

HOUSING STUDY IN THREE CLIMATIC ZONES OF CHINA

Drafted by LuYing Wang,

Under the supervision of Dr Ali Cheshmehzangi

The University of Nottingham Ningbo China

Content

1. Study of housing cases:

- Hot and Humid in Southern China- Sub-tropical
- Hot Summer and Cold Winter in China-Sub-tropical
- Hot Tropical- Hainan Island
- Discussion and suggestions

Study of housing cases

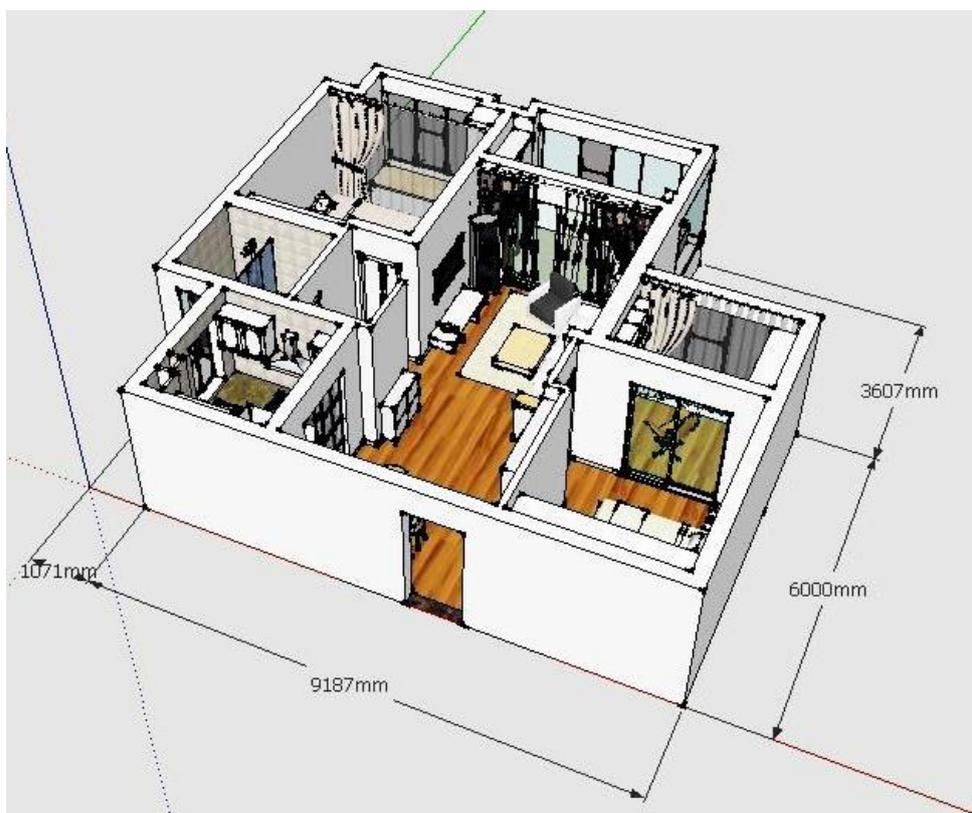
➤ Hot and Humid in Southern China- Sub-tropical (Guangzhou)

- **Climate characteristics**

The subtropical hot and humid climate is characterized by hot summers and mild winter; some of the regions in this climatic type have the maximum precipitation in summer. It can be seen in Fig 1 that Guangzhou has a lengthy monsoon season from April to September, the maximum value can reach 284mm and annual total the amount of rainfall is more than 1600mm. Generally, in hot and humid China-Sub tropical climate more or less rain falls throughout the year. The humid subtropical climate is found on the eastern side of the continents between 25° and 35°/40°N and S, and Guangzhou is one of typical city in this region influenced by the East Asian monsoon and moist tropical Pacific air. Average temperature in Guangzhou is about 26°C annually, the range of temperature is between 10°C (winter) to 33°C (summer), therefore there is a hot humid summer and warm humid winter

Climate Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max Temperature °C (°F)	18 (65)	18 (65)	22 (71)	26 (78)	29 (85)	31 (88)	33 (91)	33 (91)	31 (89)	29 (83)	24 (76)	21 (69)	26 (79)
Average Temperature °C (°F)	13 (56)	14 (58)	18 (64)	22 (71)	26 (78)	27 (81)	29 (83)	28 (83)	27 (81)	24 (75)	19 (67)	15 (59)	22 (71)
Average Min Temperature °C (°F)	10 (50)	11 (52)	15 (59)	19 (66)	23 (73)	25 (76)	25 (78)	25 (77)	24 (75)	21 (69)	16 (60)	11 (52)	19 (66)
Average Precipitation mm (in)	43 (2)	65 (3)	85 (3)	182 (7)	284 (11)	258 (10)	228 (9)	221 (9)	172 (7)	79 (3)	42 (2)	24 (1)	1682 (66)
Average Daylight Hours/ Day	10h 52'	11h 20'	11h 58'	12h 40'	13h 14'	13h 31'	13h 24'	12h 54'	12h 14'	11h 33'	10h 59'	10h 43'	12h 00'
Sun altitude at solar noon on the 21st day (°)	46.8	56	66.9	78.6	86.8	89.6	86.9	78.9	67.5	55.9	46.8	43.4	67

Figure 2-1 Climate variable in Guangzhou [xx]



Housing case:
Layout of one house

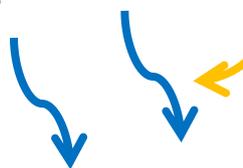


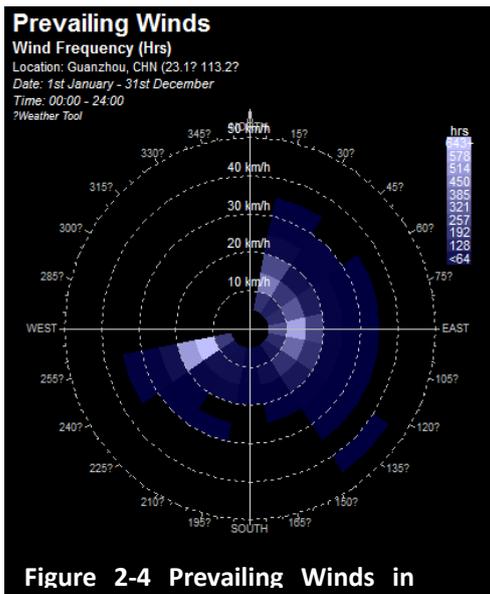


Figure 2-3 Housing Model in

Characteristics:

- Area:** 84.5m²
- Location:** Guangzhou Yuexiu District
- Building height:** Small high-rise
- Building material:** Steel concrete frame
- Architectural form:** Apartment
- Orientation of house:** South-North
- Structure:** 2 bedrooms, 1 bathroom, 1 living room, 1 dining room, 1 kitchen

• **Ventilation:**



The orientation of wind in Guangzhou is south-east in summer and north-east in winter, which is clearly showed in the figure 2-3. Figure 2-4 displays all year prevailing winds frequency and demonstrates the same data as the speed distribution wind rose; the colored segments of each spoke represent hours rather than wind speed. The maximum velocity of wind approximately reaches 35km/h. Under this circumstance, in this house, bedrooms, balcony and living room can get enough ventilation though in summer, it would significantly reduce the indoor temperature and support abundant fresh air to keep

interior environment comfort and reduce the humid in the room. In winter, in order to resist the cold wind from outside, the northwest of whole house is wall and fewer windows on the west rooms. However, the winter in Guangzhou is not extremely cold and humid, an appropriate quantity of winds is essential.

• **Shadow**

The annual sunshine duration in Guangzhou is about 1400-2200 hours, this data is in the middle level compared with most of northern cities in China. It is because humid climate with a large amount of moisture in the air to weaken the solar radiation from the sky to ground. Figure 2-5 shows

Effective Shading Coefficients

Latitude: 23.1°
 Longitude: 113.2°
 Timezone: 120.0° [+8.0hrs]
 Orientation: 0.0°

Month	Avg.SC	Max.SC	Min.SC
January	[Behind]	--	--
February	[Behind]	--	--
March	0.0%	0.0%	0.0%
April	29.1%	61.0%	0.0%
May	49.9%	92.0%	0.0%
June	64.1%	100.0%	0.0%
July	45.3%	87.0%	0.0%
August	19.5%	39.0%	0.0%
September	[Behind]	--	--
October	[Behind]	--	--
November	[Behind]	--	--
December	[Behind]	--	--
Winter	0.0%	0.0%	100.0%
Summer	53.1%	93.0%	0.0%
Annual	17.3%	31.6%	50.0%

Figure 2-5 Effective Shading Coefficients in

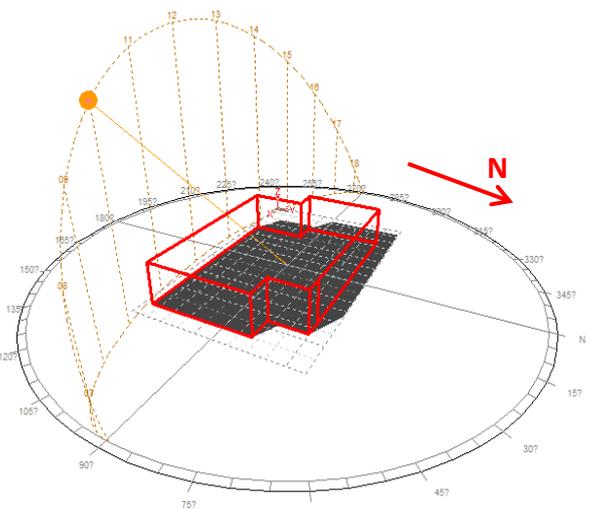


Figure 2-6 House model in shade (10am 22nd Mar)

the effective shading coefficients from Ecotect Analysis that is the capacity of glasses block out the sun's ray. According to the chart, the maximum shading coefficient can reaches to 90%- 100% during May and June, which means the sunlight completely pass through the glass. This will contributes large heat in the house, thus, sun shading is necessary for this house in summer. In terms of this house, southern bedroom is applied the double-glazing glasses design to reduce the intensity of sun radiation and large amount of heat enters into the room. Figure 2-6 generally display the house model in the shading, it shows the area and the length of shade is not large; and the average annual shading coefficient is 17.3%, which means less influence of sun radiation on indoor thermal environment all over the year.

➤ Hot Summer and Could Winter in China-Sub-tropical (Hangzhou)

- **Climate Characteristic**

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high °C (°F)	8.0 (46.4)	9.4 (48.9)	13.7 (56.7)	20.6 (69.1)	25.5 (77.9)	28.6 (83.5)	33.0 (91.4)	32.4 (90.3)	27.5 (81.5)	22.7 (72.9)	16.8 (62.2)	11.1 (52)
Average low °C (°F)	1.5 (34.7)	2.7 (36.9)	6.4 (43.5)	12.1 (53.8)	17.0 (62.6)	21.1 (70)	24.9 (76.8)	24.5 (76.1)	20.3 (68.5)	15.0 (59)	8.9 (48)	3.4 (38.1)
Precipitation mm (inches)	73.2 (2.882)	84.2 (3.315)	138.2 (5.441)	126.6 (4.984)	146.6 (5.772)	231.1 (9.098)	159.4 (6.276)	155.8 (6.134)	145.2 (5.717)	87.0 (3.425)	60.1 (2.366)	47.1 (1.854)
%Humidity	75	75	78	76	76	81	78	79	81	77	74	72
Avg. precipitation days (≥ 0.1 mm)	12.4	12.3	16.3	15.2	14.6	15.2	13.0	13.6	12.6	10.0	8.6	8.1
Sunshine hours	107.2	99.1	109.5	140.6	163.3	141.9	216.1	209.5	147.2	148.3	137.6	136.2

Source: China Meteorological Administration

Figure 2-7 Climate variables in Hangzhou

Hangzhou's climate is humid sub-tropical with four distinct seasons; it has long, extremely hot, humid summer and very chill, dry and cloudy winter. According to the above chart, the extreme temperatures have ranged between 1.5 to 33°C, but there are hottest days during mid-July to mid-August, the temperature would be more than 40 °C. Hangzhou is affected by the plum rains of the Asian monsoon and receives an average annual precipitation of 1440mm as well as the number of rainfall days exceeds half of a month from March to July. In August and September, it will suffer typhoon storms; they make strong winds and rainstorm. The city gains

about 1800 hours of sunshine annually.

Housing case:

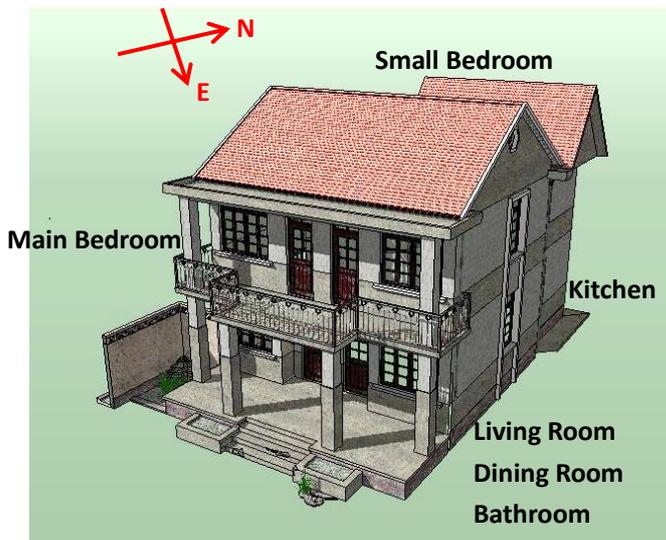


Figure 2-8 Village house in East-south

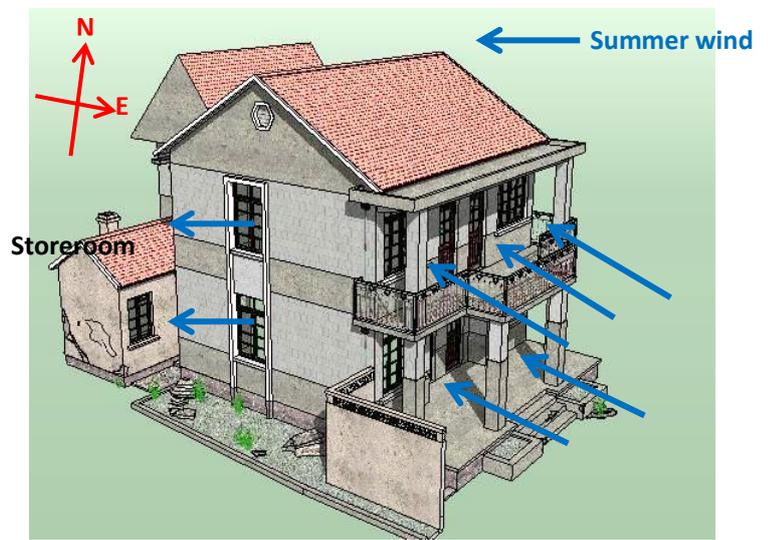


Figure 2-8 Village house in wet-south

In terms of Hangzhou housing study, rustic home is a great feature in Hangzhou's resident architecture, it has many typical characteristics related to local climate. In this report, main bedroom and first floor rooms are analyzed targets.

Characteristics:

Area: 110 m² (without storeroom, kitchen and small bedroom)

Location: Hangzhou Yuhang District

Building height: 6.5m

Building material: Steel concrete frame and aerated concrete blocks

Architectural form: Detached House

Orientation of house: Southeast-northwest

Structure: 2 bedrooms, 1 bathroom, 1 living room, 1 dining room, 1 kitchen

• Indoor Thermal

Many factors have effects on building internal thermal performance, for instant, the fabric elements include wall, floor and roof, ventilation heat loss by windows and doors. Therefore, materials of building envelope play an important role in thermal insulation. In the light of engineering aspect, the heat loss (q) is equal to $q =$

$kA \frac{T_1 - T_2}{L}$, which K is the material's thermal conductivity, A is the area of heat

transfer area, $T_1 - T_2$ is the temperature difference between the outside and interior rooms, L is the thick of building envelope. According to this function, choose fabric materials with low thermal conductivity. With respect this Hangzhou house, it use rigid preformed materials: aerated concrete blocks as

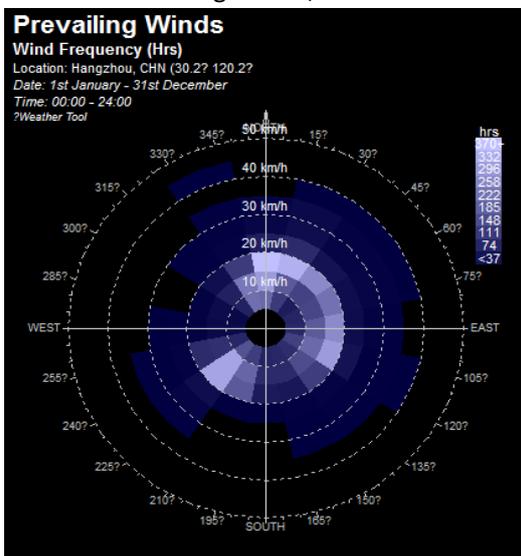


Figure 2-9 Aerated concrete block

the envelope. This kind of material (shows in Figure 2-9) has low thermal conductivity, versatile lightweight compared with normal (ie: concrete) construction materials has a low density and excellent insulation properties. In winter, Hangzhou is extremely cold and humid and resident houses applied without hydronic heating system only rely on the air-conditioning cannot produce a thermal circulation around the rooms. Thus, materials with low thermal conductivity would efficiently reduce the heat loss in winter and resist moisture permeates into the inside, and it is significantly that saving energy.

- **Ventilation**

On the basis of Figure 2-9, the most winds come from the east because Hangzhou is influenced



by warm and wet current flowing from Pacific all over the year. Great difference between summer and winter as well as a large amount of precipitation contributes typical construction of Hangzhou village house. It specially can be seen that there are a lot of windows in each room, especially on southern and northern walls because direction of wind in summer is east-south, which is used for getting more ventilation in summer to reduce the indoor heat. The building envelope has good performance in thermal insulation; in this case, windows and doors have responsibility to ventilate. All almost village houses in Hangzhou are equipped with more than 10 doors and windows. However, reduction in opening the

Figure 2-9 Prevailing Winds in Hangzhou

windows in winter is especially necessary to reduce heat loss.

- **Shade**

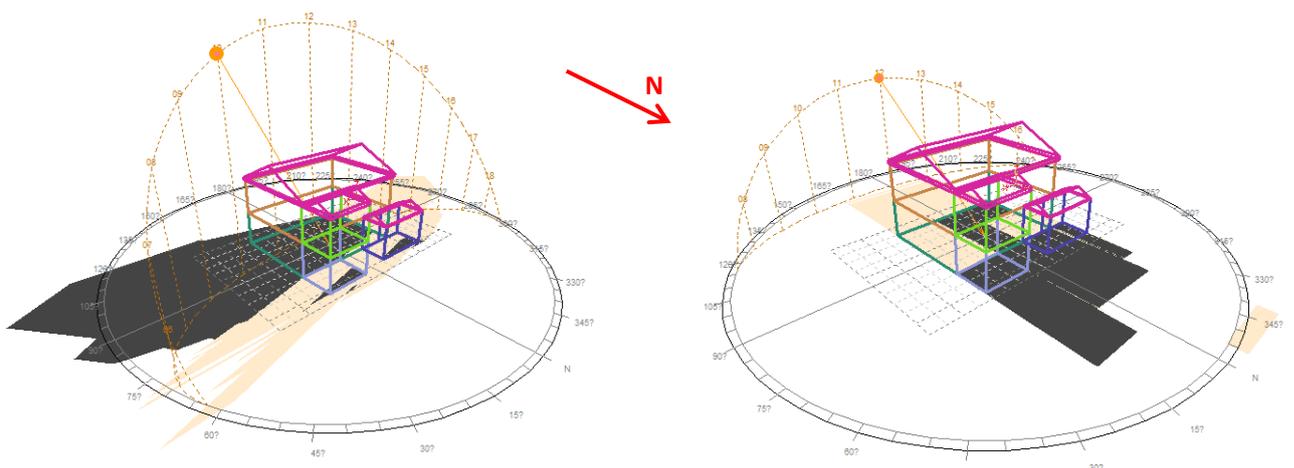


Figure 2-10 House model in shade (10am 22nd Jun & 12am 22nd Dec)

The above Figure 2-10 demonstrates shadows of house on summer and winter solstice. Hangzhou is located in the northern earth, when summer solstice it has the longest day in the whole year, on the contrary, shortest day on 22nd December. In the light of the temperature would reach more than 35°C, the max shading coefficient is about 83%; It is that using pitched roof to act sunshade to prevent sun rays taking into the room. On the other hand, sunlight in winter becomes more precious for people.

➤ Hot Tropical- Hainan Island (Sanya)

- Climate characteristic

Average Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average High (F)	77/80	78/82	81/85	85/88	87/91	87/91	87/91	86/90	81/85	84/88	81/85	78/82
Average High (C)	25/27	26/28	27/29	29/31	31/33	31/33	31/33	30/32	27/29	29/31	27/29	26/28
Average Low(f)	62/66	65/69	69/72	73/77	76/80	77/80	76/80	76/79	69/72	73/77	68/72	64/67
Average Low (C)	17/19	18/20	20/22	23/25	24/26	25/27	25/27	24/26	20/22	23/25	20/22	18/20
Rain (in)	0.2/0.3	0.2/0.3	0.3/0.4	1.3/1.4	4.4/4.5	7.3/7.4	8.3/8.4	10.1/10.2	0.3/0.4	1.3/1.4	0.8/0.9	0.2/0.3
Rain (mm)	5/10	5/10	10/15	30/35	110/115	185/190	150/155	210/215	10/15	30/35	40/45	5/10

Figure 2-11 Climate variables in Sanya

Sanya is one of cities located in southernmost China and has high-profile in Asia because of its tropical climate and has emerged as a popular tourist destination. Sunshine, beach, ocean and pleasant climate make Sanya attract tourists from all of world. With respect for the climate in Sanya, tropical monsoon climate is featuring very warm weather all year around. Owing to it is Seagirt Island, monsoonal influences are strong, affected a comparatively long wet season and dry season. From the Figure 2-11, the coldest month is January, average low temperature is 17-19°C, this is much higher than other northern cities in China, while the hottest month is June or July, the average high temperature is 31-33°C, it is warm and comfortable. Ocean water temperatures remain above 20°C around the year. Compared with southeast coast of China Sanya has appropriate rainfall capacity, average max precipitation is about 185-190mm. Summer is hot and humid, winter is warm and low temperature difference throughout all year.

- Housing case:



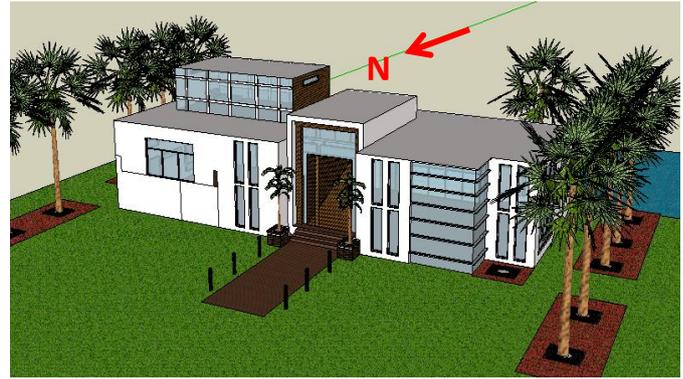


Figure 2-12 Sea view house in Sanya

In Sanya, the most typical dwellings is sea view house, there are a number of features and different characteristics relatively on basis of local climate.

Characteristics:

Area: 120m² (approximate)

Location: South of Sanya (near the sea)

Building height: 4.5m

Building material: Steel concrete frame

Architectural form: Detached House

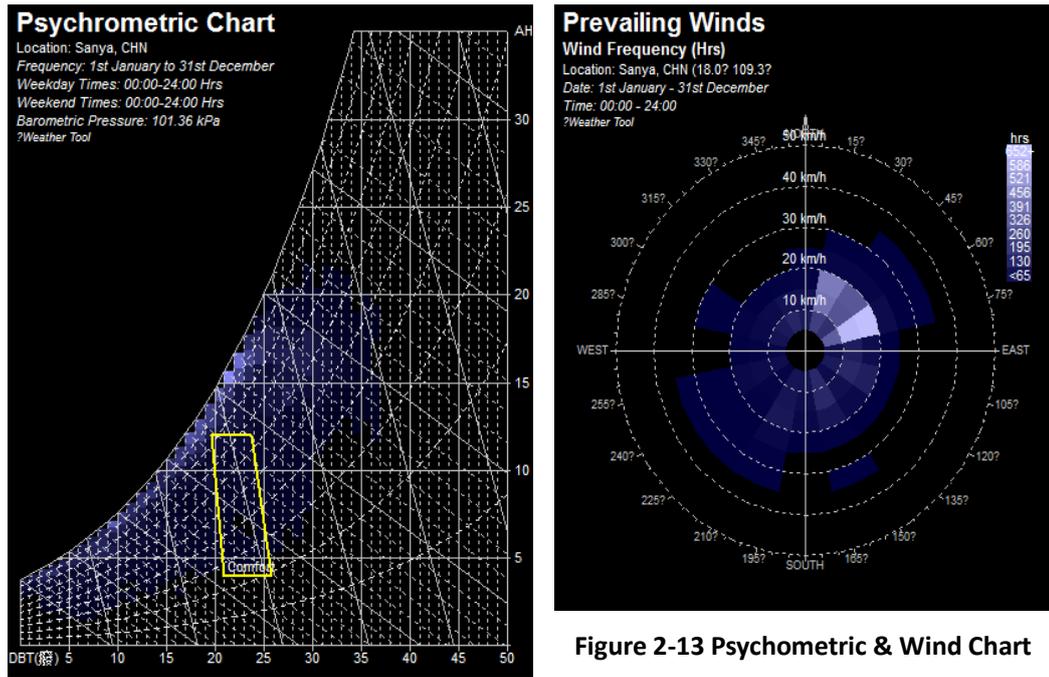
Orientation of house: South-north

● **Psychometric & Ventilation**

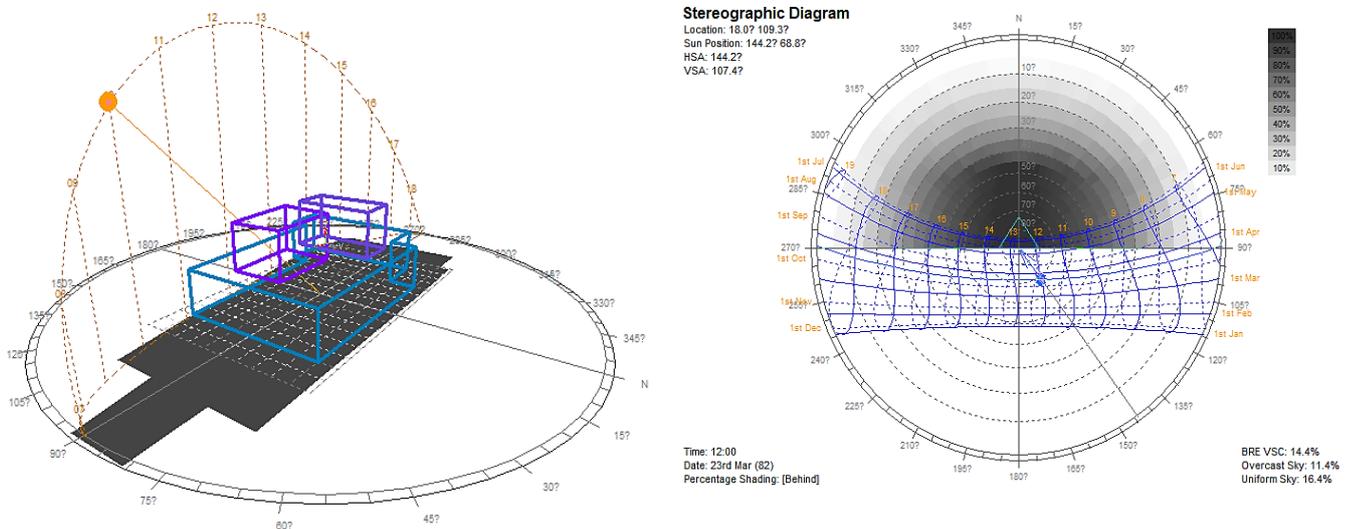
From the above pictures, it is clearly found that nearly each wall applied with French windows. For the one thing, they are provided for occupants enjoying the beautiful scenery in all perspective; for the other thing, the benefits of large-scale windows can ensure sufficient natural daylighting, which can directly the electricity consumption.

On account of house facing to the ocean, sea breezes directly pass through windows to increase internal humid and produce a comfortable cool indoor environment. In accordance with Figure 2-13, it show average comfortable zone is between 22-27°C, annual wind frequency at similar level (25km/hours)to create a balanced ventilation.

Under this condition, almost cooling system is depended on natural factors that efficiently minimizing HVAC system working time so that energy consumption greatly reduced. Moreover, flat top roof of sea view house is another feature should be considered. Hot tropical climate produced a lot of hot humid air flow from the sea, designer can specifically use this climatic feature to allow airstream easily flow through the flat roof. In this way, it is effectively cooling the whole house



● **Shade**



Sanya city, the area south of the Tropic of Cancer located on low latitude, thus, it has a very high solar altitude that is causing ground to absorb much more heat from the sun radiation and remain a high temperature in the air. That is why Sanya as a place where it is always summer. Furthermore, thanks to the high solar altitude, there is less necessary for sun-shading measures protection from sunlight. Additionally, in the light of the stereographic diagram, shades only concentrate on short time (12am to 2pm). Therefore, in this house, this is barely sun shield other components. Next, similar warm temperature also keeps small indoor and outdoor temperature difference to reduce the heat or cooling loss and energy consumption.

➤ **Discussion and suggestions**

From the above analysis of each housing case in Guangzhou, Hangzhou and Sanya respectively, they all have advantages and somewhere need to improve. Different climates response differently to buildings, however, it is crucial how to use local climatic features to make house more sustainable and reduce energy consumption. No matter what the analysis of ventilation, shading and other thermal conditions, they all provide evidence to deeply understand the energy conservation in these houses. As for somewhere need to improve, this report will give some suggestions to solve this problems and promote building energy efficiency

• **For Guangzhou:**

Guangzhou is one of first-tier cities in China, the effects of high urban density and a large number of populations lead to the 'heat island' phenomena as result high temperature and resistance of air movement in the city. The following suggestions would relieve this condition.

1. Air temperature generally decreased with increasing wind speed. This observation suggests that lower air temperature and higher wind speed to create a thermal neutral environment to release the heat stress in summer.
2. To improve the Guangzhou wind environment by remain the wind speed at 1-1.3m/s through the buildings.
3. To optimize the placement of residential buildings in a neighborhood, and provide enough space between each building for air flowing. It can significantly increase area of ventilation. To reduce solar radiation gains via building envelope and windows by installing shading devices.
4. Trees, shrubs, flower beds and grass areas are effective to reduce sensible temperature by the evapotranspiration.

5. To enlarge indoor and outdoor area of greening is an effective and sustainable method to make comfortable environment and Purify air.

- **For Hangzhou:**

Hangzhou village house conducts several passive measures such as natural ventilation, sun shading and thermal insulation of the building envelope contributes to the climatic response of the building. It is available using passive design to achieve energy saving. There are some advices to strengthen energy conservation in this house.

1. The building design more windows on the windward side, the utilization of buffer spaces, for example, the inner veranda to promote natural infiltration.
2. Village is more spacious than urban that leads to heat loss more serious. Double-layer building envelope made up of external materials with low thermal conductivity and internal wooden walls and other local sustainable resources. This can prevent solar radiation during summer and heat preservation during winter.
3. If conditions allow, the manmade water pools surrounding the buildings contribute to optimize the external thermal environment through the way of evaporative cooling.
4. Attic design can provide thermal insulation for the whole living spaces in hot summer as well as it can act as a buffer space during cold and humid winter days to conserve the heat inside for a long time.

- **For Sanya:**

Sanya is different from Guangzhou and Hangzhou, marine environment play an important role to influence the local house characteristics. Thus, utilization of ocean climate would effectively improve housing energy conservation. There are several suggestions would help improve building energy efficiency.

1. The best orientation of house is south-north or southeast-northwest within 15 degree and opening area of window should not be less than the total area of 45% to make good use of warm airstream from the Pacific and South China Sea to create an air circulation around the indoor rooms.
2. Energy-saving materials related with hot tropic climate should be used widely to reduce heat loss and unnecessary energy cost.
3. Green roof is a popular method to chill the interior temperature. Besides, Sanya

is rich in natural resources, using natural plants built in the surrounding place to cool is easily and available.

4. More low-rise building to avoid the high solar altitude cause not enough day lighting in the room.