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REHABILITATION SOLUTIONS FOR EXISTING STRUCTURES IN ROMANIA

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Summary: *The paper deals with aspects regarding strengthening of reinforced concrete existing structures in seismic zones, like Romania. Some case study and the rehabilitation of characteristic structures are analysed. The rehabilitation solutions were chosen in accordance with the actual stage of building deterioration as well as function of the actions characteristics. Classic (reinforced concrete and/or steel) and modern (Carbon Fibre Reinforced Polymers) materials and technologies for strengthening have been used.*

Keywords: *Existing reinforced concrete structures, seismic action; strengthening; classic rehabilitation solutions; modern rehabilitation techniques; carbon fibre reinforced polymers (CFRP)*

1. INTRODUCTION

Three strengthening solutions will be analyzed in the paper. The strengthened elements are existing reinforced concrete columns as vertical structure of different constructions. The rehabilitation solutions are:

- steel bracing with four angle steel shapes connected by flange plates;
- carbon fibre polymer composites (CFRP): longitudinal strips and transversal wraps;
- jacketing by reinforced concrete using longitudinal reinforcement bars and transversal stirrups.

2. REHABILITATION OF REINFORCED CONCRETE SILOS

The assessment and rehabilitation solutions for a group of silos owned by the SAB Miller Brewery Company “Timisoreana” are presented. The silos (*Figure 1*) were built 40 years ago and stand 28 m high and 7.30 m in diameter.

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Figure 1. Reinforced concrete silos

Figure 2. Reinforcement corrosion of discharge funnel supporting columns

Initial silos inspection (1999) revealed large zones of circular cells with concrete cover dislocated and corrosion of circumferential steel reinforcement. Recent silos inspection and assessment (2004) emphasized other vulnerable parts: infrastructure and charging platform (gallery).

The silos infrastructure consists of foundation raft, discharge funnel and its supporting columns and beams.

The main damages are due to water infiltration and high humidity inside of each cell bottom part, which caused important dislocated concrete cover and corrosion of the columns steel reinforcement (*Figure 2*).

The strengthening of supporting columns for the discharge funnel consists of steel profiles (*Figure 3*). This solution has a smaller cost than CFRP materials. On the other hand, steel profiles have a better buckling behaviour than CFRP strips.

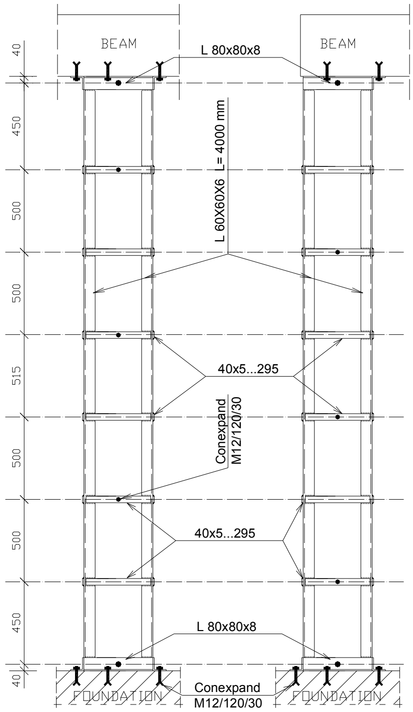

Figure 3. Strengthening solution with steel profiles

3. REHABILITATION OF A FRAMED BUILDING

The Western University of Timisoara has many buildings, among them the Main Building (*Figure 4 and 5*) that is used as administrative part as well as classrooms for students, was built in 1962-1963.
The RC structure consists of:

- transversal and longitudinal frames with eight storeys and two spans of 5.6 m and eleven bays of 3.8 m;
- floors with girder mesh in two directions and a slab of 10 cm;
- foundation with a thick slab and deep beams in two directions.

Figure 4. The Western University of Timisoara

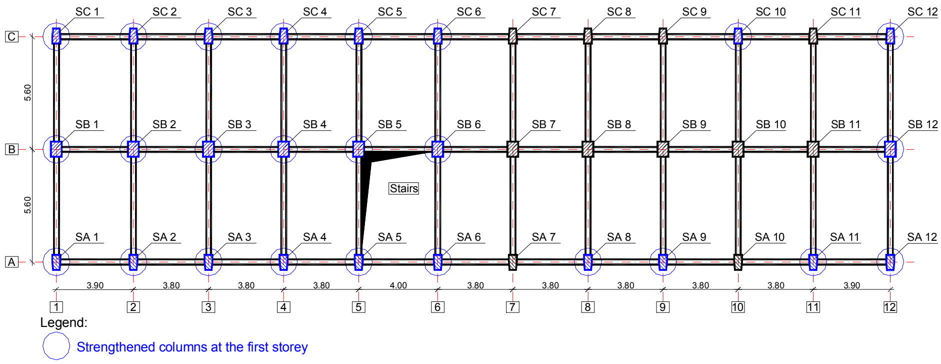

Figure 5. Framing plan – ground storey

On examination of the building and from non-destructive measurements no important damages of the RC structure were noticed. Some local damage due to incipient reinforcement corrosion was detected at the columns of the ground storey.
The analysis of the structure has been performed at both combinations of actions: fundamental combinations and special combinations including seismic action at present-day level. From the analysis it was noticed:

- weakness of reinforcement and insufficient anchorage of beam-positive reinforcement at the beam-column joint, especially in the longitudinal direction;
- the drift limitation conditions are not within the admissible limits at the ground storey.

Rehabilitation solution consists in strengthening of the columns located at the ground storey (*Figure 6 and 7*): some columns were strengthened in 1999 to prevent the local damages due to reinforcement corrosion; the other columns were rehabilitated in 2004 for decreasing the lateral displacements (drift limitation conditions) and for a homogeneous columns stiffness at the ground storey.

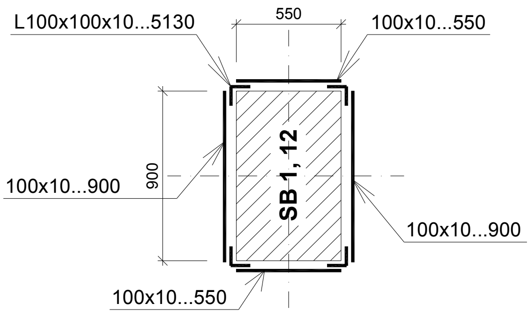

Figure 6. Strengthening solution with steel profiles

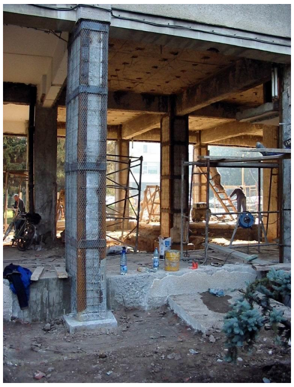

Figure 7. Rehabilitation solution of columns

4. REHABILITATION OF A MASONRY BUILDING

The "Palace" structure (*Figure 8*) is a huge building (underground floor, ground floor - restaurant, 3 storeys - apartments, timber roof), built before 1900's with a composite structure: masonry and reinforced concrete framed structure (*Figure 9*).

Figure 8. The "Palace" building

Figure 9. Longitudinal reinforced concrete frames

Initially it was an entire masonry structure, but later the ground floor was changed: some resistance brick walls were cut and two longitudinal RC frames were erected to sustain all the vertical loads. Due to this architectural operation the structure became more vulnerable at seismic actions: by the transversal direction main part of the ground floor became unstable at horizontal actions because of some erected columns with hinge

connection at both ends (masonry wall supports from the underground floor and ground storey). Other vulnerabilities of the building consist of: overall lateral stiffness values along the two main axes are different; lack of seismic joints to divide building parts having different dynamic characteristics; lack of straps at each floor.
The building assessment emphasized some aspects: concrete quality is very variable in structural elements, having different classes (C8/10 - C16/20); some cracks in longitudinal beams; corrosion of the slab reinforcement; etc.
From the static and dynamic analysis a very important conclusion could be drawn: the earthquake capacity ratios R between the actual values of ultimate bending moment (M_{cap}) and the necessary bending moment (M_{nec}), given by the present-day seismic action level, were very low for columns. That meant that the building was characterized by a high risk of collapse at seismic actions. It resulted the necessity of structural rehabilitation.
In accordance to the structural analysis, the strengthening of the ground floor was chosen in order to obtain technical and economical advantages: safe behaviour at seismic actions; slight change of the overall structural stiffness; easy strengthening technology and short period of refurbishment (December 2004 - June 2006).

The strengthening have been made on the following structural elements:

- strengthening by RC coating (7 cm on each side) of masonry walls from the underground floor of the building;
- new reinforced concrete floor with embedded steel profiles (HEB 220) in two directions, which stands as beams for the new structure;

Figure 10. Strengthening of columns

- strengthening of half from the existing columns (60x60m coated by RC to become 90x90cm – *Figure 10*) and erecting of new transversal RC beams in order to create new transversal frames (*Figure 11*);
- strengthening by RC coating of existing longitudinal beams;
- rehabilitation of some structural elements having corroded reinforcement.

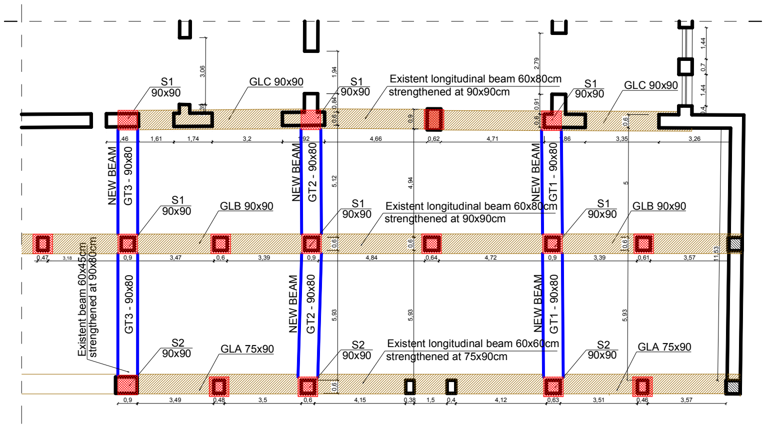

Figure 11. Ground floor rehabilitation

5. CONCLUSIONS

The main ideas which may emerge from these studies are:

a) As structural rehabilitation for existing reinforced concrete structures several strengthening solutions may be used: steel bracing; carbon fibre polymer composites (CFRP); jacketing by reinforced concrete.
b) The manufacture time is shorter in case of using CFRP in comparison to classic strengthening solutions (steel bracing or reinforced concrete jacketing).
c) The cost of CFRP solutions for strengthening is higher than other solutions.
d) Using of CFRP solution for strengthening of columns may be inadequate in case of structural stiffness increase demands.

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НЕКА РЕШЕЊА ЗА РЕХАБИЛИТАЦИЈУ ПОСТОЈЕЋИХ КОНСТРУКЦИЈА У РУМУНИЈИ

Резиме: *Овај рад се бави ојачавањем армиранобетонских конструкција унутар сејзмичких зона у Румунији. Анализирају се неки примери рехабилитације карактеристичних конструкција. Примери су бирани имајући у виду тренутно стање објекта и њихову функцију. При рехабилитацији конструкција су коришћени класични (бетон и/или челик) и модерни (полимери ојачани карбонским влакнима) материјали и технологије.*

Кључне речи: *Постојеће армиранобетонске конструкције; сејзмички утицаји; ојачавање; класичне методе рехабилитације; модерне методе рехабилитације; полимери ојачани карбонским влакнима*