Expansive Soil

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Lecture 13

Factors Controlling Swelling of Soil

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Hello everyone, welcome to the course expansive soil. To continue with the swelling behaviour of the expansive soil, today we will learn about the factors which controls the swelling behaviour of the soil. This will be the lecture number 12 in module 4.

Earlier, we have learned about what are the different factors by which the swelling gets affected. And also we learned about the diffuse double layer thickness, different type of clay minerals and how the diffuse double layer thickness are controlled by various factors.

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Today we will learn about what are the different factors which controls the swelling behaviour of the soil. The factors which controls the swelling behaviour can be divided into three groups. The first one is the soil characteristics, the stress condition and the environmental factors. Under the soil characteristics, the clay mineralogy, clay content, plasticity, soil water chemistry, soil suction, soil structure and fabrics and initial density comes.

Under the stress condition, the stress history, in-situ condition, loading, soil profiles comes; whereas, the environmental factors consisting of the initial moisture condition and the moisture variations. So, we will learn all these factors one by one and how they control the swelling behaviour of an expansive soil.

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The first one is the soil characteristics. In the soil characteristics, the first factor comes the clay mineralogy. The clay minerology one of the most important factor, which controls the swelling behaviour of expansive soil. We have already learned that, there are different types of clay minerals available. So, those minerals can be montmorillonite, kaolinite and illite and not all these minerals are having a swelling tendency.

Say for example, montmorillonite swells to a higher value, whereas, the kaolinite swells to a least value. So therefore, if a soil consisting of a minerals, which is very high expansive in nature, in that case, the soil will also expand to a very high extent.

Say for example, if a soil consisting of mineral montmorillonite, then it will have a very high swelling characteristics or swelling tendency. On the other hand, if the soil is consisting of the mineral, say for example kaolinite or illite, then the swelling will be bit different. In this diagram, we can see that two soils, one is montmorillonite and other is kaolinite are being kept inside the two tube and the water is placed over here and we can see the montmorillonite is swelling to a higher value in comparison to kaolinite.

So, if a soil is consisting of a mineral montmorillonite, then the swelling will be more and if it is consisting of a mineral, or least swelling mineral, say kaolinite or illite, or any other mineral in that case the swelling will be less. We can see montmorillonite will have a high swelling tendency and consequently, it will have high swelling pressure and high swelling potential.

Similarly, the kaolinite will have lowest swelling capacity and therefore, it will have low swelling pressure and low swelling potential. Not only the type of mineral, say for example what kind of exchangeable cations it has also controls the swelling behaviour.

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So, in this case say we will take montmorillonite as a mineral and we know montmorillonite has different type of exchangeable cation in it. And all these exchangeable cations are not equally swelling type. Say for example, if montmorillonite consisting of exchangeable cation, say sodium, or if the montmorillonite having a large amount of sodium as an exchangeable cation, then the swelling will be more.

At the same time, if montmorillonite will have more amount of calcium as an exchangeable cation, the swelling will be least. And we have already learned that, the amount of sodium present in a mineral can be expressed in terms of exchangeable sodium percentage. So, that is the value of amount of sodium present in terms of the total amount of exchangeable cations.

In this diagram we can see, the higher is the exchangeable sodium percentage, higher will be the swelling. Similarly, if the mineral has higher amount of calcium or potassium or magnesium as an exchangeable cation, in that case the swelling will be less. Therefore, the swelling is not only controlled by what kind of mineral it has, it also controlled by what kind of exchangeable cation present inside the mineral.

So, therefore the exchangeable sodium percentage can control the swelling behaviour in a direct manner, that means higher is the exchangeable sodium percentage higher will be the swelling of the soil.

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The next factor comes the clay content. Here the clay content means the amount of expansive clay present in a soil. Say for example, if two soils, soil A and soil B are having the montmorillonite mineral say in one case it is having 30 % of montmorillonite mineral and in the other case it is 50 % montmorillonite mineral of same exchangeable sodium percentage, then in that case, higher is the clay content higher will be the swelling of the soil. Remember in this case, when we compare, we need to compare this for the same type of soil.

Say another example, soil A is having 30 % of say montmorillonite mineral and soil B is having say 70 % of kaolinite mineral. So, here if we can compare, then we cannot compare these two things, because the soil A will swell more, although it is having less amount of clay content, because the clay 30 % montmorillonite is more swelling in comparison to yours 70 % of kaolinite.

Therefore, when we compare the clay content, it has to be the same type of mineral and same type of exchangeable sodium percentage. So broadly, when the clay content is more, the swelling of the soil will be more. In this figure, we can see when clay content is more than 30 %, the soil can be classified as a very high swelling soil and so on. So, therefore, higher is the clay content, higher will be the swelling of the soil.

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Next comes the plasticity of the soil. As we already know that, plasticity means the range of water content within which the soil can be molded into various shapes, or the soil exhibit the plastic behaviour. Plasticity of the soil can be defined by the term plasticity index, which is nothing but the difference between the liquid limit and the plastic limit. So, therefore plasticity index is mostly controlled by the liquid limit.

In this diagram, we can see higher is the plasticity index, higher will be the volume change of the soil. Since the plasticity index also depends on the liquid limit, higher is the liquid limit, higher will be the volume change of the soil. Say, for example, montmorillonite mineral which has a liquid limit of say 550, this is an example, and another mineral say kaolinite with a liquid limit of say 50, in this case, this soil will swell more and it will swell less.

Similarly, if we take montmorillonite, then another montmorillonite soil with the liquid limit say, around 300 %, in this case, it will also swell less in comparison to this one. Therefore, higher is the liquid limit of the soil, higher will be the swelling and vice versa.

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Next comes the shrinkage limit of the soil. In this case, the shrinkage limit is inversely proportional to the volume change. That means, lower will be the shrinkage limit, higher will be the volume change behaviour of the soil, or lower is the volume change, that means the shrinkage limits should be high.

When the soil is having a very low shrinkage limit, then the soil will have a tendency to absorb more moisture. Absorbing more moisture means the swelling will be high. Therefore, less is the shrinkage limit, higher will be the swelling of the soil and higher will be the shrinkage limit, lower will be the swelling of the soil.

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Another factors which controls the swelling of a soil is in the soil water chemistry, or the type of water present inside the pore or the void space of a soil. We have already learned that, the diffuse double layer thickness controls the swelling characteristics of a soil. And the soil water chemistry controls the diffuse double layer thickness and in consequently it also controls the swelling behaviour of the soil.

The soil water chemistry means, we can divide into many way, that salt concentration, these are the different factors in soil water chemistry, then cation type, dielectric constant, the temperature, then salt pH. These are the different factors, which can controls the diffuse double layer thickness and consequently the swelling behaviour of the soil.

First if you go to a salt concentration, higher is the salt concentration lower will be the swelling. So, high salt concentration lower will be the swelling, cation type means higher is the valency, lower will be the swelling or vice versa. Lower is the valency, higher will be the swelling. Dielectric constant higher is the dielectric constant, higher will be the swelling. Temperature, higher is the temperature, higher will be the swelling. Similarly, pH also controls the swelling behaviour.

In this diagram we can see that as we increase the salt concentration, we can see the swelling potential free swelling and the swelling pressure keeps on decreasing. Here we can see and also if we compare for two different types of salt, sodium has a higher value of swelling pressure, swelling potential and swelling volume in comparison to calcium for the same concentration. So, therefore, the soil water chemistry controls the diffuse double layer thickness and in turn, it also controls the swelling behaviour of the soil. So, this is one of the most significant factor, which controls the swelling behaviour of the soil.

So, in this diagram, two different bentonites has been taken and the swelling potential and swelling pressure has been compared with the different salt concentration and also for two different types of salts, like sodium and calcium. We could see here, as we increase the salt concentration, the swelling potential keeps on decreasing, swelling volume keeps on decreasing, swelling pressure keeps on decreasing. And also, when we compare with two different types of salt, the sodium will have higher value of swelling potential, swelling volume and swelling pressure in comparison to the calcium ion.

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The next factor is the soil suction. The soil suction also controls the volume change in a quite large extent, higher is the suction value higher will be the swelling of the soil. When the suction value is more, the soil have a tendency to absorb more moisture. Therefore, the volume change will be more. We can see here in this diagram as the suction value is increasing, the volume change characteristics of the soil is also increasing.

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Another factors which controls the swelling of an expansive soil is the soil structure and the fabrics. We know that there are two kinds of structures exist, one is a flocculated structure and another one is a dispersed structure. A flocculated structures swell to a higher value in comparison to a dispersed structure. So, by any chance if we can get a flocculated structure, then that soil will have a more tendency to swell to a higher value in comparison to a dispersed structure under the same condition.

Since the method of compaction also changes the soil structure, therefore, the compaction also controls the swelling behaviour of the soil. We know there are three kinds of compaction, which you can do in the field, one is a dynamic, one is static and the kneading compaction. Under the kneading compaction, the soil will have a disperse structure, whereas, under the dynamic compaction, the soil will have a flocculated structure. Therefore, the swelling of the soil will be quite less, when the soil is compacted by kneading compaction in comparison to the static compaction or the dynamic compaction.

In these three diagrams, we can see at the same density or same initial water content, if the soil is compacted into three different compaction procedure, the swelling of the soil will be different. Similarly, the cementation of the particles also reduce the swelling.

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Another factors which controls the swelling is the dry density. With increase in the dry density, the spacing between the particles will also decreases. As the density is increasing, what happens, particles will come to a closer space. As the particles moves to the closer space, the repulsive forces between them will increase and therefore, the swelling of this soil will be more. Here we can see the variation of the swelling pressure with the dry density has been plotted at different water content.

If we compare, here, this is the soil compacted at 0 % water content, then although the water content is same, since the dry density is different, the swelling pressure or swelling volume will also be different and we could see here, with the increase in the dry density, the swelling of the soil is increasing. Similarly, if we can take at different water content, say for example 8.2 and if we find out the values here, we could see the swelling is keep on increasing with increase in the dry density.

As the dry density increases, the spacing between the particles decreases, as a result of which the repulsion between the particles increases and the soil swells to a higher value.

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The next comes the environmental factors or environmental conditions. Under the environmental conditions, initial moisture condition controls those swelling behaviour. A dry soil sample will have a higher affinity for the water due to higher suction value. Therefore, it will absorb more water and it will swell more. Previously also, we have learned that higher is the suction value higher will be the swelling and we know that a dry soil will exhibit a higher affinity for the water, it will have a higher suction value. Therefore, the swelling of the soil will be more.

On the other hand, if a soil is in wet condition, then the swelling of that soil will be less, but the shrinkage on drying will be more. Say for example, if we take two soil, A and B say with the initial water content of 25 % and say 5 %. Then the soil A will swell to a lower value and the soil B will swell to a higher value. Now, if we dry these two soil from the same water content that is 25 % and 5 %, then soil A will shrink more, because it has more water and soil B will shrink less, because it has less initial water.

Here in this plot, we can see the variation of the swelling pressure with water content. With increase in the water content, the swelling pressure of the soil decreases. Initially, we can see there is a large variation of the swelling pressure with the water content takes place. But after reaching a certain value, the swelling pressure almost becomes constant. And also, if you compare a soil, say this is the γ_d and OMC value water content. If we compare the compacted condition, if we compact a soil on the dry side of the OMC, this is dry of OMC, this is the OMC water content and this is the wet of OMC.

If we compact a soil at dry off OMC and other soil on wet of OMC, keeping the dry density constant. In that case, the soil compacted on the dry of OMC will swell to a higher value in comparison to the wet of OMC. This is because a dry of OMC the soil will have a flocculated structure, whereas, the wet of OMC it will have a dispersed structure. Therefore, the swelling on the dry of OMC will be more in comparison to the wet of OMC.

Here we can see as the initial water content decreases, the swelling of the soil increases or as the initial water content increases, the swelling of the soil decreases.

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Next comes the moisture variation. A change in the moisture content of the active zone is responsible for the swelling and shrinkage behaviour of the soil. This we have already learned from our previous classes. So, any change in the moisture content in the active zone also changes the swelling and shrinkage behaviour of the soil.

So, the various factors, which are responsible for change in the water content in this active zones are, we will go one by one, the first one is a climate. Climate means how much precipitation and how much evapotranspiration is occurring in that area. If a large amount of precipitation and large amount of evapotranspiration, that means the soil will have a different swelling tendency.

Say for example, the precipitation and evapotranspiration mostly controls the seasonal fluctuation in the moisture content in the active zone. A large heave occurs in a semi-arid region, which undergoes seasonal long dry spell followed by the short periods. So, in climatic condition like India, which is a semi-arid region, we have large spell of dry season followed by the short wet periods. So, during the dry season, the soil in the active zone will lose water and during the short wet periods, the water content of the soil will increase. So, this fluctuation in the water content can bring a higher swelling tendency of the soil.

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Next is a ground water table. The water table if its present at a shallow depth provides a major source in the change in the moisture content of the soil due to their fluctuating water table. With a rise in the water table the soil will swell more. Say, for example, if this is a soil and water table is acting or located at a shallow depth, then due to rainfall and evapotranspiration, the water table will fluctuates as a result of which the soil in this zone will also fluctuate quite frequently and rise in the water content, the soil will undergo an expansive behaviour and the swelling will be more.

So, if the water table is present at a shallow depth provides a major source in the change in the moisture content of the soil due to their fluctuating water table. If the water table is located at very large depth like this one in this case, any change in the water content or water table depth will not bring a change in the water content of the active zone. Therefore, the swelling of this portion of the soil will not be that affected. But if the water table is located in the shallow depth, then any small change in the water table depth, the soil in the active zone will also undergo a moisture change and the swelling will be more.

The third is the drainage and man-made water sources. A poorly drained soil will result in the ponding of water and it can act as a source of water for the soil. Now, if we take a soil and if the drainage is not good inside in this soil, any rainfall or any if any source of water it comes over here, then the water will be stored or it will be ponded over here. And this water will act as a source of water for the soil below it.

And if there is a fissure or crack exist, then this water can migrate and that will change the water content of the soil. As a result of which change in the water content, the soil will swell. So, therefore if the drainage condition is not good, then in that case, the swelling of the soil will also be more.

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Next is the vegetation. Soil loses moisture due to the process of evapotranspiration and in the presence of plant and shrub, or trees, this evapotranspiration takes place. Therefore, if a large amount of vegetation is there, then the soil will lose a large amount of moisture due to the process of evapotranspiration and therefore it will undergo the shrinkage process.

Next is soil permeability, soil with higher permeability, particularly due to the fissures and cracks in the field soil mass, allow those faster migration of the water and promote a faster rate of swelling.

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Temperature, the increase in the temperature causes the moisture to diffuse to a cooler area in the pavement and the buildings as a result of which the swelling will take place.

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Now, comes the next comes the third condition that is a stress condition. In the stress condition the first one is a stress history. An over consolidated soil swells to a higher value in comparison to a normally consolidated soil at the same void ratio. The swell pressure can increase on aging on compacted place, but amount of swell under light loading has been shown to be unaffected by aging. And repeated wetting and drying tends to reduce the swell in the laboratory samples, but after a certain number of wetting and drying cycles, the swell is unaffected.

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The other factors under load stress condition is the loading. The magnitude of the surcharge load over a soil can control the swelling behaviour. If a soil is, if this is a soil profile and if a large amount of load is acting on this soil, then the soil swelling will be very less, because this the soil will exert a pressure which will be counter-balanced by the surcharge load comes from the this overburden load of this building. If there is no load or a light amount of load is present in that case, a higher amount of swelling will take place.

So, the last one comes from the soil profile. The thickness and location of potential expansive soil also plays an important role in defining the swelling behaviour of the soil. For example, if a soil have a very high expansive clay extending from the surface to depth below the active zone, then the swelling will be more. Say for example, this is an active zone. If the soil is having an expansive soil below the active zone in that case, the swelling will be quite high.

At the same time, if a soil, this is an expansive soil and if a non-expansive soil is present over this soil, this is a non-expansive soil, which is present over the expansive soil. So, in this case, the swelling of this expansive soil will be less, since the weight of this non-expansive soil can counterbalance some of the swelling pressure and therefore the swelling of the soil will decrease.

Similarly, if there is a bedrock present below this expansive soil, then also the swelling will be less. So, therefore the soil profile also controls the swelling behaviour of the soil.

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These are the few points which I discussed in today's class.

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So, these are the few references which are used for this preparing this lecture. And thank you very much for your attention.