Conference Paper

Constructive Retrofit Guidelines for Social Housing Buildings in Beira Interior Region, Portugal, for Actual and Future Climate Scenarios

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Abstract

An important part of the Portuguese social housing building stock is unappropriated regarding the actual regulation and resident's comfort requirements, which are expected to increase due to the impact of climate change. Beira Interior region in Portugal is one of the fewest Portuguese zones that presents both winter and summer most severe scenarios in many places. Future climate scenario projections for this region indicate more aggressive summer seasons, with the occurrence of heat waves becoming more significant, while winter seasons are expected to maintain a rigorous profile. The present article, which reflects the work still in progress, presents the development of a proper methodology for social housing retrofit in Beira Interior region for present and projected climate scenarios under Portuguese realistic cooling/heating habits of occupants. It focuses on monitoring internal temperatures in order to understand actual dwellings performance considering occupant behaviour, along with the construction of a dynamical multi-zone model for dynamical thermal simulations. Comparing the results with appropriate thermal comfort standards, proper retrofit measures will be identified and tested. Therefore, it is aimed the accomplishment of constructive retrofit guidelines, which are expected to be valuable tools for stakeholders interested in the retrofit of the Portuguese social housing stock.

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1. Introduction

Portuguese housing building stock currently presents about 70% of its building constructed before 1990 [1], previously to the implementation of the first thermal regulation (D.L. 40/90 of February 6th). An important part of the Portuguese social housing building stock follows the same trend [1], therefore resident's comfort requirements are not assured considering the lack of quality in materials and constructive processes used until then, especially reinforced concrete use without proper thermal criteria in the building envelope [2].

Correcting poor building thermal performances with active systems is impractical in the majority of Southern Europe contexts due to energy poverty phenomenon, where permanent heating/cooling practice does not exist [3, 4]. Portugal is characterized by intermittent or no heating habits, while cooling have an insignificant impact of energy consumption [3]. In social housing contexts, economic conditioning implies no heating/cooling habits in the majority of cases [5].

This scenario will be aggravated by the increase of comfort requirements in buildings due to the impact of climate change, where Southern Europe will experience the most adverse effects related to climate change, comparing to other European regions [6, 7]. Main impacts in Portugal during summer seasons consist in the increase of average and maximum temperatures, as well as of heatwave events, while winter seasons are expected to maintain a rigorous profile [8-10].

Considering Southern Europe's vulnerability regarding social housing building performance under present/future climate scenarios and energy poverty contexts, this article aims to provide a contribution for a specific Iberian Peninsula case – Beira Interior (BI) region in Portugal – by establishing an approach regarding social housing stock thermal and comfort performances under Portuguese realistic heating/cooling habits understanding, and its improvements by proper constructive retrofit interventions.

BI region in Portugal is delimited in this work as the set of units "Beiras e Serra da Estrela" (BSE) and "Beira Baixa" (BB), according to national nomenclature of territorial units for statistical purposes, NUTS III. It presents relevant vulnerability of social housing contexts, according to the exposed situation. Being one of the poorest economies of the country [1], its social housing building stock follows the national trend [1, 11]. Thus, its climate context is representative of a considerable extension of the central area of the Iberian Peninsula [12, 13], being one of the fewest Portuguese zones that presents both winter and summer most severe scenarios in many places (Figure 1), I3 e V3 respectively [13], while in future climate scenario projections indicate the same trend, with slightly reduced winter severity and considerable aggravation of summer seasons [8].

Retrofitting, actually with an important role in Portuguese national strategies for housing buildings [14], can resolve or minimize the exposed vulnerability considering its repercussion in the improvement and adaptation of building thermal behaviour [15, 16]. The transposition of the European Directive on Energy Performance of Buildings into the Portuguese national regulation was made by the D.L. 118/2013 of August 20th (recasted by the DL 28/2016 of June 23rd), providing the national building energy performance certification system (SCE). It consists in a framework that, among other, identifies proper improvement measures for energy efficient refurbishments. However,

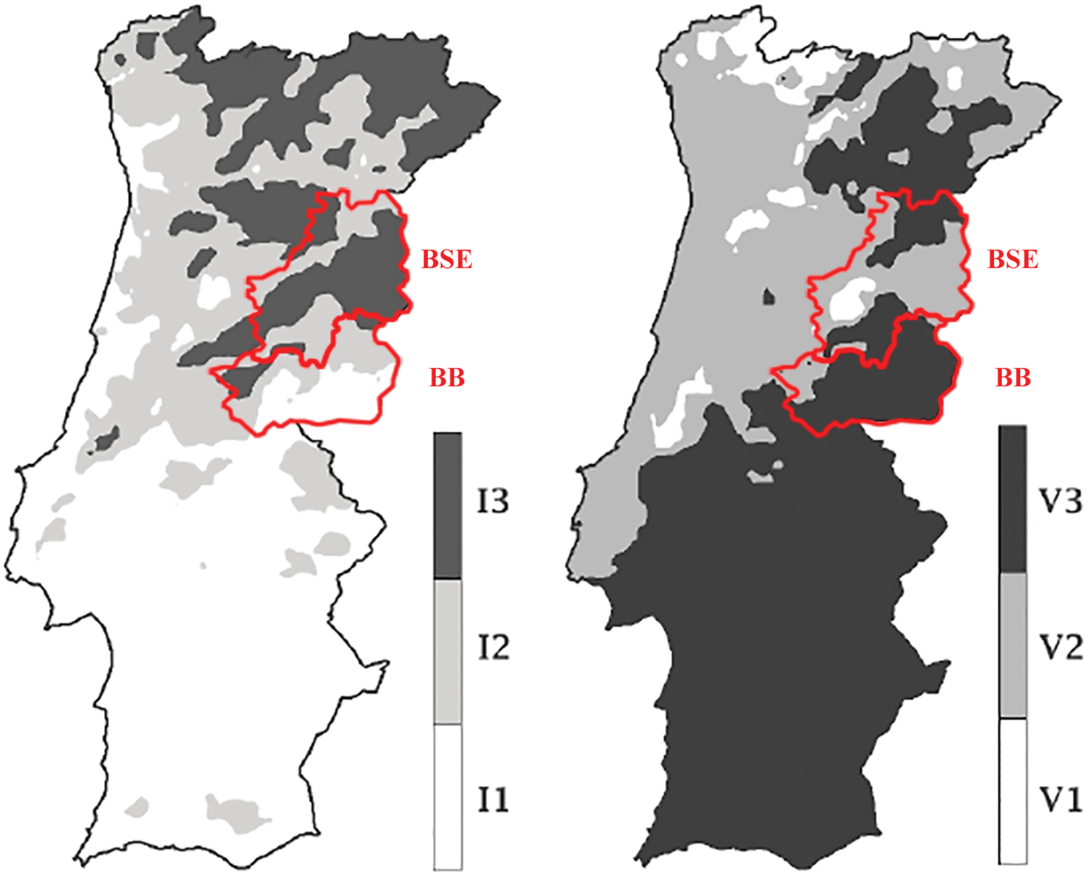

Figure 1: Portuguese climate scenarios for winter and summer seasons (Source: [13]).

the established methodology only considers permanent heating/cooling habits, which are unrealistic in the Southern European countries due to some energy poverty phenomenon, reason why proper methodologies were specifically developed to fill this gap [3]. Reference methodology developed by Barbosa et al. [17] will be adapted to this study, once retrofitting Southern Europe social housing contexts requires an approach focused on housing buildings thermal and comfort performances under climate change scenarios for projected typical weather and extreme conditions, considering occupants heating/cooling passive habits.

Therefore, social housing buildings in BI will be inventoried and characterized, being then diagnosed according to its thermal and comfort performances in present/climate scenarios under realistic Portuguese heating/cooling habits. This procedure will then allow identifying, testing and selecting valid constructive retrofit improvement measures that are expected to compose constructive retrofit guidelines applicable to multiple case studies within the region.

It is expected that the resulting guidelines can be a valuable tool for emergency response planners and stakeholders interested in the retrofit of the Portuguese social housing stock, especially the municipalities, allowing aligning and enriching applications for diverse refurbishment national programs [18] considering national guidelines for climate change [19].

2. Literature Review

Sustainable retrofitting procedures regarding general retrofit approaches and methodologies are synthetized in works such as that of Bragança and Pinheiro [20], being that Roaf et al. [21] focus in the impact of retrofit interventions in the passive performance of buildings. Many of these principles were introduced in Portugal in works such as that of Aguiar et al. [22]. Climate change events widened this understanding regarding the need of building adaptation, considering as improvements to adjust building needs to external conditions [16, 21]. While de Wilde et al. [23] analysed the importance of uncertainties in climate models and its impact on housing buildings, Gaterell and McEvoy [24] focused it in the specific field of retrofitting.

In Southern European contexts, housing building retrofit considering building thermal performance was studied in present climate scenarios by Ortiz et al. [25] and Flores [26], regarding proper passive building retrofit measures to assure thermal comfort and energy consumption decrease, respectively. In future climate scenarios, building thermal and comfort performances were studied by Barbosa et al. [17], who also focused on the importance of insulation improvement measures in dwelling performances for predicted weather scenarios and heatwave events.

Considering the specific field of social housing retrofit in Southern European contexts, studies in countries such as Portugal, Spain or Italy have an important focus on the following issues: 1) studies on reducing energy consumption and improving energy efficiency, such as those by Alonso et al. [27] and Oteiza et al. [28]; 2) studies on the economic implications of retrofit projects, such as that of Boeri et al. [29]; 3) studies on building thermal and comfort performances without active heating/cooling systems, such as that of Curado [5]. The importance to act in these contexts is reinforced by works such as that of Martínez-Hervas et al. [30], which proposes an approach based on sustainable retrofitting planning for an urban scale.

Constructed works of retrofitted social housing buildings which include passive measures for dwelling performance improvement may be found in works like the Transformation of 530 Dwellings in Bordeaux [31].

Nevertheless, lack of literature was detected for Iberia Peninsula specific case of BI or similar climates. Besides, research concerning Southern Europe social housing building thermal and comfort performances under future climate scenarios is still scarce, making the current case study pertinent.

3. Theory and Methodology

3.1. Context and case studies

The approach to define representative case studies considers three main topics: climate, building and occupants.

In what refers to climate, the selection of building case studies considers the severity of heating/cooling seasons in present and future climate scenarios. Three cities were chosen to study building performance, in order to establish an appropriate delimitation of BI climate reality [8, 13], according to Table 1 and Table 2. Guarda (part of BSE region) and Castelo Branco (part of BB region) were chosen in order to obtain 2 examples with climate severity in winter and summer, respectively. Due to summer severity, Castelo Branco is also considered to study building performance under heatwave extreme event. Covilhã (part of BSE region) was chosen in order to obtain an example with intermediate severity in winter and summer seasons.

In what refers to buildings, the social housing building stock of BI will be organized in order to identify relevant characteristics, like the constructive system, age and typology. According to the obtained data, it will be selected the most proper procedure to perform building analysis. Moreno [32] identifies three possible procedures: 1) considering a reference building which can be representative as a case study; 2) considering a specific typology which is representative of a specific group of buildings; 3) considering clusters which are representative of several groups of buildings, each one with common characteristics. Monitoring will also be performed in order to obtain real data about building thermal performance. Three buildings will be selected; each one of them in the cities mentioned above according to climate criteria, so that one dwelling of each building can be monitored. Buildings will be selected according to age (previously to 1990), general characteristics (like envelope, constructive materials and systems U-value) and dwelling specific characteristics (like place within the building, typology, area, volume, orientation, glazed area, total exposed area, number of exposed facades or possibilities of cross ventilation), in order to obtain three similar case studies that can allow the understanding of indoor comfort conditions according to the Portuguese way of life through the evolution of seasons.

Table 1: Reference heating degrees' days (HDD) and average temperature in cooling season (°C) for Guarda, Covilhã and Castelo Branco (Source: [13]).

City	Reference heating degrees' days (HDD)	Reference average temperature in cooling season (°C)
Guarda (BSE)	1924	21,7
Covilhã (BSE)	1687	22,5
Castelo Branco (BB)	1274	25,3

Table 2: Expected temperatures for BSE and BB regions under RCP4.5 and RCP8.5 scenarios (Source: [8]).

Scenario	Temperature (°C) for the coldest/hottest month of the season	BSE			BB		
		2020	2050	2080	2020	2050	2080
RCP 4.5	Summer (maximum)	28,3	29,2	29,7	31,8	32,7	33,2
	Summer (average)	21,6	22,4	22,9	25,0	25,8	26,3
	Winter (average)	5,1	5,7	5,9	7,0	7,7	7,9
	Winter (minimum)	2,1	2,5	2,8	3,6	4,3	4,4
RCP 8.5	Summer (maximum)	28,2	30,1	32,4	31,7	33,5	35,9
	Summer (average)	21,4	23,2	25,6	24,9	26,6	28,9
	Winter (average)	5,3	6,1	7,2	7,9	8,1	9,1
	Winter (minimum)	2,3	2,9	4,0	4,4	4,6	5,6

In what refers to occupants, it is predicted the definition of differentiated occupancy profiles. Needed data will be obtained from quantitative/qualitative research and appropriate literature, in order to characterize specific and general heating/cooling habits, respectively. Quantitative/qualitative research was applied in social housing studies like that of Sdei [33]. Quantitative research consists in the monitoring process itself, in order to provide data that can contribute to an understanding of the impact of typical occupancy behaviour in dwelling performance through the evolution of seasons. Qualitative research consists in developing and applying a questionnaire to occupants regarding their heating/cooling habits and in that way complements the quantitative research. Appropriate literature can provide information about composing occupancy profiles considering occupants characteristics and cultural repercussion through the evolution of seasons.

3.2. Method

Methodology proposed by Barbosa et al. [17] was adapted considering the necessary stages to accomplish the constructive retrofit guide, as defined in Figure 2.

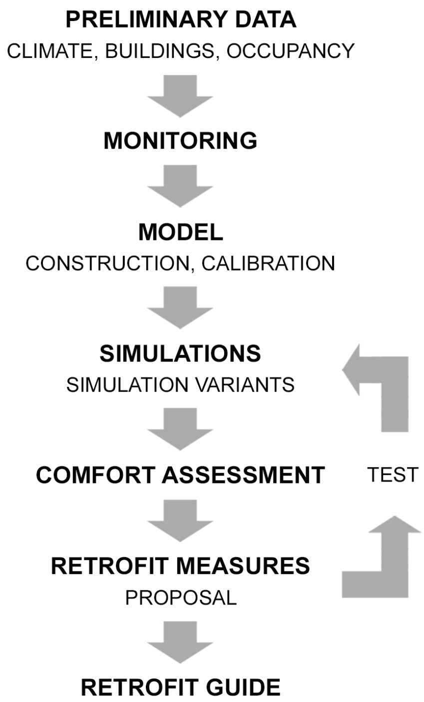

Figure 2: Methodology for the accomplishment of the constructive retrofit guidelines.

The considered stages are as follows: 1) stage one consists in obtaining all the necessary data regarding climate, building and occupants; 2) stage two consists in the monitoring process in order to obtain data about real dwelling performance under occupant behaviour; 3) stage three consists in the construction and calibration of dynamical multi-zone thermal models for dynamical thermal simulations, using EnergyPlus (EP) [34] and DesignBuilder (DB) [35]; 4) stage four consists in performing the necessary simulations according to the defined simulation variants, in order to predict building performances for both present/future weather scenarios and heatwave event, under realistic heating/cooling habits; 5) stage five consists in comparing the simulated performances with proper comfort standard standards; 6) stage six consists in the proposal of constructive retrofit measures, according to results obtained from comfort assessment, testing them by repeating the process since stage four; 7) stage seven consists in the selection of the most suitable solutions according to the obtained results, grouping them into proper retrofit guidelines.

3.2.1. Stage one: preliminary data

Regarding to climate, two main weather data for the regions of BB and BSE are considered for this investigation: for present and future climate scenarios. For present weather data Typical Meteorological Years (TMY) weather files generated by LNEG or INETI will be considered for the cities of Guarda, Covilhã and Castelo Branco, in a compatible format with EP. For future weather data, the “morphing” methodology proposed by Belcher et al. [36] is considered, using “CCWorldWeatherGen” software [37, 38] to generate future TMY weather files in EP format. The software procedure consists in importing the obtained TMY present data for each city in EP format, which will then generate the correspondent future TMY weather file in the same format for three future time slices: 2011-2040 (2020), 2041-2070 (2050) and 2071-2100 (2080). The most recent RCP scenarios from IPCC are not available within the tool, which still considers A2 (medium-high) emission scenarios according to the IPCC Third Assessment Report summary data of the HadCM3 experiment ensemble. Nevertheless, the tool has been used for similar studies once considerable similarities with RCP scenarios were detected [17]. A pertinent point is the study of heatwave periods. Real data from heatwaves that occurred after 2001 is expected to be obtained from nearby meteorological stations of the mentioned cities. Data will be processed to fit EP format, with the possibility of interpolate typical weather data for the same period in the year to fill missing data necessary for model simulation [17].

Regarding to buildings, constructive and other characteristics data will be obtained from the respective Municipality Archives and from on-site visits. Constructive solutions' thermal properties will be taken from reference values from literature.

Regarding to occupants, quantitative research will be based on monitoring data. Qualitative research will consist in a questionnaire to occupants, to be filled after monitoring periods. Questionnaires ask occupants about relevant information in order to understand why, how and when passive strategies like window opening or shading devices activation were performed, or if in any moment heating/cooling systems were used. This information allows an initial understanding of actual indoor performance in each season and its repercussion with some issues, such as humidity, ventilation and air infiltration. According to information obtained from appropriate literature such as those developed by Magalhães and Freitas [3] or Barbosa et al. [17], suitable occupancy profiles will be created and considered in simulation variants, regarding relevant occupant's characteristics, like age or daily time periods inside the dwellings, and cultural repercussion through the evolution of seasons, like discomfort tolerance.

3.2.2. Stage two: monitoring

The three selected dwellings will all be monitored in the same time period, during one month in heating and cooling seasons, regarding temperature (°C) and relative humidity (%). The monitoring stage will take place in each dwelling's living room and one bedroom, considering their importance in time occupancy during the day.

3.2.3. Stage three: models construction and calibration

The construction of dynamical multi-zone thermal models will be made using DB as the graphical interface, while dynamical thermal simulations will be performed by EP. The amount of models required will depend on the most appropriate procedure selected to analyse the BI social housing building stock (reference building, typology or cluster). Although calibration process is still to be selected, it is expected that data obtained in the monitoring phase can be useful for required comparisons between measured and simulated values.

3.2.4. Stage four: simulations

The amount of performed simulations will depend on the needed simulation variants.

The simulation variants will be performed on the constructed and calibrated models of each dwelling of the three selected buildings with different locations – Guarda, Covilhã and Castelo Branco. In present climate scenarios heating and cooling seasons will be considered. In future climate scenarios, heating and cooling seasons will be considered in time slices 2020, 2050 and 2080. In heatwave period, only Castelo Branco will be performed. Resulting combinations of variants will consider each one of the created occupancy profiles.

3.2.5. Stage five: comfort assessment

For all considered simulations, dwelling performances will be subject of comfort assessment, considering obtained internal temperatures and other relevant data. Appropriate literature such as those developed by Curado [5] or Barbosa et al. [17] can provide information about approaches and applications of comfort assessment models, which will be studied in order to determine the most suitable one to apply to this study. At the moment, the amount of discomfort hours is considered the key indicator to evaluate dwelling performances.

3.2.6. Stage six: proposal and testing of constructive retrofit measures

Proper constructive retrofit measures will be proposed, individually or combined, in order to achieve the following hierarchical objectives to all simulation variants, considering only the building's passive performance: 1) to eliminate the total of discomfort hours; 2) if not possible and active systems are required, to reduce the maximum amount of discomfort hours, taking away the remaining ones from life-threatening values.

The proposed measures are applied to the building geometry (such as increase/ decrease of glazed area) or building envelope (such as thermal insulation improvements) and are considered to resolve or minimize identified issues (such as excessive air infiltration or humidity) or potential ones (such as overheating), according to the repercussion of Portuguese way of life through the evolution of seasons.

The testing phase of proposed measures consists in repeating the simulation and comfort assessment stages, as defined in section 3.2.4 and 3.2.5, respectively.

3.2.7. Stage seven: proposal of retrofit guidelines

According to obtained results, the amount of discomfort hours decrease will be the key indicator to define the success of the tested interventions. According to it, the accomplishment of the constructive retrofit guidelines will consist in grouping the most relevant retrofit measures according to building, climate and occupancy possibilities.

4. Conclusions

The present study aimed at proposing an approach to the accomplishment of constructive retrofit guidelines so as to adapt social housing buildings in BI to its actual and future climate scenarios under realistic heating/cooling habits, aiming at improving its thermal and comfort performances. It is believed that this study can consist in an important milestone for developing other studies or tools applicable to similar contexts within Southern Europe and Iberian Peninsula.

Considerations regarding study comprehensiveness are being evaluated. Besides the repercussion in buildings thermal and comfort performance, the integration of other relevant factors such as intervention costs, feasibility or occupant's acceptance would enrich the analysis.

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