Layout Research on Traditional Villages under the Perspective of Climate Adaption

Yuanxiao Kuang*,1, Zhenyu Li2

1Master student, College of Architecture and Urban Planning, Tongji University, China
2Professor, College of Architecture and Urban Planning, Tongji University, China

Abstract
“This world, a monster of energy” with these words Nietzsche suggest that energy has the ability of being a dimension indicating changes in the world. Cities as creatures of human should obey the law of energy flow. However, energy flow in a city is so complex that we cannot describe it with a single maxim, only when under a certain perspective we can find some trace which act as an evidence of cities’ nature they conduct the formation of cities. Nowadays, more and more modern cities become homogenous which is the reflection of some dominant laws, they can be economical or political while we entitle them with globalization. In some traditional settlements, however, we can still find evidences of responding local climate and geography which at the very beginning of settlements showed strong influence. These evidences are the unique ideas acceding from ancient residents’ experience and have become specific distinctions of these cities. This paper tries to describe the thermodynamic values on morphology and typology facts of aboriginal settlements for example Shibam in Yemen, traditional Chinese settlements. Providing some ideas on how to create an efficient energy flow which is the key towards climate adaption. This paper is subsidized by the National Natural Science Foundation of China(No.51678412)

Keywords: Traditional settlements, Energy, Climate adaption, Street system layout

1. Introduction

We divided cities into two kinds, one is formed through planning the other is organized spontaneously. However, the two is not so different for the two elements gave the birth of traditional settlements simultaneously. When we start to find the regulations behind cities’ morphological facts, we can see that energy flow is the key. Nietzsche’s famous words depicted this world as a monster of energy, without beginning or end. He said: “this world is a firm magnitude of force that does not get bigger or smaller, that does not expend itself but only transform itself.” These words illustrated the possibility of using energy as a method to elucidate the function of cities.

Nowadays, the shortage of resources becomes pressing and we start to think how to create a rational energy flow in cities which contains the efficiently obtaining and consuming of energy. Although theories and background have been widely discussed among thermodynamic scholars, Architects today incorporate principles of sustainable design as a matter of necessity. But the challenge of unifying climate control and

* Contact Author: Yuanxiao Kuang, master student, Tongji University, address No.1239 Siping road, Yangpu district, Shanghai, China
Tel: 028 65987596
e-mail: martinkathur@gmail.com

(The publisher will insert here: received, accepted)
building functionality, of securing a managed environment within a natural setting—and combating the harsh forces of wind, water, and sun—presented a new set of obstacles to architects and engineers in the mid-twentieth century. Olgyay, V. (2015) This is partly because we’ve come to so far with cities of complex systems. Economy systems and political systems as well as other crucial systems have already blocked our eyes and dominated the process of urban design for a long time. It leads to a neglect of traditional ideas on climate adaption which in fact are the solution towards energy flow. Thus, Organizations and individuals focus on ancient cities, these ancient villages use aboriginal method to face the harsh environment without the help of machineries and low-tech situations forced them to solve grinding climate problems by organizing cities in a certain way. And this is exactly what we are re-consider, mechanical invasion is a fact, and architects especially American architects sense that it is a cultural threat to their position in the world. Banham, R. (1965) Shibam, known as “Manhattan of desert”, in Yemen shows us how to fight against huge temperature difference by stones and rammed earth.

Unlike Shibam, villages in northwestern China face no sand storms while it need to deal with different climate and find a compromise between comfortable city space and healthy economic systems and many other things. These elements shaped unique layouts of ancient settlement and became important cultural vernacular elements. Sometimes well socialized city will take the advantage of climatic and geographic factors, which makes them status of hierarchy and this is just patent in China. Unfortunately, due to non-scientific reasoning procedure these ideas towards climate adaption were treated as superstition while they should be basic skills written in textbooks. This kind of dislocation results in the hinder of an integrated thermodynamic understanding on the function of cities.

2. General physical status of old city in Shibam Hadharmawt

Shibam owns some 9 meters tall clay-brick walls which surrounds this settlement. During the 4th century BC the city of Shibam played a key role as the capital of Wadi Hadhramout. Walls of this city acted as a good guardian at that time and protected properties of merchants and tribes. Today Shibam City is enlisted to UNESCO heritage lists (Lewcock, 1986). At that time, housing units in Shibam together with its urban layout provided a secured manmade environment with no threat of the outside sandstorms and severe desert climate. Time goes by mud brick buildings may be in danger, they encountered flood and storms then collapsed, new buildings are usually built on the same location. That’s the reason for the intricate ages of buildings in the city.

The old city of Shibam is composed by many old buildings. Approximately 7000 villagers living there now owns 5 masjids with one completed in the 8th century. The east part of Shibam are filled with Muslim style houses. Almost every street is zig-zag shape that’s why you cannot get an overall sight even though this city is smaller than 10 hectares.

3. General physical status of traditional settlements in northwest China

As mentioned above, the birth and development of cities are so complex that we cannot point out a unified law. Architecture styles were usually a function of local building materials, contemporary building technologies and local cultural preferences. Wedebrunn, O. et al. (2010) Shaanxi as an important province of ancient China, the situation of its villages varies a lot, in which southern traditional settlements chose their location for a variety of reasons, such as agricultural reclamation, business services, transportation, scarce resource development, military defense. Southern Shaanxi Province enjoys complex terrain, many mountainous areas, existing settlements reveals an inclination of choosing flat basement to build residential areas. We can find that the main residential sites are located in the foot of the mountain, hillside and hilltop, and according to different geographical location of the site, their micro climates are also different.

Settlements that located on slope areas enjoy relatively high comfort, but whether the slope face a good direction determines microclimate of the settlement. In southern Shaanxi area, slopes face south provide good ventilation and solar radiation environment for the settlements. Relatively speaking, slopes which face north and west are poor in providing good sunshine condition and this result in the surfeit of humidity. Local wind direction is also not good for the locals which ironically lead to the initiative to choose a better slope to live in, the construction of public spaces in a favorable slope for example hilltop is a good approach towards better living conditions.

There are few examples of settlement at hilltop, mainly because of bigger magnitude of wind and the unstable wind direction at hilltop. For those who live on hilltop for a long time, traffic is a problem, so the
mountain is mostly for sacrifices, cultural places and settlements' public spaces. Usually maximum amount of solar radiation can be obtained here as well as minimum air humidity. In southern Shaanxi region, hilltop humidity is much lower than the one in hill foot. Getting sunshine and driving off the moisture become the main reason of going to hilltop for activities.

4. Thermodynamic analysis of Shibam

The old city of Shibam owns a unique form, as mentioned above, high density high rise housing, narrow streets and spacious public spaces these features are unique worldwide. In this complicated climate environment, how does Shibam manages to maintain a good thermodynamic comfort environment worth researching.

Public squares are very significant in the old city of Shibam Hadharmawt together with the special roads in Shibam they decided the general pattern of the whole city. The form of old city of Shibam Hadhrmawt is a synthesis of its unique urban layout, building volumes, special open public spaces and high thermodynamic efficient adobe walls. Buildings in Hadhramawt reflect social hierarchy in the city and the nature of socio-economic relations existed in that period, which affected the principles carried out in urban design (Damluji,1986).

Erik Johansson carried out researches on traditional settlements in dry and hot climate areas of Morocco. He explored the relationship between villages and climates by measuring the summer and winter temperatures of streets. From the layout of villages, the form of streets and shapes of courtyards, the choice of building materials, and so on he carried out analysis which pointed out that high-density layout and narrow streets do good to cooling effect. Those analysis also prove that compact spatial structure and narrow streets will contribute to a comfortable thermodynamic environment.

One thing that is fairly obvious is that Shibam owns a very complicated road system. (figure 1) Main streets are not exactly east-west direction. In the solar radiation accumulation analysis, analysis data shows a reduction in annually solar radiation accumulation for approximately 15%. (figure 2). This action became a leading principle during the design process of Masdar city in The United Arab Emirates. Designers start their urban design with the calculation of the angles of streets to minimize the annual solar radiation accumulation. And it is crucial when design in such a big scale.

Second is the unique complexity of road shapes. In any other cities, this kind of road may harm the city landscape while from thermodynamic view, saw tooth shape streets hinder the ventilation which lead to the sediment of air pollutant and prevent the refreshment of air. However, this is not the case in Shibam.

Due to the harsh climate in Shibam, huge temperature difference between day and night make heat insulation a leading problem. Through CFD analysis (figure 3) we see the function of walls and high buildings around this settlement, they block cold wind in the night so as to stop the outflow of heat in the nigh. At the same time, curly streets slow down wind speed in ground level. For a good amount of fresh air, there should be enough roughness for the distribution of positive and negative areas.

Ventilation and insulation usually are two contradictory factors. The dispersion of urban waste air requires maximum air turbulence and vertical air transportation and this means a high roughness of different air layer surface. That is to say when a building of certain height is added to the surface, it increases the roughness. Until a certain density of high-rise buildings, more high-rise buildings result in higher roughness while beyond this number the roughness began to decline. In order to increase the roughness, it is good to introduce a
number of high-rise buildings scattered in the city. Oke (1988) and Givoni (1998) proved this point. At Shibam, we can see high-rise buildings and normal buildings stand together and form a high roughness air surface, which definitely enhances air turbulence and strengthens vertical air movement.

Desert storm is an unavoidable problem in Shibam although vertical air movement is needed, this lead to the second urban design goal. It is controlling the wind speed at street level which is more detailed than the pollution dispersion. On the other hand, we mention the importance of heat insulation as a desert climate city, and rapid ventilation will cause rapid heat loss, so controlling wind speed is also for the sake of heat insulation.

![Fig 3 CFD analysis of Shibam](image)

We actually aim at an equilibrium condition, Bottema (1999) defined an upper limit to control wind speed in street level. Ideal winds on streets vary according to local situation. Under the limit, the breeze is beneficial in hot climates, under this circumstance breeze accelerates heat exchange while keep pedestrians comfortable. However, for mid latitude this wind speed maybe harmful. In these areas, two things are significantly contradictory: first, users need to strengthen street ventilation and pollution dispersion. Secondly, wind shelters low rate heat change is needed.

Shibam’s solution is a good example for us. For some roughness value can the city get into the equilibrium of ventilation and heat exchange. According to Bottema (1999) this happens when building height and width ratio is between 1:2 and 1:10, while Oke (1988) suggests an ideal height-to-width 0.65.

Above all, we can finally find the ideas of residents in Shibam. The minimum roughness and therefore minimum pollution dispersion is found when the axis of the buildings is parallel to the wind. Despite its low roughness, this configuration also provides poor shelter and should be avoided in cold climates. This is also noted by Bottema (1999): “A configuration with long buildings aligned with the wind yields not only little shelter but also poor street ventilation: the flow channeling may yield reduced vertical mixing . . . as well as unexpected lateral transport . . . “. Against design intuition and common sense, it is better to orientate buildings like what we see in Shibam.

4. Thermodynamic comfort construction in traditional settlements in northwest China

We use the status of Qingmu town to explain. Qingmu town’s location is the military choice and result of commercial operation as well, special military fortress need make part of Qingmu Town characteristics of military campus, and because Qingmu town is the only way into southern Sichuan province and only way into northern Chang’ an, the shape of this settlement behaves like a commercial town. A long and straight street facilitates the exchange of goods while the water level rise in the summer make an important cargo terminal, Qingmu town’s location determines that this town is a business-intensive settlement.

Settlements located at the foot of the mountain mostly choose valley as the settlements’ sites, such settlements generally near rivers. Humidity is fairly high, especially when the settlement is in the valley where the mountain block wind and the whole area will form a relatively closed situation. The mountain blocking sunshine make daytime settlement temperature appropriate, but during evening until morning of the second day the entire settlement humidity will rise to a relatively high value. In the test of Qingmu town, you can find a daytime relative humidity at around 30% but reaches 60% at night. In order to live more comfortable, residents need to increase the area of public spaces for more sunshine. Or the other method is to move the activities to hilltop where you can get low humidity.
Qingmu town located in the valley between two mountains, the valley takes east and west direction. Main buildings are placed in the south part of valley, that is, at the foot of south mountain while new houses are located in the north river bank. (Figure 4)

Fig 4 Qingmu town diagram
In spring and summer, the sunshine time increase with the growth of slope when the settlements located in the south part of north mountains. In autumn and winter the southern slopes enjoy same sunshine time compared with horizontal plane despite of latitude and inclination, which actually means solar radiation accumulation time and the slope is negatively related. In winter, usually the north mountain can block cold flow.

When the settlement is located on the north slope of south mountain, because of a latitude higher than Tropic of Cancer sunshine of north mountain will be blocked all over the year, the higher the height of the mountain the block is more obvious. Compared to spring and summer in autumn and winter sun height angle is smaller, the same mountain will block sunlight for a longer time which result in less solar radiation and winter temperatures will be very low and uncomfortable. Influenced by summer monsoon and winter monsoon, gully terrain expand east and west will guide wind direction. So, in spring and summer, winds are from east, while in autumn winds are from west. When the mountains take this direction, they become “tubes” that increase wind speed. As the town's location is in the south slope of north mountain, and the south mountain is higher which blocks the sunshine of the whole settlement, shortening the time to obtain sunlight. In summer survey the sunrise time is 05:30, but due to the block from south mountain, the town is able to get sunshine after 06:50, and in winter because of smaller sun height angle and less day time, sunrise time is 07:50, until 08:55 can the town get sunshine. (Figure 5)

Fig 5 Solar radiation diagram
When the water body is located around settlement, the effect is determined by both the wind direction and water body location. When the water body is located at the inlet direction of summer main wind, in winter water temperature will rise due to a large amount of heat storage. At night heat of water body is dissipated by the action of the wind, and the heat loss due to the decrease in ambient temperature is compensated. In Summer water body temperature is lower than that of air temperature, it makes the air above water cooler which result in the significantly reduction of settlement temperature. When the water body is located in the outlet location of summer main wind, water body can only reduce the temperature by evaporation. In winter, winds will pass above water and result in the rise of humidity which actually damage the comfort of settlements’ exterior spaces. Above all the function is not as good as the former situation.

To conclude, under the influence of terrain and climate, the north bank is more suitable for living. Qingmu town is divided into two parts, south bank and the north bank. As a tradition, the north bank has been treated as private land of landowner and officials while the south bank accommodates most residential buildings and
commercial street. The location of the ancient town of Qingmu town is mainly affected by the feudal landlord, so that the majority of the people live in a secondary environment, they cede their good location in terms of sunlight radiation.

4. Conclusion

From thermodynamic analysis, we can see the influence of urban layout on a good thermodynamic environment.

Wind mainly influence directions of streets and buildings. In the cold area, blocking prevailing winter wind as well as heat insulation is the major need, while a rational layout of high-rise buildings leading to a good performance of street level wind environment. In cold winter the layout of high-rise buildings should prevent high speed wind in street level, which is important for exterior area. As for solar radiation, sun height angle, latitude, air transparency and cloud, these are elements influence radiation. Different radiation influence city layout and building group composition. In cold area, sufficient sunshine is the crux to a healthy body. Thus, urban design should base on the acquisition of sunlight.

Smart strategies of site choosing, rational places for plantation, using lakes and streams to amplify the ventilation and heat exchange these are good strategies for building a good external and interior thermodynamic environment. While we planners and designers cannot decide the final run of the city, thermodynamically speaking, we can still try to provide a good energy flow. These kinds of consideration in designing the layout of the city will finally contribute to good appearance of cities both ascetically and ethically.

References
   Climate and architecture.
7) Li Li (2002). Evolving of the rural habitation pattern in JiangNan. doctoral thesis. Dongnan university, China