As a means of solving the housing deficit caused by the rapid growth of the urban population, public authorities have been promoting over the last few decades actions aimed at encouraging the production of popular housing projects. Currently, the federal government, by means of a national housing policy, is focusing investments on what is called the Band 1 of the program My House, My Life (in Portuguese, Programa Minha Casa, Minha Vida – PMCMV), which aims to create mechanisms to encourage the production and purchase of new housing units by families with monthly income of up to R$ 1,800.00. Launched in 2009, the program contracted more than 4.2 million housing units until February 2017.

With that in mind, the construction of popular housing has proven committed to meeting the demand for quantity but is inefficient regarding design and construction quality. Although, for most beneficiaries, the buildings represent an evolution in their housing pattern, basic requirements of appropriate housing are depreciated. With solutions usually focused on construction speed and scale economy, a rationalization of space production prevails. Other aspects are left in the background, such as: environmental comfort criteria, functionality, proper location and even, in some cases, construction quality.

Providing the market with quality environments is as important as supplying the housing demand, mainly under the perspective of the future resident. The quality of a building results in the welfare of the user promoted by the living conditions, and the architectural design is the way to develop these conditions.

In force since July 19, 2013, NBR 15575:2013 groups performance indicators that refer to an adequate housing model. With a new concept of
construction, it values the design activity and the involvement of the entire productive chain, providing a leap in the quality of buildings. Due to the design characteristics of housing made for low income population, meeting the minimum performance established by NBR 15575:2013 will represent an elevation in the standard of these buildings. Proposing a minimum level of performance, this standard breaks the paradigm according to which housing quality should correspond solely to the economic standard of users.

In face of the current housing production for low income population, this study raises the hypothesis that the environmental comfort parameters of the production destined for the PMCMV – Band 1 in the metropolitan region of Rio de Janeiro (RMRJ) are below the minimum limits set by NBR 15575:2013.

This study addresses the improvement of the quality of popular housing, particularly regarding living conditions, incorporated by the architectural design. The purpose of this study is to analyze the environmental comfort conditions in the construction of social housing, especially those produced for the Band 1 of the PMCMV in RMRJ, based on the criteria described by the performance standard. The study seeks to identify what attributes should be observed in design practice so that the buildings produced for the low-income population meet the environmental comfort criteria prescribed by the performance standard.

A literature review was carried out in order to gather information to contextualize the research. Firstly, the study establishes a parallel between the urbanization process in Brazil and the evolution of the housing deficit. Then, there is a brief description of state production in order to provide the reader with an overview of the policies regarding social housing, considering the historical aspects, design, construction and user satisfaction, followed by a diagnosis of the current production in the RMRJ.

Secondly, the study addresses the new design paradigms promoted by the search for sustainable development. It deals with the environmental comfort theory considering thermal, acoustic and lighting performance and presents the main design strategies linked to user comfort and health, and to energy efficiency.

Concluding the contextualization, the concept of performance and the performance standard's development dynamics are presented. Then, the next part of the study presents the criteria considered in the assessment of the thermal, acoustic and lighting performance of the housing structures.
The case study is carried out to verify the hypothesis. The case study allowed the consideration of the practical application of the NBR 15575:2013 Standard and to highlight the design solutions practiced by verifying compliance regarding thermal, acoustic and lighting performance.

The construction projects studied here were selected considering the elements that occurred most frequently in studies about the current production of social housing in the RMRJ. All units include a living room, two bedrooms, a bathroom, a kitchen and a laundry area, meeting the minimum specifications of the program. The most common housing typology is that of the "apartment" within condominiums with blocks of 3, 4 or 5 floors, representing more than 80% of the contracted units. The sample features five types of constructive systems, they are: conventional constructive system (beam-pillar), concrete walls framed on site, structural masonry with concrete blocks, structural masonry with ceramic blocks and innovative constructive system. The system that produced reinforced concrete walls framed on site was the most used one, with an incidence above 80%. The second most used system was structural masonry with ceramic blocks.

Given that the external construction material is decisive in providing environmental comfort and that the exposure and use conditions are determining factors in construction performance, the parameters used for the definition of the models were: location, typology and external construction system. The analysis considers the objects of study still in the design phase. Project A adopts the external sealing with concrete walls framed on site and Project B adopts structural masonry with ceramic blocks. Both projects are organized as condominiums with five-floor blocks in the same geographical region. These two models were chosen for having similar characteristics and, therefore, enabling comparisons.

For a housing project to meet user requirements, it is necessary to understand the exposure and use conditions to which the project will be exposed. The exposure conditions required by the standard for the evaluation of thermal, acoustic and lighting comfort are the identification of the Bioclimatic Zone of the city in which the project is to be implemented and the noise class to which the housing construction is exposed.

The thermal performance evaluation of the sealing has two requirements: suitability of external walls and ventilation openings. Regarding the first requirement, the maximum permissible value of thermal transmittance (U) and the
minimum permissible value of thermal capacity (CT) of the external walls were
determined. The second requirement concerns ventilation openings in prolonged
permanence areas – living rooms and bedrooms – which must have a total area
that meets either the minimum requirements of the local legislation or the values
adopted in the standard when there is no legal requirement in the place of
implantation. As for the roofing system, it must have thermal transmittance (U)
and solar radiation absorption that provide an appropriate thermal performance to
the bioclimatic zone.

In the second stage of the analysis, if the values of transmittance and
thermal capacity are not reached, the designer should evaluate the building as a
whole, considering each environment as a thermal zone through the computational
simulation method. In this case, during summer, the thermal conditions inside
prolonged permanence areas must always be equal to or better than the external
ones in the shade for a typical day of this period. In winter, the thermal conditions
inside prolonged permanence areas should always be better than those of the
external environment, on a typical day of winter.

External air noise, internal air noise and impact noise should be considered
to evaluate the acoustic performance of housing buildings. The standard defines
parameters for the housing unit to provide acoustic insulation between the interior
and exterior of the units, between internal common areas and private units, and
between the different autonomous units but does not establish limits for the
acoustic insulation between the rooms in the same unit. The insulation levels
required for each system in order to ensure acoustic comfort conditions are
indicated.

For the evaluation of the lighting performance of housing buildings, the
norm defines parameters for both natural lighting and artificial lighting. Two
methodologies are proposed to evaluate lighting performance: simulation, with the
calculation of the general illuminance levels and on site measurement, with the
establishment of the daylight factor, in addition to project premises aimed at
orienting good lighting performance.

Project A, made of concrete walls framed on site, has not reached the
minimum level of thermal performance on a typical winter day for the prolonged
permanence areas, however, the methodology indicated by the standard for the
simulation did not consider the building's real use, since internal sources of heat
were not accounted for and air renewal was considered to happen every hour, something that hardly occurs during cold weather, since the user tends to keep the window closed.

The minimum ventilation requirements for the rooms of the two projects were not met. In this case, the environment's geometry limited window positioning. The window frames occupied the only area that is in contact with the exterior and in order to reach the required dimensions the window sill quota was lowered. Some solutions could have been adopted in the window model to reach the minimum ventilation area, such as the opening of the lower part with the installation of a balustrade to promote safety or a substitution for rotating windows that allow 100% of opening.

Project B, made of structural masonry with ceramic blocks, has not reached the minimum level for the acoustic performance of the internal wall between the autonomous units. However, given that this index has a safety margin, a flawless construction may meet the minimum requirements. For that to happen, it is necessary to consider, for example, fully filled vertical and horizontal joints, the geometry of blocks and the direction of holes.

In both projects, in the external vertical sealing where there are windows, the blocks that are closer to the source of noise do not meet the minimum level of acoustic performance. It is observed that the greater the area of contribution of the sill on the wall the higher the sill's reduction index should be, proving the relevance of the sill in the external sealing systems.

The slabs between floors meet the minimum parameters for insulation against air noises, but no conclusive studies were found in the case of impact noises for the systems proposed.

During results analysis, it was observed that the deficiencies found may be corrected with design revision and substitution of materials.

The study has shown that several factors have a strong influence on the final performance of the building: the characteristics of materials – thickness, density, color; the execution of services; the orientation of the building; the layout, dimension and sealing of window sills. Therefore, a single variable does not account individually for the building's performance. Thus, designers must make an assessment of all the characteristics and develop their project based on them.
At the end of this study it was possible to conclude: that the external material is the main element influencing the attainment of the environmental comfort requirements of NBR 15575:2013, and the window sill is a determining element in the system; that the attempts of implementing buildings with sustainable elements are scarce concerning regulations related to thermal, acoustic and lighting performance; and that the performance assessment of constructive systems can contribute to improving the quality and detailing of the projects.

**Keywords**

Environmental comfort; social housing; NBR 15575:2013; housing performance.