

Transportation Engineering -II
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Lecture - 14
Geometric design-alignment of track

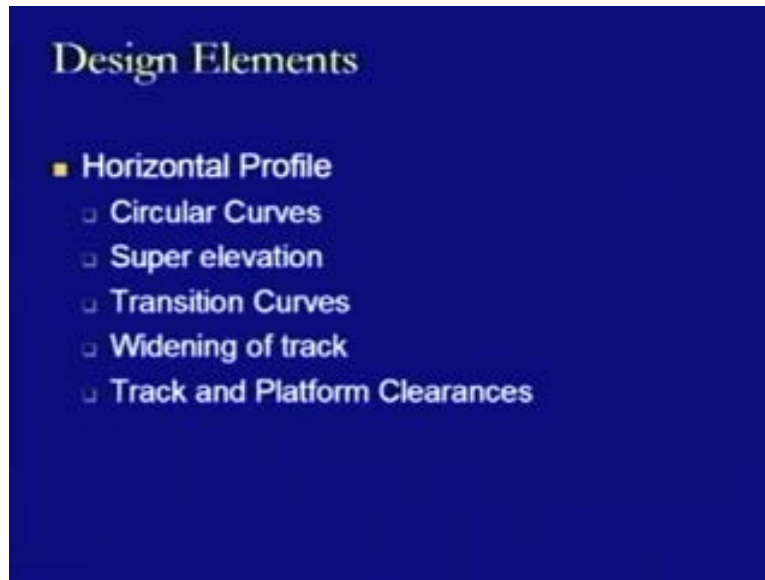
Dear students, I welcome you again to the lecture on the course material of transportation engineering 2. In this course already we have discussed about some of the specific and important issues of railways. We have already discussed about the permanent way, the gauges, the stresses and resistances offered by the permanent way and then we have discussed about different components, the rail, the sleepers and ballast. The specific issues related to those components like in the case of railway we have discussed about the wears and damages of the failures, we have also discussed about the creep of the rails, we have discussed about the coning of the wheels. In sleepers the specific aspect has been the sleeper density and then in the case of rails another thing which has been discussed is the joints. In the previous lecture we have discussed about the various fixtures which can be used to connect all these components specifically the rail and railway sleepers. Now onwards whatever material we will be discussing is related to the geometric design of those railway tracks.

In the case of geometric design the very first thing which we are going to discuss is alignment of the track. Now in the case of this lecture the lecture has been outlined as geometric design elements, the alignment of the track. Now the geometric design is defined as the design of all the physical features which have been provided so as to have a smooth operation of the system. Now these physical features may be different things which are provided so as to have a straight connectivity or so as to have curved connectivity or as to provide connectivity on any gradient. So looking at these requirements where the connectivity has to be provided between the 2 places or the 2 points we have to look at different aspects. We have to look at what is the distance between them, what is the location with respect to each other and then on the basis of those we have to decide about different elements. Now the various elements which can be talked about is in the case of alignment of track we have 2 things other than the straight portion which is provided and designed. In the case of straight portion the main thing is we are providing the rails at certain gauge distance depending on what gauge which already is being selected for the construction of that railway track.

Now the other thing other than that straight section is curve. There can be 2 types of curves one is horizontal curve another is vertical curve. Apart from these thing another elements which is of very high significance and importance is the speed. The speed of the train and its effects, some of the effects we have already discussed when we discussed about the stresses and when we discussed about the resistance. We have seen that whatever resistances or stresses are provided or they are being offered by the track or the components there is an augmentation in the value of those stresses or resistances as soon

as the stress the speed is connected to it. So therefore, the effect of a speed is another important aspect which needs to be discussed in detail.

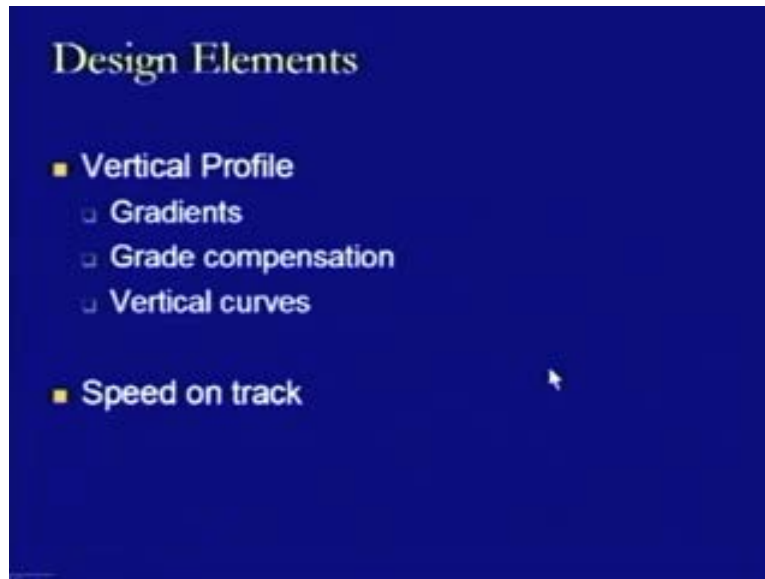
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Now within the horizontal profile what are the various things which can be discussed or may have their importance by which they are going to affect are circular curves, super elevation, transition curves, widening of track and track and platform clearances. So it means we have to discuss these aspects one by one when we take up the horizontal profile where the movement or the change in direction in plants is being provided using the circular curve. As soon as there is curve there is curvilinear motion comes into the picture the centrifugal force will also be coming into consideration and so as to nullify the effect of this centrifugal force the super elevation has to be provided. Then the another aspect, another design feature which is to be provided and designed is the transition curve. The transition curve is the curve which is provided between the straight portion and the curved portion and it has the tendency to provide the smooth transition from the straight section to the curved section without showing any point of jerk or without creating the problem of comfort.

Further, there is a requirement of widening of track because of the rigidity of wheel base of the wagons or the locomotives. So we have to look at the widening of the track because of this aspect and there are certain other reasons due to which this widening is to be provided like in the case of super elevation when the wagon or when any of the vehicle traverses this super elevated track then it has the tendency to lean in the inwards direction and due to this certain clearances on the inward side of the track has to be provided. Similarly, there may be requirement of providing the clearances between the tracks. If there are more than one track is being laid simultaneously or parallel to each other or there are some clearances which have to be provided between the track and the platform so in the horizontal profile condition all these design elements will be discussed further into detail.

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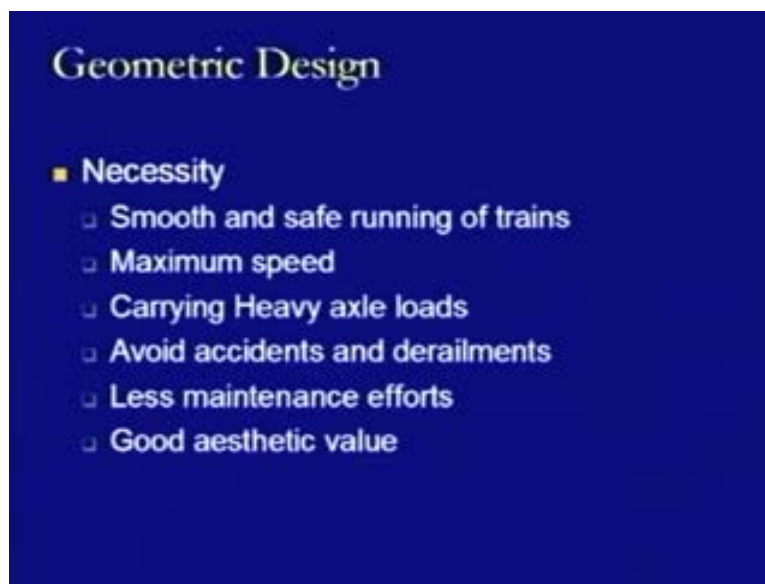


Whereas in the case of vertical profile the things which needs to be discussed are the gradients and their effect. Gradients means it is a value, it is a way by which the 2 points which have been placed at different elevations can be jointed together and that is what is the gradient and when this gradient is provided and along with gradient the curve is also being provided then as we have seen in the case of resistances wherever there is a grade provided it offers grade resistance. Similarly, wherever there is a curve provided then that curve offers the curvature resistance. It means the when the gradient and curvature both are being provided together the resistance increases to a much larger value and so as to negotiate this type of the curve a grade compensation has to be done. So in the case of gradient the grade compensation is the another aspect which will be discussed and further wherever the 2 gradients are meeting each other at that point we cannot provide a sudden change over from one grade to the another grade due to this aspect at this particular point a curve is to be provided and because this curve is provided in the vertical profile that is why the name of this curve is given as vertical curve. So these are some of the design elements which needs to be taken into consideration in detail.

Another important aspect as we have discussed just before is the speed of the track where number of design elements within these vertical profiles and horizontal profile that is when we have to design the curve. When we have to design the vertical curve, or the horizontal curve, or the super elevation, or the transition curve in each and every aspect the speed of the track has to be considered and that is what is the significance and important of the speed on the track. So therefore, the another feature which is to be taken into consideration is what are the different types of speed which can be provided on the track, how those speeds can be computed? And further how that speed contributes towards the design of the geometric of any railway track or permanent way?

Now coming to the necessity of the geometric design the geometric design has to be provided so has to provide a smooth and safe running of trains because if the geometrics are not being provided then the connectivities which are provided between the rail sections or the direction in which the rails have to move or the change over the direction from one side to another side all these things will not be possible. At the same time if we are not providing the transition faces between the different elements as we have seen previously like in the case of the curve the transition curves needs to be provided between the straight section and the curved section then also there will not be a smooth running, there will be a point at which the jerk will be observed by the passengers or the freight being moved.

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Further if the super elevation etcetera are not being designed then in that case because of the centrifugal force and the effect of that centrifugal force along with the higher speed of the trains at which they are moving there always chances of overturning or derailment of the trains. So that is the safety aspects due to which the geometric needs to be designed. Another aspect is maximum speed. We cannot run the trains at any speed, we cannot the run the train 500 kilometers per hour or 1000 kilometers per hour without designing a track of that is specification. Of course, into these conditions we have the test track on which the trains had been run or at a speed of 500 and 550 kilometers per hour though in Indian condition we are not having any track on which the trains have to move such a distance or even they have been moved at a value of above 160 kilometer per hour. So this is the one aspect which needs to be taken care of and we have to decide what is the maximum value to which the trains can run on any of the track.

Further there is need to carry heavy axle loads and when we are carrying the heavy axle loads then the system has to be designed in which those loads are not getting sink in below or they are no undulation which is getting created because of the movement of such heavy loads. Further, another aspect of this design is the avoiding accidents or the

similar sort of hazardships like derailments. This is another reason due to which the geometrics have to be designed. Then once the geometric have been designed in a proper wave for certain values where the tolerance is being provided then the maintenance requirements will also be lesser and therefore it reduces in the overall cost component of the track and finally the last thing which is of importance in these case is good aesthetic value. What happens is that if a smooth design is being provided and that design is looked up on in plants from the top or in elevation then it gives us sense of aesthetics and due to this reason also the geometrics needs to be designed and provided.

Now coming to the main point in this lecture is the alignment. Alignment is defined as the line in a space through which the connectivity is provided between 2 places. Now this line in a space means there are 2 points which have been provided at any 2 locations they may at the same elevation or they may not be at the same elevation and if we provide connectivity taken into consideration certain locational aspects, certain safety aspects and economic aspects in consideration then whatever is being finalized that is the location of a line or the centre line of that facility in space and that is what is alignment and on the basis of this alignment this alignment as we have discussed previously can be horizontal alignment or vertical alignment depending whether we are talking in terms of plan or we are talking in terms of elevation.

Now whatever alignment is provided, whatever form there are certain things which are the basic requirements of any of that alignment. The very first thing is the purpose of that line or purpose of that alignment. It means that for what reasons that alignment has been provided between the two places whether it is having the route is being provided or alignment is provided so as to move the commodities from the place where they have been produced to the places where they are going to be consumed, where it is going to work as connectivity for the mainly for the passenger traffic or where it is going to work as a point of to this attraction in that area like in the case of hill railways where they have been provided like in Shimla or Darjeeling or Nilgiri, Ooty they are also the tourist restriction in those area are like in Matheron. So we have to look at for what reason we are designing or for what reason we are providing that alignment and once that alignment is being provided or being fixed or implemented then whether it is fulfilling that purpose or not.

Another thing in this is that it is not necessary for only single purpose route or alignment has to be provided, at times there may be combination of the things like may both the things passengers and the freight may move along that alignment instead of only single thing being moved. So that means there is multipurpose condition where that alignment is being provided. Another aspect is that it should be helpful in the overall integrated development of that area in which it is being provided. It should not act then the other developmental aspects or the other developmental works which are going on in that area. The main thing is that it should act as the part of all the overall development instead of working as an individual aspect. Now if it acts as a part of overall development then only the whole thing will get fill integrated coordinated and it will be comprehensive sort of a planning or development in which it will be working.

Another aspect is the shortest route should be there as far as it is possible. This shortest route is to be provided from the economic considerations. If we have point a and point b and if we join those points a and b by a straight line then this is what is the shortest route but not necessarily every time it is possible so as to go for this shortest route. Sometimes we find that there are some physical features in between those 2 points which are not permitting us so as to draw a straight line or so as to provide straight alignment between those 2 points; like there may be a hill lock in that area, there is a lake between the 2 points then it is not possible so as to draw a straight line or if we have to do that then certain other technology needs to be used like in the case of hill lock still if we want to move through that one then tunnel is to dug whereas if the lake has to be crossed then a bridge is to be provided. It means there is a combination some more technologies which have to be used to provide that facility along shortest route but what we have to see at this point is whether provision of the shortest facility with the combination of other techniques is the cheaper or it is cheaper so as to traverse along side of those obstruction and provide a connectivity. So it is not necessary that every time a shortest route can be provided between the 2 points sometime the other aspects needs to be taken into consideration.

These aspects which need to be taken into consideration may also relate to the safety point which is another point as we talk about the hill area it is not at all possible to provide the point which is at the top of the hill connecting directly with the point which is at the foot of the hill. What we do in those cases has to maintain the safety, maintain the safety of rolling stock we provide circuitous route which moves may be along the side of the mountain and that is how the distance has been increased but the safety is being maintained.

Similarly, another aspect which is to be taken or which needs to be given consideration is comfort. In the case of comfort we have to see that the route passes through that area where the possibility of getting the jerks or the possibility of getting the undulated surfaces is less, as less as possible and that is where the comfort is to be generated or otherwise the technology to be used so as to provide comfort along that alignment and finally as we have just discussed before is aesthetics is another basic requirement in any of the alignment. The alignment if drawn in plan or if seen in elevation should provide a view which does not look like severance to the visual aesthetics but it should be a thing which can be adored or which can be praised for that type of design. So these are some of the requirements which need to be taken care but at the same time there are certain things by which we have to make compromise on all these things.

Of course, one more point which is there in the case of the basic requirements is the overall cost of the alignment. As far as possible the cost of overall cost of the should be as low as possible and this is what is being given here when we talk about this economic consideration or the overall cost then it is to be talked at 3 levels; one is the construction level, another is the operational level and third is the maintenance level. When the route or when the alignment is being constructed we have to look at various aspects by which the overall cost of the construction can be reduced. It includes the machinery, it includes the man power, it includes the material everything. In the case of operational cost the

alignment should be such that few requirements or the wearing of the various components of the system is as minimum as possible and if that can be done then the operational cost will reduce by itself. Similarly, whatever design feature have been designed, the another aspect is that what type of design is being used whether that design requires the regular maintenance or whether it requires periodical maintenance. If periodical maintenance is there by which even 3 month after 4 months only the maintenance is to be done then obviously in this case also the cost of maintenance will be reduced and that is how we can have minimum cost of overall alignment which has been constructed and this is to be taken into consideration.

Now we come to the another point that how we are going to select any alignment. There are number of factors which govern the choice of alignment, which governs the position of the alignment through which it is going to pass and through in which direction it is to be placed. In this sense the first point is the choice of gauge. Now the choice of gauge is governed again of course by the different factors as being seen before. The choice of gauge may be like whether we are interested in providing broad gauge, or a meter gauge, or a narrow gauge or any other gauge like in the case of hilly region whether we are interested in providing hill gauge and all these gauges they are having different values starting from 1676 mm to 610 mm. So that is what is the variation between the gauge so which gauge is to be provided.

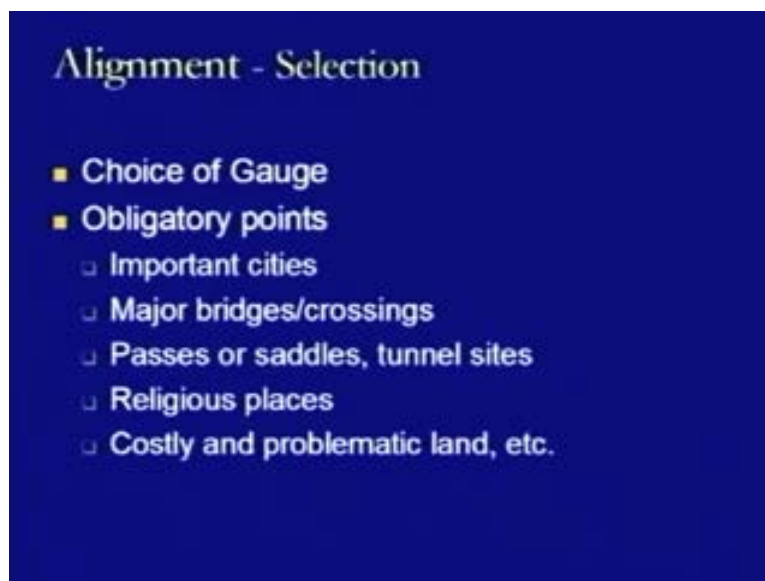
Now this choice of gauge is also governed by the purpose for which that alignment is being constructed. If there is a heavy load which is to be transported from one point to another point of this as we have discussed about an example there is a point of production and it is to be connected to a point of consumption then obviously in that direction there will be heavy load which will be kept moving throughout the year. So in that case a bigger gauge is to be provided that is what is the broad gauge is to be provided whereas the traffic is very less or it is to be provided just has to provide the connectivity between the both 2 points then smaller gauge can also be worked on. The meter gauge or narrow gauge can be provided in such cases. Another condition is that we have to look at the choice of the gauge on the basis of the physical features or topographical features of that area. On the basis of those physical or topographical features if it is a plain area or if it is a hilly area of the obvious choice of gauge will differ. So we may have a broad gauge in the case of plain area but the same broad gauge may not be provided in the case of heavy hilly area or a mountainous region where the steep gradients have been provided.

Then the next point is the obligatory points. Obligatory points means those locations or points through which the gauge through the alignment has to pass or there may be some conditions in which the alignment cannot pass through those points, so we have to look at both contentions. We have to look at through which the alignment can pass or cannot pass. In case we take the important cities then the important cities are the location through which the alignment has to pass. Similarly, as we have seen that there are certain physical features which creates an obstruction to the movement like lakes or say the hill locks, so at these locations the bridges needs to be provided or the tunnel needs to dug. So if we are looking at this type of a condition so we have to go for major bridge or we have to provide the some type of crossing at that position.

Similarly, we can talk about crossing with respect to the roads so that is the level crossing which is provided at that location. So far it is possible so as to avoid that type of crossing, the crossing is avoided but if it is not at all possible then we have to provide, we have to use the technology and provide another feature that is like bridge. In the case of passes or saddles or in the case of mountainous region then we have to go for the tunnel sites. So far it is possible we use passes between the mountain so as to run over alignment or the alignment can run over the saddles so that because they are the point of water shed condition so we have the ups and downs and at all if it is not possible then there is big mountainous range which is coming then the tunnel is to be provided. Therefore we have to locate the site where the tunnel can be dug and still it is not big length in which the tunnel is to be dug because the tunnel operation is very costly affair.

Another aspect is like another place which needs to be considered is religious place. If there is any religious place which is coming along the alignment or where the alignment has to cross that then we have to omit this type of place and in this condition we have to go around that place and this is how the deviation in the alignment will come into picture. So instead of shortest alignment now we have an alignment where the deviation will be there. In the similar form if our alignment passes through a land area which has certain problem like the land is marshy in nature or the land is having the material at the formation level where there are all chances of heavy settlement taking place then it is always better to avoid this type of location and move through any other location.

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The another point is with respect to the land is the costly land. If this alignment has to pass very near to the urban area and the cost of that land is very heavy then the cost of acquisition of the land will increase. So therefore in this case it is better so as to omit this type of land and this land can be used for other development purposes through which the revenue can be generated in different form whereas the railways or the alignment of the

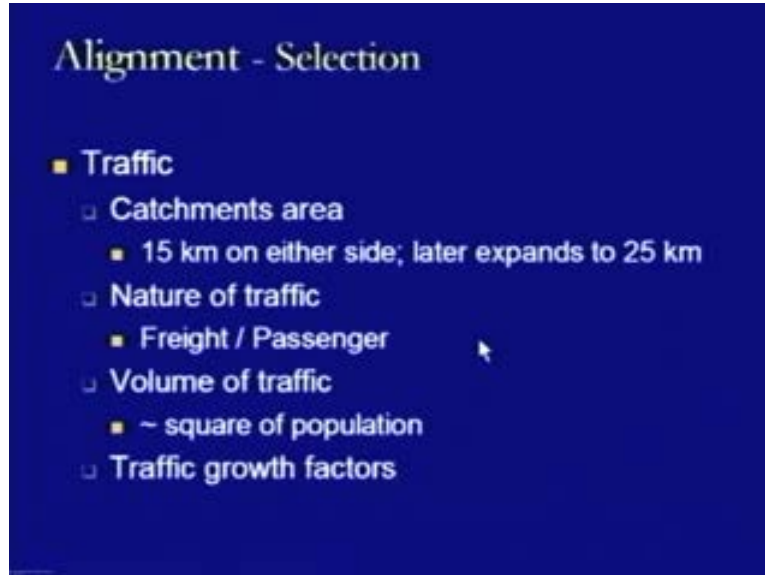
railway can be provided very adjacent to this line where the land value is not as high as it is there when you have to pass it in the case of shortest alignment.

Now in this diagram the same sort of obligatory conditions have been shown. There is a point a which is to be connected to this point b and if this is the condition where a hill lock is there then we have to pass through this hill lock and we come to this point and go to the other side and what way it can be done. Instead of passing through this one the one way is that we pass through the other side of the area and then in that condition we have to look around for that location where the bridge can be provided. In this case the bridge has been shown at three locations, that is, b, b1 and b2. So which location is going to be better, this is one another aspect to be taken into consideration.

Here what we see is that in this case the bridge is oblique to the direction of the movement of this river where in this case or in this case this bridge is again perpendicular to the direction of movement at this point and this bridge is again perpendicular to the direction of movement at this point. It means the length of the bridge at this location or this location is going to be a little lesser as compared to this location but again in these 2 cases there is further difference what we found is that in being connected with c and then there is very small curvature by which the road comes to this bridge and it becomes almost straight at this location and passes it and then again there is curvature by which it reaches this location b.

Whereas if you look at this one this curvature the connectivity from this point to this d point is straight whereas after that there is curvature being provided and due to this curvature the widening has to be provided at this location that is bridge. So the size of the bridge is increasing in width as compared to the other location and due to this curvature effect the length of the bridge is a little more than this length of the bridge. So we have to look at this another aspect which is economic consideration of using another technology by which we can just cross an obstruction and move to the other side. Now by doing this what we are trying to do is we are connecting at this point location c, or at this point location d, or at this point location e. Now if we connect through this way then what happens is these are the points of revenue generation and if we can generate some more revenue when moving along that path while moving along alignment then that is an additional advantage of that alignment. So that is why most of the alignments are made or fixed in such a way that they connect number of locations by which the revenue can be generated while moving along that alignment.

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Now another aspect of the selection of any alignment is traffic. Now the traffic is the main substance of any alignment because this is the thing which needs to be moved. In the case of traffic it may be of any 2 type, it may be freight traffic or it may be passenger traffic or it may be a mixed traffic that is combination of both. Now when a new alignment is being fixed then it is a little difficult to understand or difficult to estimate what is going to be the traffic which will be moving along this alignment. In the very starting the catchments area of that alignment is taken as 15 kilometer on either side that is if we take the in the transverse direction at 15 kilometer distance on one side or either of the side it means the total is 30 kilometer patch along the alignment through which the people will be coming or through which the freight will be coming to this alignment or its movement and slowly and slowly it is expected that this catchment will increase to a value of 25 kilometers on either of the side. It means in this case it will become 50 kilometer patch along the alignment where the alignment is the central point of that patch.

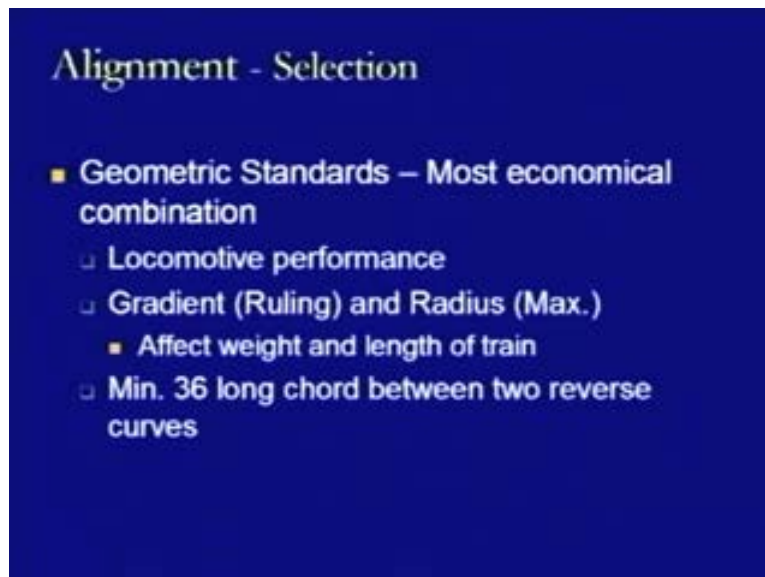
So once this catchment area increases it means the overall revenue generation is increasing. More of the persons are coming to this alignment or more of the freight which is being transported which is using this alignment means the revenue generation is there and therefore it is going to be a more economical or fruitful proposition so as to provide this alignment as compared to any other alignment. When we talk about this type of the traffic which is coming through this catchments area the main emphasis remains here in terms of volume of the traffic. The volume of the traffic is to be considered in terms of as we have seen previously when we discussed about different routes it is as taken gross million tons per year.

Now in very starting when the alignment is being laid then how that volume is going to come? It is taken as square of the population. This is the amount of the traffic which will be using that alignment. These are some of the ways by which the estimation can be

made so as to find out what is going to be the value of the traffic which will be using this alignment and another aspect related to traffic is the growth factor. What is the rate at which the area development is taking place? What is the rate at which it is expected to increase the traffic? these are the 2 things which has to be taken into consideration and this will provide as another estimate of the future traffic which will be using this type of alignment which is fixed in this area. These are some of the things which we have to take into consideration when we talk about traffic.

Another point is the type of the geometric of their standard we are providing for that alignment. As far as possible the standards should be such that they provide the most economical combination. The standard which is the thing which can be placed at any higher level we can go to very high level but as soon as we go to towards the higher level then the overall cost providing a facility increases. So it means we have to look at that standard which is acceptable but at the same it fulfills our purpose and it also fulfills requirement of provision of any alignment in an area. So therefore we have to look at this economical aspect or combination from different angles like the first thing is the locomotive performance. We have to find out available locomotive to us and what is the performance of those available locomotives? What is the speed they can move? What is the total traffic? What is the total load which they carry with themselves?

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What is their performance when they are negotiating the curve? What is their performance when they are negotiating any gradients? Up to what distance they can move on those gradients or curves without losing their speed? So all these factors have to be taken into consideration and then only we should come to certain features or certain standards which can be fixed to any of the type of the element which is to be designed under geometrics. Like in the case of gradient it is important to fix gradient as far as possible to a value of ruling gradients which is related to the locomotive performance. As far as ruling gradient is provided there is not going to be a much loss in the locomotive

performance but as soon as it is higher, steeper than this one then the locomotive performance will sharply reduce.

Similarly in the case of the curve as far as possible maximum radius should be provided. When there is a maximum radius then the loss of tractive effort will be minimum because the angle by which it is getting steered with respect to the angle in which the tractive effort is acting that angle will be very less and due to that reason the loss of tractive effort will also be lower. So whatever maximum radius can be provided is another importance aspect and both of these things going to create an effect on the overall weight of the train as well as the overall length of the train which can move on that section. Similarly, if there is any requirement of providing reverse curves then it is important to provide a 36 meter long chord between 2 reverse curves, this is another aspect related to the geometrics. Then in the case of the stations or in the case of the bridges as we have seen previously in one of the diagram where we discussed 3 locations of the bridges as far as possible that the track should be straight in nature and the train should come straightly on stations or bridges. The curvilinear nature of track near a station or bridges is not desired.

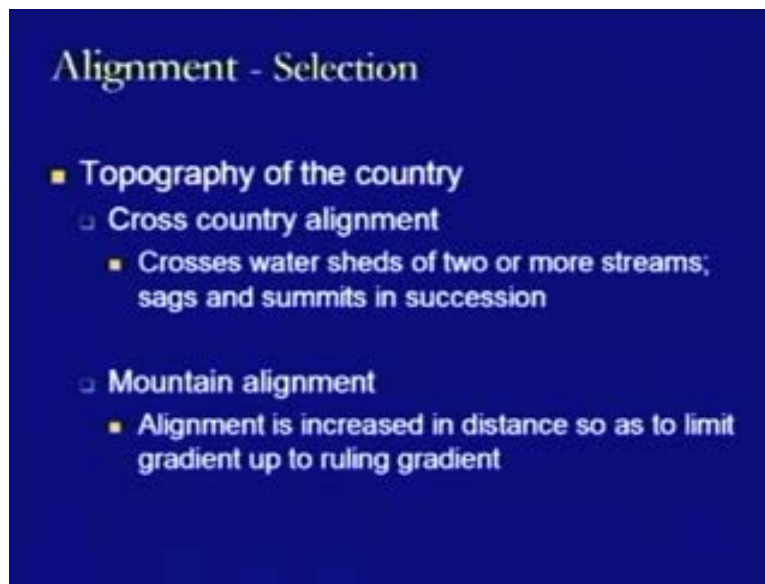
Another aspect from the economic point of view is the rise and fall. There should not happen that the whole of the alignment is being constructed in overall rise or the whole of the alignment is being constructed in fall. The requirement of providing embankment or the requirements of cutting both of the things are costly affairs whereas the cutting is the more costly condition as compared to filling. Therefore we have to balance out the total quantity which is coming out in from cutting and which is required in filling and it is how the rise and fall has to be balanced out as far as the material considerations are concerned, as far as it is possible. If it is not at all possible then only the cost escalation may be allowed. Then hauling distance is another aspect of the geometry standards. Then the hauling distance means with the help of the power available to any locomotive how much distance the load can be transported and that is what is the hauling distance. So if we are talking about any locomotive which is running with fuels then with the capacity of the fuel which is provided to the that locomotive what is the maximum distance up to which it can move subjectivities is being offered by the resistances by the track or the resistances by the atmosphere or so on. So looking at all those practical considerations the overall distances up to which it can move has to be found out. So there are all the points of standards by which it is to be designed so as to achieve the economical design.

Then another important aspect which needs consideration is topography of the country. Topography of the country means the amount of undulation through which an alignment has to pass. On the basis of that undulation which can be there may be different type of alignment conditions. The very first one is the plane alignment where the flat terrain is being provided. Flat terrain means the undulation remains more or less within the value of something like 10 percent has taken in the case of road segments but here we can say that the cross gradient which is provided is coming within 10 percent value and in such cases there is no problem at all. The another type of alignment is termed as valley alignment. Now in the case of valley alignment what happens is that the control points or the section through which, on which this ruling stock is moving that lies within the same side of that valley and this is what is the valley alignment. So the control points lie in the

same valley and we will find that there is uniform gradient means the 2 points which have been provided on the same side of the valley have been connected by a straight line curve and this gradient which is provided generally a gradient which comes within ruling gradient condition. Therefore there is no requirement of having a steeper condition in this case and this is what is the valley alignment.

Then there is another category of alignment. This category of alignment is known as cross country alignment. In the case of cross country alignment there are possibilities of having sags means the depression or the summits means the top points through which the alignment will be passing and in most of the cases the sags or summits are coming into succession, the reason behind is that this alignment is crossing the water shed areas of 2 or more streams.

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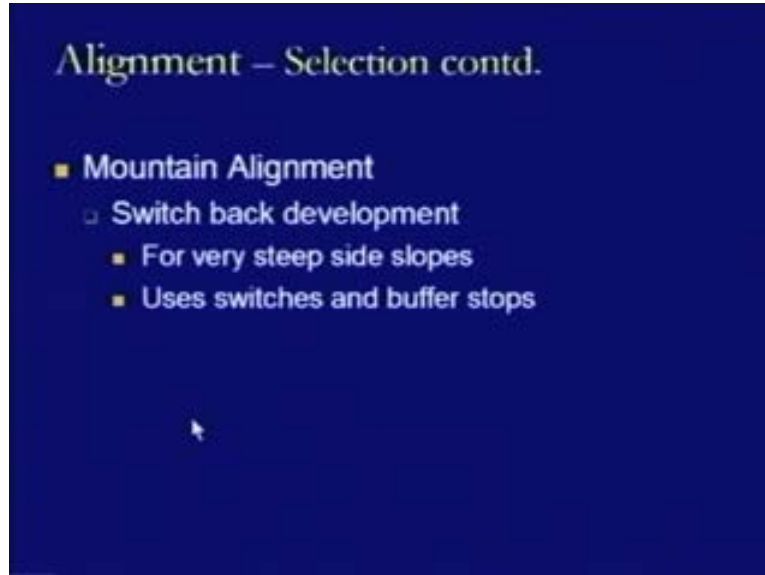
Now water shed area is the point through from which the water moves on either side of that section. So therefore, the alignment is passing through this one there is no problem of water logging, or there is no problem of drainage, or there is no problem of the flooding taking place along this alignment but in this case it is passing through this type of water shed condition then there are chances that it comes across through sags and summit and that is why the say and summits will remain on this alignment in succession. The another type of alignment is mountain alignment this is the top most condition as far as the gradients are concerned. Here the alignment is increased in distance because the gradients cannot be fixed with in the ruling gradient condition so and this case the limit of gradient of the ruling conditions or gradients probably cannot be filled in so therefore we have to provide in between at some locations steeper gradient than this one but then if the ruling gradient is to be maintained then the length of the alignment will increase and as we have taken an example that we have to connect a point which is provided type of the hill lock.

There is the another point which is provided at the foot of the hill then a circuitous route is to be provided so that it remains within the ruling gradients but then it increases the length of that alignment.

Now in the case of mountain alignment because there are different type of conditions which can be there and we have to come across of all those conditions in the different type of mountain alignments are available and in those types of mountain alignment, in those type of developments the first one is termed as zigzag development. A zigzag development is the condition which more or less like half circle loop. What happens is that it starts from one point it tries to cover up some of those contours of the topography of that area and then it returns back in the circuitous move on the same point itself but at a higher level. So this is how the half circle loop is completed then it will be moving forward in a similar form may be in the same direction, may be in other direction so as to make a reverse curve condition and it follows the side of the valleys or at times it also moves round the hill side. So these are the 2 possibilities which can be there in the case of zigzag development.

Here in this diagram we are trying to show the zigzag development. What we are trying to do is these all lines they are the contours and the values have been shown along all these lines which shows that when we are at this level it is 65,70,75,80 means it is increasing in this direction. Similarly when we look at this direction then it is also increasing in this direction. It means we are increasing the height of the point in this direction. This is the higher point as compared to this point. Similarly this is another higher point compared to this point. So when we are going for zigzag alignment then this alignment tries to follow the contour as far as possible. So what we see is that this alignment is coming from this direction and it is coming in this form and then we see that the contour is taking turns it also takes the turn in the similar form and while doing so it is going very close to the another contour now and this is how it is taking elevation. Now slowly and slowly it is going up and probably the limit of the ruling gradients is being maintained so it comes up to this point and then again here we found that it is taking turns. So we use the turn of the natural contour and by which we also turn over alignment and this is how further we can attain the height. So this is overall zigzag process by which we can move in the forward direction.

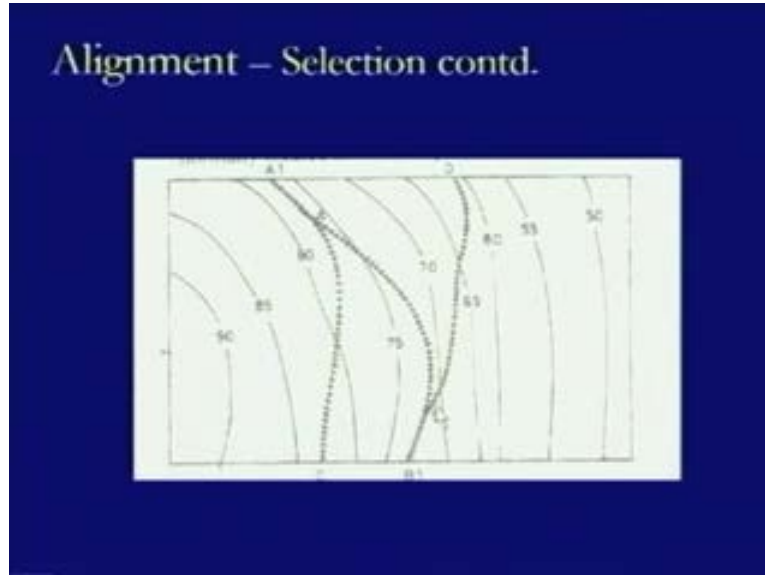
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Then another type of mountain alignment is termed as switch back development. Now in the case of switch back development is case where it is not at all always possible to follow the contours as we have seen in the zigzag condition. So what we have to do is that some steeper slopes has to be negotiated and so as to attain those steeper slopes we require certain position where the locomotive can come to a plain area and then it generates further power and using that power it goes in the other direction and takes the elevation. So in this sense it requires 2 type of things; one it requires a switch from where it will be taking change in the direction and it requires buffer to stop that is the point of to which it goes and stop and takes change of direction and then it starts moving in the other direction and this type of development where it goes in one direction it stops then it starts coming in the backward direction and opposite direction due to this reason it is termed as switch back development.

Now in this diagram what we see is switch back development. Here what we found is this is the lowest contour on the side and highest contour on this side. Therefore, we are trying to move in this direction. As far as the shortest alignment is concerned we could have provided a straight line from this point to this point and then it is observed that because of shortest distance of this one probably it will fall outside limit of the ruling gradient. Therefore we have to follow the contours but at the same time the steeper have to be attained so I am starting from here our track comes this way it is more or less following the contours and slowly and slowly it is going up and this gradient is equal to the ruling gradient. Then it comes to this point and then after this point it is going up to this level. This is the same contour, we can see that this is 70 this is 75 it is moving with 70 and 75 contour here so it is a leveled stretch. So after gradient a leveled stretch is being given and this leveled stretch helps the locomotive to attain the power back and once it attains the power at this location there is buffer stop so there is switch at this point by which we are changing the direction. So this is the direction of locomotive coming in this way and this is the direction by which it is going in this direction.

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This is switch here, similarly there will be switch here and there is buffer stop here that means the train will stop at this end and then there will be change of the direction of the locomotive and the locomotive will take the train to this direction and it will go up to this point again it will stop and comes in this way and this is how this keeps on going and that is why it is termed as it comes this way and goes this way switch back system. This is the same switch back system which is being shown here, the contours and along with the switching back condition. Then the another type of mountain alignment is the spiral or complete loop development alignment where the complete loop is formed as a bridge spiral or tunnel spiral. There are two types of spirals which can be there on the basis of loop formed. Here we can see this is the one photograph of mountain alignment where at specific type of engine is being used and then the compartments which are used to carry the passengers this is also different type, this is tourist attraction condition.

There is another alignment is being shown the train is moving along this alignment this mountain alignment. Now here we are talking about the loop so what happens is that track comes like this and it is coming from this stop area then to this stop area and it takes turns this way then it has to go to other side. Here there is river on this side, so it has to cross this hill and it is crossing this hill by this dotted line that means the tunnel is being provided in this location. So this is the tunnel spiral and then it goes in this form. This is another diagram where we see the bridge spiral where it is coming back to the same location and now it is going over the bridge in this direction. So this is another alignment of the mountainous that is spiral type of alignment. Here this is one photograph which is being shown what we found is the train is coming from this side then there is a bridge at this location and it comes to this way and finally it is comes at the top and will be going in this direction. This is the old photograph being taken Darjeeling area. This is another photograph of the same one the train is moving in this direction and goes in this way and then there is another loop by which there is a bridge and it will be coming in this way.

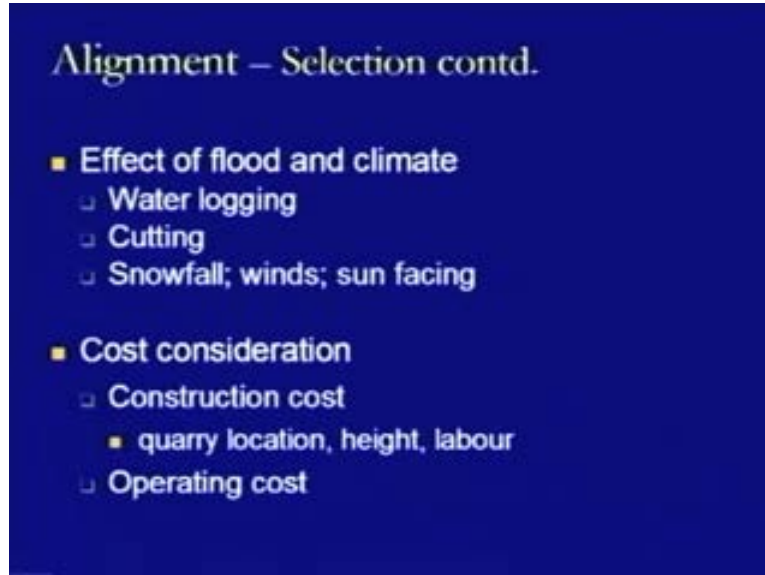
Now there are some more factors by which the alignment needs to be considered; one is the position of roads and road crossings.

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So far it is possible it should be minimum. Political considerations, at times we have to provide the alignment on the basis of the requirements of the wishes of the political or the government. Then geological formations is the another reason we have to look for the good soil, it should be free from the drainage problem, there should not be rocks and there should not be slips and slides in the area especially in the case of hilly terrain otherwise the alignment will not be safe and finally we have to look at the hydrological condition in terms of water logging, snow fall or we have to look at the sun facing condition of the alignment and the another important aspect is that the cost consideration as we have discussed previously too the cost consideration has to be considered at 2 aspect levels, that is, construction cost and operation cost. When the construction cost we are talking then we have to talk about quarry locations, the height of construction, the labor and then the basis of all the cost and all the revenues which have been generated we have to look at the returns which is nothing but the revenue minus expenses divided by the total investments.

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So what we have seen in the today's lecture is the aspects related to the geometric design and their elements and then specifically regarding the alignment, the factors which need to be considered while choosing any alignment. So we are stopping at this point and we will be continuing with the other lectures in the geometric design features in the following lectures good bye and thank you.