Course Name: Architectural Approaches to Decarbonization of Buildings

Professor: Dr. Iyer Vijayalaxmi Kasinath

Department of Architecture,

School of Planning and Architecture, Vijayawada

Week: 06

Lecture 02

Settlement planning principles for carbon neutrality- case studies

Hello students, we will continue with our series on the planning aspects. How does planning form a very important part of passive design? In the last class, we saw the theoretical part of it. This class we will look into some case studies about how appropriate planning has helped the place achieve thermal comfort and how planning can be a very effective passive design tool. So, we will take the example of the city of Jaisalmer. Jaisalmer is a city in the north western Indian state of Rajasthan. It is also known as the golden city.

It is located in the Thar Desert and is known for its magnificent fort, havelis and temples. The architecture of Jaisalmer is very unique and it has evolved over centuries due to various factors such as climate. Climate being the most predominant factor because it's a hot arid area. It's a desert climate.

Also it has a very unique culture. The geology that is the building materials available there are very unique and it has a lot of local markets. The use of sandstone and intricate carvings is the most striking feature of the vernacular architecture of Jaisalmer as can be seen from this picture. In this picture, you can see how some spaces today have been created into markets. You can see how the street width is so narrow.

You can look at the aspect ratio; aspect ratio is nothing but the proportion of the building with respect to the street width. So this is very narrow. The streets are very narrow and therefore the streets are primarily shaded most of the times of the day. And you can also see the intricate jolly work everywhere and intricate carvings and jolly work. You can see the carvings here and this makes the architecture of Jaisalmer very unique.

Let us look at the planform. Now, Jaisalmer Street has sizable open spaces which serve as community hubs. Now, if you look at the plan form, you can see a number of open spaces which can act as community spaces. So, there are these open spaces which form like community hubs. House planning and design in Jaisalmer feature courtyard layouts

with underground levels.

What does underground levels do is for another day. Houses open onto narrow streets, forming a hierarchy of spaces that act as interfaces between the street and the houses. Now, if you see here, you can see that there are narrow streets here. These streets are narrow. And then they move on to the, this is the first hierarchy.

Then it moves on to the second hierarchy. Then you have the third hierarchy. And then it opens on to the fourth hierarchy. So, the streets have a hierarchy right from narrow streets. It opens out on to small open spaces which act as community spaces.

The entire city from small houses to the king's palace is constructed using locally available light yellow Jaisalmer stone. Primarily it's sandstone. Now you can see how the embodied energy is also very less because the stone is locally available and it's a natural material. The general street orientation follows a southeast to northwest axis. Havelis are predominantly oriented towards the east and west with longer walls facing north and south to avoid direct solar radiation.

As we had already seen, you can see this is the west direction and most of the houses say if we take any particular house, you can see that the houses are at an angle and so direct solar radiation from the west does not impact the houses, at least most of the houses. Havelis are predominantly oriented along the east and west and therefore, the longer walls are along the north and south. Streets where famous Havelis with Jarokas and decorative facades are located are relatively narrow and they are winding. It matters because when the streets are winding, then it means the streets get covered up, especially when the buildings along the streets are very high. The building's height compared to the width of the street is substantial, creating shaded and cooler environment for pedestrians and social activities on the streets.

So, this is one example of how the streets are designed. You have the ground floor and then there is a cantilever. There is a ground floor and a cantilever because of which the effective a space from which sunlight or solar radiation penetrates becomes very small though you do have adequate street width and it is narrow. You can see that for most parts the streets are completely shaded. So, streets are shaded for most parts of the year making outdoor walking comfortable.

So, outdoor walking and activities become comfortable and this is very important in a place like Jaisalmer where the outdoor temperatures can rise up to even 48 degree centigrade. So, Jaisalmer streets are community hubs with open spaces and they feature house design with courtyard layouts. Now, you can see this is a typical street which has

houses on either side. You look at the planning of this street, look at the planning of the houses. These streets, these houses are accessible by a row of steps.

You have some semi-open spaces and then you have the house and you have a courtyard inside because the house is sandwiched between two houses. It's a row house. In order to get adequate lighting and ventilation, you have the courtyards which will provide substantial lighting and ventilation for the entire house. And you have very little openings. All these spaces, livable spaces are insulated from all sides.

And because of the strong radiation, the insulation due to the adjacent houses makes the house very cool. So, these houses and house designs which have courtyards also have underground levels. So, what happens is some of the houses are if this is the ground level they have spaces subterranean below the ground. So, if this is the ground level there are no spaces or house which goes below the ground level and because there is insulation due to soil this level this underground level or subterranean level is also very cool. So, when the outside is like a bakery the inside becomes remains very cool and these houses open on to very narrow streets.

So, these streets are extremely narrow -the width is very narrow. The street also has very high buildings around it as you have seen which we call as Haveli. The city including the king's palace is constructed only with stone and therefore stone which has very high thermal mass. Also helps and protects the indoors from the harsh environment. Hence, Jaisalmer is a very good example of how appropriate planning principles that can help in achieving passive design.

A small analysis was done by a group of students and it was found that students have done a small assessment of what mutual shading through varying heights in clusters, what it can cause. So, it is found that the streets in Jaisalmer not only provide protection from the sun and the harsh winds, but they also foster a comfortable environment for people to gather outside their houses. This leads to the streets becoming vibrant hubs for social interaction, especially for women. This social dynamics is enhanced by extending the thresholds of the houses which along with the height and width of the streets reduce solar radiation on the ground. Additionally, mutual shading occurs due to varying heights in clusters of buildings and it contributes to the overall pleasant and social atmosphere.

As can be seen from the small analysis, you can see that the streets; these are the terraces and therefore, they are subjected to very high solar radiation as can be seen here. But the streets, they remain cool because we have already seen how the streets are mutually shaded due to the high residences or havelis as they call along the sides of the roads. As we saw, spaces like this, they are beneficial because these are the steps and areas like this

help these semi-enclosed spaces help the women or they aid in social interaction. And because the streets are very cool due to mutual shading, a lot of activity can happen onto the street too. You can, here for perspective, though that is not part of this lecture series, you can see the sandstone and you can see the thick walls of the sandstone.

So, planning, this is how the streets are shaded during the entire day. You can see how the streets get shaded. And also it is not only the streets; it is the walls of the houses get shaded due to the mutual shading. So, at 6 am you can see that this entire wall remains shaded. So, 6 to 12 almost this entire wall remains shaded, while in the evenings this entire wall remains shaded.

And almost through the day the streets remain shaded. So, these are the streets and this is the facade on either sides and this is the cross section. So, this study shows how due to planning which is we have already seen how planning must be in a hot dry climate. So, the built form and microclimate are interdependent with buildings influencing the microclimate around them and also vice versa. Controlling solar penetration through orientation and projections is crucial in summer.

It is optimal for major east-west street orientation to have solar exposure on the street from 9 am to 2 pm with a corresponding solar altitude ranging from 54 to 86 degrees. Small projections can effectively provide shade during this period. Conversely, the north face of buildings on the opposite side of the streets receives radiation before 8 am and after 4 pm with a solar altitude of less than 35 degrees. So, buildings on the opposite streets play a role in shading the north face during these times. Now, the relationship between the built form and the microclimate seems to be reciprocal because building also impacts the local climate and the microclimate also influences the built form.

And when you have structures like these, then you can see a lot of community or community engagement happening. And also if you look at the courtyard you can see what happens in the courtyard. In the courtyard the again because of the proportion of the courtyard as can be seen the indoors remain pretty cool because during the day at least up to noon there is no solar radiation. And post evening whatever solar radiation is absorbed by the walls gets radiated back. And anyways, post 7 pm, the outdoors become cool.

So, effectively the courtyards become usable spaces throughout the day. Now, stable ground floor temperatures have been shown to exist in these houses. So, they normally do not exceed 3 degree centigrade in variation whereas the outdoors they have a variation of even up to 15 degree centigrade. So indoor temperature regulation happens very well because the maximum indoor temperature consistently remains about 8 to 9 degrees lower than the corresponding outdoor temperatures. Thus it ensures a more comfortable

living environment.

Courtyards play a very pivotal role. If you see the courtyards, the courtyards play a very important role in facilitating natural ventilation throughout the buildings even when the outdoors is calm. Mutual shading and architectural features also add to this planning to make the indoors comfortable because you have the jarokas and richly textured surfaces which results from the beautiful carvings and collectively they minimize the impact of direct solar radiation. This design approach significantly reduces heat flux into the building during summers. In winters, the lower altitude of the sun allows the reasonable penetration. Wind gets deflected through the shafts because there are some shafts too.

So in addition to simple courtyards, very narrow vertical ducts in the form of staircase shafts are strategically used to deflect wind down into the house, thus enhancing natural ventilation and cooling. The stone walls also have a large thermal inertia. So, the high thermal inertia of the massive stone walls coupled with the wind deflecting shafts effectively tempers the air before it reaches the living space. This process bears similarly to the cooling mechanism which is observed in the Iranian wind towers. So, here you can see we are taking an example of Natmalji's Haveli and you can see the section where you have some subterranean space.

So, subterranean space meaning spaces which are below the earth below the ground level and therefore these remain cool. You have courtyards. Courtyards for various purposes- Some of the courtyards are family courtyards. Some of the courtyards are used for animals to be tied or cattle to be tied.

And then you also have wind pavilions which help in diverting because hot air rises up and cool air sinks below. And this movement also, the air movement through the pavilion and the courtyard also helps in ventilation. So, the courtyard serves as a vent for the air to or the wind to go and therefore, any hot air which gets generated here rises up and moves out. The next example we take is that of Dar es Salaam. Dar es Salaam is a very vibrant coastal city in Tanzania.

It stands as a bustling metropolis and economic hub. It is nestled along the Indian Ocean and this city has a very rich cultural tapestry which also has historical influences. The city is characterized by its diverse neighborhoods and is a blend of traditional and modern architecture. It has its own challenges in terms of being accessible and having sustainable housing solution for its expanding population. In navigating the dynamics of urban development, Dirisalam seeks innovative approaches to ensure that affordable housing initiatives align with the city's evolving needs and it fosters inclusivity and resilience in the urban fabric.

Now, here if you see the race alarm, it is in Tanzania and it shows high temperatures as well as high relative humidity. So, if you look at this diagram and if you look at the sunshine hours as well as temperature, you can find that the temperature is pretty much high throughout the year and its relative humidity and see this is the maximum humidity. So the maximum humidity is also high throughout the year. Whereas it's maximum temperature is also high throughout the year. So consistently this place has high temperature and it's very humid leading to very sticky feeling.

So, to enhance endothermal comfort it is recommended to adopt cross ventilation because in climates where humidity is high and temperature is also very high the. Sweat on the body has to be taken away -otherwise it causes a lot of discomfort and one easy way of doing it is through ventilation. When breeze flows and that is why if you see people use a small piece of paper to wave or a small kerchief to wave when they are in an environment which is warm and humid. So, it is important to have breeze flowing and you can see what is required here. From the bioclimatic chart, you can see that ventilation is the most important strategy in Dar es Salaam.

So, the primary design goal for this zone is to facilitate the unrestricted flow of air within the house while concurrently preventing internal surface temperature from exceeding outdoor temperature because outdoor temperature is very high. This protective measure extends to all building facades shielding them from excess solar radiation. Buildings within this zone should prioritize being lightweight with minimal thermal storage capabilities. The interpretation of this design approach indicates that during the period from January to March, maximum temperatures surpass the range suitable for natural ventilation. Because bringing in natural ventilation during a very hot period is like bringing hot air inside.

Furthermore, the preference for open and non-compact building structure is highlighted as a strategy to amplify ventilation and contribute to overall thermal comfort in this climate zone. So, most of the houses that you saw in the first picture, the primary facades of these apartment blocks are strategically oriented along the north and south. So, you can see for most of the house, the western side is completely insulated. So, you do not get the western sun inside the house.

Now, that is as far as orientation is concerned. So, you orient in such a way that for most of the houses, the western sun gets blocked because all the houses are sandwiched between two houses and therefore, their east and west gets completely insulated. To optimize cross ventilation, louvered windows are incorporated in all the rooms. So, windows are thoughtfully positioned along different axis throughout the space and

permanent ventilation vents are installed at various heights. So, you can see that there are windows and they are louvered windows. What are louvered windows? We will look at it in greater detail when we look at openings as a passive strategy.

And this facilitates cross ventilation through the house. So, there is constant breeze movement inside the house. The roof features a continuous open air chamber enhancing permanent ventilation and the open plan layout of the living space minimizes air flow resistance establishing efficient flow paths for cross ventilation. So there aren't any hurdles here which will block the wind movement. What they have done is they have had a very open plan in which the breeze moves through the rooms enhancing cross ventilation. Any shrubbery at this height, any trees at this height would have prevented it from happening.

But they have ensured that there are no obstacles in the path of the breeze. So, permanent ventilation vents at different heights and a continuous open air chamber on the roof enhances air flow and the open plan layout of the living space minimizes air flow resistance creating efficient flow paths for cross ventilation. These design elements collectively contribute to a well ventilated and comfortable living environment. So, these houses also have daylighting, very well lit houses because there are lots of openings.

The balconies are well shaded. So, they have used sun shades and other shading devices to strategically place along the openings, balconies, windows. And this design choice protects most apartments from morning and afternoon solar radiation. The building materials contribute to thermal comfort because they have used lightweight walls and roofs with external reflective surfaces which is an exactly opposite strategy that is being used in Jaisalmer which is a hot dry climate. And therefore these surfaces also effectively reflect undesired solar radiation enhancing the overall thermal performance of the building. Balconies and solar devices are integrated into windows on the north and south facing facades to generate midday shade particularly in the southern facade which is exposed to intense sunlight during the hottest season.

Major windows are deliberately avoided on the eastern and western facades with these areas allocated for bathrooms even in the houses which are placed in the end. This design choice protects most apartments from morning and afternoon solar radiation. So, passive design principles for different climate conditions should be taken into consideration when designing for different climates and this includes a proper site analysis and deciding on how you will orient your building in order to reduce solar intensity in order to have a proper building orientation like how we have seen as two strategies in the hot and arid region you can see the strategy of planning as compact planning whereas in hot humid planning has to be to be free planning. So, we should have free and open plans which are

not compact in a hot and humid condition.

So, you should not have narrow streets, but you should have streets which facilitate proper ventilation in the hot humid climate. Whereas in the hot dry climate it has to be opposite. You should use appropriate solar shading, appropriate building materials, should use appropriate window sizes, all of these we will see in the forthcoming classes. And the design of energy efficient zero carbon buildings and homes depend on how we use these features to reduce the energy consumption in the building which the energy can be used in the building through active means such as air conditioners. If we are able to design the building properly with planning as an important feature, then the load on electricity can drastically come down.

Therefore, to achieve sustainable housing, it is important to build considering the prevailing climate condition with planning as an important strategy. With this we will stop this class and we will continue our next class with yet another strategy. Thank you.