Strengthening of buildings according to Eurocode 8 and national standards

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Summary

The European codes are currently being introduced in Slovenia. Eurocode 8 has already been accepted as a parallel code to the existing national codes for structural design in the earthquake prone areas. Therefore, the need for comparison between the new and the existing codes through the case studies is one of the most important issues in the current Slovenian practice. The paper presents a case study of a mixed reinforced concrete and masonry five-storey building constructed in Ljubljana in 1907. The parametric analysis of the earthquake resistance has been performed by the inelastic pushover analysis. The present configuration of structure is compared to gradually upgraded configurations. The comparison of the load-bearing capacity of the upgraded structure and the demands given by Eurocode 8 illustrate the problems of strengthening historic buildings.

1 Slovenian national standards and Eurocode 8

Slovenia is in a transition period and some codes of the former Yugoslavia are still in active use. After the independent state had been established in 1991, it was decided to adopt the European codes as Slovenian with the needed modifications related to the local circumstances. Therefore, the entire Eurocode 8, including its Part 1.4, are to be a base for the future Slovenian code. Presently Eurocode 8 has been accepted as Slovenian prestandard for an experimental application period. However, in this transition period the old 1988 Yugoslav code is still valid. Eurocode 8, Part 1-4 gives the major guidelines and criteria for the design of building in seismic areas, and they also influence the rehabilitation works. The major dilemma is, how strictly should the existing buildings be treated in the process of rehabilitation. The fact is that older masonry and reinforced-concrete structures were not constructed according to any seismic code. The strict respect for the existing codes increases the investments in the rehabilitation or even makes them restricted in the cases of valuable cultural monuments. The case study, presented in the sequel, illustrates the problems of decision making regarding the future use of a historic building from the beginning of this century.

2 Case study

The building was erected in 1907, twelve years after the last strong earthquake in Ljubljana (Fig. 1). In the future the building will be adapted for the university use. The building is 54.8 m long and 20.8 m wide. It has five storeys and a basement. The heights of the first, second, third, forth and fifth storey are 4.5 m, 3.9 m, 3.9, 3.5 m and 2.6 m, respectively. The main structural system of the building consists of clay-brick masonry walls, reinforced concrete columns and reinforced concrete slabs. The slabs were designed to carry live load of 20 kN/m^2. The masonry walls and columns are wider in the lower storeys. In the first storey the masonry walls are 0.75 m and 0.60 m wide while in the fifth storey their width is 0,40 m. After having analysed of several configurations of plan layouts, the one that is shown in Figure 2 was chosen. It was a compromise between the structural and the future user demands.

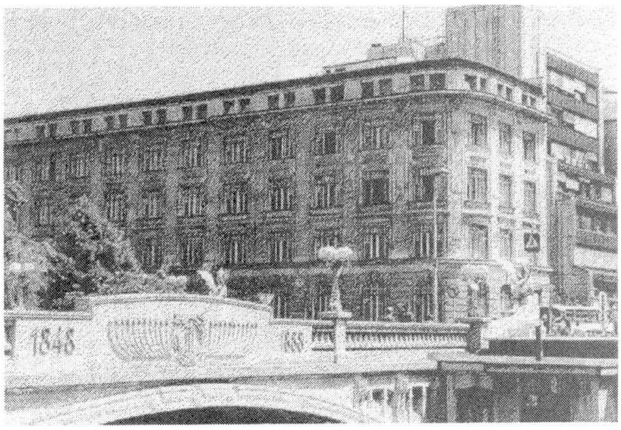

Figure 1 The building build in 1907

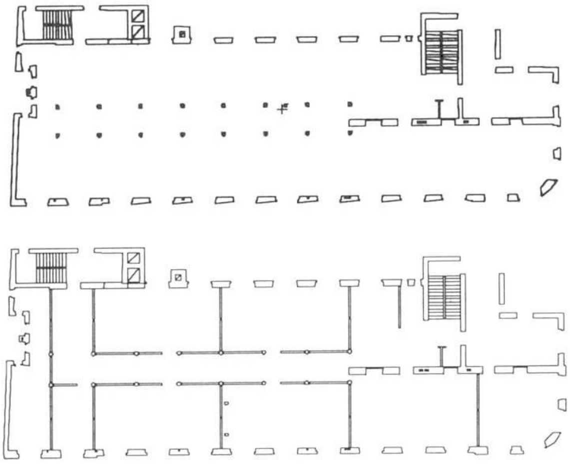

Figure 2 The plan of the existing and strengthened 1st floor

The earthquake resistance analysis is based on inelastic method. In Figure 3 the storey diagrams calculated for the weaker direction of building are compared.

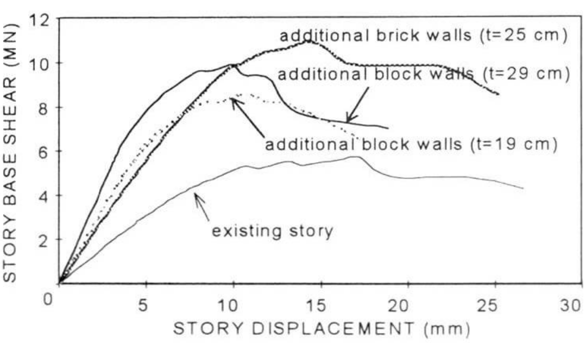

Figure 3 Comparison of storey base shear diagrams in the case of confined walls

The influence of additional walls on the existing structure caused the lowering of torsional effects. The results of the analysis clearly show the importance of proper selection of materials and confinement of walls. It can be concluded that the most effective walls can be build from solid clay brick masonry that is less stiff than hollow block masonry of the same strength. Therefore one of the main tasks in the structural design of strengthening is selection of suitable materials. They should be compatible to the original materials as it can be seen from this case study.

In the national codes the safety demands are differentiated according to use of each building. Importance category I is demanded for public buildings of higher importance (hospitals, schools etc.). Residential buildings and less important office buildings are considered as buildings of importance category II. The herein-described building can be strengthened by masonry to meet the demands of the national codes for the buildings of category II. If the same building would be used in the future for more demanding purposes, another strengthening technique should be necessary. It will be anyway the case when Eurocode 8 comes in force as the national code.

The existing built heritages in European towns that are located in earthquake prone areas generally do not fulfil the demands given in contemporary codes. It is to be discussed in which extend and with which techniques the structures can be strengthened. . In the process of strengthening a special attention should be paid to the selection of materials. Their characteristics should be compatible with the characteristics of the originally used materials.