Geotechnical problems on historic buildings consolidation

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1. Considerations on historical buildings

- The built part of the cultural heritage is entirely preserved, focusing as well towards the historic, architectural, artistic and structural aspects.
- The structural interventions have to ensure the demanding performance of the structure for durable resistance, materialized by justified interventions which imply the structural conformity and the modification of the structural sub ensembles.
- Because of historic conditions, the buildings were placed on locations where the supporting soil had hidden vices. These vices led in time, to the modification of the physical–mechanical characteristics of the founding layers.
- All these factors indicate the appearance of degradations in the structural elements of the historic buildings.
- The intervention over the foundation structures demands, first of all, detailed analyses of the supporting soil and its evolution in time as well as the analyses of the geotechnical characteristics.
2. Investigation methods for the supporting soil and foundations

• **Investigation steps**

  I. Estimation of the site’s general characteristics:
  
  • the presence of some old, existing cellars under or near the building,
  
  • the existence of old foundations on or near
  
  • the existence of some drains or sewage out of order,
  
  • the existence of closed fountains.
2. Investigation methods for the supporting soil and foundations

II. Researches regarding the quality of the foundation and of the supporting soil.

• Excavations near the foundation:
  – foundation’s depth and quality of the materials used,
  – the foundation dimensions
  – the structure of the foundations,
  – supporting soil layers,
  – ground water table, etc.
  – position of these drillings - according to the position of degradations and the building’s characteristics, the type of the ground and the knowledge about the building.
2. Investigation methods for the supporting soil and foundations

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- In situ methods are dynamic (heavy) penetrations and static standard penetrations:
  - the layers of the ground,
  - the physical – mechanical characteristics of the layers,
  - the water table,
  - the slipping surfaces.
2. Investigation methods for the supporting soil and foundations

II. Researches regarding the quality of the foundation and of the supporting soil.

• The geo-electric method is one of the most efficient for the research of the soil’s layers, the ground water table coming from wage or drains and the characteristics of the supporting soil.
3. Disturbing factors for the stability of the placement

– The main modifying factors for the places are:

  • The modification of the ground water table (due to the sewage systems).
  • The effect of the underground water’s aggressiveness, of the vagrant streams, of the ground’s aggressiveness.
  • The presence of local loss of stability for some sites (due to the digging at the base of the slope and along the inclined plan, long rains, swelling – contracting phenomenon, freezing effect, vegetation modifications, etc.)
### 3. Disturbing factors for the stability of the placement

Degradations and causes of degradations for historic buildings  
(Ulitsky, V.M. & all, 2006)

<table>
<thead>
<tr>
<th></th>
<th>Damage type</th>
<th>Causative factor.</th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>Disjoining of brickwork above foundation cut.</td>
<td>Annual freeze-thaw of wet brickwork. Moisturizing of brickwork occasioned by made-up ground (cultural deposits stratum) level increase.</td>
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<tr>
<td>II</td>
<td>Steel or timber beams decay in intermediate floor above basement.</td>
<td>Increased humidity accompanied by poor or no venting in basement area, waterproofing failure in walls and ceilings.</td>
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<tr>
<td>III</td>
<td>Damage to anti capillary waterproofing in brick walls</td>
<td>Ageing of materials, fragility of old waterproofing.</td>
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<tr>
<td>IV</td>
<td>Damage to waterproofing on basement floor.</td>
<td>Mechanical damage during trenching and floor work.</td>
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<tr>
<td>V</td>
<td>Decay of timber beams in foundations.</td>
<td>Ground water level fall-off or biological timber decay on account of micro biotic contamination of ground water.</td>
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<tr>
<td>VI</td>
<td>Damage to walls waterproofing in buried service beds</td>
<td>Poor sealing services embedding, destruction of old waterproofing.</td>
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<tr>
<td>VII</td>
<td>Crumbling of mortar in brickwork.</td>
<td>Aggressiveness of ground water. Decrease of mortar strength in time, leaching (lixiviation) of mortar.</td>
</tr>
<tr>
<td>VIII</td>
<td>Timber piles heads decay.</td>
<td>General decrease of ground water level, water temperature increase, fungus on timber.</td>
</tr>
</tbody>
</table>
3. Disturbing factors for the stability of the placement

Degradations and causes of degradations for historic buildings
(Ulitsky, V.M. & all, 2006)

Traditional foundation structures in historic buildings, with their characteristic damages
4. Consolidation methods for the Sighisoara fortification

The fortification is placed on a hill, (about 600m) in a wide pass, on the left side of the Târnava Mare River, and it is surrounded by other hills, 400-600m high. The fortified town Sighisoara, was founded at the end of the 14th century, at has a number of buildings included in the UNESCO List.
3. Consolidation methods for the Sighisoara fortification

• Because of natural conditions the fortification suffered many degradations. The most important refer to the stability of the town’s wall. In March 2006 on 55 m long the eastern wall collapsed.
• The outlay of the event showed that the wall was built out of brick masonry, using lime mortar and having behind a dry stone masonry built under a 60° angle.
• For extra research of the supporting soil, geo electrical measurements and three heavy dynamic penetrations.
• The overturning stability of the wall concluded that had an overturning stability factor of Fsr=1.18 > Fsadm=1.15.
• The wall’s loss of stability appeared because of the dislocation of some stone blocks in its’ central zone. These dislocations appeared because of the loss of mortar due to the rain water coming from the mayor’s house.
4. Consolidation methods for the Sighisoara fortification
4. Consolidation methods for the Sighisoara fortification

There were two proposals to consolidate the town’s wall.

1. For the standing, but bending of the wall the proposal was a consolidation with micro piles (Ø1.80 to 1.00m), drilled in the wall, than grouted on low pressure and at the end bended by a reinforced concrete girder. The use of anchorage with Ø28 injected anchors was proposed if the bending was more than 1/10.

2. For the collapsed wall it was proposed a micro piles cap (Ø180) on three rows (Figure 7), the rebuilding of the stone wall out of stone blocks using hydraulic lime; behind the wall the dry stone masonry it was to be rebuilt.
4. Consolidation methods for the Sighisoara fortification

Proposal 1.

Proposal 2.
5. Reformed Church in Cuzaplac

The western tower of the Reformed Church in Cuzaplac was built in 1884. Twenty years later, between 1905 and 1906, the old church was demolished and a nave was built to the tower, with a polygonal apse holding some elements from the old medieval ones (the organ, Gods table from 1886, the stone doorway etc). The building has two sub ensembles realized at 20 years difference: the tower (3 stories high) + spire (1884),
5. Reformed Church in Cuzaplac

• The two sub ensembles are not joined together.
• The outer wall of the tower is built out of stone masonry up to the height of 5.11 m, from where it was continued out of brick masonry.
• The nave walls are built out of brick masonry, with lime mortar, having buttresses.
• The roof structure is made out of soft wood, having main and secondary eclectic frames, using hanging and compressing devices. The roof cover is tin on timber deck. The slab, over the nave is realized using the ceiling elements.
• The floor over the first floor of the tower is a bohemian brick vault and the middle floor is made out of timber.
5. Reformed Church in Cuzaplac

- The foundations are continuous rigid footing, made out of stone masonry and lime mortar. The foundation level is at -3,20m for the tower and at -1,60m for the central nave. The width of the foundation is the same with the width of the wall.
- Morphological, the church is placed at the base of a hill, using an artificial terrace, having 2,5 x 3,0 m.
- The supporting soil has a succession of layers: fillings of dusty – sandy earth, vegetal elements, stone, dark brown brick, 1,5 m high, followed by some clay layers, sandy – dusty clays, yellow – brown clays, hard clay, contracting clay, representing the founding ground for the church.
5. Reformed Church in Cuzaplac

The main damages observed are:

(i) high moisture content in external walls;
(ii) displacement of the nave (10) on the S – W direction (the cause of the 10 – 80 mm cracks on the two sides of the G axes buttress);
(iii) dislocation of some timber elements of the main frame;
(iv) biological decay of elements and joints in the roof frame.
(v) The slid give birth to the bending of the foundation and the dislocation of the axes G buttress.
(vi) The damp phenomenon was increased by the non professional interventions, such as bad side walks, degradation of horizontal waterproofing, a waterproof plastering 15 years ago.
5. Reformed Church in Cuzaplac

The interventions on the building consisted of:

1. Draining system on both sides of the wall. Breathing rendering (lime based).
2. Elimination of the rain water from near the foundation.
3. Consolidating the dislocated wall with metal bars in 3 sections on its’ high, grouting lime/cement mortar in cracks.
4. Replacement of the bricks that suffered any degradation.
Thank you very much for your attention!

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