Study of anomalies in Central Tejo buildings and regristation in a database

Warning Criteria Definition

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ABSTRACT

Until the mid-nineteen Century, the traditional masonry construction was the building type most used in the world and in Portugal. The reversal of trend is related to the appearance of reinforced concrete, although its mass use is more evident from the second half of the twentieth century.

In Lisbon, 56% of previous buildings to 1919 have repair needs, which indicates that the rehabilitation of buildings should be a bet in the construction sector.

To achieve a deeper or rehabilitation activities in a given anomaly must be properly evaluated anomalies in question so that rehabilitation or repair is effective and does not return to surface defects repaired.

The proposed evaluation method consists of three phases: phase 1 where each anomaly is evaluated according to five criteria and is determined the state of anomaly and the risk is that the anomaly; phase 2 wherein the evaluation target is a building element or part, which is based on the assessment conducted in phase 1; phase 3, which is the proposal of measures to be taken for each detected anomaly.

In buildings of Central Tejo, Lisbon center that fueled the early twentieth century and is currently exhibition site, six types of anomalies have been identified: fissures, efflorescence, disintegration of mortar joints, delamination, erosion and corrosion. For each of the identified anomalies is presented a proposal for the method.

Key-Words: Evaluation Method; Central Tejo, Anomalies, Repairs

INTRODUCTION

Until the mid-nineteen century, the traditional masonry construction was the building type most used in the world and in Portugal. The reversal of trend is related to the appearance of Reinforced Concrete, although its mass use is more evident from the second half of the twentieth century.

In Portugal there are 3 544 389 buildings, according to the 2011 Census, of which 206343 are buildings whose construction period is prior to 1919, corresponding to 6% of the total built. Of these 206,343 buildings, approximately 56% (106 612) feature needs repair and 22 381 (11%) are buildings that are in a very poor state.

Analyzing only the municipality of Lisbon, there are 10 279 buildings whose construction period is prior to 1919, which corresponds to 20% of buildings in the capital (52,496).

Previous buildings to 1919, 5785 correspond to buildings that have repair needs. With regard to the number of buildings in a very poor state, this value is equal to 894 buildings (8%).

These data point the way to a stronger focus on urban rehabilitation and maintenance of existing buildings.

In 2015, the increase in this sector activity level was equal to 29.9% for the period 2014, according to the "Associação dos Industriais da Construção Civil e Obras Públicas".

In the masnory building can be found two kind of anomalies: structural anomalies and non-strucutral anomalies.

Structural anomalies are anomalies that may affect the building structure and, therefore, should take special care either in your analysis or in repair The main structural abnormalities seen in masonry is the Cracking. The appearance of cracks in these structures have very different origins, such as differential settlements, temperature variation, variation in water content, excessive overload existence of metallic elements within masonry, among others.

Cambers / deformation of masonry panels, structural changes such as increasing the number of levels, and smashing resulting from excessive loads are other structural abnormalities that occur in masonry structures.

Non-structural anomalies are anomalies that do not affect the safety of the structure, but if the fault develops over time and affect the masonry may compromise the safety of the structure.

This type of anomalies may be associated with two main causes: lack of maintenance of the elements and the action of water. In this category of non-structural abnormalities, especially the breakdown of elements, efflorescence, parasitic vegetation, fungi, lichens, patina, spots from seepage, ruptures, leaks, pollution, thermophoresis.

Intervention in buildings is an action that leads to high costs and constraints in the normal use of them. Thus it is necessary to take several criteria in order to intervene in building an efficient manner.

The main criteria to consider are technical, economic, functional, comfort, aesthetic, social and environmental. To these criteria join the type of anomaly found, its extent and its foreseeable development.

The proposal method is composed by three phases:

- Phase 1, where each anomaly is characterized;
- Phase 2, where the element or part of it is characterized;
- Phase 3, which outlines measures to be taken in order to solve the problem and protect the structure and its users.

PHASE 1

Phase 1 consist to evaluate all existing anomalies in the building in question. The evaluation of the anomaly is performed by classifying the different criteria considered necessary to conduct a proper evaluation of the anomaly.

The criteria considered in this first phase are:

- Element Type Affected;
- Characterization of Anomaly;
- Risk;
- Interdependence with other anomalies;
- Evolution of Anomaly.

The first criterion to be evaluated is the Element Type Affected. With this criterion it is intended to take into account the fact that the anomaly develop an element that has structural function or not, and how it can compromise or not building security.

This criterion is evaluated based on the scale of 1 to 3, where 3 is the most serious value and the less

serious. Table 1 shows the meaning of each level to the test “Element Type Affected”.

Table 1 - Assessment levels for the criterion "Element Type Affected”

ELEMENT TYPE AFFECTED	
Level 3	*Structural Elements*
Level 2	*Non-Structural Elements*
Level 1	*Finishes / Coatings / Others*

The Characterization of Anomaly is the criterion which is evaluated more concrete way the anomaly. Like the previous criterion, the evaluation is made based on the scale of 1 to 3. Table 2 shows meaning of each level to the criterion “Characterization of Anomaly”.

Table 2 – Assessment level for the criterion “Characterization of Anomaly”

“CHARACTERIZATION OF ANOMALY”	
Level 3	*Very Serious Condition*
Level 2	*Serious Condition*
Level 1	*Little Serious Condition*

The next criterion to be taken into account in this assessment is the Risk. This criterion aims to determine whether the anomaly and the likely evolution of the state into question the safety both of users and the building itself.

Unlike previous criteria, the scale used for the evaluation will be 0-2, where zero corresponds to an absence of risk and 2 to a Maximum Risk. The meaning of different levels for this criterion is shown in Table 3.

Table 3 – Assessment levels for the criterion “Risk”

RISK	
Level 2	*High Risk*
Level 1	*Moderate Risk*
Level 0	*No Risk*

The Interdependence with Other Anomalies is another criterion for evaluation. The purpose of this criterion is taken into account if the abnormality in question is associated in some way with other anomalies, and this can be, therefore, a problem to be.

The evaluation of this criterion is performed using the scale from 0 to 2, similar to the risk criterion. Table 4 refers to the meaning of the different levels considered.

Table 4- Assessment level for the criterion “ Interdependece with other Anomalies”

INTERDEPENDENCE WITH OTHER ANOMALIES	
Level 2	*Yes, with serious consequences*
Level 1	*Yes, without serious consequences*
Level 0	*No*

The last criterion to take into account is the Evolution of Anomaly. The objective of this criterion is to assess the state of evolution of an anomaly. An anomaly is evolving a more serious fault than if it is stationary. The binary system is the scale used to assess this criterion. Table 5 refer the different levels considered.

Table 5 – Assessment levels for the criterion “Evolution of Anomaly”

EVOLUTION OF ANOMALY	
Level 1	*In evolution*
Level 0	*Stable / No information*

Evaluated all criteria, the next step is to determine a classification level of severity for each anomaly. The result of adding all the scores obtained in the different evaluation criteria reflects the overall score of the anomaly, this score will determine the state of anomaly.

The overall score ranges from the minimum of 2 and maximum of 11. The state Anomaly can be classified into three categories: Little Serious Condition, Serious Condition and Very Serious Condition. In Table 6 is shown the correlation between the possible overall scores and the state of Anomaly.

Table 6 - Correspondence between the overall score and the State of Anomaly

STATE OF ANOMALY	OVERALL SCORE
LITTLE SERIOUS CONDITION	2
	3
	4
	5
SERIOUS CONDITION	6
	7
	8
VERY SERIOUS CONDITION	9
	10
	11

Apart from determining the Anomaly of State for each identified anomaly is highlighted likewise the scores awarded to the risk criterion. An anomaly that presents a high risk is an anomaly that should be taken into account more than one to present a lower degree of risk.

In order to highlight this criterion, the classification of Risk criteron will be displayed differently, presenting the risk level does not in cash but having the meaning assigned to the rated level in a generic way, as can be seen in Table 3.

PHASE 2

Phase 2 of the method is an overall assessment of anomalies. The ratings obtained for each anomaly, this phase passes through the objective scan a specific area of an element with different anomalies and different classifications.

The criteria analysis for Phase 2 are:

- Element Type Affected;
- Density of Anomalies;
- Density of Risk.

The criterion Element Type Affected to evaluate the structural importance of the element to be evaluated. The method of evaluating these criteria is similar to that described for Phase 1.

The first criterion specific of this phase is the Density of Anomalies. This criterion is intended to assess the level of density for each category considered in the state of anomaly in an area determined by the appraiser.

The density is determined based on a scale from 1 to 3. Table 7 shows the meaning of the different levels considered.

Table 7 – Assessment levels for the criterion "Density of Anomalies"

DENSITY OF ANOMALIES	
Level 3	*High Density*
Level 2	*Medium Density*
Level 1	*Low Density*

The Density of Risk criterion is evaluate the density level of each of the degrees of risk considered (High Risk, Moderate Risk, No Risk) in an area determined by the appraiser.

The density is determined based on a scale of 1 to 3, such as in density anomalies criterion, meaning it is possible to observe in Table 8.

Table 8 – Assessment levels for the criterion "Density of Risk"

DENSITY OF RISK	
Level 3	*High Density*
Level 2	*Medium Density*
Level 1	*Low Density*

Evaluated all criteria, the next step is to assign the element or just an area considered a classification in terms of their status and the overall risk level that abnormalities cause the element.

The method for obtaining the final grades is to determine an overall score for each of the criteria to be evaluated, the state element and the risk.

The overall score for the state element corresponds to the sum of the assigned density values and the classification of the element type.

This score ranges from the minimum of 4 and a maximum of 12. By the score, the element or part is classified as Little Serious Condition, Serious Condition and Very Serious Condition, classification already used in Phase 1.

The correspondence between the overall score and the levels assigned to the state of the element is translated in Table 9.

Table 9 – Correspondence between the overall score and the State of Element

STATE OF ELEMENT	OVERALL SCORE
LITTLE SERIOUS CONDITION	4
	5
	6
SERIOUS CONDITION	7
	8
	9
VERY SERIOUS CONDITION	10
	11
	12

The assignment of gravity to a particular element, unlike what is observed in Phase 1 of the method has some constraints to translate a greater reality evaluation. The following constraints to take into account are:

- *If the element has a high density (Level 3) anomalies classified as Very Serious Condition, the state of the element is considered to Very Serious Condition;*
- *If the element has a high density (Level 3) anomalies classified as Serious Condition and the density of anomalies classified as Very Serious Condition is Medium or Low (Level 2 or 1), the state of the element is considered to Serious Condition;*
- *If the element has an average density (Level 2) anomalies classified as Very Severe and record simultaneously, the state of the element is considered to Record;*
- *For all other cases, the state of the element is determined using the overall score.*

As regards the risk criteria, the procedure is similar to that described for the state of the abnormality. The overall score for risk is the sum of the risk density values assigned and the classification of the element type.

The overall score, similar to what happens to the state of anomaly ranges from a minimum score of 4 and a maximum score of 12. Depending on the score, the risk will be classified as High Risk, Moderate Risk or No Risk. Table 10 shows the correspondence between the overall score and risk levels.

Table 10 – Correspondence between the overall socre and Element Risk

ELEMENT RISK	OVERALL SCORE
NO RISK	4
	5
	6
MODERATE RISK	7
	8
	9
HIGH RISK	10
	11
	12

Like the successful for the state element, assigning a level to the risk also presents some constraints in order to reflect more realistic assessment obtained mode. Thus, the constraints to take into account are:

- *If the element has a high density (Level 3) High Risk deficiencies classified the degree of element considered high risk;*
- *If the element has a high density (Level 3) anomalies classified as Moderate Risk and density of defects classified as High Risk is Medium or Low (Level 2 or 1), the degree of risk element is considered Moderate;*
- *If the element has an average density (Level 2) anomalies classified as High Risk Moderate Risk and simultaneously, the degree of risk is considered Moderate;*
- *For all other cases, the degree of element of risk is determined using the overall score.*

PHASE 3

The third and final stage of the proposed method is the advice measures. This phase consists of the presentation of measures to make the users / owners of the building.

The measures are proposed by the person / entity responsible for the assessment of defects, and are provided that these measures are of a technical nature, actions to be taken in order to solve the problem in question, and measures preventive, with the aim of safeguard the security of users and the building, in order to minimize the risks inherent abnormality in question.

CENTRAL TEJO

The Central Tejo is a set of buildings that are located in Avenida de Brasília, next to Belém, and was the first thermoelectric plant operating in Portugal, being active for 63 years between 1909 and 1972. In 1986 the Government Portuguese ranks the buildings of Central Tejo as Public Interest.

In 1990 is inaugurated the Museum of Electricity, being in operation until 2000, reopening renovated in May 2006, working as such until June 2016. On 5 October 2016 is inaugurated the new Museum of the EDP Foundation, Museu de Arte, Arquitetura e

Tecnologia (MAAT), which the Central Tejo is an integral part.

It's possible identify six buildings in Central Tagus, namely:

- Building of High Pressure boilers;
- Building of Low Pressure Boilers;
- Offices and substation building;
- Machine room building;
- Building of Coal Bunkers;
- Bunkers Ash Building.

In buildings of Central Tejo six different types of anomalies were identified:

- Fissures;
- Efflorescence;
- Disintegration of mortar joints;
- Delamination;
- Erosion;
- Corrosion

For each identified anomaly has materialized the proposed method. Table 11 is shown the different parameters to evaluate for the Fissures anomaly.

Table 11 - Phase 1 of the method applied to anomaly "Fissures"

Scale	Descrition
Element Type Affected	
3	*Structural Elements*
2	*Non-Structural Elements*
1	*Finishes / Coatings / Others*
Characterization of Anomaly	
3	*Fissure open > 2 mm*
2	*Fissure open between 1 and 2 mm*
1	*Fissure open < 1 mm*
Risk	
2	*Global collapse risk with involvement in building / users;* *Commits the architectural value;* *Another risk to which the assessor considers relevant and high-grade.*
1	*Risk of local collapse without major consequences;* *Another risk that the appraiser considers pertinent and moderate*
0	*No Risk*
Interdependence with Other Anomalies	
2	*Yes, with serious consequences*
1	*Yes, without serious consequences*
0	*No*
Evolution of Anomaly	
1	*In evolution*
0	*Stable / No information*

In Phase 3 presents measures to be implemented by the owner in order to solve the problem in question, as well as measures aimed at protecting the structure and users. Then presents a set of measures to anomaly "Fissures".

- *Identify the root causes of such anomalies, in order to act effectively;*
- *Fissures whose opening is greater than 2 mm should be monitored, using crack gauges placed under the fissure, in order to record the activity of the same and thus help the decision to intervene in their repair by trained;*
- *Fissures whose opening is between 1 and 2 mm, which are considered more important, according to the criteria Aspect, Altitude, Extension, Affected elements and Proximity to Structural Elements Main, should be monitored, using crack gauges placed under the crack of order to record the activity of the same and thus help the decision to*

intervene in their repair by trained personnel;

- *If the fissures are causing a high risk of falling of the vestment, this surface must be properly anchored and secluded area to ensure the safety of users;*
- *The remaining occurrences are periodically monitored in order to verify that they do not evolve unfavorably;*
- *Other measures that the appraiser considers appropriate.*

CONCLUSION

The assessment of the state of the anomalies is a very important tool because it allows us to understand the anomalies and realize the seriousness and the risk that a anomaly causes either the safety of the structure or the safety of users.

As the evaluation is performed using a method allows the evaluator to focus only on some criteria whose evaluation of them will serve as a basis for the final result and have a tool that makes the task easier, making more objective an evaluation depends on the evaluator although it is not possible to categorically eliminate the subjectivity of who evaluates.

The criteria for analysis in Phase 1 of the method, Element Type Affected, Characterization of Anomaly, Risk, Interdependence with Other Anomalies and Evolution of Anomaly, are independent each other and criteria for assessing the anomaly in different perspectives.

In addition the end results show the state of the malfunction, the highlight result of the risk criteria makes who analyzes the results to be charged to the risks that certain abnormality is for the connection of the building and its use.

Phase 2, on the other hand, allows those analyzes have knowledge of the overall state of the element, based on all detected anomalies.

The method, in its most general form, guarantees freedom to the evaluator to decide the characterization of the different levels of evaluation for each criterion, adjusted properly to the object building analysis.

To Central Tejo, the method allows to have a tool of analysis of anomalies that will support and base the decision to intervene in buildings of this old industrial complex.

Periodic monitoring of the identified anomalies and periodic inspections to different buildings are critical because they allow not only to understand the evolution of anomalies, as well as detect an early form any problem arising in the building. The maintenance of the building ensures a sense proper operation of buildings.

Regarding future developments, these undergo a possible adjustment of the levels of each criterion to new realities that may arise during the application of the method.

The identification of the causes responsible for the detected anomalies leads to greater knowledge of them and more effective resolution of the anomaly. When completed the causes, the most effective techniques in tackling these problems can be made to the recommended measures, improving the proposal made in this dissertation.

In the event appear new and different anomalies already detected, the method should be implemented for these new abnormalities,

categorizing the different levels for that anomaly, and should be broken down performance measures in order to solve the problem and / or guarantee structure and users.

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