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THE EFFECTS OF THERMAL STABILITY IN RESIDENTIAL LOFT SPACES DURING SUMMER PERIODS

This paper aims to verify the procedure for calculated and measured values, the effectiveness of varying insulation thicknesses for selected rooms and assessment of the highest allowable daily internal air temperature increases during summer periods. Residential building lofts are considered suitable, because in addition to solving problems with sub-standard, common roof leaks, sloped roof constructions significantly impact the architecture of the building and complement its overall character.

Keywords: **residential building lofts, summer period, thermal stability, thermal comfort conditions, calculated and measured values**

1. OVERVIEW OF CURRENT PROBLEMS

The design and realization of residential loft spaces in buildings and/or optimization of roof cladding construction design should adhere to relevant standards based on the geographic location of the structure. The past decade witnessed the arrival of many new building materials, construction technologies and procedures in dealing with roof cladding. Roof cladding solutions differ from country to country and are based on material inputs and production design, all of which depends on vernacular traditions, raw material base and specific characteristics. An envelope/partition construction creates a defined boundary area between the interior and exterior or within a building space. The room is characterized by a particular thermal environment, which is dependent on the thermal state of the structure. An indoor space is regarded as thermally stable when fluctuations in the internal state do not exceed standard limits.

Thermal stability of the room for winter and summer periods is based on transient thermal conditions. Summer thermal comfort conditions are assumed to be adequate for assessment purposes of residential buildings in terms of indoor thermal stability:

$$\theta_{ai} + \theta_s \leq 51 \qquad (1)$$

where:
θ_{ai} - indoor air temperature [°C],
θ_s - average inner surface temperature [°C].

Table 1. **Optimal parameters characterizing the thermal comfort of the indoor environment for residential purposes during summer periods in accordance with local regulations [2]**

Building type	Maximum permissible air temperature $\theta_{ai,max}$ [ºC]	Relative air humidity φ_i [%]	Minimum required ventilation rate v_i [m/s]
Residential	25.5	35 to 50	0.1

Summer thermal stability of the room is assessed according to STN [1] and it, is based on the maximal daily increase in room temperature $\Delta\theta_{ai,max}$, which satisfies summer thermal stability conditions, when:

$$\Delta\theta_{ai,max} \leq \Delta\theta_{ai,max,N} \tag{2}$$

where:
$\theta_{ai,max}$ - maximum permissible air temperature [K],
$\theta_{ai,max,N}$ - maximum permitted daily indoor air temperature [K].

Table 2. **The maximum permissible daily increase in internal air temperature during summer periods in buildings not equipped with air conditioning systems [1]**

Thermal Rating	Maximum permitted daily indoor air temperature $\Delta\theta_{ai,max,N}$ [K]
A	5
B	7.3

2. SCOPE AND AIMS OF THE PAPER

The contribution focuses on thermal stability issues for loft spaces during summer periods and takes into consideration high ambient air temperatures and high levels of solar radiation. Summer climatic conditions dramatically increase the risk of solar-radiation-induced overheating and are aggravated in loft spaces that use lightweight roof cladding.

The paper is based on theoretical analyses and test-measurements. It evaluates the proportional influence of various alternating envelopes, cladding and internal partitions for residential loft spaces suitable for transient summer thermal stability design parameters and aims to minimize energy consumption, which may occur during active cooling.

3. EVALUATION OF SUMMER THERMAL STABILITY IN SELECTED AREAS

Proposed alternative treatment procedures for loft envelope/cladding structures include:

- Improving thermal performance by increasing the thickness of insulation - increasing the external thermal resistance of building structures.
- Modification of transparent structures - improved thermal insulation properties of un-shaded windows with reduced solar transmittance.
- Increasing the heat-accumulating properties of boundary structures.

The paper involves the evaluation of thermal stability in proposed areas of a double-storey apartment loft extension with a known cardinal orientation for alternative envelope and transparent structure solutions.

In Figure 1 sections of transverse and longitudinal partitions and various internal structures are circled within the test room. The present mezzanine level is a multipurpose space and consists of an entrance hall, kitchen, living room and dining room with a spiral staircase that opens onto an upstairs gallery. South facing illumination of the room is realized using two double glazed wooden windows on the first floor; South-East illumination is realized using floor - to - ceiling PVC framed double glazing while the second floor loft is illuminated by Velux GGL skylights which are orientated to the North.

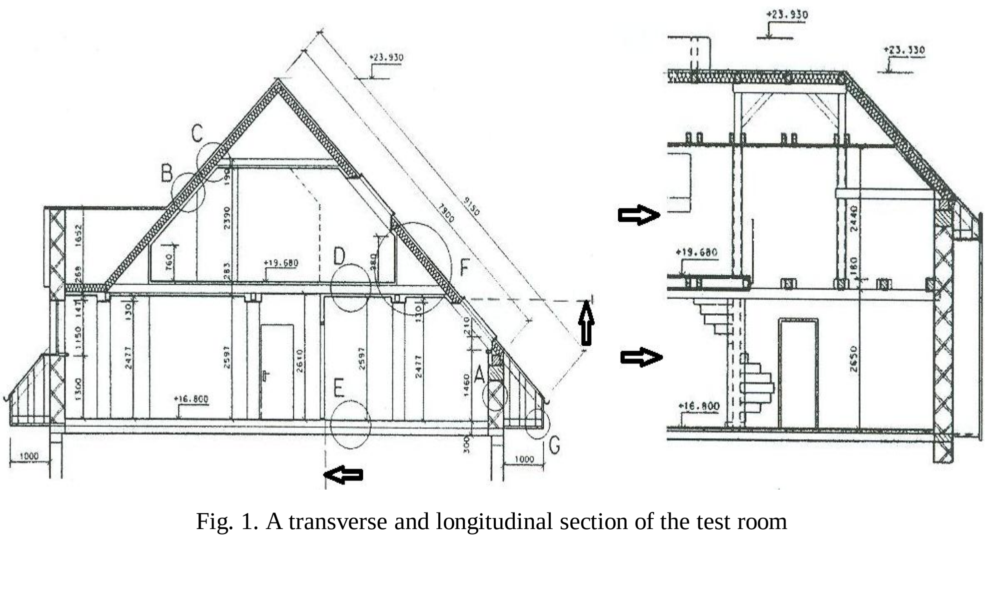

Fig. 1. A transverse and longitudinal section of the test room

Proportion of surface areas compared to the total area of the room (as a percentage) is illustrated in Figure 2.

For purposes of the analysis, the compliance of desired adjustments required the selection of the following roof systems:

- sloped roof cladding - lightweight design,
- envelope and gable - mass design.

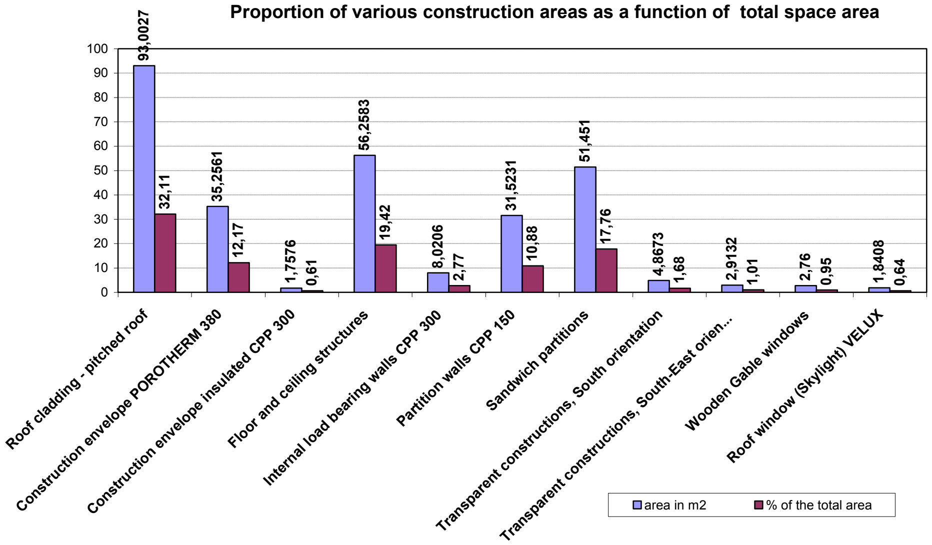

Fig. 2. Graphical representation of the proportion of surface structures compared to the total area of the test room

The first of these compositions is represented by 32.11% and the second by 12.78% of the overall surface area under consideration. Both compositions are adapted in order to enhance thermal performance by increasing insulation thickness as a method for improving the thermal stability of the room.

- By comparing the effect of altering insulation thicknesses, it can be deduced that a 114% increase in thickness of the insulation failed to produce the desired reduction in the maximum increase in internal air temperature.
- Another alternative that compared the effect of changing exterior finishes also failed to achieve a greater reduction in the maximum internal air temperature.
- By comparing the effect of altering transparent glazing structures, an initial favourable reduction of maximum indoor air temperature was achieved, but further improvements of glazing parameters failed to produce significant reductions.
- Comparing the impact of mass changes in the insulation layers by increasing the weight of internal envelope structures achieved the greatest reduction in the maximum internal air temperature.
- Summer thermal stability was considered satisfactory for the test room once modifications were carried out involving mass changes in envelope structures and

changes in transparent glazing constructions; these achieved the greatest reduction in the maximum internal air temperature rise for the room in question.

Figure 3 compares the overall efficiency of structural variants for envelope claddings for summer thermal stability.

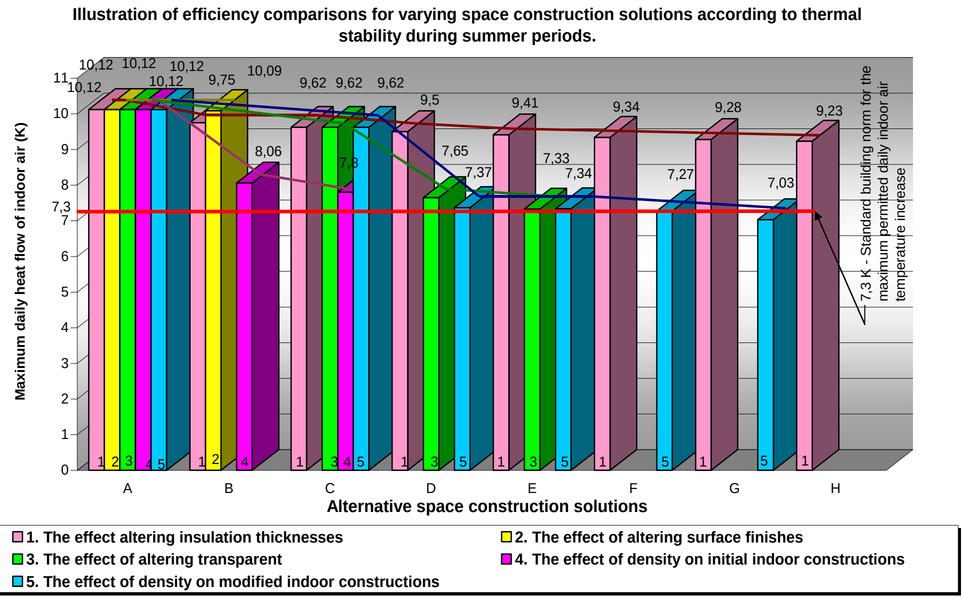

Fig. 3. Graphical representation comparing the effectiveness of structural variants of envelope claddings for the test room in terms of summer thermal stability: 1 - impact of changes as a result of variations in insulation thickness, 2 - impact of changes due to external finish variations of vertical walls, 3 - impact of changes in transparent glazing, 4 - the effect of mass regarding initial thermal insulation thicknesses, 5 - the effect of weight adjusted for the thickness of the insulation and changes in transparent glazing structures

CONCLUSION

It is necessary to design pitched roof cladding as a whole from the outset - from the inner to surface layers, including transparent roof structures with regards to indoor climatic conditions [3].

Significant influences affecting the thermal balance of loft spaces in summer include physical meteorological factors such as ambient temperature, solar radiation, air flow and atmospheric precipitation [4].

High ambient temperatures, solar radiation, cladding with little accumulation ability and poorly ventilated air layers will warm up an indoor space rapidly. Daily fluctuations in indoor temperature will be higher, which adversely affects thermal comfort for loft space occupants.

The results of the test analyses regarding the effects of alternative solutions, envelope and related constructions for the production of summer thermal stability produced the following results:

- Increasing the thickness of the insulation above the threshold ensures the most efficient thermal insulation in winter, but has little effect in decreasing the highest daily summer temperature increase of internal air. Similarly, increasing the insulations' thickness may be considered negligible in relation to decreasing the maximum indoor temperature.
- Altering transparent glazing for greater energy-efficiency with reduced transmission of solar radiation can decrease the maximum daily-indoor-air-tempera-ture increases several times more than increasing the insulation thickness of lightweight pitched roof claddings.
- Replacing low thermal storage envelopes and complementing structures with a material of high thermal storage capacity can achieve the greatest reduction in the daily maximum indoor air temperature.

Excessive overheating in the summer can be avoided by:

- Determining the size and shading of roof windows depending on their orientation and inclination.
- Increasing the thermal storage of envelope structures.
- Ensuring sufficient air exchange and ventilation.
- Increasing the thermal resistance of external building structures.

If these optimal envelope design requirements cannot be realized, it is necessary for loft spaces to incorporate active cooling or air conditioning at the cost of increasing investment and operating costs to achieve thermal comfort [5].

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STATECZNOŚĆ TERMICZNA W LOFTACH W OKRESIE LETNIM

Badania dotyczące stateczności cieplnej i warunków komfortu cieplnego ludzi przeprowadzono w loftach. Opracowanie ma na celu zweryfikowanie wartości wybranych parametrów wyznaczonych na podstawie stosowanych procedur obliczeniowych i porównanie ic z wartościami zmierzonymi w warunkach rzeczywistych. Oceniono efektywność różnych grubości izolacji dla wybranych pomieszczeń oraz najwyższy dopuszczalny dzienny wzrost temperatury powietrza we wnętrzach w okresie letnim. Lofty uznaje się za odpowiednie do kształtowania przestrzeni mieszkalnych, ponieważ pomimo problemów m.in. z niestandardową przestrzenią do zaaranżowania czy przeciekami dachów, nachylone konstrukcje dachowe wpływają istotnie

na architekturę budynku i nadają jej niepowtarzalny charakter.

Słowa kluczowe: **lofty, okres letni, stateczność cieplna, warunki komfortu cieplnego, wartości teoretyczne i pomierzone**