Assessing the technical condition of unfinished or temporarily out-of-service large-panel buildings

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ABSTRACT

This paper presents a study of unfinished and temporarily out-of-service large-panel buildings. The tests were performed in order to assess the state of structures degradation. The use of specialised equipment for non-destructive testing enables to reduce the number of destructive tests. The proper development of research methodology and the definition of methods for obtaining reliable results makes it possible to reliably assess the technical condition of buildings.

KEYWORDS: *large-panel, NDT, degradation, unfinished buildings, out-of-service buildings*

1. Introduction

In Europe, there are many facilities that are either out of service or have not been completed for various reasons. These buildings are degraded by environmental influences and vandalism. They are often located in attractive locations where the high costs of demolition and new construction make it rational to modernise them [1]. Currently, prefabrication is an alternative to monolithic construction due to economic and social conditions [2]. The use of existing buildings is profitable for investors and at the same time fits into sustainable development.

Commonly used diagnostic tests to assess the condition of in-service buildings are described in [3]. Despite the continuous development of testing methods, the accurate evaluation of the degradation stage of unfinished and temporarily out of service buildings is a complex issue. Mistakes made at the stage of assessment and interpretation of results may lead to wrong decisions about the further renovation method [4]. The environmental influences in the absence of proper maintenance of the object accelerates the destructive processes.

The technical condition of an object should be identified by the use of appropriately selected measurement techniques. The actual strength parameters are important, which are sometimes reduced as a result of poor workmanship or the aggressive influence of the atmospheric environment, e.g., precipitation, variable temperatures (plus or minus).

This paper aims to present the possibility of using non-destructive methods to assess the technical condition of uncompleted or decommissioned buildings. Currently used non-destructive testing techniques allow for effective data acquisition [5], but should be confirmed by destructive testing results.

2. Investigations

A pilot study of two buildings was carried out. In both, non-destructive tests were carried out with specialised equipment using ultrasound and electromagnetic methods. Locally, the results obtained were confirmed by destructive testing. The test methods used are shown in Figure 1.

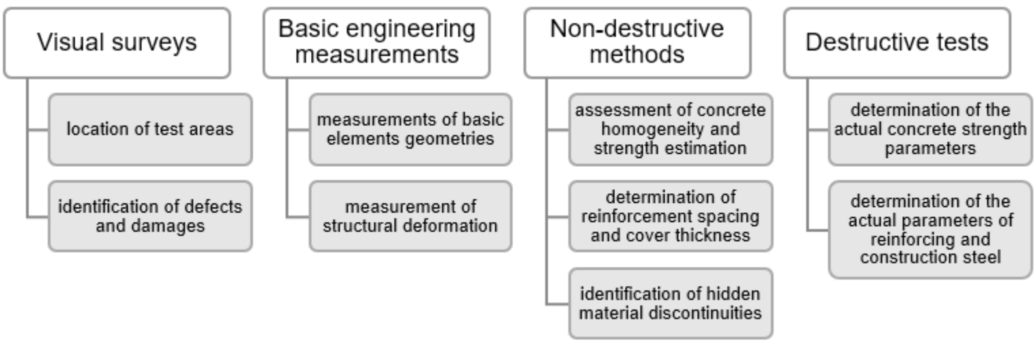

Figure 1. Research methods used

The first analysed building was constructed in large-panel technology in the OWT system in 1980 (Photo 1).

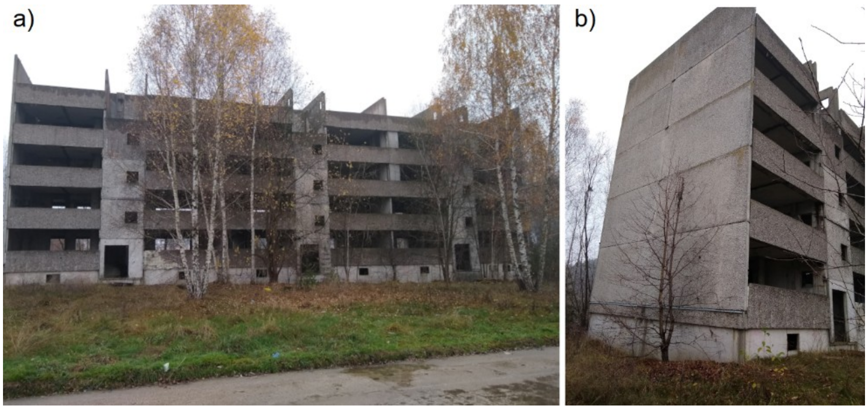

Photo 1. The unfinished building: a) front view; b) curtain wall

The building has five storeys above ground and one underground. The erection of the construction had been interrupted before the roof was completed. The structure was not protected against the aggressive influence of the external environment for more than three decades. Over the course of several years, the technical condition of the building gradually degraded. Structural elements as well as entire buildings required ongoing repair or modernisation [6]. As a consequence of the previous analysis of the results of our own research, damages to large-panel buildings have been identified [7], in the form of typical defects and those resulting from the lack of proper facility management and protection from environmental influences.

In the first stage of the inspection, visual assessment and basic engineering measurements were carried out to identify defects, improperly made welds, sections, geometric deviations, as well as exceeded assembly tolerances and places of corrosion of concrete and reinforcing steel (Photo 2).

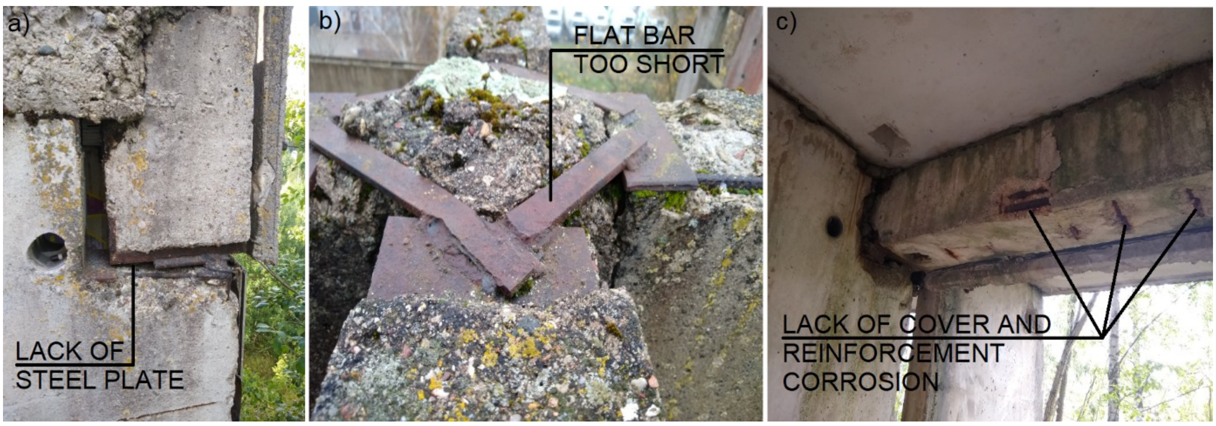

Photo 2. Examples of observed defects: a) lack of plates; b) flat bar and welds too short; c) lack of cover and corrosion of reinforcement

The condition of concrete fillings in horizontal and vertical connections was also analysed. An irregularity that was systematically identified in successive tested elements was the use of flat bars of insufficient length in welded vertical wall joints (Photo 2b). As a result, the welds were too short, which could lead to joint failure. The connections of the beam-walls (external three-layer walls) to the transverse walls were also incorrectly made. In some places the connection plates were missing (Photo 2a), or there were too many pads causing the load-bearing element to tilt. The joint fillings were made carelessly. Numerous delaminations and separations from the precast elements were found in the concrete, as well as large losses in the concrete, resulting in the lack of proper working of the dowel connections. Observed corrosion damage was evident on both exposed rebar and steel connection sections. In order to determine the degree of concrete degradation of the structural elements, non-destructive testing of the walls and floor slabs was carried out using an ultrasound equipment. The principle of operation of the ultrasound method in terms of assessing the homogeneity, discontinuity and strength of concrete has been described in [8]. Limitations and possibilities of verifying the results by combining individual methods have also been published [9]. Scanning of internal walls along selected measurement lines was performed, determining the velocity and propagation time of the longitudinal ultrasound wave (P-wave) in the partition with transducers of 54 kHz frequency, using two-sided access to the elements.

In order to compare the results, measurements were taken at the same points on the internal walls using a head, which is a transverse wave source (S-wave) that does not require two-way access to the test object (Figure 2). Each point in Figure 2 is the average of six readings taken on a given wall. A total of 10 walls on each storey were tested.

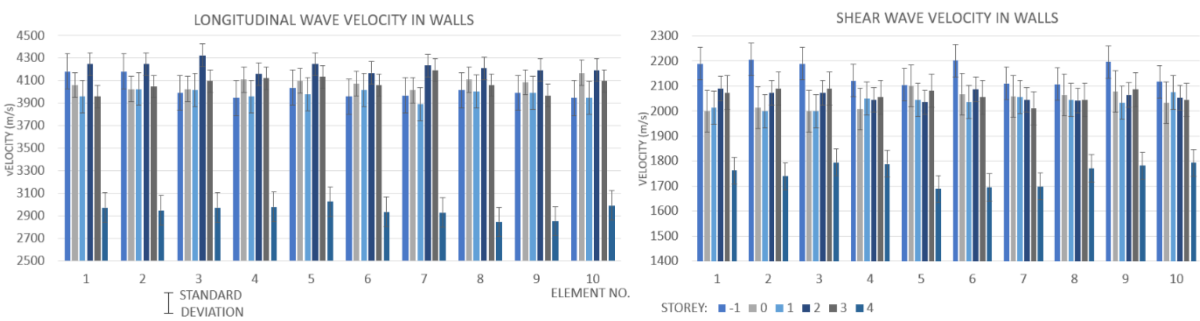

Figure 2. Diagram of the velocity of wave propagation in reinforced concrete walls depending on the concrete condition on a given storey: a) longitudinal wave; b) transverse wave

In [10] methods were given to assess the quality of concrete based on the velocity of ultrasound wave propagation. In the case of storeys -1 to 3, the longitudinal ultrasound wave makes it possible to classify the concrete into the "good" category, while on the last storey into the " weak" category. In the walls of storeys -1 to 3, the shear (transverse) wave velocity ranges from 2000 - 2300 m/s and is defined as typical for concrete. The results of the concrete quality test, carried out using longitudinal and transverse waves, appeared to coincide. They indicated a significant degradation of the walls of the top storey, resulting from corrosion processes.

In order to assess the homogeneity of the concrete and to determine its compressive strength, a series of tests were carried out with a set of sclerometric hammers. The tested surfaces were sanded with a carborundum stone, and in some places a mechanical grinder was used. The rebound number qualified the concrete in most of the precast elements to class C16/20, and some even to class C20/25 and C25/30. The rebound number read on the elements of the last storey did not indicate a decrease in strength compared to the lower storeys, as shown by the results of the ultrasound tests. This confirms the validity of applying comprehensive tests using different methods. The lack of difference in the readings taken on the walls of the fourth storey may be due to the progression of the concrete carbonation process, which forms a hardened layer near the surface. This results in an overestimation of the surface test results.

The results obtained using sclerometric and ultrasound methods allow us to locate potentially highly degraded structural elements and those that require drilling and laboratory testing. On the basis of destructive tests, the concrete of the fourth storey walls was locally classified as class C12/15 (formerly B15).

In order to identify material discontinuities, B-scans of selected walls and vertical joints were performed (Photo 3a) using a Pulse-Echo head. The B-scan generates a cross-sectional image of the component under investigation, perpendicular to the scanned surface. Defects and discontinuities are colour coded from turquoise to red. No significant irregularities were detected in the walls. Numerous material discontinuities were found in the joints (Photo 3b), which could be the result of the separation of concrete fillings from the surface of the prefabricated elements, or of their careless filling, which results in improper joint working.

In the next step, an electromagnetic test of the reinforcement distribution and the thickness of the cover were carried out (Photo 3c).

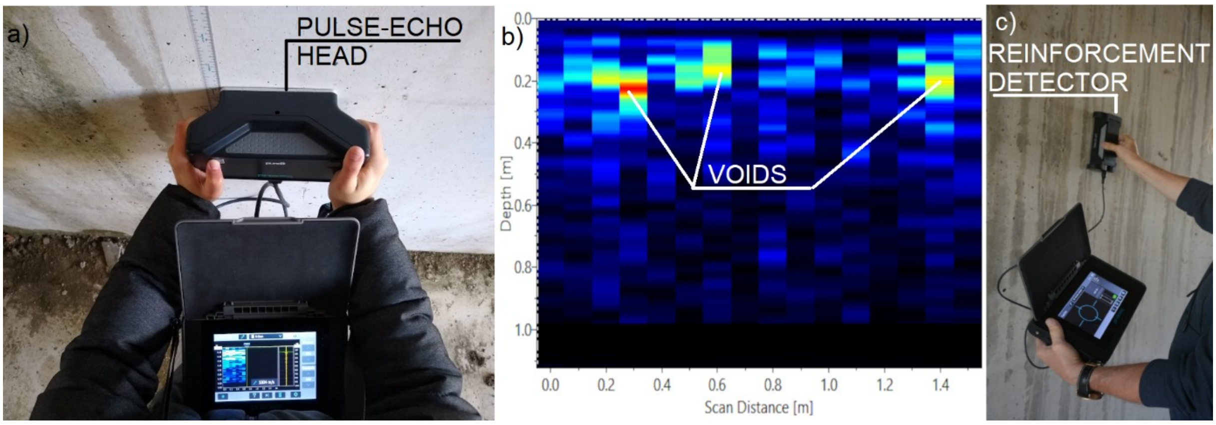

Photo 3. Non-destructive testing: a) B-scan performance; b) fill scan result; c) electromagnetic testing

In all investigated structural elements the thickness of the cover was insufficient. The strong carbonisation of the concrete caused the cover to become detached. Reinforcing bars were visible in some places. They were heavily corroded and showed local section losses of up to 0.4 mm. The reinforcement distribution was mostly in line with the archival design and the system solutions.

The second building analysed was the OWT-67 large-panel office building, with eleven storeys above-ground and one underground (Photo 4a).

Photo 4. Out-of-service building: a) front elevation; b) core drilling; c) destructive testing

It was constructed in 1978 and decommissioned in 2011, followed by the removal of the window frames. For over 10 years the building was unheated, unprotected from the weather conditions and exposed to vandalism. Visual examinations revealed corrosion of the reinforcing bars of the beam-walls, which had been exposed during the inadequate dismantling of the window sills. On the outside, damage to the sheet metal forming the facade of the office building was located. The defects were caused by furnishings being thrown through the windows or by acts of vandalism. These did not indicate a threat to the durability of the structure.

The walls and floor slabs were tested using ultrasound, sclerometric and destructive methods (Photo 4b and c). The results of all tests were convergent and allowed unequivocally to classify the concrete as C16/20 (formerly B20). The concrete was characterised by a homogeneous structure despite the fact that more than a decade the building was without supervision, heating or external joinery.

The B-scans made it possible to locate material discontinuities in the wall joints. The inadequately placed concrete was also visible during visual inspection, after the removal of suspended ceilings covering installations. Cracks up to 1.1 mm in width were found above the door openings. After the crack had been cleaned of debris, a measurement of the depth of the crack was carried out using the ultrasound method. The maximum crack depth was 65 mm, with a precast thickness of 140 mm. The results obtained with the reinforcement detector confirmed the reinforcement distribution in accordance with the design specification. Insufficient cover thickness of less than 10 mm was found locally.

3. Analysis of test results

The test results of the office building, despite being unheated and lacking joinery, did not indicate significant degradation of structural elements. The lack of a roof and the much longer exposure of water and cyclic temperature changes to the unfinished building caused advanced damage to the concrete and reinforcing steel. The selection of test methods should take into account the degree of building degradation. In order to determine the actual strength characteristics of degraded structures, it is necessary to carry out tests with different testing methods and correlate as many results as possible. On the basis of the tests carried out, the usefulness of non-destructive testing for the initial assessment of visible defects was determined. Ultrasound methods make it possible to assess the quality of precast concrete. Comparative use of ultrasound and sclerometric methods makes it possible to locate places where destructive strength tests are necessary. Performing only sclerometric tests may result in misinterpretation of the results due to the influence of the surface carbonation process and delamination of the concrete structures. Tests carried out with a reinforcement detector to assess the cover thickness, diameter and distribution of the reinforcement prove to be helpful in selecting the appropriate repair methods.

A significant problem was noted in terms of the number of tests necessary for a meaningful analysis of the suitability of the building for upgrading and future service. In large-panel structures, prefabricated joints are particularly important, as they are responsible for the proper redistribution of internal forces in the whole structure. Assessing their condition is extremely difficult and the identification of plate degradation in welded joints is not possible without excavation. Pulse-Echo measurements, or B-scans, can be useful in detecting material discontinuities in vertical joints.

In the case of assessing the technical condition of decommissioned or unfinished structures, it was recommended to: carry out a visual inspection of the structure and initially locate defects; assess the homogeneity of precast concrete comparatively using two methods, i.e. sclerometric and ultrasound; perform B-scans of vertical joints to identify potential material discontinuities; use electromagnetic testing to assess the quality of reinforcement work and locate areas for sampling rebar; perform a limited number of destructive tests to confirm the results obtained by non-destructive methods.

4. Conclusions

Modernisation of unfinished or decommissioned buildings should be preceded by studies and numerical calculations, as well as economic analysis. In the case of out-of-service buildings, archival documentation can be difficult to find and knowledge of the actual state of the structure is limited. In such a situation, a comprehensive assessment of the technical condition using different testing methods is important. The application of non-destructive methods is characterised by the advantages of short duration, low workload, lack of damage and low costs as compared to destructive testing. Ultrasound methods are recommended for concrete testing as they allow, in contrast to sclerometric methods, the analysis of the entire cross-section of the tested element.

The calculations of the current load-bearing capacity of the structure must consider the actual strength of the materials as determined by the tests, as well as represent the geometry of the elements and discontinuities of the materials. Ultrasound and electromagnetic methods can provide the necessary data for numerical calculations. The problem of defining unambiguous procedures and methods for obtaining reliable results of non-destructive testing and the scope of necessary destructive testing is a subject for future work.

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