significant impedance contrast with their underlying bedrock [8].

2.2. Measurement Campaign

To define the soil parameters in the Tiznit region, 23 ambient noise measurements were conducted during a geophysical investigation campaign. The aim is to determine the average shear wave velocity (V_{s30}).

Given that the thickness of the geological layers is known (determined from the results of seismic refraction profiles), This configuration can be simplified using a two-layer model with adequate impedance contrast, enabling the determination of the fundamental frequency f_0 at the surface through the H/V spectral ratio method. This allows for the determination of the average shear wave velocity in the superficial layer, and consequently, the soil class.

The H/V measurement instruments used in this study consist of a high-dynamic, high-sensitivity, short-period triaxial velocity sensor (S3S2), connected to a VIBRALOG seismic acquisition system. This system records seismic events on a flash memory. During normal operation, VIBRALOG amplifies, filters, and converts the sensor outputs, storing them in a pre-event memory. The system is triggered when the predefined trigger criteria are met. By selecting the appropriate file length, it ensures that entire events are recorded. The recorded signals are then converted into a format compatible with the HVLAB program, which calculates the spectra using selective windowing of the signal segments unaffected by undesirable noise.

The calculation of the average shear wave velocity to a depth of 30 meters is performed using the equation below [9]:

$$V_{s,30} = \frac{30}{\sum_{i=1}^n \frac{h_i}{V_{si}}} \quad (1)$$

Based on the V_{s30} values, the site can be classified according to the National Earthquake Hazards Reduction Program (NEHRP) classification presented in Table 1 [10]. Additionally, a spatial mapping of V_{s30} is developed using the IDW interpolation method in ArcGIS.

Table 1. Site classification by NEHRP [10].

Soils Classification	Soils Profile	V_{s30} (m/s)
A	Hard Rock	$V_{s30} > 1500$
B	Rock	$760 < V_{s30} < 1500$
C	Soft Rock and Very Dense Soils	$360 < V_{s30} < 760$
D	Stiff Soils	$180 < V_{s30} < 360$
E	Soft Soils	$V_{s30} < 180$

3. Results and Discussion

Table 2. V_{S30} results and site classification based on NEHRP.

Station	X (m)	Y(m)	V_{S30} (m/s)	Site Class
S1	80026,61	305320,66	273	D
S2	79059,66	305357,01	280	D
S3	79332,31	305912,26	331	D
S4	80259,29	305844,17	290	D
S5	80852,42	305910,63	334	D
S6	81626,09	305626,64	331	D
S7	81599,14	306459,27	328	D
S8	80578,54	306353,35	386	C
S9	78552,17	307050,47	435	C
S10	81847,01	308168,69	335	D
S11	82476,93	307668,35	335	D
S12	78600,37	307558,72	380	C
S13	79186,09	308201,97	358	D
S14	79125,34	308902,83	330	D
S15	78622,62	309176,79	314	D
S16	79022,52	309771,59	365	C
S17	80896,42	309667,94	292	D
S18	83550,57	309202,86	379	C
S19	84155,04	309579,54	343	D
S20	84584,65	309940,57	281	D
S21	79601,04	310226,63	384	C
S22	79056,03	310147,34	376	C
S23	80059,03	307215,55	348	D

Earthquakes can cause damage to buildings and infrastructure. For geotechnical studies, soil classification is necessary for development planning and land use management. The National Earthquake Hazards Reduction Program (NEHRP) provides a soil classification based on shear wave velocity calculations. Soft soils (E) with a V_{S30} less than 180 m/s, stiff soils (D) with a V_{S30} between 180 m/s and 360 m/s, soft rock/very dense soils (C) with a V_{S30} between 360 m/s and 750 m/s, rock (B) with a V_{S30} between 760 m/s and 1500 m/s, and hard rock (A) with a V_{S30} greater than 1500 m/s (Table 1).

The V_{S30} values calculated for each site according to the equation are presented in Table 2. The 2D shear wave velocity mapping for the 23 H/V measurement sites is shown in Figure 3. The V_{S30} range for Tiznit varies between 254 m/s and 435 m/s. According to this figure, the maximum V_{S30} values are observed in the west at site S9 with 435m/s and in the southwest at site S8 with 386 m/s. These sites are classified as category C.

The lowest V_{S30} values are observed in the southwest, at sites S1 and S2, with 273 m/s and 280 m/s, respectively, as well as in the northeast at site S20, with 281m/s. These sites are classified as category D. A high V_{S30} corresponds to a low amplification factor, while a low V_{S30} is associated with a high amplification factor. The distribution of site classifications is illustrated in Figure 4. In general, sites classified as category D exhibit a higher amplification factor than those classified as category C.

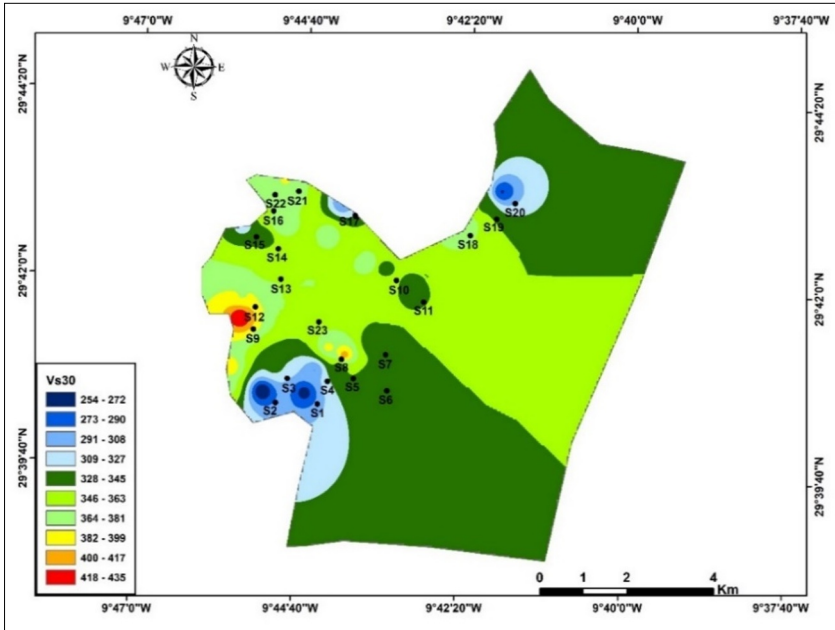


Fig. 2. VS30 map of Tiznit based on ambient noise measurements.

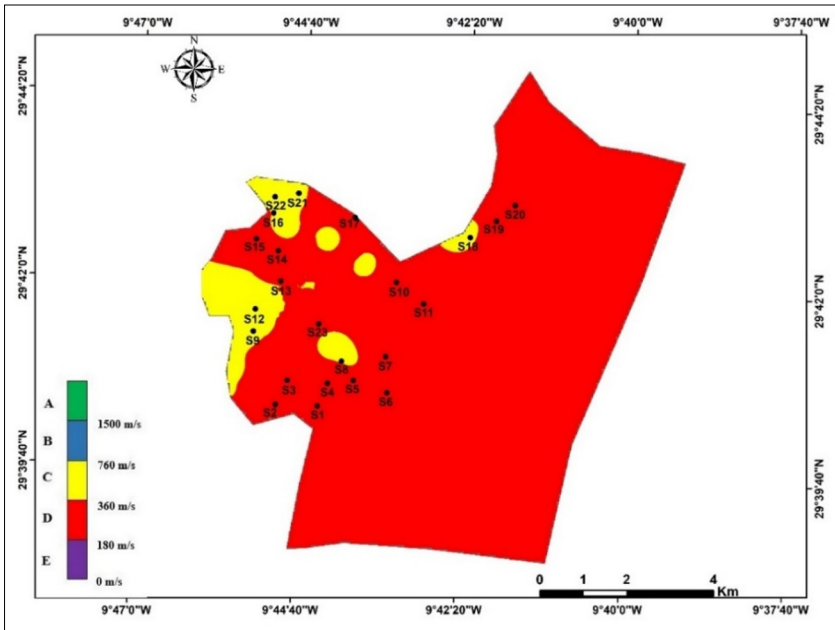


Fig. 3. Site classification map of Tiznit by NEHRP classification.

4. Conclusion

The results show that the region of Tiznit is divided into two classes according to the National Earthquake Hazards Reduction Program (NEHRP) classification. The highest V_{S30} values are 435 m/s in the western part (site S9) and 386 m/s in the southwest part (S8), categorizing these sites as class C. However, the lowest V_{S30} values, measured in the southwestern parts (S1 and S2), belong to class D. Low V_{S30} values indicate these sites have a high amplification factor, while high V_{S30} values suggest a low amplification factor. Based on this research, it is recommended that governmental authorities and relevant institutions consider site classes in building construction to mitigate seismic risks.

Funding

The authors declare that this research received no financial support and confirm the absence of any potential conflicts of interest in this paper.

Author Contribution

All authors (Fadoua Cherki, Mehdi Tadili, Benaissa Tadili, and Nadia Mhammdi) reviewed and approved the final manuscript. Fadoua Cherki contributed to the study's conceptualization, methodology, and draft manuscript. Mehdi Tadili and Benaissa Tadili provided essential supervision and guidance, while Nadia Mhammdi contributed to data analysis, interpretation, and manuscript revision.

Ethics approval and consent to participate

Not applicable.

Consent for publication

All the authors have agreed to publish this article.

Competing interests

The authors declare that they have no competing interests.

Acknowledgement

The authors would like to express their sincere gratitude to Engineering Office IservicePro for their valuable support and guidance during the course of this research. We also thank Institut Scientifique (IS) for providing the necessary facilities and resources to carry out the study.

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