Wall-ACE v1.1

User manual

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Wall-ACE
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Contents

1 Overview

Given a wall configuration, the software evaluates the energy savings that can be achieved by means of a refurbishment using the Wall-ACE products.

The analysis is performed through a dynamic simulation of the one-dimensional heat transfer within the wall before and after retrofitting, considering outdoor temperature and irradiance profiles on the outer side and a constant air temperature on the internal side. The transient heat conduction equation is solved through the application of the finite difference method with Crank-Nicolson scheme and Gauss-Seidel overrelaxation [1, 2]. Uniform time step (15 minutes) and mesh size are considered. Energy losses and energy gains are then evaluated by respectively integrating the negative and positive heat flux densities.
The simulation period can be either hourly, monthly or yearly. For hourly runs, results refer to a steady-periodic regime. For monthly and yearly runs, initial conditions are evaluated by running a pre-simulation of the previous month.
Eventually, for both the pre-retrofit and post-retrofit cases, the static and dynamic thermal properties of the wall are evaluated according to the standards EN ISO 6946:2007 [3] and EN ISO 13789:2007 [4], respectively.

The basic view of the software is reported in Fig. 1. The description of the wall, the boundary conditions and the simulation period need to be defined, together with one or more retrofitting choices. The input data can be saved as *.mat* files (MATLAB data files) and loaded at any time, whereas the results can be exported in *.csv* format (comma delimited files).

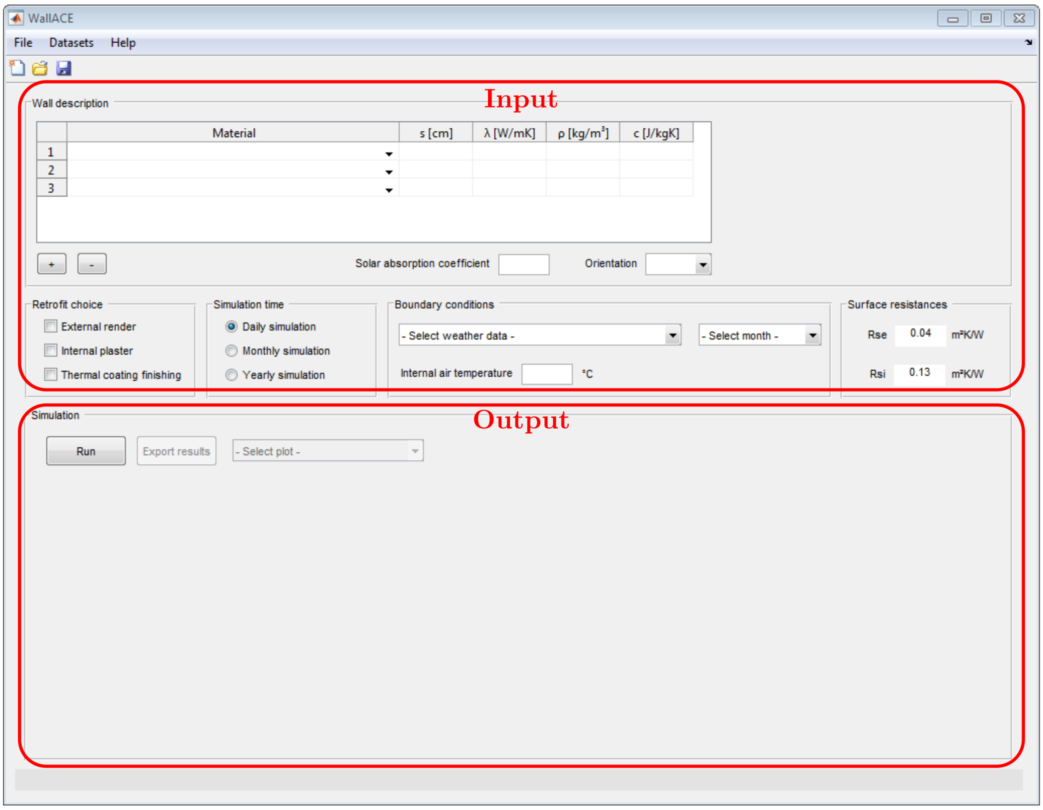

Fig. 1: Overview of user interface.

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Input

2.1 Wall description

Information on the wall construction can be entered in the table, as shown in Fig. 2. The first and last rows of the table respectively refer to the outermost and innermost layers. A list of predefined materials is available. When a material is selected from the list, the corresponding thermal properties (thermal conductivity, λ, density, ρ, and specific heat capacity, c) are automatically loaded. The thickness of the layer (s, in centimetres) is therefore the only value that needs to be manually entered. If necessary, the user can modify the predefined values of the thermal properties. Custom materials can also be added by selecting *Custom* from the material choice list. The user will therefore have to manually complete the table.

When an air gap is entered and its thickness is provided, the software automatically evaluates its equivalent thermal conductivity in order to obtain the correct thermal resistance according to EN ISO 6946:2007 [3].

An unlimited number of layers can be selected. They can be added or deleted by respectively pushing the plus and minus buttons.

To perform the dynamic thermal simulation, which takes the effect of solar radiation into account, the solar absorption coefficient and the wall orientation also need to be entered. A few reference values are reported in Table 1 [5, 6].

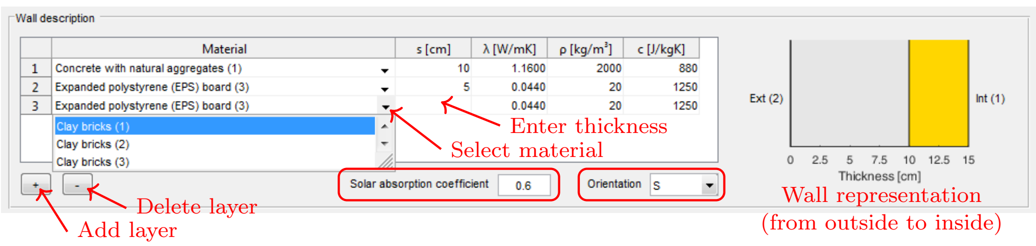

Fig. 2: Inputs to describe the wall.

The pre-defined dataset of material properties can be updated by modifying the file *Materials.xls* contained in the folder linked by the menu *Datasets* $\rightarrow$ *Materials* (the software needs to be restarted for the changes to take place). Data added in additional sheets will not be loaded.

Table 1: Solar absorption coefficients.

Material	α [−]
Light colour ($S < 20$, $C < 30$ in Natural Colour System (NCS))	< 0.3
Medium colour ($S < 40$, $30 < C < 60$ in NCS)	$0.3 \div 0.6$
Dark colour ($S > 20$, $C < 30$ and $S > 40$, $C < 60$ in NCS)	> 0.6
Black paint	0.98
White paint, acrylic	0.26
White paint, zinc oxide	0.16
Brick, red	0.63
Concrete	0.60
Roof tiles, red (dry surface)	0.65
Roof tiles, red (wet surface)	0.88

2.2 Retrofitting choice

The possible retrofitting options regard the addition of the following Wall-ACE products:

- External high performance insulating render;
- Internal high performance insulating plaster;
- Thermal coating finishing.

For each material, whose thermo-physical properties are reported in Table 2, a thickness in the range 1-12 cm, 1-12 cm and 3-30 mm can be respectively applied.

At least one option needs to be selected for the simulation to run.

Table 2: Thermo-physical properties of the WALL-ACE products.

Material	λ [W/(m K)]	ρ [kg/m^3]	c [J/(kg K)]
External high performance insulating render	0.027	203	998
Internal high performance insulating plaster	0.028	136	998
Thermal coating finishing	0.027	136	942

2.3 Boundary conditions

Simulations can be run for a day, a month or a year. For daily and monthly runs, the month needs to be selected. The daily simulation is carried out considering average daily boundary conditions of the selected month.
Weather conditions (external air temperature and solar radiation) can be specified by selecting the weather data file of the location under investigation (*.stat* files for daily simulations and *.epw* files for monthly and yearly runs). Additional weather data files can be downloaded[1] and loaded by copying them in the folder linked by the menu *Datasets* $\rightarrow$ *Weather data*.
Eventually, the internal air temperature needs to be specified, and its value is considered constant throughout the simulation period.

The solar radiation impinging on the wall is evaluated according to the model reported in the ASHRAE 2009 [7, Ch. 14]. For the daily simulations, the solar position is evaluated on the 21st day of the month. An overview of the inputs is shown in Fig. 3.

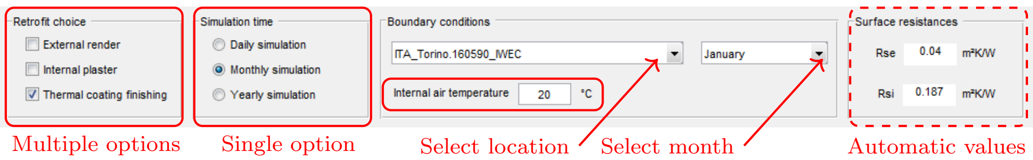

Fig. 3: Retrofit choice, simulation time and boundary conditions.

2.4 Surface resistances

The standard surface resistances are selected for horizontal heat flux according to EN ISO 6946:2007 [3]. When the thermal coating finishing is selected as retrofitting option, the internal resistance of the refurbished wall is automatically adjusted to take the low-emissivity of the material into account. The new thermal resistance is evaluated according to EN ISO 6946:2007 [3].

[1] https://energyplus.net/weather

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Output

3.1 Dynamic simulation and energy savings

When all the input data are entered, the simulation can be launched. Once completed, energy losses and energy gains are evaluated for both the pre-retrofit and post-retrofit walls. The corresponding energy savings are reported in percentage. Then, the possibility of exporting and plotting the results becomes active. Any change in the input data will reset the results and require a new simulation to run. An overview of the outputs is shown in Fig. 4.

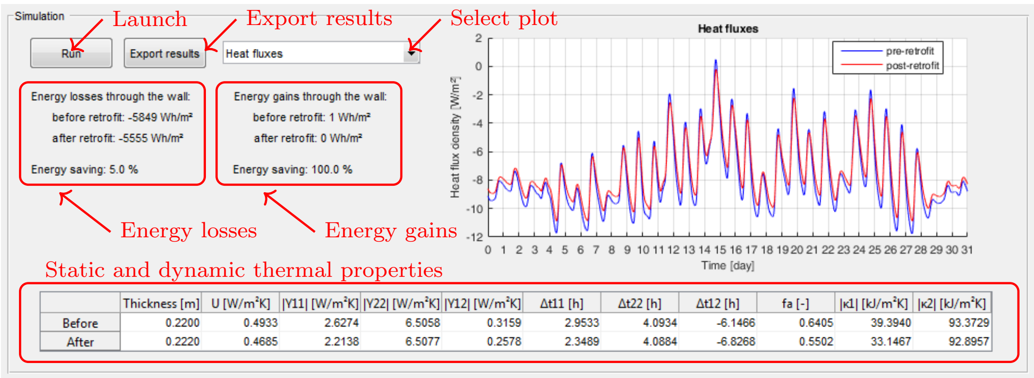

Fig. 4: Overview of the outputs.

3.2 Dynamic thermal properties

The dynamic thermal properties of the wall before and after retrofitting are evaluated according to EN ISO 13789:2007 [4]. The overall thickness of the wall and its U-value [3] are additionally reported.
In detail, the following parameters are evaluated:

- Thickness: overall thickness of the wall — m
- U: thermal transmittance (U-value) — $\mathrm{W/(m^2\,K)}$
- $|Y_{11}|$: modulus of the internal thermal admittance — $\mathrm{W/(m^2\,K)}$
- $|Y_{22}|$: modulus of the external thermal admittance — $\mathrm{W/(m^2\,K)}$
- $|Y_{12}|$: modulus of the periodic thermal transmittance — $\mathrm{W/(m^2\,K)}$
- Δt_{11}: time shift of the internal thermal admittance — h
- Δt_{22}: time shift of the external thermal admittance — h
- Δt_{12}: time shift of the periodic thermal transmittance — h
- f_a: decrement factor — adim.
- $|\kappa_1|$: modulus of the internal areal heat capacity — $\mathrm{J/(m^2\,K)}$
- $|\kappa_2|$: modulus of the external areal heat capacity — $\mathrm{J/(m^2\,K)}$

3.3 Graphics

The following graphics can be visualised by clicking on the - *Select plot* - menu:

- *Boundary conditions*: external and internal air temperature profiles and global solar radiation impinging on the wall;
- *Internal surface temperatures*: internal surface temperature profiles the for both the pre-retrofit and post-retrofit walls.
- *Heat fluxes*: comparison of the heat flux densities on the internal side for both the pre-retrofit and post-retrofit walls.

3.4 Report

A complete report of all the inputs and resulting outputs can be exported in *.csv* format by clicking on the *Export results* button.
Detailed tables containing all the interface temperatures between materials and the heat flux densities entering the internal environment for the pre-retrofit and post-retrofit walls are also included. The temperature profiles are numbered from the outermost to the innermost interface. If an air gap is present, the average temperature of the air within the air gap is additionally reported.

Bibliography

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[3] EN ISO 6946:2007, Building components and building elements - Thermal resistance and thermal transmittance - Calculation method, International Organization for Standardization, Geneva, Switzerland, 2012.

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[5] A. Arenghi, L'influenza del colore, in: G. Galbusera (Ed.), Prestazioni estive degli edifici, TEP Srl, 2010, pp. 65–76.

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