Retrofitting of Historical Masonry Buildings in Seismic Zones

Corneliu BOB
Professor
"Politehnica" University
Timisoara, Romania
cbob@mail.dnttm.ro

Sorin DAN
Lecturer, Dr.
"Politehnica" University
Timisoara, Romania
sorin.dan@ct.upt.ro

Catalin BADEA
Lecturer, Dr.
"Politehnica" University
Timisoara, Romania
catabadea@gmail.com

Aurelian GRUIN
Researcher, Civil Eng.
Building Research Institute
Timisoara, Romania
agruin@incerctm.ro

Dimitrios PAVLOU
Professor
Technological Institute
Halkida, Greece
dpavlou@teihal.gr

Summary

The paper is focused on the analysis, redesign and rehabilitation solutions applied for old existing structures in seismic zones. The old malting building, erected between 1857-1876 at the "Timisoreana" Brewery, is a five storeys masonry structure and a tower composed of: walls of 140 – 50 cm thickness; inter-storey floors - brick masonry vaults supported by steel profiles; a tower, of about 14 m height and 2.80 m diameter, supported by an interior dome.
The main structural damages were: vertical cracks in the tower masonry structure; corrosion of steel members: horizontal circular rings for confining the tower; profiles for supporting the floor masonry vaults. The static and dynamic analysis at different actions showed up major structural vulnerability, mainly due to the period of design and erection (19th century).
In order to preserve the old building as architectural monument and to reduce the seismic failure risk, some strengthening solutions were designed and applied. The strengthening solutions were selected in order to obtain technical and economical advantages: safe behaviour at seismic actions; slight change of overall structural stiffness; easy strengthening technology and short refurbishment period; low rehabilitation cost.

Keywords: masonry structures; old buildings; seismic zones; stability; strengthening; CFRP.

Rehabilitation of a tower structure

The old malting building, erected between 1857-1876 at the "Timisoreana" Brewery, is a five storeys masonry structure and a tower (Fig. 1) composed of:

- walls of 140 – 50 cm thickness;
- inter-storey floors - brick masonry vaults supported by steel profiles;
- a tower, of about 14.00 m height and 2.80 m diameter, supported by an interior dome.

Fig. 1: Old malting building

Structural assessment

The assessment of the structure was performed in 2007 according to the present-day Romanian codes for existing structures and codes for design loads magnitude. The main structural damages are: vertical cracks in the tower masonry structure; corrosion of steel members: horizontal circular rings for confining the tower; profiles for supporting the floor masonry vaults.
The static and dynamic analysis at different actions showed up major structural vulnerability, mainly due to the period of design and erection (19th century):

- the tower, about 14 m high, presents general instability at seismic actions: the total bending moment at tower base leads to an eccentricity $e_0 = 1.78\ m > D_{ext} / 2 = 1.50\ m$ where D_{ext} is the tower exterior diameter;
- in some zones of the tower masonry structure actual stresses, due to various loads, are greater than the tensile strength R_{ti} of masonry:
  - $\sigma_{ef} = 0.93$ daN/cm^2 > $R_{ti} = 0.8$ daN/cm^2 at the tower – dome crossing (50 cm width masonry);
  - $\sigma_{ef} = 3.10$ daN/cm^2 > $R_{ti} = 0.8$ daN/cm^2 at the tower base (20 cm width masonry);

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- in the masonry dome, which supports the tower, the actual stresses by parallel direction are:
  - $\sigma_\theta = 0.85$ daN/cm^2 > $R_{ti} = 0.8$ daN/cm^2 at the lower part of the dome;
  - $\sigma_\theta = 2.19$ daN/cm^2 > $R_{ti} = 0.8$ daN/cm^2 at the upper part of the dome;
- temperature variations inside-outside the tower produce actual stresses $\sigma_t = 1.0$ daN/cm^2 > R_{ti} which causes the vertical cracking.

The structure, also, presents general and specific detailing lacks: no rigid floors at two storeys; no straps at all levels; the ratio between span and width of masonry shear wall is too large.
These major vulnerability classify the structure as having high risk of failure at present seismic code design magnitude.

Strengthening solutions

In order to preserve the old building as architectural monument and to reduce the seismic failure risk, the following strengthening solutions were designed:

- for general stability of masonry tower: vertical reinforcement (Fig. 2) bars (4 x 2ϕ28) embedded at the upper side of the tower in a RC beam (Fig. 3) and welded on steel profiles I 30 placed in the dome, at the tower base (Fig. 4); vertical CFRP wrap (4 x 2 strips of 20 cm width) on the entire tower height (Fig. 2);
- in masonry structure, at zones with stresses greater that masonry tensile strength, were placed horizontal RC straps: at the tower – dome crossing (Fig. 2); at the base of dome; at the level of steel profiles I 30 network (Fig. 4) for its embedding into vertical masonry structure;
- on the vertical cracked tower: corroded circular steel rings for confining the tower on outside face were replaced by horizontal CFRP strips – Fig. 5.

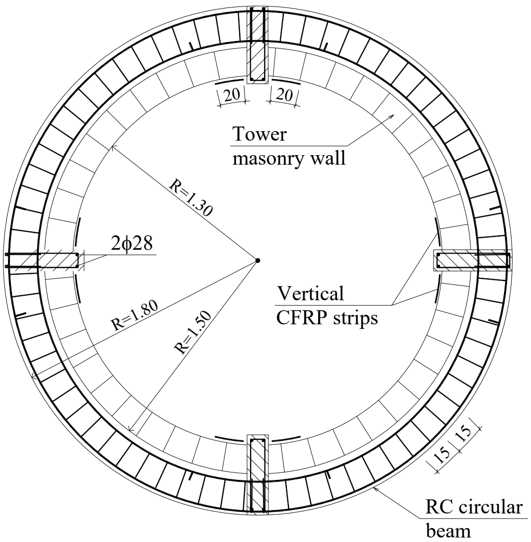

Fig. 2: Tower strengthening at base section

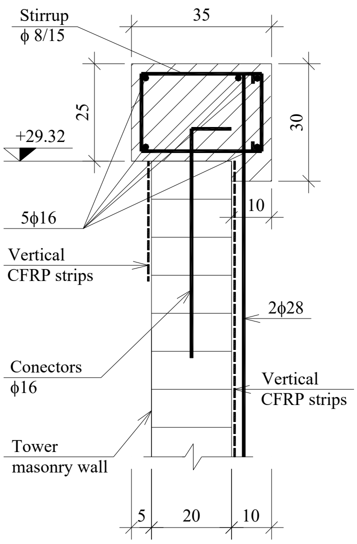

Fig. 3: Tower strengthening at top section

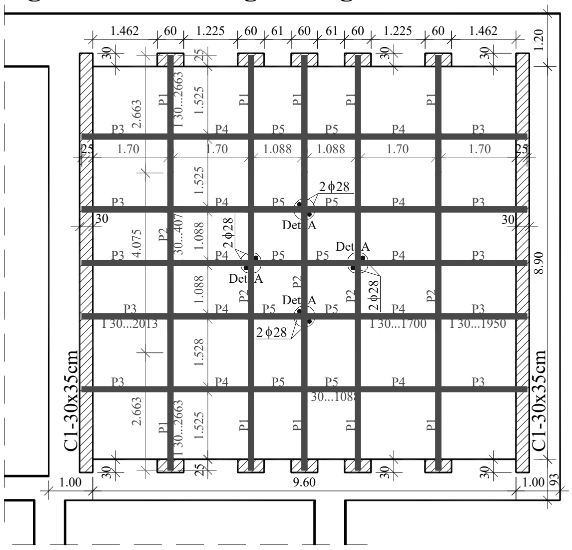

Fig. 4: Steel beams network for tower stability

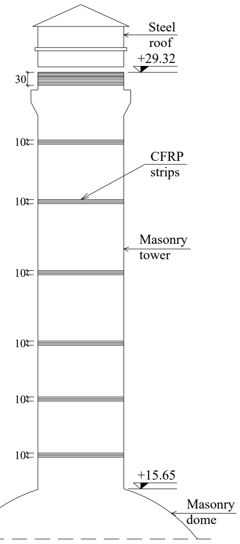

Fig. 5: CFRP strips for tower confinement