On Geometric Form Genesis Directed by Buildings' Efficency- Canton Tower Case Study

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ABSTRACT

Lately, energy efficency in architecture and urbanism has played a crucial role. Wind and facade exposure to sun, being important elements of energy efficency particularly in the sense of energy renewability, might produce significant obstacles if not properly estimated in the process of designing and up building. Thus the creation of optimal geometric form is very important for further proper functioning of the building. The final geometric form when created applying various geometric transformations or deformations from starting basic forms (such as prisms, cylinders, cones, etc .) might be easily investigated in the sense of sunlit and its constructive stability under wind influence using any various software, for example VASARI for the sake of effecient energy consumption.

In the paper we discuss the process of deriving the geometric form of the Canton Tower, Guangzhou, China, with respect to insolation and wind gust following the change of iso-photes and wind iso-gust lines in accordance with the geometric form derivation.

Key words: building's geometric structure, energy efficiency, insolation, wind effects

1. ENERGY PERFORMANCE OF BUILDING

Energy performance of buildings is frequently estimated and analyzed for a variety of purposes. Interests in the energy performance range from global to regional, individual buildings, and finally individual systems. Users of energy performance data include policy makers, owners, designers, operators, building raters, and researchers. Many tools (or approaches) have been developed to analyze building energy performance in different ways, at different levels of precision, and at different stages in the life of a building. With each of these tools, the building energy performance is quantified in a manner that fits the needs of the users. However, the methods and metrics from these tools are often inconsistent with each other. In addition, performance numbers are sometimes misrepresented or misused to predict energy savings beyond the accuracy of the numbers. (1)

Energy efficient building (EEB) is one having high level of useful energy which means that in process of energy transformation the loss of energy is minimized. In order for building to be categorized as EEB, it has to use low level of energy on one hand and to fit the everyday needs (such as heating, hot water systems, cooling systems, ventilation and lighting) for the users' comfort on the other. The most common sources of reusable energy are wind and sun, whose exploitation is determined by the climate region and weather conditions.

In order to make one building as efficient as possible there are wide range of engineering methods. Some of these are wind turbines and solar collectors. The use of mathematical and physics calculations while establishing which materials will be used is the process showing most accurate parameters such as percentage of façade sun exposure or influence of the wind on the building.

Design of the EEB demands introduction of norms and suggestions for the building performance analysis. In addition to this, development of new IT tools is needed as best solution for early phase of planning and optimization of future building. (2) Modeling of the building geometry which best exploits energy of the sun and wind would reduce mistakes and enhance the final produce. This way influences and performances are already tested via software which allows integration of 3D model and influences that the building is exposed to. (3) Building geometry is an important input to the analysis process; however, there are no agreed-upon standard definitions of these terms, specifically for the use in energy analysis. Without standard definitions and metrics of building geometry, the analysis results may be questionable and difficult for meaningful comparisons. These building geometry definitions and metrics are intended to be used for characterizing building geometry in measured energy analyses and for defining detailed energy simulation inputs. This study aims to help other users have a better understanding of building geometry definitions. (1)

1.1. Software for the simulation of the daylight and wind energy- Vasari

In this paper we present simulations of the daylight and wind energy. For simulations Autodesk Vasari (http://www.vasarienergy.com/index.htm) was used because this software allows the engineer to design the most optimal geometry according to the next parameters: degree of the façade sun exposure, percentage of the façade part influenced by sun and the side that is in the shadow. Using the Vasari, in the following text will be shown visualization of impact these two factors have on a variously geometry of the building.

In order to calculate impact of the wind energy software allows the user to predefine climate conditions, geographical location, date and time for the duration of the simulation. In this way it is possible to vary the geometry if he building using the same preset of the influential parameters. After further analysis of the data engineer is able to determine the best form of the building for the conditions given.

Results are to be interpreted and analyzed in the way needed and here they represented as gradation of colors depending on the influence that is being illustrated.

2. PRIMARY GEOMETRIC FORM AND OBJECTIVE OF THE STUDY

The main objective of this study is to investigate the influence of solar insolation and wind power on surfaces of high-rise building. The analysis is based upon genesis of the form of Canton tower, whose geometry is general hyperboloids. (Figs.1. and 2.)

Fig. 1: Canton tower, Guanghzdou, Kina

Fig.2: Aerial view of Canton tower

Primary geometric form from which the general hyperboloid is derived is cylinder. (Fig. 3.) If we consider sun rays to be parallel then they form illumination dividing line whose ends are linked with the ends of the base diameter. If the base circle is substituted with ellipse the new form is elliptic cylinder (Fig. 4.) whose characteristics are same as in the cylinder in Fig. 3. The change of the sun position will induce the change of the illumination dividing line, but its link to the end points of the diameter of base will remain. If the dimension of the axis of the upper ellipse is reduced the new form, truncated cone, is created. (Fig. 5.) Percentage of the sun expose of the façade for this form stays the same according to change in the sun position.

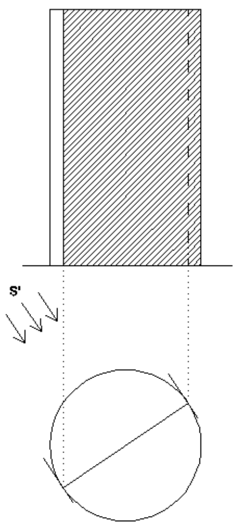


Fig. 3: Cylindar

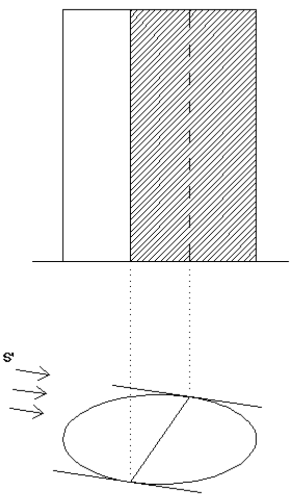


Fig. 4: Elliptic cylindar

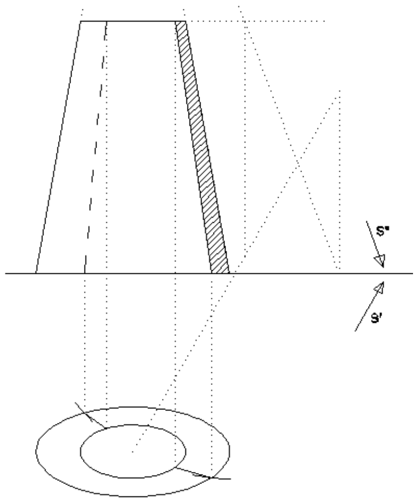


Fig. 5: Truncated cone

2.1. Analysis of he transformation of primary geometrical forms - twisting

In order to design the form of the Canton tower, it is needed to transform primary geometrical forms such as: cylinder, elliptic cylinder and truncated cone. To define the twist deformation, we select a fixed bottom plane B and a straight line A (called twist axis) perpendicular to plane B. (Figs. 6,7,8) (4) Rotation of the upper bases of this forms by the angle α in xy plane, which is parallel to plane B, (point a transits to position a1), induces the formation of rotational hyperboloid (Fig. 6.) and general hyperboloid (Figs. 7. and 8.).

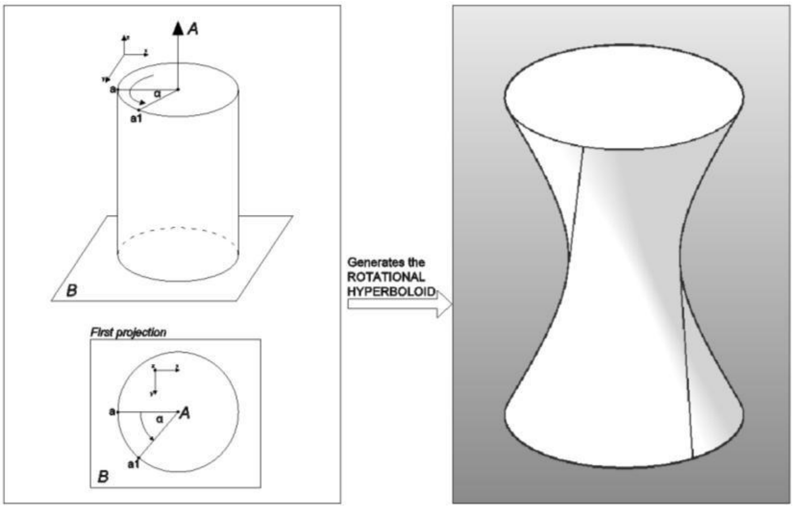


Fig. 6: Rotational hyperboloid- Twisting cylinder

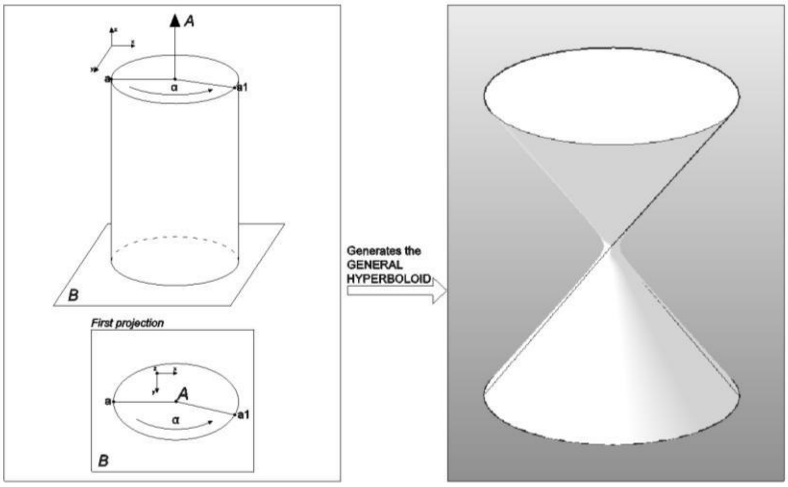


Fig. 7: General hyperboloid (Type I)- Twisting elliptic cylinder

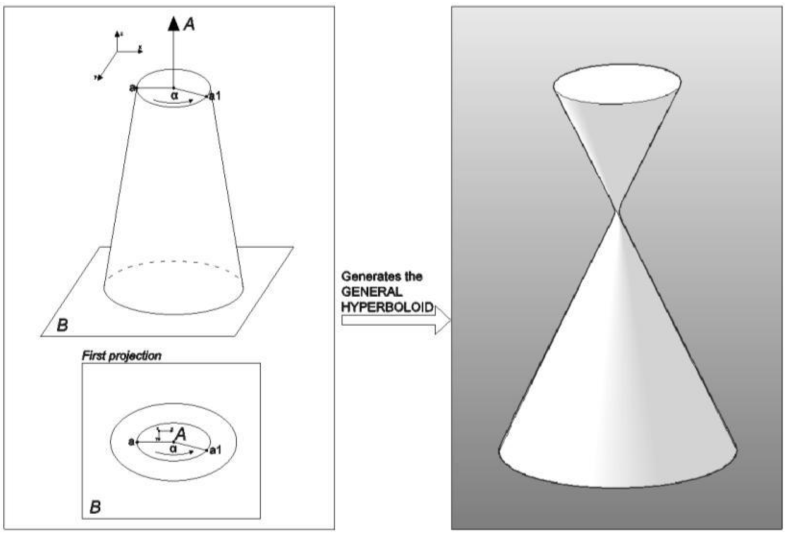
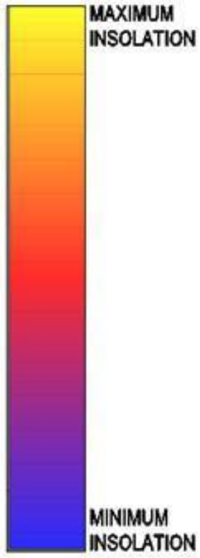


Fig. 8: General hyperboloid (Type II)- Twisting truncated cone

2.2. Analysis of the insolation of modified forms

In figures 9 to 11 one can observe level of insolation for three forms where the position of the sun is the same. The highest level of insolation is reached for the lower part of the form while the upper parts reach very low levels, because of the upper bases. The rest of the form is in the shadow.



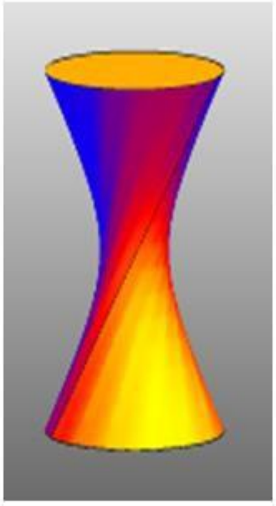


Fig. 9: Rotational hyperboloid

Fig. 10: General hyperboloid (Type I)

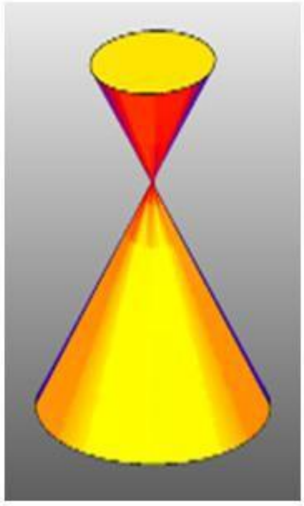
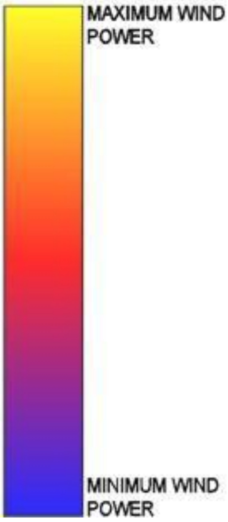


Fig. 11: General hyperboloid (Type II)

2.3. Analysis of the wind impact on the modified forms

If one does comparative analysis of the impact of the wind on the generated forms one can see which form has optimal stability. Cylinder, elliptic cylinder and truncated cone are forms with very good stability at the base (if the height is not disproportional to the diameter of the base) and so the simulations of the wind impact are not necessary. (Figs. 3, 4, 5) However, forms generate by the twist rotation could evoke stability problems. Structure of general hyperboloid can be unstable in the middle section and in this case there are little chances for the constructive reinforcement. (Figs. 13, 14) Rotational hyperboloid is much more stable which is determined by the small degree of rotation of the upper base. (Fig. 12).



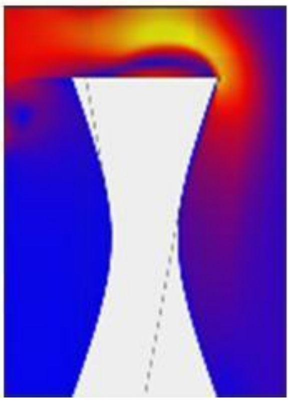


Fig. 12: Rotational hyperboloid

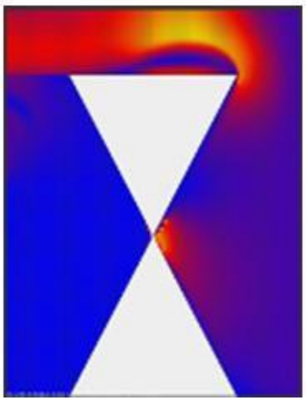


Fig. 13: General hyperboloid (Type I)

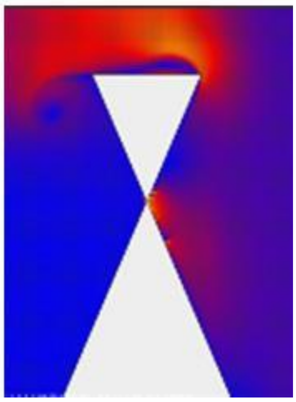


Fig. 14: General hyperboloid (Type II)

2.4. Study of shape building of canton tower and analysis of insolation and wind power

Geometry of Canton tower is gradually generated (Figs. 6, 7, 8). Lower base is actually larger ellipse while the upper is smaller one rotated for the angle α, which is the angle needed for the ellipses to be perpendicular, which can be seen the structure in the first projection. (Fig. 15.)

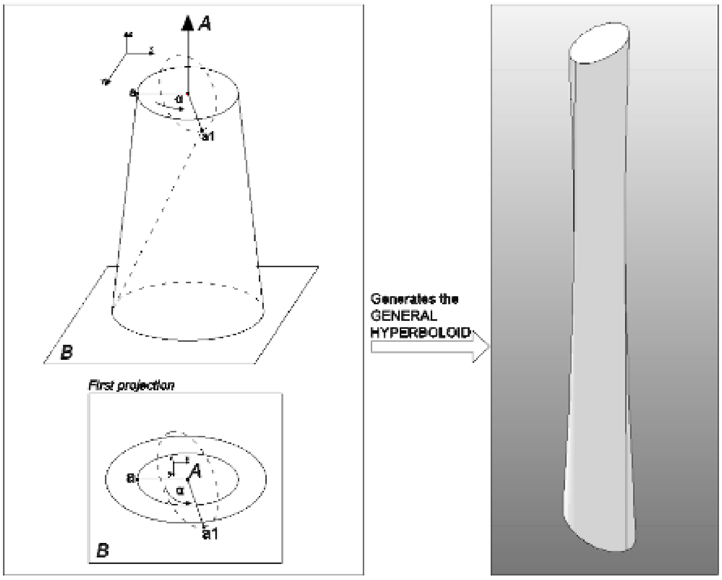
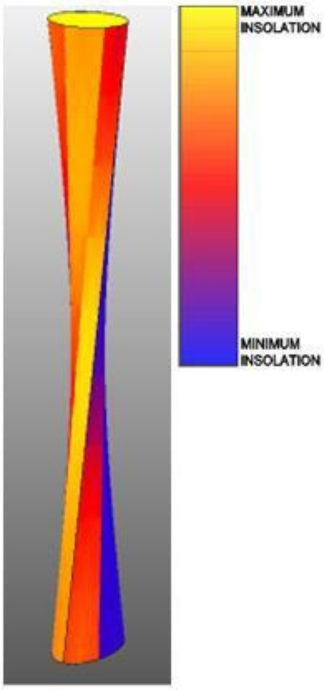


Fig. 15: Geometry of the Canton tower seen in first projection

Three dimensional geometry of the tower is optimal solution according to the impact of the wind power and insolation. In Fig. 16. the simulation of the insolation is represented. Engineers used the knowledge about the climate of this region of China and recognized the need for ventilation and air conditioning. Urban designers and architects increasingly face up to produce environmentally high quality urban buildings which effectively reduce the global energy consumption. The project introduced here aims at investigating the inter dependences between shapes of building in respect with energy performance, because the urban context and urban climate are often neglected in building energy analysis. (5) This geometry implies low level of insolation and therefore the energy spent for air conditioning is minimal. However, in the zones where the insolation is high engineers have installed solar collectors with the photovoltaic cells in order to transform solar energy into the electricity. The problem that the designer team faced was the frequent monsoons. (Fig. 17.) In order to keep the free form rotation of the bases is incomplete. This way the structure is more stable and the additional constructive stability is secured.



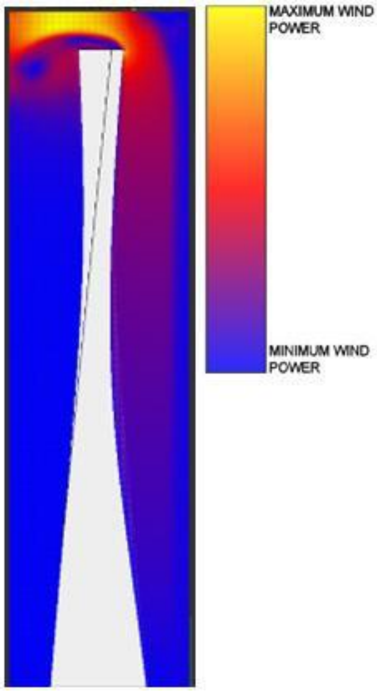


Fig. 16: Insolation analysis of the Canton tower Fig. 17: Wind simulation for the Canton tower

CONCLUSION

Different geometric shapes have different capacity to receive solar energy under the same conditions due to their geometric properties. (6) For basic geometric shape, i.e. cylinder, the percentage of insolation is the same for all sides. The cylindrical shape is considered as the optimum shape in the total solar insolation on high-rise buildings. In order to compare the effectiveness among buildings' shapes, the total solar insolation received on cylindrical shape is used as the base reference to other generated forms tested. Interactive use and integration of 3D modeling software for the analysis of the energy efficiency would forestall errors in the early phase of the design and save the resources needed to improve existing structures. With appropriate modification performed on to the geometric shapes, the impact of solar radiation on high-rise building envelopes can be reduced. Hence, it can be assumed that the energy consumption for cooling introduced in such high-rise building will be minimized, as for the wind impact.

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