REMOTE SENSING FOR NATURAL HAZARD STUDIES

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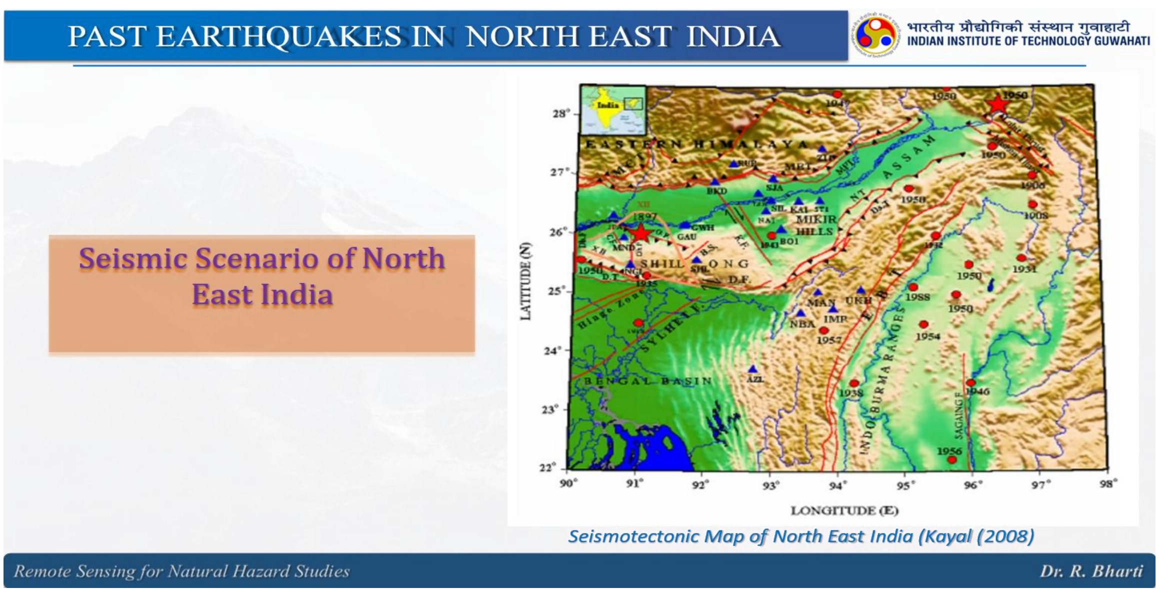
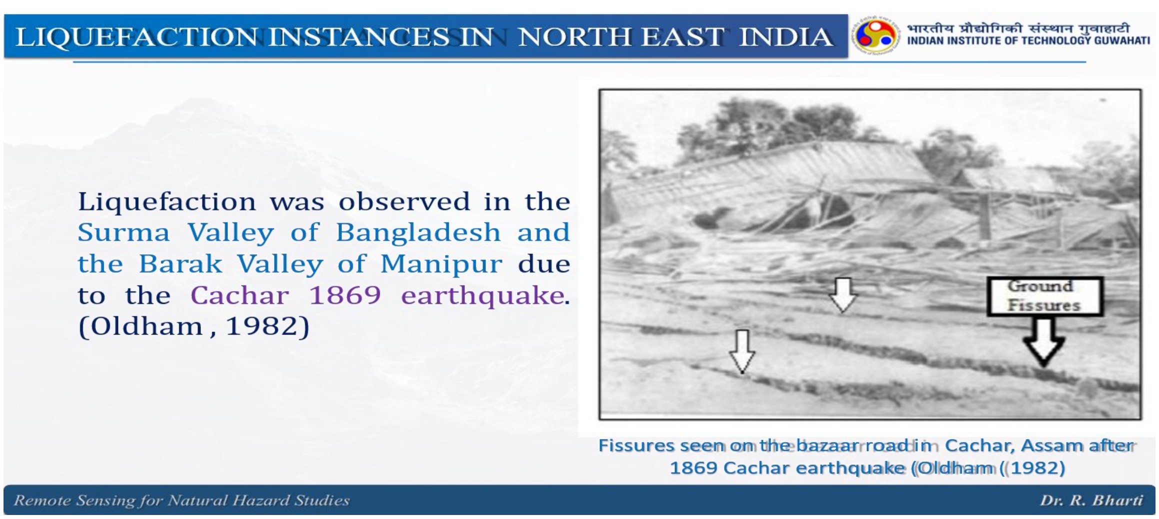
Lec 31b: Introduction to Liquefaction-Part B

Hello everyone, welcome back to Part 2 of Lecture 31. So, today we have started module 9, and this is the second part. So, in the first part, we have tried to understand liquefaction, how it happens, why it happens, and now let us understand the effects of liquefaction. So, here you can see that the effects of liquefaction are excessive strain, foundation settlement, bearing capacity failure, flotation of structures, and lateral spreading. So, you might have observed this in the earlier slides; in part 1, I showed you one video. And it was very clear that structures were floating. That means it gets tilted when the soil loses its shear strength. Then, lateral flow loss of support, loss of lateral support, loss of bearing support.

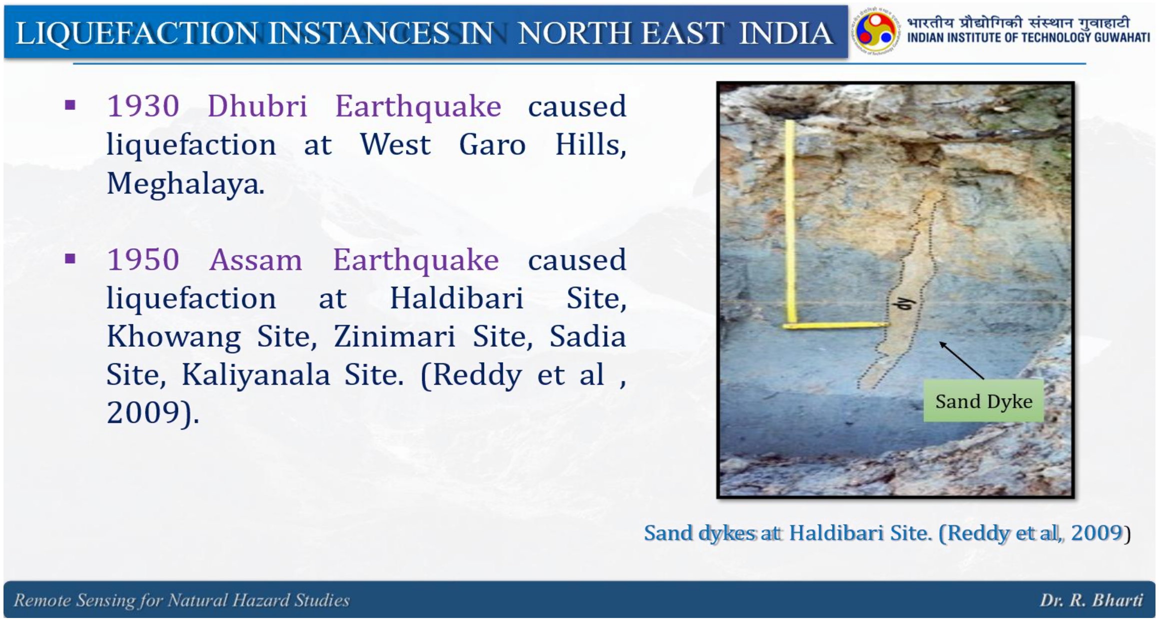


These are the effects of liquefaction, and this is the map that illustrates the seismic scenarios of Northeast India, and this is from the paper by Kyle (2008). It is this seismotectonic map of Northeast India, and here you can see all these points. So, it says that the tectonic activities are happening in Northeast India. For more details, you can refer to this paper, and you will get the legend and everything. When we talk about Northeast India, it is in seismic zone V. In the north, the Indian plate is subducting under the Eurasian plate. In the east, there is an eastern collision subduction Indo-Burmese zone. Then it has a strike-slip fault along Docky in Shilong, which is in northeast India. In addition, there is a Bengal basin and a Tripura fold belt. So, altogether, it makes sense. Seismic zone V, and here you can see how it is moving because of continental drift, colliding with the Eurasian plate, which leads to the formation of the Himalayan ranges. So, this map shows views of India's northward movement towards the Eurasian plate through time. So, here you can see that the time is also given. When we talk about the earthquake activity in northeast India, here is the list. So, you can see the earthquake's date, magnitude, epicenter, and reference.

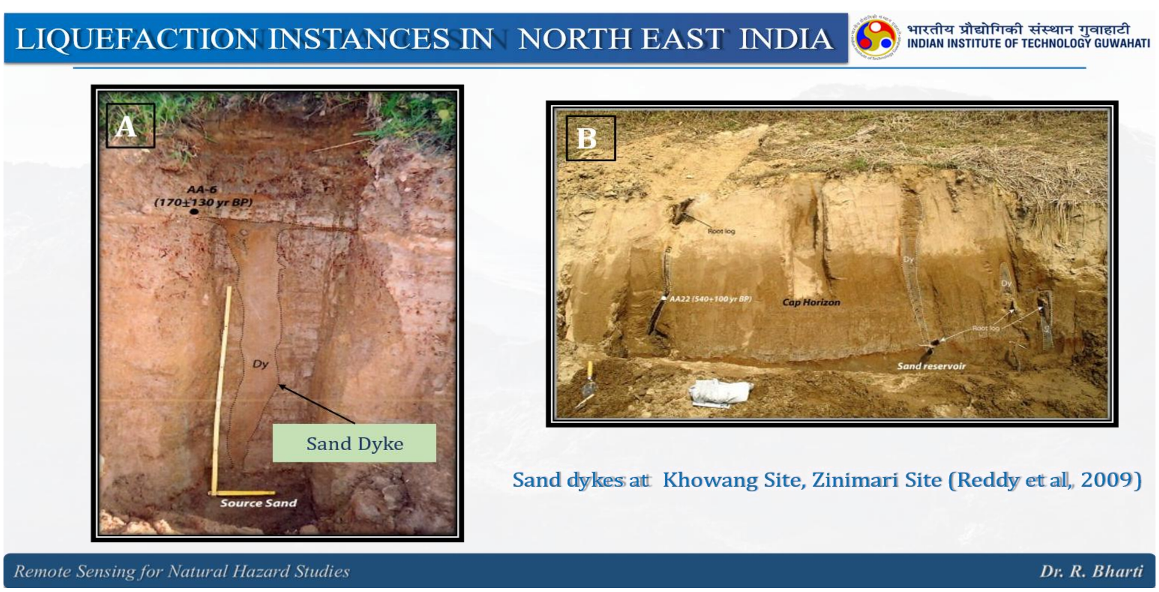
So, these papers explain the earthquakes. In the year 1869, the Kachar earthquake occurred on January 10th with a magnitude of 7.5. This is the 1897 Assam earthquake, which occurred on 12th June, and the magnitude was 8.1. Then we had the 1923 Meghalaya earthquake on 9th September, and the magnitude was 7.1. Then we had the 1930 Dhubri earthquake on 2nd July, and the magnitude was 7.1. Then we had the 1943 Assam earthquake, and the magnitude was 7.2. Then we had the 1947 Arunachal Pradesh earthquake, which occurred on July 29th, and the magnitude was 7.7. Then, subsequently, the 1950 Assam-Tibet earthquake occurred, which had a magnitude of 8.6, followed by the 1984 Silchar earthquake, which had a magnitude of 6. Then, the 1988 Indo-Myanmar border earthquake measured 7.8. So, these were very devastating earthquakes; when there are more than 4, we consider it to have a huge impact on the structures of mankind. So, in the 2009 Assam earthquake, we had a magnitude of 5.1; then in the 2016 Imphal earthquake, we had a magnitude of 6.7; and recently, we had the 2021 Assam earthquake with a magnitude of 6. So, this explains that the northeastern part of India is under seismic zone 5, and because of the different features present around this area, it makes it very vulnerable.



So, liquefaction was observed in the Surma Valley of Bangladesh and the Barak Valley of Manipur because of the Kachar 1869 earthquake. So, here you can see the fissures in the ground that were observed, and this was reported by Oldham in 1982.

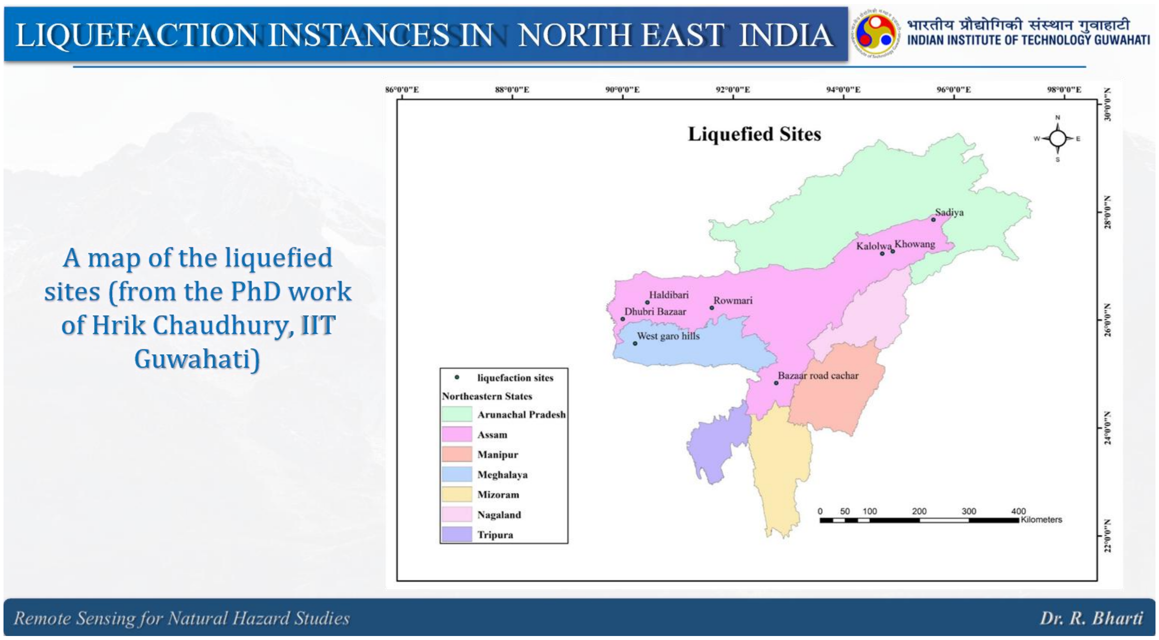


Then came the 1930 Dhubri earthquake. It caused liquefaction at West Garo Hills, Meghalaya, and again in the 1950 Assam earthquake, which caused liquefaction at the Haldibari site; here you can see this map, which shows the sand dikes. So, this is from Haldibari from the 1950 Assam earthquake, then sand dikes at the Khoang site, and this is from Reddy et al. 2009. So, here you can see that they have nicely marked the boundary.



So, this is for the sand dikes; here you have the sand reservoir and cap horizon. root log.

So, these are nicely captured in this photograph. Then Kalyanala site is again from Ready et al. 2009, and here you can see the presence of sand dikes, and this is the source sand. So, how is it getting reached here? So, due to the recent Assam earthquake in April 2021, ground fissures were noticed near Sonitpur. So, here you can see this fissure that was identified, and here you can also see that this is very fine-grained soil. which is not present in the surrounding area. So, this is from Sonitpur; this ground feature was identified. This is the scenario of liquefaction in Northeast India.



So, this is from one of my PhD students' works, Hrik Chaudhary, and here you can see that Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura are highlighted with different colors. And here you have these liquefaction sites. So, when we talk about this factor governing the liquefaction potential, we need to understand these parameters. The first factor is the earthquake intensity; then, what was the duration of the earthquake? Because if the intensity is high and the duration is short, that also causes damage. But if the intensity is low and the duration is long, it will also have a major impact. If the intensity is low and the duration is low, then probably we will not have that much of an impact, but we need to understand both the intensity and duration when we are talking about the liquefaction potential study. So, we have the next parameter, which is the building load. What is the load on the soil in the top layer? Then, what is the condition of the groundwater table, because subsequently, that will interact with the soil column, and it will lose its cohesion? Then comes the depositional environment, which was the environment of deposition, aging, and cementation of the material, the top layer of the soil column, and then you have the rock. So, subsequently, what is happening with the cementation? What kind of cementation is present, then, confining pressure? Drainage condition: Is there any other way of bringing the water into the soil column? Then you have soil types because different types of soil have different behaviors. They have different engineering properties. So, they will have different shear strengths.

FACTORS GOVERNING LIQUEFACTION POTENTIAL

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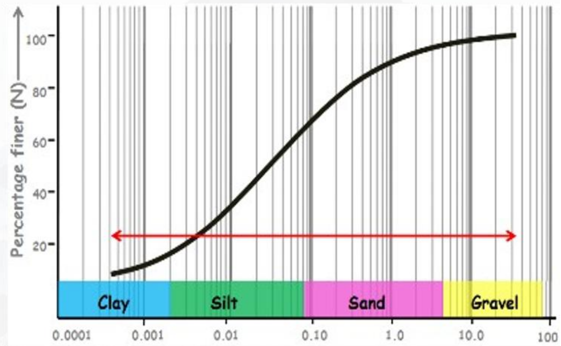
Soil Relative Density:

- Soil having low relative density signifies that the medium already has very low resistance. In such a scenario, liquefaction triggers quickly.

Particle Size Distribution:

- If different size particles are present, then pores between bigger particles can be occupied by smaller particles. It will be densely packed. Same-size particles will have voids. This triggers liquefaction quickly.



Particle Size Distribution
(https://www.elementaryengineeringlibrary.com/)

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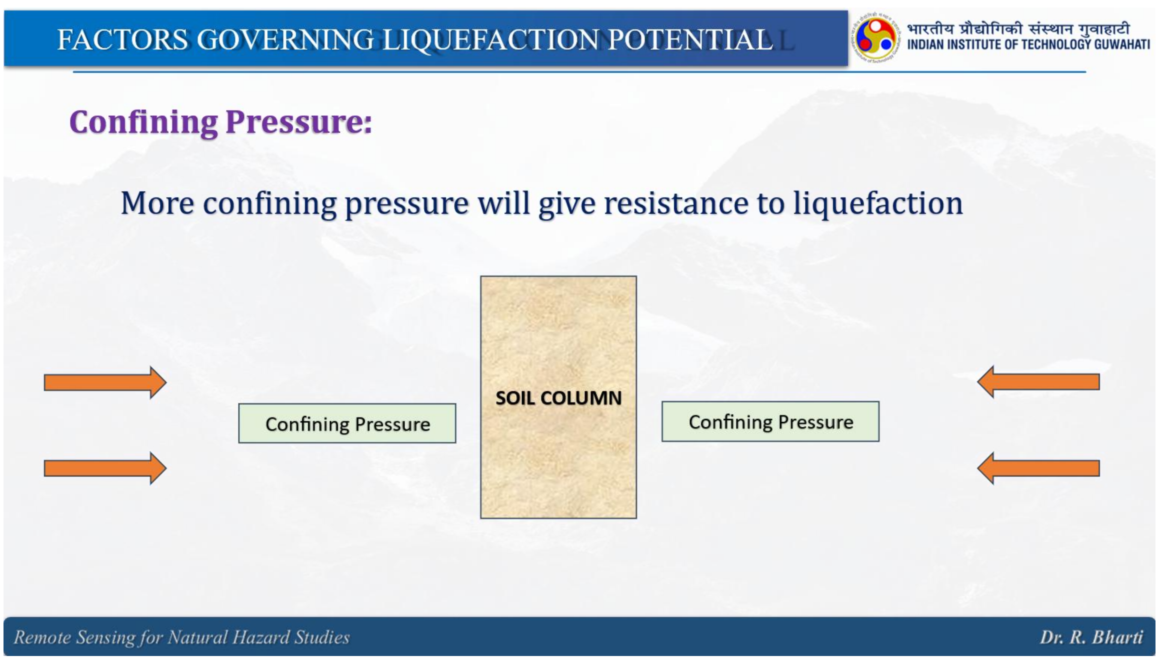
Then, soil relative density and particle shape influence the shear strength, as particle shape also has an effect. Then, particle size distribution and all these factors, in a combined way, contribute to the chances of soil undergoing liquefaction. So, this is how we analyze the liquefaction potential of a particular soil column. When we talk about earthquake intensity, the application of external loading, such as earthquake loading, triggers liquefaction; hence, the more the intensity there is, the greater the chances of liquefaction.

So, intensity is one of the parameters. If the duration of the earthquake loading is significant, then the particle conditions also degrade for repeated loading and pore pressure generation, which will trigger liquefaction. And, as we discussed earlier in the previous slide, the greater the chances of liquefaction are triggering. Then comes the most important parameter, which is the groundwater table. The liquefaction phenomenon very much depends on the pore pressure generation.

If the groundwater table is at a significant depth, then there is no scope for pore pressure generation. But if the groundwater table is near the surface, then you have a high chance of liquefaction. Then comes the soil type because when we have different types of soil, clay soil, peat soil, sandy soil, silt soil, chalk soil, and loamy soil, they have different engineering properties. So, the cohesionless soils are prone to liquefaction, as we also understood at the beginning of the first lecture. If the soil is plastic, that would mean the innate cohesion gives resistance against liquefaction.

So, if the soil is plastic, then the inherent property of cohesion will provide resistance against liquefaction. Then comes the relative density; the soil having low relative density signifies that the medium already has very low resistance. In such a scenario, liquefaction triggers quickly. When we talk about particle size distribution, if different-sized particles are present, then bigger particles can be occupied by smaller particles, resulting in a densely packed structure, and the same-sized particles will have voids. This triggers liquefaction quickly. So, all these parameters have a direct impact on the liquefaction potential of the soil column; therefore, the shape will also have an impact.

You can see the clay and sand. Then, aging and cementation particles kept for a significantly longer duration will experience cementation and natural packing due to several hydrological processes that will resist liquefaction.



Then, when we talk about the confining pressure. So, here you can see that this animation, the more pressure confined, will give resistance to aging. Liquefaction occurs because there is no scope for dissipating the pressure. Then comes the drainage conditions. So, if the drainage conditions are good, then the pore pressure generated can be dissipated easily, and liquefaction can be avoided. When we talk about the depositional environment, it also has a significant role. Soil deposits close to a river will have a high groundwater table and the same particle size, which increases the chances of liquefaction. So, under different environmental conditions, the same soil can have different potentials for liquefaction. So, here you can see that this is the same video because it nicely explains the liquefaction theory. So, you can just go through it again.

So, here are three factors required for liquefaction to occur: loose granular sediment, water-saturated sediment, and strong shaking. That means the seismic activities occur when you have loose granular sediment here. The interaction with the groundwater occurs at the same time as when you are experiencing seismic activity. What happens? There will be a release of the pressure, and this soil column will start failing. So, this is the actual scenario of San Francisco; with this, I will end part two of liquefaction.

So, here you can see I have listed the references, and if you are interested in going into detail about my contents, you can refer to these papers, and you will get all the details.

Thank you very much.