Suggestions on the definition of building shape in national standards

--Simulation of typical building models with EnergyPlus

Y.B.Zhao[1,*], L. Chen[2], P. Xu[2] and H.J.Sha[2]

[1]School of Mechanical Engineering, Tongji University,
Shanghai 201804, China,
[2] Institute of HVAC and Gas Engineering, Tongji University,
Shanghai 201804, China,

ABSTRACT

♦ Building shape coefficient is defined as the ratio of building superficial area which contacts the outdoor air and the building volume. Smaller building shape coefficient helps save energy. High-rise buildings are very easy to meet the national standard limits for the shape coefficient of 0.4 or 0.3. The purpose of the thesis is to explore the impact of high-rise public buildings shape coefficient of energy consumption and put forward some suggestions to refine the request in national standards about the shape coefficient. Energyplus is used to simulate the energy consumption of high apartment and high office building in China's typical climate areas and to study the impact of building shape on building energy consumption. It is found that the present definition of building shape coefficient can not reflect building energy consumption correctly. Then this paper analyses how building energy consumption varies with shape coefficient. Finally, this paper puts forward some different difinitions of building shape coefficient and compare with the original to find the most reasonable one.

KEYWORDS

High public building, Shape coefficient, Energy consumption, Suggestions for national standards

* Corresponding author email: zhaoyunbo0313@126.com

INTRODUCTION

With the rapid development of China's GDP and the continuous improvement of people's living standards, the energy problem has become a "bottleneck" that constraints to China's further development. Some studies have shown that the building shape can have a significant impact on the energy costs of heating and cooling. Young

Choi's study was an attempt to identify the energy consumption characteristics of high-rise buildings comprehensively. Energy consumption was analysed according to building shape and mixed-use development through quantitative data and a review of the energy consumption characteristics of the residents through empirical surveys. Recently, Simulation software is widely used in calculation of energy consumption. However, most studies were limited in residential buildings.

High public buildings consume a large part of energy because of its high energy consumption. There are plenty of public buildings and more high public buildings are under construction. High-rise buildings are very easy to meet the national standard limits for the shape coefficient of 0.4 or 0.3. However, the impact of shape coefficient on building energy consumption is enormous, and they should not just stay in the level to meet the limits. The purpose of this thesis is to explore the impact of high-rise public buildings shape coefficient of energy consumption and put forward some suggestions to refine the request in national standards about the shape coefficient[1].

RESEARCH METHODS

This paper first analyzes the impact of floor height, the number of stories and plat shape on building shape coefficient and further building energy consumption. The value of high office's building shape coefficient is far less than the limits in national standard. So, different limits should be given for different volume buildings to provide guidance to the shape design of the high-rise buildings. Secondly, with the help of the energy simulation software, the EnergyPlus, the original models of high-rise office buildings in Harbin, Beijing, Shanghai, Guangzhou, Kunming, the five typical climatic zones in China are built and calibrated. At last, in order to overcome the short come of present definition of building shape coefficient ,the paper proposes three different definitions and finds the most reasonable one whose varies proportionally with building energy consumption.

BUIDLING SHAPE COEFFICIENT ANALYSIS

There are three respects of building shape coefficient. It is defined as the ratio of surface area to volume according to "Energy Conservation Design Standard for New Heating Residential Building". It is required by the code that $S<0.3$ or 0.4(S is shape coefficient of building) in different climatic zones.

High-rise buildings are very easy to meet the national standard limits for the shape coefficient of 0.4 or 0.3. Based on calculation, a building can meet the limit as long as it is 5m high and its area comes to $900m^2$. Large public buildings are different to residential buildings. The heating energy consumption per unit area of large public buildings is only 50% to 80% of the residential or small and middle public buildings. But the other energy consumption of unit area is 5 to 15 times[2]. Therefore, it is more necessary to control the building shape in the subtropical region than the heating region for large public buildings[3].

EnergyPlus is the mostly used energy simulation software abroad. And it is more and more accepted by domestic researchers. This paper built the original models of high-rise office buildings in Harbin, Beijing, Shanghai, Guangzhou and Kunming, the five typical climatic zones in China with EnergyPlus. The building structures and the thermal performance referred to “Energy Conservation Design Standard for New Heating Residential Building” and some architectural cases in related literature. The results were corrected with the data in Tsinghua University’s annual report on building energy consumption[4][5].

Fig 1 shows 3-D rendering for selected building models considered in the simulation analysis.

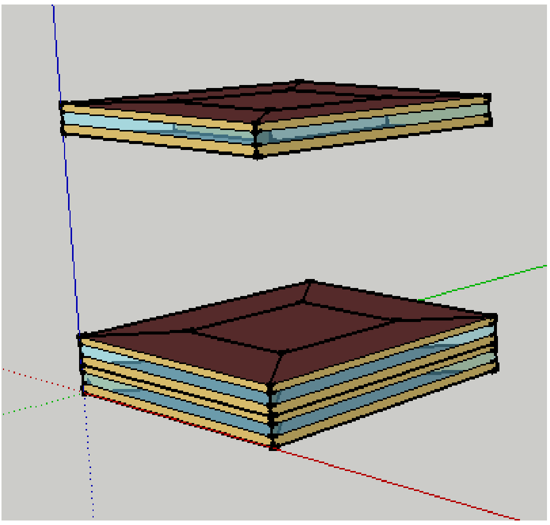

Fig.1 Typical office building model

Firstly, the paper studied on the relationship between floor height and energy consumption. A comparison was carried on among a group of building models whose heights were from 3.5m to 4.0m at intervals of 0.1m. Fig 2 shows that the higher the building, the bigger the shape coefficient. Fig 3 shows that the higher the building, the more the total energy consumption. The national standards tell that build with smaller coefficient consumes less energy. The definition of building shape in national standards cannot reflect the relationship between shape coefficient and energy consumption for buildings with different heights. With the floor height increasing, the building envelope per building area gets larger, as a result, more heat transfers through the building envelope.

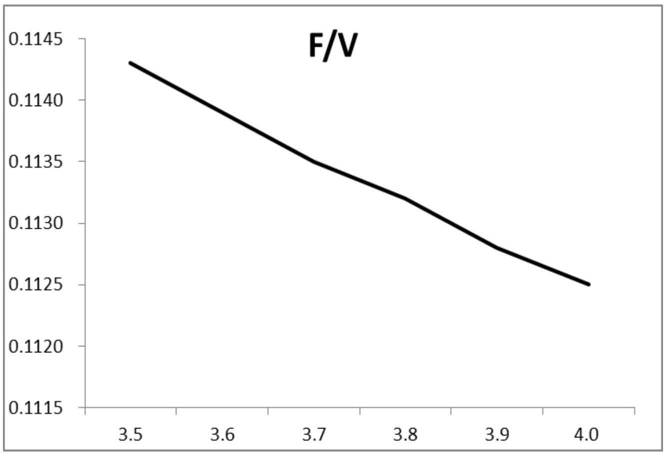

Fig.2 F/V at different floor heights(（Vertical axis: Total energy consumption MJ/M2, horizontal axis: floor height, the same with the follwing pictures））

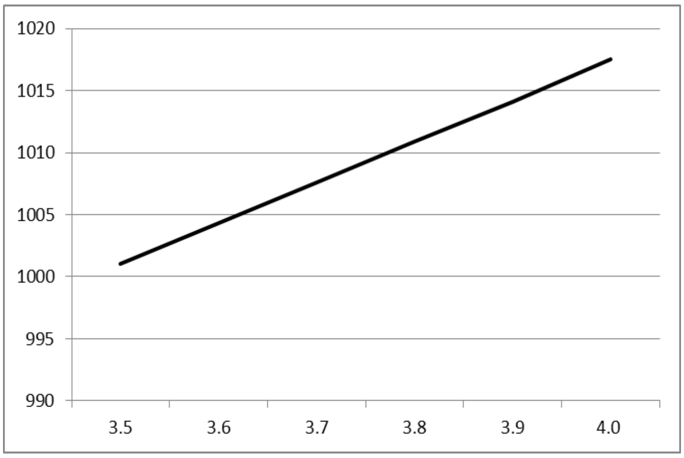

Fig.3 Total energy consumption at different floor heights in cold area（Vertical axis: Total energy consumption MJ/M2, horizontal axis: floor height, the same with the follwing pictures）

Then, the paper studied on the relationship between the number of stories and energy consumption. A comparison was carried on among a group of building models whose numbers of stories were from 10 to 30 at intervals of 5. Fig 4 shows that the bigger the number of stories, the bigger the shape coefficient. Fig 5 shows that the bigger the number of stories, the more the total energy consumption. The definition of building shape in national standards can reflect the relationship between shape coefficient and energy consumption for buildings with different numbers of stories.

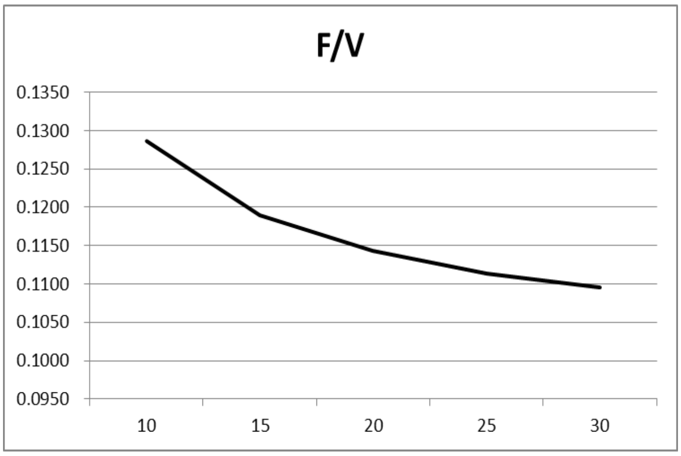

Fig.4 F/V at different story numbers（Vertical axis: Total energy consumption MJ/M2, horizontal axis: floor height, the same with the follwing pictures）

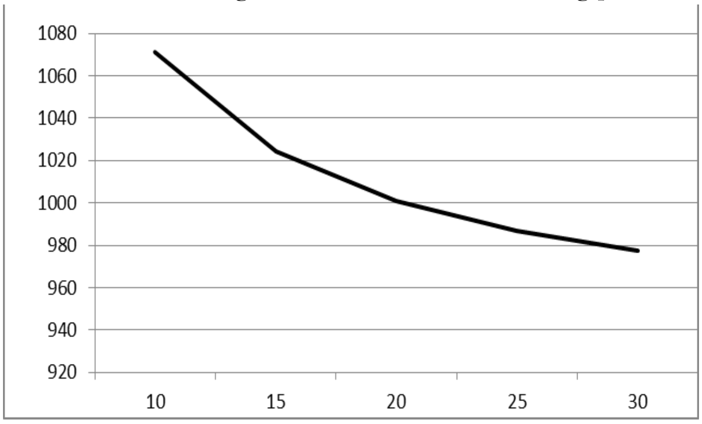

Fig.5 Total energy consumption at different story numbers in cold areas（Vertical axis: Total energy consumption MJ/M2, horizontal axis: floor height, the same with the follwing pictures）

Then the paper studied on the relationship between the plat shape and energy consumption. A comparison was carried on among a group of building models whose aspect ratio were 1, 1.14, 1.31, 1.51, 1.78 in order. Fig 6 shows that the bigger the aspect ratio, the bigger the shape coefficient. Fig 7 shows that the impact of aspect ratio on energy consumption is far less than compared with the impact of the number of stories. Fig 8 shows that the best aspect ratio exits consuming the least energy. The definition of building shape in national standards can reflect the best aspect ratio.

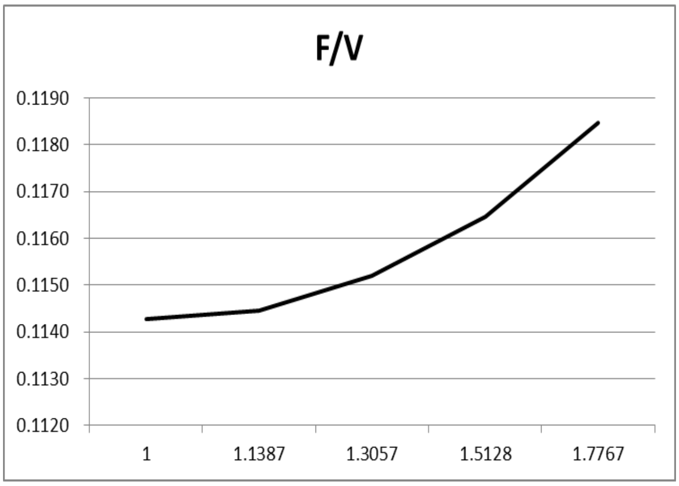

Fig.6 F/V at different aspect ratios（Vertical axis: Total energy consumption MJ/M2, horizontal axis: floor height, the same with the follwing pictures）

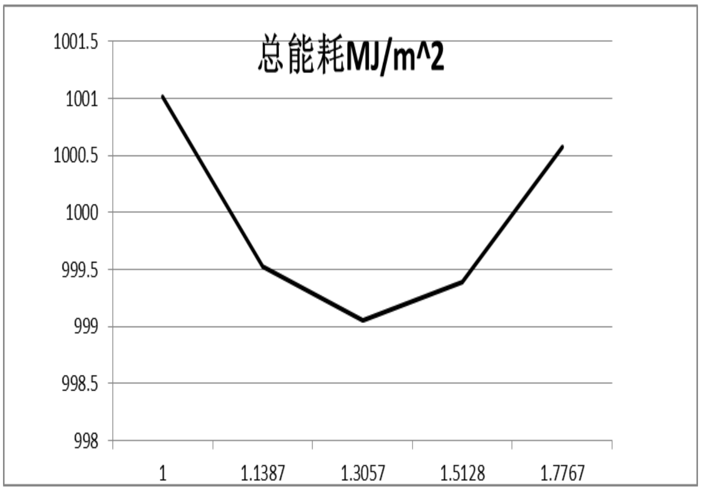

Fig.7 Total energy consumption at different aspect ratios（Vertical axis: Total energy consumption MJ/M2, horizontal axis: floor height, the same with the follwing pictures）

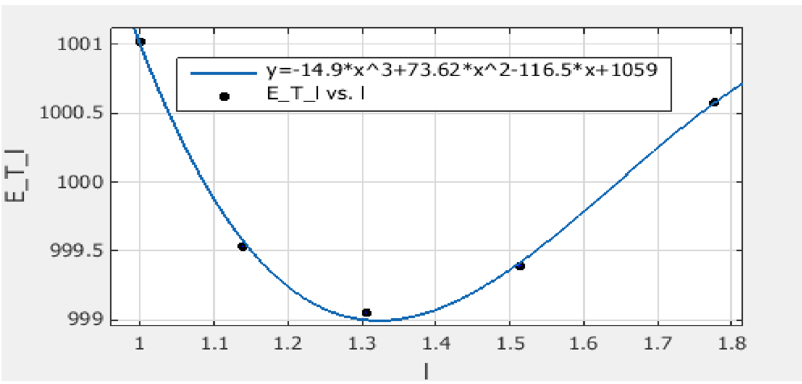

Fig.8 Total energy consumption at different aspect ratios in Beijing

At last, the paper studied on the change low of the total energy consumption with the number of stories and the aspect ratio. Fig 9 shows that the impact of aspect ratio is less than 10% compared with the impact of the number of stories among buildings in different volumes.

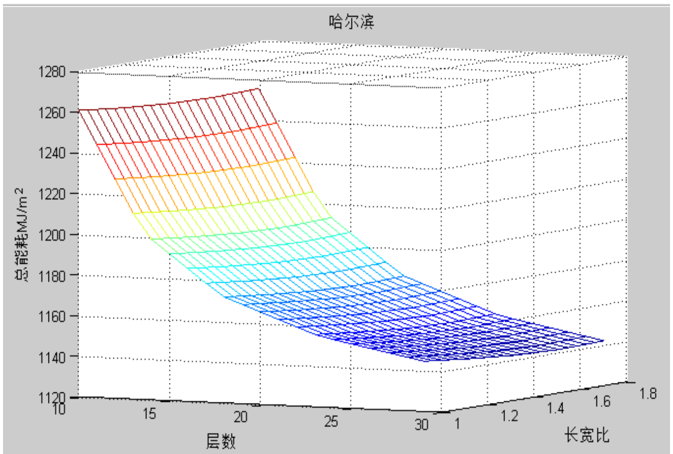

Fig.9 Total energy consumption at different numbers of stories and aspect ratios in Harbin

NEW BUILDING SHAPE COEFFICIENT DEFINITION

For the building with simple plat shape, floor height, the number of stories and plane shape do not have the same impact on building shape and building energy consumption, reflecting the defects of the building shape definition in National Standard. The test proposes three other different definitions, including the ratio of surface area exposed to air to building area, the ratio of surface area exposed to air to plant area and the ratio of surface area exposed to air to 2/3th power of building volume. It tells that the combination of aspect ratio and the ratio of surface area to building area is the best one in fig 10 and fig 11.

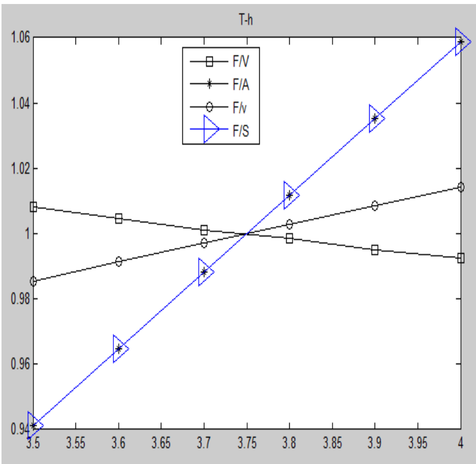

Fig.10 Shape coefficient at different floor heights

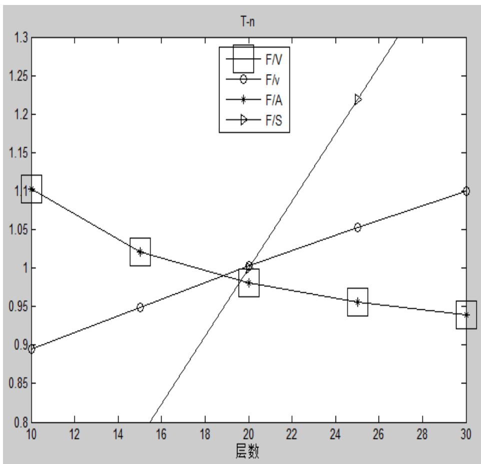

Fig.11 Shape coefficients at different numbers of stories

CONCLUSION AND IMPLICATIONS

The study found that standards on building shape coefficient were too simplified and some of these were even incorrect. They can hardly provide guidance for building shape design. This paper proposes some suggestions for national standards. 1. The value of high office's building shape coefficient is mostly far less than the limits in national standard. So, different building shape coefficient limits should be given for buildings of different volume. 2. Floor height, the number of stories and plat shape do not have the same impact on building shape and building energy consumption for the building with simple plat shape, reflecting the defects of the building shape definition in National Standard. The paper proposes three other different definitions, and it was found that the combination of aspect ratio and the ratio of surface area to building area is the best one. 3. For buildings of the same volume, optimal aspect ratio is between 1.2 to 1.6, consuming the least energy. The optimal aspect in high-latitude is smaller than that in low-latitude because of the solar radiation. 4. For buildings of different volumes, the impact of aspect ratio is less than 10% compared with the impact of the number of stories. Therefore when cmparing the shape coefficient of buildings of different the number of stories, they should be replace by the square building of the same the number of stories and plat area.

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