ENERGY CONSUMPTION CONDITIONED BY SHAPES OF BUILDINGS

In accordance with long-term strategic objectives of reducing emissions and improving energy efficiency, adoption of the European Parliament on May 18, 2010 and the adoption of 2010/31/EU raised the commitment by 2020 to reduce total greenhouse gas emissions by at least 20%. The Directive requires Member states to design all new buildings with nearly zero until December 31, 2020. Aims of Directive can be applied in conjunction with excellent thermal parameters of buildings envelope design energy-efficient buildings and shape solutions. For optimal design EEB has a major impact outside geometry, i.e., compact of shape and surface topography. After construction of the EEB is a possible number of parameters to modify, but the shape that has been proposed in the early stage of architectural design usually remains unchanged throughout the life of building.

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

INTRODUCTION

No general guidelines are available for architects and designers on the impact of the form on the energy efficiency of buildings. Some studies have shown that the building shape can have a significant impact on the energy consumption [1-3]. In this paper are compared some buildings shape. Using the results of comprehensive parametric analysis, a correlation is developed to predict the impact of building shape to energy efficiency.

1. MORPHOLOGY OF BUILDINGS

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.

According the study [4] we can create matrix of the most possible buildings shape of office buildings. From this study we get eighteen groups of possible
ground plan of buildings and eighteen groups of vertical structure of the building (Tab. 1).

Table 1. Morphology of buildings - ground plan and vertical division

<table>
<thead>
<tr>
<th>Plans</th>
<th>Simple</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevations</td>
<td>Simple</td>
<td>Complex</td>
</tr>
</tbody>
</table>

Created four groups of ground plan and vertical division of buildings can be a good tool to optimize the shape of buildings in terms of minimizing heat loss through the envelope. From this study we can create some possible shapes combination plans and elevations (Figs. 1, 2).

Fig. 1. Created shapes of buildings - simple ground plan
From this compared shapes of simple and complex ground plan in terms of shape factor and their variations compared to the ideal cube with the same volume are shown in Figure 3.

The difference between minimum and maximum shape factor $FT$ are shown in Figure 4.

![Fig. 2. Created shapes of buildings - complex ground plan](image)

**Fig. 2. Created shapes of buildings - complex ground plan**

![Fig. 3. Shape factor: simple ground plan (left), complex ground plan (right)](image)

**Fig. 3. Shape factor: simple ground plan (left), complex ground plan (right)**

![D6 $FT = 0.261$](image)  ![Difference 88%](image)  ![N12 $FT = 0.493$](image)

**Fig. 4. Min. and max. shape factor from analyzed shapes**
2. CASE STUDY

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 Design Builder, whose computational kernel is made up of program Energy Plus [5]. All shapes are compared the same volume \( V = 42,875 \text{ m}^3 \) and the same total heating floor area \( S_{\text{pdl}} = 12,250 \text{ m}^2 \), an essential element in creating the planned shapes of buildings is cube with dimensions 3.5x3.5x3.5 m. 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 Table 2 analyzed shapes are show in figures. They were compared to the four basic shapes of buildings, as well as a rectangle with varying aspect ratio (effect of ratio on the shape factor can be seen on the chart - Figure 5).

Table 2. Analysis shapes of buildings that were comparison of energy consumption

<table>
<thead>
<tr>
<th>1</th>
<th>1:2</th>
<th>1:8</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Shape 1" /></td>
<td><img src="image2.png" alt="Shape 1:2" /></td>
<td><img src="image3.png" alt="Shape 1:8" /></td>
</tr>
<tr>
<td><img src="image4.png" alt="Shape 4" /></td>
<td><img src="image5.png" alt="Shape 3" /></td>
<td><img src="image6.png" alt="Shape 2" /></td>
</tr>
</tbody>
</table>

\[
y = 0.1753x^2 - 0.2662x + 0.262 \\
R^2 = 0.9473
\]

Fig. 5. Effect of the ratio ground plan on shape factor
2.1. Boundary conditions

The different shapes were simulated at day intervals parametrically for different orientations (Fig. 6) and for different ratio of glazing to external wall - from 0% to 100%.

In envelope design was considered a massive structure - better accumulation. All of envelope constructions meets the requirements of a standard STN 73 0540 [6]. In Table 3 thermal properties of building of envelope constructions are considered in the calculations.

Table 3. Building’s envelope thermal properties

<table>
<thead>
<tr>
<th>Building component</th>
<th>Construction details (quantity of insulation)</th>
<th>U W/m² · K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground floor</td>
<td>100 mm XPS polystyrene</td>
<td>0.292</td>
</tr>
<tr>
<td>Floor</td>
<td>150 mm concrete - heavyheight</td>
<td></td>
</tr>
<tr>
<td>Wall</td>
<td>450 mm brick, 60 mm mineral fibre</td>
<td>0.300</td>
</tr>
<tr>
<td>Roof</td>
<td>200 mm concrete and 200 mm polystyrene</td>
<td>0.141</td>
</tr>
<tr>
<td>Window</td>
<td>Double (with 16 mm argon, total solar transmission 0.43)</td>
<td>1.345</td>
</tr>
</tbody>
</table>

Fig. 6. Initial orientation of buildings to the cardinal point

2.2. Results of parametric simulation

In Figures 7 and 8 are for the intended shapes graphically illustrate the dependence of heat on the orientation and % of glazing to external walls. The graphs in Figures 7, 8 show that the thermal property of transparent and nontransparent building envelope constructions is most favorable to minimize heat loss of 60% glazing (the ratio of heat gain and loss is the most optimal).
2.3. Dependency of shapes of buildings on need for heating

In Figure 9 are for the shapes with an aspect ratio of 1:1 to 1:8 depending on the impact of regression indicated ratio and heating load. In Figure 10 is for these shapes expressed a linear relationship of heat and proportionately 1/FT and $E/E_{ref}$ ($E_{ref}$ = cube of equal volume and specific surface).
CONCLUSION

During preliminary design phase we cannot forget on impact of buildings shape on heating load. We try to minimize heat loss due to shape solutions of the building - expressed by the shape factor FT. Figure 1 and 2 show that the most favorable shape factors have shaped buildings are approaching the rotary cylinders. The other images shows that the shapes of compact (less jagged, approaching the cube) is a small effect on the orientation of the heating load. In rectangular shape the impact is significant - the difference by aspect ratio 1:8 is 10%. The overall difference in the analyzed shapes (the same volume and the same area of buildings) is 20%.

In the initial phase of building design should not forget on the architectural aspects that have considerable impact on energy consumption.
Acknowledgements

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REFERENCES