The contribution of the pedestal paving system to building maintainability

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Abstract

The pedestal paving system technology appears as an alternative that can both increase the performance and the economical efficiency of the building. This technology may turn the process of planned maintenance easier and cheaper, as well as the detection and repair process of developing problems of plaza/roof terrace waterproofing systems at an early stage to prevent any spreading of damage. In order to reach those benefits, it is essential to have technical information about the pedestal paving system to support the stage of design and the stage of technological selection, making the alternative selected suitable to the user's requirements, based on life cycle cost approach. Founded on the information above, the aim of this paper is to systematize and critically analyze the main characteristics of the technology that regulates the selection, design and production stages. Based on the state of the art of the pedestal paving system, the main characteristics which may influence building maintainability are discussed, using a qualitative approach. Findings from this study can provide companies with information on pedestal system technology benefits to reduce building life cycle cost. It occurs as a result of the higher building adaptability provided by the technology, reducing the probability of functional obsolescence of roof and plaza assemblies. In addition, the use of the pedestal system optimizes maintenance activities due to easy surface removal/reset, minimizing damage and waste.

Keywords: Maintainability, life cycle cost, adaptability, pedestal paving system.

1. Introduction

The pedestal paving system can be considered an interesting solution to pave waterproofed plaza decks and roof terraces due to the potential reduction of the whole life cost of a building. It is a technology that allows access to the hydraulic and electrical systems that may be installed in the drainage void, as well as access to the waterproofing system, facilitating the maintenances required by these systems. In addition, it is possible to prevent the early deterioration of the wearing course, which is normally object of problems such as efflorescence, cracks and uneven surface, resulting mainly from the substrate movement. It also enables more freedom for layout changes in external areas and may turn the areas adaptable to change of possible uses, by the execution of supplementary hydraulic and electrical installations. These possibilities allow reducing the chance of functional obsolescence of buildings, increasing their added value. Therefore, it is possible to use this technology as an element of marketing differentiation.

The technology has to be properly applied, that is, duly designed, executed and used, so that the advantages of its use can come to fruition. In this context, the study herein aims to present and discuss this constructive technology, especially in terms of maintainability and reduction of the whole life cost of a building. The study is based on an extensive bibliographical revision with a focus on the main functions of the pedestal system, complemented by a field study (Bernardes, 2009) comprising the analysis of six buildings in operation, in which the technology was applied, and also interviews with the undertakings managers and technology suppliers.

2. Characterization of the Pedestal Paving System

In the course of utilization of roof terraces and waterproofed plazas, surfacing functions were assigned to the protection layers of the waterproofing membrane, being used to pave: ceramic, rock, and pigmented cimenticious slabs, among other types of wearing course. The history of application of such surfaces comprises the use of different methods, with records of failures (CBD 1966; Gomes 1968). This situation encouraged systemic studies, especially in cold weather countries, to analyze the cause of failures, e.g., the study by Schild et al. (1978) in which, among other things, the concern with the integrity of the mortar bed used to set pavers and slabs can be observed.

In those countries where an increasing utilization of a solution called Protected Membrane Roof (PMR) or Up Side Down (USD) took place, proposals were made for wearing surfaces made with sand-set and with pedestal-set paving units. With these non-adhered solutions, the amount of water retained over the waterproofing membrane could be drained quicker, without causing damages to the wearing course (GRIFFIN and FRICKLAS, 1996). In doing so, the Digest 75 (CBD, 1966) stated that proper systems of roof terraces drainage are fundamental, because most terrace surfacing can be displaced by water or frost action.

In addition to this concern, other drivers may have propitiated the development of paving methods with sand bed and, later, with pedestals, as for example, the accessibility to installations, equipment and subsurface layers of the roof and plaza deck system, recognized by Griffin and Fricklas (1996) as an advantage of the non-adhered solutions.

The concept of the pedestal-set method dates from the Roman Empire. In the old Roman thermal bath located in the English City of Bath, the environment heating of the so-called west baths and east baths was provided by the blowing of heated air from under a layer of paving slabs which had their corners set over layers of broken paving pieces (Fig.1).

Fig.1 – Ruins of the floor elevated by stacked flagstones from the Roman thermal bath in the city of Bath (Bernardes and Barros, 2009).

Today the pedestal system is described as a system in which the paving slabs have their corners placed on typically plastic pedestals, resulting in a level deck and in the concealment of slope, which helps the drainage of stormwater through the open joints existing among those slabs (ICPI, 2008). Normally the pre-manufactured pedestals are conceived to allow height adjustment in order to achieve a levelled surface, besides transferring the loads coming from the paving slabs to the substrate (CSTC 1985). According to the AFNOR NF P 84-204-1-1 (2004), the pedestal system has the role of protecting the waterproof layer while creating a surface for people circulation. The system is illustrated in figure 2:

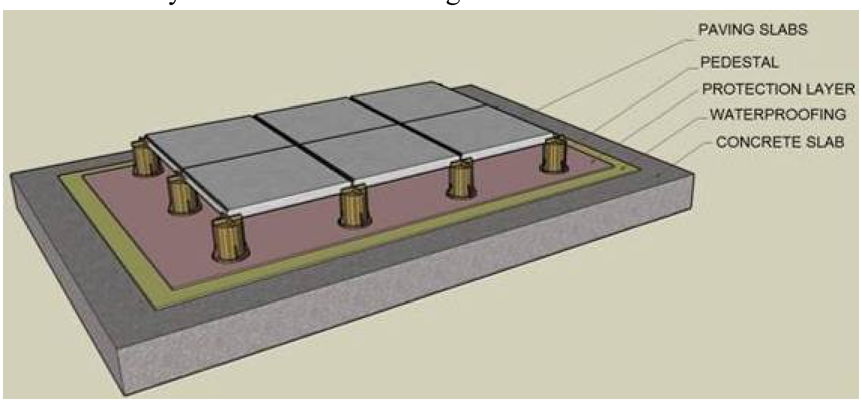

Figure 2 – Paving slabs on pedestal

Nowadays the pedestal system for pedestrian circulation is a plaza deck and roof terrace surfacing more applied than the type bedded in sand or in mortar (Griffin and Fricklas (1996); LES CAHIERS TECHNIQUES DU BÂTIMENT (2007)). The elements and the main functions of the pedestal system for the circulation of people are described in Table 1, based on Bernardes and Barros (2009):

Table 1 – Elements of the pedestal system and their main functions.

ELEMENT	MAIN FUNCTIONS
PAVING SLABS	To form a safe circulation surface
	To enhance the esthetical value of the environment
	To help the mechanical waterproof protection
	To allow easy access to the lower layers and to the installations of the drainage void
	To shade roof tops
PEDESTALS	To give support and stableness to the wearing surface
	To guarantee the spacing among paving slabs
	To adjust the surface level
	To correct variations of quote and tilting in the substrate
	To distribute tension on the substrate
JOINTS	To hold the system perimetraly
	To allow stormwater drainage
	To allow small movements of paving slabs
	To allow the cooling of the drainage void air
	To allow the substrate water drying
DRAINAGE VOID	To drain effectively and quickly the water resulting from rain and snow melting
	To allow the flow of several installations
	To allow the temporary retention of intense rain waters

Several materials can be used for the system manufacturing. Concrete is largely applied to paving slabs, besides stone, wood and ceramic slabs.

Granite slabs in pedestal systems were advocated by Hunderman and Gerns (ca.2000) as components used for the recovery of the roof terrace of the Kennedy Center for the Performing Arts, due to their lower susceptibility to freeze-thaw damages and their lower propensity to deformations.

As to the pedestals, there are a large number of models all over the world. The products they are made of vary a lot, too, the most common being polymers such as polypropylene, polyethylene, PVC, polycarbonate and expanded polystyrene.

3. The Influence of the Pedestal System in the Reduction of the Whole Life Cost of a Building

The main aspects benefitting the whole life cost reduction of a building through the use of the pedestal system are: durability, maintainability and obsolescence, which are addressed below.

3.1 Durability

The ASTM C981 (2005) addresses the importance of sufficient drainage for plaza systems and highlights that it must be able to minimize the saturation cycles of the wearing surface and its substrate, as some materials used in the wearing surface absorb water and can deteriorate when subjected to the freeze-thaw cycling.

As stated by Griffin and Fricklas (1996), in a roof terrace, the advantage the pedestal system has over the sand-set system is that it fosters a quicker and more effective drainage. In addition, the first allows ventilation drying of subsurface areas, whereas the second does not. It is believed that such characteristics of the pedestal system wearing surface allow an enhancement of the paving system life cycle, which can obviously be considered as added value to owners since, according to Chew et al. (2004), these owners have required more durable buildings.

Ruggiero and Rutila (1990) also emphasized the importance of the efficient drainage propitiated by the pedestal system through the joints among the paving slabs, accounting for preventing problems associated to the freezing of support beds used in other laying techniques. The authors claim that plazas historically presented problems resulting from the lack of drainage within the system components, resulting in long-term deterioration of waterproofing membrane and wearing surface.

Another point for the durability of the paving surfaces with the use of the pedestal system is mentioned on the AFNOR NF P 84-204 -1 (2001) when it emphasizes that in roof terraces, this technology minimizes the thermal shock of the waterproofing layer. It is clear that this also happens in the plazas. According to Wong et al. (2003), the roofing materials shielded from direct exposure to solar radiation and not submitted to intense temperature variations would be more durable. A longer roofing system service life would mean fewer roof replacements and hence, the reduction of maintenance and replacement costs.

3.2 Maintainability

Dunston and Williamson (1999) define optimal maintainability as being: “The design characteristic which incorporates function, accessibility, reliability, and ease of servicing and repair into all active and passive system components”, that minimize the costs included and maximize the “benefits of the expected life cycle value of a facility.”

According to Silva et al. (2004), in the last decades, researches realized the importance of maintainability of the buildings in order to reduce costs and achieve better functioning of facilities. In addition, they emphasize that the lack of attention to the matter of maintainability during the design and construction phases has hampered and made the maintenance process more expensive.

Not foreseeing proper and sufficient space so that maintenance works can be performed and, to design permanent fixtures - which should be removable at the performance of maintenance - are design failures that jeopardize the building maintenance process (Assaf et al., 1996). A research made by Chew et al. (2004) in Hong Kong, revealed that up to 40% of maintenance faults were related to design. Assaf et al. (1996) mention studies in which some building defects are considered to be associated with the lack of accessibility to services.

According to Ruggiero e Rulita (1990) and AFNOR NF P 84-204 -1 (2001), the use of the pedestal system can ease the temporary removals of the wearing surfaces (Fig.3), which strongly contributes to its maintainability.

Fig.3 – Simulation of maintenance in a pedestal system with granite slabs in a commercial building in the city of São Paulo (Bernardes, 2009).

For this to be possible, it is the designer’s duty to limit the weight of the paving slabs, allowing safe handling by means of manual processes, using proper tools or mechanized techniques in order not to cause injuries to employees. In Brazil, for example, the paving slabs typically commercialized are 35kg in weight and dimensions are of approximately 60 x 60 x 4 cm (concrete paving slabs), being handled with a fixture similar to the one shown in figure 3.

According to Ruggiero and Rulita (1990), the use of wearing surfaces that are disassembled with relative ease results in more serviceable systems. They add that, ideally, in order to enable the maintenance and trouble shooting of system components, the wearing surface must consist of small modular components that facilitate temporary removals and reinstallation, being this an important characteristic of the pedestal system.

Barret et al. (1988), MacElroy and Winterbottom (2000) and ICPI (2008), emphasize the ease of maintenance and repair of the waterproofing system as an advantage of the utilization of the pedestal system in relation to other methods. The ICPI (2008) adds that after repairs, the components can be reinstalled without evidence of movement and that the replacement of the paving slabs, when damaged, is made easier. Hunderman and Gerns (ca.,2000) highlight that, additionally, there is simplicity in the maintenance of the drainage system.

The Digest 75 (CBD,1966) had already stated that the plenum formed with the use of pedestal systems can have enough space to allow maintenance works, without disturbing the surfacing. The waterproofing ease of maintenance was also an argument so that the Headquarters - Department of the Army (1993), recommended the application of pedestal systems in plazas.

Reroofing is an operation that causes inconveniences. Comparatively, rewaterproofing is an economic disaster, because a waterproofing membrane is far less accessible than a roof membrane (Griffin and Fricklas 1996). The research made by Bernardes and Barros (2009) identified that in one of the buildings the expense with the repair of an earth-covered membrane was around seven times the initial cost of waterproofing.

Upon the potential maintenance costs with the application of adhered surfacing, it is evident the importance of more and more using the concept of maintainability applied to the parts of the building, so that the investment in maintenances are rationalized and the life-cycle cost (LCC) is reduced, even if it results in higher initial costs. As stated by Dunston and Williamson (1999), designers must be able to demonstrate that cost increments in the design stage and construction, due to designing for maintainability, can be offset by reduced maintenance costs.

3.3 Obsolescence

Another favourable aspect for the reduction of a building LCC by the application of the pedestal system is the possibility to use the drainage void space for placing several building installations systems, e.g., fire extinction hydraulic systems, garden faucets, lighting circuits (fig.4), rain water pipe deviations in apartment rooftop, among others installations that are still to come. This benefit, resulting from the use of the pedestal system, allows higher flexibility in the use of spaces, then reducing the risk of buildings functional obsolescence (Bernardes 2009).

Fig.4 – Installation embedded in the drainage void area of a pedestal system in a commercial building in the City of São Paulo (Bernardes 2009).

As stated by Allehaux and Tessier (2002), when the capacity to perform the function to which an element was conceived for is reduced, such element turns to be functionally obsolete. They also add that in office buildings the greatest causes for this occurrence are related to building services and especially to technical installations design. For them, besides reducing the market value of the office buildings, the functional obsolescence of these systems is considered one of the main causes of their obsolescence. For the evaluation of this type of obsolescence, the authors identified several aspects, among them the compliance with user's needs, flexibility and maintainability.

It is added that a part of a building, when considered functionally obsolete, will have achieved the end of its service life and, from then on, it will have to rely on an onerous modernization process in order to return to its functionality. This process, many times, implies the replacement of materials and components and their final disposal counts on desirable and increasingly environmental restrictions.

In the initial brief to designers, building owners should prioritize systems that benefit the maintainability while reducing the potential of the building functional obsolescence, which is recognized with the utilization of the pedestal system, able to foster higher adaptability to the roof terrace/plaza decks and to the building installations placed in the drainage void, meeting the changes in user's needs.

4. Life-Cycle Cost (LCC)

According to Lounis et al. (1998), life cycle cost (LCC) analysis is "a method of assessing the economic performance of a project or project alternatives over a designated study period, and encompasses all relevant costs including the costs of designing, purchasing/leasing, constructing/installing, operating, maintaining, repairing, replacing, and disposing of a particular building or system", at the end of its life. In addition, Wang N, et al (2009) state that the life cycle assessment is the best way to merge the long-term environmental and economical evaluations of building designs.

As stated by Griffin and Fricklas (1996), although the pedestal system has a more complex design and execution, and probably presents higher initial cost, it allows easier access for maintenance and repair of subsurface components. As a result, there is the possibility to reduce the building operational cost making the system economically more attractive.

The WBDG (2007) helps the evaluation of the importance to reduce a building operational cost when it states that, viewed over a 30-year period, the operation and maintenance costs account for approximately three times the initial building costs (earlier design, development, construction, and manufacturing activities).

According to the BRE (2000)[1] apud Chew et al. (2004), the LCC concept must take into account other factors such as: the life expectancy of a building component and energy efficiency. Regarding the energy efficiency concept, Gomes (1968) emphasized that the use of the pedestal system is recommended in a roof terrace when the aim is to enhance its thermal performance, because this system provides shade and a ventilated plenum above the waterproofing, which minimizes its superficial temperature. For the author, the action of the solar radiation over the roof terrace is reduced by the insulation provided by the ventilated plenum of the pedestal system. As a result, the cooling costs of the building are believed to be lower.

As stated by Bernardes (2009), the initial cost of a pedestal system in Brazil, if compared to adhered surfacing alternatives of roof terraces and plazas, is normally superior for a same type of surfacing material. However, for the author, a lower whole life cost is to be expected to the pedestal system solution when taking into account the expenses with repair and replacement of the waterproofing layer, which occurs with no damage to the wearing surface.

Bernardes (2009), supported by the concepts of ABNT NBR 15575 (2008), suggests, to the typical Brazilian utilizations of the pedestal system, a minimum design life of 20 years for the paving slabs, stating that there would be technical and economic possibilities of estimating 40 years, according to experiences reported in other countries. This minimum period suggested aimed to discipline the commercialization of the system in Brazil, due to the absence of codes of practice, standards and technical regulations, without forgetting the autonomy and obligation of the building owner for deciding on the amount of money that can be spent and the length of life required for a building in the early stages of any building program (Chew et al. 2004).

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[1] Building Research Establishment (BRE). (2000) ''Centre for whole life performance'' October 2000, <http://www.bre.co.uk/whole_life/buildingfabric/>.

5. Conclusions

The study has identified the main functional characteristics of a pedestal system that favours the whole life cost reduction of a building. Emphasis is given to the rationalization of the maintenance process of paving layers and of subsurface installations (maintainability); the adaptability provided to the external spaces upon the user needs alterations, reducing the building functional obsolescence potential; the reduction of operational costs given by the thermal insulation provided; and the increase of service life expectancy of the several elements of the roof terrace/plaza systems, mostly the waterproofing layer. Such issues must be incorporated to the owners' expectations regarding buildings, maximizing investments in a long-term point of view, while reducing the use of other resources, non-renewable and increasingly depleted.

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