Environmental Geomechanics
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Lecture – 18
Particle Energy Field Theory - II

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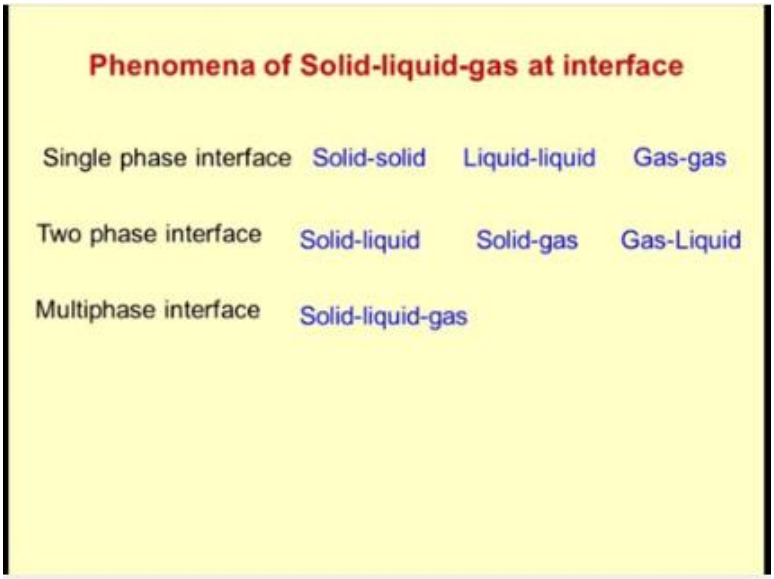

Next, comes the interface, what happens when we talk about the solid, liquid, gas interface, now this is a very complicated thing, and this is what people are trying to study and master at different levels, I would say in different universities. The first one is single-phase interface, solid to solid interaction; I just gave you a good example like WBM; water-bound macadam that is the name is water-bound macadam, clear, design of filters.

Any other example which comes to your mind; in soils let us say you are adding another type of soil, amendment of soil, alright, soil replacement. If you want to decrease the plasticity index of the material, what you are going to do; you are going to reduce the liquid limit by adding some silt fraction or coarse grain fraction into fine-grain soils, clear. So, if I am paying only with the particles and if I am creating a different state of the material, this could be a solid to solid interaction.

So, reduction of plasticity index is another good example of solid, solid interaction, is not of much interest I would say because this part is well understood and look at the liquid, liquid interaction, can you cite some examples of liquid, liquid interaction, which are occurring in nature, so this is one of the examples, where the leachates in the liquid form is interacting with the groundwater, any other example which we might have cited by this time.

There is another example, seawater intrusion, so seawater because of its density, higher density than the freshwater has a tendency to diffuse into the aquifers, nice, any other example; more contemporary, you might be watching in the news; **"Professor – student conversation starts"** oil and water, where it happens; oil spills, excellent, so this is another interesting topic, oil slicks, we call them in the ocean, slicks or oil spills.

Oil spill is used normally on the ground, oil slicks are normally on the water bodies, so this is a very good example, you are talking about liquid, liquid interaction, where the oil gets, creates an interface with the seawater, any other example; liquid, liquid, any types of fluids, liquids coming across or interacting with each other with different densities, different viscosity; sewage when entered rivers, it could be; sewage disposal system.

Yes, you are right, but sewage is the multi-phase system, please remember, another example is you start your day with that, you have a cup of tea, and in that, you add few drops of honey, is it not, this is another interesting interaction, liquid, liquid interaction. So, you can think of several other situations now, these types of situations have to be modelled, gas, gas, sorry; where do you come across gas, gas interaction?

Sir, the fumes from factories are expelled, correct, very nice, so fumes which are coming out of the stacks of the factories, there interacting with the atmosphere, excellent example, gas, gas, any other example of gas, gas; landfill, you have a different type of gases, interacting with each other, you cannot control that I am going to have only methane gas, though the objective is to decompose the material in such a manner that I should get control emission of methane gas.

But truly speaking, we have all sorts of gases which are also interacting and forming a consortium of gases in the landfill, so these are another good example where people will like to work particularly, environmental geomechanics guys, so these are the micro details of the MSW disposal, I hope you can realise now, only disposing and talking about MSW is a big issue with many people are already thinking.

These are the minor details on which technology should work, alright. **"Professor – student conversation ends"** Now, let us talk about the 2-phase interface, so 2 phase interfaces would be let us say, solid-liquid, one good example would be spillage of anything which is occurring on the soil mass, and then percolation occurs. Another good example would be WBM itself, though we consider this as a single-phase truly speaking, this is a 2-phase interface. Why?

WBM without water is not going to function properly; the compaction is not possible, so water has its role when you are talking about WBM, clear. So, good example solid, liquid interaction would be; you have particle sizes of different sizes and the moment you add a little bit of water, they get compacted easily, compaction curve, unless you add water, you cannot compact the material.

So, this is a good example of solid, liquid interaction, all sorts of the spillage; you are talking about the slicks earlier, now we are talking about the spillage. So, there is a tanker which is carrying some petroleum or chemicals, and some accident happens, and this tanker is spills everything on the ground, this becomes a point source of contamination. In conventional geomechanics, we have talked about point loading.

You remember, line loading uniformly distributed load, circular loading, square loading, triangular loading, different patterns of the loading. Now, what I have given you an example is the example of the spillage which is creating a point source of migration of contaminants into the subsurface because as compared to the infinite domain which we are talking about of the soil mass, that size of the tanker is going to be extremely small.

So, this can be considered as a pipe, sorry as a point source of leakage, pipe lines which are carrying crude oil and somebody punctures them, just to tap, unauthorised stealing of the oil, so after they have filled up their buckets, what happens; that is how the thing is simply percolating into the ground, so this also becomes a point source of contamination. What about solid gas interaction?

MSW will be a very good example of 2 phase systems, where the solids are interacting with the gases, municipal solid waste, the composition of the waste is taking place, all sorts of gases are developing, creating, getting created and these gases interact with the solid phase of the material also, anything else apart from the solid-gas interaction which you might think of; decomposition of organic matter in the soils because of UV rays, alright.

And this decomposition causes gases; methane gas and these gases get trapped in the sediments, soils, hydrates which we talked about, this is a wonderful example of the solid gas interface, in fact, we will putting it in the 3 phase system that will be more complicated. Gas, liquid you can think of, the methane which is coming out of the hydrates interacts with the seawater, would be one example of gas-liquid interaction.

Then we have to talk about multi-phase interface, and this is a solid-liquid gas system, clear, so what normally we do is in environmental geomechanics, we try to create interfaces. See you have to; you have already dealt with these things in the disguise of a capillary action when you are studying in the soils, you remember your capillary model, so there is a water which is available in a pot, and then you put a capillary tube.

And then what happens; this water rises in the capillary tube and then we said the sides of the capillary tube are equivalent to the grains of the soil, clear, so you have a capillary tube, you have water column, you have air interface, contractile surface normally we talk about, so you have air, water interface and then sides have a glass or soil particles, this is the third interface. So, we have done it, but we have ignored it thereby taking surface tension.

But in most of the realistic situations, what you have to do is; you have to do justice to the material, and we have to talk about the interactions, which is occurring between the solids, liquids and gases, okay. So, let us move ahead with the type of energy fields.

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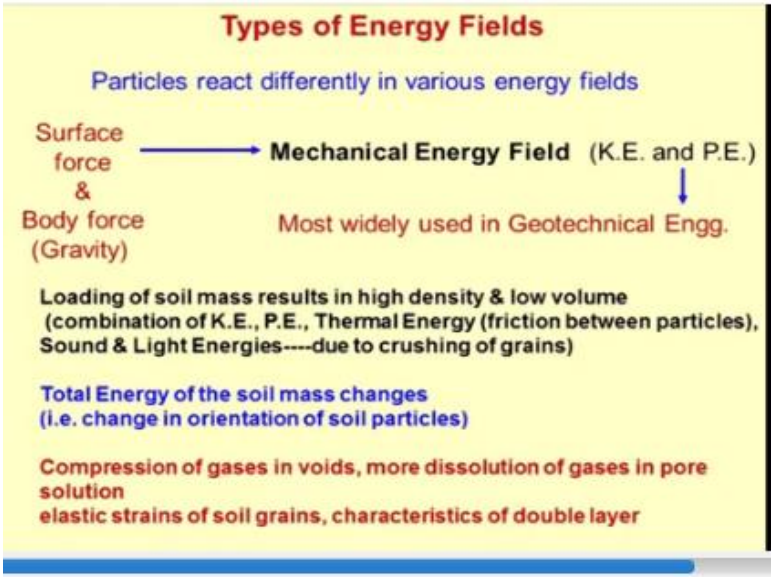

The basic hypothesis is that a particle would react differently in different energy fields and what we are interested in is we are trying to understand the response of the particle when it is exposed to an energy field, so this becomes particle energy field theory. So, we talked about the individual particles, we talked about particle systems, and now we are talking about the different types of energy fields, okay.

The third component of TEF theory, I hope you have studied these concepts of body forces and the surface forces, the grain structure of soils, if you remember, so we have single grain soils, we have fine-grained soils, coarse-grained soils and so on. So, when we say the surface force and the body forces or the gravity forces. Surface forces could be electromagnetic or whatever, these depend upon the mechanical energy field.

Conventional geomechanics deals with the flow of water because of hydraulic gradient, the height of 2 points in the tube and then finding out what is the elevation had, what is the pressure had, what is the velocity had, all are mechanical attributes, so when we talk about the mechanical

attributes, we use the concepts of kinetic energy or potential energy, is this part clear so, most of the systems which you are dealing with in conventional geomechanics be it consolidation.

You take the sample of soil, you load it from the top and then what happens; the static energy or the potential energy is getting converted into kinetic energy, we will discuss these points. The sample consolidates what has happened; the particles are traverse in there moving with some velocity towards each other, the initial particle was in static state, you apply pressure on this, this was the static stress.

And this static stress got converted into kinetic energy; water starts coming out because of the porous pressure generation, kinetic phenomenon, so this is what is mostly used in geotechnical engineering, and it does not include the influence of environmental stresses and just let me remind you environmental stresses are thermal stresses, chemical stresses, magnetic stresses, electrical stresses, bio stresses, radiation stresses and so on and the combination of these.

Now, this whole theory that is mechanical energy field concept is based on the density and volume, so when you are taking a certain amount of soil with a certain volume, and you compact it, clear, compaction theory, the density changes why; because the particles, because of compaction are coming close to each other, so from the steady-state where the potential energy was controlling the system, now the kinetic processes come into it.

Because of compaction, particles crush also, is this correct, because of the crushing strength is less as compared to the compaction energy, the particle would get crushed. If you are doing compaction of granular material, there will be a lot of sound coming because of the compaction of the friction of the particles, sometimes there could be heat which is getting generated because of this friction also.

Sometimes, there could be particles could be charged, and if you bring them close to each other, there could be a generation of the electromagnetic field also, are you getting this point. So, truly speaking when we talk about even a simple phenomenon, like compaction or consolidation, the way we are handling this in conventional geomechanics is not correct, why? Because truly

speaking, we have not really used the conservation of the energy, which is the situation or which is the very critical phenomena to estimate the initial and final states of the material.

And how much energy gets stored in the system or how much energy comes out of the system, clear. So, truly speaking, if you really want to recreate the compaction theory or consolidation theory, what you should be doing; you should be measuring all the sorts of energies which are getting generated in the process, is this okay, the sound, the heat, there could be a spark also because of the chemical processes and whatever.

So, if I go for a neo classification system of the soils whether they are compactible or not, whether they will consolidate or not, what I should be doing? I should be modifying all my tools which I am using to quantify these mechanisms. So, suppose soils are thermally active, you understand, what are thermally active soils; calcareous soils are the soils which have lots of sulphates in them.

And the moment you add water to them, what is going to happen; the sulphates and carbonates would react with water, and the whole process could be endothermic, sometimes it could be exothermic also, that means the heat might produce or sometimes the system might get also cooled, alright. So, I am sure now you realise that even a simple phenomenon like seepage through soil mass is not so simple the way it has been treated.

And why it has been so simply; because you have ignored the attributes of contaminants and the soils completely, you never bothered about the chemistry of the soil, you never bothered about the chemistry of the percolates, you agree with this, so active percolate like sulphuric acid when it comes in contact with the soils which have lot of calcium in it, what is going to happen, when sulphuric acid reacts with calcium is going to be an exothermic reaction, are you getting this point.

So, that is the need of the our; so why we are talking about energy field theory because we are trying to develop something which is more holistic as compared to the one which we have been using until now, is this part clear. I have cited several examples, now you just think and apply

your mind to create a situation where the energy conservation concept can be utilised in geomechanics to reframe the things.

Load deformation characteristics; the best way would be if I plot the stress-strain relationship and you might have done in your 10+2 physics, if I integrate over the surface of this graph, the area which is confined by this sigma versus epsilon relationship, this is nothing but the work done, clear. So, this is another way of looking at the concepts, so the total energy of the mass chain is becoming useful.

What I will have to do; all the consolidation tests and compaction tests I should be doing in a calorimeter now then only I can measure what the heat of liberation is, what is the heat of reaction, what is the heat of sublimation, are you getting this point, when interaction starts, you do not have much control, it depends upon attributes of the geomaterial and attributes of the percolate.

And in nature, any sort of this thing might happen, hope you are getting the answer to the question if I asked you sometime back that despite doing the best possible sampling, despite doing the best possible testing and despite using the best possible software's, why your system is failing? **"Professor – student conversation starts"** whenever we design, we always want to go to like reality, according to our learning of the subject.

Probably, there might be some lag in that process, correct, so do you realise the lags, so these are the key things which have been not included in this discussion of the classical geomechanics, yes, sir, whenever we develop theory like in engineering, we always have some over like assumptions and approximation's like as long as these thermal energy or sound and light energy are not as much that influence my consolidation process are there.

I can still like I am of the viewed like I can apply because going into this, it is also not easy sir, very good, so I hope you are ignoring a fact that be marine clays would have a substantial amount of calcium in them which you have completely ignored, listen, look at the counter logic,

so I am yet to see a marine deposit which would not have an organic matter which would not have calcium content in it.

And what are the constituents of seawater? Chlorides, sulphates, so they are all the time interacting with that, I hope now you are convinced, so the simple answer is that for the sake of convenience or maybe to begin with the subject in the 1930s and 1940s, people will start working on these concepts with a lot of limitations and assumptions but unfortunately, in 2020 also, people are following the same thing, and they are not ready to change.

When you are observing that the requirements to understand the material are much more and much more critical because you are dealing with typical projects right now, is this okay, sir, while doing the hydrometer analysis, we actually add hydrogen peroxide and heat it right, so what we do like exothermic reaction takes place in like soils like marine clay and black cotton soil, so the readings are we get are actually not representative, right.

The materials itself is not representative study or what it used to be, so for the sake of convenience and to cover up your ignorance, you are simply saying just treat this and get rid of organic matter and I will deal only with the particulate system which is not correct, you are finding out the response of the material which is totally different than the one which was existing in nature, that itself is a gross injustice.

That means, you have to stop this practices and think of something which is better and more comprehensive, first thing is to realise that whatever I have been doing is incomplete or incorrect, then the second stage is how to correct it, how to complement this, you understand, so these are the sequence of learning, it is interesting I think. The logic is good, so, unfortunately, what did you do?

You brought the sample from the field, you said to get rid of organic content, put in the oven, you kill most of the material there itself, then you washed it with sulphuric acid, hydrochloric acid, then H2O2, then you boiled it also, alright, so no way this material is same as the one

which was existing in Bay of Bengal on which you wanted to create a structure that itself is a big deviation.

Then, second thing is you added something more to this, to deflocculate it clear, in nature nobody is going to add the flocculent, so you have to deal with the sediments which are lying in the nature, you wanted to get the response of that system, not the one which is created by you as per your convenience. **"Professor – student conversation ends"** So, I am sure you must have realised that when we talk about the particulate systems like soils, the energy is associated with the orientation of the particles, flocculent structure, dispersed structure.

So, flocculent structure if I tamp it, what happens; it gets converted into the dispersed structure, why? No, you are basically, supplying more energy to order so, let us discuss a bit about this thing. Another thing is that now you realise that there are gases which are present in the voids which we have ignored completely in the conventional geomechanics, we never bothered about the pore gases.

We never bothered about the dissolution process of the gases into the pore fluids, so when you do load, a stress-strain relationship what happens; when you are applying pressure on the soil system, the chances are that the gas might be getting dissolved into the pore fluid, so that itself is the sort of reduction in the volume, clear and these type of volumetric reductions we are not taking into account in a realistic situation.

So, we have to talk about these issues, I am sure you can realise that the mechanical energy field-oriented theories cannot take into account these effects, because you have only 2 components either mechanical energy field, position head kinetic energy component, velocity head and the pressure head but the only situation which is used to solve most of the problems in geomechanics. Similarly, we do not talk about the effects of the elastic strength of the grains.

We always assume them to be incompressible, but now I think with our discussion for at least 8 lectures, you must have realised that there are ample opportunities for the soil grains to get deteriorated or to get upgraded also, the bacteria does tricks, the chemicals might be doing this

trick, so longer the interaction between the chemicals and the soils, what is going to happen; mineralogical alteration, we discussed today morning, is it not.

So, that means when even quartz comes in contact with bases, hydroxides at elevated temperature for a pretty long time, there is an alteration in the material property, we will discuss this quite in details, and I use the word zeolites to define this. That means the material itself is getting changed and you are still assuming the compressibility of the particle to be incompressible.

We do not talk about characteristics of the double layer and double layer formation is the electromagnetic process, you remember double layer concept, so you have the particle of clay, when it is dipped in the water, you have cations which are present in the system, the concentration is very high close to the particle, and it decreases as you go away. So, this composition or the this system where the clay particle is having adsorb water.

And the cation is known as a double layer, so mechanical energy field cannot take into account the effect of double layers.

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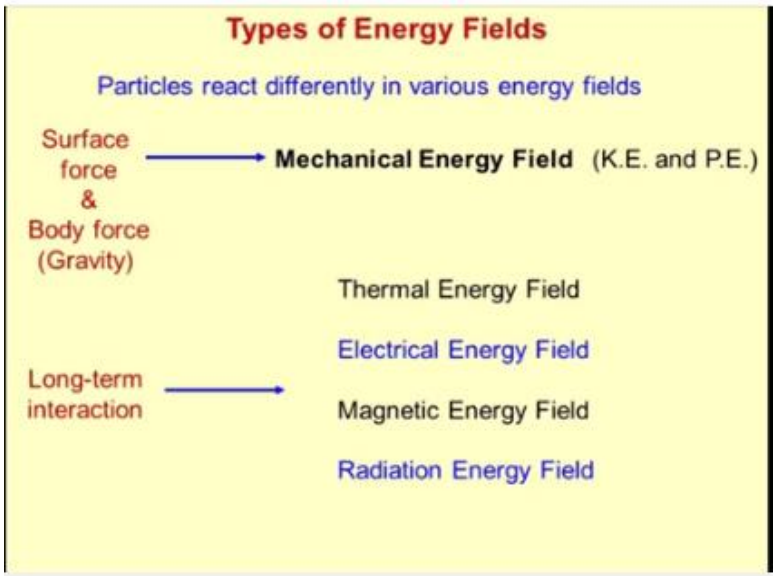

Now, when we talk about the long-term interaction whatever I have discussed until now is going to become more critical than the immediate testing. In conventional geomechanics, we have done

mostly the tests which were short-duration test, clear, even if you do a CV test, consolidated drain test normally, it is done for 3 weeks, 2 weeks, maximum, hydraulic conductivity test we do for how many days; 7 days maximum.

Consolidation test might go for 3 weeks at most, clear but these are not long term, so long term would be in let us say decades, 100's of years of the interaction. So, when we talk about the long term interaction, then I am sure you will realise that the mechanical stress component or the mechanical energy component is going to be extremely less as compared to the other stresses, you remember the analogy that most of the geotechnical structures are sitting in or may be directly exposed to the environment, embankments, dams, roads, foundations.

Though they are covered but still they are in touch with the long water continuously, clear, so thermal stresses are going to control the stability of the embankments much more as compared to the mechanical stresses, are you getting this point now, is this part clear. So, these type of analogies we will now create to see what is the response of thermal energy field which could be solar, which could be from the forging unit, which could be from the buried cable, which is an emitting lot of heat, which could be from a rocket launching pad, which could be from for any other industrial activity, disposal of waste at an elevated temperature, clear.

An electrical energy field, I hope you understand, magnetic energy field, radiation energy field and so on, so when we talk about long term interaction, these energy fields become important, we have to include them in our analysis.