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EXTENDED ABSTRACT

Seismic Risk Assessment of Historic House of Kalantar According to Ialian Guideline

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1. Introduction

The importance of seismic vulnerability of historic buildings in Tabriz and the high seismic risk in this region, such as the recent Turkmenchay earthquake in 2019 (5.5 magnitude earthquake), justifies the study of seismic vulnerability of historical buildings based on a principled method specific to historical buildings. Since there is no guideline in Iran to assess the seismic vulnerability of historic buildings, therefore, the present study has aimed to evaluate the seismic vulnerability assessment of the Kalantar historic house in Ultimate Limit State (SLU) and Damage Limit State (SLD) based on the Level1 and Level3 of Italian guidelines for historical monuments (DPCM, 2005), by emphasizing on the reliability and the limits of the simplified mechanical model (Level 1). The first level of evaluation (LV1), is oriented to highlight, on a regional scale, critical situations in terms of seismic vulnerability and to provide a classification of risk and a priority list for further investigations aimed at the conservation of the architectural heritage. Adopting a force-based approach, this level relies on a simplified structural model that requires integrating a limited number of geometrical and mechanical parameters with qualitative data derived from visual tests, construction features, and stratigraphic surveys. The LV3 is based on the global structural response of the building in order to define the values of acceleration leading the structure to each limit-state. In this case, the displacement-based approach is adopted, for which the global behavior is governed by the in-plane capacity of the walls discretized in panels where the nonlinear response is concentrated. The seismic safety is evaluated for each level by an index summarizing the comparison between the expected seismic demand and the seismic capacity. It is worth noting that LV1 and LV3 are based on simple and accurate global models, respectively, which are both represented by the combined effect of floor diaphragms and the in-plane response of structural walls, so, it may be concluded that they are directly comparable.

2. Methodology

This study included the analysis of one of the historical houses of the Qajar period in Tabriz to measure its seismic safety index. This building was selected from the historical context of Tabriz (Iran). The Kalantar historic house was analyzed according to the Italian guidelines on cultural heritage(DPCM, 2005). The seismic safety index of the selected building was calculated based on the first and third levels of the guidelines. First, the seismic safety index of the building was calculated based on simplified mechanical equations in LV1 (ratio of capacity to seismic demand). 3Muri software was used to determine the seismic safety index of the building based on the third level. The analysis method in this software is based on the equivalent frame.

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2.1. Level 1 Analyses

The evaluation of the building at this level is based on the simplified mechanical relationships (force-based relationships) presented in the first level of the assessment of the Italian guidelines (DPCM, 2005) for houses, palaces, and villas. The main assumption is that the ultimate limit states are reached. And the vulnerability is caused by the in-plane failure of the walls. The first parameter that is calculated is the shear strength in each floor in different directions, which is calculated according to equation (1):

$$F_i = \frac{\mu_i \, \xi_i A_i \tau_i}{\beta_i} \tag{1}$$

In this equation (A), the area of walls resistant to shear force in the x and y direction on the i-th floor is equal to 54.2m2 and 35.2m in the x and y directions of the ground floor, respectively, also in the x and y directions of the first floor, it is equal to 30.28m and 18.2m6 respectively.(β) is the irregularity coefficient of the plan, which has a direct relationship with the distance of the center of mass and the center of stiffness and an inverse relationship with the distance of the center of stiffness from the farthest wall in the corresponding direction. The values of 1.08 and 1.08 were obtained for the x and y directions of the ground floor and 1.14 and 1.12 respectively for the x and y directions of the first floor. (μ) is the homogeneity of the hardness and resistance of the masonry walls. The value of this parameter in the x and y directions of the ground floor and first floors was calculated as 0.8, 0.86, 0.8, and 0.87, respectively, (ξ) is the parameter related to the dominant rupture of the piers. Which is considered to be 1 for shear ruptures and 0.8 for compressive and bending ruptures (usually thin foundations or negligible vertical loads). In the present study, shear rupture is assumed and the value of this parameter is considered equal to 1. τdi is the design shear strength of the i-th floor, which is a function of τ0 and the average normal stress. In the calculation of this parameter, the knowledge coefficient is also applied, according to the knowledge level, therefore, the knowledge coefficient is equal to 1.23. τdi is calculated for each class according to equation 2.

$$\tau_{di} = \tau_0 \sqrt{\frac{\sigma_0}{1/5\tau_0} + 1} \tag{2}$$

The values of (τ_{di}) in the x and y directions of the ground floor were 107.5 kN and on the first floor were 90 kN and 90.7 kN, respectively. The values of shear strength in the x and y directions were equal to 4669.3 and 3025.8 kN respectively on the ground floor and 3. 1950 and 1317.4 kN on the first floor. It should be mentioned that the lowest shear strength obtained is considered the main shear strength, in this building, the shear strength of the y direction of the first floor = 1317.4 kN F_{slu} is considered as the shear strength of the building. After calculating the shear strength based on equation (3), the acceleration can be calculated:

$$a = \frac{q\,F}{e^*\,M\,C_T} \tag{3}$$

In this equation, q is the behavior factor of the building, and M and e^* are the effective seismic mass and the ratio of the participating mass, respectively, which in this study, the ratio of the participating mass with the assumption of uniform failure of the building is equal to 0.89. CT is the normalized spectrum, which is the result of the ratio between the spectrum of elastic response and ground acceleration, in which construction effects are included, regarding the calculation of this parameter, since it is not mentioned in the internal regulations of our country, the parameter was considered according to NTC08(NTC, 2008) for the ultimate limit state equal to 2.5 and the vulnerability limit state equal to 2.49. Finally, the acceleration values were calculated a_{SLU} = 2.29 N/Kg, a_{SLD} = 2.3 N/Kg. Therefore, according to the Italian guidelines, the seismic safety index can be calculated based on equation (4).

$$I_S = \frac{a}{\gamma_1 S\, a_g} \tag{4}$$

In this equation, γ: is the importance factor of the building, which according to code 2800 is equal to 1.2, ag is the acceleration related to the desired limit state, which for Tabriz city in the ultimate limit state is equal to 3.43 (0.35g) (IRSt2800) and for damage limit state is 1.37 (0.14g)(IRSt2800), and parameter S, which is the soil coefficient, is considered equal to 1.17 according to NTC 08 (Technical standards for constructions). The calculated safety index value of this building was equal to 0.476 for ultimate limit state and 1.195 for damage limit state.

2.2. Level 3 Analyses

Numerical analysis of the building is done based on the third level of the Italian guidelines by 3Muri software. 3Muri is engineering software for seismic analysis of masonry and composite structures developed in Italy. This software uses a displacement-based analysis approach and determines the total horizontal force required to move the building to the target displacement Based on the results, the safety index was 0.758 for the ultimate limit state and 1.31 for the damage limit state. Also, the shear strength was equal to 3143.1 kN based on pushover analysis.

3. Results and discussion

The results of both assessment levels were compared. They showed that the seismic safety indexes obtained by level1, are less than level3. Therefore, the level1 of the analysis appears to be more conservative than the other (level3), because it takes into account fundamental simplifications to describe the behavior of the structure: the seismic capacity of the building is measured in terms of forces rather than displacements; So that the non-linear behavior of the structure is not considered correctly.

4. Conclusions

The Kalantar historic house was investigated using two evaluation methods provided in the Italian guidelines to evaluate and reduction of seismic risk to cultural heritage. Based on the findings of both evaluation levels, this building was not safe against the seismic conditions of the region in the ultimate limit state. But it was safe in the damage limit state. In fact, it can be said that the results obtained from both levels of evaluation are consistent with each other. Among the advantages of using manual calculations of this instruction (level one) is not needing detailed information about the mechanical properties of materials and performing destructive and semi-destructive tests. Although the results of this method are more conservative than the numerical analysis method, it is a fast, low-cost, easy and practical method to analyze and check the safety status of historical monuments.

5. References

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