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Structural Observations on Macedonian Tower, Edirne

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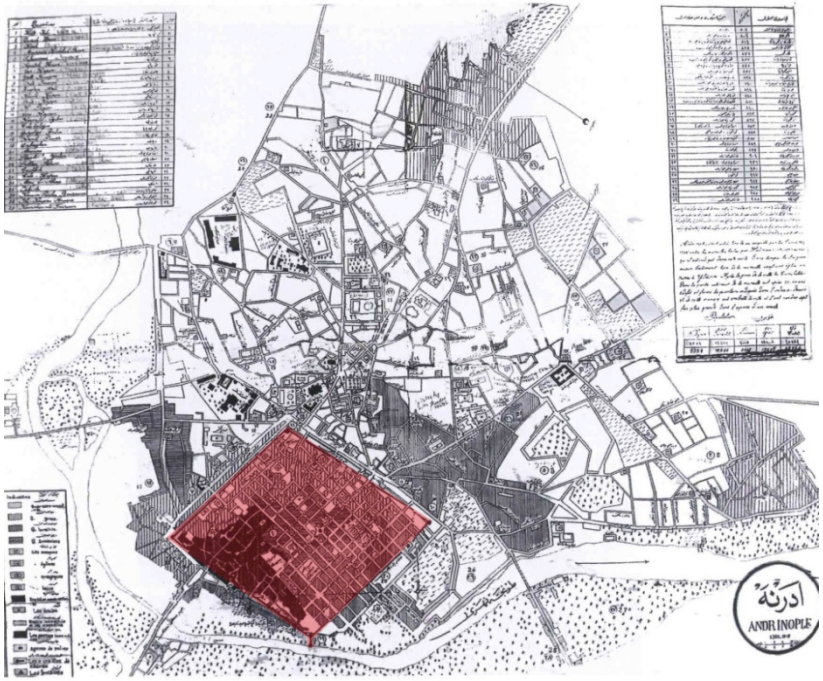
Outline

- Introduction
- Characteristics of the structure
- Existing state of the building
- Investigations
- Results
- Proposals for future

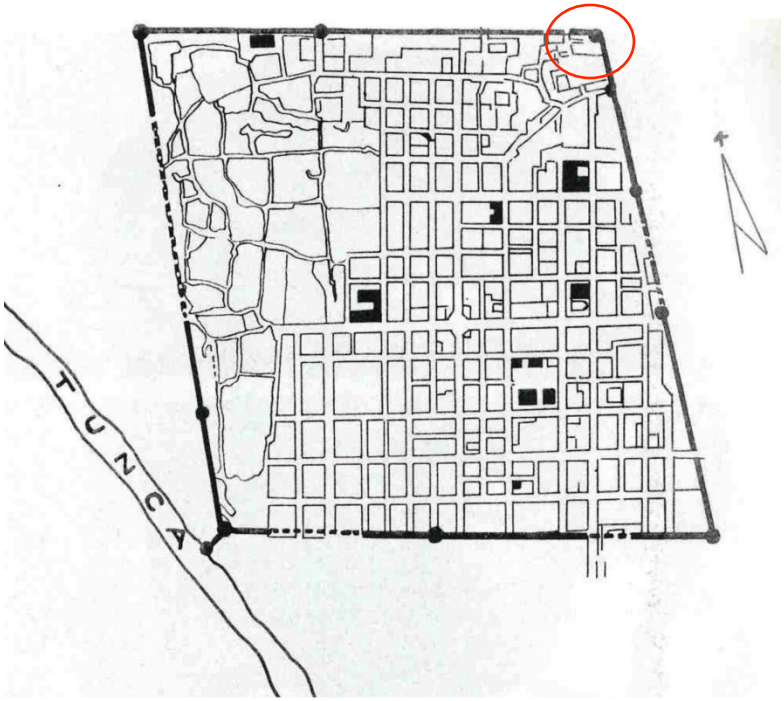
Introduction: Macedonian Tower, Edirne

Macedonian Tower, Edirne, 2014.

Introduction: Macedonian Tower, Edirne



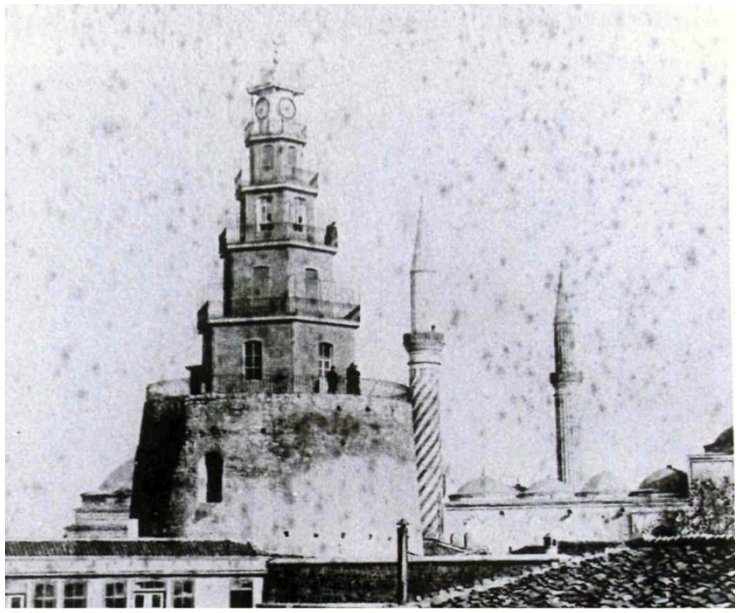
Edirne city plan from 1918 (Eyice, 1979)



Edirne city plan, 19th century (Peremeci, 1940)

Phase 1: The fortifications were demolished except the Macedonian Tower with some part of its adjoining city walls

Introduction: Macedonian Tower, Edirne--Evolution

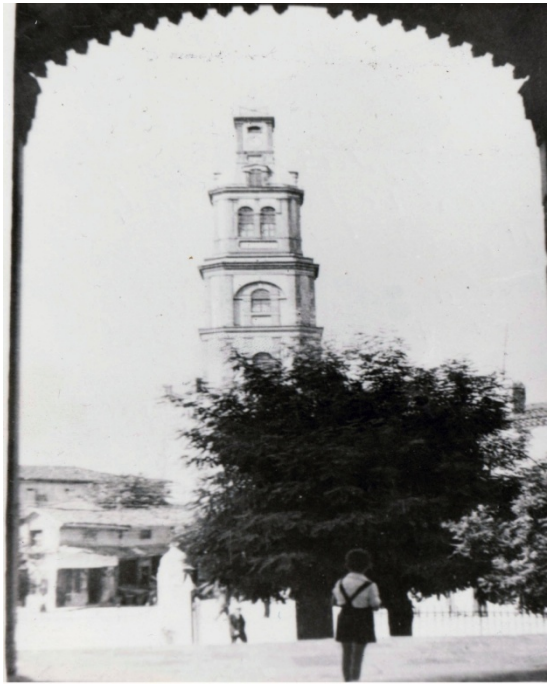


The addition of timber structure (Archives of Edirne Museum)

The timber structure between 1884-1894 (Archives of Edirne Museum

Phase 2: The building became a clock tower with an addition of a four storey timber structure

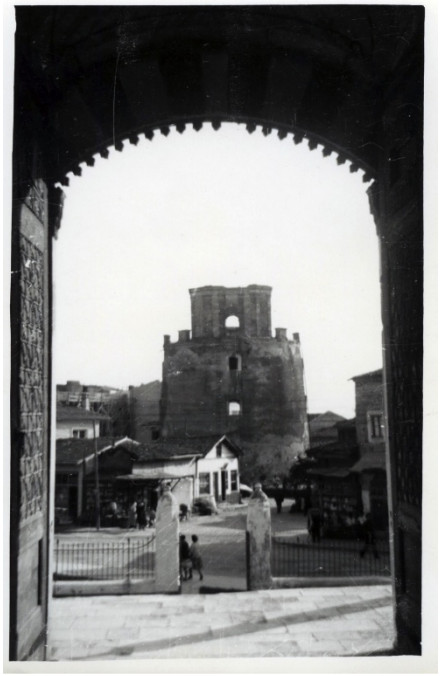
Introduction: Macedonian Tower, Edirne--Evolution



The masonry structure , which is constructed in 1894 (Archives of Edirne Museum)

Phase 3: The newly added timber clock tower was replaced with a masonry structure with almost same height

Introduction: Macedonian Tower, Edirne--Evolution

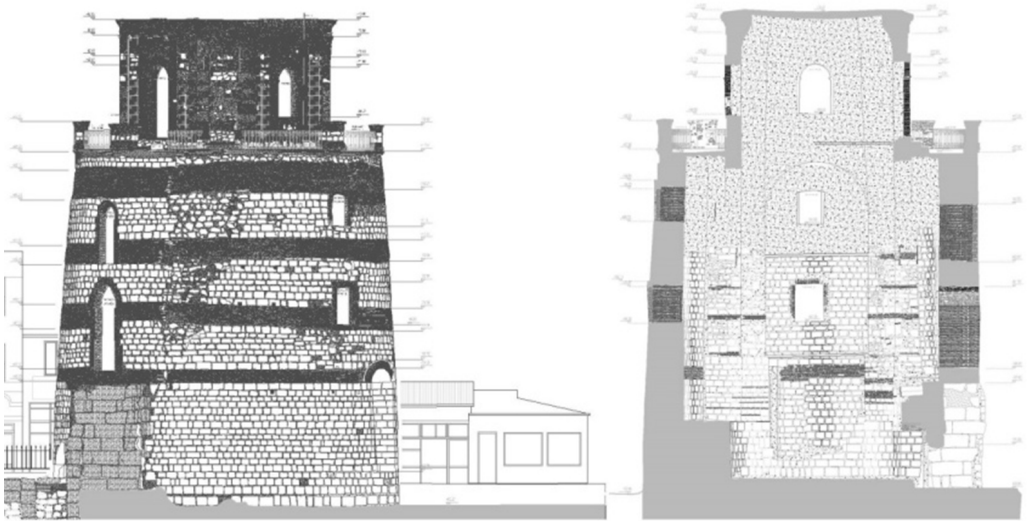


The masonry structure, 1953 (Archives of Edirne Museum)

Phase 4: The masonry addition was demolished due to the security reasons with the employment of explosives immediately after an earthquake in the 50's.

Characteristics of the structure

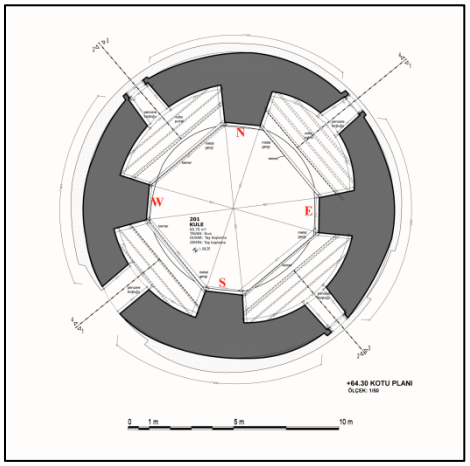
Macedonian Tower, Edirne, 2014.



Scaled drawings form the Macedonian Tower, Edirne (Muka Architects, 2015)

- Approx. 16 m high on a round base
- Stonework masonry with brick bands
- Wall thickness ranges from 2.00 m at the foundation level to 1.50 m at the top.
- The structure ends with a chamfered square crowning, which is originally remaining part of a later addition from 19th century.

Characteristics of the structure



Plan (Muka Architects, 2015)

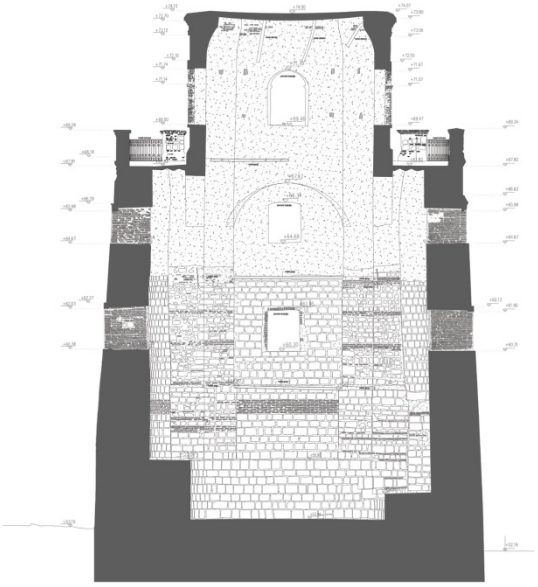
Interior space (2014)

Reinforced concrete roof of the tower (2014)

- 4 piers in the interior space.
- Employment of iron tie rods and anchors.
- Some iron elements in correspondence with the missing floors.
- The remaining section of masonry clock tower is at the top.
- Floor arches between the fortification walls and the clock tower.
- The clock tower is square in plan and has brick walls 65 cm in thickness.

Existing state of the structure

Macedonian Tower, Edirne, 2014.



Scaled drawings form the Macedonian Tower, Edirne (Muka Architects, 2015)

Random fills and irregular patterns of the walls, 2014

- brick bands -- consistency ?
- random fills and irregular patterns (earlier repairs and alterations)

Existing state of the structure

Decay and vegetation on masonry walls

The roof of the tower

Damages on the upper part of the structure

- surface loss
- degradation of binding material
- corrosion of later structural steel members
- vegetation on surfaces

Investigations: Documentation

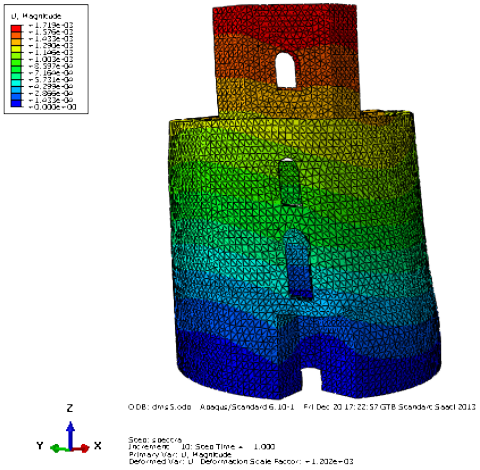
Ortho-photo images from facades

Total Station :
Leica TCR1205, Leica TCR805 Ultra
GPS:
Leica System1200
Laser Scanner:
Faro Focus 3D Laser Scanner

Images from scanning phase

Investigations: Numerical Analysis

FE model of the tower, 2015

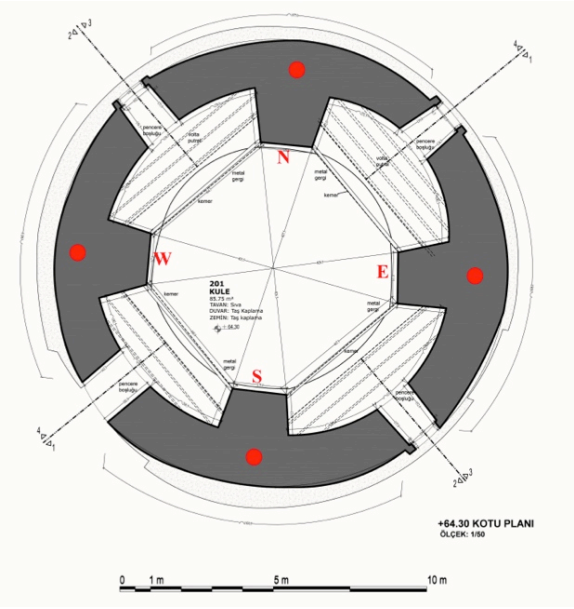


Displacements of the structure under lateral loading, 2015

- Homogeneous material, behaves within the elastic range under compressive and tensile stresses.
- The initial parameters, density (2200 kg\m³), modulus of elasticity (1.5 GPa) and Poisson's ratio (0,20)
- Sufficient number of elements (four-node tetrahedral element) with max edge dimension of 30 cm
- Rigidly fixed to the ground for all types of analyses

Investigations: Experimental phase at the site

Ambient vibration test equipment on the roof, 2016



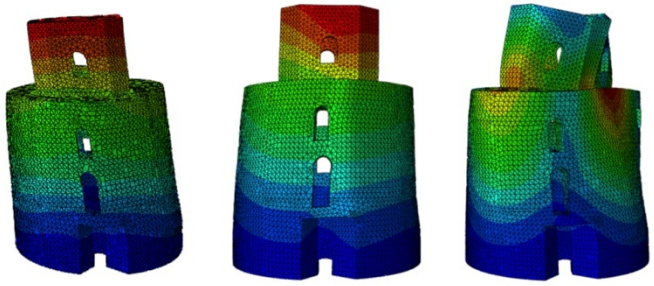
The location of sensors at the roof, 2016

Results of the vibration tests

Natural frequencies	Dynamic test (Hz)	Mode classification
1	3.731	Bending
2	3.912	Bending
3	6.425	Torsion

- The structure is assumed to be excited by wind and traffic.
- The sensors were placed on 2 different levels. Four sensors were placed on upper level and two at the bottom level.
- The recording duration was approximately 20 min with 100 Hz sampling frequency.
- Digitized data was recorded with a notebook computer, and then analyzed on another computer at a later time (the Frequency Domain Decomposition method, implemented with the ARTeMIS extractor software)

Investigations: Numerical Analysis



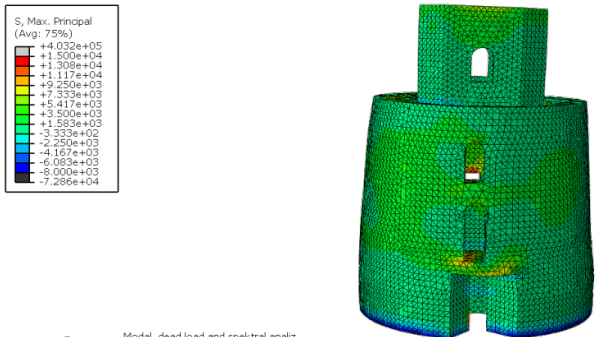
Three mode shapes according to the Eigenvalue analysis

Natural frequencies	Test results (Hz)	FEM initial (E=1.5 GPa)	FEM (E=1.15 GPa)	Mode classification
1	3.731	4.425	3.783	Bending
2	3.912	4.564	4.015	Bending
3	6.425	6.536	5.694	Torsion

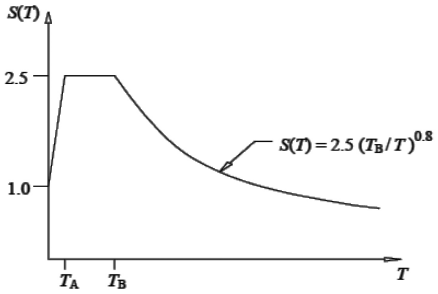
The results of Eigenvalue analysis and site tests

- Initial material properties of the model was modified in order to match test results

Investigations: Numerical Analysis



Stress distribution of the structure under its own weight



Spectrum graph according to Turkish code

$A(T) = Ao\ I\ S(T)$
$Sae(T) = A(T)\ g$

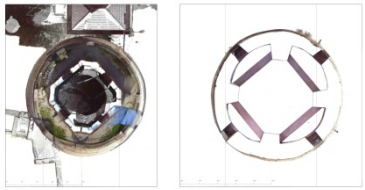
- the structure under its own weight
- spectrum analysis

Local site class	T_A	T_B
Z1	0.1	0.3
Z2	0.15	0.4
Z3	0.15	0.6
Z4	0.2	0.9

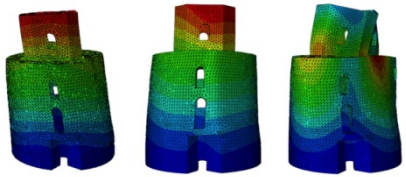
Local site classes according to Turkish code

Results and conclusion

- Documentation



- Numerical analysis



- Ambient vibration tests

Natural frequencies	Dynamic test (Hz)	Mode classification
1	3.731	Bending
2	3.912	Bending
3	6.425	Torsion

Forthcoming studies:

- Material characterization
- Local concentrations regarding the stress distribution
- Demands for the future re-use of the building

Thank you