Κέρδη από Θερμική Μόνωση σε Υφιστάμενα Κτίρια: Μια Αξιολόγηση για τις Ελληνικές Κλιματικές Συνθήκες

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Gains due to thermal insulation in existing buildings: An assessment for the Greek climatic conditions

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Summary of presentation

The presentation focuses on the assessment of the effectiveness of thermal insulation (internal versus external) for retrofitting residential buildings using typical Greek wall assemblies, for the Greek climatic conditions and the conditions of the Greek KENAK.

The base case used for the comparative assessment is a residential building without insulation, built before 1980, when the first Greek Building Thermal Insulation Regulation (OHJ 362/4-7-79) was issued.

The effectiveness of the examined insulation configurations has been studied for a representative "building element" (external wall assembly) whose sides are exposed to predefined outdoor and indoor environments (using a one-dimensional heat transfer analysis) and for a representative building taking into account different wall orientations and interactions with the ambient environment (using the commercial tool TRNSYS). The examined insulation configurations matched commercial products. The required heating (winter period) and cooling (summer period) energy requirements have been calculated for different scenarios with the scope to maintain predetermined indoor thermal conditions.

The examined basic ***wall assembly*** comprised a double brick (of 100 mm each) with intermediate air gap (50 mm). The performance of commercial type "external insulation" (consisting of 80 mm EPS and 8 mm cement-lime mortar) was compared to that of "internal insulation" (consisting of 80 mm EPS – for comparison reasons –and 12,5mm gypsum plasterboard).

The thermal performance of the wall assembly without, with external and internal insulation has been assessed by using two characteristic parameters, the time lag (the time needed for a periodic temperature wave to propagate from the outdoor to the indoor surface) and the decrement factor (reduction in amplitude of the periodic temperature wave at the indoor surface compared to the outdoor surface). The main insulation layer in both external and internal insulation configurations was considered to be EPS 80. The thermo-physical properties of all the materials used in the investigated wall assemblies were taken from the Greek Regulation of Energy Efficiency in Buildings (KENAK, 2010). Two different sets of meteorological data, corresponding to Greek climatic zones B and D, were used to simulate the wall assembly performance for a period of one year.

The externally and internally insulated wall assemblies clearly outperformed the non-insulated wall assembly. The time lag was improved, during winter and summer, by ca.

17% with the internal and 26% with the external insulation systems, when compared to the non-insulated case. Similar results were obtained for the decrement factor that was improved by ca. 87% and 95% with internal and external insulation, respectively. Better relative time lag and decrement values, of the order of 9%, were obtained with the external insulation system in comparison to the internal insulation.

Predictions of the time evolution of the instantaneous indoor wall surface temperature and heat flux due to convection, for a period of one year in the cities of Athens and Kozani, indicated that the addition of an insulation layer (internal or external) results in significant reductions of the amplitude of the temperature oscillations on the indoor wall surface. Calculated heat fluxes are lower than in the non-insulated case, corresponding to lower energy consumption of the HVAC systems.

Thermal losses were calculated on the indoor surface of the examined walls, for a 1-year period, for the cities of Athens and Kozani. Using external or internal insulation, the losses were about 20% of the corresponding value without insulation (i.e. 80% less losses). Insignificant differences were recorded between internal and external insulation. Both the internal and external insulation configurations are practically thermally equal, since both examined wall assemblies exhibit almost identical thicknesses and consist of materials with identical physical properties, resulting to similar U-values and thermal masses. As expected, the absolute values of the annual thermal losses in the city of Kozani are higher than in the city of Athens, due to the harsher winter conditions in Kozani; however, both insulation configurations were found to be practically equal in terms of their respective thermal behaviour.

Application of thermal insulation in building envelopes is known to have a significant impact on the hygrothermal behaviour of the wall. The Dew Point Method (ASHRAE, 1989) was used to estimate the water vapour condensation in the examined wall assemblies. Condensation occurs if the vapour pressure is higher than the saturation pressure at any point within the wall assembly. For climatic zone B (Athens), no condensation was predicted with the external insulation system using a 1-year period. With internal insulation, vapour condensation appeared during only one day (15 January) on the region near the external side of the EPS layer, where the water vapour comes into contact with the cold region of the wall, and lasted accumulatively approximately for 9 hours over an entire year. It can be concluded that both internal and external insulation could be used in climatic zone B without the risk of water vapour condensates. In contrast to the case of Athens, vapour condensation within the wall structure is more important in Kozani (climatic zone D); as expected, it appears only during the winter season. The Maximum Continuous Time of Vapour Condensation (MCTVC) was calculated for each specific location inside the wall assembly, in order to estimate the most adverse conditions for vapour condensation. Predictions of the MCTVC values across the wall, in the case of internal insulation in Kozani, indicated that the maximum time that vapour condensates are continuously produced is approximately 7.5 days and it takes place near the wall/insulation interface. In this case, various additional measures (e.g. water vapour barriers or retarders) should be considered, in order to prevent the free migration of moisture from the indoor environment into the wall. It should be noted that, as literature data indicate, the thermal resistance of EPS is minimally reduced as a result of moisture absorption. No vapour condensation was calculated with the external insulation configuration in the city of Kozani. It can be concluded that external and internal insulation can be safely used in the climatic zone D, with the addition of appropriate measures to eliminate the possibility of vapour condensation on the wall/insulation interface in the case of internal insulation.

The TRNSYS simulation environment has been used for the simulation of the energy performance of a ***residential apartment, forming the middle floor part of a multi-storey building.*** The performance of the apartment was simulated over a 12 month period of time. Initially, the 99.6m² model residential apartment (living room, kitchen, 2 bedrooms and bathroom) was considered to have no insulation (built prior to 1980). However, it has been assumed that the windows were recently replaced by modern insulated aluminium frame and double pane low-e glazing, and that no thermal losses occurred through the floor and roof of the apartment. These assumptions minimized the effects of windows, floor and roof losses in the calculations and allowed us to focus on the effects of the external or internal insulation applied on the apartment envelop. Thermal bridges, electrical and occupant heat gains have been taken into account according to KENAK. The building performance was simulated for two climatic zones in Greece (B and D). Indoor comfort temperatures were set to 20°C and 26°C for the winter and summer seasons, respectively. Heating and cooling elements were allowed to operate, with different scenarios for zone B and D. Air infiltration was calculated according to KENAK, 2010, for selected windows and doors. Infiltration was assumed constant during the year. For some scenarios, night ventilation was taken into account for the summer period.

Three characteristic insulation configurations were examined in combination with two different occupant behavior scenarios:

- NO: No insulation installed.

- INT: A 80 mm EPS layer is installed at the inner surface of the external walls (internal insulation configuration), covered by a 12,5 mm gypsum plasterboard.

- EXT: A 80 mm EPS layer is installed at the outer surface of the external walls (external insulation configuration), covered by a 8 mm cement-lime mortar coating.

The examined occupant behaviour scenarios were:

- PASS (Passive occupant behaviour): no fixed or movable shadings of the building, window panes remain closed during the entire year, no night ventilation.

- ACT (Active occupant behaviour): balcony overhangs in the northern and southern openings act as fixed shading fixtures, external retractable vertical mats act for shading of the eastern kitchen window and the western living room window, occupant could modify ventilation and shading according to climatic conditions (e.g. night ventilation (00:00-07:59), if the outdoor temperature is higher than 18°C and the internal air temperature of the respective zone is higher than the outside temperature, rolling down of shading mats when indoor temperature raises above 25°C).

The results are summarized in the following table for all cases examined in terms of percentage savings in relation to the no-insulation case. It should be noted that these percentages refer only to the test case examined (100 m^2 apartment with insulated floor and roof and insulated, double pane low-e glazing windows).

Zone	Insulation type	Occupant behavior	Heating load (% reduction in relation to no insulation case)	Cooling load (% in relation to no insulation case) (-: increase)	Total energy (% reduction in relation to no insulation case)
B	**INT**	**PASS**	81	-13	24
	EXT	**PASS**	93	-16	28
	INT	**ACT**	74	8	47
	EXT	**ACT**	86	13	56
D	**INT**	**PASS**	64	-32	43
	EXT	**PASS**	77	-39	51
	INT	**ACT**	60	-10	54
	EXT	**ACT**	72	3	66

Both external and internal thermal insulation of the building envelop can reduce the annual energy requirements of a 100 m^2 apartment between 25-65%, depending on insulation type, climatic zone and occupant behavior. Significant reductions (of the order of 60-90% in comparison to the no insulation case) can be expected in the energy consumption of this type of building during the heating season, independent of climatic zone and occupant behaviour. However, both internal and external insulation can increase the cooling load requirements in the summer season. The occupant behavior (such as shading, night ventilation) can compensate this adverse effect. In poorly ventilated houses and/or with insufficient shading, the implementation of an insulation layer, either external or internal, was found to increase the cooling demand.

On average, external insulation offers ca. 8% more energy savings than internal insulation on a yearly basis (when compared to the no insulation case), independent of climatic zone and occupant behavior. Advantages of external insulation are minimized in climatic zone B (only 3% more energy savings).

Regarding investment costs, internal insulation requires ca. 50% less investment than external insulation (for the same area coverage and thickness of insulation material). For all examined cases, the payback period ranges between 6 – 12 years.

The internal insulation cases depict decreased payback periods (between 6 – 9 years) compared to the respective external insulation (8 – 12 years range). As anticipated, the payback period is noticeably higher in Zone B (Athens) compared to Zone D (Kozani). The lower temperatures of Kozani during winter ensure increased energy saving potentials with the implementation of insulation. However, the payback period for the climatic zone B, it is two years shorter with the internal insulation systems.

Annual cost savings are higher in the cases where insulation is more effective, i.e. when higher initial energy demands are involved (Zone D – City of Kozani) or when the “active” occupant behaviour scenario is adopted.

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