Environmental Geotechnics
Prof. D. N. Singh
Department of Civil Engineering
Indian Institute of Technology, Bombay

Lecture - 48
Swelling, shrinkage and cracking characteristics of soil- 1

(Refer Slide Time: 00:15)

Swelling shrinkage and cracking characteristics of soils. In your opinion, what should have been the sub topics for this subject, swelling shrinkage and cracking characteristics of soils mechanism of; do you find any sequential effect or correlation between swelling, shrinkage and cracking? You must have heard about swelling.

Student: (Refer Time: 00:51). Swelling, shrinkage, cracking (Refer Time: 00:54).

Good, that is right. So, which one is more important out of the three, if I ask you a question or how would you grade them let say swelling, shrinkage and cracking?

Student: (Refer Time: 01:23).

They are not independent ok. So, there should be something with links these three things together.

Student: (Refer Time: 01:38).

Well, this is a parameter, now if I ask you question the mechanism.

Student: (Refer Time: 01:46).

Sorry, mechanism.

Student: (Refer Time: 01:50).

Cracking is due to.

Student: (Refer Time: 01:54).

Very good, excellent and cracking could be because of swelling also. So, if you put it like this that swelling, shrinkage and cracking they are interlinked. And what is the most important parameter which would govern these three phenomena, truly speaking not the moisture content, moisture content itself will depend upon other parameters, but the most prominent parameter would be.

Student: (Refer Time: 02:29).

Sorry.

Student: (Refer Time: 02:31).

Well, not so prominent.

Student: (Refer Time: 02:35).

Mineralogy, temperature. If I ask you question that correlate these three mechanisms with some strength parameter, so what would be your answer? What type of strength is going to control swelling, shrinking and cracking characteristics of soils, compressive strength or tensile strength?

Student: Compressive strength.

Compressive strength? Tensile strength? Well, the correct answer is tensile strength governs most of the properties of geomaterials, but very unfortunate we do not talk about tensile strength of geomaterials at all, and that is the limitation of classical geomechanics that most of the theories are dealing with compressive strength of the material, we never

talk about tensile strength of the material. So, before we graduate to understand the tensile strength properties of geomaterials or soils, you have to understand what are the components of tensile strength or in other words how tensile strength gets mobilized, what are the parameters which influence tensile strength and what are the mechanisms which are responsible for generation or mobilization of tensile strength.

So, coming back to the issue, when we talk about swelling shrinking and cracking characteristics as you most of you are right and you said that all interlinked and ultimately, they control that tensile strength properties of the soil mass. So, in today's lecture and tomorrow lectures, I would like to give you the fundamentals of these three mechanisms and ultimately this discussion will lead to a very elaborate discussion on tensile strength properties of soils, clear. Determination of tensile strength is not a easy task, most of the time you do triaxial test from there you will get tensile strength and so on.

So, with this in view what I am trying to do is, I am trying to give you a good idea about these three mechanisms. First is swelling characteristics, here we will be talking about intrinsic expansive behaviour of soils, followed by potential expansive behaviour of soils. What is the difference between intrinsic and potential expansive behaviour of soils, any idea?

Student: (Refer Time: 05:35).

Ok, then you have to wait for some time and you will have to wait till I discuss these things in details. Another sub-topic is swelling a concern what is the meaning of a word concern here, problem, problematic. So, there are two sides for any coin all right. And then let us see swelling is a problem, but swelling could be a boon also. Any guess, how it could be? We mostly talked about swelling has a problem, problematic soils, we never give importance to swelling properties of soil in a positive way, can it happen? Do you think that this characteristic of a material is a boon for civil engineers?

Student: (Refer Time: 06:43).

Can be, it is a good realization that is right.

Student: (Refer Time: 06:48) while for any grout materials in suppose, you are injecting something and you allow the soils that it fills in the cracks or something like that.

Good, let us see; so, I will be discussing in details both pros and cons of swelling that is swelling a concern or a problem to our profession and I will try to highlight that problems are less and benefits are much more. So, you should have more respect towards the soils which are swelling type of soils; I will try to do this. Swelling and suction what is the correlation between these two mechanisms. And I think they should give an idea that why everybody has been talking about swelling has a problem, because we have not done in depth of this mechanisms, but the moment you correlate the fundamental behavior of the soil as swelling to its suction, you will realize that lot of things can be you know brought to a level where you can utilize them in day-to-day life very easily. So, this is where we discuss mechanism of swelling.

Then the question is what are methodology for identification of materials or they determination of swelling soils, I am sorry this should be methodologies for identification or determination of swelling soils, it should not be off. So, this is where most of the time we use classical concepts, classical methodologies are it not. Anything can exist beyond this that is what we will be talking in new methodologies. New methodologies are the methodology which have coming up new methodologies, followed by determination of swelling potential of soils and in whole technique to determine swelling characteristics of soils.

So, I am sure that this will give a very new perspective as far as swelling properties of soils are concerned. And of course, having completed this I will discuss shrinkage characteristics of soils and then once these two properties are done, we will be talking about cracking characteristics. And then ultimately, I intend to correlate all these three to understand how would you determine the tensile strength of geomaterials. I hope you will appreciate this in more of a philosophy; we are, people are trying to work on the models to interlink you know sub modules in such a way, so that you can get in an answer to a question.

What else you find in this subject more let say provoking; thought provoking, when we talk about swelling, what is the phenomena, how would you define this phenomenon?

Student: It is a increasing volume due to changes in moisture content going to.

Correct. In the context of what we have been discussing in the entire course can you use few keywords to say that yes whatever we have been discussing these three sub-topics happened to be a good example of our perennial discussion. Can you use few keywords, basically these three topics are nothing but interaction problems? What would have interaction?

Student: Soil, water.

Soil, water.

Student: Interaction.

Interaction could be contaminated, could not be contaminated, soils of what type where the minerals are hyperactive clear. So, truly speaking these three mechanisms talk about the best possible interaction which a soil can have with nature or environment which could be either man made, which could be even natural all right. So, with this intension I thought of including this discussion in this course.

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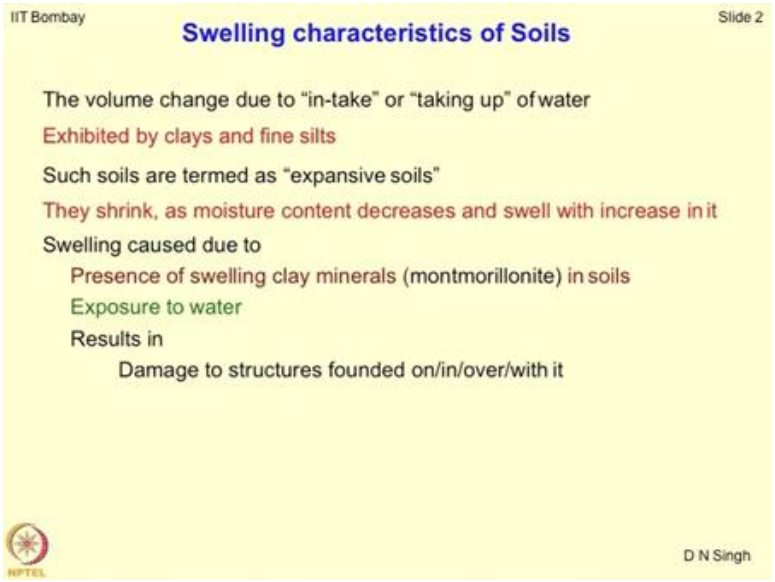

So, let us talk about swelling characteristics of soils, basically whenever volume changes either because of intake or taking up of water by the soil, we call it as a swelling characteristic. This is mostly exhibited by clays and fine silts and such soils are termed as expansive soils not expensive soils, only few change the word letter a to e, it becomes

a different term altogether. So, what happens here, they shrink has moisture content decreases and they will swell as moisture content increases.

So, what is the meaning of this type of mechanism that this system is very live, it understands how it has to behave, and this is are although you know keywords like sentiments, emotions, memory of the material comes into the picture, you agree under a given circumstances. So, you put a certain load on the soil mass, it knows how much it has to exhibit; you release the load, it knows how it has to exhibit its response and so on. So, swelling is caused due to presence of swelling clay minerals. Most of the minerals present in the clay mass will not swell except for if you have montmorillonite in soils and the circumstances would be exposure to water.

So, these minerals will become very active because of their exposure to water. So, this exposure is nothing but the interaction and this will result in damage to structures which are founded on it, over it, in it, with it and so on. So, keep on changing these words and you have a different type of problem which come across you know in your profession. So, these are the basic swelling characteristics most of you correct when you are defining the swelling properties of soil. I was asking you what is meant by intrinsic expansive behaviour, any guess, what it would be? What is meant by intrinsic response? When use the word hydraulic conductivity, do you find this term coming over somewhere, what is this term?

Student: (Refer Time: 14:03).

What is meant by, what is the difference between hydraulic conductivity and intrinsic permeability of the soil mass?

Student: Intrinsic and permeability, it has it depend only on the soil properties.

Correct, very good.

Student: Which one it has got fluid properties also.

That is right. So, when you define hydraulic conductivity it is a mapping of two things, one is fundamental property of the porous media which is capital K, if I define small k as hydraulic conductivity multiplied by pore solution parameters like viscosity, intensity.

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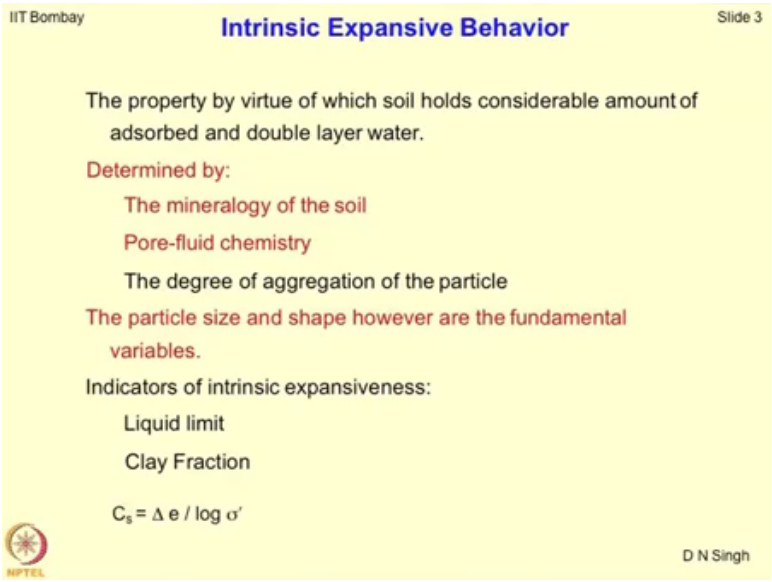

Yeah, you are quite close to answer this question that intrinsic expansive behaviour is the property by virtue of which soil holds considerable amount of adsorbed and double layer water, the fundamental behaviour of the clay minerals all right. Now, what are the parameters which are going to govern this type of behaviour, you are talking about surface area, cation exchange capacity and so on, and specific gravity, structure of the grain and so on. And this can be determined by the mineralogy of the soil, each mineral will have its fundamental response or behaviour. So, this is how it becomes intrinsic response of the material.

Of course, when you change the pore fluid, chemistry, this response may change. So, this is basically determined by the mineralogy of the soil and pore fluid chemistry. Now, this is are important the degree of aggregation of the particles; what is meant by degree of aggregation, clod formation. So, you add a little bit of water because of the charges which are present in the fine grain material, the tendency of this particle is to form a sort of a agglomeration or aggregation or the clod all right.

So, more the clod formation it shows that the system is hyperactive. More trivial the pore-fluid chemistry the system is hyperactive; the more trivial the mineralogy is the system is hyperactive. And of course, the particle size and shape are the fundamental variables for the materials, why it is so because both on the shape and the particle size the surface area will depend strongly. So, find out the particle size more the surface area;

more the surface area, more the degree of aggregation; more the surface area is a fundamental property of a particular mineral of the soil. More surface area the interaction is going to be much more with the pore-fluid and so on, this part ok.

What are the indicators of intrinsic expansiveness; any guess, what are the indicators of this mechanism?

Student: (Refer Time: 17:13).

Sorry.

Student: (Refer Time: 17:15).

First is liquid limit. See, indicators are nothing but the traits; so, high liquid limit.

Student: High plastic limit.

High plastic limit, high indices and the indication is that the soil is going to be showing more intrinsic expansive behaviour and clay fraction all right. So, more clay fraction, more liquid limit; more liquid limit, more clay fraction, more swelling properties, more intrinsic properties of the material and so on. And of course, you must be knowing this relationship where C_s is your swelling index = change in the void ratio/log(σ') starting from a known σ' value.

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What about the potential expansive behaviour? Now, let me ask your question why should be bisect or dissect in for that matter the expansive behaviour of the soil, why should we study intrinsic behaviour separately and potential expensive behaviour separately, is the question clear?

Student: (Refer Time: 18:42).

Very honest response ok all right, I have trying to make you think that why do you require this type of you know philosophy to be generated. Yes please.

Student: (Refer Time: 18:57) because of some external intensity how much it can (Refer Time: 19:04).

Student: To differentiate the pressure exerted by the potential means potentially and internally.

What is this potential?

Student: As the whole.

Ok, we think it like this. Individually, we have a separate response and a behaviour ok, but when we come in contact with someone else, what happens our response, what happens our behaviour, how do we react, how do we interact. So, something which is intrinsic is your behaviour of nature, clear. So, let us now see with this background what is meant by potential expansive behaviour of the material. So, can you refine it further now?

Student: (Refer Time: 20:02) irrespective of its properties like when it reacts with an external agent like water.

Student: But the soil itself is changing because of some external (Refer Time: 20:16). So, how can you classify to do (Refer Time: 20:17).

Ok, Sumith.

Student: Sir basically about the response of the soil when external load is coming on the soil and intrinsic means the internal behaviour of the soil particles on the swelling.

Student: But that is changing because of an external.

See, think of a situation that you have soil grains which are separated and which are placed quite at a distance, are you going exhibit any swelling or shrinkage?

Student: Sir, potential expansive means these swelling under a given circumstances that this contaminant is going to react.

Ok that means, soil must be intelligent enough to understand that with what type of contaminates going to interact, you are right. That means, the first thing is the material should identify the circumstances and it should be much more intelligent to understand how it is to react, is this part ok. Suchit, what is your guess about this?

Student: Sir as a discuss means individually each and every particle, how it will means take up the water and it will flow and in the group the soil particles, how they will interact and they will swell, so that could be the difference.

Ok.

Student: When you know overall case there are (Refer Time: 21:50) balancing each other and intrinsic case you get see the both will (Refer Time: 21:54).

Ok, let us go ahead with this what comes to my mind I have to right to put it here. This is basically what you are saying is correct defined as the Neeraj, defined as the pressure exerted against an unyielding support due to swelling; that means, the system is understanding how it has to behave. So, potential expansive behaviour is defined as the pressure exerted against and unyielding support due to swelling. Material wants to react, clear, it has a tendency, but there is a fixed support fixed, it is a constant volume. So, this is where intrinsic responses not very important, this is where the potential behaviour is coming to picture, what is the potential of the material, so that is how you are always talk about swelling potential of the soil.

Given situation, given in a circumstance, given a chance how system is going to exhibit and what amount of pressure on a system which is rigid fixed - retaining wall. So, you use the backfill material as this type of soils what type of pressure is going to get exerted on the retaining walls in the long run, which is much more higher than the active or passive or pressures which may get mobilize subsequently all right. So, this happens to be the potential response of the material that means, the material is capable of or it has

that potential inside. So, that is what I said to grain silting quite at a distance are never going to show anything, but when they come close in contact with each other, this is where the mechanisms develop and this is other response can be observed.

Now, potential expansive behaviour can be determined by both intrinsic expansiveness and the void ratio, because this is nothing but the matrix response of the system. So, for a soil of low void ratio if external agent is removed, soil asserts, potential expansiveness is this part clear now. Now, if you use sodium montmorillonite which exhibits high intrinsic expensiveness and very high potential expansiveness. Now, this is where we are talking about the matrix and even the osmotic type of a thing, the type of pressure which may develop because of the double layer or the osmotic behaviour between the two grains which are saturated with water. So, kaolinite exhibits low intrinsic expansiveness and potential expansiveness. So, these are two extremes, is this part clear now.

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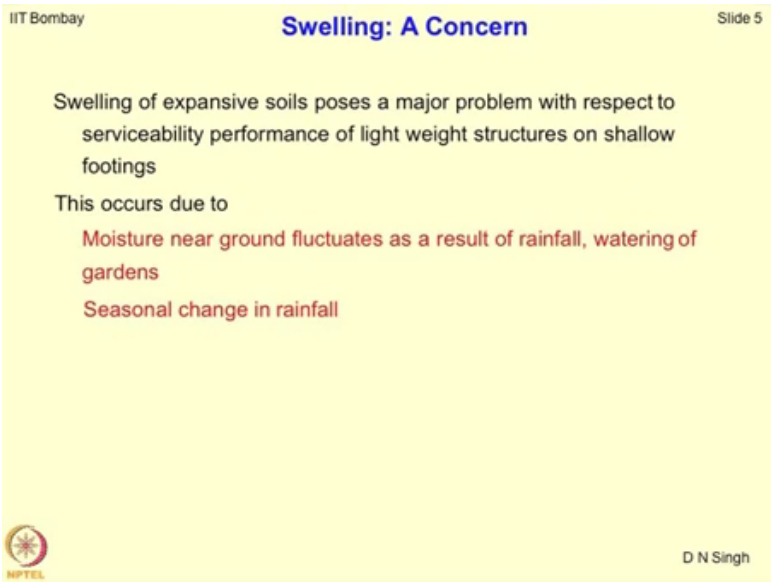

Now, let me talk about why swelling is a concern of course, all of you are aware of that the swelling of a expansive soil poses a major problem with respect to serviceability performance of lightweight structures on shallow footings. It is very well known to everybody. What are the reasons for this, this occurs due to moisture near ground fluctuates as a result of rainfall, watering of gardens, water logging and so on, even fluctuation of water table, seasonal change in the rainfall, which may cause swelling of

the material? And because of these type of mechanisms, this structures which are founded maybe under stresses or distress.

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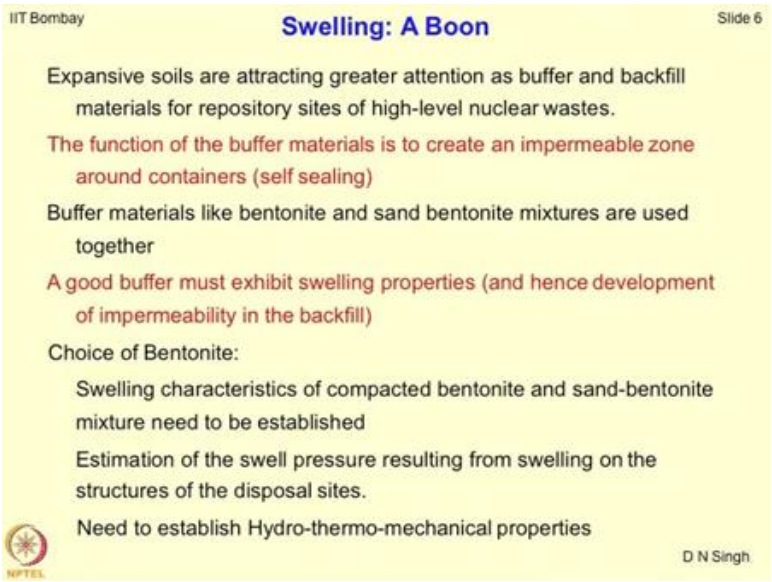

Swelling as a boon, are you find this ok or no? Expansive soils are attracting greater attention as a buffer and backfill materials and that is why this property is a boon for repository sites of high-level nuclear waste. If you do not have any clay mineral, where swelling is extraordinarily high, you cannot design buffers for the disposal sites for the repositories. So, if you remember in my first or second or third lecture, I was talking about selection of the ideal buffer material. You compact the clay and as long as its intrinsic response it is not suitable for preservation of dispose waste or isolating the dispose waste.

But the moment potential behaviour comes in the picture, even after compaction what is happening the system is active and then what happens it for the choke supports which are present in it because of swelling. So, this is we have swelling is a required definitely, so that all the pores which are present in the matrix of the soil they get clogged because of the material itself. And based on the concept most of the time GCLs or buffer materials are selected for designing the backfill material.

The function of the buffer material is to create an impermeable zone around containers or canisters and this is where the concept of self sealing, self healing minerals comes into picture. So, if nature was not you know so helpful, you would have always synthesize

materials which have been good, self sealing, self healing minerals. But we are thankful to nature that we get some soils, where the swelling potential itself is very high. And these type of minerals are very useful for all sorts of you know waste handling and disposal and their isolation from the environment. So, a good example of this is a vermiculite type of a clay where the swelling is too high. So, buffer materials like bentonite and sand-bentonite mixtures are used together; why they should be used together why do use bentonite and sand bentonite mixtures? You require access swelling by the way.

You think of a situation where all the pores gets filled up for clogged because of the swelling of the soil. So, this is what actually you require, because by simple compaction you cannot create a structure which is totally impervious. Now, sand is always mixed with bentonite because it is very difficult to compact clays all right. So, you cannot compact clays alone unless you mix a bit of sand into it. So, we will find in 21st century everybody is trying to characterize sand-bentonite mixes. Most of the studies which are being taken up in the present scenario, everybody is trying to understand the behaviour of sand-bentonite mixtures. And these are all they following in the category of repository characterization schemes.

A good buffer material must exhibit swelling properties and hence development of impermeability in the backfill. So, I am sure with these concepts you will be now respecting swelling properties or soil much more, is it not rather than being so much bothered about that is swelling is too much what is to be done. Because since 42 years back we have adopted different technique swelling the foundations in expansive soil is it not, but the present day requirements are required materials which are going to cater to the needs of the environmental protection, you are agree or no?

So, Choice of bentonite, swelling characteristics of compacted bentonite and sand-bentonite mixtures need to be established. Estimation of the swell pressure resulting from swelling on the structures of the disposal sites has to be studied and you have to establish hydro-thermo-mechanical properties. I have coined a new term today and discourse hydro-thermo-mechanical properties, what is your understanding about this term? Yes, Neeraj.

Student: (Refer Time: 31:32).

Very good, excellent, that is true. So, hydrothermal mechanical properties indicate to the fact that how mechanical properties of the soils are going to change when they come in contact with elevated temperatures. What about hydro?

Student: Water interaction

Water interaction that is true particularly water retention; so, if you read this term hydro thermo mechanical response, if you heat up a soil mass particularly in case of your waste repositories where the temperatures are very high. How mechanical properties are going to change at elevated temperatures; and at those temperatures what is the amount of moisture with still is retained in the soil mass. If this moisture goes out what is going to happen, the soil mass is going to crack; that means, you will see later on tensile strength is very much susceptible to drop in moisture content. So, the moment moisture content goes beyond a certain limit, the tensile strength of the soil will be less and it cannot stop formation of cracks. And once the cracks start in the system, the whole engineering work gets defeated, is this part clear.

So, whether you are constructing a basement, whether you are constructing a backfill, whether you are constructing a repository, if after placement of the backfill, if it cracks because of any reason the whole engineering has gone in waste. So, this term is become very important in the present scenario people are trying to study hydro-thermo-mechanical response of sand-bentonite mixtures at elevated temperatures. And later on I will tell you that the characterizations schemes for this type of phenomena would be heavily dependent upon suction properties of the soil mass.

Student: (Refer Time: 33:54).

Problem is that bentonite itself is a thixotropic material, it has any strength or not?

Student: Sir, if it is disturbed, it is not (Refer Time: 34:19).

So, at the time of drilling a whole itself you are disturbing a soil; how would you stop this disturbance, the vibrations will be good enough to create thixotropic effect in bentonite, your point is valid.

Student: (Refer Time: 34:39) to need make the slurry to it, to achieve it fully expansion it needs a penetration. So, that it is an stimulate the whole (Refer Time: 34:49).

Slurries will never expand first of all, they will always shrink. Jain, you should always keep basics in your mind. The whole idea of creating a slurry is, it has no further chance to swell, it is always shrink. So, shrinking will create more problems; that means, you will be having shrinkage cracks in your material rather than expansion cracks that is right so, but these two mechanisms are totally different all right.

Yeah, it is a good idea you can include here that you require a swelling type of material to give temporary stability to the structures that is right. My idea here was to show you that these minerals are becoming very important in certain industries, where now geotechnical engineering is finding lot of scope to deal with, is it ok.