16th World Conference on Earthquake Engineering, 16WCEE 2017
Santiago Chile, January 9th to 13th 2017
Paper N° 5014
Registration Code: S-J1463181570

SEISMIC BEHAVIOR OF REINFORCED CONCRETE ROOFS ON MASONRY BUILDINGS

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Abstract

The 2016 Central Italy earthquake has demonstrated the seismic vulnerability of historical masonry buildings which are typical of the small towns of that area. The majority of the houses were seriously damaged and a great number of them totally collapsed causing the loss of many lives as well as economic and cultural losses. The lack of awareness and of proper retrofit intervention led to a disruptive scenario. Among many collapse mechanisms that have been detected, the one due to reinforced concrete roofs has been the most discussed. Firstly because of its dangerousness, secondly because the replacement of old wooden roofs with reinforced concrete roofs is indeed a widespread retrofit intervention since it is highly recommended by national codes. The aim of this intervention is to improve the robustness of the structure achieving the so called "box-like behavior". A concrete roof is able to distribute the loads more evenly and to connect the walls to each other and finally to avoid the slipping of the beams that was common for masonry buildings with a wooden roof. However, in most cases, the retrofit intervention, done by private owners with the belief of making their house safer, turned out to be destructive. The reason of this failure was the ineffective connection between the top beam ring and the masonry walls that should have been consolidated before the intervention. Thus, the significant increase of stiffness and load at the top of the buildings led to the collapse of walls and to the overturning of concrete roofs, which remained undamaged. Fig.1 shows the effects of the Central Italy earthquake in a building retrofitted with a reinforced concrete roof. It can be seen the clear detachment of the roof that collapsed under the seismic action disrupting the masonry walls and then overturned. It is also clear the poor quality of the masonry that could not bear such a high load.

Fig.1 – Masonry building before and after the Central Italy earthquake, Pescara del Tronto.

The paper proposes simple analytical models to illustrate the collapse mechanism of masonry buildings retrofitted with reinforced concrete roofs. As the failure of concrete roof depends on the characteristics of other components of the structure, local collapse mechanisms involving walls have been analyzed as well, especially the ones due to out of plane forces. These types of mechanisms, such as wall overturning or vertical flexure, involve the loss of some structural

components of the building compromising its equilibrium and favoring the overturning of the roof. The models, based on kinematic linear analysis, are used to evaluate the horizontal forces that are able to activate a specific collapse mechanism. The building is composed of macro-elements which move following a mechanism that must respect the boundary conditions. The load multiplier is the unknown horizontal force that is proportional to the vertical loads applied to the macro-elements. The method is able to determine the most probable collapse mechanism which is the one that requires less energy to be activated. The final purpose is to determine a safety coefficient that can be used to establish the safety level of the building. It would be so possible for private owners with reinforced concrete roofs to understand the safety level of their buildings and if further retrofit interventions are necessary.

Keywords: masonry buildings; collapse; retrofit; concrete roofs; Central Italy earthquake.