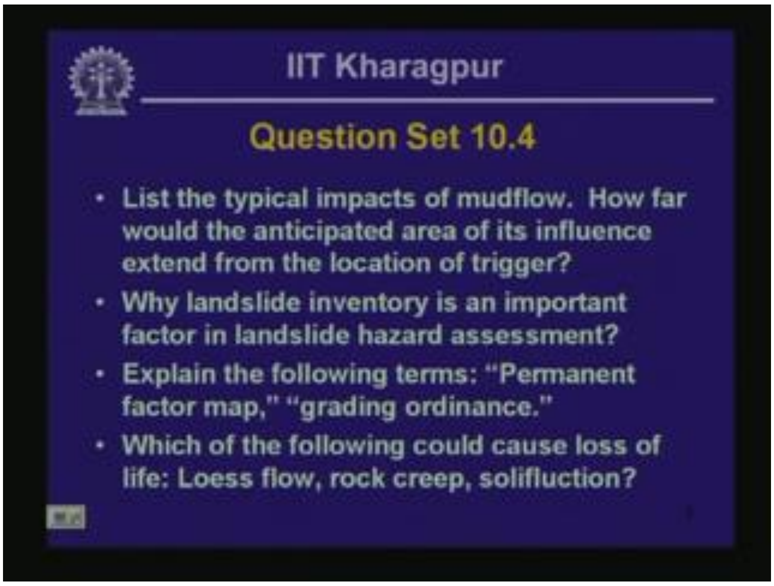
Engineering Geology
Prof. Debasis Roy
Department of Civil Engineering
Indian Institute of Technology, Kharagpur

Lecture - 37
Geologic Hazards – Subsidence, Collapsible & Expansive Soils

So, today we are going to talk about geologic hazards related to subsidence and those related to expansive and collapsible soils.

(Refer Slide Time: 01:04)



Now let us look back first at the question set of the previous lesson. These are the questions. In the first one, first question I asked you to list the typical impacts of mudflow, how far would the anticipated area with its influence is expected to extend from the location of the trigger? There are two parts to this question. So, to answer the first, part mudflow really is a very fast landslide, and as a result, typical impacts of mudflow could include damage to property, infrastructure or even loss of life.

Now to answer the second part, mudflow essentially involves flow like behavior of soil material, and in this particular instance, the soil that flows actually behaves like a viscous fluid, and it flows to a great distance from the location where the flow is triggered. So, you could easily expect the impact of mudflow to continue down gradient from the location where the slide is initiated to distances of a few kilometers.

Second question was like this. Why landslide inventory is an important factor in landslide hazard assessment? Now the thought in this regard is like this that if an area is prone to frequent occurrence of landslide or there are very many instances of landslide in recent past in a given area; in that situation, you would expect that similar unstable behavior to continue over the next few years in the near future. So, that is why if you get an area, you can ascribe a large number of landslides in a given area, then that area is likely to be more landslide prone than other areas, where only a few landslides occur over a reasonable length of period in the past.

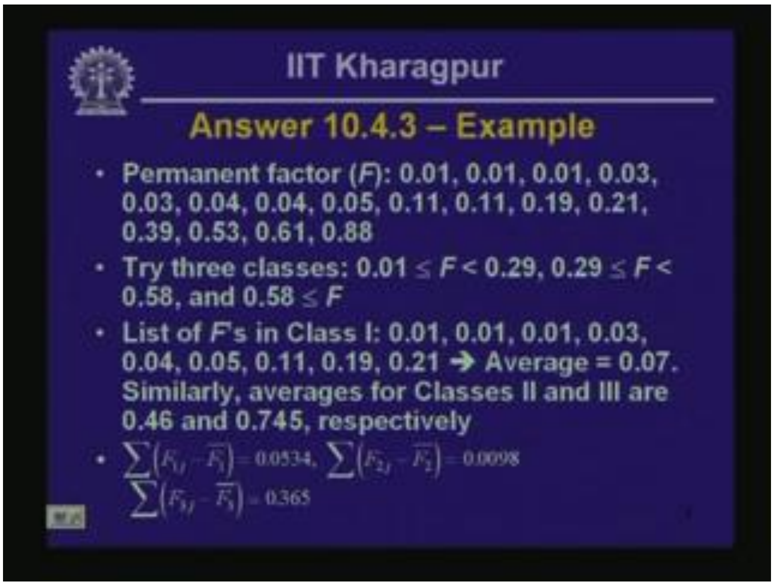
Now the third question that I asked was for you to explain the terms permanent factor map and grading ordinance. In permanent factor map, what you do basically is to actually prepare a map of relative hazard of landslide in regional scale. And in order to prepare that, there are certain steps followed, and I am going to just quickly take an example in the little bit to illustrate the steps involved there, but before that let me finish up with the other questions.

So, the next part of this third question was what is grading ordinance? In grading ordinance, generally the local government passes a local enforceable guideline that actually limits the limits the possibility of doing some excavation or steepens some slopes in a given area. So, you cannot at your own will excavate or alter the geometry of a slope within the jurisdiction of the local government which introduces such grading ordinances; however, this type of thought is quite rare in India, but I am sure that as more and more awareness comes into the technical community, the thought process is going to also get guided in this lines as it is in other developed countries

Now the fourth question; let me finished the fourth question before I give the example regarding the preparation of permanent factor map. The fourth question again asks for the possible impacts or cause rather of which of the following actually. I gave you three possibilities, lowest flow, rock creep and solifluction, and asked you which one of the three would cause loss of life.

Now as was evident from what I discuss before that for loss of life to occur, we need to have a very fast landslide in general. So, out of these three processes, lowest flow is a very fast landslide process. On the other hand rock creep and solifluction, they are very slow processes. So, no loss of life is expected to occur as a result of rock creep or solifluction, whereas lowest flow could give rise to a large number of loss of life. Now let us get back to the steps which are involved in preparation of permanent factor map.

(Refer Slide Time: 07:08)



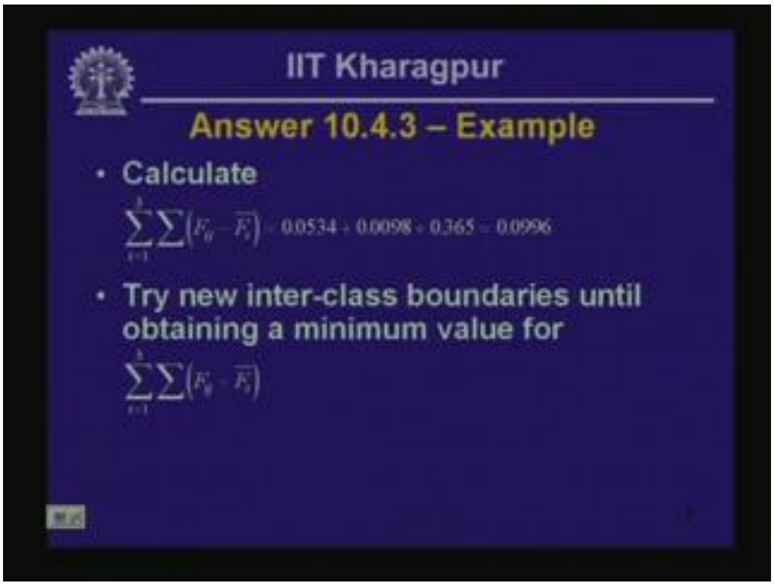
So, this is an example here. So, you remember from the previous lesson that I was dealing with on this particular issue. You have to combine all the factors that affect landslide possibilities in a given area and express the quantities as fractions associated with different types of units that have different types of hazard possibilities. So, the factors in this particular example are as shown in the first bullet there. These are all arranged in ascending order, and then what you do? You try several different classes; for example, if you have got a very small proportion of a given land unit affected by landslides all underlain by landslide debris.

Then we are going to call it class one, and for that, in the first trial let us take the limits of permanent factors of zero 0.01 to 0.29 for that particular class. Class two is intermediate landslide hazard, and here the factors of the area that is affected by landslide are underlain by landslide debris, ranges between 0.29 and 0.58. And if you have got more than 0.58 percent of a given area underlain by landslide deposits are affective by landslide activities, then we are going to call it class three.

Now what we are going to do the in the next step is to list all the factors that come in class one, and those factors are shown in the third bullet there and take the average of these quantities, and the average in this particular case is 0.07. Similarly, we calculate the averages for classes two and three, and the averages for these two classes are respectively 0.46 and 0.745 for the example shown there. Then we calculate actually there is something missing here; you should take a note of this one. We prepare sums of F 1 J minus the average of the factors in the first class; we take the square of the deviations and some sum up the squares. So, the squares are missing.

So, you have to really have an exponent on the terms that appear within bracket; the exponent is two in this particular case. So, you really take the sum of squares and then you sum up the whole thing. And what you get for the first class? For class one is a quantity 0.0534. Similarly, sum of squares of F 2 J minus F 2 bar; F 2 bar is the average of class two. You find out all the deviations, take squares and sum it up for class two, and you get a quantity of 0.0098. And similarly, you get a quantity of 0.365 for class three, then we move on to the next step.

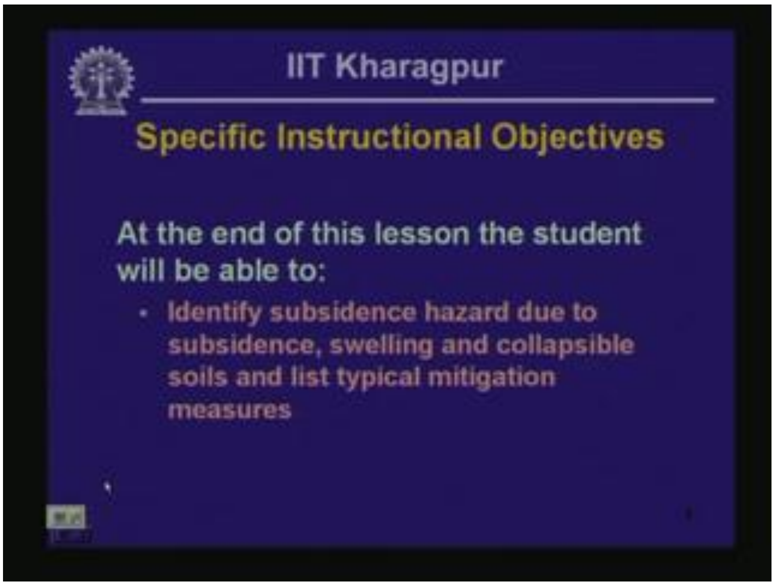
(Refer Slide Time: 10:55)



Here what we do? We sum up all the three quantities that we obtained in the previous step like this, and we obtain a double summation. Here again the squares are missing. So, you should note that there are squares in these terms which appear within bracket. So, the result of this particular calculation of this step is 0.0996, and then what is done? We will try new interclass boundaries. If you recall, we had boundaries at 0.29 and 0.58; in this particular trial, we are going to try new interclass boundary and carry through the same steps again to compute the double sum result which we obtained in the previous step.

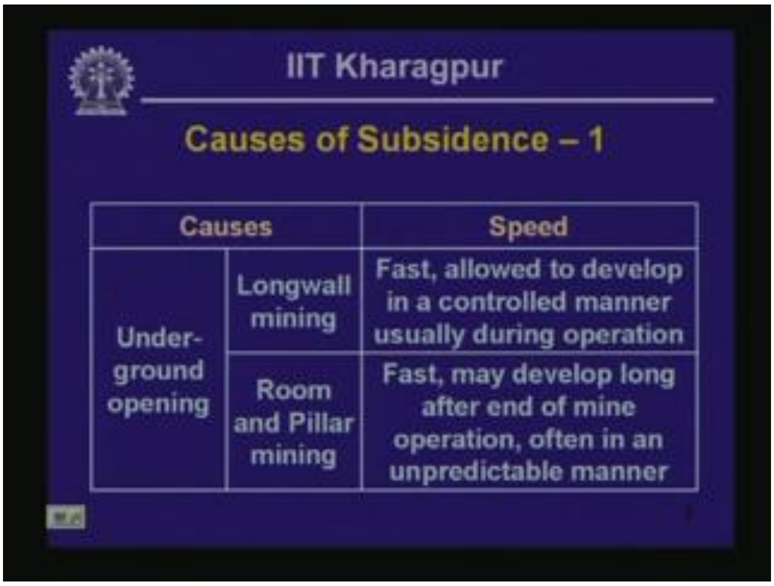
And we try to see whether this number is going up or going down, and our objective is to minimize the double summation quantity, the result of double summation. And once we have obtained the minimum value that is the interclass boundary that classifies the region into three zones of low, intermediate and high landslide hazard. And then a map is prepared showing the areas that come under the low hazard, intermediate hazard or high hazard. So, that is how a permanent factor map is really prepared that actually completes also the question set of the previous lesson.

(Refer Slide Time: 12:54)



And now we move on with the subject matter of this particular lesson. So, what we want to learn from this lesson? We would like to be able to identify subsidence hazard, then hazards due to swelling and collapsible soils, and list typical mitigation measures for each of these individual hazards, okay.

(Refer Slide Time: 13:16)



The first thing, there are three sub topics really; subsidence, expansive soil and collapsible soils, and we are going to take these three subtopics one by one. So, first we consider the subsidence hazard, and let us first have a look at the possible causes of subsidence. So, if we have got any underground excavation for that matter underground opening, then that could be a cause of subsidence hazard. And an underground opening could be created as a result of underground mining activity such as long wall or room and pillar mining.

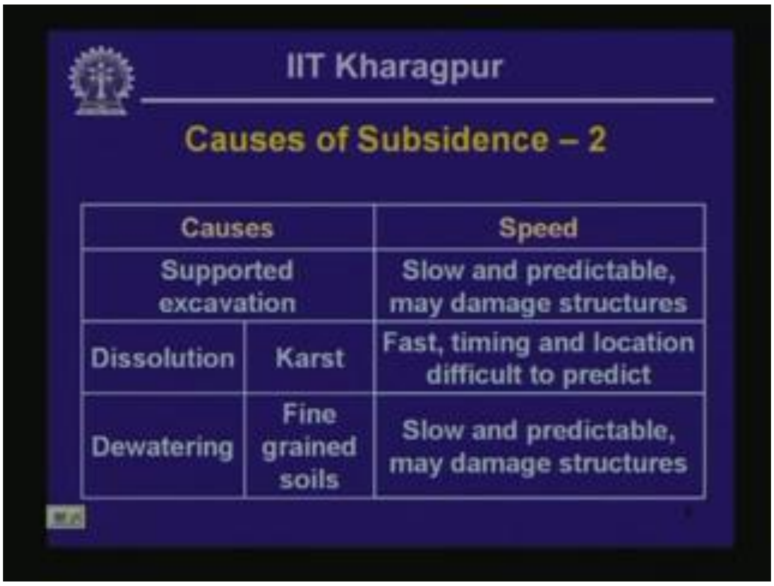
Now what happens in a long wall mining? For instance, if you have got an area underlain by economic minerals such as coal, what is done in long wall mining? A large area is gradually mined out and the opening is allowed to collapse in a controlled manner. So, long wall really allows the collapse of the roof of the mined out area, and as result, it also allows subsidence to develop, although, in a controlled manner at the shallower depths. And the effect of this subsidence could, in fact, extend to the ground surface.

Room and pillar mining on the other hand involves mining out the coal deposit or any other economic mineral by leaving out some pillars, and typically, those pillars also include the economic mineral that is being mined out. So, room and pillar mining really is a little bit uneconomical, because this particular process has to leave out some of the economic minerals but anyway because these pillars are left out. The opening the mined out area is it remains relatively stable after the mining has been completed in a given area.

But the problem here is depending on the time of exposure and depending on weathering or depending on many other factors such as fire that spontaneously developed within mined out area of abandoned coal mines. Some of the pillars that were left behind during the original mining activity could eventually fail, and because of this, some subsidence could develop near the ground surface in a very fast and sometimes unpredictable manner.

So, you really need to understand what is the difference between these two processes of underground mining. One is long wall mining, another one is room and pillar mining, whereas in long wall mining, you allow the subsidence to develop, but that is done in a very controlled manner. So, the sequence could be engineered and the hazard because of the subsidence could be managed in the process. On the other hand, in case of room and pillar mining, the control is really not there that much.

(Refer Slide Time: 17:01)



There could be other types of underground excavation which also leads to subsidence such as if a tunnel is excavated within a few meters from the ground surface; that also could cause permanent deformation at the ground surface. Now supported excavation of other types can also cause slow and predictable subsidence, and because of the fact that here the deformation is quite slow and predictable, this could cause damage to the structures, but the loss of life in this particular case is minimum.

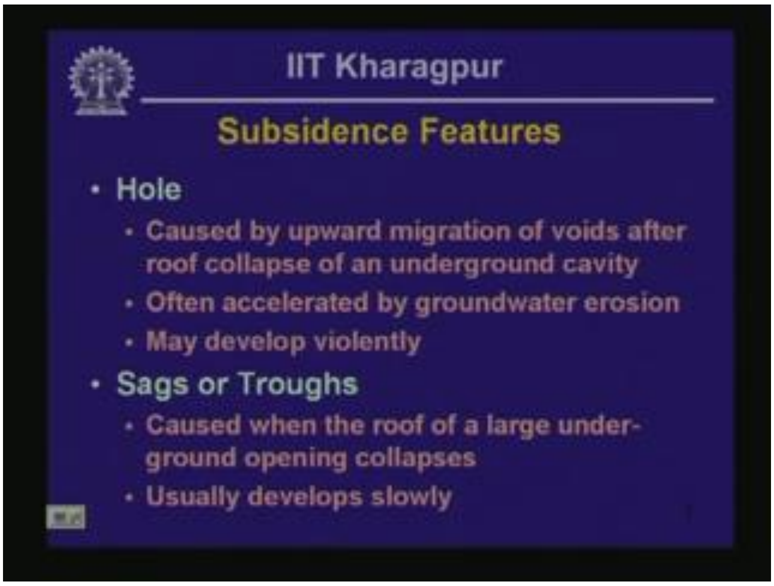
In comparison, the behavior of subsidence features that develop because of room and pillar mining could be very fast in some instances, and it could be quite unpredictable. So, in that situation, there could be property damage, and even in some instances, there could be loss of life also because of that. Dissolution of some type of soluble rock such as limestone in caustic terrain could also lead to subsidence. And this type of subsidence often is fast and timing and location of development of sinkhole because of dissolution of underground near surface soluble rock is quite difficult to predict.

So, this also has the potential to lead to loss of life as well as it could damage properties. Then dewatering is also another agent that causes subsidence, and we have discussed this particular aspect in some detail when we were talking about groundwater. And dewatering related subsidence is particularly significant in case of fine grained soils or aquitards; this type of damage is slow and predictable in general, if the subsurface soils is properly characterized and the amount of dewatering that is going on in a given area can also be quantified.

But in some areas near the location of dewatering activity, properties could get damaged because of the relative displacement that could prevail across the particular structure in consideration. So, because of the fact that in this particular case especially near the location, where the dewatering is going on, there is a possibility of uneven settlement uneven subsidence, the structures that are constructed near this particular location could be damaged because of the uneven settlement

You should realize that if the entire breadth of the area across the structure settles uniformly, then there is very little possibility of damage to the structure especially if the subsidence occurs at a slow pace. Now on the other hand even if the subsidence occurs at a slow pace, there is an uneven settlement uneven subsidence across the structure or across the building, then there are could be a substantial damage caused because of the uneven settlement.

(Refer Slide Time: 21:19)



So, these in a nut shell are the different types of agents that could cause subsidence and their effects really about the nature of damage that could be caused because of these individual agents of subsidence. Now let us look at the features that could be caused by subsidence resulting from the causes that we discussed in the previous two slides. The first one that could develop, the first type of feature that could develop is called a hole where you have got a relatively small area affected by subsidence. And in this particular case, typically, the ground deformation develops quite fast, and because of the fact that the extent of the ground deformation is quite narrow or quite focused within a small area.

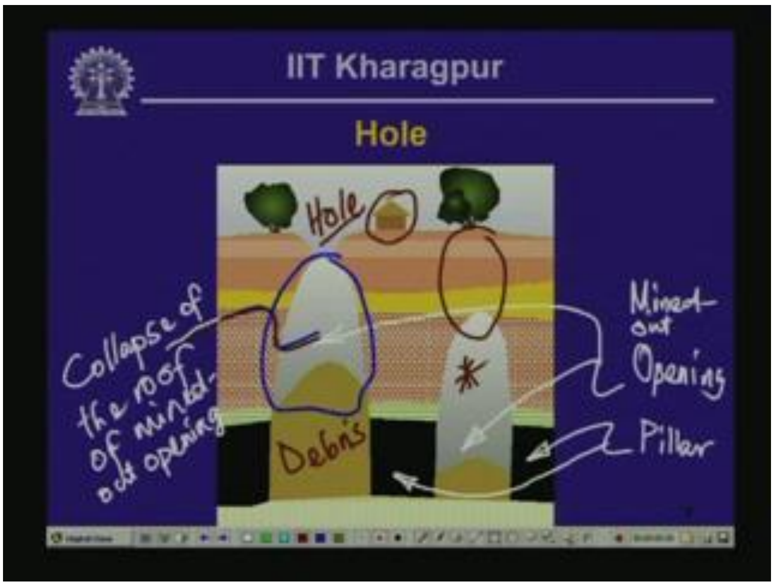
So, if there is any property within this particular area that is affected, severe damage could be caused to those properties. Now examples of holes are those that developed in areas underlain by shallow underground mining activity, typically room and pillar mining and where very few mine pillars give way at a given time. So, as we are going to see in the next little bit that could cause a hole to develop within the ground. A hole could also develop because of groundwater erosion in which groundwater carries soil fines into the cracks and crevices within rock underneath or into the excavation that may be there within the rock because of the presence of a tunnel or cavity within the rock at a shallow depth.

So, hole could develop because of groundwater erosion, hole could also develop because of the dissolution activities related to groundwater, particularly if you have got soluble rocks present near the ground surface. And this type of holes that develops because of the dissolution of shallow soluble rock is called a sinkhole, and as I mentioned, hole could develop violently and in a very unpredictable manner. So, this could also cause loss of life in addition to property damage. The second type of subsidence feature that we are going to consider here is called sags or troughs.

And in this particular case, the subsidence develops over area which has got a wide horizontal extend typically in comparison with the previous subsidence feature that is hole or a sinkhole. And sags typically developed as a result of collapse of the roof of an underground mine opening or underground excavation over a large areal extent. Room and pillar mining often is a cause of the development of sags or trough. This type of subsidence typically develops relatively slowly, and as a result, the property damage is relatively minor in this particular case in comparison with the other subsidence feature as well as is the chance of loss of life in this particular case is also minimum.

Sags or troughs could also develop when the roof of an underground mined out area collapses over a large areal extend because near simultaneous failure of a large number of pillar in case of room and pillar mining as well; so, that you should also remember. So, sags or trough could develop because of long wall mining as well as because in some instances in areas underlain by abandoned room and pillar mines as well if a number of pillars give way at the same time, alright.

(Refer Slide Time: 26:46)

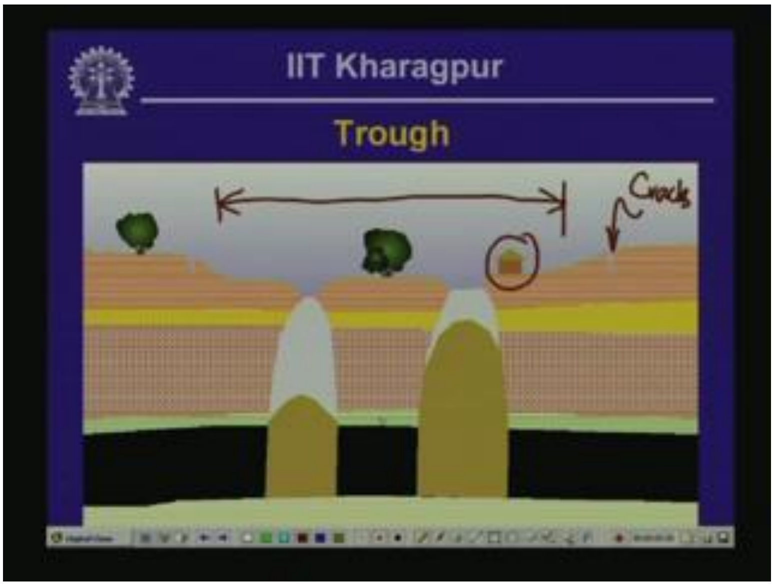


Now this particular cartoon actually shows how a hole could develop. What is shown here is this. This one is the pillar as we explained a little bit earlier, and these are the openings. This is the openings which are already mined out, and in this instance, this one is another mined out opening and another pillar is out here. So, in this instance, what happened? The roof in this particular area collapsed. So, roof here collapsed, and that collapse of the roof of mined out opening; this collapse actually led to the dumping of debris.

So, this one is the debris that got generated because of the roof collapse, and in the process, a hole formed in this particular area. Now you can easily imagine if this particular building that is shown here was to be nearer to the hole, then the building would severely have had to undergo severe damage. Now there is a little bit of roof collapse out for this particular opening as well, but the collapse is yet to day light near surface. And eventually, there is a possibility of development of another hole in this particular area in this instance.

And you really do not know it is difficult to predict how long it is going to require before a hole develops in this particular area, but what we can say that the area shown in this particular cross section is in general susceptible to development of subsidence holes, okay.

(Refer Slide Time: 29:49)

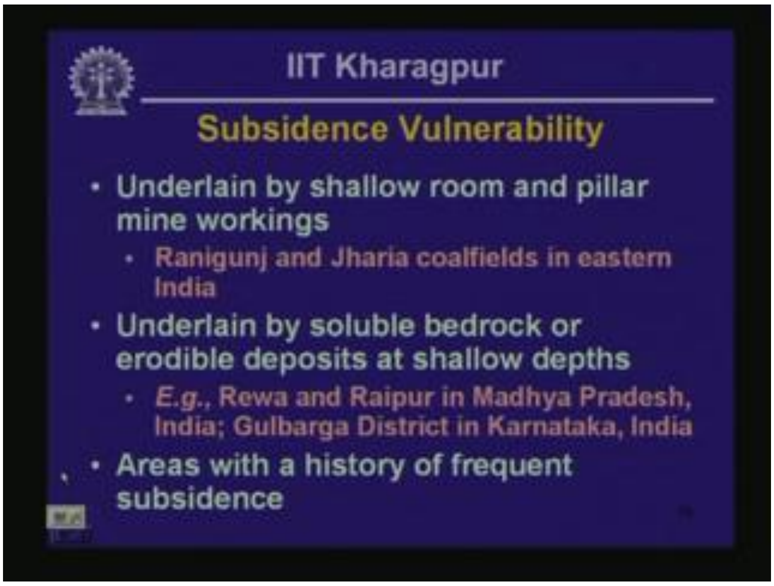


Now let us look at the other type of subsidence feature which is a trough, and you can see in this particular case, simultaneous collapse of several different openings is the cause for the development of this type of feature. And as a result, what you can see is development of subsidence over a relatively wide area; often what happens? You have got cracks appearing at the boundary of the area that is likely to undergo subsidence of this type, and these cracks appear before the actual subsidence occurs. So, the presence or appearance of cracks could be taken as a precursor to the development of this type of subsidence feature.

Now another thing I want you to notice that this particular structure is within the zone affected by the subsidence, but since away from the margins of the trough, the relative settlement or the differential settlement is typically small. As a result, the possibility of property damage is rather small if the property is located away from the margin of the subsidence feature; although, even if the property falls within the affected area.

Now long and pillar mining allows this type of feature to develop in a very controlled manner, and it could actually sequence the mining. The engineers could sequence their mining activity in such a manner that the inhabited areas, they could be speared from this type of damage, alright.

(Refer Slide Time: 32:06)



So, subsidence vulnerability then how do you actually assess subsidence vulnerability, and that to a large extend it follows from the discussion that we already had regarding subsidence. Areas underlain by shallow room and pillar mine workings, they are particularly vulnerable to subsidence. And there are instances of this type of subsidence in eastern India in the coalfields of Ranigunj in western West Bengal and Jharia in the adjoining Jharkhand area. That area is affected by subsidence because of shallow underground room and pillar mining.

And what happen? What complicated the matter in many of these areas is because of the of the burning of the coal that is left behind from previous mining activities. And this burning is causing mine pillars that were left behind the collapse and some areas in are they are sinking in the Ranigunj and Jharia coalfield area in a very unpredictable and disturbing manner.

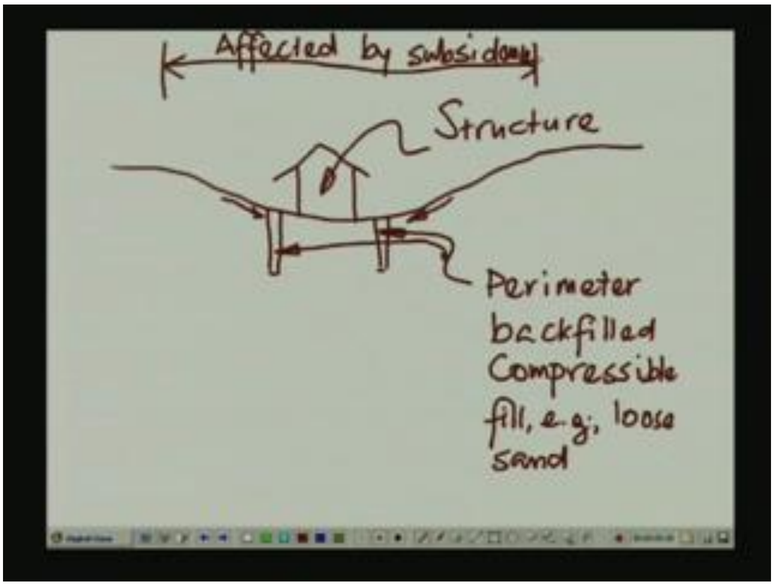
Now areas underlain by soluble bedrock or erodible deposits at shallow depths, they are also vulnerable to subsidence. Examples in the Indian contacts include Rewa in Raipur where soluble bedrocks or soluble rock is found within a shallow depth from the ground surface and sinkholes develop quite frequently in those areas. Gulbarga district in Karnataka and, in fact, in many other areas of Karnataka in southern India is also affected by erosion related subsidence features that we discussed a little bit earlier. Now subsidence vulnerability is generally considered to be present in areas which has a history of frequent subsidence in near past as we have discussed earlier.

(Refer Slide Time: 34:40)

Now what are the mitigation strategies to counteract the effects of subsidence? You can identify the areas where there are underground cavities. The cavities could be manmade or they could be solution channels or caves, caverns because of groundwater movement through soluble bedrock. Then you could try to predict the development of subsidence as is a strategy in case of long wall mining. You could avoid or evacuate hazardous areas, then there could be structural measures which include backfilling or grouting of underground caverns and cavities or mined out areas.

Then you could include some measures which can absorb compression such as perimeter trench. I am just going to explain it in the next little bit, just bear with me for a second. You could also have structural design so that the building is capable of absorbing a relatively large amount of differential settlement, but this measure could be quite expansive actually, and this could make residential development in the area unviable. Then you could have flexible utility connections connecting the building to connecting into a residential building or commercial properties such as swear lines or gas connection or telephone cables. So, these are the measures typically included in areas affected by subsidence, but let me explain what I meant by perimeter trench option which I considered here, okay.

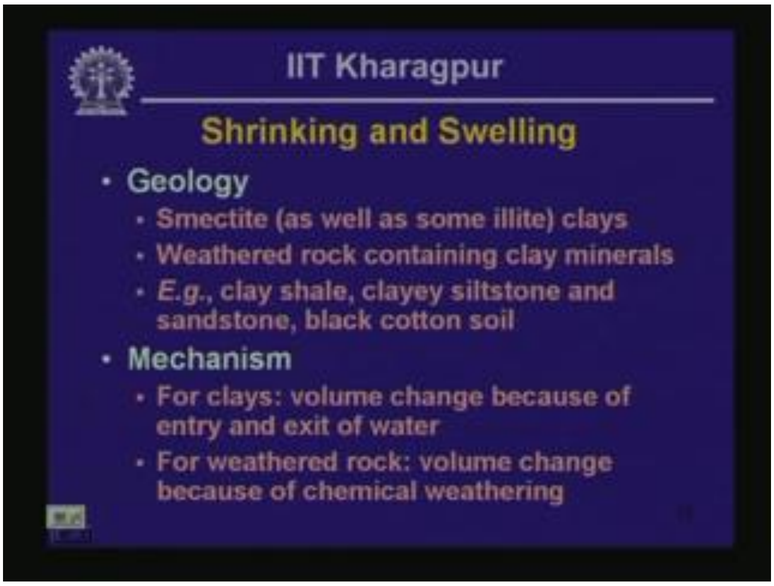
(Refer Slide Time: 37:07)



Let me open of a page here. So, let say you have got an area that is that you expect is going to be affected by a subsidence of this nature, and you expect that the structure is out here. So, you can imagine that the soil layers because of the development of this type of feature, the soil in this area is compressed towards the structure, and that causes many structural failures. So, what is done in these instances if you could dig a trench and backfill the trench with soft compressible material such as loosely spaced sand or other clay filling, other soil filling.

These are the perimeter trenches, and we backfill as I mentioned backfill the trench with compressible filling such as loose sand. Then that to a large degree controls the damage that could be caused to a structure within the zone of subsidence, because the compressible backfill within the perimeter trench is going to accommodate the amount of compression that is absorbed within the area affected by subsidence. So, this is the area in this particular case affected by subsidence, okay. So, that is the function of perimeter trench, okay.

(Refer Slide Time: 39:29)

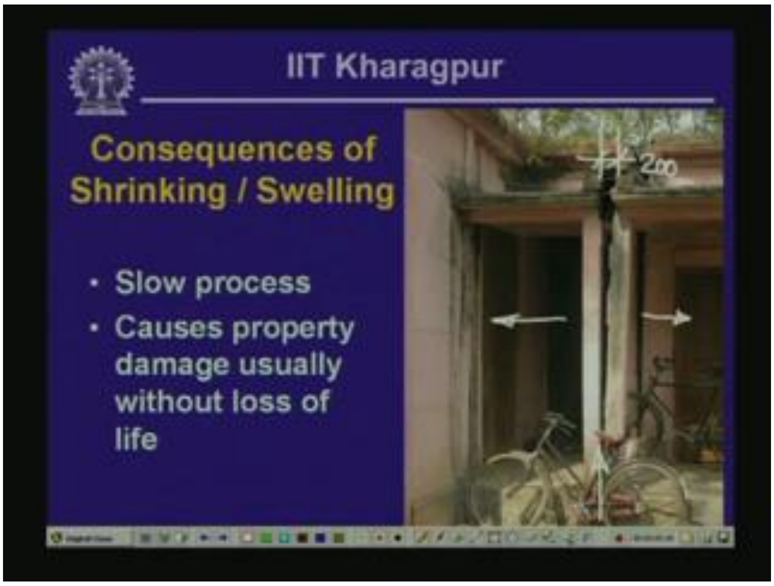


Now next topic is really shrinking and swelling soils. Now what kind of geological setting readily gets associated with shrinking and swelling soils, they are as follows. Smectite minerals and sometimes illite mineral; if there is an abundance of smectite and illite clays, then that is an area you should watch out for as far as swelling and shrinking is concerned. Then weathered rock containing clay mineral; that is also susceptible to swelling and shrinking, because weathering of many types of rocks that leads to the development of clay minerals actually leads to an expansion in the volume of the material.

So, that leads to swelling. Examples of typical geologic settings affected by shrinking and swelling are as follows clay shale, clayey siltstone, sandstone and black cotton soil. Now let us look at very quickly the mechanism that leads to the development of shrinking and swelling. For clays, what happens? There is a volume change triggered by entry and exit of water in between the plaque like particles that we talked about some time back in this course. And for weathered rock, volume change is initiated because of the chemical change or chemical weathering of the rock forming minerals.

And particularly as the rock minerals, they get weathered and lead to the formation of different types of clay minerals, there is a volumetric expansion associated with that type of activity. So, that is the reason why if there is an abundance of clay minerals particularly smectitic and illitic minerals, then that area you can expect a lot of swelling and damages related to swelling and shrinking, okay.

(Refer Slide Time: 41:53)



Now this is an example of consequences of shrinking and swelling; typically, the process is quite slow in many situations, because it requires entry and exit of water into the matrix of fine grained clay particles. So, the process generally occurs at a slow pace, and this, in fact, could lead to a severe damage of property, but usually the possibility of loss of life could be discounted. Now on the right, I show a picture of an office complex in south western west Bengal, which is underlain by swelling soil. And here you can see that the portion of the building towards the left, it has separated out from the portion of the building which is towards the right of this particular picture.

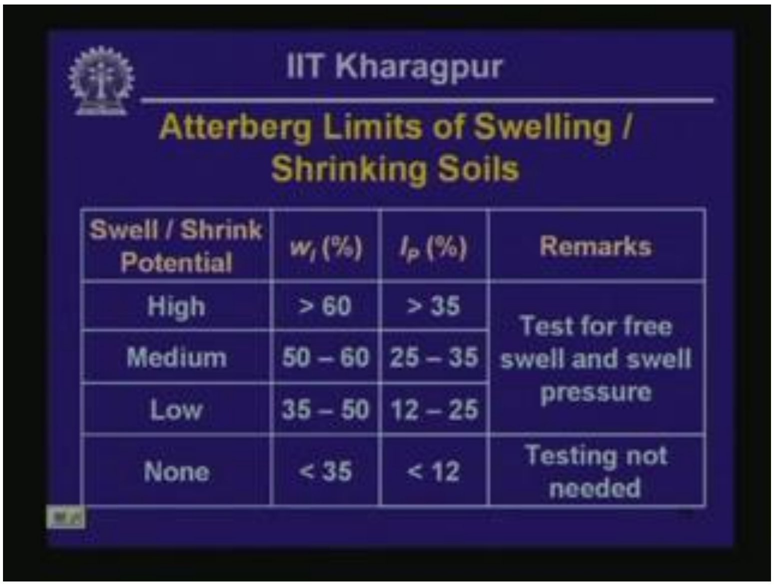
And what is happening here is that the soil is pushing in this direction, and that is actually splitting the building into two different parts in this particular case, and this crack here is approximately 200 to 250 millimeter in this particular case. So, this entire thing is occurring because of the presence of swelling clay underneath this particular structure. Now you should realize that this swelling clay is not categorized; actually that was one of the sites that we investigated. This particular swelling clay is not categorized as high swelling clay. In fact, the swell potential is medium to low in this particular instance, but even then you can see that quite significant property damage has been initiated because of the swelling activity of the underlying soil layer.

(Refer Slide Time: 44:21)

Shrinking and swelling is largely accounted for by identifying the hazard and accounting for the possibility of shrinking and swelling. So, hazard identification is typically involves identification of mineralogy and clay content; usually greater the clay mineral, a clay mineral percentage, plasticity index and stiffness, greater is the soil potential. Usually soils affected by swelling exhibit an appearance of popcorn. Actually if you look at the natural surface of shrinking and swelling soil, they often take the appearance of popcorn just like you can imagine the surface; it looks like the surface of a Cauliflower.

Then we need to assess the engineering behavior of the soils that are likely to be affected by shrinking and swelling, and there are many correlations that are available which allows the engineer to estimate the pressure that the structure to be constructed on swelling clay, because of shrinking and swelling, because of water ingress and egress from the mineralogy and from Atterberg limits.

(Refer Slide Time: 46:04)



Swell / Shrink Potential	w_l (%)	I_P (%)	Remarks
High	> 60	> 35	Test for free swell and swell pressure
Medium	50 – 60	25 – 35	
Low	35 – 50	12 – 25	
None	< 35	< 12	Testing not needed

We are going to look at how do we actually quantify the shrinking or classify or identify the shrinking and swelling tendency from Atterberg limits of the soils, and that is shown in this particular table here. And what you can see here is generally high shrinking and swelling is associated with soils which has got liquid limit of greater than 60 percent. You should look back at your previous notes to check out what is meant by liquid limit, and plasticity index of the soil that are characterized as of high swell and shrinkage potential.

Typical plasticity index ranges above 35 percent, and when you have got very low liquid limit, typically smaller than 35 percent or small plasticity index typically smaller than 12 percent, then it is typically assumed that there is no shrink soil potential. And there are two more classes in between; one is medium shrink soil potential, and another one is low shrink soil potential as shown in this particular table.

Now if you ascribed some shrink soil potential to the soil at a given location, then you have to do laboratory testing of the material, bring sample of the soil to the laboratory and do some testing in order to quantify how much of swell pressure that could be associated with the deposit or how much of pressure, a structure is going to encounter because of entry and egress of water into the soil underneath the structure. So, once that can be ascertained, then special structural design can be done to accommodate the amount of movement, or it could require some ground modification in order to minimize the entry and egress of water that is the prime that causes the swelling or shrinking in the first place, okay.

(Refer Slide Time: 48:54)

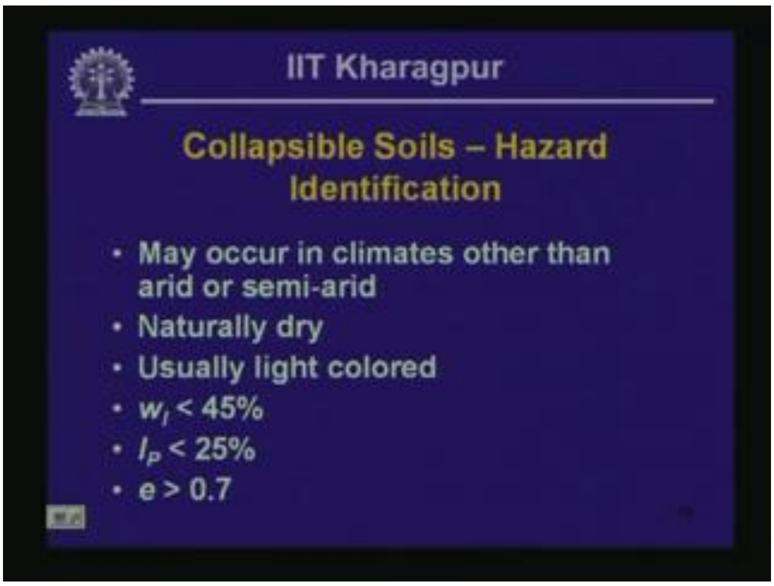
So, that actually leads us to the typical mitigation strategies associated with shrinking and swelling. First as usual as we have seen over and over again, the first mitigation strategy is to avoid the areas which are affected by shrinking and swelling, but that is not always possible. So, we have to move on to the other mitigation measures. We could remove the problem soil within the zone of moisture change or the zone which is affected by entry and egress of water which is typically within the top three to five meters from ground surface.

Then you could control moisture ingress and egress by drainage control underneath the structure or control over development of lawns or development of plantation within a close vicinity close proximity of a particular structure. You could also go for chemical stabilization, mixing up the soil with lime or fly ash typically, and that minimizes the tendency of shrinkage and swelling to a great extent.

(Refer Slide Time: 50:27)

The final topic that we are going to look at in this case is that associated with collapsible soils. Collapsible soils are those soils that collapse without any additional loading because of wetting; when water gets entry into the soil, the structure collapses. This type of soil is often found in arid and semi-arid climates. Typically, the soils that have weak inter particle bonds such as those because of deposition of salt or calcium carbonate deposits at the grain contact; they get classified as collapsible soil. Mechanism that leads to collapse is as follows. Soil structure collapses when entry of water dissolves the weak cementation bond that causes the collapse.

(Refer Slide Time: 51:33)



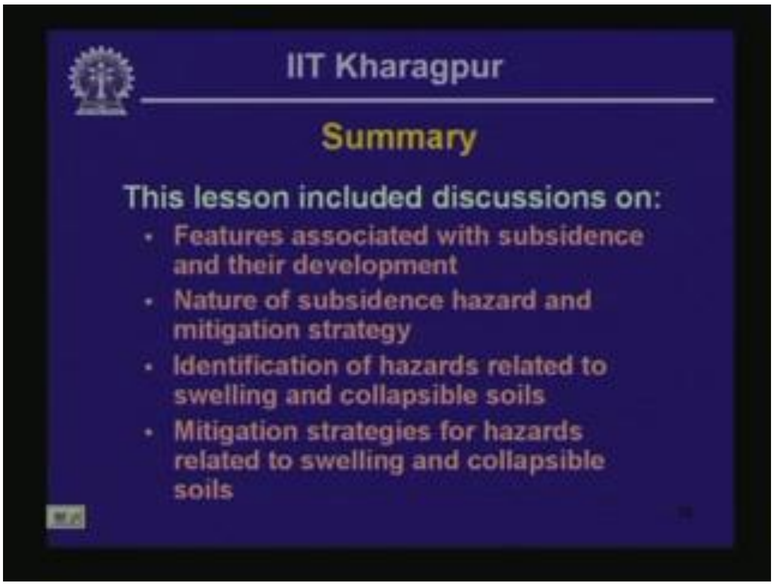
As we did for shrinking and swelling soils and rocks, we are going to try to identify the hazard associated with collapsible soil. Collapsible soils typically could occur in climates other than arid or semi-arid, but they are more in abundance in areas that are arid or semi-arid. The collapsible soils are typically dry. They are usually light colored, and they have got liquid limit typically below 45 percent, plasticity index typically below 25 percent, and the void ratio is typically above 0.7.

(Refer Slide Time: 52:28)

Mitigation strategies in order to avoid problems associated with collapsible soils. If collapsible soil is uncounted at shallow depth, then it is imperative that the soil is not allowed to get wet or pre-wetting before any structure or facility is constructed followed by heavy compaction of the soil before the construction of the structure or building or road or other facilities. If collapsible soil occurs at great depth, then what could be done is to go for deep foundation that transfers the load of the structure to a layer underneath the soil that may be affected by collapse because of entry of water.

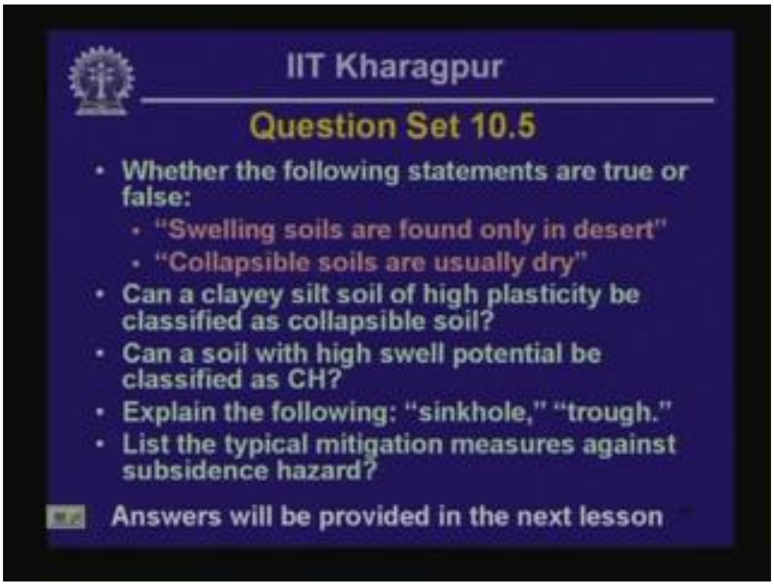
In this case also, we could go for chemical stabilization, and that typical procedures involve treatment of the soil with sodium silicate and or calcium chloride solution, which reinforces the weak cementation bond and give some permanents to the strength of the inter-particle bond. Alternatively, we could also go for jet grouting; that involves pumping of grout material cementitious or other grout material at great pressure to actually reinforce the inter-particle bond as well as to compact the potentially collapsible soil.

(Refer Slide Time: 54:23)



So, these are the typical mitigation strategies that one often uses for collapsible soils. So, now we have come to the end of this particular lesson. We summarize this lesson what we learnt here. We looked at a list of the features associated with subsidence and how the features develop, nature of subsidence hazard and mitigation strategy, identification of hazard related to swelling and collapsible soils. And we also looked at the mitigation strategies to account for the hazards related to swelling and collapsible soils.

(Refer Slide Time: 55:12)

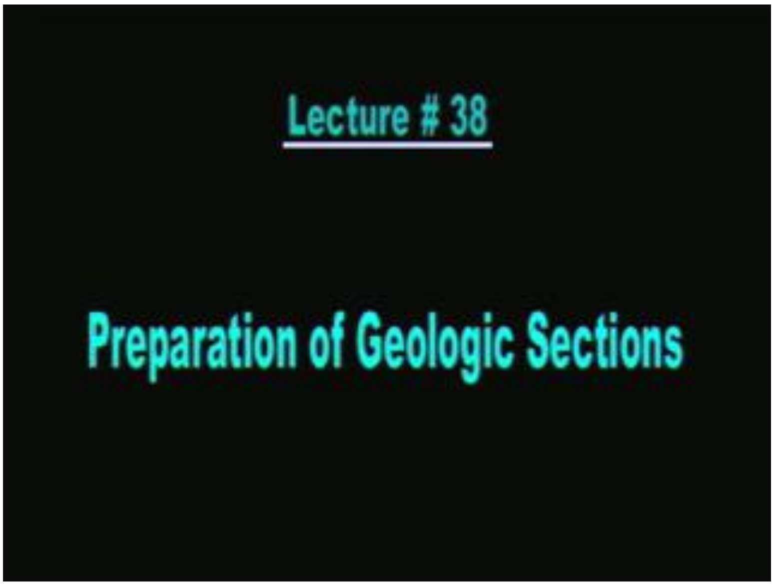


We end this lesson with a question set. The first question that I ask is whether the following statements are true or false. The first statement is swelling soils are found only in desert. Second one is collapsible soils are usually dry. Second question, can a clayey silt soil of high plasticity be typically classified as collapsible soil? Third one, can a soil with high swell potential be classified as CH. You should look back to your earlier notes in this particular course to answer these questions. Fourth question that I asked was explain the following sinkhole and trough, and finally list the typical mitigation measures against subsidence hazard, okay. So, that brings us to the end of this lesson. Try to answer the questions that I gave at your leisure. I am going to give you the answer to this question when we meet with the next lesson; so, until then bye for now.

Thank you.

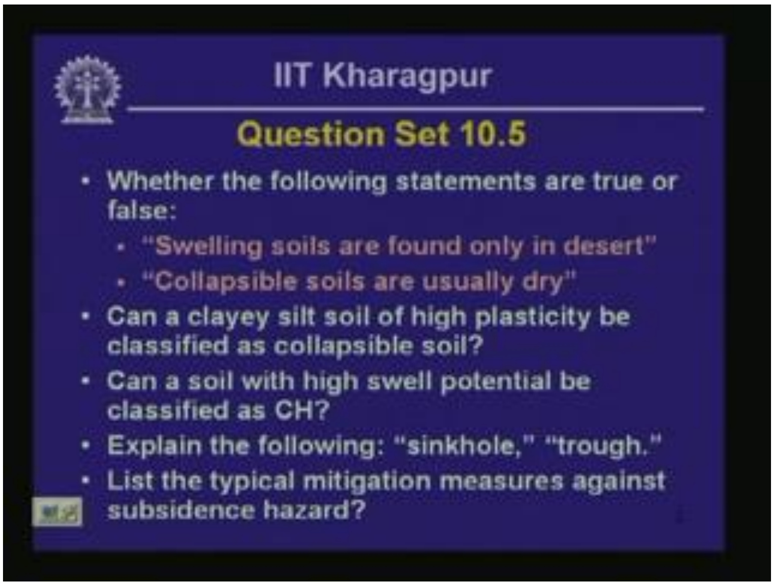
(Refer Slide Time: 56:25)

(Refer Slide Time: 56:32)



Hello everyone and welcome back. We are going to get into the first laboratory session of this course today, and we are going to talk about preparation of geologic sections from geologic maps in this particular laboratory. We have already looked at the salient features of geologic maps and geologic sections earlier in one of the theoretical lessons. Today, we are going to have a practical demonstration on this business of preparation of geologic sections. I will also take this opportunity of wrapping up the question set of the previous lesion before we begin with the preparation of geologic sections.

(Refer Slide Time: 57:35)



This is the question set of the previous lesion. The first question that was asked was whether the following statements are true or false. The first statement was swelling soils are found only in desert. This is more often than what is true; however, swelling soils are also found in non-desert environment particularly in fine grain soils where there is a lot of smectite minerals present. Swelling soils could also be present in situations where there are a lot of clay minerals between rock joints. In such situations also, there could be a lot of potential for swelling in the shallow layers near the ground surface. And these geologic settings are not necessarily found in desert. They also found in other hydrometeorologic environments.