

International Studies in Vernacular Architecture
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Lecture 08
Bamboo as Vernacular Resource Material

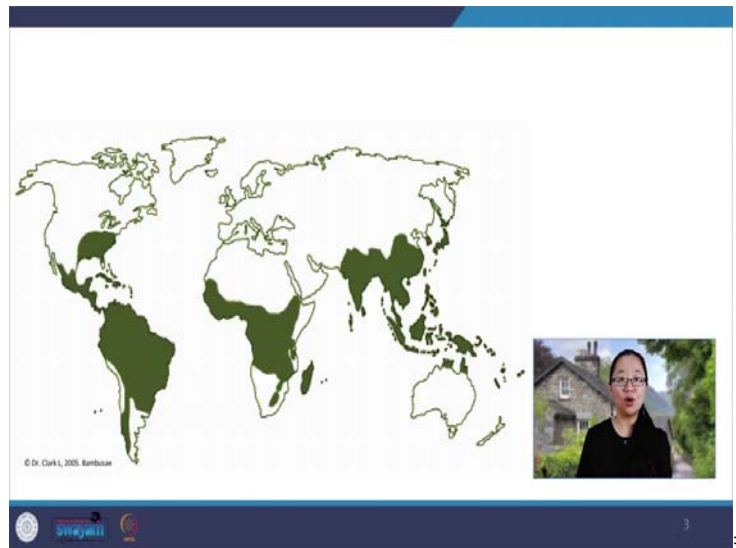
Hello, welcome to International Studies on Vernacular Architecture course. In this lecture, I am going to talk about bamboo as vernacular resource materials. Today, we will begin with the characteristics of bamboo plants, followed by how it is used in vernacular architecture, and how it is used in the contemporary world today.

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From ancient times, bamboo already gave men tools to work with, instruments to make music such as flute angklung, paper to write, cooking and eating utensils, bamboo shoots as food and even to make a house. Across the world astoundingly bamboo is used to make all parts of the house except the fireplace and chimney. It can be used as structural frame, floors, walls, partitions, doors, windows, roof rafters, as well as water pipes and scaffolding.

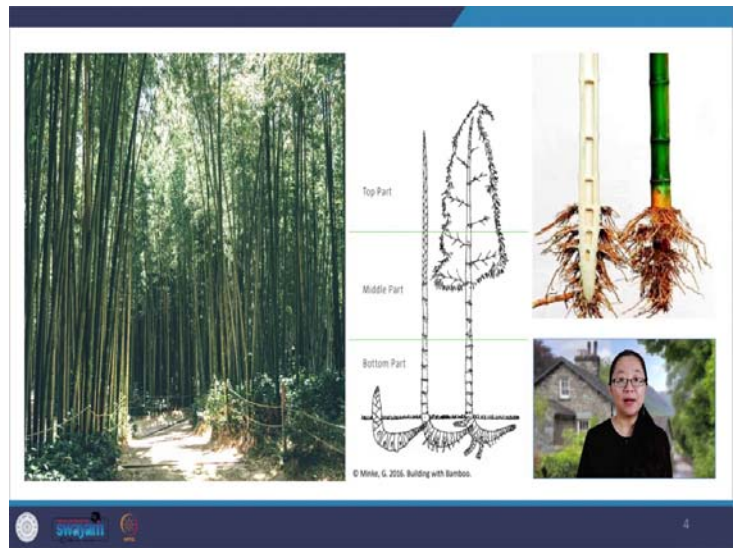
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Bamboo grows on almost all continents, as you can see in the picture from America, Africa, Asia, Southeast Asia, and the northern part of Australia except Europe. There are tropical and subtropical Bamboos that thrive in different ecological needs from cloud forests to semi-arid zones. The majority of species are found in warm zones with humidity levels of over 80 percent in tropical cloud forests, and in clayey and humid soils.

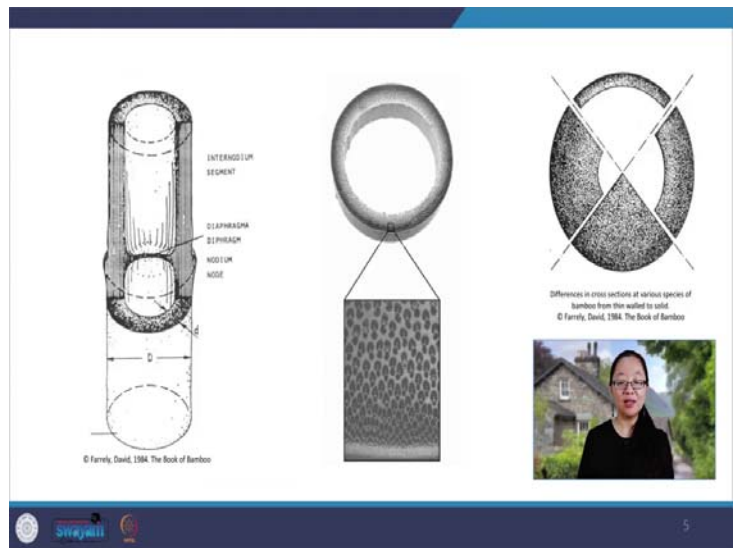
For this reason, they are often found near water, a few grow in dry climates. In China and Japan, there are also species that can survive temperatures below zero degrees. Approximately there are 1400 bamboo species exists today. Bamboo also grows extremely rapidly and is usable as a construction materials after 4 to 6 years. Because of this rapid regeneration using bamboo as building materials for keeping up the rapid demand of housing is more sustainable for the environment.

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Bamboo plant itself belong to a grass plant, like corn, rice and sugar cane. Its structural behavior can vary greatly, depending on the site where it grows, also depend on the species, its age and moisture content. In general bamboo columns have a special feature that gives them a high strength weight ratio. They are around or nearly so in cross section, and usually hollow with rigid cross walls strategically placed to prevent collapse in bending.

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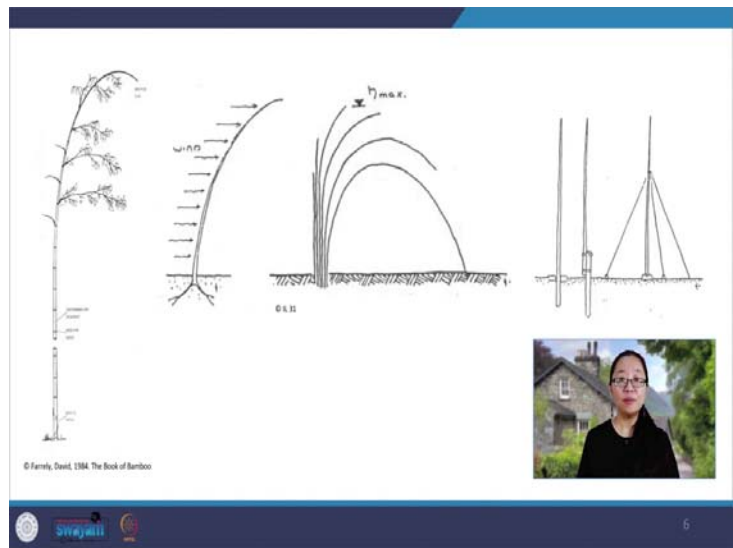


Within the culm walls, the strong hard tissues and high tensile strength are most highly concentrated near the surface. In this position, they can function most efficiently both in giving mechanical strength and in forming a firm resistance shell. Depending on the species,

the thicker columns have moderate elasticity, while the thinner ones have more elasticity and considerable strength.

The reason for this elasticity is a conical profile, bigger in the ground and smaller towards the top. This character can create a variety of forms, but at the same time due to these changes on the diameter and the thickness of the bamboo stem along its length. In addition to the stem does not grow totally straight, precision in construction is difficult to obtain.

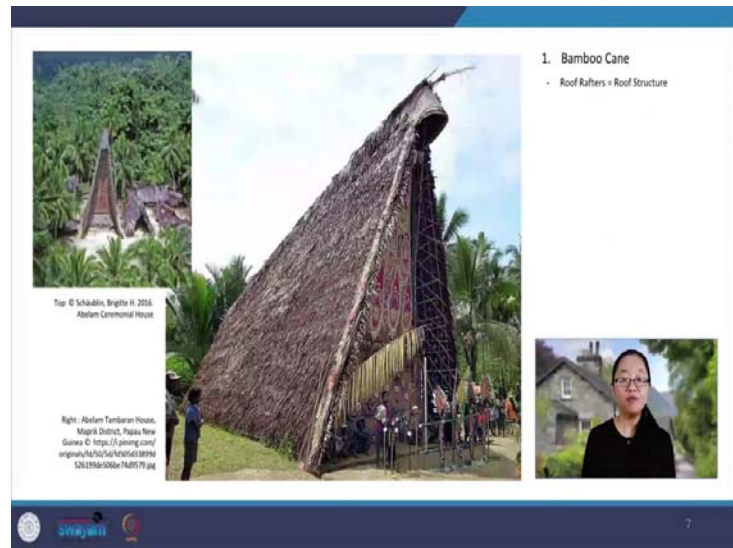
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From the age of 2 years, the canes can be used for making plank boards, and at this age the bamboo canes are more flexible. Normally between 3 and 5 years, the lignin of its tissue becomes a structure as hard as wood, but still flexible and light.

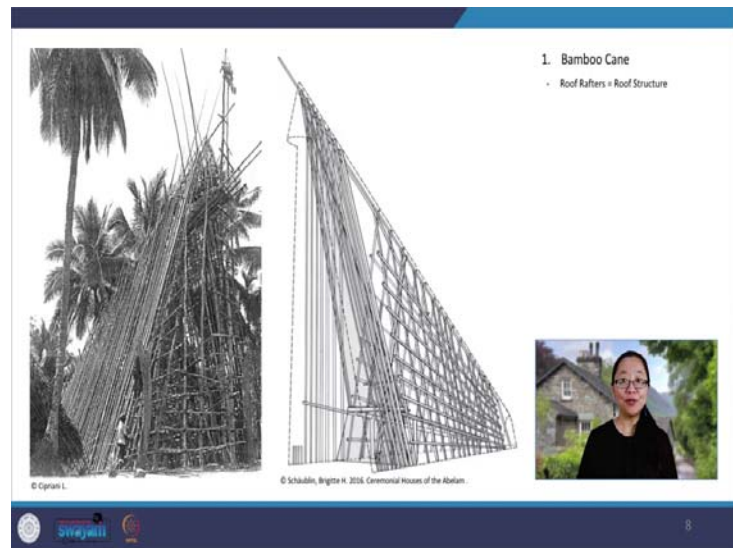
And thus, are ideal for use in construction. Due to its favorable mechanical characteristics, great flexibility, rapid growth and lightweight bamboo is used extensively as vernacular building materials with many applications. Now, we will look at some examples of how bamboo is used in vernacular architecture.

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Before use in construction bamboo cane is cleared from its roots, leaves and branches, bamboo cane is generally used for structure roof rafters, wall and floors. These Abelam Ceremonial house in Papua New Guinea uses this bamboo cane for roof rafters, that also function as rigid arc structure. This rigid arc rafter roofs appears to be a very ancient type of structure.

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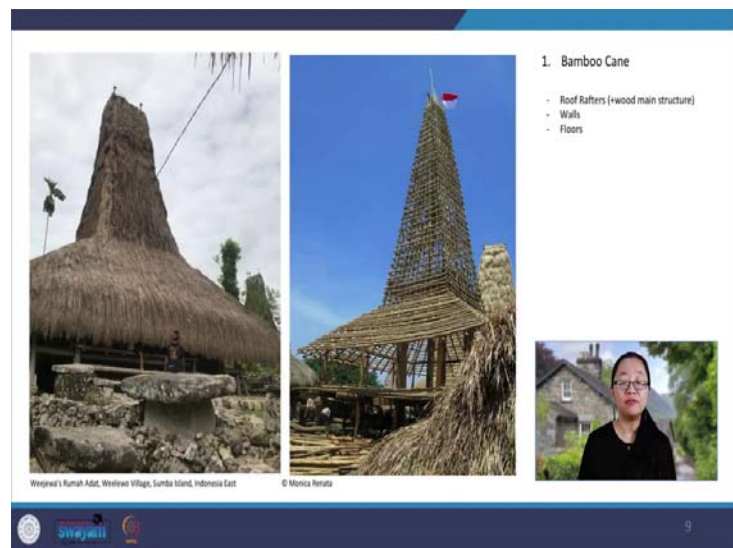


The bamboo cane are placed on each side leaning against the ridge pole, the rafters are stabilized from the inside from with the help of 2 or 3 bamboo battens on each side. The poles are subjected to compression and bending loads resulting deformation under their own

weight in particular, and under additional external load which must be taken into consideration as part of a structural system.

The higher the building, the more likely a bending curve occurs in the shape of the building. In other words, it is not entirely triangle in section there is some curve in the middle of the pole or bamboo cane due to bamboo elasticity. Rigid arc requires a more stable culm wall size and pole size from the bottom to top in order to decrease the compression on each bamboo poles.

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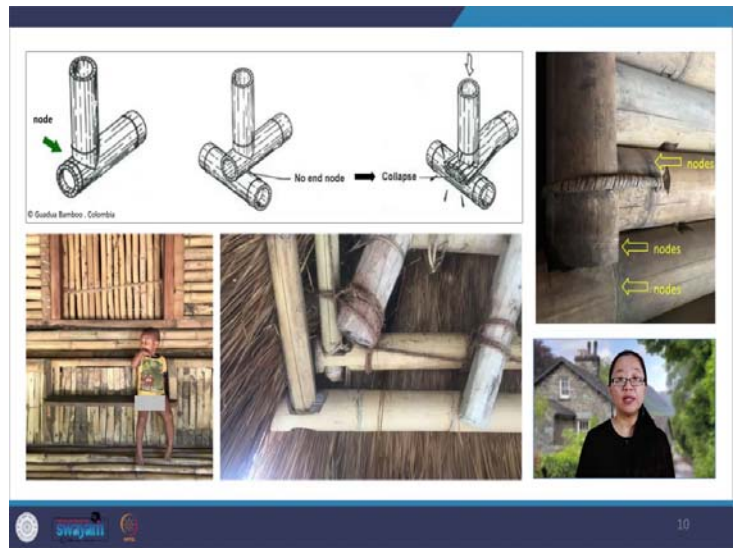


Another examples of bamboo cane use is in these Sumbanese vernacular houses in Weelewo Village, Indonesia East. They use 4 to 5-inch diameters bamboo canes for roof rafters, while the main structure use wood as roof structure columns and beams. As we can see in the picture, the bamboo roof rafters are quite dense, creating a head tower like structure.

The tower likes roof structure is strengthened by diagonal bamboo bracings. This type of bamboo construction is also called rigid arc. Apart from the roof rafters in the Sumbanese Houses bamboo canes are also used extensively for floors and walls. It is interesting to note that the villagers understand that bamboo is more easily damaged than wood.

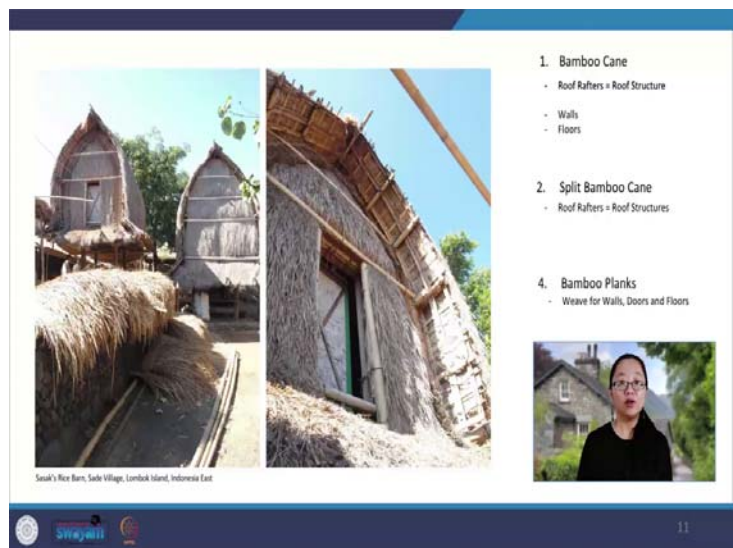
So, the main structure of the house, namely the columns and beams are made of wood while the floors, walls, roof rafters are made with bamboo which can be replaced easier if necessary.

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The joinery is without nails, almost all bamboo joinery are tied with rattan or coconut husk, or jungle roots, and some joinery in the corner is made by cutting a hole in the bamboo as can be seen in the pictures. In creating bamboo joinery, it is important to note that bamboo can crack. So, in construction using bamboo nodes is very important. Bamboo columns or beams need to have a node at both ends, or as close as possible towards the ends. If not the pressure of a structure on the joint may cross the bamboo.

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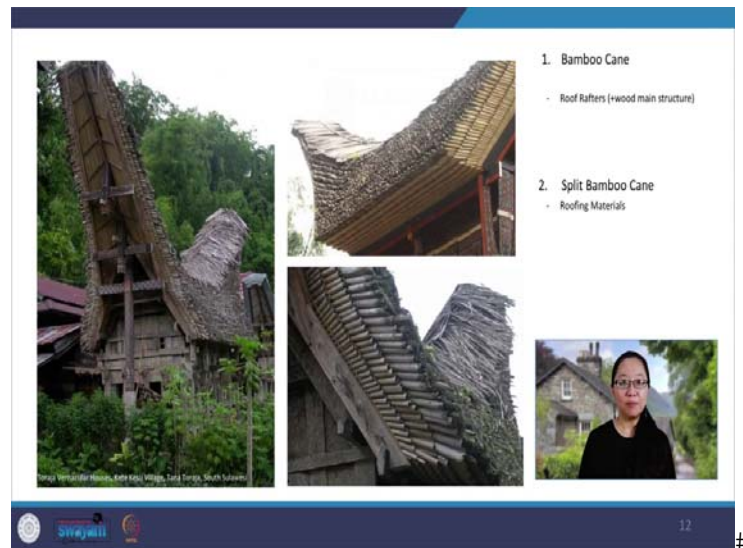
In contrast to the rigid arc in Avalon tribe of New Guinea and Sumbanese vernacular architecture. In the case of Lombok rice barn Indonesia, the Sasak people use ben bamboo as roof rafters, creating a curve convex roof form. This form is also known as ben arc roofs,

which resulted from the high elasticity character of the bamboo plant mentioned earlier. If you look closely, some of the rafters are split bamboo cane to make it easier to bend.

The majority of building shows ben elements whose curvature increases continually towards the thinner end of the cane. Their forms are often similar because they are mainly determined by the natural bending of bamboo. In order to achieve symmetrical shapes. The canes are often used as pairs, so arrange that two opposing canes are formed into arc by crossing the strongly curved cane ends.

The floors and walls are made of woven bamboo planks. And this rice barn is supported by four main wooden pillars on silt. On the lower part, the open area also functions as ballet for relaxing and gathering.

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Another bamboo application in vernacular house construction is the Toraja people in South Sulawesi, Indonesia. Their house and their rice barn have the same typology just different in sizes. This type is called Tongkonan. Built on wooden piles and have saddle back roofs whose gables sweep up in an exaggerated pitch.

The unique bamboo applications is in the roof constructed with layered bamboo canes cut or split in half bound together with rattan and assembled transversely in layers to keep the rainwater from entering the house. The layers are put over and under roof of bamboo poles, which are tight longitudinally to the rafters. Sadly, nowadays, the bamboo roofs are increasingly replaced by zinc roof and nails.

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1. Bamboo Cane

- Weave as Structure (small cane like reed)

2. Split Bamboo Cane

- Roofing Materials

© International Bamboo and Rattan Organization

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Besides the bigger bamboo canes like the examples mentioned before, the small ones are also used as structures, like the ones used in Sidama vernacular house in Ethiopia. The house is a beautiful onion-shaped dome. It is constructed with a triple layer of bamboo canes split in half, bamboo strips and ropes for structural support.

Bamboo strips are longitudinal segment of the cane, then they are obtained by making cuts parallel to the fibers. The construction of the house begins with juniper tree poles which are arranged in circular as a component for foundation. Because of its longevity and being proven to protect against pests like termites.

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1. Bamboo Cane

- Weave as Structure (small cane like reed)
- bundled into composite beam

2. Split Bamboo Cane

- Roofing Materials

3. Bamboo Strips

- Weave as Structure - Walls + Roofing

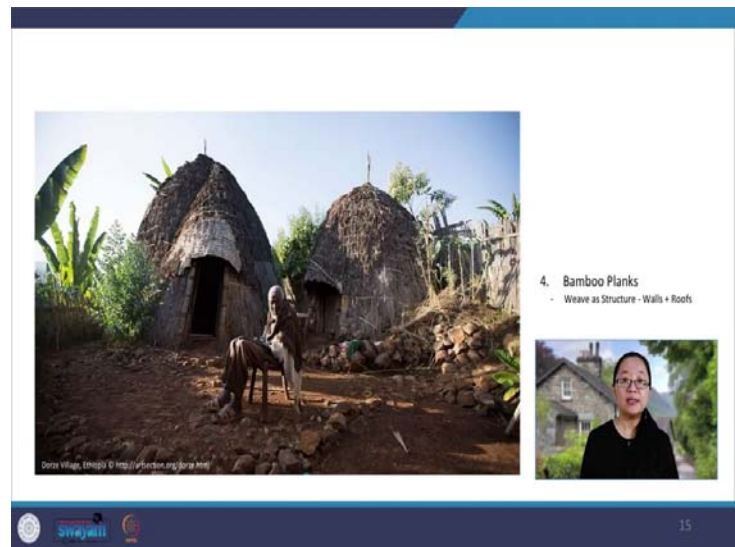
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Thin bamboo are placed around the perimeter of the house, it can be placed up to 100 to 150 centimeters underground. The construction of the walls is made by splitting the bamboo to smaller strips and use whole bamboo with smaller diameters and then weave them from the bottom up until midways. Then, a sheet of unfinished woven bamboo is placed on top followed by weaving the top and bottom part together.

In the process, they use a pole in the middle of the interior to support the top dome. The material used for waterproofing the hut is bamboo sheet for insulation and rain protection. It is placed in four layers all around the hut. The exterior wall of the Sidama hut then is weaved with a pattern. Also function as cover on the outside, which ties everything together and protect the house against the wind.

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The second dome house type is the Dorze tribe house. The house is slightly convex in profile with round plan and framework of flexible with bamboo in the interior that is sometimes central support, often divided by internally by partitions. Although similar in shape, Dorze tribe construction technique is different from the Sidama neighbor is that of small bamboo strips and canes.

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Dorze people uses bamboo planks and strips. Bamboo planks is obtained from the intermediate part of the stem, which when open forms a flat surface. To successfully make a plank it is necessary to use mature bamboo. The construction of the house begins with drawing a circle. A compass of toepol, a piece of string and a sharpened bamboo stick draws a line on the back soil of the house platform.

The average diameter of a house is about 7 to 8 meters. On the circle, split bamboo species are driven into the ground approximately 10 centimetres apart. A series of horizontal rings are interlocked between the vertical pieces from the bottom to the top. The diameter of horizontal rings of bamboo gradually reduces until the top of the house of the ring is almost close. When the house reaches certain height the builder must construct a scaffolding from which to continue the work.

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As yet barak stated that after the main body of the structure is woven, a projecting nose like canopy is added. On a small house, the canopy will simply form a cap over the door. Curving a third way of the way down its head and keeping out the summer rain. On the large house the canopy forms an anteroom which can easily accommodate 8 people. After weaving is completed stretching begins.

Sometimes straw and bamboo shoot are combined in patches for stretching. The very top of the house where the weaving is drawn together into a dome is finished by pegging some vertical strips of bamboo string into an attractive top knot. The house is completely watertight and has no opening except for the door. The floor is clay, smooth and harden with a mixture of water and manure.

A small house can be finished in 5 days. While the time needed for a larger house is 22 days. The height of a house sometimes exceeds 8 meters, and is usually not less than 6 meter. In time the vertical split bamboo will rot away. The house is then cut from its rotten base lifted up and replanted in the earth.

This is done as often as necessary until the house becomes too low for normal human activities. As a rule, the height of the house is reduced by about 20 centimeters every 4 years.

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Bahnar Communal House, Vietnam

2. Split Bamboo Cane
 - Walls
 - Floor Beams
3. Bamboo Strips
 - Weave as Walls
4. Bamboo Planks
 - Floors

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Another example of bamboo use in vernacular architecture is the Bahnar communal house of central highlands in Vietnam. This communal house are towering wooden houses with bamboo floors and walls that are built on stilts that can reach up to 100 feet in height. The roof here is made of straw, the rafters are made of circle shaped pieces of wood instead of square ones.

As you can see in the picture the floor is made of bamboo plants supported by split bamboo as floor beams. The walls is a combination of weave bamboo planks, bamboo strips, and small bamboo canes tight with rattan arranged beautifully allowing air to ventilate the interior of the house.

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"Baduy's Rice Barn (top), Baduy's Houses (bottom), West Java, Indonesia.

4. Bamboo Planks
 - Weave as Walls

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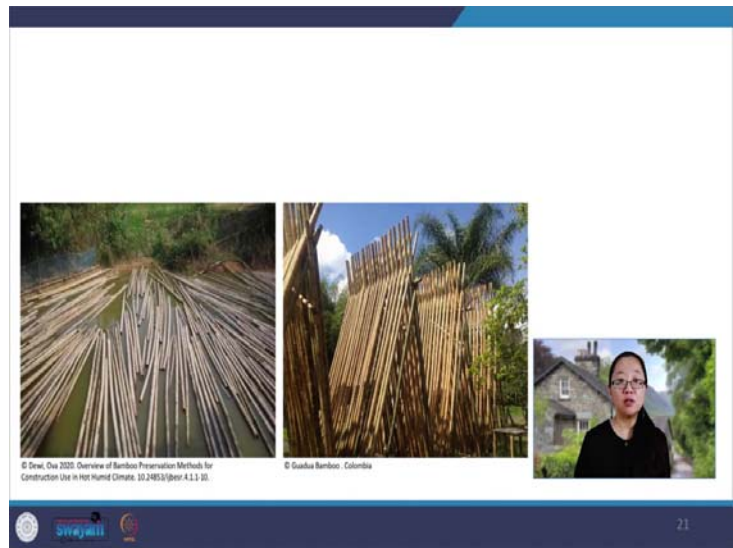
Weave bamboo planks have been widely used without plaster in rural houses in tropical climates, such as the Baduy tribe in West Java, they use weave planks for walls of their rice barn as well as their house, their main structure is wood. The weave pattern varies from one binocular society to another. And weave bamboo planks are found also used with plaster found in some colonial houses in urban setting throughout Indonesia. It is believed that the combination of weave planks and plus there is an adaptation of water and dope construction in Europe.

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So, we have seen varieties of bamboo uses in vernacular architecture, from bamboo canes, split bamboo, bamboo strips and bamboo plants. We have also learned a wide varieties of how those bamboo are used as roof rafters, walls, floors, bundled into a composite beams, roof materials and floor beams. Before we continue to look at how bamboo is used today, we need to highlight the drawbacks of using bamboo as building materials and learn the treatment to reduce the impact of those drawbacks.

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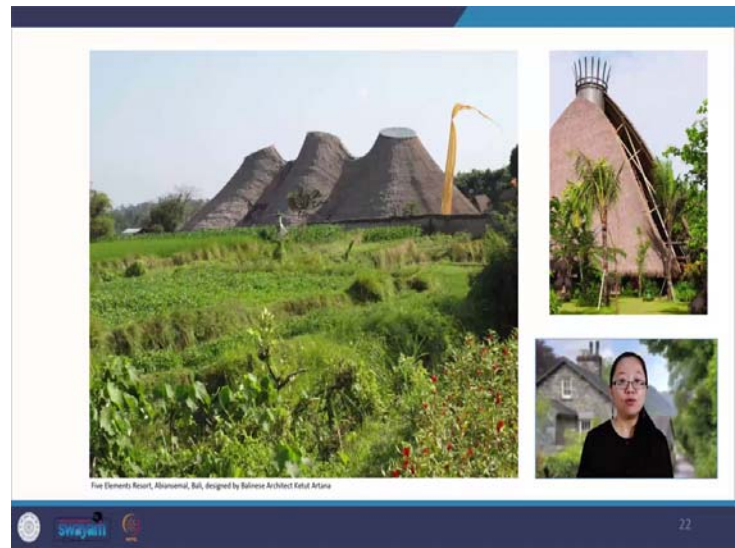
Bamboo is vulnerable to exposure of ultraviolet rays and rain. Accordingly, it requires protection during the handling, execution and maintenance of the project. And furthermore, bamboo contains a large quantity of starch which attracts insects. Also, the presence of humidity can cause the appearance of fungus and lichen.

So, to guarantee the durability in bamboo construction, it is important to take into account wood procedures of cutting and curing or drying bamboo. The first is cutting, cutting bamboo is done with a market or directly above the first or second above ground node, keeping in mind that the cut should be inclined to avoid the penetration of rain into region thereby rotting it. It is advisable to make the cut during the dry season.

When the stems have minimum humidity. Different culture have different ideal time to cut bamboo and is usually connected to moon cycle. There are many ways and vernacular technique for bamboo treatment before construction. In Southeast Asia the most common technique is to soak bamboo in running water such as river or to soak bamboo in salt water for at least 7 days depending on the species and age of bamboo.

Then air drying the bamboo with natural ventilation and sun. In the contemporary world today, treatment of bamboo has developed into several new methods such as microwave drying, injection, preservation by immersion, surface bleaching, and etc. To sum up to be able to use bamboo as building materials, one must take precautions actions to treatment before use.

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Now, we will look at the use of bamboo application in the contemporary world today. Bamboos are beginning to be used by architects to produce organic buildings forms and structures to create spaces in harmony with nature, as well as to create a more sustainable environment. The examples discussed here is located in Bali, Indonesia, and in Vietnam. The first is five elements retreat in Abiansemal, Bali, designed by a Balinese architect Ketut Artana in 2010. The design is deeply rooted in the islands action traditions, nurturing harmony among spirits, human and nature.

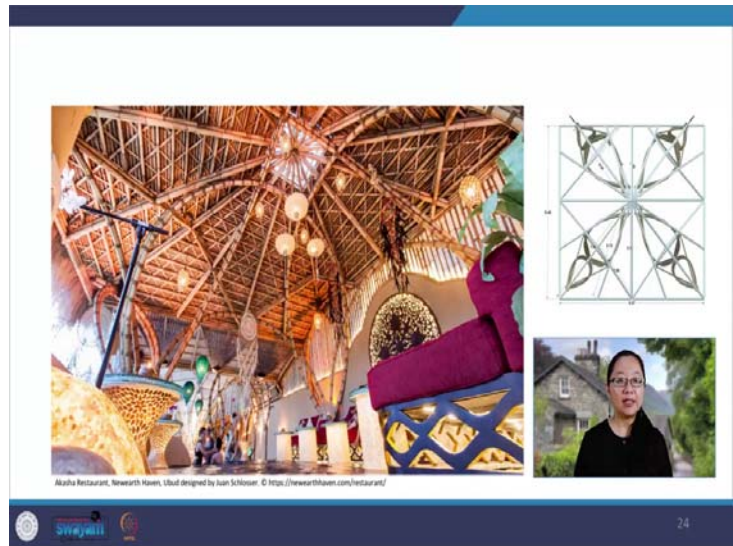
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There are restaurants, bungalows, and main halls, and all buildings are made entirely with bamboo. One of the buildings seen in the picture is the main hall, which takes on a split

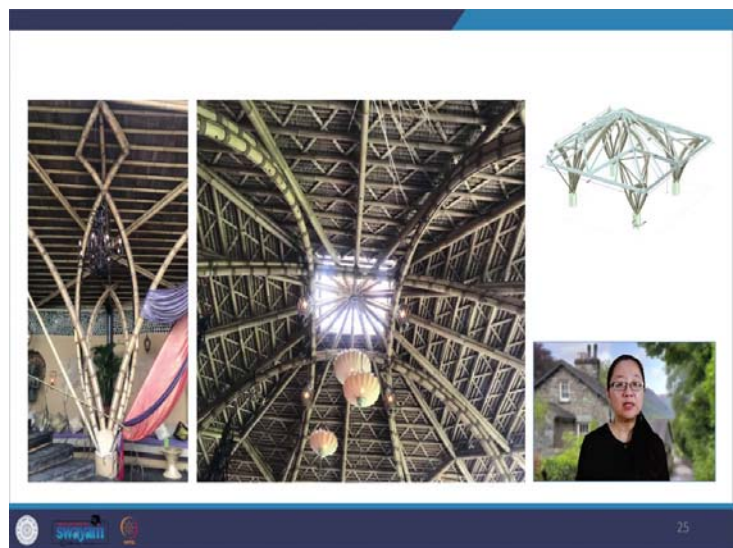
conical shape, a transform rigid arc shape with round plan. The roof structure made of bamboo canes, has a crown like ring in the middle which acts as compression ring to bound the roof. The walls are open, with bamboo canes aligned vertically in harmony, tight with ropes. The building is used for yoga practice, meditation, workshop and etc.

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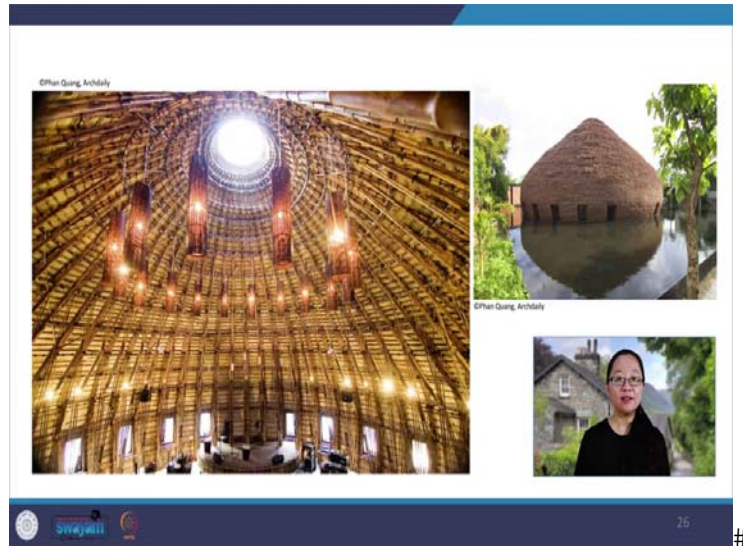
Another example is the contemporary Akasha Restaurant and Juice Bar in Ubud, Bali. The building is designed by Juan Schlosser to be the central hub of the New Earth Heaven project in 2016.

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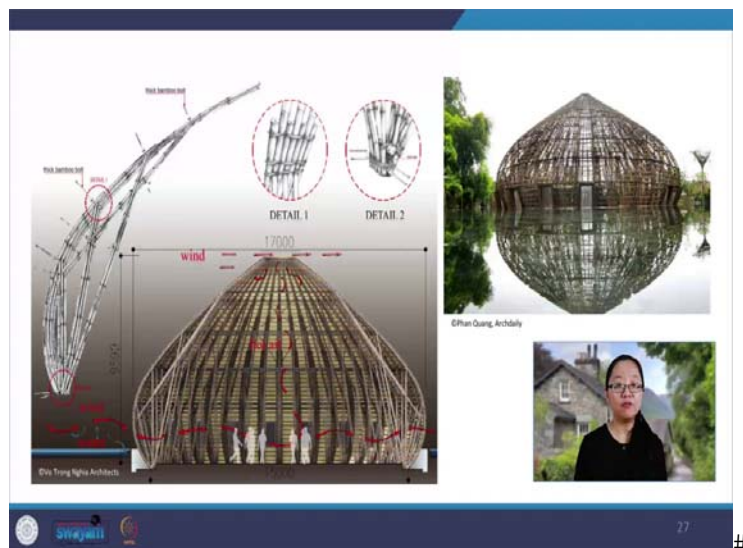
The design over a geometry space combined with organic structure forms a rigid archetype made of bamboo canes tied together with rope. The structure forms are developed from a type of sacred geometric composition transformed into a beautiful bent arc arrangement.

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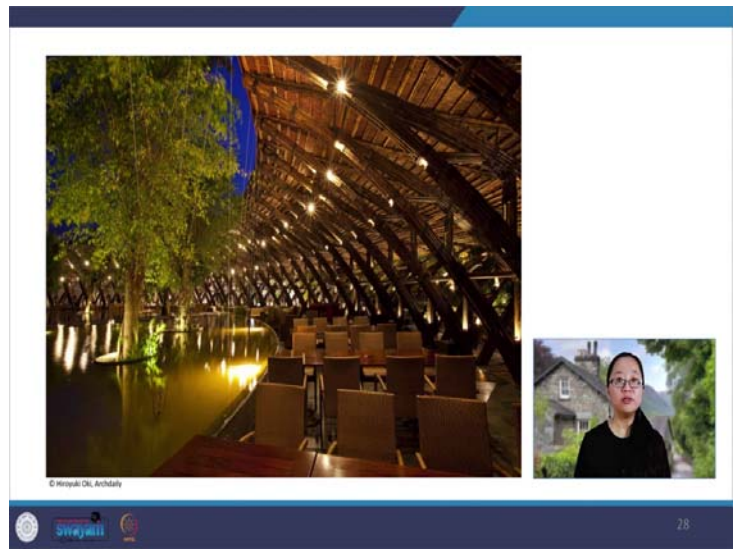
Another interesting contemporary bamboo project is designed by Vo Trong Nghia architect, the wind and water bar in Vietnam. The architect explained that the bar is designed as an enclosed space which can be used for different purposes such as music concerts, shows, ceremonies, and etc. A bent arc structural bamboo system was designed as dome with 10 meter high and spanning 15 meter across.

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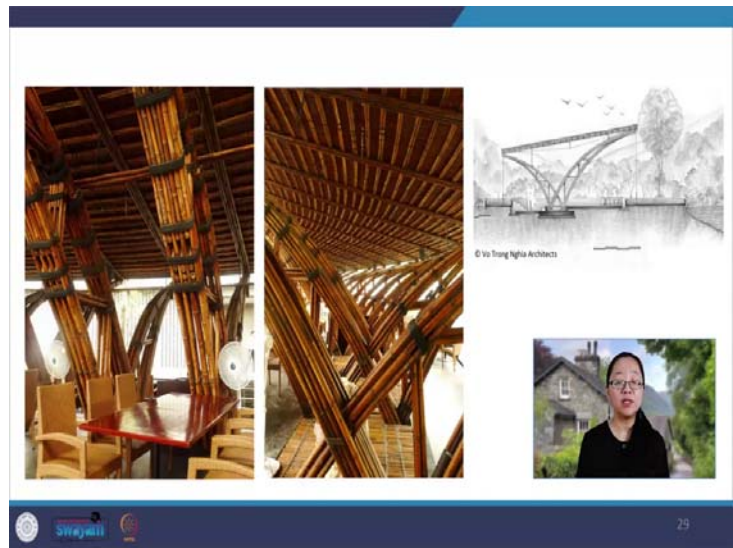
The main frame is made by 48 prefabricated units, and each of them is made of several bamboo elements bound together. The building uses natural wind energy and the cool water from the lake to create natural air ventilations. On the top of the roof, there is a hole with a diameter of 1.5 meter for the evacuation of hot air from the inside. The hole also functions as structural compression ring.

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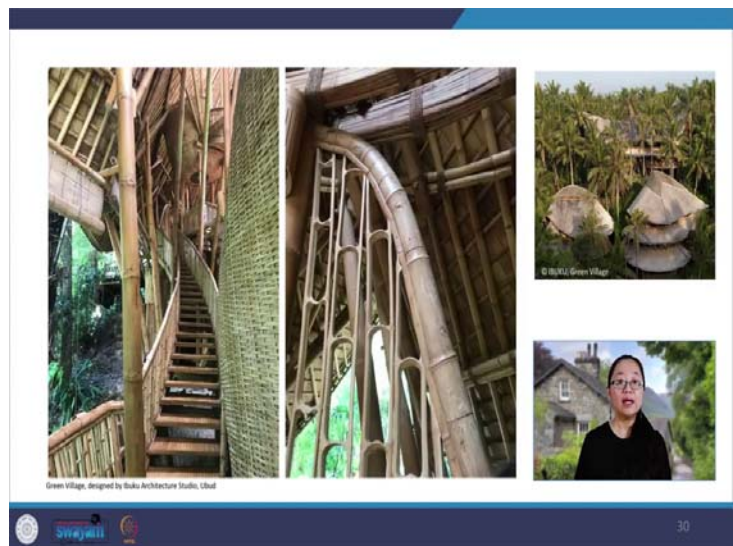
Also designed by Vo Trong Nghia bamboo wings inspired by nature flows over the natural landscape of the site situated near Hanoi, Vietnam. The architect stated that the aim of the project was to study bamboo and the potential space it can create by using bamboo not only as a finishing material, but as a structural one. This building is a pure bamboo structure using no steel or other manmade structural materials.

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This unique structure allows us to experience a 12-meter open space without any vertical columns. The open space can be used for many purposes, such as wedding parties, live music concerts, ceremonies, and etc. The shape of the roof also contributes to the ecology aspect by minimizing the use of air conditioner.

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And the last example today is the green village built in 2010 as a resort set within river valley landscape along with Bali's Sacred Ayung River Ubud. The resource have several organic shaped bamboo houses designed by Ibuku Architecture Studio. From the picture we can see various use of bamboo plant, used as building materials in details. From half bamboo

showing sections of bamboo nodes are placed as railings and ceilings, bamboo canes for columns, beams and roof structure.

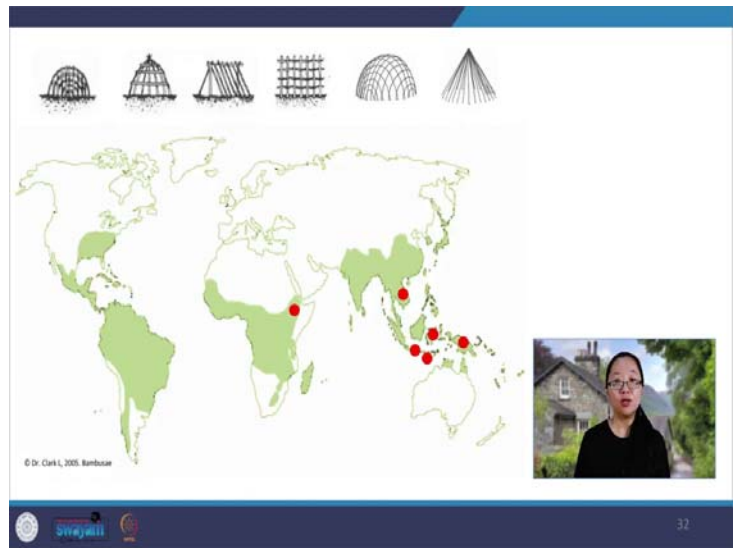
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As well as composite bamboo made of smaller bamboo bound together as curved beams, split bamboo for stairs to laminated bamboo for floors and furnitures. These houses are designed and built around the natural contours of each plot with rare views of the riverfront and the volcanoes of Bali. The concept is to create a beautiful living spaces and entirely made with bamboo in which people can live where luxury and comfort fit into natural landscape.

This contemporary project shown here represents not only modernism but also traditions and harmony with nature. Furthermore, the bamboo wings and the Green Village opens a new horizons of the use of bamboo in contemporary architecture, design rooted to vernacular know-how, at the same time, embraces new opportunities and changing needs and contexts.

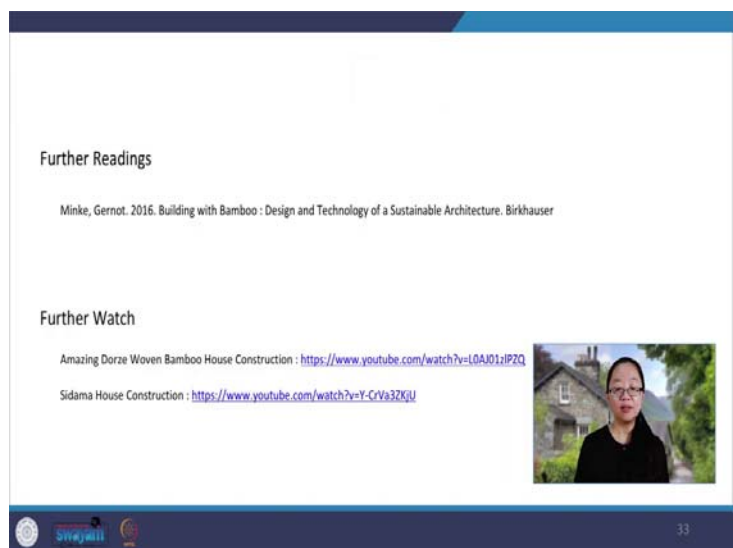
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To conclude the lecture, we discussed how vernacular builders already have the knowledge, technique and skill to create many buildings forms made of bamboo. The examples shown from Ethiopia, Vietnam and Indonesia. We have also talked about some examples of the use of bamboo in the world of architecture today, and how it can contribute to a more ecological friendly construction and use.

There are still many traditions that need to be learned. And by learning those knowledge, technique, and construction skills, we hope to build a more sustainable not only build environment, but also a more sustainable culture.

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Here are some references for further readings. And I also suggest you watch the weaving process of Sidama and Dorze houses in full length. The link is provided below. Thank you. See you in the next lecture.