Introduction to Ancient Indian Technology
Professor D. P. Mishra
Department of Aerospace Engineering
Indian Institute of Technology Kanpur
Module 5
Lecture No 25

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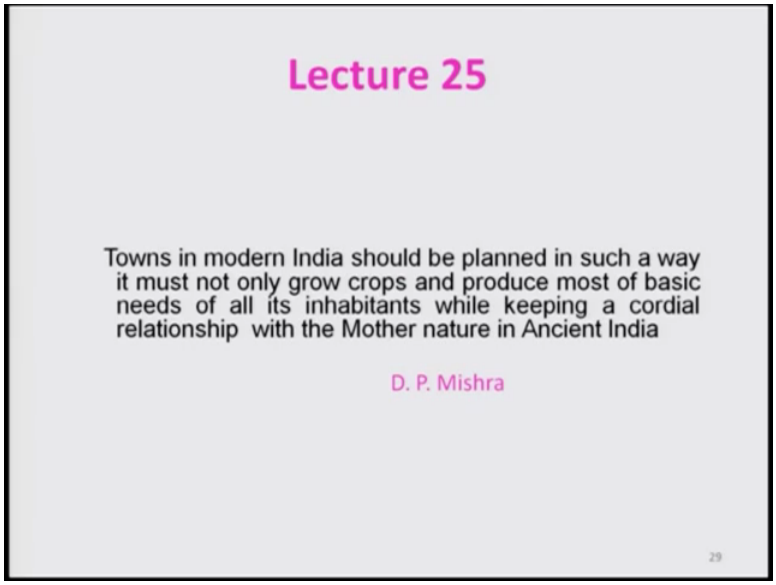

Let us start this lecture with a thought process, towns in modern India should be planned in such a way that it must not only grow crops and produce most of the basic needs of all its inhabitants, while a cordial relationship with modern nature should be maintained as in the ancient India. In the last lecture we discussed about the town planning in the both first phase and second phase of civilisation and we will continue today with certain other cities which were discussed in the last lecture like Vijaypuri, which is in Telangana and that flourished around 225 AD to 325 AD.

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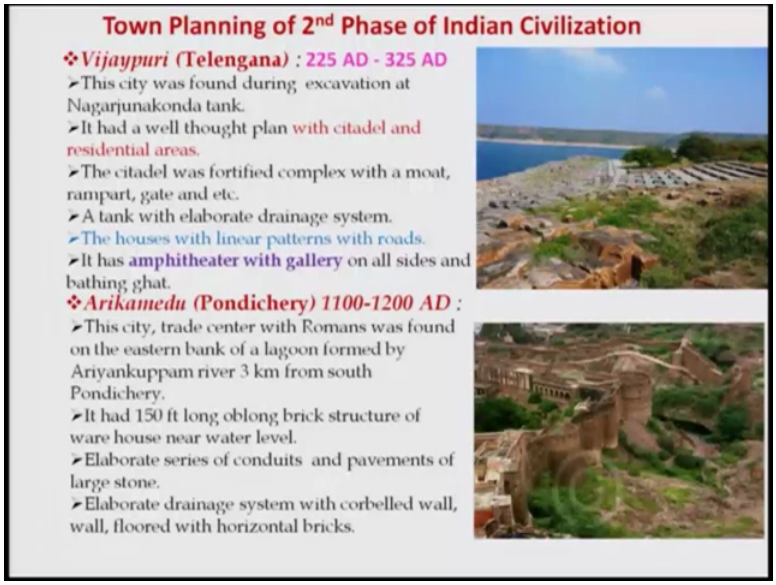

And this city was found during the excavation at Nagarjunkonda tank you know if you look at this is a very big tank which was being maintained by the people and used for water and it had a well thought plan with a citadel and residential areas. Citadel is the place where the king and the other places will be there. Citadel was fortified with a moat, rampart, gate and other things and a tank with elaborate drainage system was having and houses with linear patterns with roads. These roads were basically similar to what was found in Harappan civilisation, I think that process might be continuing till this period and it had a amphitheatre with a gallery on all sides, bathing ghats.

If you look at some of the remnants shown here, of course near this Nagarjunkonda tanks and of course some portion will be there, it is made out of stone basically. Let us look at now the another city which is Arikamedu, nowadays it is known as Pondicherry and which flourished around 1100 to 1200 AD kind of thing. City was basically a trade centre and who were having trades with roman empire which was established on the eastern bank of a Lagoon formed by Ariyankuppam river around 3 km from south of Pondicherry. It had 150 ft long oblong brick structure of a warehouse near the water levels like I think maybe some of these are warehouse where you can store the materials. Elaborate series of conduits and pavements of large stones were found in these excavated region and indicating that these are maybe for the water transport and other things.

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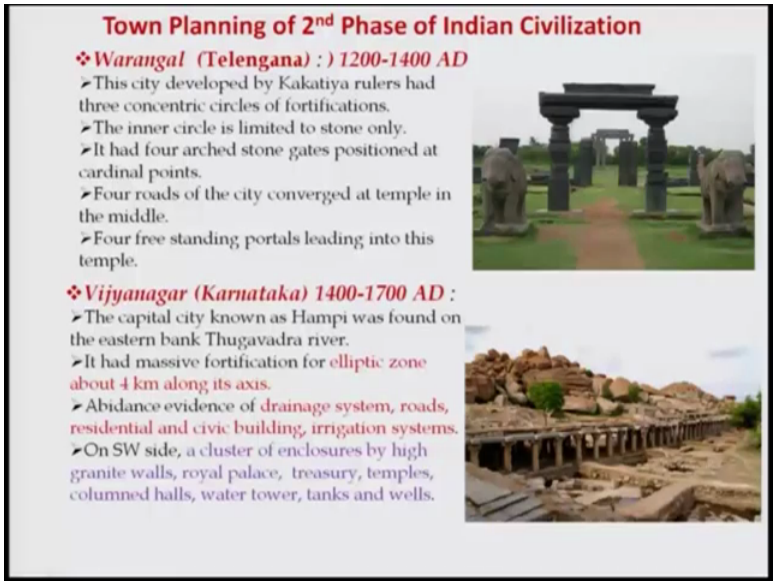

And elaborate drainage system with corbelled wall floored with horizontal bricks were also found in this site and which indicate that you know, they have a very good drainage system and space system for the disposal of the garbage. And Warangal is in Telangana nowadays earlier of course it was in Andhra Pradesh, this city was flourished around 1200-1400 AD during Kakatiya dynasty period and I had happened to visit this place maybe few years back, I was not that much interested in this part of ancient technology. But I was thrilled to see these kinds of gates which were made of granite stone and very good work you can see, very intricate work being done. And how it was done really is interesting to look at as granite is very hard stone, difficult to manage.

And it had four arched stones gates like this one here, the four sides of the fort and which is of course the fort was a cardinal point, and four roads of the city converge at the temple in the middle of the city and I remember that there was a nearby mountain and mountain was having staircase made of stone, right from there itself, and even today it is there and four free standing portals leading into this temple and there is very good, if you look at these are elephants and very nice intricate works are there and there are several other things.

And I had also seen at that time, there is a tank water tank made of stones, and there was also a well which is having linings were the stones. So how they have put it andmade it is a really important thing one has to think at that time. So Vijayanagar empire which is at Karnataka and it was around something from 1400-1700 AD you might be knowing Krishnadevaraya who was a very well-known king of Vijayanagar empire. And capital city known as Hampi

was found in eastern bank of Tungabhadra river right. And these are some remnants of the capital, of the palace which is having lot of stones and these are the part of the palace maybe some you know, meant for some kind of a hall or something because lot of pillars you could see. It had a massive fortification for elliptic zone, around 400 km along its axis and enough evidence of drainage systems roads, residential and civic buildings, irrigation systems were found in this excavation site.

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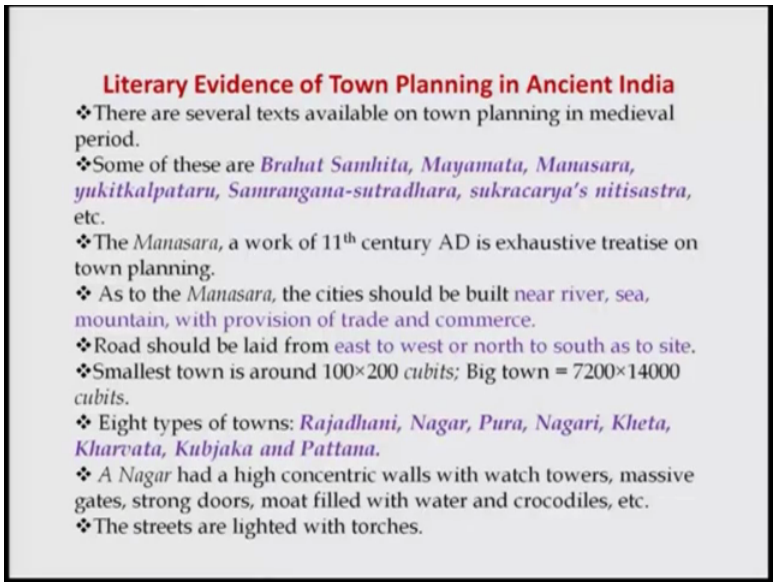

On the south western side, a cluster enclosed by high granite walls, royal palace, treasury, temples, column halls, this is one I think part of it and water tower tanks and wells were found. That mean it is very clearly can be concluded that the city was well planned and then it was really good and then lot of designs might have gone into forming this city and also maintaining it. So literary evidence if you look at, there are several text available on town planning in medieval period and some of these are Brahat Samhita, Mayamata, Manasara, Yuktikalpataru, Samarangana Sutradhara, Sukracharya's Nitisastra and several other even you will find those texts today. And the Manasara a work of 11 century AD, is exhaustive treatise on town planning which we will be discussing some of the features of Manasara. As to the Manasara this cities will be built near the river, sea or mountain with provision of trade and commerce

And roads would be laid from east to west or north to south as per the site requirements and smallest town has around 100 into 200 cubits according to this classifications. Cubits I have already discussed 1 cubit will be around 0.45 meters, Big towns have something 7200 into 14000 cubits area and eight types of towns what this Manasar had identified, one is

Rajadhani, Nagara, Pura, Nagari, Kheta, kharvata, Kubjaka and Pattana, so these are also various kinds of cities you know. And Nagara had a high concentric walls with watch towers, massive gates, strong doors and moats filled with water crocodiles, etc these are the main for protecting the fort and streets are lighted with torches.

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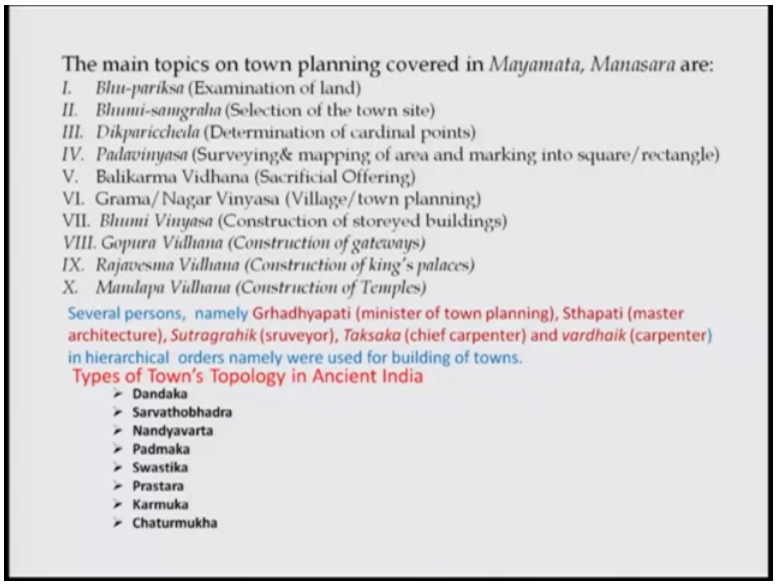

The main topics covered on the town planning in Mayamata and Manasara are Bhumi Pariksha, I mean basically examination of land, which land will be suitable for having a city, and Bhumi Samgraha is basically selection of the town site. Dikpariccheda, determination of cardinal point that means where your citadel will be there kind of things, so that will be cardinal point of the city. And Padavinyasa; surveying, mapping of areas marking into square and rectangle because that is being preferred for making the houses. Balakarma Vidhana that is sacrifice of offerings, I mean there is a ritual which was there till I think some years back when we are having this rituals.

Grama Nagara vinyasa, village and town planning, Bhumi vinyasa, construction of storey buildings, Gopura Vidhana, construction of gateways, how to make what are the materials all those things, Rajavesma Vidhana, that means construction of kings Palace. Palace can be somebody else's but king's palace is very important and then also intricate in design. Mandapa Vidhana construction of temple, of course I will be not be discussing this lecture about temple because it is quite vast and we will not be doing that. And several persons namely Grhadyapati, the minister of town planning, Sthapati master architecture, Sutragrahik surveyor, Taksaka chief carpenter and Vardhaik carpenter in hierarchal orders you know are

to be employed and then they are the people who designs the buildings and the towns and they will also be executing, they will be responsible for that.

It very clearly says that in modern, as in modern times other time also the, you know, set of engineers were there these are basically engineers who were doing. Types of town topology in ancient India, several of them mentioned in this book. One is Dandaka, Sarvathobhadra, Nandyavartha, Padmaka, Swastika, Prastara, Karmuka, Chaturmukha and some of these things we will be discussing about that.

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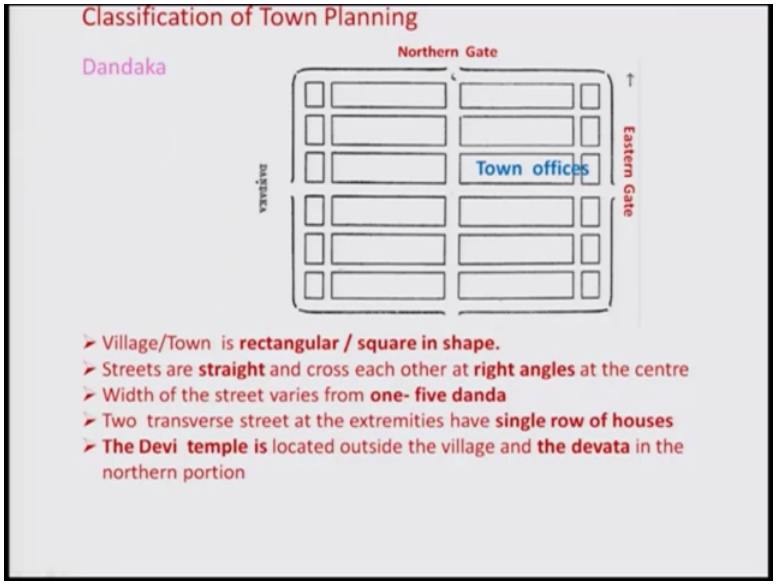

If you look at Dandaka, it look like this, this is a topology of a city. If you look at, this is your northern gate, this is one gate here and similarly eastern gate here and there might be a citadel in somewhere in the town. And this shape if you look at is basically rectangular or can be square shape and roads, these are roads, these are basically roads, straight roads and these two are bigger roads you know. It will be crisscrossing these roads and these are by lanes right and width of this streets vary from 1 to 5 danda and to transverse street at the extremities have single rows of house. If you look at these rows, single rows of house and this will be one road also, this is also roads. And Devi temple is located outside the village, whereas the Devta temple is in the northern portion of the city. Even today you will find lot of cities is having Devis at the entrance of the village or a city and that culture is still today we are having.

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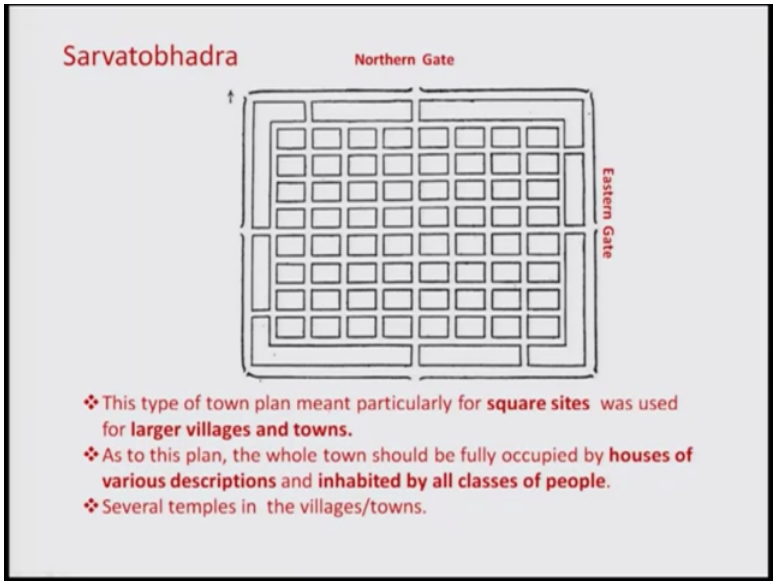

Sarvathobhadra city will be like that. If you look at this arrow, if I am putting, it is basically northern side right and this is your eastern side and this is having one gate here and there is another gate here, there is another gate, 4 gates basically but besides this in the corner you are having also small passages where people can live and this type of town planning meant particularly for square sites or a rectangular site that can be used for larger villages and towns not for small ones. As per this plan the entire town should be fully occupied by the houses of various descriptions and inhibited by all classes of people. That means there is no segregation between classes except these places that might be for some fortification or some other things, which will be there at the periphery maybe warrior people or classes will there to protect the city or maybe it will be taken by the king who will be protecting the city or administrator city administrator.

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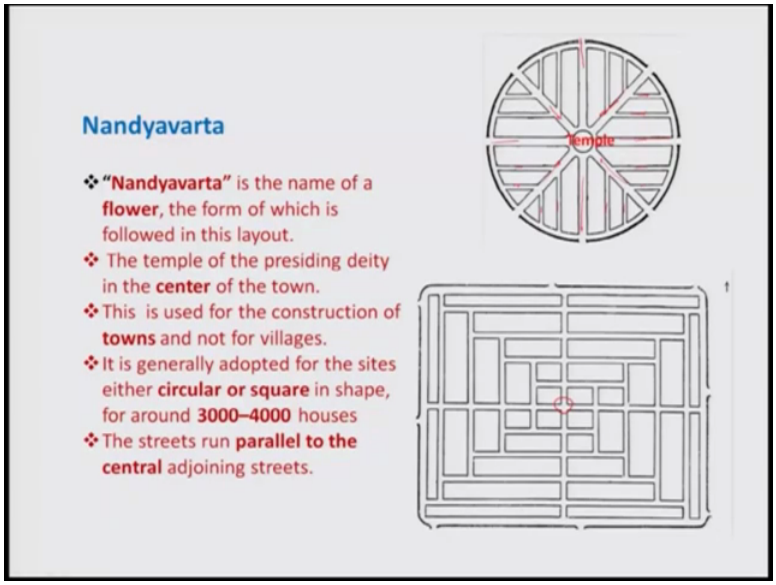

Nandyavarta is basically a name of a flower, the form of which is followed in this layout, this will be one kind of layout which will be Nandyavarta, this is circular in nature. At the centre there will be temple of course at the centre also the chief administrator or the king will be residing. There will be of course preceding deity in the centre of the town and if you look at this is the road. Main roads here and similarly this is crossing. And besides these there will be other roads which are meeting at this temple and these are small lanes which are parallel to each other you know, that is parallel to this side that is a very interesting part right these are parallel similarly this is parallel.

This is generally adopted also for square if you look at this is square size kind of thing and here in the centre there will be you know, temple and also the people who are controlling the city or the administrator will be there. And here of course these are the roads and this is good suitable around something 3000 to 4000 houses of course today you cannot adopt that because people will be thinking about 30,000 to 40,000 houses and as I told the streets run parallel to the centre joining streets you know these are the things, lanes are connected to the main streets.

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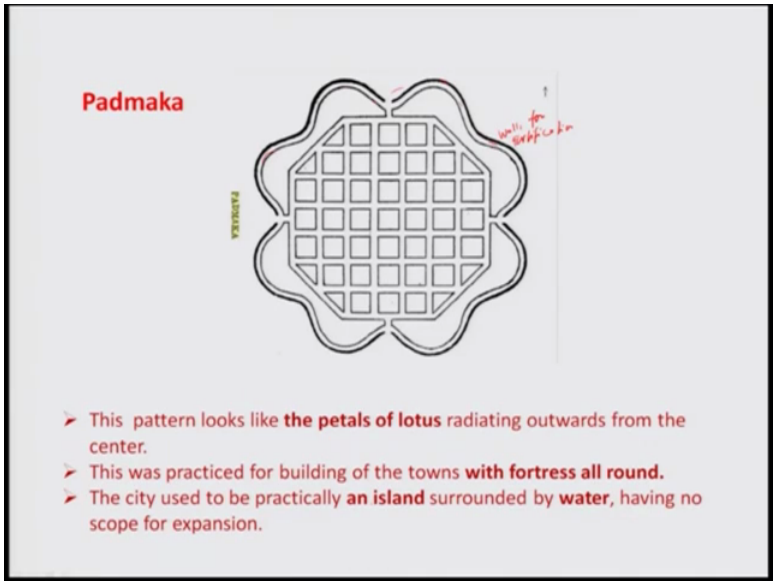

And there is a Padmaka which is similar to the petal of Lotus, and radiating outwards from the centre, and this was practiced for building the town with fortress all around. These will be basically fortress walls or for fortification, and city used to be practical an island surrounded by water where you can have, having no scope for expansion, therefore the city has been made in such a way. Of course these are we need to look at it, where it was lying. I remember the Shivaji, Chatrapati Shivaji had made some kind of a city inside the island maybe it is of that shape I do not know, you can cross check that.

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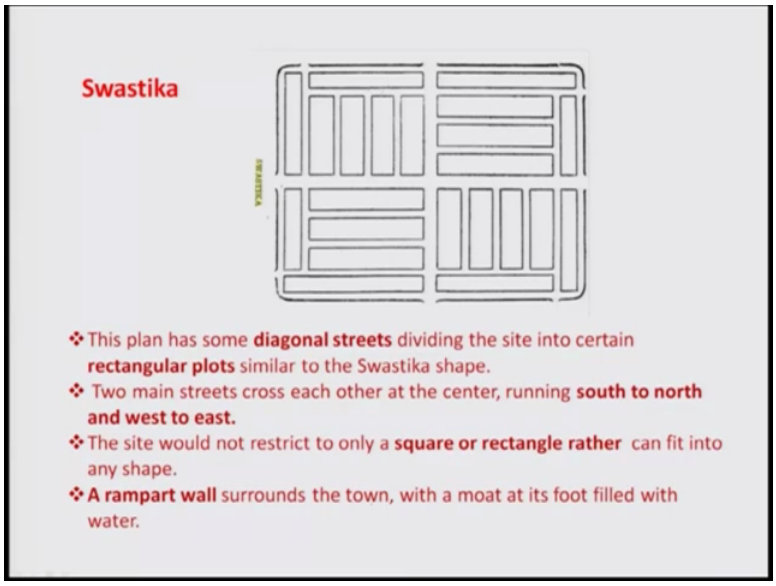

Swastika is another one which is similar to the, you know earlier things in rectangular and these are having diagonal you know streets dividing certain rectangular plots. These are you

know rectangular plots if you look at people can live in that. so if you look at these are the main roads, this is one gate here and if you look at this road will be like this, one can think of joining here and to this gate, there is another gate here. Similarly one can think of this is like a swastika, these are the roads, this looks to be like a Swastik kind of thing. Two main street each other at the centre, this is your centre and running south to north and west to east. Site would restrict it to square and rectangular so that it can fit into this. Rampant walls around this town with a moat at it foot filled with water.

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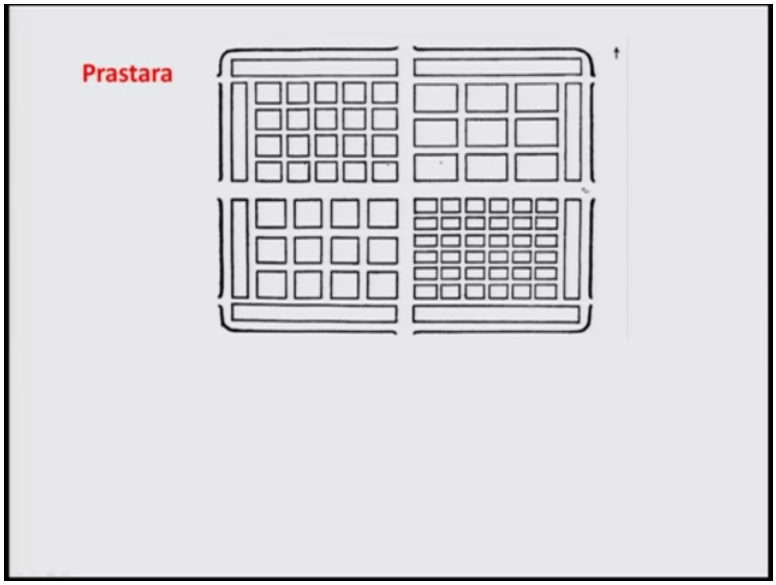

Prastara will be having what you call similar in the shape rectangular shape or maybe square. It does not suit for triangular or circular shape. Main roads are much wide if you look at these are the main roads and that side, right, of course this is the centre. These are of course the main gates gate here, this is the northern side this is the eastern side, one gate here one gate there this might be small passages and you can look at that these are bigger plots, means you know it can be occupied by the rich people that is what one can guess, and these are little bit smaller, of course this is the next size right which will be for the middle class, this maybe also idle class, this maybe the poor class kind of thing, poor class in the sense maybe from economically. The town may or may not be surrounded by a fort, this is what we talked about Prastara.

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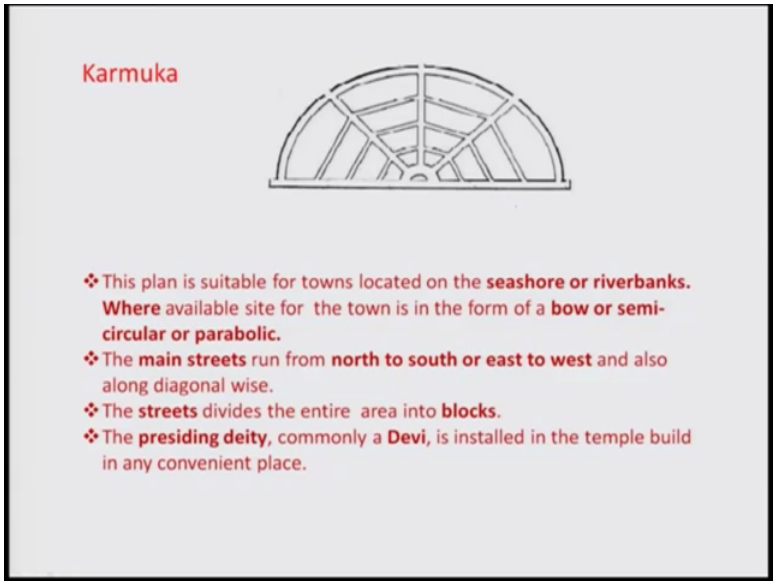

And there is a Karmuka which is a very half circle kind of thing and this kind of plan is suitable for sea shore or river bank because one side would be there. And it can be circular in shape, because this is a half circle and these are also gate kind of things. Main streets you know run from north to south east to that is alright, and street divide the entire area in blocks so these are the streets and these are lanes and these places of course you can have a house and it will connect to the main lanes. And this is you know the place where all people will come meet and maybe you are having a business centre here in the centre and so also in this there might be a street also here this type. And generally preceding deity commonly Devi is installed in the temple building in any convenient place.

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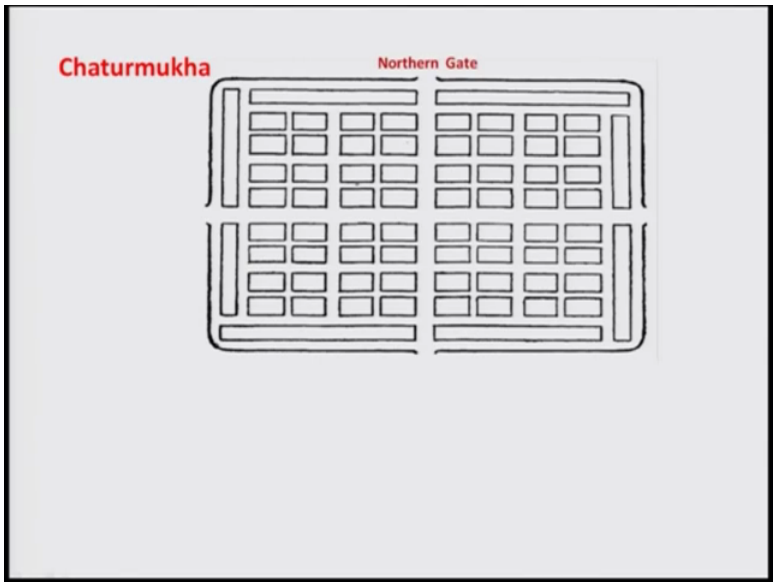

And Chaturmukha of course is a, from name itself there will be four gates. This is northern gate this I eastern gate, and then this will be southern gate and western gate here. And these are having equal sizes houses of course the side one are the larger size land areas, which will be meant for the administrative people to manage this city properly or from or protect the city from the enemies. This site can be used for the square or rectangular having four faces or four gates. Generally the temple you know is being considered near by the centre where there might be a temple where people will come and do pujas. So we have seen that various kinds of town planning you know in the literature of course I have shown you very few of them. But some of these town planning or the layout can be utilised today in the present context also and it has to be done properly right.

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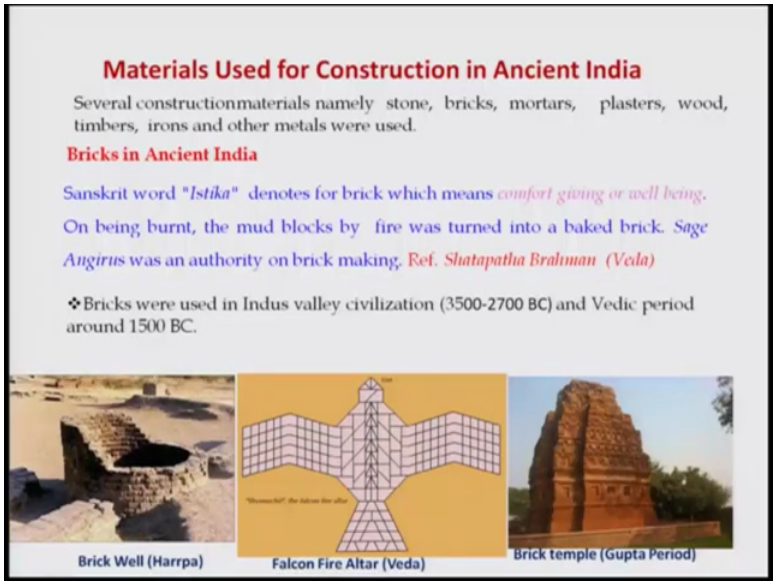

Let us look at the materials used for the construction of ancient India. As we have already learned there are several materials like stone, bricks, mortars, plasters, wood, timbers, iron other metals were used in ancient times and brick if you look at in ancient India is very old. Let me tell you that brick wells in the Harappan times, this is the well which we had we will be seeing and also later on and this is the falcon fire altar which is used in Vedas for making ‘yagyas’ and other things right. And this is the brick temple during the Gupta period it is nearby Kanpur in Bhitargaon, which is still existing because I had vested this place maybe two years back and it is quite interesting temple and made out of brick not stone.

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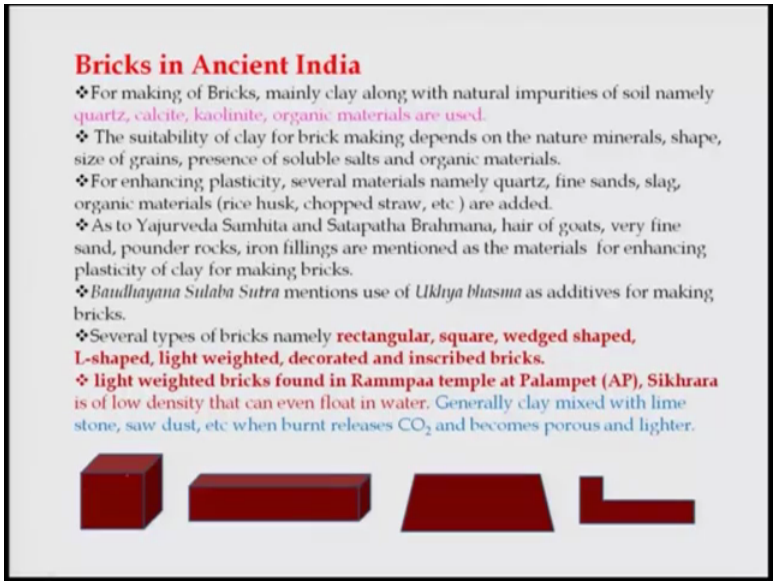

And bricks if you look at the Sanskrit word Istika, denotes brick which means comfort and giving or well-being kind of thing on being burned the mud blocks by fire was turned into bricks of course according to Sathapatha Bhraman Veda sage Angirus was the authority on brick making. And bricks were used as I told in Indus Valley civilisation and Vedic period and later on also even today we are using bricks. Bricks if you look at is mainly made from the clay with of course natural impurities of the soil like quartz, calcite, Kaolinite, organic materials and others things, right.

And suitability of the clay from the brick depends on the nature of minerals which is there in the clay and also the shape of the size of the grains, presence of soluble salts and organic materials you know, that is very important thing one has to look at it. For enhancing plasticity several other materials like fine sands, slags, organic materials like rice husk, chopped straw and other things are usually added. According to Yajurveda Samhita and Sathapatha Brahmana, hair of goats, pound rocks and iron filling are mentioned to be added for enhancing the plasticity of clay from making bricks. But of course these are the things has to be tested that is true or not, but however some of the materials can be even still used like your fine sand, which is being used today. Baudhayaya Sulabha sutra has mentioned about the use of Ukhya Bhasma basically ash as additive for making the brick.

So several types of bricks namely rectangular, square, wedged shaped, L shaped even light weighted, decorated, inscribed bricks are being mentioned in the various texts. If you look at these are various shapes, even the square, rectangular this is trapezoidal, this is L shape. I will

be discussing about that in the, particularly when you make this wells you need to have a trapezoidal bricks and also when you make an arc the brick you know size and shapes would be congruent with the align properly otherwise it will not align properly. And if it will not align, it will fall down.

So therefore those kind of sizes has to be you know made and also how we can do today, we cannot do because we do not know how to make yourself bricks, the company or the industry will do, Industry will not make according to our wish, according to our design. Earlier days I remember that brick was basically being designed and developed in rural areas by the people. Even like light weight bricks found in Rammpaa temple at Palampet in AP, Sikhara is of low density that even can float in water. How you can make because generally clay mixed with lime stone, saw, dust, etc, when burned will be releasing carbon dioxide becomes porous and becomes lighter and that kind of things were there earlier days, you know and today you will not find that kind of bricks.

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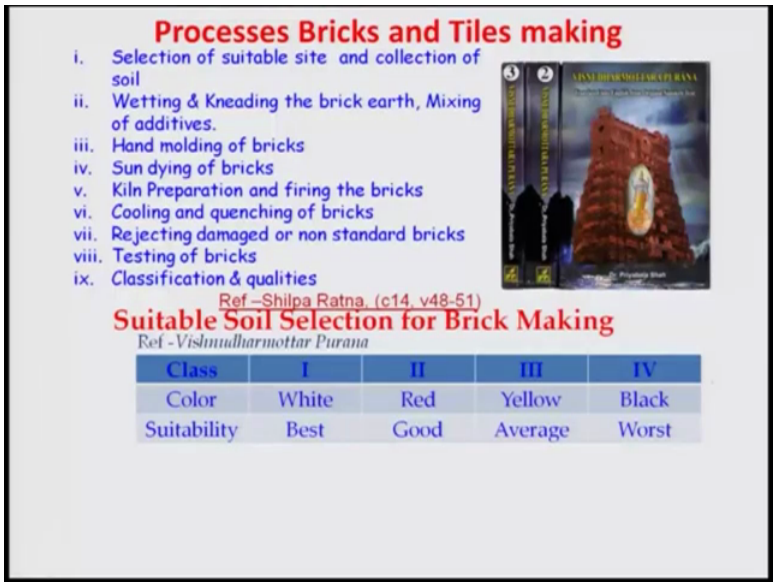

And process of bricks or tile making is being mentioned in the Shilpa Ratna and one has to select the suitable site and collection of soil because the soil has to be taken from the particular site and the site has to be selected. One has to wet you know and then add whatever the ingredients having mix it properly and then knead it for making bricks. Hand moulding of the bricks were being used earlier days, it must be sun dried and kiln has to be prepared for firing of bricks. Cooling and quenching of bricks is very important because you cannot really you know remove as it is the rate of cooling is important for getting a good quality bricks, it

has been mentioned in Shilpa Sastra. And there is some standard has to be maintained if it is not meeting the standard then it has to be rejected.

There is also way of testing the bricks and classification and qualities of the brick also has to be taken care while you are doing that. So suitable soil selection of bricks what people have talked about is something four types of soil; colour wise it is basically white is the best because plasticity will be better, red is good and yellow if you look at is average and black is the worst for making bricks. And according to that is your Vishnudharmottar Purana this is 3 volumes, (())(26.58) you know translated from Sanskrit to the English. Clay soil must be able show several properties that can be useful for making bricks, plastic when mixed with water that is very important and it must have enough tensile strength to keep it safe, clay particles must not fuse together because then it will be brittle in nature right.

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So ancient brick kiln if you look at was mainly for clamping of bricks and tiles in piles then burring together in a kiln. And temperature of kiln around 200 degree Celsius was used earlier times, even today also with the help of burning the twigs of trees like peepal, khadir, palash any other trees. As a matter of fact maybe why this they have mentioned that has to be looked at. And this is a typical what you call as shown in ancient time people were doing even in some areas they do. There is a hole where they will be using these logs of wood for burning and they will be having these things, what you call mud walls being done. And even I am aware that in using the cow dung people could bake this pottery and maybe I do not know whether people use cow dung for baking the bricks or not.

Of course in modern time smoke pipes were kept in the kiln. But there might be some kind of a smoke pipe at that time maybe just a hole and bricks or tiles are allowed to bake for about 10-15 days and this technology is still used in rural areas of India, Africa and many other to produce bricks in small scale. But nowadays it is not there because when I was a kid I had seen a brick kiln in my village but today it is not there and people do not know how to also make a kiln themselves.

Still today, in India this production of the bricks you know by local tradition is around 20% some people claim but I am doubtful about it. And it is of course considered to be inefficient process by certain expert as it lacks thermal insulation and also the burning may not be that good. Those things you know like one has to look at when we want to revive this kind of technology. One has to also improvise it because there is a break in the transfer of knowledge from the previous generation to the next generation that might be a lot of problem in that as we see today.

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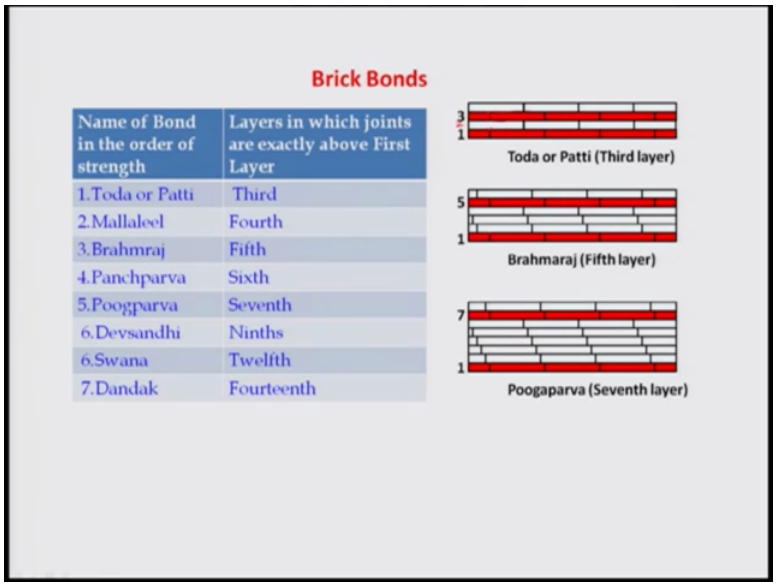

And the brick bonds if you see there are several kinds mentioned in the text. Toda or Patti is basically third kind of things and toda means if you look at is a basically third layer of joining. If you look at this is the one brick right and this is the second one, this is second layer and another layer will be this one, that means this brick layer this brick thing is being repeated here, joining here it is repeated in the third layer. Similarly 4^{th}, 5^{th}, 6^{th}, 7^{th} 9^{th}, 12^{th} 14^{th} kind of thing, various names are given here, like Mallaleel, Brahmaraaj, Panchaparva, Poogparva, Devsandhi, Swarna and Dandaka. I think these names are in Marathi, if you look at in English it goes by that.

I will show you some of them 5th layer, that means if you have this laying of the bricks in wall in such a way that this will be the joint, let us say these two bricks you know will be repeated after the fifth layer that means if you do that then strength will be much higher. But unfortunately we are only using the third layer kind of thing today I have never seen 5th layer people are using, even if you look at the 7th layer, which will be this kind of repetition will be coming at the 7th layer, similarly 9th, 12th and 14th, you know one has to find out where you can use, you cannot really use this higher you know layer in all the work. So therefore these things can be looked at in details and then also find out its utility so the strength of the wall can be enhanced.

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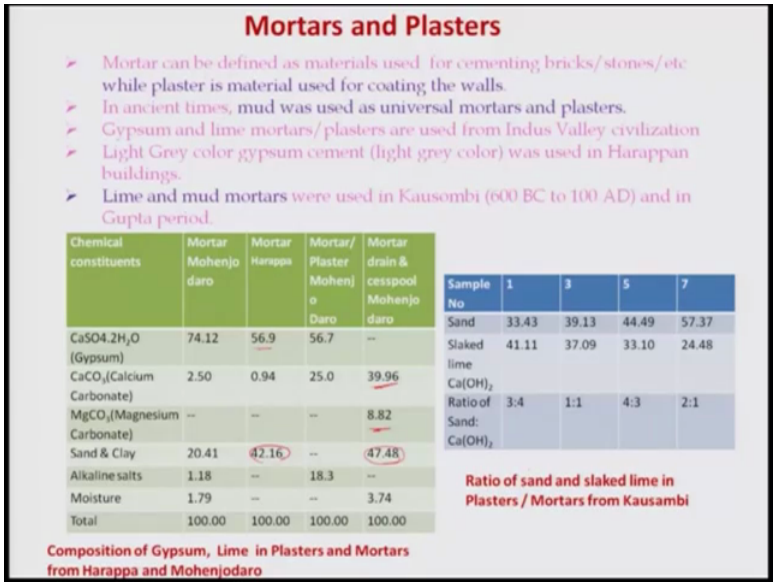

So mortar can be defined as material used for cementing bricks, stone kind of things we know, while plaster is the material used for coating the walls right. In ancient times mud was used as the universal mortar and plaster as we had seen in the rural housing lectures. Gypsums, lime mortar or the plasters were used since the Indus valley civilisation and even the light grey colour gypsums were used in Harappan buildings were people have found out. Lime and mud mortars were used in Kousombi in 600 BC-200 AD in Gupta periods and composition of the gypsum and the lime in plasters and mortars in Harappa and Mohenjodaro. If you look at the, in the mortar you will find something 74.12 % gypsum and calcium carbonate 2.5 and magnesium carbonate nil and then sand and clay is around 20.41 %, alkaline salt 1.18, of course moisture will be there. So this is the kind of things Mohenjodaro.

Of course if you go to Harappa it is changing, it is different you know sand and clay is almost double right and there is less amount of gypsum. But if you look at this main drains of this from Mohenjodaro, you look at this calcium carbonate is more and there is magnesium carbonate comes into picture and maybe the sand and clay is little higher side. So one has to say that it is not the same, it is different proportion coming but most of the materials are similar in nature. These people have you know tested it taking the samples from the Mohenjodaro and Harappa, Harappan site.

And this is from the Kousombi, the people have tested it. Let us say these are sample 1, sample 3, 5, 7 there are several samples I have taken only few of them and sand is something 33.43 and slaked lime that is 41.11, 3 by 4 is the ratio being used. It may be used for basically as a mortar kind of things, where for the plaster maybe it is 39.13 to 37.09 kind of things, 1 is to 1, sorry this may be used, 1 is to 1 might be used for the, for the mortar and 3 is to 4 might be used for plaster, right. Similarly, for this fifth one may be used for mortar right and this is used, also maybe for kind of mortar, so various ratios are being used for this mortars and plasters in Kousombi and several data you can get out of it.

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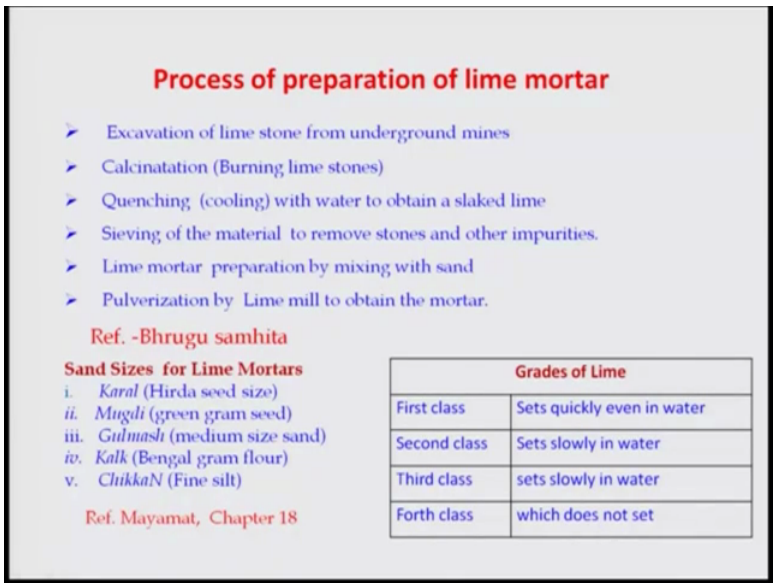

So let us look at how one can prepare the lime and mortar. And excavation of limestone from the underground mines has to be undertaken and one has to calcinate it by burning of limestone and one has to quench it with water to obtain a slaked lime. Of course the sieving of the material to remove stones and other impurities is also important. Lime mortar is prepared by mixing lime with sand, Pulverisation is maybe required for lime to obtain the mortar and this is maybe done manually and as per the Bhrugu Samhita. They have also

mentioned about various sand sizes for lime mortars. This is Karal the Hirda seed size and Mugdi green gram seed size, they have mentioned that way and Gulmash medium sized sand, Kalk the Bengal gram flour sized, Chikna is a fine silt.

So they have you know developed their way of specifying the size of giving the example of various seeds so that they can utilize keep that in mind not like in present day you know some mm kind. And according to the Mayamata, chapter 18, there is various grades of lime, the first class is the of course sets quickly in water, second class sets slowly in water and third class sets slowly, I mean little bit will take more time. Fourth class will be not be setting at all that is the kind of limes they have graded.

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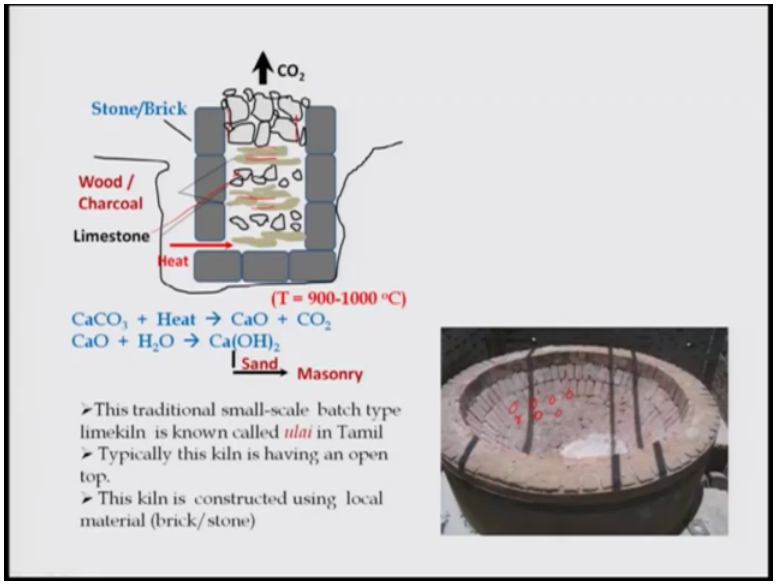

And if you look at one can think of kiln for calcination like they will be using the wood and charcoal here by layer by layer. These are the lime stones and they will be heating by putting this something wood fire and then heating it and then the gases will be going out, that way carbon dioxide they will be maintaining something 900 to 1000 degree Celsius then this calcium carbonate will be converted to CaO calcium oxide and carbon dioxide. Calcium oxide will be coming in contact with water, it will become calcium hydroxide. Once it is there, then you can use add this sand and then you can use for masonary purposes. Traditional small scale batch type limekiln is also used earlier and which is known as Ulai in Tamil nadu. Let me show you a kiln here. It is basically made out of bricks and then in this case the wood and charcoal along with the limestone will be placed and then it will be heated from the top kind of things and then it will be converted into slaked lime.

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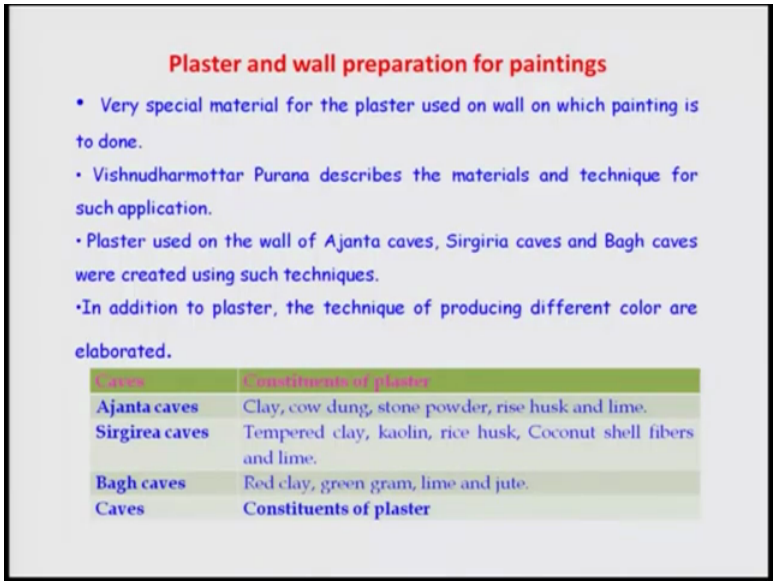

So we will see the plaster and wall preparation for paintings, very special materials from the plaster to be used on the wall particularly when you are trying to paint it. And as I mentioned the book that is Vishnudharmottar Purana discuss lateral technique for such applications. And plaster used on the walls are Ajanta caves Sirgiria caves and Bagh caves were created using might be such techniques what is mentioned but still more research has to be done to find out. In addition to the plasters, the technique of producing different colours were elaborated and lot of research is going on particularly this Ajanta caves like people are saying this plaster will be having clay, cow dung, stone powder, rice husk and lime, and people are saying that this paints are remaining because of this speciality.

And also in recent time somebody did research and claimed that the tobacco was being used in Ajanta paints so that it has still being there intact. So in the Sirgiria caves tempered clay kaolin, rice husk, coconut shell fibres and lime were used and the bagh caves red clay, green gram, lime and jute were being used for the plasters and kind of things. Therefore you know a lot of things we can learn from this things and a use even today we can revive those things but more research is required.

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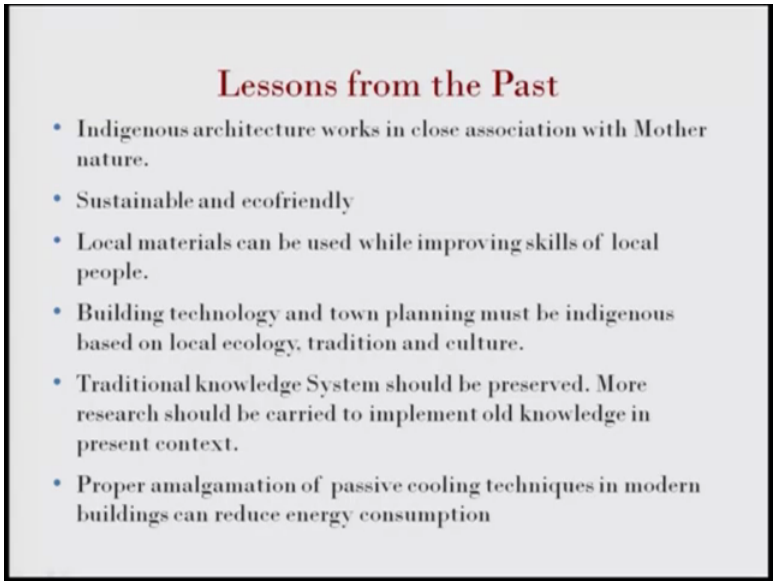

Let us conclude that what we can learn from the past and utilise and at least conceptual wise. What we need to do that basically indigenous architecture generally was in close association with Mother Nature and sustainability eco-friendly is the part and parcel of the ancient buildings and also the town planning. Local materials can be used while improving the skill of local people. Because when you do that then you know skill will be there with the people and they can be more innovative and then utilise their creative power.

And building technology and town planning must be indigenous, based on the local ecology tradition and culture which is not the case today, right. Traditional knowledge system should be preserved. More research should be carried out to implement the old knowledge in the present context. Proper amalgamation of passive cooling techniques in modern buildings can be made such that it can reduce the energy consumption, which I did not cover but I must tell you that I am having certain data people have conducted in the ancient you know way of making house ad which can even you know maintain their comfortable temperature after the global warming, so we must adapt instead of just going for the air conditioner and other systems. So with this w e will stop over her. In the next lecture we will be discussing about basically how to conserve the water and also how to manage the water in proper way for irrigation and other things so that we will not face problem in modern times using the ancient technology, thank you very much.