REINFORCED CONCRETE BEAMS BEHAVIOUR UNDER STATIC LOADS - IN-SITU CASE STUDY

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ABSTRACT

Sometimes there are reinforced concrete structures for which conventional computational methods are not sufficient to demonstrate their intended use. In-situ tests are conclusive to determine the ability of a structure to support additional loads, to determine its safety in the event of some design or construction deficiencies, degradation, or lack of design data. Thus, in-situ analysis validates the theoretical design approaches, in order to obtain data on the behavior of the studied elements.
The aim of this paper is to present the groundwork and objectives of in-situ testing of reinforced concrete elements of buildings, with a view to possible structural assessments and to present the methods for carrying out the tests.

Keywords: static loads; reinforced concrete; in-situ testing.

REZUMAT

Uneori există structuri din beton armat pentru care metodele computaționale convenționale nu sunt suficiente pentru a demonstra comportamentul lor. Testele in situ sunt concludente pentru a determina capacitatea unei structuri de a suporta sarcini suplimentare, pentru a determina siguranța acesteia în cazul unor deficiențe de proiectare sau de construcție, degradare sau lipsa datelor de proiectare. Astfel, analiza in situ validează abordările de proiectare teoretice, pentru a obține date despre comportamentul elementelor studiate.
Scopul acestei lucrări este acela de a prezenta obiectivele testării in-situ a elementelor din beton armat, în vederea unor posibile evaluări structurale și prezentarea metodelor de efectuare a testelor.

Cuvinte cheie: încărcări statice; beton armat; teste in-situ.

1. INTRODUCTION

The main purpose of in-situ testing using the static load method is to demonstrate the safety of a new built or an already in use structure. The tests do not determine its design resistance or its maximum load limit (Scott et al., 2002). Generally, in-situ tests can be used to determine the capacity of a structure to support additional loads, to determine the safety of the structure, design or construction deficiencies or structural damages, and to validate design approaches. It can also provide results on the behavior of the structure by accounting the effects of various loading modes, or supplement and validate analytical work, aiming to understand its behavior (Regier and Hoult, 2014).

The objectives of any in-situ structural assessment are to establish the existing condition of the structure, to identify the issues that might affect its structural performance and to develop and implement any necessary action (Nanni and Mettemeyer, 2001). Very often, the evaluation of an existing structure requires a structural analysis to investigate the structure's capacity and its elements to withstand the load requirements prescribed by building codes (Nanni and Gold, 1998). Frequently, assessing existing structures requires an understanding of the field conditions in order to determine the state of the structure. Information obtained in-situ is used to supplement the structural analysis performed and to determine the appropriateness of the structure or some particular elements, if any given concern (Hall and Tsai, 1989). However, in some situations, the results of the structural analysis may not be conclusive and a high level of confidence in the results cannot be achieved. In such situations, in-situ testing may be necessary to gain additional knowledge about the behavior of the structure.

In-situ testing of structures can be costly and, therefore, it is only used when analytical resources have been exhausted or are not available, and when there is great confidence that in-situ test results can help with questions about the behavior of the building, which could not be achieved through computational methods (Gold and Nanni, 1998).

Generally, an in-situ test program comprises several stages, each of which is carefully studied for a good progress of the test. First, the objectives of the test, the benefits and the risks associated with the program must be clearly defined and these should be clear to all the parts involved (Fitz Simmons and Longinow, 1975).

The aims of in-situ tests are to demonstrate that the structure, or a certain structural element, can safely withstand their design characteristics, with an appropriate safety factor against any damage and to demonstrate that service loads do not cause deflections or cracks that exceed the limits imposed for the functioning of the structure (De Luca et al., 2013).

Constraints due to the large number of elements in a building, deployment cost, execution time etc. require the number of in-situ test areas to be limited. Therefore, the part of the structure or structural elements selected for testing must be representative areas, or similar elements of the structure, so that the test results can be extrapolated to other areas. The selection process requires a careful examination of existing conditions (Bungey, 1998).

The in-situ test protocol of the building must include all loading procedures and means of assessing the performance of the structure, both during the test and after its completion (Tumialan et al., 2014).

The aim of this paper is to present the materials and methods necessary for carrying out the in-situ test for two reinforced concrete beams, as well as detailing the results obtained for the post-load test analyzes, in order to gain a better understanding of the actual behavior of the structure, for its safe operation.

2. MATERIALS AND METHODS

For the present research, two reinforced concrete beams were tested, part from two different locations of the building under consideration, for which it was considered appropriate to perform in-situ tests. The two concrete beams that were subjected to in-situ tests were selected by an expert, and the loads required to reach the reference level (service load) and the maximum reference level of the load (design load) were made available. The aim of the in-situ test was to collect data, in order to assess the exploitation ability of the structure, by analyzing the behavior of the structure at the action of the loads, in terms of resistance, stability and the maximum deflection of the beams, for a better approach on its functionality.

2.1. Types of loads used in the in-situ test

The total loading of a building, or its elements, is made up of its permanent load, which is constant, and from its variable load. The reference level load is equal to the service load of the structure. The maximum level of the load coincides with the design load. Loading shall be applied to the elements designated using one or more loading schemes chosen in such a way as to be equivalent to the effect of the worst-case scenarios for which the test is performed. The loading and unloading scheme for which the test is to be modeled, is made using the data available in the building design, if available, otherwise it will be based on the general principles of building safety checks and on the available standards (Tumialan et al., 2014).

2.2. Static load in-situ testing – Case study

The in-situ testing method using static loads is concretized by a test diagram, and is characterized by four successive phases: the loading phase, the surveillance phase when unloading at the reference level of the load, the total unloading phase and the surveillance phase when the element is fully discharged (Tumialan et al., 2014; De Luca et al., 2013; Bungey, 1998). Achieving successive levels of loading until the reference level, was achieved by progressive loading steps, with corresponding breaks at each level for controlling the stability of the equipment used, performing the necessary measurements and observing the behavior of the analyzed elements (Figure 1).

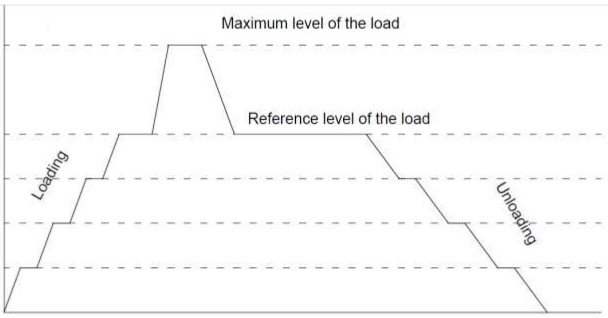

Fig.1. Loading steps of the test

To generate the load on the beams, special containers (105 x 88 x 67 cm) (Figure 2) were used to store the required amount of water.

Fig. 2. Water containers dimensions

The adopted loading scheme was the uniformly distributed load. The containers were displaced over the entire length of the tested beams, as shown in Figure 3. Since the containers used for the test did not have regular section, for each of the tested beams, the water level of each loading step has been previously calculated. The equipment of the beams, in order to measure the vertical displacement, was made using HBM, WA 300mm displacement transducers, with a precision of 0.000001 mm (T1-T5). Their position along the beams is shown in Figure 4 and Figure 5.

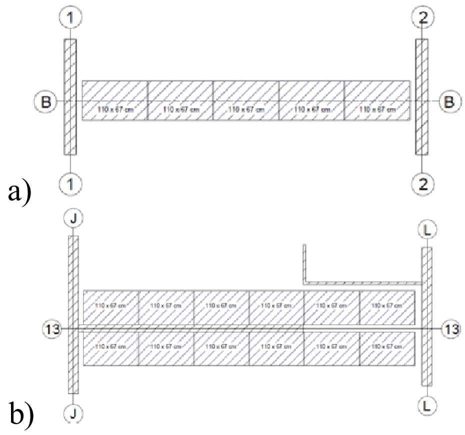

Fig.3. Distribution of the containers – a) Beam 1 and b) Beam 2

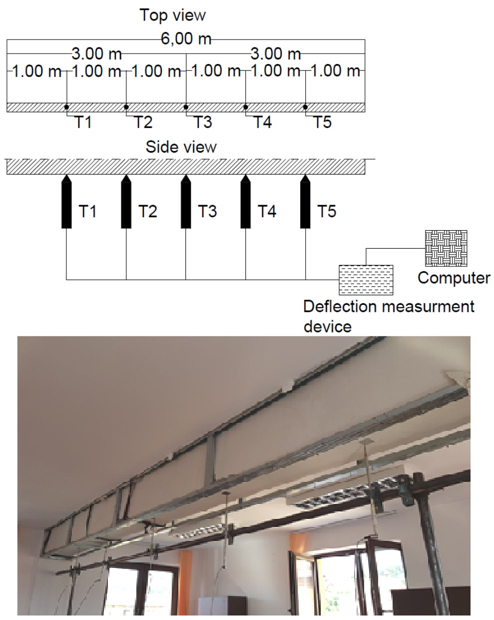

Fig.4. Positioning of the transducers (Beam 1)

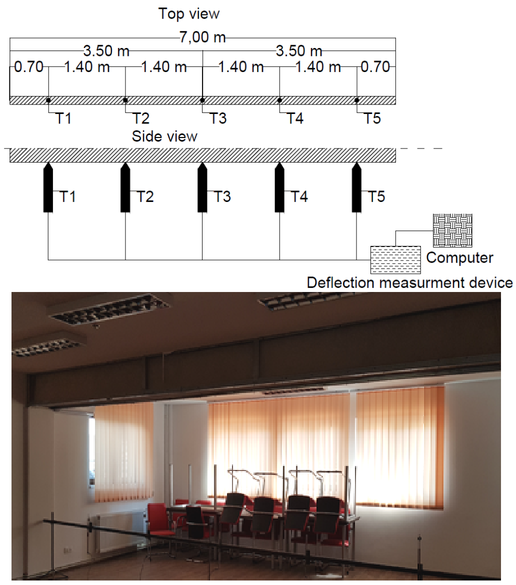

Fig.5. Positioning of the transducers (Beam 2)

The reference level of the load (service load) and the maximum level of the load (design load) of the beams are shown in Table 1. The test load values were previously analyzed by a technical expert. The successive levels of the test were reached in predetermined loading steps, as shown in Figure 6 and Figure 7. For Beam 2, at the request of the expert, an additional step was proposed, above the maximum load level.

Table 1. *Loading steps*

Step	Beam 1 Load (kN/m)	Beam 2 Load (kN/m)
1	0,81	0,70
2	1,62	1,40
3	2,43	2,10
Reference level	3,24	2,80
Maximum level	4,86	4,17
Additional load	-	5,54
Reference level	3,24	2,80

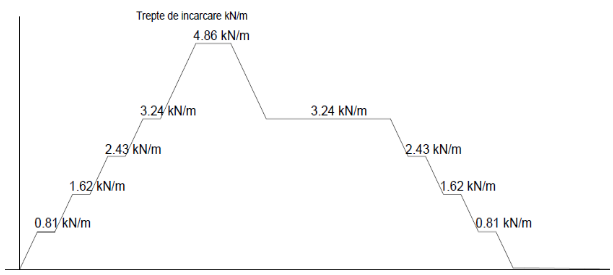

Fig. 6. Loading steps for Beam 1 (kN/m)

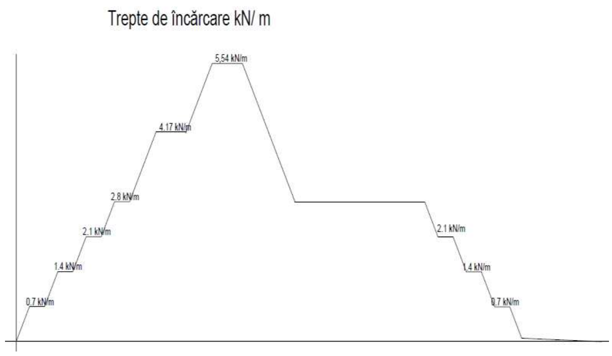

Fig. 7. Loading steps for Beam 2 (kN/m)

Throughout the entire test, the loading and unloading speed were constant. Passing from one loading step to next one was achieved only if there were no phenomena that could jeopardize the test (cracks or other defects that would prevent the construction from being exploited, signs of failure or loss of stability). Also, the switch to other levels of the test was carried out only when the indications of the measuring devices showed stabilization tendencies and did not reach the exploitation values.

The observation phase at reference level of the load, for both reinforced concrete beams, was 24 hours. Deflection measurements were performed at well-established time intervals, more often at the beginning of the phase, and rarer at the end of the test. The unloading phase of the elements at the reference level of the load to the zero level was achieved by reverse stages through the same intermediate levels as when loading the beams.

3. RESULTS AND DISCUSSIONS

The assessment of the results of the in-situ tests of the reinforced concrete beams, using static loads, was made on the basis of the analysis of the data obtained by computerized measurements and by observing their behavior throughout the test, after their processing and bringing them in an accessible form, for a clear interpretation through graphs and tables. For each studied beam, the load-displacement graphs were drawn, based on the obtained results.

By measuring fixed points throughout the test, results were obtained on the evolution of the deflection parameters under load of the studied beams. Measurement methods were performed in accordance with the test objectives, with a sufficient number of data acquired to allow an objective interpretation of the results. During the monitoring phase at the reference load level, no dangerous phenomena have arisen that could have compromised the in-situ test or affect the strength or stability of the elements. The relation between the deflection values measured at the unloading step and the total deflection values measured at maximum loading did not exceed the permitted values.

The evolution of the maximum displacements recorded both in the middle of the span of the beams, and the other transducers located throughout the length of the beams, at maximum, respectively the additional load, was a maximum of 0,3563 mm for Beam 1 and 0,0782 mm for Beam 2.

No cracks or dangerous phenomena have occurred during the test, either for the continuation of the tests, nor for the stability of the analyzed structure. The remanent deflection of the beams, after the 6 hours of surveillance after total unload, were maximum 0,0334 mm for Beam 1 and maximum 0,0033 mm for Beam 2.

3.1. Beam 1 in-situ test results

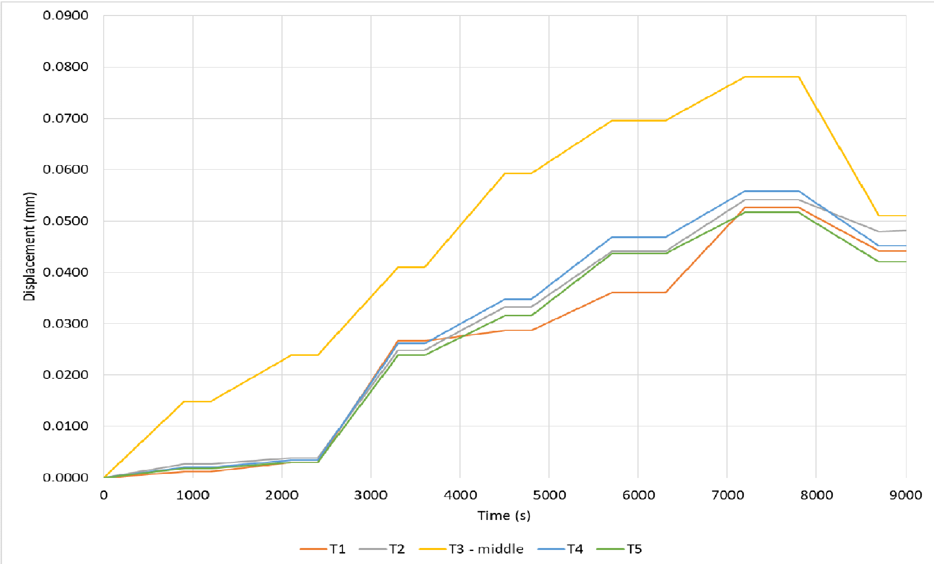

Fig. 8. Displacement graph obtained after the completion of the 5 loading steps and unloading to the reference level load – Beam 1

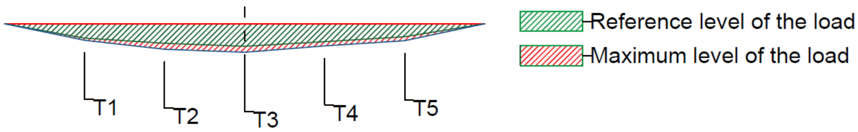

Fig. 9. Maximum deflection values at relevant loading steps

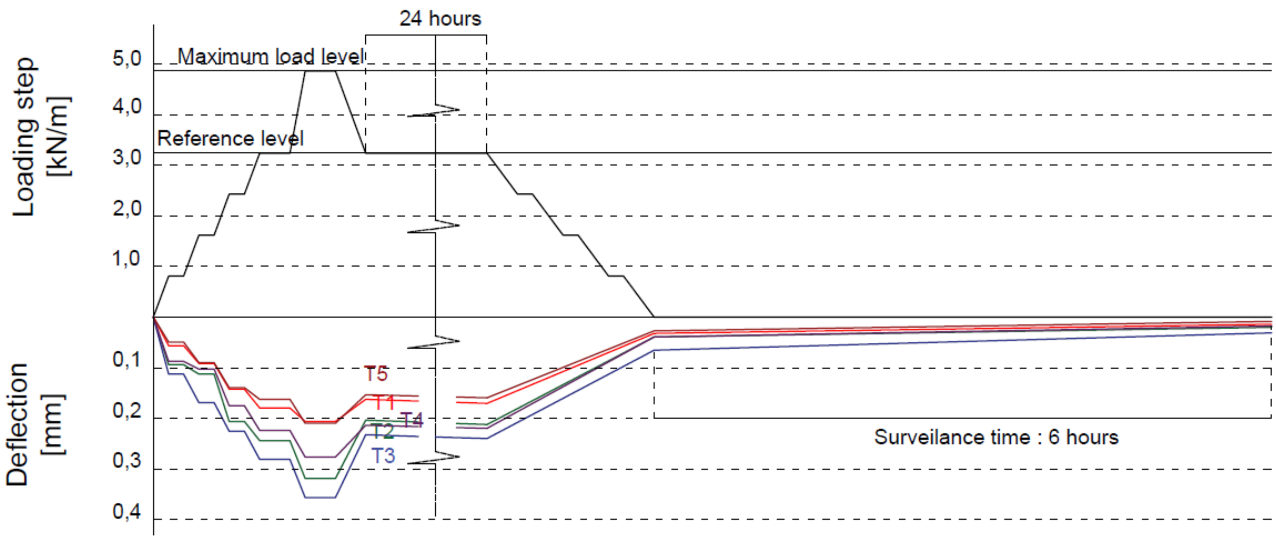

Fig. 10. Load-deflection graph for Beam 1 at the end of the test

3.2. Beam 2 in-situ test results

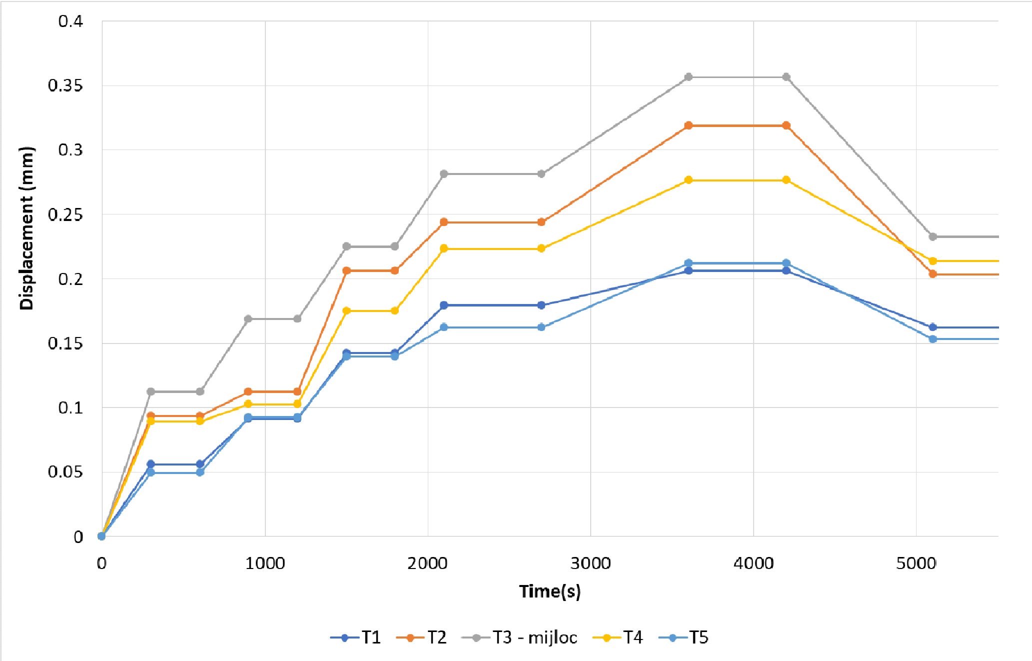

Fig. 11. Displacement graph obtained after the completion of the 6 loading steps and unloading to the reference level load – Beam 2

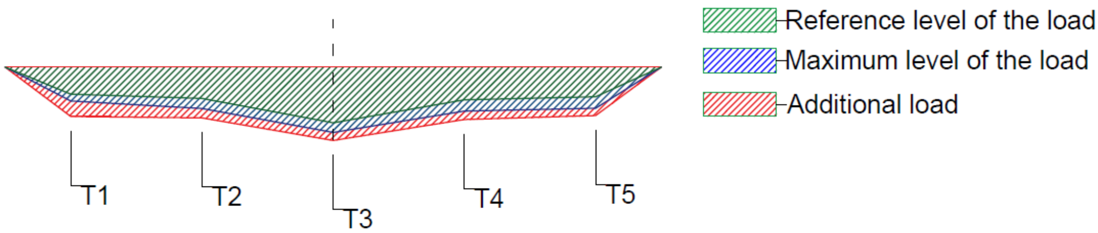

Fig. 12. Maximum deflection values at relevant loading steps

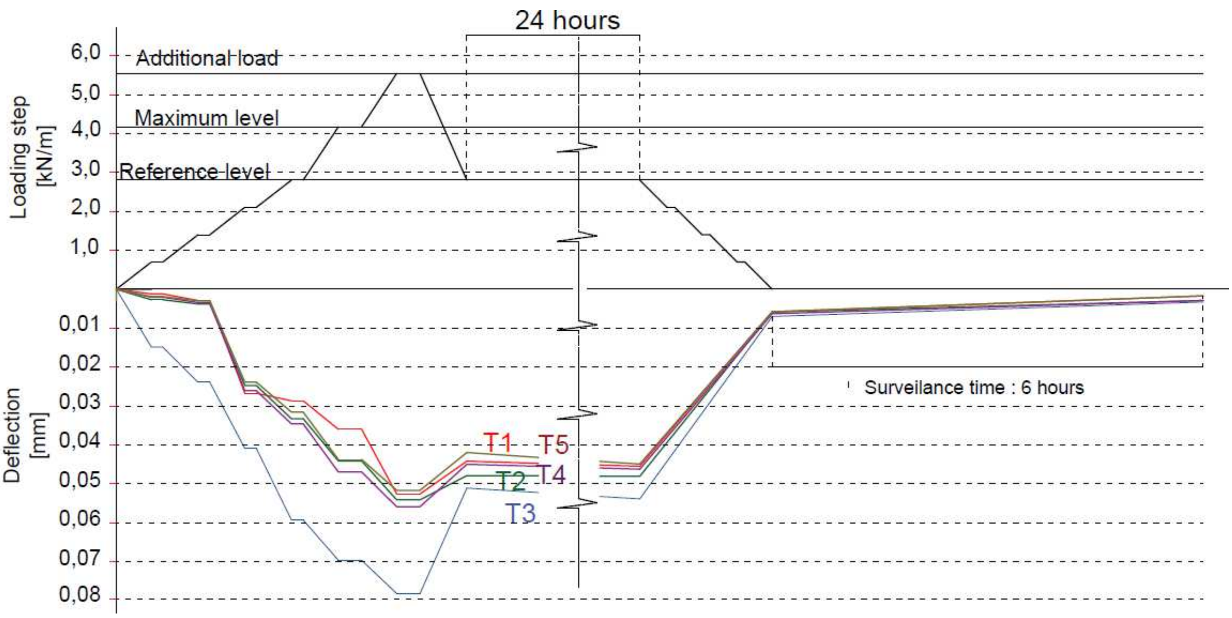

Fig. 13. Load-deflection graph for Beam 2 at the end of the test

4. CONCLUSIONS

The way in which the in-situ test was carried out was to undertake very well-established steps according to the rules in force. The results of the preliminary study provided important conclusions on the objectives and magnitude of the test. Actual load schemes took into account the measured parameter values for each of the characteristic loading levels.

After the in-situ tests on the two concrete beams, as well as after the results obtained, their behavior was observed and viable conclusions were drawn regarding the exploitation of the building in the future.

Based on the results obtained, it can be said that in-situ testing of buildings is a valuable tool, used both in the assessment of the real behavior of buildings and their possible interventions. The test is typically used to demonstrate that existing or repaired structures can safely withstand their design tasks.

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