GR 21. HWK02 - VERNACULAR ARCHITECTURE

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1. Introduction

Some would simply define vernacular architecture as 'architecture without architects'. American architect Frank Lloyd Wright defined vernacular architecture as 'folk building growing in response to actual needs, fitted into the environment by people who knew no better than to fit them with native feeling'.

Characteristics of vernacular architecture are as below:

· Use of traditional or locally available construction skills

· Use of simple technology and commonly available materials

· New structure with old techniques' as experiment and innovation are costlier than repetition

· Evolved slowly through numerous experimental trials and errors instead of specifically designed by a professional

· Functionalistic and simple design which fulfils basic needs of the people

· Born of people's needs, culture, tradition and adapted to local climate

1.1 Case Study 1(ISFAHAN) :

BRIEF

> Isfahan is a large city located in the centre of today's Iran plateau. It's not well known when exactly Isfahan was established as a city but it grew considerably from the early 11th through the 18th century. A number of Isfahan's monuments designated by UNESCO. along the river runs through the city many bridges constructed which most of them are representatives of Safavid era's architecture style.

CLIMATE

The mean annual rainfall of western region is 800 mm, while it is about 75 mm in the eastern arid region. The average coefficient of variation (CV) of rainfall in the province is 34%. Winter and fall rainfall consists of 48.4 and 27.6% of total annual rainfall, whereas it is 23 and 1% for spring and summer season, respectively. The average maximum temperature in the province varies from 16.2 to 28.2 °C and the average minimum temperature varies from 6.3 to 1.1 °C. July and August are the warmest and January and February are the coldest months of the province.(Nasiri and Modarres, 2009)

As it can be inferred by the monthly average of temperature Isfahan has the cold winter and hot summer with a sudden increase in global and diffuse radiation monthly averages up to 0.15(kWh/m^2) in summer.

Figure 1: Designed by the authors

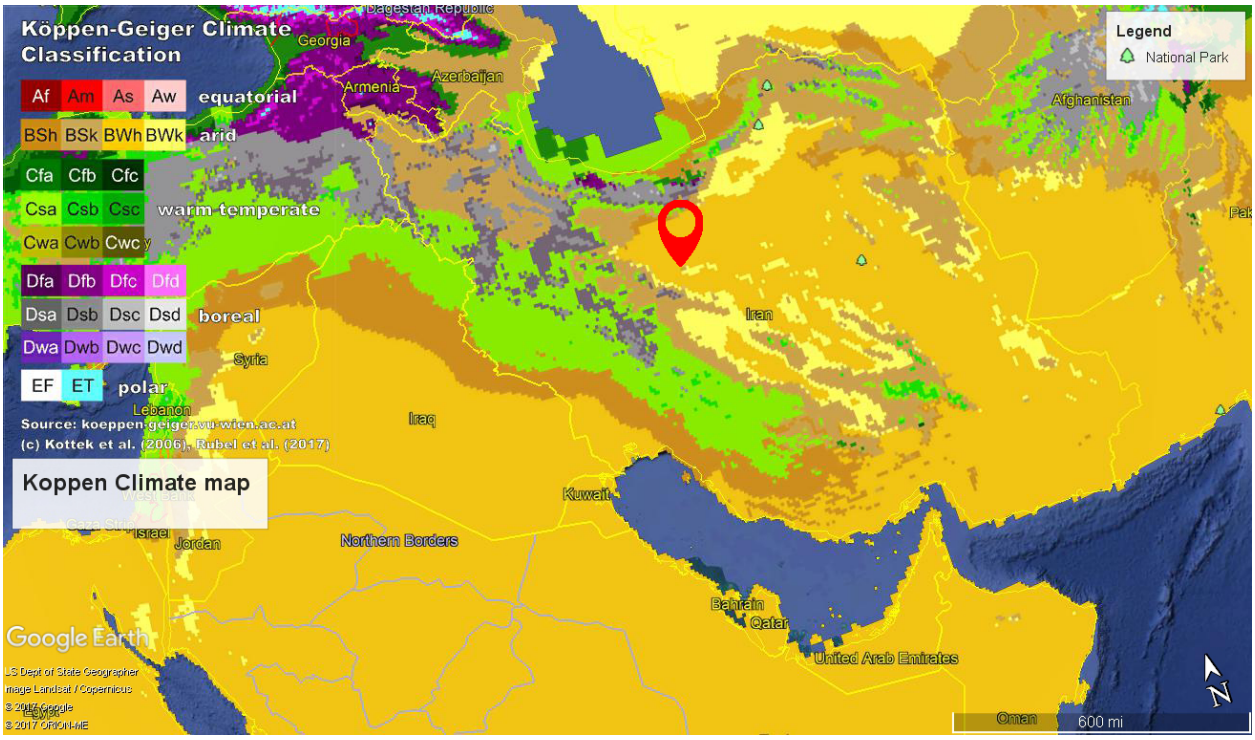


Figure 2: Koppen climate map(Iran-Isfahan)

TOPOGRAPHY

The topography within 3.2 km of Isfahan contains only *modest* variations in elevation, with a maximum

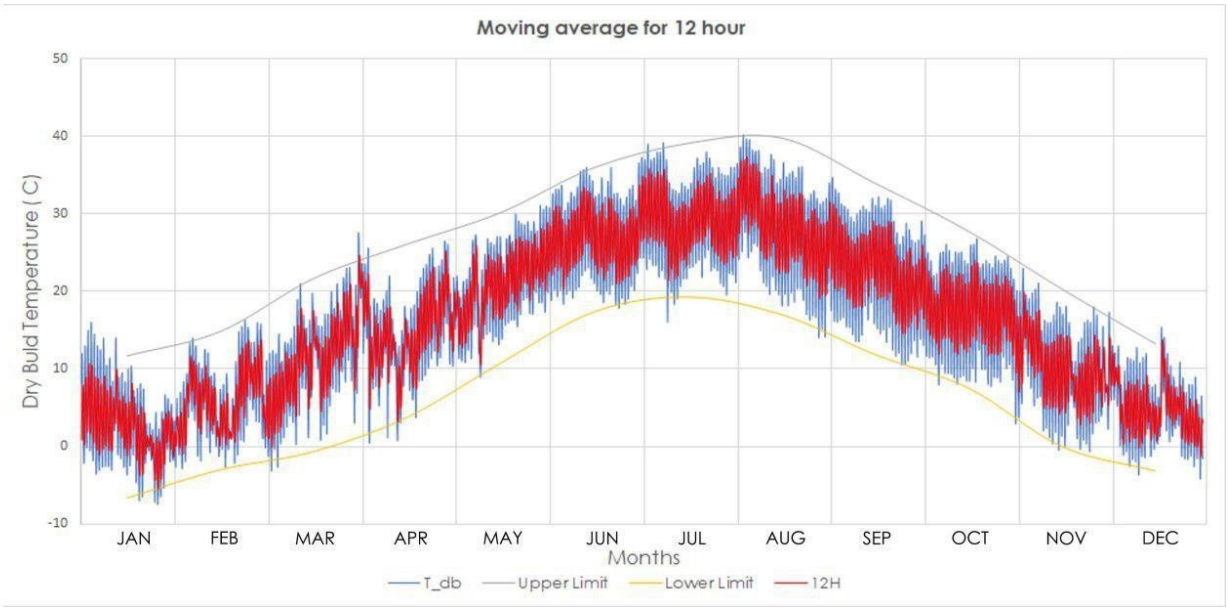


Figure 3: Designed by Authors

elevation change of *0.03 km* and an average elevation above sea level of 1.57 km. Within 16 km contains only *modest* variations in elevation (*0.7 km*). Within *50 miles* contains large variation in elevation (1.84 km).

The area within 3.2 km of Isfahan is covered by *artificial surfaces* (*95%*), within *16 km* by *artificial surfaces* (*49%*) and *shrubs* (*19%*), and within 80.5 km by *shrubs* (*51%*) and *bare soil* (*22%*).(spa)

COMFORT ZONE

According to the 19th chapter of Iranian national building Laws and regulations, the comfort zone temperature is defined in the range of 20 to 28°C for summer and winter. The Heating Degree days temperature set Point is 18°C and for Cooling Degree days is 21°C.(law's Office, 2002)

VERNACULAR ARCHITECTURE MODULES

Vernacular architecture of Isfahan as most of the arid regions of the world are well recognized by introverted atrium houses which forms the core of the house not only as the climatic moderator but also generating private lifestyle.

Atrium adobe house represents a huge interwoven shelter structure which all the windows and opening face an internal courtyard to control the heat loss and sun penetration and reducing the surfaces facing the hot winds. dense organizing the blocks generate narrow winding streets which are covered and supported structurally by groins. The main streets in the town face the direction of the prevailing wind.

TRADITION

There is a strong belief in that which according to what noble Quran wars the Muslim the territory and privacy of should be respected by the others which can be realized through introvert courtyard houses. The main characteristic of this architecture are as follows:

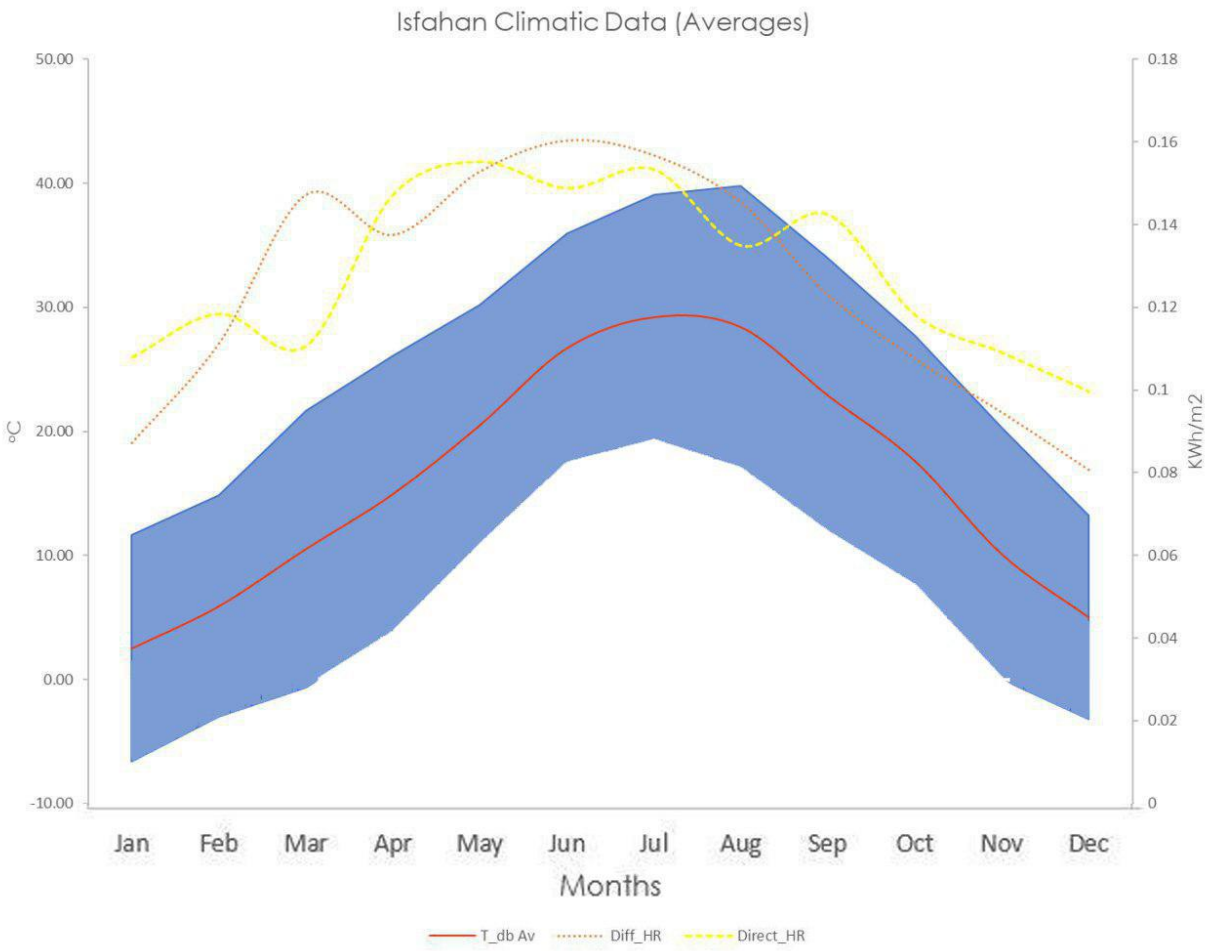


Figure 4: Drawn by the authors

It's hidden - another term is "the architecture of the veil"

- A traditional Islamic house is built around a courtyard and shows only a wall with no windows to the street outside
- It thus protects the family, and family life from the people outside, and the harsh environment of many Islamic lands - it's a private world
- Concentration on the interior rather than the outside of a building - the common Islamic courtyard structure provides a space that is both outsides, and yet within the building(arc, b)

GEOMETRY

As said before the most preferred house plan is central courtyard one. The building is made of different elements which are representative of the vernacular architecture of that specific region such as:

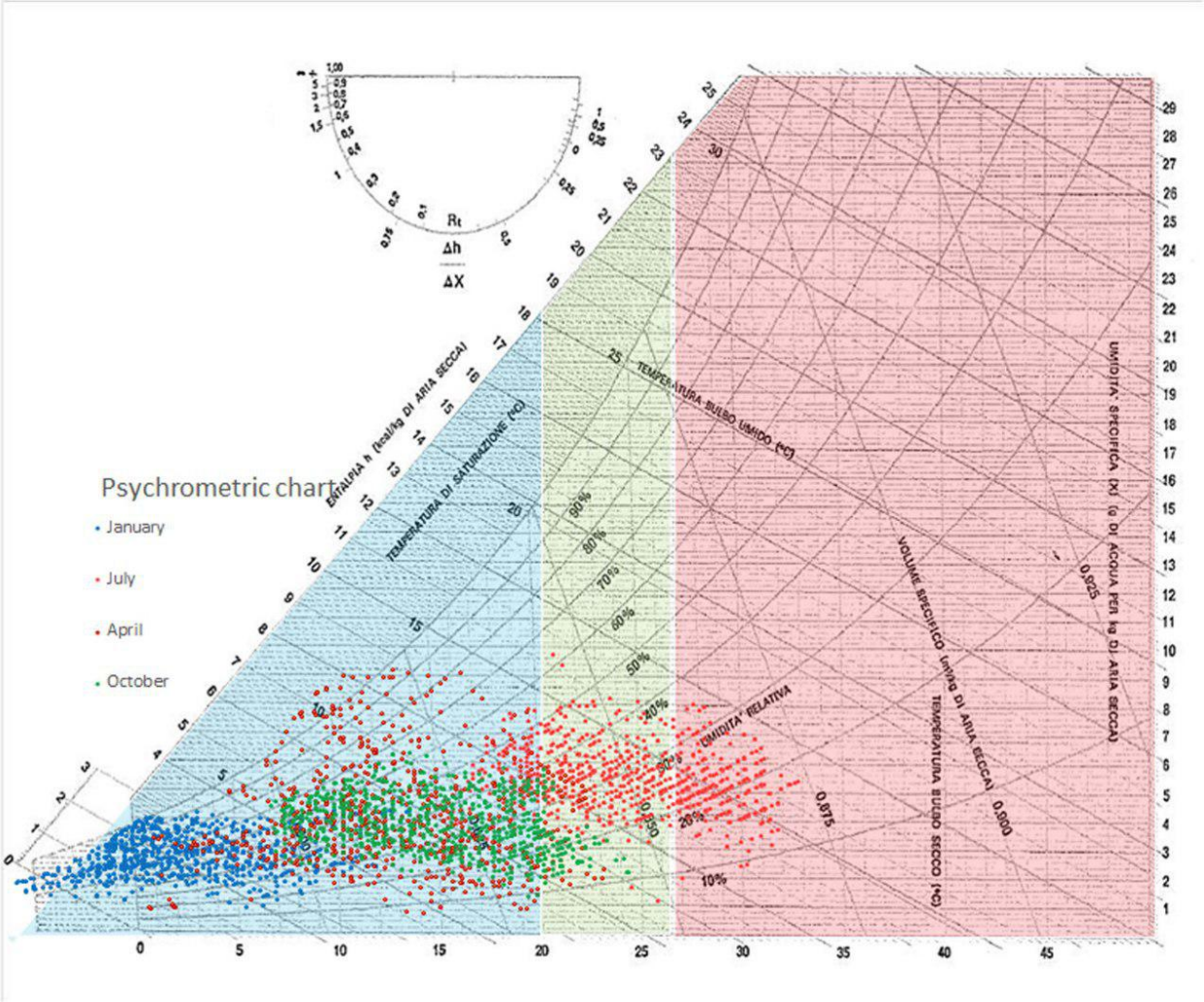


Figure 5: Designed by Authors

1. *Thick walls*

By increasing the thickness of the wall and increasing the mass, thermal inertia increase. throughout this strategy the heat absorbs through exterior facade in summer and interior spaces in winter can't be transfered easily.

2. *Central court yards*

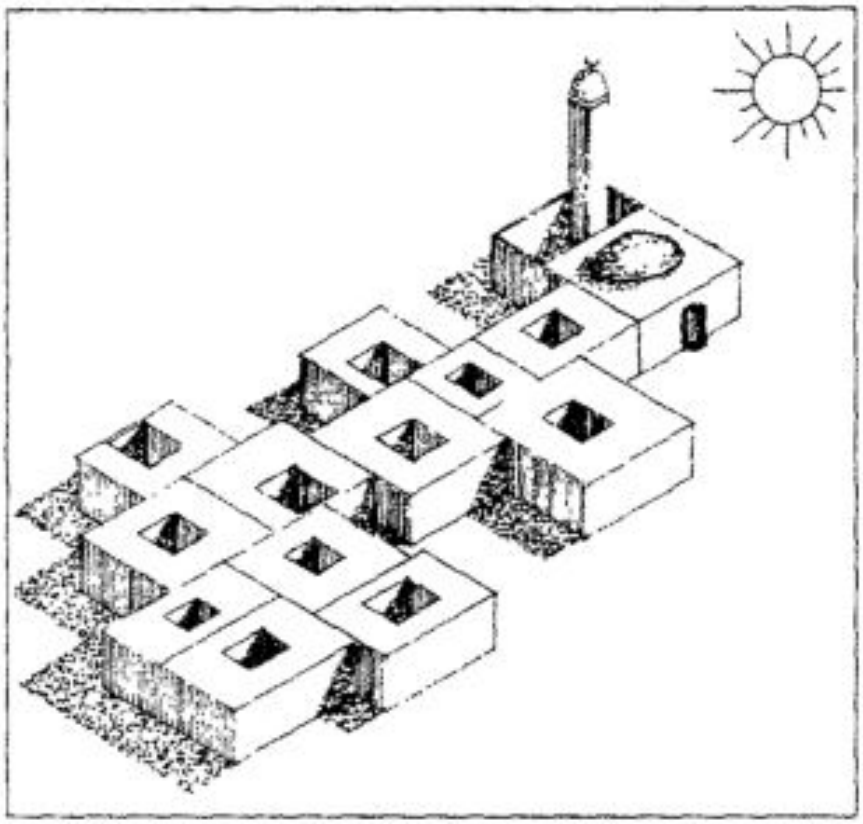
By the help of vegetation and pool inside the courtyard, evaporative cooling helps to decrease the temperature and by the height of the walls surronding the courtyard, shady area can be obtained and the open areas will turn to a fuctional space during the hot days of the summer.

3. *Wind towers*

To rendering inside temperature more pleasant and using the cool streams of the air in higher level, this strategy applied to the houses. the height, opening and openings of the wind towers changed according to the location and height from the sea level. The air trap operates in response to the condition of the wind and sun radiation in the region. The inside and outside walls absorb a lot of temperature during daytime. As a result they cause a balance of temperature at night and bestow the attracted warmth to the cold night air. The thickness of the air trap walls and the dimension of the holes inside it are designed in a manner to allow enough heat to be transferred for better comfort. The light warm air inside the air trap ascends and is sucked away at the upper elevation. As a result cool air flows from windows and doors into the house and continues all night. (Kamyar Tolou Behbood)

4. *Large windows*

In most cases, the windows and doors are installed in the northern and southern sides of the buildings, and thus, encourage a good air circulation. The south walls have more windows that promote the introduction of winter sun (Fatemeh Bigbani



Closely-knit community remains protected from the sun by shades and shadows

Figure 6: (Bena'a, 1999)

Figure 7: (hay)

Figure 8: (Kamyar Tolou Behbood)

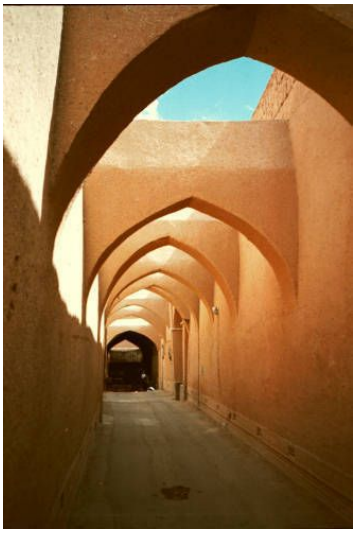


Figure 9: (arc, a)

MATERIAL

the most used material in the vernacular housing in this region is known as the COB. Cob is an ancient material, which is a combination of sand and clay, mixed with straw and water.

Production of Cob: The production of cob involved three stages:

1.Preparation f the soil mix

2.Compression of the soil mix

3.Curing the COB

Figure 10: (Bena'a, 1999)

Mixing cob material in place from the excavated construction site helps to build a monolithic wall. Indeed, the building sector is one of the largest consumers of natural resources. It also generates large amounts of waste and produces greenhouse gases that participate to climate change. Embodied energy together with operating energy of the building sector represents approximately 40% of global energy use.(Hamard, 2016)

Adobe is able to absorb heat during the day keeping the house cool and then release this stored heat at night, warming the interior of the house. This behaviour is due to the high specific heat capacity of adobe which is an important factor that allows this material to reduce the thermal gradient of earthen houses (Parra-Saldivar and Batty, 2006). On the other hand, the ability of Adobe to conduct heat is highly dependent on its moisture content, with a strong relationship between water content and heat conduction (Rees *et al.*, 2001).

Type of adobe	Thermal conductivity (kW/m/K)
Fired adobe (Viviancos *et al.*, 2009)	0.244
Concrete brick (Viviancos *et al.*, 2009)	0.627
Adobe with straw (Goodhew and Griffiths, 2005)	0.180
Adobe (Goodhew and Griffiths, 2005)	0.240

Figure 11: (J.D. Revuelta-Acosta and Rico-Garcia, 2010)

CASE-STUDY ANALYSIS

In here we analyzed 3 different cases in the same climate and region of Isfahan province. all the houses are the introverted courtyard and followed the same method for constructing the vernacular houses in the Hot&Arid climate. according to climate components which are known as the main obstacles to overcome and also the strategies mentioned in the table below.

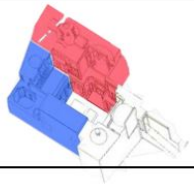
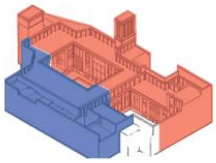
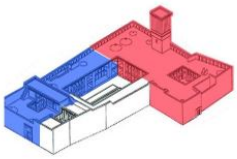
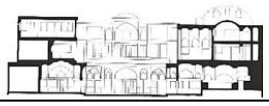
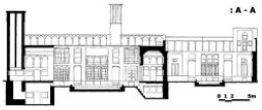
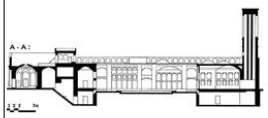
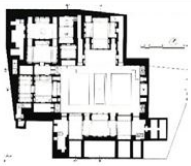
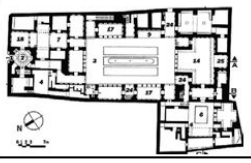
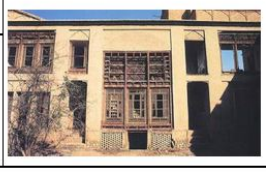
Climate Component	Architectural Strategies	Abasi	Gerami	Godarzi
The temperature Variance between day and night	high thermal capacity material(COB)			
The use of heat capacity of the soil to air cooling	the ground floor level lower than the street			
Enhancement of air turbulence	high ceiling wind tower oriented towards the prevailing wind			
Increasing indoor heat in winter	dense settlement pattern large windows in the southern front			

Figure 12: Isfahan Vernacular Architecture and their climatic strategies 1

1.2 Case Study 2 (MACAU) :

Macau, China

BRIEF

Macau is an autonomous region on the south coast of China, across the Pearl River Delta from Hong Kong. Due to its geographical location near the sea, the Pearl River Delta, and ports like Hong Kong, the area has been exposed to a century-long cultural and commercial exchange. Likewise, traditional vernacular architecture of the area responded to the hot and humid subtropical climate in many ways, such as with large porches and archways, natural cross ventilation systems with special perforated bricks and roof structures to let air move through the building, and mobile shading systems of bamboo wicker. The vernacular architecture typologies followed the micro climate of the regions.

CLIMATE

Through history climate has posed a lot of problems on design flexibility. The harmonization of both parameters result in a successful craft work. The modern architectural postulate that states that “form follows function” is contrasted by the postulate of ancient Chinese architecture; “Form follows climate and culture”

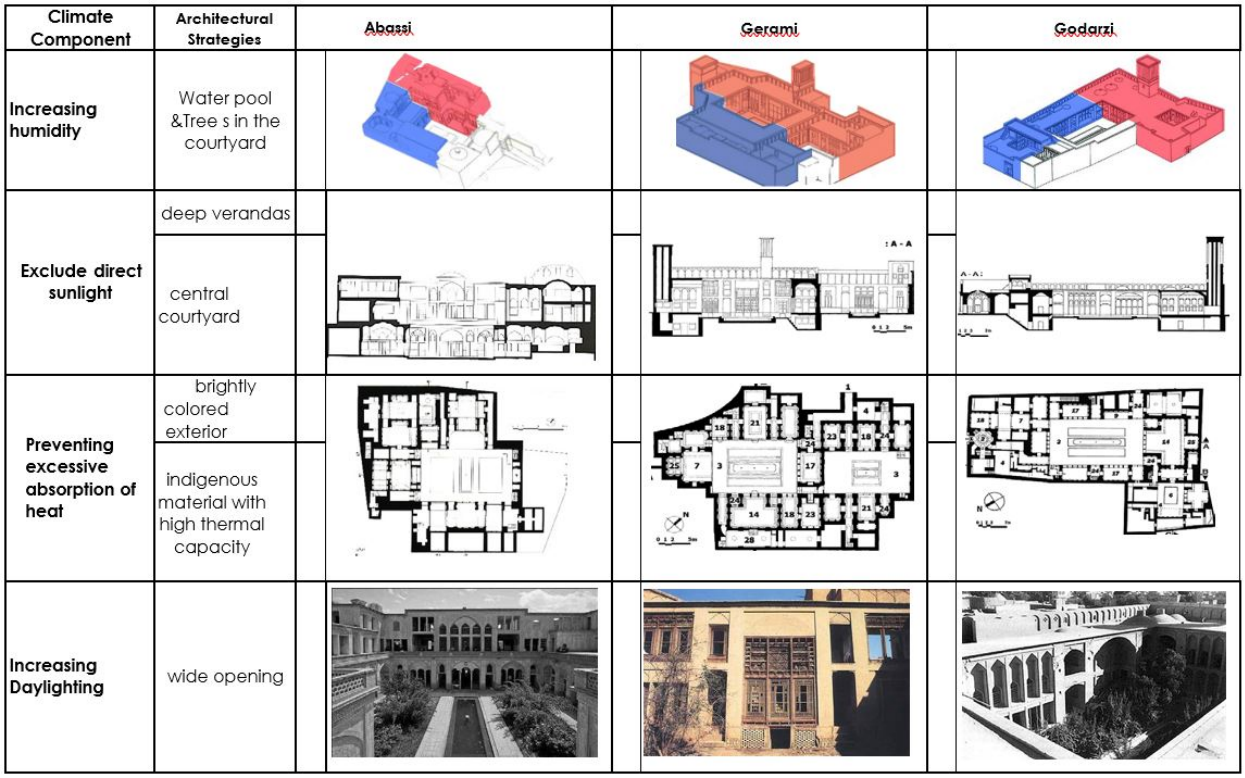


Figure 13: Isfahan Vernacular Architecture and their climatic strategies 2

The climate of china is divided into tropical, subtropical, warm-temperate, temperate, cold-temperate, and Qinghai-Tibet Plateau temperate zone. The behavior varies from region to region based on the latitude and the monsoon direction. Macau is located in the semi tropical climatic zone characterized by the hot and warm summers where tropical winds dominate and mild winters.

Average Yearly Distribution

From the hourly dry bulb temperature distribution of the year of Macau we can observe a typical hot summer mild winter climate. The trend moves from a moderately lower hourly value from January to march and suddenly rises in mid-April through with the peak in July and starts to decline from mid-September. The monthly average curve of Macau displays a moderate climate recording a minimum of **14.54 oC** during the cold months and a maximum of **28.87 oC** in July during the hot months. Also, the variance of the monthly averages for the hot and warm seasons are very minimal .

It can be observed from the upper and lower limit graphs that Macau has a more moderate temperature as their trend shows a lower deviation from the mean values

As can be observed from the plot the direct solar radiation is generally higher than the diffused throughout the year, only some few days in January, February, June and July indicates otherwise. The reduction in the direct part of the incident radiation indicates a cloudy climate during the hotter months. The average daily global solar radiation values show a more uniform pattern for Macau city zone.

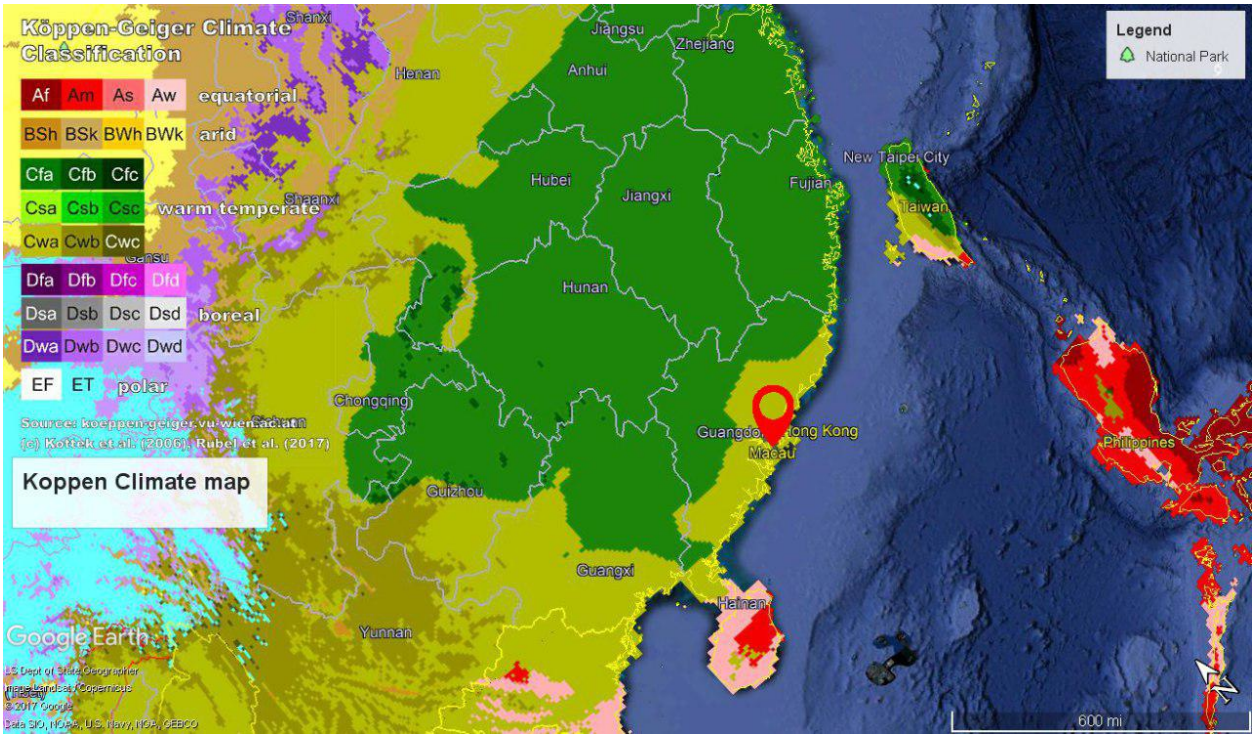


Figure 14: Koppen climate map(Macau)

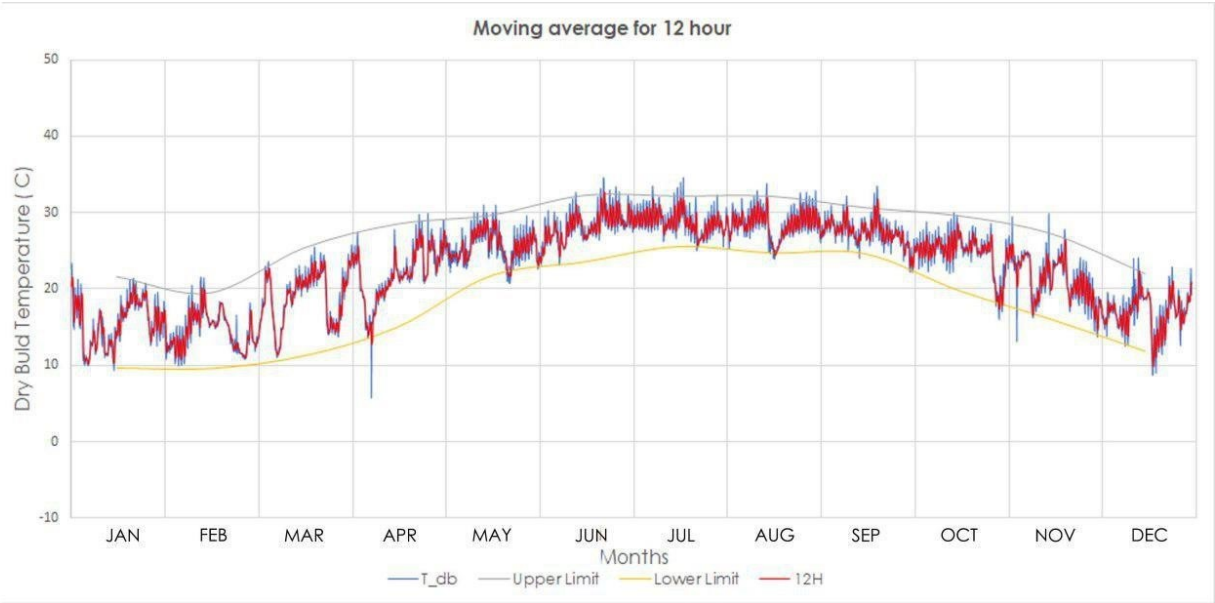


Figure 15: Designed by Authors

TOPOGRAPHY

The eastern plains and southern coasts of the country consists of fertile lowlands and foothills, and is the loca-

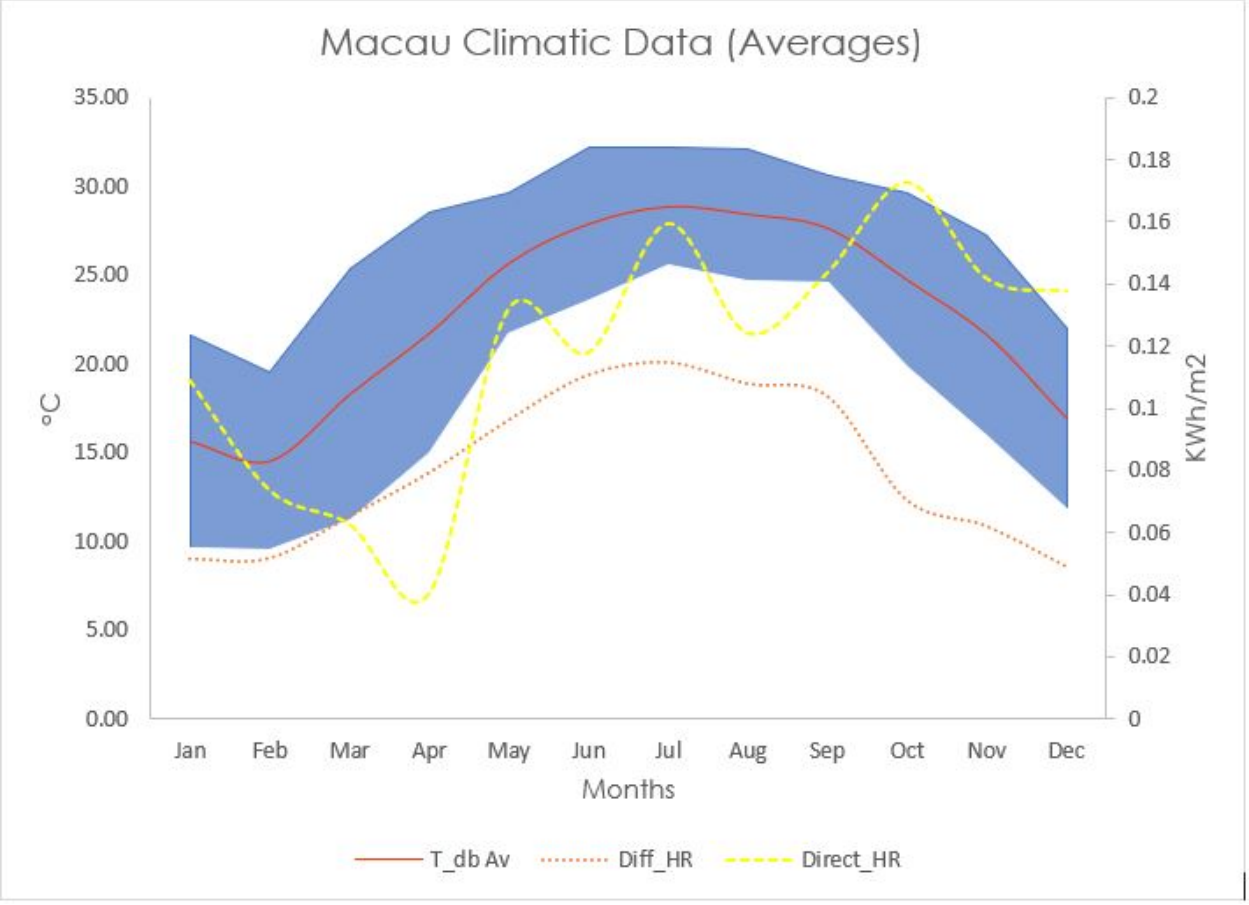


Figure 16: Designed by authors

tion of most of China's agricultural output and human population. Macau lies in the southern coastal region. The southern areas of the country (South of the Yangtze River) consists of hilly and mountainous terrain. The west and north of the country is dominated by sunken basins (such as the Gobi and the Taklamakan), rolling plateaus, and towering massifs.

COMFORT ZONE

According to the Design Code for Residential Buildings GB50096-1999 , the comfort zone temperature S is defined in the range of 16 to 29°C for summer and winter periods.(Sun, 2013)

VERNACULAR MODULES

The Chinese Ancient Architecture is based on the interplay of history and culture. Its evolution begun with the primitive societal module in timber work with stone carving, rammed earth construction and bucket Arch building. However, with time new materials such as bricks and tiles were discovered, which improved the technology of the industry. The significant Architectural technologies were developed during the Wei, Jin, Southern and Northern Dynasties (220-534). The Sui and Tang dynasties employed the use of bricks creating a peculiar design pattern during this era. The Song dynasty improved on these concepts by introducing a more aesthetically pleasing and complex modules. These designs ranged from pavilions, multi storey, palaces and terraces. The Yuan dynasty also was characterized by the Tibetan Buddhist temples and Muslim mosque.

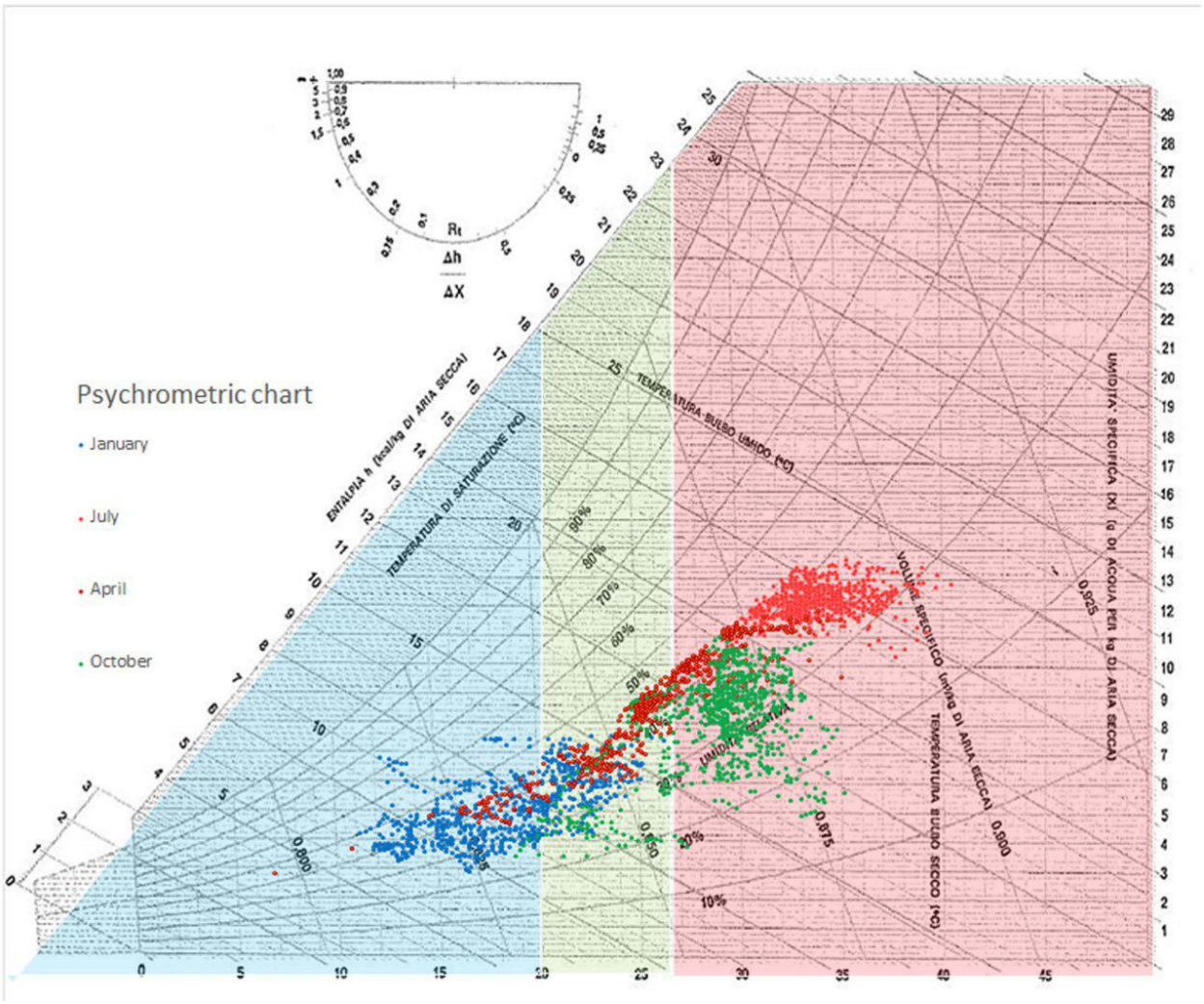


Figure 17: Designed by Authors

The peak of ancient architecture in china was during the period of the Ming and the Quing Dynasties. Technologies were discovered to increase the production of bricks and glazed tiles in large quantities. The Builders also perfected their craft and improved on their services. The ancient architecture of china was never stereotyped but showed diverse choices based on climate culture, materials and topography

A variety of vernacular dwellings were distributed throughout china based on the regional climatic distribution culture materials and prevailing security condition. The forms were categorized into courtyard, caved and wood storey. The South-eastern part which is characterized by three major vernacular architectural structure are explain below.

The Round and Square (Yuanlou)

Geometry

The Tulou structures were typical dwelling in the south-eastern part of china where Macau is located. They were large modules built up to five or six storeys usually housing over 80 families. The floor plan was usually square or round with central courtyard and one entrance. The walls were thick with dimension ranging from

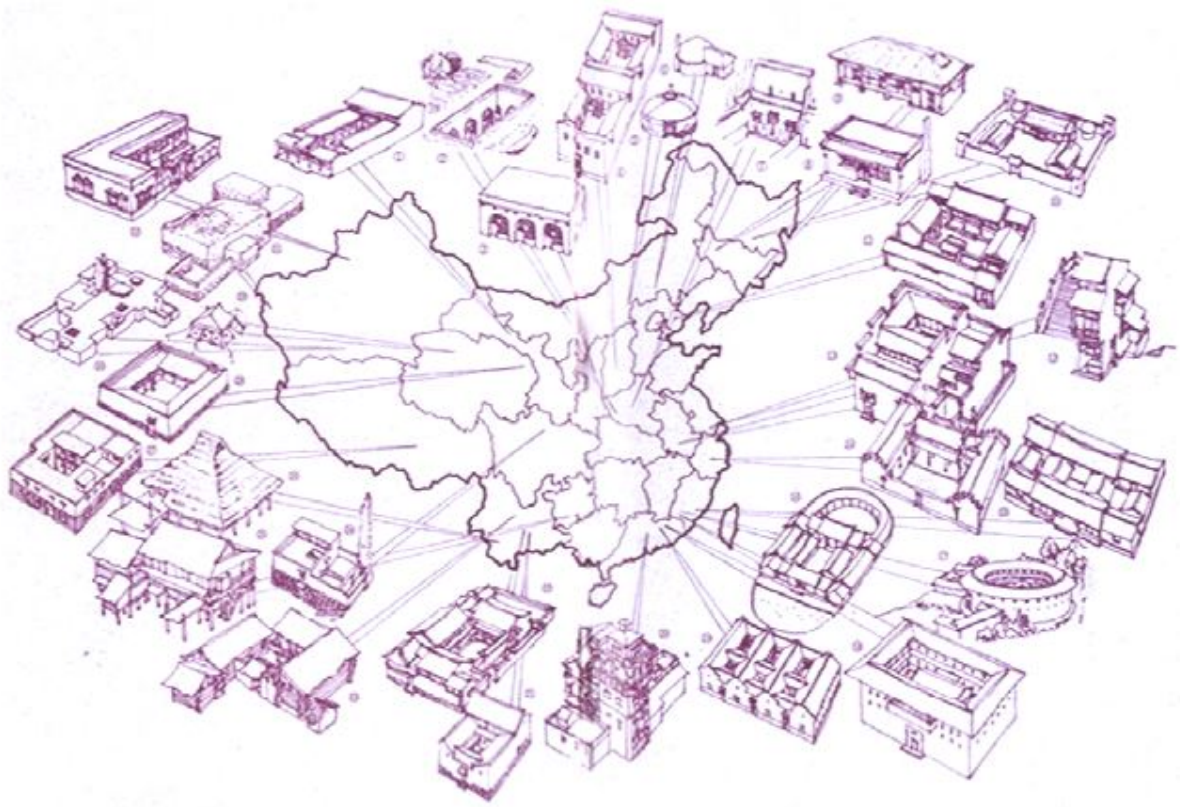


Figure 18: (Sun, 2013)

Figure 19: Hekeng Tulou Fujian, (chi)

1.8 meters to 3 meters. The shape and inward-looking orientation depicted a security tool to fight the high level of vandalism in that era. The Tulou structures could house an insanely high number of people and they were referred to as "Little Kingdoms". The base walls had the highest thickness about 6 meters and reduces as the storey increased in height.

The Material

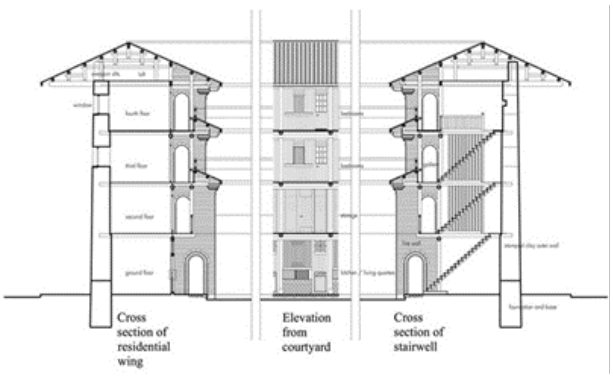


Figure 20: Southern China (Plan & Section), Source: Michi Bier,"Asian Dwelling-A Typology" published in 1991

The Tulou is a Chinese name for mud, signifying the dominant material used for this type of construction. The structure was made up of rammed earth, mixed with stone, granite, bamboo, and wood. (Sun, 2013)The choice of these materials was based on how readily they were available, their thermal inertia and how ease they were constructed.

SIHEYUAN DWELLINGS

Figure 21: Source: World Expo 2010 Shanghai, Siheyuan (Courtyard Dwelling) of Beijing,June 11, 2010

The Siheyuan Dwellings was a conventional residential building type which was adopted in the north and subsequently spread throughout the country because of its climate responsiveness. It consisted of a square outline with a central courtyard opening enclosed by rooms. They were usually low-rise settlement and usually form alleys, which link together the interior of a city. Since alleys are usually straight and run east-to-west, houses can face north and south. The structure had corridors and overhanging roofs as a solar shading device. (Sun, 2013)

The courtyards is made up of pathways, trees, lawn, water pools which provides passive strategies to enhance the thermal comfort of the zone. The original Siheyuan consisted of four house enclosed as one model. The walls were made of brick, 370mm thick to serve as heat storage and the walls were also perforated for cross ventilation.

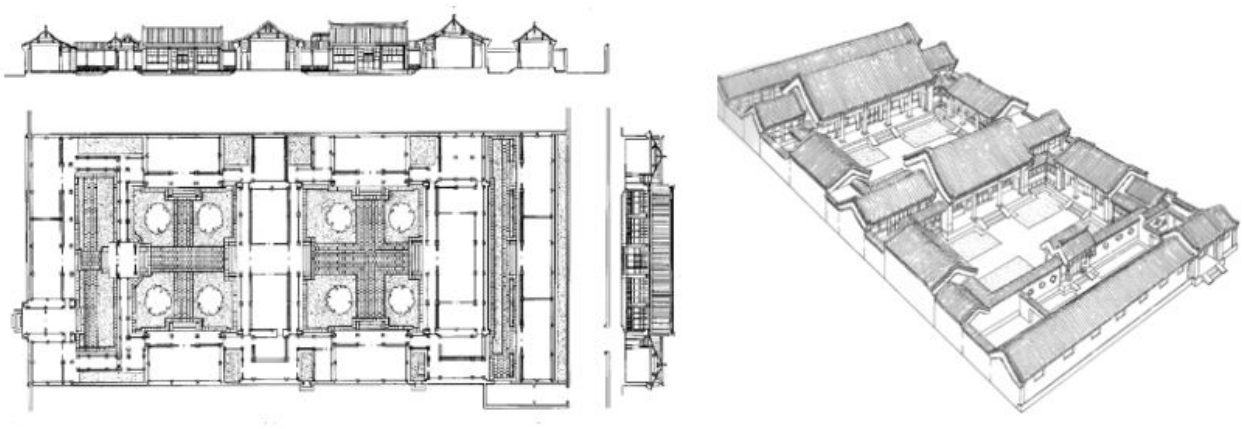


Figure 22: Plan & Sections of Typical Siheyuan (Sun, 2013)

The Material

The walls of the Sihayuan was constructed in bricks with light or reflective colours. The windows were made of single glazing rice paper with sealed frame. The interior doors and entrance gateways were constructed in paneled solid timber. The materials selection was based on availability and the craft familiarity.

Figure 23: (Sun, 2013)

The Siheyuan construction was built with regard to the principles which optimize the sun exposure, while offering a protection against the North winds, the former rules which match up to the location of the Chinese houses.On portions of the Loess Plateau in the province of Shaanxi and the South of Shanxi, the siheyuan could take the shape of a series of caves around a excavate courtyard or around troglodytic houses on the hillside.(Sun, 2013)

HUIZHOU DWELLING

Geometry

Figure 24: Huizhou Style Dwellings by the Moon Pool, source: Chinese travel tips, Hongcun village, March 30th, 2011

Huizhou was in the sinuous mountain area of southeast China. They usually are situated with their backs and sides embraced by overlapping ranges of verdant mountains and their front facing east towards meandering streams. The geometry was designed in this way to shelter their villages from the cold prevailing winds blowing from the north.These dwellings characterized by multi storey compact form with high fortress like external walls. Openings and windows were absent at the interior building space. The perimeter walls were capped with step gables with a zig zag shape. These massive walls were constructed to provide a substantial amount of security and privacy of the occupants

The Huizhou had a skywell locally refered by the indigiants as Tianjing. These were the only openings to the interior to allow natural lighting, ventilation and rain harvesting.

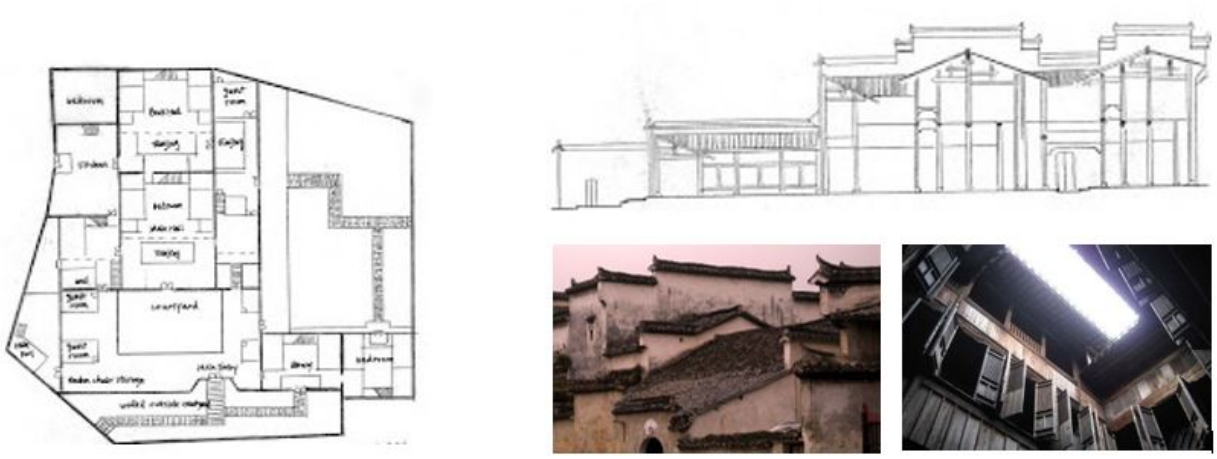


Figure 25: (res)

The Material

The walls of the Huizhou was in brickwork manufactured locally by these builders. The walls were coated with white plaster as a reflected tool for the global solar radiation on the surfaces.

The structure was decorated in wood, brick and stone carvings. The wood carvings were used to support the beams .The stone carvings as shown in the figure were located at the spandrel and partition wall areas

Figure 26: (Sun, 2013)

CASE STUDY ANALYSIS : CLIMATIC RESPONSIVE PASSIVE STRATEGIES

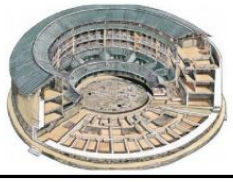
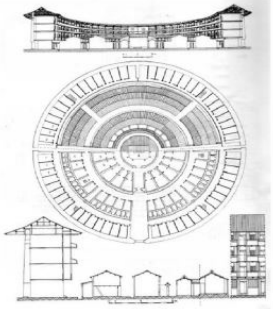
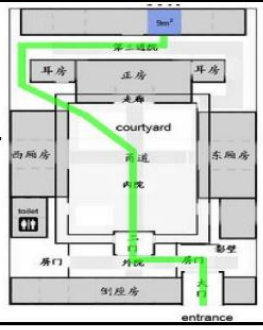
Climate Component	Architectural Strategies	ROUND DWELLING (YUANLOU)	SIHEYUAN DWELLING	HUIZHOU DWELLING
The temperature Variance between day and night	high thermal capacity material(COB)			
Enhancement of air circulation	High ceiling			
	Open corridors			
Increasing indoor heat in winter	Dense settelment pattern			
	Large windows In the south and skywell			

Figure 27: South East China Vernacular Architecture and their climatic strategies 1

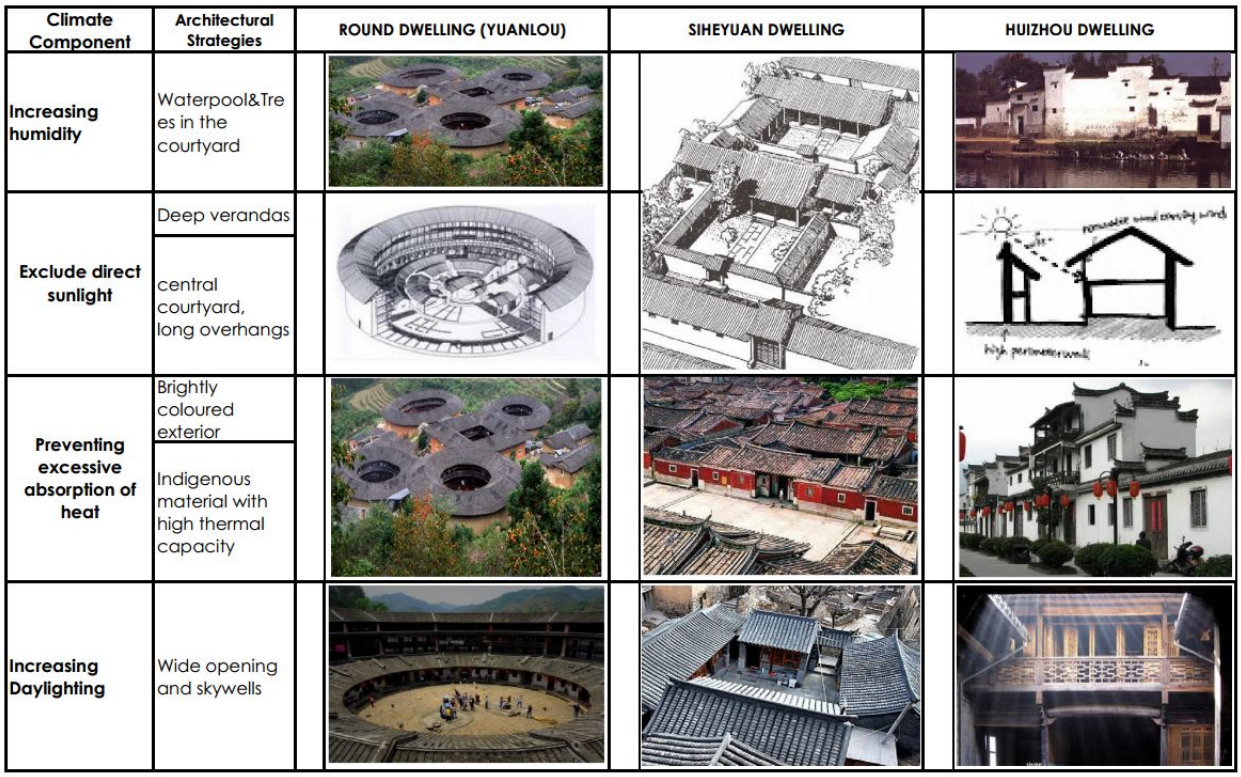


Figure 28: South East China Vernacular Architecture and their climatic strategies 2

2. Watson & Lab MAtrix Analysis

The Watson & Lab Matrix was used to analyse the passive strategies these vernicular builders adopted to minimize the energy needs for heating, cooling, ventilating and even illuminating the indoor spaces . Macau lies in the subtropical climatic zone as indicated in figure . As a result is characterized by hot summers and mild winters. The passive strategies used by these vernacular designers for this particular area was focused on the hot season. The Watson&Lab in figure 1 illustrate the strategies adopted by the local builders to guarantee the comfort zone in the dwellings.

2.1 Case study 1(Isfahan)

2.1 Case study 1(Macau)

Macau lies in the subtropical climatic zone as indicated in figure 12. As a result is characterized by hot summers and mild winters. The passive strategies used by these vernacular designers for this particular area was focused on the hot season. The Watson&Lab in figure 1 illustrate the strategies adopted by the local builders to guarantee the comfort zone in the dwellings.

CONDUCTION

The conduction heat transfer basically is a based on the temperature gradient of the area, the cross of the material, the length of the travel path and the physical material properties.

		HEAT SOURCES			
	Main strategies	Conduction	Ventilation	Radiation	Moisture transf.
Winter (Cold Season)	Increase heat gain	1.Dense settlement 2.Increasing mass thermal inertia 3.Increasing the heat capacity	1.Indirect heat gain from soil	1.Windows Orient to southern front 2.Increase the ratio of the windows to the wall	
	Reduce heat loss	1.Insulation 2.Thick external & internal walls		1.Radiant barrier 2.Low-E coating glazing	
Summer (Hot season)	Reduce heat gain	1.Increasing the heat Capacity 2.Insulation 3.bright colour for façade	1.Blocking external hot air	1.Deep verandas 2.Overhangs 3.Perforated shading 4.Low-E coating glazing	
	Increase heat loss	1.High ceiling 2.Dome shape ceiling 3.Roof opening 4.Lowering the ground floor level	1.Wind Tower	1.Increasing the exposed surface area	1.Vegetation 2.Pool 3.Evaporative cooling

Table 5

Sources	-	Atmosphere	Sun	Water&Vegetation
Sinks	Earth	Atmosphere	Sky vault	Atmosphere

Figure 29: Watson&Lab Matrix for Isfahan Region

		HEAT SOURCES			
	Main strategies	Conduction	Ventilation	Radiation	Moisture transf.
Summer (Hot season)	Reduce heat gain	1. Increasing the heat capacity 2. Insulation 3. Bright colour for façade	1.Blocking external hot air	1.Deep verandas 2.Overhangs 3.Perforated shading 4.Low-E coating glazing	
	Increase heat loss	1.High ceiling 2.Dome shape ceiling 3.Roof opening 4.Lowering the ground floor level	1.Wind Tower	1.Increasing the exposed surface area	

Table 6

Sources	-	Atmosphere	Sun	Water&Vegetation
Sinks	Earth	Atmosphere	Sky vault	Atmosphere

Figure 30: Watson&Lab Matrix for Isfahan Region

Reduce heat gain

Since Macau has a tropical climate the walls were constructed of mud which had a high thermal capacity to store heat during the day and give it out to the internal environment during the night. Also they adopted the use of brightly coloured plaster to offset the solar intensity.

Increase Heat loss

The Tulou and the Huizhou were characterized by higher ceilings and roof opening that allow the heat gain whether internally generated or stored by the internal mass from external gains to loose their intensities to the external environment . The postulate of thermodynamic states that heat flows from a higher kinetic energy zone to a lower kinetic energy zone. With this analogy the heat in these primitive dwellings were dispensed off to the surrounding soil by lowering the floor of these ancient structures .

VENTILATION

Ventilation is the introduction of ambient air into a space either naturally or artificially. For primitive design where artificial ventilation was unknown, the ambient air affected to a higher extent character of air that circulates.

Reduce heat gain

To reduce hot air circulation enclosed construction types were adopted in the Siheyuan, Tulou and the Huizhou dwellings. Also these structures were constructed close to water bodies, had central pools which were able to cool down the ambient air as it moved towards the dwellings. For example the Huizhou Moon pool, and the Tianjing.

Increase Heat loss

These structures incorporated wind towers to extract hot used air and replace with fresh cold air through the buoyancy effect.

RADIATION

Radiation is when the electromagnetic waves that travels through space transfer heat into an object on impact. This parameters is very significant in any building that strives for energy efficiency

Reduce heat gain

The overhangs and the deep verandas were used to prevent most of the direct incident radiation from entering the occupant spaces. Lighter coating such as plaster mud were also adopted to offset a higher percentage of these solar gains

Increase Heat loss

The opening spaces such as the court yards served as a sink for energy gains .The surrounding soil, larger windows and the central pools helped to increase the heat loss of these primitive structures.

3. Modern building inspired by vernacular architecture

The best example of the modern houses nowadays in Iran which is strongly affected by the passive strategies and vernacular architecture of Iran is Sharifi-ha House designed by architect Alireza Taghaboni. The main concept of the house and the volume followed introvert courtyard idea as in the ancient architecture of the hot and arid climate and for natural ventilation, by changing the rooms on the northern face of the building from static to dynamic, he turned the whole building to the wind tower.As it can be seen in the Diagram below the living spaces are placed around the void. and the rooms can rotate and let the air enters inside.

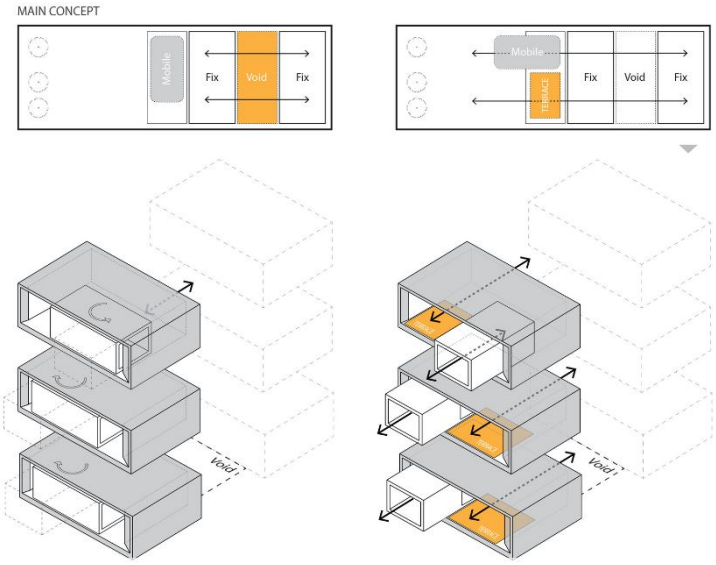


Figure 31: (tag)

Figure 32: (tag)

from the Section below its more clear to figure out the ventilation mechanism of the void by the rotating rooms.

Figure 33: Drawn by the authors

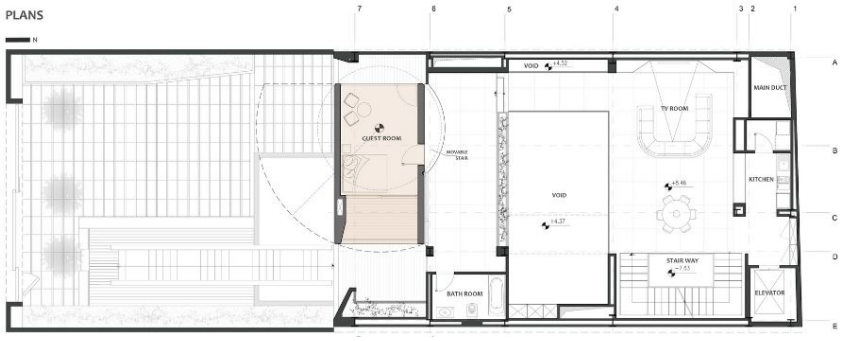


Figure 34: (tag)

References

Iran Vernacular Architecture. https://it.pinterest.com/pin/292311832034610419/, a. URL https://www.pinterest.com/pin/292311832034610419/. Accessed on Fri, October 20, 2017.

BBC - Religions - Islam: Islamic architecture. http://www.bbc.co.uk/religion/religions/islam/art/architecture.shtml, b. URL http://www.bbc.co.uk/religion/religions/islam/art/architecture.shtml. Accessed on Fri, October 20, 2017.

Tulou, Ancient Earthen Complexes of China. http://www.ritebook.in/2015/03/tulou-ancient-earthen-complexes-of-china.html. URL http://www.ritebook.in/2015/03/tulou-ancient-earthen-complexes-of-china.html. Accessed on Sun, October 22, 2017.

Central Courtyard, paradigm of paradise in traditional Persian architecture - HAYAT. http://www.hayat.it/central-courtyard-paradigm-of-paradise-in-traditional-persian-architecture/. URL http://www.hayat.it/central-courtyard-paradigm-of-paradise-in-traditional-persian-architecture/. Accessed on Fri, October 20, 2017.

Huizhou Vernacular Residences. http://mhc-arch295.blogspot.it/2009/11/huizhou-vernacular-residences.html. URL http://mhc-arch295.blogspot.com/2009/11/huizhou-vernacular-residences.html. Accessed on Sun, October 22, 2017.

Average Weather in Isfahan, Iran, Year Round - Weather Spark. https://weatherspark.com/y/105115/Average-Weather-in-Isfahan-Iran-Year-Round. URL https://weatherspark.com/y/105115/Average-Weather-in-Isfahan-Iran-Year-Round. Accessed on Fri, October 20, 2017.

Sharifi-ha House / Nextoffice - Alireza Taghaboni. https://www.archdaily.com/522344/sharifi-ha-house-nextoffice. URL http://www.archdaily.com/522344/sharifi-ha-house-nextoffice/. Accessed on Sun, October 22, 2017.

Alam Al Bena'a. *Hot-Dry region*. https://archnet.org/collections/33/publications/3445, 1999.

Dahlia Mohds Sharif Fatemeh Biabani Moghadam Baboli, Norhati Ibrahim. Design Characteristics and Adaptive Role of the Traditional Courtyard Houses in the Moderate Climate of Iran. *Elsivier*, 2015.

Erwan Hamard. Cob, a vernacular earth construction process in the context of modern sustainable building. *Elsivier*, 2016.

G.M. Soto-Zarazua J.D. Revuelta-Acosta, A. Garcia-Diaz and E. Rico-Garcia. Adobe as a Sustainable Material: A Thermal Performance. *Journal of Applied Sciences*, 2010.

Shahin Heidari Kamyar Tolou Behbood, Mohammad Taleghani. Energy Efficient Architectural Design Strategies in Hot-Dry Area of Iran: Kashan.

National Building law's Office. *Energy preservation*. National Building law's Office, 2002.

M. Nasiri and R. Modarres. Dry spell trend analysis of isfahan province, Iran. *International Journal of Climatology*, 2009.

Maryam Banaei Rana Soleymanpour, Nastaran Parsaee. Climate Comfort Comparison of Vernacular and Contemporary Houses of Iran. *Elsivier*, 2015.

Feifei Sun. Chinese Climate and Vernacular Dwellings. *Buildings*, 3(1):143–172, jan 2013. doi: 10.3390/buildings3010143. URL https://doi.org/10.3390%2Fbuildings3010143.