Accessibility on building maintenance actions

Diogo de Campos Almeida e Melim Mendes

Extended Abstract

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Diogo de Campos Almeida e Melim Mendes

Civil Engineering Department, Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal

Abstract

Buildings should display appropriate and safe means of access able to promote proactive maintenance actions and, therefore, their prior definition is an important requirement during the design stage of a new building. For existing buildings, if there are no suitable means of access to carry out the maintenance activities, or if they do not offer a secure passage, then a new, safe and effective access system should be specified.

During this research, a new methodology is proposed, with the purpose of evaluating the conditions of the current means of access. If this evaluation demonstrates these means of access do not provide adequate and safe conditions, then, this same methodology can also be a tool for the definition of a new access system, taking into consideration the constraints present at each building.

Technical Documents were developed, namely, the Building Identification Sheet, the Inspection Sheet, the Constraints Sheets and the Recommendations Sheet, as a relevant contribution to a practical handbook for procedures and recommendations, highly required for the buildings maintenance sector. Case studies, related to different contexts, were analyzed, to prove the applicability and advantages of this methodology in facades, roofs, interior spaces and confined spaces.

Keywords: access, maintenance, access constraints, anomalies, recommendations.

1 Introduction

Maintenance activity has gained an increasingly significant role in extending a building's lifespan, requiring adequate means of access, to be performed safely and effectively.

While new buildings require the design of a new access system to improve future maintenance actions, existing buildings should undergo a rigorous examination, to evaluate the safety conditions of the current means of access. If these conditions are not verified, then a new access system should also be specified. In both cases, it is crucial to determine which factors affect the specification of the new access system.

Therefore, the present research aims the development of a methodology able to evaluate the access difficulties of a given Maintenance Source Element (MSE). It can also be applied to decide if the existing

means of access are suitable to maintenance actions of that same MSE and to determine which constraints influence the definition of a new access system, should it prove necessary.

Finally, based on the registered constraints, this same methodology is also useful in determining the most appropriate access systems and safety features, if the current means of access are not suitable for maintenance actions.

2 Accessibility for building maintenance actions

2.1 Importance of maintenance

Maintenance actions demand an accurate proactive planning that should be developed simultaneously with the structural design of a new building, whereas, for an existing building, it should be improved with the registry of the MSE maintenance needs, taking into account its access difficulties. This proactive planning should meet the quality levels required by building users (Barbosa, 2009) and (Madureira, 2011).

Figure 1 illustrates the minimum and desirable levels required by building users, while showing the performance level of a constructive element and the periodic maintenance actions over time, represented by the vertical lines. Therefore, the absence of regular maintenance actions can lead to the building's degradation with the consequent reduction of its performance level.

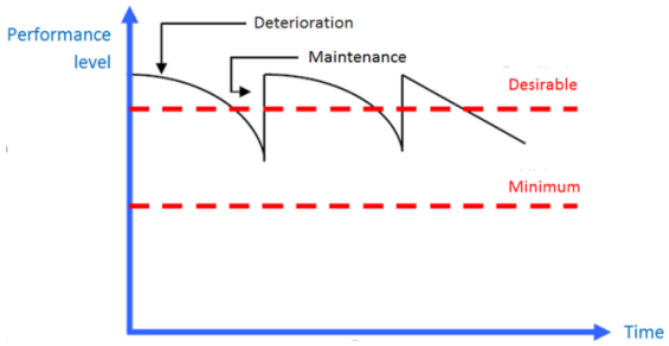

Figure 1 – Performance level of a constructive element (Barbosa, 2009)

In order to optimize the future performance of a new building, high emphasis must be given to maintenance actions. Thus, the project participants have an important role defining the correspondent access system, frequently a permanent one (Rocha, 2005)

For an existing building, its means of access, if well preserved, can avoid the need of establishing a new complex access system. Thus, according to WNSW (2000), through a proper evaluation, it is essential to confirm if the preservation conditions of these means of access provide an acceptable safety level. This is the first objective of the access methodology, developed during this research. If the security level is not acceptable, it is vital to determine the constraints that might affect the establishment of a new access system, being this aspect the second objective of the access methodology.

2.2 Access system - permanent, temporary and safety measures

When defining the access system, it is important to distinguish between a permanent and a temporary system, each one with its own advantages and disadvantages. While a permanent access system is usually defined during the design stage of a new building, a temporary access system is usually implemented in existing buildings, lacking its own means of access for maintenance actions.

Since the permanent system is generally planned at the building's design stage and implemented during the building's construction, its dimension and weight should be taken into account during the building's design (BSI 2005). Currently, the permanent access system features a wide range of solutions, although, generally based on a supporting platform suspended by vertical cables. According to (Erdly & Schwartz, 2004), the access with climbers is a specialized access system which allows a safe access to different components, with suspended ropes, requiring redundant permanent anchorage points, to support the workers' weight and ensuring their safety. For this reason, it can also be classified as a permanent access system since it demands the previous establishment of permanent anchorage points.

The temporary system can be used in two specific cases, in recent buildings which lack a permanent access system or in older buildings requiring maintenance actions. It consists in a set of elements composed of working platforms, such as, scaffolds, stair towers, mobile access equipment and stairs assembled before the work procedures, being dismantled afterwards.

In addition to the access system, the establishment of safety features is also necessary since it improves maintenance activities. Therefore, harnesses, delimitation of access paths, implementation of safety nets and lateral protections allow the activity to be performed safely and effectively.

2.3 Generic constraints that determine the choice of an access system

For many of these access systems, both permanent and temporary, a wide range of constraints impact their design, installation and functionality. Thus, they are listed below, being the safety of the workers involved in such activities and the pedestrians in the vicinity, the factor that prevails.

2.3.1 Building's surroundings, support capability and area restrictions

If a permanent access system was previously installed or is being established, the areas under the platform should be clear and free of obstacles (SAEMA 2005). If this is not possible, given the risk of falling objects, safety measures and road signs should be applied to ensure the protection of the pedestrians on public roads (REDAHK & HKCA, 2005), (APA, n.d.) and [W1].

The permanent equipment, specially, the suspension platforms may present a high area and weight, so their loading should be considered when specifying the structure of a new building, at its design stage (CENTO n.d.) and (BSI 2004). A similar situation occurs when an older building requires the implementation of a new system and, so, it's important to confirm if it needs a structural reinforcement to ensure its preservation and safety conditions (BSI 2004).

2.3.2 Weather constraints, equipment constraints and electric cables

Just as weather conditions affect the severity level of the anomalies, they should also be taken into consideration in the definition of an access system. The main ones are: a) rainfall, ice and snow; b) the wind incidence, which is, unquestionably, one of the most important factors in the definition of a permanent access; c) ultraviolet radiation, which changes the inner properties of constructive materials, making them fragile.

Furthermore, before the beginning of maintenance activities, a former inspection should always be executed on a permanent equipment, to determine any signs of damage or corrosion (SAEMA 2005). On the other hand, electric cables located on the roof must be relocated to avoid being sliced or damaged by the suspension platform movement (BSI 2005).

2.3.3 Interior and confined spaces

According to SI (2009), significant loadings should not be applied against interior walls or doors. Additionally, structural or bracing systems shouldn't suffer modifications and frame elements shouldn't support elements capable of damaging it.

Narrow or confined spaces, without an acceptable ventilation, are considered a particular risk, since serious accidents can occur, namely, the asphyxia of the workers or accidents resulting from a fire or an explosion (WB 2000). Within this category, it is possible to enhance excavations, pipe and chimney interiors.

2.4 Facade specific constraints

Since the access system might consist of a set of heavy equipment supported by anchorage points generating perpendicular strains on the facade base level, its resistance is a main factor that should be considered (SI, 2009). Therefore, to ensure the safety of an access system, it's decisive to check if the building's structure is strong enough, through anchorage points, to withstand the loading, during maintenance work (CFA 2011). It is also essential to analyze certain behaviors of these units, particularly, its thermic expansion, fatigue and lifespan and if bi-metallic corrosion occurs, protection should be applied (BSI 2004).

According to (Chew & Ping, 2003), the facade's and building's shape and structure have a major impact on the access system's definition. Thus, buildings with simple architectural designs will have a more efficient system than buildings presenting more complex designs.

2.5 Roof specific constraints

Roof maintenance requires height access, and working at height can expose workers and pedestrians in the vicinity to serious risks to their health and safety, especially, the risk of falls from height, falling objects and other serious accidents, and so, an inspection regarding the roof's load capacity, fragility and its perimeter protection should be performed (BSI 2004).

The integrity of specific elements should also be verified, such as skylights and chimneys, which require a special attention, specifically during demolition work (Decree n.º 41821). As for plates, at the design stage of a new building, plates made from highly resistant materials should be selected. In regard to asbestos plates, on existing buildings, when they become fragile over time, the asbestos fibers, with a high degree of danger for human health, can be easily released into the air after breakage. Thus, an inspection must be performed, before the beginning of work, to determine the location, quantity and the preservation state of the asbestos plates (Babor & Plian, 2008).

Another important aspect to take in account is the proximity of electrical power airlines, being a frequent cause of death and injury, so, any work activity in its surroundings should be carefully planned (HSE 2012b).

3 Access system methodology

3.1 Methodological approach

During the fieldwork, the analysis of some maintenance cases confirmed that each building has its own specific access constraints, which interfere with the execution of certain maintenance activities. The main reason responsible for this situation is the absence of an appropriate access system, not implemented at the building's design stage.

Considering the above, it is vital to develop a new methodology able to evaluate a given MSE in terms of accessibility and, when necessary, able to support the definition of a future access system and the necessary safety features, taking into account the constraints of each building.

To ensure this goal, it is essential to define technical documents, namely, the Building Identification Sheet, the Inspection Sheet, the Constraints Sheets and the Recommendations Sheet, in four stages, as pictured in the flowchart in Figure 2.

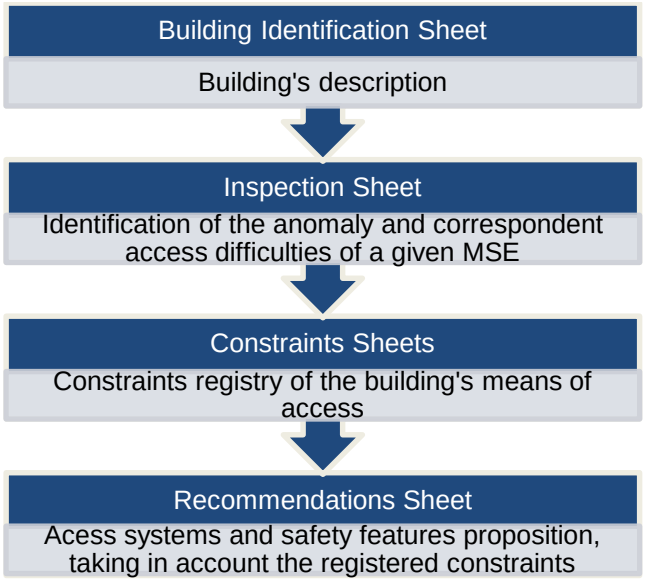

Figure 2 – Flowchart of the methodological sequence

3.2 Technical documents

First of all, it is required to proceed with the building detailed description, through the building Identification Sheet, adapted from Nogueira (2013) and shown in Table 1, filled with a case study which is explained in chapter 4.

Table 1 - Building Identification Sheet

Building Identification Sheet			
Building's name	Mechanical II Pavilion		**Photograph**
Location	Alameda Campus IST		
Purpose	Housing		
	Commerce		
	Business	×	
	Others		
Year of construction	-		
Number of floors above ground	3		
Number of floors below ground	0		
Type of sorrounding	Rural		
	Urban	×	
	Marine		
Terrain's coverage	-		
Implantation area	1950 m2		

For an accurate anomaly identification and its access difficulties of a given MSE, an Inspection Sheet was developed, shown in Table 2, already filled with the support of the anomalies list, the MSE list and the intervention level list.

After completing the Inspection Sheet, it is crucial to determine which means of access are suitable for the maintenance operation, taking into consideration their advantages and disadvantages. With that purpose in mind, the Constraints Sheets were developed, which can be qualified as checklists, by highlighting the existing difficulties of the building's elements and surroundings. Therefore, these difficulties or constraints can be classified into five categories: weather, facade, roof, interior space and confined space constraints. Only the weather and roof constraints sheets are shown in Table 3 and Table 4, as examples, filled for the case study.

Therefore, the Constraints Sheets aim two objectives: a) to determine if the building has the appropriate means of access and in operational conditions for the maintenance activity; b) if that's not the case, to determine what existing constraints will shape the establishment of a new access system.

The Recommendations Sheet, presented in Table 6, shows the possible access paths to reach a given MSE while, simultaneously, indicating which access systems and safety features should be taken, if necessary, based on the constraints registered in the Constraints Sheets. To support the filling, the access system list and safety features list were developed.

Since one of the main objectives of this methodology consists on evaluating and classifying the MSE, in terms of access, then each access path should be classified and ranked based on the information registered from the Constraints Sheets and with the support of the classification list.

Table 2 - Inspection Sheet

<table>
<tr><th colspan="2">Inspection Sheet</th></tr>
<tr><td colspan="2">Anomaly A20 – Not functioning (inoperational)</td></tr>
<tr><td>Anomaly's location
Roof's terrace</td><td rowspan="4">Image/Picture
  </td></tr>
<tr><td>Group of MSE affected
HVAC installations</td></tr>
<tr><td>Anomaly description
Equipment no longer performs the function for which it was designed for</td></tr>
<tr><td>Intervention Level
Bad</td></tr>
<tr><td>Possible causes
End of equipment lifespan</td><td>Access difficulties/observations
Working at height</td></tr>
<tr><td>Inspection Method
Visual inspection</td><td>Inspection date
11/09/2015</td></tr>
</table>

4 Access methodology applications - case study

With the purpose of demonstrating its applicability, the current methodology was tested with four different case studies, each one concerning particular contexts, with its own difficulties and complexities, regarding the following scenarios:

- Replacement activity of the Heating, Ventilating and Air Conditioning (HVAC) equipment on a roof;
- Repair activity of anomalies detected in a MSE on the frontal building's façade;
- Repair activity of anomalies detected in a MSE on the lateral building's façade;
- Repair activity of an anomaly (hypothetic) in a MSE located in a building's confined space.

However, only a case study, regarding the replacement of the HVAC system, is described in the next subchapter.

4.1 Building Identification and Inspection Sheets

This case study regards the replacement operation of the Heating, Ventilating and Air Conditioning (HVAC) equipment located on the roof, as well as its adjacent tubes on the exterior facade, of the Mechanics II Pavilion, located in Instituto Superior Técnico Campus University. The replacement operation, which took place between the 14th and 16th of September 2015, involved various activities, in particular, the prior assembly of the access scaffold, the HVAC equipment and tubes replacement and, finally, the scaffold's dismantling after the operation's completion.

With the proposed methodology, the main objective was to confirm if the scaffold's assembly was, indeed, necessary for this replacement operation or if the current means of access were enough and adequate for it. Therefore, first it was necessary to fill the Building Identification Sheet and the Inspection Sheet, visible in Table 1 and Table 2, respectively.

The field dedicated to the anomaly identification should be filled in the first place, indicating its name and code, according to the anomalies list. The anomaly localization field should include the place where the MSE is located, in this case, on the roof. The sections referring to the Group of MSE affected should also be filled, using the MSE list, as well as the possible causes of the anomaly insurgence, the date the inspection occurred and the inspection method used. A schematic photograph should also be included.

Finally, the access difficulties/observations requires the registration of the main factors that affect a given maintenance activity, while the intervention level subsection should be filled with the support of the intervention level list. After completing the Inspection Sheet, the presence of interior means of access to the roof was verified, however, due to their small size, they did not offer appropriate conditions for the HVAC equipment replacement.

4.2 Constraints and Recommendations Sheets

The Constraints Sheets were registered, particularly, the weather, facade, roof and interior space Constraints Sheets, in order to confirm whether the building's means of access were appropriate for the replacement activity or if, instead, it was necessary the establishment of a new exterior access system. In this abstract, only the weather and roof Constraints Sheets are shown in Table 3 and Table 4.

Table 3 - Weather Constraints Sheet

Weather constraints	Yes	No	N/A	Observations
Is rainfall ocurring?		×		
Is there any ice?		×		
Is there any snow?		×		
Wind incidence **(At observations, indicate the wind intensity's level, with the support of the available list)**	×			Light air
Is thunder ocurring?		×		

Table 4 - Roof Constraints Sheet

Roof constraints	Yes	No	N/A	Observations	Main constraints
Has the roof enough support capacity?	×				Absence of guard rails; Presence of too many specific elements
What's the available area? **(At observations indicate area)**				1875 m2	
What are the constituent materials? **(At observations indicate materials)**				Reinforced concrete	
Are there any permanent access elements to the roof?	×			Interior access stairs	
If so, are they in good preservation conditions?	×				
Is it an inclined roof or a roof terrace? **(Specify at observations)**				Terrace	
Dimensions of the roof's perimeter **(At observations specify perimeter's value)**				240 m	
Are there any guard-rails on the roof?		×			
If so, do they show good preservation conditions?			×		
Is the roof close to electrical towers?		×			
Specific elements					
Skylights/gaps	×				
Chimneys		×			
Gutters	×				
Others **(At observations indicate type of elements)**	×			Solar panels; metal grates; HVAC equipment	

The main constraints are synthesized in Table 5 and registered for each category. After the registry of this information, the next step is the filling of the Recommendations Sheet, visible in Table 6, which shows that the replacement operation can be done through the interior or exterior of the building, each one with its own advantages and disadvantages.

Table 5 – Main constraints summary

Categories		Registered constraints
Façade	Shape and structure	Absence of permanent access elements to the roof; Inexistence of anchoring units for climbers.
	Surrounding	Pedestrian traffic; Possible wind funneling effect.
Roof		Absence of guard rails; Presence of too many specific elements.
Interior space	Interior stairs	Insufficient width for the activity's execution; Inclined slope to the activity; Stair's steps with considerable gaps.
	Most restrictive access opening	Access opening with reduced dimensions.

In conclusion, the replacement through the exterior, with the implementation of an access system, would probably be preferable, since it doesn't cause significant restraints in the building's use. Additionally, the methodology demonstrates that, besides scaffolding, another access system could have been applied, namely the mobile access equipment.

This access system, besides allowing the equipment replacement, would grant good conditions for the tubes' replacement, as long as the workers applied the required safety features and protective equipment, namely, the use of lifelines, since this activity demands working at height.

5 Conclusions

During the development of this subject, it was noticeable, at national level, the need of further research on practical and technical advice, to aid the implementation of an access system and other safety features for the purpose of maintenance operations. For instance, this aspect was demonstrated during fieldwork, confirming that there is not a systematical approach to assist the assembly of a new access system, when necessary.

Therefore, these observations just reveal how important it is to apply the proposed methodology, aimed for the evaluation of each MSE in terms of accessibility, confirming if the current building's means of access are suitable for maintenance actions. If they are not, this same methodology can also suggest which access systems and safety features are appropriate for each access path to reach the MSE, considering the building's constraints. Finally, with this information regarding the necessary safety measures it's possible to classify each access path, allowing the comparison of each one.

This methodology required the development of technical documents, intended as an important contribution for a future practical manual with the objective of evaluating the building's current means of access. However, this documents may, and should be, developed as new constraints are detected.

Table 6 - Recommendations Sheet

Recommendations Sheet													
Scope of activities	Element requiring access	Access paths to execute the activity	Involved Categories	Is it necessary a new access system?			Are safety features necessary?			Do the weather conditions allow the progression of the activity?		Access classification by category	Access path classification
				Yes	No	Possible solutions	Yes	No	Possible solutions	Yes	No		
HVAC equipment replacement	Roof	Through the facade to the roof	Facade	×		**Temporary system** Scaffold; Mobile access equipment; Stair tower	×		Safety nets (for pedestrian traffic protection); Bracing System for the access system (because of the wind incidence)	×		2. Easy	2.Easy
		Through the interior to the roof	Interior space		×		×		Individual protective equipment of the workers (because of the space's reduced dimension)	×		2. Easy	2.5. Easy to Average
			Roof		×		×		Guardrails; Safety nets under the skylights; Delimitation of the access pathways; Anchorage points for lifelines; Anchorage points for climbers	×		3. Average	

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