Course Name: Building Materials as a Cornerstone to Sustainability

Professor: Dr. Iyer Vijayalaxmi Kasinath

Department of Architecture,

School of Planning and Architecture, Vijayawada

Week: 01

Lecture 04

Mud as a Building material

Hello everybody. So, in our last class we saw how mud as a traditional material can be used. We also saw two techniques of wall construction using mud. In this class we will continue with two other techniques of mud wall construction. First we will see the adobe wall construction. Now adobe is essentially a brick made up of dried mud that combines the components of earth, water and sun.

It's a traditional ancient building material composed of moist clay which is tightly packed sand and some binder or other something course like a straw or hay. Prehistoric period this mix in a slightly various form was called as piecing. This mixture is then fashioned into bricks and naturally dried or baked in the sun without the use of any kiln or oven or any energy intensive furnace. It is we just use sun.

The heat from the sun to dry it, which is a renewable source of energy available abundantly, specially in a tropical country like India. It is present in both modern and prehistoric architecture. Mud bricks, these were employed long before the opulent stone temples of ancient Greece and Rome. Now, these adobe mud construction techniques used to make, it varied depending on the historical period, local customs and climate. But in essence, it remained the same.

Now, these sun-dried bricks, they stand out as a prevalent and enduring mud construction technique because it is getting a lot of global popularity. Even today there are so many places where workshops are held to promote awareness, to encourage the use of this sustainable method. All you need is a small box or mould of wood or metal if you are doing it on a large scale you can have metal moulds also. And a stiff clay is required which is squeezed into this mould. And then that is turned out to cure and slowly dry.

After that, a mason can use them in much the same way as he would use a burnt brick or even a cement block. These adobe bricks can be made of any size. They can be the same like that of a burnt brick also. So, you have the 4 and a half inch by 3 inch by 9 inch. It

can be made like that or it can be made slightly bigger but not too big.

And for a thicker wall you can have it slightly big. So, here you can see that there are moulds. One mould is or you can make multiple bricks with one mould. Here is a mould where you can have 10 bricks at a time and Sir Laurie Baker has used it extensively. So, how do you test a block? So, first is your soil must have 70 to 75 percent sand content and in that you must add 7 to 12 percent cement and 1 to 2 percent lime.

So, the soil is not tested on site. So, the topsoil which is fertile must not be used that I had told you in the last class also you never use a topsoil because it is very fertile with organic matter. Normally soil below 8 inches is taken and this soil must have 70 to 75% sand content. If not then you should add appropriate quarry dust or no sand must be added to it. Then you add cement about 7 to 12% and you can add lime which is 1 to 2% because both of these act as stabilizer.

Then this is mixed completely dry and to this dry mix you add water. It is very important to understand water content because water content of adobe affects its strength and resilience. Too much water will make the brick very weak. So in order to improve its waterproofing qualities you can even add asphalt emulsions. It is occasionally added.

To modern adobe blocks. It is also possible to add a blend of lime and Portland cement as I had said and parts of many Indian states they use even fermented cactus juice as a waterproofing agent. So, each local place has its own way of waterproofing these. Follow that and modern commercial adobe they can occasionally be kill dried also so instead of making it dry under the sun you can even dry it in a kill that makes it faster or more controlled So, a process that purist could refer to as clay bricks. Therefore, they can be utilized.

Traditional adobe bricks must be dry in the sun for approximately one month. Now, what you do to the dry mixes? You add this water and after that water is added, you put it in what is called as a cube cast. And you compress it as much as possible. So you put it in a cube cast and compress it and pack it. Pack it by means of something which adds pressure to it not just manual.

Then these soil cubes are cured with wet cloth. You lay a gunny bag or something like that on this and you cure it. And you cure it for 7 days by adding a by layering it with a wet jute gunny bag or a cloth or something. And then these can be immersed under water for 72 hours to understand whether it will disintegrate or stay stiff. Then a compression also it has cement.

So, adding it keeping it under water will cure it better. And then a compressive strength test is done. So, according to Bureau of Indian Standards, the compressive strength must be a minimum of 3.5 megapascals. In my first introductory class, I had committed that I will not get too much into the chemical properties and physical strength of these building materials.

Rather, I would focus more on their environmental implications and therefore, I will not go much into the compressive strength and other qualities right now. Then what happens? A skilled mason adeptly mixes these ingredients and the smaller brick is likely to crack less. So you should ensure that you must not use very large blocks. So if care is taken to dry the bricks slowly. Say for at least a month slowly for a long duration the walls are built in the normal proper way then strong crack free walls will be the outcome and we can use this even for 2 or 3 storey houses.

Of course, the usual care must be taken to protect them from wet and to use standard bonding patterns. All those things we should take care. There is nothing new or risky or even rural about this system of building mud walls. And it is an obvious answer to the need for millions of small houses for the homeless without using any fuel or energy for their manufacture. And then you employ skilled masons who will mix these ingredients in a mold and pour the blend into a wood framed container shaping it into rectangular bricks.

These bricks undergo a meticulous drying process and as I said slow and longer drying process will lead to blocks which do not have much cracks and which become stronger. Then you have to transfer this to a shaded area for air drying which can last up to even 4 weeks. During this entire 4 weeks period, the bricks must be intermittently sprinkled with water to prevent complete drying because the curing is not yet complete. This is adaptable to hot climates and adobe bricks offer superior thermal mass. It provides very effective insulation against external heat waves.

This eco-friendly technique finds extensive use in many regions in India as well as in abroad and it shows how versatile this building material can be considering that this can be used in large parts of the world. And this natural building materials - it does not have too many energy intensive material to be added to it. Can add some organic elements like straw or hay and clay can be added you have to be careful about the sand content and water. For better strength you can add cement and lime and then you can see from this picture how these blocks can be arranged. So, this is the process where the soil is placed on the blocks and this is one and then it is left to dry under the sun which is a renewable energy source and then you stack the bricks in a particular way by sprinkling water on it periodically to ensure that it is not completely dry.

Now, these are some of the building examples which have been done with Adobe blocks. Next, we move on to COB. So, COB stands out as a very user-friendly and cost-effective mud construction technique requiring minimal resources and having a negligible impact on the environment. This vernacular method avoids contributing to deforestation, pollution and dependence on manufactured materials and power tools. It is both accessible and sustainable, fostering simplicity in construction process.

The term cob originates from Old English Latin meaning a lump of soil. To create cob you need to have a mixture of 25 to 30 percent clay, 70 to 75 percent sand and you need to have some straw also. From the picture you can see that there is straw in the mix. The composition is akin to lean concrete and it results in a material that hardens and takes shape as the water content dries out mimicking the characteristics of concrete. The construction process involves layering cob on top of each other to achieve the desired structure.

The word cob it actually is an old English root that denotes a spherical bulk or lump. So using the hands and the feet the cob builders they create lumps of earth which is combined with straw and sand. The cob is inexpensive to build and it is simple to learn this technique also. The absence of any form form work. Absence of any formwork or ramming or cement or rectilinear bricks or moulds and cobs allow for creation of very organic shapes like curved walls or niches or arches and it has a huge the thermal mass is very good and therefore it is warm in winter and cool in summer In dwellings which are built with cob walls.

Because of its resilience to both rain and cold, cob is perfect for every environment. Now, how is cob made? Cob is essentially a mixture of clay plus straw plus sand plus water resulting in a mixture, okay, with earth. And what you do now is you place the tarpaulin or some or on a firm surface you place all these mixture and you dry mix the subsoil. You add sand which is optional actually, but it is best to have sand though it is optional and subsoil in appropriate amounts. As many times as necessary to create a uniform mixture, you flip this mix.

Sand is only introduced when the soil has more clay than is necessary. So, based on the nature of the soil, you add clay or you add sand. Pour in a little water to make the dry mixture into a mould with a crater in the centre. It's usually preferable to add insufficient water than excessive amount because you can keep adding it later just the way we make a dough. The amount of water to add is not particularly standardized because it depends on the composition of the dry mix and that is also the beauty of this material.

Mix with your feet. Use your feet to press the dry materials outer edges into the crater center. Traditionally, conventionally human feet is used to make this dough. You can begin stomping as soon as the dry mix has covered the crater to ensure that all of the dry ingredients are thoroughly combined. Add water if needed. If more water is added by mistake add straw and other dry ingredients.

And then you start stomping as shown in I will name the picture 1 as shown in picture 2 and 3 start stomping. As you need water, you keep adding water or do not add more water. Then you have to make cob walls as balls as shown in picture 4. So, make these balls and keep it aside and then you start layering the cobs as shown in picture 5. So, once the cob, ribs and spine has been added, compress the brick using a spiky element like a stick or even some shoe or something like that to combine them into a single layer rather than single block.

So, do not make these only as blocks like cob rounds like this. You need to compress it and press it to ensure that these gaps get no filled and it becomes like one uniform layer. You should try to ensure that it becomes like one uniform layer as far as possible. The straw in the upper layer descends and it links with the straw in the bottom layer when it is forced against some pressure with a sharp object. This creates a stress and binds the structure together.

The straw from top layer and bottom layer have to get interspiced. Rather than remain as separate layers or separate balls. So, place the balls one next to the other and then start adding some pressure with some sharp object or a reinforcement rod or a shoe or something like that and make it into one homogeneous layer. Now, the basics of cob building method as we saw was to have a mix of clay, sand, straw and water using our hands or feet rather mixing the kneaded into a small lump which are then compact and shaped by hand to create walls and foundation. Now, the subsoil naturally varies in composition.

But it can be altered with sand or clay depending on what is more or what is less if it does not have the correct combination. Now, what are the advantages of cob wall? Cob wall is extremely labor intensive, but it uses inexpensive materials. It is earthquake and fire resistant. But then you need lot of people for stomping and lot of or it can be a slow building process if you do not employ too much of too many labours.

Subsoil naturally varies in composition. However, it can be altered as I already said. Cost wise it uses inexpensive materials. It may be used to make No, cob as a when you start making it can be used to make houses which have very earthy finishes which looks very natural. So people who are inclined towards natural living would find it very appropriate

to use cob in their buildings. So, the only four building material that you need are clay, water, straw and earth.

These are the four primary components which are used to construct cob dwellings. Even while some people might consider this to be a very primitive way of life. The reality is that this inexpensive structure is way more durable than more conventional residences and it provides the owner the growing level of comfort because it has high thermal mass. Cob walls, they resist weather remarkably well. Now it does not deteriorate even after heavy rains because of its porous nature.

When water creeps in if you stop the water then the water remains in that particular place and decay starts. But if you let the water be the water will automatically evaporate also once the warmth starts coming in. And also you should remember every cob wall building must have roofs with long eaves as it is shown in the picture. So it should not be like a cob wall with a flat roof or something like that.

The eaves must be very long. That is also called as a boot and a hat method. So, this uses a very impermeable foundation which we call as boot and a wide roof eaves which will shield the walls and protect the walls and it is a good way to prevent excessive exposure. External cob walls in very windy places are shielded from driving rain when you have a lime sand plaster if need be. Can even plaster it if need be but not necessary.

In rural areas they plaster it with cow dung. These buildings are very energy efficient. The walls of cob house are generally about 24 inches or 2 feet thick and the windows were correspondingly deep set giving the homes a characteristic internal appearance and is ideal for passive solar construction. Cob structures require little additional heating in winter and they remain cool and comfortable on summer days. They are because they are fire proof in many places they are even used in chimneys and you can see in Indian villages minus the straw these are used even in building cooking ovens.

And now we will see the CSEB construction. The raw material for compressed stabilized earth blocks or CSEB, these include local soil mixed with water, sand and a small amount of cement up to 5 percent. It provides a sustainable replacement for burnt clay bricks and cement concrete blocks because it is made from local soil. In a press or in a not it is just not a mold but it is a press these blocks are compressed sometimes manually sometimes motorized also and the soil raw or stabilized for the compressed earth block. Is slightly moist, it is made moist so that compression is better and these are poured into steel press with or without stabilizers and compressed either manually or through a machine press and you get CEB compressed earth blocks. And so you mix basically soil with little 5% cement and some gravel and you put it in a mixing mold, molding, curing that process

happens and ultimately this is what you get.

We will go through this whole process, not to worry. So, its earth as you since it is a local material you do not have to transport it from long distances making it a very earth friendly material. So, not every soil is suitable for making these CSEB in particular, but with some knowledge and experience most of the soils can be used for producing CSEB. Again top soil must not be used and a simple analysis of the soil will be good for us to be very confident in going ahead and doing it. For very sandy soils we can use cement as stabilizers and we can have lime stabilization for clay soils. These basics can be followed to make it a very enduring material.

The embodied energy of CSEB is about 11 times less than country fired brick. So, that goes to say how energy efficient it is in terms of its embodied energy content. Carbon emissions of CSEB is 12 and a half times less than country fired brick. So, for the same material which is fired and unfired there is such a big difference.

So, it becomes a very environmentally friendly material. And then what you do is you mix these raw materials put it in a mold and then you wait for 28 days for the appropriate compressive strength to be achieved by the block. So, this involves the mixing of soil and sand put 5 percent cement make a dry mix. Shown here mix it completely then add water to this and again mix it properly once you mix it properly these are put in molds for pressing this mold can be a very small ordinary one there are many types of mold you put it in molds which are like this you put it in very No modern and no very these will give a very steel molds will give a very sharp edge and you press these blocks very strong hard you press it manually all through or through machines and keep it for 28 days for proper curing and then the bricks are ready. Of course, it is important that you stack the bricks properly. After you make the mix, you stack it and leave it for curing and then you can start using it in your buildings.

These are some of the examples of building made with CSEB blocks. Auroville has done a lot of work on this. Their earth center and they have used it in many of their buildings including the visitors complex. Then you also have the symbiosis university hospital. This is just to show that it can be used even in a hospital and research center.

It can be used in a residence. Biome environmental solutions, they have used CSEB blocks. They were one of the first few to use it rampantly. Many of their projects are very earth friendly using CSEB blocks. Wallmakers have demonstrated the versatility of CSEB blocks in terms of very outgoing design applications.

Let us quickly look at the advantages of CSEB block. Now, it is a local material. So,

ideally the production is made on the site itself or in a nearby area. So, it saves a lot on transportation cost, the fuel and the money for the transportation. It is a biodegradable material.

So, well designed CHCB houses can withstand with minimum maintenance. It can withstand heavy rains, snowfall or frost without being damaged. The strength and durability has been proven since half a century. But let us imagine a building fallen down and a jungle grows on it. The biochemicals contained in the humus of the topsoil will destroy the soil cement mix in 10 to 20 years and CSEB will come back again to be again made into cement blocks. There is very little deforestation because you do not need anything to fire these blocks.

So, this will save us a lot of timber and forest which are being depleted very quickly. The resources can be managed easily or much better because each quarry should be planned for various utilizations. We can have once you dig the place for soil then a small …. what shall I say, a water body can be created there where you can have your water harvesting pond or wastewater treatment etc. So, you have to be aware that you can make it very profitable if you manage it properly. If you do not manage it properly it can be disastrous because you will have large pits on a particular place because you have reclaimed that soil you have taken the soil out.

Then CSEB blocks are very energy efficient and eco-friendly. They require only little stabilizer and the energy consumption is very less. It is about 15 times less than that of fired bricks. The pollution emission is also very less because there is no firing. So it becomes a very energy efficient option. These are cost efficient because these are produced locally with a natural resource and semi-skilled labour and almost without transport.

So, it will definitely be cost effective more or less according to each context and to one's knowledge. It is a well adapted material. So, being produced locally, it is easily adapted to the various needs, technical needs or social needs or cultural habits of the people because it is not a foreign material that we are bringing in. It is a technology that can be transferred easily because it is a simple technology and it requires semi-skill. What you need most is the combination of the soil and the other building materials with it and the compressing.

So, simple villages will be able to learn how to do it in few weeks. Efficient training center will transfer the technology in a week's time. It creates a good opportunity for jobs for people. So, CSEB allows unskilled and unemployed people to learn a particular job and rise in their positions. It has good market opportunity because according to the local

context, such as material, labor, equipment, people, whatever, the final price will vary but in most of the cases it will be cheaper than fired bricks and it has all the advantages of fired bricks. We will have in terms of importing opportunities since this is produced locally by semi-skilled people .

There is no need to import anything from far away places and that reduces our embodied energy also. It has flexible production scale which means equipment for CSEB is available from manual to motorized tool. It ranges from village to semi-industry scale and all of this is easily available. It is not a rocket science technology at all which is difficult to get. The selection of the equipment is crucial, but once done properly, we will be able to use the most adapted equipment for each our cases.

And most important is social acceptance. Demonstrated for a very long time, CSEB can become a very socially accepted building material because its quality, regularity, style allows a wide range of final house products. To facilitate this acceptance, we must banish or we must avoid the use of stabilized mud blocks. So, for speaking of CSEB, we have to do a lot of R&D. Already lot of R&D was done for more than 50 years when mud was referred to as a poor man's building material. From there to have come to a CSEB block is a long way and we can definitely over a period of time vouch for it as a very good material in terms of its strength as well as what it adds to the environment.

Only thing is we have to make it more socially acceptable. Let us quickly look at the benefits. The benefits include these have materials that are easily found and available cheap which means inexpensive sometimes even free from your own site. Their CO2 emissions during processing are very minimum.

These are locally available. It enables the use of reclaimed materials. They can be combined with other natural elements also such as lime. You can get organic shapes of buildings also. These can be recycled like organic shapes meaning I had showed the example of wall makers the building that they had done which is very organic.

It can be recycled and it is non-toxic. These can be easily repaired. We can use it to make furnitures inside the houses such as built-in seats or built-in beds and things like that. It has a good thermal mass and therefore it reduces the internal temperature during warm days and vice versa. There are certain challenges. The site has to be picked carefully to ensure that the soil availability in proper requirement or properties of the soil is good enough for a CSEB block. Otherwise, you will again start bringing CSEB block from outside and that will increase embodied energy.

The materials are heavy making transport difficult but that is also the case with brick or

stone. It is a labour intensive material no doubt because if you are going to make the blocks manually you will need a lot of labour which is a challenge but is a good opportunity for the local economy to flourish. It is better to build during dry season and it needs a good roof and a solid and dry foundation. Just a perspective to give you the embodied energy and carbon dioxide emissions of CSEB brick in comparison to country fired brick. The initial embodied energy of CSEB brick is about 572 megajoule per meter cube, whereas for a country fired bricks it is about 6000 megajoules per meter cube.

The carbon dioxide emission of CSEB block is 51 kg per meter cube. And for a country died fired brick it is 642 kg per meter cube making CSEB a very fantastic opportunity. So, proper soil identification is required and then you need to know how to organize your resources. You should have a good product developed by following the good quality of building materials that will go in. So, we will quickly see what mud does as a mortar. Mud is a material mixture used for filling in between the gaps for holding the bricks and the blocks in place and clay that we use for construction can also be used as a mortar.

There are just few things we need to keep in mind before using clay as a mortar. The clay should be free from all the unnecessary elements such as gravel and pebbles. To avoid this clay can be sieved when dry. To avoid cracks and shrinkage too much clay should not be used and when constructing the walls sometimes we prefer adding stabilizers such as lime or cement for better strength of the walls. In such cases mortar should be stabilized at least one and a half times more than the mud blocks. Normally an ideal mortar mix has a combination of clay with 40 to 50 percent sand and some amount of a binder such as a cement or lime comprising between 7 to 10 percent and mud can also be used as a mortar.

So, with this we will close the class which dealt more about the versatility of mud as a building material, a traditional building material and how it has slowly become a contemporary building material by virtue of how science has taught us to test the raw material and manufacture building material using mud. Will meet next class with another traditional building material. Thank you.