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# Consolidation and Restoration of the Moletta's Tower (Circus Maximus: Roma): Site Investigation and Monitoring

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## Abstract

This paper describes the investigations carried out for the Moletta's Tower. The investigations were finalized at the consolidation and restoration of the building, in the work of environmental restoration and enhancement of archaeological sites of the Circus Maximus in Rome, with particular attention to the verification of the interaction soil-foundations of this tower. The surveys were focused mainly to provide information and data for the following aspects: (i) the project of the works necessary to prevent or reduce any differential subsidence resulting from the reduction of the water; (ii), a general static and seismic check of the tower; (iii) design the most appropriate consolidation work needed to building safety and make it accessible to the public for turistic exploitation. The geological, stratigraphic, geotechnical and seismic characteristics of the substrate have been defined by field of surveys carried out in the following stages: realization of 3 geognostic drillings (boreholes); sampling of 12 undisturbed soil samples, analyzed and tested in a specific and standard geotechnical laboratory; execution of 6 Standard Penetration Test S.P.T; execution of 2 multichannel analysis of surface waves (MASW) seismic stretched; realization of 1 well drilling inclined to identify the foundations of the tower's walls.

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## Keywords

Circus Maximus • Consolidation and restoration • Geological and geotechnical investigation

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## 58.1 Introduction

The Moletta's Tower is located in the center of the semi-circular part of the track of Circus Maximus, (side Piazza di Porta Capena); stands out from the ruins of the Circus Maximus, as it seems almost a foreign object in a space that contains the remains of what was one of the major monuments of antiquity, the Tower is in fact the only architectural dating back to medieval times of this site.

Its origin is dated back the eleventh century, when the whole area between the slopes of the Palatine and the remains of the triumphal arch of the Circus Maximus was transformed into a fortified complex by the monks of S. Gregorio. Since 1145 the whole fortified complex passed to the Frangipane family.

With the exception of the period the end of the thirteenth century, when the tower results to have been shortened, its appearance remains essentially unchanged up to the present day.

In the age between the XIV and XVIII century, zone configuration will remain unchanged: that complex which crossed from the ditch of Velabro, with a mill backing onto the SE facade of Tower; the Tower is always incorporated into other buildings until 1934, when it was subjected to restoration and freed from the substructions.

In the early twentieth century the aspect assumed by the area of the Circus Maximus appeared far away from the current configuration: the area seems to be a vast space covered with industrial buildings arranged in accordance with random logic in which it was difficult to distinguish the archaeological remains from the buildings that rises in recent times.

A deep transformation occurs in the years between 1926 and 1934, when the restoration work and demolition of the substructures not coherent, brings the Circus Maximus to the aspect we know today.

In 2009 work began, currently underway, which finally turn to the roman citizens, the original configuration of the Circus Maximus: the isolated location of Moletta's tower and the indication of the area where stood the triumphal arch of access to the Circus. These works will allow the exploitation of the archaeological area of the Circus Maximus and the Moletta's tower will be consolidated and restored.

For a correct approach to this work the geological, geotechnical and seismic parameters of ground belonging to the Tower were been defined (Fig. 58.1).



**Fig. 58.1** Tower of Moletta

## 58.2 Geological and Geomorphological Setting of the Area

From the geomorphological point of view the area is part of the Circus Maximus More in details it belongs to the valley between the Palatine Hill and the Aventine Hill (NNE to SSW) where once stood the ditch of the Velabrum, a tributary of the left bank of the Tiber.

In particular the study area is almost flat and is characterized by a share of approximately topographical 14–16 m to sea level.

The area, under a significant layer of backfill, is characterized by the presence of alluvial deposits (a2—Funiciello and Giordano 2008) consist mainly of fine silty-clay deposits alternating with sandy levels and levels of peats at different depths (Fig. 58.2).

### 58.2.1 Detailed Geological Model

The investigations carried out have allowed to recognize the following successions subdivided as follows due to their characteristics stratigraphic, granulometric and geotechnical of the various encountered soils.

#### 58.2.1.1 Level 1: Greyish-Brown Backfill

It appears from loose to medium density, heterogeneous and heterometric, a predominantly grain size of a sand-gravel weakly clayish. Inside are found fragments of brick, mortar and pozzolanic pieces of marble. The measured thickness is between about 7 and 10 m.



**Fig. 58.2** Geology of area, from Funiciello and Giordano (2008)

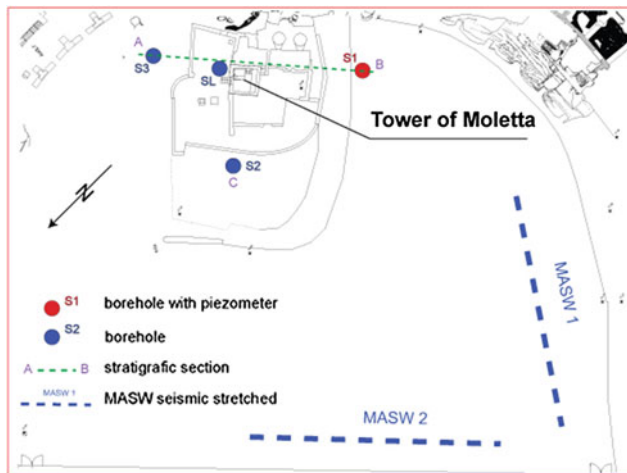


Fig. 58.3 Location of the investigation

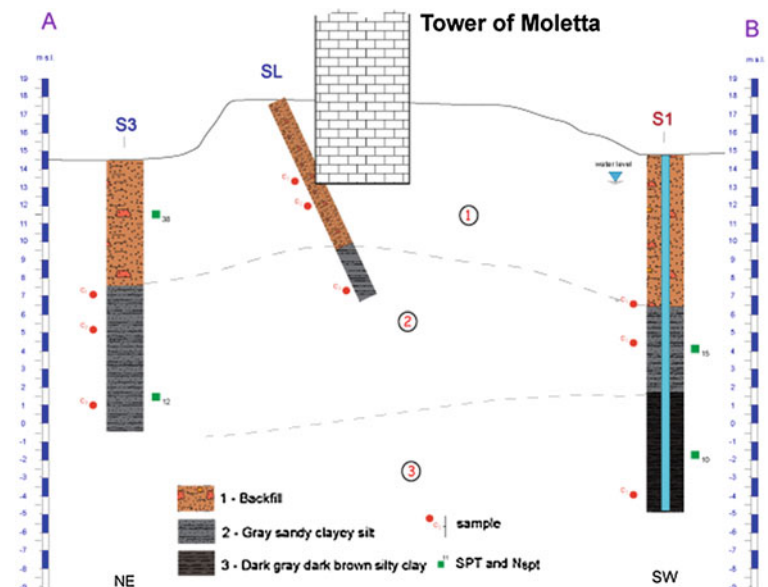
### 58.2.1.2 Level 2: Gray Sandy Clayey Silt

This level looks like stiff, at times occurs dark gray silty clay with the presence of organic matter. The thickness is approximately 7 m.

### 58.2.1.3 Level 3: Dark Gray Dark Brown Silty Clay

Abundant frustules and partially decomposed vegetation are present; fragments of wood and remains of shells. In places the clay fraction prevails. The thickness remains open and unconfined downwards because the investigations carried out have not intercepted the lower limit (Figs. 58.3 and 58.4).

Fig. 58.4 Stratigraphic correlation



## 58.3 Geotechnical Characterization of the Foundation Soils

Starting from the geological model, implemented by the stratigraphy of the geological surveys, a geotechnical characterization of soils was carried out by analyzing the laboratory tests performed on 12 samples taken during the surveys jointly with the 6 SPT performed during the same field investigation.

The main physical-mechanical characteristics detected for each level by granulometric analysis and physic-mechanical tests (direct shear tests with Casagrande box of 36 cm<sup>2</sup> diameter; triaxial tests and oedometric tests UU and CID), are summarized as follows :

physical properties

- $\gamma$  = natural unit weight of the soil;

mechanical properties

- $c'$  = drained cohesion (in terms of effective stress);
- $\phi'$  = friction angle (in terms of effective stress);
- $c_u$  = undrained cohesion;
- $E'$  = oedometric modulus (Table 58.1).

## 58.4 Structural Works: The Seismic Improvement of the Tower

The structural project consists in the seismic improvement of the tower. It has been necessary because of its refurbishment—in view of its opening to the public—and also because of the works to reduce the aquifer in the surrounding archaeological area.

**Table 58.1**

	$\gamma$ (kN/m <sup>3</sup> )	$c'$ (kPa)	$c_u$ (kPa)	$\phi'$ (kPa)	$E'$ (kPa)
Level 1 <i>Greyish-brown backfill</i>	16.00–19.00	0–3		26–30	
Level 2 <i>Gray sandy clayey silt</i>	16.69–17.59	3–28	51–81	24–32	5,106–5,543
Level 3 <i>Dark gray dark brown silty clay</i>	15.01		64		2,355

$E'$  = load range between 98 and 196 kPa

These works allow to decrease the height of the entrance further down to about 1.5 m where the digs of Circus Maximus are actually. With this purpose an existing door has been reopened and strengthened.

In addition to widespread injections of hydraulic lime mortar in masonry, the seismic improvement consists in both the reinforce of the foundations inserting a steel ribbed slab and the emptying of the tower destroying all the floors and also with the insertion of steel rings on the inner side of the walls. On the steel a rings system of tie rods with outer end-plates is placed.

In the inner space a lightweight staircase made of a steel structure and wooden steps is designed and will allow to enter (placed at about 9.5 m above the height of the entrance). Through the glass windows placed between the crenellations of the perimeter walls it will be possible to enjoy a large view of the Circus Maximus.

The consolidation won't increase the mass of the tower, on the contrary, it will slightly reduce it.

Together with the consolidation of the structure also the strength of foundations and masonry will be improved with the steel structures designed and the injections of hydraulic lime mortar.

So a general enhancement of the structural behavior and the seismic capability of the tower will be obtained in addition to a substantial increase of the resistance to vertical loads.

Choosing steel structures, even in foundation, allows a total removability of the intervention and offers the possibility to recognize vertical parts and roofs and ensures a minimum visual impact respecting the original structures.

Also a long-time monitoring campaign should be implemented with aiming at estimate seismic response characteristics of the tower both on structures and at ground surface. An integrated monitoring system (wi-fi sensor) should be implemented in order to prevent future damages and to control the effectiveness of the proposed restoration work. More in detail in the second stage of the restoration project a

simple monitoring instruments composed by tilt meters will be installed.

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