Characterization of defects in *Liceu* school buildings in Portugal

Analytical methods for the study of constructive anomalies

1. INTRODUCTION

Portuguese secondary schools integrate a heterogeneous set of buildings, in terms of spatial and constructive solutions. Over the twentieth century these buildings were used as an important tool for governments' action in order to implement their political ideals, which are reflected in the diversity of schools built during this period. Presently, there are 477 public secondary schools spread across the country, built from the late nineteenth century

The increase of school facilities throughout the last century did not take into account the necessary conservation and maintenance actions for the existing buildings. Given the age of most school buildings and their intensive use over the years, the absence of those important actions led to a considerable number of degraded and outdated buildings that currently offer unsuitable conditions for implementing new learning and teaching activities (Heitor 2009).

About 60 high schools built during the twentieth century were inspected by experts of the *Instituto de Engenharia de Estruturas, Território e Construção* (ICIST) of *Instituto Superior Técnico*, being divided into four different types: *Liceu* schools, industrial schools, pavilion schools and also singular typology schools, which fall outside the scope of the first three typologies. These school buildings are located in central and southern regions of Portugal.

This dissertation comprised a study about the characterization of the condition of 15 school buildings with *Liceu* typology. In particular, a statistical analysis was performed regarding the parameters that characterize these schools and also their main anomalies, by establishing relationships between anomalies identified, probable causes and other parameters. To this end, it was necessary to structure and organize the information from the expert reports in a database that was designed and conceived to this end, thereby allowing the establishment of statistical relations based on the defects described in the expert reports. Given the specificity and heterogeneity of these buildings, it was necessary to develop a specific methodology for the characterization of anomalies in school buildings, making it possible to correlate multiple characterization parameters and to classify the anomalies by assigning severity levels.

The constructive characterization of the school buildings was essential to accomplish the proposed analysis. The description and the statistical survey of the anomalies, causes and rehabilitation actions is preceded by a description of the school buildings inspected, in terms of structural and coating materials

and functional and building typology. Most of these buildings' design and execution took place in the period of the implementation of the construction program for the educational facilities in a political period called *Estado Novo*, a regime that lasted from 1926 until 1974. The advanced aging of these buildings and the absence of any relevant maintenance actions led to the acceleration of the deterioration mechanisms, resulting in potential sanitary and safety problems.

2. HISTORICAL OVERVIEW

The word *Liceu* comes from the Latin *Lyceum* and has its roots in the Greek word *Lykeion* that means the place where Aristotle taught his disciples in ancient Greece. The origin of this word helps understanding the importance and continuous presence of this type of educational buildings over the centuries, as an important cultural and historical symbol for the society.

The *Liceu* buildings and the concept of compulsory, secular and public education, has arisen in Portugal within the scope of the liberal reforms of the nineteenth century, under the influence of the republican model that emerged in France in the same period, and directly linked with the extinction of religious orders in 1834 in Portugal.

Therefore, the first Portuguese secondary schools were installed in convent buildings, given the lack of economic resources for the construction of new school buildings and the availability of these spaces, after the extinction of the religious orders in Portugal (Fig. 1). Given the age of these buildings and the deficient health conditions they offered, the installation of schools in convents was proved to be unsuitable for the education needs and requirements brought from the reforms.

The first initiatives to build new secondary schools were developed in this context driven by the educational reforms of this period. The international experiences introduced new concepts and the deployment of formal language in the design of the school buildings, following a rational approach to the composition and organization of spaces. These concepts are also reflected in the concerns about the schools sanitary and health conditions, as these spaces were seen as privileged places for the transformation of society and urban environments. These new buildings also envisaged meeting the demands of the educational reforms, by creating spaces for physical exercise, enhancing the outdoors, and other spaces dedicated to scientific education. An example of the implementation of these ideals is the *Pedro Nunes Liceu*, presented in Fig. 2, where a more open structure towards the surroundings can be observed (Alegre 2009).

Fig. 1 - Aerial view of *Colégio das Artes*, in Coimbra (Bing Maps).

Fig. 2 - Aerial view of *Pedro Nunes* school, in Lisboa (Google Earth).

The construction of the new *Liceu* school buildings is definitely launched in the beginning of the twentieth century, under the influence of the *École de Beaux-Arts* in Paris and the French *Lycée* building models. Three high schools are designed in Lisboa and two in Porto. The architects wanted to develop a new school typology adapted to the functional requirements of the reforms, incorporating the hygienist principles, and succeeding the functional organization of the French *Lycées*. The first step towards the implementation of these principles was the choice of the construction site. The concerns with teaching and learning conditions are a turning point in the production of these schools, seeking the suitability of these buildings towards the future.

These educational reforms of the nineteenth and early twentieth centuries are a milestone in the design of schools, which remained until the establishment of the military regime in 1926, resisting the political transition from Monarchy into Republic. The political consciousness of the role of *Liceu* schools was taken into account during the development of school buildings throughout the twentieth century.

In the year 1926 significant changes took place regarding the policy of building new secondary schools in Portugal. The construction initiatives were first held by the Ministry of Education, and later by the Ministry of Public Works and Communications, reflecting the importance of school buildings in the consolidation of the political regime.

The creation of the "Loan administration department for secondary schools" (JAEES) in 1928 allowed the formation of a 6 member board, that included a doctor, an architect and a civil engineer, who had the role of administrating and controlling the fund application for the construction and repair of secondary schools in Portugal. One of the most important responsibilities of this board was the promotion of architectural competition for the design of new school buildings that should meet the requirements described in the document "Special conditions and basis for the construction of secondary schools (finishing)", defined by the board (Moniz 2007). These tenders allowed a greater freedom of architectural expression connected to the functional organization of school buildings and were the first opportunity

to develop a program considering the hygienic and constructive requirements that could be regarded as "modernist" (Fig. 3 and Fig. 4).

Fig. 3 - *Diogo de Gouveia* school, in Beja (Branco *et al* 2008c).

Fig. 4 - *Filipa de Lencastre* school, in Lisboa (Branco *et al* 2007c).

Emerging in this period of the twentieth century in Europe, the Modern Movement ideals were moved by a greater rationalism, in terms of functional organization of spaces and the choice of new construction techniques, while the use of new materials - such as reinforced concrete - allowed the establishment of a formal sobriety. This architectural and constructive movement was an important reference for the design and the execution of the schools built in this period (Alegre 2009).

Despite the initiatives for the construction of new high schools in the 30's, the shortage of schools had not yet been resolved. The need for new school buildings remained and, therefore, new programs were developed to increase the number of schools in Portugal.

The *Liceu* buildings designed in Portugal in this period reflect these political circumstances. The schools design reproduced nationalistic symbols, which led to the withdrawal of foreign influences in the school projects. The *Estado Novo* began to develop an ideological project for the exaltation of the historical culture that involved the use of education buildings as a vehicle for communication of their political views and ideals.

In 1938, the initiative for the construction and repair of school buildings that took place during the 30's is continued through a different path. The "Buildings, extensions and improvements plan for *Liceu* schools" by the "Department of construction for technical and secondary education" (JCETS) that followed the JAEES, also known as *Plano de 38*, promoted the construction of 10 new *Liceu* buildings, together with extensions and improvements in other 13 school buildings. The construction of another 4 *Liceu* schools was added during the implementation of this plan between 1944 and 1945, completing a total investment on 27 schools in this period.

This program extended the action and responsibility of the board and centralized the design of these school projects, which resulted in the homogeneity of *Liceu* buildings and the exclusion of the possibility of using new architectural languages.

The elaboration of the "General program for the development of *Liceu* projects" written in 1940 and revised in 1943 established the spatial and functional characteristics of the schools to be designed and built in this period, which formed the groundwork for the projects development. The definition of the areas and the space dimensions, sun exposure, lighting and ventilation conditions and coating materials to be applied led to common characteristics that interpret the recommendations presented in the program, providing a greater uniformity of the projects.

The aim for monumental conception of these buildings, using a historical and nationalist vocabulary, emphasizes the social importance of the secondary schools and defines multiple characteristics that remind traditional construction and architectural solutions (Fig. 9).

Between 1952 and 1958 the construction of *Liceu* schools slowed down due to the priority given to the design and development of projects focused on technical and vocational schools. After the end of the Second World War the restructuring of the European economy was based on the promotion of industrialization after the "Economic Conference for the Organization and Management of the Marshall Plan" in Paris (1947-48). In Portugal this economical reorganization led to the need for an increase of the competitiveness towards foreign economies and the changing of the educational policy, followed by the implementation and reform of vocational and technical education sites.

With this respect, in 1947 a law on the reform of technical, industrial and commercial education buildings was published. Besides the definition of these schools regulations, this law further defines the construction, extension or adaptation of school buildings that were intended to host these levels of education. These school projects presented new demands and requirements, particularly the need of a greater teaching area and a different organization of the program. For such schools, a preliminary draft project was created, which promoted systematization of the architectural and construction solutions. Despite these efforts, the construction of new school buildings was not enough to meet the objectives, due to the increase of pre-university preparation needs in this period.

In 1958 a new plan was approved for building 16 *Liceu* school buildings throughout the national territory, which was known as *Plano de 58*. This plan sought to develop standardized projects for school buildings, taking into account the experience of the last years. In addition, these initiatives allowed returning to a modernist constructive language and to other international influences in the development of a school building as a social space open to the community (Fig. 6).

Fig. 5 – Main entrance for the *Gil Vicente* school, in Lisboa (Branco *et al* 2007b).

Fig. 6 - Main entrance for the *Rainha D. Leonor* school, in Lisboa (Branco *et al* 2008a).

The sense of modernity reflected in architectural, constructive and educational solutions marked a new phase in the development of secondary schools in Portugal.

3. CONSTRUCTIVE CHARACTERIZATION

School buildings dedicated to public secondary education in Portugal share common points in their evolution that allow their integration within the *Liceu* typology. These buildings present significant uniformity in terms of their formal and functional characteristics. However, the school buildings were also an important field of experimentation where the new architectural and constructive solutions were being developed and implemented.

From the beginning, the main building of the *Liceu* was presented as the "gateway" of the school complex, where the principal academic and administrative spaces would be found. Until the creation of the first *Liceu* schools in the late nineteenth century, these teaching spaces occupied a specific area in a large religious complex and it was not possible to distinguish school areas from the monastic ones. The structuring element was the patio, initially associated with the convent cloisters, which distributed the different teaching spaces along circulation galleries. This existing building implantation allowed a greater control, discipline and surveillance of the students.

The issues concerning the improvement of sanitary conditions led to the opening of this patio structure in order to achieve a wider solution that would improve the indoor space quality and the use of the exterior areas for recreation.

In the beginning of the twentieth century the design of new school buildings sought to respond to the formal principles and hygienist requirements through the adoption of adequate constructive solutions. The establishment of these school buildings in new urban areas, as opposed to the option of using other spaces within the old city, is the starting point for the affirmation of the new sanitary requirements, which recommends the location of schools in healthful areas.

Fig. 7 – *Colégio das Artes* patio, in Coimbra.

Fig. 8 – *Pedro Nunes* School patio, in Lisboa (Branco *et al* 2007a).

In the *Liceu* school buildings of this period, the structural materials used in the bearing walls were irregular stone masonry. Their coating was chosen to meet the hygienist requirements, to ensure easy cleaning and greater sanitation quality of the interior spaces, and ranged from limestone or cementitious renders with water-based paint (in the exterior) to hydraulic or ceramic tiles. The original pavements and stair structures were in timber and have been replaced or added in some specific areas by reinforced concrete slabs built some decades after the initial construction, during restoration actions.

In the 1930s, the first modern school projects aimed at complying with the conditions described by the JAEES. This board was responsible for organising tenders for the execution of secondary school buildings that were based on a prototype program that established the necessary requirements for a school building. This program was organized by functional centres that led to the independence of some buildings, such as the physical education block. These functional bodies were constructed using a new structural material - reinforced concrete - which allowed the use of terraces and wider openings in the facade. This constructive option led to an aesthetic expression of the buildings towards a new modern architectural language that reflected a more rigorous and pure geometry of their volumes.

In 1934 the JAEES is replaced by the JCETS whose responsibilities were increased. Besides the management of the loan, this board was meant to lead the study and the execution of new secondary school buildings in Portugal.

The *Plano de 38* defined a list of the new schools to be built and improved and a strict program to be followed in the projects concerning the spatial organization and constructive solutions to be applied. Therefore, the projects designed in this period are marked by the uniformity of the defined solutions, based on a strongly national design, which reflects the political ideal of the *Estado Novo* regime and rejects the design principles of the modern period, trying to recover some national architectural tradition elements (Fig. 9).

In terms of functional organization of these buildings, the *Liceu* schools of this period were characterized by presenting symmetric organization where the entrance was the focal element, with the distribution for the remaining school spaces being made from this point (Fig. 10).

Fig. 9 - Main entrance of the *Sá da Bandeira* school, in Santarém (Branco *et al* 2008b).

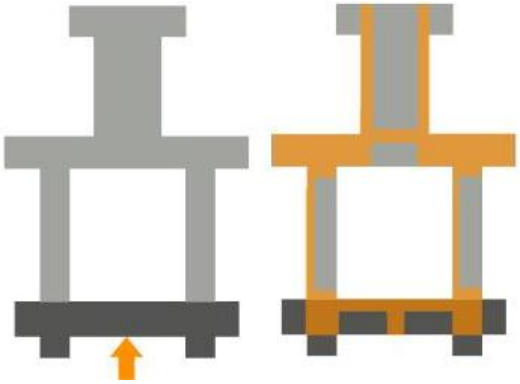


Fig. 10 – Scheme of the *Sá da Bandeira* school from the *Plano de 38*: symmetric relation towards the entrance (left) and the circulation areas (right).

In terms of constructive solutions adopted, pitched roofs were used, along with a strong decorative sobriety for the walls. Decorative stonework was used only on the facades of the main buildings marking the entrance. The structural materials used in the resistant walls were irregular stone masonry, as in the early twentieth century, which was complemented with reinforced concrete members. However, the structure of the pavements was built in reinforced concrete, a constructive solution that remained from the previous period of school buildings.

Only in the second half of the twentieth century the design of *Liceu* buildings receives again international influences that were an important contribution for the development of a new proposed methodology. The design of new secondary schools is marked by the influence received from experiences in school architecture from northern Europe and the support received from international work groups, such as the research of innovative solutions based on cost control and planning and standardization of construction elements for speeding the construction work (Fig. 11). These requirements allow exploring the potential of reinforced concrete.

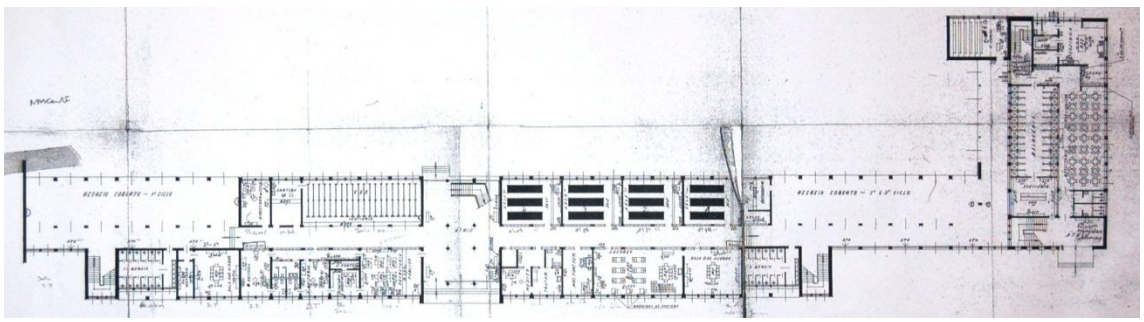


Fig. 11 - *Rainha D. Leonor* school plan, in Lisboa (Branco *et al* 2008a)

The evolution of *Liceu* school buildings typology was marked by distinct phases, which resulted in a wide range of constructive solutions that went through important transition moments and experimentation of new building materials. The introduction of these innovative materials and the new constructive and designing solutions, without a thorough empirical knowledge of their characteristics and degradation mechanisms, is an important tool for understanding the current condition state of these *Liceu* school buildings.

4. METHODOLOGY

The evolution of these school buildings throughout the twentieth century, the natural aging of materials and construction elements and the lack of maintenance and rehabilitation actions resulted in a general state of severe building degradation. In most of these buildings a patrimonial value is recognised linked to their unique characteristics or to the cultural and social symbol they represent. In fact, some of these school buildings witnessed the experiment of innovative solutions concerning space organization and construction materials that were not complemented by a controlled maintenance plan or the necessary functional adaptations for new learning and teaching pedagogies.

This patrimonial value combined with the lack of space in urban areas for the construction of new school buildings justifies the adoption of an intervention model based on the rehabilitation under the program of modernization of the existing secondary schools *Parque Escolar EPE*, adapting them to new educational requirements (Heitor 2009).

Given the necessary interventions for the schools rehabilitation, it became mandatory to assess its conservation condition in order to minimize interventions in the existing buildings and to promote the enhancement of the entire schools. To this end, it was necessary to stipulate the condition of the buildings and the need for rehabilitation as precisely as possible. In order to identify the main defects, external and internal inspections/surveys were carried out from which expert anomalies reports resulted. These reports aim to characterize constructive elements and to identify the structural defects and other anomalies related to the presence of moisture and water through visual observation.

From the expert reports, a methodology was developed for the characterization of the anomalies identified, in order to study the degradation processes that would lead to these pathological phenomena, considering multiple factors that may affect the degradation process of the construction elements (CIB 1993).

Given the heterogeneity and diversity of these buildings, it was necessary to undertake a systematic organization of the information available in the expert reports. The design of a specific database allows structuring the necessary information considering a statistical analysis, where the different criteria used

for the anomalies characterization could be found, such as the illustration of the defects by photographic records and the other parameters that support the filling of the database.

The aim of this methodology was to study the most frequent degradation phenomena from the identification and characterization of the school buildings, its surrounding urban environment and the characterization of the anomalies identified in the reports, considering their location within the building and the construction elements, the type of pathological phenomenon, their causes and most frequent recommendations.

The characterization and analysis of the identified anomalies was divided into two fundamental steps.

The first step is the identification and characterization of the school building. It is independent from the detection and characterization of the anomalies detected and intends to describe the school building, including its constructive and functional characteristics and also its territorial context.

The second step aims at characterizing the degradation state of the school building and involves the application of technical knowledge about the degradation processes of construction elements and materials, the most probable causes and the main rehabilitation recommendations. The location of the detected anomalies in terms of functional spaces and sun orientation constitute important information regarding the characterization of each identified anomaly.

The identification of the type of anomaly is an essential step for its characterization. However, the increasing complexity of existing buildings, materials and systems over time and the increasingly rigorous requirements for performance, together with the lack of maintenance and intensive use of schools, leads to a high level of degradation, triggering the presence of performance defects in increasingly complex anomaly chains (Azzalin 2005). In order to support the identification of the type of anomalies and their matching description, a comprehensive list of anomalies was prepared (Fig. 12).

A3	**Discoloration or stains (A3)** This anomaly is characterized by the expression of discolorations or stains defined by contrast with the surface, including efflorescence (*D. Luísa de Gusmão* School, in Lisboa).	

Fig. 12 - Example of an anomaly description, according to the list of anomalies adopted.

For the development of a pathological phenomenon, a degradation agent needs to be activated, often referred to as the most probable cause of the defect observed. However, anomalies can change along its evolution without any alteration of the origin. These changes may lead to new anomalies that add or

override the existing ones. With this respect, one can consider that there is a chain of preceding and subsequent anomalies, which should also be identified when filling the database.

The evaluation of the degradation condition of the elements was made through the creation and implementation of a system for the assignment of a severity level. The type of Elements Subject to Maintenance (ESM) affected the type of defect and a severity level visually assigned for each anomaly need to be taken into account in order to define a global severity level for each defect. The ESM weighing was regarded as a critical step, since the different building elements have different importance for the school building. The defects in structural elements and roof claddings have a greater relevance compared to the deficiencies limited to internal cladding elements, since the degradation processes of the former elements have more serious consequences for the durability and safety conditions of the building.

The different types of anomalies also present different relevance for the overall condition of the building. The anomalies that can rapidly compromise the durability and performance of the building construction elements are more relevant for assessing the degradation state of the building.

For the assignment of the severity levels within each type of defect, this methodology proposes a comparative visual evaluation as presented in Fig. 13. This analysis is based on the use of images of the same type of anomaly from which a comparison is made, and also based on the definition of criteria that support the input of relevant information.

These three parameters allow characterizing the level of degradation of the elements and identifying the stage of degradation, while reducing the level of subjectivity for the classification levels of severity and, consequently, the evaluation of the buildings condition (Gaspar 2005).

In this dissertation these definitions behind the database designed are presented in detail in order to support the information input.

Level 1
Wall and ceiling coating (*Diogo de Gouveia* school, in Beja)

Level 2
Ceiling coating (*João de Deus* school, in Faro)

Level 3
Exterior stairway in reinforced concrete (*D. Luísa de Gusmão* school, Lisboa)

Fig. 13 - Example of a comparative visual evaluation for the A3 defect (discolorations or stains).

5. RESULTS AND DISCUSSION

From the historic overview, it can be concluded that a large part of the Portuguese *Liceu* school buildings was built in the middle of the twentieth century, mainly in the 40's and 50's (Fig. 14).

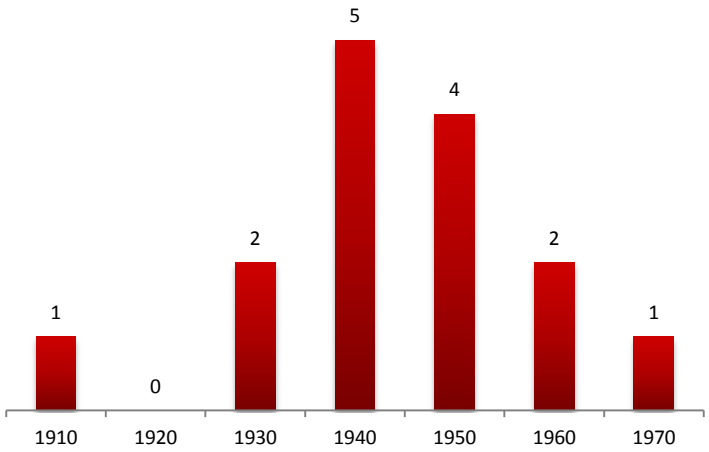


Fig. 14 - Distribution of schools by decade of construction.

Therefore, the age average of these school buildings is about 60 years. Consequently, they present a specific type of construction, generally using reinforced concrete in the horizontal and vertical structural elements (Fig. 15). In older buildings irregular stone masonry and timber elements would be found instead. Throughout the twentieth century these school buildings underwent some remodelling actions that consisted frequently of replacing these timber structural elements with reinforced concrete ones.

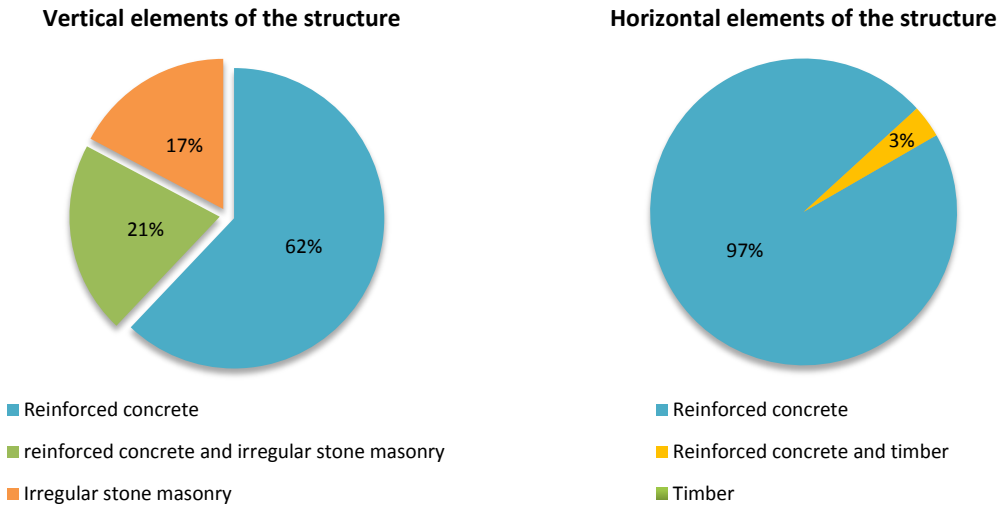
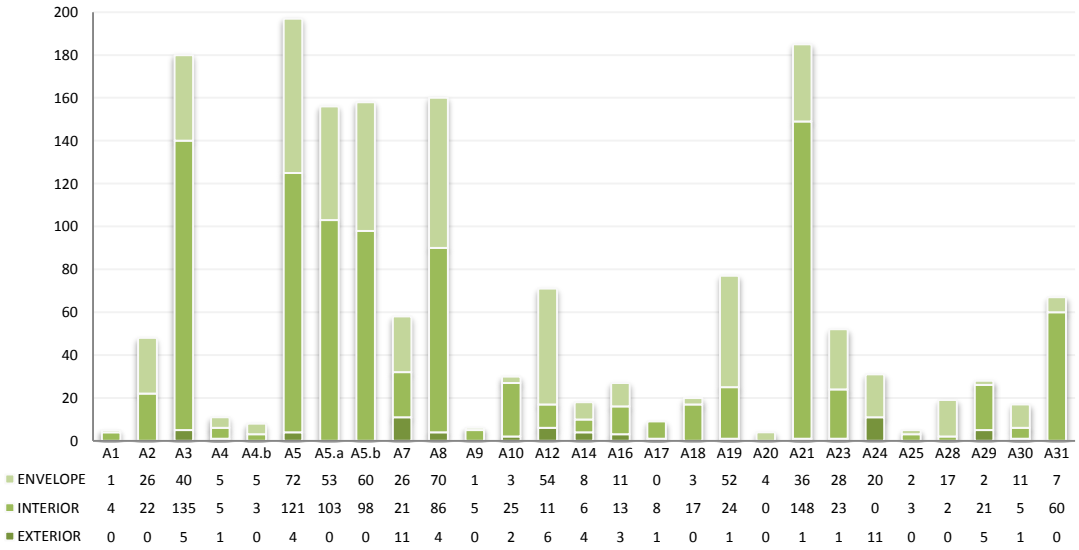


Fig. 15 - Relative frequencies of the structural elements.

Given their age, the *Liceu* school buildings have great difficulties in complying with more current performance needs. In fact, the natural aging combined with the lack of maintenance actions led to a significant decrease of the building conditions. Over time, these buildings tend to degrade since they are exposed to severe weather conditions and degradation that compromise the elements and the whole building's durability.

The school buildings survey campaign was carried out in order to detect anomalies related to structural problems and to the degradation of the materials due to the presence of water and moisture. In fact, the results obtained by the statistical analyses point to a major occurrence of this type of anomalies, as presented in Fig. 16.



A1 Differential dirt| A2 Uniform dirt | A3 Discoloration and/or stains | A4 Mapped cracking | A5 Oriented cracking | A7 Fracture / broken elements | A8 Spalling or peeling | A9 Alveolarization | A10 Deep cavities | A12 Corrosion | A14 Loose elements| A16 Lack of element(s) | A17 Localized wear | A18 Uniform wear | A19 Deficient functioning | A20 No functioning| A21 Water infiltration | A23 Biological colonisation | A24 Vegetation growth | A25 Animal waste | A28 Debris accumulation | A29 Differential settlements| A30 Graffiti | A31 Blistering

Fig. 16 - Absolute frequency of the anomalies identified in the survey, according to their specific location.

The statistical analysis shows that the most frequent anomalies are A3 (discoloration and /or stains), A5 (cracking) and A21 (water infiltration). The discoloration and/or stains and water infiltrations are the most typical defects identified in cases with moisture problems, since they are the natural indicators of this kind of anomalies.

The results obtained show that the defects are more frequent in the interior of the school buildings in comparison with the surroundings. This is due to the closer attention to the interior constructive elements, the more intensive use of these spaces and to the evident decrease of the indoor conditions. In

the interior spaces, the most common anomalies are stains (A3), cracks (A5) and water infiltrations (A21) resulting from the lack or loss of waterproofing capacity of the building envelope and the deficient sealing elements, compromising the performance and durability of the interior elements.

The analysis of the elements most affected by these defects, presented in Fig. 17, provides important information in order to understand the constructive elements that are more exposed to the indicated types of degradation.

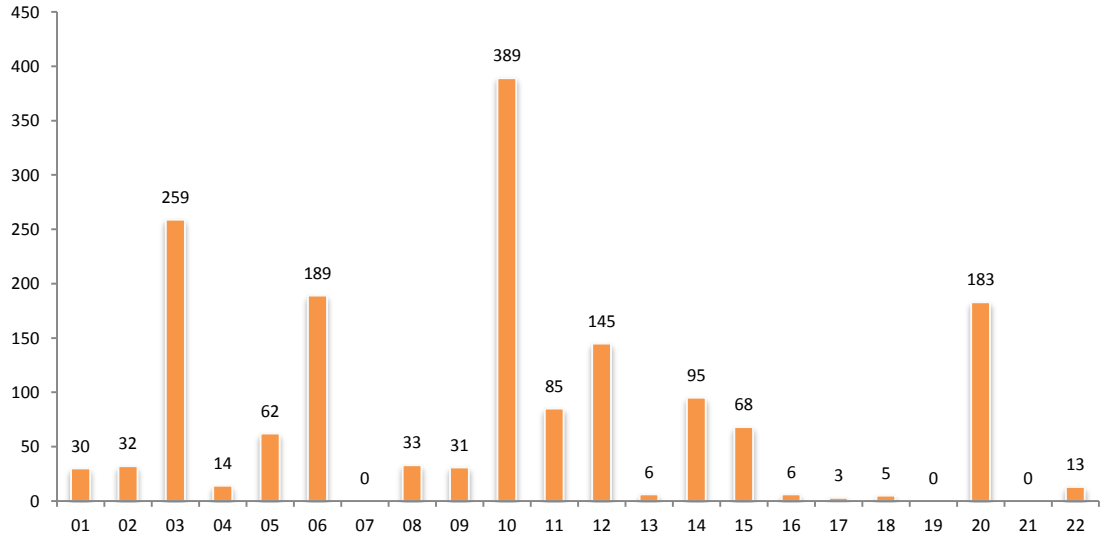


Fig. 17 - Absolute frequency of the identified anomalies by ESM.

The ESMs most frequently affected by anomalies are ESM 03 (concrete elements), ESM 06 (walls) 10 and ESM 10 (wall coatings). These results are due to the higher frequency of these elements in the buildings inspected.

The identification of the most probable causes, presented in Fig. 18, provides information about the origins of the pathological processes, allowing acting on the resolution of anomalies and preventing future occurrences.

From the analysis of the overall statistical results regarding the most probable causes, a higher frequency of causes related to the environmental factors (C2) and to the execution and/or design errors of the construction elements (C4) is observed.

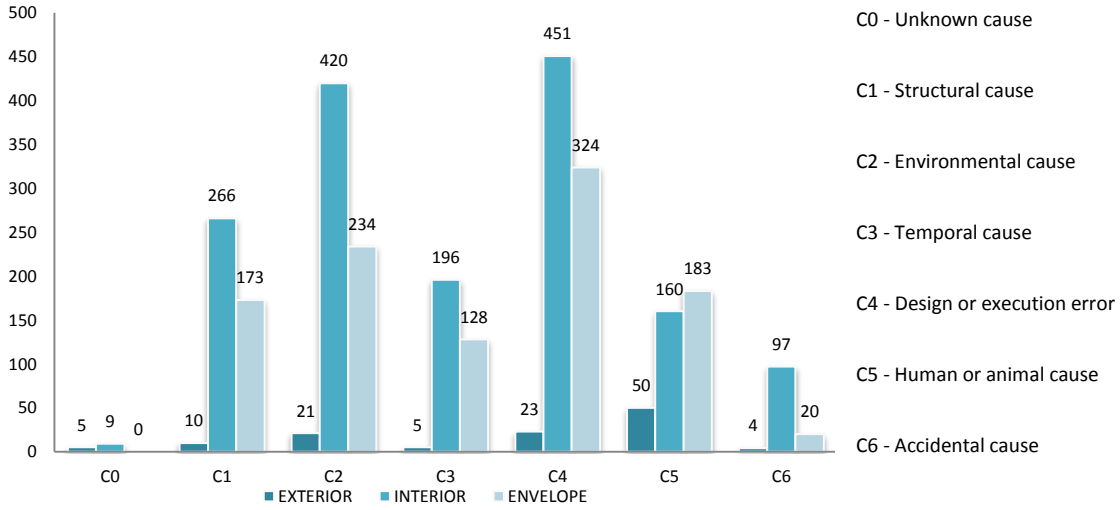


Fig. 18 - Absolute frequency of the most probable causes identified in the survey, according to their specific location.

Environmental actions are related with the lack of regular maintenance actions and with building's exposure to environmental agents of degradation over the years. Consequently, from the exposure to atmospheric agents the buildings becomes more vulnerable to indoor defects.

The other most frequent causes of the defects are related to design and/or execution errors (Chamosa 1984). The use of reinforced concrete in these school buildings overlapped the introduction of this material in constructions, when there was insufficient knowledge and practical experience about the use of this material in construction. The aging of these buildings together with the lack of regular conservation actions, results in defects that negatively affect the durability and performance of these schools. These functional elements are located in areas where conservation and maintenance actions are more difficult and expensive to perform. The concerns about these problems were not taken into account at the design and execution stages of the construction of these buildings, which explains the frequency of such anomalies.

As a consequence of these problems, the main probable causes of anomalies in interior spaces are also related to the environmental agents of degradation, due to the lack of leakage capacity and design and/or execution errors. However, for this location, an increased frequency of causes related to humans or animals' action is verified when compared to other locations, and this is related to the lack of maintenance. In fact, the main problems detected in interior areas are mostly a direct consequence of the defects presented in the coating elements, which highlights the essential role of these elements to ensure the durability and the performance of the whole building.

From the identification and characterization of anomalies and their probable causes, it is possible to analyse the statistic results for the most frequently recommendations prescribed, illustrated in Fig. 19.

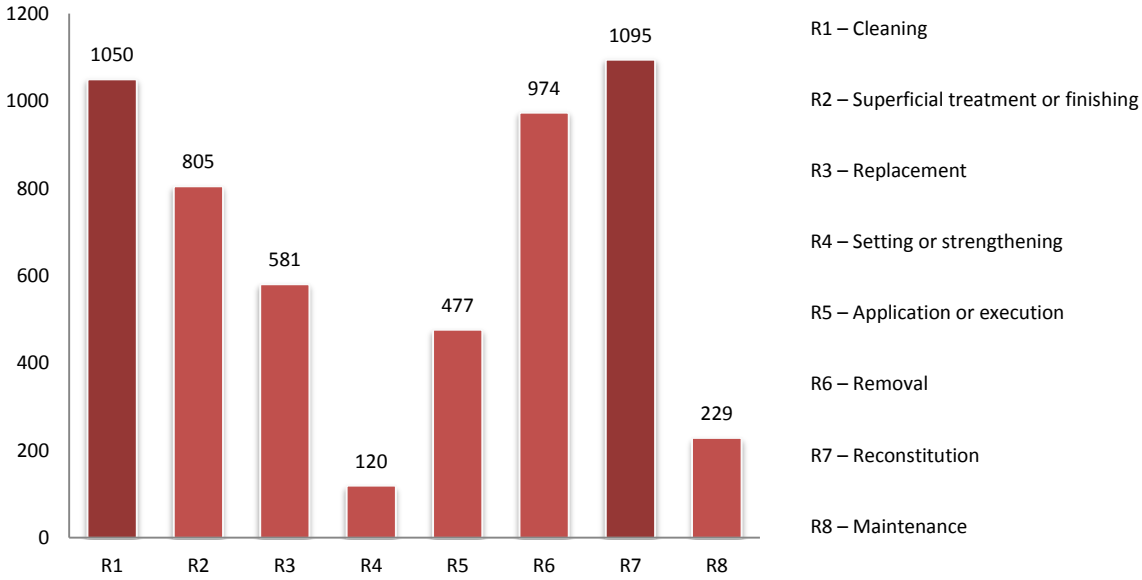


Fig. 19 - Absolute frequency of the general recommendations of the anomalies identified in the survey.

As a consequence of the lack of maintenance actions and the overall state of degradation, the most frequent recommendations are cleaning (R1) and elements reconstitution (R7). This type of actions could be included in a periodic maintenance plan, which could prevent this state of building degradation.

As mentioned, the methodology proposed includes a method allowing to classify the anomalies identified. The visual comparison of the anomalies and the weighting system, considering the type of ESM affected, the type of defect identified and the attribution of a level of severity for each occurrence, are important tools for the degradation analysis and for evaluating the general state of conservation. The statistical results obtained for this part of the study are presented in Fig. 20.

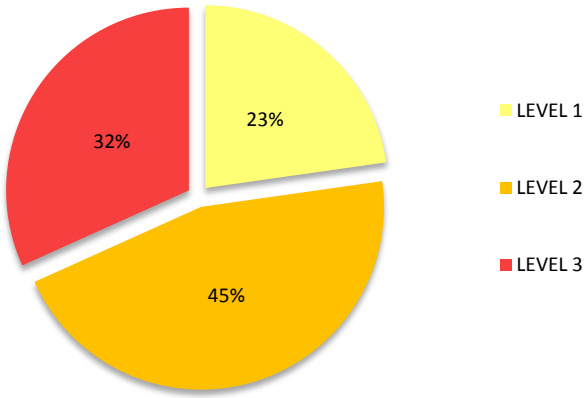


Fig. 20 - Relative frequency of severity levels of the anomalies.

Results show that there is an increased frequency of cases corresponding to the severity level 2. A significant number of occurrences correspond to the maximum level of gravity, indicating an advanced state of deterioration of the constructive elements and consequently of the buildings inspected.

6. CONCLUSIONS

The high historical and patrimonial value of the *Liceu* school buildings, comprising a huge variety of functional and constructive solutions, justifies the need to intervene in existing buildings. However, these maintenance, preservation and rehabilitation actions should be planned to ensure the quality and durability of school spaces.

The anomalies identified show important functional problems and a poor state of conservation, due to the deficient waterproofing conditions and lack of maintenance, affecting the durability of the elements. The structural problems in reinforced concrete elements are connected with their design and execution stages, since designers and contractors were still relatively unfamiliar about this new building material, as well as with the pathological phenomena leading to its degradation.

The buildings of this period were not designed to support the maintenance and repair actions of their components, which promoted the action of the main degradation agents and accelerated the end of their service life. Apart from the lack of planning of maintenance actions, such buildings present some design and/or execution errors, associated with improper performance of elements detailing that can be associated with the deficient application and lack of knowledge and experience with the use of these innovative materials, such as the reinforcement concrete.

For the future, adequate maintenance plans must be developed for the school buildings, concerning the degradation agents to which they are more frequently exposed to. This continuous action plan would allow the buildings to fulfil their expected durability.

Finally, the effectiveness of the proposed methodology was confirmed. It proved to be an important tool for statistical characterization of the overall state of degradation of school buildings. However, this methodology could be improved in order to incorporate a wider range of analysed elements. The attribution of severity levels should be supported by a more effective quantification for every type of anomaly, in order to set a more rigorous evaluation.

7. REFERENCES

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