Impact Factor:	ISRA (India) = 4.971	SIS (USA) = 0.912	ICV (Poland) = 6.630
	ISI (Dubai, UAE) = 0.829	РИНЦ (Russia) = 0.126	PIF (India) = 1.940
	GIF (Australia) = 0.564	ESJI (KZ) = 8.997	IBI (India) = 4.260
	JIF = 1.500	SJIF (Morocco) = 5.667	OAJI (USA) = 0.350

QR – Issue QR – Article

SOI: 1.1/TAS DOI: 10.15863/TAS
International Scientific Journal
Theoretical & Applied Science

p-ISSN: 2308-4944 (print) **e-ISSN:** 2409-0085 (online)

Year: 2020 **Issue:** 12 **Volume:** 92

Published: 18.12.2020 **http://T-Science.org**

Bucur Dan Pericleanu
Ovidius University from Constanta
Teaching assistant, Faculty of Civil Engineering,
România

INFLUENCE OF MOISTURE VARIATION ON THE BEHAVIOR OF INTERMEDIATE LAYERS OF SAND AND MEASURES TO PROTECT EXISTING BUILDINGS SITES

Abstract: *The paper deals with the behavior of sandy lens stratification of sites in the presence of moisture and their effects on buildings. The authors develop a particularly interesting case study by identifying and analysing the factors that can alter the vulnerability of the site. The analysis made by the authors took place between May 2014 - September 2014, during which there were telluric movements triggered from 14 to 15 May 2014 and continued in June and July, moves that have caused damage affecting their technical state.*

Key words: *heritage buildings, heritage sites, humidity.*
Language: *English*
Citation: Pericleanu, B. D. (2020). Influence of moisture variation on the behavior of intermediate layers of sand and measures to protect existing buildings sites. *ISJ Theoretical & Applied Science, 12 (92),* 231-236.
Soi: http://s-o-i.org/1.1/TAS-12-92-44 ***Doi***: crossref https://dx.doi.org/10.15863/TAS.2020.12.92.44
Scopus ASCC: *1909.*

Introduction

The article presents aspects of behavior damp sand layers (with high humidity) disposed as intermediate layers to clays and thus the effects on buildings. The case study presented is the ensemble of Răteşti Monastery located in Buzău county, Berca - a monument of national interest class. The analysis made by the authors took place between May 2014 - September 2014, during which there were telluric movements triggered from 14 to 15 May 2014 and continued in June and July, moves that have caused damage affecting the building technical state.

We mention that the effects produced affects a much larger area compared to the monastic assembly area, aspect identified by visual remarks that revealed plans of land sliding and collapse with the destruction of access roads, the occurrence of multiple cracks in the faults of both the interior land of the monastery (vizibile bumps, dislocations of access paths and green spaces) and outside the monastery enclosure of fences field movements, road movements of areas both horizontally and verticaly, slopes of vegetation, and others.

The building of the church of the Răteşti Assembly Monastery is dating from 1844, with tricon plan shape that form an enlarged pronaos. The church has a closed porch and three wooden towers. Inside, the church is painted by Nicolae Teodorescu Pitaru, leader of the Diocese of Buzău school. From Nicolae Teodorescu painting are preserved the iconostasis, the rest being repainted in 1930 and in 1987 by Nicholas Petre Solescu Brasov.

The objective of the study was to identify an existing structure for patrimonial damages caused by landslide (which led to the loss of important and authentic elements) and how much delay implementation of measures can affect the integrity of heritage structures [3, p.243]. An important focus of the work we put into developing and implementing measures that will be able to stabilize the land thereafter.

Current state structure description

From previous events reported from inside the monastery buildings were recorded cornice superficial cracks and minor degradations caused by water infiltration through the roof, but later they widened and for the construction of the church were identified these visible degradations [1, p.20]:

•multiple cracks in the cornice with evolutionary openings that generated its displacement from the museum building area;

•displacement of the roof structure – roof boarding spacing highlighting some areas left without cover;

•cracks deployments - breaks in the masonry structure in the pronaos - these cracks have affected existing brick pilasters (figure 1);

•develop cracks with vertical displacements in longitudinal walls, sloping cracks that emphasizes both land subsidence towards the church porch and the torsional effect (figure 3);

•detachment of pavement protection by cracking (figure 3);

•compaction with the separation of the building settling porch, compaction of access stairs approximately about 35 cm, deformation to the horizontal plan with dipping effects;

•the church floor deformation by compaction with its 12 cm minimum from the altar to the porch area;

•waves effects by local heightening floor near the columns;

•rotation effect of the foundation pillars columns that generated accentuated cracking of brick vaults, mostly the left vault;

•detachments with the separation of wooden vaults of the nave, the pantocrater - highlighting some of the vaults supports statically unstable;

•local detachment of paintings, plasters and displacements of structural elements on respective areas (figure 2).

The state of degradation mentioned above was accentuated by the rains since July 9th, 2014 (subsequent to telluric movements initiated in May) when there were 80 l / m - aspect that contributed to the emergence of new deformations which seriously jeopardizes the resistance and stability of the building [2, p.25].

The structure resistance is made of brick on a stone foundation. The built area of the church is 336m^2 and the maximum usable height is 7.45m. Initially the building did not highlighted obvious vertical irregularities, discontinuities in stiffness distribution, irregularities in plan, but now the foundation land movements caused structural elements separation and rotation that generate eccentric discharges, active areas eccentric loaded emphasizing the punctual discharges (the nave area with the cupola discharge or circular columns area with displacement accompanied by arch rupture that generates an additional state effort).

The church is founded at a depth of 1.7 m from the sidewalk elevation protection. Its structure is from stones tied with hydraulic lime, is encased in a very wet dusty brown - yellow clay layer with limestone concretions, with high plasticity and compressibility.

Results regarding site investigation

If at an earlier date of the events, respectively in 2010, the foundation stiffness was partially altered by land humidity and its potential landslide, effects that have been made visible by studying vertical and inclined cracks propagated in its elevation, later on the foundation presented oscillations of level about 78-80 cm that generated separation fractures and dislocations.

Figure 1 - Failure of church structure by land scouring under the foundation.

The pilots execution will be done after supporting the church walls and masonry unbinding in the areas that lost their stability [5, p.23]. Equipment vibrations near the church could generate new degradations even colaps. Pilots execution will be topometric monitored.

Figure 2 - Church interior image as a result of inspections dated 08/08/2014

Site analysis in 2010 (before the telluric movements) was conducted based on a geotechnical study. According to the geotechnical study [1, p.30] resulted the following stratification:

1. On the surface is present a concrete pavement with a thickness of 8 cm which sits on a bed made from boulders with compacted sand till the depth 0. 40m, followed by a deep loamy topsoil, dark, moist until the depth of 0.80 m from the sidewalk elevation.
2. It follows a very wet dusty clay layer, yellow-brown with purple insertions with intercalations of calcareous concretions from the depth of 1.40 m and with manganese concentrations with a dusty sand lens, yellow, wet on the base.

Dusty clay layer has the following values for geotechnical indices for taken sample at the base of the foundation (depth of 1,70m).

Granulometric composition is as follows:

- clay = 51%;
- dust = 40%;
- sand = 9%;
- natural humidity ω = 19%;
- natural volumetric weight γ_{ω} = 2.09 g/cm^3;
- bulk densities γ = 1.74 g / cm ^{3};
- the pore volume of n = 36.5%;
- the porosity index e = 0.59;
- the moisture content S = 0.85%;
- the compression module $E_{2\text{-}3}$ = 90.9 daN/cm^2;
- the specific compaction ep_2 = 2.0 cm / m;
- shear angle ϕ = 14 °;
- internal cohesion c = 0.60 daN / cm $^{2.}$

The analized land is considered a yellowish-brown dusty clay with purple intercalations discolouration, with calcareous concretions, very wet (humidity index = 0.85), high plasticity, hard consistency, with an average degree of consolidation (natural volumetric weight γ_{ω} = 2.09 g / cm ^{3}, porosity n = 35%, pore index = 0.59%).

Compressibillity is average (compression modulus $E_{2\text{-}3}$ = 9000KPa, specific compaction ep_2 = 2 cm / m) and is characterized by an shear angle of ϕ = 14° and an internal cohesion c = 60kPa.

3. The next layer was a layer of harsh plastic dust, long yellowish with lots of limestone to a depth of 3,20m.
4. Next a layer is a yellowish clay kneaded at the depth of about 4m, with a harsh plastic consistency to the depth of 4,60m.
5. The base layer is a yellowish sand, very wet yellow, stuffed to the depth of 6.20 m which includes a lens of yellowish-green clay from 5,10-5,40m.

One of the drillings conducted on site showed the following stratification:

- 0,00-0,80m concrete pavement
- 0,08-0,40 m boulders with sand
- 0,40-0,80 m topsoil
- 0,80-2,00 m yellowish brown dusty clay with lots of limestone
- 2,00-2,10 m dusty yellow sand
- 2,10-3,20 m harsh plastic dust yellowish with lots of limestone
- 3,20-4,60 m yellowish clay
- 4,60-5,10 m yellowish sand very wet and stuffed
- 5,10-5,40 m yellowish – purple clay
- 5,40-6,20 m yellowish sand stuffed with water

Analysis of the land and buildings located near the site [7, p.7], highlights potential effects of landslides caused by heavy-duty drainage of rainwater [8, p.960, p.1215]. For the church resistance structure this is an aspect that was observed in the previous period (before the rain, since 2010) by separation of concrete pavement protection and the propagation of a cracking state specific to these deformations (figure 3).

Regarding groundwater level in June 2010, according to the geotechnical study, the first level was intercepted at the 3 m from ground level.

Figure 3 - Highlights the vertical structure disposal/ failure at the porch entrance. The photo is made on 08.08.2014 when was recorded the maximum level of compaction

Later on during the period May to July 2014 visual observation of monastic assembly was conducted, inspections of constructions in the area of interest were carried out [2, p.24] which highlighted the following aspects:

– it was found an increase in opening faults produced in land registration date of the event, emphasizing the pitch breaks especially in front of the church;

– the repairing of the acces road to the monastery has not begun;

– the state of degradation of the Abbey and the Bishop House increased by accentuating cracks found mainly in the Abbey structure, its detachment from the Bishop House building structure about 35 cm, displacements of the slab beams supports – aspect that signals the imminent failure of the floors and collapse of interior walls. At that date was no longer safe to entry into the building;

– three opened surveys were conducted around the church to investigate the water level and was found: at the first hole in the east-west the water level was -1.40m, in the second hole on the south side at 1 m there was no water and the third hole on the east side upstream placed the water level at the ground level;

– uncontrolled water leaks were found inside the monastery;

– new cracks were formed in almost all existing buildings;

– it is expected that with the formation of the new cracks in the buildings structure – the first effects of the land movement till June 2014, the church resistance structure as well as the surrounding land and premises have suffered significant deformations with implications regarding their resistance and stability. The buildings in front of the church collapsed after the rains (the Bishop House and the Abbey mainly, plus all the other buildings in front of the church – downstream – were some of the nuns lived).

During the reference period 15th of May 2014 and 7th of July 2014 drills were carried out that come to complete the geotechnical study previous done (2010). According to this study there was a loamy topsoil up to 0.80m, the layer after was a very wet dusty clay with calcareous concretions from 0.8-2 m, followed by a harsh plastic dust up to 3.20m, followed by a clay up to 4.60 m, followed by yellowish sand stuffed with water up to 6.20m. The survey hole done at that time to the church (the date from 2010) highlights a stone foundation with hydraulic lime up to 1.7 m from ground level. The geotechnical study recommends at foundation level a calculation pressure of 200 KPa.

On July 4th, 2014 the geotechnical laboratory transmitted the synthetic sheets of geotechnical drillings carried out after landslides [9, p.114]. From the enclosed profile it can be observed that slipping occurred after the increase of water pressure in sand layer pores and by ascension. As a result, the first intervention (urgent) is to execute two epuisment wells (with the filter in the sand layer), whom will be used to depressed the foundation soil (in normal conditions it is a good land, evidence that the church had a very good behavior over the years). We appreciate that upstream interventions were made that changed the parameters of the monastic site enclosure (cutting vegetation, new construction or other arrangements with destructive effect on the built area).

As a ulterior solution [6, p.60] it was proposed to create a piles curtain [10, p.350; 4, p.5, 10] according to (figure 4) to give diagrams according to (figure 5).

Conclusions

The study was conducted for a historic building with authentic heritage value. The period of investigation is extended to a period of 4-5 years being initially proposed a rehabilitation solution and due to the delay in implementation of the measures related to land stabilization and after intensification of climatic activity the degradations described in chapter 3 appeared. The sliding occurred after the increase of water pressure in sand layer pores and the ascension of water on sand layer. The authors consider that all these changes occurred due to change in the parameters of the monastic site and the intervention proposed solutions to stabilize the ground in order to be able to take consolidation measures to strengthen also the church and hermitages of the monastery complex.

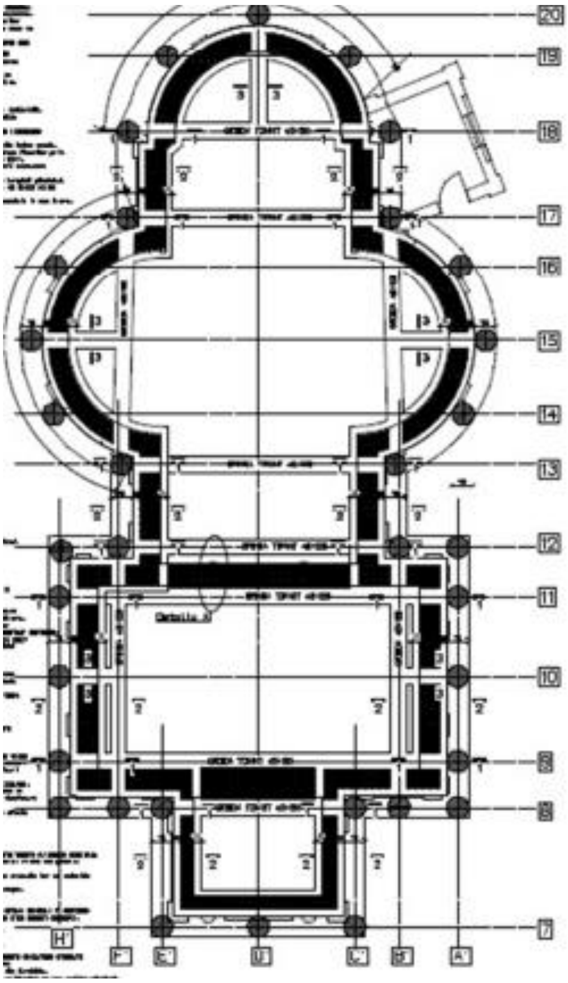

Figure 4 - Plan of pilots disposition for church consolidation

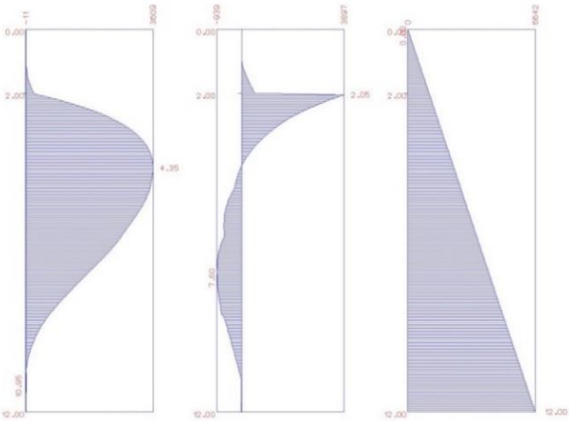

Figure 5 - Diagrams efforts for pilots dimension

References:

1. Grămescu, A.M. (2010). *Technical expertise report for the Rătești Monastery complex*,1st edition.
2. Grămescu, A.M. (2014). *Technical expertise report for the Rătești Monastery complex*, 2nd edition.
3. Grămescu, A.M., & Barbu, D.A.M. (2008). *Rehabilitation and consolidation of structures*, AGIR Publishing House, ch. 8, (p. 616), Bucharest.
4. (2004). *MDRAP. Guide regarding the design and execution of mini-pilots, indicative GP113-2004*, (p.44), Bucharest.
5. (2010). *MDRAP. Normative regarding the foundation of constructions on soils sensitive to moisture, indicative NP125-2010*, (p.54), Bucharest.
6. (2014). *MDRAP. Normative regarding the design of surface foundation, indicative NP112-2014*, (p. 155), Bucharest.
7. (2014). *MDRAP. Normative regarding the geotechnical documentations for foundations, indicative NP074-2014*, (pp. 31), Bucharest.
8. Stanciu, A., & Lungu, I. (2006). *Foundations - vol. 1 Physics and Mechanical lands*, Technical Publishing House, ch. 8, (pp. 1620), Bucharest.
9. Stanciu, A., Lungu, I., Aniculăesi, M., Teodoru, I.-B., & Bejan, F. (2016). *Foundations* - vol. I1 Investigation and testing of foundation lands, Technical Publishing House, ch. 1, ch.5, (pp. 965), Bucharest.
10. Tomlinson, M.J. (1974). *Design and execution of foundations*, Technical Publishing House, (pp.786), Bucharest.