Environmental Geomechanics
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Lecture – 17
Particle Energy Field Theory - I

We have been talking about various things related to the Genesis, scope, then of the environmental geomechanics and in the last lecture, I talked about the particle energy field theory and I gave you some hints that maybe this is one of the ways to address the issues which modern-day society is facing and this is where I also gave you an idea about that this subject requires an interdisciplinary approach.

You should have an open mind and a very different way of looking at the things unconventional observation of the things, which I was talking about and we discussed for subsequently the long term phenomena, short term phenomena, we also talked about the basics which are involved in or the assumption which has been made for analysis of geotechnical engineering systems.

And then we were discussing the shortcomings which are prevailing in conventional geomechanics, and I suggested a sort of a neo classification system which should be implemented for understanding the soils better and their response under various environmental fluxes or stresses you may call it.

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And in today's lecture, I will be talking about the details of the particle energy field theory, the subtopics would be the components of PEF theory, what are the assumptions involved in this, I will be talking about different types of energy fields until now, I have been talking about apart from mechanical stresses, what are the stresses which influence the geomaterials, so today we will try to explain these things in greater details.

And then comes the applications of all these situations or the energy fields which we are going to talk about, and then studies which are conducted by IIT Bombay researchers, my students and how we have tackled different types of energy fields and their response on the geomaterials and vice-versa that is the response of the geomaterial when it comes in contact with different types of energy.

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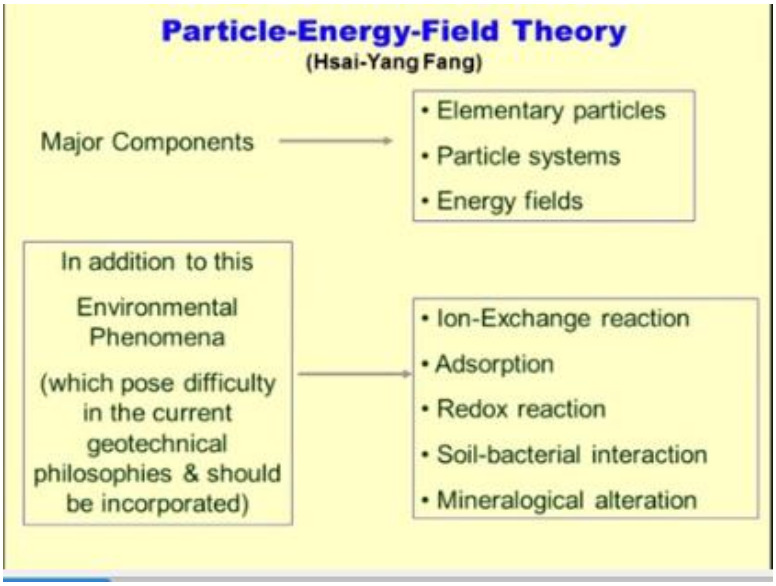

So, this is what I will be discussing under the realm of particles energy field theory, so this theory, as I discussed in the previous lecture, also was pronounced or proposed by Professor H. Y. Fang, the personality who has done a lot of work in environmental geotechnology and the credit go to him for coining this idea. So, the major components of this theory are elementary particles, particle system and then energy fields.

And in addition to this, we talk about the different phenomena which occur in the environment and which are posing great difficulty in understanding how to model them, how to incorporate them in our models. So, now what happens is if you have these type of questions in mind as we discussed in the previous lecture, ion exchange reaction, adsorption, redox reaction, soil bacterial interaction, mineralogical alteration all these issues have to be talked about.

So, what we are trying to see is; these are the good examples of how a geomaterial would interact with a given energy field and ultimately, what happens to this so, good example is; if I am trying to see the reaction between a geomaterial and the chemical flux, the first thing which I should be doing is; I will be talking about the ion exchange reactions, sometimes you also call this as a cation exchange capacity of the material.

So, this is the quantification of the interaction between the geomaterials and the energy fields similarly, adsorption; we will be talking about this redox reaction, these are all the chemical reactions where the reduction and oxidation of the material might be happening because of different environmental condition, soil bacterial interaction we have discussed a lot, mineralogical alteration.

As we have been discussing when geomaterials come in contact with extreme environmental conditions like very high temperatures and very high concentrations of chemicals, their mineralogy gets altered, and one good example of mineralogical alteration is zeolite formation, zeolite, zeolite so, a good example of mineralogical alteration would be zeolite formation which I will be discussing in details.

So, these are the practical applications where the particle energy field theory can be employed directly. So, now let me introduce one by one the major components of PEF theory, and we will begin with elementary particles.

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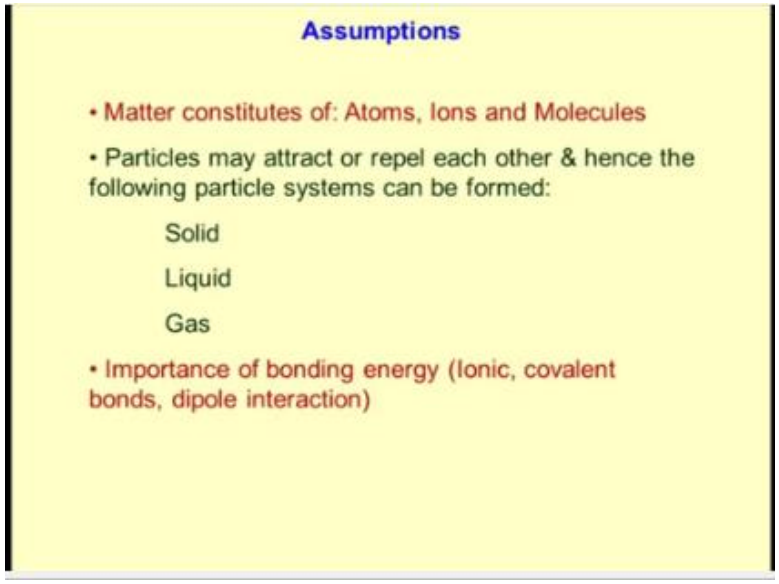

So, what are the assumptions associated with this theory? The first assumption is that the matter constitutes of atoms, ions and molecules, I am taking back you to your chemistry classes, and the particles may attract or repel each other depending upon their charges, and hence the following particle systems can be formed. I hope you are aware of this solids is the attraction between the particles and gases are neutral, Vander Waal forces and the liquids where the interaction or the particle attraction is sorry, not neutral, gases is where the repulsion is much more.

And the liquids are slightly neutral or somewhere in between, so this is where we talk about the bonding energy, most of the geoenvironmental engineering issues in the contemporary world are pivoting around the application of bonding energy, a good example would suppose soil is contaminated with some contaminant now, this contaminant could be in the gaseous phase, it could be in the liquid phase, and it could be even in the solid phase, clear.

Crystallization; what microbes do inside the soil system, so under all these circumstances, there is a bond which gets created between the soil and the contaminant, this is part clear, now, if I want to do the remediation of the soil, if I want to clean it up, remember the 4, 5 scopes of the environmental geotechnology which I talked about, there was one scope which deals with remediation of contaminated lands.

If you could not control the spread of contaminants and if the geomaterials get contaminated too much, then you would like to clean them, remedial actions so, when you talk about the

remediation you have to break the bond between the geomaterial and the contaminant, clear and this bonding could be ionic, it could be covalent, it could be a dipole interaction or so on.

So, the crux of the situation is that when you talk about remediation of soils, you have to study what is the bond strength and how these bonds can be broken and your 10+2 understanding of the chemistry would tell you; I can heat up the material to break the bond, I can wash the material to break the bond, I can use some chemicals to break the bond, is this correct or you may devise another method to break the bond.

Ultimately, it boils down to the bonding energy so, nowadays we have different tools in the market and a good example would be FTIR analysis, which I will talk about subsequently, Fourier transform infrared spectroscopy, FTIR analysis; FTIR analysis tells you what type of contamination the system has because if you look at the patterns of the FTIR analysis, you can make out what type of bonding exists in the system.

And then I can create a strategy to get rid of this. A good example of breaking of the bonds could be suppose, if you take heavy water which has a lot of minerals in it and if I boil it what happens; all your carbonates they settle down, they get dissociated from the liquid phase, so what you have done; you have broken the bond between the ions which are present in the system and the water molecules.

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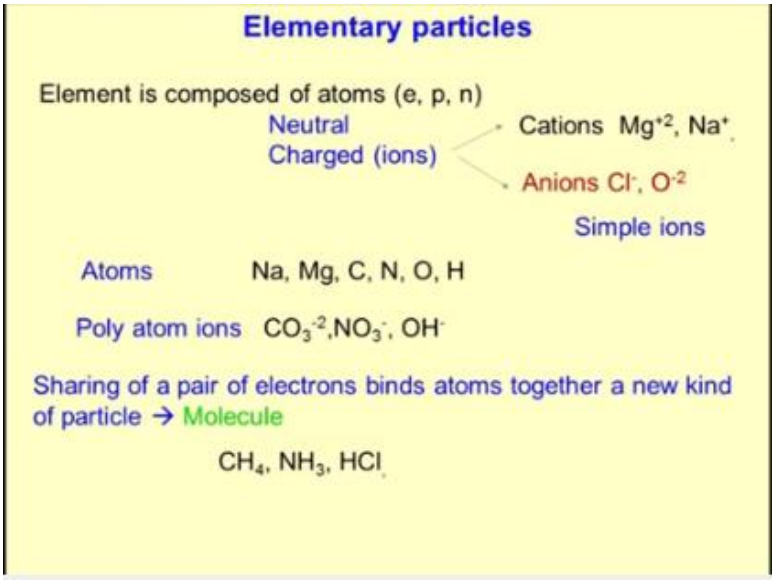

So, these type of strategies are utilized to decontaminate the geomaterials now, coming to the elementary particles all of the elementary particles are electron, proton and neutron and

depending upon the charge we sometimes have neutral systems or sometimes we have charge systems and charge systems are known as ions. Now, ions could be of 2 types; we have cations and we have anions, you are refreshing your chemistry, 10+2 chemistry, clear.

So, cations are the ones which are positively charged, magnesium, sodium, potassium, calcium, iron all those things, fine. Anions are the chlorides, oxygen, hydroxyl, OH and so on ammonium ion but before we come to that, we will differentiate between the ions also now, whatever we have listed here these are the simple ions, individual ions sometimes, they could be in a group also like I said ammonium ion, so NH_4.

Then we have atoms; sodium, magnesium, carbon, nitrogen, oxygen, hydrogen so, when you are trying to analyze the soils, you have to do the atomic analysis to understand what are its constituents and what are the charges which the soil system is carrying and what are the species of cations or anions which are present in the system. Now, these are the poly atom ions which we were talking about; hydroxyl is OH^-, NO3 nitrate and carbonates CO_3^{-2} and so on.

Now, if there is a sharing of electrons what will happen; the sharing of electron will bind the atoms together to create a particle which is known as a molecule, so water is a molecule, HCl is a molecule, ammonia is a molecule, methane is a molecule, little bit of chemistry is required, we will not use much of this but yes because you are doing environmental geotechnology, geomechanics so, you have to understand a bit of the chemical processes which occur inside the system, is this fine.

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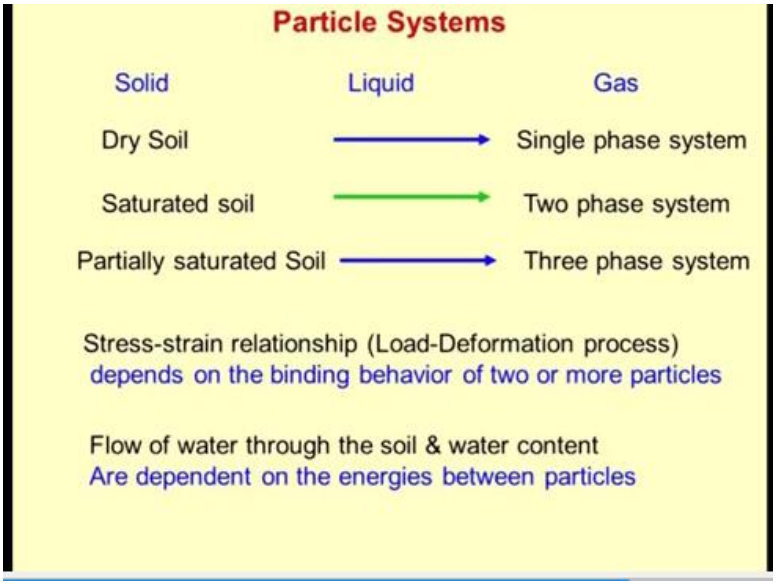

The second component is the particle systems, what are the particle systems which we can think of so, we have 3 phases of the matter; solid, liquid and gas and similarly, we have best example would be of solids single-phase system would be dry soils, we are ignoring air over here, though it will be constituted, it will be classified as a single-phase system because we are ignoring the air.

But gases could be contaminants, their fumes, water vapours and so on, we have let us say saturated soil, all the pores are filled up with water so, this becomes a 2 phase system, and then we have let us say, partially saturated soils or unsaturated soils this is what is termed as a 3 phase system, it is very interesting to see how would you model the particle systems which would govern the mechanisms associated with a different state of the material.

So, first of the mechanism which we would like to study is stress-strain relationships, so for that matter, stress-strain relationship for the dry soils, partially saturated soils and completely saturated soils are going to be different, and from the response of the load-deformation characteristics, we can make out whether the system is dry, whether it is partially saturated or it is fully saturated.

So, this again depends upon how the particles are bound with each other, a good example would be water-bound macadam; WBM, so what do you do there; you take different sizes of the particles, you arrange them in a matrix, sprinkle a little bit of water and compact it and ultimately, what happen; this forms an excellent bound system on which you design the pavements.

Another example would be the flow of water through these types of systems which might result in dry soils getting transformed to partially saturated soils and partially saturated soils getting transformed to saturated soils. So, again this is an interplay of the energies between particles, the reverse process could be I will start with the saturated soils, I will heat it up, and then I will create a dry soil.

So, I am expelling out one phase from the system of the particles and then I am interested in seeing how the response looks like.