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Estimation of the seismic capacity of civil engineering structures

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Abstract

Estimation of the seismic capacity of existing buildings is of great importance for the safety of inhabitants in the old cities and settlements. This paper presents estimation of the seismic bearing capacity and collapse mechanism of several masonry buildings typical for the historical city centres and surrounding areas along Dalmatian costs. The evaluation is performed according to Eurocode 8 and corresponding Croatian standard using static non-linear pushover analysis. Complete 3D models of masonry structures were made by TREMURI software assembling 2-nodes macro-elements, representing the non-linear behaviour of masonry panels and piers. The macro-element considers both the shear-sliding damage failure mode and its evolution, controlling the strength deterioration and the stiffness degradation, and rocking mechanisms, with toe crushing effect, modelled by means of phenomenological non-linear constitutive law with stiffness deterioration in compression.

Key words: Seismic capacity, Collapse mechanism, Historical masonry buildings, Static non-linear analysis

Estimation of the seismic capacity of existing buildings is of great importance for the safety of inhabitants in the old cities and settlements. This paper presents estimation of the seismic bearing capacity and collapse mechanism of several masonry buildings typical for the historical city centres and surrounding areas along Dalmatian costs (Fig1). The evaluation is performed according to Eurocode 8 [1] and corresponding Croatian standard [2, 3] using static non-linear pushover analysis. Complete 3D models of masonry structures were made by TREMURI software [4] assembling 2-nodes macro-elements, representing the non-linear behaviour of masonry panels and piers. The macro-element considers both the shear-sliding damage failure mode and its evolution, controlling the strength deterioration and the stiffness degradation, and rocking mechanisms, with toe crushing effect, modelled by means of phenomenological non-linear constitutive law with stiffness deterioration in compression.
The response of the structure is investigated along the two orthogonal axes, in both the positive and negative directions. Non-regular distribution of the masses is considered by the assumption of an eccentricity of the lateral loads equal to ±5 % of the maximum floor dimension at each level. Three lateral load distributions (uniform, linear and modal) with the presence of eccentricity give in total 24 analyses. Each pushover analysis results with the MDOF capacity curve which transform in bilinear SDOF ones. The capacity of the structure is expressed in peak ground acceleration corresponding to the end of bilinear curve. Type 1 response spectrum [1, 2] and soil class A are used. The design ground acceleration defined by seismic hazard map for the return period of 475 years is equal to a_g=0.22g. The seismic capacity of the buildings is defined by checking if the seismic demand represents with 475 years is satisfied. Local mechanism failure was analysed in order to check local behaviour, such us the lack of connection among perpendicular walls, poor connection among floors/roofs and walls, etc.

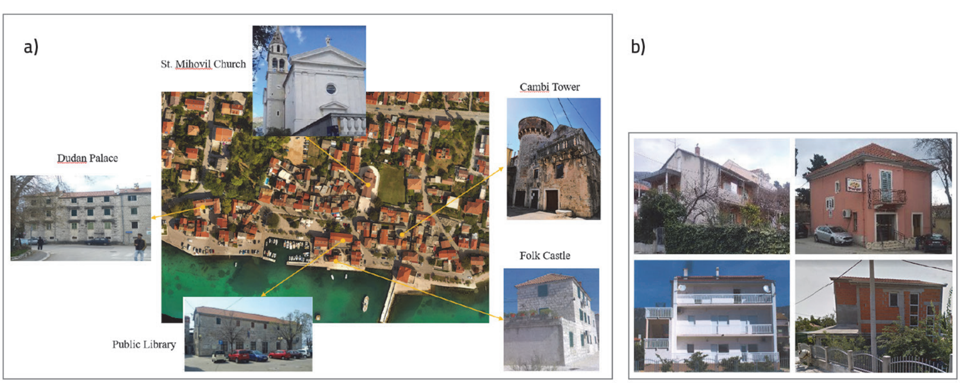
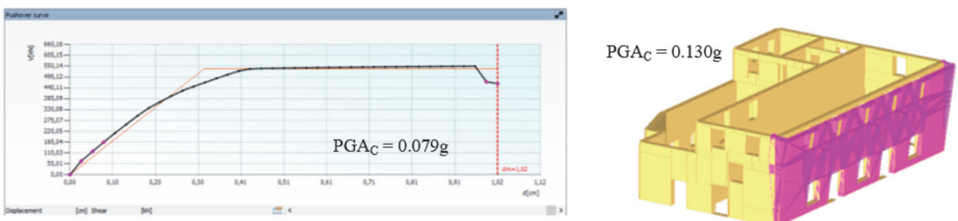


Figure 1. a) Historical centre of Kaštel Kambelovac with stone masonry buildings; b) Typical family houses outside of historical centre

The first group of examples considers stone masonry buildings in the historical city centre of Kaštel Kambelovac (Fig. 1a) built between the 15th and 19th centuries. They were made of stone blocks with mortar joints with a thickness of the walls between 45 and 75 cm and flexible wooden floors. Numerical predictions of the collapse acceleration by non-linear static analyses show that no building meets the seismic requirement equal to a_g = 0.22g in either direction. Namely, the peak ground acceleration corresponding to the collapse of the buildings are in the range of 0.07g and 0.10g. The failure occurs due to different collapse modes such as shear, bending, tension and compression failures. Evaluation of the local mechanism failure shows that critical acceleration yet it arises for the global behaviour. For example, analysis of public library showed that the lowest collapse acceleration is obtained for linear distribution of lateral forces and it is equal to 0.079g, while the lowest value of the failure acceleration in analysis of local mechanism is 0.130g (Fig. 2).



a) b)

Figure 2. Results of global and local analysis of Public Library: a) Critical pushover curve; b) Critical local mechanism failure

The second group of buildings are typical family houses (Fig. 1b) outside of the historical core made as masonry structures consist of concrete or clay blocks without or with concrete boundary elements (beam or/and columns) depending on the construction period. The results for collapse accelerations obtained by pushover analysis are compared for 2-floor and 3-floor buildings made of: (1) unbounded concrete masonry built before the first seismic regulation in 1964; (2) concrete masonry with horizontal RC beams typical for the period between 1964. and 1980.; (3) concrete masonry with horizontal RC beams and RC columns built between 1980. and 2005. and (4) clay masonry with horizontal RC beams and RC columns which are seismically resistant structures due to the applications of modern design standards based on Eurocode 8. Calculated capacity accelerations show that only buildings built according Eurocode 8 meet the seismic requirement.

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