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## ECCENTRIC SHAPES OF BUILDINGS AS OPTIMAL SOLUTION FOR BIOCLIMATIC ARCHITECTURE

### Summary

The essential idea of bioclimatic architecture is usage of sun energy for the heating purposes. Reduction of heat losses requires compactness of building forms and smaller outside contact area of coverings. Relation between covering area of a building and building volume should be as less as possible, and for such purpose the best solution is to apply symmetrical forms of buildings. Heat benefits gained from the sun lights which are dominant on the southern sides of buildings requires that the south oriented façades have larger area then the north oriented façades. Bearing this on mind, symmetrical forms of foundations must be corrected in order to provide construction of buildings with less energy demands for heating processes. In that context we have proposed solution for optimized eccentric form of foundation that is oriented in a way that responds to the purposes of climate in the area of Belgrade. As the support to this solution I have stated several other examples that were taken from our best practice.

### INTRODUCTION

*Passive solar architecture* takes care of energy savings meant for heating first of all during designing phase, by applying high quality thermal insulating materials, with allocation and dimension of windows, shape and orientation of the building, as well as by applying the specific techniques. *Bioclimatic architecture*, which is basically very similar to the passive solar architecture, represents broader aspect since it takes care of the environment (vegetation), wind chill effect and ground configuration, and off course impacts of the sun. This is a reason why I have decided to use term bioclimatic architecture in my text below. The bioclimatic architecture is using advantages of the local climate and environment in order to achieve favorable indoor conditions. There is a long tradition of using bioclimatic architecture in many parts of the world.

For each climate zone there is an optimal solution that point out how the building should look like in order to reduce heat consumption. Building like this are eligible as low energy buildings with low level of fuel consumption, but also as human friendly buildings suitable for living. The environmental aspect is also very important due to the reduction of pollution and for the protection of ozone layer in the atmosphere. Esthetics aspect is important for the bioclimatic architecture since it pays much attention to fit within surroundings.

## IMPACT OF THE BUILDING SHAPE ON THE CONSUMPTION OF ENERGY REQUIRED FOR HEATING; HEAT BALANCE WITH IMPACTS FROM THE SUN LIGHTS

The biggest impact on energy consumption has the outdoor temperature. But on the other hand it is important to have details regarding the coverings that are included in the process of heat transmission with surroundings. Beside thermal and physical characteristics of the covering (refers to the thermal insulation as well to the dimension and allocation of windows), also important is the size of area for the energy transfer. Regarding this the appropriate shapes would be those where relation between area of outside building covering and building volume are minimal or in other terms where outside area of building is as small as possible. This statement might be presented in the following way using the following equation (1) withdrawn from the literature [6] that refers to the unsettled operational regime of generation plant and presents solution of the differential equation:

$$E_{GR} = \alpha \cdot A \cdot (T_1 - T_{SP}) + \frac{\Delta T \cdot \alpha \cdot A}{1 - \exp\left(-\frac{\alpha}{\rho_z \cdot C_z} \cdot \frac{A}{V} \cdot t\right)} \quad (1)$$

In this equation  $\alpha$  present's coefficient of heat transmission,  $A$  presents the outdoor area of building, and  $\Delta T$  differences between outdoor temperatures at the beginning and at the end of monitored period. It is obvious that  $A/V$  relation is also important that refers to the heating of the building.

The previous equation does not take into consideration the benefits from the sun lights. In case that we want to avoid consideration of sun lights then we should numerically solve (with accurate values of methodological parameters monitored constantly) differential equation of thermal balance for building (see list of literature [10]):

$$mc \frac{dT_U}{dt} = \tau \cdot \alpha_1 \cdot G \cdot A_1 + P_{GR} - \frac{(T_U - T_{SP})}{R} \quad (2)$$

In this example values  $\tau$  and  $\alpha_1$  are presenting coefficients of thermal and physical characteristics of windows,  $A_1$  the area of windows with sun light,  $G$  presenting capacity of sun lights in [W/m<sup>2</sup>],  $P_{GR}$  capacity of active heating system, and  $R$  is presenting thermal resistance for whole building. Differential equation (2) might be solved numerically only if we assume that the capacity of sun lights, values of outdoor temperatures, capacity of active heating system as well as the remain thermal and physical characteristics of the building are constant during period of one hour.

With very simple procedure – reduction of the outside covering area on a building it will be possible to save energy in the amount of even 20-30% (related to buildings that are not in case of extreme situations considering  $A/V$  rate). The architects and other engineers responsible for heating are obliged to take care of these problems while developing conceptual designs. The compactness of a building form is essential for the building energy status and reduction of heat consumption, even those is not a priority. Sphere is the most

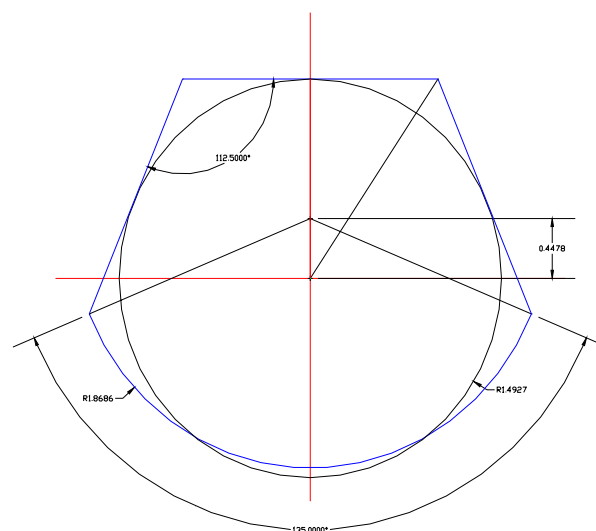
compact geometrical shape; and from all cylinder shapes the most compact is cylinder. There are also well known other geometrical shapes with similar characteristics.

### **ECCENTRIC SHAPES AND BENEFITS FROM THE SUN LIGHTS**

As we might have seen regarding the compactness of buildings, the most appropriate solution would be symmetrical form such as ball or cylinder. However, benefits from the sun light in this area are dominant on the south side. That is the reason why is necessary to orient larger areas to the south and smaller to the north. This means that the optimal building must have eccentric or asymmetrical form. Beside the sun light that varies during a year in accordance with the direction and intensity, the strong impact to the asymmetrical form of a building also have other aspects such as wind rose and slope e.g. configuration of the ground.

Standards for calculation of heat losses are containing some additions meant for orientation in accordance with the cardinal point. Their application would provide calculation of the amount of energy required for heating in situations when the area of south oriented side is large then the north side. More complex part of work is to optimize shape of a building that would result as building with minimum energy losses.

The optimized eccentric base is presented on a picture (1). This shape is compose in such way so the north side has the maximum reduction while at the same time east and west façades have been totally sloped to the north but in a way to keep east or west orientation. The south side has been moderated to the shape of circular arc in order to enlarge the area oriented to the south, south- east and south-west. In order to increase the compactness of shape the circular arc has centre dislocated from the original basic circle. We might call this kind of form convex trapezium that is considering horizontal eccentric foundation.



Picture 1 – Optimized shape of convex trapezium

Beside the horizontal eccentric form, also eligible is to have vertical asymmetry. That is important due to the fact that the buildings are used in summer as well when the situation with sun lightening is completely different. South façade has to provide max usage of the

sun light during winter period, while during summer it has to provide shade and to protect building from over heating. The main part in that process will be different height of a sun in zenith during summer and winter period.

## **ORIENTATION AS SECONDARY IMPACT AND PROPOSAL OF OPTIMIZED SOLUTION FOR BELGRADE**

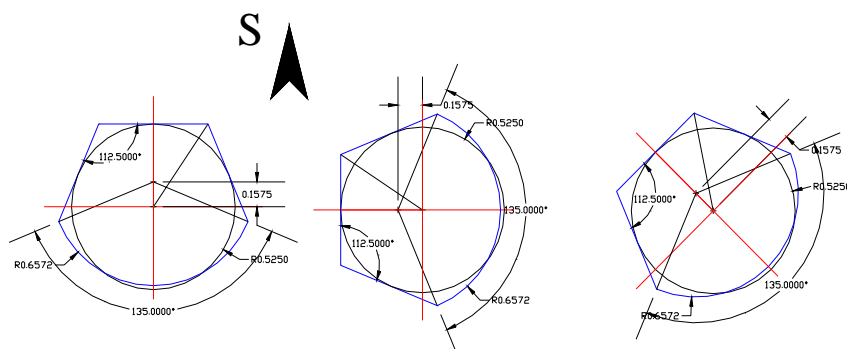
The dominant influence on the energy consumption in buildings has the outdoor temperature. Less important are the impacts from wind velocity, compactness of a building, type of insulating material and thermal inertia of the building. The orientation of the building has influence on the consumption, but as we might see this is the secondary impact. The orientation has the leading role only in situation when we review the dimension and allocation of windows as well as the wind chill factor.

Geometrical forms	$A/V$ for $V=1$	%	Percentages with added values for globe orientation
Sphere	4,84	80,6	80,6
Cylinder	5,54	92,26	92,26
Convex trapezium – south oriented	5,68	94,68	93,94
Convex trapezium – east oriented	5,68	94,68	94,68
Semi-sphere	5,76	95,96	95,96
Cube	6	100	100

Table 1 – Comparison of compactness of different geometrical forms

Including to the calculation all data related to the orientation of buildings in accordance with the cardinal points, we are receiving results showing that the impact is up to 1% top for the energy consumption required for the heating of a building in whole (see table 1). This is significantly less than the impact from the compact form.

Beside the requirements for heating during winter in climate like ours is preferable to have cooling during summer. Completely different from the situation in winter when is necessary to use sun light for additional heating, in summer period benefits from the sun light are considered as redundancies. In summer the most inappropriate orientation for buildings is to the west since the insulation has the strongest affects in the afternoon as well as the outdoor temperatures and sun lights. In such case it would be more appropriate for our eccentric form to be oriented to the east. Concerning the fact that we are using these building all year round it would be good if we could adopt as compromise solution in which buildings are oriented south – east.



Picture 2 – Optimal orientation of buildings: winter – summer – compromise

In case of a Belgrade, this south east orientation is overlapping with the influence of interim south east wind, košava. This is a possibility to use aerodynamic shape of a foundation that will reduce in much incomings of cold air into premises, wind blows and ventilation losses. This position has lead to the optimized form of a building foundation with favorable orientation for Belgrade purposes, primarily due to the wind chill factor. Also, the south east orientation of a building would provide/allow timely heating of a building after cold nights, with possibility to use sun light in the morning when outdoor temperatures are having the lowest values.

## HISTORY AND SOLUTION IN PRACTICE

Not far away from the Belgrade in gorge of Đerdap, are located remains of the 7000 years old pre historical settlement known as Lepenski Vir. The architecture of Lepenski Vir is particularly interesting since the selection of location for the settlement was carefully planned. The sunny valley of Dunav allowed prehistorically residents to survive in severe climate. The architecture is also interesting because shape of the foundation of the settlement strongly reminds of the convex trapezium. We do not know for sure how the third dimensioned sides of those houses have looked like, since the only evidence that we have are the remains of the foundations. For now on is still unclear why the houses were constructed this way, but there are some indications that this architecture is closely connected to the environment and dogma in which observation of the sun and other aspects of nature. For the sake of our purposes is interesting to review this shape that reminds a lot of an optimized form of foundation that is created for Belgrade purposes. If we know that pre historical people from the Stone Age did manage to organize their settlement in such form, there are no obstacles for us today for the sake of energy savings, applying new technologies and material not to try to construct similar buildings.

The basic principles of bioclimatic architecture were well known to the Anasasee Indian tribe from south Colorado, USA. They have established their settlement on the side of Grand Canyon located opposite to the sun.

There are also some contemporary buildings that are reminding us to the shape of optimized form for Belgrade. First of all this refers to the solar house created by Douglas

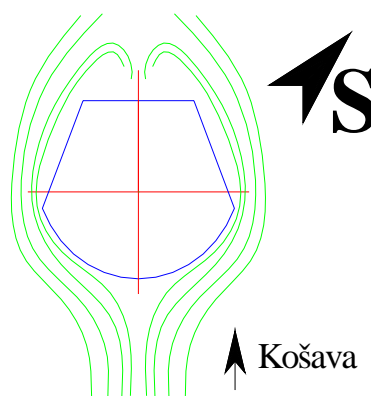
Balcome, that was constructed during seventies in Santa Fe (New Mexico). This building combines active and passive construction measures. This is particularly obvious on a building from Freiberg (Germany), constructed in 1992, that also contains photo voltage cells.

The compactness of shape is best presented on a solution creating the geodesic dome. Houses like this are selling in USA as industrial products, assembly houses and statistically are showing good results as very well constructed buildings, very resistant. Anyway I have to point out that buildings like this one are mainly presented as semi-spherical, not spherical shapes that are the most compact geometrical shapes.

## CONCLUSION

Heat consumption required for heating of buildings might be reduced in case that we take care of the compact shape of a building. In practice the impacts on the consumption of energy are also created by the outdoor temperatures, wind rose, sun lights and configuration of the ground. Due to these impacts the optimal shapes which are symmetrical must stay eccentric. The form of convex trapezium has shown the best results. This form considers benefits from the sun light during winter season. Beside that this form has also aerodynamic shape that enhances reduction of the heat losses during ventilation.

Bearing in mind stated factors my intention was to present optimized form of basic building oriented in a way to fulfill requirement of Belgrade climate. This is a form of a building suitable for minimal consumption of energy required for heating and cooling. Due to the dominant impact of local south-east wind known as – košava, the proposal is to orient building in direction to south-east, which will lead to the large extent of reduction of ventilation losses. This sort of building orientation will provide timely heating of buildings after very cold nights since buildings are using sun heat early in the morning when the outdoor temperatures are reaching minimal values. As well the south –east side orientation presents compromise between using a building during winter and summer season.



Picture 3 – Proposal of optimized solution with orientation for Belgrade

In order to support and to encourage application of such solution in practice, I made a list of similar solutions that are already in practice. There is a large similarity between optimized foundation form for Belgrade and foundations of prehistorically buildings that were found at the location of Lepenski Vir, as well as to some contemporary solar houses. This form of foundation should be taken into consideration if we want to design buildings with low energy consumption.

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**KEY WORDS**

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Sun lights  
Geometrical form  
Eccentricity  
Compactness of a building  
Energy consumption