Environmental Geomechanics
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Lecture – 12
Energy Geotechnics

We have directly or indirectly talking about the introduction of the course; the scope of environmental geomechanics and in the previous lecture, I gave you an idea about what are the current trends in environmental geomechanics or the subject as such, and after listing several yesterdays of the hard topics, I picked up energy geotechnics which is the need of our, everywhere in the world the big crisis is how to hardness sustainable energy, go to the Western world 6 months of the year, the entire country remains no bound.

And imagine the amount of energy they required for refrigeration, heating up of their houses and infrastructure and so on, come to the countries like India where we have a temperate climate, again the energy geo techniques play a very important role, we have to talk about sustainable energy by which we can cool our infrastructure and the buildings, alright. So, imagine the parts of Rajasthan and Northern India which remain under severe heat conditions, you know for almost 4 to 5 months.

Now, this is where we have talked about what are the resources which can be exploited to generate more energy and I spoke about a discussion on nuclear energy versus thermal energy and then we discussed about the volume versus concentration concept and then, later on, I took that concept to quantify like how to solve this type of problems or the philosophies by using the idea of THMC that is thermo hydro mechanical chemical coupling.

And then this is where I also talked about THMCB; thermo hydro mechanical chemical biological coupling and how these types of coupling can help you in solving the issues which are related to production of energy and particularly, the nuclear waste disposal and post disposal you know, monitoring.

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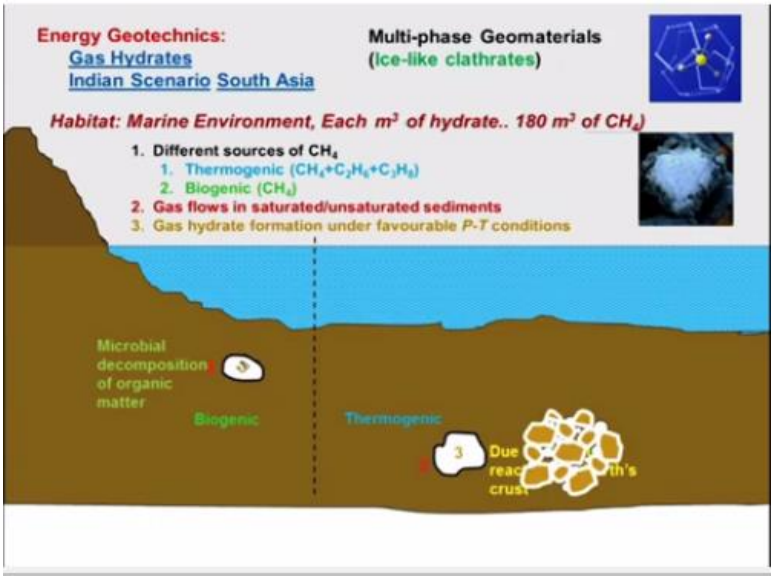

I will go ahead with this concept of energy geotechnics in today's lecture and to just give you an idea what was happening in the contemporary world and some of you who have already heard about the gas hydrates, I will discuss a bit about what these gas hydrates are, so I have provided link over here, if you click over the gas hydrates, you will get a lot of information about what is happening in the contemporary world.

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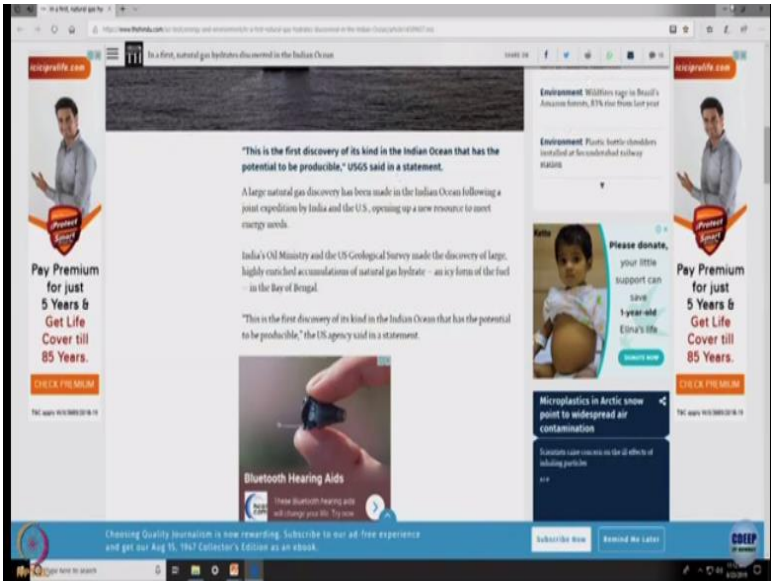

So, this is a clipping which shows in first natural gas hydrates discovered in the Indian Ocean, I mean like this is the source of energy in the days to come, and people speculate when the fossil fuel is over, this is the source of energy or this is the type energy which can be exploited for the

sustenance of the society, since it is an exciting report which you should go through, most of the time, these hydrates are available in the offshore regions or in the world body's.

And I will discuss in details about these type of structures in today's lecture in more information and what these structures have to do with the geomechanics, now as for as the Indian scenario is concerned, if you go through the current affairs, this is what is happening.

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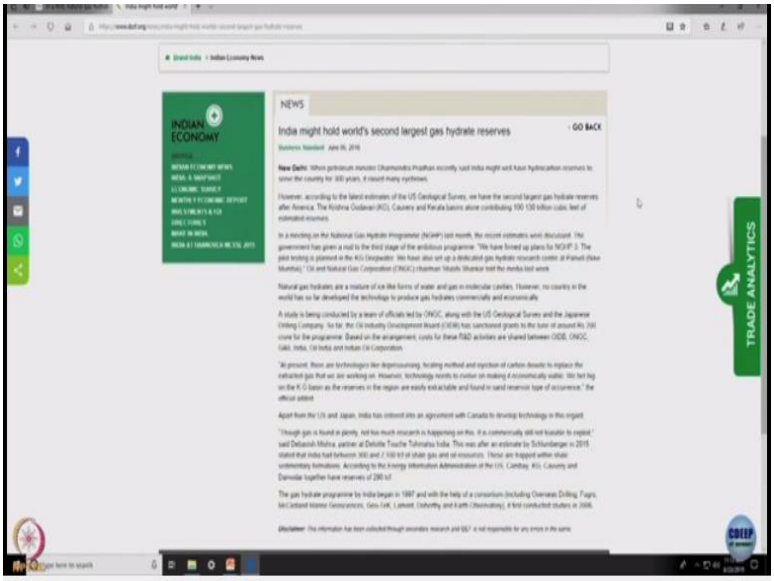

So, India might hold world's second-largest gas hydrate reservoirs, and this is excellent news, you know the region which has been identified are the KG Basin, Andaman area and north-east, so KG Basin is a very rich area in which the hydrates are deposited.

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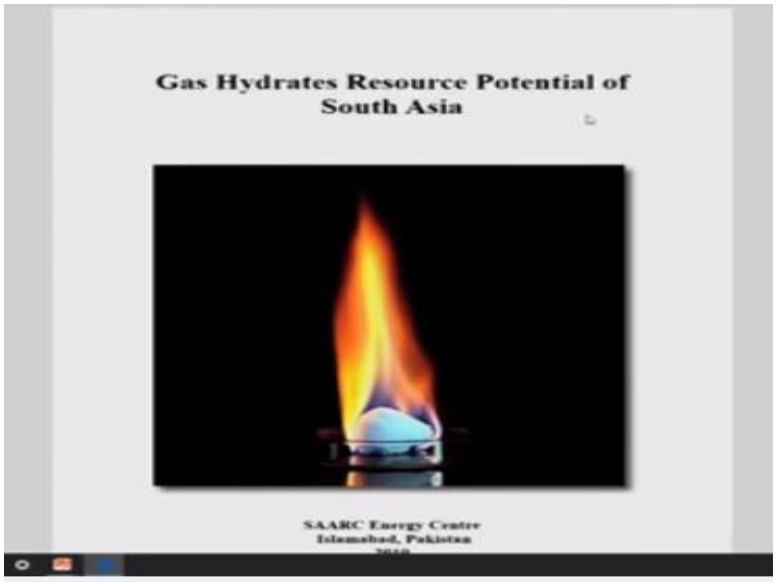

If you talk about the South Asia, gas hydrates are the resources and this is a very interesting document which is available on the net, this comes from SAARC energy centre, Islamabad, Pakistan, gas hydrate resource potential of the South Asia. Well, whenever you get time, you should go through this, this is how the hydrates looks like. So, if I expose it to the atmosphere, it catches fire because of the methane getting emitted in the environment.

So, basically what hydrates are; these are basically Ice like clathrates, this is how they look like, so what you will notice is that this is the molecule of methane, those of you who left chemistry, these are carbon attached with 4 hydrogen atoms, so these are methane molecule which gets trapped into water and because of the pressure and temperature condition, it gets trapped over there due to action of very high pressure and low temperatures.

We call them as ice like clathrates and truly speaking, this is a state of a material or a geomaterial which also is considered as a multi-phase, Americans would call it as multi-phase, alright, so many people are doing research nowadays on multi-phase geomaterials, multi-phase geomechanics. In conventional geomechanics if you remember, we have talked about only mostly started with 3 phases.

But then very cleverly, you brought it down to the 2 stages by saturating all the samples, so most of the test which you get in the laboratory were under so many condition, whether it is CBR,

whether it is hydraulic conductivity, whether it is shear strength, triaxial consolidation, you saturate the sample first for enough time, so that the air phase gets lost So, truly speaking, the conventional geomechanics does not capture the real life response of the geomaterials.

And keeping this in view, people have started working on unsaturated state of the material, they talk about the 3 phases and here we are talking about the multi phases, so the difference is we have solids, we have liquids and in liquids we have let us say water, we have gases, fluids, alright, a composition of the 2 and when you are lowering the temperature and playing with the pressure, the state of fluid may also get changed.

Very high pressures would cause dissolution of the gas, which is present in the pores of the soil into the liquid phase, alright. Similarly, a very high temperature; low temperature might change a certain fraction of the liquid into a solid phase, say water getting frozen in the pores partially. So, imagine a state of the material where you have soil skeleton, where you have little bit frozen water, you have completely frozen water, where you have no frozen water.

And then you have different type of gases, this could be fumes, this could be chemicals, this could be anything, alright, it could be methane gas, so this is the state of the geomechanics in the 21st century which people are trying to work on and these are going to be more realistic. So, whether it is an atomic waste disposal, which we are discussing the other day or whether it is hydrates; gas hydrates.

These are the good examples of how geomaterials when they come in contact with different environmental situations conditions they behave, in other words, the response of the material when it is exposed to different environmental conditions. **"Professor – student conversation starts"** Yes, please; Sir, is this methane trapped in ice like a crystal or like a crystal, solid crystal in an ice, no, gases cannot be crystallised, so methane molecules gets strapped into the crystal water, alright, okay, any other question?

So, I hope you have understood what is the state of the heart of the subject, yes, please, the geo mechanics as such, so somebody if I ask you to find out the compressibility of this type of

sediment which is the multi-phase sediment or what is the hydraulic conductivity of a fluid which is passing through these sediments or what is the shear strength of these type of sediments, clear, this becomes very, very complicated.

The simple thing would be you go out for the reconnaissance, so the way you, the way that geo-physicist were finding out the minerals location on the earth, same way you have to go reconnaissance in a ship and find out where these type of reservoirs are or sometimes if you check on the net, mid ocean fires, clear that is an indication that somewhere down below you have a reservoir of hydrates, so the methane gas is leaking and this catches fire.

And in the middle of the sea, you will find there is a big fire, alright. **"Professor – student conversation ends"**. So, these are the good indications, there are lot of people who are working on resources, so geo-physicist they were talking about location of water table, location of minerals, clear and now the shift is on finding out hydrates. So, where is the habitat of such type of elements?

These are marine environment, this could be lakes, this could be water bodies and you know wherever you have sediments so, each molecule of hydrate would be having 180 meter cube of methane gas; methane that means what is happening is as you are asking the more and more pressure which you apply on the system, the lower the temperatures, so many molecules of methane gas can be packed inside the matrix that once you take out the system and put it to the STP; standard temperature pressure condition, you can produce 180 meter cube of the methane gas.

Imagine that would be a most wonderful thing, so when you fill your car, you know diesel tank or petroleum tank, what is the capacity of the car diesel tank; it is nearly 27, 28, 30 litres, 50 litres, trucks would be about 200 litres, 500l litres and so on, for an aircraft it would be in 1000's of litres, clear. So, imagine one molecule of the hydrate crystal is capable of producing 180 metre cube of methane gas.

So, this is what is going to solve the energy crisis of the society, the cotemporary world, this is how they look like, like a cauliflower or a cabbage you may say, I will show you a lot of forecast today. So, what are the different sources of the methane gas; the first thing is; this is the question as you are asking.

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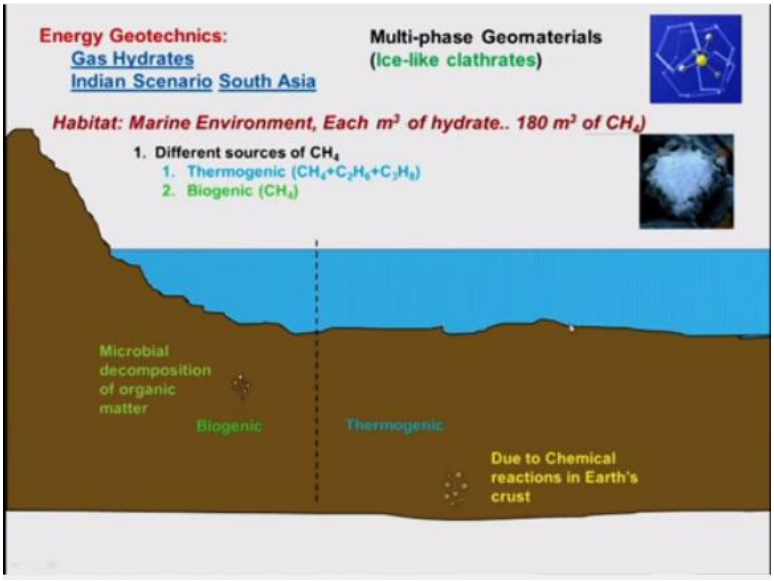

The second thing is the types of methane gas are 2; one is thermogenic, alright. Thermogenic corresponds to the situation which is due to the chemical reactions which are occurring in the earth crust, alright. Thermal processes; because of the temperature gradient of the sediments inside the sea, so what you are observing here is I have done an animation that the bubbles are coming out and this gas you know gets trapped into the sediments.

And under normal; sorry, not normal, under varied conditions of pressure and temperature, they will get trapped over there and they form hydrates. Normally, thermogenic gases are methane, C2H6, any idea, what it is; ethane, you are right, so C2H6 is ethane and C3H8, propane, perfect. So, all these thermogenic gases are methane, propane, ethane; it is a combination know, our interest is mostly in the methane gas.

So, I can produce the methane gas, I can bring it to the refinery and I can filter out all those things normally, this type of process occurs in the deep seas, so I have drawn a line over here which shows the depth of the water column, alright. So, under deep sea conditions normally,

thermogenic processes occur. The second situation which is known as biogenic methane gas, so biogenic methane gas is a pure form of the methane.

We will be more interested in biogenic methane because thermogenic methane would require some sort of a refinery and microbial decomposition of the organic matter which is present in the sediments is the main cause of biogenic methane production and I hope now you can realise that why most of geotechnical engineers like us are venturing into the you know, bio-geo interface. Now, what really happens when the sediments are attacked by the biotic activity; microbial activity?

So, this is a very interesting idea where people are trying to master becoming cross disciplinary, or inter disciplinary subject, where we have to learn a lot from biotechnologists, microbiology's and so on and to master the whole thing. So, idea is to trap these type of gases alright, now the whole realm of new or neo geomechanics starts clear, so some time back I said that I would very eager to know how much is the migration of these type of gases in the sediments.

So, until now you have been doing only constant head test, falling head test to find out what is the permeability of the water which is sitting to the sediments or the soils. Now, the situation is different, we are talking about gas migration through the sediments, alright and when gas migrates through a sediments, pressure temperature conditions are peculiar, microbial activities peculiar, so this is what has to be study.

Look at the wok which is done by my research scholar Dr. Jeevan, he is the faculty member at NIT Trichy right now and he is the one who has established the entire set of himself and he has done wonderful work on deriving the gas permeability through saturated soil, unsaturated soils under different environmental conditions, refer to his papers alright. So, this is the big challenge how gas flow occurs rather than only the fluid flow, you are talking about the water migrating through it.

Normally, the biogenic methane gas or the sediments are in the continental reefs, very close to the onshore, you know adjacent to the coastal area, so this is the differentiation between the types

of gases which you get. Now, coming back to your question, I can always take a sample and I can do different types of analysis including carbon dating to find out what type of carbon is present in what type of sediments.

So, this subject now becomes absolutely interdisciplinary and this is the future of the geotechnical engineering, alright, any other question? **"Professor – student conversation starts"** although sir, biogenic methane is in the purest form but I think its quantity will be far, far less than thermogenic form because of that we do not have that much organic matter in the sea bed, even near coastal bed.

No, no, no, never say this because you have ignored the organic matter, see, the marine clays typically have like I can have anything up to 90% of the organic matter and thus the reason no wonder why the liquid limit is so high clear, so I think you have mistaken, if you really want to understand a typical organic matter distribution in the clays, please read it on net and particularly, we have come across some clays, where we have more than 80, 90%.

No, quantity of methane is something like as long as the bacterial activity is there, it has to happen, because simple thing is when you ferment something, you know most of the pickles the way they have been formed, this is fermentation process and thus how they give a very different taste or you know ting in your tongue, when you put them. So, volumes are not an issue because reservoirs of these different side is enormous, imagine we were talking about the marine conditions, okay.

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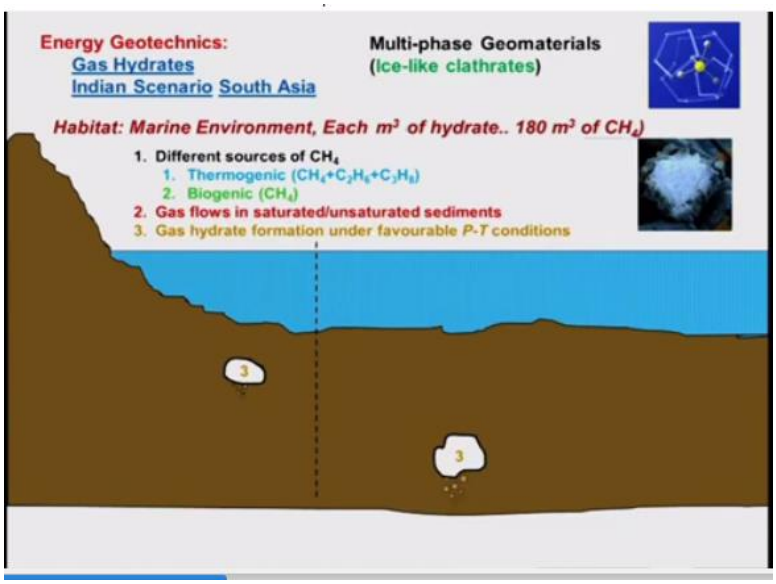

Any other question; **"Professor – student conversation ends"** you have to create when you do these type of test, different types of pressure and temperature conditions in the laboratory. So, I am happy to say that my laboratory is the only one right now in the country or may be in Southeast Asia also, we do not have many such facility you have, you can simulate and you can do testing of hydrates.

So, this is how we are very unique and very recently, we have acquired this environmental traction set up, we got it done ourselves and where you can simulate the conditions of pressure and temperature; varied temperature pressure condition and you can see how the sediments are going to behave and then later on, we like to find out their shear strength parameters and compressibility and the fluid flow and all these engineering properties.

So, Bhini is working on creation or synthesis of the hydrates in the lab condition and Lijith is working on the geomechanical stability of the sediments which I will discuss subsequently, so you follow the papers, which have been written by Bhini Rani and Lijith Nambiar from the literature we have published several papers, 2-3 papers.

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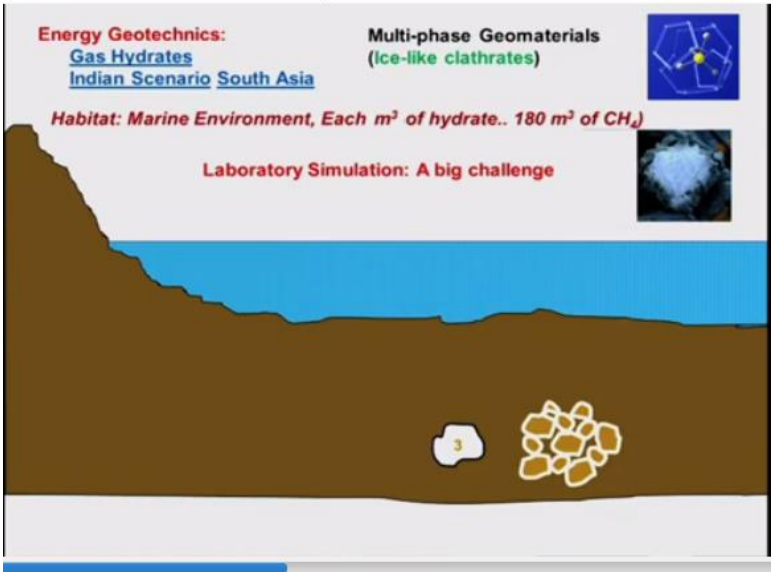

Now, it so happens that it is a very tricky interesting subject, so morphology of the hydrates would depend upon you know, the different types of freezing processes, so this is a subject which also deals with the interfaces with the frozen geomechanics. So, what I have shown over here is the morphology of the hydrates which governs the geomechanical properties can be understood like this.

This is the skeleton of the particles, sediments and if you look at the animation carefully, you will find that this is the pore filling you know, the crystallisation of water takes place in the pores and this is where the methane gets trapped. Now, these type of sediments are not going to very good load bearing sediments, I hope you can understand because the bridging between the particles is not so good.

And the permeability are going to extremely high as compared to the other situation which we call as load bearing, so what has happen? I think you missed this animation, some of you, so please do not write and see on the slides that is going to help you. So, you say, start from the pore filling, the further growth of the crystals is going to now be like this that means, the particles are getting cemented and hence the system will becoming load bearing.

So, this system would have higher bearing as compared to the previous one and further what is going to happen is; if I say cementing process, all the particles get cemented and they become

like cemented sands. So, these are the 3 mechanisms which people are trying to study and these are the conceptual models, you know remember in conventional geomechanics, you talked about a rhombic structure and cubic structure, if you remember, is it not.

This is how you visualise the entire granular material now, the same thing is being done over here with different mechanisms of the material and finding out of the response at different environmental conditions, hope this point is clear. So, a big challenge is how to differentiate between pore filling, load bearing and cementing processes and the way you talked in conventional geomechanics the moisture content.

Here, people talk about what is the gas content in the sediments, once the hydrates are formed, alright, so we call it as gas hydrate concentration and the shear strain properties are going to be a function of gas hydrate concentration and the type of morphology with the system is exhibiting, it remain same as what you have studied in conventional geomechanics as card house structure, flocculant, dispersed and so on, okay, is easy said than done you know, it is very difficult to simulate these type of situations .

And particularly, I would like to see inside what is happening inside the cells, you know how the system is getting altered from one state to another state and you can realise when you are working at such high pressures of let us say 30, 35 MPa traction pressures, you cannot look into the system because this is made up of a opaque still, alright but still people are trying to see inside and where you have to learn lot of biopsy.

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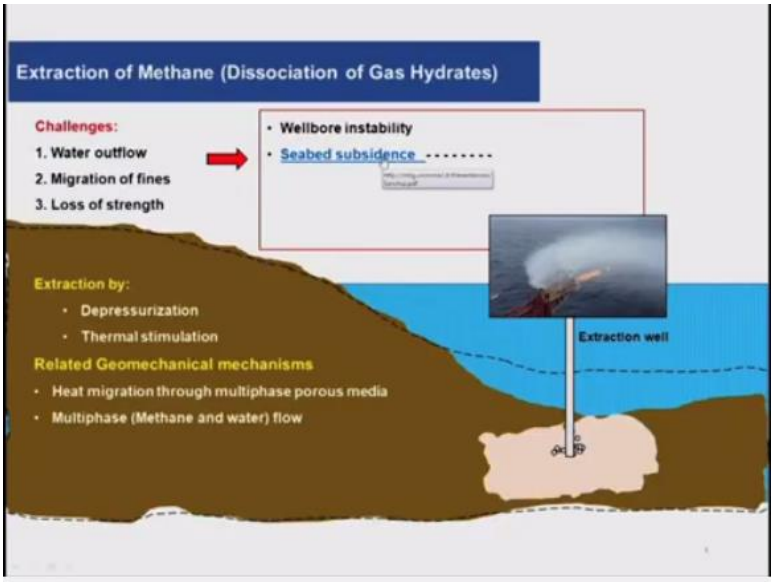

Now, look at this animation slightly carefully and this is where I have talked about the extraction process because after locating the places where the reservoirs are ultimately, you want to harness this energy, you want to tap this energy, you want to extract it from the ground is it not, from the sea bed, the way the petroleum is extracted. So, when you extract the methane gas, there are lot of challenges, you know the gas is going to get dissociated from the crystals which you are talking about, Lovinder.

So, the moment you bring it back to the normal standard temperature pressure conditions, the methane gas will liberate, this is what is known as dissociation, there is lot of science and mechanics behind this which you should study or you should attend the seminars by these guys. Ultimately, what I want is; I want to produce energy, so this is the hydrate and the moment you expose it to the environment, it will catch fire and it produces heat and this is the whole purpose.

So, most of the time, these expeditions are created by government of India, alright very expensive expeditions, the way there was a time and people used to go for you know Antarctic expedition, you must have heard about the scientist used to go there and they used to do lot research. Nowadays, mars, moon expeditions are going on, they are call it as a mission; I do not know what is the difference between mission and expedition.

Climbing up on the mountains is expedition is it not, so this is how it happens, so you know the place where the hydrate reservoirs are, you go in a ship and then lower down a casing, this is what is known as extraction well. How to design the extraction well itself is a big challenge, so what the Lijith is trying to do is; he is trying to simulate the whole process, I will tell you how. Now, once you start extracting something, first of all extraction cannot be done as long as the system remains in the frozen state.

So, what you have to do is either you have to dissociate it and for dissociation, you have to do different types of techniques, so extraction is by depressurisation; release the pressure which the system as got; if the system has because of the natural conditions and the natural conditions are because you have so much of water column, the depth of the sediments is big this much so, total height would be $\gamma_w \times \sigma_{total}$ not height.

$\sigma_{total} = \gamma_w \times$ water column + $\gamma_s \times$depth of the sediments, so this much pressure are acting on the hydrate system which has to be depressurised by allowing vacuum, so that the gas may come out. The second could be by thermal stimulation, remember the hydrates are at a lower temperature, so what you have to do is you have to go drill the well, put heater wires and heat up the entire soil mass.

Imagine, so just now you are asking about the volumes, now I am giving an idea that entire sea bed is to be heated up and once you heat it up, you are playing with the temperatures, so either you play with the pressure or you play with the temperature, you can liberate the sediments. Now, what is happening is once we are extracting something, I am sure you must have heard about you know subsidence process in geotechnical engineering.

So, the more and more water you extract from the wells or the aquifers, what happens; the entire system subsides, it settles, so most of the cities are setting you know, Thailand is a good example, the more and more mining you do the area is subsiding, alright so, these are the challenges people are trying to handle these days. So, coming back to the point when I do this depressurisation or thermal stimulation, the chances are that you know what is going to happen?

There will be a heat migration through the multi-phase system and this is how the entire thing gets liberated, so the methane is catching fire and the water is coming out during the extraction process, so there are coupled mechanisms which are associated with this. First is the heat migration into the system, once you are heating the sediments, you have to study what happens to the sediments when they get heated up.

So, later on in the course, we will be talking about you know, thermal properties of geomaterials, it is a big section which I will be discussing, I will be talking about electrical properties of the geomaterials, and that is the reason you know why we are discussing these type of topics in geomechanics because the live example is here, you have to heat the sediments to liberate the methane gas and then only you can utilise it for your purpose.

Remember one more exciting thing; now, we are talking about multi-phase porous media, alright so, we are not; the porous media is not divided of microbial activities, in conventional geomechanics, you never bothered about, we thought about only 3 phases; solids, liquid, gases, the microbial activity also comes, organic matter also comes in the play and whatever fluid force is taking place is a coupled phenomenon.

That means water and gases are travelling together through the porous system at environmental or sub environmental temperatures and pressures, so this becomes a complicated scheme. So, what is going to happen when you are extracting things, water will come out, and I am sure you must have heard in your conventional geomechanics, whenever discharge takes place through the body of the dam, because of the critical gradient was going to happen, quicksand condition or piping action will occur, clear.

So, the more and more water comes out, what it does; it takes out all the fines along with it so, this is what is known as washing out of the fines from the sediments. If the fines get washed out from sediment, what is going to happen; the voids of the cavities will get created, and the chances are that the bearing capacity of the system is going to decrease, hydraulic conductivity is going to increase, gas permeability is going to increase and so on.

So, look at the whole geomechanics is now changing, in the conventional geomechanics, you thought that everything is constant volume, inflow is equal to outflow, all the time you derive this, your control volume never deform here, we have all challenges so, migration of fines causes loss of strength, so all these problems are time and space dependent. Shear strain is a function of x, y, z and t; time, cohesion is a function of x, y, z and t, friction angle is a function of x, y, z and t.

Hydraulic conductivity itself is a function of x, y, z and t depending upon the fluid, whether the gas phase you are talking about or whether the fluid phase sorry, water phase you are talking about. So, this problem becomes very complicated which people are trying to solve right now, so these challenges lead to what; the first thing is the piping's and all whatever you have installed in the system you know, it gets unstable.

So, wellbore instability becomes a big issue that means, the chances are that the wellbore itself may become unstable, all the methane gas may bypass the extraction well and then what is going to happen; it will get liberated into the environment and if that happens, what is going to happen; greenhouse gas, are you realising, this is a very intricate and sophisticated process, you do not want methane gas to enter into the atmosphere because of the extraction process.

I am sure you must be getting an idea, these extraction wells are nothing but you know straws which we use for drinking the cool drinks from the cans or the bottles, the more and more you suck alright, what happens, we are applying negative pressure, inside the pressure was positive, high-pressure and then you depressurise it, or you apply a bit of suction, then you can suck all the gases.

So, this is something which people are trying to simulate in the laboratory including us now, when well bores instability occurs, this is one issue, the second issue is sea bed subsidence, I hope you saw this animation or not, you missed it, how many of you saw this; good, that is what I say there is no point in writing things, it should be all written in the mind, you know these are all the mechanics problems.

So, look at this again, so when you are taking out the fluids from this type of systems, what is going to happen; concentrate here, seabed subsidence, alright so the collapse of the sea bed takes place. Now, imagine whatever paraphernalia you have created on the seabed because of this collapse, it is going to get destroyed, so this could be a man-made disaster so, this is a subject which also deals with disasters associated with offshore systems.

In case, Tsunami comes the chances are; that this you know, there could be a dislocation of the sediments and the methane gas may get liberated into the atmosphere. Earthquakes; what is going to happen; because of the relative movement of the seabed chances are that if you have reservoirs along the slip line, the gases will enter into the atmosphere, and that is what causes mid-ocean fires.

So, these are the issues like if you have identified that these are the places where hydrates are, it is a good idea to extract them as soon as possible because now, sorry, nowadays, you have lot of Tsunami's affecting the system, you have earthquakes affecting the system, you have lot of human activities affecting the system, you never know tomorrow somebody might be putting you know offshore pipeline, cross-country pipeline for data communication.

Most of a fibre optic cables are running on the sea beds; I do not know whether you are aware or not, alright, so how Andaman's are connected with India; mainland India, read this all story. So, these are the geotechnical engineering jobs which people are into.

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Now, if you want to learn more about the sea bed subsidence and what it does; please read this pdf file, where people are trying to simulate these types of conditions. Santamarina is number 1 in this subject so, read the papers written by him and I wish some of you should get a chance to work with him in you know Saudi Arabia, he establishes his own lab, is what is known as American University of Sharjah.

So, mechanical and numerical modelling of gas hydrate-bearing sediments, this is what Lijith is working on, very intricate subjects, no doubt but very satisfying and very you know sure to contemplate a lot, to understand how things happen, yeah, Famy, you would have something to ask, no, alright, any questions. So, you read this text whatever is written over here, and you may get a feel of what is going on right now.

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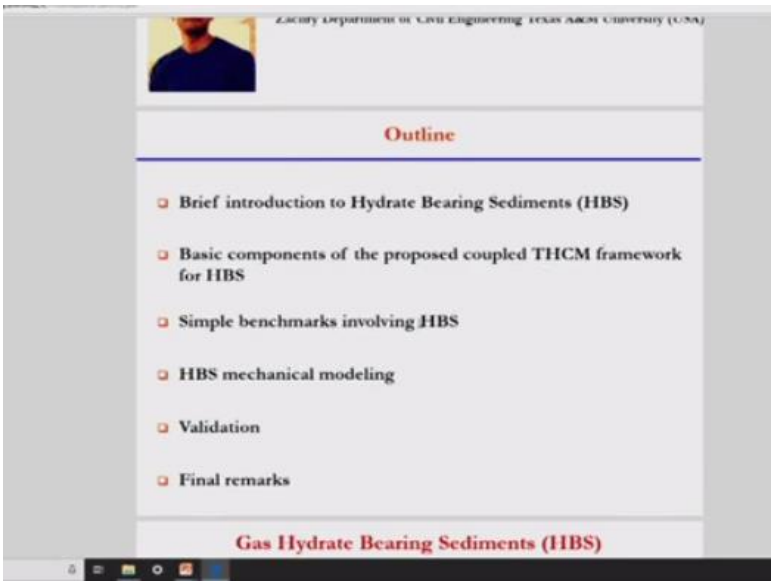

So, I hope you realise that again THMC or THCM is coming into the picture, these are hydrate-bearing sediments and worth reading whenever you get time, alright. Lijith has published an interesting literature, review paper on geomechanical aspects of gas hydrates, very recently over 3, 4 months back, okay. So, moving on to the discussion; when water flows out of the sediments migration of fines occurs, loss of strength occurs, wellbore instability takes place, seabed subsidence occurs.

Foundation instability occurs, so the rigs which have been installed on the seabed are bound to collapse and as I discuss uncontrolled methane release is going to cause a greenhouse effect, alright. How does the whole story appear to be; Srikanth, I think I have exposed to a completely different realm of geomechanics today. Yes sir, interesting yes, very interesting no doubt but apart from interesting, worth learning, yes and quite intriguing, very difficult to handle those samples at the conditions which prevailed in the ocean beds.

But I wish that people like you should be working and contributing in these areas which are the most recent areas of geomechanics, **"Professor – student conversation starts"** any questions, yes, please, the 2 methods of extraction is like you told it is depressurisation and thermal insulation and how we will find which is more suitable, what is the difference between sorry; well, you have no this of me, not you.

So, yeah it is an excellent question you are asking that how would you make sure that whether depressurization works or thermal stimulation works, most of the pumps which are available in the market they produce positive pressures or negative pressures, sorry sir, most of the pumps which are available in the market, they produce positive pressures or negative pressures, answer this question, if you can then your first question is answered.

So, the idea is how much suction you can apply, imagine, you know a simple thing what you do; you take a dropper, and you press it and put it in the ink bottle and release the suction, what is the height of the water column which you get in the dropper ultimately, so certain few centimetres, it is very difficult to make suction pumps, very soon you will realise that negative pressures cannot be created by pumps.

But look at nature you know, it has produced different types of varieties of cactus which can survive in deserts also, how come, they can lift water up to 220 meters deep also, so this much pressure these plants can apply, so all the plants which are living in the arid regions they can apply so much of suction on the soil to take out the moisture, very interesting geomechanics subject, hope you will realise.

Ultimately, the entire thing is moisture migration through porous media or vapour migration through porous media, so depressurisation is a difficult task and where would you install these type of big, big pumps on a boat or in a ship step and that too you are lifting it from a depth of 200, 250, 110 meters, imagine, clear, so this is a big question, number 2 thermal is very easy to write on the piece of paper that does thermal destabilisation.

And just now I said what you have to do is you have to insert heater wires in the ground and you have to heat it, in the middle of the sea how would you do all these things, how much area of the soil can be heated, so what is the conclusion, what is your answer, what is that you are going to recommend? So, if you point a consultant who is an expert from Japan who are already into the production stages, they will charge you what fortunes, India cannot afford.

So, what they have to do; Indians and developing nations, they have to develop their own technology, nobody is going to help you, so this question is in everybody's mind what should I do; a or b, unfortunately, there is nobody to give the answer, as a nation you have to decide what should be done, do more R and D and then people like you should answer after few months, years that well, this is what is valid for KG basin.

Because they're the type of soil is this, depth of water column is this, the pressure-temperature condition is this, go to Andaman, the pressure conditions are different, types of soils are different, so one medicine cannot be used everywhere also, are you getting the complexities and ideas, so this is the trade-off between a and b, I do not know which is going to work. So, in the laboratory, we are still in a stage where I want to synthesise them first.

Because imagine another problem is I have to bring out a sample by UDS from the sea bed, first of all, it has to be a specialised UDS, where after taking out the sample also, the pressure-temperature conditions remain constant, transporting them to the lab, then you should have a facility over here which again can assimilate the sample under that pressure-temperature condition, these are very, very expensive experiments.

And more than that, exploration itself is expensive, find out the cost of each exploration will the government of India has done until now, alright and this is the might of the nation, nobody is going to help you why; they want to sell things. So, if I have developed a technology, I like to see it to you rather than help you out in developing the technology, are you getting this idea, so this is a good question, keep thinking like this.

But then more than thinking, you have to work and you have to get a solution, so that people can utilise it, is this, okay, so yes, please, one is to simulate the; it is okay, yeah, yeah it is okay, fine, one has to simulate the conditions in the lab, how do you give this result, 200 meters, so how do we create that 200 meter, I know the pressure conditions over there, I know the temperatures also I can do different types of investigations.

Try to read on this what type of investigations are done to establish you know offshore reconnaissance to establish the thermal regime and pressure regime and to establish what type of x-ray's are done in the deep wells, I just gave you an idea about endoscopic camera's, you can lower down the camera, then you can see what is happening in the intestine, so you can see over here also.

So, this interesting area is you know, very intriguing, is this okay, while depressurisation will there be a; how we deal with the problem of cavitation's; cavitation's of; while pumping, the negative pressure may reach to; in the pipe or in the reservoir; in the pipe, so that I can control know, so in your fluid mechanics course, you must have studied, what causes cavitation; total pressure head, so that can be regulated that is a pipe flow.

But your question can be more complicated imagine; this pipe is also a part of the frozen sediments so that is a very big challenge that how fluid will pass through the frozen conditions of the steel casings and the pipes. So, there are a lot of people, mechanical engineers who work in this area; they try to see what is the transmissibility of the gases through sub-ambient temperature conditions, I hope you are getting the point, okay, check it out on net after you go to hostel today or tomorrow.

Good, what message you are getting; bigger picture, apart from environment and geomechanics course, are you getting a message, what is the message you are getting, anybody, first of all the country is expecting you to give the answers to this question because there are not geotechnical engineers in the world or the country, so you are the people who are supposed to give the answers to the ministries.

When, you know, your petroleum minister asks, say question in the Parliament what is happening to a program of hydrate modelling, so they will ask, they will send you a question mark, question, parliamentary questions, tell what is happening, all these happen, we are a part of this. So, many times your subject does not remain the books and the papers, it has to be delegated to the national activities as well, alright, anything else, sure, okay.

"Professor – student conversation ends" So, you know when you do the extraction, there is a possibility of triggering tsunami's. Also, these are man-made tsunamis, geohazards if you remember you are talking about, so any type of collapse of bed might result into a waveform, creation of waves and depending upon how much volume of the sediments is getting destabilised that much would be the surges which we are going to create, okay, sorry.

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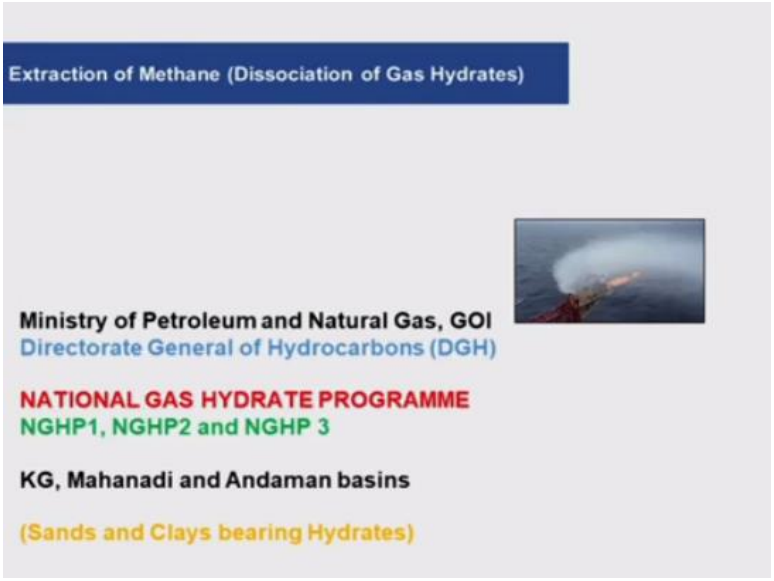

Alright, so, these type of expeditions have been taken up by Ministry of petroleum and natural gas, the government of India, I hope you are aware of what is going on in the world these days and this is the special directorate of; directorate general of hydrates or hydrocarbons which is known as DGH until now, there have been 3 expeditions; one is NGHP1, NGHP2 and NGHP3 and this is what is known as national gas hydrate program.

And they are heavily dealing with the sample collection and on-board testing on the ships and the regions which have been identified in Indian margins; we call as it is a KG basin, Mahanadi and Andaman basins, clear and it is very interesting to see that the types of soils which you get are totally different, so people who want to study the gas hydrates; Indians, they have beautiful natural laboratory waiting for them and you just go and start your career.

So, coming back to the point we have been talking about energy geotechnics, I have taken you too much into the intricacy of the subject, and I have given you an idea about you know how

these type of problems can be studied and sorted out under the realm of multi-phase geomechanics, so you have to deal with a lot of chemical engineers, you have to deal with petroleum production scientists, reconnaissance guys, petrophysicists, government officials definitely.

Fluid flow, gas flow, condensation, cavitation, subsidence, mineralogy, biotechnology, because they are the guys who will be telling what type of bacteria you have and what type of gases are going to come whether it is feasible and useful to drill over here or not if you are having more of you know pentane and butane and whatever, so this is of not much of use, I want the atmospheric methane gas, okay**. "Professor – student conversation starts"** how deep the subsidence can be, sea bed subsidence, how deep can be?

I mean, it is a question I think I answered just now sometime back that it depends upon the thickness of the sea bed, so suppose if I ask you a question, how much the one-dimensional consolidation would be marine clays in Kerala, you construct a building, you remember the Cochin case next to the Lulu building. So, what happened; the entire building settled down and then the first floor and a second floor, they were the part of the basements.

So, this is a un-deterministic process depends upon so many parameters, may need the thickness of the sediments and how unstable they may become, I hope you are aware of the fact that one-dimensional consolidation theory of terzaghi it cannot predict very precisely how much marine clays get consolidated. **"Professor – student conversation ends"** I might show you some examples, where I have seen 2 meter, 21/2 meter of settlement in the preloading stages.

Right now, I am doing a lot of work for it, Indian railways in the coastal region and there the settlements of this order, so subsidence could be 100's of metres, so if 100's of meters of subsidence is taking place, look at the height of the tsunami which is going to create that is the logic. **"Professor – student conversation starts"** what is the fact on the marine life, did they also study that thing like?

Yeah, so I am sure ONGC and there is something known as IEOT; there is the laboratory at Panvel you know, they talk about all the subjects but you have to pick up our subjects which is geotechnical, geophysical modelling and geotechnical modelling and all those things rather than going into the details of the marine life and aquatic life which is the job of maybe scientist who is dealing with fisheries and offshores environment.

Sir, at the time of extraction, can we like extract the methane directly from the gas objects, that is the whole idea because you cannot process it, so just like you know, many times what you do; aquifers or geysers; you know geysers, natural geysers, so you just puncture over there, and the water comes out, something like that, so this is what actually we will like to have, so you just put a drill casing, destabilise the hydrates, regulate the flow by putting some valves and all.

And then you get the direct gases that are what is the production process is and in the process, you get the freshwater, so you can fill up your mineral bottles in the offshore environment, imagine, so two industries you can run together. In the offshore environment itself, we are getting the freshwater H2O, the molecular water; this is what we are planning at a landfill also by the way. So, for me, these situations are universal, they may exist in the offshore, and they make in the landfill.

So, in landfill also, if I just like open the bottle of a drink you know, what do you want to do; you want to take out all the fluids, so for me, the landfill is nothing but a container in which the entire thing is contained inside, and I would like to extract only one phase of the fluid, this is what is known as selective filtration of fluids, it is an interesting subject in chemical engineering with which we are trying to learn as a geotechnical engineer, why?

The hydraulic connectivity of the water and the hydrocarbons and the gases is going to be different; I can regulate so, for me, the landfill becomes an industry, the ocean bed becomes an industry, and I will be able to take out only one phase or otherwise, I can have separators, you must have come across in chemical engineering courses. So, there is a mixed air contaminated; I want to separate out oxygen, carbon-di-oxide, nitrogen, and so on.

So, they use separators, see present-day science and technology is different, you cannot be myopic that this is what I am studying, the first thing is you have to train your mind to think multi-disciplinary, I hope you can realise, I give so many examples is it not, suppose, somebody comes to you for a consulting that in a basement of a mall; shopping mall, the beautiful problem which I was dealing with sometime back.

There are lots of cars which are parked and most of the times, these car's engines remain on, why; because the driver sit in AC room; AC cars, they do not put off the engine, so fumes getting emitted in the entire area, imagine and the whole thing is getting saturated with these fumes, and that is why they say in a stationary car, you should not put on AC's because CO is maximum, so if you do not flush out all this into the atmosphere, what is going to happen?

Now, why geotechnical engineers required to solve this problem, we will discuss this later on, though this is the pollution of the air, but geotechnical engineering plays the very important role here, my materials can be utilised to sorb different types of gases, yes please, Sir can you please explain that process which took place in the steel can, the extraction of gas hydrates when impedance and or comes into the picture, impedance; yeah.

Those are the tricks to see what is happening inside, so that is the reason we will be talking about electrical properties of geomaterials in details, how electrical properties, the thermal property should be utilised to sense something, to see something, to visualise something, to feel something, to quantify something, clear a process, yeah, is it possible to protect the sea bed like when we take the methane, replace it with something such as; yeah, very good, excellent.

So, that is what sequestration is; you do simultaneously two processes, sir is it possible, why not, so there is one inflow, one exflow in the system, balance the 2. **"Professor – student conversation ends"**.