Surveying
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Lecture - 1
Module - 6
Triangulation and Trilateration

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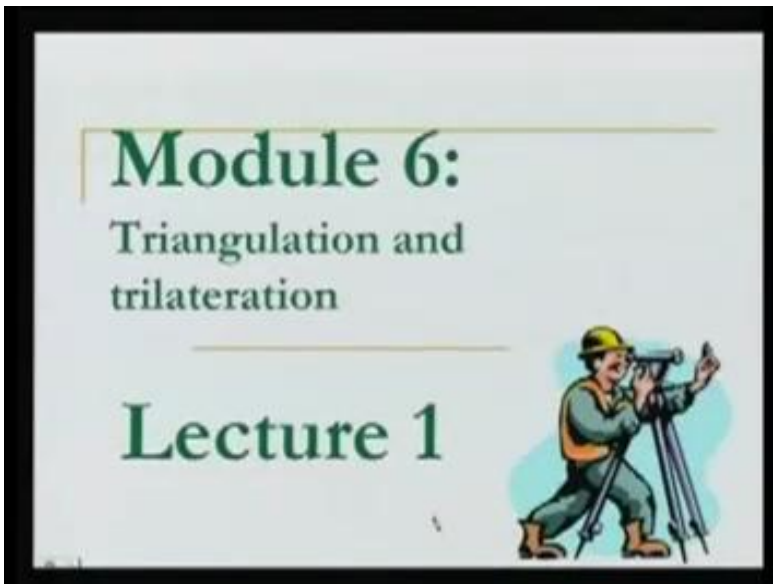

Welcome to this another lecture on basic surveying. In this, we are going to talk about the module 6. In module 6, we are going to cover triangulation and trilateration. These are also the methods of establishing control.

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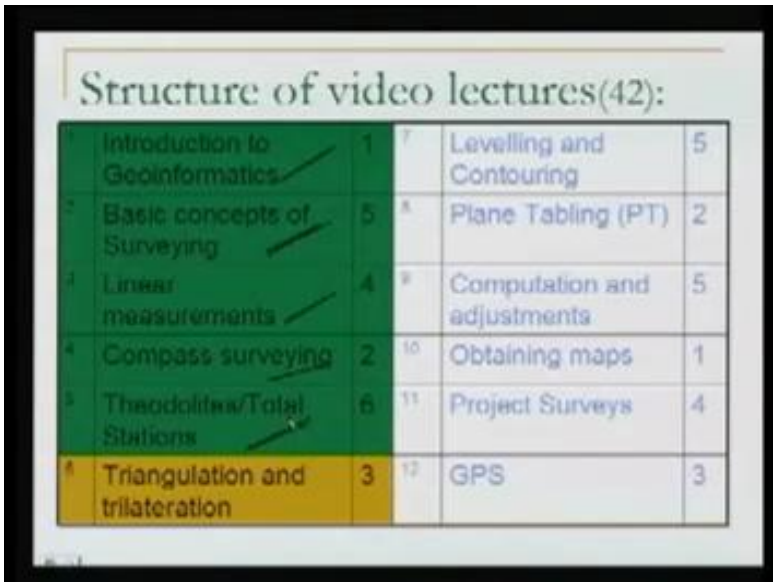

What we will do today is we will begin with lecture number 1, because surveying is basically about the measurements, two basic measurements. They are angle and for distances. We have seen the methods, which are like chain tape, invar tape or maybe the EDMI.

Now, for the angle measurement, we can make use of a device like compass, but that is not very accurate. We have seen the reasons why it is so. So, the more important device or more useful device here in this case is the theodolite. Now, the modern version of the theodolite is the total station which combines a theodolite angle measuring device, and as well as the EDMI, the length measuring device. So, total station is complete device.

So, we saw about these also that how to work with the theodolite, how to measure the angles, what are the procedures in order to measure the angles, what are the sources of errors, how to measure horizontal angle and the vertical angle, how to eliminate the errors. So, all these we have seen so far. So, our 6 module is triangulation and trilateration.

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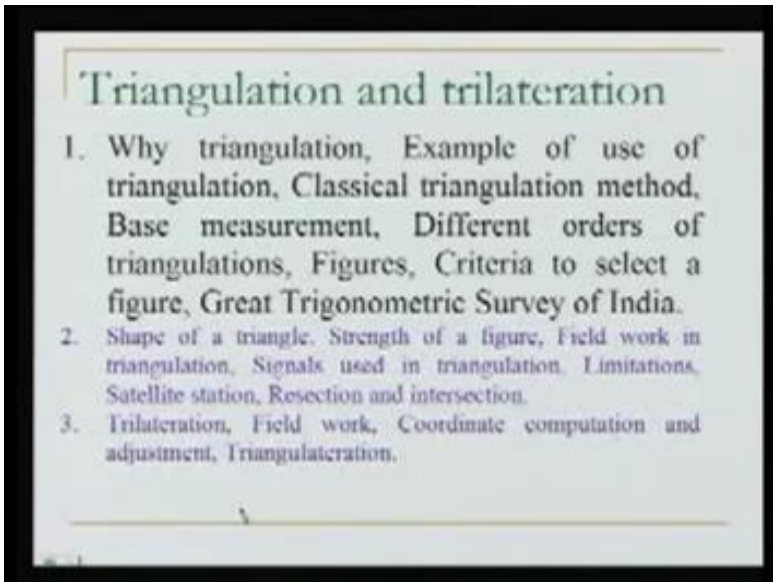

In this, we will begin with the very basic definition. We will see that what is triangulation and as well as why we need to do it. Then we will see some examples of the use of the triangulation where exactly in field we can use it, and then what is the classical method of the triangulation. We need to measure one length or may be sometimes two or three lengths in the case of triangulation. So, what are these methods of base measurement? Then, we will see the different orders of the triangulation, the triangulation figures, how do we select the figure, what are the criterion for that, and then finally, we look into the great trigonometrical survey of India.

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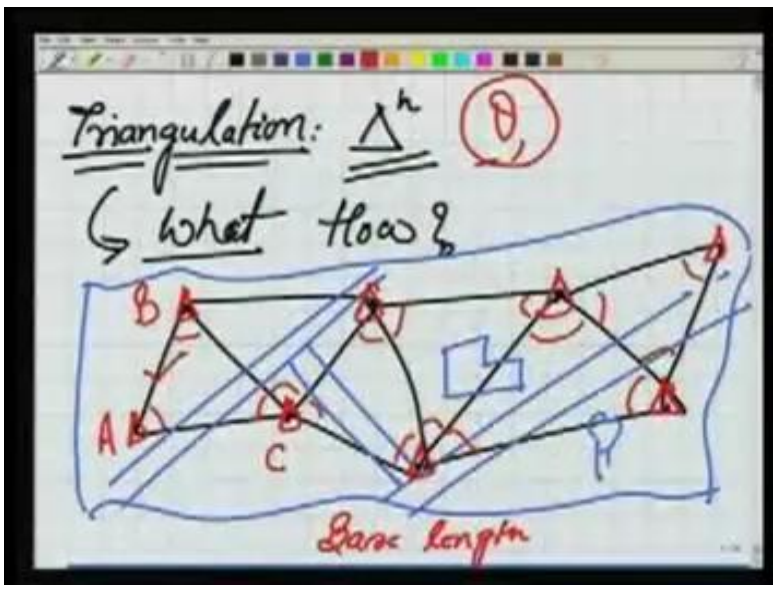

So, here we begin with this module. So, let us start with what is triangulation, and I am writing here triangulation and in order to save my time, I will use this as the symbol for the triangulation. Number one, we will see what it is, what is the triangulation and as well as we will try to see because once I am trying to answer this, what we will also answer how we do it. So, basically triangulation is a network of triangles which we are trying to do in order to establish a control network. I will come to these terms later on what is the control network though we have seen that before also.

So, the moment I say network of triangles, the meaning is we are trying to cover our ground by a network made by the triangles. Now, here in this case, the ground if I draw the ground here let us say that was the terrain over there, we have a road, some houses, some trees, and some more roads. Now, we want to make a map of this blue area. The blue area is the ground is the terrain. In order to make the map of this blue area, we do the triangulation.

So, what is the triangulation? We are covering this entire area by means of these triangles which are shown in black and red ones are the triangulation stations. Well, why the triangulation is important? Why it is significant? If you remember in those days when the EDMIs were not available or now also, even if the EDMI is available, we have to measure so many distances in order to make the triangles by measuring the lands. So, at that time when the length measurement is costly because EDMI is a costly instrument, what we would like to do? We would like to make use of our theodolite which can give us very cheap theta, the angle measurement.

So, in this figure if we have an instrument, which can measure the angles, the theodolite very cheaply and without you know much cost and we want to have some method of measuring only one length here, what I mean now in these I measure one length very accurately using some method. This method could be the chain; this method could be the invar or whatever. So, this length which we are measuring here is called the base length. I write it here or base measurement. So, we are measuring, we are putting all our efforts in order to measure this base length accurately. Then, later on because we know we have a theodolite with us, using this theodolite we measure all the angles.

So, all these internal angles of the triangulation figure are measured. So, what we did? We measured the length, only once for only one line, but we are measuring all other

angles. Now, you know that it is very easy to measure the angles because you have to be physically in one place. You have to just bisect the targets. So, standing at this point A, you can bisect up target at B and a target at C, and the angle is measured, but to measure the length if the EDMI is not available, what you have to do is, you have to stretch your tape or chain along this line is AC. Well, it may be undulating terrain. The length measurement is subjected to more errors and then, the errors in the angular measurement.

So, we are in a situation like where we can carry out the angular measurements in a better way, more accurately without much problems, but now the length measurements. Well, even if that is the case just by knowing the single line and all these angles measured as you can guess; now we can determine the coordinates of all these points having known. For example, let us say I know the coordinate of the point A. The coordinate of point A is known. So, by knowing this length and all these angles, I can determine the coordinates of the B, C, D and all other points.

So, what we have done by measuring these numbers of angles and only one length, we are able to generate a network of control points for which we note the coordinates over the ground. So, these are what the triangulation is. Triangulation as we can see here now is a network of triangles, which is used in order to cover the entire country.

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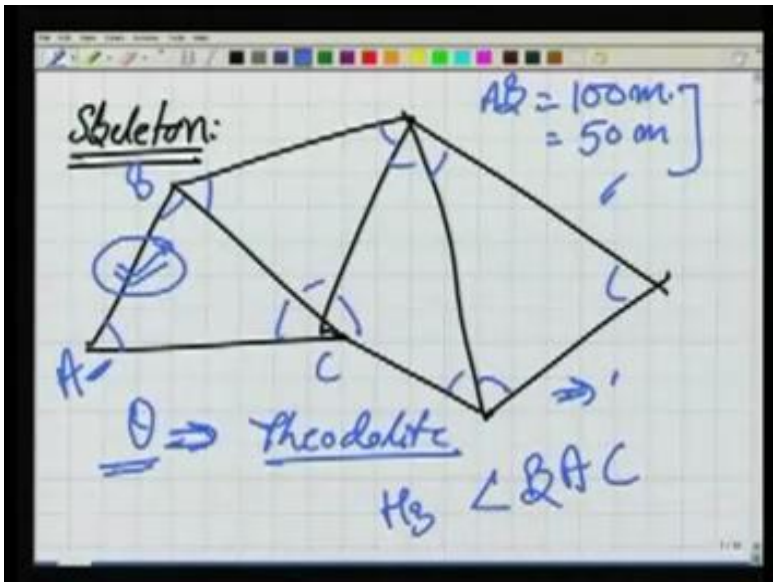

So, in a way we can also say it is giving us a skeleton of the area. We are producing a skeleton of the area, and we can use that skeleton later on for our work. So, we have

understood right now what the triangulation is. It is a network of triangles. We also know now that why we went for it because it was easier to do it with the help of the angular instrument, and only one length was to be measured. Now, we will see because we are saying the triangulation we measure one length, which is the base length and then, later on we measure the angles. For example, in this figure all these angles are measured and as well as the length is measured, the base length. Only one length having them base we will have the coordinates of all these points.

So, we are able to establish a network, a skeleton of the area. Now, the question is how we measure number one, the angles. We know the method. We can use theodolite and we also know how to measure the angles with the theodolite. We can measure the angles in horizontal plane as well as in vertical because starting from point A to point B and C, I can measure the horizontal angle that is B A and C as well as the vertical angle at A to B because we can establish the vertical control with the help of these vertical angles.

Now, the other thing is how to measure this length if the EDMI is available. Well, the length measurement will be easier. As we have seen, it is a very fast method, but in case if the EDMI is not available which is costliest instrument, not always you may have the EDMI available with you. So, in that case what to do in order to measure a length A B accurately? Well, if this length A B is small, for example, only 100 meter or less than that 50 meter, in this case you are doing the triangulation in order to cover a very small area.

Let us say your servicing department or wherever your building is just nearby area, the neighborhood of that area you just want to do a triangulation in that area. So, in that case your length of the sides or the base length will be small. So, your length could be only 100 meters or 50 meters. So, in that case you can directly measure it using the tape or chain by spreading the chain or tape on a flat stress of the ground, and also applying the corrections, but many times your base length may be of order of 5 kilometer. This is what may happen. 1 kilometer, 2 kilometers you are doing the triangulation in a hilly terrain in order to cover an area of 30 kilometers by 30 kilometers. So, your base lengths are of 2 kilometers length. How to measure that base length, if you do not have EDMI with you.

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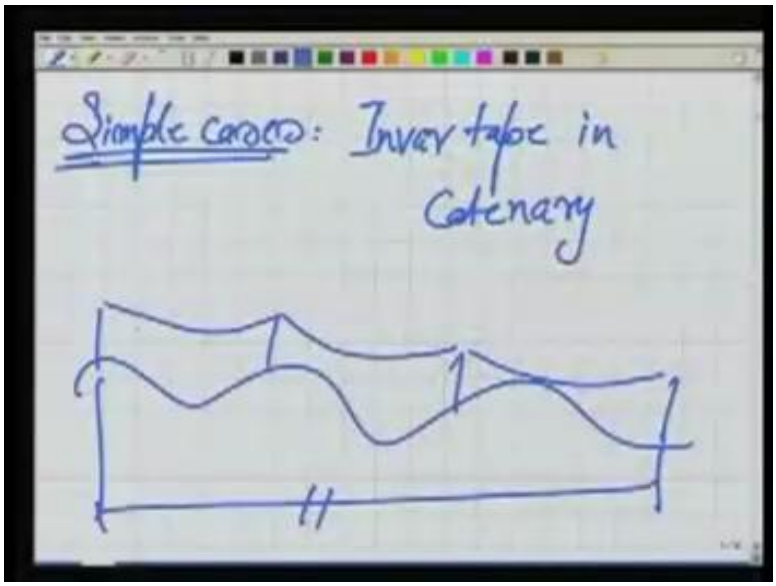

Now, in that case we go for a method in the simple cases when we want to measure a small base length as you understand.

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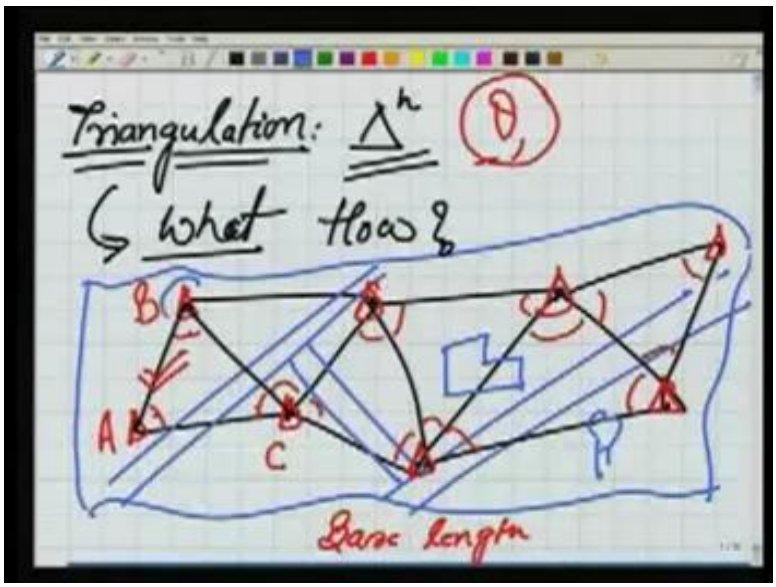

Now, in the case of the triangulation, the accuracy of these coordinates, of all these coordinates, the accuracy of all these will depend upon the accuracy by which we have measured the base length. If your base length is wrong, all these coordinates will be wrong. So, we have to excise all precautions, make the best effort in order to measure the

base length accurately. So, in the case of the simple cases, we will be using the invar tape. Why we use the invar and in catenary?

Now, you know what the meaning of that is. We discuss about that we will be using the invar tape in catenary, and we will be applying all the corrections for all the kinds of the errors, and then only we can determine the horizontal distance between these points invar because there is thermal expensing properties. It does not expand much with the change in the temperature. It will maintain its length and then, we are applying the corrections for this catenary and all the other corrections. So, we can measure a small length correctly using this approach. So, this length could be of order of 100 meters to 500 meters depending on what kind of ground you have, how much efforts you are putting into it.

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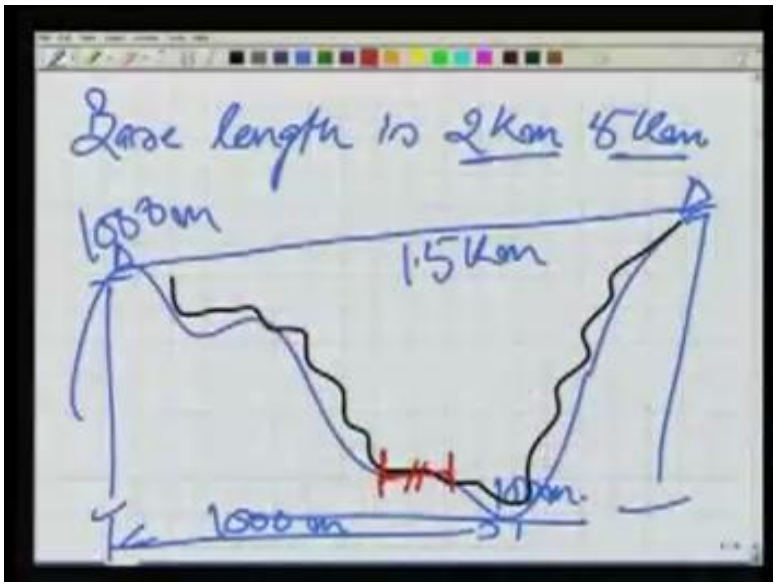

Well, what your base length is of order of let us say 2 kilometers or 5 kilometers. In that case, think of a hilly terrain. Somewhere you want to make a map of the hilly terrain. You want to do the triangulation in hilly terrain where your base length is of 2 kilometer length. Now, you want to measure that hilly terrain means a terrain like this, and these differences in heights are of order of you know this point may help and reduce the level, the height of this point maybe we can say 100 meters from main sea level, while this could be 1000 meters. A distance of only 1000 meters there could be difference like this.

So, our terrain is very much hilly. Your one station is here and the other station is here. You want to measure this as the base length, which is of order of as you can say this is 1000 meters. So, let us say 1.5 kilometers you want to measure this horizontal distance. You cannot spread your tape or chain or anything here. That is not possible. You would not like to carry out the measurement this way. So, what should we do?

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The method, which we can suggest is we say base extension. Now, what is this base extension? Even in this area, which is highly undulating, we will try to find a site which is flat, which is small. That means very small. For example, let us say it is here. I am showing it by red which is here which is flat and which is small. Now, what would you like to do? We would like to measure the base over here very accurately, a very small base and then, we would try to connect this base to this one point here and point here by some means of triangles, so that having known this length, we can compute this length. How it is possible?

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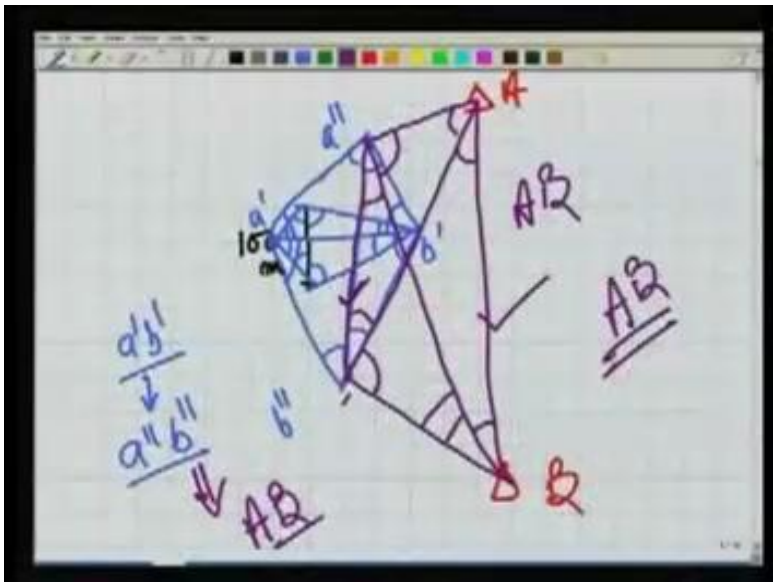

Well, this is possible. For example, let us say my small base length which I was measuring is this, and that is only 100 meters or even less than that. I could find a stress of the ground there, which is flat, and I could measure a very small base length accurately. Now, I want to connect it finally to my this big base, the actual base from my triangulation A and B which we are not able to measure directly as we know because of the problems in that terrain, it is a huge length is 1.5 kilometers of you know that kind of order.

So, what to do? Well, what we will do is, we will start with this small base that we have measured, and we will try to extend it. Let us say I measure, I establish just two points here, point a dash and point b dash, and then I measure these angles. All these angles are being measured by theodolite. Theodolite can measure the angles. That is not the problem. Once I have measured all these internal angles, I know the length of this black line we had measured that it was possible for us. I can compute the length of line a dash b dash. So, the length of the line a dash b dash is computed. Then, further I established two more points let us say it is a double dash and b double dash, and then I joined this a dash b dash to a double dash b double dash, and again using the theodolite I measure the angles here.

So, measuring these angles is not a problem because theodolite can measure any angle anywhere. So, again what I am doing is starting from this a dash b dash, and all the

internal angles which are measured by the theodolite, I can compute a double dash b double dash. So, I know the length now a double dash b double dash. Similarly, I will try to connect now this, a double dash b double dash to AB. How we can do it? My purpose is to determine this length. So, what I am doing? I know this length, a double dash b dash as well as I measure all these internal angles here. I can occupy A B and we can measure these angles.

So, once we are measuring these angles using the figure here I can determine now starting from here, and the internal angles I can compute the length of A B. So, from a double dash b double dash, we have the length A B. So, what we saw here and one more thing, please keep in mind. The moment I say standing at this point B, I am bisecting a point here b dash and a point a dash. What we are doing? We have a ranging rod or we have something called signal standing there, and we are bisecting the signal and we are able to measure these angles.

So, what we have seen now is, we have seen that we can start from a very small base length which you can measure correctly. And we can extend it further into the base length which is desirable, because the desirable length in this case was A B, which we are not able to measure, but now having done all this process, all the computations, we are able to establish the length of A B. So, what we have done? We have measured our base length.

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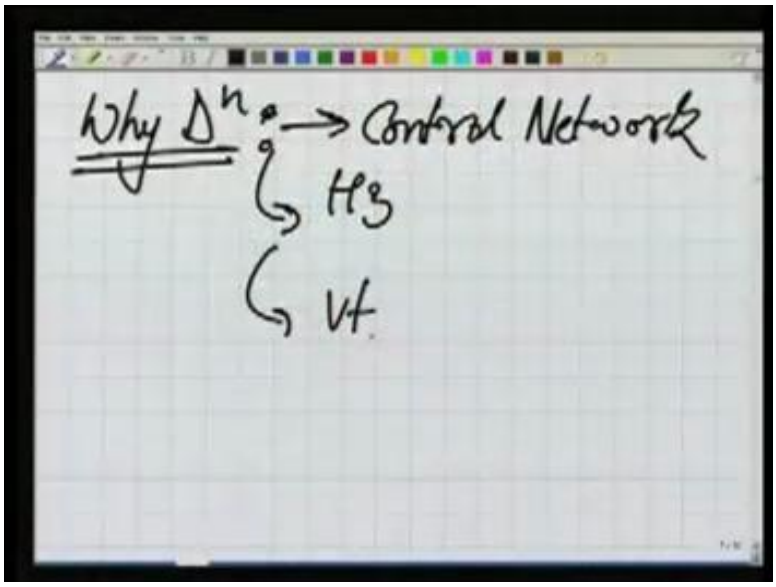

Next we will go to that because we have not yet answered that why triangulation in full by this time. We know what is triangulation, how we do it, also a little bit and also the length measurement, angle measurement in that, but we do not know right now in full that why we go for triangulation. The basic thing for going for the triangulation is I can say establishing the control network. Now, the moment I say control, control is of two types. One is horizontal and other one is the vertical control. Now, what these are? We have also discussed these before, but I would like to revisit these things in order to understand a triangulation that what the meaning of this is. If there is an area, I am going to draw a map of some area.

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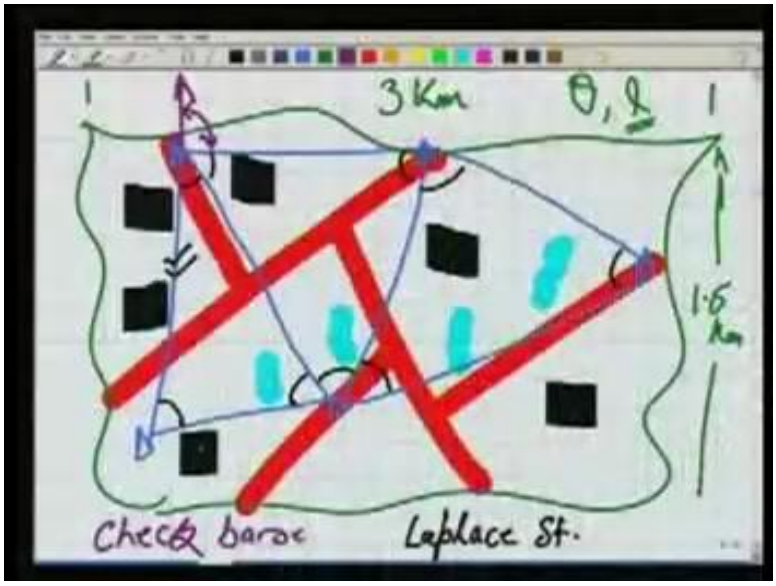

Let us say this is the area. Now, over here we have some roads. I am just showing a smaller area which you can relate easily with the area could be very large also. We also have some houses here. We have several trees and another thing here is no just again area. Now, what we want to do? We want to make a map of this area, and this area is of site let us say this is 3 kilometers wide in length and 1.5 kilometers wide. That is the size of the area.

So, we have an area this big, and we want to make the map of this area. How should we proceed? We cannot do it by compass. We can do it by compass, but compass is not accurate. We have seen one method of traversing. In the case of traversing, we are measuring all the lengths. The problem with the traversing is that you measure the angles

as well as you have to measure all the lengths and measuring lengths, it takes time. So, we do not want to do it by that method also. So, we want to do it by a method in which we are measuring a number of angles, but only few lengths. How to proceed with that? Well, what we can do is, we can begin with, I establish a point here and I establish another point and I join them. Let us say with this then a point here, and then a point here. Let us say now all these points are inter-visible. This is how we have selected it.

So, what we have done is, we are making a set of triangles here. Now, in this set of triangles, one length we want to measure accurately. So, let us say this is the length which I measure accurately by spreading my chain or tape or by base extension method as well as I am measuring all these angles now using the theodolite because measuring angle is not a problem. So, all these angles are also measured. Once this job is done, I can come back to the laboratory and in my laboratory using my field observations, using the length of all these lines, sorry length of one line which is the base length as well as all the angles.

What I can do? I can start plotting it. One more thing let me give you one more term here. The term is called Laplace station. Laplace station in triangulation we define a term. Laplace station, the meaning is a station where we are taking the bearing of one line. For example, in this network itself if I am taking the bearing of line here, so the meaning of bearing is if I take the bearing here from the north direction, I am measuring this angle that is the bearing. So, for one line we take the bearing now. Why we are taking the bearing again? It will become clear in a moment.

Similarly, as you understand now starting from the known line, our known line here is this as well as all the measured angles we are finding these lengths of all these lines in order to excise a check because in our very first lecture, we were talking about the significance of check in surveying. So, in order to excise a check, what we can do? I can also measure one more length here in the field because what we are doing is we are starting from here, which is measured base length. All the angles known we are computing this length. Now, this length, which is being computed can also be measured in the field and this measurement or the measured length and the computed length. They should agree. If they are not, our survey has some problem.

So, this kind of length which we are measuring later on is called the check lengths, check base. If I write it here, we are using it for check. It is check base or the check length. So, we have defined two terms, the Laplace station and the check base. Here well in order to plot this traverse how we will begin?

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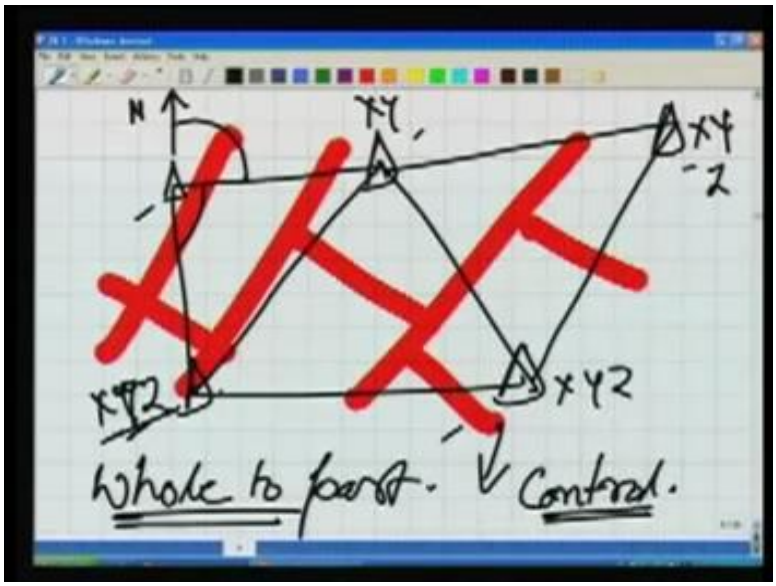

We will start our (( )) very first point, the point which was on the top. I know the direction of the north here. So, that is the direction of the north here, I know the bearing of my one line and by computation. I know the length of the line. So, I plot this, then I know the internal angles, I plot the second one, I plot the third one, fourth one and so on. So, I can plot on my drawing sheet the triangulation network which was in the previous case has been plotted now.

Now, it may not be exactly the same as in the previous case, but well here in my plotting, here in your screen, otherwise it will be same in actual case. So, this is the drawing sheet. Here in the drawing sheet, this network has been plotted now. So, this is the network which we say the control. Control means that area has been brought into or onto the drawing sheet now by means of these control points. So, these control points capture that area, or these control points capture the skeleton of the area.

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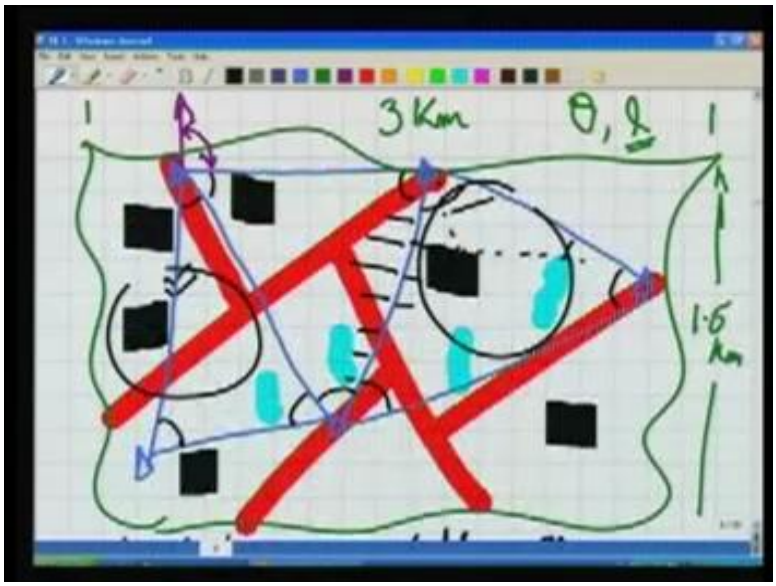

Now, what we can do in order to make the map here, I can go now in a small part of this area. For example, let us say here I start measuring the offsets or may be using by angle measurements, I measured these two angles. I fix this point. So, what I am doing here? Now, once I have got the offsets and another thing I can start plotting the things here also. So, I can start plotting my things as in the case of the field, whatever was the field. I can make the plot here because now my control is fixed. I am doing the plotting now with the help of the control.

So, if you are committing some error for example in this part that is not going to affect this part in plotting the details. So, this concept we have seen before also, and this concept we know working from whole to part. What we have done? The moment we captured this network of the control points or the skeleton of the area, we are establishing the whole and now we are working to fill up the details in the parts. So, this is you know the concept of the control. We are making use of the triangulation in order to establish this control, which we are making later on in order to plot the details.

Now, another way in which this triangulation or this control can be used, and right now the control which we are seeing is only in horizontal, but the control is in vertical also because I know not only X, Y, but the Z coordinate also of this point if I have for example in my triangulation figure. I know let us say the RL of this point. RL stands for reduce level. We talk about that later, that is the height of this point from the main sea

level. I know the RL of this point. Once I have measured the vertical angles and the horizontal angles, I know this length. The length here I will show again. I know this length it is computed as well as I know the vertical angle here. So, I can compute the RL of this point also.

So, basically what we are doing? We are computing the XYZ of all the points. So, it is a full control Y and Z, it is a full control for all the points. The other use of triangulation could be in setting of all operations or the control network, the use of control network in setting out operations.

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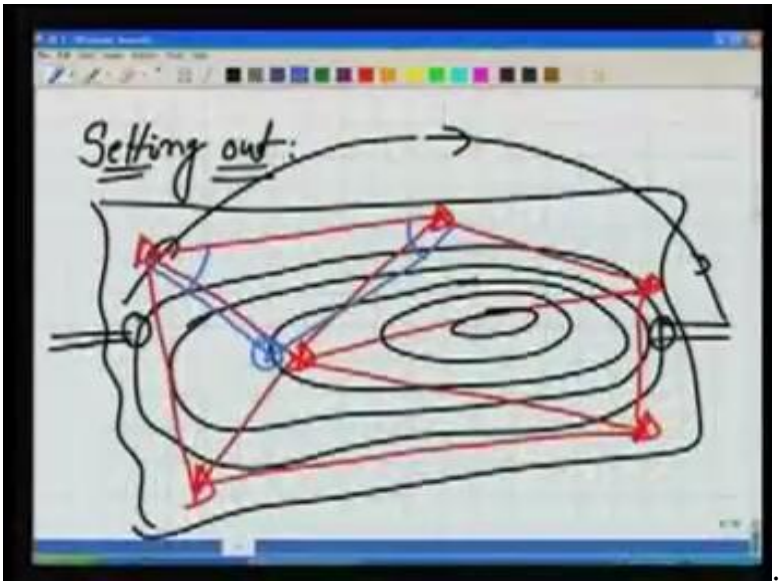

Now, here in this case I will give you one example. Let us say we have a railway line coming here, and now over here we have in this area a hill. So, right now I am showing the hill by these contours. We will talk about these contours later on. Now, a decision is taken that this railway line instead of going from outside, this way should pass through a tunnel in this hill and it will exit here. So, the decision had been taken now about the point of entry and about the point of exit, and now in the between there is the hill.

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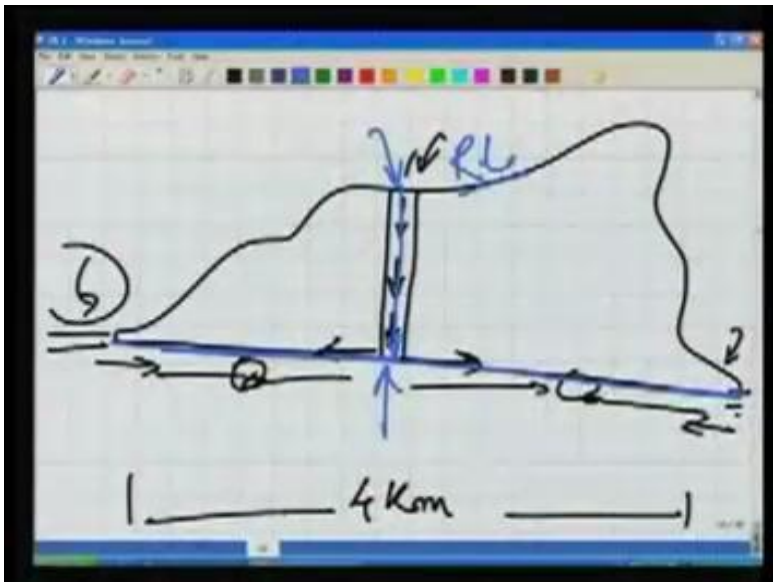

So, what we are looking at? We are looking at a situation like this way the railway line is entering here, and it is coming out here and in between there is a slope. So, the railway line has to follow this formation in order to come out of that place. Now, this length is very big let us say it is 4 kilometers. In order to excavate, the excavation for this tunnel will begin from here as well as will begin from here, and at the same time, it may also begin from some intermediate points through the shafts and all these excavations starting from here, from the shaft as well as from this end all will begin simultaneously.

Now, the challenge for the surveyor is that these people have to give directions to this party in order to move in a particular direction and maintain a particular gradient. Similarly, for this party also as well this party also, how much to dig in the shaft, so that you are at the formation level of the tunnel or at the central line of the tunnel. So, in doing this, we make use of the control which is already established and after reaching here, then this gentleman will start digging in either directions, and all these parties should meet the center line.

So, this is really the challenge. Now, how the surveying or the triangulation is going to help in this or how the control network is going to help in this? So, if you look at the previous figure, the previous figure was like this. In the previous figure, we have for example, let us say establish a triangulation network. These points are inter-visible and in

order to map this area, a triangulation was done. So, this is a network of triangles using which the area has been mapped. So, what we do? We bring this map to our laboratory.

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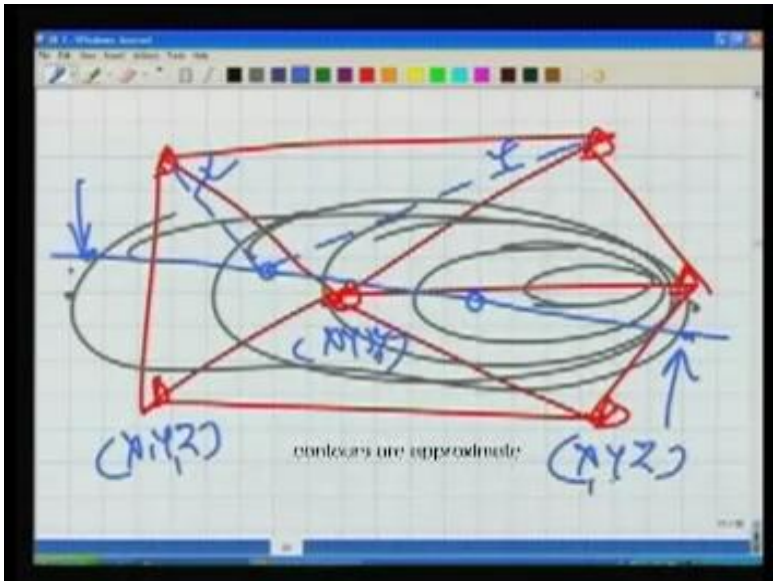

So, the map in the laboratory will again look like this in the drawing sheet that is the map of the control point as well as in this map because we have done the mapping, we have the contours and now the decision is taken about the tunnel. Well, the tunnel will pass along the centre line. Now, if this decision is taken, this is being taken on the drawing table. Sorry, yes drawing table, on your drawing board. You are working in the office and you are taking this decision. Now, the next job will be that is the entry point, that is the exit point and next job is to locate the shaft. The first shaft will be here, the second shaft will be here. So, that is the decision again being taken in the office.

Now, once in the field, there in the field you have to locate now where the shaft is, where the central line is, how much deep you should go in the shaft here. So, in order to locate the shaft here, this shaft for example, what we will do? We will make use of the control network let us say just for this case, this shaft make certain angles from the line here which is the control line, a line made by the control network. So, if I know this angle I can now with some more measurements locate this point in the field. Also, starting from here I had measured the angle as well as I measured the angle and I locate the point.

So, this is the point where my first shaft should be. So, what you are doing? You are setting out a point; you are making use of the control network to set out this point.

Similarly, you also know the RLs. You know the RL of this point, the reduce level, you know the formation level. The formation level is this. So, then in the laboratory itself you are determining the RL of this point. You know the formation level. So, you know the RL of the formation level everywhere. So, at this point if you come vertically down, how much down should you come from this RL, so that you reach the central line of the tunnel? So, all these kind of computations can be done if we have a network for which all X Y Z are known to us everywhere.

So, we are making use of the control network, we are making use of triangulation. For this purpose we have seen all these. Now, we will talk more about the triangulation because we know that what is triangulation, how we will do a little bit of it, why we do it and what is the use of it?

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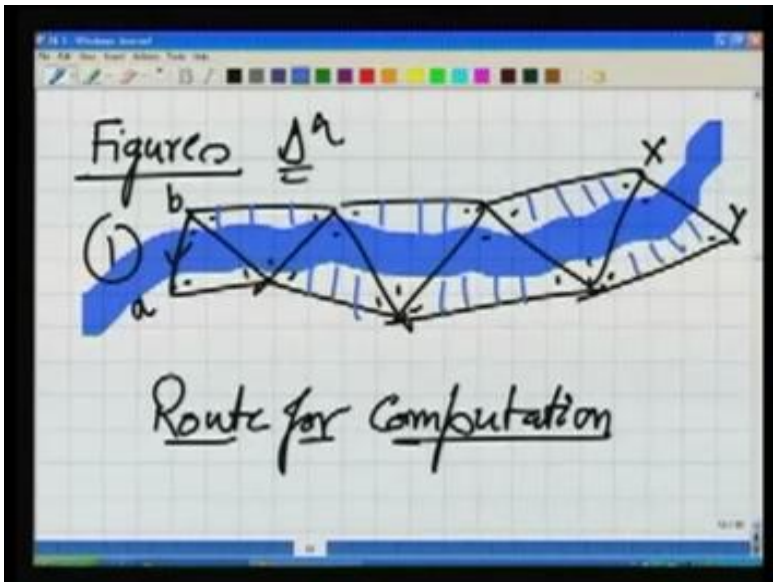

Now, the very first thing we will start with is triangulation figures. Now, what are the triangulation figures generally? So far I was showing you only one chain of triangles. What are the others? The very first figure of the triangulation is a single chain of triangles. Well, we know one length here. We know all these angles. So, having known all these coordinates of all triangulation stations can be computed, and the control network can be established. Now, this kind of chain of single triangles is not a very good figure, why it is not a good figure, because we have only one route for computation.

Now, what is this route of computation, and why it is important? Route for computation, the meaning of this is starting from a b. If you want to find the length x y, we have only one way to reach there. We will be making use of the angle because we know the angles here. So, we can compute x y. So, we have only one way, only one route. We will see in some other figures that we can go through multiple routes. So, we will have a check on our computations also. Now, this kind of figure, the single chain of triangles as you can think in which case it will be suitable.

Well, if we have let us say a river, and this river flows like this and your job is to plot or to map the outline of the river. So, this single chain of triangles will be very good figure. You just establish this, and then start plotting the off sets. You will be able to plot the boundary of the river. So, this figure is good in this kind of scenario, but not always. The other figure is the second, which we can say.

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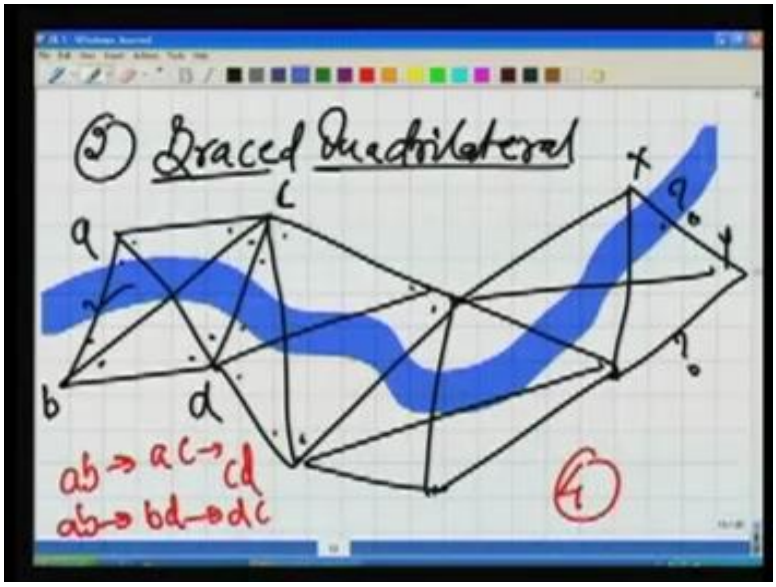

Braced quadrilateral, now what it is? You know the quadrilateral; it is a chain of quadrilaterals which are braced. The meaning is a figure like this, just a figure like this here. One length is known to you and all these internal angles are measured. Similarly, here by knowing all these internal angles, you can do the computation and you can find the length x y or any of the length here, which are unknown. So, this kind of figure gives you a flexibility of doing the computation for multiple roads.

Now, how it is? So, if you look at this, we have line a b which is the base length which is measured, and we want to determine the line c and d. In order to know, in order to compute the length of line c d what we can do is, we can start number one route. I am drawing by red. We can start from first this last triangle. You know I am starting from a b, I compute let us say a c. Then, from a c, I compute c d or starting from a b, I compute b d. Now, using the triangle here, a b d triangle and then from b d, I compute d c. So, what we are doing? We are computing the same length d c or c d through various routes.

In this figure as you will see there are four possible routes. So, we have a check on our computations as well as we will see later on that we can choose a route which is the best for the computation. So, this figure has got this flexibility. This figure has said to be the best figure. Now, where we can make use of this figure? We can make use of this figure in order to create as in the case of our river also. For example, simple river and we can create a chain of braced quadrilaterals or may be in some other case.

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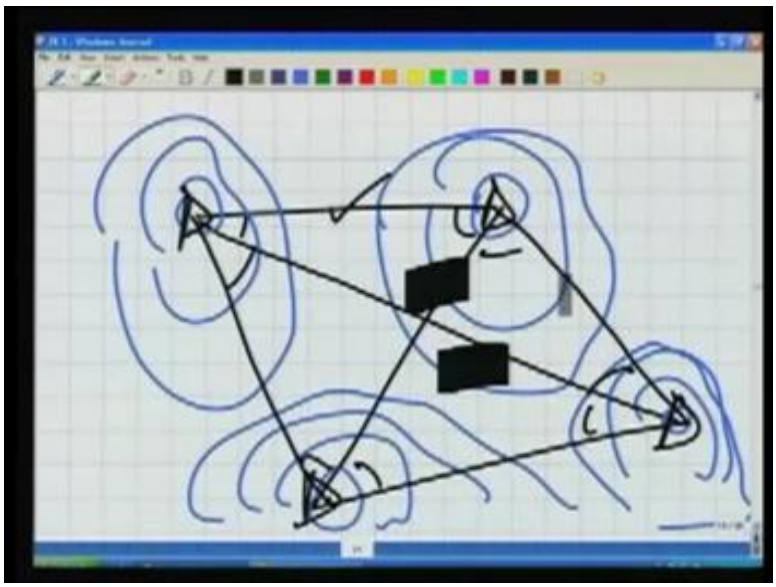

Let us say for a hilly terrain, I am drawing the contours just to show the hills. It is a hilly terrain and some point here we want to map this. So, what I can do? I would prefer to establish a braced quadrilateral here in between these hill tops and then somehow if base extension method I will measure this one, all internal angles. Now, I have got the contours established for this area and using this control, these triangulation stations, later

on I can make map of this entire area. Everywhere here I can make the map. So, this braced quadrilateral is very useful figure.

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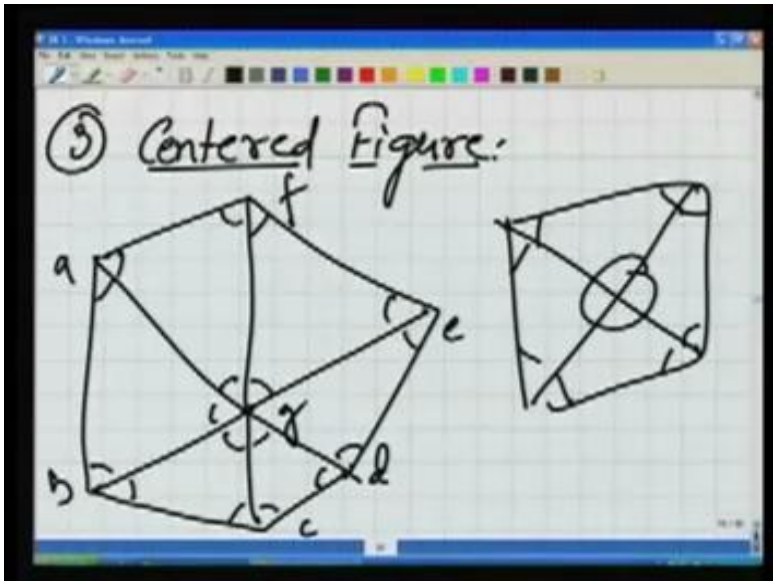

Another figure which we make use of is three centered figure. The centered figure is somewhat similar to the braced quadrilateral, but has got more work to be done again. Now, the difference in this case is we occupy the point here also. We measure all these angles as well as these. Now, this figure can also be used in a hilly terrain. These all a b c d e f are the hill tops. We have to also go to this hill top g, and to measure these angles while in the case of braced quadrilateral, we were not occupying the centre point. We were just measuring these angles. We are not occupying this point. There is no point as such here, but here in this case, we have to occupy this g in order to measure these angles. So, this kind of figure is the centered figure.

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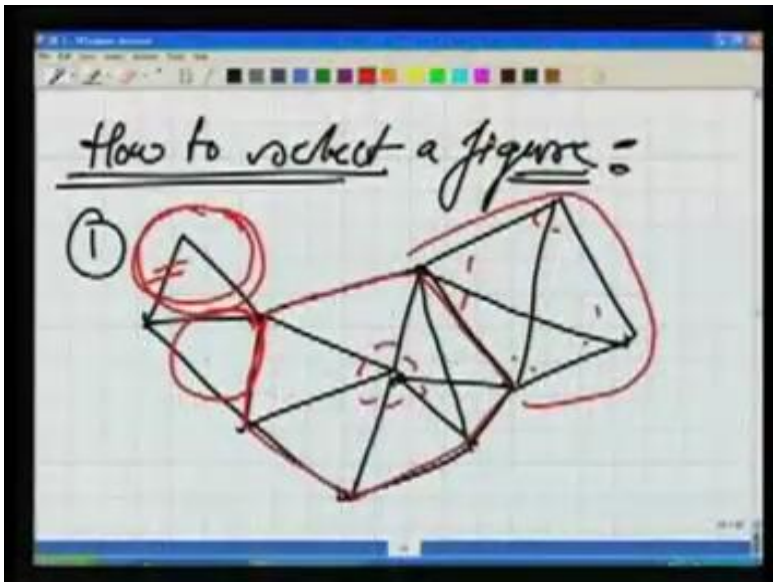

Now the question arises that how to select a figure. Basically for any problem that you are thinking you know you have to make a map of the river boundary, you have to make the map of the hilly terrain 30 kilometers by 30 kilometers, you have to map the reservoir of a dam which is you know around 42 square kilometers in the extent. So, depending on a problem, you decide that what kind of figure will be suitable for you, but some of the things, some points which we should keep in mind number one a figure could be as we have seen. Only single chain of triangles, single chain of quadrilaterals or may be only one quadrilateral.

If your area is 10 kilometer by 10 kilometer, you are going to make a map at very smallest scale, 1 is to 50000 and 100000. In that case, only one quadrilateral can do or you may also go for in some case a chain of quadrilaterals or a chain of centered figure. Many times all these figures may be combined here. I am giving you an example of the combined figure. We started with a chain of triangles and here is the figure which combined figure. Combined means we started with first one triangle, second triangle. The base length is known here. It is measured for this. Then, we have a centered figure here as you can see figure, which I am drawing now in red is the centered figure. All these internal angles are also known. In addition, there is a braced quadrilateral. So, is it combination of all the figures depending, the field condition depending whether you could locate your stations or not. Over here the requirement of the field was on the hill station.

So, you went for a triangulation, just a simple triangle, but here you found that you can find full stations and the requirement was like that. So, you went for the braced quadrilateral. So, your figure could be anything.

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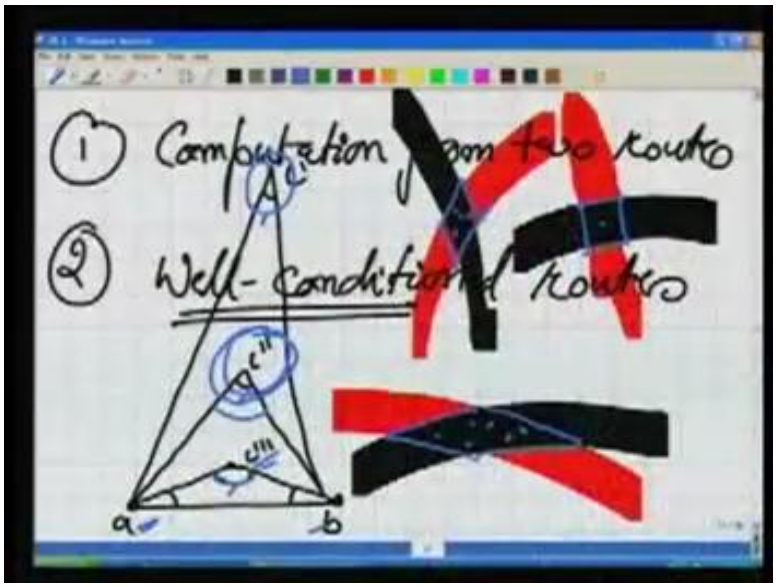

Now, while we are selecting the figure, some of the points which we should keep in the mind are, number 1 is a figure should be such that we can do computation from or through two routes. Now, what is the meaning of that? We know already the computation routes in a single chain of triangles. Only one route is possible. We should have minimum two routes for computation, so that we can have a check.

Number 2, possibly we should have well-conditioned routes. Now what are the well-conditioned routes? What is the meaning of this? We look into it in more detail in a moment, but let us say I explain it graphically. You have a line a b. You know the coordinate of a as well as coordinate of b. You are going to fix a third point c, and the third point c if you fix, let us say by a very large angle between these over here, you know one case. In one case, you are fixing it by a very small angle. That is a very small angle for c as well as the c. Let us I would say it is c dash c triple dash and a point here in between you are fixing where the angle is nearly 90 which I say c double dash because what we are doing is, we know point a, we know point b, we know this angle, we know this angle. I am just taking the arcs and I am just cutting these two arcs here or maybe we know the lengths.

I know length a c triple dash b c triple dash. I am taking these two arcs and cutting this and trying to plot the point c triple dash. Now, how these arcs will look like? These arcs if the angle is very large, the arcs will cut somewhat like this or if the angle is very small, the arcs will cut somewhat like this. If the angle is 90 degree, the arcs will cut one and for 90 degree. It should be like that let me make it little bit thick, so that it is seen as others. Now, what are the differences in these over here? In this case, see your point of intersection is somewhere within this area where it is that is the uncertainty.

So, if the angle was very large, the uncertainty in locating this point c triple dash is large. It could be anywhere in between. Similarly, over here also the uncertainty is large. If the angle is very small, you can do it graphically, but if the arcs, they intersect at 90 degree, the uncertainty is limited to only this particular thing. So, uncertainty in locating point c double dash is least.

So, what we are doing here starting from two known points, we are trying to establish the third point and establishing the third point, we have some uncertainty and it depends upon what kind of angles we are choosing, where this point is if the point c triple dash is, such that that the angle of intersection here is 90 degree. The uncertainty and establishing c double dash is least the same thing we do in the triangulation.

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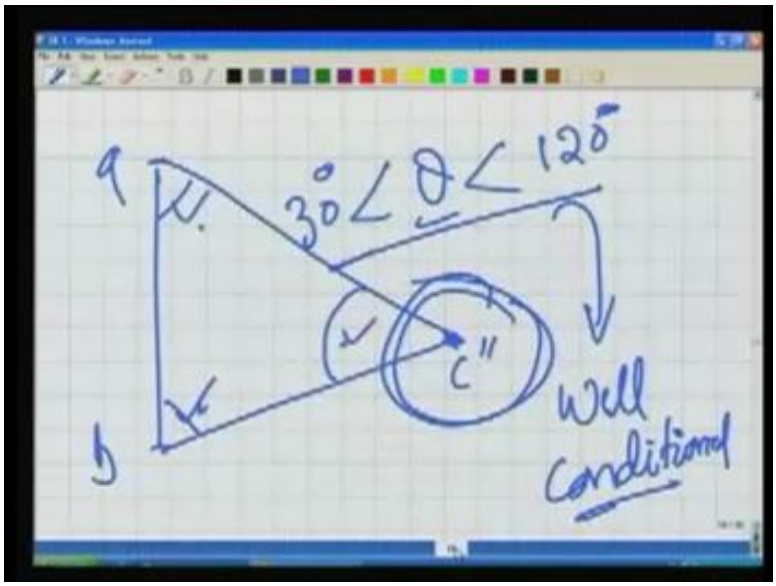

Though we do the computation common known length, the base length from the known angles, we measure these angles and we are trying to fix this point c double dash from

this a and b. Now, depending on how much uncertainty is there, it will depend upon the kinds of the angles which are there in the figure. Well, we want this angle to be 90 which is not always possible. So, ideally we say if the angle of intersection here or rather all the angles of triangle are within 30 degree and 120 degree, all these three angles are not beyond this value. Our triangle is well conditioned.

We will explain this also later on in the computation part, but right now we have been able to understand graphically that if in my triangle, the angles are within 30 and 120, they are not either too large or too small. In that case the computation of unknown points is more accurate. So, these are the well conditioned triangles. By the meaning of well conditioned route, we have started this discussion from here that we should have well conditioned routes.

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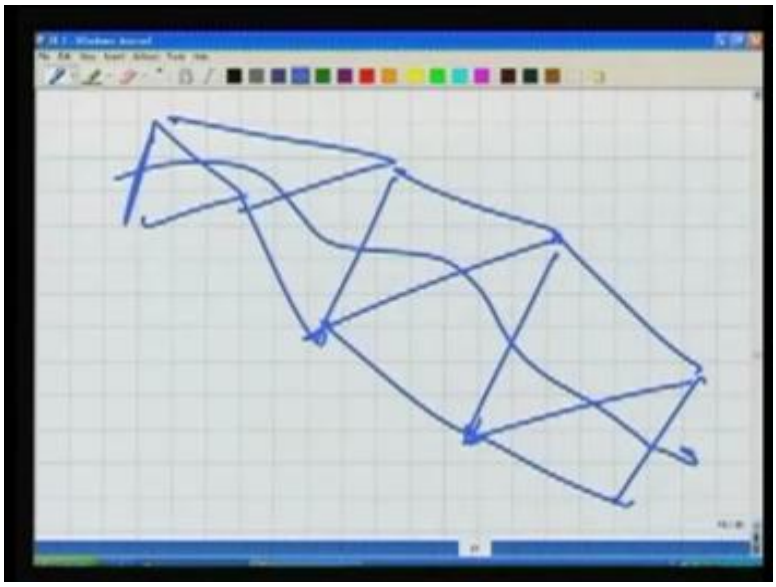

The meaning is in our triangulation network, which we are going to finally make which we are going to finally choose. Our triangle should be well conditioned, so that our computations are accurate. So, that is the second point in order to choose the triangulation network.

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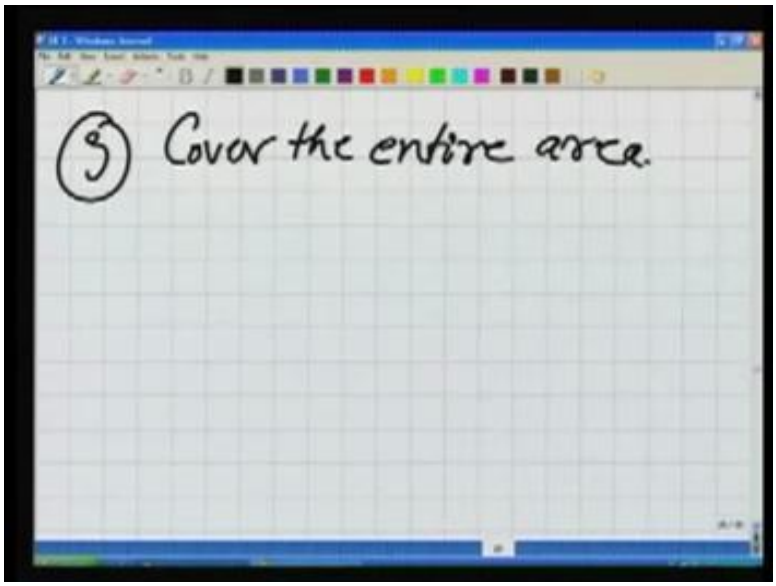

Then, the next point third, the triangulation network, which we choose should be or the triangulation figure that we choose should be such that it should cover the entire area, that is the purpose we want to establish a control network for the area. So, our control points of triangulation stations should be such that our figure should be such that, that it covers the entire area because we are going to make use of this triangulation network later on. We have seen it. We make use of this in order to make the map whole to part. We make use of this in order to set out. We saw the example of the tunnel. So, our networks should be such that it is covering, it is governing the entire area or the skeleton of entire area within the network.

Now, we will talk about the frame work of triangulation for our country because you know in any country, we have reference system and that reference system is established through the network of triangles for the entire country. There should be one network of triangles, which gives you the coordinate in that national reference everywhere. Now, what is this frame work which is covering the entire country?

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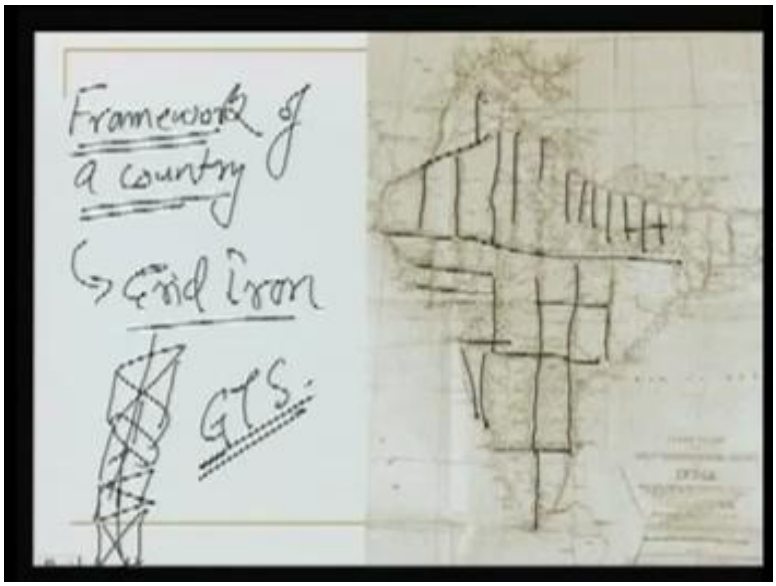

The frame work of the country could be of two types. Generally, one is the grid iron and here we are seeing the grid iron system for India. See this figure is very interesting figure and it explains that what the grid iron system for India looks like. Here each line here, for example like this. This is a chain of triangles for example it is something like this you know made of triangles, something like this a chain of triangles. It is starting from here and going all the way to the north. Similarly, some more chains of the triangles and as well as some chains which are going in this direction.

So, this kind of chain work which is generally useful or done for a large country is called the grid iron system as it appears as if there is a grid, and by this grid, the control points are established everywhere throughout the country. This is also an example of the grid trigonometrical survey for India. A survey which started some 200 years back and starting from somewhere in Chennai-Madras, this network was established throughout the country, and later on more triangulation chains were established and the network was completed.

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So, what we have the feeling, what we understand by this? We have a network of control points everywhere in the country. All of them are referring to the same reference system. So, we can measure the distance having known the coordinates of this station and this station. I think I know the distance between these two points because everything is in one reference. So, this kind of system is the grid iron system.

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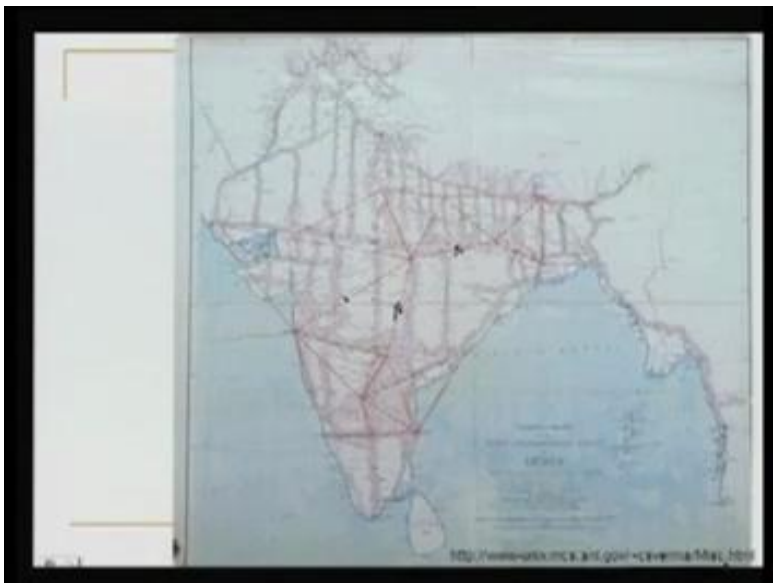

Another picture for the grid iron system. Do not confuse with these red lines, but just the background in the figure and you can see this I have taken it from this source.

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Another system for any country is centered system. The centered system is done if the country is small. India is a large country. We cannot cover entire country everywhere by the triangles, but for a small country like United Kingdom, it is possible that a chain of network of triangles is covering the entire country. As you can see here, this is the boundary of the country. Here I can show the boundary like this. So, this is the boundary while everywhere in the country, there is the triangulation network. So, this kind of figure is called the centered figure.

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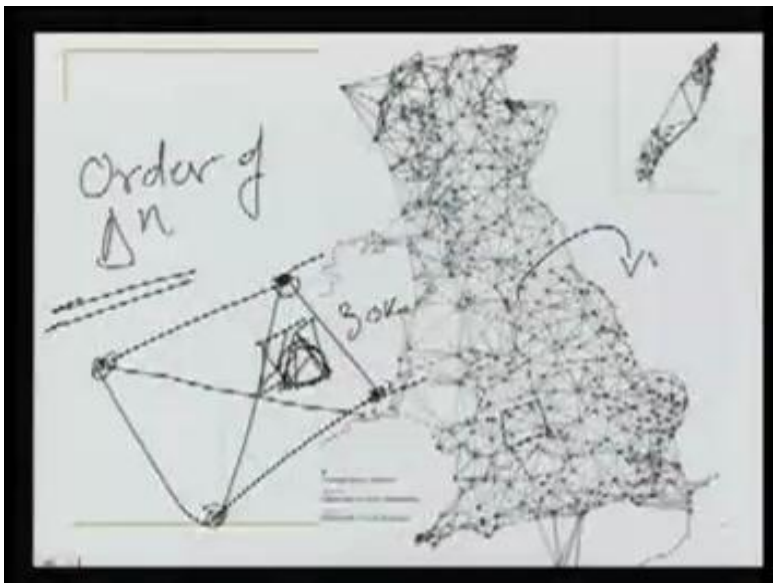

Now, we will look into order of triangulation. The order of triangulation means you know for example, for the United Kingdom, this is the very first triangulation network here which we are seeing. If we want to work in between this area, so this area is a quadrilateral here. Now, this quadrilateral, the sides are very big. They are of order of 30 kilometers and your area of interest may be only here.

So, what you would do? You would pick up the control from this main network, and you will try to extend it in this area. So, you will try to establish some more networks of triangles here which are taking the control from the first network which is allowable to us, and then extending in this area. So, in this way we see the very first network to be the primary triangulation. Then, within that we can have network of lesser accuracy which is the secondary triangulation and further, within that we can go for the tertiary.

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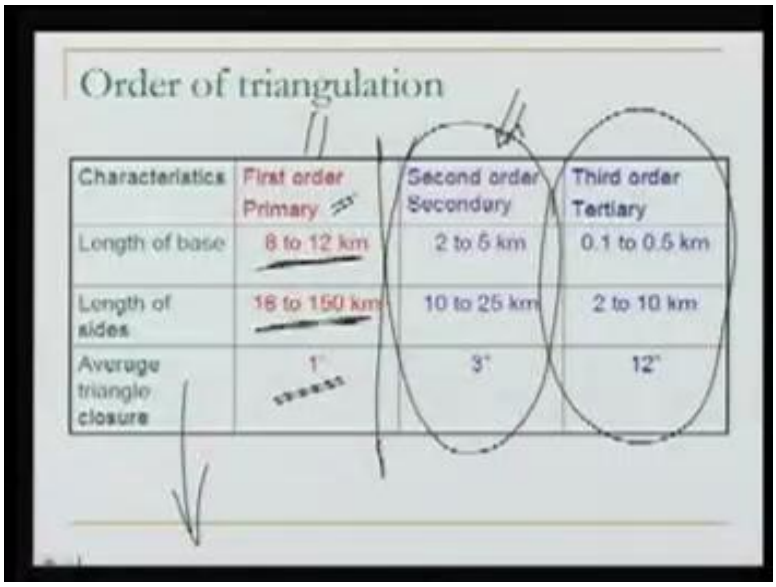

So, the details of these are listed here. Of course, there are many more details which you can find in any standard text book for the first order which are the most accurate, which are used to establish the shape and size of the earth in that part of the world that part of the country very accurately. Generally, these are very large triangles of the order of 8 to 12 kilometers base length. The sides may be 16 to 150 kilometers and these have to be very accurate. Just one major of accuracy is average triangle closure should not be more than one second. So, we have this specification for this first order of primary triangulation which is very accurate, and then within that network, we can have the

secondary one which is slightly less accurate. Then, tertiary one again for the less accurate, again we are going with that same concept. The working whole to part first is, first order is very accurate, second order slightly less accurate, third order and then, within that third order also for your own application, you can go for one more set of triangulation which is even inferior than that.

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So, in any country as we can see here, we can have these primary secondary tertiary and if you go to the field, you can locate those stations, India for example.

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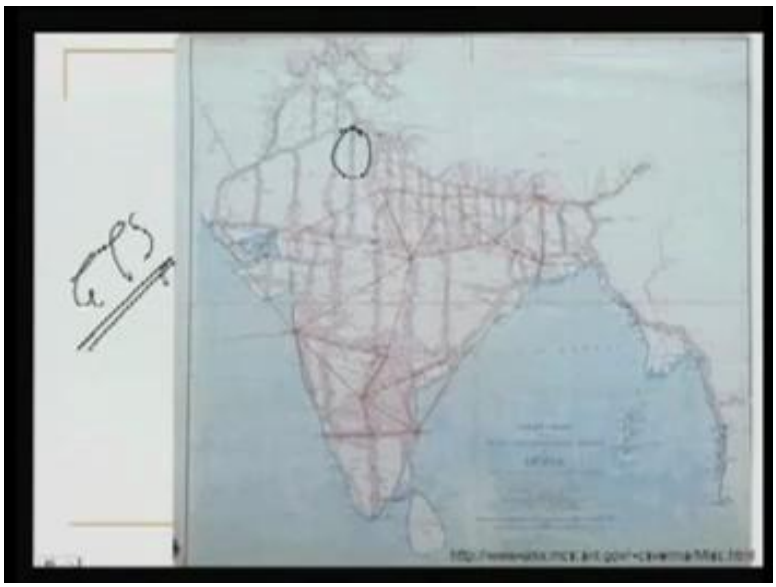

If you walk here in this area, you can locate those which GTS stations, the great trigonometrical survey stations. You can find them and you can determine. We can get the coordinates also from survey of India in order to relate your survey to the GTS. So, what we have seen today? We have seen the triangulation. Why we do it, how we do it, what are the triangulation figures and how we decide that this triangulation figure should be used. So, we have seen these concepts, then we saw about a country whether the pattern for a country should be grid iron or should be centered figure depending upon the size of the country. So, this gives us a background in order to go for our next lecture.

Thank you.