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Lecture - 6 Stresses in Component of Track

Dear students, today we are again starting with the next lecture on the lecture series on transportation engineering two course material. In the last two lectures we have been discussing about the stresses. The stresses in the different forms caused due to different reasons or different types of the loads in different sections. In continuation of the same, today we are going to discuss about the stresses in the different components of any track. Now when you talk about the any component of any track then we will be talking about the stresses in rails, we will be talking about stresses in sleepers. The next will be stresses in the ballast cushion cover that is provided below the sleepers and then finally the stresses in formation level that is the lower most level which will sustains or supports all the three things which are being listed before.

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So we will be taking up one by one all the components and we will try to see what type of stresses are induced in these and then what are the effect of those stresses in the design aspects of these components; that is rails, sleepers, ballast or sub-grade layer or the formation.

Now we will be starting with the stresses in rails. In the case of stresses in rails, very first thing is that there are number of sleepers which are provided below every rail length and this is as being defined previously also when we have discussed about the specification of any permanent way is being defined as sleeper density and it is being observed that there is a little effect of this sleeper density on the stresses in rails. So whatever the stresses are going to be caused, they are going to be caused because of the loads which are applied from the top.

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Now the point of application of that load on the rail is the area where the stresses are going to be induced and this is reason why the sleeper density or the number of sleepers which have been provided below the rail section will be creating a little amount of effect as compared to the rest of the factors. Now another thing is that there are certain times or there are conditions where in the eccentric loads are caused. Now these eccentric loads may be eccentric vertical loads which are coming from the top and as soon as there is an eccentric loading condition, that is, it is not passing through the sez of the section then there will obviously be a bending moment which will get created.

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Now because of this bending moment condition and because of the fixtures which have being provided with the rail section where in this rail section is being fixed to the sleepers using all those fastening where all chances that a torsion of a beam condition may also get created. So this is another aspect which is of caution and which needs to be taken into consideration because now as soon as the torsion of the beam is going to be there, it is going to be induced, then not only the rails are going to be affected but the things by which they are being supported or by which they have been fixed to the supporting system will also get affected. So that is why, this is another type of a stress which has to be taken care of while designing the sections.

Then in continuation of instead of the vertical load, another type of load condition which we have seen in the previous cases is the horizontal load condition. Now in this case where we are talking about the railway track, this is horizontal load condition, may be in the longitudinal direction or in the lateral direction. This is again being discussed in the previous lectures and their effects were also been examined in terms of the resistances being caused or in terms of type of the stresses or their effects being caused.

Now here when you are talking about the lateral thrust, this lateral thrust is most of the time produced at the head of the rail sections because this is the point where there is a interaction of the wheel flange with the head of the rail, because of the lateral movement of that wheel flange due to the actual shifting in the lateral direction, what happens is that it produces certain amount of lateral deflection at the rail head and as the rail foot is being fixed at the bottom to the sleeper there is again a tendency or there is again a reason due to which the twisting of the rail may also get paused. So in this case also there are two aspects which are going to be initiated or stimulated together, that is, the lateral deflection and the twisting of the rail. So we have to look at what is the total amount of lateral thrust which is going to come and on the basis of that amount of lateral thrust we have to design the fastening. If the fastenings are not having the sufficient a load bearing capacity, sufficient capacity to take up their stresses which are being induced by these type of

action than they will come out and as soon as they will come out then there are all chances of failure of the track in terms of the derailments. So that is why, this is another important aspect which we have to take into consideration.

Now the lateral deflection may also be caused due to the lateral movement of sleepers on either side. This is another case where the sleepers which have been provided at the bottom, they have not been placed in such a way that they remain in place whatever the type of the load comes up. If there is any movement of the sleepers, then also, because of that movement of sleepers, the lateral deflection may get caused. Now this is the case where there is a problem of the packing of the material around the sleepers because of which they have the flexibility or the tendency to move in the lateral direction. Now another case is that the amount of total load which is coming in the lateral direction is so heavy that it causes this type of a movement. Though in most of the cases what we found is that this is not the general case due to which the lateral deflections will be caused.

Then the next thing is the contact shear stress. Now this contact shear stress as we have seen in one of the slides previously where there has been an interaction being shown in the terms of cylindrical movements of the wheel on the cylindrical keys of a rail. Now when this type of a contact is there then that is what may cause a certain amount of shear stresses because of the repeated load conditions and when the repeated load conditions are there then there all chances that it may cause some type of wear or tearing of the surfaces.

Now this wear or tearing of the surfaces may be on the surface of the rail head, or on the surface of the side of the rail head, or it may be on the flanges of the wheel, or finally when this type of behavior keeps on going on then this may culminate into the fatigue condition. Now as soon as the fatigue condition is reached then this is the condition after which this whole of the system or whole of the rail section is going to just fail and it means this is a point where the total replacement of the system needs to be done. So it is a very costly condition and therefore it is to be seen that as soon as such sort of a thing is getting initiated because of any of the reason then we have to take care of that and it should be removed as soon as or it should be taken care of illuminated or emidied as soon as soon they have started taking place. So these are some of the things.

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Apart from these then there is another condition where the high stresses occur in lower fillets on sharp curves. Now as we have seen again when we have discussed about the coning of the wheels, there is a condition where there is a sharp curve or there is any curve which being provided on which the train or the wagon or the locomotive is moving and due to the rigidity of the wheel base by which the 2 axles have been combined together there is sort of a relative movement between the trailing axle and the feasting axle. Now, when this type of movement is there then there are chances that the stresses will get induced in the lower fillets where the things have been supported or they have been fixed in place, that is, again it comes to the same condition where the fastenings have been provided so as to fix the rail sections with the sleepers. So this is the place where we have to look at the what are the types of the stresses which are getting induced on the inner rail section or on the outer rail section and then on the basis of that the lower fillets needs to be designed or the fastenings needs to be designed. They should be able to take up the stresses so that they are not failing at that level.

Then, another important thing which is being already discussed is the temperature variations. Now as been told to you that any track which is being placed, this is placed at a certain temperature. Now this temperature if it is going below this temperature or going above this temperature then it is going to create an effect in terms of either the contractions or the expansions depending on the variation of the temperature. Now as soon as this type of variation is there then it is going to create certain the tensile stresses or the compressive stresses in the system plus when you talk about the system it means we are having the rails which are being fastened with the sleepers. So the temperature have a tendency to move the rails, it may be in the longitudinally forward direction or it may be in the longitudinally backward direction and that is the reason by which the different alterations of tensile or compressive stresses will keep on coming up.

Now wherever there is an alteration of the stresses which are being induced in any of the system, then this is another important area which creates a fatigue condition. So reversal

of stresses always related to fatigue condition and that is why we have to look at this aspect that what is the minimum and maximum temperature which can be there in that area where the section has been laid and on the basis of that, what are chances of the temperature stresses getting induced. What is going to be the magnitude of that temperature stress which is going to be induced and then finally we have to find out the amount of movement which can be there. So looking at this aspect we can see that there is sort of a movement which will be taking place in the rail section and we will be looking at this type of a movement when we talk about the rail section further.

In the next point which is also another important point which causes stresses in rail is related to the tractive effort. There is a train, or the wagon, or the locomotive which is just in a stationary condition is standing on a track and as soon as the tractive effort is applied to that then this tractive effort will be working in the backward direction, and when this tractive effort is working in the backward direction the whole of the force, the horizontal component of that force will also act longitudinally in the backward direction. This is the reason why there is a sort of a movement which will be taking place in the rail and there are stresses which will be used because of this tractive effort.

The similar is the case when you talk about the breaking of the vehicle. When you talk about breaking of the vehicle, the breaking force will also result in certain amount of stresses. Now because of the speed and because of the interaction of the metals because as we have seen there is a wheel which is of again a steel like condition and there is rail section which is also of steel. Then these metals as they come into contact with each other and there is high speed at which this rubbing action keeps going on. Then the total amount of energy which is getting dissipated at this point of application is very heavy. You can see that sort of the fumes coming out at this point and because of this reason the flow of metal takes place.

The flow of metal means whatever is the metal which is being provided at the top surface of the rail section gets heated to such a level that it starts melting in a sort of a way and this is what is known as the flow of metal, the section starts reducing and in a sense then when as soon as there is a this type of a flow of a metal which is taking place, obviously, it is going to create deformation at the rail head. So that is another important thing because as soon as the deformation of the rail head will be there it will create surface irregularities and when it is creating surface irregularities then the different type of stresses which are being induced or resistances which will be induced because of surface irregularities will also come into consideration. So we have to look at this aspect. The effect is higher with small diameter wheels because of the continuous rubbing action, because of the point which has got heated. if the diameter is less that point comes in repetitive form again and again before it gets cooled off and due to that reason the amount of energy, dissipation of energy will remain at a higher level for through out the time period and obviously when this is happening more of the flow of the metal or deformation of the rail head will take place.

The track irregularities is another case which causes heavy impact and which also causes deflection. Now in the case of track irregularities, this track irregularity may be because

of the laying of the track that is the component of the track in terms of the formation level or in terms of the ballast cushion which is being provided. If that irregularity is coming from those cases then it is very difficult to rectify them in the later cases. It is to be done. We have to take out whole of the track, rectify it and then relay it but if it is a case where the level difference is being caused because of the placement of the sleepers and the rails then probably we can do something without removing the whole of the system and that is how this type of track irregularity can be removed, and if this track irregularity is removed then the cases of impact of deflection can also be reduced.

The one point which we can discuss or which we can take as an example at this point is that we can think of a joint of the rail sections. Now the joint of the rail section is provided with the help of fish plates and the bolts. If due to any of the reason the two rail sections have been provided at two different levels then that is what is again a track irregularity, and if the train or the wheel is coming from one level and it strikes the another rail which is at a higher level then obviously this is going to create an impact, and because of the repeated sort of an impact which will be happening at this level what we found is that the shocks are going to the vehicle. That means finally they are going to be transferred to the passengers or to the freight which is being transported.

At the same time because of this sort of an impact condition created it will start deflecting downwards. So that is the case which is to be taken into consideration when we are discussing about the stresses in rails. Then as we have discussed about the stresses due to the vertical loads, in this case because of the eccentricity of the vertical loads we have seen that it may create bending stress. Now when this bending stress is being caused where certain assumptions which have been taken up; one assumption is that the rail is assumed to be a long bar and then it is continuously supported by an elastic foundation.

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Now why we say it is an elastic foundation is that whatever load is coming from the top is obviously going to create some sort of a deflection in the system. Now when there is a deflection in the system then this will go down by some amount, but as soon as the load is being removed it comes back towards normal condition and that is where the elastic foundation, condition or assumption remains valid. So this is one thing and second thing is that the rail is considered as a long bar. We can say it is a sort of a bar being supported by a system and as soon as this is a bar then this becomes a more or less a rigid condition with the chances of having some deflection at the point of application of the load.

Now on account of the vertical load what will happen is that the rail will be subjecting to certain amount of deflection and along with that it may be subjected to some bending or flexural stresses. Flexural stresses means that with whatever the material is there of that rail section it will be able to sustain the stresses or the loads up to some value and that is where the ultimate tensile strength of the rail section comes into picture. We have seen that the rail sections have 2 ultimate tensile strength conditions on a 72 kg per mm square or 90 kg per mm square ultimate tensile strength sections, and this is case related to the flexural stresses and related to the conditions being created because of vertical loads.

Now based on this elastic theory what we can do is that we can compute the value of the bending moment and this value of bending moment can be computed in the form of M equals to 0.25 p into l into e raise to power minus x divided by l and this multiplied with sine of x divided by l minus cos of x divided by l, where this is total taken into 1 parenthesis and it is multiplied with the rest of the values.

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In this case, 'M' is nothing but the bending moment which is being induced to the vertical loads placed at any point on the rail section; 'e' is the isolated vertical load which is being applied through the wheels, obviously, and 'x' is the distance of the point under consideration from the load. So if we have a point of application of any load on the rail section then if we are interested to find out the bending stress x or distance x then we will be computing the value of this bending moment at that distance x and this is how it is taken. 'I' is defined as the characteristic length and this characteristic length is given by

another formula, that is, it is the fourth root of 4 e i divided by mew. Now here this is i, it is not 1 and this e i combinely is defined as flexural stiffness of the rail where e is the modulus of elasticity and i is the moment of inertia of that rail section. So combining together, this defines the flexural stiffness of the rail section and mew is the track modulus as we have seen previously, how the computed track modulus on the basis of spacing of the sleepers and on the basis of number of the sleepers, or on the basis of the deflection which have been caused on the different number of sleepers which are being provided on any rail section.

So once we have the value of track modulus, once we have computed the flexural stiffness of the rail section then we can compute the characteristic length of that section. Once this characteristic length is of being computed then for any distance x we can compute the value of the bending moment using the equation as just given here. Now this is a diagram which is trying to show the variation in the bending moment with respect to the application of the load on the rail section. Now this dotted line can be assumed as a rail length or the rail bar and this is the point of application at which the load is being applied. Now when the load is applied at this location, then it is going to create a bending moment at this position which will be equals to p into l divided by 4.

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Now with this bending moment the variation is in the form, that if it is assumed by the sine notation as negative on this side then after certain point which is termed as the point of contra flexure will be changing its sign and it will change its sign and it say it will become positive on this side and it will attain a maximum value at some distance and again come back and will become 0 along this length of the track. So that is how the effect of bending stress will be seen and we have seen this effect of bending stress in terms of the single wheel condition and the multi wheel condition previously in the previous lecture also, that is how the relief of stress being get induced because of this overlapping of the bending stress diagrams being induced due to different wheel conditions.

Now, in all these conditions where bending moment is being induced at different locations, then the bending stress can be computed as the bending moment at the section divided by sectional modulus of the rail. Now, another thing is that as we have seen that there is point of contra flexure at which the bending moment is becoming 0. So there are certain points at which the bending moment will be 0 like it will be pi 1 by 4 or 3 pi 1 by 4 and similarly it is going to be maximum at some distance like it is going to be maximum at x equals to 0 where the x is being taken with respect to this point, that is the point at which the load is being applied. So if you go in this direction, this is x distance. So this is x distance in this direction so when x is zero, we are getting the maximum value of the bending moment similarly when x is going to be equal to pi 1 by 2 then again it is of maximum value which will be attained and likewise we will be having different locations where because of different positions of these wheels we will be getting the maximum of bending moments. There is another way by which this bending moment can be computed, in this equation we are taking 2 factors; one is the isolated wheel load in tones and there is another factor that is x which is distance from the load to the point of contra flexure. Now this distance from the load to the point of contra flexure, that is x again needs to be calculated and it can be calculated using this equation 42.3 with the fourth root of e i divided by mew.

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Using this equation there again we have e i as the flexure strength and mew is the subgrade modulus in this case. So using this value of sub-grade modulus and the e i the flexure strength of the rail section we can compute the value of x and this will be defining at what point the contra flexure will be attained and when we use this value in this equation that is M maximum equals to 0.318 W multiplied with x then that is going to give you the maximum bending moment. That is another way of finding out the value of the bending moment. Here the value of i is a moment of inertia of the rail section in centimeter 4, we have to look at the units what units we are looking at. So here the bending moment is being given in tones centimeters. Now in this case the bending stress can be computed as f is equals to the maximum value of bending moment which we have just seen divided by the sectional modulus that is Z. So if you had again on the basis of the units which we have taken it may be kg per centimeter square, it may be in tones per centimeter square. So we have to modify the units accordingly or if we put the value of this M maximum then it may transform into 13.8 multiplied with W that is the isolated load divided by the sectional modulus Z multiplied with the fourth root of e i divided by mew.

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So this f, that is the stress, is due to the bending moment immediately under the load W tons, in tons per centimeter square and it has a permissible value of 22 to 25 tons per square inch. So that is another unit. We will be looking at the SI units at the later stages where all of the specifications related to the stresses have been summarized and being noted down. Then, this is one aspect that stresses have been induced. But not only the stresses there are other conditions, that is, deflections may also gets induced because of the loading. Now when the deflections are being induced because of the loading then we have to look at the total amount of deflection which will get induced.

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Deflect	tion due to vertical load can be
compu	ted as:
	d = 9.25 W/[lµ ³] ^{1/4} (in cm)
Where	d = deflection of track in cm
	W = Isolated wheel load in ton
	μ = Modulus of track in kg/cm ²
	I = Moment of inertia of rail section
	in cm ⁴

If the deflection is more than the permissible value of the deflections then it may cause the failure of the system. Therefore, this value is to be calculated. Now in this case the value can be calculated as the deflection d of the track is equals to 9.25 multiplied with W, where W is the isolated wheel load and this is divided by the fourth root of a I multiplied by the cube of mew, that is I is the moment of inertia of the rail section and mew is the modulus of track in kg per centimeter square. So we are taking the cube of this one multiplying it with this I value and then taking the fourth root of this one and finding out the value of d. Again in this case depending on the units we will be getting the value of the d here. The value of the d we are getting is in centimeters. So we have to look at the stresses and we have to look at the deflections which have been caused because of all these vertical load conditions.

Now this is one diagram which is to be used where we have to find out the reduction factors. The reason behind the finding out this reduction factor is that there is a condition of instead of a single load the multiple load conditions.

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As we can see in a wagon there will be number of axles being provided on the basis of the length of the wagons. In this case what we have to do is that we have to look at the relief of the stresses. Similarly we have to look at the relief of the deflection. Now if you take any rail section and then there is some load which being applied at this point and there is some stress being induced at this point and there is another wheel at this location and again there is some load being induced at this one and there is a deflection being induced at this point as we have seen because of the overlapping of the bending moment diagram or because of the overlapping similarly of the deflection diagram there will be a relief.

So we have to look at by what amount this relief can be there because of the another load which is working in the adjacent condition. Similarly, we can also find out the amount of deflection which is going to be relieved off because of the application of another load or because of the application of another load whether it is going to be increased up. So in that sense what we have to do is we have to look at these diagrams. In these diagrams at the bottom we are provided with the diagram where the distance of the wheel is being shown at the x location and this distance is the distance between the two wheels and this is given in centimeters starting from 0 to 300 centimeters. So that is amount of the distance in centimeters between two wheel conditions and then on the x axis we are taking the distance from the point of contra flexure. So we are taking this value from the point of contra flexure again in centimeters and this value is varying from 50 to 100 and for all these conditions we have the curves which are going in this direction. This is the direction of the curves being provided for multi conditions, in this one, that is not clearly visible but this is the shape of the curve which will be there where multiple curve which is provided in all this area.

Now what we have to do is to find out this distance from the point of contra flexure on the basis of the value as we have seen previously while computing the bending stresses or the bending moment where the x is being computed. As soon as we computed the value of that x, so if we have to find out this value of distance from the point of contra flexure in centimeters, what we have to do is we will be going back and this is the value of x the distance from the load to the point of contra flexure which is computed as 42.3 multiplied with the fourth root of e i divided by mew.

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So once we have the value of e, that is the modulus of elasticity, i the moment of inertia of the rail section mew the sub grade modulus, then we can compute this value and then as soon as we have this value available to us we can count for that value say if this value comes out to be something like here as 95 and then there is a distance of the wheel is say is being taken as 175, so this is 150, this is 200, so this is 175. So starting from this one 75 we will follow the curve which is provided like this. So this is the curve which is being provided. So we will go along this curve and we will look at the value that is where the 95 is coming. we stop at this point on this curve and from here we will be going vertically upwards and as we go vertically upwards we will be having these two curves; one curve is moving like this another curve is moving like this.

Now this curve is related to the reduction factor curve for the bending moment where as this curve is related to the reduction factor curve for deflection. So if you are interested to find out the reduction factor for bending moment, we will be coming to this value and what we found is that this reduction factor which is being given on this side is 0 here. It is negative on this side and then it is positive on this side. So we will be taking that value in the basis of where ever we are cutting this curve. So, if we are cutting this curve here means it is equals to minus 0.2. So by this amount the bending moment will get reduced. Similarly, if we take the same value and we come to that top of this curve, that is, the curve for deflection and then what we found is that the deflection will be getting increased by the value of something around point 25 or so. So this is the amount of deflection will be increasing whereas in the case of the curve for the bending moment it has both the conditions as such here. It is coming down and it is coming back

again. So this is how we can compute the value of reduction factor and this is what is the relief of the stress will be there.

Now we come to the stresses in sleepers, that is another component. The various factors which are causing the stress in sleepers are dead and moving loads, and these dead and moving loads may be either loads which are coming through the wheels, the weight transfer from one wheel to the another wheel, the effects of speed on the rail and the dynamic augment of all the these factors.

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So on the basis of this value what we have to look at is that what type of stresses are going to be induced, whether the stresses are going to be increased because of the change of the load from one wheel to another wheel or whether they are going to increase because of increase in the speed.

Now another thing is related to the track component. Now when you are talking about the track the one same factor which comes into consideration is track modulus which again and again we have been discussing. This track modulus will create its effect in terms of the total amount of stresses which may get induced in the sleepers. Then, the elasticity of the rail and its stiffness. If the rails are quite stiff then they are obviously going to transfer a little lesser amount of deflection as far as the stresses which are induced in rail sections, whereas if otherwise, then there will be more of the deflection at the sleeper level.

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Then the design and the strength of sleeper, this is another important aspect. Whether the sleeper is heavier in nature, what is the size of the sleeper, the loads which are coming at the sleeper whether it is in a position to dissipate those loads or to distribute those loads to a wider area at the bottom, then that sleeper is fine.

The sleeper density, now in the cases of number of sleepers which are being provided the sleeper density has its role. Though as we have seen, we have learned that sleeper density has a smaller role in the case of the stresses being induced in rails. Here, if the sleeper density is more it means the stress coming from the rail sections are going to be distributed to more of the sleepers and therefore the amount of stress induced in the sleeper will be lesser and then what are the type of the fastening which are being used between rails and sleepers and how efficient they are in transferring the load from the rails to the sleepers. Now at this point, the another aspect comes from related to fastening is that their load bearing capacity; the total amount of load which they can take or sustain without breaking and that is where the total amount of load which they will be transferred from one system to the another system will be defined.

Then further the factors which are inducing the stresses in sleepers relates to maintenance. The maintenance can be of any of the thing may be components which are being provided in the track or the track overall like there can be an irregularity in the rails.

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As this is as we have discussed previously during this lecture only as taken an example of joint where there are two rails being jointed but the level of the top surface of the rail head is not seen that is at a different level. So if that type of irregularity is there then it is going to create some effect. Then what is the maintenance of those rail sections? Their connectivities? Their fixing with the sleepers?

The maintenance of wheels of coaches is another important aspect. If they have some irregularity or they have not being maintained then there are going to be more stresses being induced in the sleepers and effectiveness of supervision of ensuring good maintenance, that is, if we are maintaining all the things, all the components periodically then obviously there are chances of inducing or there are at least chances of reducing some of their stresses. Now once whatever are the load which are coming to the sleepers are taken into consideration the main thing here is that how those loads are going to be distributed. Now, in this case what is happening is that there is an alteration in the ballast reaction under the sleepers and due to that the pattern of the distribution of stresses may get modified. So, if the ballast reaction is changing because of the type of the ballast which is being used then that is one point which needs to be considered.

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Stresses in Sleepers

- Distribution of stresses in sleepers
 - Due to alteration in ballast reaction under sleepers the pattern of distribution of stresses gets modified.
 - The wave motion of rail causes movement of load on the rail seat from one edge of the sleeper to the other and makes its distribution non-uniform.

Now another thing is the wave motion of rail. This wave motion of rail as I had discussed previously again taking an example, say there is a breaking condition or there is a standard still condition of any wagon and then with effective effort this wagon starts moving. Now what happens is that there is a force which will be applied in the backward direction and due to that reaction of this force the vehicle will be moving in the forward direction. So there is movement of the rail section. Now here this wave motion of the rail is in the form of the rail which is moving just ahead of the wheel. Obviously, what happens in this case is that as soon as there is a load being applied on the wheel there will be deformation or deflection at that point so the rail will go down but the rail in the front side is not going down. It is at an upper level and as soon as the wheel moves in forward direction this sort of thing will start moving in the forward direction. That is why it is termed as a wave action. So if this wave action is happening this will cause some effect on the rail seat because at the rail seat the rail is being jointed to the sleeper and the sleeper will try along with fastenings to resist this type of movement and when it is trying to resist this type of movement then obviously the stresses will get induced in that and another thing is the distribution will also become non-uniform because of this type of movement.

Now here in this case, we are looking at the distribution of stresses and there are two types of distribution of stresses which can be there and this case it is termed as end bound sleepers.

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What is happening in this end bound sleepers is this is a case of a newly constructed and compacted sleepers. Here the deflection will be caused more at the center as compared to the ends. So what is happening is that because this is the new laid track everything is perfect, it is assumed that they are perfect and therefore the fastenings are perfect at this location where the rail is being provided then this the gauge distance and again there is a rail being provided here the fastening are perfect at this location also. So here the system is being supported or they have been fixed in nature but in this condition this is unsupported sort of a mass because of this reason what happens is there will be a deflection like this and this is maximum at this point and in this case it is termed as end bound sleeper.

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The another case is of center bound sleeper. Now this center bound sleeper is a case where the repeated applications of loads have been there for a long period of time. Now when this happens what is happening is that the load is applying again and again at this location as well as this location which is the location of the rail. Here the rail is being provided in this direction or in this direction and these are transpose to the rail. So the load is coming again and again in this location and as well as again and again at this location and finally the sleepers will be tilting in this form because the packing at this level will become loose. So when the packing at this level is becoming loose there will be more of deflection at this point as compared to the center point and that is why it is termed as center bound sleeper means it is being bound at the center but it is open at the ends and this results in higher depression at ends as compared to the center. So this is the difference between the load distribution of the sleepers under the newly constructed conditions or the old track conditions.

So in this case whatever is the load which is coming at the rail seat, this maximum load on the rail seat can be computed by using this formula P divided by Z multiplied with mew multiplied with the characteristic length l.

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This whole system is being multiplied with mew into S where S is the sleeper spacing and mew is the track modulus, Z is the section modulus and P is the wheel load and finally it transforms into P multiplied with the spacing and divided by Z into I. So in this case what happens is there is approximately 30 to 50 percent of the dynamic wheel load, this is what is the total distribution of the stress in sleepers will come out and a length of the sleeper and the rail seat is so selected that under normal loading the middle part of the sleeper is stress less.

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This is another design factor of the sleepers. What it means is that whatever is the load which is being induced at the point of the application of the rail where the rail is being connected to the sleeper through the rail seat there is going to be more of the stresses at that location but as we go along with the length of the sleeper these stresses should start reducing and as soon as we reach the central point of that sleeper it should become 0. That there should not be any stress at the center and this is what is the design principle of any sleeper. So if we are taking the distribution of the load what we have to take is that there is no overlapping of the load within the sleeper and the overlapping can be there in the ballast section. The provision of bearing plates also reduces the maximum stress in sleepers by about 32 percent on broad gauge track. The values of meter gauge and narrow gauge are not being specified here because now we are converting by uniform gauge policy to broad gauge track. So if we are providing the bearing plates, bearing plates means the thing which can take more of the loads that is why the name is bearing plate. So it will be helpful in reducing the stresses in the sleeper. So we can use these things where the heavy loads are coming.

Now once we have discussed about the stresses in the sleepers as well the stresses in the rail the next thing which comes to continuation is the stresses in the ballast. Now stresses in the ballast will be dependent on certain factors; the first factor is the live load and the dead load of a superstructure and train. The superstructure here means we are providing the rail section, we are providing the sleepers above the ballast cushion. So whatever is the load of all those things along with the live load of the movement of the rolling stock. We have to take into consideration all these loads and on basis of that the stresses are going to be induced in this section.

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The next thing is the elastic properties of the sleepers. If the sleepers are elastic in nature they will rebound back to their original location, original condition and therefore the stresses will get dissipated by itself. The section and length of the sleeper means if they are the wide area sleepers they are going to distribute the stresses to a much wider area but if they are narrow bed sleepers then obviously there will be more of concentration of stresses and we are not interested in the concentration of stresses. So that is why the section or the length of the sleeper becomes important. Here basically what we are interested is to look at that area of the sleeper through which the whole of the load will be distributed to the lower layer that is ballast.

The spacing of sleepers is going to define in the terms that what is the total load which is coming from the rail section will get distributed on the sleepers. If there are less number of sleepers the load will be more. If there is more of sleepers the load will be lesser and that is how it will be transferring the more or the less stresses to the ballast section. The degree of compaction of ballast is on other area because in the case of the ballast most of the time we are using the type of the material where the load is going to be transferred through the point of contact of that material. See we are using the stone aggregates the load will get transferred. So if the degree of compaction is good the transfer will be there, if the way of compaction is not good then they are going to be deflections and more of stresses of that nature.

The nature of the ballast bed means what is the type of the material we are using in this ballast bed and on the basis of type of the material it faces certain amount of capability of taking the loads of the stresses. Further, continuation with this one is specification is this specification related to size gradation, depth and compaction of ballast. These also have their effect with the gradation is in such a form that all words have been filled and there is a proper contact through out and there is a good amount of compaction being achieved

because of that one and adequate thickness or gap of the cushion is being provided then obviously the stresses will get dissipated to a larger area and there will not be any failure of the ballast cushion section.

Then what is the type of the sub-grade on this is the ballast cushion is slowing. The type of sub-grade section means what is the type of the soil or the material which is being available and this one and then what is the load carrying capacity bearing capacity of that section. Pattern of distribution of load or stresses whether because of reason that pattern is changing, or it is a uniform pattern, or it is a more of localized pattern. We have to look at this another aspect. What is being observed is that the pressure on the sleeper is maximum. At the centre of its width and this pressure decreases from centre towards the ends and a vertical pressure under the sleeper is uniform at a depth which is approximately equal to the spacing of the sleepers.

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On the basis of this one what we try to do is we try to observe the stresses which are going to be induced up to a depth which is equal to the spacing of the sleepers. So if we go up to this particular depth then we have to find out what is the total amount of the stresses which will be remaining at that level and whether those stresses are lesser than the bearing capacity of the sub grade soil or the formation which is provided at the bottom. If it is so then it is fine, if it is not so then the depth of the ballast cushion is to be increased.

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Now here this is what we can see how the stresses in the ballast are getting activated. This is the real section, these are the sleepers and this is the distance between the sleepers. So the spacing of the sleeper from center to center point is being shown here. This is the depth of the ballast cushion going downwards and say at this level there is a line of uniform pressure somewhere here and these are termed as the pressure bulbs which will be there and these pressure bulbs pertains to the percentage of average pressure which varies from 1 to 100. So we have to look at how the values are changing what we found is that they are very less stresses like this but as we are coming in this reason that stresses can be as high as 100 percent or counting more than that also is possible depending on this geometry.

So we have to look at up to what level these stresses are growing and whether this value of 40 or 30 or whatever is coming at this level is such that it can be sustained by the subgrades soil at the bottom. So we have to compute in that sense the value of this Pz and P x, that is the stress which is being induced below this rail seat at this level or away from this rail seat that is in this direction.

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So the pressure at the bottom of tie is this. This is known as also as tie, the sleeper this pa and the pressure at the depth z will be Pz that is we are coming to this level then it is Pz and the pressure at distance x from depth z in this direction is Px. So this value we can compute as Pa is nothing but it is load divided by width of the tie or the sleeper multiplied with half of the length. So this is how Pa can be calculated. Then the pressure at the depth 'z' below the center of the width can be computed by using the formula 5.24 Pa divided by z raised to the power 1.25, where z is the depth up to which we are interested in computing the stress and Pa has been calculated before.

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Similarly, the pressure at a distance x can be computed at a depth z by a point 48 Pa divided by z multiplied by 10 raised to power minus 2.06 multiplied by x divided by z and x divided by z, this is square of this one. So this is how we can compute the value of a stress at a distance x, at a depth z from the point of the application of the load or the rail seat.

Now coming to the stresses in sub-grade. In the cases of stresses of sub-grade the bearing pressures of different type of the soil or the material has been given here. In the case of alluvial soil it is below point 7 kg per centimeter square, for soft clay it is 1.12 to 1.141. It is same for wet or loose sand. For dry clay or firm sand it is 1.48 to 2.11 kg per centimeter square and for compacted soil it is 2.88 and over.

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So on the basis of the type of the soils sub-grade which is available to us we have to reduce the stresses to this value so that this level can sustain the stresses.

So that is why we have to fix up the depth of the ballast cushion on the basis of this value. So maximum formation pressure which is permitted on Indian railways, in the case of a motive power it is 3.5 kg per centimeter square for broad gauge and it is 2.5 kg per centimeter square for meter gauge.

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In the case of a goods wagons these values are 3 kg per centimeter square for broad gage and 2.3 kg per centimeter square for meter gauge. Now we come to certain permissible values. The certain permissible values in the case of bending stress in rails it is 36 kg per mm square. The contact stress between rail and wheel, it is 21.6 kg per mm square.

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The dynamic over load at rail joints due to unsuspended masses it is 27 tons for locomotives and 19 tons for wagons. The formation pressure it is 3.5 kg per centimeter square for locomotives, it is 3 kg per centimeter square for wagons.

Now the stress at the fish plate level is taken as 30 kg per mm square. The stress at the bolt hole level is 27 kg per mm square. The minimum ultimate tensile strength of rail section is 72 kg per mm square and the assume yield point is taken as 42.5 kg per mm square. So these are the values of the different stresses which needs to be taken when the designs are done.

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So today we have taken up the stresses in the different components of track. We have seen the stresses in rail sections, sleepers, ballast cushion and the sub-grade level. So in these three lectures which we have taken in coding response, we have seen about different type of stresses which are induced, their effects and their computation. In the next lecture we will be looking at the different other aspect related to the components. So we stop at this point and I say good by to you. Thank you.