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Preface

The 3rd International Conference on Construction, Energy, Environment and Sustainability (CEES 2025) was held in Bari (Italy) during June 11–13, 2025. The event was organized by Itecons/University of Coimbra with the Polytechnic University of Bari. The conference welcomed 225 participants from over 25 different countries.

Professor Jeffrey D. Sachs (Columbia University, USA), Prof. Patrícia Pereira da Silva (University of Coimbra, Portugal), Prof. Romeu Vicente (University of Aveiro, Portugal), and Prof. Aminhossein Jahanbin (Polytechnic University of Bari, Italy) gave invited keynote lectures. The presentation of a total of 209 papers was organized into several parallel sessions on the general themes of "Construction materials and technologies", "Building physics", "Energy", "Water and sanitation", "Environment", "Construction and industry 4.0" and "Community challenges and policies", as well as in 10 special thematic sessions organized by members of the Scientific Committee.

This Volume entitled *Construction Materials and Technologies* contains 65 selected papers presented at the conference.

Each paper was evaluated by at least two independent reviewers. The conference organizers thank the members of the Scientific Committee for their invaluable contribution in reviewing and recommending the papers selected for publication, and the conference sponsors and institutional supporters for their precious assistance. The conference organizers are also thankful to Springer, particularly the Editors-in-Chief, for agreeing to publish these papers.

The success of the conference is well reported in this video: https://www.youtube.com/watch?v=kpzar9OKrq8&t=15s

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Excel Tool for the Parametric Assignment of EN 335 Use Classes

J. I. Fernandez-Golfin, M. Conde, J. A. Tenorio, and M. Conde

Abstract An Excel tool for the parametric assignment of the use classes of the European EN 335 standard, valid for all conditions of use of wood in buildings, is developed. The assignment for the conditions of for outdoor or semi-outdoor use is carried out by using the Scheffer index, while the assignment for the conditions of interior use is carried out based on the humidity classes of the European EN-ISO 13788 standard. The tool also includes the effect of a series of factors that modify the climatic risk of using wood, depending on the conditions of aggravation or reduction of climatic risk due to the effect of local environmental conditions or construction design. The tool has been tested for seven years in Spanish weather conditions and is accompanied by a GIS viewer with the calculation factors to be considered and the direction of the dominant rain winds corresponding to each location.

Keywords Wood · Classes of use · Wood construction

1 Introduction

Wood and wood-based products provide sustainable construction with undoubted benefit. This excellent initial environmental evaluation, underscored in environmental product and building declarations, can be reversed if the improper use of the materials or an unsuitable design lead to faults that require continual maintenance, repair or rehabilitation work. For these reasons, it is necessary to establish

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guidelines that result in products being chosen and building solutions designed in such a way that the prescribed service life is guaranteed at all times [1].

Among all the agents of decay affecting wood products in service, the moisture and temperature of the material (material climate) have the greatest effect on their physical, mechanical and biological behaviour. This is the case due to the dependence that the moisture and temperature of the material have on both the viscoelastic and kinetic behaviour of decay as a result of the main biological agents (basically rot fungi and subterranean termites). Thus, correctly estimating the climate conditions in which a wood product will be in service, and implementing design measures, product limitations and, when necessary, protective treatment with chemicals are aspects that designers must be able to manage when building with wood, and its durability is included among the aims [1].

In addressing the effect of material's climate (temperature and moisture content) on the performance of wood elements in buildings, both European standards (Eurocode 5, EN harmonised standards and other EN wood products standards) and the Spanish Technical Building Code provide guidance. These standards approach the evaluation from two complementary perspectives, which must be considered simultaneously:

- Service classes: Used to adjust elastomechanical properties according to hygrothermal service conditions and to set specific limitations for bonded products based on the type of bonding.
- Use Classes: Used to estimate the risks of biological degradation of the material.

Both types of classes have similar denominations (Class 1, class 2, …) and unclear definitions in European regulations, which can cause confusion for designers.

In short can be said, that the use class only refers to the risk of biological degradation of wood by fungi and insects. In this matter of biological risk of degradation the service classes, even though is also related with the moisture content of the wood elements in service, nothing has to say. The current version of the European EN 335 (2013) standard [2] outlines the general principles for categorizing four different use classes, based on the wood's estimated moisture content over the course of a year. Additionally, this standard includes a fifth class specifically for wood that is in direct contact with saline water.

According to the European EN 335:2013 standard, to take into account the biological risk of degradation, the designer must perform an assessment of the service conditions, analysing the likelihood that the wood element will be exposed to very moist conditions for short or long periods [3].

The broad criteria for assigning use classes in the European standard EN 335 leave a lot of room for interpretation and can cause significant confusion for designers. This may result in errors that lead to an unexpected reduction in the material's service life.

In our opinion, the main flaw of the EN 335:2013 standard is that it leaves a lot to discretion and significant doubts regarding which class to assign the wood to under critical working conditions. It lacks objective guidelines that help providers decide whether the working conditions and/or design should be classified within one

use class or another. These issues and uncertainties are particularly relevant when the wood element is located on the exterior of residential buildings equipped with a thermal enclosure and indoor climate control systems. Under these very critical service conditions, wood can be assigned to a wide range of use classes (CU 3, 4, and 5). Therefore, it is crucial to establish clear guidelines and objectives.

In our view, the EN 335:2013 standard's primary, and most dangerous, weakness is its failure to provide clear guidelines for differentiating between use classes 3.1, 3.2, and 4, which can be present both inside and outside buildings.

Another shortcoming observed in the EN 335 standard is that it does not consider the varying humidity conditions that could be found in wood elements placed inside the building, which are addressed in the international EN ISO 13788 standard [4]. This oversight may lead to risks stemming from undetected humidity spots (due to condensation) that are not properly accounted for in the assessment of service conditions. As a result, unforeseen issues and premature material failures may occur, especially in use classes 1 and 2.

To address errors caused by the incorrect assignment of use classes, our research group has been working since 2014 on the MADEXTER project to develop a parametric system that eliminates subjective criteria when assigning use classes according to the EN 335 standard [1, 3] under Spanish conditions. This effort led to the first version of the MADEXTER calculator [3] in 2017, which has been evaluated at the national level since then and resulted in a more comprehensive second version, known as MADEXTER II, which is presented in this work.

2 Methodology

The method of the parametric assignment of use classes used in the MADEXTER calculator follows the general principles established in the ISO 15686-1 standard [5] since it enables the objective assignment of use classes incorporating the effect of all the variables associated with both climate and design that have an effect on the material climate.

The first version of the MADEXTER calculator was based on the methodology proposed by the European project WOODEXTER [6]. This initial version of the tool was optimized—regarding the variables involved and the values assigned to the influencing factors—through reverse engineering by investigating the causes of early degradation observed in 50 timber construction projects exhibiting premature deterioration. The objective was to ensure that the new model (MADEXTER II) could accurately assign the use class that would have prevented the observed degradation. Therefore, the MADEXTER II tool presented in this study represents an evolution of the initial version, achieved through the observation and analysis of its real-world performance in predicting potential damage in actual timber construction projects.

The assignment of the use class following the method proposed in this work begins by determining the basic climate exposure index value (*Is0*), which depends on the

conditions of use considered. The criteria used for determining this value according to the service conditions are as follows:

1. *Wood elements located inside buildings with a thermal envelope*. In this kind of application, the basic exposure index (*Is0*) values used will be those in Table 1, established according to the humidity classes, according to the criteria in the EN ISO 13788 standard [4].

2. *Wood elements inside buildings without a thermal envelope (semi-outdoor conditions)*. In this kind of applications, the basic exposure index value (*Is0*) will be calculated according to the following variables:

   a. Mean annual value of the equilibrium moisture content of wood (MCMED).
   b. Distribution of the mean monthly value of equilibrium moisture content of wood (MCMONTH) during the 12 months of the year.

   The basic exposure index (*Is0*) will be calculated using the following score criteria:

   a. By the mean annual value of the equilibrium moisture content of wood (MCMED)

      - $\leq 12\%$: 1 point
      - $12\% < \text{CHMED} \leq 18\%$: 2 points
      - $> 18\%$: 3 points

Table 1 Basic exposure index values (*Is0*) to be used in elements located inside buildings equipped with a thermal envelope according to the humidity class inside the buildings

Humidity class	Type of building and/or premises	*Is0*
1	Unoccupied buildings, storage of dry goods	1.0
2	Offices, dwellings with normal occupancy and ventilation	1.0
3	Spaces in which high moisture production is not foreseen, such as residential buildings and homes with low occupancy	1.0
4	Sports halls, industrial kitchens, restaurants, communal showers, swimming pools with systems continuously controlling the indoor hygrometry (80% maximum), or others with a similar use	2.0
5	Buildings in which a great deal of moisture production is expected, such as laundries, distilleries, swimming pools without systems continuously controlling the indoor hygrometry	3.0

Note 1: The use of humidity classes 1 to 4 is restricted to applications located on the interior of buildings in which the presence of condensation can be completely excluded
Note 2: Humidity class 4 will also include any roof or façade materials that, while located on the exterior of the thermal insulation, are protected from the outdoor climate by a waterproofing barrier

Fig. 1 Display panel for data of driving rains (Peninsula and Balearic Islands)

1. The orientation of wood element with regard to the prevailing driving rain
2. The urban layout (protection from nearby buildings)
3. The existence of geographical features such as hills, valleys, lagoons, nearby rivers, and proximity to the coast, which either provide protection or increase the risk.
4. Any other factor that, in the project designer's opinion, increases or reduces the severity of the climate of the region in the zone in contact with the wood under analysis.

Table 3 shows the criteria for assigning the possible climate severity factor values (*ks1*) for outdoors conditions according to the combined action of the exposure variables mentioned above.

The basic exposure index value (***Is0***), modified due to the climate severity factor (*ks1*) above, according to the following expression (1) is called the mesoclimate exposure index ($\boldsymbol{I_s}$).

$$Is = Iso * k_{s1} \tag{1}$$

The MADEXTER II tool incorporates the option of applying a series of additional design factors that practical experience has shown to reduce the risk of decay because they directly affect the moisture content of wood in service. The design variables considered to have a significant effect on wood decay are as follows:

b. For every month that the mean monthly equilibrium moisture content of wood (MCMONTH) is in the range:

- < 12%: subtract 0.15 points
- 18%: add 0.30 points
- 12–18% no score

c. Calculation of the Index value (*Is0*): Sum of the scores obtained in the two previous sections (*a* and *b*).

3. *Wood elements outdoors above ground*. Under these circumstances, the basic exposure index (*Is0*) of the location is calculated in two stages:

a. *First stage*: The calculation of the Scheffer Index [1, 8] for a period of no less than ten years (this study utilized meteorological data from 850 official stations during the period from 2011 to 2021, inclusive).
b. *Second stage*: Assignment of basic exposure index value (*Is0*) from the Scheffer Index value calculated in the previous step, according to the criteria in Table 2 [1].

4. *Wood elements outdoors in contact with soil, fresh water, or salt water*. Under these conditions, the calculator MADEXTER II should not be used, and use classes 4 or 5 (salt water) must be assigned as appropriate.

To make it easier to obtain the basic exposure indices (*Is0*) corresponding to outdoor conditions of use (point 3 above) or semi-outdoor conditions (point 2 above) for the whole of Spain (peninsula and islands), the authors have developed a GIS tool with a viewer that provides data of outdoor (*Is0_e*) and semi-outdoor (*Is0_se*) basic exposure indices calculated for every geographical location. There are also other relevant data for using the MADEXTER II use classes calculation tool such as the direction of the winds with rain, the Scheffer Index, or the risk of physical degradation (RDA). A full explanation of this viewer can be found in [9], and it can be accessed via the following link (also see Fig. 1):

https://experience.arcgis.com/experience/3fa031ae706b4edb87ad9e887c7243cd.

At the project designer's discretion, the basic exposure index value (*Is0*) could be changed for a climate severity factor (*ks1*), with which it is possible to take into account special environmental conditions such as:

Table 2 Conversion criteria for the Scheffer index value (IS) based on the basic exposure index (*Is0*)

Scheffer index value calculated	Season rating	Basic exposure index *Is0*
IS $\leq$ 35	Dry	3.0
35 < IS $\leq$ 70	Moist	3.3
70 < IS $\leq$ 100	Very moist	3.5

Table 3 Climate severity factor values (*ks1*) according to the exposure variables to which the wood element is subject to (outdoors condition)

Climate severity	Description	Factor (*ks1*)
Low	In outdoor applications, situations in which the mesoclimate conditions have little impact on the behaviour of wood elements as all the setting variables are protective • There is protection from the prevailing driving rain thanks to the presence of geographical features, neighbouring buildings • It is a long distance (> 5 km) from large water sources (large rivers, lakes or sea)	0.8
Medium	In outdoor applications, situations in which the mesoclimate conditions have a moderate impact on the behaviour of wood elements as at least one of the following conditions is met: • There is marked exposure to the prevailing winds that bring rain since the building is isolated away from an urban setting or it lacks protection from geographical features, and/or • It is a medium distance (3–5 km) from large water sources (large rivers, lakes or sea)	1.0
High	In outdoor applications, situations in which the mesoclimate conditions have a high impact on the behaviour of wood elements as at least two of the following conditions are met: • There is exposure to the prevailing driving rain since the building is isolated away from an urban setting or it lacks protection from geographical features, and/or • The building is located at the bottom of a narrow valley and is exposed to sunlight for a limited time, and/or • It is a short distance (1 to 3 km) from large water sources (large rivers, lakes or sea), and/or • There is persistent mist in the town for 30 to 60 days/year	1.1
Severe	In outdoor applications, situations in which the mesoclimate conditions have a severe impact on the behaviour of wood elements as at least three of the following conditions are met: • There is exposure to the prevailing driving rain since the building is isolated away from an urban setting or it lacks protection from geographical features, and/or • The building is located at the bottom of a narrow valley through which water flows and is exposed to sunlight for a limited time, and/or • There are geographical features and/or situations nearby that results in an especially wet microclimate, and/or • There are large sources of moisture (sea) within 1 km, and/or • There is persistent mist in the town for over 60 days/year	1.2

Note 1: When the different façades or the exterior envelope of the buildings are subject to different levels or climate severity (normally due to their different exposure to prevailing driving rain), the project designer may choose to adopt the most unfavorable exposure for the four sides of the building as a whole or conduct an analysis of each façade independently

Note 2: In general, on the inland plateaus of the mainland Spain, in the Guadalquivir basin, in the Atlantic coast area and in part of inland Galicia, the prevailing driving rain are south-westerly. On the other hand, on the east of the country these winds are north-easterly, while on the coast of Cantabria they are from the north or north-west. The presence of mountains, valleys or noteworthy geographic features leads to changes in the direction of the driving rain, a factor that it will be necessary to take into account using local information

Note 3: As a rule, in locations under cover (with or without thermal enclosure), the climate severity factor (*ks1*) will take the value of 1

Table 4 Criteria for assigning use classes according to the characteristic exposure index value calculated

Assignment of use classes	
Characteristic exposure index (*Isk*)	Use class (EN 335)
0–1.5	1
1.5–2.5	2
2.5–3.5	3.1
3.5–4.5	3.2
> 4.5	4*

*In the case of marine environments, it would be CU5

- Geometry of the element ($\boldsymbol{k_{s2}}$)
- Eaves and cornices, ($\boldsymbol{k_3}$)
- Distance to the ground, ($\boldsymbol{k_{s4}}$);
- Building design, evaluated according to its impact on rainwater retention and the ease of drying the element ($\boldsymbol{k_{s5}}$)
- Other variables. The additional factor ($\boldsymbol{k_{s6}}$) can be used by the project designer to take into consideration the presence of special risks which can typically appear in elements located inside buildings with Class 5 indoor humidity (risk of condensation), and in situations with an increased risk of humidification such as elements in the framework or partition walls in direct contact with or close to walls that may sometimes get wet (typically masonry walls that are subject to the prevailing driving rain or walls belonging to pre-existing buildings).

In the event of applying all or some of the reducing criteria, Eq. (1) above would be as follows (2):

$$Isk = Iso * k_{s1} * k_{s2} * k_{s3} * k_{s4} * k_{s5} * k_{s6} \tag{2}$$

where ***Isk*** is what is known as the characteristic exposure index, which is used for the parametric assignment of the use class from the EN 335 standard, according to the criteria established in Table 4 [1].

The criteria for assigning values for the reducing coefficients of climate risk ($\boldsymbol{k_{s2}}$ to $\boldsymbol{k_{s6}}$) are consistent with those proposed in the European *Woodexter* project [6, 7], described and explained in depth in [1, 10].

3 Conclusions

Since the launch in 2017 of the first version of the MADEXTER excel tool, it has been used in tens of building projects and has proven to be useful for the objective and parametric calculation of the use classes in the European standard, EN 335. It has helped project designers to optimise construction designs and/or correctly prescribe the preventive chemical protection used with wood products in buildings.

The second version of this tool, MADEXTER II, incorporates a new and simpler system for determining the basic exposure index (*Is0*) based on the use of a GIS viewer, valid for the entire Spanish geography. In any case, the calculation tool is valid for outside Spain since in applications for outdoor or semi-outdoor use it allows to enter the calculated value for each locality in accordance with the instructions contained in this work. It also incorporates functional tools of great interest for determining other very useful factors for the optimisation of the design and for guaranteeing the service life of the material, such as identifying the direction of the driving rains and the risk of the decay and cracking of the wood.

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