Waterskater Guideline

updated on 27/09/2024

Introduction

The Intergovernmental Panel on Climate Change identifies human activities as the primary driver of the current climate crisis, highlighting that while some impacts are inevitable, reducing emissions can still mitigate severe consequences. The construction sector, a major emitter of greenhouse gases, plays a critical role in this effort. As buildings become more energy-efficient, attention shifts to the emissions associated with construction materials, including their production and disposal. Therefore, adopting low-carbon materials is essential to reducing the industry's carbon footprint. In this context, earth-based composites present a promising solution due to their minimal embodied carbon and recyclability. Additionally, their hygroscopic properties can enhance indoor comfort and well-being by passively regulating humidity levels.

The passive regulation of indoor humidity through hygroscopic materials has gained recognition over the past decades. However, quantifying this effect at the whole-building scale remains a challenge. Early-stage energy simulation tools in architectural design, such as the Grasshopper plugin Ladybug, do not account for moisture transfer phenomena in building materials. In contrast, advanced dynamic hygrothermal simulation tools like EnergyPlus, WUFI Plus, and HAMBASE can effectively model moisture transfer, but they require specialized expertise, making them difficult to use during the early design stages of architectural projects.

To address this gap, the Chair of Sustainable Construction at ETH Zurich has developed a new early-stage simulation tool – the Grasshopper plugin WaterSkater. This tool integrates dynamic heat, air, and moisture calculations using the Grasshopper interface and leverages the EnergyPlus engine's CombinedHeatAndMoistureFiniteElement algorithm.

Currently, the plugin is in its final validation phase, with a trial version now available.

A guideline for the plugin and its use follows, consisting of:

- Files available for download on Github
- Set-up your first simulations
- Run the simulation
- Once you are finished
- Bugs - WaterSkater
- Limitations - WaterSkater

References in the literature:

- Posani, Magda, et al. "Integrating Moisture Dynamics into Grasshopper Architectural Design Workflow: A Plugin to Grasp the Benefits of Moisture Buffering Materials." *78th RILEM Annual Week & RILEM International Conference on Sustainable Materials & Structures: Meeting the Major Challenges of the 21st Century (SMS 2024)*. 2024.
- Posani, Magda, et al. "Integrating Moisture Dynamics into Architectural Design Workflows: A grasshopper plugin to grasp the benefits of moisture buffering materials." *RILEM Spring Convention & Conference on Advance Construction Materials and Processes for a Carbon Neutral Society*. 2024.

Files available for download on Github

Example files:

1. .xml file (Excel)
2. .3dm file (Rhinoceros)
3. .gh file (Grasshopper)
4. .epw file (Weather file)
5. .pdf file (guidelines)

Set-up your first simulations

First, you'll need to have available/installed on your laptop EnergyPlus, Rhinoceros, Grasshopper, and OpenStudio plugin for grasshopper.

Setup your energy simulation with Open Studio in the Grasshopper environment.
Please, use the weather file as a single file, typically .epw, saved on you laptop.

In the example provided, the weather file is provided using a panel with the link to the file:
C:\WaterSkater_example\2024_FRA_AR_Grenoble.074850_TMYx.epw

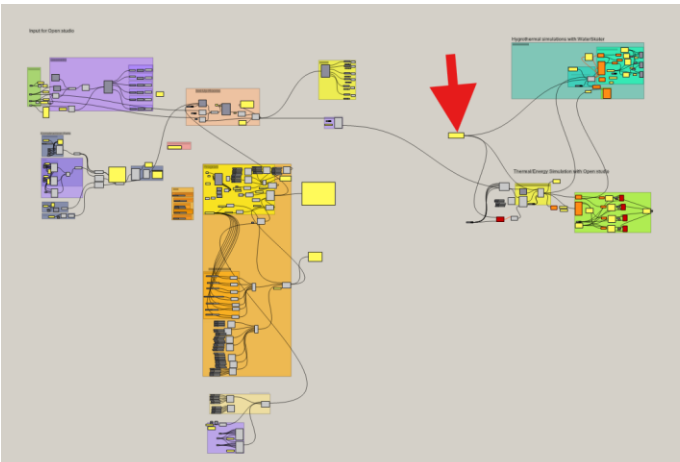


Fig.1 - Location of weather panel in the example .gh file

Run your Thermal/Energy simulation with OpenStudio and check the result, to ensure that the model you constructed works correctly and gives realistic results.

<u>You can then add WaterSkater to the workflow:</u>

- Connect the weather panel and the .idf output from Open studio component to the Waterskater component as in the .gh example provided.

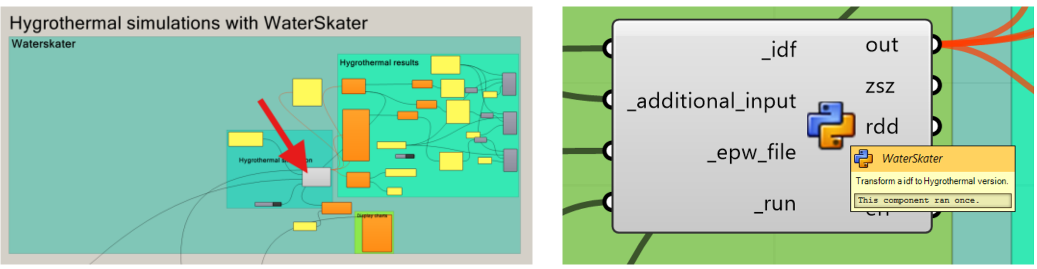


Fig.2 - Location of WaterSkater component in the example .gh file (Left) and a close view of the WaterSkater component in the same file (Right).

- For each simulation you run, create a folder with a name that gives a good indication of what simulation it is (for example *'0.Baseline'*). In the folder save the .xls file given as example. Put the location of the excel file in a panel as 'Additional_Input' in WaterSkater, as in the image below.

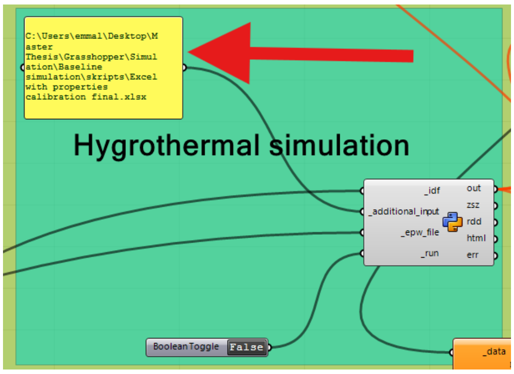


Fig.3 – Path to excel file with hygrothermal properties of material, connection with the WaterSkater component.

- In the excel file, add the materials that you are using in your simulations.
  The example Excel file contains a series of materials that are needed in the simulation, namely from material 5 on. Please leave them unchanged.

  To input your materials, you have to use exactly the same name as used in the open studio input.
  You can change the names of <u>the first four materials</u> in column B. $

  <u>If you need to add more materials</u>, you can do so by copying cells B78 to O92 and insert copied cells into B93, shifting down the pre-existing cells. B93 to 0 107 will be your new space to add the additional material. Repeat as many times as needed to have enough space to input all your materials. Then check what is the last cell filled in column A, normally it is 'material 18'. The materials that you shifted down are now missing a material number, please add on the A cell next to the materials name 'material 19', 'material 20',... and so on until all materials have a 'material n' label.

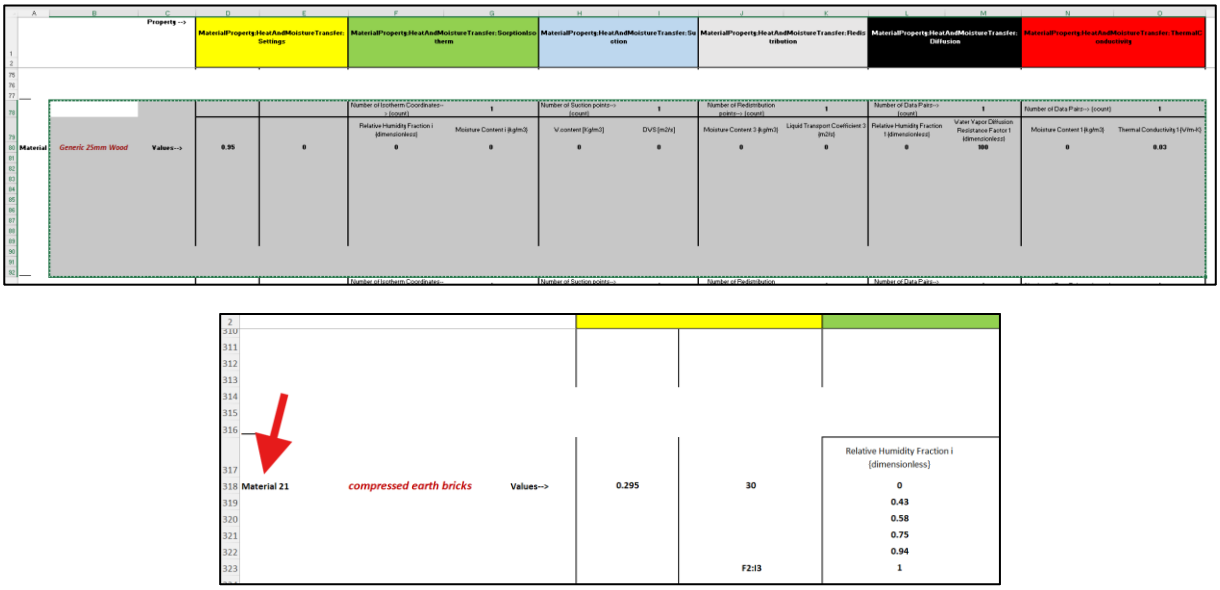


Fig.4 – Cells to be copied in the excel file to create additional materials (Top) and a close view of where to write the 'Material n' label where it is missing (Bottom)

- *Materials and Hygrothermal Properties*
  Once you have space for all materials, and you gave them the same name as you gave in grasshopper inputs for Openstudio, then you can proceed to give all material properties needed in the Excel file.

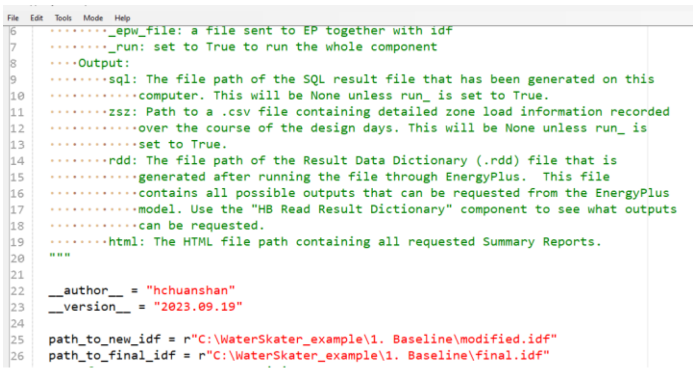
Thermal conductivity, Density, and specific heat capacity can be the same given as input in Open studio. The other data can be taken from the literature or from hygrothermal databases, for instance from WUFI software.
Porosity (m3/m3) – Is the volume of open pore volume per unit of volume of the material
Initial Water Content Ratio (kg/kg) – Initial quantity of water contained in the material at the beginning of the simulatons
Sorption Isotherm: it represent the water contained in the material when it is in equilibrium with different RH in the air. <u>This value is very important for materials that ar near the indoor air, so interior side of building component, because this characteristic strongly influence the moisture buffering performance of materials.</u> First write the Relative Humidity (RH) steps you have, Relative humidity Fraction (adimensional, for instance 50%RH correcponds to 0.5 Relative Humidity fraction). For each RH, write down the corresponding Moisture Content (kg/m3).
Suction: This property is related to the interaction with liquid water. It is based on Kunyel's formulation of moisture transfer and this property is provided in WUFI Database. It can also be estimated based on the capillary water absorption coefficient, using appropriate formula given in the literature. Provide the Water content content [Kg/m3] values and DWS [m2/s] corresponding to them.
Redistribution: This property is related to the interaction with liquid water. It is based on Kunyel's formulation of moisture transfer and this property is provided in WUFI Database. It can also be estimated based on the capillary water absorption coefficient, using appropriate formula given in the literature. Provide the Water content content [Kg/m3] values and Liquid Transport Coefficient [m2/s] corresponding to them.
Diffusion: Water Vapor Diffusion factor can be provided for one or more conditions of relative humidity. <u>This property strongly influence the moisture buffering performance of materials.</u>

- Before running the simulation, create a new folder inside the *'0.Baseline'* folder, for simulation results (for instance, folder 'Results').

- *Location of input files and related setup*

  For each simulation you run, double-click on the Waterskater component and change the red part in lines 25 and 26, substituting 'C:\WaterSkater_example\1. Baseline' with the location of your result folder. Keep the end of the location as \modified.idf" and \final.idf"

  For instance for the folder *'0.Baseline*\Results*'*, lines 25 and 26 would become:
  path_to_new_idf = r"C:\Example\0.Baseline \Results\modified.idf"
  path_to_final_idf = r"C:\ Example \0.Baseline \Results\final.idf"



```
File  Edit  Tools  Mode  Help
6         _epw_file: a file sent to EP together with idf
7         _run: set to True to run the whole component
8     Output:
9         sql: The file path of the SQL result file that has been generated on this
10            computer. This will be None unless run_ is set to True.
11        zsz: Path to a .csv file containing detailed zone load information recorded
12            over the course of the design days. This will be None unless run_ is
13            set to True.
14        rdd: The file path of the Result Data Dictionary (.rdd) file that is
15            generated after running the file through EnergyPlus.  This file
16            contains all possible outputs that can be requested from the EnergyPlus
17            model. Use the "HB Read Result Dictionary" component to see what outputs
18            can be requested.
19        html: The HTML file path containing all requested Summary Reports.
20    """
21
22    __author__ = "hchuanshan"
23    __version__ = "2023.09.19"
24
25    path_to_new_idf = r"C:\WaterSkater_example\1. Baseline\modified.idf"
26    path_to_final_idf = r"C:\WaterSkater_example\1. Baseline\final.idf"
```

Fig.5 - Location of lines 25 and 26, to be modified, in the component script.

In this folder, for instance *'C:\Example\0.Baseline \Results' vfolder,* WaterSkater will create a new .idf for Energy plus simulations, based on the input found in the .idf from open studio, updated with the material information from the .xls file, and running hygrothermal simulations instead of thermal/energy simulations. The results will also be saved in this folder.

Run the simulation

First you need to Run the Openstudio simulation (Boolean toggle=true), this will create a .idf input file for WaterSkater. A black screen with information about the simulation that Openstudio is running will appear during the simulation, and disappear when it is finished.

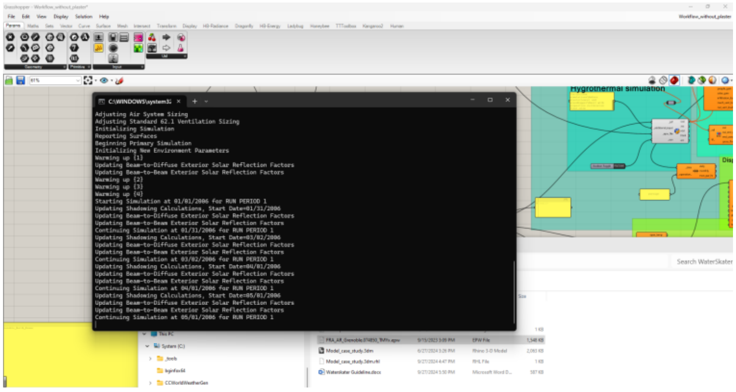


Fig.6 – The black screen with information about the simulation that pops up when Open studio orwaterSkater are running the simulation.

Then, you can run WaterSkater (Boolean toggle=true).
Results in terms of indoor air temperature and relative humidity can be read as shown in the .gh example file. We recommend copying the results into a database to further work on analysing them for indoor comfort purposes, for instance, they can be pasted into excel.

Once you are finished

Remember to set both Boolean toggle=false when you save the file.

For your next iterations, we suggest you create a new folder with a new excel file and results inside.

Check the excel file after your simulations are finished. It might happen that Water skater changed or overwrote on some materials. This is a bug of WaterSkater. If this happens, copy this “changed” excel file with a new name, add your materials, and use it in the workflow.

Bugs - WaterSkater

- Material properties in the 'excel with properties' for the hygrothermal simulation are overwritten at times. The 'excel with properties' file must be copied for each simulation, and if there is an overwriting you have to ensure that your materials are still in the Excel. If any correction is needed, work on the file changed by water skater, the changes added are those that make the Excel file work, so you can continue from there.

Limitations - WaterSkater

- Waterskater is an early design tool, developed to analyse the influence of Hygroscopic materials on indoor air conditions, aiming to check their potential benefits in moderating indoor humidity levels. The software is not suitable for moisture-related damage analyses or detailed evaluations related to moisture transfer, other than evaluating the effect outlined in the beginning of this point.

- At the moment, WaterSkater can run only one year of simulations, plus few months of preconditioning. It is normally good practice to run at least 2 years of simulations, to start with realistic initial conditions of moisture content and indoor air humidity for the final year of simulations. This is not yet possible with Waterskater.