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ADAPTABLE BUILDINGS: A PORTUGUESE CASE STUDY

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Summary

The Portuguese construction sector is currently ruled by new buildings, responsible for 95% of the annual investment in this sector. Formal aspects and initial costs are the primary design concerns, using current long lifespan construction, with little consideration given to future maintenance or future needs.

This situation represents a tremendous waste of resources (present and future), and there is a growing perception of the need to address these issues. One of the possible change trends lies in a revision of current design practices to increase building adaptability accommodating current construction logics, but there is a lack of examples bridging the gap between current (international) theory and (Portuguese) practice.

The Lisbon EXPO 98 World Exhibition was the largest example of urban regeneration in Portugal, in which several buildings addressed the need for adaptability according to different design logics, since their original uses would cease or change upon the exhibition's closure.

This paper will present the case study of an EXPO 98 building, Portugal's Pavilion by Pritzker Winner Architect Álvaro Siza, as an example of the use of design strategies to provide adaptability (at structural, spatial and material levels) within an institutional building, using current Portuguese construction possibilities.

1. Construction in Portugal

1.1 Historical matrixes

Prevailing economic difficulties have left an indelible mark that characterizes Portuguese architecture throughout History, albeit with some historical exceptions (the influx of wealth from the various overseas colonies). The most remarkable traits of this "plain architecture" were summed up by Kubler [1] as "formal austerity", "richness of interior proportions" and "coldly rational exteriors" all dictated by "clarity, order, proportion and simplicity". These characteristics determined mainly by economic hardship were based on building with massive load bearing solid walls and a reduced palette of finishes determined by locally available materials (light-colored renders in the south, stone in the north).

The rational character of Portuguese architecture was further increased in the aftermath of the 1755 earthquake which razed Lisbon to the ground, since the town's rebuilding scheme became the first occasion on which building component standardization and pre-fabrication was used on a very large scale.

The plain character of Portuguese architecture endured mainly until mid XX Century, as a consequence of both political conditions (a dictatorship), and economical hardships. In the aftermath of the Democratic Revolution of 1974, references have greatly changed, with an opening to outside influences as expressed in the more cosmopolitan architecture present in various urban centers. Nevertheless, it can be argued that there remains a longing for "heaviness" and "plainness" even in very recent modern architecture.

1.2 Current construction habits

Building construction surged during the last two decades of the twentieth century following an influx of European Community structural funding, applied mainly to infra-structures (highways) and public buildings (courthouses, universities, hospitals, etc.). Housing construction also took off, leading to enormous changes on the national urban landscape. New construction dominates the investment in the sector, with only 5% of all funds going to refurbishment and maintenance (well below western European average). Design-wise, initial costs prevail, with little or no attention given to maintenance or adaptability.

Reinforced concrete structures are dominant, due to an abundance of associated mineral resources (limestone, gravel and sand), with steel structures slowly becoming more commonplace. Enclosure and separation walls are usually made of ceramic brick infill, finished with painted mortar renders, although more sophisticated panel or curtain-wall solutions are common outside residential programs. Roofing is mainly of ceramic roofing tiles, but flat-roofing solutions (asphalt membrane or zinc) are also very common. Infra-structures (namely water-piping and electricity) are usually embedded into the brickwork, with little access. Aluminum framing and commercial interior door systems are widely available, but a very high degree of customization is still possible through "handicraft" work, especially in woodwork and stonework. This framework allows for relatively singular aspects of formal and material expression that still distinguish Portuguese architecture.

1.3 Sustainability in the construction industry

The relatively poor character of Portuguese architecture throughout History led to the use of locally available resources and the development of techniques which can be considered sustainable (socially, economically and environmentally) in the sense that they responded to physical and functional needs, within economic possibilities and without compromising local resources.

Currently, sustainability in the construction industry is being sought mainly in the energy efficiency field, for several reasons. Portugal is subject to a demanding climate, with hot summers (40 º C temperatures are not uncommon) and cold humid winters. Buildings (mainly XXth century stock) show a recurrently deficient performance in insulation issues, leading to accelerated pathologies and energy waste on acclimatization. This has expressive economic consequences since the country has scarce traditional energy resources, being dependent on oil importation. There are however various renewable energy sources available (solar, wind and tidal) which are already being pursued, as European Community and Kyoto Protocol objectives.

The other main trends for sustainability in construction - use of friendly materials and management of construction and demolition waste (CDW) - are not yet priorities, although some of the more traditional natural resources (certain types of stone and wood) are becoming increasingly difficult to obtain, while CDW is increasing at an alarming rate, equaling domestic waste in volume but lacking appropriate legal and logistical structures for disposal and reuse. The result is that illegal CDW dumping is a commonplace practice with terrible ecological and landscape consequences.

Although the need for sustainability is widely agreed upon, the main obstacles to further sustainability in construction lie in the socio-economic context of the Portuguese construction industry. Tenders are resolved on a lowest price basis, which leads to generalized price dumping with consequent low level of construction quality. Subcontracting is commonplace, leaving the biggest construction companies as "tender managers", with uncertain control over subcontractor's capacities and performance. Generally, the workforce qualifications are low, with a great proportion of unskilled workers (both national and foreign). This is compensated by sticking to known and trusted current (unsustainable) construction techniques. Innovation comes mainly from the design professionals, but at a slow pace for several reasons. There are no intermediate professionals defending the designer's interests during construction, which almost always turns the construction process into a "grinding" relationship between designers and builders (and owners). In the context of intense competition, project fees are also subject to generalized dumping, especially in officially promoted works (disregarding the official fee calculation law). Pro-adaptability design strategies such as "layering" and "scenario buffering" are practically unknown and unapplied, especially since there are no Life Cycle Analysis or Whole Life Cost tools tuned to Portuguese specificities. All these aspects leave few opportunities to implement new or different design methodologies and construction techniques, since designers may not have the financial and technological edge to make such an investment, nor the ability to guarantee a correct implementation.

1.4 The need for Adaptability

Although efforts for promoting sustainability in all sectors and aspects of the construction industry are underway, the promotion of adaptability in design is not yet a priority for change. Portugal has a long history of building reuse, especially after the extinction of the religious orders in the early XIX Century, which left a vast amount of empty large buildings (mostly monasteries) which were adapted to very different uses (universities, hospitals, government ministries, even the National Assembly). Architects have tackled the need for adaptability on an ad-hoc basis, doing their best resorting only to their resourcefulness. However most of the efforts in this field go unnoticed and unregistered, which in effect leads to a loss of knowledge. Therefore there is a real need for a systematic collection of examples and methodologies, diffusing knowledge and practices amongst architecture professionals and students alike.

2. Lisbon's EXPO 98 World Exhibition

When planning started in the early nineties, it was decided that the Lisbon EXPO should act as a dynamo for urban regeneration, and thus the riverside area of a soon to be deactivated refinery on the Eastern side of the town was chosen, with an overall area of about 5 sq km (the exhibition ground itself was smaller in area). From the onset, sustainability in construction activities was an objective. Selective demolition of existing structures (refinery, housing, warehouses) was made so as to maximize reuse of materials on site. Thus 750.000 tons of crushed concrete were used in provisional roads and as a base layer for final roads, while 100.000 tons of masonry rubble were used for soil stabilization and 100.000 sq m of existing granite paving blocks were recovered and reused in the exhibiton grounds [2]. Since the Expo intended the creation of a new central area of the city, the buildings to be erected for the exhibition had a major role in structuring the future neighborhood. The buildings designed for the Exhibition can be divided into several categories, according to different End of Life Scenarios dictated primarily by their future urban role:

a) "definitive" buildings, corresponding to Expo centerpieces whose program would continue upon the exhibition's closure ("Camões" Theater, "Oceanarium" Aquarium, "Utopia" Multipurpose Pavilion);

b) "urban" buildings, designed with a sense of permanence due to their urban and institutional importance, functioning as major thematic pavilions during the Expo, but whose use would change upon the exhibiton's end (Knowledge of the Seas Pavilion, Portugal's own pavilion, "Olympic" Center);

c) "halfway" buildings, referring to constructions that were used during the exhibition for purposes different from their final use (North Exhibition Pavilions, "Oriente" Main Entrance Gate);

d) "provisional" buildings, designed for a short lifespan, but envisioning component or materials reuse (South Exhibition Pavilions, Future Pavilion, Macau's Pavilion, Central Services Building, South and North Gates).

The EXPO 98 was a success, attracting a record number of participating countries, establishing new references for public space design in Lisbon and Portugal, and becoming a very popular weekend spot after its closure. "Definitive" buildings kept their original functions, "urban" class were recast functionally (becoming Museums or office buildings) and "halfway" buildings were finished after the Expo's end (the Orient Entrance Gate becoming the Vasco da Gama Shopping Mall and the North Exhibition Area being completed as Lisbon's International Fair Hall). "Provisional" buildings met different fates (some were rebuilt in other towns, others were dismantled) giving place to new housing and office buildings.

3. The Portuguese Pavilion

3.1 General description

The Portuguese Pavilion was one of the most important buildings of the Lisbon EXPO 98, designed by renowned Portuguese architect Álvaro Siza (1992 Pritzker Prize winner). Design started in 1994, and from a very early moment in the design process, the uncertain functional future of the pavillion was considered, while its urban and institutional reference role dictated morphology and expression issues. In the architect's own words, this building (which he saw as a modern palace) could end up being a museum or an office complex [3] [4]. The building was sited in the central area of the Expo site, alongside the main axis running the length of the grounds, in the northeastern corner of a former hydroplane docking basin on which stands the "Oceanarium" Aquarium. The pavilion's most striking feature is its 20 cm thick concrete "inverted canopy", shaped according to a catenary directrix, spanning approximately 60x60 meters suspended with steel cables from two reinforced concrete porticoes, defining a covered ceremonial plaza and framing the various entrances to the building.

Figure 1 - Eastern view of the Portuguese Pavilion Building, with the suspended concrete canopy.

It has been seen how current construction habits in Portugal are based mostly on "wet and heavy" solutions, turning the buildings into very durable entities, which works against current deconstruction theories that foster mainly disassembly as a key for sustainability.

True sustainability requires satisfaction of social and cultural requirements other than economical and environmental issues. Thus it can be argued that the abrupt introduction of construction techniques foreign to current habit, and especially foreign to current popular perception that "buildings should be solid and last for a longtime", could be counterproductive. It is therefore reasonable to consider that promoting sustainability in Portuguese construction by fostering building adaptability with current construction techniques would be a desirable way of balancing all dimensions of sustainable construction.

The design efforts to provide Portugal's EXPO 98 Pavilion with "accommodation capacity" are worthy of a praise equal to its structural prowess (which stole all the attention, as it should), since it displays diverse spatial, structural and material strategies, intent on managing the need of strong urban and institutional presence, short term public use and an uncertain functional future.

Although the analysis of the building proceeds in separate categories, they influence each other in terms of the final result, as should be in an effective architectural synthesis.

3.2. Spatial system

From the onset, the most important decision with impact on future change was the total separation of the main needs of the building - housing functions and expressing national character - into independent structures: the building and the canopy. This turned them into independent construction problems, effectively managing the conflicting needs of change and permanence associated to each part.

The building covers approximately 55 m by 90 m, with an average height of 12 m. It has two main floors above ground, a basement floor and an enclosed technical area at roof level.

The pavilion establishes different relationships with its context. The South façade is punctured only by doors, opening to the intermediate space between the pavilion and the canopy's north portico (which allows access to the plaza through several openings. The Eastern facing façade, looking into the main vehicle circulation axis, displays a great austerity punctuated only by a preeminent volume at the Northeastern corner of the building. The shorter North facing side is characterized by an open air patio, facing a series of freestanding walls looking onto a close water pond. The West side has a portico along its full length, facing the dock basin and the "Sea of Straw", a 10km wide section of the Tagus River famed for the its sunset reflections.

Other than the north facing patio, the large mass of the building is punctured by a fully interior open air courtyard which brings light into the middle of the building mass.

The two above ground floor levels have different floor-ceiling heights (4 m on the ground floor, 5,5 m on the upper floor, with false ceilings averaging 1 meter), effectively turning the upper floor into a "piano nobile" alike classical European palaces. This sense of scale is further heightened by the window size and regular rhythm. Lower floor openings have steel lintels over 3.5x2.5 m shop windows, while upper floor windows average 2x4 m, opening onto balconies. This window repetition, as well as the interior courtyard, was deemed essential to provide for future adaptability in a very deep building. However the main aspect determining future adaptability was the adoption of a 5x7.5 m module, based on the structural grid, and which was used to structure the building's ground and upper floor spatial configurations.

The pavilion design had originally to manage different scales of significance and use during the EXPO, since it was to be used as public exhibition space with complementary facilities (gift shop, book shop, café), but also in a very expressive institutional role, hosting the daily receptions to foreign dignitaries. For Expo purposes, the two main floors were divided into two "L" shaped sections, around the central courtyard.

The public exhibition areas were located in the Eastern side, along the whole length of the building. The circuit started under the concrete canopy, proceeding north to the open north patio. The areas destined for housing the exhibition were double height spaces, with a provisional fit-out, composed mainly of metallic structures and gypsum boards, and dismantled upon the exhibition's end. Loading and unloading was made through the garage or the outside covered gallery in the Northeastern corner of the building.

The remaining "L" shaped area, occupying the two western side floors of the building, embodied the spaces assigned for VIP reception and entertaining, as well as for complimentary functions of the pavilion (shops, café, bookshop and restaurant).

In this area of the building, the cellular matrix of the interior worked as the modular basis to house the very different programmatic units. Offices, reception rooms, large spaces (such as a multi-roomed restaurant) and ancillary spaces (such as kitchens) were formed by different combinations of these cells. Vertical circulation cores (stairs + lift + service ducts) and sanitary facilities were also organized within this module, mainly adjacent to exterior walls. The protruding corners of the internal courtyard also house elevator shafts running all of the floors, three of which were used while the fourth shaft is still empty (as it faced the main exhibition area where there was yet no upper floor structure, it was deemed unnecessary).

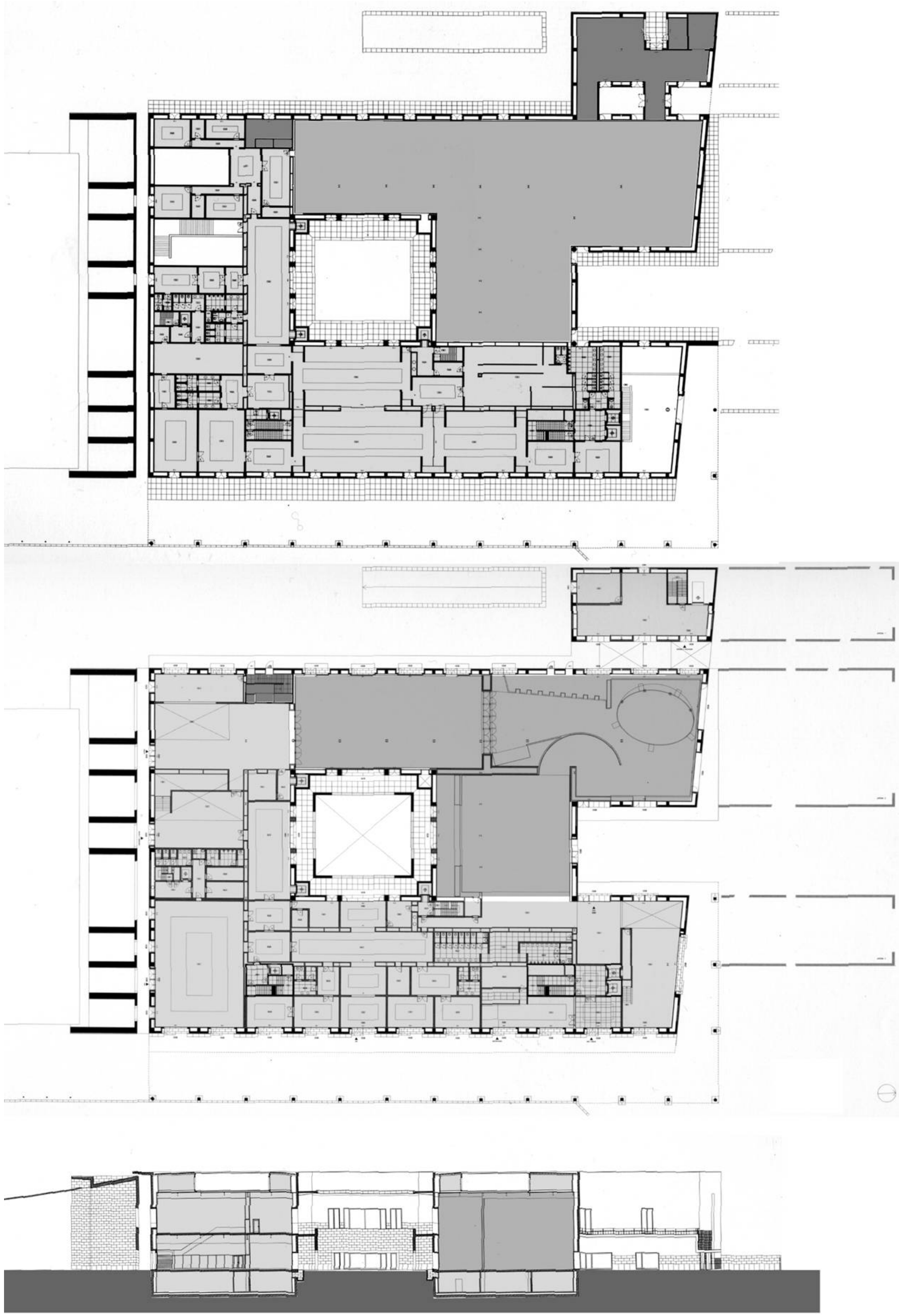

Figure 2 - EXPO 98 Portugal's Pavilion ground and upper floor plans and longitudinal section. Light Gray areas are "definitive expo spaces", medium gray are double height spaces corresponding to "provisional expo spaces", dark gray are unfinished / unused sections. Notice "thick" outside walls with cavities housing vertical ventilation ducts and variety of interior arrangements based on 5x7.5 m "cell" within 20 m deep building. In section, notice independence from canopy portico, basement with light wells for ventilation / lighting and enclosed upper technical floor protecting HVAC ducts entrances into the building.

The great spatial flexibility provided by the cellular organization and their combination was further enhanced by a blurring of the spatial distinction between "server" and "served" spaces, in effect turning circulation into a passage between adjacent rooms.

This logic was essential in achieving the original intention of creating a "palace", for historical examples in architecture show this logic of interconnecting rooms both as a strategy for circulation (even when there is a dedicated circulation space), and as a form of dramatizing the approach from the interior of the building to the light in deep plan buildings.

It can be argued that this cellular character, based on the dimensional relationship between structure, outside openings and ceiling height, is the single strongest aspect of future adaptability, effectively permitting differently scaled spaces within the building and a variety of internal circulation.

3.3. Structural and infra-structural systems

The building structure is modulated according to a 5,0 m by 7,5 m grid, with the open air patios corresponding to several modules of this grid. Although geometrically aligned with the porticoes of the canopy, the building structure is totally independent. Since the soil was very soft due to the extreme proximity to the water, the foundations use deep piles for stabilization at key points. Further soil stabilization was provided by masonry rubble from onsite demolition works.

The building has two slightly different structural systems, below and above ground. The basement level has continuous periphery retaining concrete walls and interior concrete columns with a tighter density than the upper floors, supporting the ground floor reinforced concrete slab.

On the ground and first floor levels, all outside walls (including the patios) are a 30 cm thick reinforced concrete shell with columns. The interior columns are of steel H profiles, with distances varying between 10 and 15 m. The floor and roof slabs are of the mixed type (profiled steel plate with a concrete compression layer) set on steel I and H profiles. Of the various vertical service and vertical circulation cores, only two have a reinforced concrete structure, placed on the wider west facing section of the building and working as structural bracing. Two other vertical cores have steel structures, which allow for their dismantling if necessary. The building has no expansion joints, the structure being calculated to deal with movement due to temperature differentials.

The option for an interior steel structure effectively allows future changes, especially in the double height exhibition areas, where a first floor slab will be inserted, connecting to the unused upper floor of the vertical service circulations block. The column spacing caters for varied interior configurations based on the 5x7.5 m cell, effectively allowing the creation of spaces running the full length or width of the building if necessary. The provision of a reinforced ground floor slab allows placing heavier loads within the building (for example, modern art sculptures).

On considering any building's structure in Lisbon, one must bear in mind the daily temperature variations and the seismic vulnerability of the city. The option for a monolithic building can be seen as a good solution to these aspects, effectively dispensing with a traditionally weak spot within Portuguese construction (the structural joint), although extra dimensioning efforts are required.

The design strategy pursued for dealing with HVAC systems entailed the separation of the water-based air treatment units into two separate groups. Other than the underground parking ventilators, an independent machine was placed in the basement level, connecting to the exterior through the light wells. This machine supported the definitive and provisional uses on the basement level, and the independence of circuits allowed for its disassembly or alteration without interfering with the upper floors.

The main group of HVAC machines, serving the ground and first floor spaces were placed an exterior open air "ring shaped tub" defined by a 3 meter high enclosed technical floor. This floor occupied the interior and outside perimeter of the roof, housing the air tubes entrance / exit from the building shell, thus solving water tightness problems associated with roof piercing. All descending and ascending air tubes were placed into the cavities existing between interior and exterior sides of the exterior walls (including the interior patio ones). The ventilation shafts for the main kitchen were the only exception to this logic, using one of the interior concrete vertical cores which also provides for roof access.

This core (accessible for inspection) was used to run the hydraulic parts of the HVAC system, channeling hot and cold water from the basement to the technical floor at roof level. Several extra "blind" hot and cold water exits were left at basement level to cater for future needs. (hot and cold water were provided for by an independent central, supplying all Expo buildings via underground technical galleries).

The option of running vertical HVAC conduits in exterior wall cavities effectively eased future interior spatial reorganization, since there are no vertical shafts in the building's usable depth. This solution also justified the "thick" walls, reinforcing their permanent character, albeit accessibility is near impossible due to use of brick masonry. Nevertheless water piping, more prone to premature failure, is more easily accessible.

3.4. Material system

Externally finishes include stone facings (with an average thickness of 4 cm), on the more heavily vulnerable areas (ground, balconies, corners) or especially significant areas (porticoes) set on stainless steel fixings over PUR thermal insulation. The rest of the façades (above head or hand level) are finished in painted fiber reinforced mortar renderings over cavity brick as insulation.

The roof is finished in zinc metallic sheeting over PUR insulation. Drainage is assured via sloping of the technical floor roof slabs, draining into interior accessible piping. Other roof areas were finished with gravel laid on membrane sheeting over PUR insulation.

Exterior window and door are composed mainly of solid wood with double glazing, and exterior steel profiles for durability and ease of window glass replacement. These elements vary slightly in size according to their location (between upper and lower floors) but their section is similar, allowing a rationalized production. Exterior window and door framing is of 4 cm thick polished stone, reaching 15x15 cm solid sections on the lower floor shop windows. Due to the regularity of window openings, it was possible to pre-fabricate concrete panels for the window lintels on the first floors, while metallic lintels were used on the ground floor.

All interior walls are of brick masonry, laid without touching the interior structural columns. On the two main floors the masonry is used to define "boxes" encasing the steel structure. This provides the steel elements the required fire protection, while conveying a sense of thickness to the interior walls attuned to the overall proportions and expression of the building.

Interior wall finishes are painted stucco and polished stone (on stairs and sanitary facilities). On the original EXPO public exhibition and circulation areas the walls were finished in gypsum boards, used as a sacrificial layer. These boards were placed over outside walls and upper floor windows, and over provisional metallic defining the exhibition circuit spaces. Interior doors are all wooden units, mate enamel finished. The adoption of steel framed doors would have allowed greater flexibility and reuse upon interior reorganization. Ceilings are of painted hanging gypsum boards. Floors are finished in polished oak wood (nailed, not glued) or polished local stone (on wet or service areas).

Overall, more importance was given to the quality and type of materials used than their quantity and diversity. This reduced palette of finishes was enhanced by detail design directed at expressing solidity and sophistication in a sober way. Exterior finishes aim for durability through solidity of materials and design. Interior partitions, while not easily changeable, nevertheless leave the structure untouched while providing fire protection without resorting to insulation foams which render future work on the steel elements very difficult.

3.5. Current situation

The pavilion is currently used mainly in support of events in the Atlantic Multipurpose Pavilion, as a venue for receptions and meals. Although a project for turning it into the Council of Minister's office has already been drawn by architect Álvaro Siza, it has not been executed as the building was deemed too small for all the requirements. Uncertainty as to the pavillion's future use has thus prevented its sale to the Lisbon municipality or the state (since it is still a property of the EXPO 98 organizing company).

Finished for seven years now, the pavilion shows material pathologies mainly due to vandalism (broken facing stones, bent handrails and cracked window glasses at ground level), the proximity to a seaside-like environment (rusting of some metallic technical doors), and deficient rainwater draining on balconies (leading to the formation of stalactites along the edges).

4. Conclusion

Other than its more bold structural statement, the EXPO 98 Portugal's Pavilion shows itself as a balanced synthesis of spatial, functional and formal aspects, responding to its immediate and distant context, and addressing immediate uses without compromising future adaptability. The building design offers an elegantly rational solution making use of current national constructive solutions while looking to historically based typologies for inspiration on adaptability. The building's end of life coordination logic can be described as an "Hard Shell / Soft Core" approach, pursuing the most durable outside solutions while providing both flexible spatial organization (cellular units, structural / spatial relationship, extra elevator shafts) and structural alteration capabilities (interior steel structure allowing modification by bolting). The management of infra-structures for adaptability is most evident in the thick exterior walls, housing vertical HVAC ducts.

Although the building can be considered exceptional due to the financial and political circumstances surrounding its birth, it nonetheless serves as an example of what can be made within fairly current constructive solutions, without sacrificing the architectural expression issues which usually come first on the design decision taking processes.

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