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CONSTRUCTION CONDITION ASSESSMENT – WHY AND HOW?

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Abstract: *The construction Condition Assessment falls in the responsibility of constructed facility owners, administrators and users, according to the provisions of Law 10/1995 regarding quality in construction. In this respect, this activity is a component of the Construction Quality System, as it is defined by the law. The main intended purposes of Condition Assessment refers to providing information about the condition of the building (actual performances of the building components), identifying eventual strengthening or repair works that have to be carried out and emphasizing critical problems, or other similar conditions which need to be addressed immediately. This paper presents the most important outcomes of the latest studies of the authors concerning condition assessment in case of three main categories of buildings: gas stations, hospitals and learning facilities of Technical University of Iasi.*

Key words: *Construction Condition Assessment, quality, strengthening, maintenance.*

1. Introduction

The performance loss of any construction element can be quantified and characterised in terms of its degradation extent [15]. The concept of degradation / deterioration in the field of civil engineering refers to any negative change in the physical, chemical or mechanical characteristics that may affect the strength, stability or durability of a material, element or built ensemble [5]. Also, the degradation/deterioration process of a building element, depending on its size, may be associated with diminishing or even loss of its performance degree during the in-service stage. The causes of the deterioration process may be natural (earthquake, temperature variations, wind, rain, etc.), but can also be caused by human errors (design or execution errors, lack of maintenance work, explosion) or by the anthropic changes of the environment (landslides as a result of massive deforestation or excavations adjacent to existing buildings) [2, 16].

There are various degradation factors in the service state of a construction, each having a different influence, which emphasises the need for constant evaluation and

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monitoring of the buildings' condition. The condition assessment for buildings is a concept that emerged towards the end of the 20th century, which synthesizes the performance that constructions have to meet in terms of quality requirements and costs in all stages of the building process [6]. By implementing regular inspection programs for buildings in the service state, the minimum conditions are met with regard to the extent to which the construction, as a whole or its components, meets the specific quality requirements that have been set at the design phase – both the project specifications and the regulatory documents [1, 8]. In order to identify any existing damages and to obtain the most accurate results, specific methods and equipment are used, requiring personnel with good knowledge of the principles and regulations of their application (both in terms of principles and equipment).

The first part of the article briefly presents the legal requirements that are active in Romania regarding the activity of condition monitoring of buildings. In the second part of the paper, some case studies are presented concerning the activity of condition assessment performed by the authors in case of three main categories of buildings: gas stations, hospitals and learning/education facilities.

2. Construction Condition Assessment

2.1. General aspects

The condition assessment is a defining activity in the building service stage that aims to identify, even from the early stages, any degradations or nonconformities that can produce partial or total loses in the performances of the construction elements or components. The condition assessment activity triggers specific responsibilities for all parties that are involved in the construction process: investor, owners, users, public authorities, designers, contractors etc. A condition survey can be conducted only by licensed engineers and the activity consists in the following steps:

a) review of the existing technical documentation – for a better understanding of the structural system, the materials that have been used, the degradation factors etc.;

b) on-site inspections – the engineer uses simple inspection equipment and the collected data is analysed and summarized in a brief report, presenting any existing deficiencies/damages both with the corresponding intervention measures;

c) report conclusions – if damage extent is evaluated as significant, thus affecting the structural safety , the engineer will recommend a detailed investigation, based on more complex methods and equipment, or even a technical expertise. Otherwise, the condition assessment report will present the interventions that are necessary to correct the minor degradations or deficiencies that were identified.

2.1. Condition assessment in Romania

Condition assessment of buildings is one of the 15 components of the quality system in construction, regulated in Romania by Law no. 10 of 1995 concerning the construction quality, republished with its subsequent amendments (Fig. 1). The procedure of carrying out this activity is presented by the regulatory document P130 / 1999. From a legal point of view, the first step towards the implementation of this activity coincides with introducing Law no. 8 concerning the durability, safety in operation, functionality and quality of constructions in 1977, which included the obligation to carry out condition assessment reports. Subsequently, in 1988 the first version of the regulatory norm P130 was published, which focused exclusively on the condition assessment of buildings. This norm was updated many times through the years and the last version was published in 1999, when it was correlated with the new quality system in Romania, stated in Law no. 10 [7]. Also, the condition assessment activity is regulated by the Government Decision no. 766/1997 "Regulation regarding condition monitoring, interventions in time and the post-use of constructions".

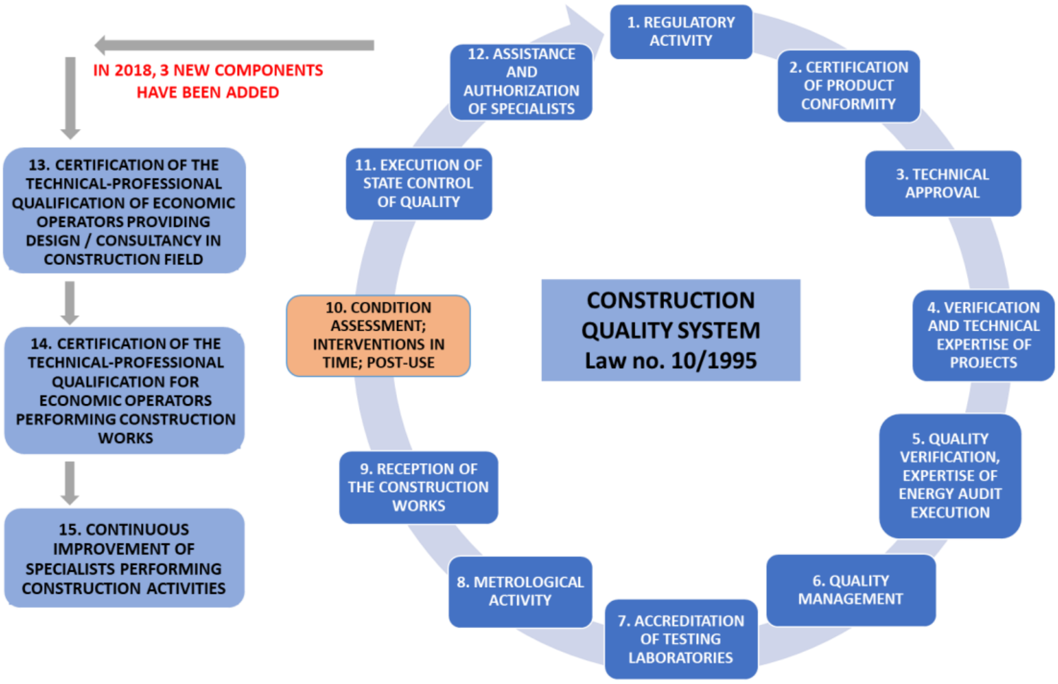

Fig. 1. Construction quality system in Romania [7]

According to the active Romanian norms, condition assessment activity is mandatory for almost all constructed facilities, with a few exceptions, regardless of their class or category of importance. This activity is stated as an obligation of the owner or the user of the construction and is carried out throughout its lifetime in the form of periodic checks carried out in accordance with the technical regulations.

The condition assessment activity is classified into two main categories: current and special condition assessment. The current condition assessment of a construction is a systematic activity for the observation and recording of events, aspects or parameters that may demonstrate any changes in the ability of the building to satisfy the basic quality requirements, as stated by [11]. Building owners are required to appoint licensed engineers in order to ensure the condition assessment activity with a frequency of at least once a year and after each special event (earthquake, flood, fire, explosions, etc.). This activity has another component, extended current condition assessment, applied in the case of slightly damaged elements or hazardous processes, by using more complex destructive and non-destructive techniques.

The special condition assessment consists in the measurement, recording, processing and systematic interpretation of the parameters that define the extent to which constructions maintain their essential requirements established by the projects or by the regulatory documents (Table 1). The frequency of the investigation process (temporary or permanent), the methodology and the necessary equipment are established by a specific technical documentation, according to the parameter which is monitored. This type of activity may be applied for a part of the construction (an element or a sub-system) or for the whole ensemble. The special condition assessment is applied in the case of the following buildings:

a) new constructions of special or exceptional importance, established by the project;
b) new buildings, during the erection stage, decided by the designers or imposed by technical norms;
c) existing buildings, during the consolidation or extending stages, decided by the designers or imposed by technical norms;
d) damaged constructions in the service state with a hazardous/dangerous evolution, recommended by the results of a technical expertise or current extensive monitoring report;
e) new or existing buildings, in the service state, at the special request of the owner or of the public authorities.

Essential quality requirements in construction [7] Table 1

Symbol	Essential quality requirement	
	1995 – 2007	2007 - present
A	*Strength and stability*	***Mechanical strength and stability***
B	*Safety in use*	***Fire safety***
C	*Fire safety*	***Hygiene, human health, restoration and environmental protection***
D	*Hygiene, human health, restoration and environmental protection*	***Safety in use***
E	*Thermal, waterproof insulation and energy saving*	***Noise protection***
F	*Noise protection*	***Energy saving and thermal insulation***

3. Case Studies

The condition assessment is a compulsory activity that aims to identify and correct any degradation / deficiencies that may arise in the capacity of the building elements to fulfil their specific quality requirements. The authors have been involved in various projects regarding the condition assessment of buildings. The most important outcomes of these projects are briefly presented in the following subchapters.

3.1. Current condition monitoring of fuel stations

The fuel stations belong to the industrial building category, having specific components: fuel tanks, fuel pump islands, convenience store, oil-water separators and utilities etc. [10]. Also, other components can be identified, such as: signalling elements (totem display and / or totem logo), car wash (adjacent to or separated from the convenience store), LPG skid, overhead canopy, dining areas and customer terraces etc.

The study presents the most important results that were obtained by performing the current condition assessment for 149 fuel stations located in Romania [4]. For the condition assessment of every fuel station, the first step was to verify the technical documentation, in order to identify the structural system and the constructive particularities. Secondly, on-site inspections and checking have been done. After the identification of specific features for the each station, investigation tables have been made, structured on three levels (Fig. 2). Level I corresponds to the main components (fuel pump islands, convenience store, fuel tanks etc.). The second (II) level of investigation divides each main component into different parts (example: structural system, envelope elements, partitioning elements, insulations etc). Next, depending on the complexity of the component that is inspected, the third (III) level of investigation sub-divides the parts into construction elements (suitable only for components of high complexity). Each investigation table consists of specific damages or degradations that are related to the particularities of the inspected element.

Fig. 2. *Investigation levels for a fuel station*

In order to present the results of the condition assessment activity, the most representative components were selected, whose degradation may have a significant impact upon the service state of the fuel station (convenience store, car wash, investigation pits of the underground fuel tanks, overhead canopy, pump islands, the fuel discharge pit and the ventilation pipes, the oil-water separator and the platforms). The damage extent, was classified according to its impact in four levels, denoted I-IV, as it follows:

- the first level (I) corresponds to construction elements that are not damaged, thus fulfilling the quality requirements;
- the second level (II) corresponds to those elements with minor and local damages, that don’t significantly affect the quality requirements;
- the third level (III) is specific to those elements with significant, generalized and progressive damages or decay processes that can affect the quality requirements (mostly the general or local strength / stability conditions);

- the fourth level (IV) corresponds to elements with major damages / defects requiring immediate interventions, or complex investigation to determine if those elements / sub-components can still be safely used.

The results for the most representative components of the investigated fuel stations are presented in a graphical form in Figures 3-5 and the investigated damages / defects are briefly summarized in Table 2.

Defects / damages corresponding to each deterioration level *Table 2*

No.	Fuel station component	Deterioration level			
		I	II	III	IV
1	Convenience store	no damages	footway local settlement, fissures, deteriorated finishing layers	rain water infiltration, structural elements defects	Structural cracks, excessive deformation, local failure
2	Car wash				
3	Inspection pits of the underground fuel tanks	no damages	sealing gasket defects, deteriorated finishing layers, fissures	destroyed sealing gasket, wall deformation, deteriorated lid	excessive deformation, lack of elements, water accumulation
4	Overhead canopy and pump islands	no damages	deteriorated finishing layers, fissures in the pump base	insufficient concrete cover, rain water infiltration, cracks	excessive deformation, lack of elements, local failure
5	Fuel discharge pit and ventilation pipes	no damages	deteriorated finishing layers, fissures	insufficient concrete cover, rain water infiltration, cracks, slightly deformed pipes	excessive deformation, lack of elements, water accumulation
6	Platforms	no damages	local settlement, fissures, gutter defects	cracks, settlements, generalized exfoliation, impractical gutter,	generalized settlements, pavement fracture
7	Oil-water separator	Separator is periodically purged	Separator is not periodically purged	absence of the separator	-

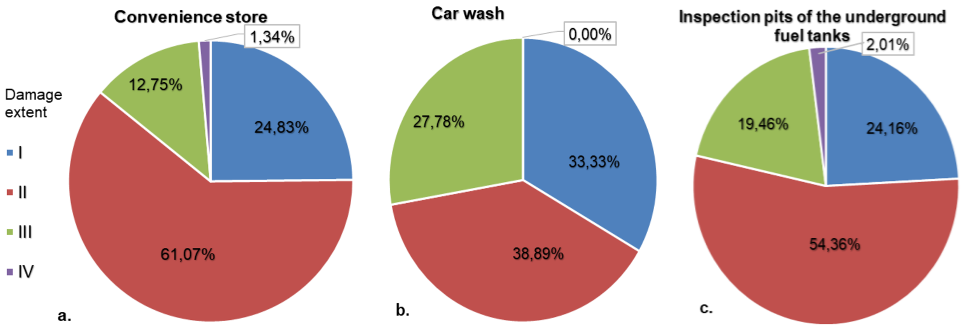

Fig. 3. *Results of the condition assessment activity: a) convenience store; b) car wash; c) inspection pits of the underground fuel tanks*

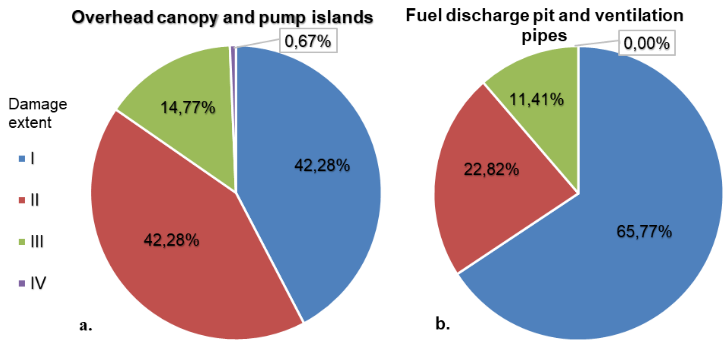

Fig. 4. *Results of the condition assessment activity: a) overhead canopy and pump islands; b) fuel discharge pit and ventilation pipes*

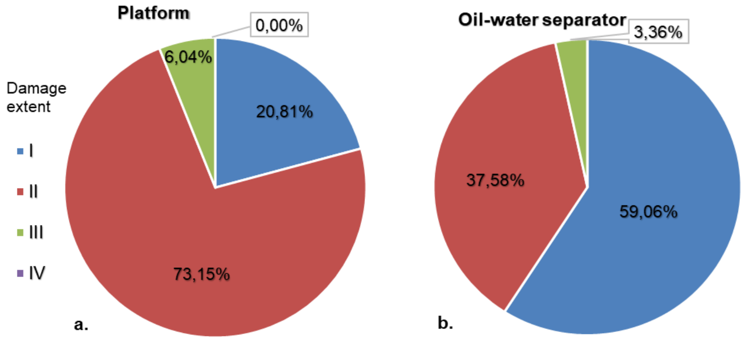

Fig. 5. *Results of the condition assessment activity: a) platforms; b) oil-water separator*

149 fuel stations have been investigated in order to elaborate the condition assessment reports. In this respect, investigation tables have been elaborated, for the seven of the most representative components. Most of the fuel stations components have no damaged elements, thus fulfilling the quality requirements. The identified damage extent of the components corresponds mainly to the minor defects category, having a local extension (level II) and do not directly affect the quality requirements, according to their specific purpose. Among the causes underlying the second level damage extent are: natural degradation of materials, exceeding the normal operating time for some of the protection and finishing layers, lack or failure to perform on time maintenance and repair works, the quality of the intervention works and the used materials and, respectively, the lack to apply the repair measures recommended in the condition assessment reports etc.

The high percent of defects corresponding to the IIIrd level was identified at the car wash, mainly due to the applied technical solution: jet wash stand with vertical structural elements and without any closing elements at the roof level. A very low percent of the investigated elements had multiple, generalized defects (IVth level), affecting the quality requirements, and thus, the normal functionality of the fuel station. For the latter situations, intervention measures have been recommended: complex investigation and safety evaluation, immediate intervention works and replacement of the damaged elements.

3.2. On site environmental noise level measurement

For this case study, the authors aimed to extend the aria of investigation of the construction global quality taking into consideration, apart from *"Mechanical strength and stability"* requirement**,** also the *"Noise protection"* essential requirement. For this purpose, several building located in Iași have been selected, both hospitals and learning facilities of Technical University. The first step of the study has been the selection of some common functional units, by taking into account the destinations of each building. The measurements have been carried out according to both standards: SR 6161-1/2008 - *"Building acoustics. Part 1: Noise level measurement in buildings. Measuring methods"* [13] and SR ISO 1996-2/2008 - *"Acoustics – Description, measurement and assessment of environmental noise. Part 2: Determination of environmental noise levels"* [14].

For the assessment of the inside environmental noise, a second class sound level meter and calibrator have been used. The sound level meter has been placed in 5 up to 10 points inside the functional unit, according to the internal volume of the space [9]. The case studies aims to assess the environmental noise level within certain types of functional units inside buildings and to compare the on-site measured values with the reference ones. Figure 6 presents the recorded noise values within 2 bed hospital words inside three hospitals, while the Figure 7 presents the measured values within the classroom of three learning facilities. Within the graphs, the allowable noise level value according to the regulatory document C125-3/2013 is represented with a blue line (30 dB(A) for the hospital ward with two beds and 35 dB(A) for classrooms, respectively, according to [3]).

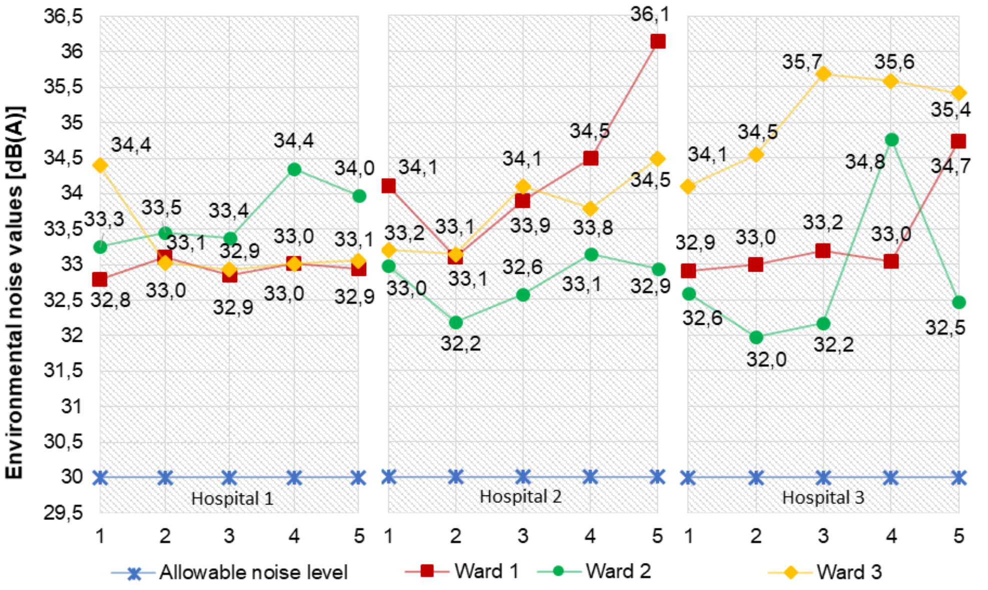

Fig. 6. Recorded environmental noise level values - 2 bed hospital ward [9]

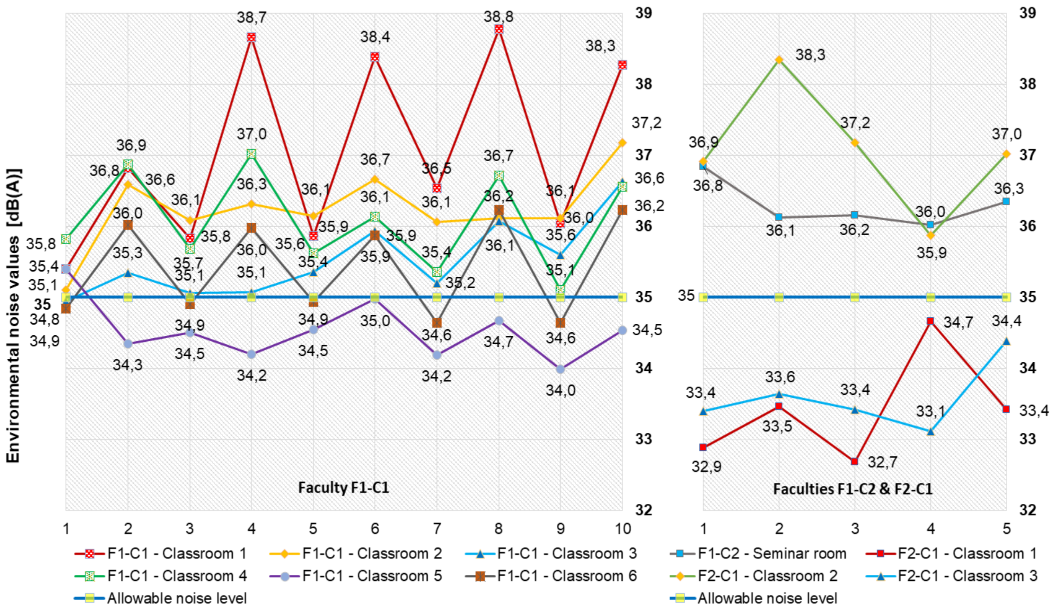

Fig. 7. Recorded environmental noise level values - classrooms inside learning facilities

By analysing the noise level values recorded inside the functional units, it can be concluded that the measured values exceed the allowable limits, for almost all the investigated units. The higher differences were recorded in the case of the 2 bed hospital ward because this type of functional unit needs specific acoustic design treatments in order to obtain the 30 dB(A) limit, for the patient rest and recover.

For the classrooms within learning facilities, inside the functional units positioned near facades adjacent to public street higher environmental noise values were obtained, mainly due to traffic noise. The main noise sources are the traffic noise (vehicle and tram movement, horns, emergency vehicles hooter) and the background noise.

In order to increase the acoustic characteristics of the construction envelope and partitioning elements, some improvements can be recommended, for increasing the absorbed sound energy. These intervention works can be applied both at the interior part of the functional units (sealing gasket replacement, replacing the actual finishing layers with some porous ones, using acoustic absorption boarding, replacing the existing exterior doors and windows with ones having increased acoustical properties) and at the exterior of the building (use of layers with silent road wear – porous asphalt, increasing the distance between the street and the building – in case of new constructions and usage of green barriers in the space between the street and the building).

3.3. Special condition monitoring of St. Nicolae Aroneanu Church

The Saint Nicolae Aroneanu church was erected in 1594 and the structural system consists of 1.20 m thick brick masonry walls, supported at the ground level by continuous footings made of raw coarse stone blocks, bounded with lime mortar (1.60 m depth). The church arches, domes and pendants are made of bricks. The structure of the church was severely damaged during on-service stage and, in order to assess the damage extent, on-site investigations have been made. Important damages were discovered: general longitudinal fractures, consecutive transversal fractures at the porch, nave, narthex, and sanctuary level and the porch walls tended to separate from the narthex. These damages correspond to a typical damage mechanism for the orthodox churches [12].

The damage extent of the structural system of the church enforce the development of a rehabilitation plan and, in the case of the St. Nicolae Aroneanu church, it was established that the traditional strengthening solution could not be applied. Instead, the base isolation solution was a suitable approach, consisting in decoupling the structure of the church from the ground. In order to apply the technical solution, a reinforced concrete structure was erected, consisting of a raft foundation below the existing foundations, a r.c. carrying frame underneath the perimeter footway and a r.c. slab over the carrying frame. The base isolation system is being composed of 48 friction pendulum sliding (FPS) isolators that are installed between the raft foundation and the carrying frame. The technical documentation of the church rehabilitation was designed by conf. dr. eng. Ionel Gosav, member of the Department of Concrete, Building Materials, Technology and Management, from Faculty of Civil Engineering and Building Services of Iași.

During the construction works, two condition assessment systems have been proposed. The first system has a very high precision (error of 0.01 mm) and it was designed for the load transfer stage, when the superstructure is decoupled from the foundations. It consists of 48 linear variable differential transformer (LVDT) instrumented to the hydraulic jacks that are used for the lifting of the church structure. The LVDTs are connected to an acquisition system, aimed to constantly record any displacement between infrastructure and superstructure, along the entire base isolation process.

The second system is an auxiliary one, and it was designed to monitor the displacement and settlement of the church structure. The first component of the system consists of 10 steel reference marks (denoted by RM1 ÷ RM10) socketed in the r.c. elements at the stone foundation level, both at the base and at the top. The second one is composed of 4 steady reference marks (denoted by RS1 ÷ RS4) being installed in the perimeter of the church (Fig. 8). The steady reference points consists of 4 r.c. piles, drilled and casted, having 30 cm diameter and a depth of 7 meters. At the top of each pile, steel reference points were installed.

The base isolation process starts with the erection of the r.c. carrying frame and of concrete straps that cross the existing stone foundations (for the FPS isolators placement). In the following stages, the transverse r.c. straps are executed (that are used for the temporary support of the hydraulic jacks) and also, the raft foundation and the perimeter foundation beams are completed. Next, the FPS isolators are installed (Fig. 8), levelled, but not loaded. Before decoupling the superstructure from the infrastructure, the value of the LVDTs and the position of the socketed steel marks were recorded. These values correspond to the original position of the church and have been considered as the equilibrium reference values during the entire base isolation process.

The structure was lifted progressively with successive rising of 1 mm, up to the maximum value of 25 mm, bringing the structure to a horizontal equilibrium position. The loads will then be transferred to the isolators and during the lowering of the structure, the pressure in the hydraulic jacks was constantly correlated with the displacement values provided by the LVDTs. Previously, after the load has been entirely transferred to the isolators, a final horizontal position check was made, both using the LVDTs and the survey method. The actual recorded values were compared to those considered reference equilibrium values, and the deviations ranged between -0.25 and +0.30 mm.

The previously mentioned systems were designed and implemented during the base isolation of the St. Nicolae Aroneanu church, the only heritage church building that has been base isolated, in Romania, and one of the few worldwide. After the rehabilitation works have ended, an additional monitoring system was instrumented, designed to verify the real behaviour of the building during service stage.

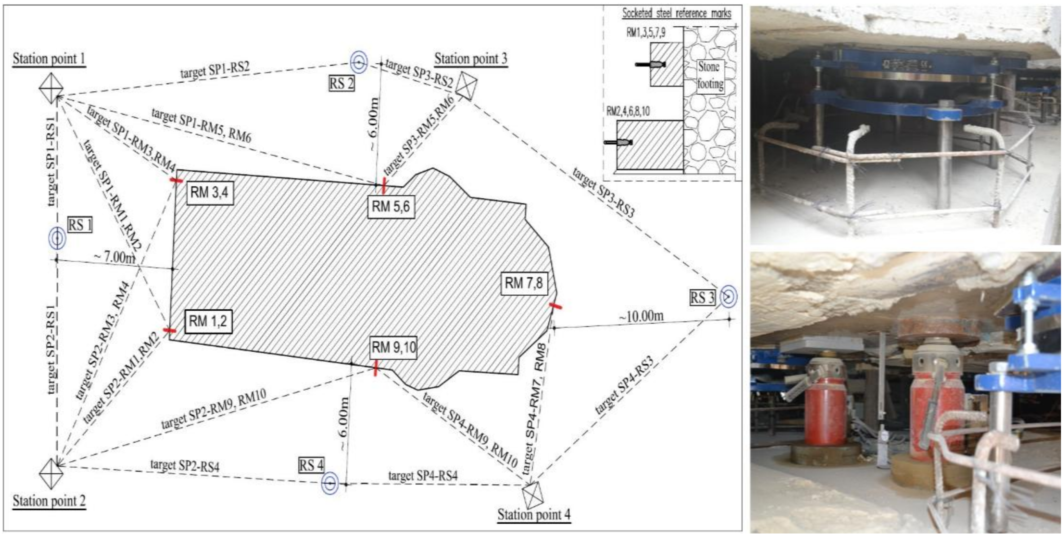

Fig. 8. *Displacement and settlement monitoring system; FPS supports and hydraulic jacks*

4. Conclusions

The first part of the paper briefly presents the legal requirement regarding the activity of condition assessment of buildings in Romania, while in the second part, the most representative results are presented, summarized from the case studies performed by the authors in the case of three main categories of buildings: fuel stations, hospitals and learning facilities.

In Romania, the necessity of assessing the condition of buildings, as a component of the quality system provided in Law 10/1995, is not generally approached by any of the parties involved in the construction industry. This paper aims to emphasize the importance of the activity, starting even from the early design phases of the construction projects, being applied during the erecting stages and, especially, being carried out along the entire service life of the buildings. Enhancing the general awareness regarding the importance of monitoring the condition of existing buildings should be considered as a national priority, since the final outcome consists in improving the quality of the built environment and, even more important, in increasing the safety degree for direct and indirect users of buildings.

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