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Procedures in the construction of a test reference year for Porto-Portugal and implications for hygrothermal simulation

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ABSTRACT

The exterior weather is a key factor in the behaviour of buildings, which may affect mechanical resistance, durability and appearance of materials and components. Also, it may influence the indoor air quality, limit the comfort of users and increase energy costs. Therefore, exterior weather data is an important input for hygrothermal simulation, as a tool to previously assess the behaviour of buildings.

In this work, the methodology to create a reference year according to ISO 15927-4 was assessed. The meteorological data were statistically analysed and the missing data were filled. Two reference years were obtained: one with gaps and the other without omissions, in order to find out what were the implications brought by filling the data. Hygrothermal simulations were conducted considering the two reference years.

The results were statistically compared and they showed the reference years presented differences, although only three months are actually different. The outputs of the hygrothermal simulations are similar in some periods and different in the periods of time close to the months that are different in the reference years. Although these dissimilarities are highlighted by statistical differences they are not relevant enough to result in a significant difference in the durability of the materials.

1. Introduction

Urban environment has a significant effect on the energy performance of individual buildings (Ignatius, Wong, & Jusuf, 2015). Therefore, buildings should be designed considering the weather condition of the area where they will be built, as climatic loads may have enormous impact on the adopted design solutions that ensure better mechanical behavior, hygrothermal performance, durability and energy efficiency (Jentsch, Bahaj, & James, 2008).

Therefore, exterior weather data is an important input for hygrothermal simulation tools, which require hourly variations of the climate parameters, such as temperature, relative humidity, solar radiation, wind, rain and atmospheric pressure, for the simulation period of time. This weather data may be measured by weather stations on site. A statistical analysis of measured meteorological parameters is of extreme importance to accurately measure the climate variations and to implement them to the buildings and cities design (Pyrgou, Castaldo, Pisello, Cotana, & Santamouris, 2017).

To ensure proper climatic loads for building design one cannot consider a single year, as it may not be the worst case scenario. One could simulate the solution behaviour considering all individual years of a weather data-set comprising several years and then design the solution for the most critical year. This procedure is time-consuming and rather confusing as large amount of data are required (Janjai & Deeyai, 2009; Lee, Yoo, & Levermore, 2010). On the other hand, one can use a typical or reference year, which is a single 12 month year of hourly data that represents the range of weather patterns that would typically be found in a multi-year data-set (Janjai & Deeyai, 2009; Kalamees & Kurnitski, 2006; Lee et al., 2010).

Several authors (Bilbao, Miguel, Franco, & Ayuso, 2004; Layi Fagbenle 1995; Pissimanis, Karras, Notaridou, & Gavra, 1988) refer that a typical or reference years are sets of data containing a sequence of 8670 hourly data values regarding climatic parameters. Moreover, Marion and Urban (1995) argues that the climate reference years are composed of files with climate data schedules corresponding to twelve months, aimed to determine through numerical simulations the energy consumption in buildings, indoor climates and solar power systems among other systems that require large number of climate parameters for the analysis.

Kalamees and Kurnitski (2006) refer that a reference year should represent the average values of the main climatic parameters as closely as possible to the long-term average values (Bahm, 1985; Du, Underwood, & Edge, 2012; Naseem, Yousef, & Hilal, 2005). In the last decades, different methodologies have been developed to generate

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climate reference years. There are several types of reference years, but they all require real and long-term climatic data-sets so that it can be related with the real local weather. They are expressed in different formats and include a wide range of parameters to meet varying demands and requirements (Al-Mofeez, 2012).

According to Lund (1996), Test Reference Year (TRY) has been produced by various and different methods and had different designations. The USA TRY, whose methodology was developed by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), was one of the first climate data-sets generated specifically for energy simulations in buildings (Al-Mofeez, Numan, Alshaibani, & Al-Maziad, 2012). According to Al-Mofeez et al. (2012), the biggest drawback of this TRY is the methodology itself, which eliminates the years that contain months with extremely high or low temperatures, until only one year remains. Thus, the USA TRY represents an actual year (Kalamees & Kurnitski, 2006). Another drawback is the fact that its basic data does not include solar radiation, although Crawley (1998) argues that for building energy simulations, the numerical tool should calculate solar radiation based on cloud types and cloud cover, information available in the USA TRY.

Crawley (1998) stated that the European TRY, generated for several European locations, follows a similar methodology to the one proposed by the National Climatic Data Center (NCDC) and the Sandia National Laboratory (SNL) for generating the Typical Meteorological Year (TMY) in the USA. Therefore, significant differences exist between USA TRY and European TRY. ISO 15927-4 (2005) describes the procedures to construct the European TRY and has been used by several authors to create reference years in several locations (Du et al., 2012; Kalamees & Kurnitski, 2006; Kalamees et al., 2012; Lee et al., 2010; Pernigotto, Prada, Gasparella, & Hensen, 2014; Sorrentino et al., 2013).

In order to minimize the drawbacks of the USA TRY, namely lack of solar radiation data, the Typical Meteorological Year (TMY) was developed by the National Climatic Data Center (NCDC) and the Sandia National Laboratory (SNL) (Crawley, 1998). Now-a-days, TMY is one of the most widely accepted methods for determining typical years and its concept has been used in many countries (Hui, 1996).

A TMY consists of 12 Typical Meteorological Months (TMM) selected from the calendar months in a multi-year weather database (Kalamees & Kurnitski, 2006), of at least 10 years (Hui, 1996). The twelve selected months are then combined to form the TMY. Data smoothing may be needed to avoid abrupt changes at the boundary between two adjacent months selected from different years (Al-Mofeez et al., 2012). TMY selection involves minimising the difference from long-term distributions, means and daily persistence of the weather indices. To determine a TMM, three basic properties are considered:

- Climatic elements should have frequency distributions close to the long-term;
- The sequences of daily measurements should be like the sequence often registered at that location;
- The relationships among different climatic elements should be like the relationships observed in nature.

There are several methods used for the construction of TMY, using different parameters and principles. Some of these are the Sandia National Laboratory Method, the Danish Method and the Festa-Ratto Method. However, Rahman and Dewsbury (2007) showed that the month selection depends on the climatic parameters that are used, i.e, the generated TMY is different depending on the analysed variables.

According to Hui (1996), the Sandia National Laboratory Method is the most widespread. TMMs are generated using a statistical analysis to evaluate five weather parameters (with a set of nine daily indices and their respective weightings): global solar radiation (daily total-25%), diffuse solar radiation (daily total-25%), dry-bulb temperature (daily maximum-5%; daily minimum-5% and daily mean-10%), dew-point temperature (daily maximum-5%; daily minimum-5% and daily mean-10%) and wind speed (daily maximum-5% and daily mean-5 %).

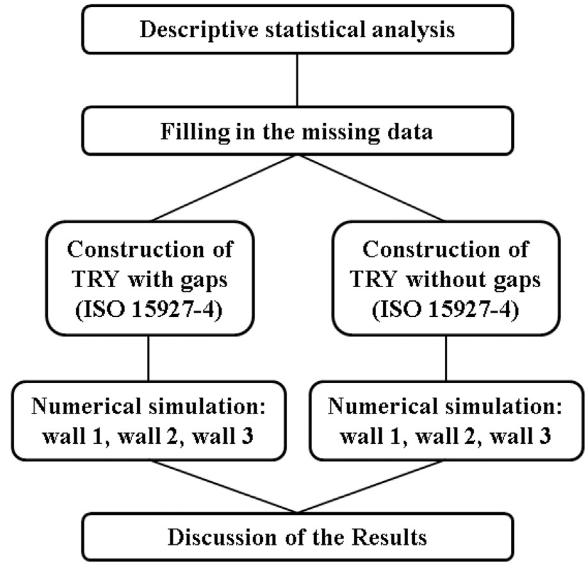

Fig. 1. Diagram of the methodology.

A nonparametric statistical method known as Finkelstein-Schafer (*FS*) is used to determine the candidate months, comparing the monthly cumulative distribution with the long term distribution. This method selects the month with the lowest value of *FS* and lower deviation from the total data series (Kalamees & Kurnitski, 2006). Because some of the parameters may have different relative importance, a weighted sum (*WS*) of the *FS* statistics is used to select the five candidate months that have the lowest weighted sums.

Bilbao et al. (2004) and Argiriou et al. (1999) analysed the Danish Method, in which, for each month, the monthly values of the parameters (daily average and maximum values of temperature, relative humidity, wind speed, pressure, duration of sunshine and global solar radiation) are compared with the long term values of the respective months and a rating is assigned to every month. If the monthly average of the climate parameter differs from the respective long-term average more than the standard deviation, the month has a zero score rating. Otherwise, the month has a score rating equal to 1. The month evaluation consists in the sum of the scores obtained for the various parameters, in a maximum of seven. The seasonal variations of each climatic parameter are eliminated by converting the daily weather parameters into daily residual values. Each individual month is defined by a function of the normalized average and the normalized standard deviation and the selected month is the one with the higher rating from a group of three with lower function values.

According Argiriou et al. (1999) the Festa-Ratto Method is a modification of the Danish Method and requires a more complex processing of the data. Its methodology involves maximum daily air temperature and average daily air temperature, daily average relative humidity, wind speed and global radiation. The selection of individual month involves the conversion of meteorological data to normalized residual values in accordance with the long-term basis trend.

According to Crawley (1998), ASHRAE developed the Weather Year for Energy Calculations (WYEC) as a data-set specifically designed for use in building energy simulations. It was intended that typical weather patterns could be represented by a single year or a group of several months. This data-set uses the TRY format but includes solar radiation data. In the early 90s, ASHRAE updated the WYEC, starting with the TMY data format and expanded it to contain hourly luminosity values, quality assessment data, updated data of the calculated solar radiation and data adjustment of solar time to local time. These modifications led to the design of the WYEC2.

To generate the WYEC, the month selection is based on the average