Transportation Engineering -II
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Lecture - 12
Ballast

Dear students, welcome you back to the lecture series on the course material of transportation engineering 2. In today's lecture we will be looking at one of the another component of railway track or the permanent way that is ballast. In our previous lectures we already discussed about 2 of the components of the railway track, that is, sleepers and rails and their associated features like creep in rails, the wear or defects in rails. Similarly, in the case of sleepers we talked about the sleeper density of sleepers. In today's lecture the lecture has been outlined as ballast, the functions and requirements of ballast, the types of ballast, the design of section. In the case of the ballast we are starting with the definition, the ballast is a layer of broken stone gravel, moorum or any other gritty material placed and packed below and around the sleepers for distributing the load from the sleepers to the formation and for providing drainage as well as giving longitudinal and lateral stability to the track.

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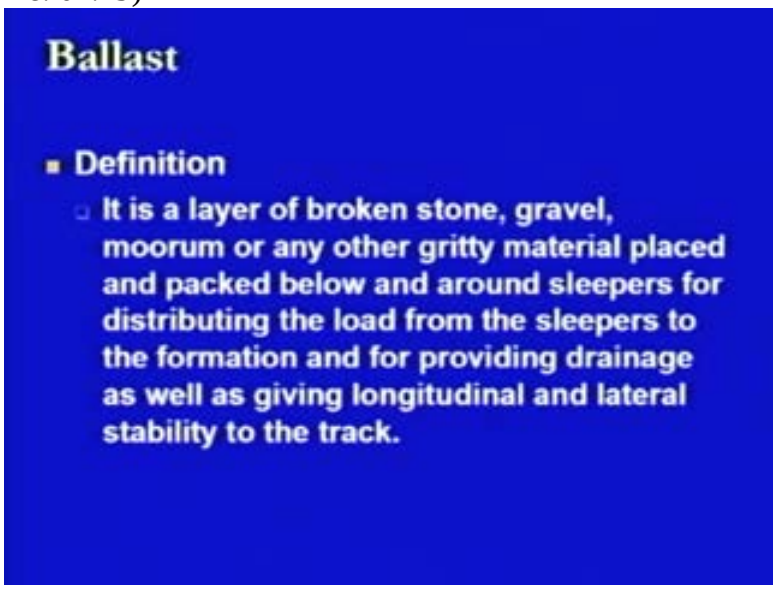

So the definition itself is trying to define certain things, where it tries to define in the very first line is that we have different type of material which can be used as a ballast cushion in the railway track. This ballast cushion can be made of the broken stones, or the gravel, or the moorum or any such material which may be suitable for the provision of the ballast cushion depending on the requirements of the ballast cushion or whatever are the properties which are required to provide that the ballast cushion. Another aspect is where this ballast cushion is to be provided, in what form it is to be provided; 2 things needs to be done. One is that is to be packed below or it is to packed around the sleepers. There

are two conditions which will be there; one is, it is going to provided below the sleepers that is termed as the ballast cushion and it is going to be provided on the site of the sleeper that is termed as packing and the reason behind providing this ballast cushion below the sleepers or on the side of the sleepers is this distribution of loads.
Now these distribution of loads have to be done in the vertical direction and it is also to be done in the lateral direction. There are two types of stabilities which needs to be taken care of one is vertically downward direction another is in the lateral direction and that is what it is speaks of when it sees the longitudinal and lateral stability to the track. Within this one, one thing which needs to be taken care of is that whatever loads are going to be distributed from the top through the ballast cushion to the formation level, the load or the should be such that they are below the load taking capacity or load bearing capacity of the formation level. At the same time whatever material is being used in whatever compacted form it should have good drainage properties. So these are some of the important things which are already being outlined with in the definition of ballast.

Now look at the different functions which are provided by the ballast cushion. The very first thing is that it provides level and hard bed for sleepers. As we see that this is the ballast cushion which is provided the top of the formation levels so its level surface which is being provided. At the top of this level surface then the sleepers are placed and one of the sleepers are placed in position then to maintain their position they are packed from the sides. So that is why they are providing level and hard bed for the sleepers.

Another thing is as soon as the sleepers are packed from the sides, they are hard in position by the ballast. So the ballast is another function is to hold the sleepers in position. then the next function on the important function is to transfer distribute the loads to a wider area. So in this case because wider amount of ballast is being provided in the case of rail section in the case of sleepers the size of the rail section or the sectional area of the rail section or the sectional area of the sleepers is already being defined is much lesser in size or in as compared to the ballast cushion this values are very less. So by using the ballast cushion what we are trying to do is to distribute the load to a wider area so that the formation level or the material which has been used in the formation level can be of inferior nature and still in position to take the loads of the stresses which are coming from the top without and deformation or settlement taking place.

It should be able to provide elasticity and it provides resilience to the track, that is another aspect. What happens in this case is because of the type of the material which is being used and the wide is being placed between those materials there is sort of mutual arrangement of the particle with respect to load and in this form whatever the loads are coming from the top as soon as the load is being removed because of the elasticity the track comes back towards the normal condition and that is how it maintains its level and it is what is resilience of the track is. Further it should be able to provide longitudinal and lateral stability, that is going to be defined in terms of the amount of materials which is being provided and basis of that amount of materials especially the depth of the material of the ballast cushion the stability will be governed. So this is one of the functions of the ballast.

Then it should be able to or it should provide the effective drainage. If the drainage is not there then life of the material which is used in the ballast or the life of the sleepers is going to be affected. So that is why effective drainage is required. Then it should maintain the level and it should also maintain the alignment of the track. Now this is going to be governed with respect to the other components also because the rail is fixed to the sleepers and sleeper is seated in the ballast cushion. Therefore finally it is the ballast cushion which is trying to maintain, which is trying to keep the sleepers in position and when the sleepers are in position the rails also will remain position and that is how the levels of the rails as well as the alignment of the track will be maintained.

So now we come to the next aspect of the ballast, that is, requirements. On the basis of the functions which we have seen that it should be able to transfer the load to much wider area at the same time it should maintain the longitudinal and lateral stability and should provide the drainage to the system. There are certain requirements which need to be taken care. So in the case of the requirements what we are looking at is very first thing is toughness and it should be able to resist the wear. Now here the toughness property which defines the resistance to the impact. We have seen in the previous lecture they are certain conditions where the impact is directly being transferred to the ballast section from the rail track, like in the case of the joints. At another time wherever there is an impact being induced in the rail section because of the oscillation or any other surface irregularity at the top then it is going to be transferred to the ballast section. Now because the ballast section is having a inferior characteristic as compared to materials which have been used in the rail sections, it should able to enough to resist the wear due to all those impacts of the forces which are coming from the top. This is one of the requirements of the ballast.

Another one is the hardness, hardness is another property which defines the abrasive nature of the material. Now in the case of the ballast cushion we are using same type of material in certain depth. So here what is happening is that as soon as the load is being applied the material will be transferring the load from one material to the another one which is being used in this cushion through the point of contact. At this point of contact because of the application of the load there will be a relative movement and due to this relative movement the abrasion of the surfaces may take place. So the resistance to this abrasion is defined as hardness and the ballast should be hard enough so as to resist this type of the action.

Then another one is that it should be cubical or it should have sharp edges. Now in this case the difference here is of the shape is that it is not cubical, it should be cubical, or it should have sharp edges, the reason of the load distribution phenomena or the concept which we are using. Here as we have seen that there is a lot material which is being used as in certain depth and the load is coming from the top. Now as soon as the load gets applied to one particle through the point of contact this load material will get distributed to all those materials, all those say stone which are contacting this particular particle on which the load is being applied. So through this point the load is now distributed to further 4 particles and this keeps on increasing towards the downwards side. Unless until there are sharp edges by which all the materials get inter locked there will not be a

corrosive mass and the load transfer capabilities will not be there. So in this case as soon as we have the material which are sharp edges by which they have a good compact condition is being achieved the load will be distributed to a much wider area as compared to the any other material being used as a ballast. Then it should non porous in nature and it should non water absorbent. It is taking more of the water it is a one sort of an indication of losing their strength; if material takes more water it has the lesser strength, if it is taking less of water then it is having more of strength.

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So this is another requirement of the ballast. It should able to resist attrition. Now when we are talked about the hardness previously where we are talking about the condition where there may be rubbing action which is taking place between the materials and the surfaces of the rail sections at the joint or the surfaces of the sleepers around which these materials have been provided. So in that case it termed as abrasion however there is another phenomenon which is termed as attrition. Attrition is the case where the rubbing is taking place between the same sort of materials that is the material itself like for example is stones. So if large amount of stones is being used as ballast cushion then the mutual rubbing of the stone materials will create a breeze, will create a removal of the material at the top surface of that material and that will termed as attrition and we are not interested in getting the material is eroded from the top surfaces of the ballast because as soon as this material is being eroded from the top surface of the ballast there will be a formation of the dust and this dust will come to the top surface that is finally it will be coming to the rail section and it may create certain corrugation at that section. So this is the harmful effect in the case of the ballast.

Then ballast should be durable enough, the durability is in terms of its resistance to the weathering action. The ballast section in all the railway track condition they are laying in the open, so they are subjected to all the weathering agencies may be the sun heat, may be the wind or may be the pore of the water that is the rainfall. So in all the cases they are certain reasons, they are certain chances by which the life of this material may get

reduced; if they are not durable enough, if they are having the mineral composition which because of certain other mineral which are coming with the water or with the other weather agencies react and they loses its strength then that ballast material is not required. So the material should be durable enough, it should have adequate resistance against weathering agencies and that is what is durability.

Further as we discussed before also it should have a good drainage property. The good drainage property is required to remove the chances of flooding. If there are chances of flooding then it may take the materials along with it or the chances that slowly and slowly the material will lose it strength. In both the cases the track will lose its strength and it is going to be harmful in terms of stability of the track and the chances that there may be any mishappening may take place as soon as the heavy load is starting over such type of sections. Further whatever are the requirements; whatever are the characteristic which are sought for any ballast cushion of the material which is to be used in the ballast cushion. One thing which needs to be maintained is that the material should be cheap and it should be economical and it should not happen that we are trying to get the material from the distance at which it is available and that material is having a very very high strength and then we get it from the there but at that point of time it incurs the transportation cost at a heavy value. So most of the time the material which is available reasonably in that area or locally is to be used as the ballast material and that is how economy and the cheapest of the material can be maintained.

Now once we have the idea of the different type of the functions as well as the requirement of the ballast cushions. Now we will be discussing the types of the ballast which can be used. The first type of the ballast which can be used is the broken stone. In the case of broken stone this is the material which is available from the crushers or from the location where the bigger rock material have been reduced to smaller particles. In most of the cases of Indian railways we are using the broken stone as the ballast cushion. These are procured from hard stone like granite, quartzite, hard trap etc. They are economical long run though they are costly in the initial condition because of the other material which are available which may be the waste materials but this is not a waste material. Here this has different application where these materials can be used, that is why initially this material may have more of value which is to be incurred but as far as the life expand is concerned they have better life expand because of their better properties and therefore if you take the total life span of the ballast material it is going to be more economical as compared to the rest of the type of the material which can be used for the ballast cushion.

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Then another type of material is sand. Sand is the type of the material which is mostly used for CI pot sleepers. As we have seen in the case of the sleepers when we discuss the CI pot sleepers they are the inverted pots. Now in the case of the inverted pots if we are using the stone ballast section then it is very difficult to insert those stone ballast into the pots section whereas if we are using the sand as the ballast cushion then it is very easy to insert the sand or as soon as there is the compaction from the top of the inverted CI pot sleepers the sand by itself will start moving inside and it will lock this pot sleepers in its location. So that is why in the case of the CI pot sleepers it is better to use the sand as compared to the other material. Then in the case of low density areas with the wooden sleepers or with the steel truck sleepers the sand can be used. This is the condition where the traffic intensity is quite less or the loads are lower. In these cases we can go for the wooden sleepers or we can go for these steel truck sleepers and there we can instead of using the heavy material as the ballast cushion we can go for sand material as ballast cushion.

In all these cases coarse sand is generally preferred instead of finer sand which has a tendency to move away with weathering agencies, the coarse sand will remain intact at the same time it will be having the better drainage property. These sands cause excessive wear on rail top on moving parts of the rolling stock which is one of the problems associated with the sand. In the case of sand as we have seen when we discussed about the wear of the rail section too where it was discussed with respect to the position of the wear what we have found is that this sand particle may get attached to the top surface of the rail section and when the rolling stock moves that particular section there is a grinding effect of this material and because of that grinding effect of the materials corrugation may get induced into the rail section. So this is starting of the wearing of rail top surface, at the same it may also create an effect of the similar nature in the moving parts of the rolling a stock. So it is detrimental both for the rolling a stock as well as for the fixed features of the permanent way or the rail way track.

Then another type of the ballast which can be used is blast furnace slag. Now this blast furnace slag or Cinders they are in generally the sort of the waste material which is coming out of the blast furnace. Here the other operations have taken place. So this blast furnace slag or Cinders they can be used in specific location, not on the normal track like yards or sidings. These are the locations where the movement is very low and there is a movement at much slower speed and due to this reason there will not be effect by which these materials will be coming into there will create effect on the top surface of the rail sections. So this is why they are used in the yards sidings now another aspect related to this one is economy. We are trying to reduce the cost of construction of the sections. These are also used as the initial ballast in new constructions, we have discussed these situations. We have discussed the situations with respect to the concrete sleepers and we have also discussed the situation with respect to the long validate rails or the continuous validate rails.

Now in the case of the long validate rails or continuous validate rails because the system has not stabilize so far, so in the new construction cases there are chances of irregularities getting creep in. So in that condition if we are using the good type material as the ballast cushion then it may be sort of a waste or it may be a sort of loss of material as well as the money. So in this case first of all what we do is we use this ballast furnace slag in the new construction and as soon as it is stabilized this is placed by a better quality of the material as the ballast cushion. Obviously, these are available easily and they are quite cheap as compared to the other material but they have the corrosive effect and they are harmful for steel sleepers and at the same time they are also for different fittings which are provided with rail section and sleepers.

Then another type of material which is used as the ballast cushion is moorum. Moorum is used again as the initial ballast in new constructions; it is also used in some locations as a sub-ballast cushion. on this sub-ballast cushion is the condition where we are trying to increase the depth of the ballast cushion but then instead of proving the same good quality of the material from the top to the bottom it is being provided in 2 different layers and the top layer is being provided with the higher quality of the material whereas the sub layer is being provided with the lower quality of material like moorum. So this is how it is used.

Another specific case in the case of the moorum is using as a blanket material on block cotton soil. In large amount of area where the railway tracks have been provided there is the black cotton soil available as the formation level. The problem with the black cotton soil is as soon as it takes the moisture it will swell out whereas if the moisture is removed it will come into a squeezed condition along with this one. There is tendency with respect to the load taking capacity of the material. When it is having a wetness or moisture in it then the load taking capacity of the blanket soil is very very less whereas when there is no moisture in it is totally in dry condition then it has very high load taking capacity. So therefore, if this material is used as the blanket material at the top of it then it will try to remove the water which is going to the black cotton soil by draining towards the side and this is how the black cotton soil can be maintained at the same level as it is there without making any fluctuations in the overall pavement structure. Then there are other types of

the ballast cushions which have been used in the materials, which have been used at the different points of time and they can also be used if available in locally in that area like gravel, river pebbles, kankar ,brick ballast etc. So these are all different types of the ballast material which can be used as a cushion in the railway track structure.

Now we come to the comparison of all these ballast material. The comparison of this ballast material can be made on the basis of various types of properties as we have seen so far. The property may relate to its strength characteristic, may relate to the drainage or may relate to physical property, likewise. One such property which we are going to discuss is drainage property. In the case of drainage property most of the cases whatever material we have already discussed as the type of the ballast cushion material they all have a quite good drainage property available to them and therefore there is no problem of flooding taking place in this type of material. Another respect related to this is the cost at which they are available for construction. In the case of aggregates they are going to costliest one as far as the materials are concerned and that is followed by sand and then rest of the material. We have the moorum mostly have available, as the locally available material where the ballast furnace slag available in those area where the industrial activities are taking place. So it depends on the type of the area, it depends on its distance at which the material is available and that is going to create effect in terms of cost. Then another comparison is that in what way we can use them whether that is can be used as the there is a suitability of using this material as the packing material on the side of the sleepers.

What happens here is as the rolling stock moves at the higher speed, there are all chances of lying of the material along with the speed, along with the moving base and if this happens that is flying of the materials happens the material will start coming out of its locations and slowly and slowly there will be reduction in the material which is being placed on the sides of the sleepers. So there will be loosening effect in terms of the packing of the material on the sides of the sleepers. So, this is one of the biggest problem in the case of those type of materials which are having a lower strength or which are having lesser weight or specific gravity. So in those all conditions as there is a heavy speed of or heavy traction is being used there will be a section in fact by which all these material will start coming up. So this is why it is to be taken into consideration so that there is no reduction in the lateral strength of the track which is imparted by the packing material to the sleepers.

Another point of comparison is wear. This wear can be discussed in terms of 2 aspects; one is the wear to the material itself. This is the case related to the inherent characteristic of the material. As have seen there is a stone, there are moorum, then ballast furnace slag is there, gravels are there then rival fibers are there likewise so many materials are available which can be used. As the loads are coming from the top if the material is of inferior quality then it will start breaking if it is starts breaking then there will be rearrangement of particle and there are all chances that the settlement may also take place. Further if this is the differential phenomenon which is taking place then there are surface irregularities will be caused in the whole of the railway structure or the section.

So, third thing is that if this type of wearing of the material is taking place and it is getting transformed into a smaller material then this smaller material will be sustained by the moving rolling stock at higher rate as compared to the other bigger material which have been provided. Therefore there is a loss of material not only in terms of strength but in the quantity of the material also will be lost along with the section effect. Then another aspect is that as this material further reduces to a finer particle condition, that is, the dust condition then that dust condition will be having its effect on the rail sections and the moving loads are rolling stock which will be moving at the top of the rail section. This again we have discussed previously. Now, this is the wear of the material and then another case is the last which we discussed is the wear of the other material that is the components of the railway track. So both are the things needs to be taken care of if we are trying to provide type of the material in different locations.

Then another aspect is the stability or the resilience property of the track. In all of the conditions the resilience property of the track is available whatever material we are using or all those materials which already being discussed here. As per the stability is concerned the stability is going to be little more in case of those material which have higher resilience property as compared to the other material. In this case obviously the materials like gravel or rival gravel or the stone aggregate, crushed stone aggregates which are used for different locations they have higher value of stability as compared to the other one, but if the compaction of the rest of the materials is also there then they can also provide a good amount of stability. The another point of comparison is the maintenance of track. This maintenance of track is again related with the previous conditions like the wear or the drainage property or the resilience stability aspects. Heavier is material obviously lesser is the maintenance requirements in that one. Then further there are point of comparison are suitability or unsuitability of the material of certain locations where the material can be used for the normal track conditions or they needs to be used for the specific conditions like the yards or the shunting grounds.

We have to look at whether all the materials can be used in all the locations or they cannot be used as we have seen the ballast furnace slag more of the suitability in terms of use in yards or that type of sections. Therefore, they are unsuitable for the normal track conditions. Then what is the effect of the material on the quality of track? that is another aspect. In the case of the material which have the good properties and good drainage conditions and strength characteristic they improve upon the quality of the track but the other materials may have some problem and therefore the quality of the track may not be improved by that amount.

Availability and procurement is the another aspect. Most of the time it is trying to procure the material from the locally available conditions otherwise it is going to add to the transportation cost and overall cost of construction will be increased. So it is always better that the material is available at the place where the construction is going on or within that region. Then harmful effects which we already discussed if it breaks down there is wearing of the thing or there is chemical composition that one which may create its effect then all such things are the harmful effect of the material it may be talked in terms of the corrosion effect or any other material decay due to the mineral composition

and consequence of the mineral or the consequence of the material is being used as a ballast cushion. So these are all the points of comparison of different materials.

Now we look at the sections of the ballast cushion and this one this is the rail section is being shown here and the distance is nothing but the gauge distance between these two rail sections. These rails are being placed at the top of the sleepers and then at the bottom of the sleeper the material is being provided, at the same time a material is provided on the side of the sleeper, like this, or this side of the sleeper, like this. This side of the sleeper where the material is being provided this is termed as ballast shoulders where this depth upto which the ballast cushion is being provided. This material is being provided this is termed as ballast cushion.

Now in the case of this amendment condition this ballast cushion having the slope of one is to point 5 is to 1 whereas this thickness of the ballast cushion where is depending on the type of the gauge is being used. In the case of broad gauge it is 20 to 25 centimeter in depth whereas in the case of metal gauge it is 15 to 20 centimeter in depth and for narrow gauge it is 15 centimeters in depth. Then this is the another thing related to this ballast section is then what should be the minimum depth of this cushion below which the load bearing capacity of the foundation level or load bearing capacity of the formation level may not be in a position to take the loads and it may fail.

Here in this diagram the same thing is being try to depicted, there is the sleeper and this is the point of application of the load which is coming at this sleeper which is generally the point of centre of the sleeper and therefore this is the center to center spacing of the sleepers and this is the clear spacing of the sleepers and the load dispersion is in term of it is assumed that it makes an angle of 45 degree with the vertical. So therefore from the edge of the sleeper this is the width of the sleeper, from this edge of the sleeper the load will get distributed in this form at angle of 45 degree from this side whereas it will get distributed at an angle of 45 degree in this side like this. The similar is the condition which will be happening from the other sleepers side and so we have this envelope wear. This is the load distribution area of this sleeper in this case whereas the load distribution area of this sleeper in this case and there is no overlapping of these load distribution area. So the point of contact of this distribution up to this point this is termed as the depth. So this is the depth of the ballast cushion which is to be found out.

Now the same thing is being shown here. This minimum depth of the ballast section can be found out as half of difference between the sleeper spacing and the width of the sleeper. So this is the sleeper spacing is being taken as the center to center sleeper spacing and this is the width of the sleeper. So, if we just take the difference between these two values and make half of that that is going to be the minimum depth of the ballast section which has to be provided. The same condition is being shown in this one where the load is also being shown here and here this is the connectivity of this sleeper with the rail section so the load taking capacity of disconnectivity is also into consideration. Now when we are talking about this minimum depth of the ballast cushion and there is dispersal at 45 degree. So this distances db at the same time the distance between this point and this point also becomes db and same is the condition from the

other side. Therefore the distance between this point and this point is nothing but it is twice of db. So we have this twice of db, this is the total distance at this level and then we have the width of the sleepers as w on this side and the width of the sleeper as w on the other side. So what we are trying to see is that in this condition we look at this one this is 2 db plus this is half of the w which will be taken into consideration as far as the sleeper spacing is concerned this is half of the w which will be taken in this side. So the total distance has the sleeper spacing is nothing but 2 db plus w. so using this equation of s equals to 2 db plus w we have found out that value it is s minus w and half of that is the minimum depth which is to be provided. So that is the concept of profaning on the minimum depth of the ballast section on the basis of the load distribution criteria of the loads which are coming from the top, that is, from the rail sections to the bottom of the sleepers which is also termed as the bottom of the tie bar .

This is another diagram where the stresses in the ballast section have been shown. Though we have discussed previously but it belongs to the ballast cushion condition. We are looking at the same aspect here again. Here what is being shown is that this rail section and these are the sleepers which have been provided therefore there is the transfer of the load P through this rail section to this sleeper and finally to the ballast cushion which is being provided at the bottom and this sleeper is having width as this one and there is a length in this direction, that is, just transfer to this distance and this is the bottom of the sleeper which is also termed as the bottom of tie because the sleepers are also termed as the tie in the western European conditions or in the American condition. This is another word which is being used for the sleepers.

So here we have different conditions which are happenings. We have the pressure at the bottom of the tie, that is, at this level whatever the loads are coming from this one, so how it translates into the pressure at this level, this is one thing. Another thing is as we go down then how this pressure is behaving whether it is reducing then at what way it is reducing, so this is what is Pz, the pressure at depth z and another condition is that if you go away from the point of application the extension of the point of application of this load P in the transverse direction, that is, by the this direction, this direction then what is the behavior of this stress and this is being termed as Px which is the pressure at distance x from depth z. This one, along the point of application of the load P.

So we can find out these different values. The pressure at the bottom of the tie or the sleeper is given by Pa is equal to the load divided by the bearing area. Now the bearing area is going to be the bearing area of the bottom of the tie, the bottom of the tie having the width as w and length as l. Now because there are two rail sections which have been provided we assume that one rail section will be having its effect only up to half of the rail length, half of the length of the sleeper.

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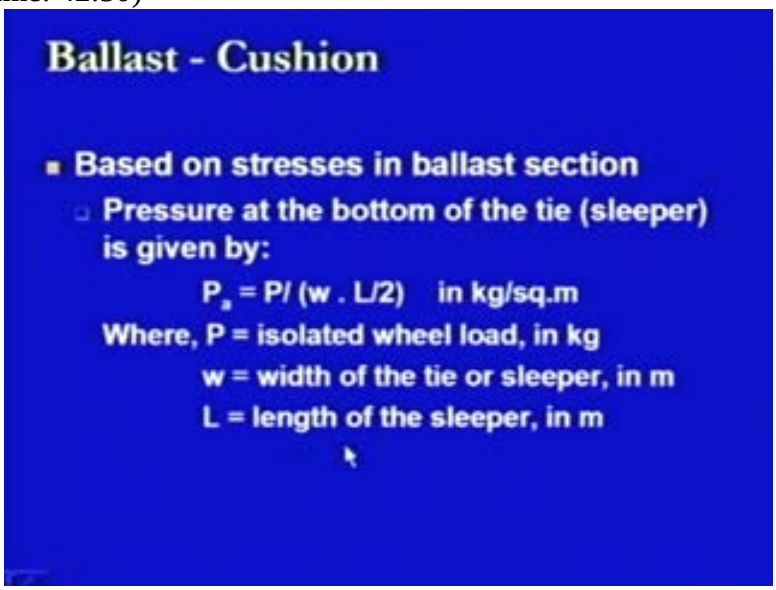

Therefore, the sectional area on which the p will be acting as w into l by 2. So this is what is Pa. So here this P is isolated wheel load in whatever units you are taking in kg, w is the width of the sleeper in meters and l is the length of the sleeper in meters. Then there is another condition, the pressure at the depth z in centimeter below the center of the tie width and this is computed as Pz is equal to 5.24 multiplied with Pa which is being calculated previously as P divided w into l by 2 and this value totally of divided by a value of z is raised to be 1.25. Now here z is the depth in centimeters as we have seen in the diagram too whereas the pressure at distance x in centimeter at depth z is given by Px equal to 0.48 pa divided by z and this is multiplied with ten raised to the power minus 2.06 multiplied by square of x divided by z where z is again depth in centimeter and x is the distance from the depth z in centimeters. Pa is the same value as we have found out previously; p divided by w into l by 2.

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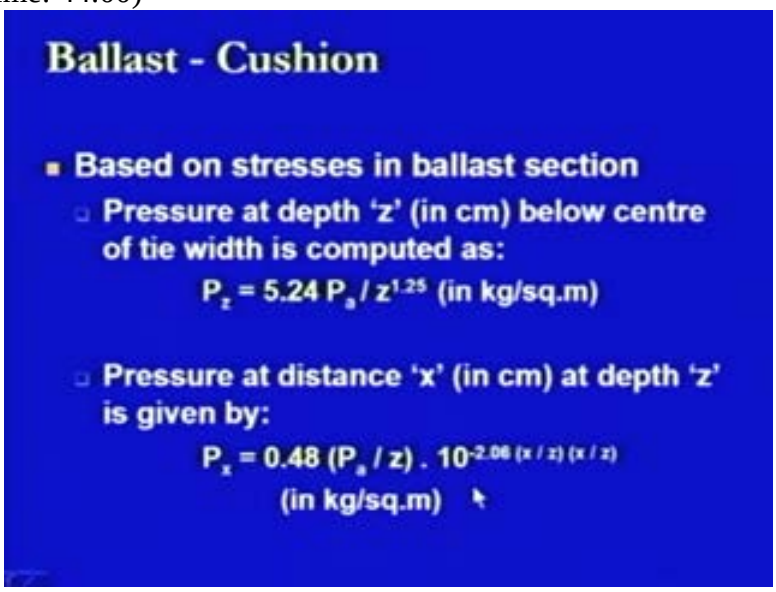

Now we come to the specifications of the ballast. The specification of the ballast related to different aspects: the first one is the quality. The ballast should be hard and durable, we have already seen that this is one of the important property. It should not wear out because of any physical reason and not because of the weathering reason. So both of the things can be taken into considerations as per as the quality is concerned. It should be free from inorganic and organic residues, inferior and harmful substances. This is another important thing which has its effect on the life span of the material as well as the life span of other component which have been used along with the ballast material. So if it is inorganic in nature or organic residues and there are other some harmful substances are there they will react with the material of the ballast, they will react with the material of the other component and this is how they will create an effect on life span of all these things.

Then another aspect is the top width top width varies between 3350 mm to 1850 mm depending on the gauge which we are using, that is, whether we are moving from broad gauge to the narrow gauge. The depth of cushion we have already seen when we have also seen the specification of the permanent way on Indian railways. We have also being discussing this aspect again and again. This is depth of cushion in the case of broad gauge or the meter gauge is defined on the basis of the classification of route under that category. So in the case of broad gauge we have seen there is a classification as A, B, C,D and E whereas in the case of the meter gauge the classification was Q, R1, R2 and S type of routes.

So in the case of A and Q this depth of cushion is 300 mm as minimum in the case of B, C and R1 roots it is 250 mm and in the case of D and R2 it is 200 mm for E and S roots it is 150 mm. In the case of narrow gauge the depth of cushion is 150 mm as minimum.

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Then another aspect is related to the physical properties of the ballast cushion. Physical properties are related to the wearing aspects of the material. In this case there is one test which is conducted to check of abrasive quality of the material, that is, reducing into the fine powder form due to the rubbing action of one other type of material. This is found out by conducting the abrasion test. This abrasion test value at the maximum can be 30 percent and in some cases this permission taken from the authorities can be relaxed to 35 percent. This 30 percent or 35 percent defines this is the amount by which the material can be reduced to the powder form and this is the maximum value by which it can be done.

The another property related to the physical properties is impact value. Impact value is related to the resistance with respect to the impact or the jox which are coming because of which the bearing of the surface may take place. So in this case the maximum value can be 20 percent and again this can be relaxed to the value of 25 percent. Then another property is elongation and flakiness index. Elongation and flakiness index tries to define the quantity of the material which is quite long as compared to; it is related to the 3 dimensions of the material, that is, length, width and thickness. If the length is much more as compared to the thickness than the width then it is termed as elongated material whereas the thickness is very very less as compared to the length or the width of the material then it is termed as flakiness material. In this case the combined value of this one of the different value of this one that is taken separately it can be at the maximum 50 percent each. Specific gravity at minimum level can be 2.65. It is one of the indirect measure of the strength, more of the specific gravity more is stronger is the particle. Water absorption at the maximum is 1 percent. It should be not more than this one.

Then the next aspect related to ballast is size and gradation. The size is designated as 50 mm size for the ballast and there are 3 sieves which are use for examining this 65 mm sieve, 40 mm sieve and 20 mm sieve. In the case of 65 mm sieves or retained on 65 mm

sieve is desired is nil and at maximum it is 5 percent. Then retain on 40 mm, they should vary between 40 percent and 60 percent and retained on 20 mm it should not be less than 98 percent of the material which is machine crushed whereas in case the material is hand broken then it should not be less than 95 percent. So this is the specification of the ballast. There is another specification related to the oversize of the ballast, it has to be rejected more than 10 percent of the ballast remains on 65 mm sieve.

Similarly, in case the retention on 40 mm sieve exceeds 70 percent then also it has to be rejected. In between those values, values being permitted on these values, if the values goes, if there is sort of penalty which is to be imposed by the Indian railways. Then in the case of 20 mm sieve it is 2 percent in machine crushed condition, 5 percent in manually crushed condition permitted for passing on 20 mm sieve. Then another cases related to gradation is the undersize as we have seen in the case of the oversize the material should not be smaller in size. Here if it is to be rejected the retention on 40 mm sieve is less than 40 percent or it is to be rejected on a 20 mm sieve is less than 98 percent for machine crushed ballast or 95 percent for hand broken ballast.

Now we come to some of the specific aspects of the ballast, some definitions that is packing. Packing is the compacted ballast cushion which is laid below the sleepers as per the gradation where there is the boxing; boxing is relatively loose ballast which is placed on the side of the sleepers to provide them lateral stability. This is 2 types of the conditions which are there; one is the material which is being packed and another material which is boxed between the two sleepers, which are placed side by side from the top, it is being defined by the layer of level of rail section. Then another aspect related to the ballast is screening. Screening of the ballast is procedure of renewing the ballast section which has degraded. What happens is along with time as the ballast is being used for longer period of time at any locations as the loads are keep on coming from the top or there is the wandering agencies which have role to play in the degradation of that material. This material keeps on reducing in size or it keeps on losing its strength. So in those conditions as level comes we have most of the material got degraded then it is better to renew the ballast section so that the strength or stability of the section can be further improved and bring back to the level at which it was there previously.

Now there are certain regions due to which ballast section get degraded. They are like the crushed material clogs, the voids causing the drainage problem, this is one aspect because there is continuous hammering action coming from the top. The material gets reduced to the smaller size and slowly and slowly it happens that the voids get lost because of the smaller particle and then voids are got clog then the water cannot be drained out. So this is the thing which is happening and there is the saturation, there is the flooding of the water or the stagnation of the water or the pounding of the water on the side then we have to go for renewal. The penetration of the ballast in the formation is another reason. Here is happens is that the loads are so heavy so type of the ballast which is being used is such or it is of smaller size that it is reduced to the smaller size due to which now slowly and slowly it starts getting sinking into the formation level and when this is happening then this penetration happens then surface regularities will induce in the track. Therefore, it is important to screen out this type of ballast.

Then another aspect is the blowing away of the ballast, that is, ballast has gone blown away or it is the section effect of the rolling stock which is moving at the top of the rail section. This is again we have discussed. So in all these conditions we have to go for the screening of the material. So the material is taken from that location and it is screened in this form. So this is the screen which is placed the material is being taken from the location and then it is rolled over this screen and the finer particles are coming to this side, they are got this screen or received like this way and they are removed. Whatever material is being made here this is the retained material is to be used as the ballast will be taken back and delayed. So this is what is the screening process in this case.

So this all about the ballast. What we have discussed today is the functions of the requirements of ballast, the different type of the ballast materials which can be used for providing the cushion so that the load can be distributed to a wider area and then we have discussed about their specification and requirements and finally some of the definitions. In another lectures we will be taking up further other aspects related to geometrics of the permanent way. We have already covered all of the components of the permanent way. One component which is being left is the fastenings which also we will be taking in the subsequent lectures. We stop at this point and I say good bye to you.

Thank you.