Transportation Engineering -II
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Lecture - 10
Jointed or Welded Rails

Dear students, we are back with the lecture series on the course material of transportation engineering 2. Today's lecture is based on the jointed or the welded rails. What we have seen in the previous lectures specially the first previous 2 lectures is that there are certain reasons due to which the rail sections which are provided on the track gets eroded ,or wearied out ,or damaged or they fail out. Now looking at all those aspects which we have discussed previously what we found is that the joints are those points which are the points of weaknesses and which causes number of wears or tears or the damages. We will start from these particular points.

So we are going to discuss today's lecture about the different aspects related to the different joints as well as the valedictories and their advantages.

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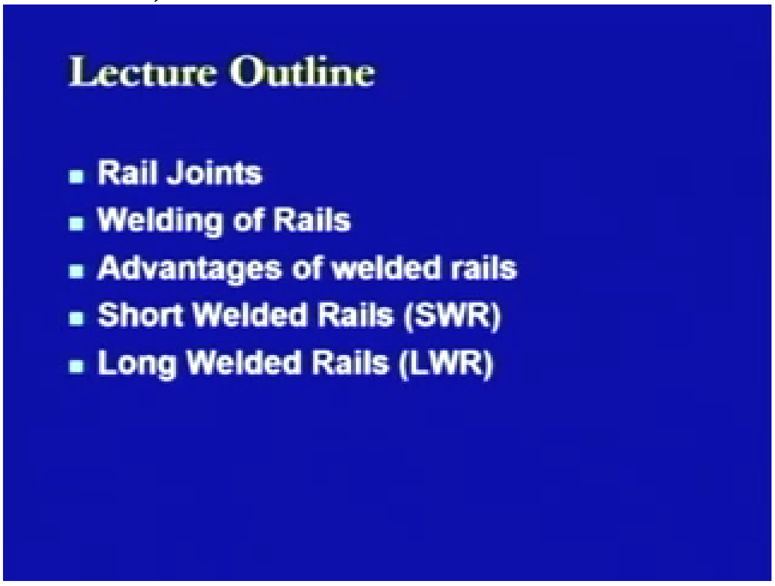

In this lecture, the lecture has been devised as rail joints, the welding of rails, advantages of welded rails, short welded rails, long welded rails. Now coming to these rails and the joints of these one we have of course discussed about number of factors which are the problem, which are caused at any of the rail joint. We will be trying to look back again on all those factors which we have discussed previously under different lectures. What we have found is that the joints are the weakest link in a track. This is a point of discontinuity and because of this point of discontinuity and the gap being provided between the two sturdy rail sections, what we found is that whatever load is coming at this point is unsupported in nature and that is why this is one of the weakest link in any of the track.

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Another thing is that there is a break of continuity in the two directions. It is a break in the horizontal direction as well as in the vertical direction. Now when there is a break in the horizontal direction it is going to create certain amount of jerk and because of these jerks the discomfort will be stimulated. Now if this discomfort is there everybody will be feeling that there is some sort of a pushing behavior which is coming from the track whereas in the case of the vertical direction also this break of continuity causes the loss of stability. So this is another aspect which needs to be taken care of when we are designing or devising the joints.

Now one more thing which we have seen when we have discussed the wear of the rail sections or the end of the rail, what we have found is that there is a blow of wheels at the end of the rail section and this has further resulted in the rear. Now looking at the same aspect in this case because we are talking about the joints, what is happening is that due to these blows of the wheels at the ends of the rail section the fish plates get loosened out. At the same time whatever other accessories are fastenings being provided at that location will also be coming out of their shape. Some of these things are like the ballast pad or the fastenings which are trying to keep the system at the place. It may be in terms of the metal plates which have been provided below so as to disperse a load to a wider area or support the joint. We are looking at different types of the joint a little bit further in some of the slides. So we will be looking at some fastenings which have been shown which tries to support the joint systems.

Then there is another aspect is the wear and tear of track components. Now because as we have seen that there is a break of continuity and this is resulting in the impacts or the blows which are coming to the rail section from the top that is the moving loads, it finally results in wearing of the surfaces. This wearing of the surface may be at the topmost surface of the rail head section or it may be on the end section of the rail head. So this is another aspect which is to be taken care of and if propagates in any of the direction then it may also create an effect on other track components like sleepers or the ballast being provided below this joint so as to keep the joint in place.

Then the distortion of track geometry is other aspect. It depends on the type of the forces which have been applied at this joint and their direction and the final result of those impacts. Now if there is no space there has been a moment of one rail section with respect to another rail section then obviously it is going to distort the track geometry, and in that sense it may also result in the buckling of the track. So this is one type of distortion which may be there or there may be some other distortions like the formation of the kink at the point where the two rail sections are getting joined. So this is another sort of a distortion to the rail track alignment. Now because of these reasons the movement of the rolling stock on that type of section will become a little hazardous and it will not be a safe enough, at the same time it will also be creating discomfort to the passengers or maybe a discomfort or jerks to the freight which is being moved on that section.

Further, when we look at the impact of the rail joint what happens is that because it is going to create an effect in all the components which have been provided at that rail joint it reduces the life span of all those components and these components are nothing but they are the rails, sleepers and fastenings. So it means the periodical maintenance which is required to be done after certain period of time instead of that time period we have to do it beforehand. So this is another aspect, it is going to create an effect in terms of the monetary value because it will be increasing the maintenance cost of the system, it may be increasing the overall cost of the system. Then another aspect is the noise being created because of all those features which we have discussed so far. Whatever sort of deformation, distortion of the track is resulted due to the problems of the joints or due to the certain movements of the different components of the joint then it is going to create a noise in terms of the interactions of the rolling stock with these static measures that is rails.

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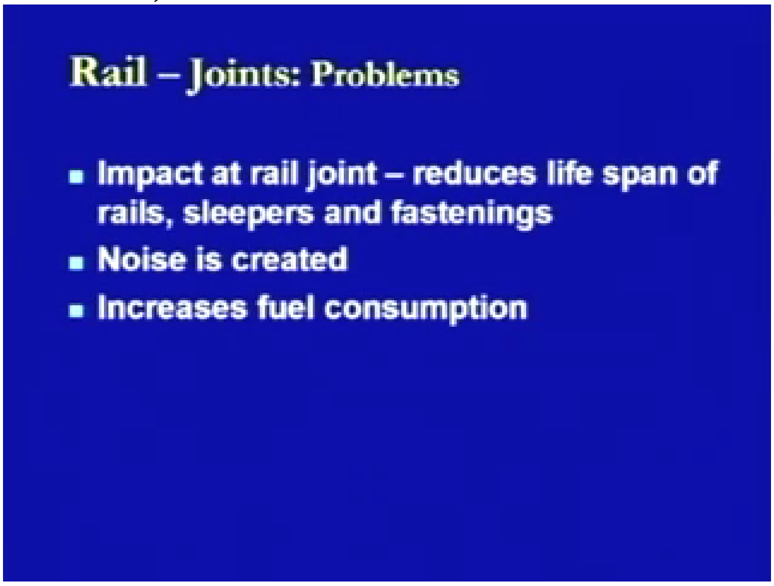

So this is another problem at the joints. The more noise is created as compared to the continuous sections being provided on which the rolling stock is continuously moving and finally it is also going to result in the higher fuel consumption. Now in this case what is happening is because as we have seen that there are so many things which are happening at the rail joint the terms of the problem, in terms of the wears, in terms of the impacts it has its effects in the form of higher consumption of the fuel also and this is another aspect where the economics needs to be taken care of because the final value or the total amount which is to be incurred for the operation of this system or the operation of the stack increases. So these are some of the problems which are associated with any of the rail joint.

So, on the basis of all these problems whatever we have seen, what are the requirements of the rail joints that we will be looking at. In this case the very first thing is that we have to maintain or hold the rails ends for continuity. There should not be any distortion, there should not be any formation of the kink at the rail joint due to which the rail ends are not continuous in nature and they are going out of the shape, that is, what we can say or they are going out of the alignment with respect to each other. So this is one aspect that we have try to maintain or we have to try to hold the rail ends at the same level, at the same location so that the continuity of the rail section is maintained.

Another aspect is the sufficient strength and stiffness should be there. Now in the case of the rail joints because of the two rails which have been placed one after the other on the same alignment on the same path they have been joined together using fish plates and fish boards. Now in this case when we are joining these by the fish plates and fish boards then these fish plates and fish boards have certain amount of strength or the capacity to bear the stresses and that is from where the more strength or stiffness is coming in at the point where the two rail sections have been joined together. So this is how a sufficient strength and stiffness can be maintained in any of the joint section because otherwise it is a weakest point and it may breakdown or there may be any other problem associated at this level.

Another aspect is adequate expansion gap. Now this is related with the length of the rail section which is provided on the two sides of the gap or the joint. In most of the cases if we are using the rail sections as being manufactured by any of the company then it may be around 13 meters in length in the case of the broad gauge. So at every 13 meter there may be a gap and then there may be a gap at every further distance which is taken in terms of an expansion gap, what is happening is that as we have discussed again before also it is an effect of temperature change. All the rail sections or the tracks which are laid at any point of a time they are laid with respect to certain temperature.

If there is any difference with respect to this temperature that is a temperature of the surrounding is either more or lesser that is going to create the effect in terms of expansion or contraction of the rail sections and these expansion gaps needs to be provided so as to take care of all those expansions or contractions which are taking place in the rail sections because of the difference in the temperature. So this is one of the aspects which needs to be taken care of. If the expansion gap is not adequate then obviously it is going to create a jam condition of the joint and then further if there is a movement it will result in kinking or it will result in the buckling of the rail sections. At the same time if the expansion gap is very very large then it is going to create a higher amount of impact on the next rail section depending on the direction of movement of the rolling stock.

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Therefore in both the cases where we are talking about a wider gap or we are talking about a lower gap it is going to create a problem. So, that is why certain amount which is being provided as far as the variability or tolerances are concerned in the gap needs to be provided.

The another aspect here is because we are talking about the joints and the certain sort of fastenings have been used as to join the two rail sections as well as join the rail sections below. One thing which is to be taken care is easy removal or replacement of the different components or the materials. Now at the section where the joint is being provided most of the time there may or may not be a support being provided. In Indian conditions we are providing the joints which are not being supported. So in that case it is not being supported by the ballast cushion which is being placed around the sleepers or below the sleepers. So if we have to remove this material then it should be easy to do that or if we have to replace it then that should also be easier. At the same time the flexibility should be there so that as and when it is required that work can be done from the maintenance point of view.

Then provision for the wear at the rail ends has to be made. It means that whatever wear is going on we are not going to change or replace the rail section as soon as the wear as started. We have seen in the case of a wear that there is a certain amount of percentage by which the wear is allowed as far as the weight of the sectional weight of that component is concerned maybe it is head maybe it is the overall rail section. So in that sense we can wait up to that point up to which those wear as occurred and then after that there is requirement of changing or removing or renewing of the rail section. So, the provisions have to be taken care in this way. Then adequate elasticity has to be there because we are talking about the strength and stiffness, then it should not result in a condition where there is a movement of the two rail sections because of the loads which are coming from the top. Now in this case as the load comes on one rail section it is going to get a as you can say deform towards another direction whereas the other rail section which is being joined to this one will remain in its position.

Now as soon as the rolling load moves from this rail section to the other rail section it is going to deflect in the downward direction whereas the previous one should come back to the normal level. If it is not coming to the normal level then there will be undulations being created into the track and these undulations as we have seen previously are going to create or cause the stresses in the track. So therefore, there should be adequate elasticity in those components which are joining the two rail sections at this point and that is how the total elasticity of the system can be maintained and then as we have talked about the cost component or economics, the initial as well as the maintenance cost should be as low as possible and that is to be happen if there are lesser of removals or replacements required or the periodic maintenance of the system required is not short enough it is to be turned in a longer time period then only we can sustain in this case.
So therefore, as we have discussed about all these requirements. Now we can look at the various types of the rail joints. The rail joints can be provided in terms of or they can be classified as according to position of the sleeper at rail joint, or it may be done in terms of according to the position of the rail joint, or there may be some special joints, there may be insulated joints or there may be welded joints.

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So these are some of the type of the rail joints which are provided globally depending on the requirements of the tracks. So we will be looking at all these joints one by one. We start with the first one that is according to the position of sleeper at rail joint and this category also again there are further classifications or categorizations of the different types of the joints which can be provided. In this case we can look at the first joint, that is, the supported joint. The supported joint means in this case the joint is supported directly on any system mostly a sleeper and the rail end becomes slightly high. What happens is that as we have seen that in the previous cases all those rail sections have been supported with the sleepers. Now as soon as a sleeper is being provided below the joint then it causes some amount of change in the level of that transactions at the joints and that is it is going a little above as compared to the normal level of the rails and the wear and tear of a sleeper and maintenance. These are of some problems associated in this case because what happens is that the load which is being transferred to the joint is directly coming to the sleeper and when it is directly coming to the sleeper then the whole of the load is going to be dispersed through that medium and in the previous case when the sleepers have been provided below the rail sections then the load is coming through the rail sections so some of the load is being taken care of by that section and then finally a reduced load comes to the sleeper.

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So it means in the case where the sleepers are directly being provided below the joints there is more of wear and tear of the sleepers. At the same time if that sleeper is to be taken out, then first of all, all of the system as to be removed, all fastenings have to be taken out and then only it can be maintained, renewed or removed. So that is another problem associated in the case of supported joints. One example of this type of a joint is a duplex sleeper. We can look at this aspect in this one and here in this diagram this is one rail section and this is another rail section and this is the joint in between these two rail sections.

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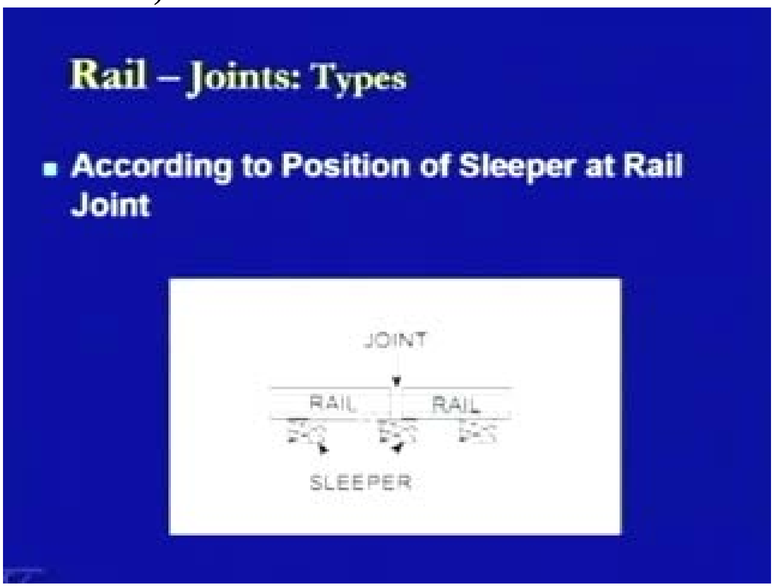

In general condition what happens is that there is a sleeper being provided below the rail section in this case as well as in this case but if a sleeper is provided at this location where the joint is there then it is known as the supported joint. So this is one type of the joint available.

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Another type of joint is suspended joint. In the case of suspended joint what happens is that some portion of the rail will remain as a cantilever. Cantilever as you have read in the structures, it's a part of the system which remains suspended in the forward direction away from the point of support. So in this case there is a problem of loosening of packing at the joint. What happens in this one is that because of the loads which are coming at this one and because the joint is not being supported the loads were directly going to be dispersed to the ballast and when these are going directly to the ballast section then in that case because of the loads that ballast will start coming out of its position and that is the one reason of the loosening of the packing at this level, but in most of the cases we are providing the suspended joint. So that’s why it's one of the formally used joints throughout.

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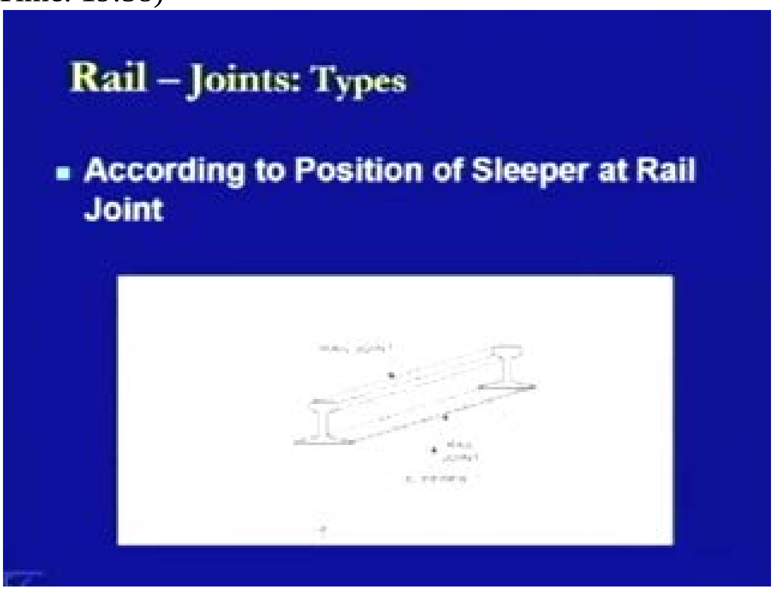

In this diagram we are trying to look at the same sort of a joint this is a rail section being provided and this rail section is having a joint at this level, this is the joint.
So in this case the one sleeper is provided just before this joint on this rail section and another is being provided after this joint on the other rail section. So in this case this is the total amount of rail section which remains suspended after this support. At the same time in this case also it is going to remain like this and this is what is a cantilever section. So there is no support being provided at this point, only support which is available at this point is the ballast or the cushion which is being provided as a packing on the sides of a sleepers or below the sleeper. So that is why the load is directly coming to the ballast position here. So this is what is a suspended joint.

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Then another type of a joint is known as bridge joint and in the case of a bridge joint we use a metal flat or corrugated plate which bridges the joint and that is why it is termed as bridge plate.

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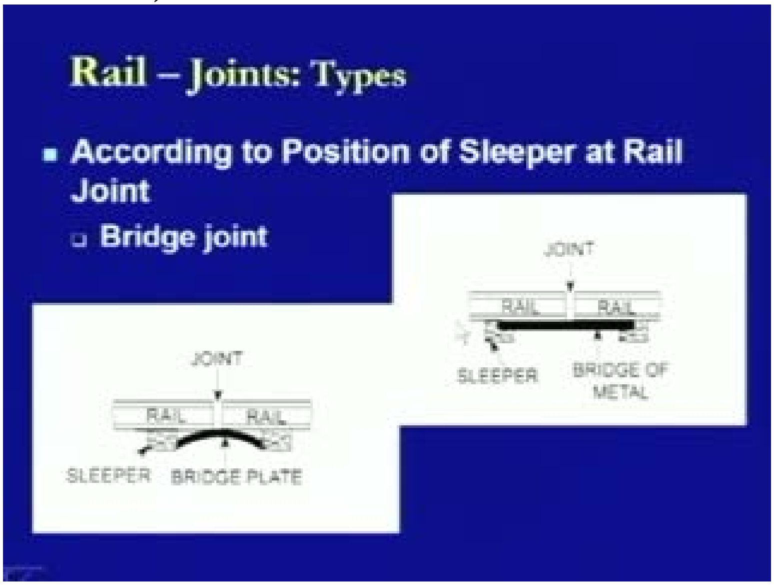

So if we look at this one. In this case, this is one rail section being supported on the sleepers and this is another rail section being supported on some of other sleepers and here a plate is being provided in form of arc and this is how this joint is supported. There is another case where instead of providing it in the form of an arc and this is a plate being provided as the sort of a bearing plate and this is embedded here in this paper and from this side in this sleeper and that is how it is supported at this level. Now because of this support whatever load is coming from the top will get dispersed by the wider area of this speed and it will go to the sleeper as well as to the ballast cushion being provided at the bottom. So this is bridge joint.

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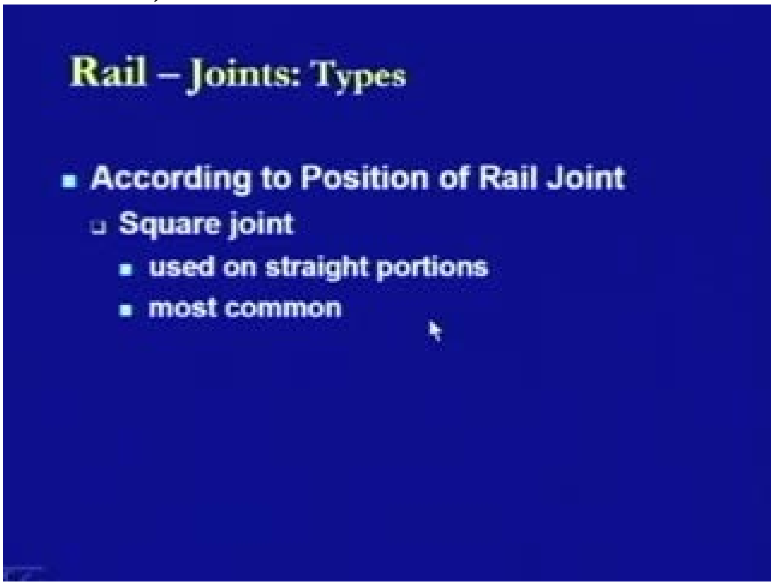

Then another one is on the basis of position of the rail joint. In this case the first type of a joint is the square joint. The square joints are mostly used on straight portions and this is one of the most common type of the joint which is provided on the railway tracks or the permanent way.

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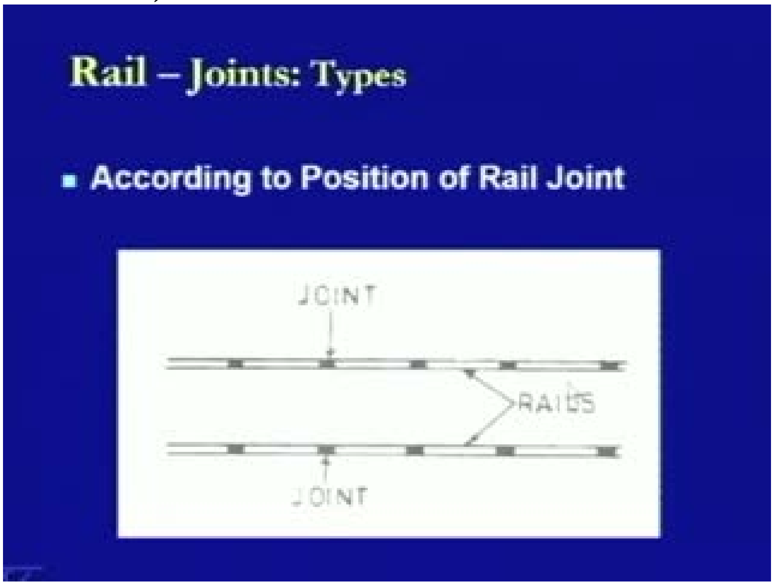

What we see is that this is a square joint where these are the rail sections being provided. This is all these are the rail sections on this side as well as on this side and the joint is provided on this location it means the joint on the other rail section being laid parallel at the gauge distance is going to be just opposite side to this one and that is how at every regular distance we are going to have a joint on both the cases, this rail as well as this rail and this is why they are termed as because this is making a sort of a square condition. So this is why they are termed as the square joint.

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Another type of joint in the same sort of a condition is a staggered joint. Now in this staggered joint this is mostly provided on curved tracks. In the case of curved tracks what is happening is that there is a larger distance to be travelled on the outer curve as compared to the inner curve. This is what we have seen already when we have discussed the coning of wheels or when we have discussed other features. So in that case whatever is the rail length being provided, the rail length is a constant rail length and if you use the same rail length because of the difference in the distance being travelled on the two tracks the joint will be coming at different location and that is why it is termed as the staggered rail joint. Now this staggered rail joint as we see in this case the length of the rail section remains constant, it is not changing but because the distance travelled on this one is more as compared to this one so the joint is coming at this location with respect to joint which is coming at this location on the inner rail and this is how they are not opposite to each other and they are termed as staggered rail joints.

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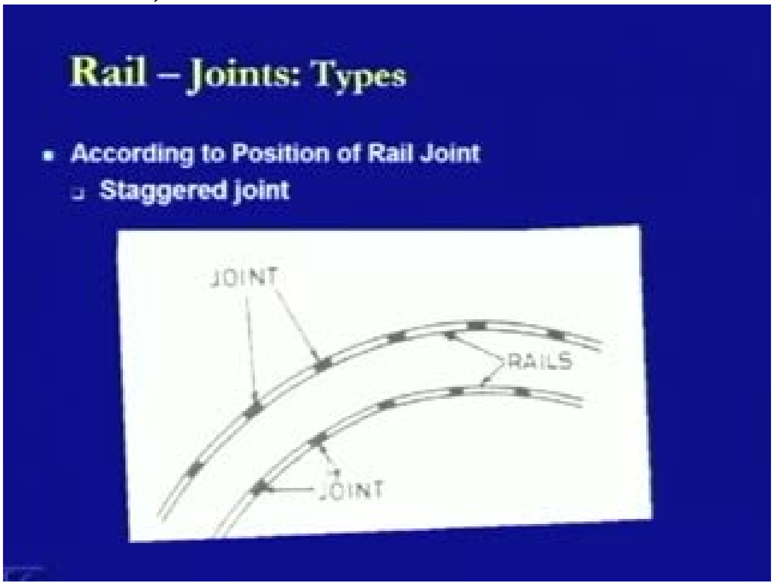

Then there are some special types of joints. One joint, which is known as base joint. In the case of base joint we use flat or corrugated plate and these plates are bolted to the sleeper using some bar type of inner fish plates or angle type outer fish plates. What happens in this one is that there are two types of fish plates being used whereas inner and outer fish plates. Outer fish plates are of angle shape and that is why these outer fish plates they come out and then they are bolted to the sleepers whereas the inner side of the fish plates which are provided on the gauge face they are of bar type, they simply just to the surface of the flanges of the rail sections.

Then another type of a joint is known as compromise joint. This compromise joint is provided at those locations where the combination fish plates are provided.

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We will be looking at this combination fish plate when we take up the rail fastenings but just to mention here is that these combination fish plates are provided at those locations where the two rail sections which are being joined together they are of different sectional areas. So in those cases the normal conventional fish plates are not provided instead the combination fish plates are provided and at that location the joint which is provided is known as compromise joint.

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Then there is an expansion joint as we discussed it is provided so as to take care of the amount of expansion taking place in the rail sections because of thermal stresses.
There are insulated joints being provided in the locations where we have to just stop or remove the flow of the current. So what we do is that some sort of filler is being filled at the joint level. Then there are welded joints. Welded joints are those joints where the two rail sections are joined together by using a weld. So instead of some sort of fastenings being used like fish plates or fish we will be using the welds.
So those are the welded joints, we will be looking at these welded joints in further detail.

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Now, the joint needs to be avoided at certain locations; what are those locations? The level crossings, wherever the level crossings is being provided, that is, there is a crossing of a road and rail section at the same level, at that level the joints should not be provided in that position. Another one is if there are short bridge spans, then in that case also on the bridges the joints should not be provided. Then approaches of the bridges, the reason behind in these two cases that if the joints are provided at the bridge level in the case of the short bridge spans, then whatever stresses will be induced because of the impact condition at that position due to the rolling stock that may create problem, that may create some defects in the bridges. Those are the smaller bridges, whereas in the case of the approaches of the bridges again similar reasons of stresses are being induced we try to avoid the joints. Then there is another location at the end or center of the span of the long bridges again the joints should be avoided.

Now what we have seen is the different types of the joints where there are been connected together using fish plates and fish bolts. Now as we have seen whatever is the condition, whatever type of accessories we use where remains the points of weaknesses. So one thing is that we have to remove those points of weaknesses as far as possible and one way of doing that is the welded rails. So in the case of the welded rails there are certain advantages. The advantage, if we look at is that it reduces the maintenance cost. Now the jerks which are being induced to those joints or there is requirement of a removal of the components which are providing at the joints because of the continuous wearing of those components.

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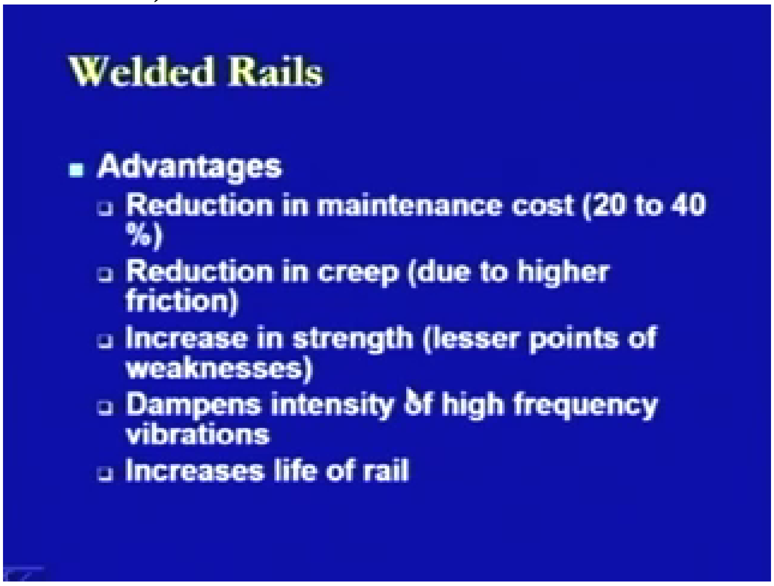

In all such cases the maintenance cost is involved whereas as soon as we have welded the joint therefore there will be a reduction in the maintenance cost and this amounts to something like 20 to 40 percent of the total amount. Then there is another aspect is the reduction in the creep. As we have seen that the there is a longitudinal movement of the rail sections due to different reasons. Now this longitudinal movement is going to be resisted by the fixtures which have been provided at the bottom of the rail sections and these fixtures are there connectivity with respect to the sleepers. Now, if we can increase this sort of a resistance or the friction which is induced by the connectivity's of the fixtures which have been provided between the rail sections and the sleepers or the number of sleepers which have been provided at the bottom of the rail sections then probably the creep can be reduced further. So if we are having the valedictories then this is another possibility that we will be having a big rail section and that big rail section works together so that the frictional resistance will increase and this increased frictional resistance will reduce the creep. Then it will also be increasing the strength because there is a discontinuity and forces which are acting at this point of a discontinuity are directly going to the ballast section and therefore there is a sort of a further wearing of the ballast section at that level and which results in the loosening of the ballast section.

In this case when it is being welded there is no such transfer of load to the lower levels which are having a lesser of strength as compared to the higher levels, that is, the rail sections. So it means as soon as the two rail sections have been jointed together it is going to increase this strength and there will be lesser points of weaknesses available on the overall rail section, overall track. Then it also dampens the intensity of high frequency vibrations because as we have seen that the points are not there where there will be some impact taking place. So, due to that reason because this is being welded together it is going to dampen that frequency vibrations and obviously as the reduction in creep is there, as there is lesser requirements of maintenances as we have increased the strength of the total section obviously this is going to result in the increased life of the rail section. So these are some of the advantages of rail sections and this in this case when the life of the rail section is increased obviously finally it is going to reduce the overall cost of construction as well as overall cost of maintenance of these tracks. So once we have got an idea about what are the advantages of any of the welded rail sections then we were looking at different types of methods by which the welding can be done between the two rail sections.

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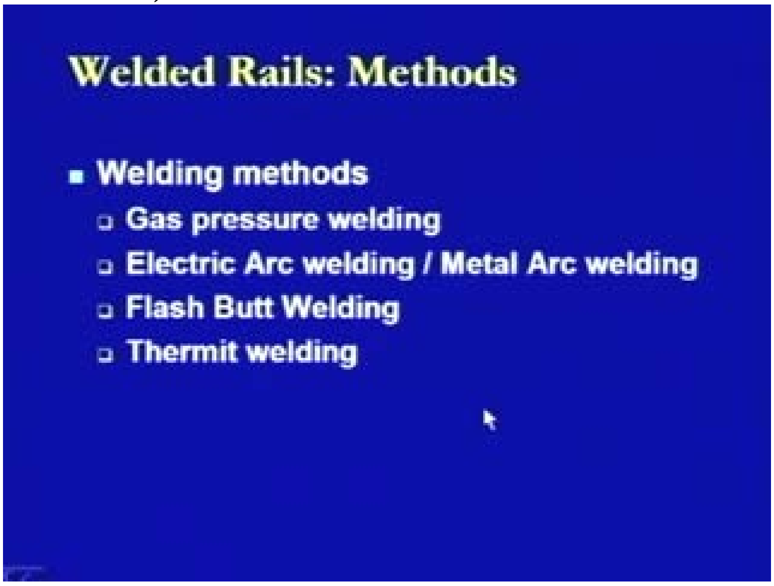

Now therefore in general methods gas pressure welding, then we have electric arc welding this is also termed as the metal arc welding, then there is a flash butt welding and finally there is a thermit welding. So all these welding processes which are available they have been at different point of time globally depending on the requirements, depending on the facilities available and then they have their advantages and disadvantages with respect to each other. We will be looking at what are these type of welding and what are the relative advantages and disadvantages of the flash butt welding and the thermit welding in the coming sections.

So as we have seen that we have 4 methods of welding. We will be looking at all these 4 methods one by one. The first one is gas pressure welding. In this case of gas pressure welding what we do is that we use two types of gases: oxygen and acetylene. They are used together maybe in 2 different cylinders and then at a temperature of 1200 degree centigrade, this is amount of temperature up to which we have to go at which the two rail sections which have been butted together to each other, the metal will start just flowing and it will become one section. So this is what is done in the case of gas pressure welding. This is one of the cheaper ways of welding and it is also resulting in good quality of weld but what is being observed is that there are some limited outputs only which are available in our conditions.

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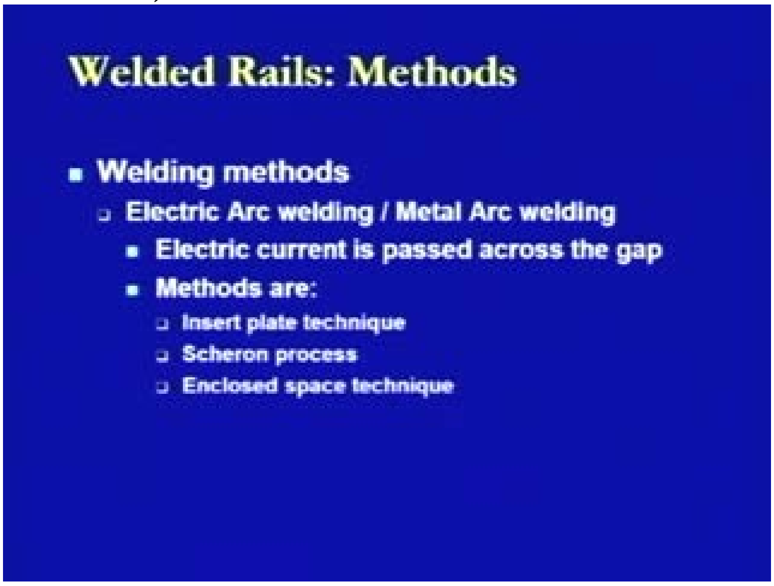

Then there is another method electric arc welding or metal arc welding. In the case of electric arc welding or metal arc welding what we do is that the 2 butting sections of the rail they are treated as 2 different terminals where the electric current will be passed through these 2 terminals across the gap. Now this electric current may be passed using different methods, the methods are the insert plate technique or Scheron process or the enclosed space technique. Using any of these methods we can do this electric arc welding or metal arc welding though this metal or electric arc welding is again is lesser in use.

Then next of the 2 methods, that is, flash butt welding and thermit welding. Here in this chart a comparison of these 2 welding methods as well as their principle has been laid down. What we see is the certain points on the basis of which we can make a comparison between these two welding processes. The very first thing is that what is the principle of welding in those 2 cases? In the case of a flash butt welding what we are doing is we are passing 35000 electric current between the two rail sections so as to join them together. whereas in the case of a thermit welding we are using an exothermic chemical reaction between the iron oxide and aluminium and this exothermic chemical reaction what happens is that we get iron and aluminium oxide and this is the principle by which the joining is being done.

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Welded Rails: Methods

Description	Flash butt welding	Thermit welding
Principle of welding	Passing 35000 Amp electric current	Exothermic chemical reaction bet^n Fe_2O_3 & Al
Quality of weld	Excellent	Good
Strength of weld	Good in fatigue	Weak in fatigue
Time required	3-6 minutes	10-12 minutes / 30-45 min. conventional

Now as far as the quality of weld is concerned, the quality of weld is quite good in both the cases and of course it is a little better in the case of flash butt welding as compared to the thermit welding. Then if you look at the strength of weld the strength of the weld is to be taken or is to be considered in terms of the repeated loads which are coming from the top at that section and the behavior of that joint where that welding is being done and this is what is termed as fatigue and it is observed that the flash butt welding locations they are good in fatigue whereas the thermit welding is weak in fatigue.

Then there is a total time required for doing the welding at any location. In the case of flash butt weld welding method it is taking 3 to 6 minutes per welding process whereas in the case of thermit welding condition there are two time periods depending on the type of method being used. There is one conventional method and another one is a short period method. So in the case of the conventional method it takes around 30 to 45 minutes time period whereas in the case of short term method it is taking 10 to 12 minutes time period. In this case generally a preheating is done so that time is being reduced in the thermit welding process. Then further some more points are there on basis of which comparison can also be done between the 2 same welding processes.

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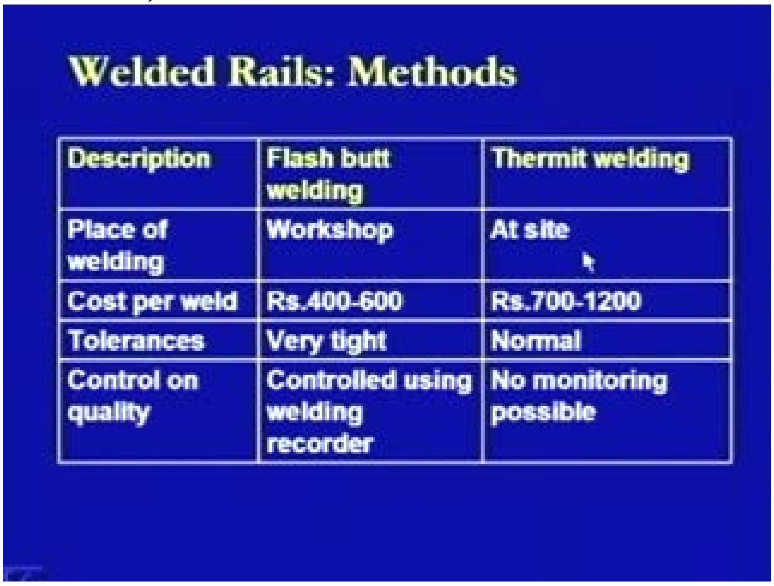

Welded Rails: Methods

Description	Flash butt welding	Thermit welding
Place of welding	Workshop	At site
Cost per weld	Rs.400-600	Rs.700-1200
Tolerances	Very tight	Normal
Control on quality	Controlled using welding recorder	No monitoring possible

In the case of flash butt welding, welding is to be done in the workshop maybe this workshop is maintained at the side level whereas in the case of thermit welding it can be done at site, that is, wherever the track is being laid we can go to that position and we can weld the joints wherever they are available. The cost per weld is around 400 to 600 rupees in the case of flash butt welding but it is higher in the case of thermit welding and ranges between 700 to 1200 rupees. Tolerances are very tight in flash butt welding so it means that the variations are very less permitted whereas in the case of the thermit welding they are the normal conditions and the control on quality is it is control being done by using a welding recorder. This welding recorder as a flexibility of recording the process of the welding wherein whatever parameters are there which needs to be maintained they all got recorded. It may be in terms of the pressure, it may be in terms of the load being applied or it may be in terms of the temperature etcetera. Whereas, in the case of the thermit welding there is no such monitoring possible. So that is a type of a combination or type of the comparison between the two types of welding processes and what we found is that the flash butt welding process looks like that is of course cheaper but at the same time it is also providing a better quality of weld as compared to the thermit welding process.

Now based on these welded sections which have been provided the overall tracks which are being jointed can be again classified.

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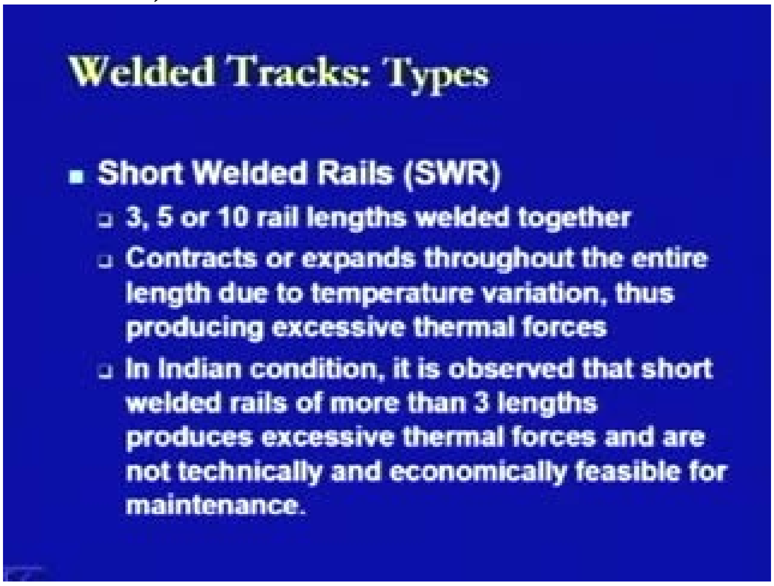

They can be classified as short welded rails. In short they are termed as S W R or these S W R or the short welded rails they are in general a combination of 3, 5 or 10 rail lengths which are welded together. It means if you are talking about the 10 rail lengths welded together in a broad gauge condition it is going to transform into 130 meter rail length. There is if we talk about an individual piece it is 30 meters rail length. So this is how we have removed the number of joints in this case and in this one where contraction or the expansion takes place throughout the entire length and this obviously this contraction or expansion is because of the temperature variations and therefore it means they are excessive thermal forces will get set in in the whole of the length of the rail section and in Indian conditions as we have seen that there are the variations of temperature going from very low to very high condition.

So in that sense it is observed that the short welded rails of more than three lengths they are going to produce much higher thermal stresses and so as to remove these conditions where higher thermal stresses are there due to which there will be higher level of expansion and it will be creating a problem of kinks or it will be creating a problem of buckling of rails. So these have been limited to three rail lengths and they are not being found technically and economically feasible for maintenance also. Then another case is a long welded rail case. In the case of long welded rails what we are doing is this is of course again termed as L W R and this is based on the theory of expansion and contraction. In this case we are having more number of rail sections being jointed together and it is more than obviously the tang rail sections which have been jointed at the maximum in the case of the short welded rails.

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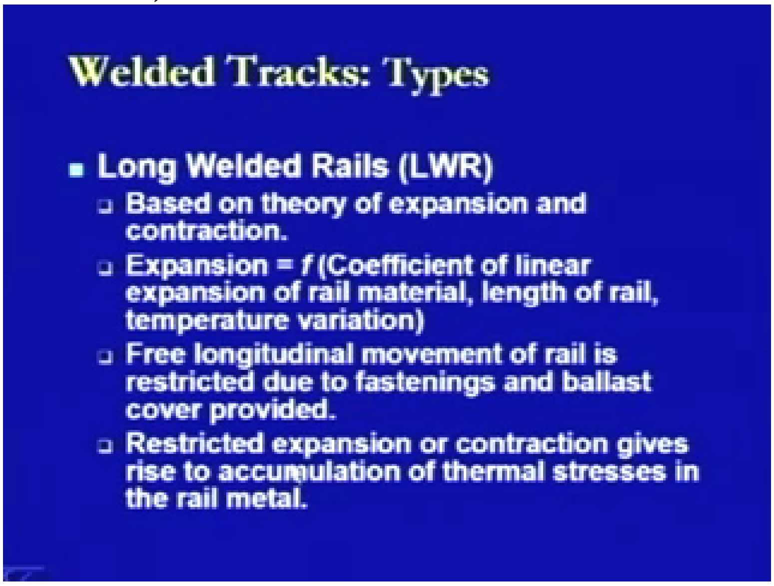

Here, we are trying to look at the total amount of expansion or the total amount of contraction which is going to take place in the number of rail sections which are jointed or welded together. So based on the amount of expansion and contraction the length of the rail section is to be decided. Here whatever expansion is taking place this expansion is going to be a function of the coefficient of linear expansion of rail material, the length of the rail section and the temperature variation. The higher is the temperature variation higher is the expansion in the rail section and if this coefficient of linear expansion of the rail material is higher then also it is going to create higher level of expansion in the overall length of the rail section. Then further it is going to be proportional with respect to the rail length and therefore again in this case the expansion will be more if the length of the rail section is more and that is one of the reason why the short welded rails in the Indian conditions as we have seen previously have been restricted up to a length of 3 rail sections.

Now in this con- sense how we can control or how we can decide upon what is what should be the total length of the long welded rails L W R rail section and here the free longitudinal movement of the rail is restricted due to fastenings and ballast cover provided as we have seen previously that there are certain amount of resistance which is going to be offered to this movement of this expansion on the rail section and this resistance is coming through the accessories which are being provided between the rail sections so as to connect them to the sleepers. So in this case what is going to happen is that these fastenings or fixed features will be creating a resistance. At the same time the ballast which is being inserted or packed on the side of the sleepers that will also be helpful in creating a resistance to the movement. So there are certain amount of resistance which is trying to restrict the movement. So this restriction or this amount of free longitudinal movement is to be measured with respect to the resistances being offered by the track itself. So this restricted expansion or contraction gives rise to accumulation of thermal stresses in the rail metal and this accumulation of thermal stresses in the rail metal is going to decide that what should be the length of the rail section. So in this length of the rail sections there are certain locations where these rail sections should not be provided. What are those rail sections?

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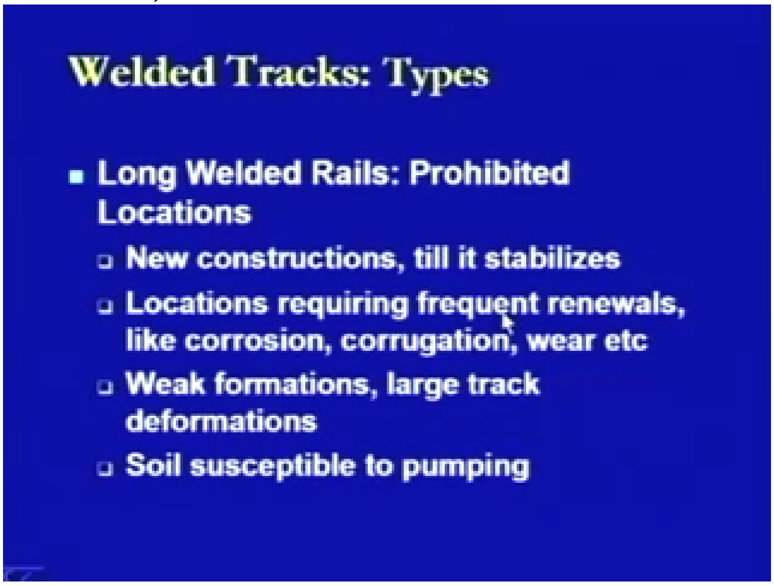

The new constructions. Now whatever new railway track is being laid down as soon as the load start coming from the top there is a readjustment of the material which is provided at the bottommost layers. These bottom layers are the ballast cushion and the sub grade soil or the formation layer on which the ballast is being placed. Therefore, there will be a certain amount of settlement which may be taking place because of the heavier loads which are coming repeatedly from the top. In such conditions if there is any problem associated with the rail occurs then the whole of the long welded rail section has to be removed if the L W R is provided. Therefore what is being suggested here is we have to wait till the section stabilizes and as soon as the section stabilizes then that section can be converted to the L W R section, that is, the long welded rail section.

Another case is the locations which are requiring frequent renewals like the places where there are more of corrosion, corrugation, and wear etcetera. What happens in these cases like as we have seen in the case of locations near the coastal areas or we have also looked at the locations like tunnels where the wear of the surfaces or wear of the overall rail section is more as compared to the other locations. So in all these locations the long welded rails cannot be provided or should not be provided because if you are doing that then the renewal of the maintenance problem will be there, either you have to cut down the section, remove the section and again validate or it is better that you have a smaller remove whatever is the affected rail length and that is how it is maintained.

Corrugation is another aspect which is location specific. It is not that it is happening everywhere so that is why whatever locations where the corrugation is taking place we can remove or rectify those locations or we can renew those locations and if we have to do it with the long welded rails then it will not be possible again. The next thing is the weak formations. In the case of weak formations as we have discussed before also that it is related to the conditions or the stabilizations of the stability of the railway track we have to look at the amount of deformation which will be there. If the amount of deformation is very large then obviously we have to go with the smaller rail sections. If the soil is susceptible to pumping, that is, it is getting removed along with the gradients being induced in the any of the direction then in those cases also there will be a settlement taking place as the loads are applied from the top. So these are the other locations where L W R's prohibited.

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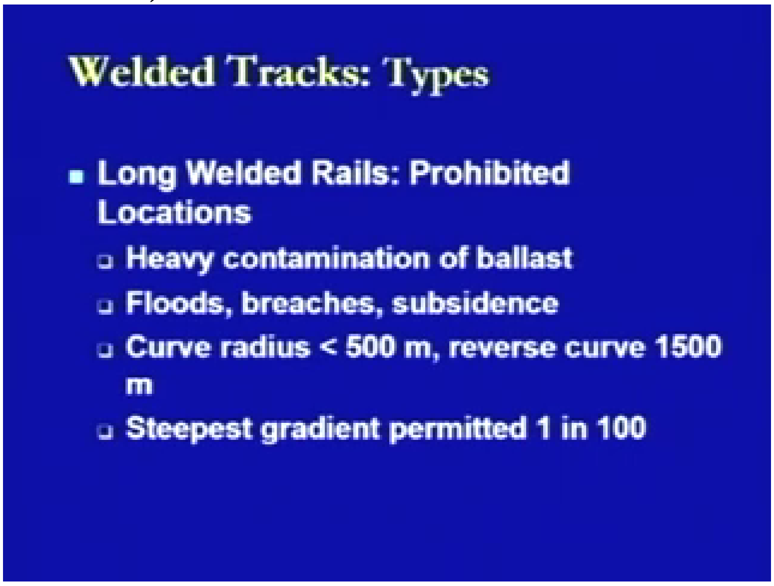

Then further those locations where heavy contamination of the ballast takes place, like the locations where the industrial area where the affluence are coming and they are contaminating the ballast. So if such type of locations are there then the life of the ballast is going to be affected because there will be some reactions which may takes place so at that locations also L W R's are prohibited. Then another location is the location where there are chances of floods, there are chances of breaches or subsidence. Then the locations where the curve radius is less than 500 meters or there the reverse curve is provided with the radius of 1500 meters or more. In those cases also long welded rails should not be provided. Then the long welded rails should also not be permitted based on the gradients and the steepest gradient permitted is one in hundred. So these are some of the locations on which the L W R's cannot be provided. Now the higher category of L W R is termed as C W R, that is, continuous welded rail section.

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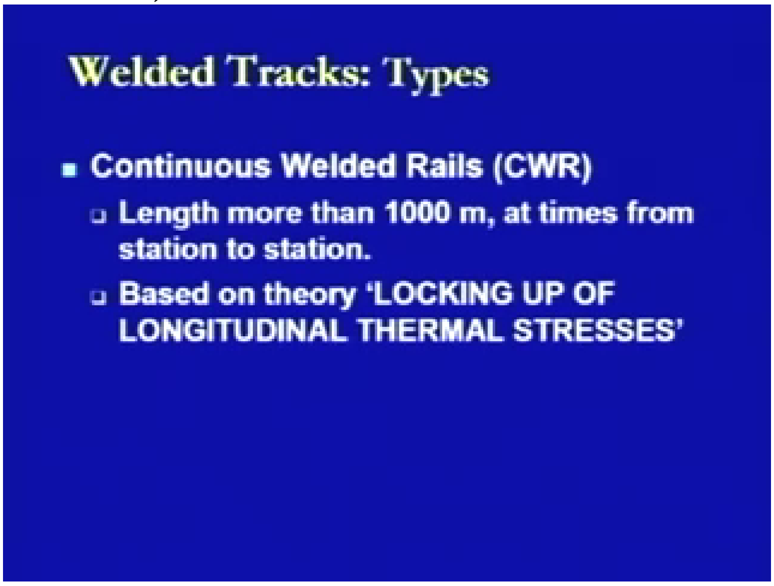

This continuous welded rail section may be of a length more than 1000 meters and at times it may be from one station to the another station. what happens is in the case of a short welded rails as we have seen it is having a length of up to 130 meters whereas in the case of long welded rails the length may go up to a length of 1000 meters. now this is a further category where the length can go more than 1000 meters and even there are sections where the rails have been provided condition from one station to the other station means going to certain kilometers continuously and this is based on locking up of longitudinal thermal stresses, as in the case of L W R we have seen that that there are certain amount of resistance which is being offered by the track and this resistance is trying to resist the movement of the rail section in terms of expansion of the rail.

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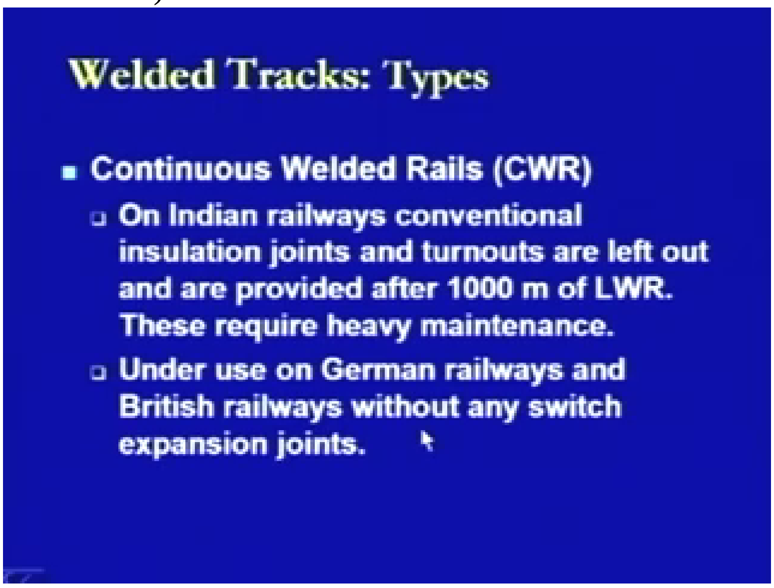

Now we have to look at what point those thermal stresses get locked. As soon as this amount is there, this length is available to us at which the locking has happened then the rest of the section is going to be free of the movement and this is what is the concept behind this one. What happens is that it has a tendency of removing the points of weaknesses such as the switches or the buffer joints which are provided along and in this case further on the Indian railways it is recommending that the conventional insulation joints and turnouts are left out and they are provided after 1000 meter of L W R. L W R is having a longer section as 1000 meter, after every 1000 meter we can provide the insulation joints or we can provide the switches so that the turnouts can be maintained and of course in this case these require heavy maintenance. Then these continuous welded rail sections they have been used on the German railways and British railways without any switch expansion joints which are provided in the case of L W R, we have discussed after every 1000 meters. In this case the sections are running from one station to another station throughout without any switch expansion joints. So now we are going to look at the length of the L W R sections, this is going to be governed by the thermal forces as we have seen previously.

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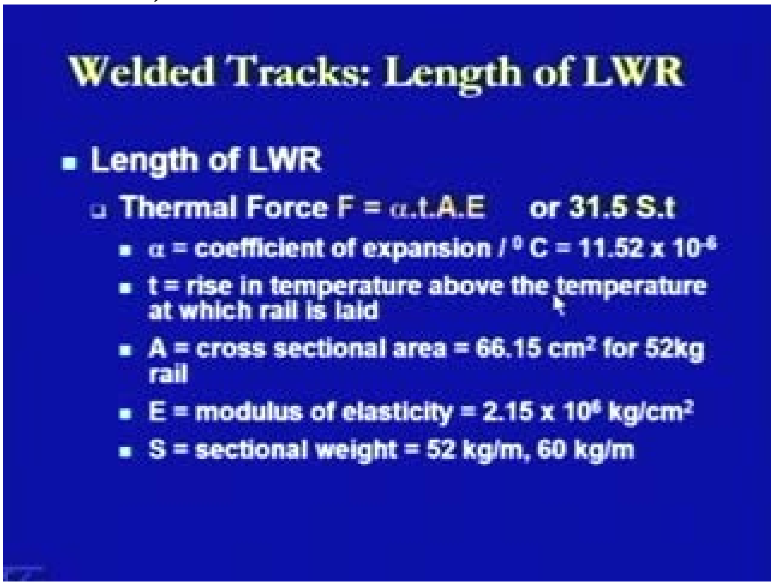

This thermal force is given by F is equals to alpha t. A. E where alpha is the coefficient of expansion per degree centigrade, t is the rise in temperature above the temperature at which the rail is being laid, A is the cross sectional area of the rail section and E is the modulus of elasticity. The values of certain constants are also being shown here So this of this value the thermal force can be computed or this value can also be computed by a formula like 31.5 S into t where S is the sectional weight of the rail section and the t is the temperature by which it is increasing.

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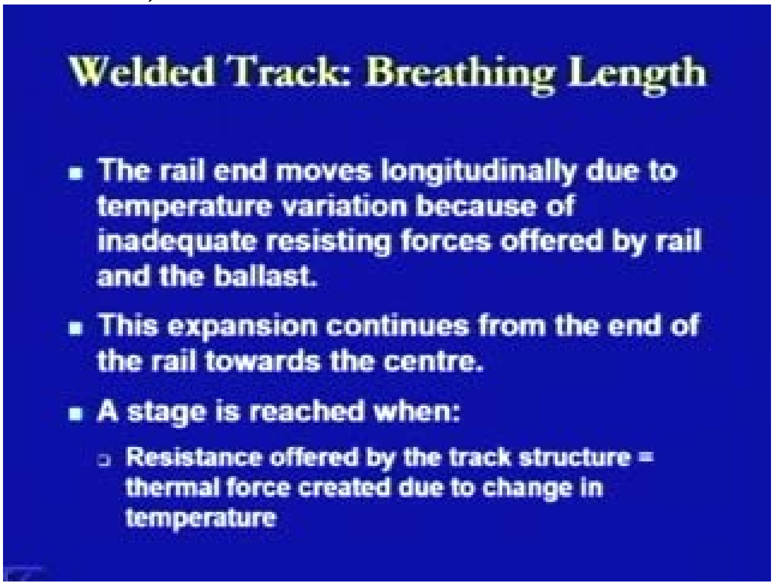

So in this case what happens is that the resistances forces which are being induced by permanent track has to be considered with respect to the thermal stresses and the point at which or going to become equal that is the point at which the locking of the stresses will be taking place. It means as the length of the track increases the resistance will be increasing, so we have to go along the length of the track and we have to find the point at which the thermal stress equals to the resistance offered by the track and this resistance is coming through the sleepers and their connectivity's with the rail sections. So this expansion continues from the end of the rail towards the center and is stage is going to be reached where the resistance offered by the track structure is equals to the thermal force created due to change in the temperature.

So as soon as this stage will be reached what happens is that this is there is no movement which is taking place beyond this point and this is what is that, this is termed as the locking of the stresses and this portion of the L W R at the end which goes under movement due to temperature variation this length is termed as breathing length.

So this length which is being taken is something around 100 meters from the end of the rail section in the case of the board gauge track whereas in the case of a meter gauge track it is around 150 meters length. So, on the whole if you are taking about any this L W R section it means in the board gauge condition the 200 meter rail length is there which is going to be affected because of the temperature stresses or there is a 300 meter rail length which is going to be affected by the rail thermal stresses. Any length more than this one is not going to be affected by this thermal stresses and therefore there will not be any movement in that section. So due to this reason with this concept the longer sections of the rails have been used as a continuous welded rail sections which are going even to a distance more than thousand meters in length.

So this is a concept behind the different types of rail tracks, that is, S W R, L W R or C W R rail tracks. So we have looked at the different types of the joints; maybe the simple joints in terms of position or in terms of the location or we have also looked at the types of the welded joints and the ways by which the welding can be done in today's lecture.

So we will be stopping at this point and we will continue with another thing related to these tracks in the coming lectures. I thank you and good bye.