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Seismic Risk Prioritization of Steel Buildings Using Fuzzy Inference System: A Case Study of School Buildings in Selected Regions of Tehran

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ABSTRACT: The first and most important step in the preparation of seismic retrofit plan for existing buildings is the analysis of their vulnerability by conducting retrofit studies and preparation of qualitative and quantitative vulnerability evaluations. However, most of the existing buildings in Tehran are in urgent need of retrofit studies due to reasons such as high seismicity, up-gradation of building and seismic codes, the abundance of old buildings and so on. In these studies, it is very important to identify the seismic status of the buildings which are in the first priority of seismic retrofit, especially the ones with public use like schools. A seismic risk prioritization technique for steel buildings was proposed in this paper using a risk assessment hierarchical structure and fuzzy inference system. Afterward, this technique was applied in a case study, validating the results obtained for the steel buildings of the schools in Tehran. At the first of the prioritization process, the required information of the buildings was classified according to the designed hierarchical structure; Then, after quantification of the qualitative data and the fuzzification, the data were modeled and defuzzificated based on the fuzzy inference system; This process was performed for all stages of the hierarchical structure to obtain the seismic risk parameter. After the qualification, this parameter indicated the risk of buildings and their requirement for retrofit or rehabilitation. The results that are distinguished by urban districts, determined the high-risk steel school buildings requiring retrofit studies and have shown the role of each effective parameters on the seismic risk of the buildings. These results indicated that among 160 steel school buildings in the studied districts of Tehran, 83 buildings require studies for retrofit or renovation of which 32 school buildings have a more critical situation. Another study also showed that in 6th and 8th districts a high percentage of the school buildings (above 60%) are in high and very high risk status and require special attention.

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1. INTRODUCTION

The process of the seismic risk prioritization of steel buildings has been introduced using the fuzzy inference tool. At the core of this process, there is an optimized hierarchical structure specifically designed to determine the seismic risk of steel buildings. The input parameters of the process are selected to comprise all the factors affecting the building's seismic risk and are evaluated by a fuzzy inference system (FIS) in several steps to determine the seismic risk parameter. In order to test the productivity and validation of this process, 160 steel school buildings of Tehran's selected districts (with the different population, urban texture, and seismic conditions) have been studied. Using the results of this study, it can be determined which schools have more critical risk situations than others and require more attention through retrofit or renovation. The advantages of this process are easiness, comprehensiveness, and flexibility in application.

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2. HIERARCHICAL STRUCTURE OF SEISMIC RISK ASSESSMENT

The hierarchical structure shown in Figure 1 is a proposed and developed model derived from the one presented by Tesfamariam and Saatcioglu in 2008 [1] which evaluates the seismic risk through seven levels and ten stages of fuzzy inference.

All parameters of this structure, such as plan and vertical irregularity, diaphragm type and so on were considered as input parameters of the prioritization system which requires their data to be collected for each building and the other parameters of the hierarchical structure are obtained from the evaluation of these ones.

3. CASE STUDY: SEISMIC RISK PRIORITIZATION OF STEEL SCHOOL BUILDINGS IN SELECTED REGIONS OF TEHRAN

Due to being located on several active and semi-active faults, Tehran was considered as a zone with high seismicity.

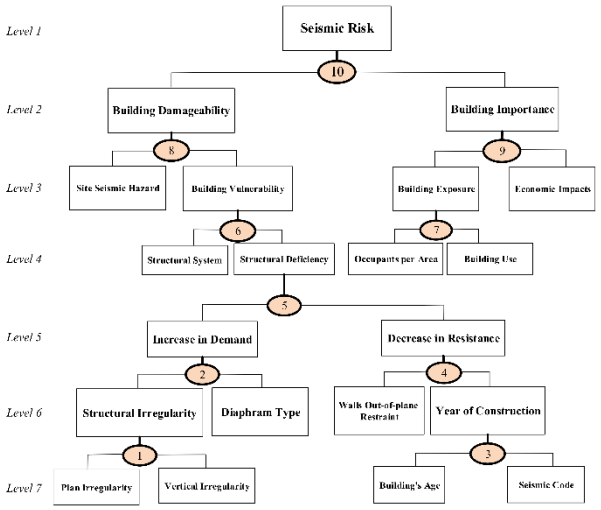

Fig.1. The hierarchical structure of seismic risk assessment

Considering the fact that almost 15% of the population of Tehran daily spend their time in schools [2], the improvement of school buildings should be taken seriously into considerations.

In this regard, a case study was conducted to determine seismic risk prioritization of steel school buildings in 3rd, 6th, 7th, 8th, 12th, and 13th districts of Tehran. These districts have been selected for reasons such as the high seismicity due to its closeness to active and semi-active faults, the variety of schools' structural texture, the high economic, historical and political significance and relatively large populations focused on these areas.

Therefore, the information of 3194 school buildings located in the selected districts of Tehran has been collected by the Organization for Development, Renovation and Equipping Schools of Iran (DRES) [3], from which 808 steel buildings were extracted. Among this number of steel buildings, 160 buildings have the information needed to perform the seismic risk prioritization.

In completing the seismic risk prioritization process, data evaluation should be done for each stage of the proposed hierarchical structure from 1 to 10 (Figure 1) to determine the seismic risk value of buildings.

The results of the seismic risk parameter are categorized qualitatively in four levels: *Very High*, *High*, *Low*, and *Negligible*. The determination of these levels done by a technical expert is similar to the "cut off" values presented in the 2008 paper by Tesfamariam and Saatcioglu [2].

4. VALIDATION

In order to validate the results of the seismic risk prioritization, we have taken the results of seismic risk evaluation for 20 school buildings from the DRES's assessment. Therefore, all rules, components and the initial assumptions that are considered for input and output data were calibrated through the validation of prioritization results.

According to Figure 2, the percentage of correct results was 80% and the dispersion percentage was calculated as 19%.

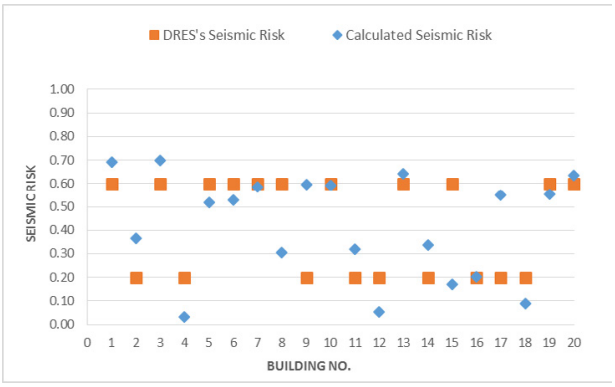

Fig. 2. Comparison of the calculated seismic risk results with the received ones from the DRES

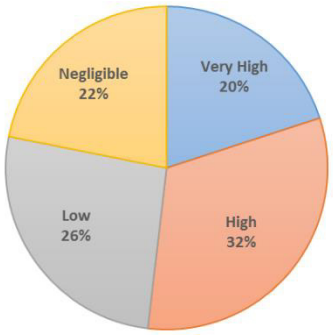

Fig. 3. Seismic risk status of 160 steel school buildings of the six districts of Tehran

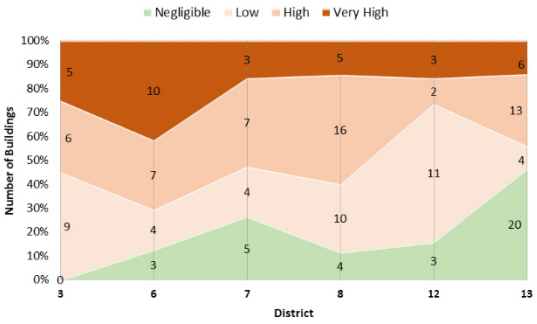

Fig. 4. Seismic risk status of 160 steel school buildings divided into the studied six districts of Tehran

The most important reason for the errors existed in the results is mainly because of the human-based error of the judgmental and non-technical evaluation carried out by the DRES.

5. DISCUSSION AND CONCLUSION

The results of the seismic risk prioritization approach validated through two types of control procedures and were ensured to have high accuracy and proper performance can be cited and used in preliminary retrofit studies.

According to Figure 3, about 52% of the steel school buildings in the six districts under study require retrofit or rehabilitation actions of which 20% should be noticed

immediately.

Figure 4 demonstrates that the most critical districts in terms of the level of need for retrofit were district 6th (71%), 8th (60%), 3rd (55%),7th (53%), 13th (44%) and 12th (26%) which have the risk status of *High* and *Very High*.

As a practical and specific conclusion, the seismic risk status of 160 steel school has been investigated and the result was as follows: buildings with *High* and *Very High*-risk status are mostly irregular in plan and height, due to high age they are less robust and consequently earlier seismic codes have been used in their design and construction, population density and hence their percentage of occupants per area is higher, the economic loss of these buildings caused by earthquake damage is higher, mostly they are used in educational applicant and their experimental period is more than other buildings. Also, the high-risk status of the buildings with flexible diaphragm and walls with the ability of out-of-plane movement indicates that these two parameters have a significant impact on the seismic risk prioritization and are desirable to be taken into considerations.

Because of the flexibility and efficiency of the proposed hierarchical structure in the prioritization method, this method is applicable to RC and masonry buildings as well as to buildings with other uses such as emergency and medical centers. Users can also add or modify parameters in the hierarchical structure.

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