

POLYTECHNIC OF TORINO
FACULTY OF ARCHITECTURE 2
Degree in Architecture
Honors theses

Effects of the yielding induced by excavation of metropolitan galleries, on historical buildings in masonry. The *Industriele*, Amsterdam

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To solve the road traffic is becoming a necessity for a lot of cities, more and more congested. For this reason, one of the adopted solutions is to build underground lines.

It becomes essential to improve the monitoring techniques of the ground and buildings involved by the excavations of such galleries, with particular attention to the static and aesthetical damage of the historical buildings in masonry façades, more sensitive to such movements.

In the specific case of Amsterdam the particular condition of the ground requires a more severe analysis.

We have studied particularly the structural behavior of the building called *Industria*, built in the 1913 in Dam Square, involved by the jobs for the realization of the new underground line called Noord/Zuidlijn, that will cross the historical “heart” of the city.



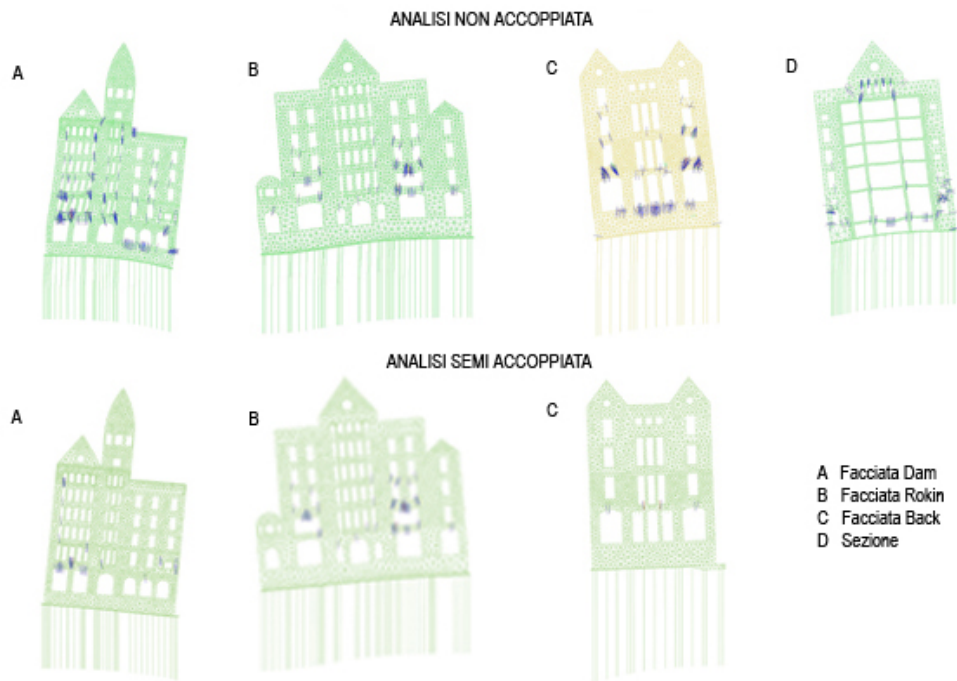
View on Rokin street, long which will be constructed the underground line Noord/Zuidlijn. At the bottom, is visible the *Industria* building

To this purpose an ample numerical analysis has been performed in the form of classical non-linear smeared crack models, with the contribution of the DIANA Code and the and the knowledge of Science of the Constructions.

The structure of the buildings has been analysed modelling the most important bidimensional sections, parallel and orthogonal to the trace of the tunnels. The model has included a representation of the piles foundation, while the settlement of the deep soil layers have been assigned based on geological evidences.

We have considered opportune to treat the Un-Coupled case at first, in which has not been taken in consideration the interaction of the ground structure, and then the Semi-Coupled case, in which the spring elements have been inserted, able to absorb the effect of the yielding caused to the passage of TBM (Tunnel Boring Machines).

In the case of Semi-Coupled Analysis an evident reduction of the visible crack damage has been found. Particularly has been noticed that the presence of the springs elements, lead to a rigid rotation of the whole façade and therefore of the wall of foundation made in concrete, limiting so the crack extension.



Comparison of masonry façades behaviour
in Un-Coupled and Semi-Coupled Analysis

The position of the façade, in comparison to the axis of the tunnels, is one of the most important aspect for the evaluation of the damage; two separate zones has been introduced: the hogging zone (the most dangerous) and the sagging zone. Knowing the zone where the façade is situated, we are able to define analytically the tensile stresses.

If the deformation is essentially due to bending, the maximum tensile stresses are located in correspondence of the extreme fibres on the upper side of the façade, with appearance of straight cracks (for instance: façade DAM).

In the case the deformation is due to shear strain, the deformation will result on diagonal cracks tilt to 45° in correspondence of the extreme fibres on the façade (for instance: façades BACK and SECTION).

In the profile SECTION the façade in masonry, interacting with the inside concrete structure, has determined a greater flexibility with consequent less severe stress in the masonry structure.

The settlement profile of the façade ROKIN differs profoundly from the previous cases, because the tunnels are parallel to the façade: it will result a transitory yielding showing cracks that open and close during the advancing of the excavation machines. For this reason this façade will result less critical than the previous.

From the comparison of the two type of behavior has been deduced that for value of slenderness (height over width) lower than 1.5, it's more important the shear behaviour to determine the threshold value (stocky beam), while for higher value, it's more important the bending behaviour (slender beam). The relationship of slenderness will influence therefore the structural response.

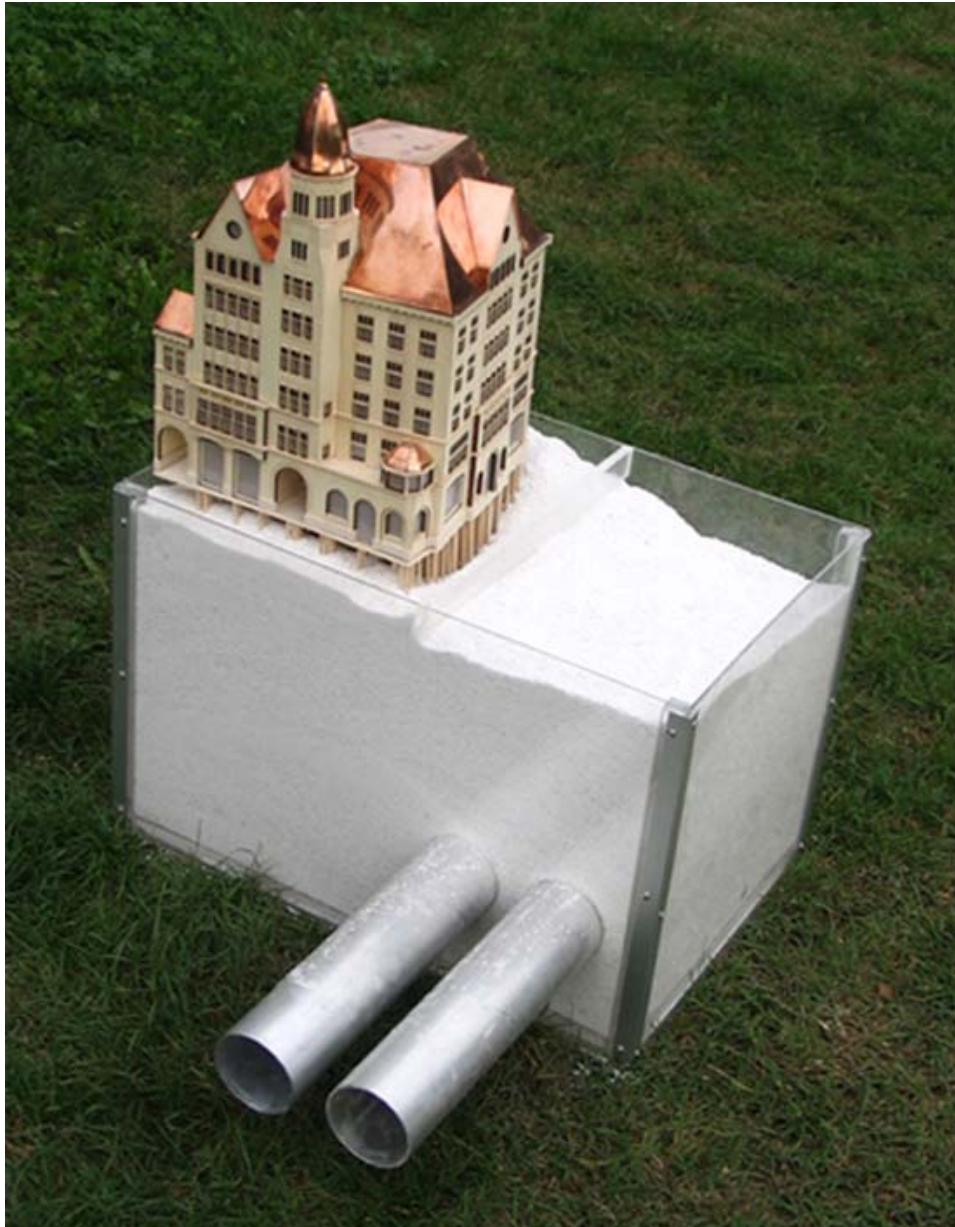
In the analysed case, the presence of a deep wall of foundation in concrete has also influenced the behaviour of the upper structure in masonry. Fundamentally the wall bends under the movements of the ground as a reverse beam.

The results from the numerical simulation allow to establish the value of the critical angular distortion. Exceed that value, some containment precautionary are necessary to prevent the damage of the façades.

The calculated value can be compared with the results, coming from real time monitoring during excavation.

As a reference of the empirical method of evaluation of the damage, we have reported from the English literature, the case of Hotel Ritz, placed near the tunnel of Jubilee Line (London), similar to the case of *Industria*, regarding: geometric composition, construction materials and position referred to the trace of the tunnel.

The construction of the uderground Line1 in Turin has allow us to consider the approach of analysis adopted in Our city. The similarity found in this case concerns mainly the techniques of construction of the stations and galleries, by the TBM.



Model to simulate the “volume loss” during the excavation of tunnels and the interaction with the soil-overhanging building

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