Assessment and Rehabilitation Issues Concerning Existing 70’s Structural Stock

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Abstract. The last 30 years were very demanding in terms of norms and standards change concerning the structural calculus for buildings, leaving a large stock of structures erected during 70-90 decades in a weak position concerning seismic loads and loads level for live loads, wind and snow. In the same time, taking into account that a large amount of buildings are in service all over the country, they cannot be demolished, but suitable rehabilitation methods should be proposed, structural durability being achieved. The paper proposes some rehabilitation methods suitable in terms of structural safety and cost optimization for diaphragm reinforced concrete structures, with an example on an existing multi storey building.

1. Introduction
The towns’ development during the historical ages involves difficult changes in architectural and structural conception [1]. Usually, the change between two different approaches for these aspects appears gradually, and follows the civilisation steps of changes. Because our evolution has grown very fast, the cities must adapt and change with the same speed. This aspect leaded to a peculiar situation: the central town areas are populated with old buildings from different historical stages which does not comply with modern structural safety requirements [2] [3], are important for the town history and also not comply with current architectural requirements for use of interior spaces [4]. Examples of these aspects are given in literature for existing buildings of different types: from historical building from XVIII Century [2] to rather modern buildings from the XX Century with industrial purpose [5], [6] or hospitals and administration purpose [7]. Taking into account the large distribution of changes occurred in buildings structures, load type and intensity, the literature proposes lines of priorities of the upgrade process [8], [9], and identifies ways of assessment for these structures taking into account the stability [10], [11] and strength [12], [13], mainly from seismic point of view [14], [15].

The building considered in the present paper can be classified after the literature in the category of buildings with large durability [16] that can be considered for rehabilitation in order to use its entire life span at maximum capacity. It is a complex of fours independent reinforced concrete structures that formed a spa complex that includes a hotel, situated in one of the most valued Romanian wellness resorts.
2. General aspects concerning the building status
The building in discussion is placed in South Carpathians Mountains and was designed and built during 1970 decade. The assembly is consisting in four sections, for which a general view can be seen in Figure 1. Besides D sector, all sectors have three basements used for wellness and treatment, the superstructure level being different. The highest sector is B – where hotel facilities were provided – that has 17 floors.

2.1. Structural system
All the structures are cast in place reinforced concrete structures, in mixt solution – spatial frames / diaphragms in different proportion chosen in regard with the number of levels and horizontal print for each section.
As figures 2, 3 and 4 shows, for the small heights sectors, the spatial frames prevail, the diaphragms being used only on the structure perimeter. The situation differs for section B, where the concrete walls are mainly used. The particularity here is that the columns are prevalent at the first four ground floors, and concrete walls at the rest of the floors. An important aspect to be mentioned is the joint between sectors, which is a small dimension joint, provided only for settlement.

The foundations are slab foundations 70 cm thick for the main part of the structure, and there are some isolated foundations for façade columns support.

The materials used are concrete C12/15 for infrastructure, and superstructure above +20.00m, and C16/20 for the rest of the superstructure. The reinforcement is made of PC52 longitudinal rebars and OB 37 for stirrups at all elements.

The coherence between the design and site situation was checked using nondestructive tests based of vibration change at transmission in different environments [17]. In the areas where the result were not conclusive, carrots were taken for laboratory tests. Following the tests, the compliance of design requirements for materials resistance was 80% fulfilled. The geometry and reinforcement content was 99% respected.

2.2. Structural integrity
Generally, the structure shows a good behaviour and integrity. Following the detailed visual analysis of the structural elements, it was observed that they did not show generalized degradation or pronounced cracks. Some small degradation of concrete cover layer (Figure 6), small segregation areas and some small carbonation areas were found at sector A (Figure 5).

Figure 5. Carbonated concrete beams and exposed reinforcement.  
Figure 6. Visible rebars on columns due to inadequate concrete cover.

Water infiltrations are also present in some areas, and technical floor show ware marks. Finally, it can be said that the structures shown a good behavior in time, and it is suitable for rehabilitation and further use.

3. Considerations regarding the suitability of the structure to the current resistance and stability requirements
Structure design was finished during 1976, when the following conditions were stated.

- The seismic design norms prior to the 1977 earthquake were P13-63 and P3-70, associated with the seismic map given by STAS 2923-63, which frames a large number of localities in the macro seismic zone 6 for which, according to the norms in Force, it was not required to design the structures to the effect of seismic forces, regardless of the material from which they were made. This provision led to the situation that the entire 1963-1977 built-up fund in the 6th zone (among
which Baile Herculane where the discussed building is situated), is not calculated at the action of seismic forces.

- The level of normalized loads was lower than the ones required by present norms used for seismic rehabilitation purpose P100-1/2006 and P100-3/2008, according to which the examined building is in the seismic area with the ground acceleration \( ag = 0.16g \).
- The partial safety factors considered in the calculation of the calculations were much lower than those in the Eurocodes. A comparative study of these issues is outlined in Table 1.

### Table 1. Seismic zoning, partial safety factors and standard loads.

| Years       | Building Design | Assessment | Difference [%] |
|-------------|-----------------|------------|----------------|
| 1976        | N/A             | N/A        | N/A            |
| 2016        | N/A             | N/A        | N/A            |

| SEISMIC ZONES | | |
|---------------|---------------|-------------|
| Normative P13-63, and STAS 2926-63: It was not considered a seismic area | Normative P100/1-2006: Grade 7.5 on the Richter scale: Design acceleration to earthquake 0.16g |

| SAFETY FACTORS | | |
|----------------|---------------|-------------|
| Own weight permanent elements (structural elements) | 1.1 | 1.35 | 22.7% |
| Weight of insulation, finishing | 1.3 | 1.35 | 3.8% |
| Live loads | 1.3 | 1.5 | 12.5% |

| LOADS | | |
|-----------------|---------------|-------------|
| Live load for Hotels | 150 x 1.3 = 210 daN/m² | 150 x 1.5 = 450 daN/m² | 13.3% |
| Live loads for halls | 200 x 1.3 = 260 daN/m² | 200 x 1.5 = 300 daN/m² | 13.3% |
| Live loads for traffic areas | 400 x 1.3 = 520 daN/m² | 400 x 1.5 = 600 daN/m² | 13.3% |
| Live loads for roofs | 75 x 1.4 = 105 daN/m² | 75 x 1.5 = 112.5 daN/m² | 7.1% |

| MATERIALS | | |
|-----------------|---------------|-------------|
| Minimum concrete class existing in structures C12/15 | Minimum concrete class by norms for M ductility class C20/25 |

The first issue to be discussed was the response of overall structure to the seismic requirement of present norms. From this point, the following considerations can be made:

- Structure geometry:
  - This requirement is considered respected because the construction of all sectors is regular both on horizontal and vertical direction. For the B sector, the centre of rigidity and the centre of the masses coincide, the building being symmetrical in both directions, a major advantage being not required at general torsion.
The structural system is continuous and ensures a clear, direct and uninterrupted transmission of the seismic forces, regardless of their direction, to the ground.

- It can be considered that the slabs insures the lateral stiffness at each level and thus the seismic forces are transmitted relatively uniformly to all diaphragms and columns.
- There are no significant discontinuities in the route of the seismic forces discharge.
- The structural regularity in plan and elevation of the sections is satisfied.

- Structural redundancy: there is a high degree of redundancy in the structure, since the failure of one diaphragm does not affect the entire building. As a ductility level, the structure is considered to have a medium ductility because it can form plastic hinges only at the base of the diaphragms and these have the required level of reinforcement for medium ductility elements (such as bulb-shaped ends).
- Because at the design date the site was not considered a seismic area, there are no seismic joints between the sectors.

In the light of the findings considering the state of the structure and the change in norms and utility of the structure, the following conclusions can be considered.

The structures respect the original project in a large proportion. However, the concrete classes in the project used in the structure of resistance do not fully meet the requirements imposed by the real norms. According to the non-destructive tests, there were differences between the concrete classes in the project and those from the expert elements. The actual concrete classes were used to calculate the resistance structure.

The degree of fulfilment of seismic conditions for the detailed qualitative assessment of structure is 64% from the required bearing capacity at seismic loads, meaning a construction which, under the effect of the design earthquake, may present structural degradations that do not significantly affect Structural safety but where non-structural degradations may be important. On the other side, the structures are separated by a 2.5cm compression joint that is not sufficient to allow specific level shifts caused by seismic action so buildings can collide.

4. Considered rehabilitation

The main issue that had to be corrected was the behaviour at seismic loads. The seismic joints were re-designed, so that their final size to summing the level displacements of the adjacent buildings to which a safety space of 5cm is added, obtaining a 12.5cm total length. Because the vicinity was insured with cantilevers, both slabs and beams were cut 5 cm each near the settlement joint in order to increase its size at all levels. In this way, the lateral drift for each floor is solved for the new seismic conditions.

The bearing capacity of all elements had also to be insured. Measures to increase it was taken for each type of structural element. The main beams were consolidate by adding reinforcement both on upper and lower sides, the columns received additional reinforcement on all sides. The diaphragms did not require an increase of strength due to their massiveness. Foundations check both as pressure on the ground and as reinforcement. The pressure at the base of the foundation was verified based on the conventional pressure presented in the geotechnical study and the capacity of the land is not exceeded.

A problem was to insure the lateral displacement of the first ground levels, weaker due to lack of diaphragms compared with other floors. Since it is not technologically possible to consolidate all columns, a study has been carried out in several consolidation variants. Considering the technological conditions of execution, the solution was to introduce three diaphragms at the level of the ground floor in positions with maximum influence on lateral structural movement.

Degradations produced by a bad execution (insufficient coating) were repaired by removing the segregated concrete until a solid, rugged support was found. After dust clearing, the exposed reinforcements were treated with passive solutions and a new coating of mono-component sulphate-resistant thixotropic single-component thixotropic mortar was used.

Degradation caused by environmental factors (degraded cover layer, exposed reinforcements) were treated also by cleaning the affected surfaces and replace the lost concrete with the same type of mortar.
5. Conclusions
The case presented shows that structures in the 1970’s have a high durability and their life span is not yet consumed. It is easy to notice that the structures that have a high density of reinforced concrete diaphragms in both directions also fulfil the conditions of lateral displacement and seismic loads imposed by the current norms.

Thus, we can assume that the rehabilitation of these structures is a simplified process compared to similar reinforce concrete frame structures, implying only punctual rehabilitation in areas with diaphragm deficiency.

In conclusion, if the structures are properly maintained, the rehabilitation process is economically viable and the building's durability is greatly improved.

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