BUDOWNICTWO
CZASOPISMO TECHNICZNE
TECHNICAL TRANSACTIONS
CIVIL ENGINEERING
WYDAWNICTWO
POLITECHNIKI KRAKOWSKIEJ
2-B/2012
ZESZYT 3
ROK 109
ISSUE 3
YEAR 109

VLADIMÍR GELETKA, ANNA SEDLÁKOVÁ*

SHAPE OF BUILDINGS AND ENERGY CONSUMPTION

KSZTAŁT BUDYNKÓW A ZUŻYCIE ENERGII

Abstract

This paper provides analysis of buildings shape (ground plan and vertical division) and their impact of shape factor – FT of buildings. For some shape is provide a parametric analysis obtained from a comprehensive whole building energy simulation. Parametric analysis regards orientation of buildings and ratio %glazing to the wall.

Keywords: energy consumption, energy efficient building, directive EEB

Streszczenie

W niniejszym artykule przedstawiono analizę kształtu budynków (rzut poziomy i podział pionowy) oraz ich wpływ na czynnik kształtu FT. Dla niektórych kształtów przygotowano analizę parametryczną opartą na pełnej symulacji energetycznej. Analiza parametryczna dotyczy orientacji budynków oraz procentowej proporcji przeszklenia do ściany.

Słowa kluczowe: zużycie energii, budynek energooszczędny, zarządzenie w sprawie budynków energooszczędnych

---

* Eng. Vladimír Geletka, PhD. Doc. Eng. Anna Sedláková, Institute of Building and Environmental engineering, faculty of civil engineering, Technical university of Košice.

1. Introduction

Generally, the quality of the buildings we can affect in the initial phase of architecture design. Therefore it is important to optimize the input parameters, which affect on observed function the most.

Some guidance for architects are available to predict annual energy performance. These case studies have shown, that the building shape can have a significant impact on the energy of heating and cooling. For example Mahdavi [1] use relative compactness of buildings related to some shape on energy performance of buildings. Ourghi et al. [2] have developed a simplified analysis tool to predict the effect of shape selection on the annual energy use to the relative compactness of the building. Similarly Adnan al Anzi [3] set some regression equation related to shape of buildings, window to wall ratio, solar heat gain coefficient, to the energy performance.

1.1. Shape of buildings, indicator assessment

The shape factor *FT* of a building is represented by its surface-area-to-volume ratio and is a measure of a building´s compactness. Buildings with a higher *FT* are less compact and therefore have a larger surface area for a given volume. The surface area of the building is the boundary that separates heated spaces and unheated spaces, and accounts for a large percentage of heat losses in buildings.

Standard heating requirements in Slovakia, depending on the shape factor *FT* use STN 73 0540[4] as the energy criterion. Residential buildings are distinguished mainly by the shape, size and number of floors, these differences can be expressed by the shape factor FT of the building. Heating is considered continuous with a standardized degree days 3422K.day. Rising heat transfer coefficient values affect the heat reduction capacity. Buildings meet requirements if the shape factor fulfils the condition $E \leq E_N$ (need for heating must be equal or less than heating loads determined by regulations) Fig.2. This standard specifies the maximum heat transfer coefficient *U* for a building envelope construction. Thermo-technical qualities of building envelope structures are defined by the mean heat transfer coefficient U_{em}.

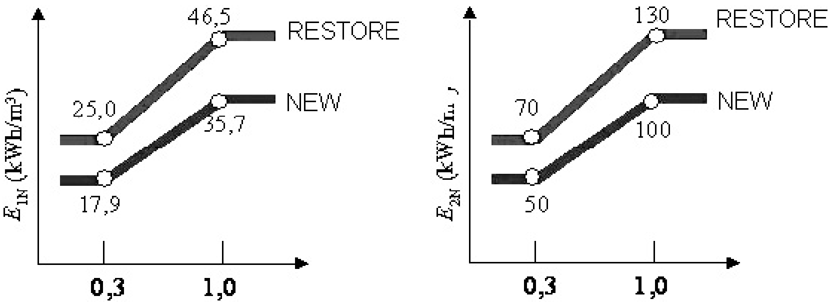


Fig. 1. Normalized heating load according to standard STN 73 0540,
left: use per unit cubic meter, right: use per unit of floor area [4]

Rys. 1. Znormalizowane obciążenie grzewcze wg normy STN 73 0540,
z lewej: zużycie na m^3, z prawej: zużycie na jednostkę powierzchni podłogowej [4]

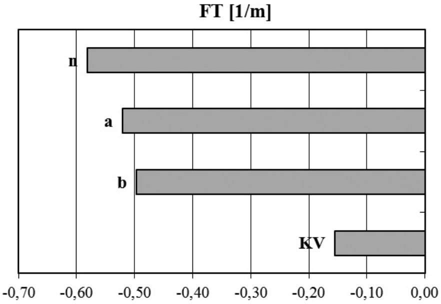


Fig. 2. Correlation coefficient sensitivity of building dimensions on shape factor FT

Rys. 2. Korelacyjny współczynnik wrażliwości wymiarów budynku na czynnik kształtu FT

In foreign literature can we found a evaluation factor so called the relative compactness of buildings [1]. In order to compare the surface to volume ratio of different shapes, the volume must be equal. Therefore the ratio of changes to compare different building shape were derived from the reference cube.

$$RC = \frac{(V/A)_{building}}{(V/A)_{ref}}[-] \tag{1}$$

where:

$V / A_{building}$ – parameters of considered shape [m^3/m^2],
V / A_{ref} – parameters of reference shape, sphere or cube [m^3/m^2]

1.2. Effect of geometry building size on the heat transfer surface area

Generally from the function of heat transfer through the building envelope result´s that the smaller surface to the volume of buildings, it is appropriate less need for heating. As describes Markus and Morris [5], in terms of geometric solution we can solves two problems: geometric problems, that is to say relationship heat transfer surface and the size of them bounded space, or quantification of the geometric effects on building heat losses.

By considering dimensions of square building parameters within the ranges as shown in Tab.1. and their combination. In Fig. 2. is presented correlation coefficient sensitivity of of dimensions of square building on shape factor FT.

Table 1

Dimensions of square buildings – range of values

PARAMETER			MED.	MIN.	MAX.
INDEX	NAME	UNIT			
a	Width	[m]	20	6	32
b	Depth	[m]	20	6	32
n	Number of stories	[m]	4	1	8
KV	Constructional height	[m]	3.5	2.8	4.2

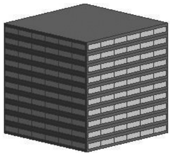
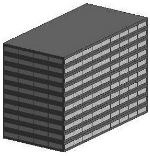
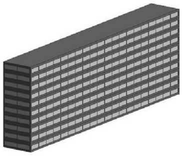
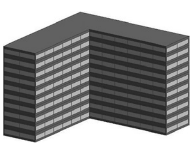
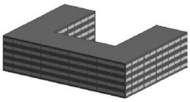
As seen in the Fig. 2, number of stories have the most impact on shape factor of building. These correlation coefficient was determined by combination of buildings dimensions as shown Tab. 1. Shape factor FT doesn´t shows heat loss, but is parameter, from which thermal losses depends. When considering quantitative thermal variables of transparent and non-transparent buildings envelope constructions and resulting average heat transfer coefficient (primary variable describing the quality of the building envelope in terms of heat loss) must buildings satisfy conditions of the annual energy consumption of buildings.

2. Impact of some buildings shape on energy consumption

For comparison need for heating load was selected several types of frequently occurring forms of administrative buildings, which were simulated in a dynamic simulation program EnergyPlus [6] (response function method). All shapes are compared the same volume ($V = 42875$ m^3) and the same total heating floor area ($S_{pdl} = 12250$ m^2), an essential element in creating the planned shapes of buildings is cube with dimensions 3,5x3,5x3,5m. Research the effect of orientation of buildings to the cardinal points, % of glazing on exterior walls and ratio of rectangular ground plan affect on the need for heat. In Tab. 2 are shows in figures analyzed shapes. They were compared to the three basic shapes of buildings, as well as a rectangle with varying aspect ratio ground plan(from 1:1 to 1:8).

Table 2

The shapes of buildings, that were comparison of energy consumption

1	1:2	1:8	2	3
				

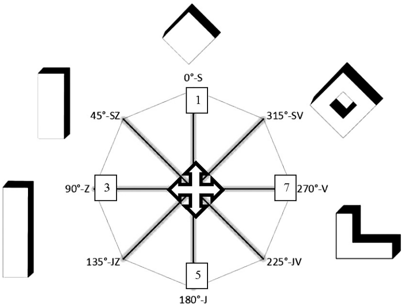


Fig. 3. Orientation of buildings to the cardinal point in terms of minimizing heating load

Rys. 3. Orientacja budynków względem stron świata w kategoriach minimalizacji obciążenia grzewczego

The different shapes were simulated at day intervals parametrically for different orientations Fig. 3 and for different ratio of glazing to extern al wall – from 0% to 100%. In Fig. 3 is presented orientation of mentioned buildings to the cardinal point in terms of minimizing heating load (best orientation of buildings). Was considered a massive structure – better accumulation. All of envelope constructions meets the requirements of a standard [4]. In Tab. 3 are thermal properties of constructions considered in the calculations.

Table 3

Building envelope thermal properties

Buiding Component	Construction details (quantity of insulation)	*U* [W/m^2.K]
Ground floor	100mm XPS polystyrene	0.292
Floor	150mm concrete - heawyheight	
Wall	450mm brick, 60mm mineral fibre	0.300
Roof	200mm concrete and 200mm polystyrene	0.141
window	Double (with 16mm argon, total solar transmission 0,43)	1.345

2.1. Results of parametric simulation

In Fig. 4 is for the intended shapes graphically illustrates the dependence of heat on the orientation and % of glazing to external walls.

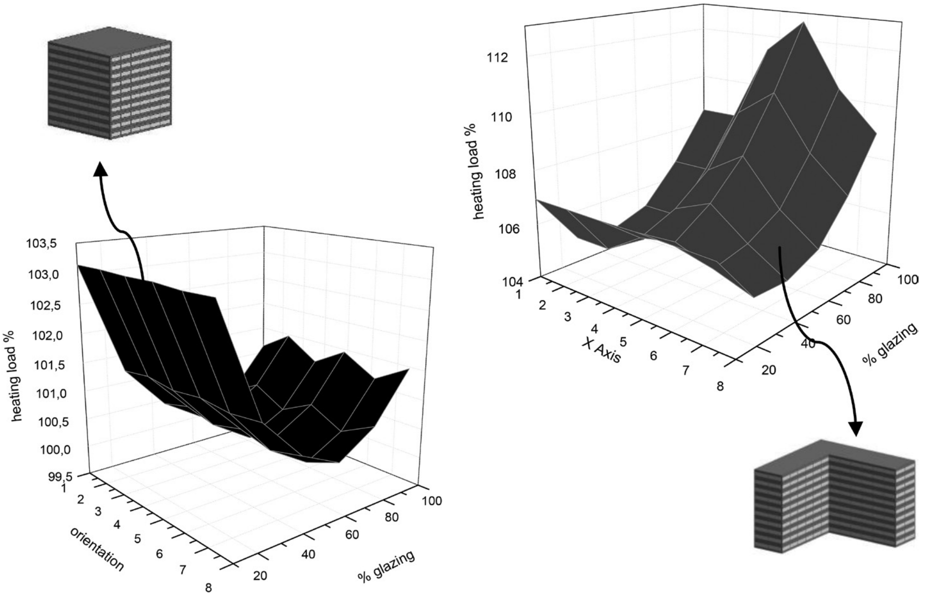


Fig. 4. Heating load due to orientation and % of glazing to the external walls for shape 1and 2

Rys. 4. Obciążenie grzewcze spowodowane orientacją i % przeszklenia ścian zewnętrznych dla kształtów 1 i 2

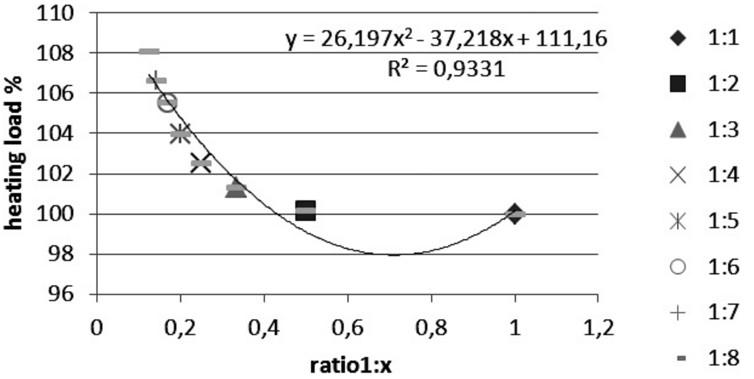


Fig. 5. Regression dependency of the ratio of ground plan and heating load % (100% = cube – 1:1)

Rys. 5. Regresyjna zależność od proporcji rzutu poziomego do % obciążenia grzewczego (100% = sześcian – 1:1)

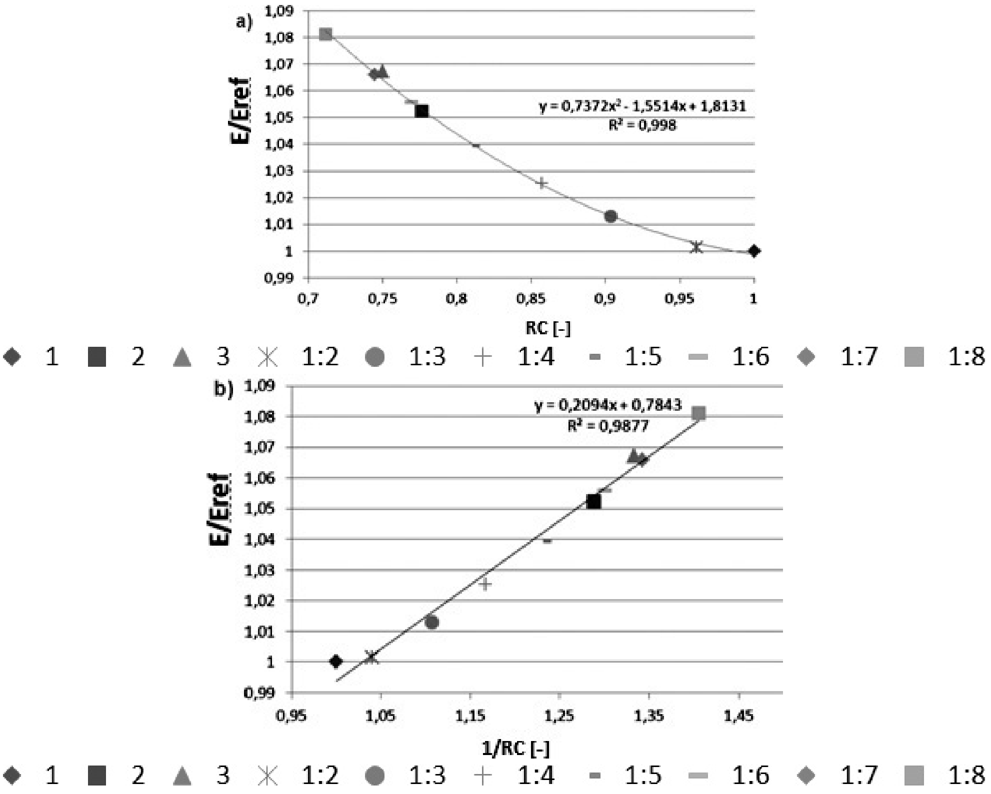


Fig. 6. Dependency of ratio energy consumption of buildings E to the energy consumption of reference building Eref to the a) relative compactness RC b) ratio 1/RC.

Rys. 6. Zależność proporcji zużycia energii w budynkach E do zużycia energii w budynku Eref a) zwartość względna RC b) stosunek 1/RC

In Fig.5 are for the shapes with an aspect ground plan ratio from 1:1 to 1:8 depending on the impact of regression indicated ratio and heating load.

Energy use for heating for any shape of building E, is normalized relative to the annual energy use Eref obtained for the reference building (with a square floor plan) to facilitate the comparative analysis. Fig. 4 illustrates the impact of the relative compactness on annual heating energy use for a buildings with 60% window to wall ratio. The results of Fig. 6 indicate that the energy use decreases as the relative compactness increases. Indeed, as the relative compactness increases, the exterior wall area exposed to ambient conditions decreases.

3. Conclusions

Architectural design has considerable influence on the need for heating, therefore it is necessary to optimize the energy concept solution already in the initial phase of building design. From parametric simulation results, that exist dependency between architectural shape solution of building and energetic consumption related to the reference building. The effect of buildings shape on total building energy use depends on primarily window to wall ratio and orientation to the cardinal point. Relative compactness of buildings can be a good tool to assess the impact of shape on the energy efficiency of building. This may be a good tool to determine the dependencies and optimize architectural design of the buildings in the early design stage.

This publication is the result of the Project implementation: Research centre for efficient integration of the renewable energy sources, ITMS: 26220220064 supported by the Research & Development Operational Programme funded by the ERDF.

References

[1] Pessenlehner W., Mahdavi A., *Building morphology, transparence and energy performance*, Eight international IBSPA conference, Eindhoven, Netherlands, 2003, August 11-14.

[2] Ourghi R., Al-Anzi A., Krarti M., *A Simplified Analysis Method To Predict The Impact Of Shape On Annual Energy Use For Office Buildings*, Energy Convers Manage J, 2007, 48:300–5.

[3] Alanzi A., Seo D., Krarti M., *Impact of building shape on thermal performance of office buildings in Kuwait*, Energy Conversion and Management J, 2009, 50, 822-828.

[4] STN 73 0540, 1-4 Thermal properties of constructions and buildings, 2002.

[5] Markus T.A., Morris E.N., *Zdanija, klimat i energija*, Gidrometeoizdat, Leningrad 1985.

[6] EnergyPlus Version V6.0, Documentation, October 2010.