Environmental Geomechanics
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Lecture – 19
Particle Energy Field Theory - III

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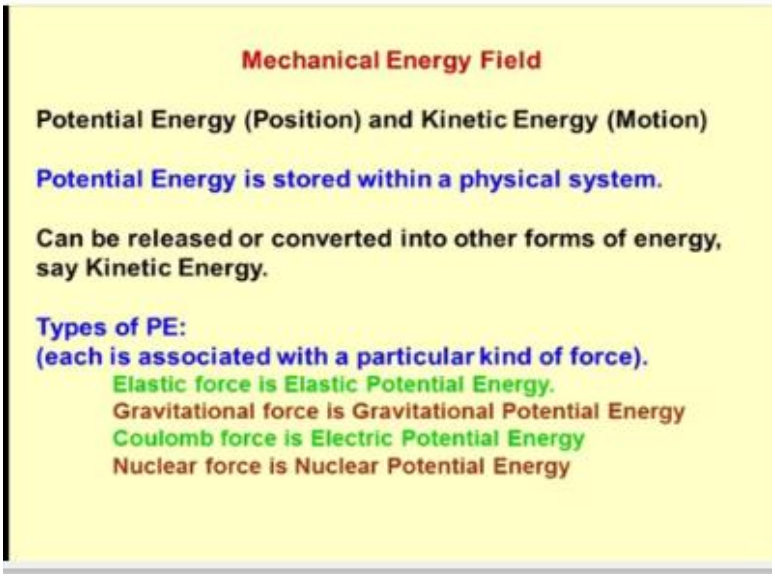

Potential energy and kinetic energy; kinetic energy converts to motion, potential energy converts to position, potential energy stored in the system and this can be released or converted into other forms of energy say, kinetic energy compaction process, consolidation process and so on. Types of potential energy, this all is associated with the kind of force; elastic force, or we call it as elastic potential energy which is stored in a spring or a rubber band.

Gravitational force, it is the gravitational potential energy, Coulomb force, in electrical potential energy, and then we have a nuclear force which is present in nuclear potential energy, so these are the components which we might think of when we talk about the potential energy concept, okay and it is possible that there could be a conversion of these components into the kinetic energy.

Fission process would be a good example of the kinetic energy of conversion from potential energy to the kinetic energy, is it not, activation of neutrons.

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So, let us talk about the potential energy and kinetic energy separately, the compaction process; simple compaction process as I said is an example of protection energy, initial sample densifies as you compacted, particles are coming closer to each other from the initial state the system acquires kinetic energy particles move, they come together, and this is what the compaction process is.

Consolidation process; reduction in volume, densification, movement of water out clear, distortion of the soils, I hope you understand bending and crushing also is it not; you must have studied in the particulate mechanics, this is the process what is bending? I have a particle, another particle in C-phi soil, cohesion and frictional material, normal soils and this is the clay platelet.

I can assume this as a beam which is simply supported on rollers and now if I load it what is going to happen; the plate is going to bend as long as the crushing strength of the particles is very, very high.

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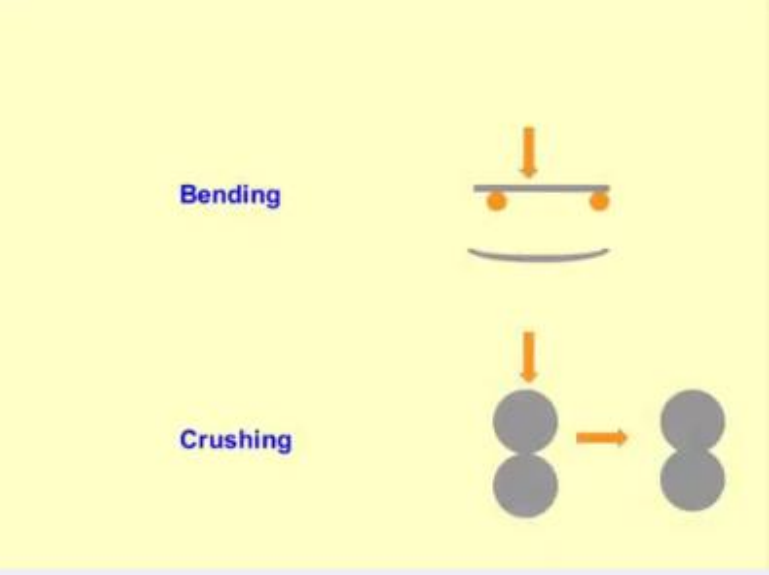

So, this is the deformed form of the plate clear, so one of the ways to deformation of the geomaterials would be the bending, the second one is crushing I hope you understand what the crushing is, two particles are sitting close to each other, and if I apply further stress and the stresses are higher than the crushing strength of the particle what is going to happen, this is what will happen, assimilation of the particles.

Because at this point, the stress intensity is maximum so, the crushing occurs over here, and particle becomes flattered at the contact, and hence the stress is reduced, so deformation of the particle could be because of the crushing, it could be because of bending, it could be because of rolling also I am sure you must have heard about, is it not. So, the kneading process you understand what is kneading process.

You take the soil, and you add water and then how do we mix it; our fingers go into the soil mass is it not, this is how we move, there is a strategy why your automatic compactors cannot really knead the soil properly particularly clays, so each time when you lower down your fingers in the mass, the friction is getting mobilized from all your fingers clear, sheep foot roller whole, how sheep foot roller was evolved, maybe somebody must have thought about this.

Look at the contact area; we will just compare the material from top the compaction area is less, so when you knead it, so much of the area is getting exposed to the material which you are building, so it is a better and better interface which is getting created that is one of the

logics of your sheep foot roller. Then comes the shearing process, which is also a good example of potential energy.

I mean you are just changing the relative, you are relocating the particles particularly, in the granule material so, when you shear what happens; the system densifies, can you relate it; dilation, so before the dilation occurs there is a densification of the material, and then the material becomes too dense, and further shearing would cause dilation.

Look at your volumetric change versus strain curve, kinetic energy; any type of movement of water or the gases, so when you are compacting, you are expelling water sorry, air and when you are doing consolidation, you are expelling out the excess pore water pressure in the form of hydraulic conductivity. So, these are kinetic energy which we are talking about, vibrations of any sort, dynamic loading on the system.

These are the components of potential energy and kinetic energy then you can utilize them in solving the geotechnical engineering related issues. I am sure you must be realizing that most of the energies which would influence even these mechanisms, we have not talked about yet and they will be now following other good example is the fluid which is present in the soils is very susceptible to the temperatures and pressures.

The rheology of the fluid is going to change, the compaction characteristics, consolidation characteristics are going to change.

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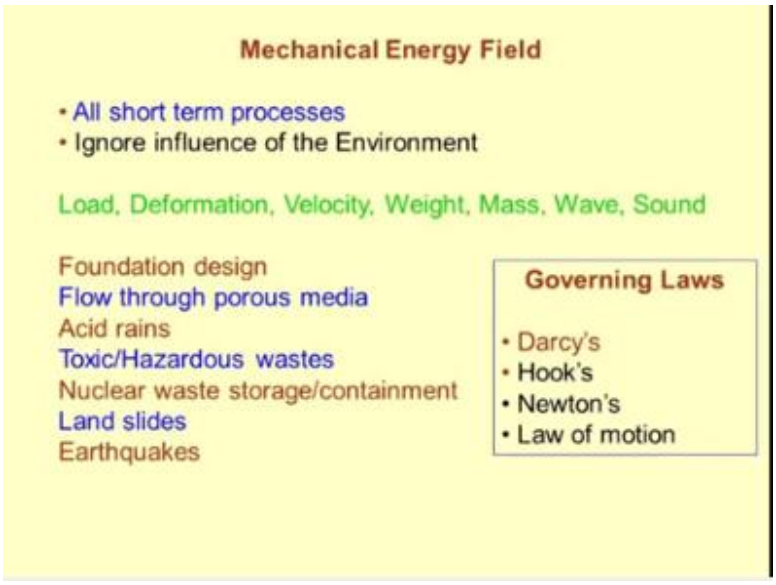

A little bit more discussion on the mechanical energy field, these are all short term processes, ignored the influence of the environment, some of the examples of mechanical energy field systems could be loading, deformation, velocity, weight, mass, waves and sound and where do you use them; in all these instances; foundation design, flow through porous media, acid rains, dissolution has occurred.

And now dissolved contaminants in the gaseous phase have become a part of the fluid system which is precipitating, toxic and hazardous waste disposal, nuclear waste storage containment, landslides, earthquakes. The interesting thing is that you will realize that when you deal with these situations, these are the tools or the laws which you use is it not, the stress-strain relationship is nothing but your Hook's law, we call it as a constitutive law.

Landslides when we talk about or when we deal with the landslides we usually use Newton's law of motion is it not, Darcy's law is the flow of water through the porous media so, law of motion. So, honestly speaking in the mechanical energy realm, we are following these laws which are governing most of the processes.

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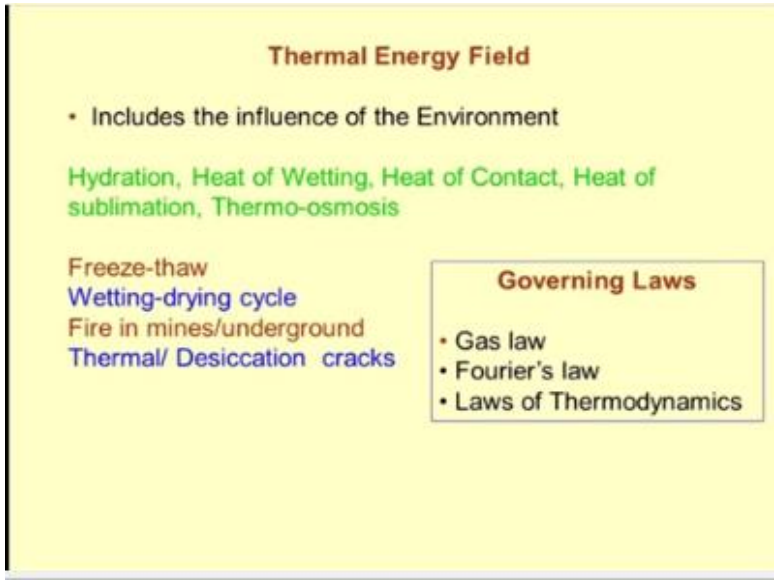

So, let us move on to the thermal energy field, I have cited several examples in my lectures earlier, where I have touched upon what thermal energy field does to the soil mass, even those who are in the field of petroleum, exploration, energy geotechnics, thermo active systems, they all talk about thermal energy till nowadays, the response of soil mass when it is exposed to elevated temperatures or lower temperatures.

So, this includes the influence of the environment sometimes, we also call thermal energy field in the form of thermal stresses, and thermal stresses cause cracking before a drought happens what happens to the ground; it cracks because of the movement of the moisture, so thermal energy field is very critical for cracking of the soils and cracking of the soil is directly related with the tensile strength of soils.

Are you seeing now how things are getting interlinked, so as I cited just some time back when we deal with the thermal energy field, the thermal processes could be because of hydration, calcium oxide comes in quantity with water hydration occurs, calcium hydroxide gets formed, exothermic reaction, you can feel the temperature, correct.

Next time when you get some soils which are having a lot of calcium carbonate in it or calcium compound in it, keep them on the pump add 2, 3 drops of water, and you will see slowly that you feel that heat, I have guided 2 PhD thesis on this concept; one is by Dr Susha Lekshmi, another one is Dr Kadali Srinivas, and this answers your question that how classification system can be created based on the thermal energy field.

If you go through the published paper you will realize that we have tried to create a classification system for the soils based on their heat of wetting and then I have said that you need not to do any of these particle size analysis and another classification schemes which you follow because these tests are going to be more accurate and easy to perform, I can perform a heat of wetting test in a calorimeter which is a controlled environment.

And I can measure the type of temperatures with the system, exhibits when it comes in contact with any type of contaminant or water or gases. So, now I am sure you realize this is a bigger domain of the things which we are dealing with. So, when we talk about the neutralization of contaminated soils; one of the methods could be by the purging of gases, by the purging of chemicals, by the purging of water.

And a lot of chemistry is happening inside the soil system which could be exothermic or endothermic, so go through the papers written by Srinivas Kadali and Dr Susha Lekshmi, until now only concrete technologists were using these concepts, the heat of hydration, you agree. They were attributing the cracks which developed on the concrete surface because of the heat of hydration of the cement.

But now, we realize there are many soils which have a pretty high amount of calcium in it and these calcium even if it reacts with the water or when it reacts with the different types of acids, might create heat so, hydration, the heat of wetting, heat of contact, heat of sublimation and thermo osmosis are the terms which are being used in the present day scenario in the context of environmental geomechanics.

Each of this keyword has a big history, big knowledge and lot of information is available on it, so one life is less to master everything so, if you are trying to decontaminate the soils by using thermo osmosis concepts, I am sure you have to spend enough time to understand the whole process and the mechanisms, is this fine, I hope you understand what heat of sublimation is.

Material directly becoming gaseous; acquiring gaseous phase from the solid phase like camphor, a good example is gas hydrates so, the moment you expose them to the environment what happens; the entire thing vaporizes. So, some of the practical examples are freeze-thaw, soils freezing and thawing, wetting and drying cycles, fire in mines underground space, thermal and desiccation cracks.

The compaction curve which you normally developed in the laboratory by bringing the soil and mixing water for once is not the real replication of the response of the material, fire in mines we have not done directly because these are the direct effects of extremely high temperatures to the soils, you can add to this list explosions also, explosions in the landfill or explosions under underground space particularly, ballistic explosions, which countries do to check their nuclear power.

And desiccation cracking has been done by my several students Dr.Uday Kala and one; and now, when you are using this thermal energy fields, the governing laws would be the gas laws you must have heard about PV=nRT. Believe me, when you are dealing with the hydrates you have to understand the gas law T into V curve, pressure and temperature curve or pressure and volume curve.

Fourier's law; laws of thermodynamics, depending upon the state of the soil, composition of the soil, lot of thermodynamics may prevail into it, hope it is is clear to you, so these things

cannot be ignored are you finding it okay, very new angle which is getting added to the conventional geomechanics is this fine.

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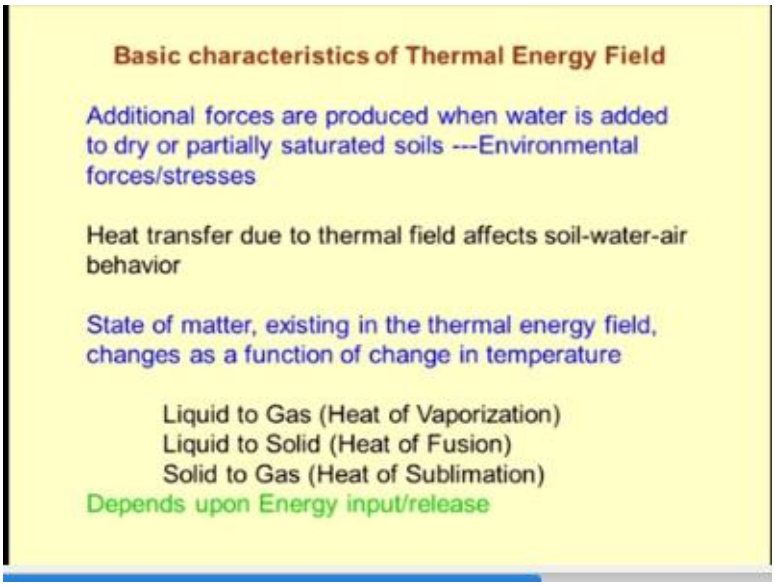

Now, when you talk about the basic characteristics of the thermal energy field, what happens, what heating does? Heating as I said is the responsible factor for breaking the bonding between the states of material, so soil in contact with water and when I heat it, what will happen; water evaporates, so basically thermal energy field simulates environmental stresses or the forces which are acting on the system.

Now, there are ample situations where the; when the heating of the soil mass takes place, the movement of moisture occurs, we call it as a vapour phase migration. So, when the vapour phase migrates in the geomaterial, you have to find out what is the permeability of the system when the coupled process is taking place, so you are heating from one end, and heat migrates to the second end because of the conductivity of the material through the soils are poor conductor of heat.

But what is happening is because of heating, the saturated soil is getting converted into unsaturated soil at this end, where you are heating it and suction gets generated. What does this suction do? This suction attracts the moisture towards it at that end, now I have created a situation where the heat is migrating in this direction and the moisture is migrating either in the opposite direction or in the same direction.

This becomes a coupled phenomenon, we call it as soil water-air interface, so a state of the matter changes when you expose the system to the thermal energy field, this is the explanation of what is the heat of vaporization, liquid to gas conversion clear, at elevated temperature the pore fluid which is present in the soils might change to gas sometimes, the gases may get condensed when you are working in the lower temperatures, clear or when the pressures could be high.

So, a reverse phenomenon might take place; the second one is liquid to solid; the heat of fusion okay, say water getting converted to crystals of ice. Now, we were discussing these things when you are talking about the gas hydrates, you remember, the type of 3-grain arrangements load-bearing.

And then bonding and then we were talking about the pore filling, those 3 states of the material, then there could be solid to gas conversion also, this is what is known as the heat of sublimation. So, now I am sure you must be realizing why I am discussing all these things because these are the ways to quantify the thermal processes in the geosystems. **"Professor – student conversation starts".**

Sir, what are the modelling software's are you working? I do not use any software because none of the modelling software can utilize these concepts which I am talking about. So, when you start realizing the legacy of our lab, let me use the word we are trendsetters, we are not followers, so we create situations where now people are realizing is what they said is correct and let us now cope up with them, we are in that mode.

So, before you start being software's and all, software from there, the data will come unless you have modelled all these things. **"Professor – student conversation ends".**

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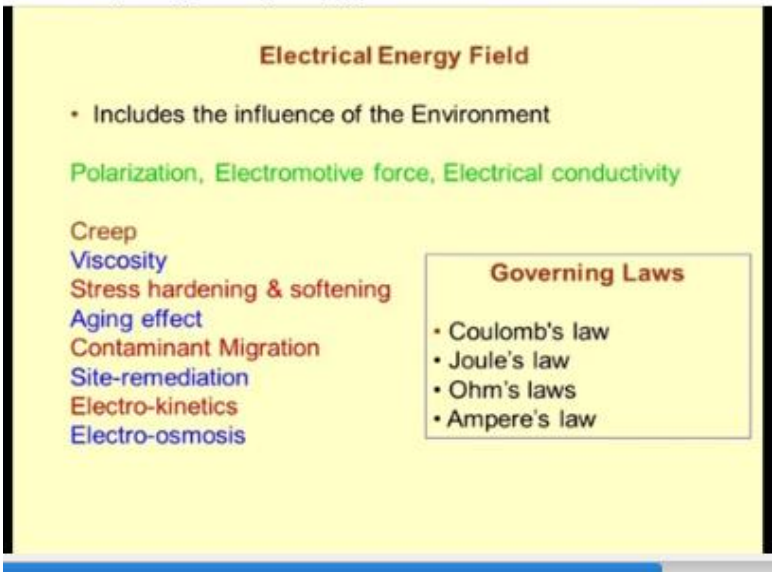

So, electrical energy field; this will now taper down slowly because electrical and radiations are not much experienced and not much known, so this also includes the environmental factors; polarization, electromotive force, electrical conductivity these are the keywords which are typically used, but electrical energy field is being utilized in the contemporary application or monitoring purposes of environmental geomechanics concepts.

So, because these are electronics age, sensors age, so, people have started working on this a lot and my lab has done excellent work in this context, we have developed a different type of sensors for moisture content, measurement particularly, high frequency and impedance spectroscopy and all those things, if you see the papers you can realize.

So, if you are using electrical field concept, you can study the creep phenomena better, viscosity changes which you are talking about the stress hardening and softening process, ageing effect in soils, then site remediation if you really want to check how much the soils are getting remediated, you can use this electrical energy field, electrokinetics, electro-osmosis these are the subjects which have to be developed.

And what are the governing laws; the governing laws are Coulomb's law, joules law, Ohm's law, amperes law fine. Right now, the stage is where we are just trying to see how soils react to electrical energy field and internationally also you will find that people are progressing day by day, high frequency impedance spectroscopy is being done to decode the answer, read the papers which are written by Ajaz Massod Bhat, which I will be teaching also in the class, he was my master's student in 2001-2002.

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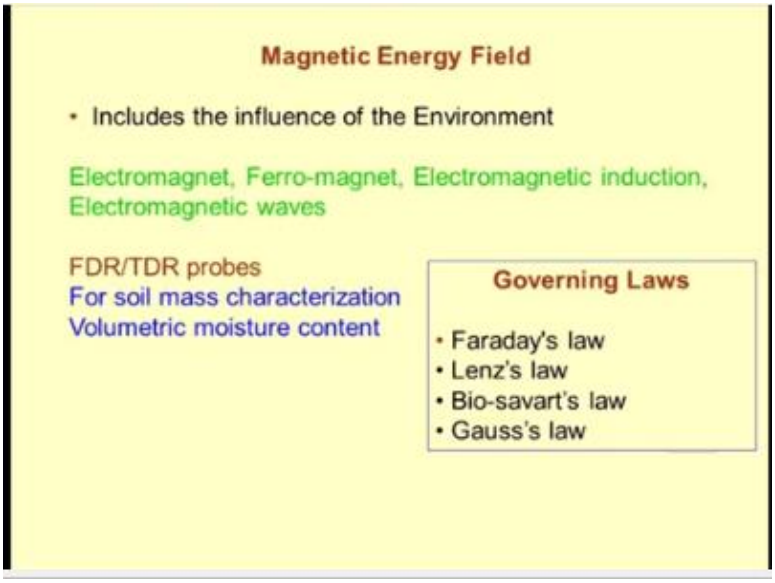

And he has done a path-breaking work of how current migrants through the porous media, magnetic energy field; as I said last time and one of you are asking this also includes the effect of the environment in terms of the electromagnet, ferromagnet, electromagnetic induction, electromagnetic waves and the current day state of the art in geomechanics is that people are using these gadgets, FDR and TDR probes; finite, this is FDR is known as frequency domain reflectometry and TDR is known as time-domain reflectometry.

So, FDR and TDR probes are being utilized to find out the moisture content of the soils; I think this logic I had given you at that time also and the magnetic response is also responsible for characterization of the soils and the current trend is nobody talks about the grain material moisture content, everybody wants to find out the in-situ moisture content of the soils and that is what is known as volumetric moisture content.

So, when you are dealing with these type of thoughts and these type of projects, the governing laws would be Lenz's law, Faraday's law, Bio-savant's law and Gauss law which you must have studied in electromagnetism. If you are very eager to learn about the magnetic energy and how it really influences the particles, Susha's papers, you should follow.

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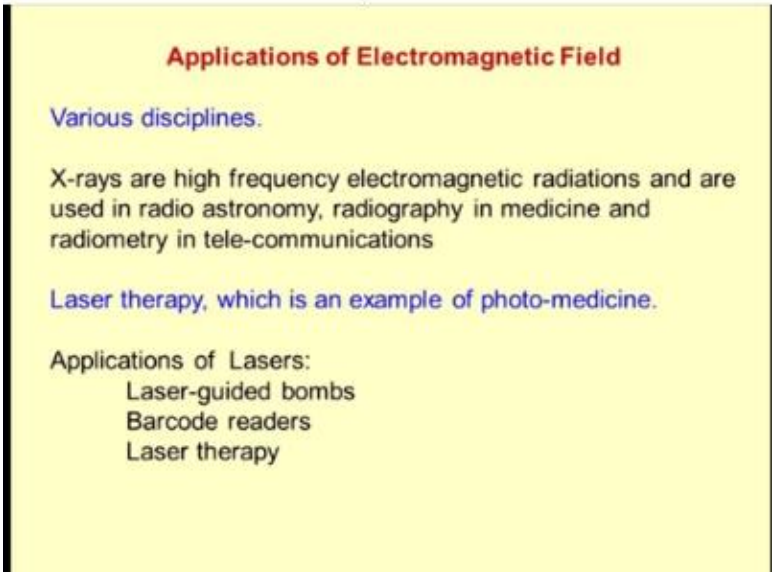

The last one which I am going to talk about is the sorry, application of the electromagnetic field; there are various disciplines in which the electromagnetic fields are used, x-rays of a different type for telecommunication, radiography in medicine, radio astronomy, laser therapy and application of lasers I am sure you are aware of this laser-guided bombs, barcode readers and laser therapy which is being done.

So, in present-day science and technology, electromagnetic waves have special applications, and we are learning all these subjects from different disciplines, particularly, electronics people or electronic guys, nanoelectronics guys and so on. This is status as on date of environmental geotechnics related to electromagnetic fields.

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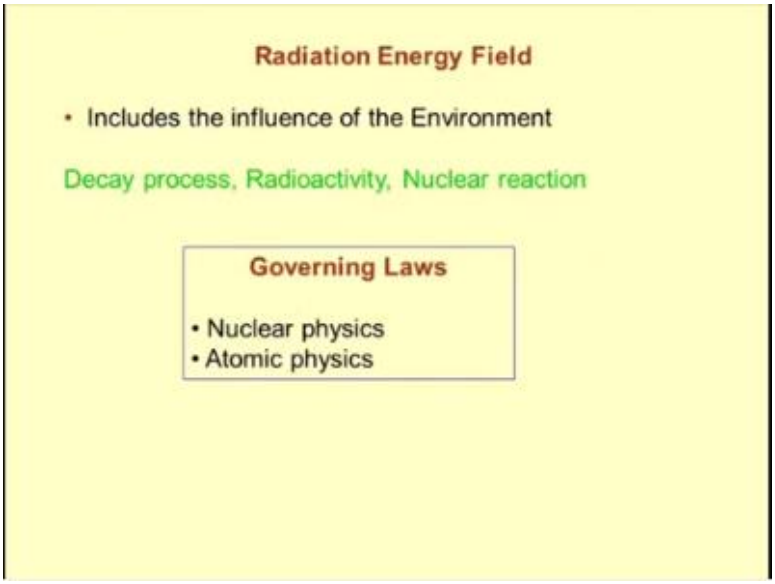

Radiation also is one of the attributes of the environment, and it deals mostly with the decay process, radioactivity and nuclear reactions, off late my research is now going more into the issues related with decomposition decay, and recreation of materials and the reason is simple because we have been dealing with a lot of projects associated with the atomic energy and nuclear waste disposal and municipal solid waste disposal.

And when you talk about the decomposition process, the radiations become very, very important, extremely difficult to handle the situation but still we are trying, we are learning this and the governing laws here would be the laws of the atomic physics and the nuclear physics.

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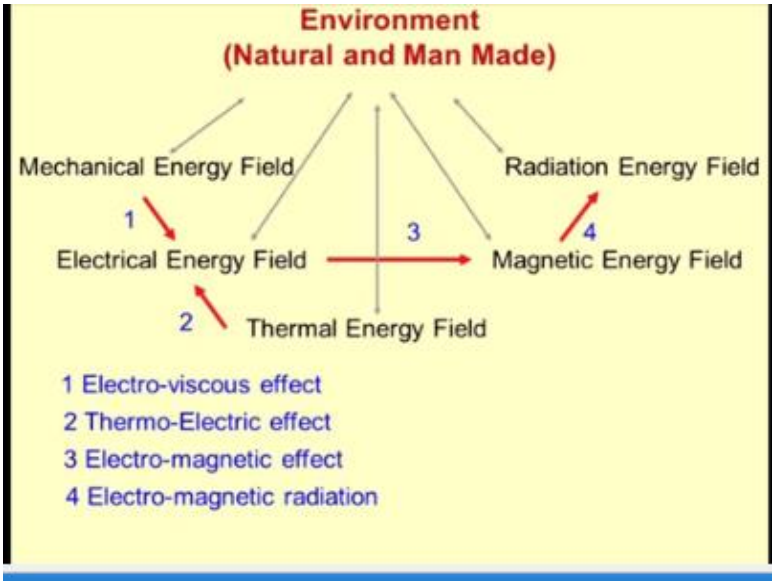

Just to show you, to sum up today's discussion where we are heading, we started with the environment, and this is where we bifurcated into 2 natural and man-made, and then we were trying to use these theories of particle energy field theory to get the answers to the real-life questions, clear. So, here you will observe that most of the processes which are happening in the environment can be clubbed or can be studied by either a single energy field or by a combination of the 2.

So, the mechanical energy field is well known, electrical energy field there is the interplay between the 2; mechanical, electrical, we call it as electro viscous effects, you are talking about the dissolution of the gases in the fluids and their rheology getting changed, then we can have a thermal energy field, which is also interacting or getting superimpose or coupled with the electro energy field, thermoelectric effects in soils.

Magnetic energy field, electrical energy field, magnetic energy field they are coupled with each other we call them as electromagnetic processes and then radiation energy field and magnetic energy field, they are also interlinked, we call them as electromagnetic processes. So, this is the future of environmental geomechanics, and when I say these energy concepts; these energy concepts will be beneficial in quantifying the processes, the mechanisms which occur in the geomaterials.