The impact of the cultural value on the seismic vulnerability of a historical building

I. Onescu¹, E. Onescu² and M. Mosoarca²
¹Politehnica University of Timisoara, Romania
²Research centre for sustainable development, Politehnica University of Timisoara, Romania
iasmina.apostol@upt.ro

Abstract. Romania is a country located in Eastern Europe. It has two important seismic areas, Vrancea and Banat. Vrancea seismic region is located close to the biggest city of Romania, Bucharest, which is also the capital, while Banat seismic area is located in the western part of the country. The most important city from the Banat area is Timisoara, which was also elected to be the European Capital of Culture 2021. Beside the general seismicity of the area, which is characterised by shallow earthquakes of crustal type, Timisoara city presents also two seismic faults that cross the western part of the city. The peak ground acceleration is considered to be $a_g=0.20g$, while the maximum recorded magnitude was $MW=5.6-5.8$. The paper is a part of a larger research work which aims to assess the seismic vulnerability of the historical buildings in Timisoara city and their specific failure mechanisms, through both empirical simplified and mechanical numerical analysis. This study presents a new methodology that was previously proposed by the authors in their work and that considers also the influence of the cultural value in the process of assessing the seismic vulnerability. The consideration of the architectural, artistic, urbanistic and social elements can considerably influence the seismic vulnerability of a building. The highest the cultural value, the highest the need for rehabilitation work. The study is focused on one of the most important historical buildings of the city, Elite’s Palace, and compares the results of the empirical seismic vulnerability assessment with and without considering the cultural value. This kind of research could provide valuable information for the local authorities and could represent the base of a prioritization list for the future rehabilitation work.

1. Introduction
Timisoara is one of the most important cities in Romania. The first official recognition of the city is dated back in the 13th century, when it is described as a fortified fortress. At first, there was only the district of ‘Cetate’, developed inside the fortified walls [1]. Later on, there were developed another two areas, named Fabric and Iosefin districts, outside the defence walls, keeping an unconstructed area between them. During this time, there was made also the first urban plan for the city, diving it into main districts and suburbs, as presented in Figure 1a [2].

In the 18th Century, the original defence walls were replaced by a modern masonry fortress made in Vauban architectural style, as presented in Figure 1b [3]. After the demolition of the massive walls, the three districts merged together, forming the nowadays city of Timisoara (Figure 2a) [4].
Figure 1. Timisoara city: a) the plan made in 1716 [3]; b) the fortress in Vauban architectural style

Figure 2. Timisoara city: a) the map nowadays; b) the position of the two existing seismic faults [3]

Timisoara is located in Banat seismic area, which is the second most important seismic region in Romania [5]. The area is characterised by shallow earthquakes of crustal type, with small focal depths. The peak ground acceleration in Timisoara is considered to be $a_g = 0.20g$ according to the Romanian Design Code [6], while the maximum registered magnitude was $M_W = 5.6$ [7]. The most probable macroseismic intensity for the city was determined following Eq. (1) and Eq. (2) [8], [4].

$$I_{EMS-98} = 1.45*M_W - 2.46*log(R) + 8.166$$

(1)

$$R = \sqrt{d^2 + f^2}$$

(2)

Where $I_{EMS-98}$ represents the macroseismic intensity according to the European Macroseismic Scale, $M_W$ is the magnitude, while $d$ and $f$ are the epicentral distance and the focal depth. Considering the fact that in Timisoara, there are two seismic faults in the western part of the city (Figure 2b), there was considered for the most probable seismic scenario an epicentral distance of 5-10 km and a focal depth of also 5-10 km, leading to the most probable macroseismic intensity of IX EMS-98 [9], [4].
2. Case study building
Timisoara was selected to be the European Capital of Culture 2021, leading to a high number of expected visitors. Many of the cultural events will be held in the main public spaces of the historical districts, so a cultural promenade was proposed, as presented in Figure 3.

![Figure 3](image_url)

**Figure 3.** The proposed cultural promenade for Timisoara city [2]

The case study building is located in the Iosefin district, which appeared as a residential area in the early 1744, but the name of Iosefin was offered in the year of 1773 [4]. The district was designed for the German settlers, following both sides of the river Bega, having a large decorated house and luxurious gardens [10]. The height regime varies from buildings with only basement and ground floor till buildings with basement, ground floor and two stories above, as presented in Figure 4. All the buildings in Iosefin historical district are in a protected area, but despite this fact, the majority is in a poor condition, due to the lack of proper maintenance and restoration work [2].

![Figure 4](image_url)

**Figure 4.** The representative height regimes for Iosefin district [2]
Almost all of the buildings are made in the masonry of burnt clay brick and lime with massive perimetral walls and also a structural median longitudinal wall, parallel with the main façade [11]. Usually, the structural walls have thicknesses between 40 and 80 cm, while the transversal walls have thicknesses between 10 and 15 cm. That is why the transversal walls present only a role in increasing the rigidity of the building and defining the interior spaces in many cases. The horizontal structural elements are made in masonry, as vaults with thicknesses of 10-15 cm above the basement and sometimes above the ground floor and in wood, as wooden floors with one or two layers of wooden beams for the rest of the levels. The wooden framework is usually very complex and rigid, with influences from the German construction typologies [12]. The level height is between 3.20 and 4.20 meters, while the total height of the buildings is compressed between 4.80 and 15.10 meters until the starting point of the roof [2]. Most of the buildings are made in Neoclassic, Art Nouveau and Eclectic architectural style. The district is connected to the city centre through an Art Deco historical bridge, the Traian bridge [13].

The case study building is one of the most representative buildings in Iosefin district, located at the inflexion of the most important boulevard of the area, as presented in Figure 5. The building has several names, such as Mocioni Palace, Elite’s Palace or Sinaia Palace. The name that will be used in this paper is Elite’s Palace. Historic images of the building are presented in Figure 6.

Figure 5. Elite’s Palace in Iosefin historical district: a) position; b) aerial view

Figure 6. Historical images of Elite’s Palace [14]

The building was built in masonry in 1888 for the economy fund of Timisoara, in Eclectic architectural style, with basement, ground floor and two levels above [10]. The massive masonry walls present thicknesses of 90 cm at the basement, 80 cm at the ground floor and 70 cm at the other floors and are parallel with the main three facades. Above the basement, there is a masonry vault of 15 cm,
while above the rest of the floors, there are wooden floors with a single layer of wooden beams. The main front has a length of 38 meters, while the secondary fronts present a length of 36, respectively 37 meters. The height of the building is 14 meters until the starting point of the roof, while the height of the ground floor is almost 5 meters. The three wings of the building form an interior courtyard. The rhythm of the façade is given by the bosses-like elements from the ground floor that brings the building to the human scale. For the superior levels, the bosses-like elements are present only on the corner of the building, as a sign of the direction change. The roof is made with a complex wooden framework, presenting a height of almost 5 meters and an opening a bit over 14 meters. The general condition of the building is a good one, with decay to the non-structural and architectural-artistic elements due to the climate factors and exposure of materials [15]. A plan of Elite’s Palace is presented in Figure 7, together with a nowadays image.

![Figure 7. Elite’s Palace: a) basement plan [14]; b) nowadays view;](image)

3. Empirical seismic vulnerability assessment

The empirical seismic vulnerability assessment represents a quick and simplified methodology that can be applied at urban scale, in order to be able to provide a vulnerability map with not so many resources needed. The methodology is called the Vulnerability Index Methodology and was developed by Benedetti and Petrini for the first 10 parameters [16] and by Formisano and Mazzolani for the last 5 parameters [17]. The first ten parameters analyse the building as an individual structural unit, while the last 5 parameters consider also the influence of the adjacent buildings, analysing the building in the aggregate condition. The vulnerability form investigates geometrical and structural aspects, such as in plan and elevation regularity, type of floor and physical condition. The vulnerability index is determined following Eq. (3) [18] and later on normalized in the range 0–100, while the damage distribution is obtained based on Eq. (4) [19] and Eq. (5) [20].

$$I_V = \sum_{i=1}^{10/15} S_i \times W_i$$  \hspace{1cm} (3),

Where $S_i$ represents the class score and $W_i$ represents the weight associated with each parameter.

$$\mu_D = 2.5[1 + \tanh\left(\frac{I_V + 6.25 \times V - 13.1}{\theta}\right)]$$  \hspace{1cm} (4)

$$V = 0.58 + 0.064 \times I_V$$  \hspace{1cm} (5),

Where $\theta$ is considered 2.3 for residential buildings [21]. The correlation between the most expected damage state and the damage grade $\mu_D$ is presented in Table 1 [4].
Table 1. Correlation between damage state and most probable damage level

| µ₀   | Damage state                | Most probable degradation level                                      |
|------|-----------------------------|---------------------------------------------------------------------|
| 0.0-1.5 | D1                         | Slight (no structural damage, slight non-structural damage)          |
| 1.5-2.5 | D2                         | Moderate (slight structural damage, moderate non-structural damage) |
| 2.5-3.5 | D3                         | Substantial to heavy (moderate structural damage, heavy non-structural damage) |
| 3.5-4.5 | D4                         | Very heavy (heavy structural damage, very heavy non-structural damage) |
| 4.5-5.0 | D5                         | Destruction (very heavy structural damage)                           |

Following Eq. (3-5), there was determined the damage distribution for Elite’s Palace, both for 10 parameters (Figure 8a) and 15 parameters (Figure 8b). A comparison between the vulnerability curves for the isolated structural unit and the aggregate condition is presented in Figure 9, highlighting the fact that for a macroseismic intensity of IX EMS-98, the most expected damage state is D3. Despite the fact that the bearing capacity of the building is not expected to be exceeded, there should be considered the fact that damages to non-structural elements could mean losses of valuable architectural elements. Also, there can be seen a 5% reduction of the seismic vulnerability when the influence of the adjacent buildings is considered, due to the fact that the aggregate works together in case of an earthquake.

Figure 8. Seismic vulnerability curves for Elite’s Palace: a) for first 10 parameters; b) for all 15 parameters

Figure 9. Comparative seismic vulnerability curves for Elite’s Palace for both 10 and 15 parameters

4. Seismic vulnerability assessment influenced by the cultural value
The cultural value of a historical building should be considered by the local authorities when there are made prioritization lists for rehabilitation work. The structural integrity is the most important, but there should be considered also the architectural-artistic elements that might be lost, the urbanistic and social-economic value of a building. That is why there was proposed a new vulnerability form, starting...
from the existing form presented previously. This new form considers another 27 parameters, distributes into 3 main categories, such as architectural-artistic, urbanistic and social-economic, as presented in Table 2 [2].

Table 2. The seismic vulnerability assessment form that considers also the cultural influence

| %   | Criteria                                           | No. | Element                                                                 | A  | B  | C  | D  | Weight |
|-----|----------------------------------------------------|-----|-------------------------------------------------------------------------|----|----|----|----|--------|
| 70% | STRUCTURAL                                        | 1   | Organization of vertical structures                                     | 0  | 5  | 20 | 45 | 1      |
|     |                                                   | 2   | Nature of vertical structures                                           | 0  | 5  | 25 | 45 | 0.25   |
|     |                                                   | 3   | Location of the building and type of foundation                        | 0  | 5  | 25 | 45 | 0.75   |
|     |                                                   | 4   | Distribution of plan resisting elements                                 | 0  | 5  | 25 | 45 | 1.5    |
|     |                                                   | 5   | Plain regularity                                                        | 0  | 5  | 25 | 45 | 0.5    |
|     |                                                   | 6   | Vertical regularity                                                      | 0  | 5  | 25 | 45 | 1      |
|     |                                                   | 7   | Type of floors                                                          | 0  | 5  | 15 | 45 | 0.75   |
|     |                                                   | 8   | Roofing                                                                 | 0  | 15 | 25 | 45 | 0.75   |
|     |                                                   | 9   | Details                                                                 | 0  | 0  | 25 | 45 | 0.25   |
|     |                                                   | 10  | Physical conditions                                                     | 0  | 5  | 25 | 45 | 1      |
| 15% | ARCHITECTURAL ARTISTIC                            | 11  | Representative architectural style for the area                         | 0  | 5  | 25 | 45 | 1.5    |
|     |                                                   | 12  | Originality (global, elements)                                          | 0  | 5  | 15 | 25 | 1.2    |
|     |                                                   | 13  | Original woodwork/joinery                                               | 0  | 5  | 15 | 25 | 1      |
|     |                                                   | 14  | Original stucco                                                         | 0  | 5  | 25 | 45 | 1      |
|     |                                                   | 15  | Original statues                                                        | 0  | 5  | 25 | 45 | 1      |
|     |                                                   | 16  | Original gable/fronton                                                  | 0  | 5  | 25 | 45 | 1      |
|     |                                                   | 17  | Original balconies                                                      | 0  | 5  | 15 | 25 | 1      |
|     |                                                   | 18  | Original mosaics                                                        | 0  | 5  | 15 | 25 | 1      |
|     |                                                   | 19  | Original paintings                                                       | 0  | 5  | 15 | 25 | 1.2    |
|     |                                                   | 20  | Actual state of decorative elements                                     | 0  | 5  | 15 | 25 | 0.5    |
|     |                                                   | 21  | Authenticity/unauthorised interventions Official monument (national,   | -15| 0  | 25 | 45 | 1.2    |
|     |                                                   |     | regional, local, protected area)                                       |    |    |    |    |        |
|     |                                                   | 22  | Particular construction techniques/materials                           | 0  | 5  | 25 | 45 | 1.5    |
|     |                                                   | 23  | Actual state of original materials                                      | 0  | 15 | 25 | 45 | 0.5    |
|     |                                                   | 24  | Representative historical events connected with the building            | 0  | 5  | 15 | 25 | 0.5    |
|     |                                                   | 25  | -5                                                                        | 0  | 15 | 25 | 0.75 |
|     |                                                   | 26  | Archaeological site                                                      | 0  | 5  | 15 | 25 | 1.5    |
|     |                                                   | 27  | Representative/original wooden framework                                 | 0  | 5  | 25 | 45 | 1      |
|     |                                                   | 28  | Restoration work already made on the building                           | 0  | 5  | 15 | 25 | 1      |
| 10% | URBANISTIC                                        | 29  | Representative for the street profile                                   | 0  | 5  | 15 | 45 | 1.5    |
|     |                                                   | 30  | Representative for the urban silhouette                                 | 0  | 5  | 15 | 45 | 1.5    |
|     |                                                   | 31  | Annexes                                                                 | 0  | 5  | 15 | 25 | 1      |
|     |                                                   | 32  | Located in touristic area                                               | 0  | 5  | 25 | 45 | 1.5    |
|     |                                                   | 33  | Representative/particular shape of the roof                             | 0  | 5  | 15 | 25 | 1      |
| 5%  | SOCIAL ECONOMIC                                   | 34  | Public/social functions                                                 | 0  | 5  | 25 | 45 | 1.2    |
|     |                                                   | 35  | Importance for the local community                                      | 0  | 5  | 15 | 25 | 0.5    |
The vulnerability index is obtained following Eq. (6) and later on normalized in the range of 0÷100, while the damage distribution is determined following Eq. (4) and Eq. (5).

\[
I_{\text{V,CULT}} = 0.7 \times \sum S_{\text{STRUCT}} \times W_{\text{STRUCT}} + 0.15 \times \sum S_{\text{ARCH-ART}} \times W_{\text{ARCH-ART}} + 0.10 \times \sum S_{\text{URB}} \times W_{\text{URB}} + 0.05 \times \sum S_{\text{SOC-ECON}} \times W_{\text{SOC-ECON}}
\]

Where \( S_i \) represents the class score and \( W_i \) represents the weight associated with each parameter.

Following Eq. (4), Eq. (5) and Eq. (6), there were determined the vulnerability curves influenced by the cultural value for Elite’s Palace, both for the buildings considered as an isolated structural unit and in aggregate condition, as presented in Figure 10. A direct comparison is presented in Figure 11, highlighting the fact that the most expected damage state is definitely D3 for both situations. There can be seen a small reduction of the seismic vulnerability when the aggregate condition is considered.

![Figure 10](image1)

**Figure 10.** Seismic vulnerability curves for Elite’s Palace influenced by the cultural value: a) for building considered as isolated; b) for building considered in aggregate

![Figure 11](image2)

**Figure 11.** Comparative seismic vulnerability curves influenced by cultural value for Elite’s Palace

5. Comparison of results

In order to be able to define how much the cultural value influence the seismic vulnerability of Elite’s Palace, there was made a direct comparison between the original seismic vulnerability curve and the new proposed one, both for building considered as an isolated structural unit (Figure 12a) and in aggregate condition (Figure 12b). The comparison illustrates the fact that, indeed, when the cultural
value of a building that is important for the heritage of Timisoara is considered, the seismic vulnerability increases with 7.9% for the isolated condition and 7.6% for the aggregate condition. A seismic vulnerability range influenced by the cultural value was determined based on the possible variability of damage ($V_{\text{mean}} - 2\sigma$; $V_{\text{mean}} - \sigma$; $V_{\text{mean}} + \sigma$; $V_{\text{mean}} + 2\sigma$), where the value of $\sigma$ was determined as the standard deviation equal to 3.49, as presented in Figure 13. The expected damage is D3.

![Figure 12](image12.png)

**Figure 12.** Comparison between original and influenced by the cultural value seismic vulnerability curves: a) for the isolate condition; b) for the aggregate condition

![Figure 13](image13.png)

**Figure 13.** Seismic vulnerability influenced by the cultural value range for Elite’s Palace

6. Conclusion

This paper presents the seismic vulnerability assessment of one of the most representative historical masonry buildings in Timisoara. The assessment was made following a European empirical methodology, the Vulnerability Index Methodology, illustrating the most expected damage state of D3, meaning significant damages to non-structural elements and minor damages to the structural elements. There could be seen the fact that when the influence of the aggregate condition is considered, the seismic vulnerability decreases with almost 5%.

Based on a new proposed vulnerability form, it was possible to consider also the cultural value of the building, so the seismic vulnerability assessment influenced by the cultural value was obtained. The comparison of results has shown the fact that, for both the isolate and the aggregate condition, the seismic vulnerability of Elite’s Palace increases with almost 8% when the cultural value is considered.

This study highlights the importance of considering the architectural-artistic, urbanistic and social-cultural components in the process of vulnerability assessment, in order to preserve the most important buildings for the local community. This proposed extended methodology could help the local authorities to obtain a quick and optimised prioritization list for the rehabilitation work.
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