Surveying
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Lecture No. # 01
Module No. # 0 7
Leveling and Contouring

Okay, welcome to this another lecture on basic surveying.

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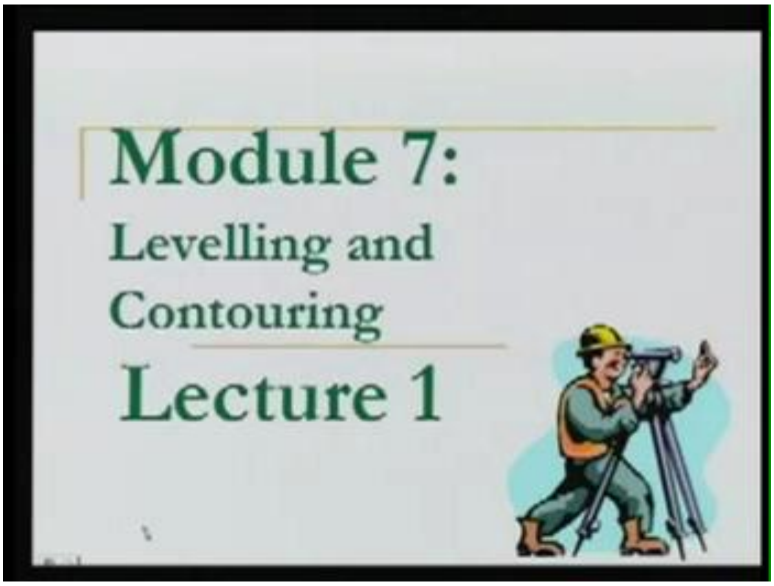

Today, we are going for module 7. And this module is about leveling and contouring. We will begin with lecture number 1 today.

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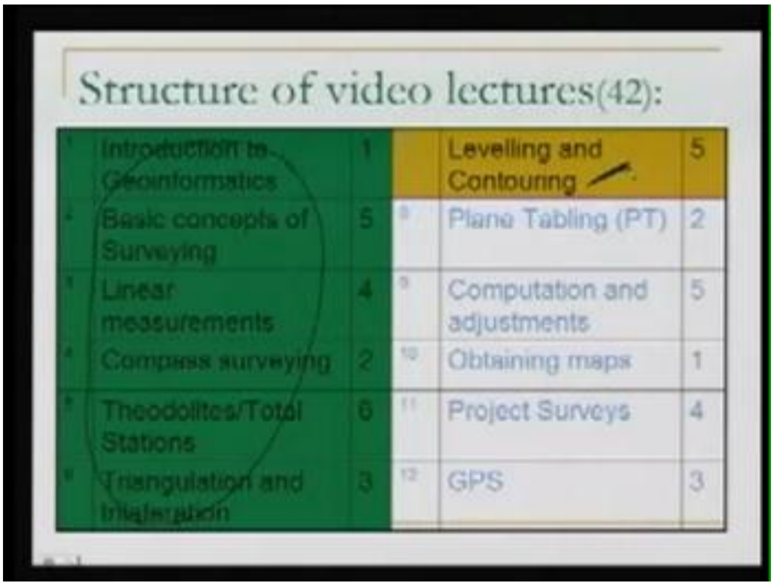

Now this is all what we have done so far and mostly, we were talking about the horizontal control. So far we looked into some instruments which will measure the horizontal angle or vertical angle also, the linear distances or the sloping distances, and we can establish the control in horizontal. In case of triangulation in our last module, those triangles along with the vertical angle measurements can also be used for trigonometrical leveling, and that way we can establish again the vertical control. Now we will look into detail about this vertical control today and this is what our module number 7 is.

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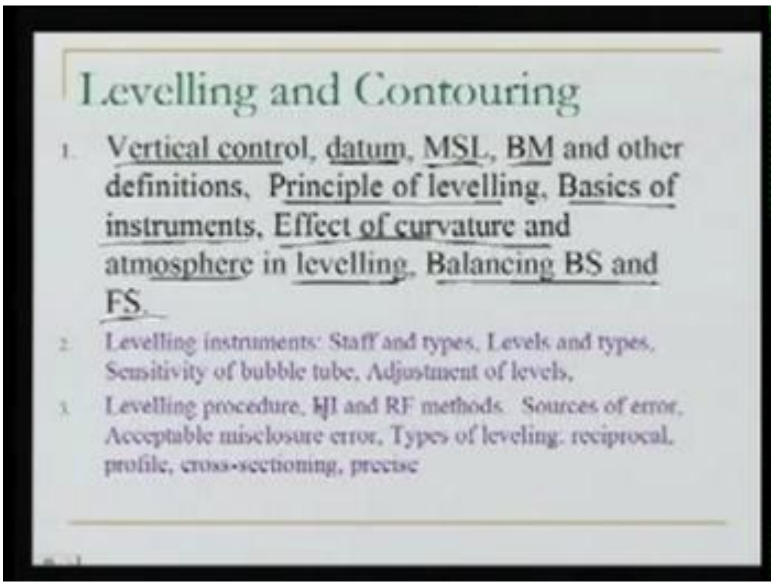

In this module in our first lecture today, we will be talking about again something more in the vertical control. What is datum? MSL mean sea level; what is the meaning of this? BM it stands for benchmark, and some other definitions which will be required in this chapter on this module. Then we will be looking into the principle of leveling, basics of instruments, effect of curvature and atmosphere in leveling procedure. And finally, we will also try to see that what is the meaning of balancing back site and fore site. So, we are going to talk about the vertical control first.

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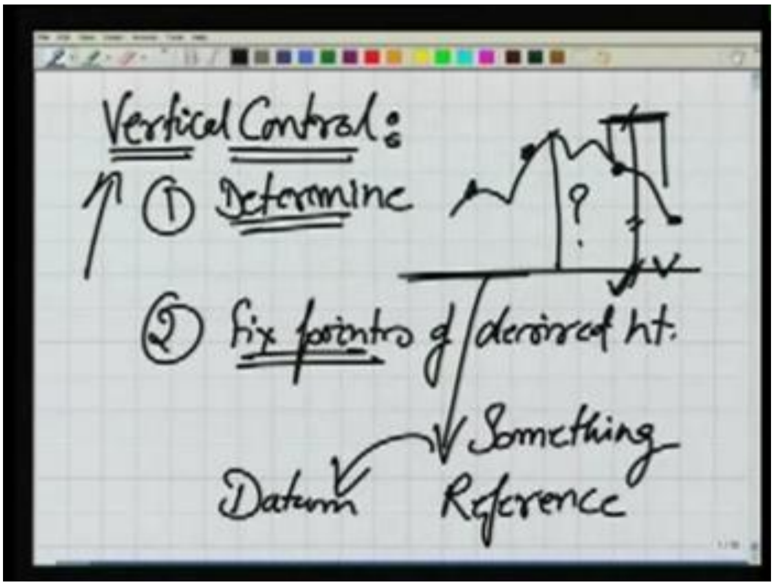

Now what is the meaning of this? The meaning of vertical control is we are going to number one; determine the heights of some points on the surface of the earth. For example, if this is surface of the earth, we want to determine from somewhere that what is the height of this point, number one is this. Number two, in vertical control or when we are talking about the leveling, we do another thing; that is we fix points of desired. I am just writing height here so far; we will be using a different word later on. So, what is the meaning of this?

The meaning is if somewhere here, we want to construct a house and the roof top of that house should be at a height of let us say 10 meters from somewhere. The somewhere is this line, and the roof top here should be at a height of 10 meter. So, what we are going to do when we are going to construct this building here. So, this height of the roof top has to be fixed in such a way that it is at 10 meters from here. So, this is fixing the points. So, first one was determining the elevations of the points; second is fixing the points at desired elevations.

Now this is something which we covered basically in leveling, or this is also we say the vertical control. We are establishing the control network. We are fixing some points of desired heights, or we are determining the heights of some points along the surface of the earth. So, this is establishing the vertical control. Now in this, we look into some definitions. Number one definition is our saying this is something; we are measuring the height with reference to this. So, this is a reference and this reference in our surveying terminology, we generally say as datum also datum. Now the very first question is what this surface could be; where this surface is?

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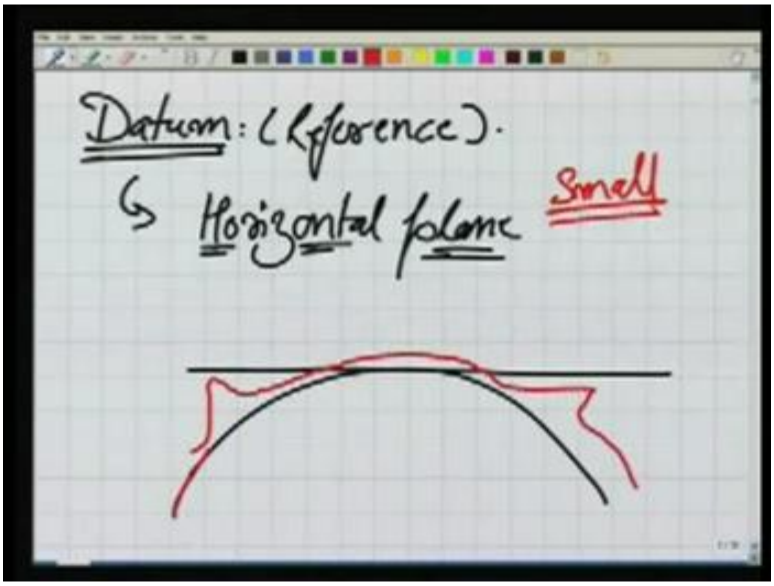

So, we are going to talk about now datum or the reference. Well, the question is can it be a horizontal plane? Now what is the horizontal plane? Well, this is my earth. We know the shape of the earth, and if I draw tangent to it somewhere; this is my horizontal plane. Can we use this horizontal plane as a reference plane for determining the RLs? Well, let us see it now. If this is the average plane of the earth surface, and if the earth is something like, this is the surface of the earth the red one. Well, if my area is very small. If the area of my work is very small, we can always take a horizontal plane as my reference because we know it we have seen it before also.

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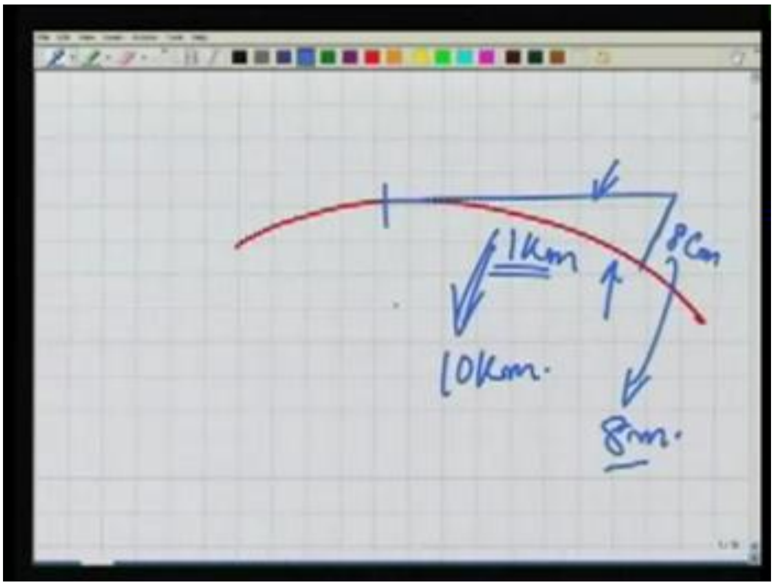

That in my earth the tangent from the earth it deviates by 8 centimeter in 1 kilometer. So, if my area is small only 100 meter by 100 meter, 200 meter by 200 meter; you know that kind of extend smaller area. I can take the horizontal surface also as the reference or may be in this room. Now in this room in order to measure the RLs of different points, the height of this point or the height of this point the height of this point. The elevations of different points in order to compare them; I can take the floor of this room as a reference, because it does not matter here, because the area is very small.

Now what will happen if the area is very large and if we take the horizontal plane as the reference? Now let us see at that. Well, we know this value. In a distance of 1 kilometer, the horizontal plane deviates from the general curvature of the earth by its centimeter. And if this distance is 10 kilometer, then this deviation becomes 8 meter, because this derivation is not linear; it is non-linear. And we will see it also how to arrive at that later on. Now because of this reason because just in 1 kilometer; it is going away by 8 centimeters. What is the meaning of that? The meaning is the moment our areas are bigger, our horizontal plane starts deviating from my average curvature of the earth.

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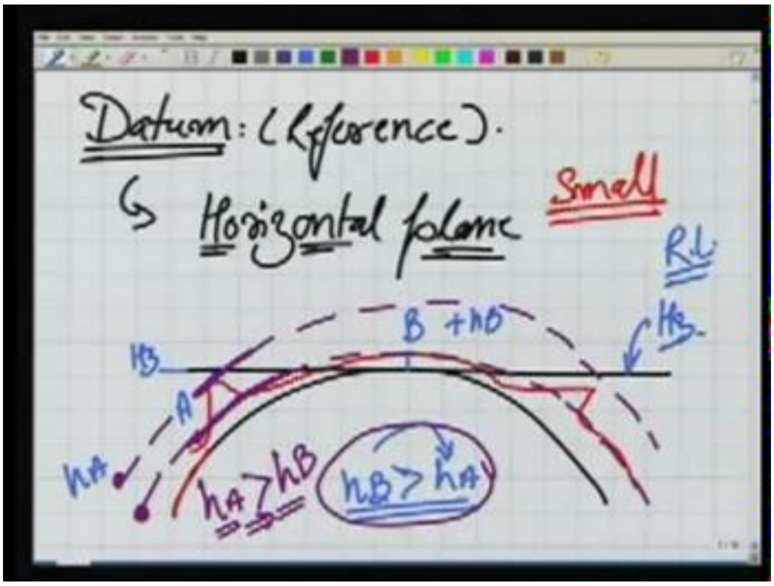

Well, what is the problem because of that; let us look here. If I am taking this horizontal surface as the reference and finding the RLs of points with reference to this, then in that case the RL of point A here will be or I am just saying I will not say RL right now; we will discuss this term RL later. Let us say the elevation of this A with reference to this horizontal plane is negative here and some value h A while for a point here B, it is positive; it is h B. So, what is the meaning of this? H B is more than h A. So, ideally if I put a drop of water at B, it should flow towards A, because we are saying B is higher than A.

So, if B is higher than A, the water should flow from B to A, but let us look at here. We know the gravity; the water will flow because of the gravity. And the gravity is nearly same along a surface which we will define in a moment which is nearly parallel to the curvature of the earth, nearly I am saying. So, the gravity is nearly same along this line everywhere; we say this as equipotential surface. Similarly, the gravity will be also same along a surface which passes through the point B and both these. The one which is passing through A and the one which is passing through B, both are nearly parallel to the average curvature of the earth.

Now what is the meaning of this? If the gravity is same all over if I highlight this all over the surface, the gravity is same as well as it is same here. The meaning of this is the point A if I put a water drop at point A that water should flow from A to this lower surface.

The water should everywhere flow, because in terms of gravity, the surface which is passing through A is higher than the surface which is passing through B and the water flows because of the gravity.

So, what does it say? It says now if I take the horizontal surface as my reference, it is giving me the wrong result. The actual result should be that h A should be higher than h B, and then only the water from A will flow towards B as it is true in terms of the gravity also. Now from here from this diagram, one thing becomes very clear to us. That if our area is large as we have seen also here; we cannot take the horizontal surface as the reference surface. Rather, we should take a surface which is we say equipotential or which is in other terms in a simpler word I can say which is parallel to the average curvature of the earth.

So, let us start defining a surface which is parallel to the average curvature of the earth, because we know along that curvature along that curve, the gravity will be saying; it will be an equipotential surface.

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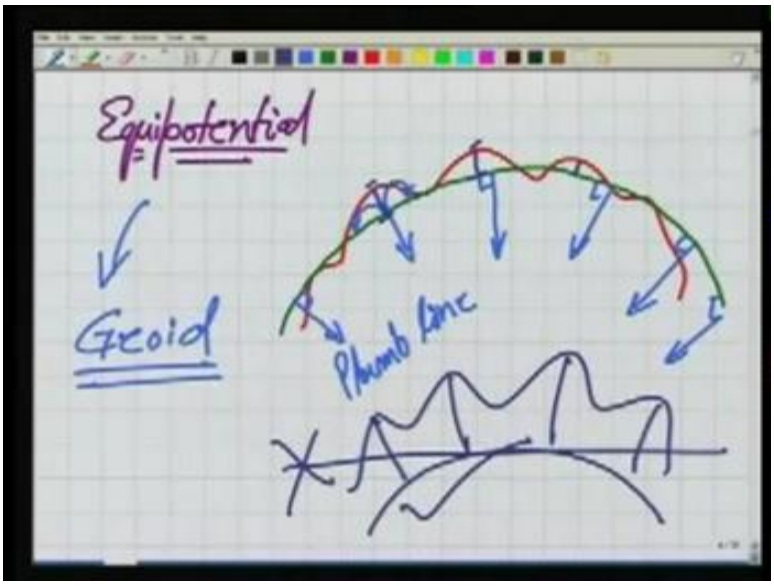

Now that kind of surfaces which is equipotential; now what is the meaning of that? The meaning is if this is my earth, all over the earth I can define a surface, and everywhere I can define the line of gravity or that is called plumb line. If I suspend a plumb up at this point, it will look or it will get suspended in this direction. Similarly, here it will get suspended in this direction, in this direction and in this direction. So, these are the directions of the plumb up or we say the other directions of the gravity at that point.

Now everywhere this direction is perpendicular to a surface, and this surface we say equipotential surface; that the gravity potential everywhere along the surface is same. So, what is the meaning? If I keep a drop of water here, it will not go either this way or this way. It will just stay there; it is a kind of horizontal surface at that point. The water will only try to follow the direction of gravity; it will try to come down. So, this kind of surface, we can term as geoid, and we have seen this before also in our very first few lectures when we were talking about the basics of surveying; we again discuss about the surface, the geoid.

So, basically, we should use the geoid as our reference, because this is related with gravity, and this helps us. Because we are talking of our civil engineering process or anywhere, the height for us means the water from higher point should flow to the lower point. This cannot be realized by a horizontal surface. This will be only realized if we start measuring the RLs or elevations. For example, here I start measuring the elevations of these points from this surface. So, if this is my geoid, the elevations of different points are to be measured from the geoid not from a horizontal surface no, but yes from the geoid. Now how can you establish the geoid?

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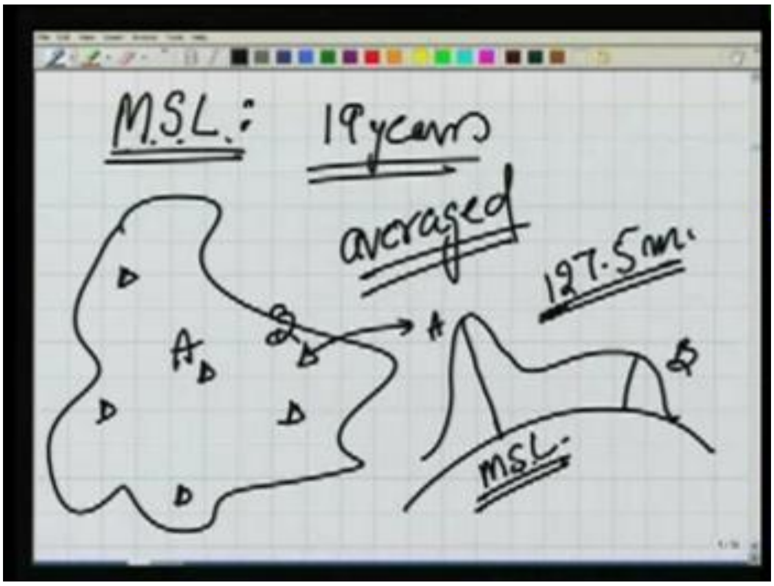

Now to establish this geoid or this datum, it is realized or generalized by mean sea level, because we know the water surface is also equipotential. So, the mean sea level means the sea level has been observed for a period of 19 years for all its variations; it does vary, and then it has been averaged out. So, that averaged value is the mean sea level. For every country, they have defined their own mean sea level. Similarly, for India also, we have defined our mean sea level. So, that becomes the reference, the mean sea level.

Now once the mean sea level has been defined everywhere in the country; for example, if this is the country and everywhere we have some permanent points for which we know these have been established by the methods of vertical control; we know their elevations from that mean sea level. So, what is the meaning? All these points are referring to same curve or the same reference. If I say this point A is higher than B, how do I say? From the geoid, point A is somewhere here, and point B is there. So, this is point A, and this is point B, and both of them have been referred to the same mean sea level.

So, if you are going anywhere, you will find several points in your locality also which have been established from the mean sea level, particularly, if you are travelling in the trains, all the railway stations; they write that this particular railway station is higher by 127.5 meter, for example, from mean sea level. So, you will know what is the meaning of this.

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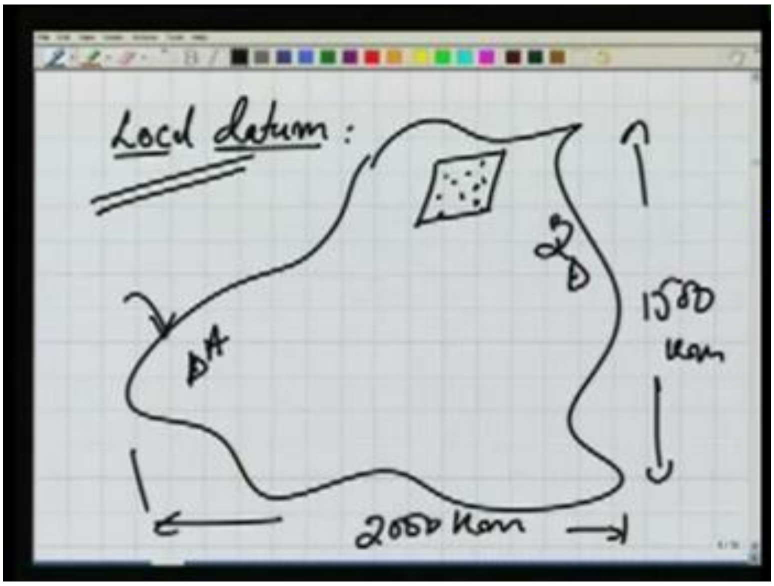

We are going to define one more term here that is called local datum. Because mean sea level is a global datum; a global means in terms of our entire country. We have one reference system for entire country, and all the points in the country can be referred to that one. So, if I am doing a survey in a big country; this is the big country. I am doing a survey, and in that survey, it is essential that the points; let us say the size of the country are 2000 kilometer by kilometers; we use country here, okay, and we want to refer these two points to the same survey. We want to have something so that the heights of these two points need to be related to each other.

So, in that case, I need to measure the height of A and b both from the same reference which is the mean sea level, but many times that is not required. If I am working in a building project which is you know in an area of let us say one kilometer by one kilometer a smaller area, and I do not have any need to refer the heights within this to this absolute system the mean sea level, rather, I want to work in relative heights there. So, what I can do? I can establish a local datum there. I need not to go for this global datum. So, that kind of datum which we can establish locally; we say that is a local datum.

For example, I can say, okay, there is a wall, and for this wall, the height of the point is zero. So, the moment I say this is 0; that becomes my local datum. And now because the geoid; there is one geoid here, another one, another one. These are the layers of the geoids. So, the geoid which is passing through this becomes my reference; all the points in my study area, I am referring to this particular datum. So, this is my local datum.

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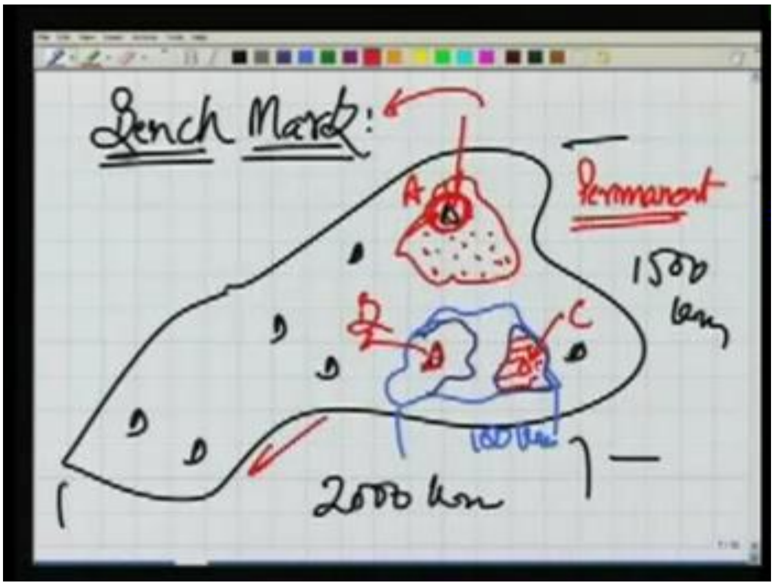

Now another term which we are going to talk about is benchmark. As I said in a big country, okay, again the country is very large; the dimensions are 1500 kilometer and 2000 kilometer. The heights of points have been established; some points have been established very accurately so that I can use this point later on for my local survey here. So, the height of this point is accurately established; let us say this point is A from the mean sea level by some method. So, those points for which we know the heights or we know the elevations from the mean sea level accurately, we say those as the benchmark.

Because now this benchmark serves a purpose that we can use this and we can refer other points here. I can now find the elevations of all these in relation to this. I need not go to the sea here to go to the main benchmark there; rather, I can do my survey with the benchmark here. So, these kinds of benchmarks are called generally permanent benchmarks which are established permanently. Similarly, what I can do? If my study area, for example, let us say that is my study area and this is 100 kilometer. I have already one benchmark here, and I want two teams.

I want one team of surveyors to work in this area while the other team of the surveyors will be working in this area. So, what I would like to do? I would like to establish one more benchmark here with the help of the benchmark B. So, the benchmark at C is being established first with the help of the benchmark at B, and then later on the survey in this area can be carried out using this benchmark at C. So, this kind of benchmark which is established just for some temporary period, we say temporary benchmark; it is not permanent.

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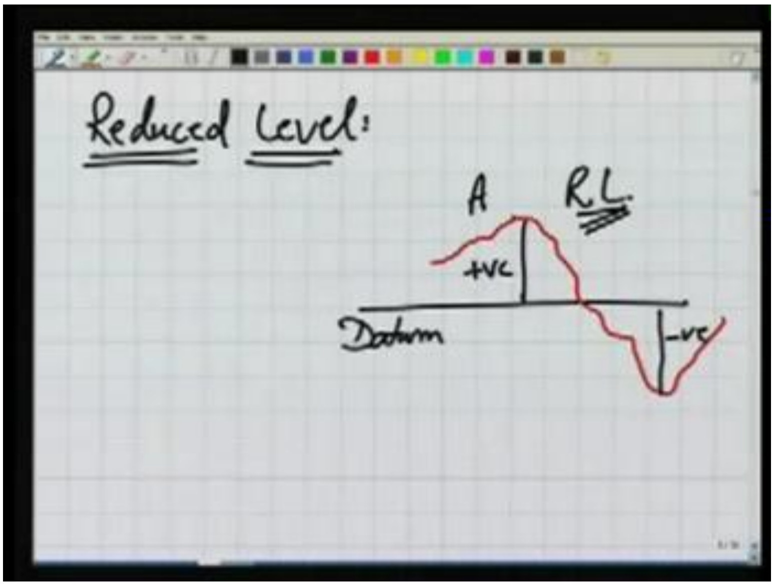

Let us go for another definition, and this is the definition of reduced level. So, far we were referring heights of elevations of the points, but in surveying, we mostly say reduced level. What is the meaning of this? The meaning is the elevation of a point, for example, A from the datum is the reduced level of this point A. Similarly, this reduced level could be positive or could be negative. So, whenever we are referring our levels to a datum, we said them as reduced level.

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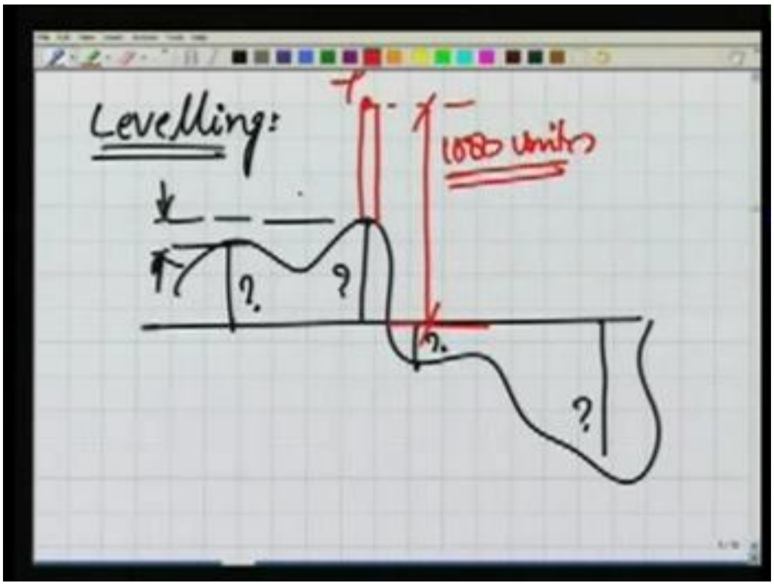

Then another definition; now we come to this term leveling again. So, what is the meaning of leveling? The meaning of leveling is from a datum, we are trying to determine the elevations or the reduced levels of points. Well, what is the value of this; what is the value of this; what is the value of this; what is the value of this, or maybe we can also say we are trying to determine the relative level. The relative level means what is the difference between the RLs of these two points. We are trying to determine the relative level, or as we said earlier also, not only we are going to determine these elevations; we are also going to fix some points at certain elevations.

For example, let us say we want to create a tower here or we want to construct a tower and a tower of total height from the datum certain value 1000 units. So, fixing this point here; fixing this point T is also the job of leveling.

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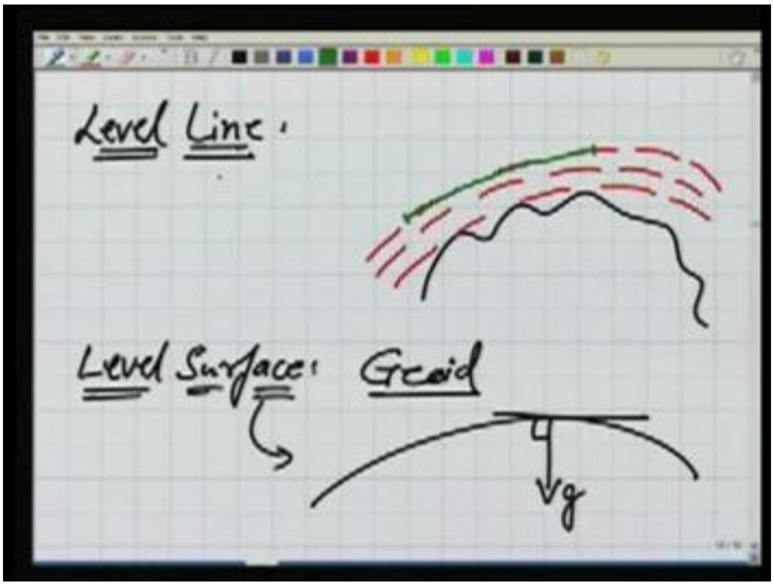

Next in the definition are the level line and the level surface. So, what is the level surface? Level surface is nothing but geoid; any surface you know which is parallel to the geoid, equipotential surface is the level surface. And we know the definition of that that everywhere in that surface, perpendicular to that surface will be in the direction of the gravity. So, if this is my surface, anywhere I drop a perpendicular. So, this indicates the direction of gravity, okay, a line on the surface. So, this is my level surface. Now you can imagine the surface.

We will have a level surface at any height; for example, if my earth surface is like this, I can have a level surface here or may be here or may be here. Everywhere we will have infinite of these surfaces. Now wherever my level surface is a line on that surface if I draw a line which is following the surface, we say this line to be the level line, okay. So, this line is level line.

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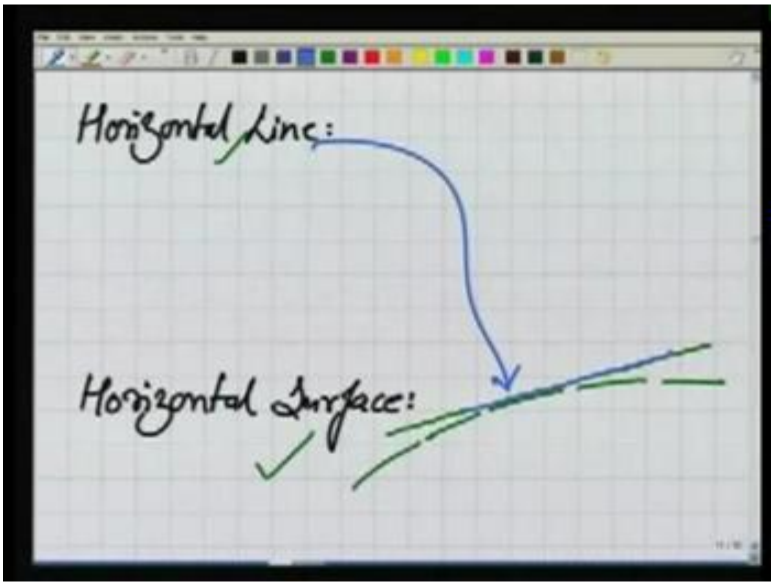

Similarly, we can define now horizontal surface and the horizontal line. Well, horizontal surface is if this is my level surface, anywhere a surface which is tangential to that is the horizontal surface, and a line which is on the horizontal surface is the horizontal line.

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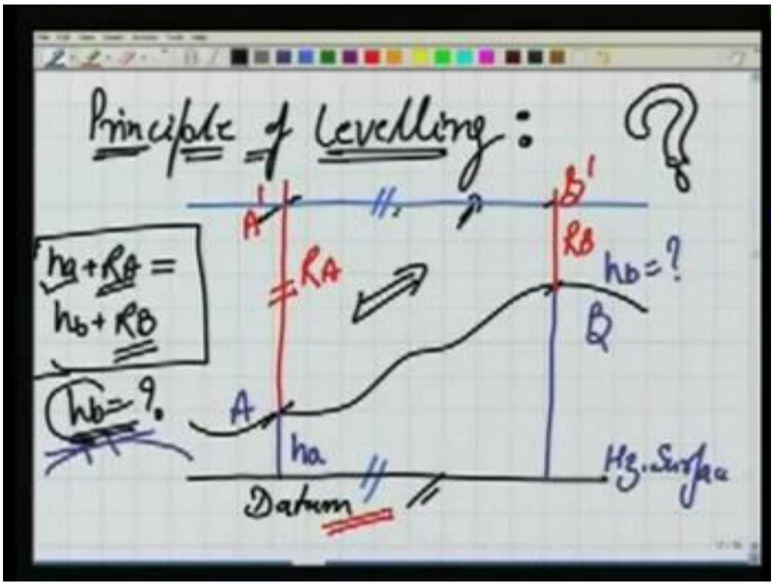

Well, having seen that now will go to the principle of leveling. We have seen the basic definition so far; we have understood the terms which are useful and which will make use of. And now we are going to see you know how we actually carry out the leveling. Okay, in order to do that, let us start let us say this is our datum, okay, our reference surface, and over here is our ground. And our job is we want to determine the relative difference between two points or I can say that the otherwise also. If I have point A here and a point B here I know h a; that means I know the RL of point A. I want to determine the RL of point B, h b is what? How to do it?

Well, over here I have taken this datum H a horizontal surface, okay. The area is very small; that is very small here. You know may be within my hand only, and within my hand. I can consider that the geoid and the horizontal surface in a very small area will be same. Now there are two points; one point here one point here, and I want to determine the difference in elevations of these two points; how to do that? Now in order to do that, if somehow I can establish a line which is parallel to my datum somehow and same; we will try to see how we can establish that. If I can establish a line which is parallel to my datum, as well as if I can now also determine somehow that how much is the value of this A, A dash and B, B dash, okay.

We have established this blue line. This blue line is parallel to the line here datum, and somehow we are establishing the values of A, A dash and B, B dash. Let us say we say because these are the readings; we will take the readings on something later on. I say this as RA and this is as RB. Now from here we can write very well that h a plus RA should be equal to h b plus RB. Now using this relationship, you can very well determine what is the elevation of h b; what is the value of h b because the only unknown here. You know h a; this is you are determining somehow, this is also you are determining somehow. So, you can also determine now h b.

So, using this principle, this is actually the basic principle of leveling. Whenever we do the leveling as we will see now, we will be making use of this principle. What we will do? We will try to establish a surface a line which is parallel to my datum as we have done here, and then we will read the intercept at these points here, okay. How it is realized in practice; that we will see now. Okay, before we go further, we would like to see how we realize this principle what we just discussed, because we want to realize this. We want to actually do this thing in the ground; how we will realize this?

So, far because over here, I am taking the datum to the horizontal surface and I have done a horizontal line here, but in actual practice, we know that we should not take the horizontal surface as the datum. So, how this principle will look like in case of if we are considering the geoid as the datum or the equipotential surface as the datum. Well let us see.

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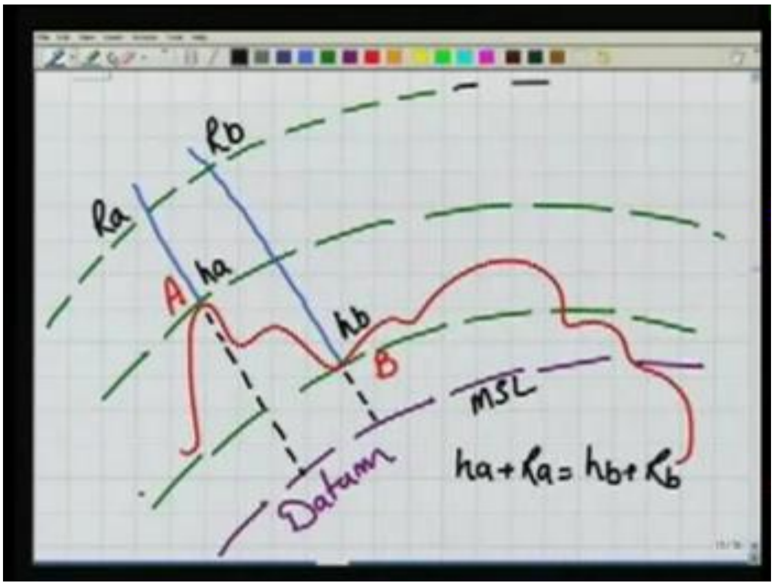

Over here, we have our datum; it could be the mean sea level, okay. So, I write it down this is mean sea level. Next over this datum, this red one is the surface of the earth where we have two points A and point B. Now this point A is at h a elevation from datum; its RL is h a, and for this point B the R L is h b. Now what we are trying to do? Let us say one of them is known, and we want to determine the other. So, if h a is known, we want to determine what h b is. In order to do that because now my area is big; big area means I cannot take the horizontal plane; rather, what I am doing? I am going to let us say I erect or let us say before that at B, I draw a surface which is parallel to mean sea level, or we can say it is also passing through the B is a level surface.

Similarly, passing from A, this is also level surface. So, anywhere the difference between these two level surfaces will be the height difference between these two points, obviously. So, what we want to do? We want to determine this difference between these two level surfaces first, then we will apply it on the known h a in order to determine h b. Well, how to do that? What we do at A, I keep something you know over which I can take the measurements, and at B also, I keep a similar kind of thing. Let us say a vertical rod and another vertical rod.

Now over here in between, I establish one more surface which is parallel to my datum, or I can say this is also equipotential surface. Now this is the surface along which I can bisect this rod and this rod. So, wherever these rods are being bisected, this height we say R a, and this height we will say R b. So, we can write the relation here again. It is the same relationship as in the previous case, but the only difference here is because we want to make use of datum and the datum is not a horizontal surface; rather, it is the equipotential surface.

So, what we will try to do? In order to determine the relative difference in height between these two or may be if I know the RL of A, I want to determine the RL of B; what should I do? I should try to establish a surface which is parallel to the datum, and using this surface, I will find the R a and R b, and then using this equation, I will find the desired values. So, my reference surface something which I am using here for the measurement now, the measuring surface has to be parallel to the datum.

Now if this is very small if this difference if the distance between these two is very small; as we know if the area is very small, we can consider a horizontal plane here, and we can also establish a horizontal plane here, okay. Instead of this, I can establish horizontal plane and then I can carry out the same job, okay, but if the area is large, we should establish somehow of measuring surface which is parallel to mean sea level. Now how actually we realize all these things in actual practice? For this we have some instruments.

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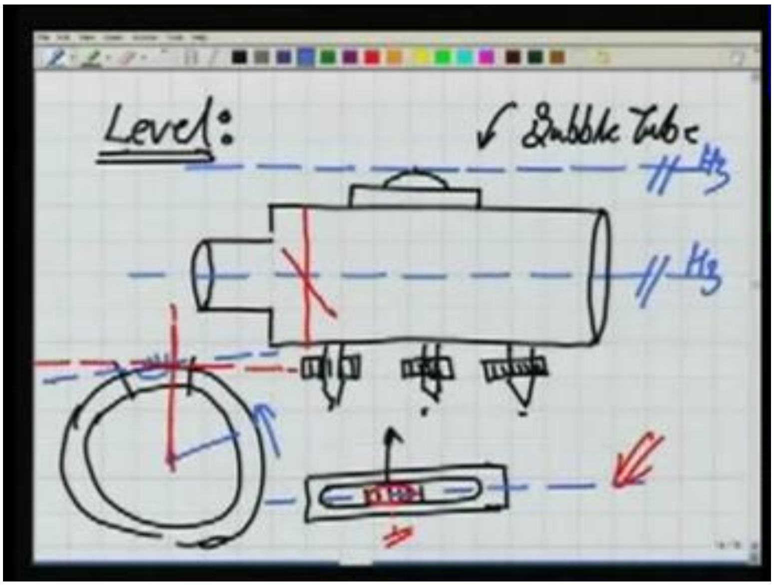

Number one is level. I am not going to show you the actual level today. In our next class lecture number two of this module, we will see the various kinds of levels which are there, but today we will understand the principle of the level what it is. A level is made of a telescope. So, if it is a telescope, it has the eyepiece, then this is the body of the telescope and in the same cap less type telescope which we saw when we were talking about theodolite. This is the objective.

Over here, we have already defined the line of sight. The line of sight in the telescope is defined as the intersection of crosswire; that is the intersection of the crosswire. There also is a crosswire and the center of the objective lens. So, this is my line of sight; along with this telescope, we have some nuts there and some leveling arrangement, where using these leveling screws, I can change the level of this instrument. We will see it, and this is same thing as we saw in the case of theodolite also; we have three leveling screws.

Well, in addition to this, the most important part of this, on top of somewhere else we have a bubble tube if this is bubble tube. Now what is bubble tube? We have already seen this when we were talking about the theodolite. We know a bubble tube is a part of a very large circular glass tube. So, I am just cutting a little part from here of this glass tube, and I am encasing it in some casing. And if I see it in the plan, this is casing; inside this casing is my bubble tube. And in the center of the bubble tube, we have some graduations, and this is the point which is the center of the bubble tube.

Now because the bubble tube is part of a big tube circular tube; in this tube, we leave a little air which we say the air bubble. Now whenever I will define one more term here at the center of my bubble tube, we define a line which is parallel to the bubble tube at its tangential, tangential at this point; tangential at the center of the bubble tube to the circular of the bubble tube; for example, here that was the circular tube. So, that is the line which I am talking about, and this line we say access of bubble tube, okay. So, we can see the axes of the bubble tube.

Now this bubble tube because there is a little bubble here if I rotate this tube, you can think that I am rotating this big tube circular tube. If I rotate it, this bubble will have a tendency to be always on the top. So, this bubble will be all in top as well as these variations will be also in the top. What I mean if this bubble I am showing it by red here if that is the bubble here. This bubble is in center or this graduation the center graduation is in the center of the bubble. The moment we have a situation like this, the meaning is this point is exactly pointing upward. If this point is pointing upward, this blue line here access of the bubble tube will be a horizontal line.

So, basically using this bubble tube bringing the bubble in center as such we say, bringing the bubble in center we can make this blue line or the access of the bubble tube horizontal. So, that we know now. So, what we can do with the bubble tube? We can establish a horizontal line which is the access of the bubble tube. Now in this instrument, this instrument is made in such a way that this line access of the bubble tube here and the line of sight, these two are parallel. Well, what we can establish now? By making this access of the bubble tube horizontal, I can also make this line as horizontal. So, now, I have got a telescope, and in that telescope, I have made my line of sight horizontal, okay.

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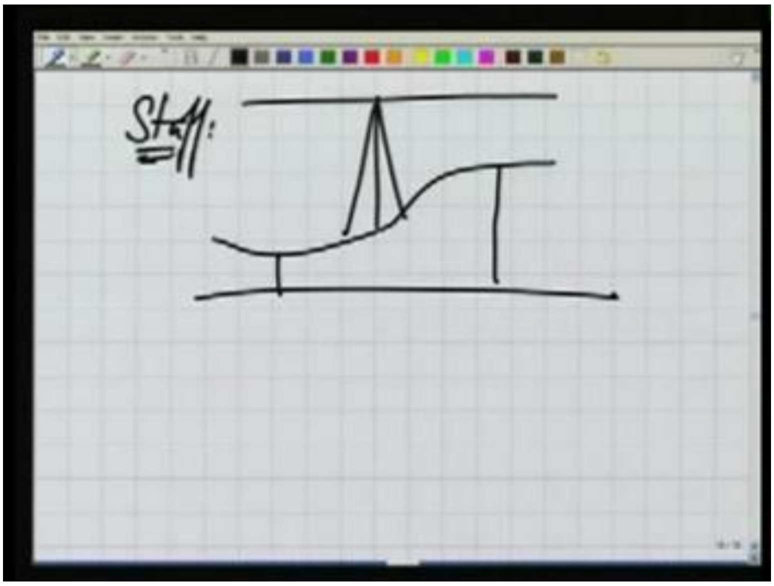

Along with this level, one more instrument which is very very important is we say staff. Now what is this staff? As we were seeing, how we were doing the leveling; that was our datum two points. We want to determine you know difference in heights between these two points or the relative RL differences. What we are doing? We are establishing the horizontal line of sight or horizontal line as we know now, and we can do it by level.

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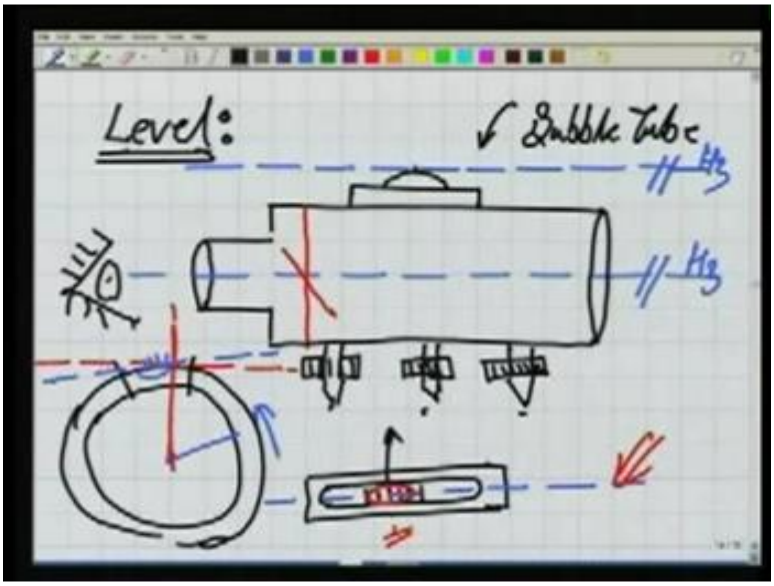

When we look through our telescope, your eye is here. So, the meaning is you are looking along a horizontal line.

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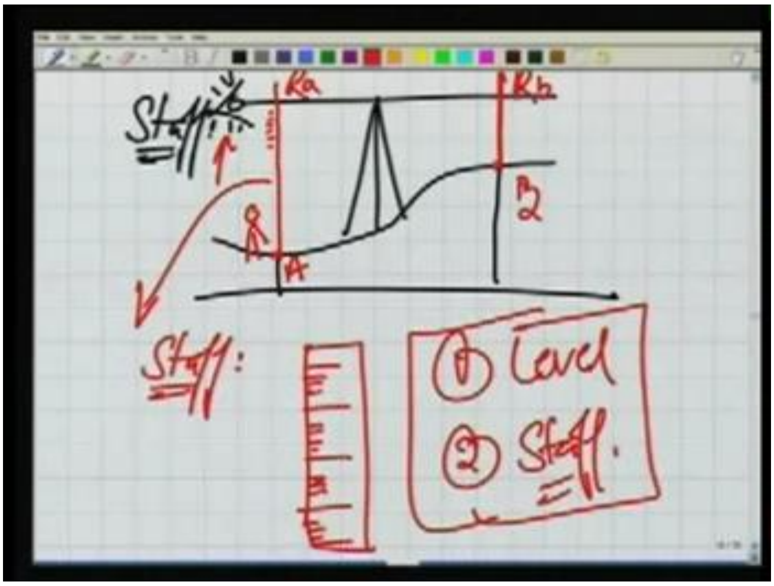

So, if you are looking along a horizontal line, your eye is here. Now what we do? We keep I said two something earlier two rods I said, but these rods are actually called a staff. Now what these are I will show you those in the next lecture. They are way basically the vertical scales, and these are all graduated. We will see the kind of the graduations also in those. So, these are basically vertical scales like this, and someone is holding this vertical scale here so that it is kept vertically here, and we have the graduations.

So, from here when we are observing, we are taking the reading R a, this point A, and if this is point B, we are also taking the reading against this staff which is R b. So, we are making use of now two things. Number one, level for making a horizontal line of sight, and number two, a staff, and by making use of these two, we can determine the difference in RL of these two points or their relative height differences because we can find that difference. Now next in this, we will see that what happens.

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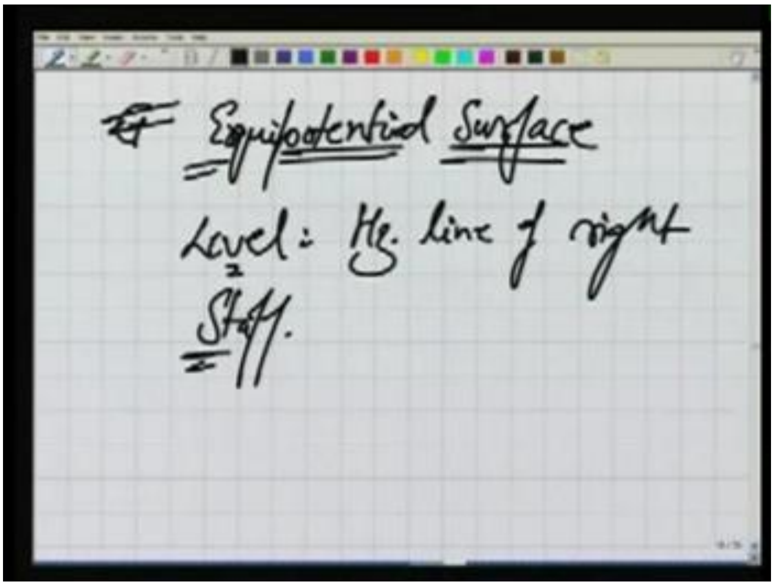

Because basically we need to measure along our datum is equipotential surface. How our level, okay, level makes you or gives you a horizontal line of sight and the staff. How we make use of these two in order to measure from the equipotential surface.

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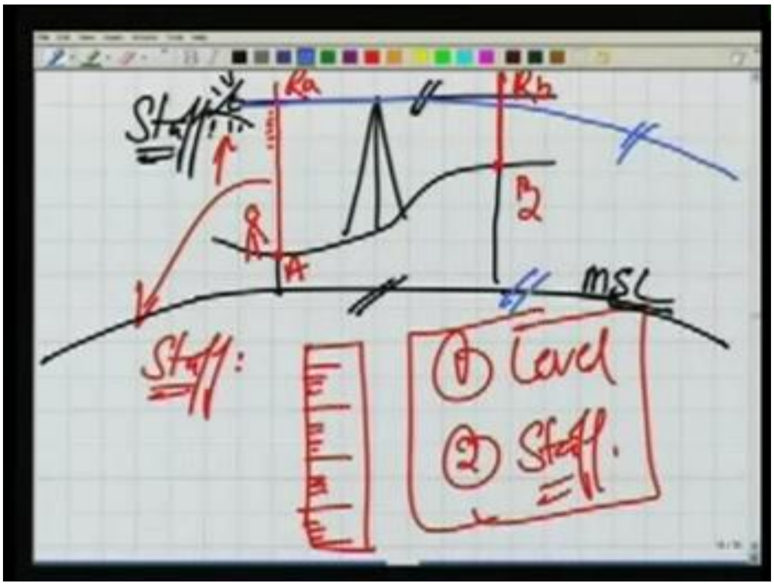

Because the principle that we are talking so far in this case, this is the horizontal datum, and that is the horizontal line of sight; we have no problem, but in actual practice, it is not the horizontal surface rather it is a geoid or we say let us say the datum is mean sea level. So, if the datum is mean sea level, we should establish over here a line of sight which is parallel to mean sea level. Now how to establish a line of sight which is parallel to mean sea level; that is really not possible. So, what we do? We realize it in little pieces.

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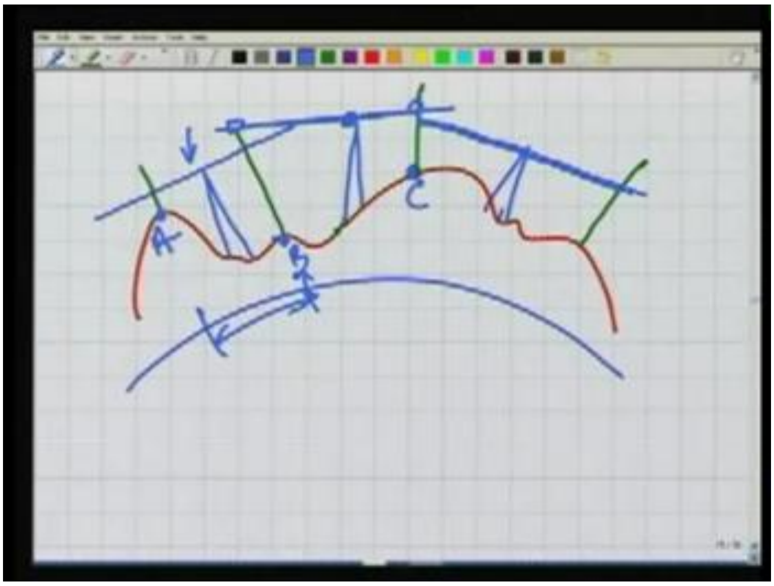

Well, very first time here; we have a horizontal line of sight. We determine the difference in elevation between points A and B in a very small area; for a small area, we can consider that our datum and geoid are nearly same. Sorry, the datum which is the geoid or MSL and the horizontal surface or horizontal line is nearly same. Then we establish another horizontal line here, and then we take again the observations R a, R b so that we know the elevations of this point C. Then again we go to this; again we establish the horizontal line of sight. So, what we are doing?

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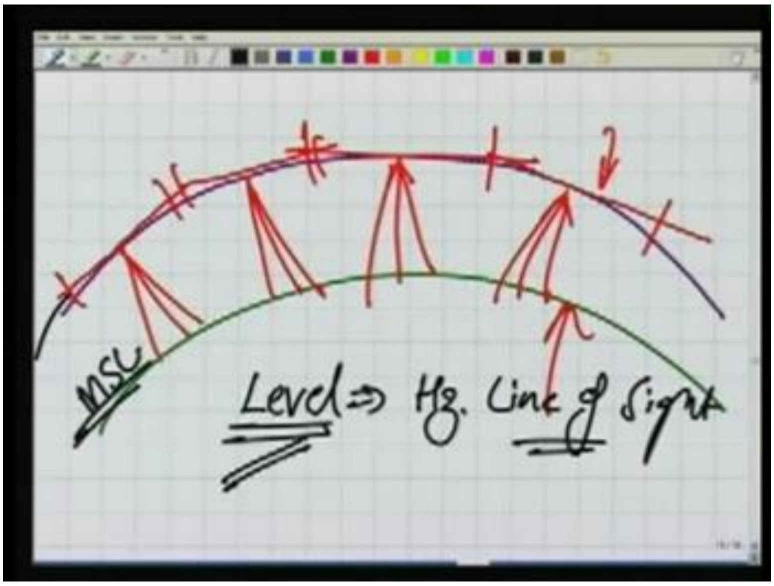

We are basically realizing as we can see if this is my mean sea level, I want to establish a surface which is parallel to the mean sea level over here; this is this is parallel to the mean sea level. This is what is desired, but we cannot establish it. So, instead of that, what we are doing? We are establishing it in little pieces, one piece, another one, another one and another one. And this is how we are moving along the surface which is parallel to the mean sea level or we can say we are moving along a level surface by working in these little distances.

So, this is actually the principle of leveling by which even if we are using level, we are using level which gives you a horizontal line of sight, but it is still using this level we can determine the RLs of points from mean sea level. You know we can establish the level surface using the level which gives us, in fact, the horizontal surface or horizontal line. Now having said that or having understood this thing, we can make use of this level any staff combination in order to determine the elevations of various points.

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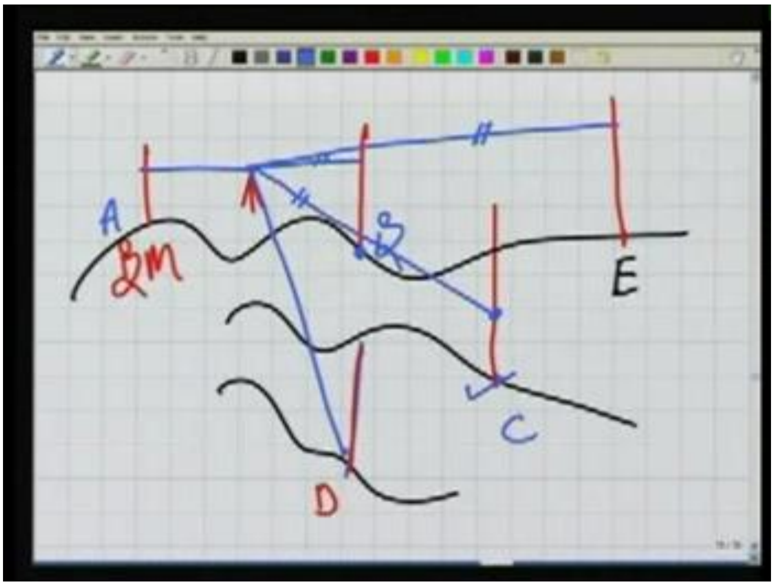

For example, if we have big area, I keep my level here. I know this is my benchmark; benchmark means I know the RL of this point, and I take a back sight. We will talk about this back sight or the sights again later on. I take a sight, then I set my level or the staff somewhere. Let us say this is staff and I take again one more sight. By doing this, I know the RL of this point B, benchmark was A. Similarly, if there is a point C, I want to determine RL of C; I will take a sight again here.

So, what we are doing here basically the telescope for which we have made the level, the level is now horizontal or the bubble is in center; the access of the bubble tube is horizontal. So, line of sight is also horizontal. Now if I rotate my level in a horizontal plane, it will make a horizontal plane in the line of sight; wherever I am looking, I am looking along the horizontal plane. So, because of that reason, this is horizontal; this is also horizontal. So, by doing that, I can determine the RL of this point also; similarly, any other point, I can determine the RL here also. Let us say this is of D and so on. If there is a point here also E, I can determine the RL of that also.

Now this is the horizontal line. So, this is the basic principle of leveling, and we will make use of this, and we will see many applications of this, but before we go further, there are some problems with this.

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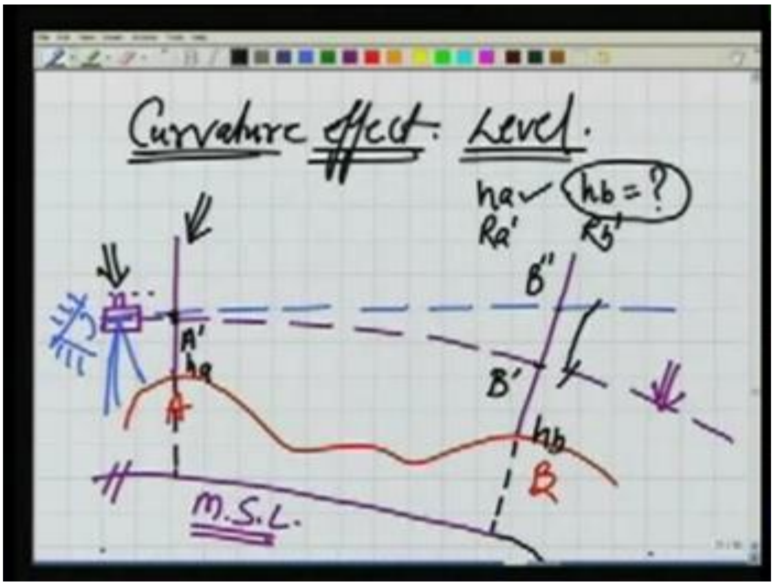

One problem is the curvature effect. What is the effect of S-curvature when we are doing leveling with a level? Now I am going to give you one case. Well here is a point A, and there is a point B. We want to determine the difference, and this is our mean sea level. So, ideally in order to determine the differences between these two points A and B, I should establish a surface which is parallel to the mean sea level, but what we do? Because we are making use of level and staff combination, I keep a staff here, and I keep a staff here. A staff is kept in both the places in the direction of the gravity you know vertical. So, that is why I am showing it like this because this is perpendicular here, okay.

Now I keep my level somewhere here, and that is the eye. From here, I am looking at. But the level we know it makes a horizontal line of sight. So, what this level will do? It will make a horizontal line of sight. So, I am looking along this sight the horizontal line of sight, while at this point if I could establish a surface which is parallel to the mean sea level it, should have been like this. Let me just correct this one so that they look similar or parallel. So, the mean sea level or our datum is somewhere here. So, ideally in ideal case of measurement, this mean sea level is there.

We should establish a measuring surface this measuring surface which is parallel to the mean sea level, but we cannot do it. We cannot see along the level line; we cannot see along the level surface that is not possible. What we can do best, we can establish a horizontal line of sight as we have seen. So, what we are establishing by our level? The level is kept here with the bubble tube. We are establishing this horizontal line of sight. So, it is obvious here as you can see. The RL of A is h a and RL of B is h b from mean sea level, okay.

Now in order to determine if I know h a, h a is known, I want to determine h b. What should I do? I should read the values if I write it as A, A dash. A dash is this point here, A, A dash and B, B dash. So, I should take my observations in my staff at A dash and at B dash, and these observations will be R a dash and R b dash. So, this is my measuring surface. If I have taken these observations, now I can easily find the value of h b by taking these observations R a dash and R b dash. But am I taking R b dash or R a dash? I can say well, I am taking Ra dash because my level here is very near to the staff at A, because if this is my staff, this is my level; I am very near to it. So, the horizontal surface at my level is same as the level surface.

So, there is no difference in the readings here at this point, but for this point B, if this is as we saw if it is one kilometer apart, there will be a difference of 8 centimeter. This difference if I highlight it, this difference will be 8 centimeter if this distance is of order of 1 kilometer. So, what we are doing if we are establishing this horizontal surface over here the blue line which we do using our level; we are introducing the error. We are introducing an error which is of order of 8 centimeter. Now what we will do? We will try to see the exact nature of this error what this error is. So, right now, what we have seen that instead of looking at B dash, we are sighting at B double dash; this is what is happening. Now this value, how much is this?

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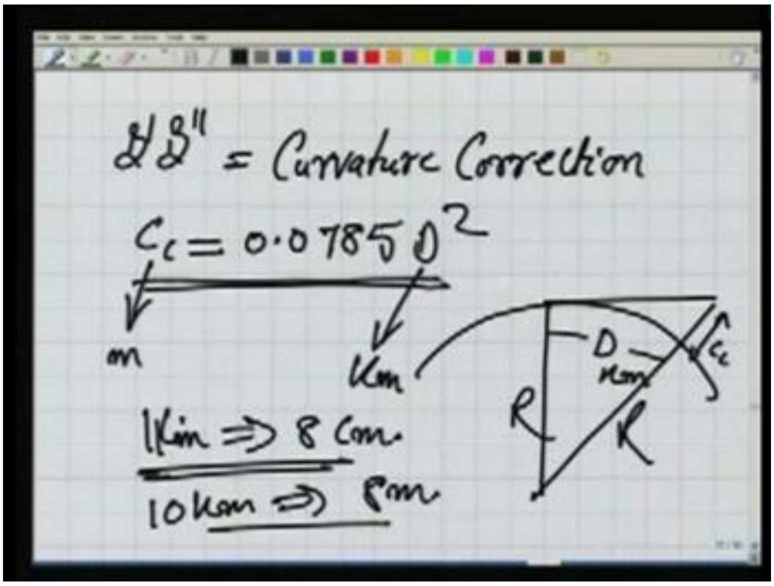

B B dash B double dash is actually we say B dash B double dash; we say the curvature correction or error due to curvature. This is the error due to curvature, okay, because my line of sight is horizontal; it is not following the curvature of the earth. It is not parallel to the mean sea level; it is not same as the level line. So, because of that reason, we are introducing an error of B dash B double dash. So, what should I do? Because I am taking an observation in this staff which is kept at B at B double dash. So, my reading will be some value along this staff at B double dash not at B dash

Now one more thing; this curvature correction Cc, its value is generally given as 0.0785 D square; this value can be computed. We can very well write you know how much is the derivation of tangent from the earth surface; if you know the radius of earth for a distance D in kilometer, I can find this Cc. So, we can you know derive it. So, after derivation, it has been found that this is Cc is 0.0785 D square, where Cc is in meter, and D is in kilometer. Now this also gives us the answer that initially we were saying you know in 1 kilometer, there is a derivation of around 8 centimeters, and in 10 kilometer, there is a derivations of around 8 meter. So, that you can see you can prove again from here.

So, this is about the curvature correction. So, whatever the observation we are taking at B double dash, we should correct it by Cc. So, then it is equivalent to as if we are taking observations at B dash, but this is not the only thing. We know there is various layers of the atmosphere and the line of sight. Line of sight means the reading which is here; what we are seeing? Over here looking through the telescope, I am seeing this staff here and the cross wire of the telescope, the middle vertical here because how do we take the observations.

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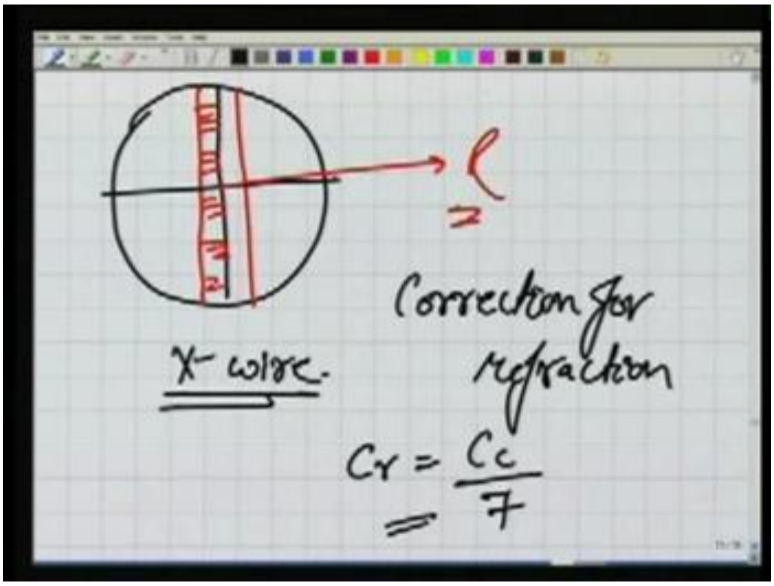

If this is my field of view, this is my cross wire in my telescope. We will be seeing the staff; a staff is a graduated scale. This is how we will be looking at, and that is the value which we say as R the reading. Now in our case here, what we are seeing. The line of sight which is reaching us or the graduation which is actually reaching us is also being affected by refraction of the atmosphere; because the line of sight will not be now horizontal, rather it will have again some curvature a little curvature. So, if I draw due to the effect of atmospheric layers for an average condition, we do not see exactly along the horizontal line; rather, we see along a little curvature. And this curvature has been found to be one by seventh of curvature of the earth if we apply the same logic.

So, what exactly we are looking at? We are looking at in my instrument a point in my staff a point which is B triple dash which is a point here. So, what will be the correction now? I would like to apply the corrections now; number one, first to take this point up where my horizontal lines would have bisected, then this point down to B dash where my level surface would have bisected. And as we know the curvature of this is one-seventh of the curvature of the earth. So, similarly as we found here the correction for curvature, we can find also the correction for refraction. And that we write as Cr; that is correction due to curvature divided by 7, you can determine that

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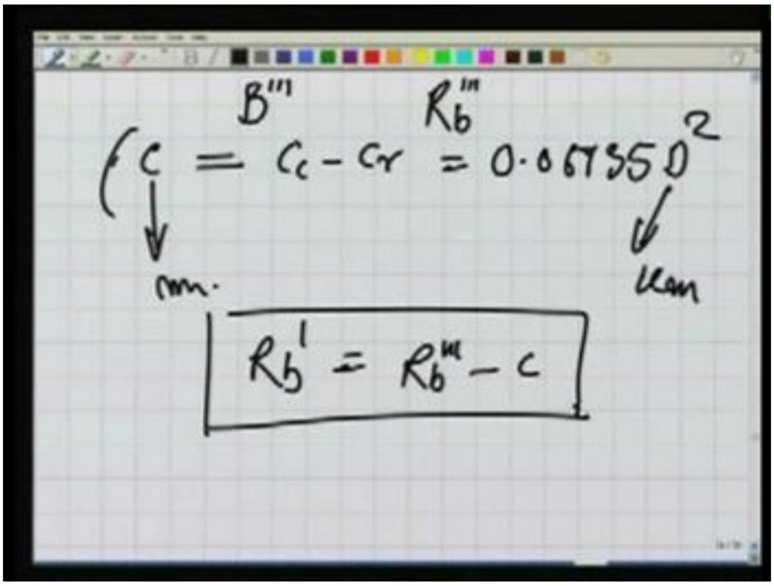

Now if it is so the total correction, if we say total correction C in my observation, because what we are observing? We are observing at B triple dash, how much should I apply that? Something which I am observing at B triple dash is let us say R b triple dash. I should apply some correction to this. So, this correction will be now Cc minus Cr. So, this value if you compute it, you find this value comes out to be 0.06735 D square; again D is in kilometer, and this curvature correction is in meter. So, my actual reading which I can say as R b dash should be R b triple dash minus C, the correction for both the total correction. This is the total correction due to curvature as well as refraction.

So, we have seen today what is the meaning of leveling, how do we do that; what are the levels and a staff, and finally, how to apply correction for curvature and refraction. Thank you.