**00:00:00**

**Wan Zuhairi Wan Yaacob**

Thank you so much, Professor Kotake for the introduction. My name is Wan Zuhairi bin Wan Yaacob. I am the lecturer from Universiti Kebangsaan Malaysia and then I am a geologist, all right. So I think you probably have heard about the – the words of geology, okay, a field that study about the rocks. So that’s geology. So today I am going to discuss with you the topic on Engineering Geology, okay, so there is a work of engineering coupled with the geology.

So basically that’s the field where you apply the science of geology for engineering processes, because where you want to build engineering structures, you need to put it on the rocks, so you need to know what is the information about the geology of the area yeah. Again, the topic that I chose is “A Glimpse.” A glimpse mean you just see very quickly, so it’s not really very critical for you. You can have the choice. You want to see – you want to see it, or just to give a very short watch on that particular things, so that’s the glimpse, okay, the brief. So I’m going to talk briefly about the engineering geology and also the rock mechanics, yeah.

So before I begin, I would like to introduce you to my website. So, you can see my website at www.wanzuhairi.com, and then I also have Facebook, okay, www.facebook.com/dwzwy [ph], and also I have blog that provide you all the information about my research, okay. So if you want to know more about my research in my laboratory in Malaysia, you can browse my blog, okay, you can see different kinds of research that I do in Malaysia, okay.

And then this is the contents of my presentation today. I would like to talk about more on fundaments of engineering geology, what is the most important characteristics or the most important things in engineering geology, because I know that within 45 minutes, I cannot train you to be a good geologist, but at least when you go home, you have something in your mind about geology, okay. Why geology is very important? Because when you go out to work, you will work with the geologists. So at least you know how they think, how they do their work, and then you can use that type of information to better communicate with the geologists at your workplace, okay.

This is a very important introduction about engineering geology, especially in civil engineering, because the task of civil engineering is to design, to construct, and to maintain the engineering structures, okay, and when you build engineering structures, you have to put it on the ground, you have to put it on the soil, or you have to build it in the ground, okay. So when you build larger structures that – that have a contact with the rocks, then you need the information about the – about this material, about rock material. So that’s the task of engineering geology, to provide you the information about the – the rocks, whether it is okay or not okay to build large structures in this particular area, okay.

For example, this is example of Hoover Dam in Colorado. It’s a thin-arch dam, okay. It is very thin, made of concrete, and then it manage to hold the water pressure behind this dam, okay, but the most important things is the interaction between the dams and the – the rock. You see that, the interaction between the dams, this structure, and then also the rock.

**00:04:57**

So that’s why we need information, the knowledge of engineering geology to give you whether this site is okay to build a dam or not, okay. The second example is mining. You try to extract minerals from deep under the ground, so you need to know the stability of the roof on top of your head, all right, so you need information about rock engineering or engineering geology. Therefore, you can have a very stable condition under the ground for you to extract the minerals, yeah. And then for the third example that I put there is tunnel, okay, tunnel. You know tunnel? Okay, this is tunnel, okay, this is tunnel, tunnel, where you – where the car can drive in and then drive out, okay. So that’s the tunnel.

And then if you see the tunnel and then you can see on top of the tunnel, there are rock anchors or rock bolts, okay. So these are rock bolts, all right, and then they are used to hold the rocks together. So that means when you drive into the tunnel, there will be no rocks come out from this, hard rocks [ph], and then hit the car below this - below this rock, hard rocks. So that means the important things to know is how you can describe or how you can determine where to put that rock anchor, where to put that rock bolts, then you need to know – you need to have the knowledge of geology, okay. Are you with me? Understand? A little bit, okay, that’s good.

So all civil engineering works are carried out on or in the ground, that’s the first sentence, and then another statement from Mathewsen [ph], the author of the book, 1981. He says that an engineer is a person who can do for 1 dollar what any fool can do for 2. So I will say that engineer is very, very bri - brilliant. They can build anything on everything. You can have a bridge in Japan, for example; you can have a deep sea tunnel in Japan, although we know that Japan is very active with earthquake. But they are very brilliant. They can build it probably with the minimum amount of budget, money, okay. Less money, but they manage to - to build a very good engineering construction, whether – although the site is not better or suitable for that kind of construction, yeah.

This is the – the things that I would like to share with you about civil engineering and geology. So we have a – a [Unclear] that comprise of engineering geology, mining engineering, and civil engineering. So this particular or this combination of these three fields we produce you what we call a geotechnology. It’s a big field and then engineering geology is a study of the engineering suitability of the sites by using geology information and then civil engineering is using scientific method, technology method in order to design, construct, and maintain the engineering structures such as dams, tunnels, big foundations or big structures, highways, and etcetera, yeah. So this is the combination of interaction between different types of fields, especially the geology and also the civil engineering. Okay. This is also very, very important, all right, for engineering geologists. This is engineering geologists. This guy is engineering geologist, all right. And then this guy has two face; one in front, another one at the back, all right. So the back face is looking at the process, the earth process. For example, you have earthquake in Japan, you have tsunami in Japan. So this is what the geologist will see, alright. And then at the same time, this guy will use this information in order to design or help engineer to build the bridge, for example, or probably the large structures such as buildings and etcetera.

**00:10:00**

So in this case, engineering geology will use the geologic information or geologic process in order to help engineer to produce engineering products, okay. So that’s the function or that’s the purpose of having engineering geology in your team, alright. So you need a team. You have several engineers, you have geologists, you must have architect, so you are working – you – you will work together to produce a very nice structures and safe for people to – to use – to use that, yeah.

Okay, this is very fundamental. This is very, very important for non-geologists, all right. This is very basic for engineers. Probably, they must have some ideas about the fundamentals of engineering geology. The first thing that – the first fundamental things is rock type, alright. This is the rock type, for example, and then this is what we call granites, all right. There are various – various types of rocks, and then geologist knows how to name the rock, oaky. So that’s what we call the rock type, for example, granites, and then the second fundamental things is called structure, rock structure. So you can see here, this is a cross rock and then you can see the cracks. See that? Fractures, all right. That’s what we call rock structures, okay. And then if you have this in your foundation area, this is not good, because the rock is weak, no good for foundation, for example, okay.

And then another fundamental things is weathering, okay. Weathering is a process, it’s a natural process that can weaken the rock. The rock become loose, weak, then it’s no good for engineering design, yeah. So for example, this is a fresh rock, something like that, this is fresh, something like that, but because of the weather, sun, wind, frost, what else? Probably roots of trees. So this rock can change its color and become weak, all right. This is what we call weathering, all right. So we have a fresh rock in the inside and then we have a very weak material on the outside, all right. So the most important things that you have to keep in mind about fundamentals of engineering geology, the first one is, you have to know about the rock type, the rock structure, and also the rock weathering, yeah.

So this is the rock type. Okay, when you ask the geologist, normally we categorize rock types into three categories; the first one is igneous rock, number two is sedimentary rock, number is metamorphic rock, okay. And then you can see this is the part of the volcano mountain, all right. It’s like the volcano like Fuji, Fuji Mountain, yeah, and then you have magma, which is a molten rock deep inside the earth and then when magma going out, it produce lava, all right. When they solidify, when magna solidify, it will produce rock. This is what we call igneous rock, and then when the magma moves out into the surface and then solidify from liquid to solid, this type of another rock also we call igneous rock, all right. So there are two types of igneous rocks. The first one is the rock – the igneous rock that is formed deep inside the earth and then igneous rock that is formed outside the – the earth, all right.

The second terms is sedimentary. This is the rock that’s produced by the loose material that is transported by wind, water, air, and then accumulated in rivers, sea, and produce a layer of sedimentary rock like this, okay, and then the third rock is called metamorphic rock, all right. With time, because of the pressure, because of the temperature, sedimentary rocks can transform into metamorphic rock.

**00:15:05**

Okay, transform. It can change because of heat and pressure. It will become another – another terms of – of rock type which is called metamorphic rock, okay. This is a definition of rock, definition. If you want – if you ask architect what is rock, architect will say that rock is a type building material, okay. Rock can be used to – to make a building, all right. And then if you ask engineer what is rock, engineer say anything that can – can be blast, that’s rock, all right. So engineer say, rock is a hard or brittle material that require blasting. Blasting means you put dynamite and then you bomb – you bomb the rock. So for engineers, if you need a dynamite to bomb the rock, then that’s rock, okay. For geologists, rock is an earth material produced by the rock forming processors. For us, rock is something that’s produced by the process of diagenesis, a process rock forming process, okay. So that’s a rock for geologists.

Now, we have already understand the three fundamentals of engineering geology; rock type, structure, weathering. We know that rock type can be divided into three; igneous, sediment, metamorphic, and then if you have a rock or you can see a hill of rock or hard rocks, you can divide the rock into two main engineering properties; rock substance and rock mass. This is also very, very important, rock substance and also rock mass. I will tell you the difference between rock substance and rock mass, okay. For example, you have a tunnel, this is a tunnel and then this is rock, okay, this is rock, and then on this rock, you can see so many fractures - fracture or I will – I will introduce you a word called discontinuity. There is also another terms for fractures. Fracture is similar with discontinuity. And then if you take a small sample near this excavation, near the tunnel, a small sample, that is intact rock, which is equivalent to that one, all right. So that’s your rock substance, okay. If you take bigger sample - bigger sample, then we can catch one discontinuity here. If you make a bigger sample, a large – a larger sample like this one, then that’s what we call rock mass, okay. So if you take a simple rock, something like this, okay, for example, this is rock, small, so this is what we call intact rock or rock substance.

But if you take bigger rock with maybe fractures inside, that’s what you call rock mass, okay. For example, that is a rock substance and then if it’s containing rock and fractures, that’s what you call rock mass, okay. And then this is what we do with rock material, okay. You take this rock material, okay, this is, for example, rock material and then you cut it, you cut the rock and then you see what under microscope. When you see under microscope, you can see different types of minerals, okay. This is the view under microscope and then geologists are trained to identify different types of minerals that are present in the specimen of rock and then they will use this information under the microscope to identify what kind of rock that exists in that particular area and then what are the connection between different minerals in that particular rock, all right.

**00:19:59**

If you have a very strong rock, it means the minerals will be cemented or interlock between each other, then the rock becomes strong, okay. And then sometimes you need a rock – you take the rock and then you change it to this type of what we call core sample and then you test the strength by using a machine, for example, you do uniaxial compressive strength. You put it under pressure, under a big stress, then you get the value of strength of this part - particular material, yeah. Okay, that’s what you do with rock material, only a small sample of rock. But what should you do with the big rock, rock plus structures or rock plus discontinuity here.

Okay, this is what I call rock mass, a big – a big outcrops that contains rock materials and also discontinuities. Discontinuities is what you can see here, okay, with joints, fractures, faults, folds, and also bedding planes. So if you have many fractures, the rock will be no good for any engineering constructions, because the rock can be considered as weak. So this is the example of weak rock, no good, because so many fractures, so many cracks, so many joints that if you put something on the top, then every - everything will be collapse, okay.

So this is example of the comparison between strong and weak rocks. Strong rock must have uniaxial compressive strength more than 100 megapascals, while for the weak rocks less than 10 megapascals - less than 10 megapascals, and then little fracturing, no or very small amount of fracturing. But for the weak rock, fractured and bedded, so many fractures on that particular rock. Minimal weathering, very small weathering; deep weathering, very big weathering; stable foundations, settlement problems. If you put something on top of it, it will collapse, settlement, okay, settlement problems with that kind of rocks. Stand in steep faces. If you build a slope for – for – for –f or strong rock, you can make it stand almost 90 degrees, it won’t collapse. But with the weak rocks, you need to design a very gentle slopes, then it becomes stable. So very good for aggregate material, you need a stone aggregate to build big foundations, so this material is good for aggregate resource and then the weak rock is never used for aggregate materials for engineering construction because it is not good.

Okay, I will explain about discontinuities, rock structures. This is the basic things, okay, the basic things about why you have that kind of structures for rock, why you have cracks, why you can see joints on rock. Basically, if you remember, this is what we call plate tectonics theory, okay, where you can see plate’s move and hit between each other, all right. So, when the - this is a process what we call the dynamic of the earth when the plates move. When the plates move, it will produce waves, and then that’s what we call earthquake, all right. So, this is a - this is a big force, very big force. The - the force is very, very powerful and then normally we can split it into three types; compression, tensional and also shear because of the dynamic of the earth. Earth always moves, the plates always move and generate these kinds of big forces, all right, compression, tensional, and also shear.

For example, this is a small pots, all right, this is a big pots, this is a small pots. You take one rock, you give a compression by using the uniaxial compressive testing, for example.

**00:25:00**

You can have a plastic deformation and then you can have fracture. This is a small fracture on a small rock, all right. But the most important thing is the big fracture in a big rock, something like this, all right. This is a big fracture in a big rock, okay. For example, like that, this is what we call ‘fault’ and then this is what we call ‘fold,’ okay.

Okay, this is example of fault, okay. Why is it fault? Because this line was located here before, all right. This - this line is similar to this, right, see, all right. This line, this black line before this –before this – before it move, it is located somewhere here, but it moves because of the faults, okay, because of the faults, that this is what we call discontinuities or fracture or faults, which is no good for engineering design and abilities here. So you have many faults, one, two, three faults or fractures on the rock mass. Same thing here. This rock before this happened is located here, but it moved. So you imagine a very big rock move, okay, because of the force of the earth that produce a big earthquake, for example, okay.

So this is what we call discontinuities of structures and then you can imagine, if you build a large structure on top of this rock, it will also move along this plate because this is very big plate, okay. And then how we describe discontinuities? How you describe these things, okay? How describe - how you describe the structures? I just give you 10 points. I do need to discuss this, because if I explain one by one, I need probably one day to – to – to complete all these things, but the first one is orientation. Orientation means the direction of the planes of the fractures, okay, so orientation - number one is orientation. Number two is spacing. Spacing means the distance between one structure to another structure, that’s what we call spacing. Number three is persistence. The length, the distance from here up to there, that’s persistence you measure. Is it 3 meter, 4 meter, 5 meter? That’s persistence. Roughness, you have to go and check the condition of the planes, roughness. Is it rough? Is it smooth? That’s roughness.

The strength of the wall, okay, you have to go check – we have to go and check the strength of this wall along here, the strength. You have to probably bring a straight hammer or take the sample out and then do sort of like uniaxial compressive strength testing or something like that. And then number six is aperture. Aperture means there is a gaps here opening. Is it open? Is it open? The fracture is open or not? If the fracture is open, then it’s weak. If it’s close, it’s good, all right. So you have to measure the aperture, the distance perpendicular to this discontinuity. That’s the aperture. Filling, what is inside - what is inside this aperture, that’s filling? Water seepage, because water will weaken the rock, all right. Water will make the rock become weak, so you need to measure if there is any water or ground water coming out from this structure and then number of sets and also the block size.

Okay, the first things that I want to explain to you is orientation, okay.

**00:30:00**

Orientation means what is the position of the joints. For example, for example I will take out my passport, all right. This is your joints, for example, this is your - and then you see the joints, these fractures and then what is the orientations, the orientations, all right? You measure the orientation. Is it dipping towards you or dipping towards me or dipping towards the others? Okay, that’s orientation, all right, the position of this thing. For example, here the orientation is like this. And then these is orientations. This is the orientation. So orientation is very, very important in engineering design. For example, you have this conditions where you have discontinuities. For example, foliation plates and then you have dam, all right, two conditions. The first one is the place is parallel to the dam - to the axis of the dam and then the second conditions, you have flotation which is perpendicular to the axis of the dam, all right. Which one is more stable, okay? Which one is good for dam, right or left? This or that good for dam, good for this design, good for the construction of the dam, which one is good? This one or that one? If somebody say correct, I will give a present. All right, which one is good? All right, this is favorable, this is good. This is no good.

Why? Because these plates is no good because it’s weak. Then the water reservoir behind this dam can seep through these structures and then you end up with no water in your dam, okay, or probably your dam will collapse because of these orientations. And then you have another designs, another orientations kind of - kind of design to the structures that you want to build. This is the highway. This is your structures. One is the orientation is away from the slope like this and then this one is orientation onto or towards your design. Which one is more stable? Right or left? This one is more unfavorable, this no good, because this rock can slide and become less like, because the plane is sitting like that, so it becomes weaks. This is the – this is the – the - the planes where rock material is very, very soft, very, very weak that will slide and then you can have a place like this, so you got a problem. In this case you have a stable foliation plates, okay. That’s what we call unstable block. That means the whole block can go into the highway and then you’ve got problem with your - with your design, okay, or with your - with your constructions.

Weathering, okay, I think this is not critical. Weathering is the – the process where the rock become - change its condition from fresh, Grade I, it become change into – change its color and also its quality, okay. This is Grade III or Grade IV. Geologists tend to give a grade for weathering, okay. You have a very good rock, you put Grade I, Grade II you can see weathering here, discoloration like this - discolorations, change color - color change. From I change color, you put Grade III and IV. If you go up, the quality is no good. It becomes soil at the top, okay. So you have fresh rock here, Grade I, Grade II slightly weathered, Grade III moderately weathered. This is rock and then if you have highly weathered Grade IV, completely weathered Grade V, and soil at the top. These three grades you can consider as soil, okay.

**00:35:00**

So you have rock material and then you can have soil material, okay. It depends on the weathering states of your - of your profile. This example, you can have a – a big hill, you cut it to make the highway, for example, and then you can have a fresh branch or Grade I, very fresh, and then you can have Grade II or Grade III at the top. It’s like a soil where you can plant grass or something like that, okay. So this is how we put in grades to rock; grade I is very good, grade V and IV is no good, okay, because it’s already changed the color, change color. Fresh, weathered. Okay, so this is how we classify the rock, how we classify the rock based on the parameter of the discontinuities, okay?

You remember the important parameters? The 10 – the 10 I gave you just now starting from orientation, spacing, persistence, aperture, water – what else? Rock size, you got 10. The 10 parameter I gave you just now, that’s the important parameters that we must get from rock, okay. Okay, this is the – you know this, this is a core where you drill - where you put the drill on top of the surface, you drill into the ground, you take the sample out, you have a core sample. This is rock that you carried from under the ground, you drilled under the ground, and then you can see the fracture, these fractures.

See cracks, fractures, all right. And then you already know that this is weak because so many fractures, one, two, three, four, five, six, seven, many fractures. This is less fractured, see. This is strong, because no fracture. So this is how we identify whether the rock is strong or not based on the number of fractures. If there are so many structures, it’s weak. If we – if that is very far from one to one fractures, it’s good, okay. But this is no good, because many fractures, okay. So how we can categorize or we can calculate this quality is by using what we call a system of rock quality designation or RQD by Deere et al, 1967.

This is the formula where you sum of the lengths of core sticks more than 10 centimeter, multiply by 100, divided by the total length of core. So you measure each core from here to here. Is it 10 centimeter or more than 10 centimeter? If it is more than 10 centimeter, you measure it and put it here, all right. This is from here to here probably 10 - more than 10 centimeters. You measure it, put it here, and then you calculate what we call the RQD or rock quality designation. And then it is used to classify the rock whether the rock is good or no good, yeah. This is core recovery. Core recovery means when you drill 3 meter, you come up with core 3 meters. So you drill 3 meter deep inside the earth, then you come – you come up with 3 meter of core, that’s what we call core recovery.

This is example, okay, of core and then these is fractures, that’s the scale, 10 centimeter. So you have the first core more than 10 centimeter, the second core more than 10 centimeter, the third core also 10 - more than 10 centimeter. So you have a total of recovery 2 meter or – or – yeah, about 2 meter divided by 2 meter because the total is 2 meter here from there to there 2 meter. So 2 meter is divided by 2 meter, multiplied by 100%, you have 100% core recovery, and then the RQD also similar, because you have the first core more than 10, second core more than 10, the third core looks like more than 10, then you can have 2 meter divided by 2 meter multiplied by 100, you have 100%. So this is a good rock, excellent.

**00:40:00**

So you can use this scale to give you 100% excellent, good rock. If less than 25%, very poor, it’s no good for engineering design, engineering construction, etcetera.

This is the [Unclear]class. This is the first one; this is the second one, more difficult because so many parameters, six parameters altogether, six parameters. The first parameter is called uniaxial compressive strength, the strength of the rock. Number 2 is RQD, which is this one, RQD, second parameter. The third parameter is these discontinuity spacing. The fourth parameter is conditions of the discontinuities. Number five is groundwater. Is there any water or not? Number six, rating adjustment based on the orientation of the discontinuity. So you have six parameters. You sum all these parameter together like that. Up – and up is rock mass rating equivalent to JA1 plus JA2 plus JA3, JA4, JA5 and JB altogether. You sum up all those things and you get your ratings from 0 to 100. This is very simple, okay, very simple to do.

Okay, so that’s – this is the example. You have first parameter strength, UCS, megapascals, is it 250 over 100 to 250, 50 to 100, 25 to 50. RQD, is it more than 90, 75 to 90, 50 to 75, and then you give ratings, you put ratings here, all right. For example, we did RQD for this one just now, it give you 100, this 100 RQD. If 100 RQD, you see the ratings. RQD 100, you give rating 20, you put the numbers 20, and then you add the number together and then you can have this value, RMR value, 80 to 100, probably 60 to 80, probably 40 to 60, probably 20 to 40, and then you can see the class of rock. The Class I is very good rock; Class V is very poor rock. It means there are so many joints on the rock, so many fractures on the rock, yeah.

Okay, so finally, I will explain to you one case study. This is a very critical problem that occurred in - I think in California or probably in Los Angeles I can’t remember, but it’s what we call St. Francis Dam Failure, okay. This is the dam, okay. So that’s the dam, okay, and then that’s the water behind the dam, and then this is the dam after the failure. It breaks - it breaks and then it will produce a large, a big flood water coming out from this dam, and then the failure occurred in 12 March 1928, 500 died and then the main reason for this failure is because of the geological factors. The engineer forgot to consider the geology of this particular site. And then after this event, then the science of engineering geology has been proposed, after this event, okay. And then probably we would like to know why this failure occurred, all right. You can see that cross-section from here to here. That’s the dam. You can see two types of rock. The first one is sedimentary rocks - remember, igneous, sedimentary, metamorphic, three types of rock. Here you can see two types of rock, sedimentary rock and also metamorphic rock. And then you see the structure there, the planes, the weakness planes that I told you just now, the fractures. You see the trend of the fractures and then in between - in between, there is a fault, all right – in between, there is a fault. It means the structure or the foundation can easily move through this particular point, fault, all right.

**00:45:04**

It can move easily from that point, and then in that sedimentary rocks, there is a gypsum, all right. Gypsum is a material that easily dissolve in water, all right. Gypsum is very hard when it’s dry, but when it dissolve in water, it would easily dissolve and then make the foundation very weak, okay. Okay, that’s the reasons why the failure occur, the first one is because of the faults. This is part of the San Andreas fault, the famous fault in the world. If you go to California, US, America, you can visit this fault, all right. It’s very big. It cross the west side of the America, this fault, very, very big. You can see it from the aeroplane, very big fracture, all right.

And then this one is called San Francisco - San Francisquito fault and then it’s part of the San Andreas fault, so you visit. You put a very big structure on the fault, this is big, very huge, big structure, and then you can imagine the weight of the dam and then also the weight of the water. There are two weights here, two components of weights. Dam and also water put it on the faults and then fault can move because it’s already weak along that point, and then you have also sedimentary rocks, which is also weak when – when it contains gypsum and then also underwater, it become easily dissolved. And then the orientation is no good. Orientation, remember orientation, all right, which is parallel with the axis of the dam, also no good for the dam foundations. As a result you have this, and then as a result you have 500 people died, because the engineer failed to identify whether the site is good or not for dam construction. That’s the reasons.

This is the guy. His name is Mulholland - William Mulholland. He was the architect, he was the engineer, he was geologist, so he built this dam by himself. He decide everything, okay, and then this is the report – this is the statement of the report that produced after the dam failure. It says that this substrate was totally inappropriate for the dam footing, and failure of the fractured and weathered – see that, fractured, remember fractured - weathered, remember weathered, so that means the rock is weak because of the fracture and because of the weathering – weather and then conglomerate is the name of the rock, the name of sedimentary rock, conglomerate, alright, was the major cause of the dam failure, okay. And then what the William Mulholland said? He take the blame – took the blame by himself. He said that don’t blame anyone else, you just fasten it on me. If there was an error in human judgment, I was the human. So he took the blame of what happened in – in that particular dam, yeah.

Okay, so I think that’s all of my presentation today. Probably very difficult for you because I am trying to compress all those thing in 45 minutes, but at least you must put in your mind that there are three fundamental things about engineering geology; the first one is rock type, second one is structures, the third one is weathering, okay. So with that, I would like to thank you. *Arigato gozaimasu* for your kind patience to listen to my presentations and then I end my presentation with thank you, bye.

**END**