Ground Improvement
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Lecture 45
Chemical Stabilisation (Contd.)

Hi everyone, let us continue with the soil stabilization by chemical and we have already discussed quite a few aspects of chemical stabilization and in this lecture, I will try to discuss on cement and other admixtures for stabilization and we have discussed mainly on lime which is quite popular and it is similarly popular that the cement stabilization and fly-ash lime stabilization also nowadays.

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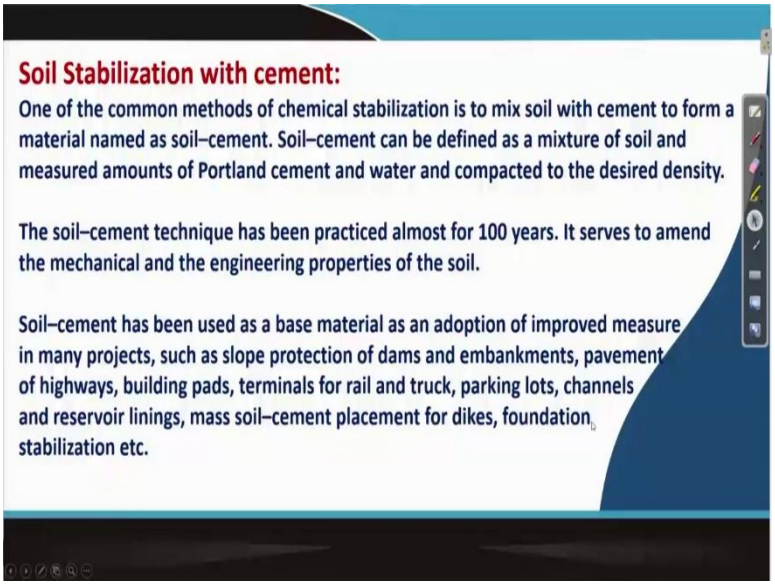

Let us take this quickly to that aspect so let me take the first slide that soil stabilization with cement. Actually, this stabilization with cement is a one of the common methods and this one will mix with soil and form a material name soil cement and this soil cement can be defined as a mixture of soil and a measured amount of Portland cement and water and then compacted to the desired density, that is soil cement and soil cement as a material and this measured amount of Portland cement means, it is a very nominal amount one or two, three percent not more than that sometime and that give you huge strength gain, which will try to discuss in this.

And this soil cement technique actually has been practiced almost for 100 years. It is not a new technique, very old technique and its served to amend the mechanical and engineering

properties of the soil that means to improve the strength, to improve the compressibility or may be decrease compressibility or improved compressibility characteristics that means to reduce the compressibility and sometime permeability, radiation of permeability all sorts of the properties of the soil can be amended by using cement and soil cement has been used as a base material and for adoption of improved measures in many projects such as slope protection of dams when you make a dam and the protection of slope is very important for them because dam will be constructed not for few years.

Generally, it is supposed to have long life and for the protection of that slope sometime we use soil cement and then pavement of highways also we use that soil cement, then building pads, so below the building sometime if the soil is not good, we can add with cement and then we can improve the strength, then the terminals for rail and track that means terminals points can be… a construction of terminal points that limestone soil chemical stabilization can be done.

Then parking lots, then channels and reservoir lines that means when water flows from the channels then it will be eroded sometime but to protect from that, soil cement layering can be given then mass soil cement placement of dikes when you dike, you construct by soil then you can mix with cement that will give you better strength then foundation stabilization and many others.

That means soil cement has a very large varieties of the application similar to lime stabilization also. In fact, compared to lime stimulation, cement stabilization will have more application.

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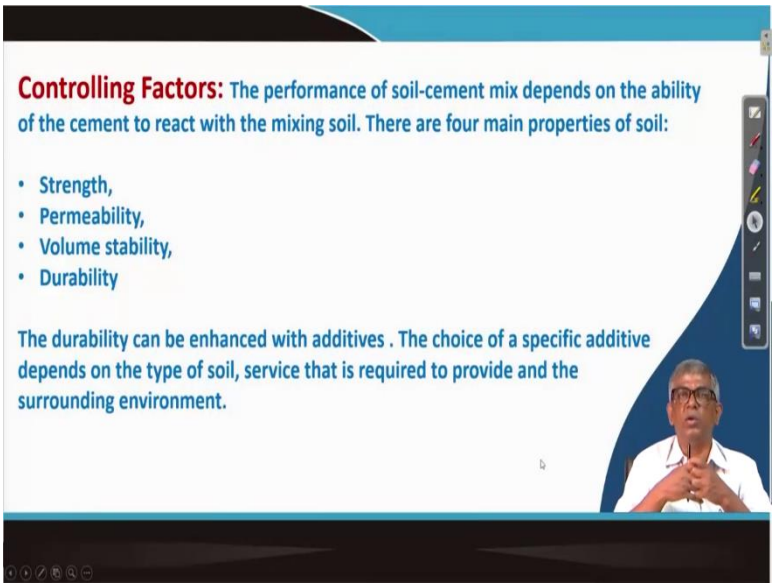

Then the controlling factors, the performance of soil cement mix depends on the ability of the cement to react with the mixing soil that means cement has to react with the soil similar to the lime, cement also react with some minerals in the clay and there are four main properties of the soil which will be affected because of the mixing of cement with soil and their strength and then permeability and volume stability and then durability and this all those things automatically will get actually and then durability sometime may not be ensured and this can be enhanced with additives.

I have some number of additives to increase the durability and the choice of specific additive depends on again type of soil and service that is required to be provided and the surrounding environment. You have to see the environmental condition and which property is most important that actually we have seen and if by cement alone cannot be achieved or cannot be provided for a longer period of time then we can suggest some amount of additives and there are different types of additives which we will discuss subsequently.

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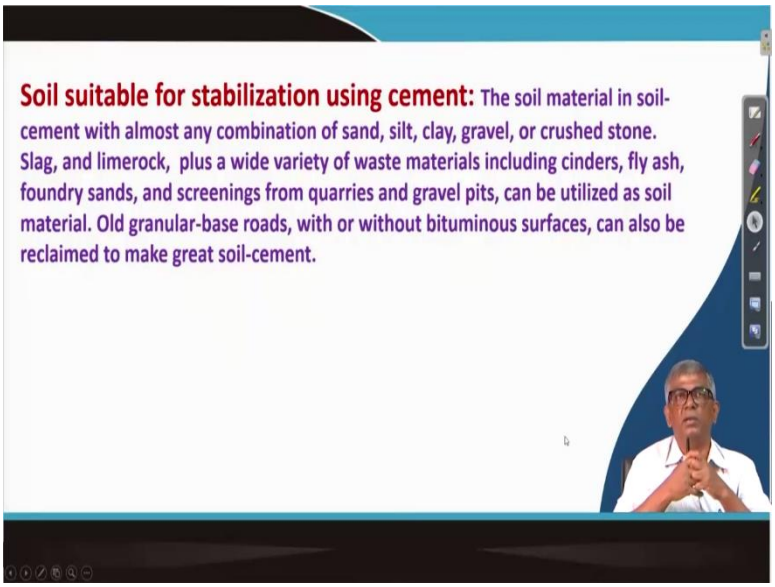

Let us see the next slides and suitable for stabilization using cement, the type of soil which we have mentioned in the lime, we have mentioned here also similar to that cement also can work with in many combinations of sand, silt, clay, gravel that means these are all different combination, gravel crushed stone, this can be used with cement to give improved properties.

In addition to that there are slags, lime rock plus a variety of waste materials including cinders fly-ash, foundry sands and screening from queries and gravel speeds can be utilized as soil. This can also be so used as soil mixing with sand and can be used for different activities development work and old granular base roads sometime can be renovated by using this type of cement. So, that means what are the type of materials or soil is required to improve by using cement is discussed here.

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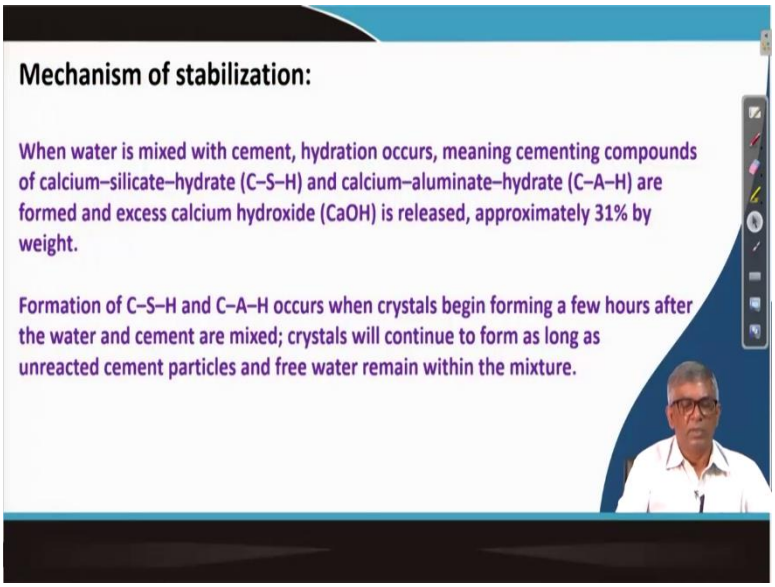

So, let me go to the next one and mechanism of stabilization, again similar to the lime how it works? Here also when water is mixed with cement then hydration occurs meaning cementing components of the calcium silicate hydrate that means reacting with water cement reacting with water that is calcium silicate hydrate that is (C-S-H) or calcium aluminate hydrate CAH are formed and excess calcium hydroxide is released approximately more, around 30% by weight.

This is the reaction happens when water is there and this formation of C-S-H or and C-A-H occurs when crystals begin, forming a few hours after water and cement are mixed. Actual materials when you mix with cement and add water within few hours CSH and CAH will start forming but crystals will continue to form as long as unreacted cements particles and free water remains within the mixture. As long as water and cement are available to react it will continue to happen CSH and CAH formation.

This is the mechanism for working by, it is actually in the lime stabilization. What used to happen is the alkaline medium that clay particles breaks and from there actually alumina silica comes out and from there it reacts with lime and it will form C-S-H and C-A-H whereas in the cement actually react with water and then C-S-H and C-A-H formed, that is the difference and they are actually cementitious material they will react and it will form some bonding in the soil particles and by that it will give you the strength gain or decreased compressibility and all those things.

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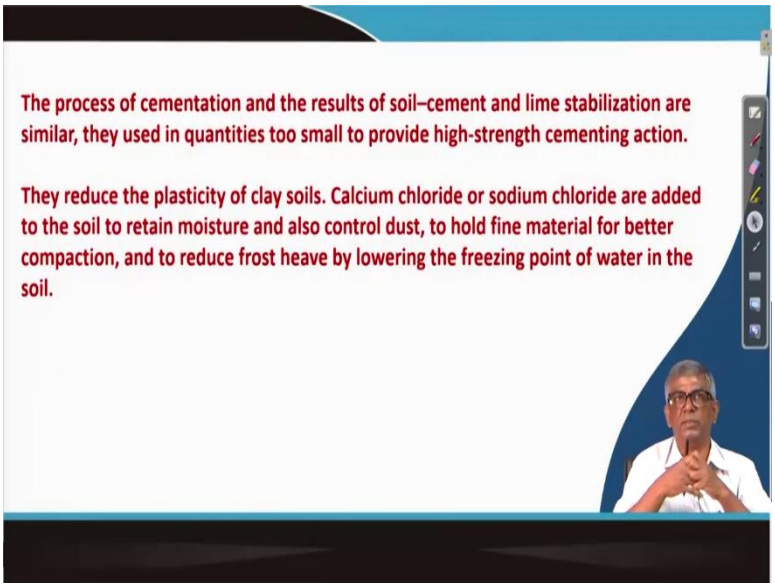

And this process of cementation and the results of soil cement and lime stabilization are similar. The process of cementation and the results of soil cement and soil stimulation are similar and they used in quantities too small to provide high strength cementing action. So, both cement and lime they are used in a smaller quantity and how small or how big that has to be investigated and then determined.

And they reduce the plasticity of the clay soils, actually plasticity will be reduced that means if it is a plastic soil it will convert to close to non-plastic and that is the requirement of most of the compaction work or stabilization work and calcium chloride or sodium chloride are added to the soil to retain moisture and also control dust to hold fine materials for better compaction and to reduce the frost heap by lowering the freezing point of the water in the soil.

That is the purpose of adding, I have mentioned before, that is the one that, sodium chloride can be used to hold the water and what is the reason? That is explained here, so actually to control dust and to reduce the moisture that is the requirement.

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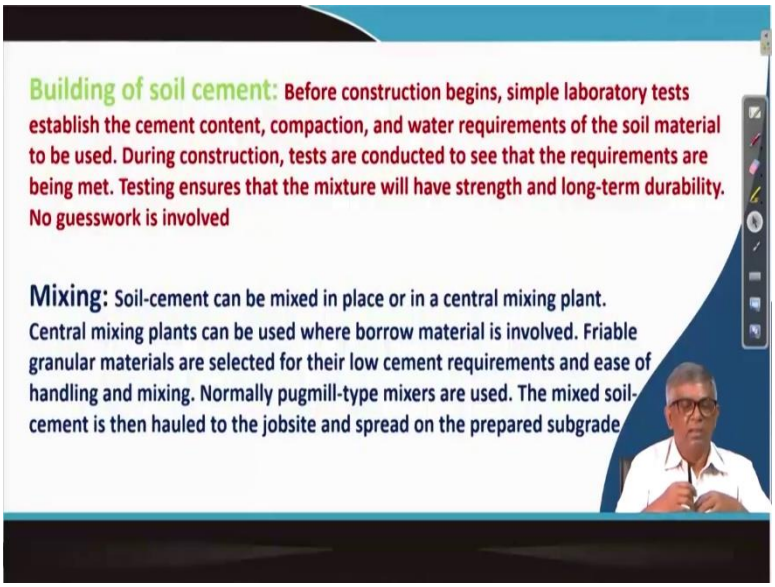

Let us go to the next one, the building of soil cement. Before construction begins, as you have mentioned that simple laboratory test establishes, the cement content, compaction, water requirements of the soil material to be used like I have mentioned the slime stabilization here also in the siemens stabilization when will use stabilization by using cement, you have to carry out different test and you have to find out what is the amount of cement is required? What is the compaction that is required? What is the water that is required? All those things have to be determined and during construction, tests are conducted to see that requirements are made.

What are the requirements and whatever we are providing that we are achieving has to be ensured by doing test and testing ensures that the mixers will have strength and long term durability, that means whatever required and no guess work will be done here then your results may not work and then after knowing the quantity of various components then you have to mix it and mixing can be done in two ways, it can be mixed in plants or it can be mixed in the in place that means heat mixing also possible there.

When it will be used in plant actually that central mixing plants can be used where bottle borrow material is in, that means when we are making supposed embankments and we are using borrow materials and all types of borrow materials sometimes difficult to do, friable granular materials are selected for the low cement requirements and ease of handling and mixing. When you use that cement stabilization and borrow material and you have to select variable general materials where actually less amount of cement is required and mixing and

handling also will be easier and normally a pug mill type mixture are used to use this and the mixed soil cement is then halt to the job site and spread on the prepared subgrade.

That means you have to select a friable granular material and mix with the determined predetermined amount of cement or add mixtures and mix in a plant and then transfer it to the job site and spray it on the prepared sub gate. This is it and then you have to compact it.

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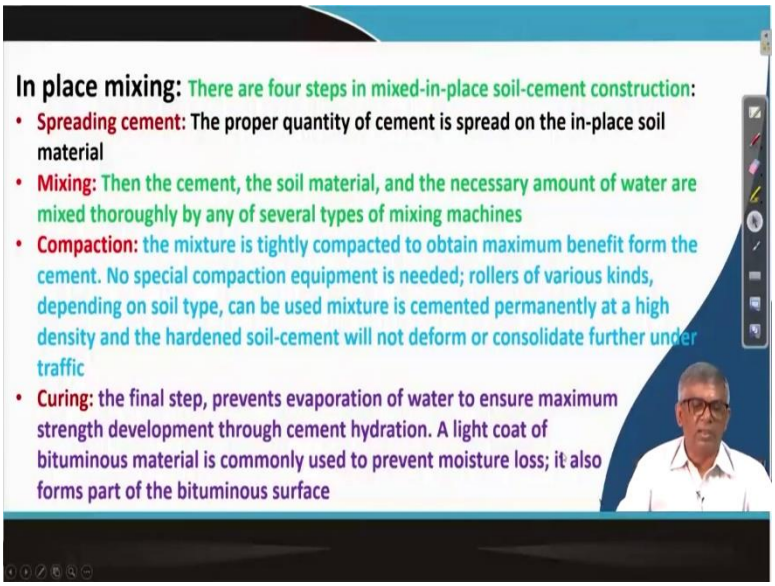

After mixing let us see the next step and then of course as I have mentioned that mixing can be done two different ways actually one is in the plant and it can be done in place mixing that means easy to mixing. There are four steps when you do in place mixing, the spreading of cement that means on the site, you have to spread the cement, quantity of cement is spread.

The determined amount of predetermined amount of cement to be sprayed on the soil in place of soil material and then you have to mix it, the cement and the soil material and the necessary amount of water are mixed thoroughly by any of several types of mixing techniques.

Machines are there in the site, how at the sites soil can be mixed after spreading then there will be scrubbing and then mixing as portable there are some machine to be selected and then after that compaction will start, the mixer is tightly compacted to after obtain a maximum weighting benefit from the cement, no special compaction equipment is needed actually, rollers of various kinds that depending on soil type can be used, mixture can be used, cemented permanently at high density and the hardened soil cement will not deform or consolidate further under traffic.

That means, there are no special type of the roller is required, the type of soil is present at site and then we are spreading the cement and after mixing then you have to see the type of material finally and then depending of the material you can select different types of rollers which we have discussed, if it is sandy type then you have to use then vibrated roller or some roller. If it is a little clay or soft type of material then you have to use shift foot roller and some other similar type of roller.

Like that you have to use then rubber tire roller, all different kinds of rollers are there to be used and then you have to make a very compact ground and that ground will be cemented permanently at high density and will be hardened and which will not deform or consolidate further under any traffic loading. That means if that way compact mix and then road is made, then while traffic movement it will not deform or further any consolidation will take place. So, that is the compaction.

Then curing, of course the final step actually prevents evaporation of water to ensure maximum strength development through cement hydration then for that actually a light coat of bituminous material is commonly used to prevent moisture loss. Curing means actually you know that normal concrete construction also curing is a very important step that means you have to… that cement actually reacts similar to that here also cement will react with water actually and you have to provide the water and if whatever amount water you know you have provided but it is evaporating then strength will not be enough so because of that you have to ensure that proper curing that means, loss because of evaporation should be prevented, for preventing that a light coat of bituminous material is commonly used in the site and it also forms part of the bituminous surface so that you can use that bituminous coat, that will act as a bituminous surface which is beneficial also.

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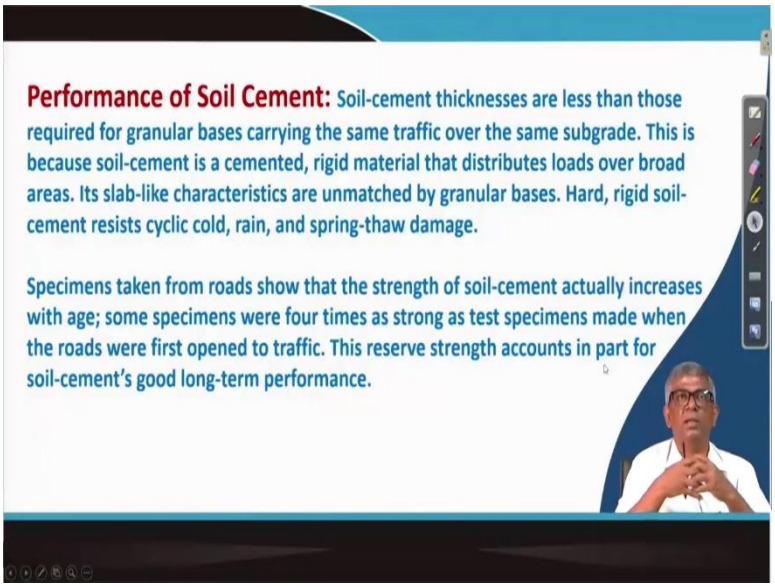

Let us go to the next one, the performance of the soil cement. The soil cement thickness is less than those required for granular base is carrying the same traffic. Suppose if you design for a particular volume of traffic and the base if you design for the normal granular material and cement treated material then obviously the thickness will be less when it is cementite.

And this is because soil cement is cemented, rigid material that distribute the load so when it is a hard material it distribute the load over a wider areas, that means intensity of load will be reduced on the soil and that will help and its slab like characteristics that means when cemented soil will be almost like a slab will work, it will not deform like soil that characteristics actually unmatched by granular bases, if you make the granular bases which will not be able to give you that type of slab reaction.

And this hard rigid soil cement also resists cyclic cold that means sometimes cold sometimes hot sometime. If it is a granular base then sometime it will be affected, sometime if it will rain and sometime with no rain, that will also affect it and sometimes spring thro would be there. If the granular base because of this cyclic, cold, rain and spring thaw sometimes it will be damaged but if it is cement treated then this cyclic effect of this event will not cause any damage, that is the advantage also.

And specimen taken from roads so that the strength of the soil cement actually increases with age that means because we know that the reaction as long as the reaction will take place, again it will continue and some specimens were four times as strong as test specimen made when the roads are fast open to traffic you can see that during construction sometime we have taken the specimen and then finally tested some strength and when finally open to the traffic

when you test it again we have seen as high as 4 times increase. That is actually very advantageous that, sometime material will be degraded but here actually when the soil is treated with cement the strength gain will continue to increase. That is very important aspect of soil stabilization. The reserve strength accounts in part for soil cements good long-term performance, so the because of this additional increase that it gives you better long-term performance.

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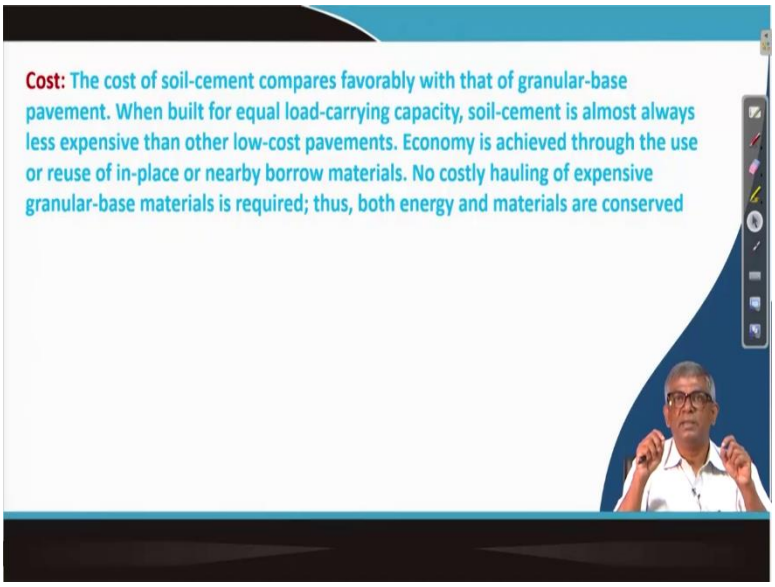

Then cost obviously, when you use granular base the thickness will be more but when you will be treated with cement the thickness will be reduced that will actually give you, of course the cost of cement is there so because of that, the cost wise they are almost similar or marginally favourable but it will have better performance because we can say that it is economical the cost of soil cement compares favourably with that of granular base payment, when built for equal load carrying capacity soil cement is almost always less expensive than other low cost payments and economy is achieved through the reuse of in place or nearby borrow materials.

Because of all these, actually the borrow materials if you take from distance then of course cost will be more otherwise you can have nearby borrowed materials that obviously it will be very beneficial and no cost hauling of expensive granular base material is required.

Thus, both energy and materials are conserved. So, that means cost wise how beneficial this is discussed here. Basically, the thickness will be reduced and then many other benefits is

there so because of that most of the time compared to the granular base when you cement it stabilize base is used, it is most of the time economical in many ways.

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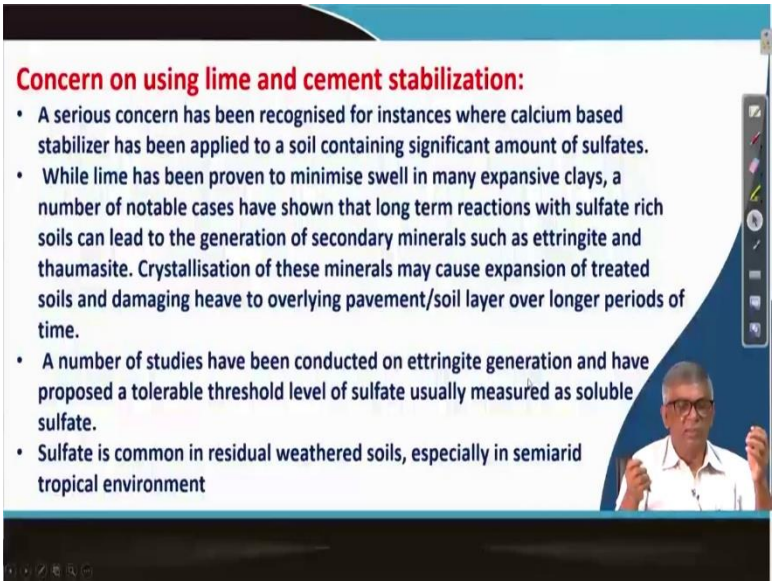

Let us go to the next one and concern in using lime and cement stabilization there are some concerns and the serious concern is recognized for instance where calcium-based stabilizer has been applied to a soil containing some significant amount sulphates. We have mentioned that in soil lime stabilization that you have to find out the sulphate contents actually.

If certain amount of sulphate is used or present and if you use lime stabilization then actually it is some amount of problem actually will be there. What type of problem it is discussed here? When lime has been proven to minimize swell in many expansive clays a number of notable cases are shown that long term reactions with sulphate rich soils can lead to generation of secondary minerals such as ettringite and Thomasite, that means with the lime, it will react with this sulphate and these 2 minerals actually react and then ettringite and Thomasite is actually creates.

And crystallization of these minerals may cause expansion of treated soils and damaging heap to overlying pavements or soil layer over the longer periods of time. So, that means if the soil is contains a significant amount of sulphate and this lime treated soil actually then this will react and over the time actually there is 2 minerals are there, new crystal are formed and these two crystals, that is a soil actually and though we have seen that by lime stabilization we can decrease the soiling potential but if sulphate is present then over the time this development of these 2 crystals actually it will again swell and because of this soil actually it can damage the pavement or the soil layer over it and that is why you need to

ensure that when you are making a treatment with lime that you have to see that that presence of sulphate compound should be within the tolerable limit, that is the important thing is mentioned here, that is the concern and a number of studies have been conducted on the intrinsic generation and had proposed threshold level of sulphate, usually measured as soluble sulphate.

There are actually threshold values which should not go beyond that. I do not remember about that number actually that value what percentage or what amount that I do not remember. It will be inside in the code actually there are 11 lime sterilization code which is there, you can refer that and you can find those details.

And sulphate is common where it gets soil, it is known. They are actually available in residual weathered soil especially in semi-arid and tropical environment, semi-arid tropical environment actually residual weathered soil contains sulphate and if you know that, it is the type of soil then it can be avoided to do lime stabilization. Because of that concern.

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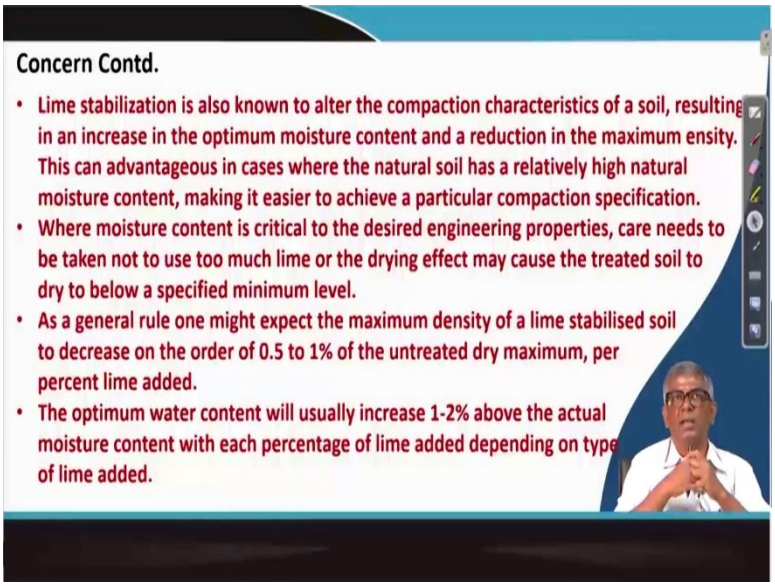

Then continue again further lime stabilization is also known to alter the compaction characteristic of soil, how? The resulting in an increase in the optimum moisture content that means when a lime treated soil, it increases the optimum moisture content and reduction in maximum density.

This is what happens and I will show you the graph, you can say it is not beneficial but still you have other benefits, we go for it and this can again, increase in optimum moisture content and decrease in optimum dry density sometime it is disadvantages but some soil it can be

advantageous also you can see this can be advertised in cases where the natural soil has a relatively high natural moisture content and if the soil has a very high natural moisture content and reduction is very difficult.

If the optimum moisture content become high then you need not reduce it further. So, that is why it is beneficial so because of that when the soil contains high natural moisture content that is actually beneficial and this can be advantages in cases where the natural soil has a relatively high natural moisture content making it easier to achieve a particular compaction specification, so compaction specification is moisture actually dry density and that maximum dry density at particular moisture content.

And if the natural moisture content is very high and then compaction is difficult, if you reduce the moisture content that way actually beneficial finally and also where moisture content is critical to the desert engineering properties that means if the reduction cannot actually be allowed, the care needs to be taken not to use too much slime or the drying effect may cause the treated soil to dry a below specified minimal level.

That means that you have to take care, you are using lime to increase the optimum moisture content and that is not good so care has to be taken also how much increase happen or how much decrease happen, there is a general rule, as a general rule one might expect the maximum density of a lime stabilized soil to decrease in the order of 0.5 percent to 1 percent of the untreated dry maximum.

When it is untreated soil whatever dry density is there detailed with slime the decrease by .5 to 1.% of lime added. If I add one percent of lime then your decrease of maximum dry density will be 0.5 to 1 percent compared to untreated soil, that is the amount so if it is acceptable then… if you use 3 percent then approximately you can find out how much decrease will happen if that is acceptable, then only can accept this method.

Similarly, how much increase of optimum moisture content will happen? The optimum water content will usually increase by 1 to 2 percent above the actual moisture content with each percentage of lime that means if you add 1 percent of line, then your optimum moisture content will be increased by 1 or 2 percent, if you use five percent of line then automatically you can see how much optimum moisture control will increase. If that is acceptable then only you have to use. These are all different concern which is discussed here. So, you have to take care during adopting this method.

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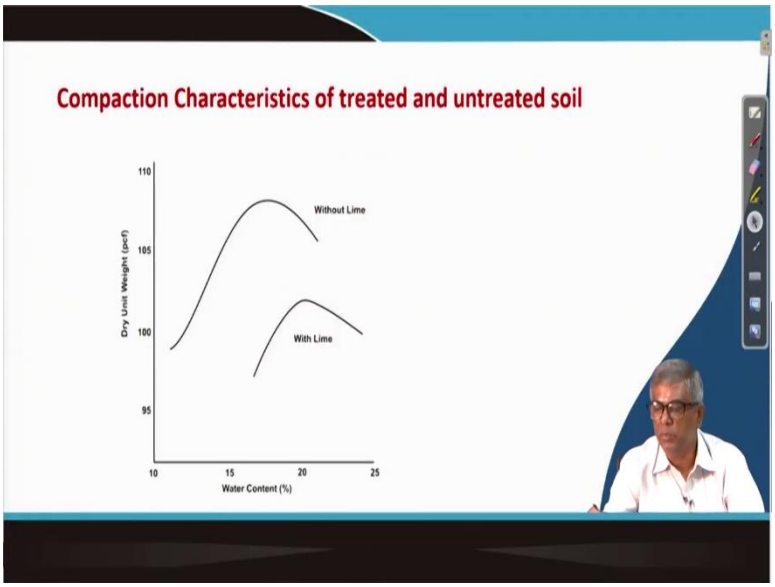

And this is that curve which I was trying to tell that is, without lime when you do the compaction curve a particular soil, you can see the optimum moisture content here and up to a maximum dry density here but when you treat it with lime the optimum maximum dry density optimum moisture quantity is here and maximum dry density is here. Reduction of dry density is happening and increasing optimum moisture condition is happening but still if it is satisfied your requirement this can be used because otherwise of plastic soil cannot be utilized for any foundation actually.

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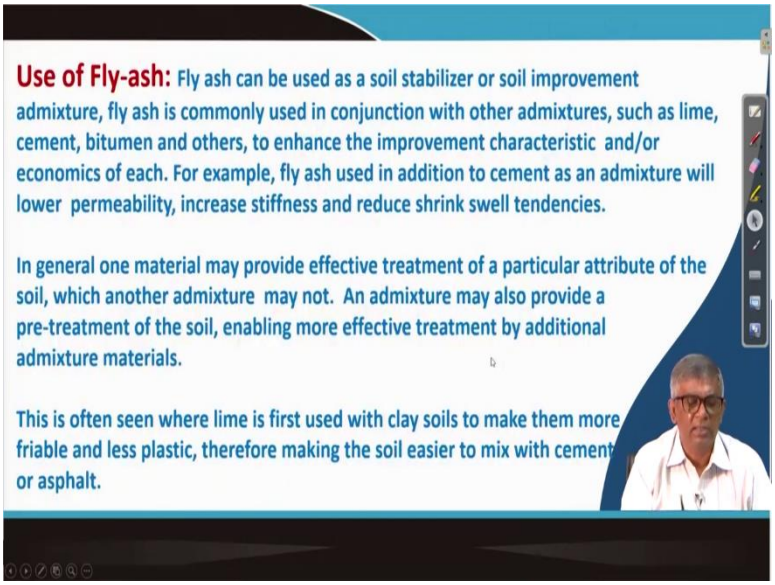

Then let me continue the last slide perhaps, the use of fly-ash. As I have mentioned that sometime additives, so fly-ash can be used as a soil stabilizer or soil improvement mixture

and fly-ash is commonly used in conjunction with other admixes such as lime, cement, bitumen and others to enhance the improvement characteristics or economics of each because either lime or cement whatever amount is required sometime that thing can be provided by fly-ash and that way it will give you some sort of economic. For example, fly-ash is used in addition to cement as an admixture will lower permeability increase stiffness and reduce sink soil tendencies.

That fly-ash used in addition to cement that means when you are using only flyer and then some amount of cement then it will give you so much of benefit, that's what it is mentioned here and in general one material may provide effective treatment of a particular attribute. That means you have to suppose increase strength, decrease compressibility then decrease permeability, so there are 3 or 4 attributes so by mixing one particular thing it can give you address one attribute which another admixture may not.

Suppose, I am using this one which will give you this but other one will not be able to provide that because of that an admixture may also provide a pre-treatment of soil enabling more effective treatment by additional. When you are using one it will help in up to some and then you are adding other one then it will give you another and this together will give you more benefits. That is the beauty of mixing of one or two materials and this is often seen when lime is first used with clay soils to make them more friable that means the it can be easily handled and less plastic after mixing with lime you are making friable and less plastic and therefore making the soil easier to mix with cement or asphalt. Sometime, we can mix with asphalt or cement to give some benefits so before that you can mix with lime to achieve some benefit and then further addition of lime or cement or asphalt will give you further benefits, like strength increase and other things and use fly-ash and some more.

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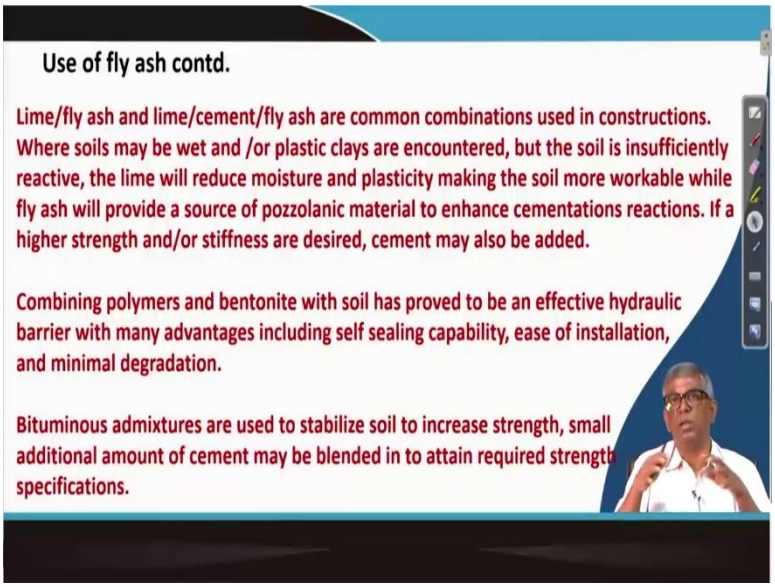

lime fly-ash or lime cement fly-ash are common combination used in construction so where soils may be weight and or plastic clays are encountered but the soil is insufficiently reactive, the lime will reduce moisture and plasticity making the soil more workable while fly ash will provide a source of fluorescent ring material to enhance cementitious reactions. This is the thing you can see where soils may be wet and or plastic clays are encountered either too much of water or plastic soils or encountered but the soil is insufficiently reactive, it is soft but insufficiently reactive.

The lime will reduce the moisture and plasticity both and making the soil more workable while fly-ash will provide a source of fluidic so that means lime and fly-ash how it works? By using lime, we are making less plastic more fireable and then applying the fly-ash, and supplying the prison link materials then they will react together and will give you the desired strength and stability and other things. And by that actually it will enhance cementation reaction if a higher strength and or stiffness is required you can further fly and again further cement can be used, then it will get again further strength. That combining polymers and bentonite with soil has also proved to be an effective hydraulic barrier.

If you want to make a permeability reduction then that actually again bentonite with and polymers and can be used to use some very good barriers and with many advantages including self-sealing capability, the ease of installation, and minimal degradation. That means in combination of polymers and metabolites views these are the benefits can be obtained and similarly bituminous and mixtures are used to stabilize soil to increase strength and small amount of cement may be blended to attain required strength and specification.

Sometimes bitumen can be used to reduce increase the strength and in addition to that some amount of cement can be blended to have the desired strength and other things so that means, lime alone can be used, cement alone can be used, sometime combination of two or three materials can be used to achieve desire strength.

like this there are several things there in the chemical stabilization this is a very good research areas and continuously research is in progress and many other things are available in the literature but by and large in the practice what are the things in practice, I tried to bring it here and discussed and with this, I will close this chemical stabilization and maybe, I will try to do some more topic in the subsequent topics. With this today I will close the module chemical stabilization. Thank you.