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THESIS: Modelling and testing of green roof using the PASLINK methodology for characterization of its energy behaviour.

Abstract

Within the development of a project carried out by a construction company located in the Basque Country which aim is to build dwellings by means of prefabricated modules, a need for evaluating the thermal and hygroscopic behaviour of its flat roofs has been found. During the roof design the thickness of insulation has been defined to fulfil the most severe climatic conditions considered in the Spanish Building Code. This way the roof could be installed in any other location without changing anything in the production chain.

The possibility of changing the roof cover from gravel to vegetation has been analysed by means of experiments under real conditions. The CTE does not accept the possible improvements on the cooling and / or heating demand of non traditional building components to be considered unless these improvements are proved. The vegetation cover is not considered as a traditional building component and thus its impact on the reduction on the cooling demands of the building cannot be taken into consideration unless it is quantified.

This is the main reason of carrying out this research by means of experimental validation of the green roof thermal behaviour. These experiments have been used to identify and validate two models: one to simulate the hygrothermal (thermal and hygroscopic) behaviour of the gravel covered roof and the second one to simulate the thermal behaviour of the vegetation covered roof. The only difference between both roofs is the cover, while the rest of the roof structure has been maintained the same: interior concrete layer (8.5 [cm]), rock wool layer (8 [cm]) and exterior concrete layer (15.5 [cm]).

The first set of experiments has been carried out to the gravel covered flat roof test sample. This roof test sample has been designed to be as similar as the real flat roof. The possibility of analysing the hygrothermal behaviour of the flat roof under one dimensional assumption has been checked by means of a 3D simulation of the roof test sample. The experimental design of the roof test sample has been made under the assumption that the one dimensional analysis is possible. Thus 5 temperatures, a central heat flux sensor and a relative humidity sensor has been installed in the interface of each of the layers composing the roof test sample. Some of those sensors have been installed in order to permit to validate the results of the 3D simulation on the temperature homogeneity in the interior surface of the roof test sample. Once this fact has been validated the experimental data have been used to identify and validate the thermal and hygroscopic properties of the different layers of the roof test sample covered by gravel.

Since the tests have been carried out in a PASLINK type test cell the obtained experimental data are dynamic (steady-state conditions are never achieved). A PASLINK test cell has been upgraded and an innovative system to test roof samples has been designed for this thesis. The innovation is

mainly regarding to the design of a special insulation frame for the roof test sample that minimizes the border effects (and thus uncertainties) during the testing period.

The experimental data have been treated by means of the LORD software to obtain the thermal characteristics of the different layers of the roof test sample. Both, the thermal resistance and thermal capacity of each of the layers have been obtained. Those values have been used to calibrate a one dimensional model of the roof test sample on the Wufi Pro 4.2 software (this software permits to analyze the hygroscopic behaviour). This model has also been validated by means of the experimental data.

Once the gravel covered roof experiments were finished, the gravel layer was changed by a vegetation cover. The vegetation cover is made up by a drainage layer, a soil layer and the plants or canopy layer. The vegetation covered roof has only been used to identify and validate a model that can simulate the Page 6 of 381 thermal behaviour of the roof test sample covered by vegetation. The same identification and validation process has been followed with the vegetation covered roof. But in this case the vegetation covered roof has been more complicated to be modelled. The common part of the roof has been modelled in a similar way to the gravel covered case and thus it has served as a validation to compare the results of both covers. But the soil and drainage layers thermal conductivities are very dependent on their water content. The two extreme working conditions for this part have been identified and validated: completely dry situation and completely water saturated situation. This way the thermal conductivity and thermal capacity of the soil and drainage layer have been obtained for the upper and lower bounds.

The calculation of the soil layer external surface temperature is the most important factor regarding to the improvements of the green covers in the cooling demands associated to the roof. This temperature depends on many factors but mainly on: solar radiation, evapotranspiration rate, water content of the soil plus drainage layer, Leaf Area Index of the plant, long wave radiation heat exchange and the convective heat transfer to the outdoors air. During this research an innovative model to obtain this temperature is proposed based on the mass convection theory. Actually, a similar model to the sol-air concept is obtained. This model has been validated for the following extreme two cases: the soil and drainage layers are completely water saturated having all the required water for evapotranspiration process. This is the optimal working mode of the green roof for hot, dry and sunny summer periods and of course it needs of an irrigation system to maintain those optimal conditions on time. The other working mode is the case of a not irrigated green roof during long periods of hot, dry and sunny summer without rain. This is the worst working mode for the green roof.

Once the two models have been identified and validated, both roofs thermal behaviour have been simulated for three different locations considered in the CTE: Burgos (climatic zone E1, considered extremely cold in winter), Almeria (climatic zone A4, considered extremely hot in summer and Zaragoza (climatic zone D3, considered an intermediate case)

The heating demands have been compared and no considerable difference has been found in case of changing the gravel cover for a green cover.

For summer periods the green cover reduces the cooling demand up to a 75% in case the green cover is maintained water saturated by means of an irrigation system. But in case the green cover does not have an irrigation system it behaves worse than the gravel cover case when it dries completely. The tested green roof dries completely after 8 days of hot, sunny and dry days. Once the roof is completely dry the evapotranspiration effect disappears. Since the soil and plants absorb much better the solar radiation than the gravel cover, the cooling demand can increase up to a 65% compared to the gravel covered case. Note that if any rain is happening this percentage is reduced.

The hygroscopic behaviour has been studied and no interstitial condensation risk has been found in any of the locations considered for the simulations. Only, under the worst simulation conditions for the indoors air conditions, a slight risk of mold growth has been found. A water vapour barrier in the hot face

Keywords: green roof, PASLINK test cell, energy behaviour, simulation models.