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SPECIAL MONITORING OF THE SERVICE BEHAVIOUR OF A HERITAGE BUILDING IN ORDER TO REHABILITATE AND URBAN REINTEGRATION

BY

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Abstract. During the use of the existing building fund in Romania appeared degradations/damages due to the action of harmful environmental factors, settlements, etc. In these circumstances, the assurance of the safe exploitation of the construction is required as a first-rate necessity. This is possible following the conclusions of the special monitoring report (a survey activity of construction behaviour consisting in the measurement, processing, recording and systematic interpretation of the values of the parameters defining the safety, stability and durability requirements stipulated by the project or in the current norms).

The special monitoring was achieved through settlements measurements (by topographical methods - levelling), by mounting special devices (which measure the openings of the existing cracks in the masonry walls) and completed with the current monitoring of the technical state (presented by graphic and photographic degradation’s survey). Based on the results of the special monitoring programme, structural rehabilitation methods were recommended.

Keywords: structural monitoring; topographic methods; rehabilitation.

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1. Introduction

The cultural heritage of Iaşi County is in an accelerated process of degradation, being threatened with irreparable deterioration and loss due not only to the passing of time, but also to the major socio-economic changes in recent years. The protection and preservation of heritage is done by restoring monuments of national and local importance so as to become tourist attractions.

Problems occur when structures are not categorized as heritage buildings/historical monuments, but have a historically enviable value. Thus, the value of the fund built (and/or abandoned for various reasons) cannot be contested, a certainty being the potential for re-utilization of out-of-use buildings. The process of rehabilitation and conversion constitutes a viable, economically profitable alternative that advocates against demolition and reconstruction. Also, the current trend towards sustainability in the field of construction, favours the conservation and recycling of resources with the aim of reducing emissions of carbon dioxide and fuel.

During the use of the existing building fund in Romania (housing, social-cultural buildings, industrial, engineering, agro-zoo-technical, etc.), a series of degradation/damage has occurred due to the action of harmful environmental factors, settlements, explosions, landslides, embankments, functional or structural changes, height regime changing and, in particular, due to the action of requests from earthquake. As a result, numerous constructions no longer have the initial load capacity to be able to take on new demands of some degradation factors.

In these circumstances, the safety assurance of the deteriorated construction fund is required as a first-rate necessity. In the period after 1850, and especially after World War II, a large volume of housing constructions was achieved in Romania, with which to cover the needs of the birth increasing rate, the industrialization and urbanization process, as a particular result of the modernisation programmes of those periods.

In order to maintain conforming constructions, it is compulsory to achieve and maintain throughout the existence of construction, the following requirements under Law 10/1995 - Quality in construction:

a) mechanical strength and stability;
b) fire safety;
c) hygiene, health and the environment;
d) safety and accessibility in service;
e) noise protection;
f) energy saving and thermal insulation;
g) sustainable use of natural resources.

2. Building's description and its structural system

The purpose of monitoring consists in the rehabilitation and reintegration of the "Bagdazar" sports-hall, located in Iaşi, 14 Sărărie Street, a building owned by the "Gr. T. Popa" University of Medicine and Pharmacy Iaşi which is in an advanced stage of degradation.

During the nearly one century (since it was put into operation), the building has been affected by more than 14 major earthquakes. At the same time, the lack of construction maintenance (current / general), the condensation occurrence, the degradation of the physical and mechanical characteristics of the materials, the degradation of the soil (as a result of the rainwater infiltrations), the lack of hidro-insulation at foundations and, last but not least, the vibrations induced by traffic on the adjacent street have favoured the deterioration of the whole structure made by brickwork masonry.

Even if it no longer meets the requirements of rigidity and stability given by the actual norms, this building is still at the service stage, being used for almost a century as a gym building, the original destination being preserved to date.

The construction was carried out in the year 1923 with the destination of the gym, having a floor height regime, consisting of a main section and annexes.

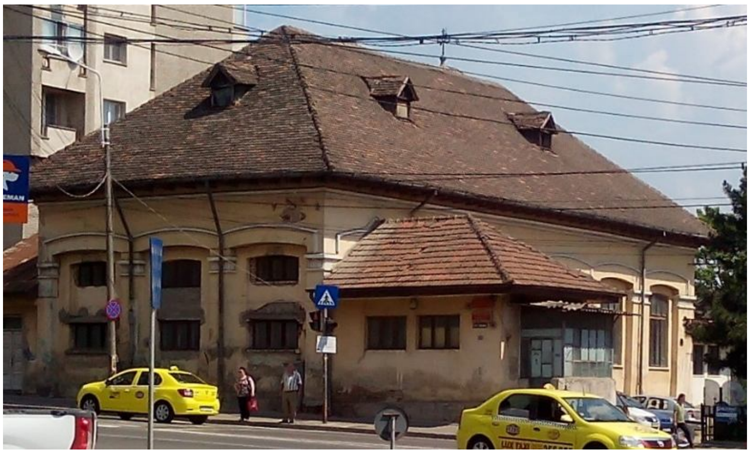

Fig 1 – "Bagdazar" Sports Hall - current perspective

The structure of the Gym Hall is as follows:

Infrastructure:

- Continuous foundations (made from stone masonry) over the brickwork masonry. Foundation depth is 1.20 meters.

Superstructure:

- Brickwork bearing walls with thickness of 50 cm and 30 cm;
- Brickwork partition walls having thicknesses of 12.5 and 30 cm;
- Structure is a bearing masonry without elements of confinement (reinforced concrete columns or belts);
- In the gym area, upper floor is at + 6.40 m and consists of wooden beams with clay-straw covering;
- Roof is made of wood with ceramic tile cover and galvanized sheet in the left side section
- Attic is made of pressed brick.

Extends over a total area of 385.23 m^2 and has 3 entrances (Fig. 2,...,5). Considering its function, it requires a large amount of natural light, thus the glazed spaces constitute a percentage of almost 50% of the surface of the southern wall.

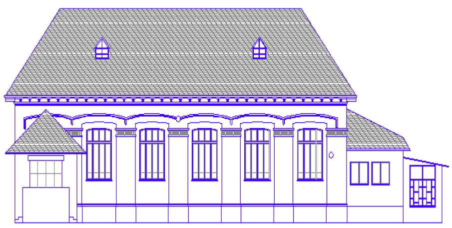

Fig. 2 – South façade.

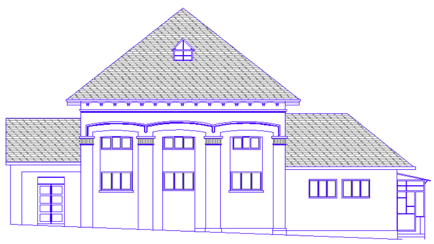

Fig. 3 – North façade.

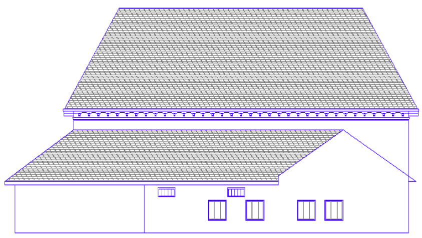

Fig. 4 – West façade.

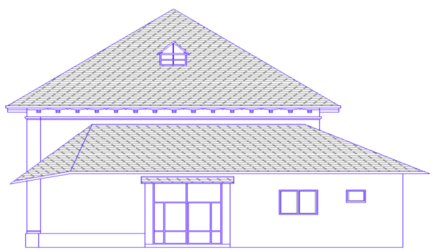

Fig. 5 – East façade.

3. Special Monitoring of the Analysed Structure

Special monitoring is a task's list with the main purpose to evaluate the structure's behaviour consisting of the systematic measurement, recording, processing and interpretation of the parameters values defining the extent to which the constructions maintain their safety, stability and durability from the project.

The objectives of the special pursuit are:

1. Ensure the safety and stability due to structure lifetime, through timely detection of dangerous phenomena and areas where they occur;

2. Surveillance of the evolution of foreseeable phenomena, with possible adverse effects on operating skills and on conditions for ensuring the strength and stability requirements of construction;

3. Operational alert for the attainment of the warning criteria or limit values given by the measuring and control devices;

4. Identification of the limits to which existing degradation (fissures and cracks in the walls of masonry, dislocations and fractures of foundations, settlements of the ground foundation) develops an evolutionary character.

Special monitoring was carried out by the settlement's measurements by topographical methods (levelling method), by mounting on the walls of the openings witnesses to the existing cracks (rulers) in masonry walls and was supplemented with the current monitoring of the technical condition (presented graphic mapping and photographic manner).

The special tracking activity will be permanent until the goal is abolished.

3.1. Settlements Monitoring by Topographic Procedure

The construction monitoring and deviations from verticality by topographical methods consists of measuring the position's modification of isolated points (rigid fixed into the construction's walls), materialised by settlements benchmarks (*mobile landmarks*) related to the reference points (*fixed benchmarks*) located outside of the area with potential to be settled.

The mobile landmarks were installed as follows: two landmarks on the South façade (M1 and M2) and two other landmarks (M3 and M4) on the western façade of the building. The landmarks, made of steel OL50 (Fig. 6), were reported at a fixed F1 landmark, mounted on the reinforced concrete column near the south-east corner of the building. For this column, it is considered that there is no risk of settlement.

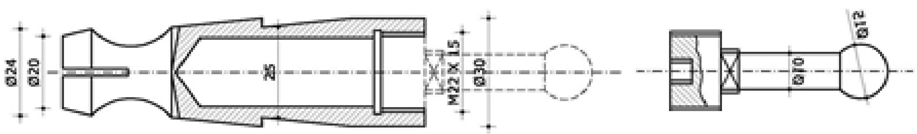

Fig. 6 – Mobile landmark.

The landmarks were mounted at approximately 1.20 m height, measured from the level of the landscaped terrain, so that the topographical stadia could be easily placed on them. The M1 marker was mounted on the intermediate masonry columns because in its area it was found the sharp detachment of the foundation ground.

The M2 landmark, mounted on the same façade, was intended to demonstrate whether the identification of the settlements in the right of the masonry column in which M1 was mounted, are local or general. The M3 and M4 landmarks were mounted on the corners of the western façade, areas prone to settlements (Fig. 7).

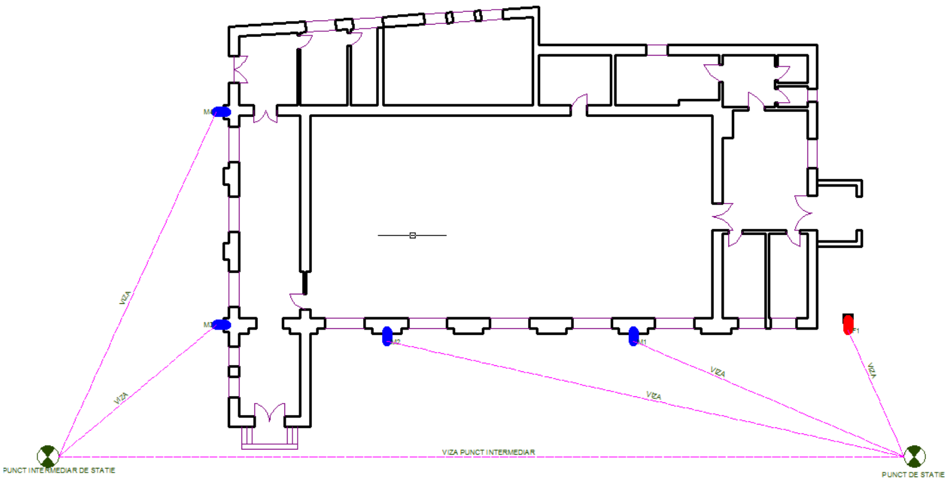

Fig. 7 – Mobile and fixed landmarks placement draft

3.2. Making Measurements with Digital Levelmeter

The deformations monitoring of a construction due to foundation ground's deterioration, by topographical methods, is to measure the modification of the quotas/level of isolated (fixed) points by reporting to reference point. Measurements were carried out over a period of 3 years, during periods when the temperature (at the time of measurements) did not exceed 22°C (spring, autumn).

The precision levelling method has been chosen in the closed circuit. It was applied the geometric level II procedure, using two station points by transmitting the ±0.00 m level (assigned to the F1 marker) at the first station point S1 (for determining the relative level of M1 and M2), as well as to the second S2 station point (for determining the relative level of M3 and M4).

Table 1
Registered Vertical Displacements for Each Mobile Landmark

Aimed points	Level reference RN	M1	M2	M3	M4	Measurement date
Relative level [m]	0.000	–0.551	0.310	–0.281	–0.491	Oct. 2014
	0.000	–0.552	0.309	–0.283	–0.493	Jun. 2015
	0.000	–0.560	0.312	–0.289	–0.498	Oct. 2016

Vertical displacements (2 ÷ 9 mm) of the landmarks on the left side façade – the inner courtyard (M1 and M2), as well as 7 ÷ 8 mm of those on the posterior façade (exposed to car traffic vibrations) M3 and M4, was found.

3.3. The Cracks Evolution Monitoring

Cracks monitoring devices (Fig. 8) mounted in June 2014 were checked and photographed in order to identify the evolutionary character of fissures / cracks. The devices were mounted in position 0 both vertically and horizontally (the intersection of the two systems of orthogonal axes), fixed by four dowels and hallway screws of 100 mm.

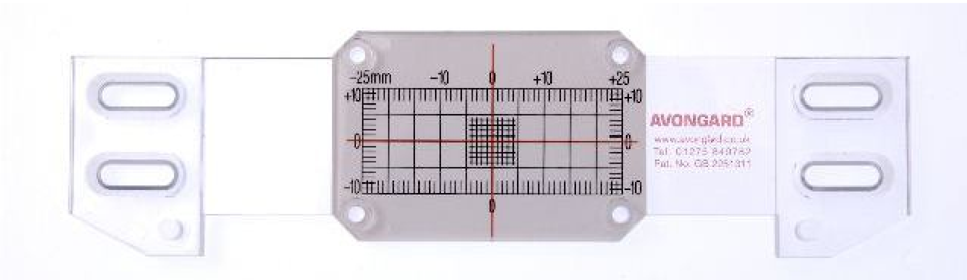

Fig. 8 – Cracks monitoring devices (ruler) “Tell-tale” type

The location of the rulers was the following (Fig. 9):
- On the main façade were mounted two devices (rulers), one on the vertical fissure-inclined from the top of the window gap and a device on the vertical crack that starts from the base of the roof beam;
- On the left side façade, a device was mounted on the vertical fissure in the masonry column adjacent to the window gap;
- On the posterior façade, were mounted to the masonry column adjacent to the window gap and on the crack at the top of the window gap;

A total of 9 rulers have been mounted.

Fig. 9 – Rulers placement to cracks evolution’s monitoring.

By interpretation of the variations recorded by the mounted devices, it can be concluded that the cracks were of an evolutionary nature (from 3 to 11 mm), this being possible due to the advanced state of degradation, the vibration induced on infrastructure and, obviously, onto the walls of the structure due to road traffic from proximity and the decrease in the characteristics of the foundation ground (water infiltrations).

4. Assessment of the Deterioration Technical State of the Building Analysed from Functional and Structural View-Point

For the assessment of the technical condition of degradation of the structure analysed (functionally and structurally), it was considered the analysis of the damages, deteriorations and non-conformities of the building, as well as the determination of the causes that led to its occurrence.

The degradation of construction falls within the classical typologies of the specific damage to the old constructions of the full brick masonry:

- the degree of structural damage **R2** was evaluated, placing the construction in the 2nd degree seismic risk;
- the degree of structural seismic insurance **R3** was evaluated, framing the construction in **A class at seismic risk**.

The main relevant degradation was:

- Vertical, inclined and horizontal fissures and cracks on the masonry walls at all four facades, depending on the bearing capacity due to seismic actions (Fig. 10);
- Cracks around the gaps of doors and windows, due to the fact that these areas are concentrated areas of tension in the building's strength structure (Fig. 11);

Fig. 10 – Inclined cracks on the masonry wall.

Fig. 11 – Fissures over the lintels (where are present).

- Vertical cracks in the walls of the building to the openings due to lintels absence (Fig. 12);
- Detachments of exterior plasters (local and extended areas); the lack of thermal insulation determines the formation of dew point at the level of plasters, and in the presence of low temperatures, by increasing the volume of water due to frost, expels plaster (Fig. 13);

Fig. 12 – Vertical cracks in masonry parament.

Fig. 13 – Plaster detachments.

- Detachments of the socle due to wetting by raising the level of groundwater and the penetration of surface water, but also of frost-thaw cycles (Fig. 14); The lack of waterproofing caused the occurrence of the gelivity phenomenon. The upward migration of water led to the expulsion of plaster from the socle and the walls;
- Crushes and breakdowns of the socle bricks due to faulty evacuation of rainwater. Under the self-weight of the brick masonry pillar, the bending phenomenon in the socket is observed (Fig. 15);

Fig. 14 – Detachments of the socle.

Fig. 15 – Crushes and breakdowns of the socle bricks.

- The annex building (without seismic joints) and in the event of an earthquake the two structures would not independently oscillate, the annex would induce adjacent horizontal forces on the walls of brick masonry (Fig. 16);
- On the western façade, non-compliant attempts can be observed to embed the lintels, which already shows the displacements (probably due to the lack of the reinforcement), and the supporting area is too small (Fig. 17);


Fig. 16 – The annex building (without seismic joints).


Fig. 17 – Non-compliant attempts to embed the lintels.

- Infiltrations of water to the socle and cornice due to snow thawing and non-compliant drainage of rainwater (Fig. 20);
- Settlement of the foundation ground, demonstrated by local fractures and failures identified at the façade socle (Fig. 21);


Fig. 20 – Infiltrations of water to the socle.


Fig. 21 – Rainwater infiltration.

- Water infiltrations at the level of the straw floor (clay-knit reed) due to the degraded roof and gutter (Fig. 18);
- Vertical cracks present inside the building at the level of non-bordered gaps (Fig. 19);

Fig. 18 – Water infiltrations in the straw.

Fig. 19 – Non-bordered gaps.

- Settled and non-waterproof sideboards that allow rainwaters to access the infrastructure (Fig. 22);
- Cracks in the walls due to the lack of uneven belts and unequal soil‘s settlements (Fig. 23);

Fig. 22 – Settled and non-waterproof sideboards.

Fig. 23 – Major cracks under the roof.

Based on the records from the special monitoring report of the Bagdazar Gym building, presented above, it is found that the degradation state of the construction was amplified between 2014 ÷ 2016 and continue. This phenomenon is supported by:

- the emergence of new cracks,
- the evolution of cracks identified in the year 2014 (described by the devices mounted on the façade of the building) and
- the variation of the position of the settlement landmarks mounted in the exterior walls.

5. Identification of the Causes that Produced Damage, Degradation, Crashes

Excluding the degradation of masonry structures as a result of design and execution mistakes, the main causes of the deterioration of the masonry structure analysed were:

- Degradation of physical and mechanical characteristics of materials due to the passage of time (bricks and connecting binder);
- Lack of construction maintenance (current/capital) and the occurrence of condensation phenomenon, which implicitly leads to the degradation of materials used in the composition of the structural system;
- Degradation of the foundation ground as a result of rainwater infiltrations, losses from supply or sewage installations, lifting of groundwater level or their paths due to new constructions on the neighbourhood;
- Lack of waterproofing at foundations lead to the production of the frost phenomenon in brick masonry and mortar, which occurs due to the internal tensions that arise as a result of the increase in the volume of frozen water (approx. 9%) in the pores and cracks, leading to increased water permeability, weight reduction, mechanical strengths and elasticity modulus;
- Permanent action of natural factors: gravity, growth of the vegetal layer, atmospheric agents, meteoric waters, temperature differences between day and night and between seasons (freeze-thaw cycles), winds, tainted atmosphere, underground waters, biological factors (bacteria, mushrooms, moss, lichens);
- Seismic actions (the more than 14 earthquakes of which the structure was affected);
- Vibrations induced by traffic on the adjacent street favoured the emergence and development of cracks at the level of the load-bearing walls of the socle.

6. Elimination Methods of Deterioration/Damages and for Increasing the Resident's Safety

Following the evaluation outlined above, it is necessary to strengthen the Bagdazar gym building or, in extreme case, even demolishing it. The magnitude of the degradation caused by uneven settlements, environmental actions and repeated seismic actions require special attention to be given to the remediation and consolidation of the analysed construction, having in view its function of protection of large crowds of people (children attending the hours of "physical education", courses taking place in the building's premises).

Urgent interventions are necessary, in particular in solving the rehabilitation of energy absorption capacity and rigorous avoidance of the emergence of deformations, ceding to accidental and seismic actions.

The proposed consolidation solutions of the degraded building are:

Foundation:

- Injection of large cracks with cement solution;
- Thermo-insulation and waterproofing at the foundation level;
- Total replacement of the perimeter sidewalk around the building (Protection of the foundation against meteoric water. The newly realized sidewalk will have a length greater than the cornice to ensure the waters removal);

Walls:

- Injecting the cracks in masonry walls;
- The sewing and restoration of masonry on the fractured areas and where the brickwork's crushes occur;
- Strengthening the bearing walls of brick masonry, using composite materials reinforced with FRP glass fibre, both on the inside and on the outer part of the walls;
- The embedment of the structural anti-seismic elements of reinforced concrete:
  - Lintels over the gaps
  - R.C. corner-columns
  - The introduction of a rigid plate (a reinforced concrete floor across the ground) capable of transmitting horizontal actions in the vertical elements of the structure, with the role of unifying and coordinating the movements of the structure, ensuring the plate's rigidity in horizontal plan
- Thermo-insulated (with mineral wool):
- Replacing the damaged straw floor with a R.C. floor (thermoinsulated);
- Replacement of the strength elements of the rooftop framework (fire protected);
- Replacing ceramic tile coatings with bituminous membrane (2 layers) mounted on wood;
- Installation of a system for the collection and evacuation of water (gutters and spouts).

Taking into account the environmental protection legislation, thermal rehabilitation with eco-sustainable materials using hemp, cellulose, sheep wool mattresses or soy foam is proposed. At the same time, thermal protection can be increased by mounting in the glazed spaces of the laminated wood carpentry with tri-panel glazing. This dual-role method, also ensuring sound protection, necessary due to the intense traffic carried out on next street.

After decoying wooden floors, all structural elements of degraded timber will be identified, for their consolidation or in full replacement with new elements capable of satisfying the requirements of strength and stability according to the rules.

For the elimination of the cause of degradation of the foundation ground it is necessary to provide the underground channels for sewage drainage ducts, repair of the spouts and execution of the sidewalks of the building for the removal of rainwater. Foundations retrofitting will be executed in areas where cracks penetrate to the foundation.

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URMĂRIREA SPECIALĂ A COMPORTĂRII ÎN EXPLOATARE A UNEI CLĂDIRI DE PATRIMONIU ÎN VEDEREA REABILITĂRII ŞI REINTEGRĂRII URBANE

(Rezumat)

Pe parcursul utilizării fondului de construcții existent în România au apărut degradări/avarii datorită acțiunii unor factori nocivi de mediu, tasări, etc. În aceste condiții, punerea în siguranță a fondului de construcții care prezintă avarii se impune ca o necesitate de primă urgență.

Acest lucru este posibil ca urmare concluziilor raportului de urmărire specială. Urmărirea specială este o activitate de monitorizare a comportării construcțiilor care constă din măsurarea, înregistrarea, prelucrarea şi interpretarea sistematică a valorilor parametrilor ce definesc măsura în care construcțiile îşi mențin cerințele de rezistență, stabilitate şi durabilitate stipulate din proiect sau în normativele actuale.

Urmărirea specială s-a realizat prin măsurători ale tasărilor prin metode topografice (metoda nivelmentului), prin montarea de martori de deschidere a fisurilor existente (riglete) în pereții de zidărie şi a fost completată cu urmărirea curentă a stării tehnice curente (prezentată sub formă de releveu grafic şi fotografic al degradărilor). În baza rezultatelor programului de urmărire specială s-au recomandat metode de reabilitare structurală.