Soil Mechanics
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Lecture - 13

Welcome to compaction of soils part 3. In the previous lecture we have tried to understand about factors affecting compaction and another method of laboratory compaction that is AASHTO modified compaction. In this lecture we will be introducing the moisture density relationships of cohesive soils as well as cohesive soils. Another important factor which affects the compaction behavior of the soil is the soil structure or the soil fabric of clay soils which will also be discussed. Thereafter we will be introduced to field compaction and desirable properties of a compacted structural field for any embankment dam, dike construction.

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So in the previous lecture we have seen principles of compaction and moisture destiny relationships. We also understood about the role played with water in the compaction process. We also studied the AASHTO modified compaction test and the two laboratory methods; one is a standard proctor compaction, the other one is the AASHTO modified compaction. We also introduced the terms like zero air voids line or 100 percent saturation line. We also discussed about salient differences between standard proctor compaction test and AASHTO modified compaction test and in the end of the previous lecture we also covered the factors affecting compaction. So, in this lecture we will continue with this factors affecting compaction by discussing factors like soil structure and compactive effort. Thereafter we will go to field compaction and different compaction mechanisms available in the field.

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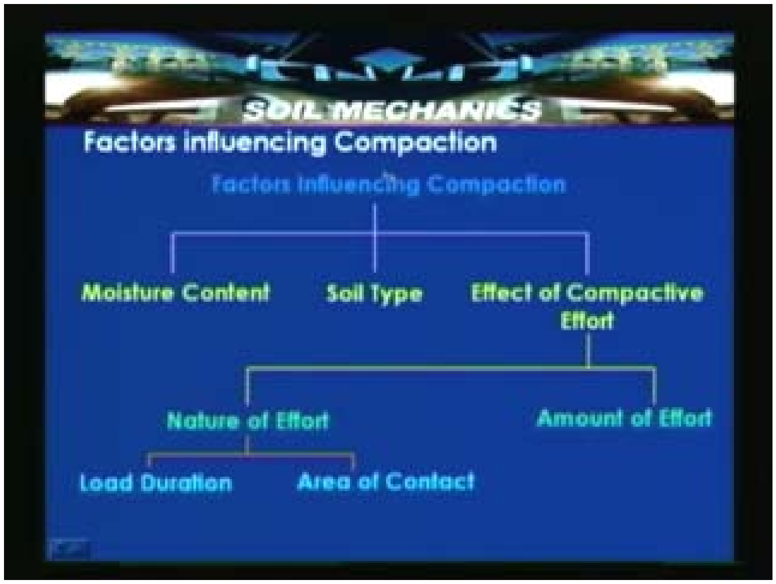

So if you recollect factors influencing compaction, they are basically moisture content, soil type and effect of compactive effort. So this effect of compactive effort is a very important factor which can influence the compaction process particularly. It also implies that we have seen in standard proctor compaction tests and modified proctor compaction test. With an increase in the compacted energy, we are able to pack the particles as close as possible to get the higher densities. It means that we can increase the compaction density, compaction energy in such a way that we will be able to pack the particles as close as possible. So the pros and cons of these particular factors will be discussed in this lecture. So here compactive effort is the nature of effort and amount of effort. This nature of effect is again like the load duration that is for how long the compaction load is being applied to that and area of the contact, whether the area is adequate or inadequate for compacting the soil.

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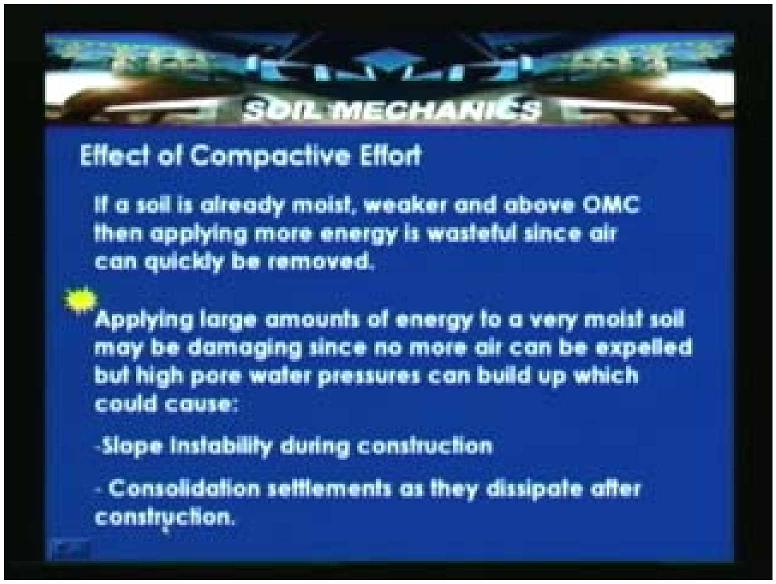

Now, if we look into the effect of compactive effort the soil is already moist, weaker and above OMC that is above Optimum Moisture Content then applying more energy is wasteful since air can quickly be removed. Applying large amount of energy to a very moist soil may be damaging since no more air can be expelled but high pore water pressures can build up which could cause slope instability during construction. So these pore water pressures which are built up during the process of construction can cause slope instabilities or further consolidations causing settlements in a structure. So, applying more energy to a wet soil on the wet side of the Optimum Moisture Content is undesirable because these things can cause instability conditions to a particular structure.

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If you look into it the nature or effect of the compactive effort, the load duration and contact area, let us put these two factors together like longer time duration that is the time of application of the compactive load leads to reduced shear stiffness response and greater compaction. So the shear stiffness response between different particles will try to reduce and then finally the particles lead to rearranging themselves into a denser state. So longer time duration leads to reduced shear stiffness response and greater compaction so greater contact area leads to greater depth of influence. So we are also interested to know that when these layers are compacted in the field we should see that the uniform degree of compaction is achieved in the entire layer so that the density achieved is uniform in the soil mass.

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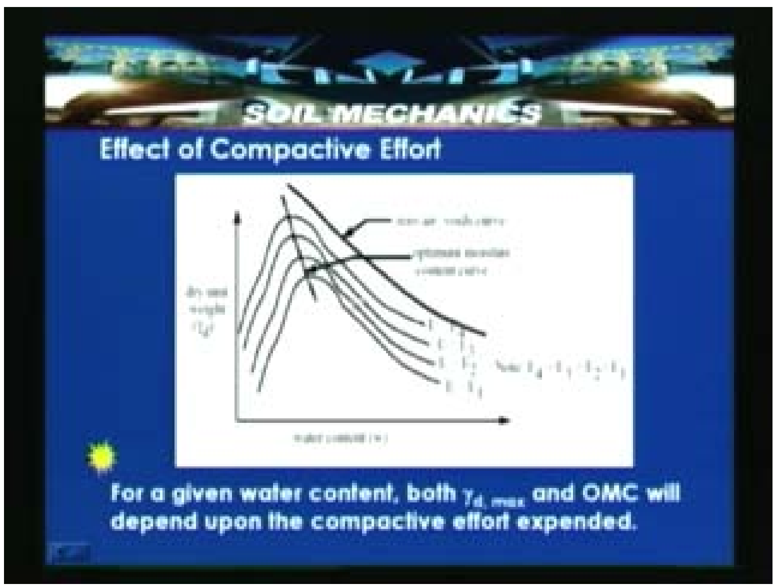

We have seen this curve in the previous lecture. With increase in energy, for example E_1, E_2, E_3, E_4, where E_1, E_2, E_3 and E_4 are the compactive energies and E_4 is less than E_3, E_3 is less than E_2. E_2 is less than E_1. For example, E_4 is greater than E_3, E_3 is greater than E_2 and E_2 is greater than E_1. In that case if you apply increasing energy in this direction, then what you are seeing is that where the maximum dry unit weight and optimum moisture content is occurring it is called line of optimums and you see a lateral drift towards the dry side of the curve. It means that by applying more energy we are able to shunt the air quickly so that the air is expelled out quickly with more compactive energy that the particles could be arranged into new positions with more energy. So, for given water content both the gamma d max that is the maximum dry unit weight and optimum moisture content will depend upon the compactive effort expended. So whatever the compactive effort expended for given water content both gamma d and gamma d max and OMC will depend upon this compactive effort expended.

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Let us look into this effect of compactive effort further by discussing about degree of compaction that generally increases with increasing compactive effect. However, beyond a certain point increased compactive effect produces only very small increase in dry unit weight. That is, it takes a great deal of additional compactive effort E to see significant increase in dry unit weight. When we are doing a field compaction in order to see or ascertain that how many layers are required to be allowed to a particular layer to achieve a particular degree of compaction that has to be ascertained or decided well before the project. For that if you look into this, beyond a certain point increased compactive effort produces only very small increase in dry unit weight.

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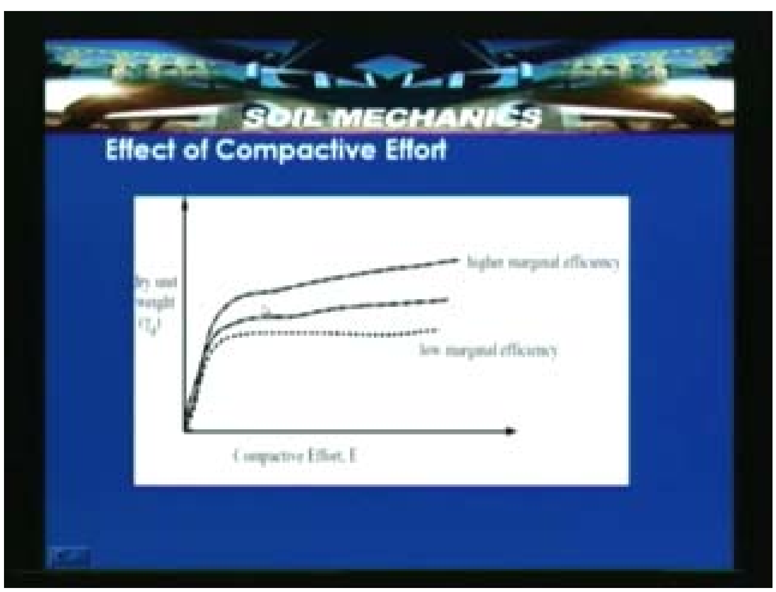

That means if you apply a compactive effort with low marginal low marginal efficiency and higher marginal efficiency or a medium efficiency here you will see that the dry unit weight versus compactive effort shows, after certain point the gamma d increases very very marginally which may be around 10 to 20 percent increase. That means it takes a great deal of additional compactive effort E to see the significant increase in the dry unit weight. Sometimes applying a certain energy that is compactive effort beyond a certain point the maximum gain in getting higher dry unit weights seems to be negligible. Sometimes it takes more compact effort to get varies negligible increase in the dry unit weights. So that is actually a point which has to be noted here. After reaching a particular point here even high marginal efficiency, the gain in the dry unit weight is very very less.

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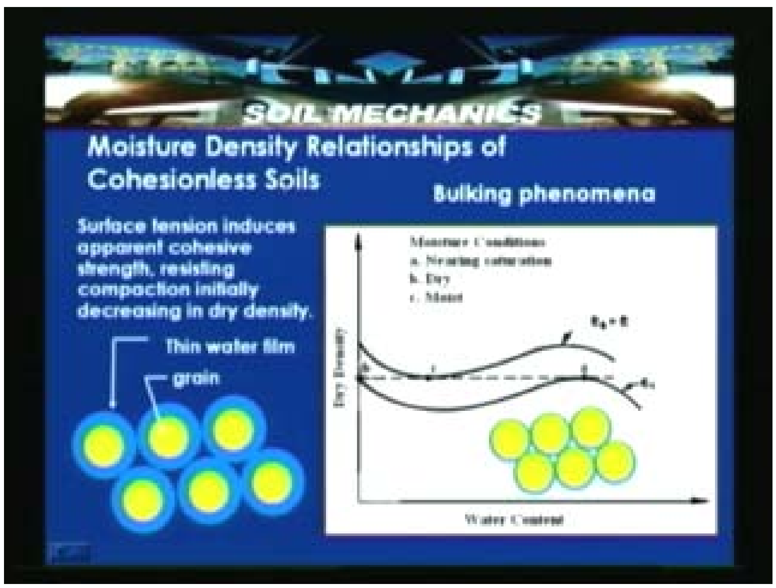

Now let us try to discuss a peculiar behavior of cohesion less soils which causes phenomena called bulking phenomena. We will be discussing cohesive soils later. Let us consider cohesion less soil. In the cohesion less soils particularly sandy soils if they are under moist conditions means if there is a moist condition then all the particles are covered by a thin film of water which actually prevents the particles coming closer because of the surface tension forces induces something like an apparent cohesion to the sandy soil mass.

We have discussed this earlier and we will also be discussing capillary phenomena. But, if you look into this particular chart the dry density or dry unit weight on the y axis and the water content is shown. So two different curves are shown with different moisture conditions where b is particularly indicating the dry condition and c is the moist condition and a is the nearing saturation almost saturation, that is sandy soil mass is subjected to saturation.

So, if you look into the run of these two curves one is having an energy e_1 and the other one here is having an energy $e_{2,}$ which is greater than $e_{1.}$ Let us consider this particular curve here where in the dry state you are having a dry density or drying weight b and with an increase in water content you are seeing a decrease in density. Then after adding further amount of water there is a increase in the dry density or unit weight and then it reaches a point p_k and then thereafter again the density decreases. This peculiar behavior will be there only for sandy soils because if you consider this sandy soil or a grain as a uniform grain or basically a single grain structure with certain arrangement of the particles, they are covered by a thin water film as you are seeing here the light blue colour which is nothing but a thin water film surrounding the soil grain. So because of this surface tension induces apparent cohesive strength which resists the compaction initially and leads to decrease in the dry density. So the moist sandy soil always appears to have low density. So moist sandy soil suppose to have a low density because all the films of water are covering that grains which are actually practically preventing the particles from closer it something like while discussing honeycomb structure we also discussed this particular, behavior. So surface tension induces apparent cohesive strength resisting the compaction initially and decreasing the dry density. Once this particular condition moist condition arises then the density decreases further.

After adding a certain amount of addition of water then what will see is that the washing of this thin films of water surrounding the grains. That is what is actually shown here. At point a, what happens is that the films of water which are actually surrounding the grains will get almost washed out or diminished to a very very negligible extent. It will allow the particles to come closer. In the process what will happen is that there will be increase in the dry density. Therefore more amount of water level increases in the voids which are there between the soil grains. Again the rho w is less than rho solids because of that the density decreases.

Particularly for sandy soils we will see the typical phenomena under moist conditions, there will be a decrease in density because of the apparent coefficient and because of surface tension caused by the thin films which are surrounding the solid grains. These thin films get washed off by adding more water. So it enables us to see that the particles are rearranged into new positions or densely pattered positions. That is what actually happens particularly for the sandy soils. So that is the reason from c_2 to this particular point the increasing density is because of the gradual thinning of the water films which are surrounding the soil grains. So this is a peculiar phenomenon for sandy soils which is called bulking of sand. Having discussed cohesion less soils we knew that cohesion less soils and cohesive soils are entirely different type of soils.

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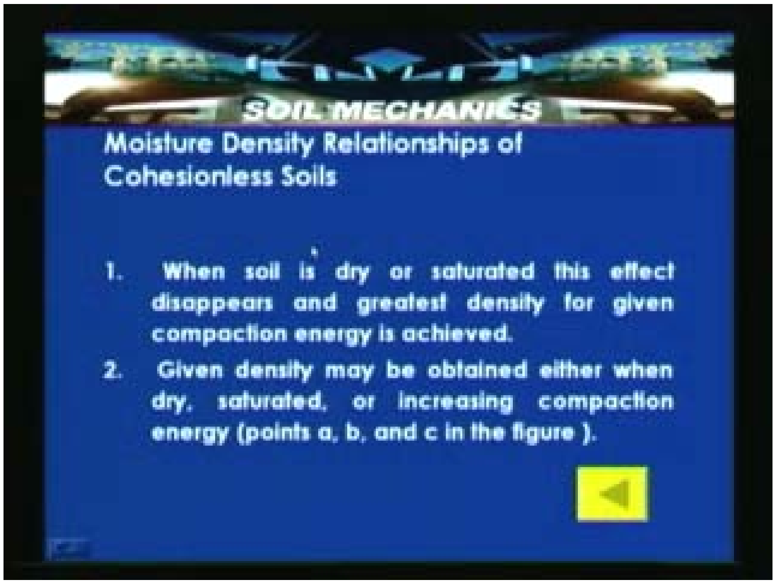

The cohesive soils, when the soil is dry or saturated this effect disappears and greater density for given compaction energy is achieved. Given density may be obtained either when dry or saturated or increasing compaction energy. We have discussed for the moisture density of relationship of the cohesion less of the soils. When the soil is dry or saturated this surface tension or apparent cohesive effect disappears and greatest density for a given compaction energy is achieved, that is actually for behavior for cohesion less soils.

When soil is dry or saturated this effect due to the apparent coefficient induced by the surface tension forces between the soil grains disappears and greatest density for a given compaction energy is achieved. Given density may be obtained either when dry, saturated, or increasing compaction energy. That is shown in the figure as point a, b and c. At point a, the soil is almost in the saturated state. Having seen this particular behavior of sandy soils, now mostly the soils with silt, compacted silty soils or silty clays, clay silts have a particle fabric which is different from the sandy soils. So, if you have got a clay soil what will happen to the soil structure on the dry side of optimum and the wet side of optimum? Let us look with different compaction energies.

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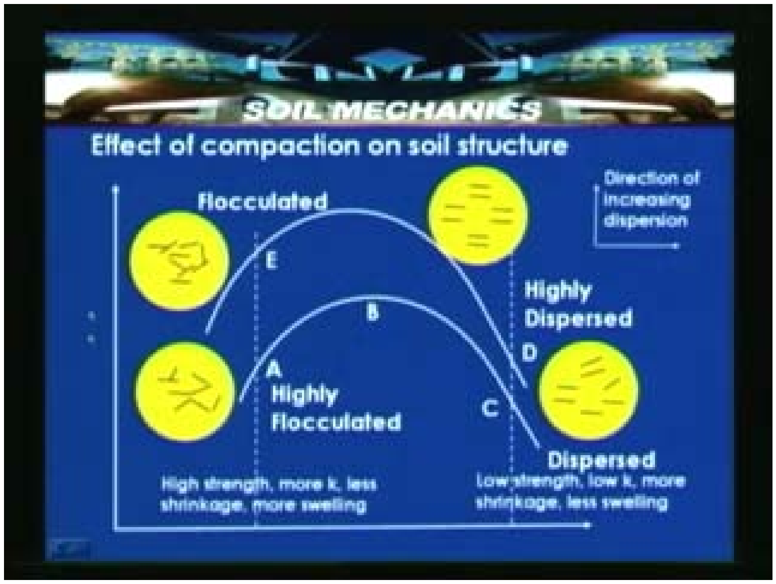

In this slide what you see is that gamma$_d$ or dry unit weight is plotted. The dry unit weight is plotted on the y axis and water content or moisture content is plotted on the x axis. You see here, this curve is for standard proctor compaction and this is for modified proctor compaction. The upper curve is for modified proctor compaction and this is for standard proctor compaction and with increase in compactive energy there is a decrease in the optimum moisture content and increase in the dry unit weight of a soil. That is actually indicated here. Here you consider points A, B and C. A is on the dry side of optimum and C is on the wet side of the optimum. B is at the point where maximum dry unit weight and optimum moisture content exist.

Let us consider point E on the modified proctor comparison curve which is on the dry state of optimum and D is on the wet side of optimum. So if you look into the typical soil structure first the soil structure is explained then the mechanism is explained. So here at point A the soil structure is highly flocculated in nature, particularly for a clay soil with plate-like particles with face to edge orientations you have got very highly flocculated structure with more void ratio, means less dry unit weight and that is what is actually indicated here that dry unit weight is less because of the highly flocculated structure. Similarly on the wet side of optimum you see a dispersed structure. So particles have more or less undergone orientation. It is transformation in orientation where the particles are arranged in nearly parallel positions but some particles are still parallel and are not completely subjected to complete degree of orientation. At point C the structure is said to be dispersed structure.

Similarly, if you consider by applying more energy this highly flocculated structure reduces to a flocculated structure as what you see here with reduction in the voids and it causes something called high dry unit weight. Contrast to this at point D you will see that a highly dispersed structure that almost all the particles are arranged into parallel positions. And in between from point B or at this particular point E dash you see that a 50 percent orientation would have undergone and the structure may be neither flocculated nor dispersed structure.

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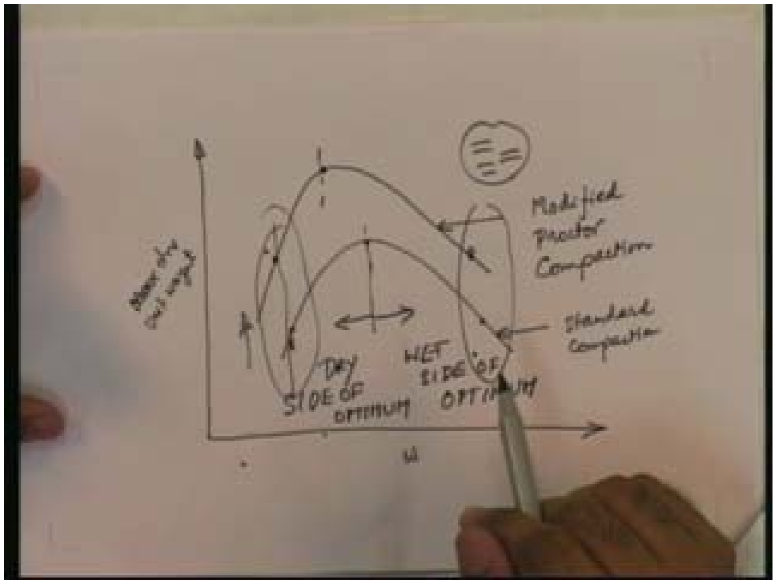

Here what we are discussing is something called dry unit weight versus water content. So we have drawn two curves. The curve which is on the top is for modified proctor compaction and this is for standard compaction. Now what we are discussing? This is dry side of optimum and this is wet side of optimum. So at this point the maximum dry unit weight and optimum moisture content was achieved for the same soil with increase in compaction energy that is modified proctor compaction. This is for standard proctor compaction with maximum dry unit weight and optimum moisture content. So what we are finding is that how the soil structure will be there particularly at these two points. Here, the soil is same but is subjected to different types of compactive energy.

Compaction energy is increased in this direction. So with that, here the particles are initially in the highly flocculated structure and are changed to the flocculated structure which leads to some increase in the dry unit weight of a soil mass. Here what you see is called a dispersed structure. All the particles are not undergone the complete transformation into parallel orientation. Here what you see is that a completely dispersed or highly dispersed structure with particles almost taking parallel positions. So this peculiar behavior can be possible particularly with cohesive soils. These particular two drastic soil structures can affect most of the engineering properties of the soil mass. That means, if you compact on the dry side of the optimum the strength of the soil mass may be maximum.

If you compact on the wet side of the optimum the strength of the soil mass may be less. But if you compact on the dry side of the optimum the coefficient of permeability which we will be discussing later, that is the capacity which tells whether the soil can allow the passage of water or not which actually increases on the dry side of the optimum. But on the wet side of the optimum the soil tends to become impermeable. So here what you are seeing is high strength and more permeable and also prone for more swelling because on the dry side of optimum the earlier researches have indicated that the soil is more prone for volume changes. That is increase in the volume can take place because it tries to suck the water from outside or freely available water and the soil tends to change the water that is change in the volumes by inviting more water into the voids which are in between the soil grains. High strength, more permeable, less shrinkage and more swelling can be possible on the dry side of optimum. On the wet side of optimum, it is low strength because soil grains are occupied with water because of the abundant water available in between the soil grains and low permeability.

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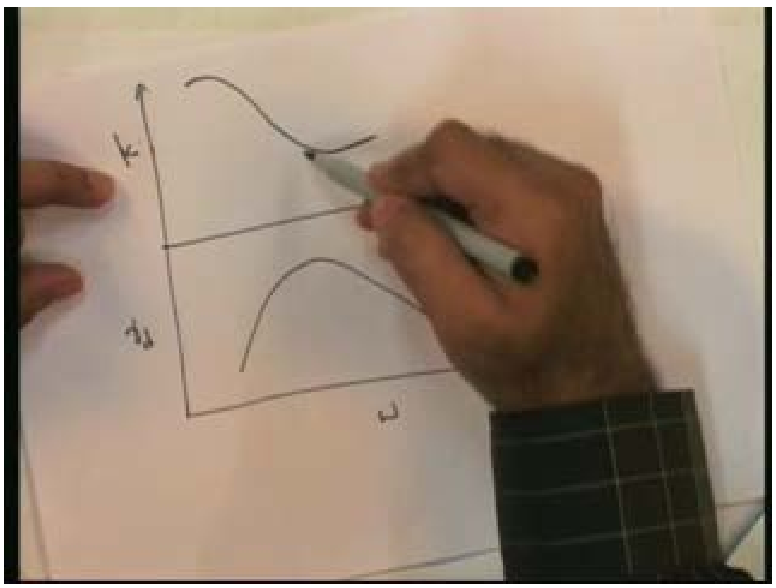

If you vary this permeability, that varies like this. For a given compaction curve, if this is the compaction curve with gamma d and water content and if the coefficient of permeability is indicated by k, initially on the wet side of optimum the coefficient of permeability decreases. So, it is always desirable to decide depending upon the type of the structure. For example, a water retaining function is required. Then it is advisable to compact the clay on the wet side of the optimum where the strength may not be a very high criteria. Suppose for load baring structures like for roadways or air field pavements or railways it is advisable to be compacted on the dry side of the optimum where the strength is very much required to support the load coming on to the sub grade. So it depends upon the type of application or type of the structure whether to compact on the dry side of optimum or wet side of optimum. We will be discussing this while we discuss field compaction methods.

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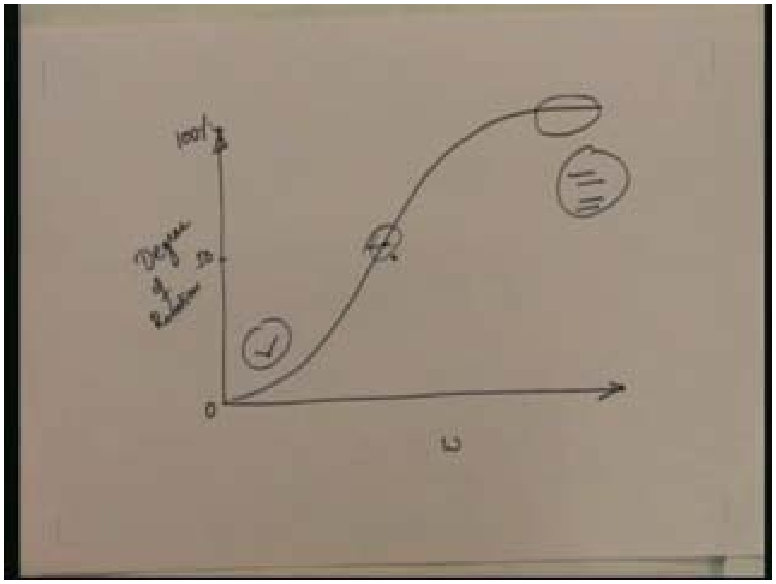

Another thing which I would like to discuss is now if you again plot our water content versus degree of rotation that is change in orientation which is 0 to almost 100 percent that is 50 percent. Then as the water content increases what you will see is that at optimum moisture content most of the plate-like particles would have undergone transformation from flocculent into 50 percent transformation undergone here at gamma$_{dmax}$ and OMC. Then on the wet side of optimum most of the particles would have almost changed into parallel positions here. Here you will see a flocculent structure with this particular orientation. So what I mean to explain here is, the degree of orientation of particles is around 50 percent.

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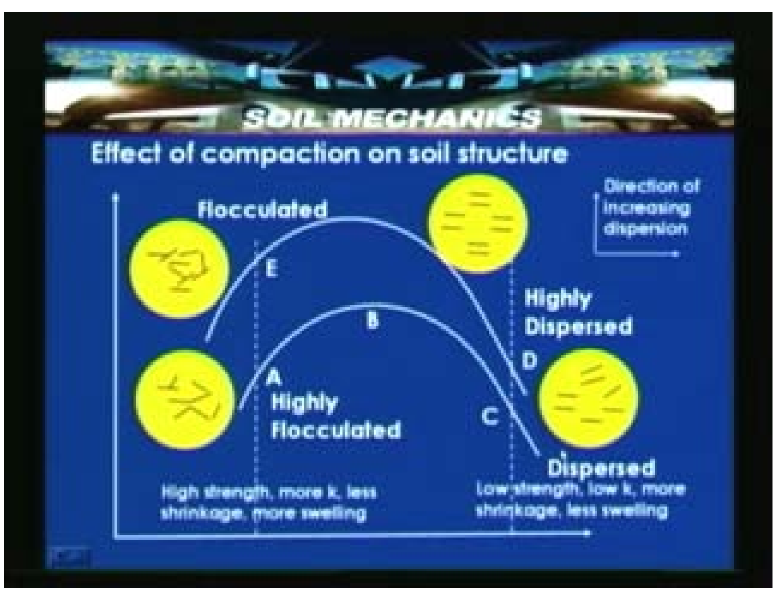

So the structure is a neither flocculent not dispersed, the structure is not very clear. Here at point E the structure is flocculated and at point D the structure is highly dispersed. So whatever we have discussed just now are summarized here, that is high strength, more permeability or more or more k and less shrinkage and more swelling. Similarly dispersed structure has low strength, low permeability and more shrinkage and less swelling. So less swelling is possible because here already abundant availability of water will inhabit soil from sucking further water. With this what we have summarized is the property of compacted soils, the soil structure is severely affected where at point A we have a flocculent structure and at point B we have a dispersed structure.

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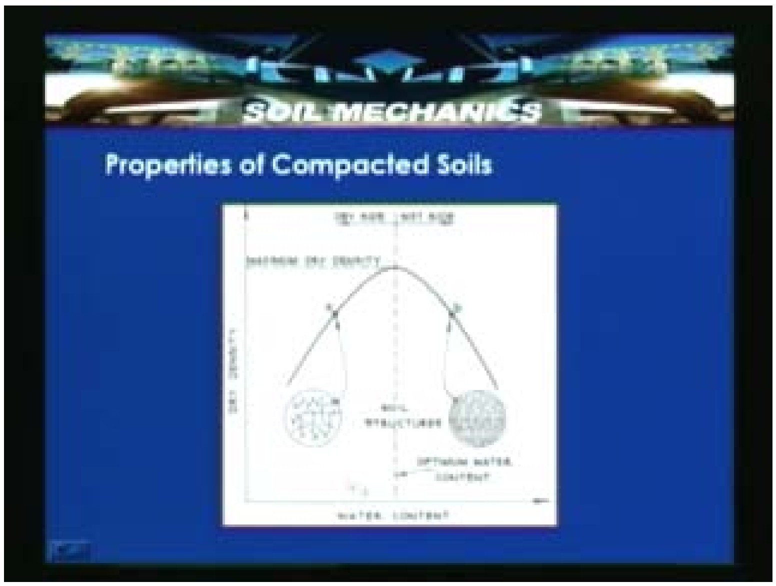

So these two different structures will influence the soil behavior. Particularly the compacted soil or compacted structure fields entirely depend upon these two factors.

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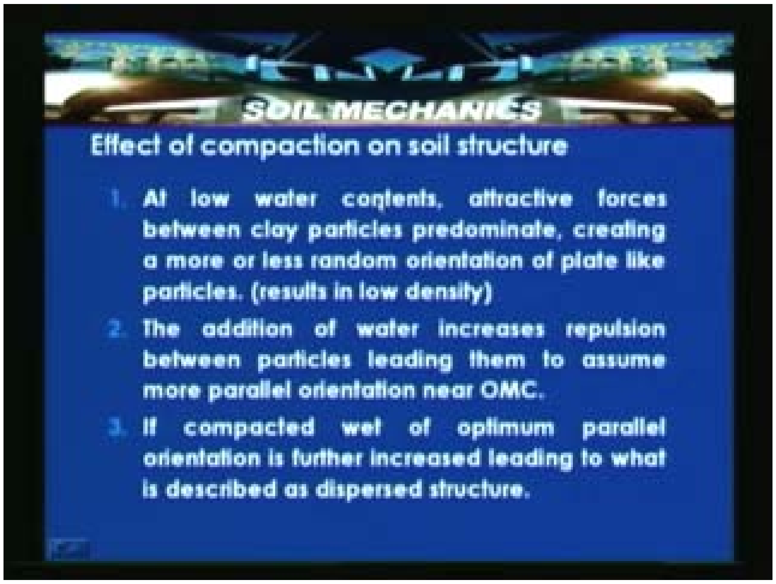

Now let us look at different reasons. At low water contents the attractive forces between clay particles predominate creating a more or less random orientation of plate like particles which results low in density. That means at low water contents what we have seen is that attractive forces between the clay particles is predominate creating more or less random orientation of particles. That means depending upon the energy highly flocculated or flocculent structure is possible. The addition of water increases repulsion between the particles leading them to assume more parallel orientation near OMC because on the dry side of the optimum with less amount of water there will be a sort of attraction between edge to edge or edge to face orientation. This actually leads to this flocculent structure with high void ratio so addition of water to the soil mass increases repulsion between the particles leading them to assume more parallel orientation near optimum moisture content.

If compacted wet of optimum parallel orientation is further increased leading to what is described as a dispersed structure. That is what actually we are trying to discuss. If compacted wet of optimum parallel orientation is further increased leading to what is described as a dispersed structure. The addition of water increases repulsion between the particles leading them to assume more parallel orientation near optimum moisture content. If compact wet of optimum parallel orientation is further increased and the structure is entirely transformed from flocculent to dispersed structure with 100 percent degree of rotation of the particles, plate shaped particles. The moisture density relationships of the cohesive soils are discussed here.

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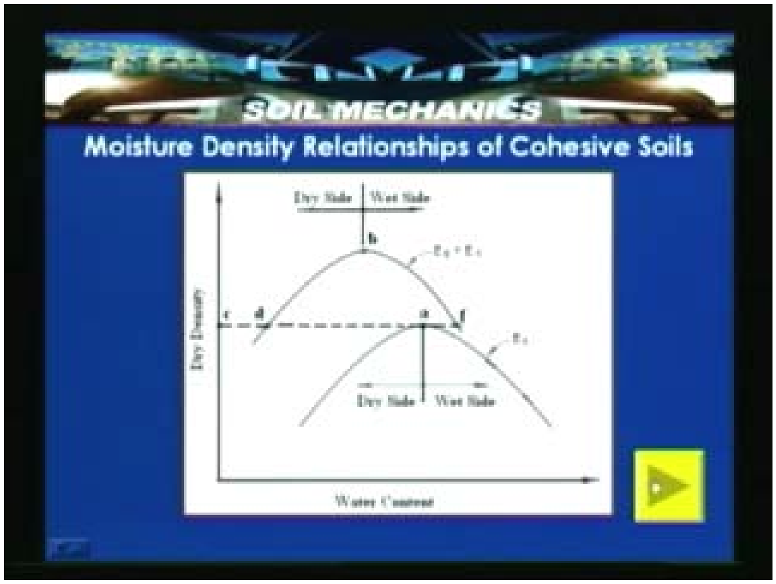

The same thing is dry side with standard proctor energy or with modified proctor energy.

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So you can see here, wet side of the optimum has high saturation because the water is comparatively more and low permeability and resisting densification. So, high water content that is the high degree of saturation and low permeability with resisting densification. Another relationship is the resistance to densification by dry side and wet side lead to peak density. Given density may be obtained through different compactive efforts and varying moisture contents like c, d, a and f as shown here.

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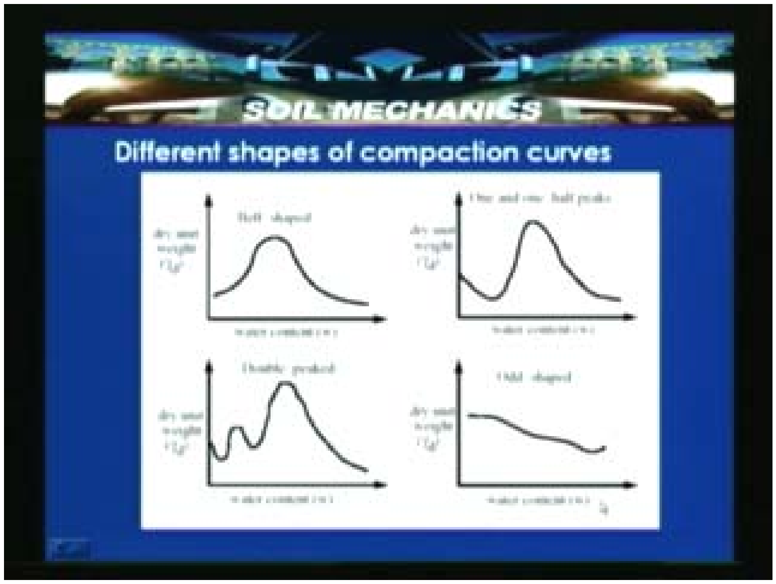

So, we have tried to discuss about the effect of soil structure on the cohesive soils, particularly how the soil structure can induce a different behavior of soil from the compaction point of view. As we have discussed, it is possible that different type of soils exist and different types of mixers of soils with different grades of composition can be possible. It is also that different types of compaction curves are possible. So most common shape of the compaction curve is the bell shaped curve as we have discussed. It is a bell shaped curve with dry unit weight with water content is shown here. The other one is one and one and a half peaks are also possible for some sandy soil mixtures.

Under moist conditions there may be a decrease in the density because of these surface tension forces importing the apparent coefficient here which will actually not allow the particles to come closer shows a decrease in the dry unit weight. Further with addition of the water we will be seeing an increase in the dry unit weight and then there will be a decrease in the dry unit weight with increase in water content. So this particular type may be possible with one and one and a half peaks. They are not very common but it is possible that double peak curves or odd shaped curves can exist where it increases and again decreases and again it decreases. The odd shaped curve is something also possible for certain type of soils. What we have seen in this slide is the different shapes of the compaction curves. Mostly the compaction curve is typically a bell shaped curve which is valid for clayey soils. And then this one and one and a half peaks curve may be possible for sandy and clayey soil mixtures or clay sands or so.

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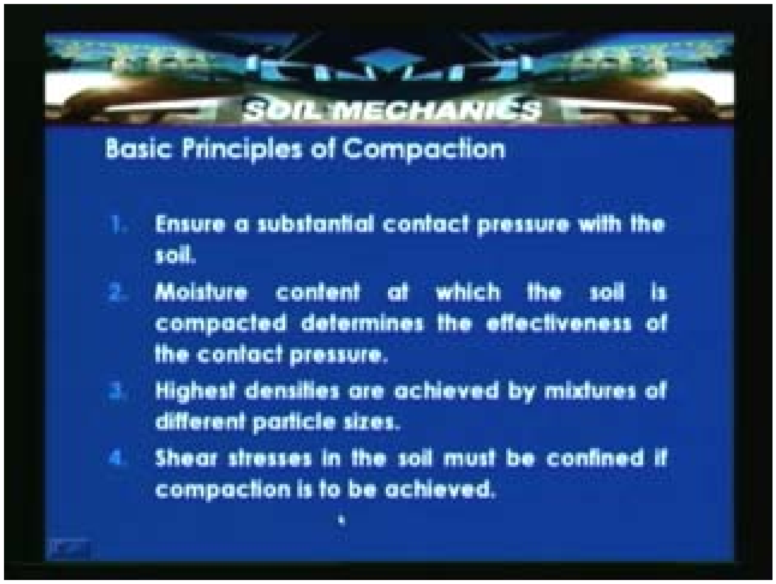

Let us look at the basic principles of compaction. Ensure a substantial contact pressure with the soil. Moisture content at which the soil is compacted determines the effectiveness of the contact pressure. Highest densities are achieved by mixtures of different particle sizes. That is what we have discussed that a well graded soil can have better density than the poorly graded soil. Shear stresses in the soil must be confined if compaction is to be achieved. So having seen these laboratory methods, now it is required for us to understand about the field compaction and field compaction methods, different types of compaction methods are available for cohesive soils as well as cohesion less soils and what is a compaction equipment or compaction plant which is there to compact the soils in the field? And also we should be aware of the ascertainment of the degree of compaction. We must also know how to check compaction when it is done in large areas so that the compaction ascertainment can be done in the field. If that is not done then it leads to a poor engineering and it affects the performance of the structure.

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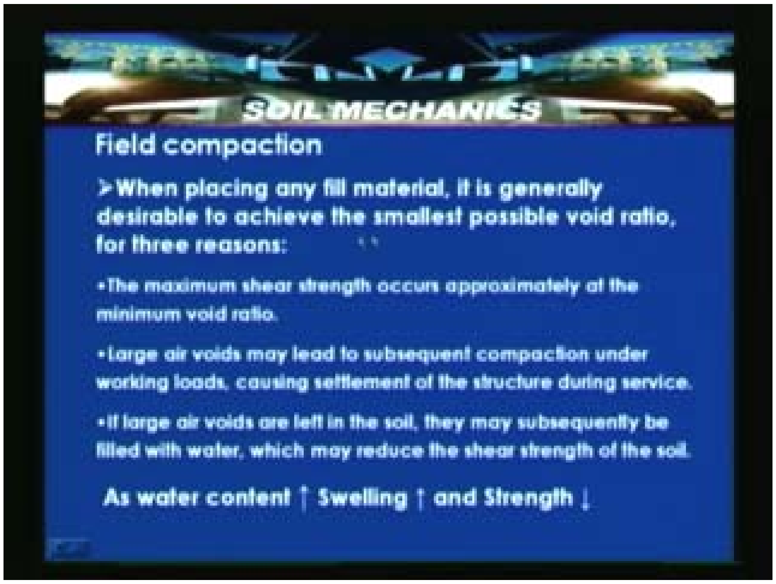

When placing any fill material, it is generally desirable to achieve the smallest possible void ratio for three reasons. In the field if you look into it, what are the prime criteria generally desirable to achieve the smallest possible void ratio? When placing any fill material it is generally desirable to achieve the smallest possible void ratio for three reasons. The reasons are; the maximum shear strength occurs approximately at the minimum void ratio. That means when the particles are compacted close it is possible that maximum shear strength occurs approximately at the minimum void ratio.

Large air voids may lead to subsequent compaction under working loads causing settlement of the structure during service. If large air voids are there, it may lead to subsequent compaction under working loads once it is released for traffic or so and causing settlement of the structure during the service that is actually under air void. Suppose if large air voids are left in the soil, they may subsequently be filled with water which may reduce the shear strength of the soil because the voids filled with water will be subjected to increase in pore water that leads to decrease in the shear strength of the soil. So there are three possible reasons for compacting the soil if you look into it, the maximum shear strength occurs approximately at the minimum void ratio.

Large air voids may lead to subsequent compaction under working loads causing the settlement of the structure during surface. During the service, if large air voids are left in the soil then they may be subsequently filled with water which may reduce the shear strength of soil. And with increasing water content, as the water content increases the swelling of a soil increases and strength of the soil decreases. So, with increase in the water content, the swelling of a soil increases. Of course this depends upon the type of the clay mineral for some of the soils which is negligible like compacted silts is negligible. Water content increases, swelling increases which actually decrease the strength of given soil mass.

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In natural location and condition soil provides the foundation support to many man made structures. In the natural location and condition, soil in its virgin condition provides foundation support for many man made structures. But soil is also extensively used as a basic material of construction earthen structures like dams, dikes, embankments for roads railways and airfields. Now we are slowly introducing ourselves to the concept of fill compaction. Before that we have to introduce the desirable properties of a fill material for their use either in dams or in the embankments or highways or railways or airfields. For situations where the natural topography needs to be changed to make the area more suitable soil is widely used as a building material we have also discussed this before, soil is a widely used construction material.

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Hence, that desirability of utilizing soil as a building material stems from its general availability, durability and it's comparatively low cost. So, the reasons for utilizing the soil as a building material or a construction material are its general availability, durability and it is comparatively low cost. This material is available abundantly, but now the current scenario is that scarcity of the earthen materials causes to look into the alternative materials like waste products like fly ash and other materials being used in the urban areas.

When soil is used for construction purposes it is typical for it to be placed in layers to develop a final elevation or a shape whatever we are looking into so each layer is compacted before being covered with a subsequent layer. So the soil is compacted in layers to bring it to a certain shape so that the structure can be formed. Properly placed and compacted soil possesses strength and support capabilities that are as good as or better than many natural formations.

Sometimes the properly placed and compacted soil possesses strength as well as supporting capabilities that are as good as natural soil or sometimes better than many natural soil formations. The desirability of utilizing soil as a building material stems from its general availability and its durability and comparatively low cost. With the scarcity of the materials one turns to look into the alternative materials in the urban areas. Now the current scenario is to use or materials which are available in the urban areas like fly ash and other materials and because of the scarcity of the natural earthen materials people are tending to use materials like fly ash.

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With earth fills, it is possible to support buildings, highways and the parking areas on the compacted soil mass; such soil is referred to as a COMPACTED EARTH FILL OR A STRUCTURAL FILL. What are the desirable properties of a fill material? If you look into it, soil should have adequate strength which is a prime requirement. Soil should be relatively incompressible so that the future settlement is not significant. Soil should be stable against volume change as the water content and other factors vary. Soil should be stable against volume change as a water contents or other factors vary and soil should be durable and safe against deterioration or ageing, so soil should not undergo any deterioration and soil should possess proper permeability depending upon the requirement for a given structure.

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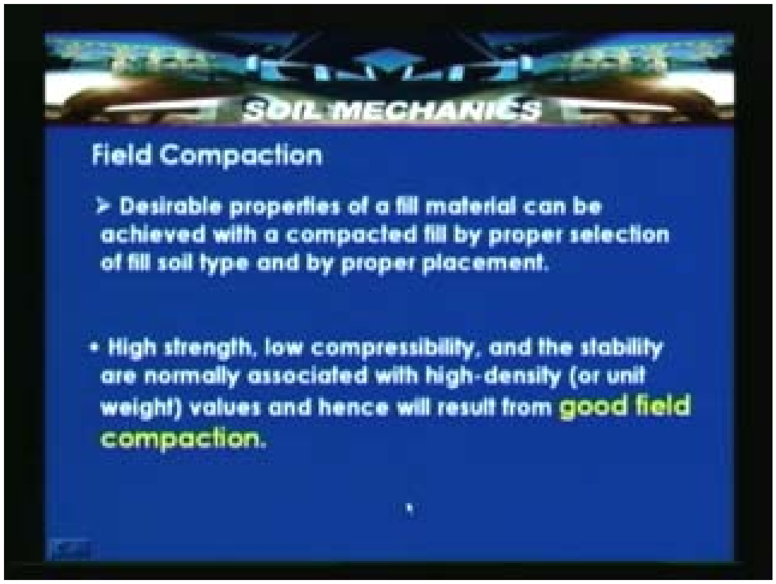

After having seen the desirable properties of fill material, the desirable properties of the fill material can be achieved with a compacted fill by proper selection of the soil type and proper placement, that is the proper placement methods and the method of the field compaction. High strength, low compressibility and the stability are normally associated with high-density or unit weight values, hence will result from the good field compaction. So, a good field compaction can lead to high strength, low compressibility and the stability is normally associated with the high density or high unit weight or low void ratio. These are all possible with good field compaction methods. Virtually any type of soil can be used for structural fill material that is what is being discussed, any type of soil can be used as a fill material provided it does not contain organic or foreign material that would decompose or undergo compression otherwise undergo change after it is in place.

Granular soils are generally considered to be easiest to work at sight due to the following reason: material is capable of developing high strength with little volume change. So by applying proper fill compaction energy these particles will tend to arrange into the dense pack positions and induces higher strengths. Permeabilities are very high, that is one disadvantage that the permeabilities of the granular soils are very high. So this type of granular soils can be used as fill materials behind retaining walls or retaining structures. When these granular materials are highly permeable the water pressures can be got rid off otherwise with poorly drained fills the water tries to get collected in the soil mass and induces pressure on the retaining structures. So, for example for retaining structures granular soils are preferred because of their excellent drainage conditions which can be advantageous or a disadvantage.

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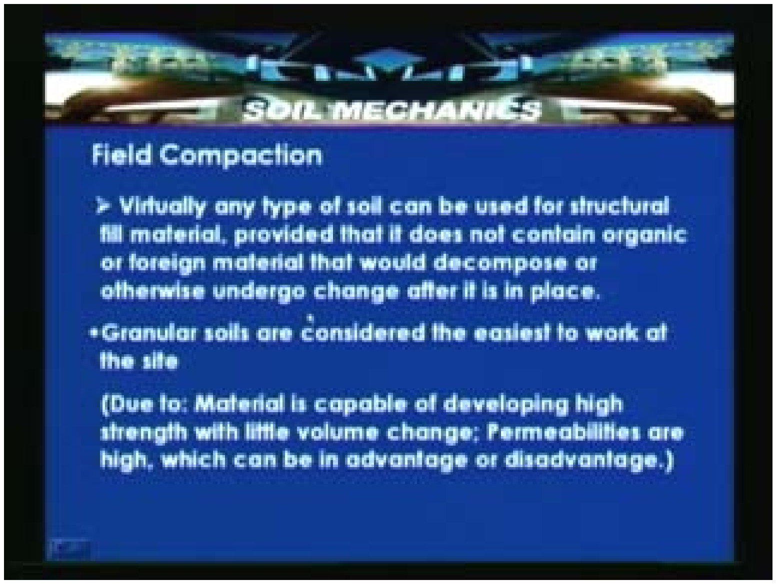

For such structures where the water movement is likely to be restricted then it is a disadvantage, for some water movement can be allowed like retaining structures just example we are considered. High permeabilities are of their advantage. Granular soils are considered to be easiest to work at the sight. Virtually any type of soil can be used for structural fill material provided it does not contain organic or foreign material that would decompose or otherwise undergo change after it is in place. That is the reason why while selecting a fill material for a particular construction project the care has to be taken to fulfill the desirable characteristics of a fill material.

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When it comes to fine-graded soils, compacted silts are stable and capable of developing fairly good strength and have limited tendency for volume change and to some extent also have low permeability. Compacted silts are stable and capable of developing fairly good strength and have limited tendency for volume change. Silty soils can be difficult to compact if wet or if the work is performed in wet periods. That is during the rainy season or post rainy season, it has been done. The silty soils can be difficult to compact if wet or if work is performed in wet periods. Properly compacted clay soils will develop relatively high strengths. Stability against shrinkage and expansion of a given soil is again the function of the type of the clay mineral.

For example, kaolinite is less susceptible for shrinkage and swell characteristics. Montmorillonite based soils can cause more susceptibility have got more susceptibility towards shrink and swell characteristics. So the stability against the shrinkage and expansion is a function of the type of the clay mineral that depends upon whether the soils are particularly koalinite based or Montmorillonite based.

Compacted clays have a very low permeability. The water movement has to be restricted because of this the materials like compacted clay liners were evolved. Lot of work has been done in this field by using the advantage of this particular impermeable property of naturally available clay soils. Compacted clay liners are used to encapsulate the municipal and hazardous soil waste. Clay soils cannot be compacted when wet. That is the reason is being told that clay soils cannot be compacted when they are in wet conditions. So compacted silts are basically stable and are capable of developing fairly good strength and have limited tendency for volume change.

Silty soils can be difficult to compact if wet or if work is performed in wet periods. Properly compacted clay soils will develop relatively high strengths. Stability against shrinkage and expansion is a function of the type of the clay mineral and because of this poor impermeable property for certain type of structures like compacted clay liners on covering the soil waste the water movement has to be districted. So this property can become an additional property for preventing the water movement.

Compaction is achieved in the field by traversing a fairly thin layer of soil with a type of compaction plant or compaction equipment by allowing a sufficient number of passes. So the layer thickness and number of passes must be chosen to ensure that the required density is produced throughout the layer with no undesirable density gradients. That means these density radians, the decrease in density in certain area and increase in density in other area should not occur. So the layer thickness and a number of passes must be chosen to ensure that the density is produced throughout the layer with no undesirable gradients.

Compaction plant or equipment of greater weight can transmit compaction energy to lower levels so layer thickness can be increased and number of passes can be reduced. But it is also undesirable to use heavy equipment in certain soils which can also cause erecting a certain type of failure along the surfaces of certain soils. So with an increase in the weight of the compaction equipment, it also possible that layer thickness can be increased and number of passes can be decreased. But it is also undesirable, to have heavier equipment running on the certain type of soils. It can actually cause the following failures as shown here.

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It causes rutting and degradation. So compaction plan which is too heavy can damage a compacted soil surface by applying too much pressure and causing a failure called rutting failure or degradation failure. Some plants might just be too light to remould stiff clay lumps or move the granular particles closer which means a balance has to be achieved. If the equipment is too light the frictional forces between the clay lumps will be very very high and it is very difficult to bring the clay lumps closer and therefore a sufficient amount of compaction cannot be achieved. If the soil is of a granular nature and if the energy is not sufficient because of the low capacity compaction plant or equipment then pure compaction cannot be achieved.

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So, compaction equipment or a compaction plant whatever we are using is achieved by specialist items of plant which are designed to apply energy to the soil by means of pressure and where suited, this is assisted by kneading or remoulding action or vibratory effect. We have discussed that in sandy soils and clay soils, clay soils can be compacted by applying a static pressure and sandy soil can only be compacted by applying a vibrating energy. So to suit all these requirements and different types of soils, different types of compaction equipments have been developed. They are basically divided into rollers. Different types of rollers are used depending upon the type of the soil.

Rammers are used for different types of sandy soils and other types of soils. The next type of equipment is called as vibrators. These vibrators are basically the vibration method used for compact the sandy soils. So in this lecture, we try to understand about the compactive effort and its influence on the degree of compaction.

We also tried to introduce a factor called soil structure. Then we discussed how the soil structure changes when we transform from dry side of optimum into wet side of optimum. And then we have also covered typical compaction characteristics of cohesiveness soils and cohesive soils. We tried to introduce and discussed about desirable properties of fill material and their characteristics. We defined the fill materials which are used for different man made structures called as compacted earth fill or a structural fill and then desirable properties were discussed. We also discussed about generally used materials like gravelly soils and compacted silty soils, their behavior and the possibilities of using the fill. Then we introduced a fill compaction with different compaction equipments like rollers, vibrators and rammers. This will be discussed in the next class along with different compaction equipments and the suitability for different type of soils.