Building Materials and Construction
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Module - 11
Lecture - 3
Steel: Uses in Construction

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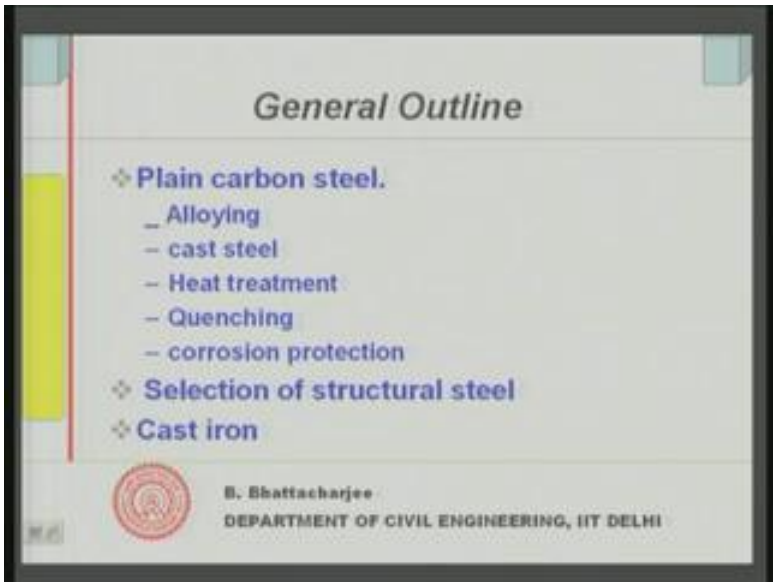

Well looked into the micro structure of steel and it is you know of the phase equilibrium diagram. Now, you can look in to the use of steel in, construction however refer back to the equilibrium diagram of now. And then because we have to understand some other processes and properties of certain types of steel, that we use in construction.

So, general outline today would be mainly discussing about the plain carbon steel effect of alloying. We will discuss about cast steel, heat treatment, Quenching and something about corrosion protection. Then, will discuss about selection of structural steel and then followed by that something about cast iron lastly some usage of steel in construction will be discussing today.

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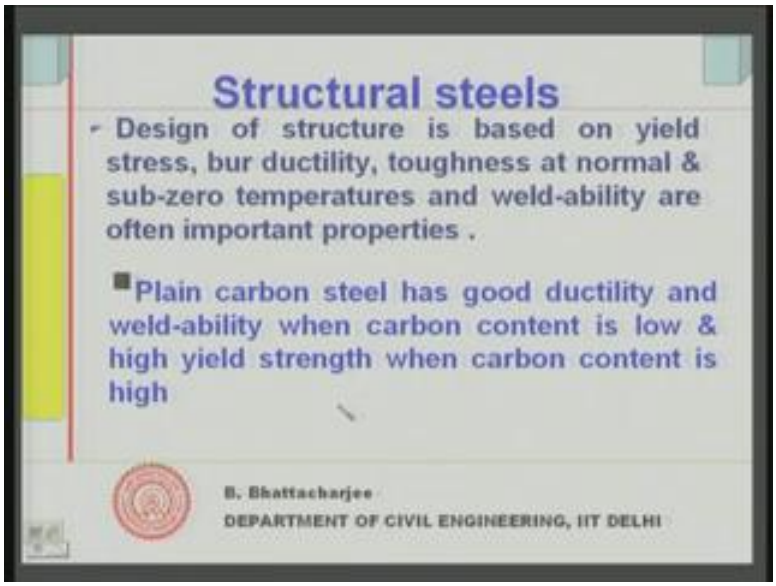

Now, you know structural steel if you look at it, by this time we have become ever that basically stability is a measure criteria therefore, design of structure is based on yield stress. That is useful stress beyond that there is excess of amazons, that you do not use that stress. So, yield stress is a useful stress for us for our purpose of design also ductility, toughness, at normal and sub 0 temperatures and weld ability this are other important properties.

So, stress is a main thing in stress but then you look at ductility, toughness at normal sub 0 and that is our requirement for the steel. So, this is the properties which we require write plain carbon steel has good ductility and weld ability, when carbon content is low why it is low we see right now.

And it has sufficiently high yield strength, when carbon we know its yield strength increases when we have high carbon content although I may not have ductility. We will see that, because all both the things cannot get together. If I get the ductility I do not get normally the strength yield strength, high yield strength and if I have high yield strength then high ductility then yield strength is low.

You can recall that we discussed about, strength hardening in that case also, increase by the processes of strength hardening. We can increase the strength, useful strength, proof stress etcetera, but its ductility has reduced. So, even chemically we can try to improve the yield strength ductility gets reduced.

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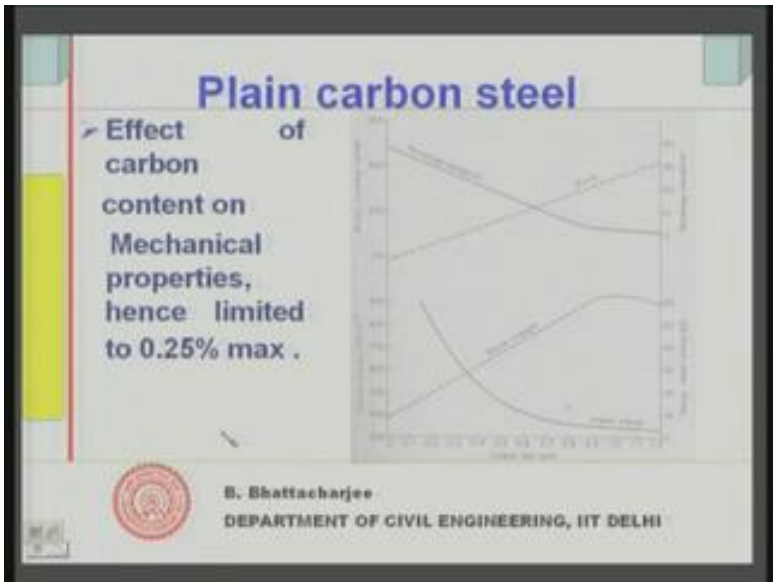

We will see some of this write now; you see this is the idea plain carbon steel if you look at it. If I have carbon content plotted along this direction, carbon content product along with this direction and is this direction I plot tensile strength. So, this exercise tensile strength and this is the curve as my server content increases, tensile strength increases right.

Impact energy course starts reducing, because the stress strength have depend up on the stress strength have area under the tensile strength have high. But as I go high strength increases, but impact energy reduces, because area under the strength curve is not more as high. So, percentage along as an available this is pretty high at lower strength lesser curve and content, but as it increases this reduces down significantly.

So that means, my ductility reduces and this is the hardness right, so this harness also increases thus I increase the carbon content. So therefore, what happens? If you increase that carbon contents strength increases; tensile strength increases, hardness increases. But percentage alongession available that failure that is decreases and impact energy decreases.

So, that is what you increase carbon it becomes better, if you low carbon off course else stress or time stress is reliably low. So, that is the idea is and therefore, what you do is we actually restrict it 2.25 percent maximum in case of mile steel which we used easily for construction very often. So effect of carbon content on mechanical properties you

have seen and we see that, to restricted to 0.25 percent maximum for that ductility requirement.

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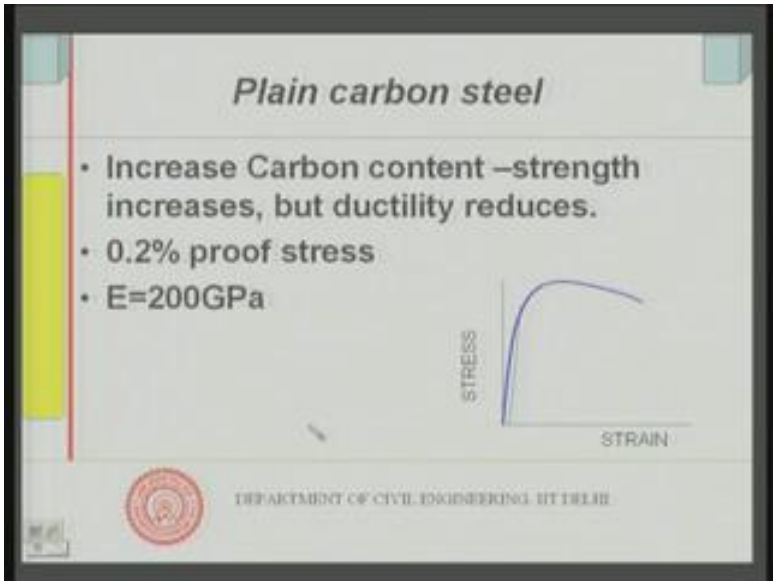

That is what finally, comes to if you increase carbon content strength increases, but ductility reduces And then, defined the useful strength in terms of what is called 0.2 percent proof stress you might have state this earlier. But again that is repeat right and this looks like this, because whenever your stress strength does not have a sharp yield point we cannot use, you do not know what is a useful stress that I can use.

Because, beyond a point that you can see in this diagram as well, beyond a point actually this is you know it is plastic you know it shows deformation. So which point shall I use for my useful strength. We define a terms of 2 percent proof stress and that would look some like this; 2 percent proof stress is look like this what I will do is, I draw a line parallel to my stress strength curve at 0.002 strength this strength is 0.002 percent.

So, 002 strength draw a line parallel to the stress strength curve that is a elastic you know portion of the stress strength curve and wherever, it cuts the 2 percent proof that I can have 1 percent proof stress or 2 percent proof stress. So, thus corresponds to 0.002 to strength draw a line parallel to the stress I curve linear portion the stress and curve right I can get it. So, thus proof stress and off course we know that most often most of our plain carbon steel we have a modules of elasticity 200 GPa.

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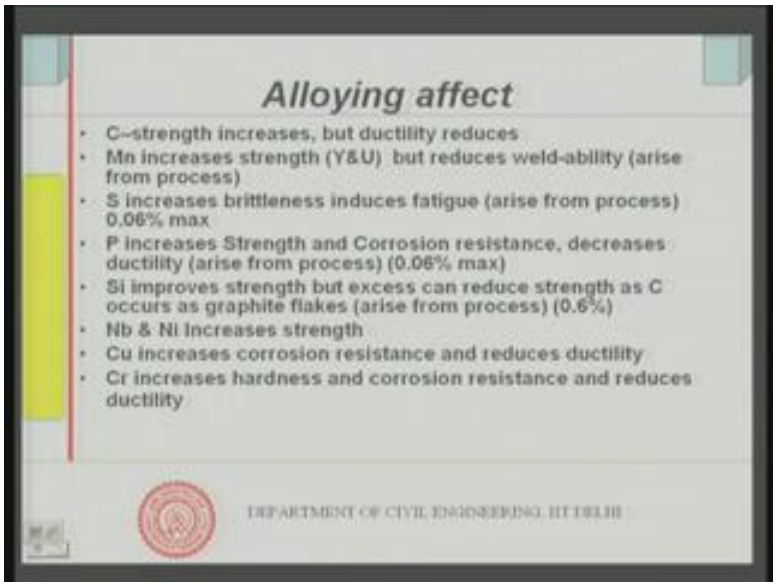

So, let us see a alloying affect on plain carbon steel alloying what we have seen so far, carbon increases strength but ductility reduces. But in steel while you are producing there are several other elements, which come through the processes those you do not add them, but several other elements which come to the processes and control there percentages.

So, specification of this steels will say this much should not be more than this all you know that kind of thing or ranges of the percentage of this material, that should be there is actually specified in most of the time in the codes. For example, Manganese it arise from the processes and it increases the strength both yield and ultimate strength, but it reduces the wide ability.

So therefore, the percentage again this restricted in the relevant code. Sulfur increases brittleness induces fatigue and this also arise from the processes, because I do not over you are getting going the process might be getting something which would bring at this into the steal. So, this there it comes from the processes actually and this percentage is actually control 2.06 percent maximum.

Because, it increases the brittleness and induces fatigue you know low as done possibly fatigue strength. Phosphorous increases strength also increases corrosion resistance, but decreases ductility and it also arises from the process and it is maximum percentage as

0.06 percent specified maximum percentage is 0.06 percent. Silicon improves strength, but excess can reduce strength as carbon then focuses graphite flakes.

Silicon also arises from the process we do not have them in terms only, but and if you add too much of silicon. Then, the carbon come graphite and graphite flakes and whereby it is actually reduces the strength. So excess, but improves the strength excess can do this Nobelium and nickel increases strength. Copper increases corrosion resistance and reduces ductility; chromium increases corrosion resistance and reduces ductility. And these are the affect of various kind of a alloying in plain carbon steel.

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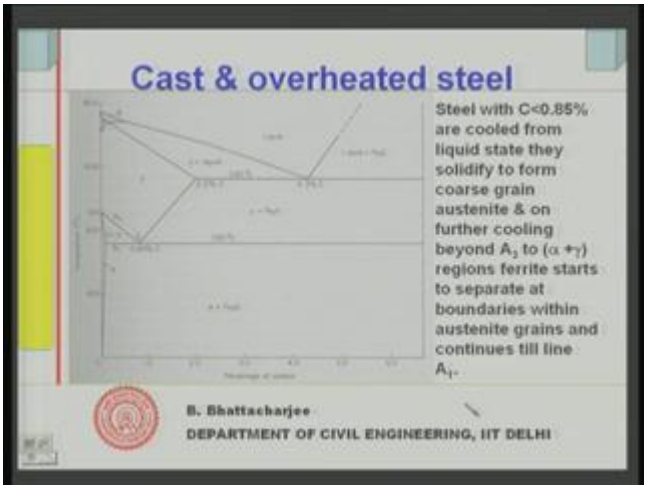

Let us look at, cost and overheated steel certain process we can do a plain carbon steel and will see that, they will enhance the property or kind of changes the property and make them useful from different point of different way. So let us see, what are those let us see what is cast steel. Now cast steel deals with the situation where, actually the steel is coming from the liquid molten state that means, it is coming from that this top most place it is a the liquid.

Then, we have dealing mostly with the situations where my carbon content is less than 0.85 the point is that I mentioned that they. So is less than 0.85 which as the steel having more than 0.85 percentage of carbon is not really much useful as for as civil engineering construction is concerned.

So, they have there off course other use in 2 link etcetera etcterara. But in civil engineering we are dealing with mostly low percentage of the steel with low carbon percentage is besides the cost which is higher, which will disused separately.

See if you come here, this is the liquid state and then you have a cost steel is produce by cooling it from cooling it from these situations. And let us see, what happens you see steel with carbon less than 0.85 percent when cool from liquid state they solidify to from coarse grain structure. So, austenite you know this is austenite if you remember if you recall our last class discussion.

So, you will fast deal with austenite liquid and then off course below 8.5 below austenite permission. And A3 line up to A3 line it will all austenite formation, if we cool it further beyond A3 and go to A1 you know the here the combination is freight plus austenite. If you remember again from our previous discussion, so alpha just is freight and this is austenite the combination of freight and austenite forms.

Then here, the freight will starts separate at the boundaries within the austenite grains and continuous still A1 what will happen? You know if you come from here first liquid then, you have come somewhere here it all austenite formation and then as you come down to this A3 beyond A3 at the austenite again boundaries freight will starts separating about and that is will form delay 1. And if you go further beyond this then what will happen? Well will continue with this and we can see that on cooling below A1.

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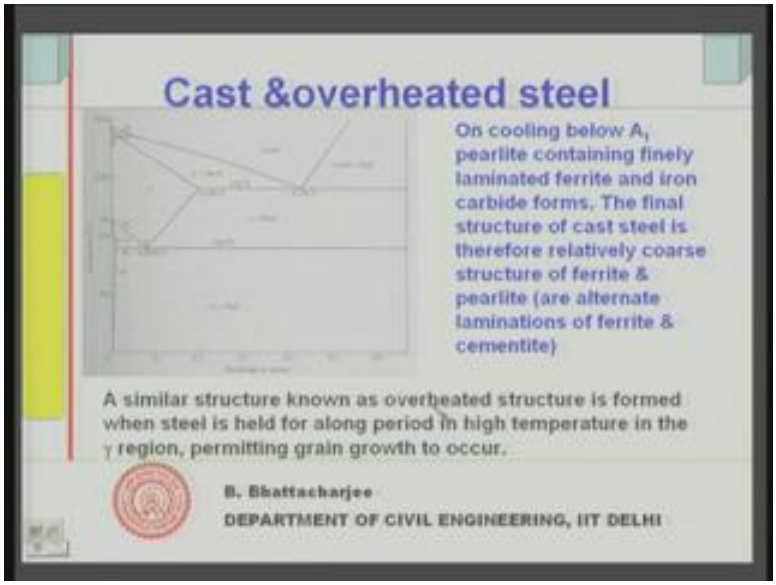

That is this line, this line, cooling below this line, pearlite containing finely laminated ferrite and iron carbide forms. Now, in this region you have got ferrite and cementite which is iron carbide right. If this is what it is and this is called pearlite. So it has got finally, laminated structure laminated ferrite and iron carbide forms. There in alternate laminations of ferrite and cementite right, that is got a look of the pearl.

So, that is why they called pearlite which below 8.5 percent this pearlite form take place. The final structure of the task you therefore, relatively course structure of ferrite and pearlite. Now this has got a poor structure laminating, because the greens there has form that there is not be fine and it has got poor structure.

And that is for and that is ferrite pearlite is a structure of the mile steel below you know 0.85 plain covers steel below 0.85 percent of the carbon. You can get a similar structure known as overheated structure, when you heat it up at this region; you know when steel is heated for a long period in high temperature in this region and permitting grain growth to occur.

So, this is cast and this is called overheated steels of cast steel you look like this. It will have a ferrite pearlite structure and what is pearlite? Pearlite is essential affect ferrite and I mean it has got alternate laminations of laminates of ferrite and cementite. So, this is what you will have because alpha is the ferrite plus carbureted this together this is what you get in mile structure. So, one can see this and microscope the structures and 1 can see this in microscope the structures yourself right. So that is what it is…

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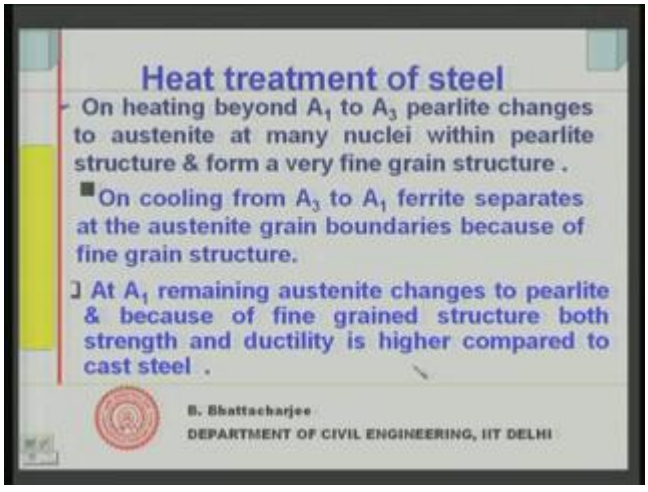

Let us see what happens when you treat the steel heat treatment of the steel right. Supposing I have this steel same ferrite structure now, I heat it up. So, if I heat it up to say first A1 and then to A3 this pearlite up to this is A1 nothing will happen. Because, it is same structure and beyond A1 what will do? What will happen? Pearlite will change to austenite at many nuclei within pearlite structure and form a very fine grain structures.

So, when you a cooling it cast steel that is got a core structure of ferrite pearl when you heat it gain there was say. And go beyond this point, go beyond this point, towards A3 the pearlite will change to austenite and since it starts in many places, many nuclei. What will happen we have fine grain structure at many location that will start and within that pearlite structure itself and form a very fine grain structure, right.

Then, again let us say with cool it back so we heat it and if we cool it back from A1 to A3 ferrite separate at the austenite grain. So, now we have got very fine grain austenite structure forms and when I cooling it back this austenite will tend to start again form and ferrite and that the grain boundaries, because of fine grain structure of fine grain structure itself.

At A1 all remaining austenite changes to pearlite and because of fine grained structure both strength and ductility is higher compared to cast steel remember. We said that, when I have got fine grain structure then it strength increases. So therefore, in my cast steel actually did not have a very fine grain structure.

Now, with this heat treatment I can get a fine grain structure and therefore, what you can see on heating beyond A1 to A3 pearlite changes austenite and when nuclei with in pearlite structure and form very fine grain structure. So that is very important on cooling from A1 to A3 that is start we show ferrite separate as the austenite grain boundaries because of fine grain structure.

At A1 austenite changes to pearlite, because of fine grained structure both strength and ductility is higher compared to cast steel. So, that is what it is so heat treatment gives you a better structure in terms of fine grain structures and therefore, its strength ductility increase. Let us see, some other processes which you can change.

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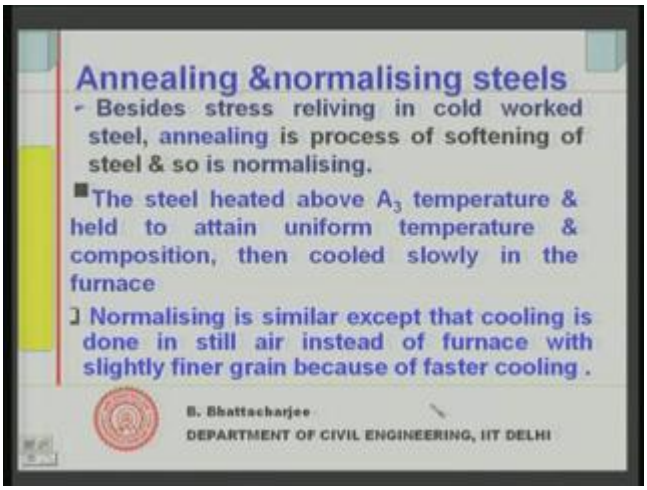

Now, this is one thing, so I increase the strength and ductility. But I might like sometime to so finite out for machining. Now, those process which are involved annealing and normalizing. Now remember will talked of annealing in the case of strain hardening, if I want to relief this strain hardening what I did? I did any link I heated up beyond re crystallization temperature and when I cool it intricate lights and all the history of strain hardening was lost.

Well this is different this is not we are not really looking at the stress leaving. Annealing is a terminologies in both cases, here it is used not to the strain harden. But 2 simple plain carbon steel right, so besides stress reliving in cold worked steel, annealing is the process of softening of steel and normalizing also does a same thing. Let us see what this process the steel is heated above line A3 this line is A3 line and we remember just in the backgrounds same equilibrium diagram have. Because, we have repeating, so the system has potted in the background if we can call.

So, A3 is here and right it is heated above A3 temperature and held to attain uniform temperature and uniform composition. So you heated beyond A3 line and we are discussing all steel with 0.85 less than 0.85 percent steel have been 85 carbon. And see if we heat it up, for sufficient time so that, it becomes uniform in structure then also in composition.

So all grains become actually austenite, right composition and then cooled slowly in the furnace. So, when cooled slowly in the furnace that is what is actually annealing process. It actually in this process you will get actually course grain structure resulting in

softening of the metal. Normalizing is similar except that cooling is done in still air instead of furnace and therefore, it is a cheap a process and it has slightly find again because of faster cooling.

Since cool very slower process the grain formation will be course and you know in this 1 it was cooled in furnace. You will have a very slow process of cooling and there is why you get on finding structure right. And we come from a A3 to below that is why it is. So, essentially the steel heated above with 3 temperature and held it to attain uniform temperature and composition then cooled slowly in the furnace. So, normalizing we put it in steel air and do the same thing.

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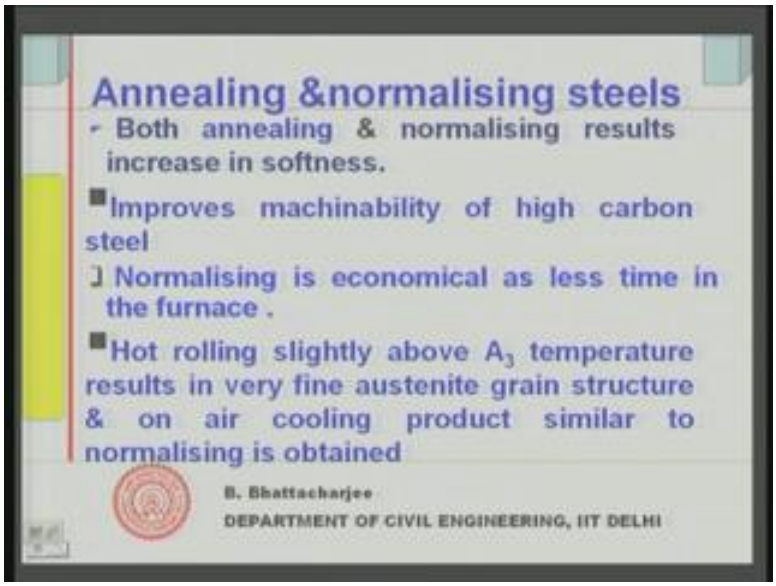

What does it do? This effect is both annealing and normalizing results increases in softness, because the course name structure. So therefore, it is soft; this is not strong and what does how does it help? It helps us machinability of high carbon steel Helps us in machinability you can cut or machine it easily. Last normalizing 1 that is the last 1 out of the 2 is economical as less, because we put less time in the furnace let us got slightly fine grain structure.

So, we process steel by hot rolling process and hot rolling slightly above A3 temperature results in very fine austenite grain structure and on air cooling products similar to normalizing is obtained. So, when you hot roll slightly above A3 temperature results in

very fine austenite grain structure and then cool it something products similar to normalizing, we gets hot rolling is gets as this kind of product which is machinable right.

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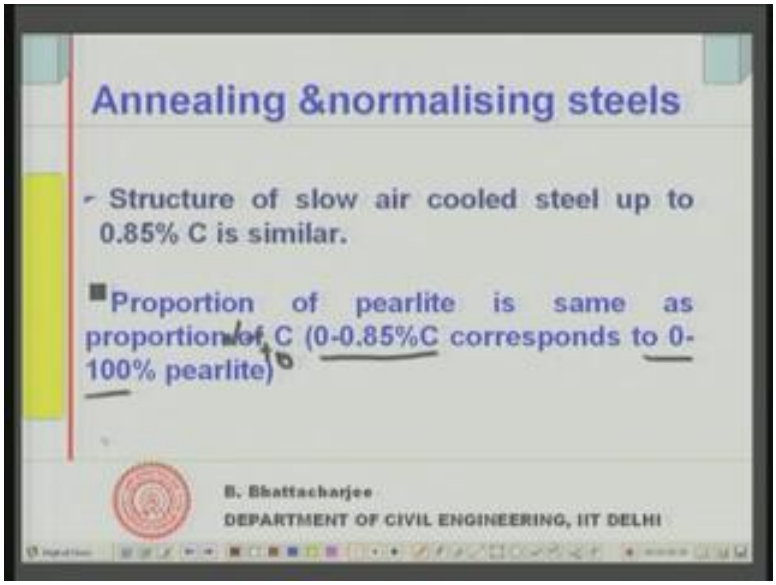

Structure of slow air cooled steel up to 0.85 percent carbon is similar and 1 important issue I would like to tell you is, a proportion of pearlite is same as proportion is proportional to actually proportional pearlite it is proportional to percentage of carbon proportion of pearlite is not same,, but it is proportional to carbon percentage that is going carbon percentages is vary from 0.85 percent 0 to 100 percent pearlite.

So, at 0.85 percent carbon you have 100 percent pearlite present pearlite is 100 percent and if you have less percentage of pearlite will change according in the structure, From the percentage of pearlite in the structure of the steel, we can find out for the percentage of carbon in directly, so this is what it is right.

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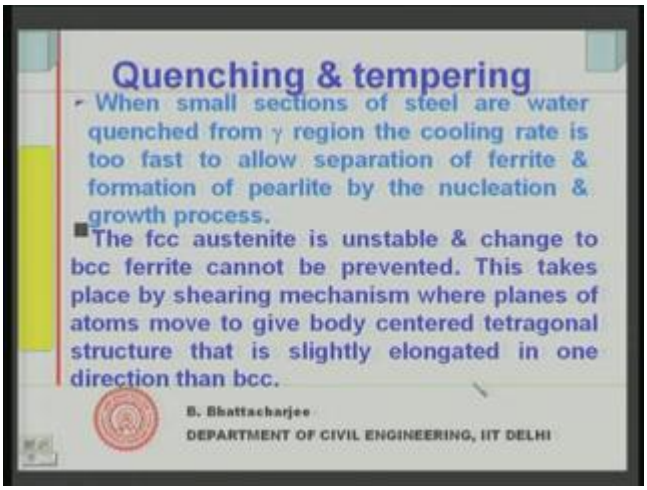

Then look at, another process how you change or improve the properties of the plain carbon steel the process is known as quenching and tempering. And you will see some of very important for as last time, last lecture will discuss about strain hardening which is very important and now, will see this is very important because use many of the strain forces steel based on both this principles.

Now, what is quenching? When small section of steel are quenched with water or water quenched to form austenite or gamma region right. Quenched form actually austenite region from gamma region, the cooling rate is too fast to allow separation of ferrite and formation of pearlite by the nucleation of growth process. What we doing, we heard if you remember in this austenite region; gamma region I heat up.

So, this steel are even if it is cast steel I am producing when I am producing it a rolling model what I am doing I am now quenching it at a very rapid cooling you know quenching with water therefore, actually rapid cooling takes place. Now, these cooling become so fast that it does not allow separation of ferrite formation and formation of pearlite is not possible.

So, below from this region if I am cooling it here this formation of ferrite alpha and then formation of pearlite is not actually becomes possible, Because, nucleation and growth process has hampered, right this is not this restricted. So what happens? We know that, this is actually face and that cube austenite it is should become body centered cube.

Now we are cooling it rapidly and such condition face centered cube austenite it is unstable. But it does not have time to get quickly convert in body centered ferrite structure. But since it is unstable it cannot be prevented also, something in between happens something else happens. And it is actually some sort of body centered cubic formation takes place.

But this takes place by sharing mechanism, where plains of atom move to give body centered tetragonal structure which is not same as a ordinary ferrite. But it is a kind of elongated in 1 direction right so it is not same as the original, because now it is cooling rapidly. So the original structure formation is hamper, the nucleation process cannot take place.

But when it is cooled actually the austenite structure is not also stable. So it is tends to from something which is different than the conventional body centered cube ferrite structure. It is forms body centered cube, but it has it got slightly elongated face elongated in 1 direction. So that is what happens, when you are try to come from this right,

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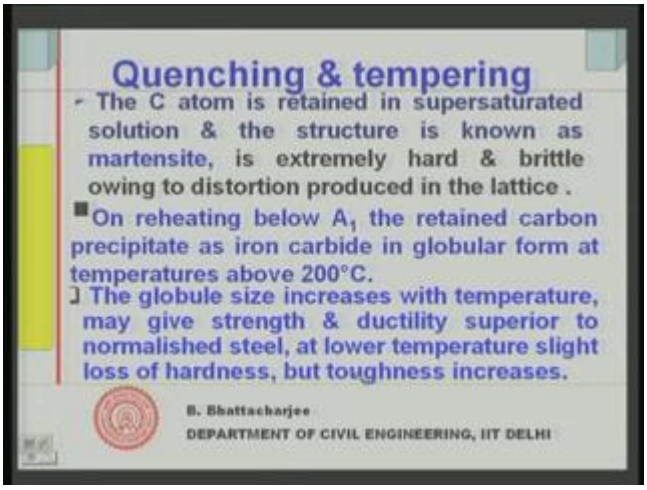

The result is off course, you can see the results is C atom remain off course it remains it goes interstices goes all right forms a solution. But it is in a supersaturated states, it forms a supersaturated interstices solutions and the structure is known as martensite, which is extremely hard and brittle owing to the distortion produced in the lattice. Because, now the lattices become distorted and going to this distortion the structure is extremely hard when it is also brittle; extremely hard in brittle right.

So, quenching produces in an extremely brittle and hard structure martensite alright. If I heat it below you know, if I reheated now that would what would form just if I leave it like this But supposing I reheated below or allow reheated below and you know then what will happen the carbon then iron carbide forms in globular form.

So, when I heat it reheat it up to 200 degree centigrade the retain carbon precipitates iron carbide. Carbon that was retaining precipitates is iron carbide in globular form at temperature above 200 degree centigrade. And this globule size increases with temperature and may give strength and ductility superior to normalized steel. At lower temperature slight less hardness, but toughness increases.

So, if I reheated up to 200 degree centigrade and above the carbon which was there is gets precipitate into a globular form and that is gives you higher strength. If I reheated slightly high temperature steel get highest strain, but if I do it as a slightly lower strength temperature off course I get slightly less strain. But still it will be much higher than the normalized.

So that is the idea of a quenching and tempering, so first I would be quenching quill it rapidly and if I reheated it will be heavy like this. So, similar sole of effect I can get first I quenching, but then do not reheat it. But allow it to actually cool it slowly are temper that portion that is temper it by retaining the heat slowly along to slowly. So that, it remains temper it does not first cool it quickly then you reheated in a way in cool it and then reheated and that is what you get it. So, by tempering process that is what you get right.

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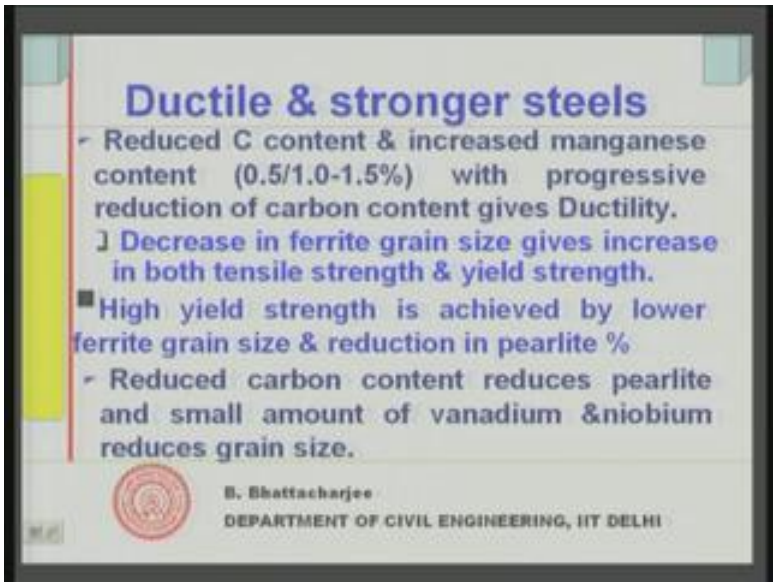

So, this is the process of quenching and tempering it will useful as you see using this process actually we get what is called thermo mechanical re treated reparse. We will discuss is some time later on in 1 of the lectures right.

So let us, how we get the ductile and stronger steel did use carbon content and increase manganese content with progressive reduction of carbon content gives ductility.

So, if I want to get ductility manganese is used to get ductile steel, and then if I want to get strongest steel decrease in ferrite grain size; gives increase in both tensile strength and yield strength this is 1 issue. The other way is, to high yield strength is achieved by lower ferrite grain size and reduction in pearlite. So, for reduce pearlite is low carbon high yield strength and therefore, if I combine this aspect reduce carbon content, reduces pearlite and small amount of vanadium and niobium reduces grain size.

So, we talked about when niobium earlier and niobium nickel, so this niobium is actually able to reduce the grain size and vanadium wants able to reduce grain size. So, I reduce the grain size lower carbon content strength increases. So, it is 1 of the way get stronger steel course the process we have seen is certain process you can get stronger steel right.

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So, what you have seen in case of plain carbon steel generally off course you use mostly wide steel which is less than 0.25 percent carbon and normalized steel quit often be using, because we need also machinability etcetera. So, that is what you do and normalized you know normalize steel quit often use for structural purpose and that so what most commonly used.

But these special types of treated steels are used in fact, more in river and when you discuss about river will see their utility. So, some this special steel off course special places again special steels are used. So, when you see some usage for example, persistence steel or cables, suspension cables would discuss about the steel. And whatever we discuss so far will give us a proper understanding, why we use those kind of steel in such situations.

But 1 major problem with steel is off course, satiability high temperature. Because, we know the twince acceptable to high temperature steel cannot with stand you know it fire resistance are much poor compare to concrete and therefore, you usually what do you do actually cover the steel up with concrete. And case it concrete or sometime we put it in gypsum boats or water feel column extra this is 1 usage which of course, we discuss in terms in term in the connection with fire protection.

So, gypsum concrete in field I mean what you called enclosed column steel or steel structure numbers reduced to take care of file protection. The other issues of course is,

corrosion protection and see what you do you like to corrosion protection. Corrosion of course, in steel when we are looking at it; it can be dry corrosion in this occurs it high temperature thus would march up on interest. But we know about wet corrosion, you know that is electro chemical process we have discussed it at length in the connection with rework corrosion in concrete.

So, Here will not discuss a corrosion process, but you know that it is a and it is electro chemical and occurs in electrolyte. What we do to protect again corrosion is protective coating of paint, Aluminum or zinc are in various kind of protective painting in organic you know a proxy, paints are various kind of paints or aluminum or zinc coating would you apply.

We can use Cathodic protection may be what you do is we actually, since we know that corrosion in electro chemical process we apply current from outside what is known as impressed corrosion. Such that, it neutralizes the affect of the electro chemical corrosion current also, a second method could be make your steel a cathode instead of a node.

Because, we have seen it a node the metal dissolves a cathode off course some other reaction takes place. Supposing, I put metal which has got more corrosion tendency then the steel is itself and connect it together, invite structural system. Then, that metal is self will create and protect the steel that is score sacrificial node. A detail of this is not off course, in scope of our discussion, but cathodic protection is measured used as a regulation practice in barred steel pipe.

So, where, we use over all in an off sources structures, so wide we use actually sacrificial demo such a aluminum. Because, relatively cheap remember that process is farley costly, because in sacrificial node from time to time. The node that has been scarifies that is aluminum node, which has become a node which connect to the steel to protect the steel make steel Cathodic.

The Aluminum be consume with time and then you have to replace it so; this is the costly process and wants to monitor also the corrosion quit often. In impress current you can have better operated, so you apply so an auxiliary electro the current into the structure and protect it, by opposing the electro chemical corrosion.

So, this is cathodic protection but again this corrosion on this not really in the scope of a lecture detailed this corrosion we just introduce this steel. Coating forms barrier I just like to give some formation about coating; coating form various aluminium or zinc coating you know zinc coating is applied.

Now, this once when applied them from their own oxides right quickly the form oxides at the surface of the steel and provides a barrier for further corrosion to takes place. Addition of copper and some other alloys like, chromium stain less steel you know and its other chromium high percentage of chromium.

So, this is this do not corrosion steel that is, but stain less steel cannot be use in structure accept in exceptional cases, because is very very costly relevant will be very costly. But in exceptional cases 1 may use even stain less steel which does not crude Because, it is the exposal condition which dictate. So, that is about corrosion protection increase amount of phosphorus chromium is protective oxide against corrosion as I said.

So, all this corrosion protection you know forms kind of productive coating, because they themselves from oxides. And this oxides is actually also barrier, between the outside environment and the steel and day by protection steel. But remember maintenance of steel is relatively costly, because you have to pay from time and again when it lost again when it would a plenty to protect it.

After all steel is produced is in nature not available in, iron is not available in metallic form pure metallic form is actually in form of prides or oxides. So therefore, it will have a tendency to get covered it and we produce iron at the expense of considerable energy. So, you would like to dissipate this energy with raise its chemical potential in other words.

So, would like to dissipate that energy come back to the normal state of its potential and therefore, I do not have you will have a tendency it will form oxide. So you protect them rate of this oxidation we reduce that is what you said discuss about the river corrosion also. And that is what you like to reduce it down and that is why you may to domain maintain it through painting or whatever the cathodic protection.

But it is a costly process and this is 1 reason, why it has not been used in countries where concrete is cheaper, but never the less steel is also equally useful material for us, not only

that in concrete you cannot do though steel enforcement where as you see in our next lecture let steel is a best enforcement till date. So, that is what it is following of corrosion protection found detail can improve your corrosion protection very easily.

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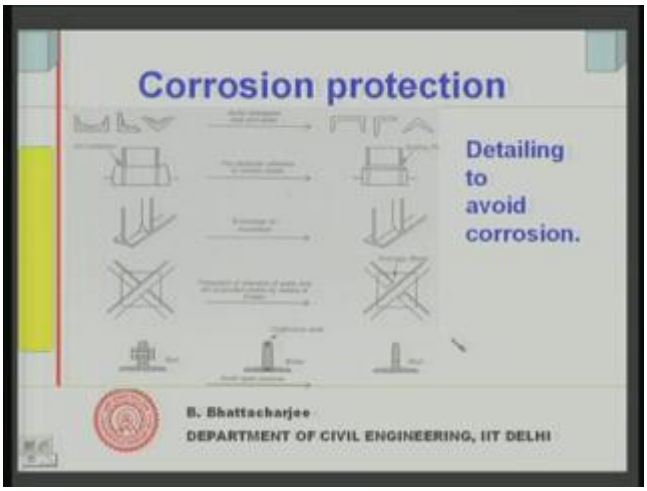

For example, do not allow dot 2 accumulate or you know what are dot 2 accumulate, so you if your structure is something like this dot accumulated here right. And if it is something of this kind, so detailing of the structures you know then dot cannot accumulate here right. So, dot collection should be avoided so you know, attention to dot collection.

For example, if there is a tray trap like situation here or tray where dos can collect; if it is other round then you can if you select up actually then they have this dos cannot collect. So, dot collects it will attract more moisture both moisture and oxygen is available corrosion. Accuracy actually corrosion is a phenomenon, where presence of what are in oxygen is mass.

So, we can keep the structure no both moisture out of it and oxygen you cannot keep out, but moisture out it would actually ensure that there is no corrosion.

Similarly, you have something like this, you have something like this and something like this water can actually air movement will be relatively less. If the air movement is available in the particular 1 this 1 is like this, this particular plate was something like this now here this allows for air movement. So, if air movement the moisture will be go away paper cannot deposit and therefore, corrosion protection.

In fact, what you have done you have provided a gap between this top. This was actually connected completely joined here with fill it does you can see. Now, if you leave with slightly up so air can move easily and therefore, no more moisture, no air and air movement ensure that there is no moisture vapor condensation here and drying of is easily and therefore, corrosion it will protect from corrosion.

Similarly, if you see if you provided sort of drainage break, if you provide instead of this drainage break is provide them water will not really penetrate water will not strict here corrosion of the prevention of corrosion principal. So, this detail is very important as for as steel is concern for example, this is bad which will allow water will come in, this is better no water can penetrate and this is the best.

So, does no water can actually accumulate here this will have bolted. So, water will accumulate here and off course the corrosion will proceed it is weld at between water can still go and what is this join get together thus. So, by detailing when improve the corrosion protection in case of structures as you can see here right; this is important to avoid corrosion.

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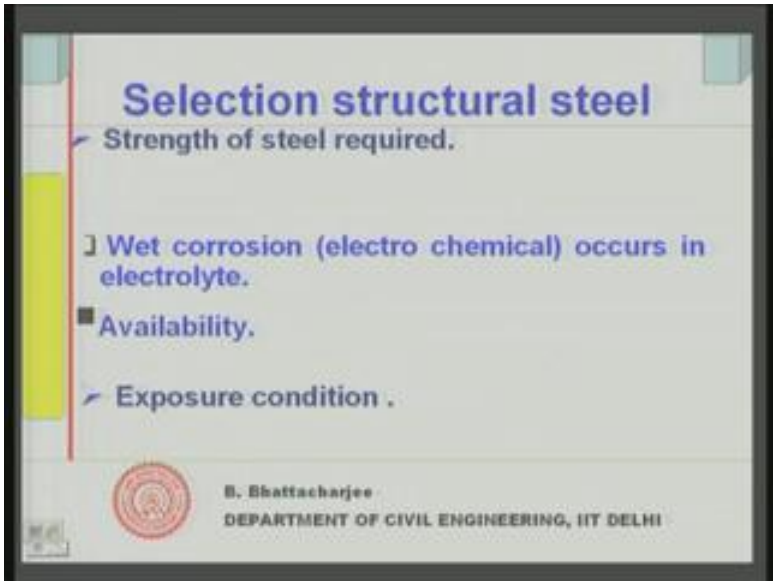

How do you select them structural steel? Strength of steel required as you have seen strength of steel is mainly requirement. Then, corrosion is important is issue we have to see you know, because steel you cannot steel thermodynamics is lonely is tend to have form oxides.

How to see that environment expose condition is very, very important .So, expose condition is important availability is important ductility and other mechanical properties are equally important. Other mechanical properties are also important and other mechanical properties availability exposure condition you know protection in corrosion, which steel is available. Supposing a steel is not available you cannot use it, available to be once a major factor go 1 what is our requirement what still I am going to use.

Exposure condition would decide again what steel I should use because; if it is highly corrosion coin aggressive environment then you have to choose steel according. So that is chemical properties over all right now. But I mention that fire properties is not as good, so you normally use and case is you can have better improve fire steel with improve fire is since today bonds steels are have other, which have bought better file distances.

But it is 1 of the drawback of the steel, so we normally structure a members used a buildings as similar situation you know stable to fire or fire haste what you do in case a steel, in either in concrete or in gypsum.

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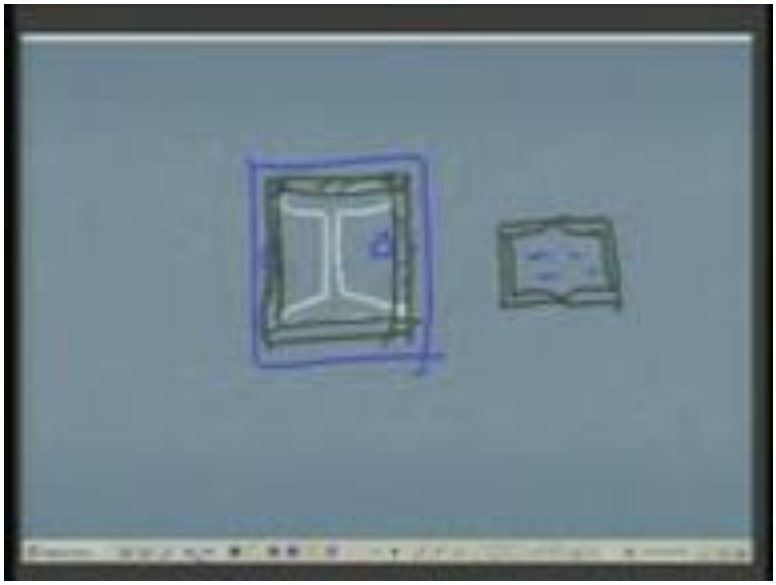

I just like to give you the example of this 1, because if this is my steel section. Let us say, this is my steel section you know you say high section let us say. So, what we do is we make concrete enhancement here; encase this concrete encase this concrete, so provide

fire protection; or we can encase this in something like, gypsum board you can put gypsum board here.

Because, we have seen that earlier 1 for earlier exchange itself gypsum is a very got very good fire resistances. So, I can provide gypsum boards here or incase here in concrete sometime we have what is known as water field column. For example, the columns systems like this is like channel this channels made in to box write this is a channel section. So, this is used in very tall buildings this has been used channel section you have water here you have water field columns.

So, such columns all of them will connect together and you have went at the top for your position, etcetera, etcetera; this is a used in very formality story building. So, wherever there is a problem related to you know where ever expect the fire has a disable there in that case you use steel with enhancement or you know you use steel enhance steel members or use actually provide encase them in concrete or in gypsum.

So that is the kind of fire protection measures we use for steel right. So cast iron is one of the steel that is used you have talked about the ductile and slightly high steel and then cast iron is another product which is used of the iron carbon system.

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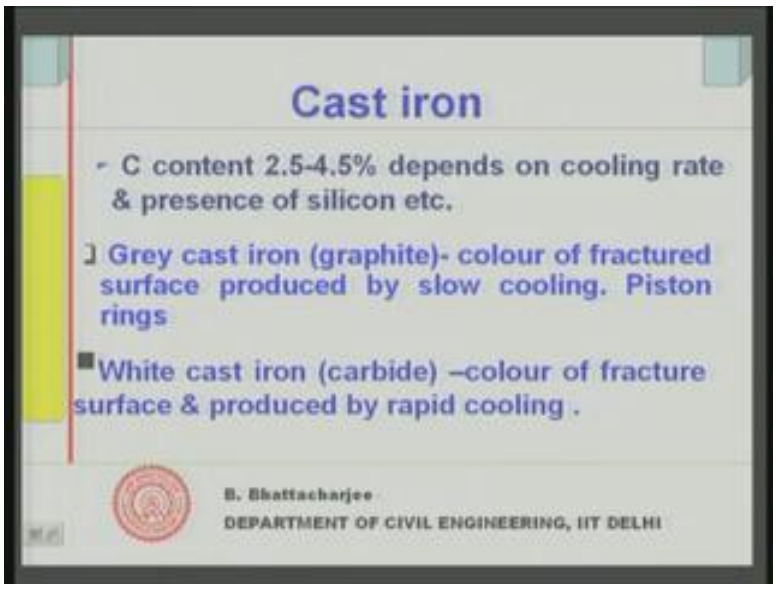

If a system this has got 2.5 to 4.5 percent of carbon and depends up on it is you know dependence is property depends up on cooling rate and presence of silicon extra. There

are 2 types of cost iron: grey cast iron and the name comes from the color of the fractured surfaces right. And its produce by slow cooling, generally used in piston rings extra, extra you have graphite present in then.

White cast iron will have carbide and it is produce from rapid cooling and the color of the fracture surface is white and that is have its name right. This is also used cast irons again they have high resistance corrosion. So, used in waste pipes, silver pipes and so on some pipes CI pipes are quite commonly used. All though these days off course, they have been replace by a large with polymeric, PVC and similar other pipes right polymer or plastics pipes. But this is be used when very much there in use.

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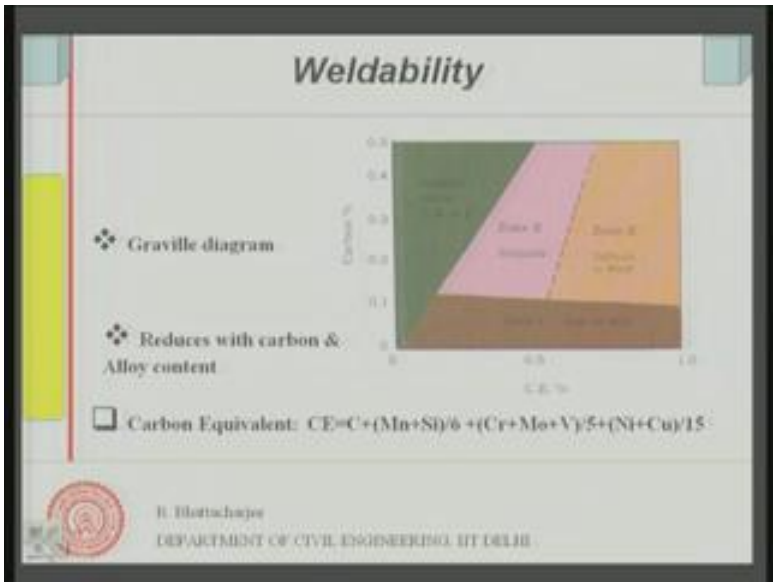

So, one issues Weldability is another major property and we see that, Weldability we can find out. So what is known as graville diagram and looks like this right. Now, this reduces with carbon and alloy element as I explain this diagram little bit later. But let me just look at this, the more the alloy element I had into the iron coldabilty reduces. And we have something called carbon equivalent, which is plotted on this direction this called carbon equivalent.

Carbon equivalent you know which is plotted along this direction and carbon equivalent is define C plus manganese plus silicon divided by 6 chromium divided 95 and nickel and copper divided by 15.

So this your carbon equivalent and this side is your carbon equivalent is obtained by this equation and this is your carbon. So, as I increase my carbon equivalent percentages and carbon percentages this line is 45 degree line because carbon equivalent test C plus some thing. So, this will be always greater than the carbon percentage so this zone is invisible zone. This zone is weldable, this zone is difficult to weldable; this is readily weldable.

So, what we see is as my carbon equivalent increases along this direction for a given carbon content. Let us say, this carbon content this becomes difficult to weld. So, reduces carbon and alloy content; Weldability reduces with carbon and alloy content right, so this is Weldability of plain carbon steel.

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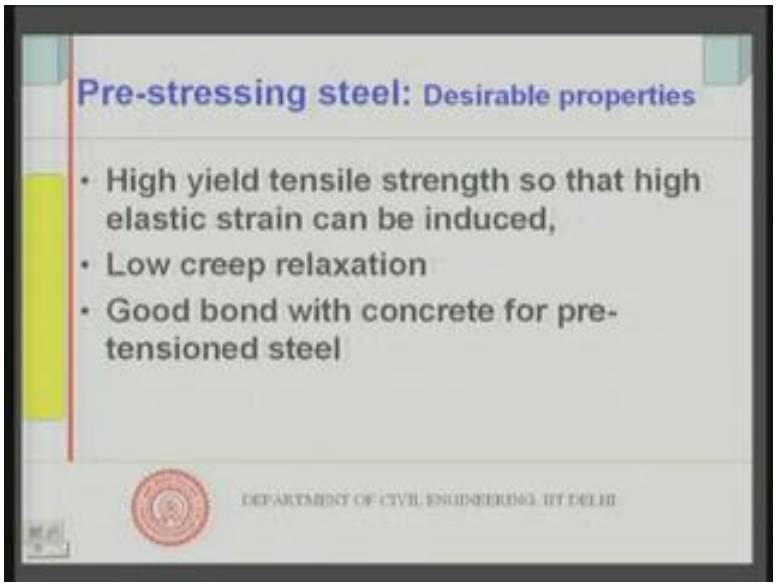

Let us, discuss some quickly before in this lecture discus some usage and some of the steel that use in cases like, pre stressing steel. Now, what are the desirable properties of the pre stressing steel; it must of high instance you know why you do use pre stressing steel? You might discussed or mention this sometime in connection with the concrete.

Concrete is week in tension it is brittle, so to improve it tensile load carrying capacity we either rain force it, and then use a composite call rain force it. The other ways to please stress it, using some steel, so what you do? You have you pull the steel wires are strains are whatever they are and then hanger them into the concrete. Something like this, its looks something like this pre stressing is look like this you might have seen it, but still just recall this see if we look like this.

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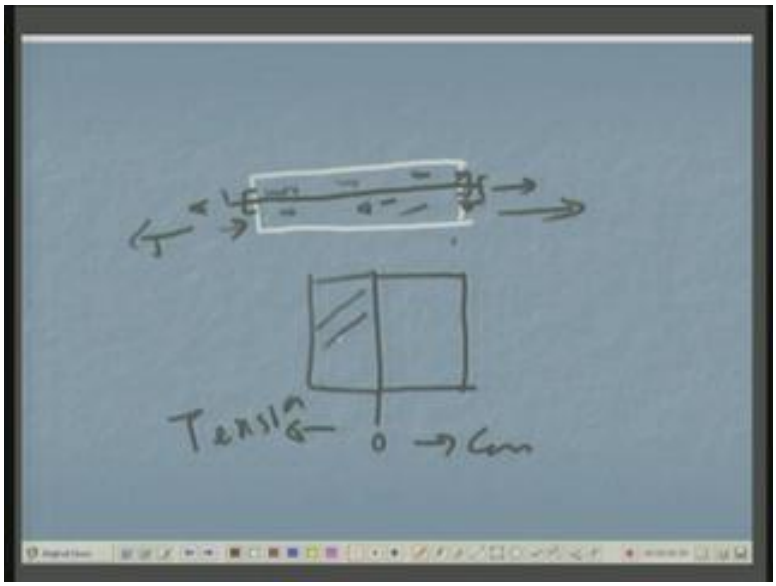

Let us, say is this is your concrete specimen just let say beam element then, I pass where through this a simple case that have pass the wire through this I am pool it. After pooling I anger it up here, simple case I anger it up here. So, when I anger it up here what will happen? Since have already pulled and given some strain to it may be last week or within last week range.

So, what will happen? It try to short him, because I have pulled it up put some stress to on to it and then it will this will try to actually short term. So, when this is try to short term this will actually apply a composite force on to the concrete.

So, the concrete is in initially under compression. Now when we actually apply tension to the concrete structure and cut of this, map of this wires, so I have a composite section where I have a peace testing wire which has been pulled and put is anchor this concrete is being compressed. So, under free compression so if it is free compression you know this is the compress stress then I apply some tensile stress.

Tensile stress this is 0 stress, this is 0 stress, this is compression and this side is tension. So, apply some tension on this side it will neutralized this compression able to with strain this. So, a pre stress concrete member would be able to which tends amount of tensile stresses, because concrete itself if we can tension. So by pre compressing it, I can make the concrete system to actually some amount of tension and extra, extra.

So details are of course, not really part of hard disk at the movement, so pre stressing is that. I actually pull the steel and this should have high yield tensile strength. So that, high elastic strain can be induced right now, you mention about low creep relaxation in case of concrete. So, this under load if it is deforming so I have pulled it up and if there is a creep and it is deformed some amount of relaxation.

We have seen that, in the change situation there is a relaxation in case of concrete; same thing happens I case of steel also. So, this should have low creep relaxation otherwise the pre stressing lost should be there; high pre stressing laws will be there. So this are the property desirable of pre stressing steel.

It should over good bound with concrete for pre tensioned case, that I have talked about is a pre tensioned situation, where you cast the concrete after over the pulled pre stressing where as strength. You know first pull the words and cross the concrete just about it so; the compression from the pre stressing wire to the concrete is transferred through bond. So, where it is transfer through bond I need good bond strength also.

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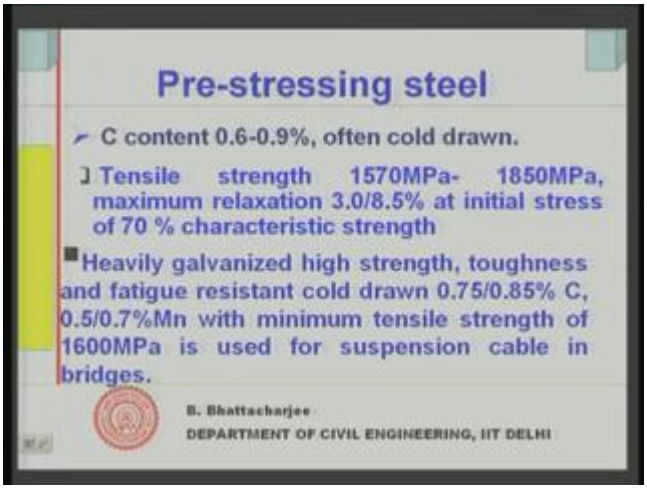

Therefore, these are the desirable properties so what kind of pre stressing steel we use? Is carbon content is 0.6 to 0.9 percent often cold drawn, work harden cold drawn; to increase tensile strength right. Carbon content is this much tensile strength might rain form from 1570 MPa, about 1850 Mpa, maximum relaxation is 3 to 8.5 percent, at initial stress of 70 percent characteristics strength.

So, this is the property of the pre stressing steel we desire under what is the know that is why we have carbon content this, and then strength something like this it is cold drawn; this will cold drawn. Heavily galvanized high strength, toughness and fatigue if you are looking at cable; cable suspension just like cable. This is another kind of a steel which as, sustain high tensile strength; it stresses high tensile stresses that is must high tensile strength.

Suspension cable of cable suspended bridges, but there expose to also corrosive. So therefore, they are Heavily galvanized high strength, high toughness right they should be able to which stand a lot of fatigue, because there will be horizontal movement did you went. Suspension bridges cables are they have to there are lot of horizontal movement of the deck.

So, it has to it stresses related to this swing of the decades extra extra therefore, it must have lot of toughness or impact it has to which tend. Good fatigue instance, because reversal of stresses would be there right. Because, not only because of the role load of the deck, but also because of the forces.

So, you need high strength, toughness and fatigue resistant therefore, cold drawn with this much 0.75 to 0.85 percentage of carbon and 0.5 to 0.7 percent of manganese because easily ductility and therefore, then toughness. So, render the stress under curve will be higher, with a minimum tensile strength of 1600 MPa is used for suspension cable in bridges.

So, pre stressing steel we have seen the usage of the other types of you know high strength steel in suspension and that is now it is clear, why do use this manganese because it will make it that type and this has to have high strength therefore, this is what do use should have high strength. Therefore, use actually percentage of carbon is higher and then again the cold drawn.

So that, work harder to get a very relatively high strength and you can see, that normal mile steel useful strength is about only 250 mega pascal that is was use enforce steel other which will have about 415 or 500 MPa useful strength proof stress 2 percent proof stress. But here we trying to look at the get the strength, which is about 1600 MPa off course, a useful strength would be this and this is what is used for suspension cables in cable strength bridges.

So, I think this should finish our discussion on structural steels what is left off course, the river when enforcement by and that is what you will discuss in the next lecture.

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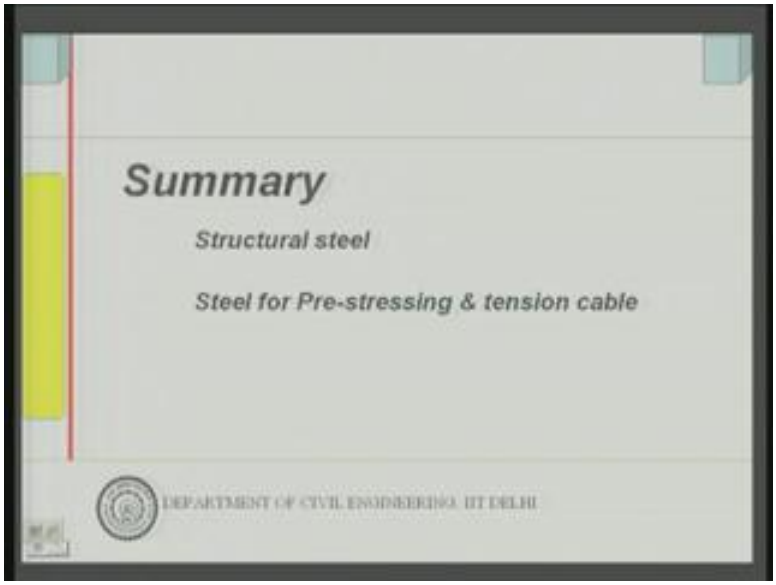

Now in this lecture therefore, we discussed structural steel. Plain carbon steel and the various process by improve this plain carbon steel or make them useful in different manner. Some of them will discuss in the already a lecture, name the strain hardening and then we have now also look into cast iron and some utility somewhere, the use some steels special steel that are some steels that use in specific use in construction name in the pre stressing purpose.

Then tension cable suspension regions that is all well; this is the usage of steel plain carbon steel in nut sale or in brief in civil engineering construction. Then, there are several other usage which really did not discuss, because this is outside the time limit of this course. So, there was several other usage which are there while we use steel in construction right dibbed the special case which will discuss at length in one of our next lecture itself we discuss rebar use of rebar in steel head length. I think with this we can conclude the discussion.

Thank you.