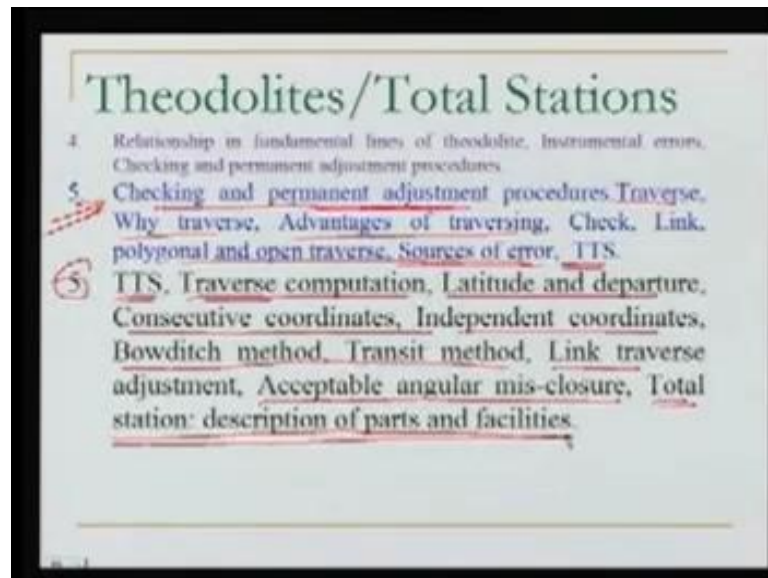


**Surveying**  
**Prof. Bharat Lohani**  
**Indian Institute of Technology, Kanpur**

**Module - 05**  
**Lecture - 06**

Welcome to this another lecture on basic surveying. We are on module number 5 in which we are talking about theodolites and total stations. We have already covered 5 video lectures in this module and this is the lecture number 6. Now, what we will do in this lecture number 6, before that we would like to go to, what we did in lecture number 5 that is number 6 here.

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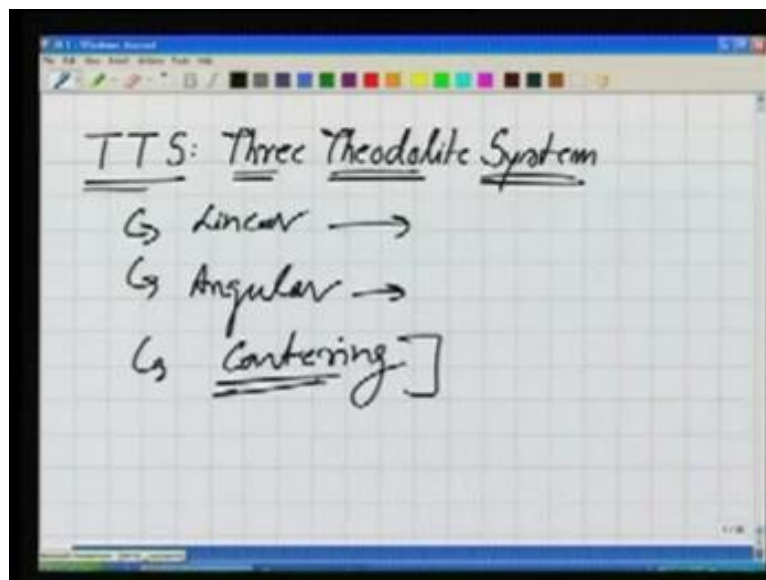
In our previous lecture the lecture number 5, we checked various errors in the instruments, how to find a test, how to carry out a test. In order to determine, if there is a presence of error in the instrument, and if at all that error is there, what to do in order to eliminate it by a strategy of observation or may be by permanent adjustment. Permanent adjustment means, we are doing something in the instrument, so that the error can be eliminated can be minimized.

Then we saw also the traverse, why we need to do the traverse, the advantages of the traverse and the different kinds of the traverse. Towards the end of the lecture, we are talking about the sources of the error, what all sources of the errors are there, and we left this TTS. We will discuss about this TTS today, in addition today we will talk about

some computations for the traverse. In case of the compass, we did not compute the coordinates rather we plotted the traverse.

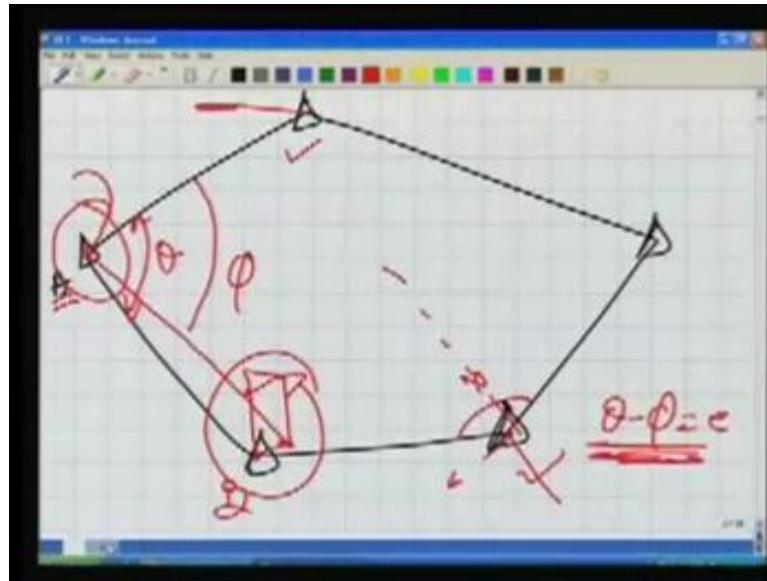
So today, we are working with the theodolite, and in this we will see how we carry out the computations for the traverse. In that some definitions, like independent coordinates and all then some methods, in order to eliminate the errors in the traverse, also for the link traverse. And finally we will see, what is the acceptable angular mis closure in a traverse, how to arrive at that. And, towards the end of the lecture, we will have a demonstration on total station; we will look at the various parts of it, what are the facilities and how to use it.

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Now, talking about the errors in traversing, we discussed the error could be, because of linear measurements, because of angular measurements and also because of centering. The linear errors, we know how they that introduced, if you are using the chain, tape or even the EDM there will be some error, how to take care of that, how to apply corrections for that. We also know the kinds of the errors in the angle measurement; this is what we have been doing so far.

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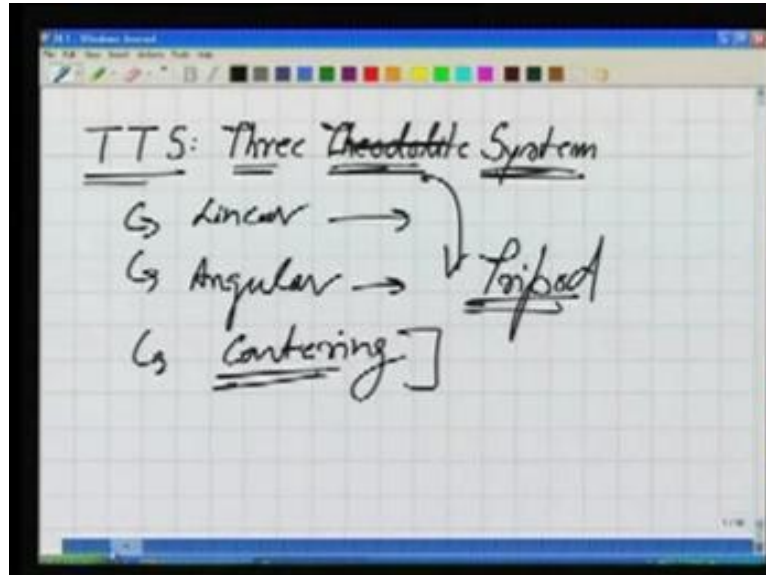
Now, what are the centering errors, why they are important in traversing, this is what we would like to see now. The meaning of the centering error is for example, if we have to carry out a traverse like this, then these are the traverse stations or survey stations. If we are measuring this angle here, in order to measure this angle, we need to put our theodolite, so that its vertical axis is exactly over this point A, then we say the instrument is centered not only theodolite, we have to also ensure.

If I am using a ranging rod here, and another ranging rod here, then the base of the ranging rod should also be exactly at point B, and over here. If, my base of the ranging rod is slightly shifted, then instead of measuring the angle theta, what I am doing? I am measuring the angle to this particular point. Let us say this angle is phi, so theta minus phi is the error, so this miscentering of even the ranging rod, I am saying ranging rod in this case it could be any target. In case of the total station we use the target, so it could be the target.

So, if there is miscentering, either of the theodolite or total stations or of the target or ranging rod, there will be problem and we will have the error. Now, we have seen the consequences of this error, what will happen? How this error will vary, what will happen? If the length of the line, length of lines of sight is short or long, what will happen, if this error of miscentering is small or large also its direction. In which direction this miscentering is there, is it in the direction of the bifurcates of this angle or

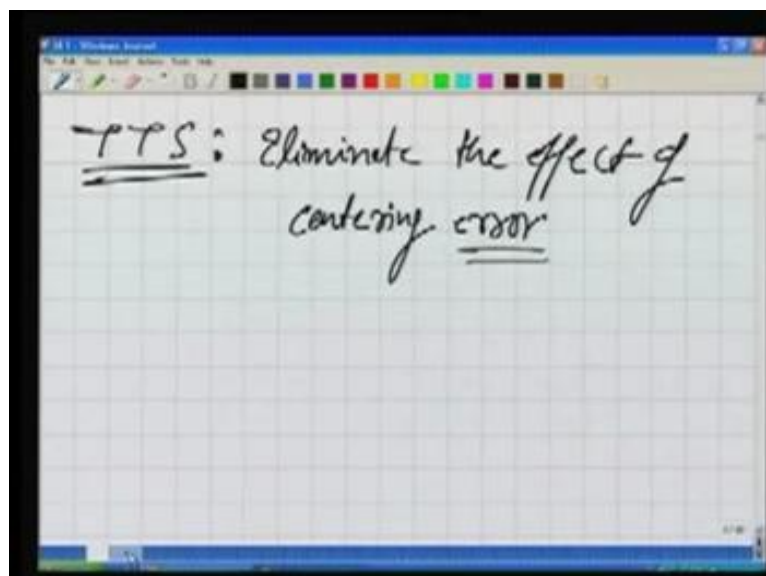
is it in some other direction, because in the direction of the bifurcation, the effect of this is maximum.

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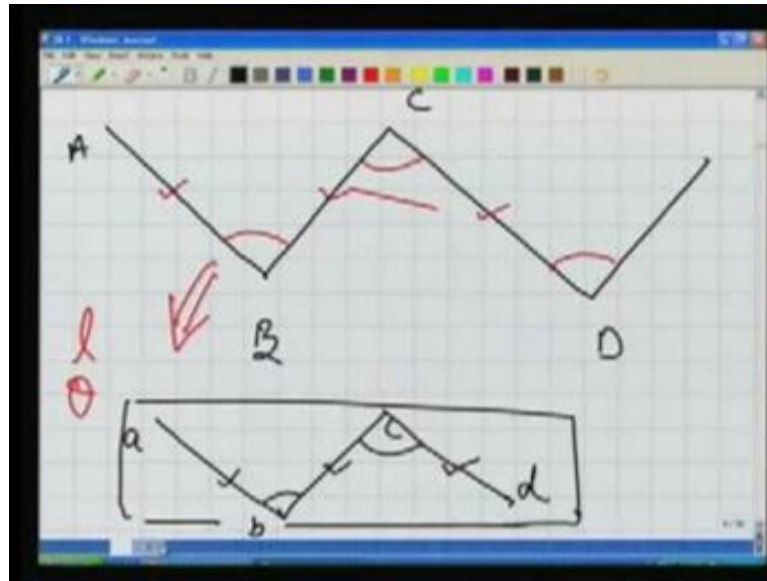
What we will see now, we will see a method, which we say TTS, and this TTS stands for three theodolite system or three tripod system. Instead of theodolite, tripod is better word three tripod system, how does this work, what we try to do in this.

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Basically, we eliminate the effect of centering error will limit it is effect, what is the meaning of this.

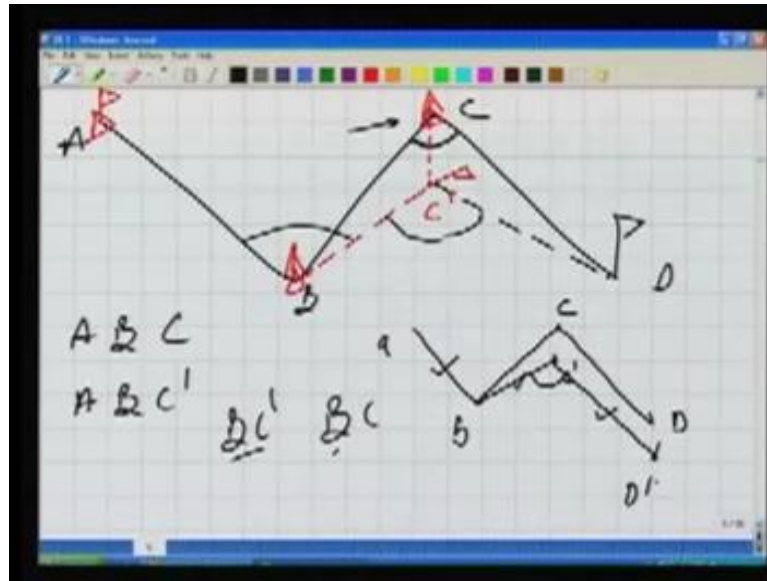
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For example let us say, there in the ground we have a traverse, and this traverse is A, B, C, D. Now, in this traverse we are measuring the lengths, there in the ground we are working, so I measure the length A B, I measure the angle at B, similarly, I measure the angle at C, I measure the length B C and so on. If, all these measurements linear, as well as the angular measurements are without any error, there is no error.

And, if you plot it on our drawing sheet, what the plot will be, will plot this a b to this scale will mark the angle a b c. And again, will plot the b c to the scale, so these are plotted, similarly we have plot this angle b c d, and will mark the point d as per the scale. So, this is true representation of the ground, this is what we always want, so in this case there is no error of miscentering.

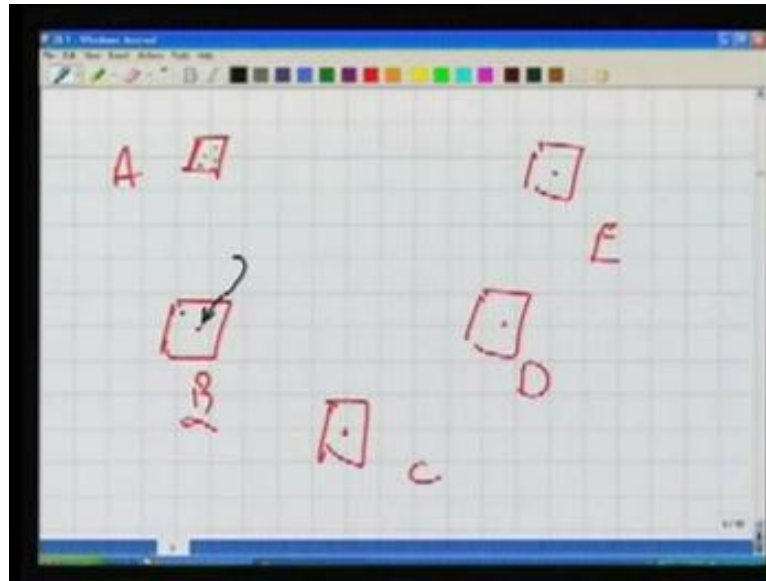
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Let us say there is a case, when there is error A, B, C and D. And let us say the what we are doing in the conventional method there is a ranging rod here, there is our theodolite here, and another ranging rod here. There is miscentering error of the ranging rod, and the ranging rod is instead kept here then over here, so there is no ranging rod it is the miscentering error. Now, this miscentering error, because of this what will happen, we will measure the angle, if this point is C dash. So, instead of the angle A B and C, we will measure the angle A B and C dash, also we will measure the length B C dash, instead of B C.

Now, what will be the effect of this, the effect of this if you plot this survey on our drawing sheet the plot will start with a b, now at b we are making the angle a b c dash. So, instead of going to the actual plot, the actual plot would have been c and d, what I am doing, I am plotting now the angle at b which is the wrong angle larger than the actual angle, so I plot it in this direction. So, the point c dash is plotted here, so it is not really c dash it is the c, because we do not know that we are doing the miscentering error. And then from after this step what we do, we take our theodolite to point c, now how these points are marked in the ground, why we take our theodolite to c not to c dash.

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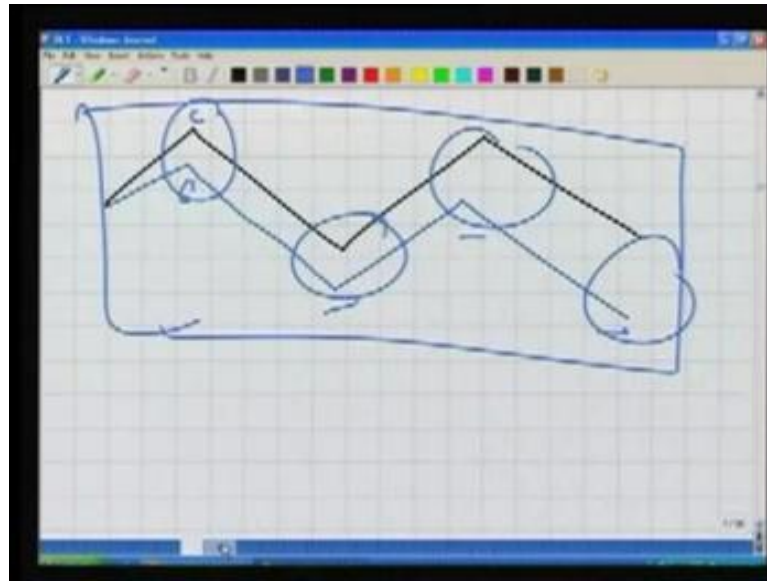


These points are marked in the ground by some blocks, the way the distances are marked, so there in the ground A, B, C, D, E are marked like that. Now, what is the miscentering? Miscentering means, we want to center our instrument or ranging rod at this point, but we are doing it somewhere here or here or here. Now, next time when I am bringing my theodolite, let us say the miscentering for the ranging rod was this, but next time when I bring my theodolite, I put my theodolite at this point, because naturally the desire will be we center it correctly, so the theodolite is centered correctly, but the ranging rod was centered wrongly.

So, because of that now, our theodolite we put at point C, and we measure the angle there is no miscentering error, so we measure the angle B C D. Now, what happens in the plot, in the plot we have plotted at B a wrong angle A B C dash. Now at C dash, we formed angle B C D, so this B C D if I draw it like this is smaller than this angle. So, an angle is smaller than this will be plotted like this, and then I plot the length.

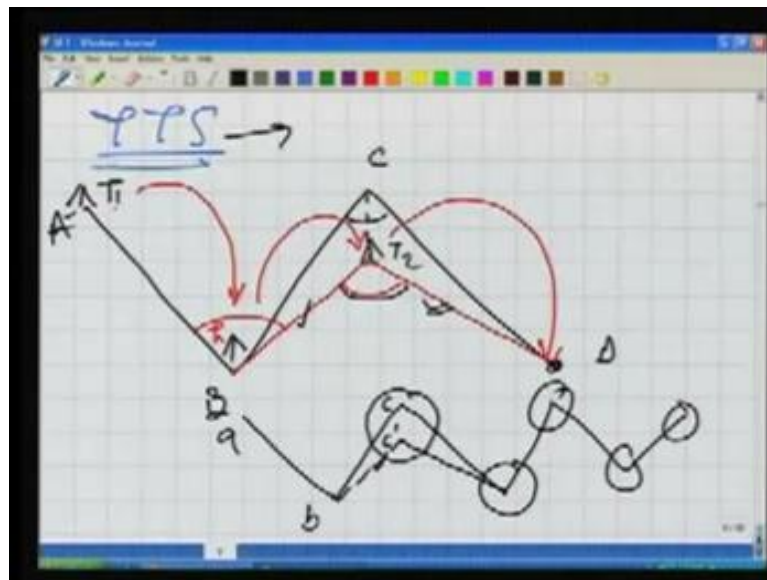
Now, what is happened here, because of the miscentering of this ranging rod, because now the theodolite has gone there is no miscentering in the theodolite, but the miscentering was only of the ranging rod. This angle at B has not measured wrongly, and because of that the point C dash was it shifts here, even if this angle is measured correctly now, B C D, B C D is correct. So, we are plotting this B C D here, our point D shifts here to D dash.

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So, what will happen, finally our actual traverse was like this, but now, after the plot, our actual traverse it gets shifted. So, because of this c c dash shifts all the points they shift from their position. So, this is what the conventional way, in conventional method if we have miscentering in one point, all the points will be shifted.

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Now, what we do in the TTS, in TTS the procedure is slightly different. Well, A B C and D in the case of the TTS the procedure is, we have one tripod here, we have another tripod here and we have one more tripod here. Let us say, there is miscentering error again, and we have one more tripod kept here at this point, so what we are doing now.

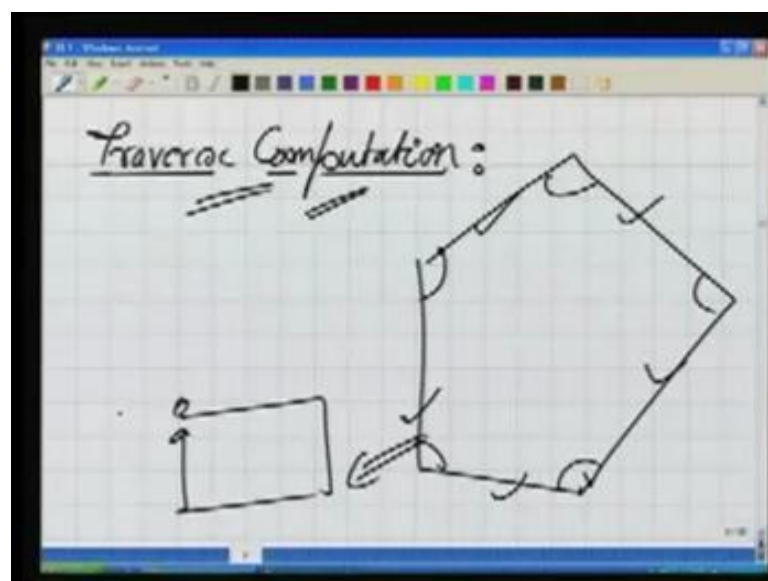


We are using the same tripod, and on that tripod at some point of time, we can put the theodolite all total station then we take the theodolite out and replace it with the target. So, our tripods are fixed here, this tripod is fixed here, this tripod is fixed here, this tripod is fixed here.

Well, there is target number one T 1 and the target number two T 2. From B, the angles between these points are measured, so from B I bisect target number one, and then target number two. So, the angle measured it wrong, so because of this miscentering the angle measured is wrong. Next this target will move to this tripod, and this theodolite there was a theodolite, this theodolite moves to this tripod, and this target T 2 it moves to this point. So, what happens in that case, because now theodolite is here not here theodolite is at the same point, where my target is?

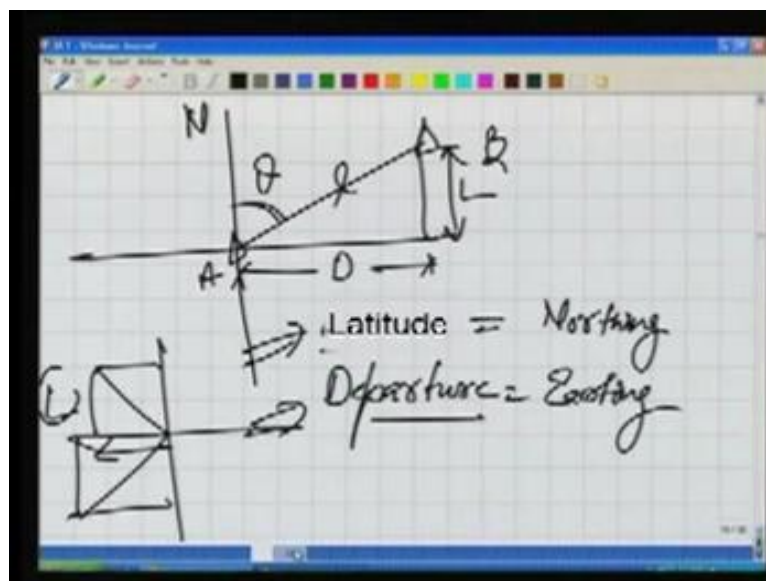
And then next I measure this angle, well if you plot it a b will be plotted like this, a b. Now at b, we are plotting the wrong angle, instead of the correct one this is the correct one, I plot the wrong angle. So, then measure the distance, plot the distance, I get the point c dash, now at point c dash, I plot this angle not this angle. So, by plotting this angle and by plotting this distance, I reached to point d, and then henceforth the rest of the traverse. So, what do we see here, even if there is miscentering error here, c has gone to c dash there is no shift in d, similarly there will be no shift in other points. So, by doing this TTS three tripod system, the miscentering error can be limited to a particular point.

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Now, what we do in case of the traverse we go to the field, and in the field we have a traverse. We measure all the lengths and all the angles, this is what is done in the traverse, in the case of the compass traverse what we did, we plotted it on a drawing sheet. Now, here before doing the plotting we want to do some computations, because in the case of the compass traverse, if you recall we came to know about closing error, after the plotting of the traverse. Well, these two are not meeting, there was a closing error, but here we want to determine the closing error, just by the computations. So, what these steps are, what are the computation, what are the computations that we need to do.

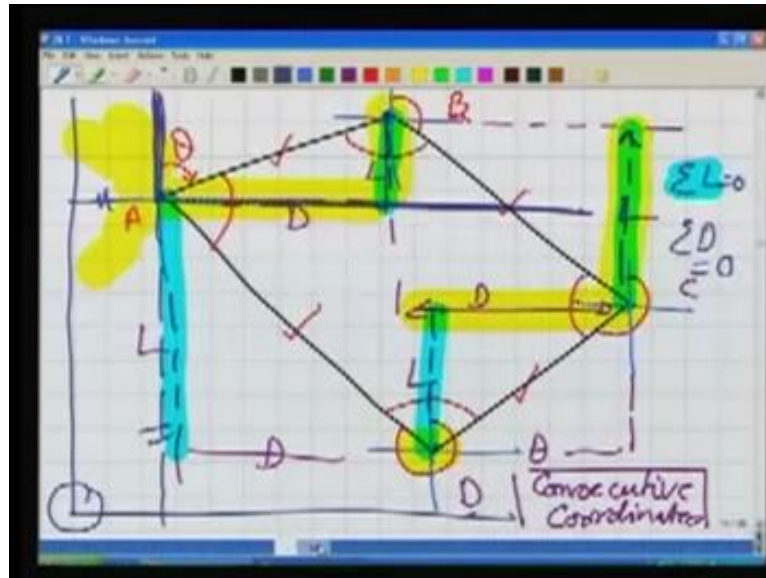
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For that, we will need to define couple of things. Let us say, there is a line and for this line the bearing is measured, this is the direction of north and line is A B, it is a traverse line. We define a term latitude, latitude means this particular value here, you can compute it, because you know the length of the line and you know the angle here. So, you can compute the latitude, and departure this departure is D this also can be computed.

This latitude and departure are also called northing and easting, and depending in which quadrant, because for this line this latitude and departure both are positive. If a line is here both will be negative, if a line is here one will be positive, one will be negative. The latitude will be positive, departure will be negative, so depending which quadrant we are talking about we can compute these values like this.

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Now for a traverse, we do these computations, let us say there is a traverse and for this traverse we want to compute the latitude and departures, what I do at each point first I am drawing the direction of north. These are the meridians, and for each line we have measured the bearing, we know the bearing of each and every line, even if we have not measured the bearing of each and every line we can compute it.

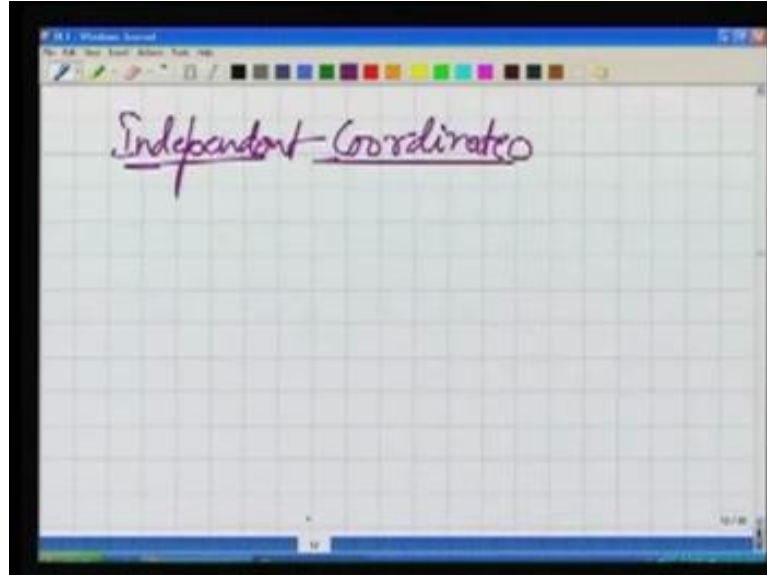
Let us say, this bearing is known only this bearing was measured for A B, then we had measured the internal angles this angle, this angle, this angle and this angle using the theodolite or total station. As well as we know these lengths, using the EDM or using the chain, we also know these lengths having known these things. We can very easily compute now, for each and every point or each and every line the corresponding latitude and departure. So, this will be the value of latitude, and this will be the value of departure.

Similarly here, now just take care of the sign, the sign will change, so that is the value of the departure, and this is the value of the latitude. Similarly here for this point, this is latitude and this particular value will be departure, and here this is latitude and this is departure. So, the way we are computing the latitudes and departure here at the moment, we are computing them with respect to the previous point.

So, we computed for B with respect to A, for C with respect to B, for D with respect to C and for D A line or for A with respect to D. So, this is why, these values of latitude and

departures they are called consecutive coordinates, because for each line we can compute these, and we can write them as per their sign, whether it is positive or negative sign.

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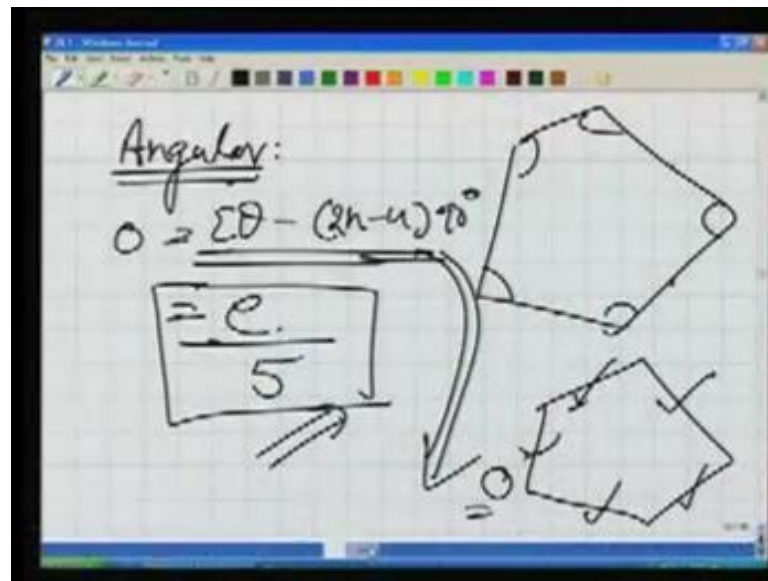
We define one more term that is called independent coordinates means, now here in this case, we know for each line the consecutive coordinates. Let us say, we assume that somewhere here is the origin of a new origin, let us say this point is our origin and I show this origins by slightly thicker line. Now, if I consider this as the origin, now for this point the latitude and departure values are known that is the departure, that is the latitude.

Now for point C, the consecutive values we know, what we can do, we can add this latitude and this departure. In the previous values this departure and this latitude, so we can compute the coordinate of C again with respect to the point A. Similarly, for point D we can compute it is coordinates with respect to the point A. So, these coordinates, which are all with respect to a single point, which is the origin or the independent coordinates.

In this case, we had assumed the origin to be here, we can assume the origin to be somewhere else. For example here, the only thing we need to know is the translation of this A with respect to this coordinate system, this value and this value and henceforth for all A, B, C, D. We can compute the independent coordinates with respect to this origin. Now, we are going to talk about one more important thing, now here in this diagram only just look at this diagram.

If I find, sum of latitude and sum of departure, it is a close figure the latitude is going positive, is going negative, is going again positive here, and is again it is negative here. If you do it again let us say, the latitude is positive, negative, further negative and again is positive, what to you see, if we add all these latitudes the sum of these should be equal to 0, because our traverse is closed. Similarly, for the departure also their sum should be 0, because the traverse is closed, however now what are the sources of the error.

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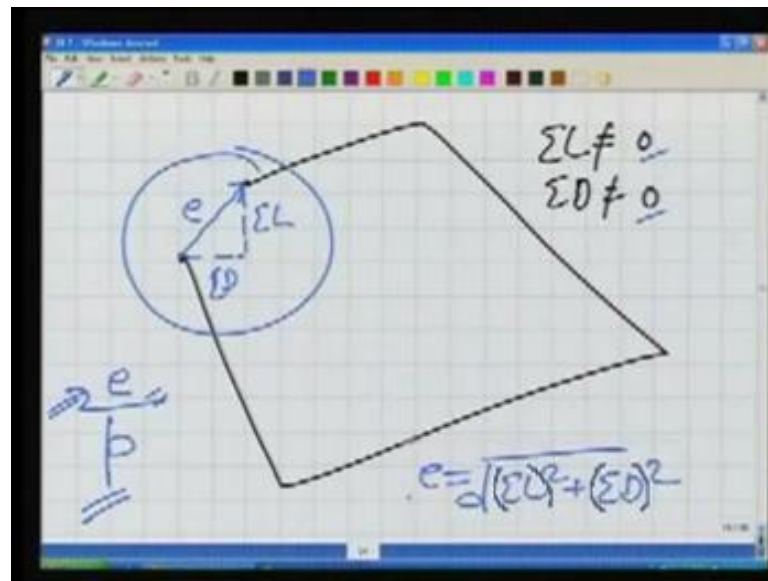
We have seen in a traverse, we may have the angular error, so what we can do for a traverse, we can adjust the angles for the sum of internal angles  $\sum \theta - (2n - 4)90$  this should be equal to 0. If it is not equal to 0 rather it is equal to some value error, this error can be distributed depending 1, 2, 3, 4, 5 planes are there. So, thus the value of the correction to each angle, if we apply this correction to each angle what we get, we get now some of the this particular value  $\sum \theta - 2n - 4$  into 90.

In this case, after applying the correction for this that will become 0. So, angular corrections can be applied. So, if the angular corrections are applied, and then we plot the traverse still the traverse will not be closed, why because still we have not applied any correction for length, when we measured the length in the field, the length has got error. So, no correction had been applied for the length so far, we have applied the corrections only for the internal angle, so what will happen our length will have the error.

And if you plot this traverse, as we have seen in the place of the compass traverse, we had applied the corrections for the local attraction. We had applied the corrections for the

internal angles, but still our traverse was not closed. Same problem will be here, can we determine this whether the traverse is closed or not, now this thing can be answered from here. If you are finding this sigma L and sigma D and if they are not equal to 0, sigma L is not equal to 0, sigma D is not equal to 0 the sum of latitude is not 0, sum of departure is not 0, that means there is problem.

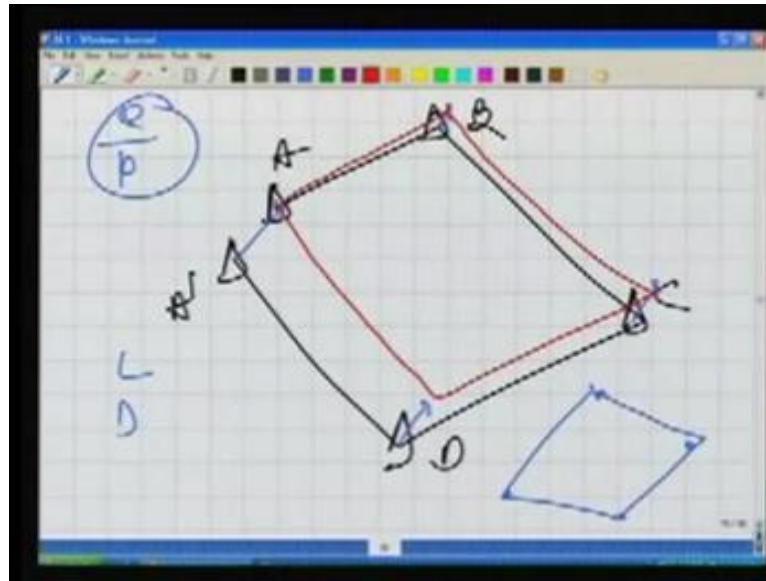
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Our traverse is not closed, now for this traverse if you compute sigma L and sigma D, you will find they are not equal to 0. So, why they are not equal to 0, because there is a closing error, I can further divide this closing error and the components are, this will be sigma L and this will be sigma D. So, the closing error e can be written as sigma L square plus sigma D square thus the closing error, so here in this case, without plotting the traverse on a sheet. We can determine by computing the sum of latitudes and departure, and then putting them here this way, if they are not equal to 0 then we are sure yes there is a closing error, which is because of the length.

Now, we have seen about this closing error using this closing error, we can further define a relative precision in the traverse. P is the perimeter of the traverse, e is the closing error and this is the term which we use, many times in order to assess. Well, how accurate my traverse is larger this value, poor is the traverse and that will control the accuracy, sometimes this value is not acceptable as per the norms. We would like to go to the field again and do the traversing again.

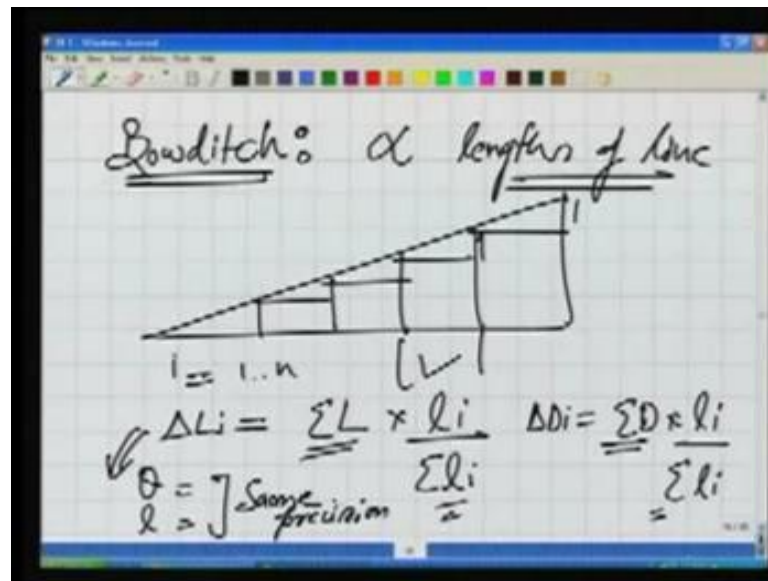
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Well, if it is not so  $e$  by  $P$  is within acceptable limits, but still no, the condition is  $e$  by  $P$  is within acceptable limits our traverse looks like this, this is very important traverse is A, B, C, D and A dash. Ideally this A dash should have been at A there is a closing error, can you just leave it line. Now, like this we have computed for each point their latitude and departure and all that, we cannot leave it like this there in the field think of the field, there in the field it is a close traverse, these points A, B, C and D they form a close traverse in the field, it is not an open traverse.

So, how can this be open here, it has to close, if it has to close we need to apply the corrections here. Again will go back to the compass, in case of the compass we had applied the corrections, and we moved each point in such a way that we found a new traverse, which was the close traverse. And we know, how to apply the corrections, we had closed the traverse, what we will do now will apply the corrections again in the similar way.

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The first method of applying the correction is Bowditch method, this is the same method as in the case of compass we have used. In case of compass, we discuss only the graphical method, here we can apply the corrections mathematically by some computations; how do we apply the corrections in Bowditch method, here the assumption is the corrections are proportional to the lengths of line.

If you remember in the case of the compass traverse, we use a figure like this and this is how we had applied the corrections. And each correction was proportional to the length of that line, so we are doing the same thing now, for applying correction for latitude and departures using the same principle. So, the correction in this case, is given as correction to the latitude of a line  $i$ ,  $i$  varies from 1 to  $n$ ,  $n$  is the number of lines. So, correction to the latitude of line number  $i$  is total error in the latitude,  $\Sigma L$  into length of that line divided by the perimeter, which is  $\Sigma l_i$ .

Similarly, we can also write for  $\Delta D_i$  the correction for departure for the line  $i$ , so that is again now the perimeter. So, what we are doing here, we are distributing the error in latitude and departure in proportion to the length, whatever is the length. Now, here in this case, in the case of the Bowditch method this method we use, when our angular measurement and linear measurement both are nearly of same precision. We know now, what is the meaning of the same precision, how we can see the compatibility, we know this thing.



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The image shows a digital whiteboard with the following handwritten content:

Transit Method  $\theta \gg \rho$

$$\Delta L_i = \frac{\sum L}{\sum |L_i|} \times L_i$$
$$\Delta D_i = \frac{\sum D}{\sum |D_i|} \times D_i$$

Now, in the case of another method there is one more method which is called transit method. We use this method, when our angular measurement is very, very precise than the linear one. Now, what this method does it changes more of the length, less of the angles, while in the previous case both changed, how we apply in this case. In this case again, the correction to the latitude of a line is given as total error in the departure, which is the sigma of L multiplied by this is latitude, latitude of that line divided by sigma modulus of L I, now what is the meaning of this will discuss in a moment.

Similarly, we can write it as; it should be departure of that line, departure sigma modulus of departure, so what we are doing here. We are distributing the corrections for individual lines, the correction means the total error in the latitude is sigma L, we want to distribute it. So, we are distributing here in proportion to the latitude of the line, and for that we are not taking the algebraic sum here; we are just taking the numerical sum. So, this is how also, we can apply the correction to our observe to compute latitude and departures.

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$$\underline{\underline{\sum L = \sum O = 0}}$$

$$\underline{\underline{e = 0}}$$

↓

Once we apply the correction this way, it will be ensured you can do it in a numerical, now this will become 0, if it is so our mis closure error is also 0. Henceforth once we have done it, we can compute our independent coordinates. And then we can take those coordinates to any software or to our drawing sheet, and we can plot the map.

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**Gales traverse table Part I**

Line	Length	Point	Angle	Corr ction	Corrected angle	WCB	DR
AB	✓	A	✓	-3	✓	00 42 (bearing)	N 00 42 E
BC	✓	B	✓	-3	✓	Compute	Compute
CD	✓	C	✓	-3	✓	Compute	Compute
DA	✓	D	✓	-3	✓	compute	compute
Sum			360 (12 0)		360 0 0		

For doing this traverse computation we use a table, which we say gales traverse table. Now this, gales traverse table is a big table, I am showing it in three parts though conventionally it is not written this way, because I want to make it clear here in our video screen. So, this is why I am showing it in three parts. Now, there is a traverse

which is A, B, C and D in the ground, so how we do it there in the ground; we are measuring the bearing of one line.

Let us say A B bearing is measured, and all the internal angles. So, all these internal angles are measured, we know it as well as all the lengths. Now, how we proceed, we know the length of this line, we know the length of this line similarly, all these lengths we know then for this angle between A and B; B A D. So, all these angles also we know, we can write it as angle at A, angle at B, angle at C, angle at D. So, we know all these angles, because we have measured them.

Now, what we do we apply the correction for sum of these angles. Let us say, I sum up these angles, and the sum comes out to be this value this is wrong, because there is an error here. So, what we need to do, we need to divide or distribute this error in all the angles, so the distribution in this case will be minus three. So, this is the correction value, we apply this correction to these individual angles, and will have the corrected angles.

So, ((Refer Time: 31:58)) we know now the corrected angles, so if you sum up these corrected angles, the sum will be 360. We have measured the bearing of one line here; line A B using this bearing which is observed, we can compute the bearing of other lines, because we know the internal angles, so this we have done, we already know it, how to compute it.

Well, we convert this whole circle bearing in quadrantal bearing. So, this can be converted to the quadrantal bearing like this, similarly others can be also determined. Now, why we converted in quadrantal bearing, because in order to convert the length, and the bearing of a line into the corresponding latitude and departure, we need the quadrantal bearing, so using that we can compute easily, so this is why we are converting it here.

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**Gales traverse table Part II**

Line	Length	Point	Consecutive coordinates				Correctors					
			N	S	E	W	N	S	E	W		
		A										
AB			✓		✓			⊖	✓			
BC		B		✓		✓		✓				✓
CD		C		✓		✓					✓	
DA		D	✓		✓				✓			✓
Sum												

$\sum L = 0$      $\sum D = 0$   
 $e =$

Next part of this table is the next part is only this actually, that will attach to the first part, I am showing this in order to have a correspondence with the previous part. Now, in the next part we compute these consecutive coordinates, latitude and departure values they may be positive or negative. So, northing and southern or southing, the meaning is the latitude value. Northing means positive value for line A B, let us say it is positive, for line B C it is negative and again it is negative, then it is positive.

Similarly, we can compute the departure values or the easting values, these easting values can be negative and can be positive. So, we write these as per their sign, whatever their sign is we write them there. Then, we can sum these positive values, negative values and sum them again that will give us the sum of the latitude, whether this value is equal to 0 or not, this is something which we are going to check, same thing we can do for the departure. If you find these values are equal to the 0 there is no closing error, and we can directly compute independent coordinates from the consecutive coordinates.

But, if these two values sum of latitude and sum of departure, it is not equal to 0, then we know there is some e, closing error. We need to distribute it, we need to distribute these errors correct adjust our traverse. So, how do we do it, depending you are using the Bowditch method or you are using the transmit method. We can find these correction values, whatever the correction and with the sign of course, this is important we must take care of the sign. So, we can find these correction values in the length of A B, this is so much of correction is required in it is latitude.

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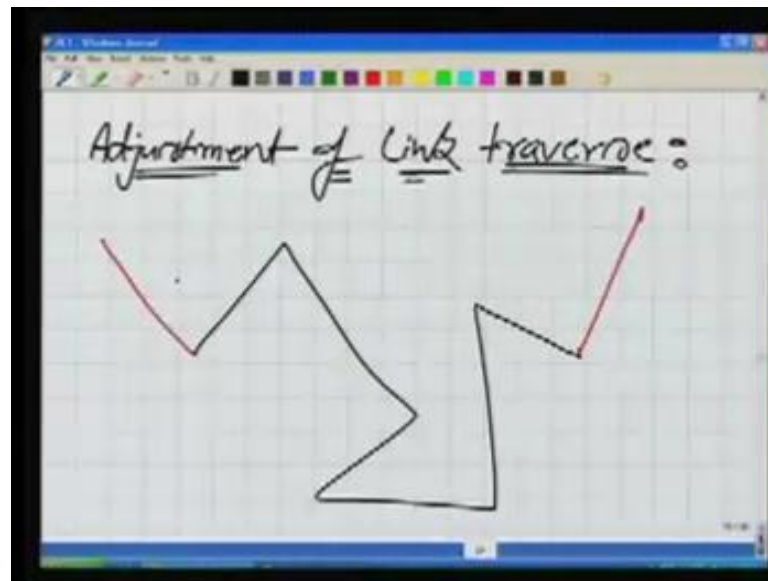
**Gales traverse table Part III**

Line	Length	Point	Corrected Consecutive coordinates				Independent coordinates	
			N	S	E	W	N	E
		A						
AB		B	✓					
BC		C			✓	✓		
CD		D	✓					
DA		A		✓	✓			
Sum			∑L		∑D			

Once we have done it, the third part of the table is this. Now, we are computing the corrected consecutive coordinates, because we know the correction value, so we can compute these corrected consecutive coordinates. The time will not be permitting me to do a numerical here, but I will appeal you, I will request you that please go through the book, and you can solve some numerical on this line. Once we have these corrected consecutive coordinates, we know now, how we can compute the independent coordinates.

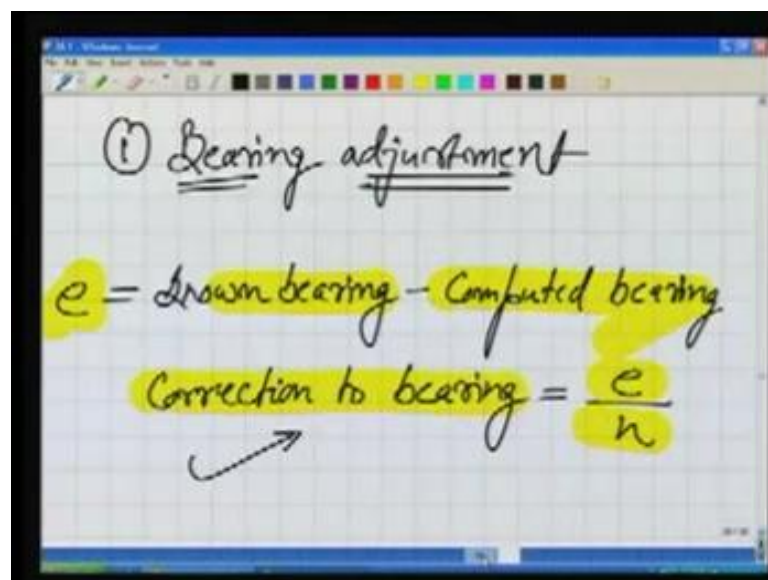
The only thing is, what generally is done, we try to take our entire traverse in such quadrant. So, the selection of the origin, you can select the origin accordingly, and then you have these coordinates for all these points. Now, once we have got the final corrected independent coordinates there is no closing error, and you can use these coordinates in your work.

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Now, we will see in case of the link traverse, how we apply the correction, how we adjusted. The link traverse is as we can see here, we know this line and we know this line, these lines have been done with some higher order survey. Then, we are doing a surveying or a traversing in between.

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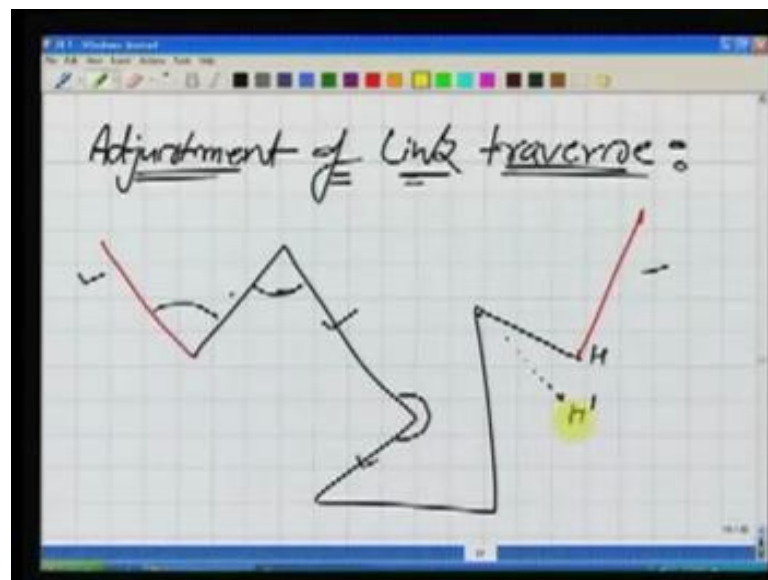


Now, what kinds of adjustments are required, number one is bearing adjustment the meaning of this is, what we can do is starting from our known line here, that is our known line. We know the bearing of this line from this line, we know the internal angle here in between as well as we know this internal angle, we know this internal angle. So,

what we can do using the known bearing of this line, we can compute the bearing of this line, then bearing of this line, then bearing of this line so on, what we can do we can compute the bearing of our final line also.

So, starting from a known line and using the internal angles in between, we can compute the bearing of the known line. Now, these two bearings will not be same, our known bearing and the computed bearing they will be different, if there is error, so that is the value of the error. So, what we can do, we can find the correction to bearing using the error value divided by number of the lines. So, this is the correction to the bearing, and this correction can be applied to the bearing of each line.

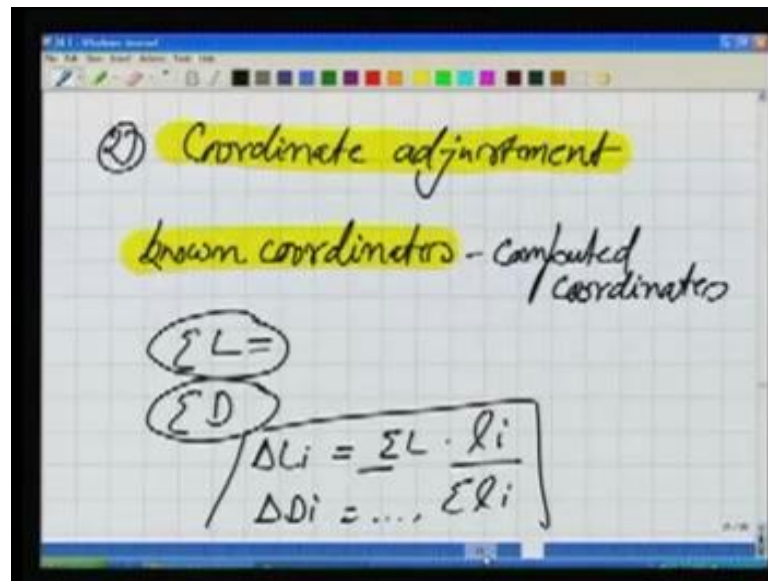
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So, what we will do, we will find this value of the correction will apply here to each of these lines, and on the basis of this we can compute new values of these internal angles. Well, we applied the corrections for the bearings, will if I start for example let us say, it is starting from this line, I plot this line at the known internal angle, because this internal angle is known to me, then using this length this angle and this length, I plot this point then using this angle, and this length I plot this point and so on.

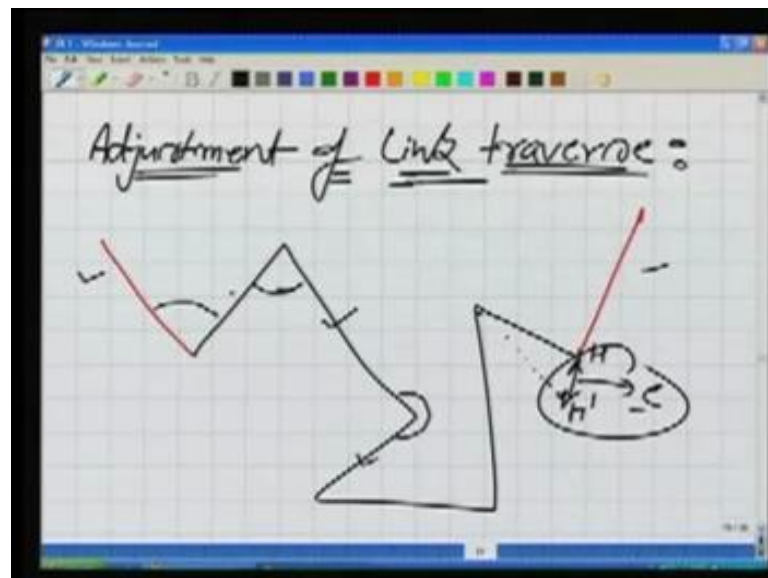
If I keep doing it, the angles have been corrected and the bearing has been applied, will I finally reach this particular point H or will I reach somewhere else, H dash. Still, as in the case of the traverse, close traverse we have not applied corrections in our lengths of the line. So, the chances are we will end up somewhere here.

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So, it is similar to the correction to the coordinates, so we write it as coordinate adjustment for link traverse. Now, how do we know it, how do we apply it, we find the we know the coordinates.

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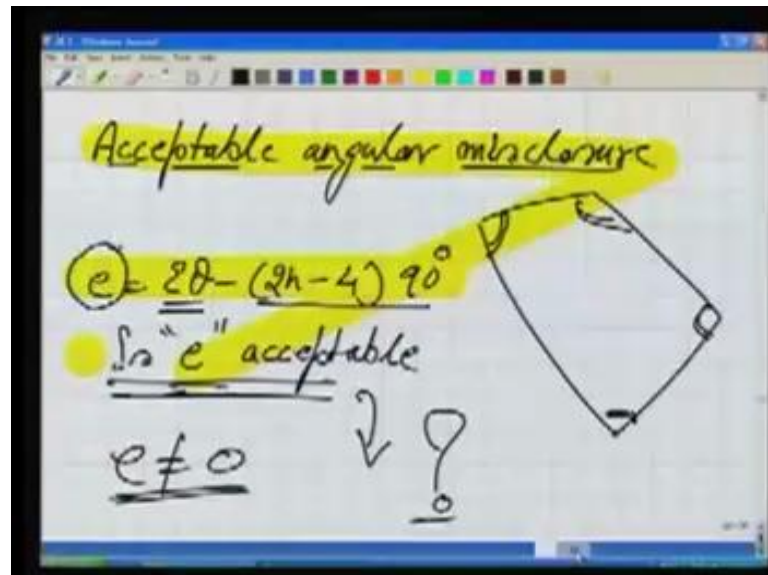


We know the coordinate of this point H, this is a known line and we compute the coordinate starting from the known line here, and the lengths and the angle values. So, the coordinate of some point H dash are computed, these two coordinate values will be different. If they are different there is a closing error  $e$ , so this closing error is same as with we are computing  $\Sigma L$  and  $\Sigma D$ . So, once we have done it, we can now



apply correction to each and every line to its latitude and departure using the same rules, what we discussed so far. So, we can for our link traverse also, for each line it can be corrected for its latitude and departure as per the closing error here, and as per the rule that we are choosing.

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Now, having done this, we are going to talk about one more term, which is acceptable angular mis closure. Now, what is the meaning of this, we have been talking about this very often. We say, that if you are doing a traverse, we are measuring these angles, if you find the sum of these angles minus  $2n - 4$  into  $90$   $360$  in this case. And, we find this particular value, if this value  $e$  is  $0$  there is no angular mis closure, but if  $e$  is not  $0$ , it is the finite value. Well, that value of  $e$  is that acceptable, how do we determine it, whether it is acceptable or not.

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The image shows a whiteboard with handwritten mathematical equations and a diagram. At the top, the equation  $e = \sum \theta - (2n - 4) 70^\circ$  is written. Below it, a boxed equation  $c = \sum \theta - c$  is shown with arrows pointing to  $\sigma_\theta$  and  $\sigma_e = ?$ . A second boxed equation  $\sigma_e = \frac{1}{(n)^2} \sigma_\theta$  is written below. To the right, a diagram shows a right-angled triangle with an angle  $\theta$  and a circle containing  $\sigma_\theta$  and  $n$ .

There is a procedure for that and in this procedure what we can do, when we are measuring an angle, in measuring this angle theta there are some errors, which accrue into which get introduced, this is because of bisection, this is because of you know reading. We have seen that, if you are measuring by repetition or reiteration, what will be the error in measuring any angle. We have seen how to determine this thing also. So, we know for the theodolite which we are using in the field, for a person who is working in the field what is this value, which is there in measuring one single angle.

Now, in a traverse there are n number of such angles measured. So, the final error is dependent upon all these angles. We can write this equation as e is sigma theta minus c, because this part is constant and we want to see now, this error in individual angles how it is going to propagate in our final e. So, if we solve it the usual way will arrive at this, so the error finally in the traverse, which is the mis closure error is computed like this, where n is number of the sides, now what is the meaning of this.

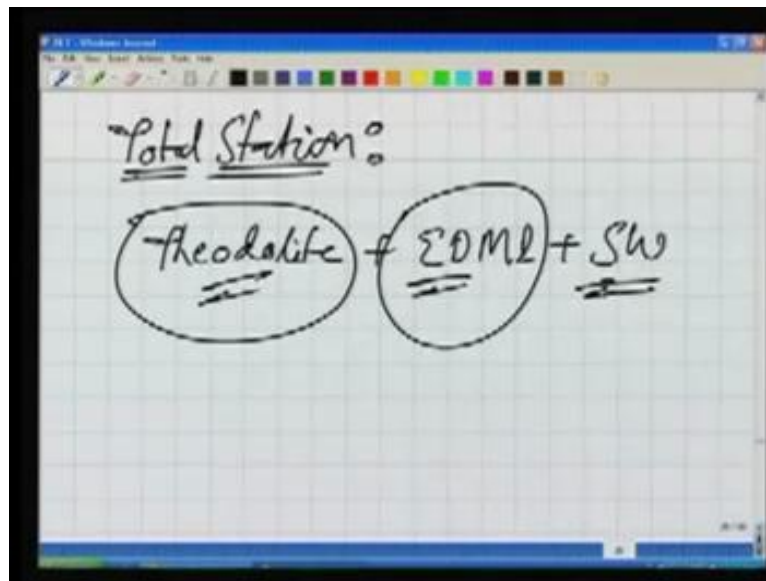
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The image shows a whiteboard with handwritten mathematical equations. At the top, it says  $\sigma_\theta = 2''$  and  $n = 9$ . Below that, it shows  $\sigma_e = (9)^{\frac{1}{2}} \times 2''$ . A box is drawn around the equation  $\sigma_e = \sigma^n$ , with an arrow pointing from the box to the equation  $\sigma_e = 2''$  which is circled. A dashed line also connects the box to the circled equation.

If we take sigma theta as 2 seconds, let us say and n is 9 they are 9 sides, so you can compute 9 this to power half and 2 seconds, so that comes out to be 6 seconds. Now, what is the meaning of this, is it acceptable or not, so it will depend upon your, this gives you that when you are working with your instrument with this error, then this is the error which is going to come anything beyond this.

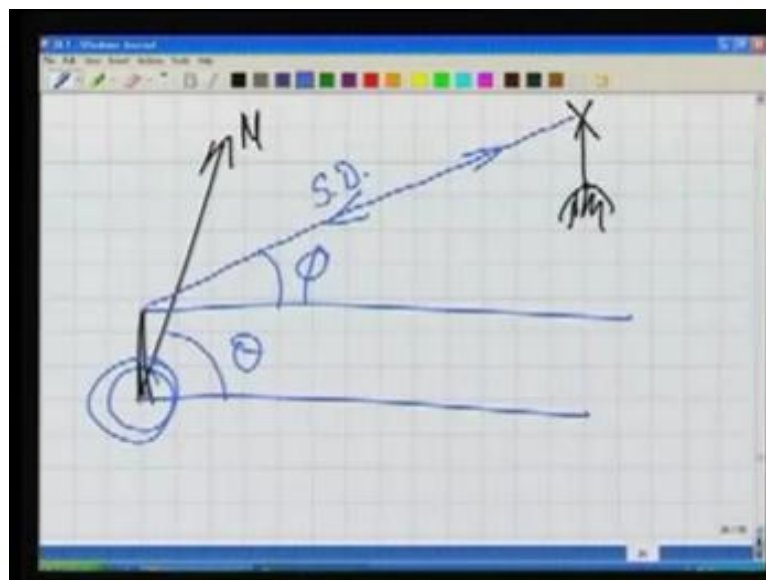
You can say it is not acceptable or you can define a limit, how much beyond, you can define that limit, but this is how we can determine that the kinds of the instrument which we are using the theodolite, which is controlled here, what kind of error will be introduced. Finally, this kind of the error will be introduced, so this has to happen this has to occur. Now, beyond this anything beyond this, that kind of measures can be given, and we can say well whether it is acceptable or not.

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Now, we will talk about total station, what is total station? It is basically a theodolite plus EDM plus some software inbuilt, when we put these three together that becomes a total station, the theodolite does the angle measurement, the EDM does the length measurement, and the software some algorithms inside they do all the computation part.

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So now, what can be achieved? If we have a total station, let us say this is northing or the direction of north, your total station is kept here, and there is a point in the ground and you want to determine the coordinate of this point. So, you have a target kept here, target means something the total station will bisect. Now, the EDM which is there in the

instrument will fire the electromagnetic radiation. And once you are bisecting the target, it will be reflected from there, it goes there gets reflected, and this distance which is called slopping distance is measured.

While we are measuring the slopping distance at the same time the total station has got the theodolite. It also measures the vertical angle  $\phi$ , and as well as the horizontal angle from our azimuth, let us say  $\theta$ . So, it has measured the horizontal angle from the azimuth this angle is known, the vertical angle is known, as well as the distance is known. So, if the coordinate of this point are 0 0 0, let us say, thus the northing thus the y axis for example or direction of north.

We know the angle in this plane, we know the slopping distance, we know as well as the vertical angle. So, having known all these three, you can compute the coordinate of this point with reference to the coordinate system here. So, it is a very quick process. The length measurements, the angle measurements all are being done simultaneously. And all these measurements are going into the software, and software has done all the computations.

So basically, this is the concept of total station of course, there are many more facilities in a total station, depending what kind of work you are doing, if you are doing the traversing; if you are doing the stacking; if you are doing the leveling; if you are doing the contouring, for what kind of work what software you needs to use, what program you need to use all these things are there in the total station.

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Now, we will have a demonstration of the total station, here is the total station. As you can see in case of the theodolite we go to the ground, we set it over the tripod and here is also a tripod with us. So, we first set the tripod level the tripod, there is ((Refer Time: 46:26)) which we talked in theodolite same thing here. Then we put the total station on top of the tripod.

And now, I can center it accurately by shifting the total station on the tripod head, once it has been centered, we will look for the centering in the case of the total station using the optical pyramid, the optical pyramid is here. Well, then we clamp it, so now the total station is clamped and is ready to work, here is the battery and it is connected to the total station, I switch on the power.

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Now, here in the panel when I switch on the power, it will start giving some messages. And then I can now level it, so this is the panel for leveling, if you look closely in this window here, I keep this panel parallel to two foot screws and by moving this foot screws, we can see it is being centered. So, we are doing the leveling using the foot screws, I have kept this panel parallel to this foot screw.

Now, if you look at this window, if you look at this window what we see, the moment I change this. First I use these two foot screws, either inward or outward and I bring this lower one in the middle, then I use the third one, the third footer screw and this also comes to the middle, now the instrument is ready. So, I press the enter by pressing the enter instrument will try to orient itself.

Now, it is orienting, orienting means it is knowing the horizontal circle, where it will read the angles, the vertical circle all these it is moving now, is trying to orient itself. And now it has oriented, now it is asking for the temperature, because we are using the EDM, we need to input the temperature, so whatever is the temperature will input that. Let us say, 42 today then the pressure, because that is also required for the computations of the distance, then some other things for example, let us say the horizontal reference

Well, I choose I move my total station, and I say well this is the line of my north, and that is my horizontal reference. So, I put it as 0 that is my 0 line enter, then it gives me a window. Now the instrument is ready for taking the measurements, what we need to do now, we need to bisect the target. So, there we can see the target and to bisect the target, I can rotate the instrument and I will bisect the target. So, using this I can bisect the target now, now the target has been bisected.

The procedure is same as in case of the theodolite, we make use of the refer site then our eyepiece is there we need to focus the eyepiece. We have the objective lens we focus the objective lens. Now, once the target has been bisected, I can hear a beep, it is telling me yes the target has been bisected and that beeps helps us. Well, after that we come to the panel and here in the panel, we press a m, it starts scanning then it is doing the measuring and it gives the slopping distance.

So, right now the distance from the instrument to the target is 2.075. At the same time, if you press enter, it will tell me some more things you know these are the value of the horizontal angle, vertical angle, the easting northing values, the elevation value all these are being computed. So, what we need to do here in the case of the total station, we need to give the height of the target. We need to give the height of the instrument, what is the height of the instrument; we need to give that height.

So, it takes into account all these values and does the computation inside, and gives us those values as you can see in the panel, so all these values are shown in the panel. Now, whatever we are doing here, we can make use of the panel and we have a menu system. For example, I am going to the menu system and in the menu if I press enter, enter it takes you further down, and I am going to use let say 7, some method for distance measurement. The, I am going to choose the measurement method, so far we are measuring with a target, that means the reflector was there. Now, we are going for number 2, number 2 means no reflector.

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Well, I choose no reflected 2, the moment I choose 2 what will happen here in the instrument. If you can see there in the wall a red dot is there, and I can take this red dot anywhere, wherever I wish. So, if we can see in the instrument, I am working in the instrument just by my fingers the instrument is very, very smooth, just by using the fingers I can rotate the instrument, and that will move the red dot, wherever I need to. So, if I fix the red dot, there let us say that may be a corner of the building, that may be part of the pole or anywhere any point where I cannot reach.

So, what we can do now, I am measuring now again, to measure I am using this a oblique m. And now, it is starts scanning and doing the measuring, and now it is giving me again the coordinates of that particular point. If you see the slopping distance the slopping distance is 2.493 meters, the value in the units I have fixed the units here, right now the angles are being measured. It is up to 400 you can see in goons, it is not in degrees we have to change it, also the distance is being measured in meter.

So, we can change these units inside this instrument and all the computations can be done accordingly. This reflected less method of measuring the distances or coordinates very, very useful. For example in this room, if we want to measure up there in the roof top the ceiling, so any other methods will fail. But in the reflector less what we can do, I can take this dot to the ceiling, it goes to the ceiling, and that is the point where I want to measure the coordinates of. Now, you can see that point I am moving that point, and this dot in your screen is moving.



So, for this point for example I need the coordinates, with reference to the point where I am standing, so what we need to do now. We have fixed that point and then I am coming back to the panel. Now here in the panel, again I press a m that is for the measurement. So, it is scanning now, and after that it will do the measurement, and it has given in the distance, the distance as you can see in your screen is 3.011 that is the slopping distance.

The horizontal angle and the vertical angles they are also given, 395 and 62 do not confuse with the units, we are not using degrees here. If you go further down in this menu there are some more things, the vertical distance depending where our reference is and some more things the easting value, the northing value. And finally the elevation, elevation of that point from our reference is 1.666 meters.

So, all these computations are being done inside the instrument. So, this is the total station, and at the moment we have seen only a few functions of the total station, not all. But, what we saw, how we can set it up, how we can center it, how we can level it, what do we do this is the power, which is on the power from here. And then how to initiate it, how to start taking the measurements, there are many programs inside the total station, which help you to conduct your work automatically they are very, very helpful.

So, some we can make use of the targets, when we are working with the total station or we can work without the target also. So, what we saw today, we saw the three tripod system, in which the error due to miscentering can be limited to a particular station. Then we saw the computations for the traverse, we can compute the latitude, departure, we need to compute them. And then using them, we can find the closing error, we can distribute the closing error using the method Bowditch method or transit method.

Then once we have done it, we have discussed the independent coordinates, which you get finally. We can make use of these and we can plot our network for our further work. Then also we saw today, the total station which we philosophically speaking is only a combination of theodolite, EDM and some software, all put together becomes a total station. So, if you have an opportunity to go to a laboratory, where you can see the total station, please visit the laboratory and start working with that. That will give you more understanding of the instrument.

Thank you.