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The identification of damages occurred in reinforced concrete structures during Durres earthquake 2019

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Abstract

The earthquakes occurred in Durres in September and November 2019 has made so many damages in reinforced concrete structures that were build before and after 1990. Especially the greatest one of November 26 with Mw = 6.4 was destructive for so many structures . It was made the survey of the damages to make a classification based in two phases. The conclusion of the survey was that the damages occurred because of materials used, structural elements in poor details and the absence or inadequate use of RC shear walls. Some other buildings have unplanned floors without permit which were not included in the design of the structure and have leadhet in damages. Some recommendations are given in this paper to reinforce the structures according to Eurocodes, that must be implemented in these damage buildings.

Key words: reinforced concrete structures, earthquake damage, structural system, dynamic behaviour

1 Introduction

This paper present a site survey of the damages made by Durres Earthquakes, which include a visual inspection of some type of structures in general and some structural elements in particular. To give a more specific opinion about the type of damages occurred needs a detailed analysis and experimental test should be conducted. The type of structural systems, choosen to be presented in this paper are reinforced concrete frame structures, combined structure (masonry and RC frame) and a masonry structure. In this combined type of structure which was build in Durres before 1990 with RC structure were so damaged. The damages occurred were seen in exterior and interior partition walls, columns, joints and stairs. All of the objects of this typology, built before 1990 were built according to Albanian Construction Codes KTP and those after 1990 sometimes using also Eurocodes norms. Damages also occurred because of the materials used and their properties. To have a full detailed situation of the objects and their grade of destruction an explicit in situ and laboratory testing is required. For every object damaged urge to implant reinforcement according to Eurocode. Here we present some damages illustrated in pictures.

2 Damage identification

Damage identification was the first thing to see the effect of the Earthquake. Some buildings were not affected by damages and some others were destroyed. Damage classification was made based on the structural system, material properties and details used. Ground effects were also a very important element in damage of structures. For some objects the double resonance phenomena or liquefaction has created collapse or serious damages.

2.1 Damages in RC frames with masonry infill walls

Most of RC frame structures without core with masonry infill experienced huge damages by this Earthquake. Before 1990 in Albania the most common buildings were built using masonry structural systems. The buildings with combined structure (RC frame with masonry infill) were the first built shortly after 1990. The structural systems are called combined because they have a RC frame and masonry exterior walls (38cm). These buildings exhibited many problems connecting to non structural elements such as partition walls, doors, plaster, stairs etc: Figure 1.

Figure 1. Exterior damages on 6 story building with combined structure

Such buildings were designed by Albanian Code KTP which does not give exact rules on how masonry infill should be modelled in the openings. The out of plane displacement of the walls from the frame were observed maybe because the wall follows the out of plane movement in the direction of seismic wave propagation. Sometimes the connection between walls and concrete frame was inadequate or totally missing. The materials also had a significant role in the seismic behaviour especially the concrete quality (which was very poor in most cases) and the adherence with steel bars. During the investigations the steel bars used in this building could be seen through the cracks. They were smooth and significantly affected in the bearing capacity of constructive elements.
The stairs were another element damaged by the earthquake. In the structural system without a concrete core the stairs are the only connection between floors, so their bearing capacity was exceeded (Figure 2) the column damage is observed also because of exceeding bearing capacity.

Figure 2. Damages in stairs and columns

Exterior and partition walls have sustained huge damages by the earthquake, due to the inappropriate way of designing and constructing. Poor detailing of exterior and interior walls could be observed. Because of that, fracture of infill walls was quite a common sighting after the earthquake, as shown in Figure 3.

Figure 3. Damages in masonry exterior walls

The damages occurred affected the bearing capacity of the entire structure, so the building was demolished by explosion.

2.2 Damages in RC frame structures

The structure observed have a structural system with RC type without core. These types of structures show defects especially in columns and beams. Another problem that has caused damages was the absence of shear walls. The poor quality of the concrete used was the most important element leading to serious damages. This reason is presented in Eurocode 8, recent finding on collapse vulnerability of nonconforming concrete columns [1]. Visual investigations revealed damages in some parts of the column and imperfection of reinforcing steel. The handmade concrete used onsite in some buildings was non homogeneous and with low compressive strength. The aggregates used with improper granulometry and the corrosion of steel, has resulted in decreased bearing capacity. Most of the columns damaged were the ones at the ground floor because of exceeding their bearing capacity, Figure 4.

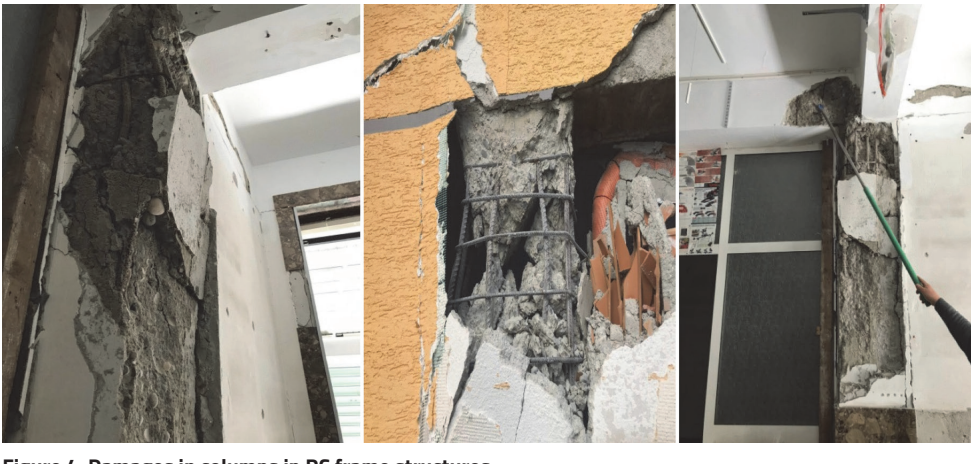

Figure 4. Damages in columns in RC frame structures

In case when the joints were realized according to technical norms the building did not sustained a lot of damage of column because of the plastic hinges did not occur. The stirrups in the critical zones of the damaged columns were positioned at a distance larger than 20 cm and the hooks were short.
The building shown in Figure 5 was built after 2000 and collapsed due to the earthquake. It wacs a 4 storey building, with a tall ground floor 5m height. The collapse occurred because of the soft storey effect and the plastic hinges created by non appropriate design of the joints and reduction of the general stiffness of the building. It was subsequently demolished by controlled explosion.

Figure 5. Damages occurred in a RC frame structure

For the object shown in Figure 6 the structural elements were not affected. The structural system was a RC frame with central core. The only problem was the in and out of plane movement of the walls because of the absence of right connection with the frame. The columns and beams did not suffer any damage.

Figure 6. Damages in a RC frame structure with central core

2.3 Damages in masonry structures

The buildings using load-bearing masonry type of structure were built before the 1990. The example presented in this paper is a 5 storey building with damages located primarily in the exterior walls because of the absence of reinforcement. The extent of damage in such buildings was not significant with cracks only in the exterior walls that did not affect the general structural stability, Figure 7.

Figure 7. Damages in a masonry structure

3 Recomendations and conclusions

After the site inspection a classification was made based on the degree of damage that occurred in every building. The damages observed on site were different from one building to another; some have suffered non-structural damages and some others were collapsed. All the buildings have problems with exterior and partition walls. Their connection with RC frames is inappropriate in most cases. The absence of the reinforcement in infill walls was also observed. The connection between columns and beams in some cases have created plastic hinges, with columns sustaining more damaged than the beams. The masonry structures have reacted well - but the RC frame structures with infill walls were the most damaged. The RC frame structures with central core and regular shape suffered non constructive damages in general. The damages or the collapse of these structures was in the case of soft storeys or short columns. The quality of materials was a strong element in damage grade of the structures.

To make an intervention to the structural system it is important to have a classification of the buildings,- depending on age and their structural system. The grade of damages is necessary to convert according to EC-8-prEN (1998)-3 [1], in Limit State classification. For further analysis is required information about structural system and geotechnical conditions, details of construction elements, materials used, information of damaged and non damaged elements and the intervention made to them at any time during their lifetime.

Some buildings need interventions to the structural system to modify their capacity and seismic behaviour. Some construction elements need to be retrofit or partial demolition. The intervention should be according to Eurocode norms which need to be soon formalized in the country. Another important thing is the cost of intervention which sometimes is very high and maybe the demolition is more effective.

References

[1] Eurocode 8 - Design of structure for earthquake resistance. Part 1-4. "Strengthening and repair of buildings" Commission of the European Communities, Brussels, 2001.