Thermal Comfort in the Modern Movement – Consequences of Constructive Definition on the Summer Behaviour of a Housing Building in Porto, Portugal

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Abstract. The knowledge of the properties of construction materials, as well as the way they are organized in the construction systems, namely those of the facades, are essential to understand the functional performance of buildings, namely their thermal comfort. This article presents a research oriented towards the constructive characterization of the facades of a multifamily building and the consequences for its thermal comfort in summer. The building here analysed is Edifício Lino, built between 1951 and 1954 in Porto, designed by the architects Arménio Losa and Cassiano Barbosa, prominent figures in the architecture of the modern movement in Portugal. The importance of studying buildings at this time is related to the need to define strategies for use, maintenance and possible intervention in the existing heritage in order to respond to the contemporary expectations of habitability of these works of the Modern Movement, often forgotten due to the temporal proximity. From the study carried out, it can be concluded that thermal comfort emerges as a central concern of the reference architects of this time, who considered this issue an inexorable architectural quality.

1. Introduction.
"The intervention in modern heritage buildings are not simple, the whole process has to be very careful with the questions of materiality, authenticity, it is an architecture that has a very own spatiality that often does not accept great changes [1].

This article is based on the results of a research where architectonic principles, materiality and construction choices taken by two prominent architects of the Portuguese Modern Movement - Arménio Losa and Cassiano Barbosa, at the Multi-family housing project - Edifício Lino, from 1953, are contrasted with comfort parameters. Through these parameters and computer simulations we pretend to create the fundamental bases of a restoration intervention to be carried out in the future. This intervention shall be attentive to the temporal, spatial and tectonic peculiarities of this kind of construction.

The Modern Movement architecture has always search for the well-being and the comfort of man. Housing, work, body and mind culture [2] are the principles of this architecture.

"The notion of comfort appears as a clearly modern feature. (...) modern comfort is considered as an architectural quality, and it is necessary to attribute it to furniture, certain finishes, efficient mechanization of the kitchen and bathroom, and (...) elements that control the environment." [3]

This notion of incorporating comfort as intrinsic quality of the architecture was always present on all the works of Losa and Barbosa. Prior to any restoration project we must verify how these materials and qualities have behaved over time and, above all, confirm that the comfort values (thermal, light
and noise) of these buildings are acceptable for contemporary standards. As Ana Tostões argues "the current regulations on safety, energy performance and environmental comfort put reuse actions in pair with the requirements necessary for the construction of new work, often calling into question a qualified recovery. Thus, one of the objectives of the restoration will have to go through the meeting of a specific lexicon, which considers the character of the built along with the mutations necessary for the experience of space." [4]

With the measurements carried out in situ we will be able to verify how the mechanisms designed in order to respond to the demand for comfort, imposed by the architects of the modern movement correspond to contemporary expectations of habitability and legislation and which changes will have to be implemented. Good solar orientation, window frames, ventilation shading systems, insulation and waterproofing systems were part of the construction lexicon applied in all the works of these authors; these systems were designed for the well-being and comfort of modern man's homes.

The future intervention should be able to decide which strategy to implement that optimizes these systems, and that maintains the identity, whether through changes, replacements of elements or simple reparation. The characterization of all systems and materials that integrate the construction of the apartments of the Edifício Lino is fundamental for a complete evaluation of the type of actions to be taken for its efficient use, assuming that the main objective is to maintain identity and integrity of the building. For this and as shown in figure 1, it is necessary to understand the building from its historical framework to the current state.

**Figure 1.** Edifício Lino, from implantation to detail.

2. **Climate context and thermal characterization of the building**

The climatic framework of Porto and consequently of Edifício Lino is important to verify its compliance with the reference Thermal Transmittance coefficients established by Portuguese Ordinance No. 379-A / 2015, required for each portuguese climate zone. The objective is to understand the response of the materials used in the envelope constructive systems of one
representative apartment in Edifício Lino, in order to perceive its compliance or not with the values stipulated by Portuguese legislation. Table 1 presents the climatic data of the city of Porto.

**Table 1.** Porto city weather data.

| City                  | Porto |
|-----------------------|-------|
| Winter climate zone   | I2    |
| Number of degree days (GD) (ºC days) | 1610 |
| Heating season duration (months) | 6.7  |
| Summer climate zone   | V1    |
| Average outdoor temperature (ºC) | 15.3 |
| ZREF (m)              | 9     |

The Thermal Transmittance (U-value) defines the overall ability of conductive or convective barriers to transmit heat. It characterizes the amount of energy in the form of heat that is transmitted through 1 m² of wall surface, in the period of one second, when the temperature difference between the inside and outside is 1 ºC. The coefficient of thermal transmission of a building element is calculated by dividing the thickness of the material (e (m)) by the value of thermal conductivity (λ (W/m°C)) resulting in the thermal resistance of the building elements. Using the calculated value of the thermal resistance Rt, of a given building element, the Thermal Transmittance, U-value. The calculation of the total thermal resistance of a given building element is calculated by Equation 1 as shown in EN ISO 6946:2007.

\[ R_t = R_{si} + \sum R_i + R_{se} \text{ (m}^2 \text{. ºC/W)} \]  
(1)

where:
- \( R_t \) - Total thermal resistance of the building element;
- \( R_{si} \) - Interior Surface thermal resistance;
- \( R_i \) - Thermal resistance of the building element layers I;
- \( R_{se} \) - Exterior Surface Thermal Resistance.

It should be noted that ITE50 of the LNEC (National Laboratory of Civil Engineering) [8] indicates values for \( R_i \), \( R_{si} \) and \( R_{se} \) for the present thesis used the values of \( R_{se} 0.04 \) and \( R_{si} 0.13 \), defined for the horizontal heat flow, due to the fact that all the envelope elements with thermal requirements are vertical so the flow is horizontal. The thermal resistance value of the non-ventilated air gap (that exists inside the walls) was also considered, being this 0.18 (m². ºC/W).

The U-value can be obtained from the thermal resistance according to Equation 2:

\[ U = \frac{1}{R_t} \text{ (W/m}^2 \text{. ºC)} \]  
(2)

The U value of the 4mm plain glasses used in Edifício Lino with wooden frames were also retrieved from ITE50, being this 5.1 (W/m² ºC). Table 2 presents the reference Thermal Transmittance of envelope elements.
Table 2. Reference Thermal Transmittance of opaque and glazing elements, $U_{ref}$ [W/(m²·ºC)] in accordance with Ordinance No. 379-A/2015.

| Uref [(W/m²·ºC)] | Climatic zone | Current zone of envelope |
|------------------|---------------|--------------------------|
|                  |               | In contact with the outsider or with non-useful spaces with Heat loss coefficient btr>0.7 | 0.40 |
|                  |               | Vertical opaque elements | Horizontal opaque elements | 0.35 |
|                  |               | In contact with other buildings or non-useful spaces with Heat loss coefficient btr 0.7 | 0.70 |
|                  |               | Vertical opaque elements | Horizontal opaque elements | 0.60 |
|                  |               | Glazed spans (doors and windows) (Uw) | Elements in contact with the ground | 2.40 |
|                  |               | 0.50 |

Thermal inertia allows to dampen temperature variations, keeping it more stable inside the building, therefore further away from extreme values causing discomfort. Thermal inertia can be calculated using the Equation 3:

$$I_t = \Sigma M.s_i.S_i /A_p$$  \hspace{1cm} (3)

where:
- $M.s_i$: Useful surface mass of element $i$ [kg/m²];
- $S_i$: Area of the interior surface of element $i$ [m²];
- $A_p$: Useful area of the Pavement [m²].

According to the Portuguese regulation (Decree Law n.º 118/2013) three classes of thermal inertia are defined: strong, weak and medium. The Edifício Lino Apartment in study has a strong thermal inertia class due to its high thermal mass, $I_t > 400$ kg/m², as it can be seen in Table 3.

Table 3. Thermal inertia calculations of the Apartment in study.

| Elements               | $S_i$ (m²) | $M.s_i$ (kg/m²) | $r$ | $S_i$. $M.s_i$. $r$ |
|-----------------------|------------|-----------------|-----|-------------------|
| Exterior wall          | 43.5       | 130             | 0.5 | 2828.2            |
| Interior wall type 1   | 20.4       | 150             | 1   | 3182.4            |
| Interior wall type 2   | 38.5       | 198             | 1   | 7619.1            |
| Interior wall type 3   | 19.6       | 240             | 1   | 4704.0            |
| Roof                  | 57.8       | 150             | 0.5 | 4336.5            |
| Pavement Slab type 1   | 43.8       | 150             | 0.5 | 3285.0            |
| Pavement Slab type 2   | 14.2       | 150             | 0.5 | 1065.0            |
| **Totals**             | **58 m²**  | **1174 kg/m²**  |     | **465.86 kg/m²**  |

The definition of the envelope elements helps understand which walls present thermal requirements and thus realize if the organization of the different materials in the construction systems are able to comply with the regulations in terms of Thermal Transmittance. The analysis of figures 2 and 3 shows the type of envelope elements in which the Thermal Transmittance should be considered: the walls of the north and south facades (in red), the respective glazings because they are in contact with the exterior and the wall between the apartment and the common staircases of the building (in yellow). This is because it is a space in direct contact with outside, with fixed windows. It should be noted that
the envelope elements marked in green, when in contact with spaces that are also interior, are spaces without thermal requirements. It is important to emphasize that in the walls between apartments, the architects kept the wall with two rows of bricks and air gap between them, for sound insulation; while on the east wall of the building that is in contact with another collective housing, without thermal requirements, they only applied a row of bricks, demonstrating sensitivity to an efficient resources’ management.

![Figure 2. Plan with envelope elements.](image)

![Figure 3. Section [AA‘] (top) and Section [BB’] respectively with envelope elements.](image)

The constructive details of the north and south facades were characterized, as well as the wall between the apartment and the staircase in order to calculate the value of the thermal transmittance (U [W/m² °C]) of each of these elements. This calculation allowed to understand whether the elements with thermal needs are in accordance with current standards. The constructive details presented in figure 4 are redesigns of the originals elaborated by the architects.

2.1 Analysis of results

The calculation made and presented to the different building elements of the apartment under study, reveals that none of these meets the thermal requirements of Ordinance No. 379-A/2015 presented in Table 2. The north facade where the kitchen and the north bedroom are located, and the south facade with the living room and the south bedroom, being vertical opaque elements have as $U_{ref}$ the value of 0.40 (W/m² °C), however in the present building, with all these elements exceeding 1 (W/m² °C) these requirements are not met. The same applies to elements in contact with non-useful spaces such as the dividing wall between the apartment and the vertical access that exceed the $U_{ref}$ value of 0.70 (W/m² °C) for this type of elements, i.e. also do not meet this requirement.

The glazed spans also do not meet, given the value taken from the ITE50 for simple 4mm glazed spans with wooden frames, of 5.1 (W/m² °C) to be much higher than the $U_{ref}$ requirement of 2.40 (W/m² °C). The weighted mean, in the relationship between the area and the building elements increases the U values, accentuating the discrepancy between the recommended and the calculated values.

The study of the vertical sections allows us to realize that the architects of the work had a logic in the distribution of the chosen materials, the order of the ceramic bricks following from the outside to the interior is: brick of 6cm thick, then the air box of 5 cm and then 8 cm of ceramic brick as the last
material i.e., there could be here the intention of the latter, with greater thickness, allow to increase the capacity of thermal accumulation, although slightly there is a clear intention here to obtain better thermic and acoustic comfort inside.

| Building Material | $\varepsilon$ (m) | $\lambda$ (W/m°C) | $R_t$ [m² K/W] |
|-------------------|------------------|------------------|----------------|
| Tile              | 0.06            | 1.30             | 0.005          |
| Mortar lime and sand | 0.02         | 0.80             | 0.003          |
| Ceramic brick 6   | 0.06            | 0.34             | 0.18           |
| Air box           | 0.05            | 0.18             | 0.18*          |
| Ceramic brick 8   | 0.08            | 0.34             | 0.24           |
| plaster           | 0.02            | 0.80             | 0.03           |
| Stucco            | 0.01            | 0.40             | 0.00           |
| Total $\varepsilon$ (m) | 0.237        | $\Sigma \varepsilon r$ | 0.649          |

Interior surface thermal resistance, $R_{in}$ [m² K/W]: 0.13
Exterior surface thermal resistance, $R_{ex}$ [m² K/W]: 0.04

Thermal transmission coefficient of wall $U$ (W/m²°C): 1.22
Thermal transmission coefficient Simple glass 4mm with wooden frames $U$ (W/m²°C): 5.1*

Weighted Average of the value of $U$ (W/m²°C): 3.36

*Value tabulated by TESIS

Thermal transmission coefficient calculation
3. Thermal comfort evaluation - "In situ" Measurements in cooling season

After the results obtained in the constructive analysis and its calculation of the U, realizing that these doesn’t correspond to the minimum required values, comfort measurements were carried out on site with the expectation that these may demonstrate that the living conditions of this building are good or at least acceptable. These measurements also allowed the validation of the conditions considered in the thermal simulations that were intended to be carried out.

The experimental evaluation of the hygrothermal performance of the building required monitoring during the cooling season in order to obtain key summer data to understand the thermal behavior of the building. Being an ongoing investigation there is still the intention of conducting the same type of monitoring in winter.

Measurements of temperature and relative humidity were performed in situ by placing portable temperature and humidity monitoring data-logger equipment, two indoors and one on the outside that record the desired values for the necessary parameters. These data needed to reach the operative temperature, important for the study.

For the measurements, two scenarios were used, one with all blinds closed (Scenario 1) and the other with all blinds open (Scenario 2). During the tests performed there were no changes in the opening of the glazed windows, which were always closed. It is also important to mention that the apartments were without any occupancy and therefore without internal gains.

The choice of scenarios is due to the approximation of the usual conditions of unoccupied buildings, also allowing and in order to optimize the intervention, develop and verify the values of comfort in an ideal scenario of simulated occupation.

The results presented in this study were obtained in a measurement campaign carried out in the building, in a period of seven days, representative of the cooling station - May 21 to 29, 2020. Although this period doesn’t correspond exactly to summer, it was an atypical week of spring with very high temperatures that corresponded to what was expected from a summer campaign.

These measurements highlight in Scenario 1 the maximum and minimum temperatures in this period, which inside the apartment were 24.8°C and 19.3°C, and outside, 34.8°C and 15.3°C, demonstrating that, while the difference of the indoor temperature peaks is 5.5°C, outside this value is 19.5°C. Comparing the temperature peaks of the interior with the outside, the difference between the maximum temperature of the outside and the inside is 10°C and between the minimums if of 4°C.

Although these results in the apartment are favorable, they are not in line with the luminous comfort, because there is no entry of natural light into the spaces. In Scenario 2 the indoor temperatures present a slightly higher variation, of 7°C, and the maximum temperature in this period was 27.3°C, and a minimum of 20.3°C. Comparing the tests in the difference between the peaks, although smaller than in Scenario 1, are relevant due to solar gains during the day and heat losses through the openings at night. This difference between temperatures is 7.5°C and 5°C in relation to the maximum and minimum peak respectively. This proved that the studies and solar concerns of the architects in the building design, has positive results in the summer season. The results of this process allowed us to understand how the design of the building responds in this solstice where the angle of solar height is greater and, as it is possible to observe in figure 5, with the angle of 70° used by Losa and Cassiano for the solar study in its buildings, the Lino Building is no exception and allows natural lighting during summer in the spaces, but mostly without direct incidence, which would consequently increase the interior temperature.

For Relative Humidity, in both Scenarios they met EN 15251:2007, which recommends for existing Category III buildings, a maximum and minimum value between 70 and 20%. In Scenario 2, the building reaches category II i.e. for rehabilitated buildings. The justification of these positive values is due to the high temperatures recorded outside that provide lower humidity, which consequently, inside the apartment, without any sun protection of the blinds, allowed the indoor temperature to increase and thereby reduce the relative humidity. It can be concluded that by the
correct use of blinds, during this season, the values can even be optimized and provide the best comfort, whether thermal or luminous.

"Temperature and humidity are the most important aspects of indoor environmental conditions (...) determine to a large extent the conditions of thermal comfort, due to the impact they have on several of the thermoregulation mechanisms of the human body" [5]

Figure 5. Solar incidence, angle of 70⁰ in summer. South Room left. Living Room right.

To better compare the hygrothermal comfort in the apartments, the Operative Temperature were thus evaluated during the cooling periods, with Scenarios 1 and 2 indicated above. This evaluation also allowed to understand the comfort conditions defined by EN 16798:2019 in order to understand whether the apartments are within the parameters for category III (Pre-existing building category). Graphs shown on figures 6 and 8 were plotted from the operative temperature for an occupant sitting in the center of the compartment in summer clothes (0.5 clo). The indoor air velocity was considered as zero due to all the windows being closed and the average radiant temperature equal to air temperature.

For these graphs, the temperature and maximum and minimum relative humidity of each day were evaluated, in order to establish an average weekly value of each factor, so that through the online tool CBE (Center for the Built Environment) Thermal Comfort Tool, it was possible to verify that the values collected in the building are in accordance with the comfort zones of the EN-16798 standard. Based on the interpretation of the Graphic presented in figure 6, it is observed that it doesn’t comply with the EN-16798 standard in Scenario 1. However, this only happens due to the inoccupation of the building - although the collected values are outside the comfort range of the standard, it should be noted that the temperatures are lower, i.e. it meets the norm by excess, with no cooling needs. Easily in this season and conditions one could reach the values of the norm, just by opening the blinds, which was done in Scenario 2.
In Scenario 2 the operative temperature has a greater variation throughout the day, due to the opening of blinds, since with the simple glazing of 4mm there are more solar gains during the day and consequent increase in the temperature of this surface and heat losses at night with the decrease of the temperature.

In figure 7 it is possible to observe the greatest variation of the exterior temperature in relation to the interior operative temperature. This reveals the importance of thermal mass, because the thermal discomfort is due to these high variations if these are not absorbed.

Through the consultation of Graphic presented in figure 8 allows verifying compliance with the EN-16798 standard, throughout the week, between category III when it reaches the lowest operative temperature and category I on the days where they are higher, it is important to emphasize that the building, despite having the blinds open throughout the day, always remains within the comfort zone recommended by the standard.

**Figure 6.** Evaluation of comfort in the apartment with blinds closed, from 21 to 29 May.

| Temperature [°C] | Legend: |
|-----------------|---------|
| Maximum average temperature recorded |
| Category I | Category II | Category III |
| Minimum average temperature recorded |
| Category I | Category II | Category III |

Results of the apartment with closed blinds

Data entered for maximum temperature values:
- Air Temperature: 22,4°C
- Radiant Average Temperature: 22,4°C
- Air speed: 0 m/s
- Relative Humidity: 62,7%
- Metabolic Rate: 1 met
- Clothing Level: 0,5 clo

Data entered for minimum temperature values:
- Air Temperature: 21,4°C
- Radiant Average Temperature: 21,4°C
- Air speed: 0 m/s
- Relative Humidity: 69,6%
- Metabolic Rate: 1 met
- Clothing Level: 0,5 clo
Thermal comfort simulations

The collection of thermal comfort data in the building apartment allowed to conclude, as mentioned in the previous point, that even in conditions where the blinds are fully open for a week, the values comply with the standards. Due to the fact that the building is presently unoccupied, and that an occupation scenario would be difficult to monitor in a representative and controllable way, it was decided to simulate a situation of occupation of the apartment, establishing occupant’s constant heat

**Figure 7.** Operative temperature and exterior temperature from May 21 to May 29. Scenario 2.

![Operative Temperature °C](chart)

**Figure 8.** Evaluation of the comfort in the apartment with the blinds open, from 21 to 29 May.

- **Legend:**
  - Maximum average temperature recorded
    - Category I
    - Category II
    - Category III
  - Minimum average temperature recorded
    - Category I
    - Category II
    - Category III

Data entered for maximum temperature values:
- Air Temperature: 24.6°C
- Radiant Average Temperature: 26.2°C
- Air speed: 0 m/s
- Relative Humidity: 51.6%
- Metabolic Rate: 1 met
- Clothing Level: 0.5 clo

Data entered for minimum temperature values:
- Air Temperature: 22.6°C
- Average Radiant Temperature: 24.5°C
- Air speed: 0 m/s
- Relative Humidity: 62.7%
- Metabolic Rate: 1 met
- Clothing Level: 0.5 clo
exchanges with space and electrical equipment that contribute to the heating of space as televisions and lamps i.e. the usual occupancy.

Simulation tools are important for testing something that is currently impossible to test since the building is unoccupied. DesignBuilder, a graphical interface available for the EnergyPlus (U.S. Department of Energy) energy simulation method. The program has BIM interoperability, facilitating the import of 3D models. DesignBuilder is a versatile computer program that provides several simplified options for the early stages of the project and more complex options that allow for a more detailed analysis of the energy model. The program allows the analysis of energy consumption, carbon dioxide emissions, comfort level of occupants, lighting, computational fluid dynamics (CFD), environmental impact assessment, among others.

The program uses EnergyPlus the U.S. DOE building energy simulation program for modelling building heating, cooling, lighting, ventilating, and other energy flows. It builds on the most popular features and capabilities of BLAST and DOE-2 but also includes many innovative simulation capabilities such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, and photovoltaic system. The simulations were carried out through the EnergyPlus program through the DesignBuilder, where the typological characteristics of the apartment type were inserted (the middle apartment or the one in which the floor and ceiling slabs have no thermal losses and are thus in the ideal conditions). Complementing the typological model were also inserted all the materials that are part of the construction system of the apartment, as well as the frames sized and characterized according to the existing one.

After inserting all the characteristics of the building, the operative temperature, ambient temperature and relative humidity were simulated, but to obtain these results, it was necessary to first find a day with the maximum and minimum temperatures, 25 and 15.5 ºC outside in order to match the measured "in situ" behavior of the building and thus validating the simulation conditions.

The objective of the simulated values in the program is to find the category of the apartment taking into account the adaptive comfort method preconized on the EN-16798 standard. The adaptive comfort method is only valid with some conditions such as the lack of mechanical refrigeration equipment, being priority given to the opening and closing of windows. Occupants should be on sedentary physical activities with metabolic rates ranging from 1.0 to 1.3 met. And there may still be variables of the inhabitants' clothing, that is, more clothing in winter, less in summer. This method is important because in order to create the basis for minimal and optimized intervention, the fact that people adapt to the existing one is relevant to maintain the characteristics of offering identity to the from the implementation to the materials used in the construction system.
The interpretation of Figure 9 graph allows us to state this in an ideal scenario of occupation and taking into account the adaptive comfort requirements of the EN-16798 standard, with all the restrictions presented above. Edifício Lino is in Category I within the acceptable limits with Operative temperature from 20.8 to 25.8 °C i.e. only 5°C of temperature asymmetries.

5. Conclusions
"(...) the work of architecture is not only the demonstration of the artistic value of the architect. The architect will seek, as an artist, to create a work of art. But this work of art has to be useful and serve. Otherwise it will be sculpture, monument, but not architecture." [6]

Losa and Barbosa founders of ODAM (Organização dos Arquitectos Modernos), an organization of Oporto’s architects that at the 50’s defended the values and principles of Movement Modern, in particular the need to integrate comfort and functionality with the aesthetic and avant-garde values of architecture. As such, constructive and material options, should be integrated on the proper design of the building. As referred by Maia, “at Edifício Lino, the architects were able to express their formal and spatial ideas, applying the common construction lexic in order to guarantee, passively, comfort of all the interior spaces” [7].

The results obtained in the "in situ" measurements complemented by the simulations of the Edifício Lino proves the excellent performance of this kind of buildings – designed without any mechanical support, planed with passive ventilation strategies, that benefits of a good solar orientation and facades and window frames take advantage of and control solar incidence.

Despite the poor condition of the construction, abandoned and unused for decades, our study proves that with cleaning and simple reparation of the constructive elements as well as the implementation of a necessary maintenance we can prolongate the life of the building and match current comfort standards. The proof of this are the results obtained in the "in situ" measurements complemented by the simulations. The operating temperatures are, however, those that, through data collection and simulations, allow the building to be in category I of adaptive comfort where the difference in indoor temperatures should not exceed 5°C throughout the day. Mendonça, points that in
the construction of buildings, "if there is no" strict application of principles, rules or standards that promote the rational use of energy and the conscientious introduction of new technologies, these levels of thermal comfort will tend to be achieved with greater use of mechanical heating and cooling systems, which will increase energy consumption in the sector, hence the pertinence of optimizing bioclimatic design. [8] An environmentally conscious design has the ability to respond to contemporary concerns and create the best conditions of comfort without mechanical supports or the implementation of new materials to optimize insulation.

Our measurements complemented by the simulations have proven that the capacity of the Edifício Lino, as it can be inhabited according to nowadays expectations related to adaptive comfort in summer. To improve its comfort performance, the building only needs to be occupied, inhabited and used daily, perhaps this is the greatest achievement and what we must learn from the architects who designed these time challenging buildings.

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