Ground Improvement

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Module No. # 06

Lecture No. # 15

Heating and Freezing Methods, Blasting Methods-I

Today, we would be talking about the use of heating and freezing methods as well as blasting methods in ground improvement. This is something, that these three methods are not really usual, but then, when there is a certain circumstance, one needs to really use some of these things.

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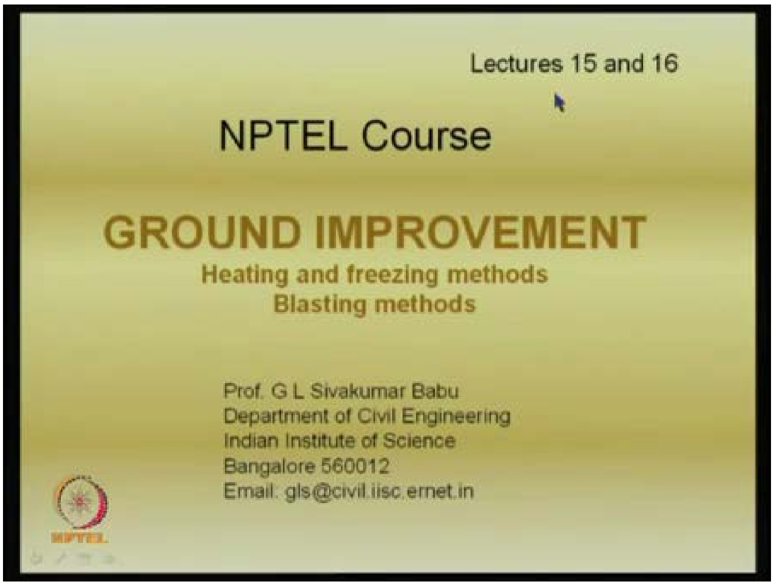

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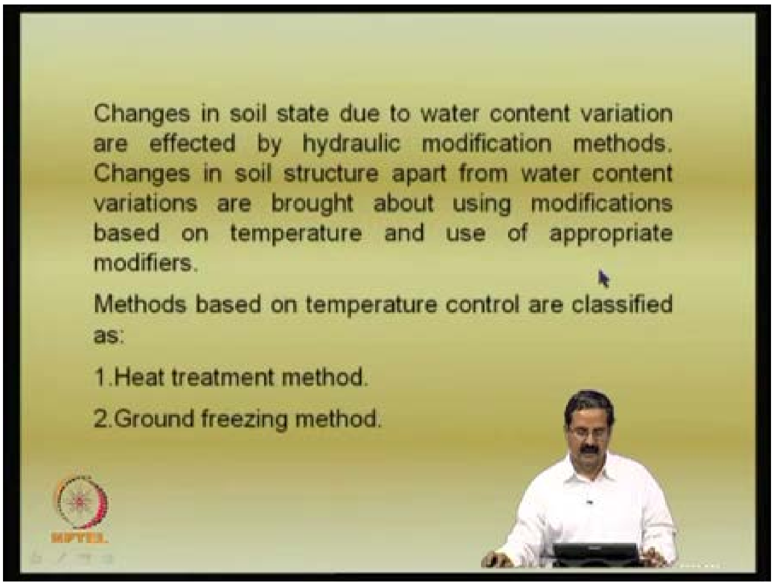

What we discussed in the earlier classes was that, suppose use pre-loading or use of pre-fabricative vertical drains, this results in changes in salt state, because of the water content variations. So, these water content variation what we call was hydraulic modification methods, is the way that we remove the water content. So, that it improves the strength of the soil or accelerates the consolidation of the soil. But then, there could be some cases where you can also change the soil structure. Say, for example, this soil structure is something that is a very the particle arrangement of soil part including the way that dissemination bonds, there are many issues in soil structure the way it is defined.

So, the water content changes could be one thing, but at the same time, if you are able to change the soil structure, whether by introducing some methods, so, we call them as some sort of what you call the temperature control methods. We call them as thermal modification methods and you can also use some modifiers. Many modifiers would be discussing in the subsequent classes. We have a lot of modifiers here. So, we discuss how to improve the change the soil structure. So that it improves the overall performance in terms of the bearing capacity as well as settlements or even permeability.

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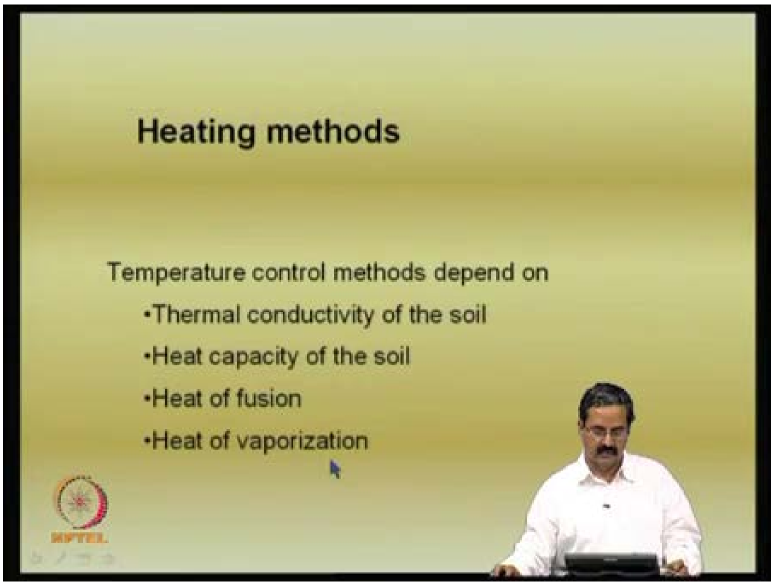

So, would be talking about the methods based on temperature control which we say, it is a heat treatment method and ground freezing method. The heating methods are something that are very unique. Because you need to have some more information about the properties of the soil here. One is called the thermal conductivity of the soil. Actually, these are very important parameter and heat capacity of the soil, heat of fusion, heat of vaporization, these are all some terms that influence the method itself and also the way that you control the temperature.

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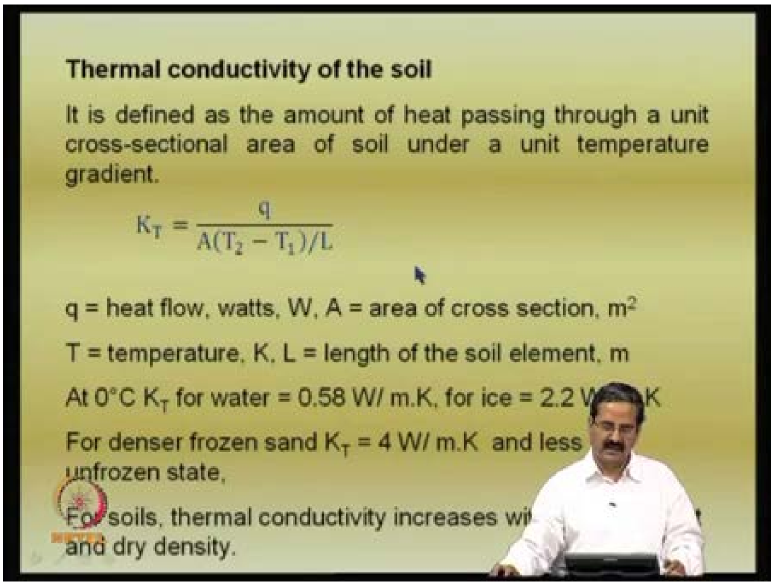

You would like to see the definitions of some of these terms. One is, what is basically, what is a thermal conductivity of the soil. It is actually the amount of heat passing through 1 unit of the cross sectional area of the soil, under a unit temperature gradient. So, you have a temperature difference T 2 minus T 1, is a temperature gradients and a length of the sample is, say 1 meter or whatever. Area of cross sectional is there and then, the q is a heat flow in watts and area of cross section. So, you will get what is called the thermal conductivity of the soil and this is a very important parameter and by the definition of the term itself, one can make out that one can determine the property of this K T in a laboratory, in a simple manner.

What you have to do is that you have to find out the heat flow and introduce some temperature gradients and then, you have a length of the sample, area of cross section of the sample is known. So, you will be able to get K T value, and this is in fact, the function of the temperature and at 0 degree centigrade for water, it could be 0.58 watts and actually, this is expressed in terms of the watts per meter per kelvin and for ice, it is 2.2. So, you can see that for ice, it is much higher. And then for denser frozen sand, this is a typical value. Say for example, somebody has observed in literature. K T value would be about four units and in the unfrozen state, it is less as similar to that. Say in the case of ice, it is 2.2 and it is less in the case of when it becomes water. Like you know 2.2 and then there is a difference good difference.

Similarly you have a dense frozen sand, you have about four units and then, when it is not frozen you have a lesser value. because this thermal conductivity, like you know once you heat the soil what happens is that water content is removed and then it the stiffness increases, the strength increases. there are. So, many properties that you get. And for soil’s thermal conductivity increases with water content and dry density. This is an important factor that we should understand, that higher is water content higher is a thermal conductivity. Water is there. So, because of the presence of water, there is an increase in the thermal conductivity. And also in the dry density that particles come closer to each other when the soil is dense and you have a better thermal conductivity.

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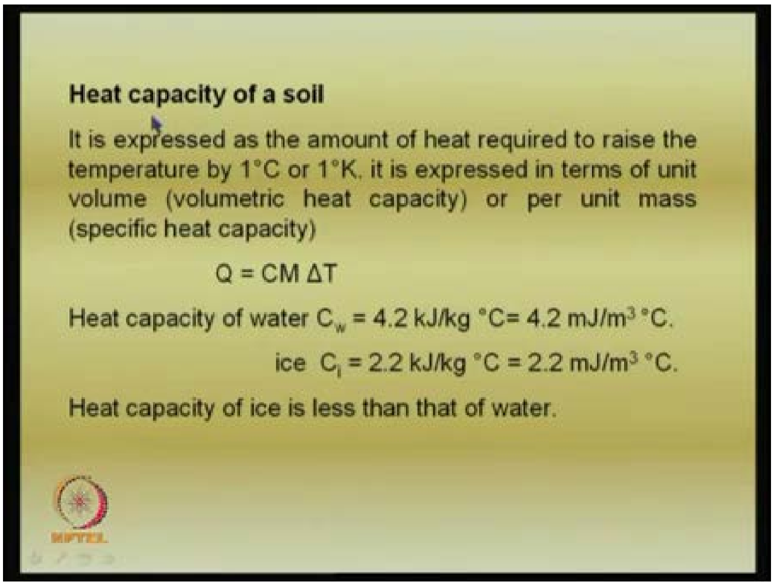

The term heat capacity of the soil is another term that we should understand. It is the amount of heat required to raise the temperature by 1 degree centigrade or 1 degree kelvin. It is expressed in terms of unit volume, like you can say volumetric heat capacity or per unit mass. Either we call it as specific heat capacity. This is the equation, Q is C M delta T. So, normally we can say what is a heat capacity of the water.

It is actually heat capacity is for say for example, water it is 4.2 kilo joules per kg per degree centigrade and you can see that it is about 4.2, you can say million joules we call it per meter cube. So, 1 meter cube of water has if you want to raise it by one degree centigrade you have this much of energy spent. So, even for ice if you want to for the ice also you have this much of temperature. This is another property that we should see. So, the heat capacity of the ice is less than that of water. This, one should understand.

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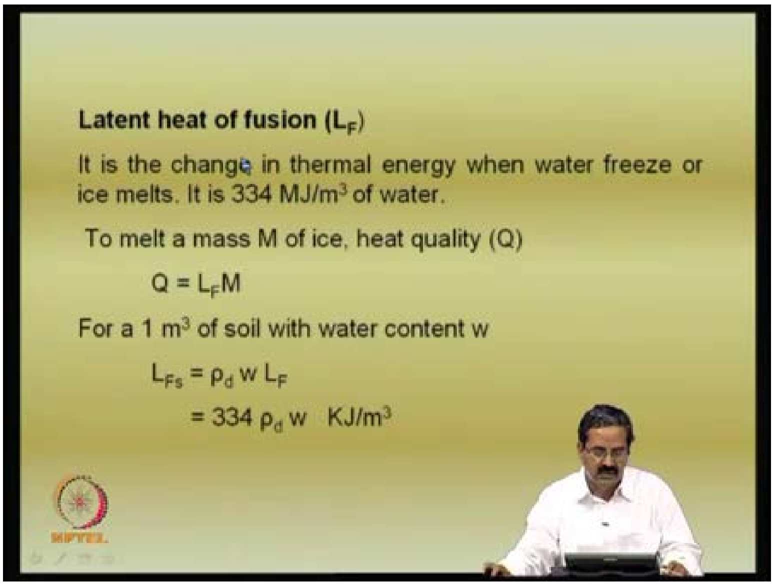

The another term that people use, it is called latent heat of fusion. All materials have some sort of internal energy and whatever is the thermal energy. In this case, is a change in thermal energy when the water freeze or ice melts, water freezes or ice melts. It is about 334 million joules per meter cube of water. And to melt some mass of ice the heat quantity. Q is L F M and for the meter cube of soil with water content, you have this 334 units into dry density and water content.

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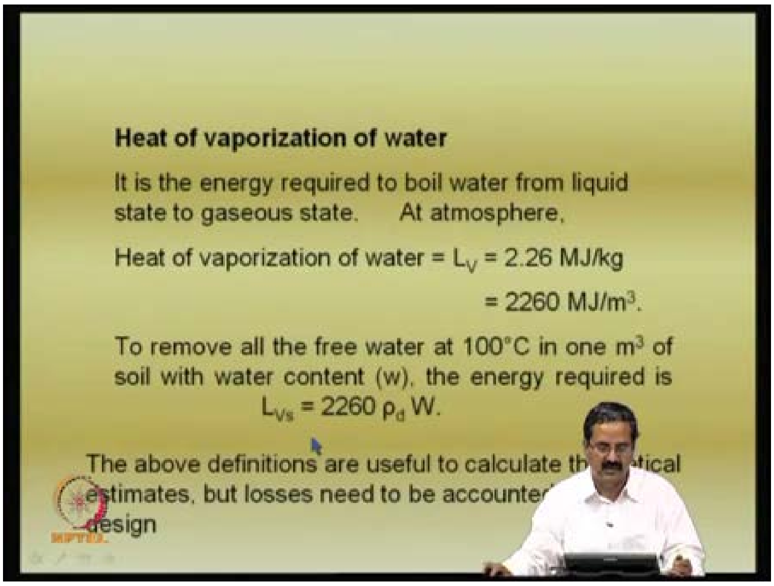

So, there is another term that we have which is called heat of vaporization of water. It is energy required to boil water from liquid state to gaseous state and at atmospheric conditions, we say that the heat of vaporization of water like you see that, one water is getting heated there is a vapor pressure. So, that latent heat is in terms of 2260 Million joules per meter cube. So, as a simple example to remove all the free water at 100 degree centigrade in 1 meter cube of soil with water content W, the amount of energy required is L v s where it is equal to 2260 rho d, means the density of the soil and the water content. See the thing is, some of the definitions are quite useful, because they will give some information about the thermal properties of soils.

But one should understand like say for example, the ground temperature is a minus 10 degrees. And you would like to make it to 10 degrees. Minus 10 to plus 10 degree centigrade. You will be able to get some sort of information here. What is a energy required? Essentially, why this calculations are required is that you know the property of the soil, you know the other input parameters. You will have a rough idea of what could be the basis and which one can calculate the required energy. Say for example, we have a situation where, the material is to be heated. When the material is to be heated, what is a energy you have to give in. One must calculate. So, to that extent all these definitions are important, otherwise the design will not be complete.

So, using all these terms one can design some sort of heat supplying system or even heat require system. say for example, we would like to take heat from the soil. So, you may have other way of doing it. Both are possible, whether you can a supply heat to the soil. So that, it becomes very stiff. Say for example, when the temperature water is removed, what happens is that, when this soil is heated to a very high temperature, say for example, 400 degree centigrade. That is what in olden days people were using, the burning of bricks is an classical example. You are trying to use this temperature to bring all the particles together, make a very good soil structure so that they are very strong. The in situ strength, the intact strength of the brick is going to be very high because of the heating. In what way it helps? It brings the particles together and because and the water is also removed. So, that means it is going to be very stiff and this stiffness is values are going to be very good.

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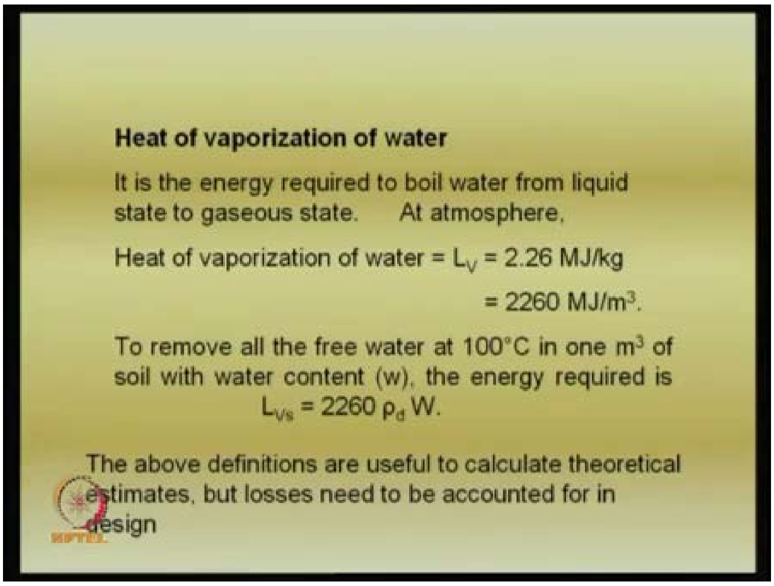

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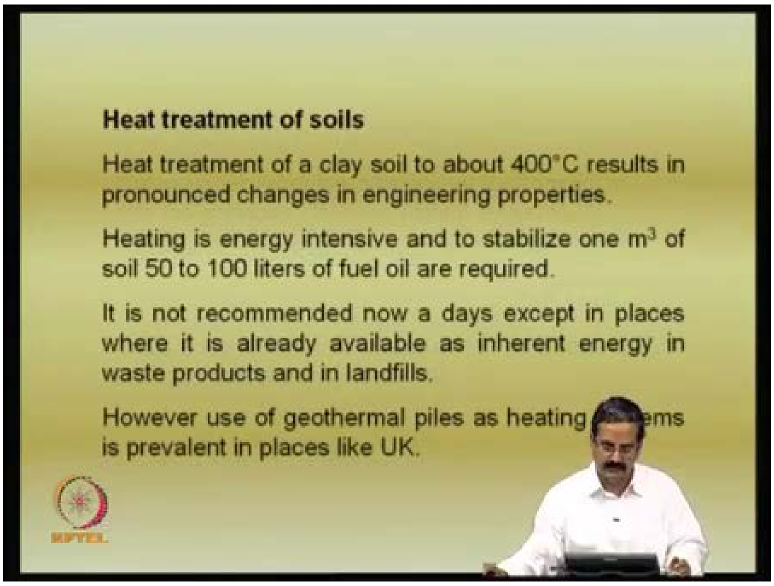

So, this definitions one should make use. How do you go about treating the soil. Actually, this is very important concept here say for example, as I just mentioned there could be even mineralogical changes that would take place when higher temperatures, one should check it up. Particularly say for example, if there is a halo settlement present, definitely it could be, there will be significant changes in water content. In fact, I was testing the soil from Cochin area, which soils from Cochin area are very soft. What happens is that you take that soil and then keep it in the atmosphere for some time. You can find out its liquid limit in a natural state. The moment you bring that natural soil, put it in a plastic covers and tie it and then bring it to the sample and then find out it liquid limit, you get some water content.

But then, you take the same amount of soil and keep it for air drying and then because of the air drying, air drying means essentially subjecting it to ambient temperatures, like some example whatever exists here. Either it is in Bangalore or Kerala. What happens because of the ambient temperature, again the soil particles will come together and then the soil particles come together and then they become much more stiffer. The whole soil structure becomes much more stiffer. And In fact, in one case I was able to see that, say for example, the initial liquid limit in the natural state was about116 percent. when you air dry it, the liquid limit will come down to 75 percent. In fact, 75 percent is something, 116 to 75 percent is quite low. Then suppose you keep the same soil in the oven, which I did actually as a part of my doctor (( )) long time back. So, when you keep that in the oven and then bring it back and cool it outside and then again start doing one more liquid limit test, it comes down to about 60 percent.

So, initially the water content was some, the initial water content or the initial liquid limit of the soil in the initial condition was about, original condition was 116, it reduce to 75 degrees because of the air drying. And one side, do the liquid limit on the over write sample. It is about 60 percent. It is quite a big difference, say from 116 to 160 percent is quite a big difference. And suppose you want to calculate the compression index or any parameter or stiffness or anything, definitely one can show that temperature has a significant role.

Of course that way it is not even, when the soil is in situ soil, so it is very difficult to, it extends to 100 of meters of areas, even depths about 10 to 20 meters and all that. So, it is not easy to stabilize them by temperature but at least, you can understand that the properties are quite variable and temperature has a significant influence in temperature neither in behavior. In fact, as we able to see it, both in terms of the compressibility, shear strength and permeability as well and this has been published in AC and geotechnique in some of the papers. So, what I want to say is that the heat treatment is a very important point and then see the heat, because of the heat there are so many changes that could take place apart from just water withdrawal alone. There could be structural changes then, there could be a bonding between the two clay particles and all that.

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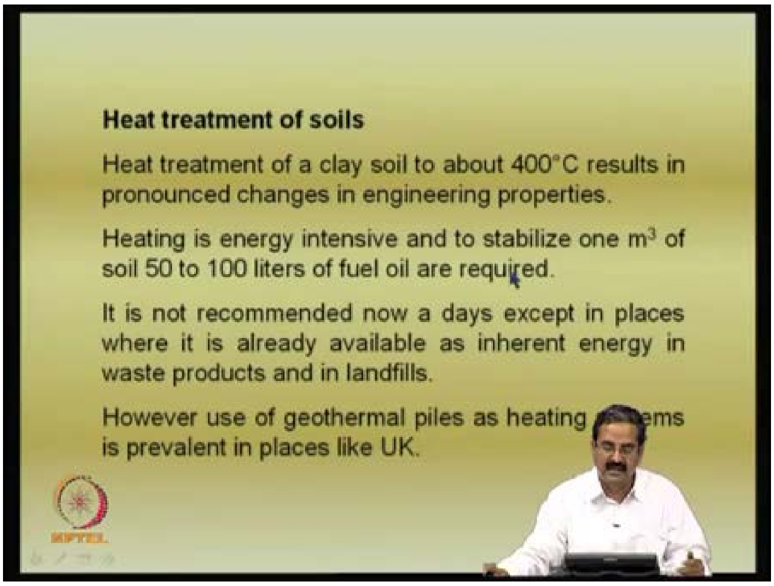

So, but then one should understand that heating is this technique itself is energy incentive. And in fact, the estimate say that, to stabilize 1 meter cube of a soil about 50 to 100 liters of the fuel oil are required. In fact, its not an easy solution. And sometimes recommendation in, there is a tendency to say that, it is not a very good material. In fact, people have been using. See nowadays even in the industry of science we are going for a press the bricks, if you take the bricks alone. Instead of going for a bricks burnt bricks, we say that you go for pressed bricks.

Because they have the same strength as that of heated bricks. Why should you use lot of energy outside and which I say for example, the nowadays what is happening is that, you must be able to, what you call the carbon print is something which is to be reduced. like what happens if you try to heat anything, lot of carbon is consumed and the carbon print is increased. What it means is that, so, you must be able to reduce their energy requirements to the extent possible. That is what, nowadays are talking about in terms of the sustainability in construction. So, one thing is that in some places if heating is required and to stabilize 1 meter cube of soil. of it depends on the type of why that we are doing it is about it needs lot of fuel. So, one classical example is that as I said, people are trying to use that to a limited extent and only places where it is, it can be used quite well and it has a very good use.

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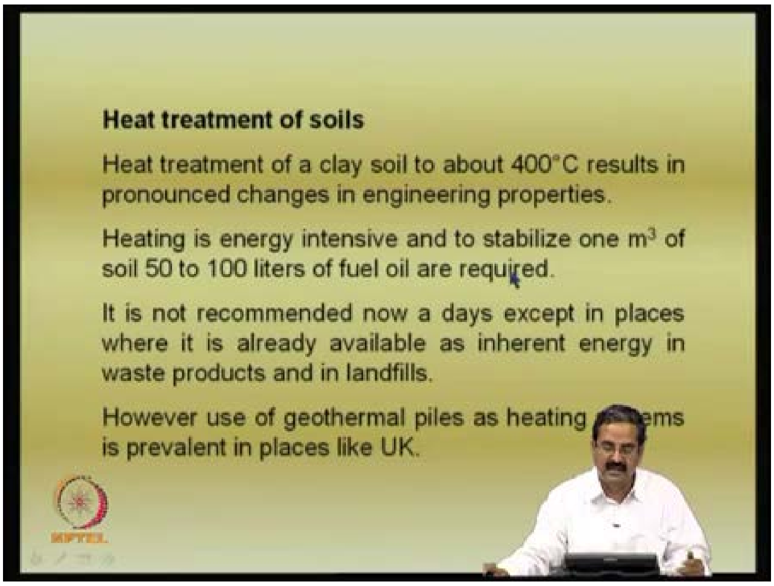

Say for example, in land fields where there is lot of temperature, the temperature could be you may be able to convert that temperature into some sort of energy. That is one way. Then, some sort of that energy require systems are having it in land. People have, they have energy require systems in landfills. So, that is a reason. So, in this case the heat treatment of the soil is not done in the case of landfills. It is just that in a landfil automatically heat is there, because of the various exothermic and endothermic reactions which take place over a period of some 10 to 20 years. Because of these reactions, there is some internal energy and temperatures also are raising. Say for example, it could be 30 degrees initiate the time of dumping but because of various reactions it could go up to 70 degrees. So, 30 to 70 degrees is a good difference. About 40 degrees temperature difference (( )) is there and then it could generate heat and then, that heat if you can recover, it is very useful. So, that is what some people are doing in modern landfills.

The other important application that I find in the recent times is that in geothermal piles. What it means is that, see in many countries the like particularly in UK and other places the houses need some sort of heating arrangement, because it is in the winters systems it is very cold and what we do is that normally, we have electrical heating systems which are quite expensive so.

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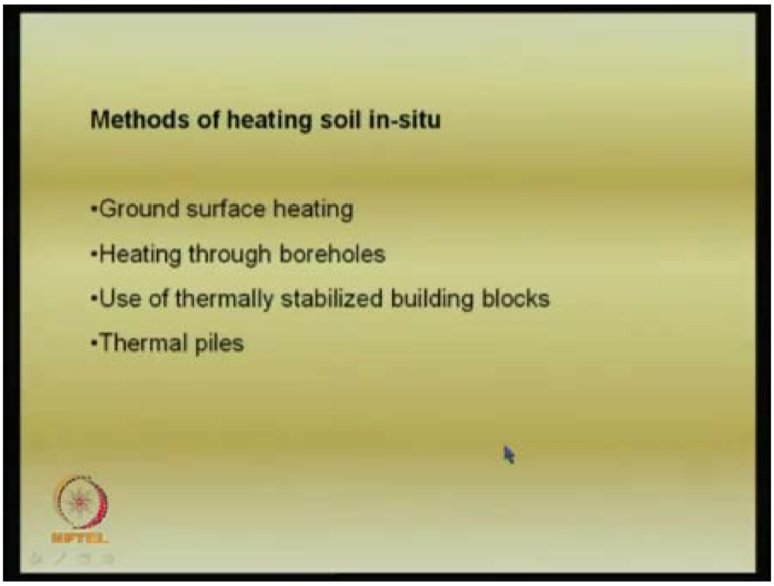

In fact, there people are trying to go for this geothermal piles. What it means is that, you have some sort of energy require systems that I will show you they can be quite useful. So, there are some methods of heating the soil in situ which could be like ground surface heating, through the bore holes, use of thermally stabilized building blocks, thermal piles. We will discuss some of these things. Ground surface heating is something that, like which is not quite appropriate in some places because it needs lot of heating and all the equipment. It needs lot of network of piles.

Of course, I have just gave an example of the Cochin marine soil. If you remove the soil in an subjected to air drying and then you want to use it in some form and then again use some sand and all that, it can be used. Then heating through bore holes similar to dewatering systems. One needs to have bore holes and this is a quite effective. Then use of thermally stabilized building blocks like there is another technique, say for example, the way that we can impart heat is either by surface heating or through the bore holes or even, you can heat certain materials and then like bricks itself and then make them as building blocks or even they can be used for improvement of bearing capacity also.

Like, you have a bigger blocks of materials, one can use when there is a soft soil, you have a building block that can be much stronger. So, one can use. But as I just mentioned heating with or stabilizing with temperature has been little more, people have been little a serious about some of these things. And they find that if it is going to consume lot of heat energy and also like talking terms of the carbon print. If it is going to lead to lot of carbon emissions in the atmosphere, then let us discuss that. That is a stand that people have taken.

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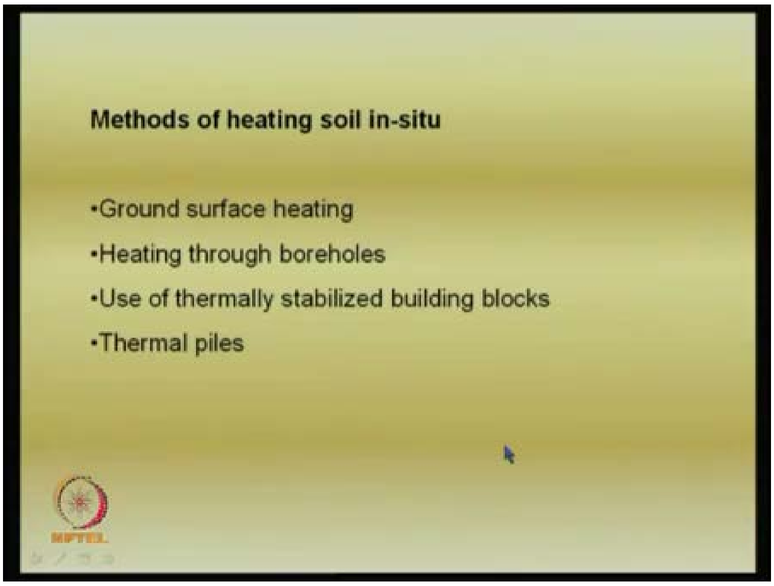

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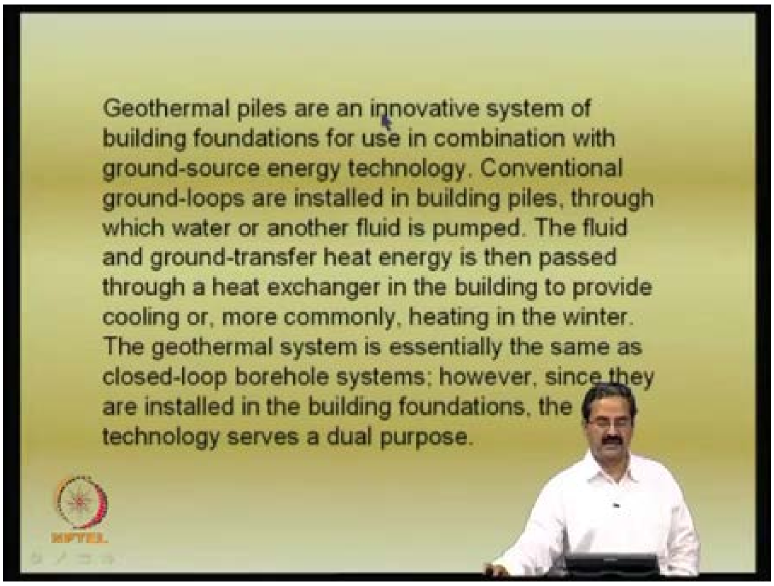

So, as a result of which people who are using heating, for housing have gone to this thermal piles. Where like instead of using the regular conventional, the electricity for the heating, you are using the temperature in the ground to create this heat. So, this geothermal piles are an innovative system of building foundations for use in combination with ground source energy technology. Like we are treating the ground as some sort of source and you try to take the energy from the ground. So, conventional ground loops are installed in the building piles through which the water or fluid is pumped. In fact, you have lot of arrangements for this. This fluid and ground water heat transfer heat energy is then passed through a heat exchanger and in building to provide cooling or more commonly heating in the winter.

So, you have all these systems essentially, you need to have a system of how to recover the heat from the ground and use it into the building. So that, now the minus, say for example, if you go to places like in US the temperature outside would be minus 30, minus 40. In Chicago, it is quite cold. So, if you want to really increase a room temperature, you need to have some sort of systems. So, this geothermal system is essentially it is same as, it is similar to our closed loop bore holes.

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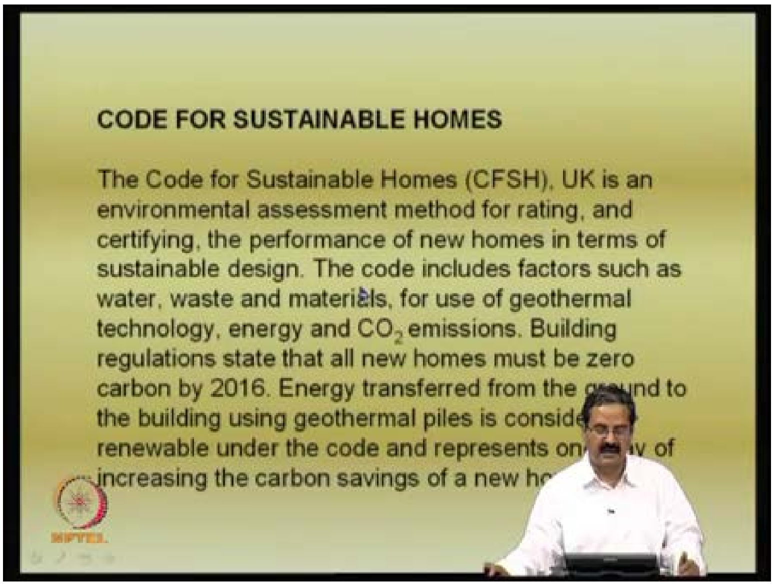

Like, I will show you that they have an example here. This is a conventional pile that we have, like a screw pile we call it. And in the case of a bored pile, you have a system like this. Where you have a pipes and all that recovery systems. Then it is connected to the actual heat recovery system. So, you are essentially tapping all the heat from the underground and use it for your, use it for the heating of the houses. So, this is very important concept people have been able to understand that.

And in fact, in the codes of UK, they say that the codes for sustainable homes. They try to say that whatever is a heat that is coming, should be used in such a way that like say for example, the code has some factors for a waste water and materials and for use of geothermal technology and it calculates the how much of C O 2 emissions are there because of your construction activities. Like even, it could be your own use of electricity bulbs in the house. Many things could be tailor-made to see that you have, the building regulations state that all the new homes must be 0 carbon by 2016. Like which means that you may have a good house but the thing is that, it should not pollute the atmosphere in any way, like by your cooking activities. So, that was an interesting concept and that is why the geothermal piles have been quite effective. So, it is a new way of increasing the carbon savings of a new house.

So, the people have realized that you earlier we thought that the heating just by the heating the soil, by increasing the temperature may be useful but later we realize that it is not really sustainable. Because, it leads to lot of carbon print. But now, we discover a new way of trying to reduce the carbon print using this materials like, what is called geothermal piles. Which are very, like there is lot of work done on these lines. In fact, there is a, what is a role of a, there are two engineers that are involved here. One is a geotechnical engineer, one is a thermal engineer. There are two engineers that are involved trying to design the whole system and try to see that, I know the properties of the soil, I know how much of heat recovery it can give. And there is also another heat mechanical engineer ,who has good experience in thermodynamics and all that. He will be able to design the heating system to suit based on a geotechnical requirements which is the interesting thing. And finally, you have what is called sustainable homes, which is a very nice concept.

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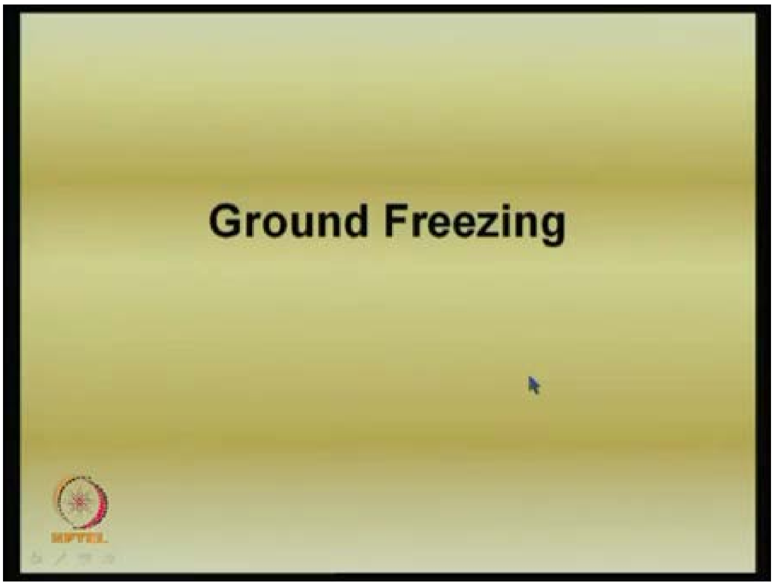

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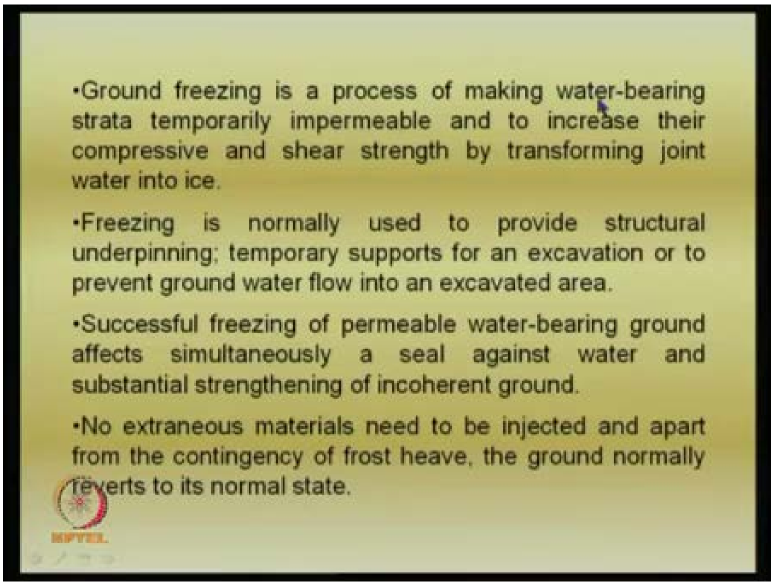

Then you have, what is called a ground freezing. This ground freezing is another important technology, which we need to discuss. Here as opposed to increase in the temperature, we reduce the temperature. Reduce the temperature. It has certain advantages and ground freezing is a process of making water-bearing strata temporarily impermeable. And to increase their compressive and shear strength by transforming joint water into ice. Say for example, you have a rocky area and between the joints and all that you have a number of lot of water particles and all that. So, what we do is that if we freeze them, so the strata becomes temporarily permeable and it also has a higher strength. Both compressive and shear strength. That is an important point. And it has been a quite a useful application in many places. Particularly for structural underpinning temporary supports for an excavation or to prevent a ground water flow into an excavated area.

In fact, last week only had a problem in which you need to construct a pipe of 2 meters diameter pipe into the underneath a highway, which is about a 36 meters width and there is a water table. Putting this particular pipe is required because there is a new apartment complex coming up. And it has a lot of waste water and as well as, it has water supply. It also needs water supply. So, the companies are provide a trying to provide this sort of requirements through pipes but the pipes have to be pushed through the roads, national highways or important highways and there is a water there. So, if you want to remove the water as it is, the problem is you have to total dewater which is not easy. It may leads to lot of problems and second thing is that since the moment he start excavating the because of the presence of water, the soil is collapsing. So, it is a very tough situation and what is that, why this soil is collapsing is, the strength of the soil and the presence of water is so poor.

That you have the, your pipe is there. But then, the water pipe plus the soil plus water, it is just coming out inside. And the possibility is that, if you keep on putting the pipe further, whole soil may come out along with water and there is always a road that is there. And the foundation for the road itself may just get collapse. So, that is a worry. So in fact, there is some thinking if the ground freezing could be one alternative but it is a quite an expensive proposition in Indian conditions. But at the same time it is well practiced in abroad.

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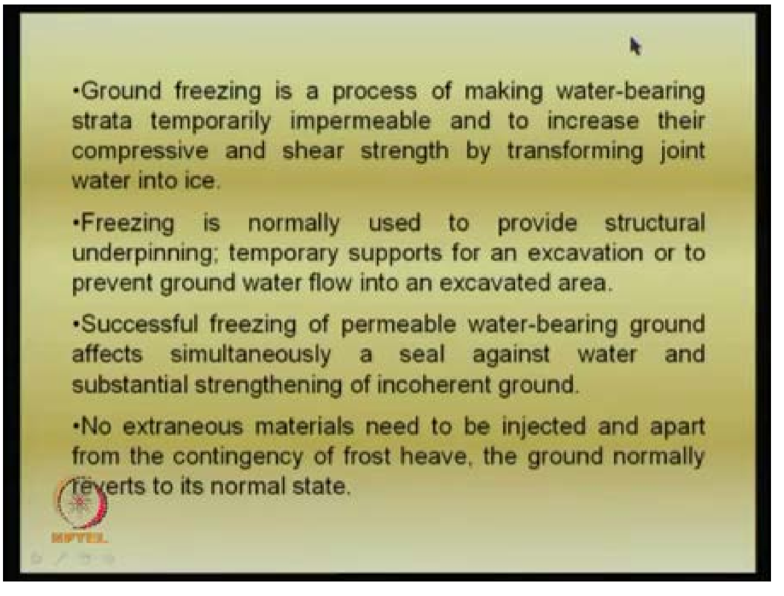

And we will see that it is a technique to provide structural underpinning and it supports excavation and it also prevents a ground water flow into an excavated area. So, the successful freezing of the permeable water bearing ground affects the simultaneously a seal against water and substantial strengthening of the incoherent ground. In fact, the ground is not uniform and all that. See it is very interesting that the soil has a different varieties of materials that it could be soft rock, it could be a hard rock, it could be a clay. But there is a presence of water everywhere in all the pores.

So, what you are trying to do is that, you are trying to make all these water ice totally ice, in the form of an ice. And it becomes very strong. In this case because the water cannot also come out and the whole material is much stronger. And now it becomes like, it acts like a seal against the water and also a stronger. It has two purposes. And So that way the freezing has been is affective on these lines and a few other important points are that no extra materials, no extraneous materials need to be injected and the apart from the contingency of the frost heave the ground normally reverts to its normal state.

See normally these problems are there, only for the temporary purposes in some cases like here I am trying to put a pipe in a particular area and once I keep the pipe beneath the national highway and then keep it for about on either side, if I keep in one month my purpose is solved. So, in one month only I need the freezing time. So, that the road does not get collapsed. So, once I place a pipe under the national highway then on either side once I complete this particular stretch beneath the national highway, I can go back with other construction activities later. So, if I can maintain the freezing for about one month and see that the soil does not collapse while the pipe is put into the, beneath the ground then there is no problem. So, soil should not collapse. That was the main thing.

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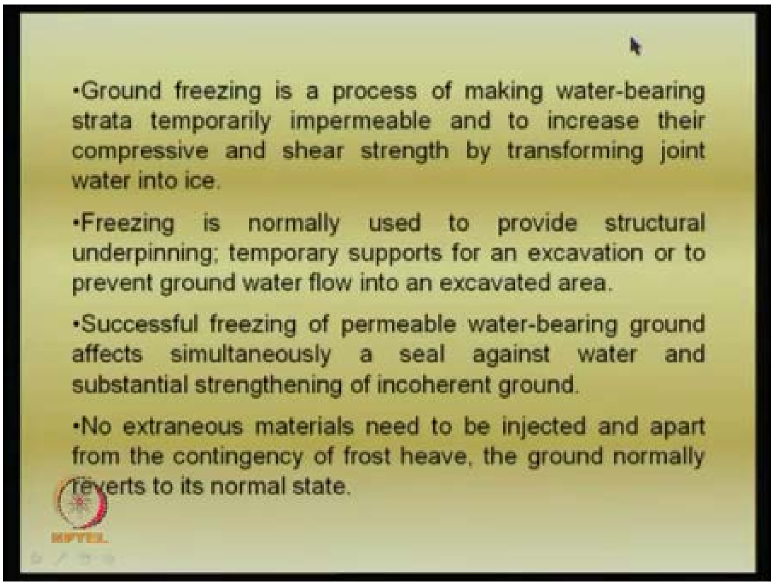

The successful freezing of the permeable water bearing ground affects simultaneously a seal as it works as a seal, as well a strengthening measure. And then the advantage is that it does not need any extra material to be injected. So, for example, in some cases we normally try to put lot of hydracids into the ground. Like bentonite to reduce the permeability and all that you do not need that. And one difficulty is that, there is a frost heave, like there is a possibility of volume increase because of the frost heave, like the volume of the ice is slightly more than the volume of the water. So, there is a increase in the volume and that still can be handled. And this purpose is only required for about short time during a construction.

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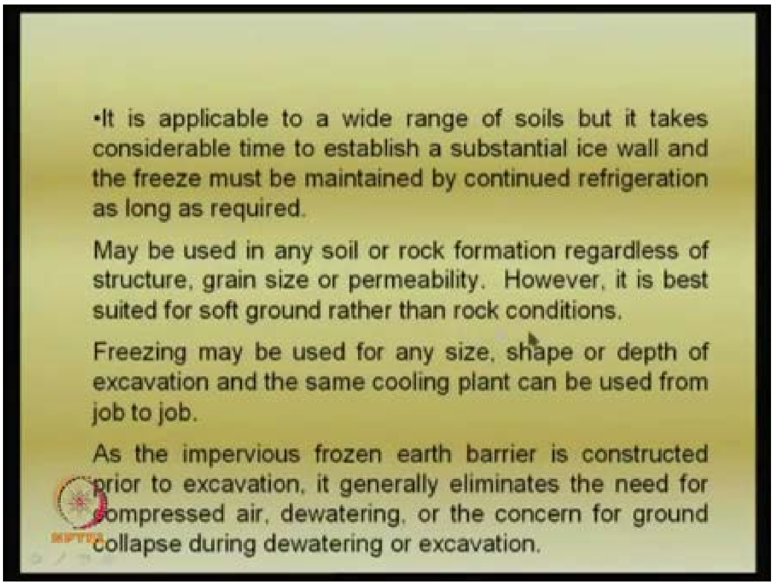

It is applicable to wide range of soils but it takes a considerable time to establish substantial ice wall and the freeze must be maintained by continued refrigeration as long as required like we have the freezes in the house. They have to have a continuous refrigeration. So, you have to create that ice wall and then it should last for that purpose. And it is used in any soil rock formation regardless of the structure grain size or permeability, but it is good for some soft grounds rather than rocky conditions. Of course, wherever there is a lot of water and it can be a frozen very well, it is good. Freezing may be use for any size, shape or depth of the excavation that the same cooling plant can be used from job to job.

Like the think you have a cooling plant, say with you, a cooling company you have. So, the cooling plant can be useful for certain, say one month in a particular site and once the site job is over, you can remove it and then take it to some other job. So, essentially what you are doing is that you are maintaining the system for about a month, then after that it is not done. As the impervious frozen earth barrier is constructed prior to excavation, actually, we should do prior to excavation. All these things is before excavation, not later. You are doing excavation. Beginning of the excavation, you should plan. Yes this is a water, that is water table is there and if I excavate this, the water may come like this or the soil may fail like this. So, you do not want failure to take place. So, what you do is that, you freeze the whole area. So, as a impervious frozen earth barrier is constructed prior to excavation, it generally eliminates the need for compressed air, dewatering or the concern for the ground water collapse during dewatering or excavation.

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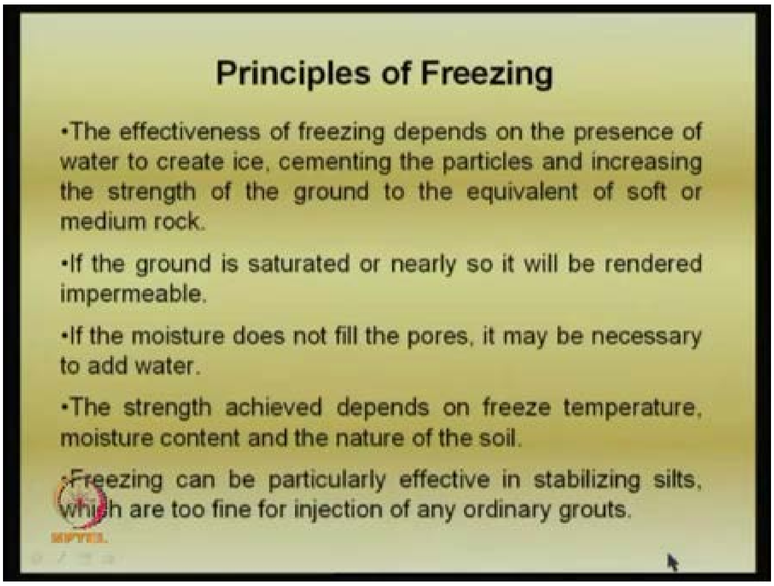

So, what are the principles the effectiveness of freezing depends on the presence of water to create ice. Actually what it means, is you need to have water there and then you should form ice. And then there is a cementing particles and increasing the strength of the ground to the equivalent of this. So, it should be a good one, where there should be a binding of particles and all that. And it should increase the strength of a ground.If the ground is saturated or nearly so, it will be rendered impermeable. The possibility is that once you have a saturate soil because of the formation of ice, water is not allowed to flow. If the moisture does not fill the pores, it may be necessary to add water. So, sometimes you may have to add water also. Say for example, as I just mentioned presence of water is required to create the ice. Then it is not there, you better put moisture to make it more efficient.

So, the strength achieved depends on the freeze temperature, moisture content and the nature of the soil. So, there are couple of factors like this. Like the temperature required, you need to design this freezing can be particularly effective in stabilizing silts which are too fine or for the injection of ordinary cement and grouts. Actually as I just mentioned we will be using some modifiers to improve the properties. Like in grouting is one technology that we use, which would be discussing later. And we use a grouts and sometimes a the grouts need to penetrate the silty material. And if the silt is too fine, the grout may not penetrate. And when that is a case possibly freezing can help because it does not, it has to just arise the water. That is it.

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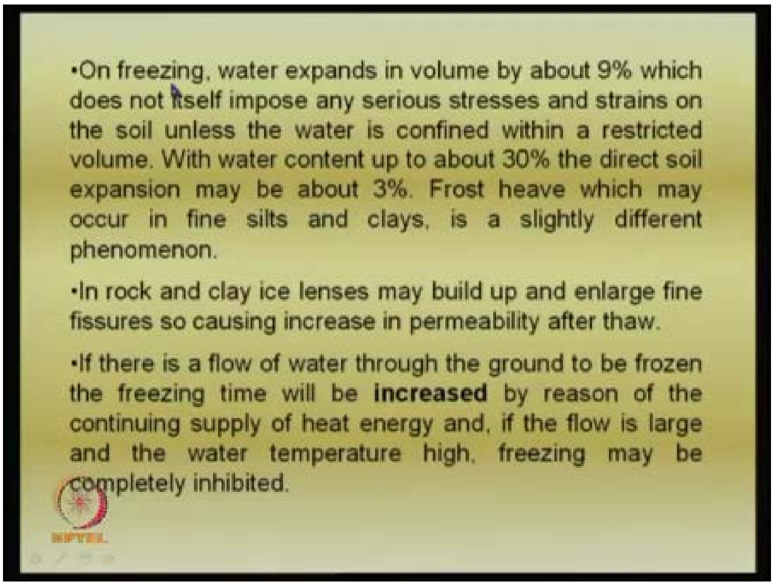

On freezing water expands in volume by about 9 percent, which does not itself impose any serious stresses and strains on the soil unless the water is confined within a restricted volume. Actually, as I just mentioned when the water becomes ice there is a marginal increase in the volume. So, it is about 9 percent and it will not really lead to much changes in the stresses and strains in the soil. When the with the water content up to 30 percent, the direct soil expansion may be about 3 percent like about 10 percent what do we see frost heave which may occur in fine silts clays slightly different phenomenon. In fact, I am not sure if you have seen the frost induced heave and all that. you know it is of it is not about frost induced heave is about just effect of frost like formation of ice here but the frost has a different, frost here is a different connotation here. What we are addressing is only about volume changes because of this formation of ice.

In rock and clay ice lenses may build up and enlarge fine fissures. So, that it can cause increase in permeability after thaw. Actually, what happens is that as I said, if it is a too rocky, if it is a soft rock, it is fine but when there is this ice formation the volume might increases there it creates some sort of fracturing and once you come back to normal state, what happens that it may lead to normal state means after a freezing and thawing. We call it freezing and thawing. So, after the when it is not under thaw condition, there will be an increase in permeability because as I said the volume increase is there and there could be little fracturing there. So, that leads to an increase in permeability in the soil structure.

Then, if there is a flow of water through the ground to be, if there is a flow of water through a ground to the frozen like if there is a water current. Say for example, there is a standing current water table is one thing. But if there is a flow of water then it is a very not easy. So, you must be able to handle that as well and freezing time will be increased by the reason of a continuing supply of heat energy and if the flow is large and the water temperature high freezing may be completely inhibited. Sometimes it is may not even work if there is a problem like this.

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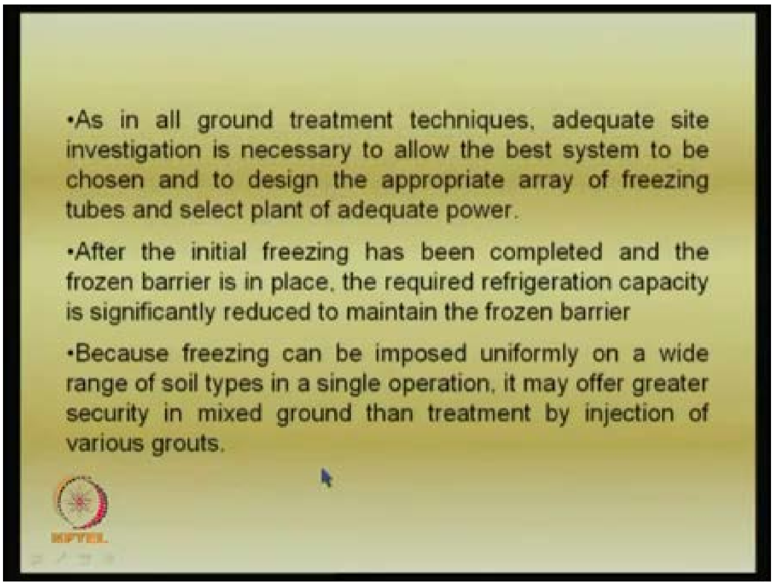

Because our objective is to see that, it should be cost effective also and if there is a nearby rivers and all that which can pass through and obstruct, lead to lot of difficulties. It is not easy. So, in this actually adequate soil investigation is required, because you are trying to have the depth of excavations at 10 to 15 meters or whatever. You should be able to know the type of soil, type of rock, water table and all this, to design the best system. and also choose appropriate design parameters and appropriate array of freezing tubes and select the plant of adequate power.

Actually what you have finally doing is that, you are trying to get the tubes and all the plants installed. So, that the process becomes quite effective. The another important thing is after the initial freezing has been completed, like we just a initially freeze a material and the frozen barrier is in place the required refrigeration capacity is significantly reduced to maintain the frozen barrier. Actually, we first create the frozen barrier and that needs more energy. Once the whole area is frozen like after that you have to the energy requirement is going to be less, like it is just required to maintain the freezing conditions. Similar to your fridge in the house like it needs initial pick up and then there is a initial consumption of power. Then after that the power is maintenance of the maintenance is much simpler because it does not consume much power.

So, in the same lines here also we have to do that. Then, because freezing can be imposed uniformly on a wide range of soil types in a single operation, it may offer greater security mixed ground than treatment by injection of various grouts. Actually, these are very interesting advantage. Of course, we have not practiced much in India but then in the west where the already in many materials under frozen conditions and all that. This becomes and then the technology is also well developed. Say for example, temperature control methods are well developed and if the soil is so variable and it is not easy to handle. But here in the freezing techniques you have to handle only water, nothing else. So, if you keep the water in the frozen conditions the problem solved. So, that is much simpler, than trying to have lot of various grouts depending on the soil type in the area.

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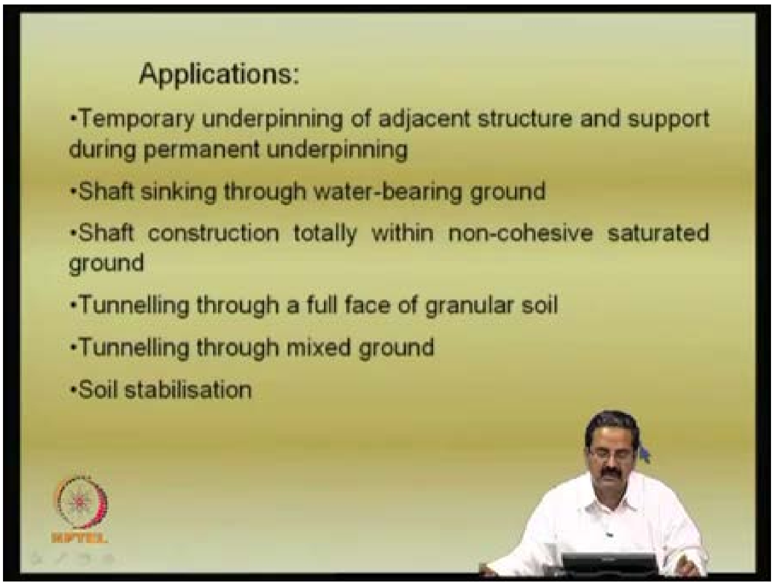

So, this has been quite effective in underpinning of the adjacent structures and support during a permanent underpinning. Like at least, it has been quite useful before you try to make permanent measures. You are trying to create a permanent measure like a retaining wall and all that. But the first thing is that you freeze the ground and then try to do all the excavation and all the process could be there that can be done. So, in shaft sinking through the water bearings ground, say for example, you are trying to create a shaft, vertical shaft in to the ground. Say for example, you have a metro station at different levels and then the whole water is there. Water table is there. And you have a what is called lift here. Again, which has to go through the various levels water.

So, you need to better, you need to sink a shaft there. So, in that case definitely this technology is helpful. Shaft construction totally with non-cohesive saturated ground. In the sandy soils saturated ground, definitely this has been quite affective. Tunneling through a full face of the granular soil. Like, you are trying to make tunnel through the sands. Then sand is because there is no caution and simply collapses. So, this can be achieved tunneling through mixed ground, like again as I said mixed ground is sometimes always tricky soil stabilization.

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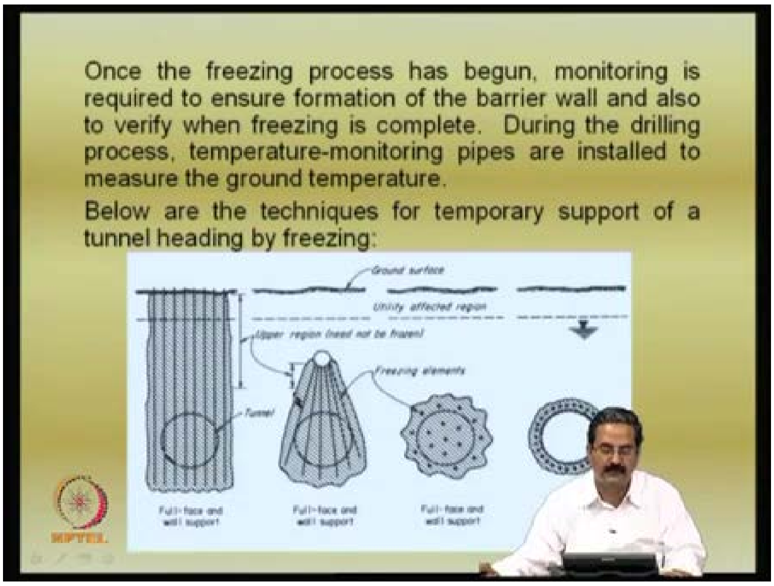

So, it has been quite useful like as I just mentioned. So, this is like you are trying to construct a full face one tunnel here, say for example, 10 meters or something and this is a water table level here. And this a tunnel what we do is that we try to keep the whole area frozen. So that you can still do this and then it does not lead to release of stresses and whatever you can do that. Like tunnels, the material does not collapse. And so, this has some strength to handle on its own. So, this is on full face and wall support and this is another one. This is called full face and wall support again. The another way of doing it .Say for example, this area only needs to be frozen because this is where the scene of activity like you are trying to put, as I just mentioned and trying to put a water pipe here or a water tunnel for watering purposes, all that.

So, only this is an important area to be frozen and this is to make sure that if the pipe is too deep, then the stresses may not come on to the top. That is one important thing. One should do lot of stress deformation analysis here. And the otherwise is that full face and wall support, another way. Like as I just mentioned, you have an system of pipes here what you just call freezing elements, which will freeze the whole area. Then this is called, what is called utility affected region. This is one area which is like you know it is a very important and freezing elements. So, these are all the freezing elements in the section. This is one way. And then wall support also, like wall should not crush in a tunnels the wall should not crush. What happens if the lot of pressure is there then the tunnel gets crushed.

So, the objective is essential that we are trying to see that this is avoided. That is the whole objective here. And one thing we should remember is that once that freezing process is begun the monitoring is required to ensure formation of the barrier wall. So, you have to monitor, whether the barrier wall has formed and whether the very freezing is complete, because you need to have lot of sensors here. Trying to monitor the temperature as a well as all the other properties essential temperature we monitor. So, that if you from laboratory test if you say that, yes the soil have enough strength and then the freezing temperature should be in this range. Then if you are able to get all these from the sensors, then it is fine. During the drilling process the temperature monitoring pipes are installed to measure the ground temperature.

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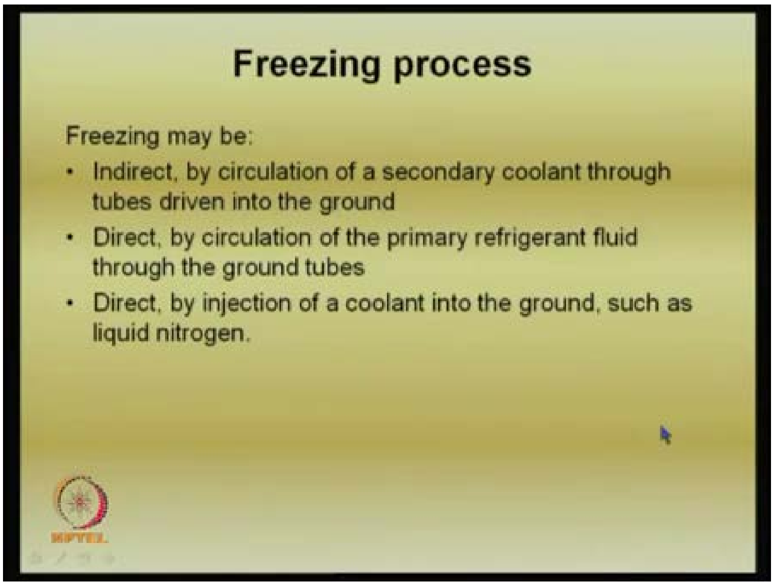

So, this is what we do and how do you do this? The freezing process can be done in many ways. One is by indirect methods and the other one is by direct methods. Indirect means by circulation of secondary coolant. Like you have different coolants, in the refrigerator also we have different coolants. Even in the chemistry labs and physics labs you have lot of coolants, which will try to reduce a temperature of the chemical. Also, you can have a secondary cooling through the tubes driven into the ground. So, you can see, we will see what are all the coolants now. The other one is direct methods by circulation of primary refrigerant fluid through the ground tubes.

Then, other one is that by again directly injection of the coolant into the ground. Say for example, I did not know how many have you heard of a liquid nitrogen. Many people have liquid nitrogen plant in institute where they carry the, for experiment purposes a liquid nitrogen and then bring it back to the laboratory. So, to make it very cool and even people can handle it with, it is not going to be risky. So, people use that particular materials and freeze a ground.

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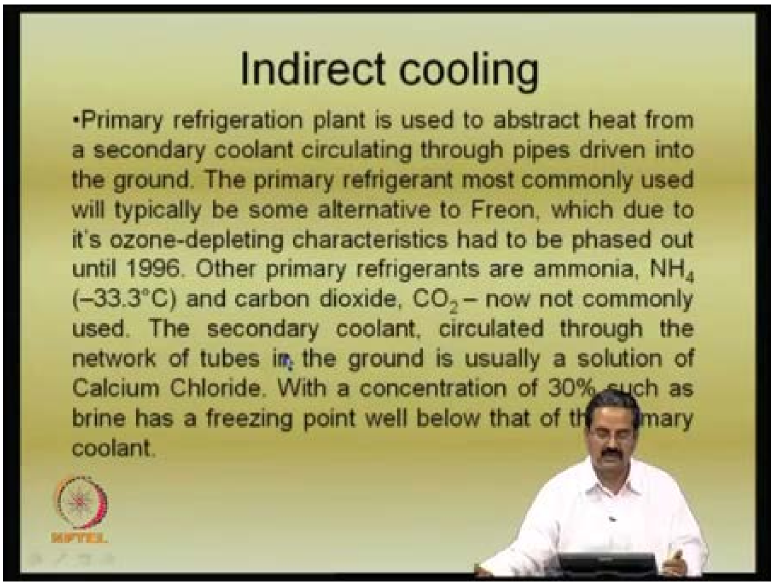

So, in this indirect cooling primary refrigeration plant is used to abstract heat from the secondary coolant circulating through the pipes driven to the ground. So, you have a refrigeration plant which can take all the heat from the because of the cooling. The primary refrigerant most commonly used will be some Freon's, there are different types of materials which due to, actually Freon's and many other materials have been removed because of the ozone depleting characteristics. So, we are using a some other refrigerants now a days. The other primary refrigerants are the ammonia, then N H 4, carbon dioxide also. They are also sometimes not used, because it depends on, the thing is that as I said like one should use the coolant that is going to be leading to less pollution of the atmosphere.

People have been using the calcium chloride which is a solution of a calcium chloride with a concentration of 30 percent such as brine. Brine is called nothing but calcium chloride has a freezing point well below that of primary coolant. So, you have a primary coolant, you have up secondary coolant and you must be able to choose this proper, the coolants in such a way that, the coolants will give you proper temperature difference and also see that the whole area gets stabilized. As the material gets stabilized you have more strength. And you must be able to design a proper system, circulation system. that is what it means.

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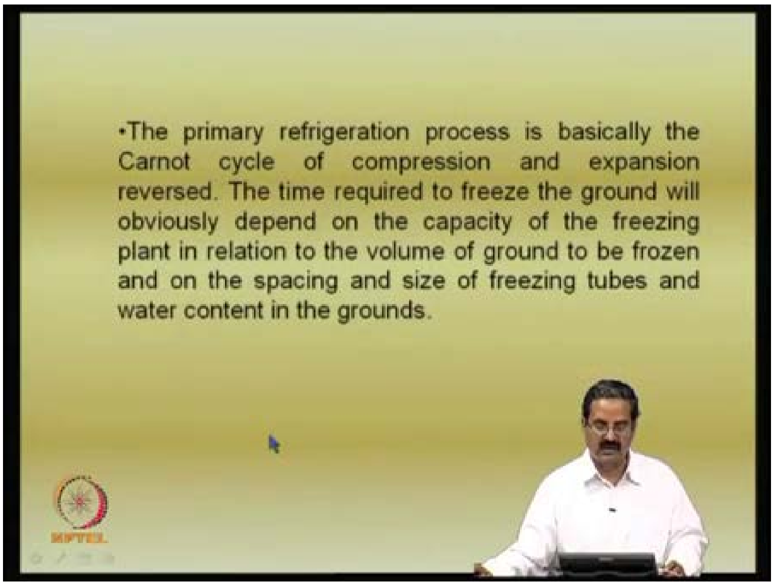

And in fact, the secondary process is one, but the primary process is something that we studied in, based on the principles of thermodynamics in second year engineering. Where there is a Carnot cycle, where you have the pressure and volume change and all the certain processes is involved. And one should have a background of thermodynamics. And also as I was just mentioned a few minutes back, you need to design the system, you need to have a geotechnical engineer and also the hydro mechanics or what is called thermal mechanics person where, he will understand what is a significance of the temperature variations and how to control them.

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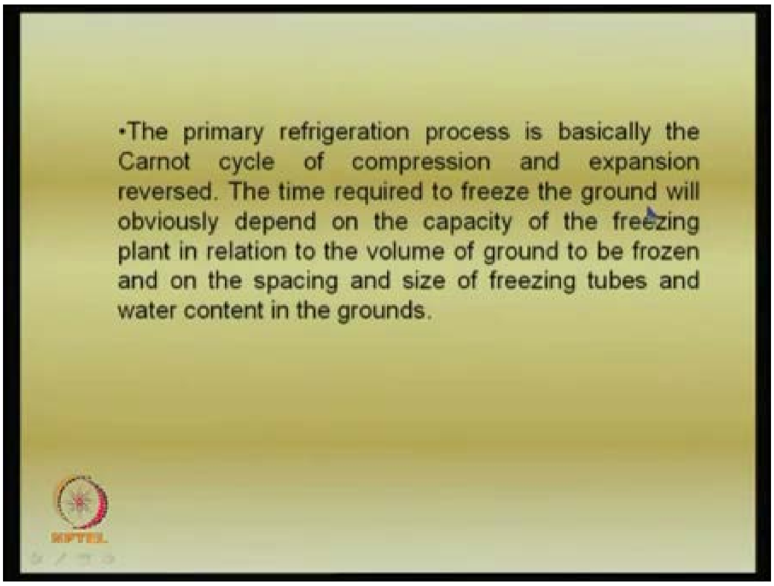

So, the time required to freeze a ground will obviously depend on the capacity of the freezing plant in relation to the volume of the ground. So, you have some volume, big volume. Say for example, there is a metro station coming up, there is a water table. So, all that area has to be frozen. So, that could be some volume and that volume has to be maintained because you are trying to construct all the walls and the approached roads and all that for the metro. So, you are trying to see that during the process of construction this collapse of soil is not there. If this something soil collapses then, it is a risky. So, it permits careful excavation that is what it means.

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So, the design in fact, is a function of the time required to freeze the ground and how do you get this time, it actually depends on the capacity of the freezing plant in relation to the volume of the ground to be frozen and we should design this spacing and the size of the freezing tubes and water content in the region. So, this is a very important. This is a typical example. You can see that all these pipes are here. A simple system. And of course, you can see it is actually, in somewhere in the west.

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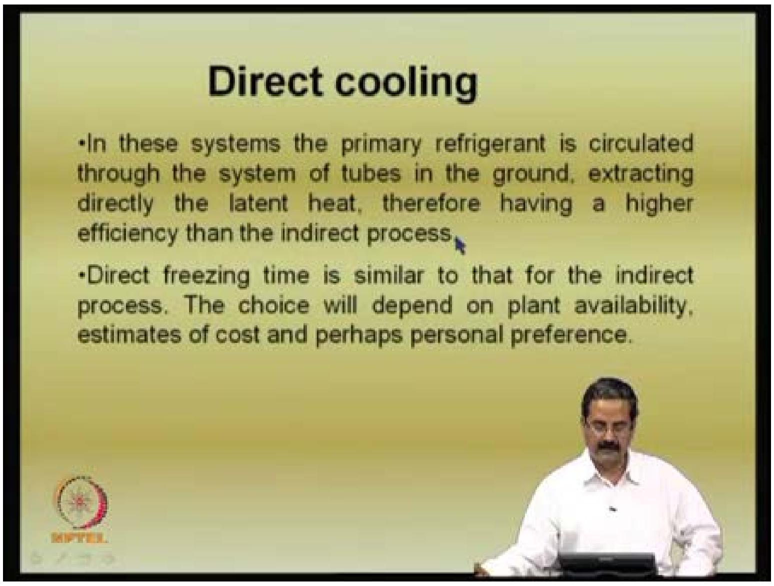

Direct cooing is something that is also very important which we do. Like most of the times you can use both of them together. In this systems the primary refrigerant is circulated through the system of tubes in a ground, extracting directly the latent heat. As I just mentioned, the latent heat in the soil is directly extracted. And it has a higher efficiency compared to the indirect process. Direct freezing time is similar to that for the indirect process. The choice will depend on the plant availability estimates of cost and perhaps even personal preference. Actually, what happens is that, it all depends on experience. The thing is some companies may have a only a one set of doing things and there could be a combination and all that is essentially, finally the cost also. The cost of using direct cooling and indirect cooling and how do you merge them together and all that, is an important variable in designing the freezing system in a ground.

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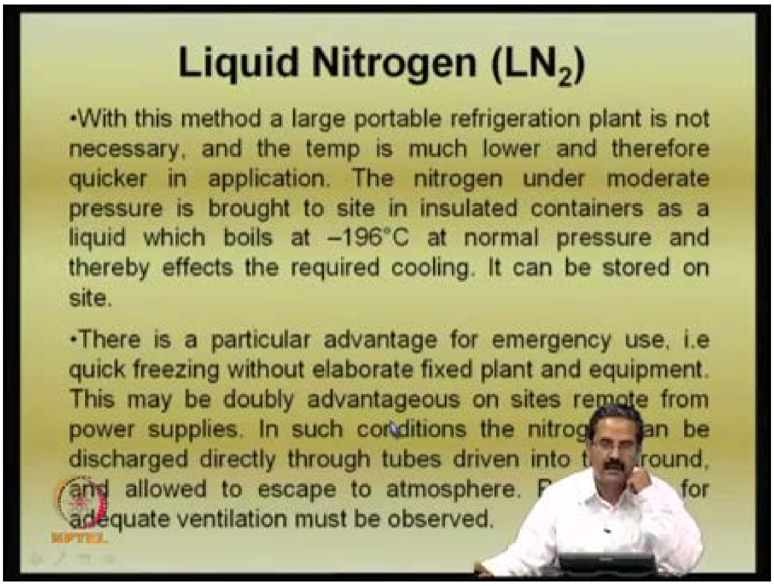

This liquid nitrogen is something very popular and in this case a large portable refrigeration plant is not required and the temperature is much lower and therefore, quicker in application. The nitrogen under moderate pressure is brought to the site in insulated containers as a liquid in which boils at minus 196 degree centigrade. You can see that, just people would be carrying next to the library, we have a plant in the interest of science. And you have this very low temperature and the moment you bring it back to the normal temperature, it cools a lot. So, that way this is a very important thing. And it can be stored on a site and it does not need as a set refrigeration plant. Like you want to stabilize this area temporarily. So, that you are freezing all that material like the ice you want to the formation of ice. So, the particular, it is an advantageous, because it is very quick freezing without elaborate fixed plant and equipment. This may be double advantageous in on sites remote from power supplies. So, when there is a power problem in such conditions one can use this. Nitrogen can be directly discharged through the tubes driven into the ground and allow to escape to the atmosphere. Precautions for adequate ventilation must be observed.

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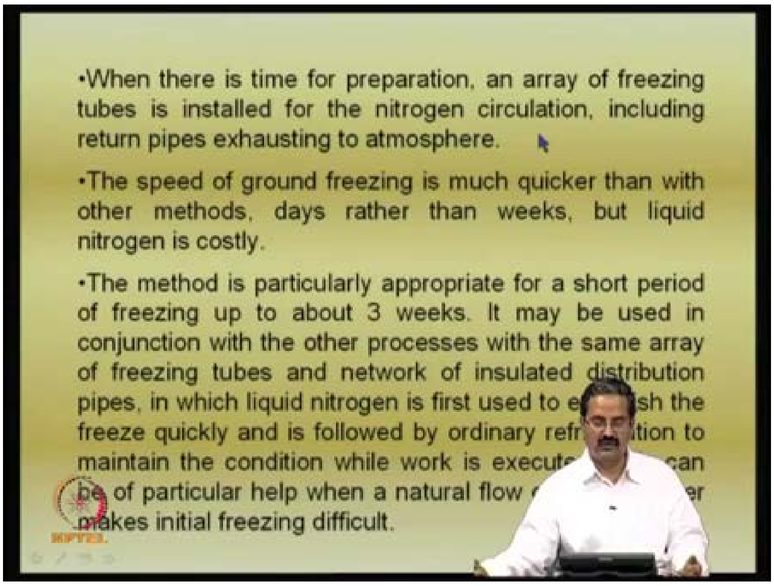

This is how it looks like. You can just see that. It is such an interesting very cool. Like, I handled it. It was very nice. You can see that, even this is been used to prepare ice creams. So, in the sense that is what I see in what that some of the materials are there. It is quite, it cools the things so much. So, when there is time for preparation an array of freezing tubes is installed for the nitrogen circulation. So, what we do is that when you have a lot of information. So, we have the tubes installed for the nitrogen circulation including return pipes and exhaust into atmosphere. The speed of the ground freezing is much quicker than with other methods say, the days other than weeks will be required. But the liquid nitrogen is somewhat costly.

The method is particular appropriate for short freezing of up to three to four weeks. it may be used in conjunction with other process, with the same array of freezing tubes and network of insulated distribution pipes. So, what it meant was that you can use first liquid nitrogen to establish the freeze quickly and then you can have ordinary refrigeration to maintain the condition while the work is executed. This can be a particular help and a natural flow of ground water makes initial freezing difficult. Like as I just mentioned, whether there some initial conditions or initial water table levels or there is a flow in water table, it is always difficult to freeze the area. So, what we do is that, if you can really freeze that area, the possibility is that it can help in the freezing of this method and then one can do a subsequent operation. So, I will take further on this and then we will discuss about a few more things related to the other method of blasting. So, at this stage I like to stop.

Thank you.