The design of a Novel Roof Tile Shape Using CFD Analysis

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Introduction: *Reduced building cooling consumption has great relevance in hot climate regions. In these areas, the roof plays an important role in reducing the effects of solar radiation when compared to other building elements, due to its extension and exposure to the sun.*

*In **ventilated roofs**, a ventilation ducts is created under the tiles where air flows from eaves sections (intake vent) to the ridge, and helps to dissipate the excess heat in summer.*

*Moreover, in **tiled roofs** the air-permeability of the overlapping tiles is an additional and diffused intake/exhaust air-vent system.*

Several studies have demonstrated the performance of ventilated roofs in reducing solar heat gain.

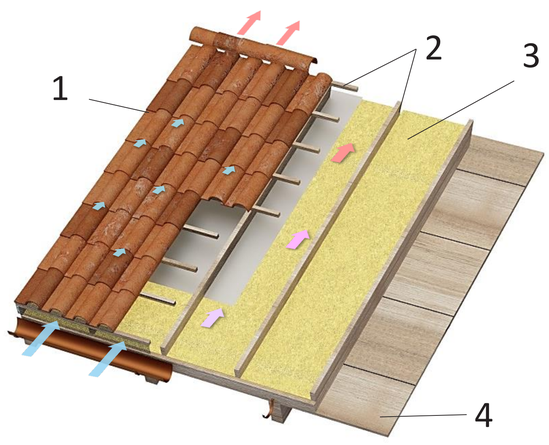


***Figure 1**. Typical ventilated tiled pitched roof. 1-tiles, 2-batten & counter-batten, 3-insulation, 4-deck*

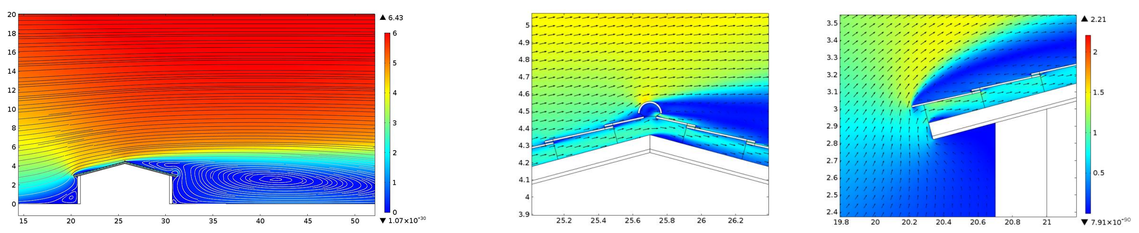


Figure 2. Velocity magnitude (m/s). M. Bortoloni, M. Bottarelli, S. Piva. Summer Performance Of Ventilated Roofs With Tiled Coverings. Climamed Conference, 2015.

Objectives: The **air permeability** of roof tiles is numerically analyzed to compare standard and novel tile shapes in order to improve the above sheeting ventilation effect, as proposed in the European project HEROTILE.
10 variations of standard Marseillese tile have been designed.
The design variants include modifications - to the side, or the front, or both - with the aim of increasing the air permeability in different wind conditions.

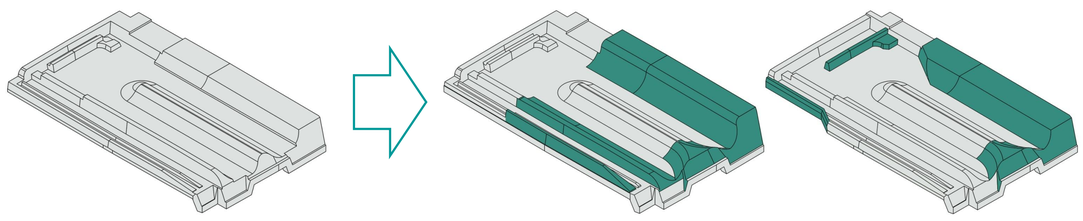


***Figure 3**. standard (on the left) and novel (on the right) Marseillese tile shapes. Green parts are the design variants*

Computational Methods: The standard tile shape was imported in COMSOL from the industrial CAD, with minimal pre-processing to remove surface mesh features that can lead to problems in the CFD simulation stability. The CFD module was used to solve the 3D, steady-state, incompressible flow field, using the RANS-based standard k-ε turbulence model.

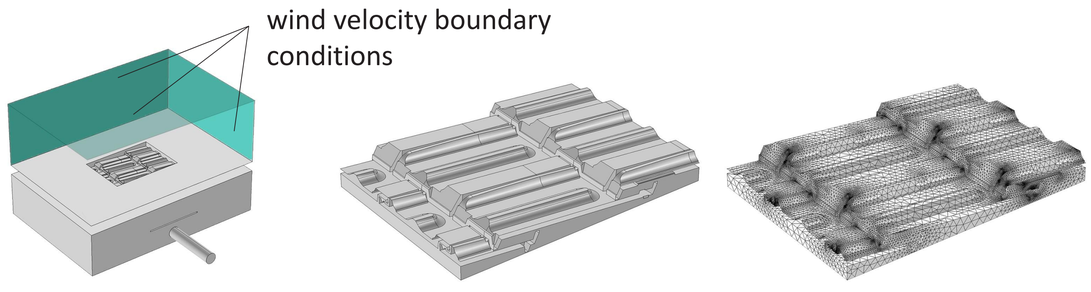
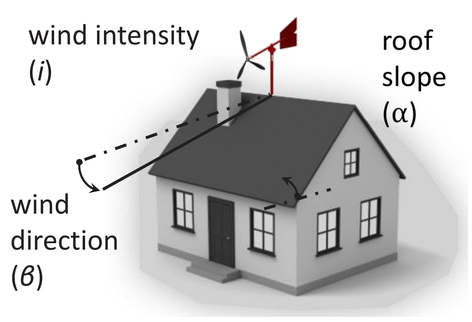


***Figure 4**. Domain and mesh configuration*

A parametric analysis was carried out: wind speeds “i” were simulated blowing over the tiles, with three roof slopes “α” and six horizontal wind directions “β”, to represent 72 wind conditions over a common pitched roof.

$$\begin{cases} i = 0.5, 1.0, 2.0, 5.0\ m/s \\ \alpha = 10°, 20°, 30° \\ \beta = 0°, 15°, 30°, 45°, 60°, 80° \end{cases}$$



Results: The reference (SM) and new tile (PM) were compared in terms of air pressure drop and the volumetric flow rate through tiles.

In the *standard tile*, the air-flow rate (AFR) decrease as the angle β moves from facing the tiles head-on around to side-on, the opposite is true for *project tile*;

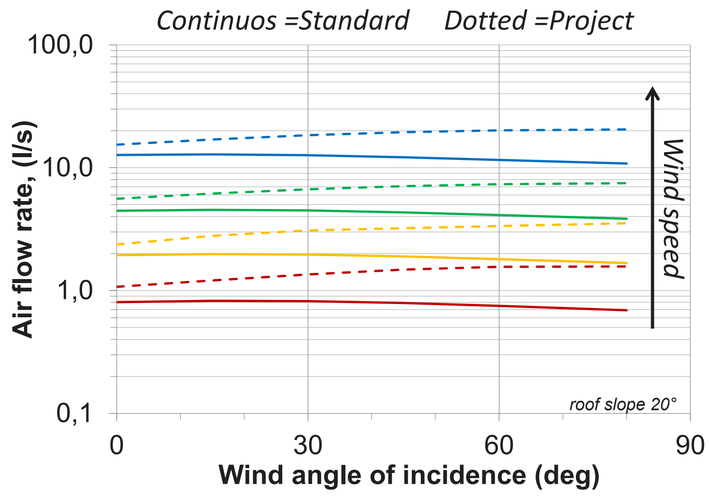


***Figure 5.** Air permeability as a function of wind direction.*

According the pressure difference between an internal and external point probe, the AFR diverges in clockwise and anticlockwise directions respectively in *standard* and *project* tiles.

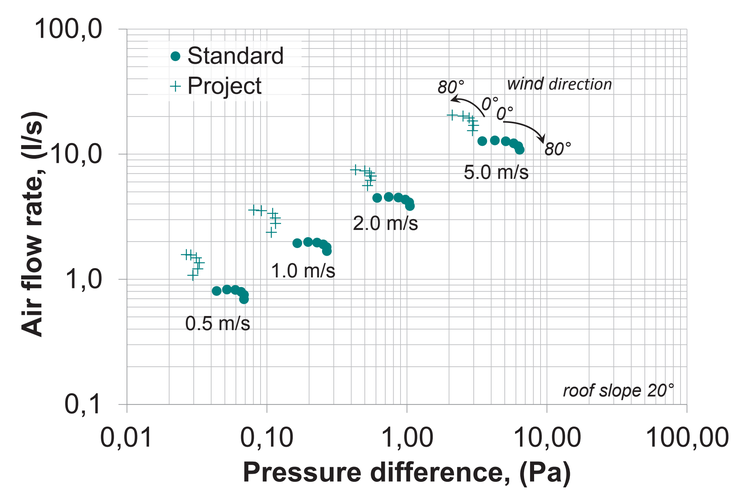


***Figure 6.** Air permeability as a function of pressure difference.*

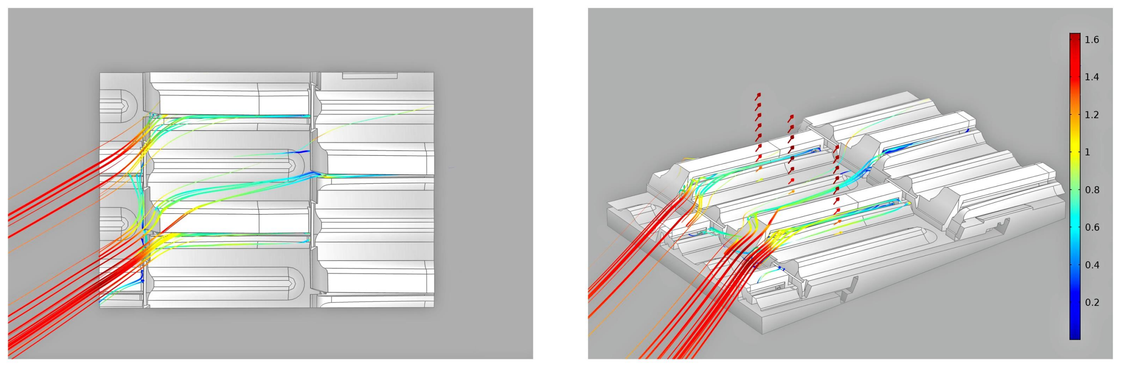


***Figure 7**. Air-flow stream lines through the tiles..*

Conclusions: New Marseillese shapes produced a small improvement in the air permeability.
A flow rate increase through the novel shaped tiles was related to both the enlarged open area between the tiles and the original design of the head lock.
Some solutions were less affected by the wind direction.

References:

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http://www.lifeherotile.eu/