BRANZ

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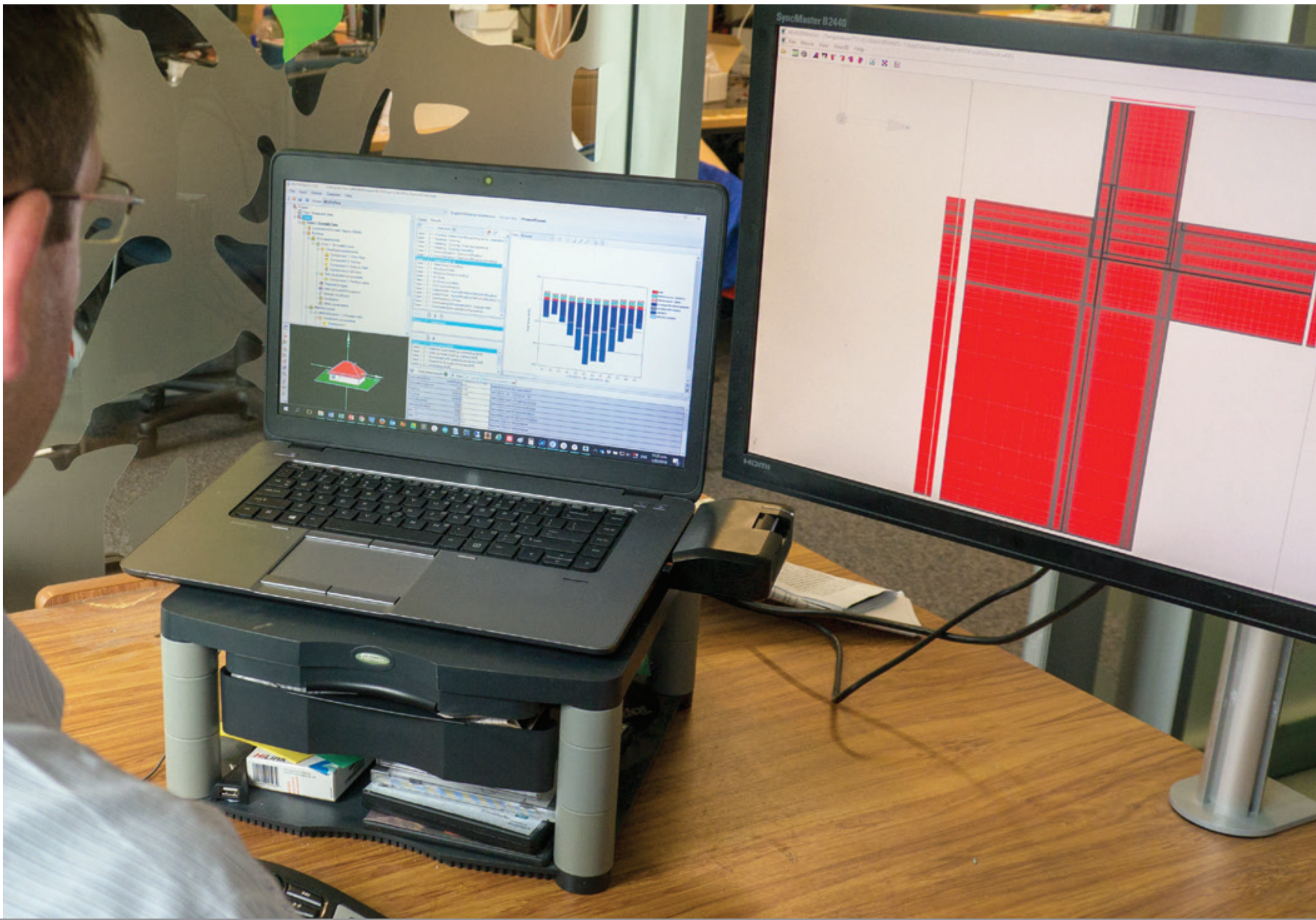
BULLETIN



AN INTRODUCTION TO WUFI

June 2018

- WUFI is a software tool used to study the movement of heat and moisture through building assemblies.
- WUFI is able to calculate heat and moisture movement through construction elements and predict moisture accumulation.
- This bulletin outlines where and how WUFI can be used to inform design decisions to remedy moisture problems.

1.0 INTRODUCTION

1.0.1 The movement of heat and moisture through building assemblies is complex. Tools used to study this are called hygrothermal models, and the WUFI family of software packages are the leaders in this area.

1.0.2 WUFI is able to calculate heat and moisture movement by simulating the many transport phenomena at play as well as calculating the storage of moisture in individual components. This allows issues with moisture accumulation from air and vapour movement to be predicted as well as potential mould growth risk.

1.0.3 WUFI modelling is an established and accepted analysis technique in the building science community throughout the world. Use of WUFI has been accepted by courts in some jurisdictions, and the software is sufficiently robust to achieve widespread use and acceptance.

1.0.4 This bulletin outlines what WUFI is and where it can be used to inform design decisions to remedy moisture problems. It also provides some information on the limitations of modelling.

2.0 WHAT IS WUFI?

2.0.1 WUFI is the acronym for Wärme Und Feuchte Instationär, which loosely translates to heat and moisture transiency. It is a computer software package for simulating the passage of heat and moisture through building construction elements or assemblies (Figure 1).

2.0.2 WUFI was created at the Fraunhofer Institute for Building Physics (FIBP) in Germany. BRANZ is a development partner with FIBP.

2.0.3 As WUFI was originally used for solid masonry structures, ventilated cavities presented a challenge, which is where BRANZ has contributed. BRANZ scientists spent time understanding the role that ventilated cavities and airtightness play in moisture risks for our structures and helped FIBP to add New Zealand climate information to the tool. This means WUFI is well suited to simulating New Zealand buildings.

2.1 VERSIONS OF WUFI

2.1.1 There is a family of WUFI simulation packages for different applications. Each has strengths and weaknesses.

2.1.2 WUFIPro performs calculations on one-dimensional assemblies. A one-dimensional model is built in WUFI to show a cross-section of a roof, wall or floor assembly. For a traditional stud wall, you can simulate a cross-section through the timber or the insulation but not both at the same time. However, it is possible to make two models, one that goes through the wood and one through the insulation. WUFIPro is fast and has tools to simulate multiple scenarios quickly.

2.1.3 WUFI2D is more comprehensive in that two-dimensional cross-sections can be simulated. This allows for concurrent simulation of the structure and the insulation but does come at the cost of speed and complexity of use. WUFI2D was used extensively and benchmarked against the drying rate experiments of BRANZ weathertightness work.

2.1.4 WUFIPlus is similar to EnergyPlus in that it is a whole-building simulation package. It is essentially a set of WUFIPro models joined together to form a structure. In addition to heat and moisture in components, it simulates solar heat gain, ventilation and other parameters.

2.1.5 WUFIPassive is similar to WUFIPlus but aimed at assisting passive house certification.

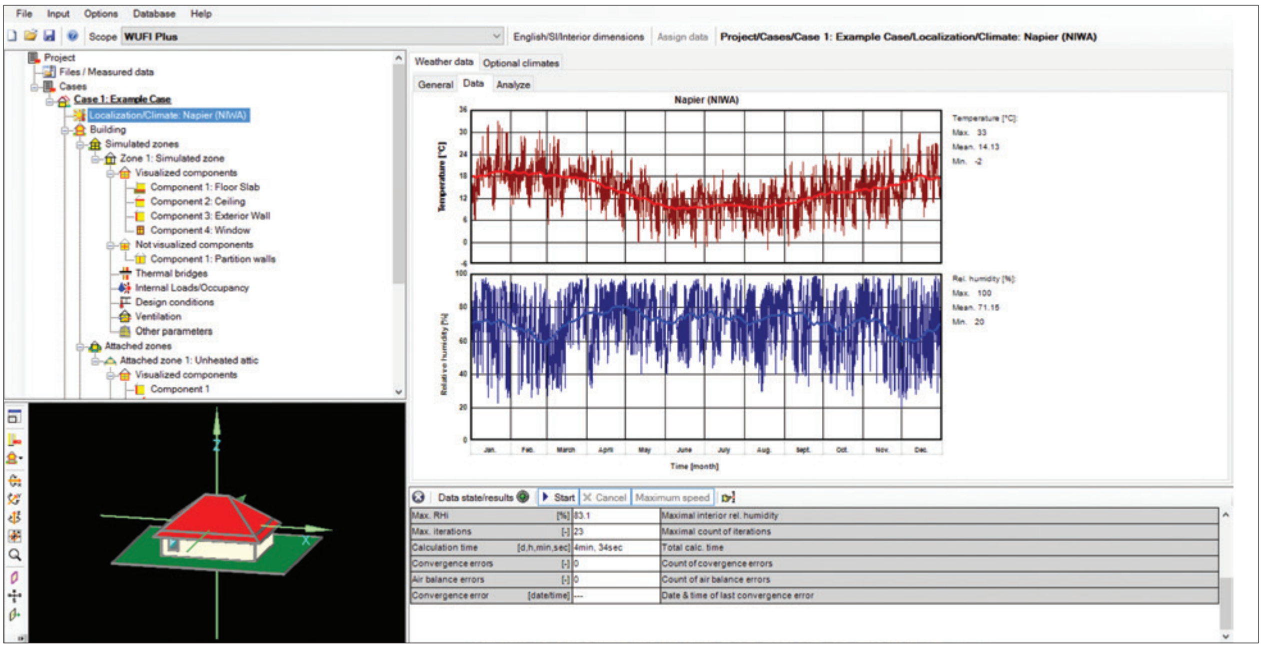


Figure 1. Screenshot from WUFI®Plus.

2.2 WHAT IS WUFI USED FOR?

2.2.1 WUFI can be used to model almost any type of construction provided the material properties are known and the user makes reasonable assumptions about the geometry if the version they are using requires it. Applications include wall assemblies, roof assemblies and foundations (including slabs on ground and suspended timber floors). At the macro scale, whole-building energy and hygrothermal analysis can be done using WUFIPlus.

2.2.2 There are two main uses for WUFI – assessing the wetting potential and drying potential of a structure:

- Wetting potential – WUFI can be used to assess whether a design will accumulate moisture inside the assembly due to air-carried moisture or water vapour diffusion. It is particularly valuable for deciding if a vapour control layer is needed or where a vapour control layer will be a useful addition to a structure.
- Drying potential – WUFI also allows a user to simulate a certain percentage of rain falling on the building enclosure to determine how the water absorbed by the cladding will dry out over a period of time. It also allows a user to deposit a percentage of the incoming rain load at a point within a wall to assess the structure's ability to cope with water ingress. As part of BRANZ weathertightness research, WUFI was used to simulate the drying of introduced moisture and was directly compared to experiments. From this, BRANZ scientists were able to build confidence in the ability of cavity walls to cope with claddings that have become wet from rain exposure but also establish relative drying rates from further inside the structure.

2.2.3 There are post-processors that allow a user to get an idea of potential mould growth and corrosion potential of steel embedded inside masonry. Currently in the first stages of development at BRANZ is a post-processor for predicting corrosion of fasteners in timber structures.

3.0 WUFI INPUTS

3.0.1 The first step is a build-up of the construction as a series of layers. In the one-dimensional version, it is assumed that the construction is continuous in the other two planes (vertically and in/out of the screen).

3.0.2 An example of a 20 mm cavity wall from the WUFIPro interface is shown in Figure 2. The different layers (from left to right) are exterior plaster coating, fibre-cement sheet, 20 mm air cavity, wall underlay, insulation and interior lining.

3.0.3 WUFI has a range of material properties in a database covering most construction materials, but these are typically European or North American materials. Comparable New Zealand materials may be slightly different. For most purposes, the database materials will be close enough to provide a reasonable result. If greater precision is required, the actual material properties must be entered into WUFI, but these may not be readily available. Specific testing of material properties may be required depending on the purpose of the modelling.

3.0.4 BRANZ maintains a database of materials that will ship with WUFI in the future.

3.0.5 After the model is built, if the materials are not in the database, several material properties will need to be input into WUFI such as:

- density
- heat capacity
- porosity

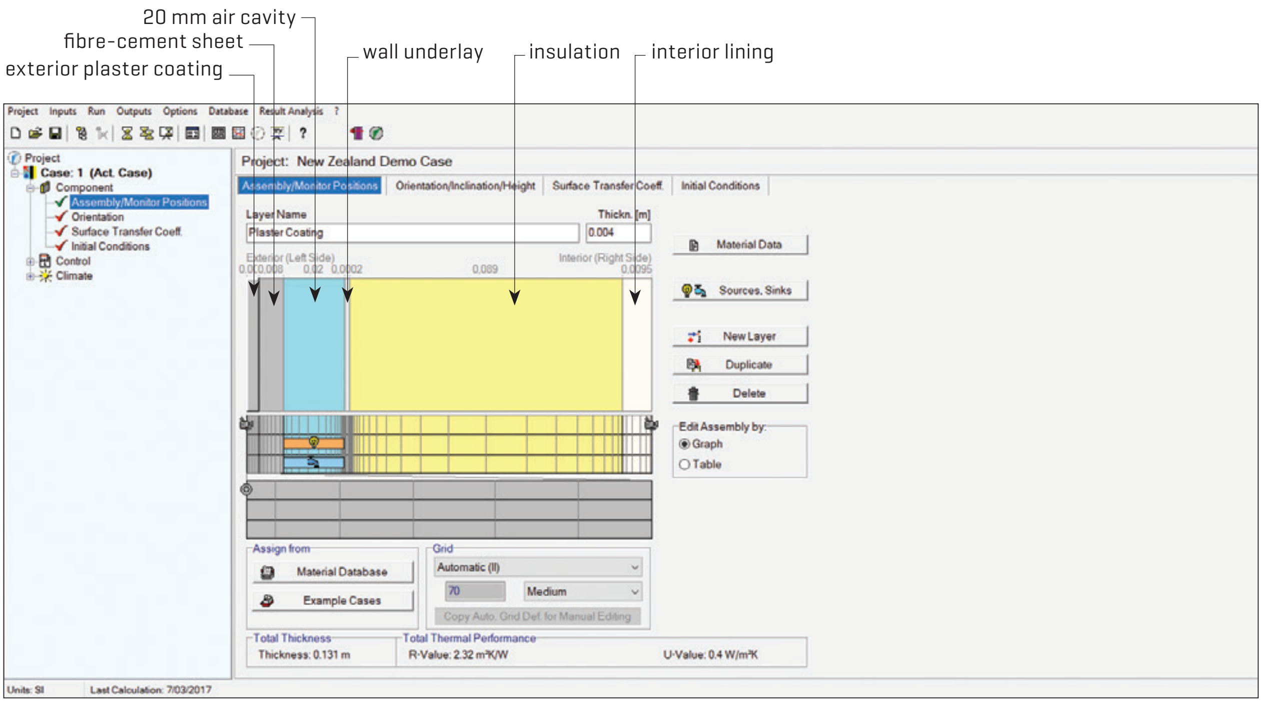


Figure 2. WUFI model of 20 mm cavity wall.

- moisture storage function (sorption curve)
- thermal conductivity (moisture content dependent if possible)
- liquid transport coefficients (with moisture content)
- vapour resistance curve (with moisture content).

3.0.6 In addition to material properties, surface transport coefficients are critical to a realistic model and include:
- diffusion thickness
- heat transfer coefficients
- solar absorption and emission coefficients.

3.0.7 Boundary conditions are also needed in order to run a simulation including:
- external temperature
- internal temperature
- external RH
- internal RH
- solar radiation
- rain – not strictly necessary depending on what the user is trying to learn from the model.

3.0.8 Selecting the correct inputs is critical to achieving a meaningful model, and this is where particular skill is required. Building a model is not difficult, but selecting the correct inputs and then being able to understand the outputs is very important.

3.0.9 A period of time can be chosen to run a simulation. The benefit of WUFI is that the performance of assemblies can be simulated over an extended period because a single point in time is of limited value. Therefore, a start and end point must be chosen. To get an understanding of ongoing performance, a 3-year period is typical, although shorter or longer periods can be selected.

4.0 OUTPUTS GENERATED

4.0.1 The results output by WUFI are large and comprehensive, so discussing these at length is out of the scope of this bulletin. Generally, WUFI will be able to determine the changes in material characteristics of every material in the assembly from the beginning to the end of the simulation period including;
- moisture content
- relative humidity
- temperature.

4.0.2 Graphs can be generated that demonstrate these changes throughout the simulation period. However, a skilled operator must do a reality check to determine whether the outputs equate with reasonable expectations as a small input error can make a big difference and adversely influence the output.

4.0.3 One of the great advantages of WUFI is that it allows 'what if' or parametric scenarios to be evaluated. Many factors can contribute to the difference between satisfactory performance and failure. For example, what if:
- the orientation is changed from north to south?
- the wall reflectivity (paint colour) is changed?
- the geographical location is changed?

4.0.4 Post-processors like WUFIBio and the WUFI-VTT tool are useful tools for assessing the mould growth potential on a surface from the results that WUFI calculates. Directly inferring risk of damage from temperature and humidity values is difficult, and tools like these allow these parameters to be turned into an easily readable metric (Figure 3).

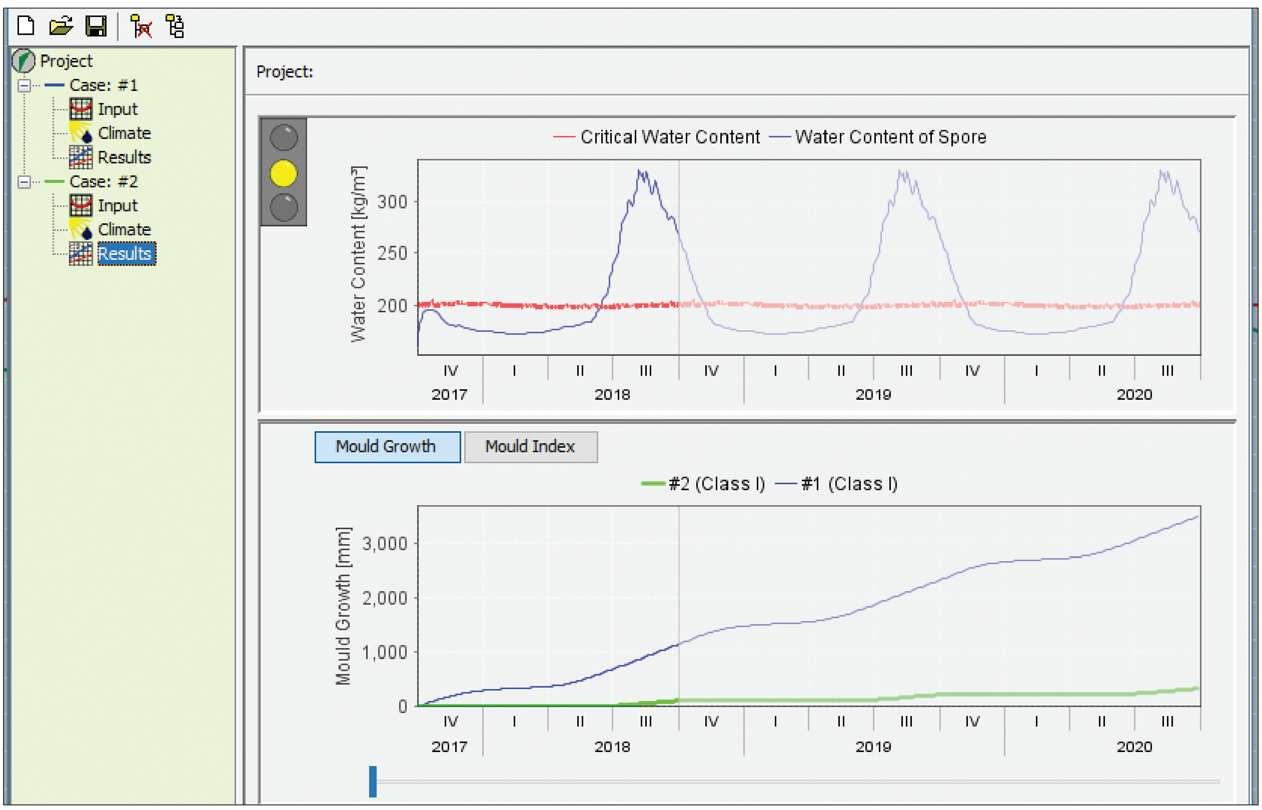


Figure 3. Example output from WUFIBio.

5.0 LIMITATIONS OF USING WUFI

5.0.1 WUFI requires a skilled operator with a good understanding of the building science involved. A user must understand the limitations of the particular version they are using and how that applies to the construction they are simulating. Of particular importance are the boundary conditions (both indoor and outdoor). Applying realistic conditions to the construction are key to having a representative result. Understanding the usage patterns of the building when it is completed will be beneficial.

5.0.2 Users also need to be reasonably experienced and have a good understanding of physics and material properties (including the various transport phenomena). Taking thermal modelling as an example, WUFI adds another level of complexity over and above that. It is not just a case of turning a switch and modelling moisture as well. WUFI has to perform a thermal model in order to simulate moisture and, in doing this, considers multiple transport processes and material properties, many of which have a temperature dependence.

5.0.3 WUFI generally simulates a perfect wall assembly without real-world defects, although there are tools available that do allow some simulation of water leaks and airflow, which can be a dominant transport mechanism. The results should be evaluated with some consideration that the real building will not be as perfect as the model and that defective details will have a profound effect on real-world performance.

5.0.4 At least a brief report of the results and various assumptions and inputs should be provided as simply providing the graphical outputs to an untrained eye is likely to cause misunderstanding.

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