

Managing the conservation of 20th century cultural heritage

Esmeralda Paupério¹, Xavier Romão², Catarina Costa³, António Arêde⁴, Aníbal Costa⁵

¹ Construction Institute, Faculty of Engineering of the University of Porto, Porto, Portugal; pauperio@fe.up.pt

² Department of Civil Engineering, Faculty of Engineering of the University of Porto, Porto, Portugal; xnr@fe.up.pt

³ Construction Institute, Faculty of Engineering of the University of Porto, Porto, Portugal; catarina.costa@fe.up.pt

⁴ Department of Civil Engineering, Faculty of Engineering of the University of Porto, Porto, Portugal; aarede@fe.up.pt

⁵ University of Aveiro, Porto, Portugal; agc@ua.pt

ABSTRACT: Natural deterioration caused by the ageing of the materials and their exposure to severe environmental conditions leads to a significant increase of the vulnerability of constructions. When facing the need to make conservation interventions to preserve or restore degraded cultural heritage elements, there are a number of restrictions that must be dealt with. Such restrictions are related to the safeguarding of the heritage's cultural value and significance that has to be weighed against safety and durability requirements, as well as against duration and budget constraints of the intervention. To assist in this decision-making process, a methodology is proposed which consists of an intervention index that gauges the criteria influencing the type of intervention. The development of this index is presented for the decision-making process related to the conservation intervention scheduled for the reinforced concrete decorative elements of the 20th century Teatro Nacional de São João (São João National Theatre), in Porto, Portugal. The selected criteria are presented and the advantages of the proposed procedure for the development of a sustainable conservation plan are addressed.

1. Introduction

“Twentieth-century building materials and construction techniques may often differ from traditional materials and methods of the past. There is a need to research and develop specific repair methods appropriate to unique types of construction.”

Approaches for the Conservation of Twentieth-Century Architectural Heritage, Madrid Document 2011, ICOMOS

The conservation practice of historic and heritage reinforced concrete constructions in Europe from the late 19th and early 20th centuries is, currently, facing new challenges associated to the

need for their consolidation, conservation and repair. Given that many of these constructions are relatively recent, the need for conservation interventions is a concern that is now starting to appear. Since the approach for interventions in 20th century constructions is different than that usually utilized in older constructions, there is a lack of professional experience and know-how in their repair that must be overcome. These aspects are particularly relevant when dealing with decorative elements in reinforced concrete.

To help in the decision-making process about which type of intervention will be carried out, an adequate balance of the several constraints must be sought. To assist in this decision-making process, a methodology is proposed which consists in the development of a case-by-case intervention index that gauges the referred criteria influencing the type of intervention. The referred index weighs the influence of several qualitative and quantitative criteria which are graded according to the characteristics of the cultural heritage element under analysis.

The development of this index is presented for the decision-making process related to the conservation intervention scheduled for the reinforced concrete decorative elements of the 20th century Teatro Nacional de São João (National Theatre of São João), in Porto, Portugal. A detailed analysis of the selected criteria is presented and the advantages of the proposed procedure for the development of a sustainable conservation plan are also addressed.

2. Concrete degradation process as a result of steel corrosion

Reinforced concrete, which is made by cement and steel, forms a composite material with a reduced lifespan, when compared to natural and traditional construction materials such as stone or timber. Among other sources of decay, reinforced concrete deterioration is often caused by the corrosion of embedded steel. Since the origin of this deterioration usually starts from inside the concrete element, available repairing approaches are seen to be considerably intrusive. Therefore, this particular source of decay is especially difficult to address when dealing with the repair of reinforced concrete decorative elements or sculptures, where conservation operations could destroy their authenticity (Fig. 1).

Normally, the embedded steel reinforcement is protected against corrosion by being buried within the mass of the concrete and by the high alkalinity of the concrete itself. This protection, however, can be destroyed in two major ways. First, by carbonation that occurs when carbon dioxide in the air reacts chemically with the cement paste at the surface and reduces the alkalinity of the concrete. Second, chloride ions from salts combine with moisture to produce an

electrolyte that effectively corrodes the reinforcing bars. Chlorides may come from seawater additives in the original mix, or from prolonged contact with salt spray or de-icing salts. Regardless of the cause, corrosion of reinforcing bars increases its volume and causes expansive forces within the concrete. Cracking and spalling of the concrete are frequent results of this expansion phenomenon. Rust stains on the surface of the concrete are another indication that internal corrosion is taking place.



Figure 1 – Examples of reinforced concrete decorative elements and sculptures exhibiting some level of material degradation.

In sum, 20th century constructions may present two types of problems associated to reinforced concrete degradation:

- ✓ Problems related to the structural stability of constructions
- ✓ Problems related to the conservation of decorative elements

The problems related to the structural stability of constructions are the result of a reduction in the load carrying capacity of reinforced concrete elements due to the loss of concrete, to the loss of bond between steel and concrete, and due to the decrease in thickness of the reinforcing bars themselves.

The problems related to the conservation of decorative elements raise important questions associated to the safeguarding of the heritage cultural value and significance that have to be weighed against safety and durability needs. During the decision-making process about what intervention has to be carried out to preserve, rehabilitate, or restore degraded cultural heritage elements, an adequate balance of these constraints must be found. To assist in this decision-making process, the proposed methodology will enable the development of an intervention index that weighs the influence of several qualitative and quantitative criteria associated to the state of conservation and characteristics of the cultural heritage element under analysis.

3. Case study: the São João National Theatre

The São João National Theatre is a National Monument located in the city of Porto, Portugal. The construction of the current theatre started in 1910 under the direction of architect Marques da Silva, the most important architect of Porto at the time, after the original building was destroyed by a fire in 1908. The style of L'Ecole des Beaux-Arts in Paris, where Marques da Silva studied, is clearly found in the São João theatre's architecture.

The Beaux-Arts architecture expresses a neoclassical architectural style that involved sculptural decoration along conservative modern lines and employed French and Italian Baroque and Rococo formulas combined with an impressionistic finish and realism. An abundance of balustrades, statues, columns, garlands, pilasters between doors and windows, and grand staircases is typical of this architectural style. In the case of the São João National Theatre, these decorative elements exist in all the façades (with a total area of approximately 4800m²) and are made of reinforced concrete (Fig. 2). Some of the decorative elements having vegetal and geometrical patterns are seen to be repeated throughout the façades.



Figure 2 – Façades and reinforced concrete decorative elements of the São João National Theatre.

A few years ago, the façades of the São João National Theatre began to exhibit severe signs of deterioration due to the long-term weathering of the concrete surfaces, the corrosion of steel reinforcement and the fall of pieces of mortar (the latter enforced the need to install façade nets to prevent such pieces to fall over the pedestrians). The development of a conservation project for the façades was therefore needed with some urgency. Considering the previously referred degradation issues related to the steel corrosion and concrete spalling, the conservation and preservation of such rich and dense array of decorative elements presented numerous issues and several intervention options not easy to choose from.

Besides the severe cracking and spalling levels found in the concrete due to corrosion of the reinforcement, significant damages were also found to be related to bird dropping deposits and to the presence of black crusts. In order to illustrate the state of degradation of some of the reinforced concrete elements of the theatre façades, Fig. 3 presents some examples of damaged reinforced concrete decorative elements of the façades of the São João National Theatre.

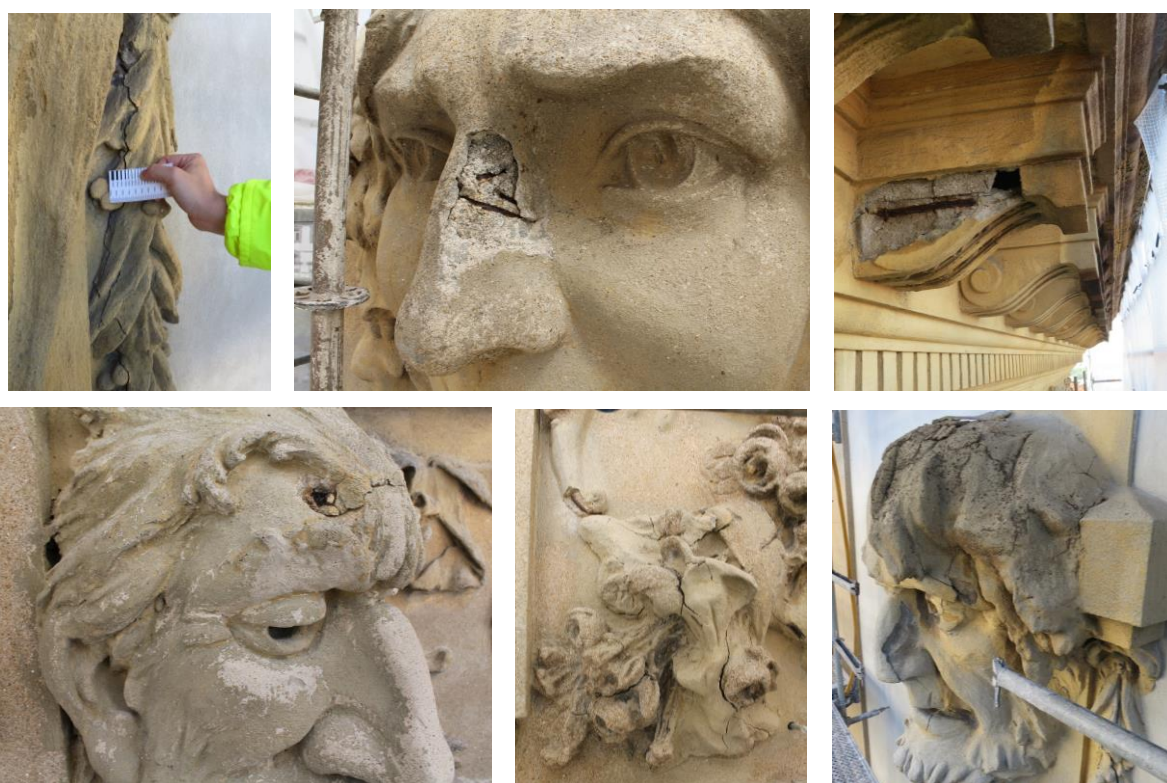


Figure 3 – Examples of damaged reinforced concrete decorative elements of the façades of the São João National Theatre.

To adequately plan and prepare these interventions, a survey of the damages and degradation levels found on the façades and their decorative elements and sculptures was needed. A first assessment of their state of degradation was carried out before the cleaning operations of the façades took place, which resulted in an incomplete characterization of the elements' condition. A reliable assessment was only possible after the cleaning operations (Fig. 4). In addition to the damage survey, several concrete samples were taken from the façades for laboratory analysis and testing in order to determine the components and mix proportions of the original concrete, thus enabling the development of a repair mix with properties compatible with the original concrete.



Figure 4 – Cleaning operation to remove limewash (left), cleaning operation by micro-abrasion (centre left), example of a decorative element before (centre right) and after (right) the cleaning operation.

The cleaning operations also revealed that a conservation intervention had been previously carried out on the façades in the mid-20th century because some decorative elements exhibited additional layers of mortar over the original ones which altered their original volumetric proportions. In other cases, by visual observation and by comparing the several types of mortars, it was possible to conclude that some of the original decorative elements were replaced during that intervention. Given these aspects, the current intervention project foresees the possibility of making casts of original elements to replace similar ones previously intervened in the mid-20th century. These replaceable elements are those exhibiting a current state of degradation that implies a level of repair incompatible with the simultaneous upholding of their authenticity and of their safety against falling.

Given the difficulty of balancing all the factors that influence the type of intervention to be carried out in a given decorative element under analysis, an intervention index was therefore developed to help in this decision-making process. Even though the fundamental purpose of the

intervention is to replace as few elements as possible, the main objective of the proposed index is thus to identify which elements exhibit the need for a more severe repair intervention along with a higher potential for replacement.

4. The proposed intervention index

The proposed index was developed such as to establish a quantitative measure that would recommend either the in situ repair or the replacement of the element under analysis. This index weighs the influence of several qualitative and quantitative criteria which are graded according to the characteristics and the level of degradation of the element being analysed. This index was developed such as to account for several restrictions that may control the type of admissible intervention. Some of these restrictions are related to the safeguarding of the heritage's cultural value and significance that have to be weighed against restrictions related to safety and durability requirements, as well to duration and budget constraints.

The proposed intervention index I_{TI} is quantified for each individual decorative element and reflects the weighted combination of seven criteria (C1 to C7) according to:

$$I_{TI} = \frac{\sum_{i=1}^7 C_i \times w_i}{\sum_{i=1}^7 w_i} \quad (1)$$

where C_i corresponds to the grade assigned to the i th criterion and w_i is the weight factor of the i th criterion. Some of the selected criteria are graded directly while others depend on the value of auxiliary parameters (P1 to P9). A description of the selected criteria, of the information and parameters considered for their quantification, and of their weight factors is presented in the following:

- C1 – Durability of the decorative element: The grading of this criterion combines information about the level of cracking of the element (P1), the existence and location of the reinforcement (P2), the level of corrosion of the reinforcement (P7), and the amount of repair required by the element (P8). The weight factor w_1 is considered to be 5.
- C2 – Meeting the deadline for completion of the project: The grading of this criterion combines information about the size of the element (P3), the difficulty of making a cast of the element to replicate it (P4), the difficulty of fixing this replica to the façade (P5), and the amount of repair required by the element (P8). The weight factor w_2 is considered to be 5.

- C3 – Risk associated to the fall of the decorative element: The grading of this criterion depends on the life-threatening hazard due to the fall of a decorative element and on the possibility of observing the state of conservation of that element from the ground. The weight factor w_3 is considered to be 5.
- C4 – Authenticity of the decorative element: The grading of this criterion depends on the decorative element being authentic or not (i.e. the decorative element is a replica or it has been previously repaired). The weight factor w_4 is considered to be 4.
- C5 – Repetitiveness of the decorative element: The grading of this criterion depends on the number of times a given decorative element is repeated on the façades (P6). The weight factor w_5 is considered to be 3.
- C6 – Evolution of the state of degradation of the decorative element since 1995: The grading of this criterion reflects the evolution of the state of degradation of the element based on its condition in 1995 when the state of conservation of the façades was surveyed and conservation interventions were carried out in some parts of the building. The weight factor w_6 is considered to be 1.
- C7 – Replacement potential of the decorative element: This criterion depends on information about the level of cracking of the element (P1), the level of corrosion of the reinforcement (P7), and the amount of repair required by the element (P8), and its grading combines data about the size of the element (P3), the difficulty of making a cast of the element to replicate it (P4), the difficulty of fixing this replica to the façade (P5), and the level of cracking of the element (P1). The weight factor w_7 is considered to be 5.

By combining the grading of the several criteria using Eq. (1), the intervention index I_{TI} is then obtained. The index ranges between 0 and 3 and if a value lower than 2 is obtained, the decorative element under analysis is recommended to be repaired and consolidated. Otherwise, the replacement of the element by a replica is suggested.

5. Application of the intervention index to the São João National Theatre

To apply the proposed methodology, a preliminary identification and numbering of the individual decorative elements was necessary. This operation was carried out by the team of conservators, architects and engineers involved in the project. In some cases, this identification was not a simple operation due to the high level of interconnection between consecutive decorative forms

(Fig. 5). In these cases, individual elements were selected based on symmetry and repetitiveness criteria.



Figure 5 – Examples of the high level of interconnection between consecutive decorative forms.

Although the proposed index establishes a set of objective criteria to characterize a given element, the grading of some aspects sometimes involves a certain degree of subjectivity. Grading the difficulty of making a cast of the element to replicate it (P4) or defining with absolute certainty the authenticity of a decorative element (C4) are examples of factors that may involve some degree of subjectivity. The cleaning operations of the façades are also decisive in the results of the index. As previously mentioned, a reliable assessment of the state of degradation of the decorative elements is not possible before such operations expose the true state of the elements which is, many times, hidden below several layers of dirt, black crusts or paint.

In order to illustrate some of the results obtained when applying the proposed methodology to the São João National Theatre, Fig. 6 presents the value of I_{TI} for seven reinforced concrete decorative elements. As can be seen, the replacement of elements 3, 6 and 7 is suggested by the results. For the case of element 6, and comparing with the result obtained for element 5 which is similar to element 6, the “replacement” result given the index is because this element exhibits a high level of degradation with severe steel corrosion and concrete spalling, and more than 75% of its volume requiring consolidation. On the other hand, element 5 presents no steel corrosion, no spalling and less than 25% of its volume requires consolidation. With respect to element 7, the decisive characteristics for the “replacement” result are its level of steel corrosion and concrete cracking, the fact that it requires the consolidation of more than 50% of its volume and the fact that it is not an original element. In terms of element 3, aside from its high level of cracking and of needed consolidation, the fact that it is a small element easy to replicate is also a decisive factor to obtain a “replacement” result.

1	2	3	4	5	6	7
						
1.21	1.71	2.48	1.47	1.77	2.52	2.34

Figure 6 – Sample results obtained by the proposed intervention index when grading different types of reinforced concrete decorative elements of the São João National Theatre.

6. Final remarks

The conservation practice of historic and heritage reinforced concrete constructions from the late 19th and early 20th centuries is different than that usually utilized in older constructions. The lack of professional experience and know-how in their repair is particularly important, namely when dealing with decorative elements in reinforced concrete. The fundamental purpose of an intervention is to maintain as much of the elements as possible, involving repair and consolidation operations that will safeguard as much as possible the elements' authenticity. Aside from the need to safeguard the cultural value and significance of the heritage, other important issues must also be weighed, namely those related to safety and durability, as well as to the intervention's duration and budget constraints.

Given the difficulty of balancing all the factors that influence the type of intervention to be carried out in a given element under analysis, an intervention index was therefore developed to help in this decision-making process. Even though the fundamental purpose of the intervention is to replace as few elements as possible, the main objective of the proposed index is thus to identify elements exhibiting the need for a more severe repair intervention along with a higher potential for replacement. These replaceable elements are those exhibiting a current state of degradation that implies a level of repair incompatible with the simultaneous upholding of their authenticity and of their safety against falling.

Although the proposed index involves a set of objective criteria to characterize a given element, the grading of some aspects is sometimes subjective. Furthermore, a reliable assessment of the state of degradation of the decorative elements is not possible before cleaning operations expose the true state of the elements which is, many times, hidden below several layers of dirt, black crusts or paint.