Building Materials and Construction
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Module - 11
Lecture - 4
Steel: Uses in Rebar

Well, in the last lecture of the series of lectures that is module relevant on metal and steel. We shall discuss about uses of steel in reinforcement rebar reinforcement in concrete.

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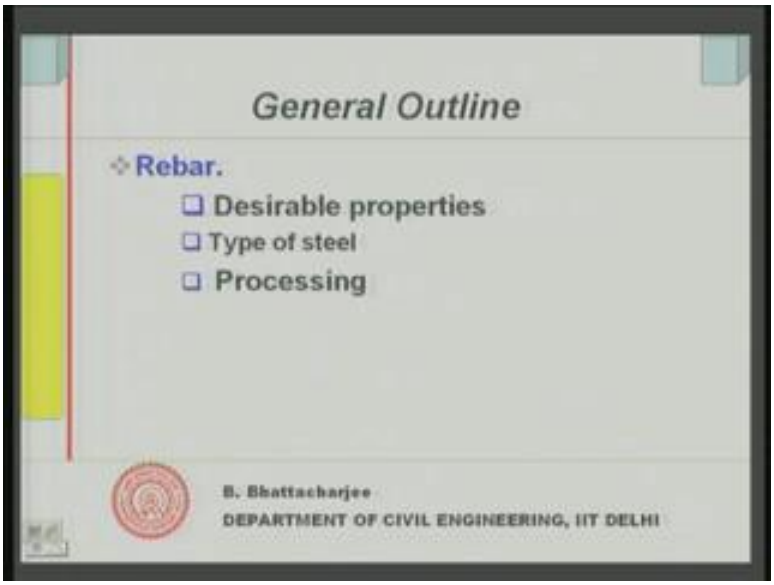

So, general outline of this lecture would be something like this, mainly will concentrate on rebar. Because is the reinforcement bar use of reinforcement bar in concrete thus the most commonly used location where in steel finds is use, steel is used extensible in construction as rebar more than, possibly any other use course in making shortening moles extra. But then other materials are which also go there for example timber, but reinforcement it is still date it is steel some from our steel or other forms. So, that is why this whole of this discussion today in this lecture would be debuted to reinforcement. So, first will discuss about the desirable properties, type of steel and the processing of rebar also will discuss.

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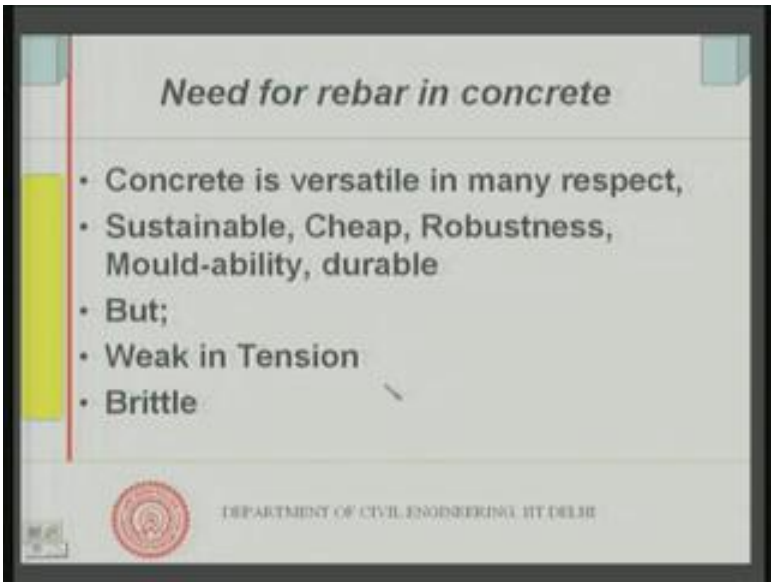

Now, why do you need a reinforcement bar in concrete; rebar is a short form reinforcement bar in which, commensally this reuse reinforcement bar in concrete. So, why need it at all you have seen that concrete is versatile in many respect but you also know.

So, versatility of concrete let us look back in to this, this is sustainable cheap robustness mould ability it is durable, but so you know that this is weak in tension and it is brittle this is note as you discuss are if stated this point time again, because concrete being a particle at system bonded with chemically bonded chemical bonding sort of; I mean, sort of inorganic material semen that boneset together not chemical bound through wended bonds out of there. But these cannot be very strong because bonds are not be very strong bond this bonds are not very strong.

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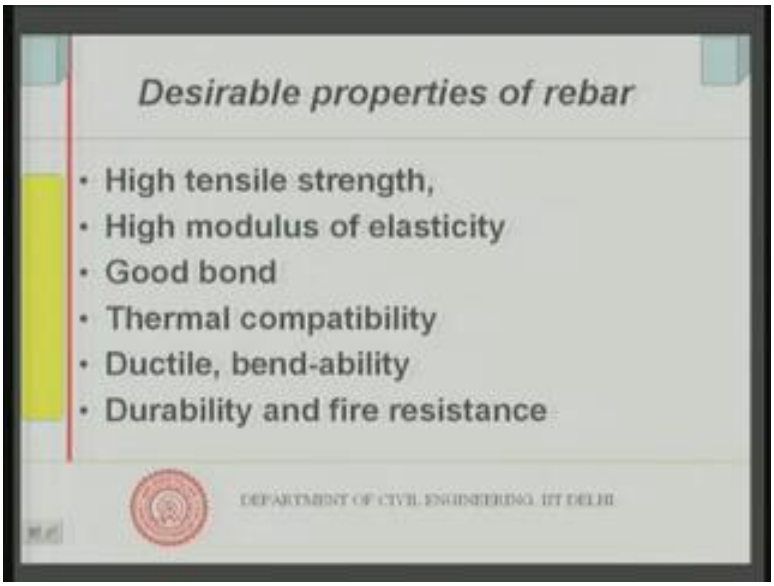

So; therefore, it is weak in tension it can't resistance and it is also brittle doesn't have lot of elongation to the capacity and on the other hand we know that steel has steel has got good tensile property. So; therefore, it should very well anyway desirable properties of rebar are it must have high tensile strength. Since, I am putting into the enforcement it must have good tensile strength, must have high modulus of elasticity if it doesn't have high modulus of elasticity what will happen under the same load it will deform more low modulus of elasticity, means; it will be form more modulus of elasticity stress divided by strain.

So at a given stress you will have you know if the modulus of elasticity is low strain is simply stress divided by modulus of elasticity. So, if you have low modulus of elasticity deformation was more, which would mean that it would since they have bonded together. Since the steel or the reinforcement and the concrete the bonded together the strains are same in both the material. So, if the strains are same and if the enforcement deforms a lot it will course, concrete also deform by the same amount are nearly same amount because this there will be balance between the 2 any way. So, it will also cast concrete to deform especially in tension.

So, you need causes concrete to deform in tension concrete will crack. So, it must have high modulus of elasticity to ensure that concrete does not crack in tension even after reinforcement. It must be able to errors that tensile crack. So that's why you need high modulus of elasticity of the reinforcement next have good bond with the concrete to transfer, the stresses from concrete to the reinforcement or vice versa. Very important property must thermal compatibility that is, coefficient of thermal expansion more less formula coefficient less similar.

If not, what will happen only expand mode the other supposing is not expanding whether same amount much less then, it will actually restrain the expansion of the 1, which expanse more relate causing actually crack formation because of this crack formation we can material. For example: suppose in steel expand or enforcement expanse more under the same temperature gradient and the concrete expanse, then concrete will try to resist this expansion and in the process it will be actually subjected to kind of tension and this tension will cause cracking of the concrete.

So, thermal compatibility is very important property it must be ductile and must be bend ability the ductile bend ability is property that's required of reinforcement, why need I need ductility because concrete is brittle. But my structure cannot be brittle my structure have lot of deformation capacity, it must give lot of warning before be failure and as you said in, some cases of esteem loading it must you know it must can be damage, but never collapse and that can come from, lot of deformation capacity rotation capacity in case of joints.

So; therefore, I need for structure snide ductility and concrete not being ductile reinforcement provides this ductility. Reinforcement must be bendable because my in the concrete element I like to bend them. So; therefore, this are the properties desirable and finally off course durability and fire resistance, there enforcement itself must be durable and it must be resistant fire. So, thus those are the desirable properties of the reinforcement.

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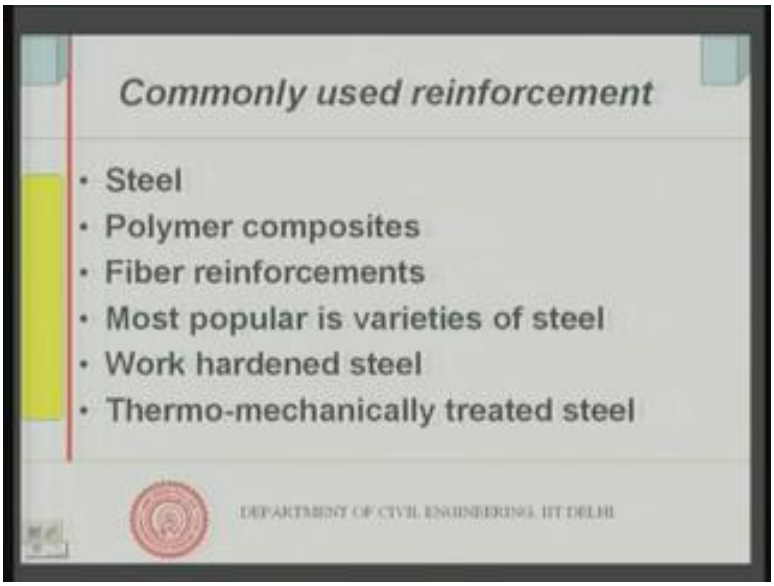

Let us see what are the commonly used reinforcement most commonly used polymer composites have been tried, but not much successful because the desirable property that, we talking about we don't get them they are will just discuss this at this moment in the moment. Well we have used fiber reinforcement also in concrete, but this is different purpose, they improve the crack restriction what is the matrix itself, but cannot sustain the kind of load 1, in structural load that comes let us say inflection member like beam, etcetera.

So, the fiber reinforcement is definitely note the reinforcement replacement or mentionable reinforcement. Fiber reinforcement is there, but there definitely not the replacement for reinforcement. Therefore it is steel finally steel is fiber the best material there has been used as, the reinforcement compare to steel, because it more or less satisfy most of the properties that, we require from there reinforcement will discuss this some of this point, but most popular varieties of steel together using or work harden steel, then thermo mechanically treated steel this are the type of steel that use.

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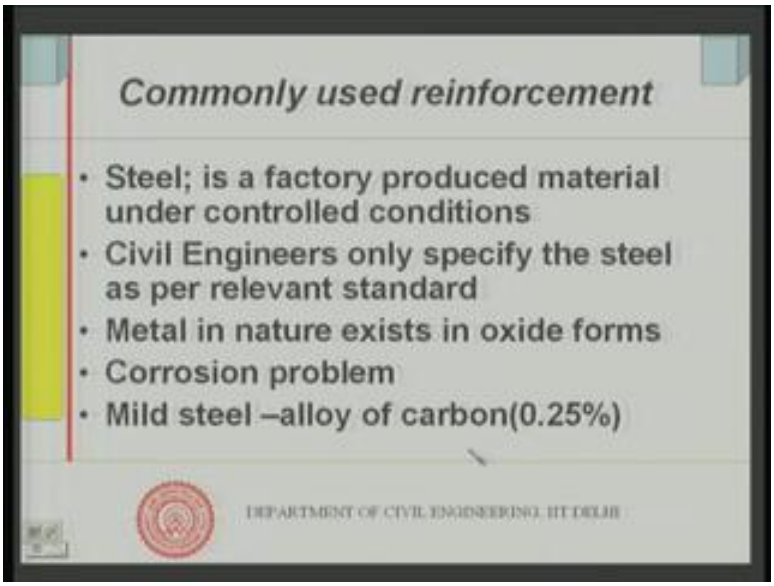

So, before we look into few things will just talk about and will go back or other before we look into this steel further, will go back to and discuss about something about the polymer, composites why they can be used much write polymer composite. Why they can be use much as reinforcement? You see the polymer composites our problem is polymer composites now desirable properties which are strength.

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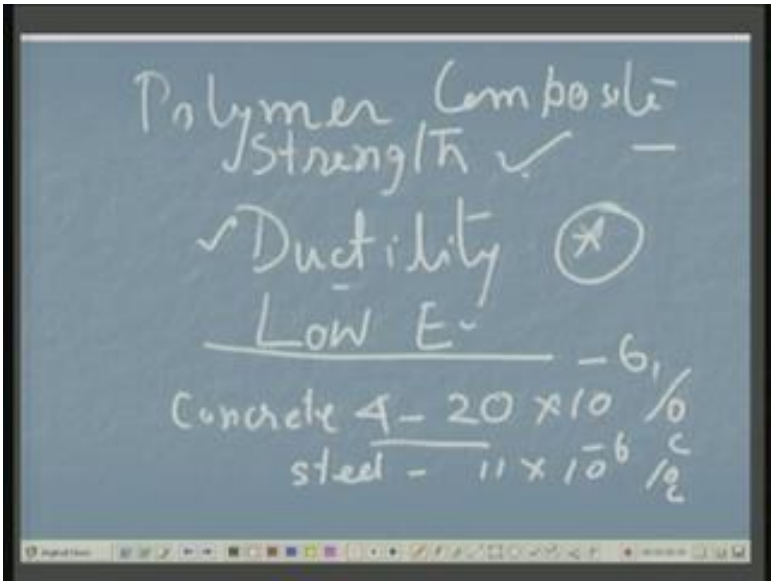

You can get this strength from many of the polymer composites because carbon fibers are very strong. So, supposing you have carbon fiber reinforced and say polyester are some like carbon fiber some in some matrix. Now, is a strength you can increase the strength significantly; you can increase the strength significantly say in epoxy or some fiber in some carbon fiber or gas fiber in epoxy or similar sort of thing, there can be well as number of combinations possible, but you get strength.

But carbon fibers are not ductile; so, many cases you will not get the ductility you not get ductility you may not get, but supposing you get ductility also then you will get low modulus low E. So, you may not get this you know if you get this and this you may not get this. So, this combination of strength ductility and high modulus velocity, which is there in steel you don't get in polymer composites, there has been vary as a time.
But there been used in some case because steel has got certain disadvantages, main disadvantages come from corrosion and its fire resistance. So these are the major disadvantages of the steel. So; therefore; people have try out some this. But limited use of polymer composites have been there as a reinforcement 5 it the use of polymer composites. You know polymer composites in places where the bending moment is nearly 0, where bending moment is nearly 0. That is flexural load effect is nearly 0 or distribution reinforcement which are to take care of shrinkage and such sort of thing very loss stresses, there polymer have been used. Some especially, in places where the exposer condition is such that the reinforcement would be you know, the structure is prompt to river corrosion in a very large way.

So, polymer composite have been used thermal compatibility is another issue, you look at the thermal compatibility of steel. You know, coefficient of thermal expansion of concrete various from about 4 to 20 into 10 to the power of minus 6 par degree centigrade of Kelvin whatever you call it right 1 ever degree centigrade. So, this of concrete coefficient of thermal expansion concrete. If you come to steel, in normal temperature it will be eleven in to 10 powers 6 rough clear and close to this bar degree centigrade.
So, you can see the steel is highly compartable if it comes to thermal compactable. The polymer composites not necessarily not show, this short of you know this short of

behavior. So, it is another reason why steel is very in as a most popular reinforcing material and it finds is maximum use, in construction as reinforcement and concrete. So, this is another reason why this is having so popular. So, that is why some of these properties desirable properties which you know, which are relatively you know going to discuss much in details are just mention.

Now, steel is a factory produce material and it is produced under controlled conditions and that besides the reason in a course of civil engineering materials of steel is used possibly or its if you take the in the next material after cement in use in industrial use in the world cement is highest use material next should be steel and in construction tool cement or concrete is maximum use material and steel would be the next use material. So, but then you see the number of hours devoted to lecture number of lecture hours devoted to concrete has been very large in this course also where as steel where discussing must the whole reason, is as a civil engineer has to very little as for as the steel is concerned.

Because it is factory produce specify the steel as for relevant standard off course you understand also little bit and that why there is a same portion devoted to this, metal and steel in this course. You can get this strength from many of the polymer composites because carbon fibers are very strong. So, supposing you have carbon fiber reinforced and say polyester are some like carbon fiber some in some matrix. Now, is a strength you can increase the strength significantly you can increase the strength significantly say in epoxy or some fiber in some carbon fiber or gas fiber in epoxy or similar sort of thing there can be well as number of combinations possible, but you get strength. But carbon fibers are not ductile; so, many cases you will not get the ductility you not get ductility you may not get. But supposing you get ductility also then you will get low modulus low E. You can get this strength from many of the polymer composites because carbon fibers are very strong according to the relevant standard, that is it.

So, the problem is the steel or corrosion problem which has discussed earlier on the previous lecture also and fire system problem of steel. Steel is not sufficiently resistant to

fire, but then we provide sufficient cover to the reinforcement to ensure the fore resistance. So, the code suit specify the minimum covered required for specific higher resistance and by this time we know that fire resistance is express in terms of hours you know time in hours.

So, if you know the specified fire hours of fire resistance accordingly the cover that is required to reinforcement specified in highest 456, 2000 as well. Again another issue off course is corrosion and again the concrete is supposed to provide production to the corrosion to debarred and therefore cover to the concrete strength of the concrete cover region is extra, which have discussed at year at length they are the that is of the protection is done.

So, this corrosion is the fires these are the 2 problems and that are what we take care of by you know various ways in reinforced concrete and have discuss this set line. So, now we now discuss this, now use mile steel that has been used very often earlier mild steel has been used and you know its alloy of carbon 0.25 percent maximum, 0.25 percent curve.

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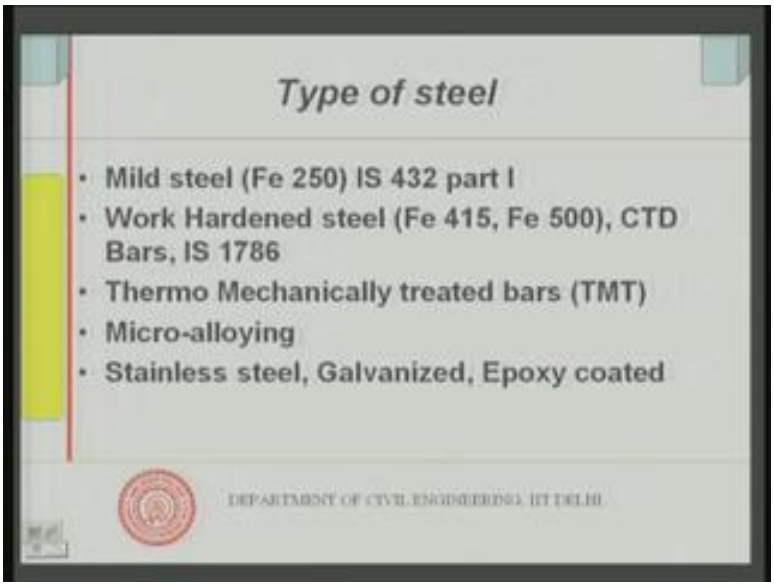

So, this has been used very much and the code that else which Indian code that is which is highest for 32 part 1, if it 25 grade this mile steel actually there has been used and we have used a work harden steel which is cold to deformed bus and you have 2 grades of steel they are Fe 400 and 50 and Fe 500, and then this covered in IS 1786; Then there are thermo mechanically is treated bars and this to have same kind of grades 400 and 15 and 500 you can do micro alloying; sometimes stainless steel galvanized steel has been used epoxy coated bar should be used, I will just discuss then them and straightly inline.

Now, Fe 415 means that it useful strength is 250 characteristics strength is 250 Fy as we call it is 250 is usually mile steel Fe 415 means; the useful strength or Fy yield strength characteristic yield strength is 415 Fe 500 characteristics yield strength is, 500; 415, we can get from CTD bars and can get from thermo mechanically treated bars also in the same grades. And some steels are available as corrosion distance steels with micro alloying some sort of alloying with chromium copper nickel extra in product improve is corrosion resistance, then we able to stainless steel they have been used in exceptional cases.

As rebar where is in exposer environment is very severe or it’s a monumental structures. in a very monumental structure 1 can use it because the cost is not a factor here, because is extremely costly very high percentage of chromium in this 1; Galvanized steel has been used with some success limited success, because of the cost again. But coated bars are to protect additionally again reinforcement has been also in used is this are again, reinforcement corrosion protection which has discussed under in the context of river corrosion in concrete.

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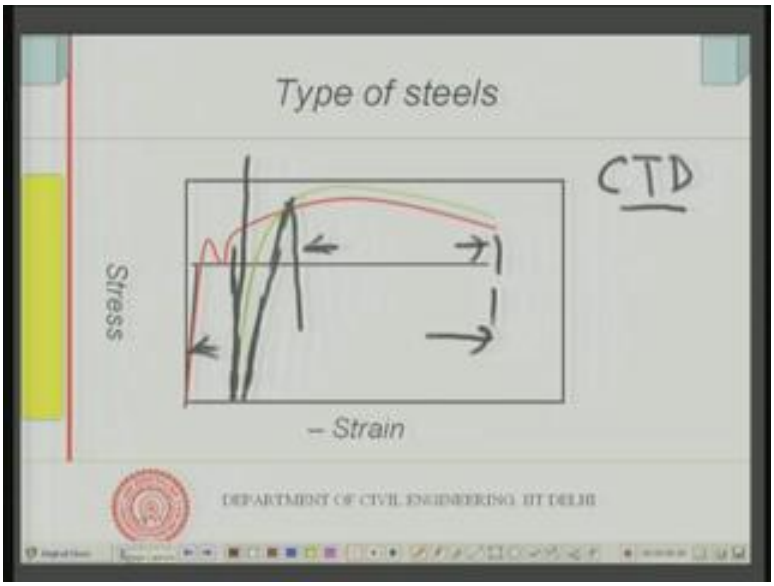

So, this is the types of steel available now this is our stress strain diagram of mile steel that we have seen earlier stress strain diagram of mile steel is something like this. And what I do I want to use in structural steel or rebar for the rebar also, I actually idealized the stress strain curve and the useful strength is this value. So, this is 250 just draw a line parallel line to the x axis and the load will point and this is 250 and that are what do use. In case of you know, this is the steel we use most commonly we are using for reinforcement.

Now, off course this is not much in practice, because its strength being load, but it has got high ductility as you can see it is got high ductility, satisfy all the requirement you can actually sort of produced in a read bar and a bond strength early off course, plain mile steel bars very use, plain surface the bond strength would be relatively less. But if you do being its bond strength is somewhat higher and that's what has been used in practice earlier very much. But till 19, 18 since 19, 18 in India off course the work harden steel or a kind of CTD bars hole to said deform bars where used.

So that you give the permanent strain and you have a stress strain y axis will shift here y axis will shift here somewhere here. So, the y axis in the particular case just to show this will be the y axis, this will be the y axis in this case can what to how produce this first of all this was our mile steel. So, you have actually given some permanent deformation to it and when I given permanent deformation when I have release it you know it followed this curve, because this a permanent deformation that I given, and now I apply reapply the load to it its stress in curve would be like this.

We have talked about stain hardening are here and this is what strain you know strain harden steel actually. So, what we are doing we are actually work harden steel as we fall it. So, this called twisted deform bars and that's why they known as CTD bars cold twisted deform bars this is the cold twisted deform bars. So, they give a much higher useful strength because you said our useful strength will be 0.02 percent 0.2 percent proof stress and which will be some here, may be 415 and 500 we can get and this is what is CTD bars which are most commonly use in reinforce concrete structures and may be now it is very much in use. But what happens, your ductility has now reduced this was your RDA ductility this was your RDA ductility. Now the ductility as reduced, but you have reasonably good ductility.

So that, you can uses; so you compromise you get strength higher useful strength higher
But, useful strength higher, but ductility uses some and then modulus of last velocity is practical purpose is use it is same. So; therefore; thermal compatibility they will remain same all though fire resistance would be somewhat lower, because if you heat it up and then cool it no fire resistance. You know that, they can be all this effect of train hardening might be lost depending up on situations.
So, the fire resistance property is not as good as mile steel, but other things because that fire resistance is provided by the concrete cover even mile steels has have a fire resistance. So that's not an issue that's why we became a very popular material and has been used, extensible as reinforced reinforcement in concrete for the years composition as the same as the mile steel only thing is it is work harder.

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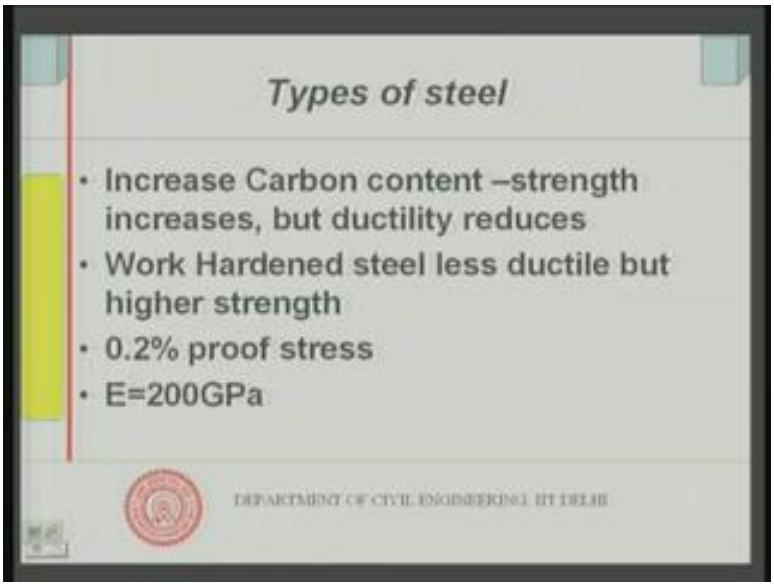

So, CTD bar has use extensibly as reinforcement what are concrete and it is in fact steel is in very much in use. So, we have seen earlier the define increase carbon content strength increases but ductility reduces. So, strength increases ductility reduces work hardened steel, same thing it is less ductile but higher strength. What it that means that, both strength in ductility if I want to get not plain carbon steel I can not get either of this way.

So, you need this is what has been used mostly so you did not off course in case of I mean you didn't high carbon steels are never use, for reinforcement more even higher percentage of anything beyond mile steel was never used for reinforcement because of the ductility reason and cast in other division also. So, what kind of steel has lets the time, but higher useful strength. I will say and we use 2 percent proof stress which, we discuss and it has got also its modulus are velocity 2 00 GPa, which use for you mean our structural design; so, this is 1 type of steel.

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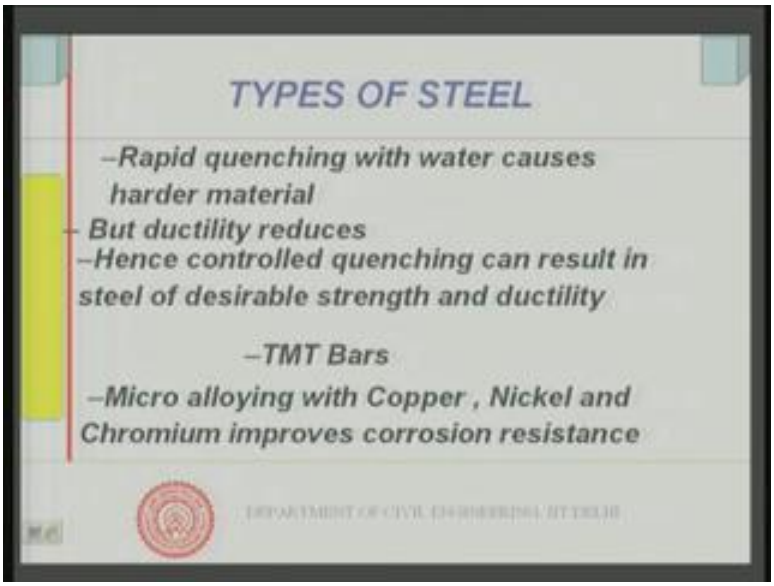

Now, we talked about quenching and tempering no rapid quenching with water causes harder material that's what; we have seen earlier the marten site formation. We seen that when, you rapid quenching marten site formation takes place because of you know hindrance to production of or formation of pearl light and face centered ferrite cubes, you have the started ferrite formation and you need carbon coincide solid solution elongated face centered cube formation that takes place and when, it temper it actually it becomes a harden marten side and very strong material is formed which, is harden brittle that what you have seen.

So; therefore; this process 1 can increase now you said that marten site is brittle. So, it is ductility reduces, but strength increases but supposing I do control quenching I do controlled quenching not, un control quenching in small role rebar or reinforcements. You know, with cylindrical sections then possibly I can form some marten site and some again, ferrite pearlite structure inside I can leave intake.

So; therefore, I can make a sort of a some sort of composite strain you know and in controlled quenching situations, and therefore I can get high strength and maintain the ductility by ensuring that the ferrite pearlite structure inside. TMT bars has enough TMT bars are this kind of product TMT bars are this kind of product what is TMT thermo

mechanically treated bars. So, you with these bars are produce by a thermo mechanical process. We can do also some micro alloying in this kind of bars to improve the corrosion resistance to improve the corrosion resistance to improve that corrosion resistance. So this TMT bars are becoming more and popular and replacing the CTD bar to certain extend replacing the CTD bar to certain extend.

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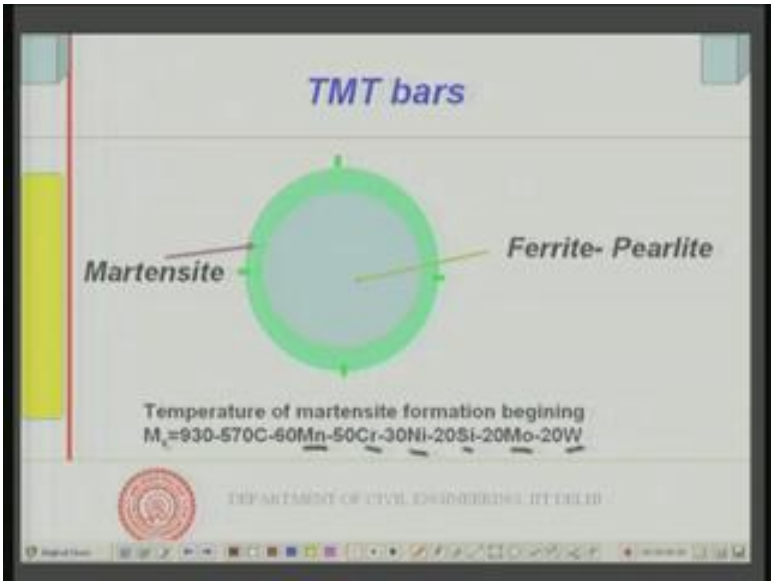

Let us look at something more, about TMT bars the structure is something like this. Because I said that you do what we do actually controlled quenching. So, in the process the controlled quenching process what you do we actually quince it partially it is ribbed again to have better boned you can this just emotional you can many more review.

So, what we do we actually do controlled quenching so spray water for quenching purposes such that the top some portion of it gets rapidly cooled and when, it is rapidly cool marten site would fondly only on the outside prefer and this ensure that, actually tempered because inside steel remains hot. So, first quickly I cooled it marten site form then reheating takes place, through this core which is hot which has still remain hot and cooling gradually, at a very slow process, and therefore ferrite pearlite formation take place here. Here in the referee the marten site formation take place, because marten site

because it has been quenched. Now, when this gets tampered during this process during the process of production then, this material is very hot where as this material is relativity, soft but you know and it has got high tensile strain, but this is ductile.

So, I have got a composite section now this is ductile and lower strain this is brittle. But much higher strain this I can control the thickness of the soon I can control to find out, what strength I desired because the composite system will act together to resist the tensile low, the tensile low. So ,what is TMT bars are look like a temperature of marten site formation beginning of marten site formation, that's available it is you can see that it is 930 minus 570C, 60 Mn manganese this manganese this manganese this chromium this nickel this silicon. Now, all of them actually if you put them the reduced on the temperature of formation of marten site. So, all this percentage material percentage they bring down the temperature so marten site formation. So, that thermal mechanical is treated steel and that's has been used now as going for some.

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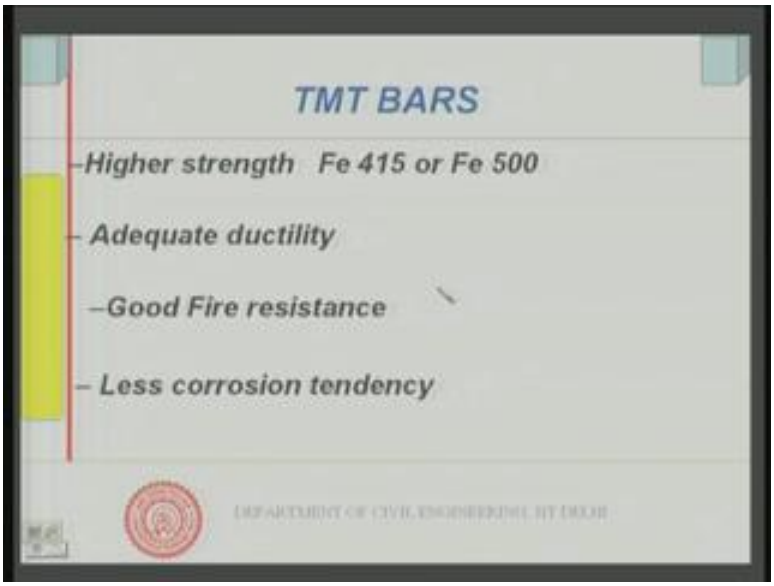

This gives you can get higher strength 415 and 500; as you have seen, you can use 415 and 500 you can use 400 or 500 great. So, this is can be design to 400 and 5 00 here, I can have adequate ductility; so you know this combinations can give me the strength

ductility that I desires strength and ductility as I desired and better I am not say good fire resistance it has god somewhat better fire resistances can be obtained compared to let us CTD bar by generally one can obtain better fire resistance can have somewhat lesser corrosion tendency although this not very sure, because CTD bar you have to work harder.

So, you already given some energy to it and the tendency of the deform material would be go into solution easily, where as in this one, this tendency can be reliability less. But may not be very largely different may not be very largely different compare to the CTD bar. But there can be less corrosion tendency.

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Let us see what are the manufacturing processes TMT manufacturing processes, actually there are when we produce them steel bars are rolled out from billets scraps and ingots extra after purification.

So, you can have scrap steels or billets and then ingots or even you know scrap all of them you can Mel them together and then steel bars are usually produce from all of them. After off course, purification necessary purification and they are rolled out from, the rolling meal, and then in the after come out from the rolling meal. I can produce the

TMT's and the 2 process, which are used this 2 process; one of them is known as thermex process other is that temp core process.

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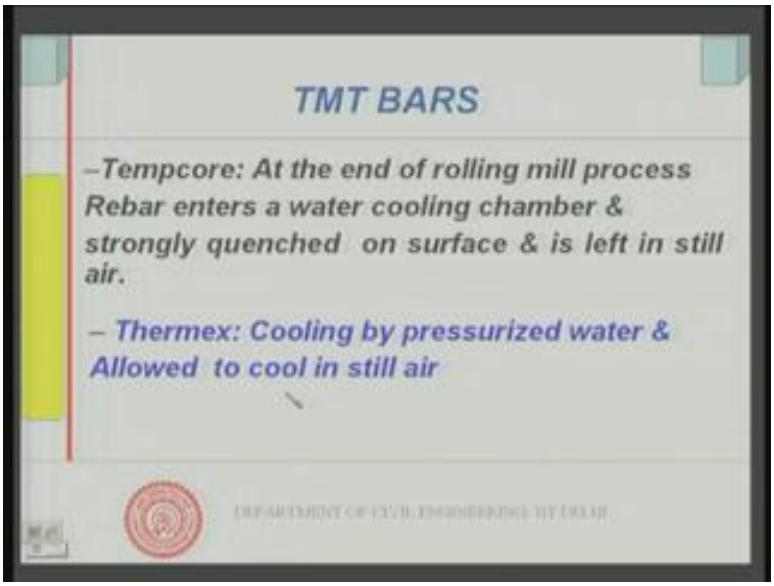

So, there are 2 process through which you do that, temp core process this is the only process difference basically it remains same see what happens at the end of the rolling mill process, rebar enters a water cooling chamber. There is the water cooling chamber and it is spread actually and the strongly quenched on the surface is left in still air. So, then you leave it in the still air, it is leave in the still air in this 1 similar thing only process, is different cooling by pressurized water and then allowed to cool in still air.

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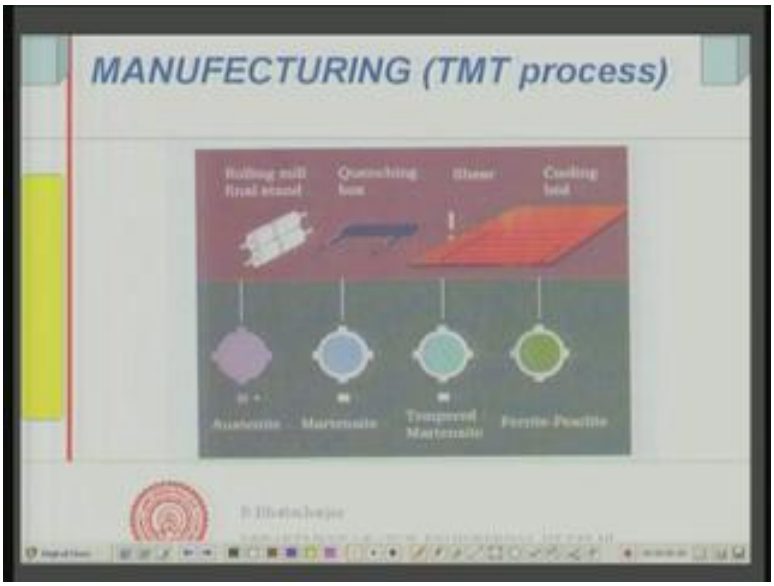

So, this 2 processor available developed in 2 different places and that's why the 2 process both are used in situation. Let us see the process for the you can see, this is your rolling meal financed final strength that is coming out rolling meals. You know, from the rolling meal final strength, so which is coming out. So, this is which is coming out. So, when it comes it set such temperature where it is because you do it at higher temperature, the rolling hot role situation. So, do it at such temperature where it is actually austenite gamma or that's we have seen.

So, now what you do you have a temper where you actually cool it, you know why do cool it actually is a quenching box. This is a quenching box, where cooling it this is a quenching box where we cooling it. So, this quenching box where your cooling. So, in this stage what will happen when this quenching actually marten site formed this portion would have got cooled fully this portion got cool fully and therefore marten site we deform. But inside has cooled down little bit and cooled down little bit and from austenite to actually ferrite state and similar state it as come to, but it is still warm still warm it still warm.

So, here actually as it progressive shared and cut into pieces and in this state the marten site is getting temper. You know, it being getting tempered in other words its getting

reheated it was quenched it was quenched and cool down. Now, this is getting reheated because this inside is hot and this inside heat, is retain it has to dissipate through this surfaces it has to dissipate heat through this surfaces and therefore, it is getting tempered. So, in the process are tempering I have at the surfaces hard marten site of the surfaces and in the cooling bed is its finally cools, the inside remains as ferrite pearlite and outside is tempered marten site. So, you can see that outside tempered marten site will have a much highest strength then, the you know, ferrite pearlite face which is inside. But, it will have much less ductility; so, this portion provides ductility this portion provides strength high strength.

So; therefore, both high strength and ductility you can get from this system. So it is strength is similar and strength is you know it is same similar kind of strength is CTD bar. You can get that is 415 grade, you can produce you can produce for 500 grades and ductility the minimum percentage elongation required, for specified in the code you want get that also. So, this steel is becoming very popular this is as reinforcement bar and being commonly used on most of the construction.

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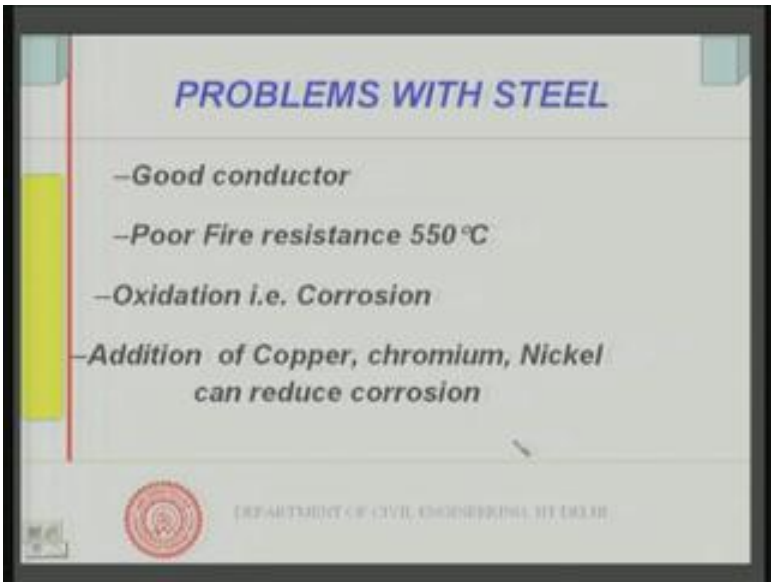

Problem with steel is good conductor; I mention therefore, poor fire resistance. In fact is you know, if I thing I may drawn it sometime earlier regarding the fire resistance of steel. But let me read others same thing again fire resistance of steel you know if you plot it temperature, verses strength of steel in fact as you subject it to strength of steel. You know, what will happen is this initially there is no much decrease in strength, but then after that this is significant desire is an idealized curve actual curves.

So, this in significant decrease in strength certain temperature and we assume the steel at 550 degree centigrade it just cannot sustain any load. This is 1 thing, but this is 1 thing and fire design is based on this, but thing is that fire material design of fire is based on this but actual building, when the it is subjective to let as a fire have been. Let us say, lets disgrace from the degrades limit, but let us go, to lets structure steel building.

Now, 1 portion the fire it might have gone 550 degree centigrade and the steel would have possibly sort of crampled or buckled something local hints formation might at taken place. But the other places it will be still, it is in good condition it can still which send the strength. So, just by formation of a hinge at a given location and a whole structure may collapse. So, it doesn't mean the 550 degree at 1 place in the structure, in a steel structure the whole structure collapses. Because the mechanism formation has to takes place in the structures steel for its collapse.

Similarly; 550 degree material you know this material for the material we assumed; 550 degree, whenever a still reach it actually it has lose its capability which turn the fire it is in terms of its stability insulation quality any way it is very bad because good conductor both electricity and heat. So, its conductivity if you remember we mention some time may be K is equals to 5050 watt per meter degree centigrade 50 watt meter compare to concrete this 2 or 1. So this is not very high thermal conductivity, this is problem and at 550 degree centigrade it really cannot twist and anything; in fact, residual strength also become slow work.

So, if I has been subjective to high temperature then it is cool residual strength off course it recovers most of good lot of it, but it becomes lower. So, the steel has got this problem

for us fire is concerned and CTD bar shows this more than mile steel because work harden steel if will get a nil a stalisation might takes place and some sort of loss of strength do takes place.

So, resistance strength also not very high and then we know off course its oxidation and corrosion problem which is we have discuss gain at length and corrosion protection also discussed; with reference to steel bar the corrosion. You know, resistance is something of this kind we use a epoxy coated epoxy coated bar can be used quit often epoxy coated bar various other coating. So, coating have been used of the bar to in order to protect one. Of course, the main thing is if I may good concrete and make it what approve water free. There is no question of free where corrosion there is no question, of corrosion of rebar or pre stressing steel that is inside major problem becomes a sometime many times concrete itself may not be as good as you desire.

So, that creates the problem in several points so that's what I why you see corrosion. But coated bars have been used then, corrosion register steel been used. Because he have said that, you can actually metallurgical improve the steel to make it corrosion resistance.
So, both have been used, but again from the enforcement concrete point of view fundamental thing is such cheaper due to be make a good concrete provide additional cover provide, adequate cover good cover concrete adequate cover this will ensure that actually the corrosion of rebar is protected.

But, this is any way is 1 of the issues and 1 can has to do design it accordingly there is no it is not a negative thing I mean if does not stop us from using steel. As a reinforcement material as, I told you no other material no other substitute has been available till date.
Because stress strain covers of most of the you know, composites either develop low modulus of velocity; they will not have ductility even if they have strain. So that's why steel still remains or this major problem associated steel; we have said that, addition of copper chromium nickel extra can reduce corrosion.

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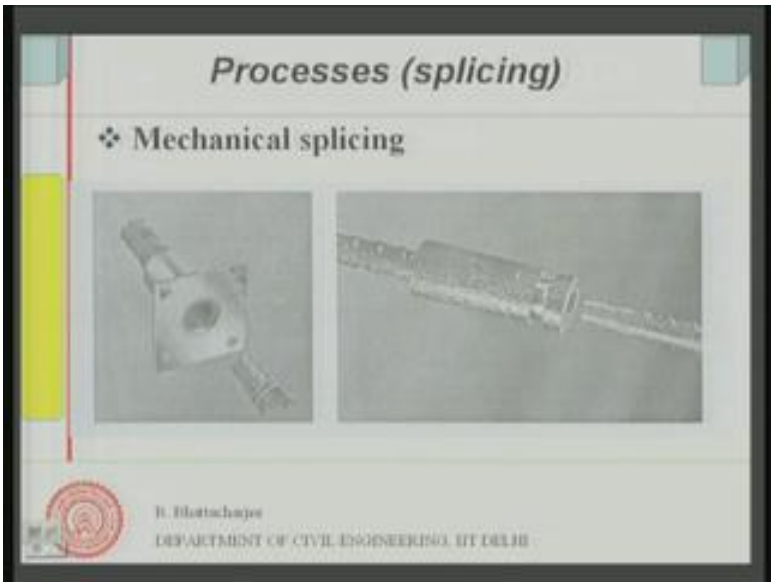

So, this is regarding the material that is when use in rebar and is being used even now very much. Let us see, what you do processing we know that whenever you are using rebar to pieces, then will provide clear plan because the stresses to transfer from concrete to the reinforcement and you need some minimum developmental length in order to ensure the stress is transferred from concrete to the rebar, but sometime we can well them and also do splicing. So, today we have mechanical splicings available for rebars and 1 can use them can use them and look something like this.

So, we have actually threaded portion here and that's a slip not through which it will go and then you can splice them effectively. So, the mechanical prices are splices are available for the purpose of joining rebars and there definitely much better in the sense that your, actually wasting or using much less steel the cost my be there you know, the cost effective. There also cost effective and then you do not have to relieve at the site whether, it has been put or not suppose in this is may the regulation practice.

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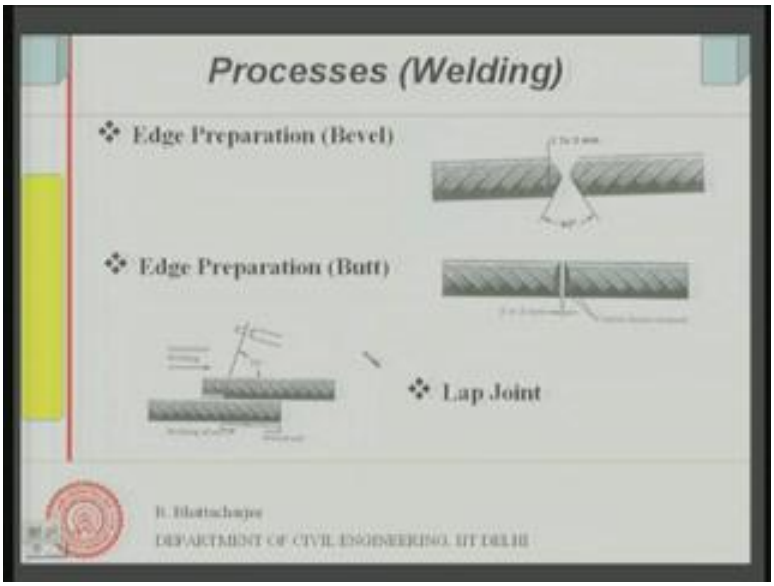

So, this is 1 thing the other ways off course the welding And weld ability off course, you have seen earlier and this are the some good construction practices that should going. For example, if it is say table ins preparation should look something like this, 60 degree and dimensions are also specified 2 to 3 millimeter. Similarly if you have but welding this how the bar should be prepared may not 2 to three millimeter gap and the bar should be prepared like this for bar weld and this filled with the material the material. In this case this is filled up with the well material if it is lap joint would look something like this. This is what, it is right horizontal welding and the angular then shown something like this and would a length has been shown.

So, this is the lap joint so welding practices somewhat has been shown in this diagram and this can actually welding and mechanical spicing can replace generally, providing lap length over concrete. Whenever, we need to join and extend I rather like to mention few points going back to the corrosion, which I did not mention you see this we remember that corrosion is in. Electrochemical process corrosion is in electrochemical process and therefore, a node and cathode formation takes place in the rebar is help.

Now, supposing using 2 types of rebars and this quit often people do use because and then say, the situation where TMT bars are available only in certain diameter is being just say, this new bar is being introduced or certain availability of the certain diameters are not there only few diameters are available. Then people tend to use sometime 1 diameter 1 type of bar another diameter. That means; use CTD bar in conjunction TMT; if you do that, you are actually creating a galvanized situation. The CTD itself my testers or node and TMT might be cathode are if you off course corrosion resistance bar used with ordinary bars.

This can cause at a galvanic situation in a most concrete condition therefore use of multiple types of bars, is not wise thing to do. In case of rebar use same type of rebar throughout any way coming back to the processing this is what it is.

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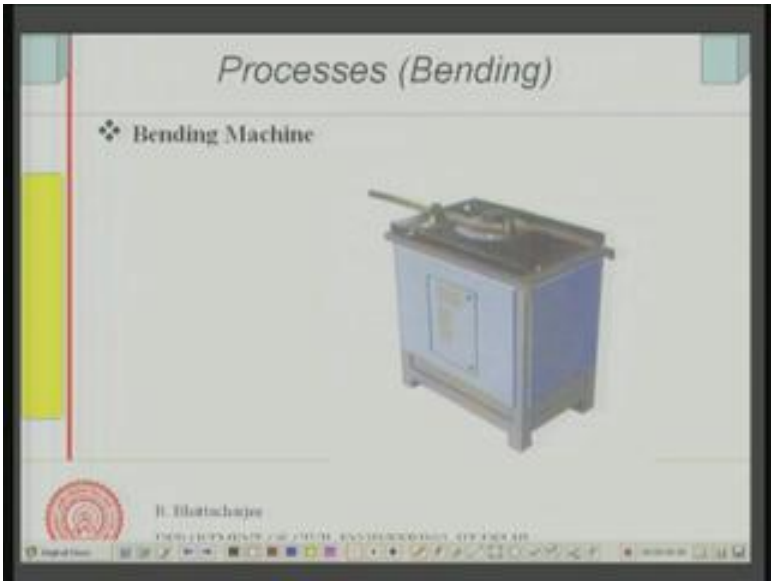

Now, modern construction practices is improved significantly and this is I like to introduce the earlier construction process manual bending. Today you have both semi automatic and automatic bending machines available, in fact there are commercial organizations available, which can do the bending for them is a quality of construction can be improve through quality of construction can be improve through mechanization.

As we have seen, in case of concrete we have seen the concrete in case of concrete manually produce concrete you cannot control the proportion. Therefore, you have you know the ranges of the material proportion that becomes wide and hence, gives rise to larger standard deviation and thus poor quality situation, are at least wastage of raw material cement extra is a economic situations reliability less. Economic situation mechanization on the other hand produces quality material.

So, where quality is in question mechanization has as an big way although it might be slightly costly in the beginning, but in the long run it will be cheaper. So, same thing goes in case of bending and cutting and processing of the steel rebar; you know, fabrication of the rebar. So, we have now all mechanized machine for example this a cutting machine which has got simply, you can feed the length and it can cut automatically I will just show, some more of them say bending machines semi automatic bending machines are available.

Now, this kind of bending machine what it does it this kind of bending machine if you look at it you know what it does is you have a role this is a spindle, which wrote about it this another spindle which are rotates and another spindle, which rotates and another spindle which rotates. And you can see the rebar coming as a rebar enters here and you know, this bars fill this bar between this bar and this also rotating this bar can be located where ever I want because this are rotating this.

So, the rotation of this 1, and this 1 are not same, so as it enters due to different RPM or rotation of this particular 1 the bar comes through this and goes away. And depending up on, whatever angle of bending want you can get the bending accordingly as you wish. So, this are automatic bending machines are semi automatic bending machines which are the automatic as we shall see fully automatic machines are available. And you can commercially obtain fully fabricated bars, rather than doing it is the side where site is congested one issue the quality second issue where site is congested you can you might fabricate also where and bring it together.

Now, obviously such factories would require high in basement high capital in basement because it is mechanization. Such capital investment are offset by various kind of economic consideration some of them I will not mention. But some I can always mention because more technical, because in such factories they can minimize. The wastages using every cut peaces inside, you have wastages and minimal producing at the side. Suppose you must talk you must find out the cost of acquiring this phase and maintaining it also inventory cost and similar other storage and inventory cost those who come into picture cost of actual bending fabrication also bigger.

You produce from the you get it from the factory suppose all this cost analified it delivers it at the site like red mix concrete, you can have redimix fabricated frebars. So, this are be used in sites actual sites 1 can use less in a pre cause plan So, you can use some semi automated machine like this, which provides you bending this would be another such figures; steer up making machine is the automatic machines of semi automatic machines.

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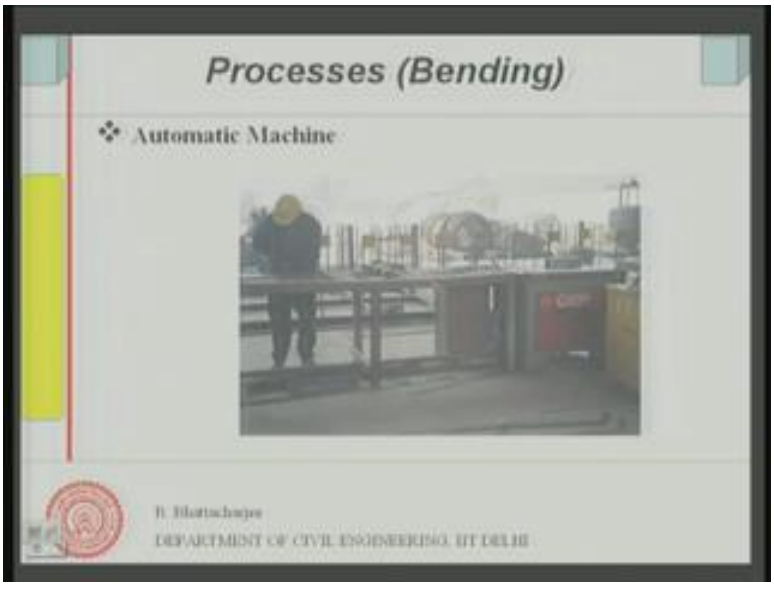

So, which you can make steer up it can give you where complete bend shapes which you want, but semi automatic you may need people.

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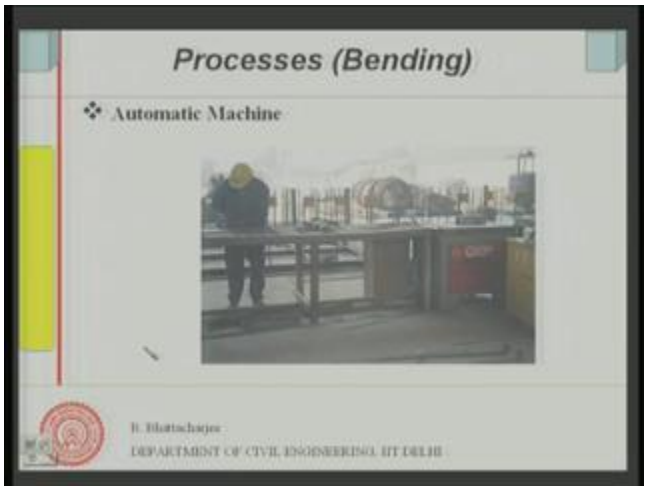

For example: this is really a pre casting I mean, pre fabrication site. So, this are the semi automatic machine as just 1 mentioned this photography shown, because idea is here steel where comes in they can come in roles and then, you can have a you know, you can have a it comes in roles.

So this can roll out and you can have a cutting machine you can have a cutting machine wire automatically; you know, this bar comes in and then we chopped of at the requisite length. Because as shown your machine which can cut we can cut to the automatic length. So, this length you fix into the machine and feed feed into the machine and I will go on shopping. The wires to the required length are it can stated go in to the steer up making machine, where off course we need manual help and semi automatic machine like this and then, it can do the processing.

So, you pre casting this would be a very useful thing where you can use automatic or particular semi auto machine and steel comes as role its like this. And from this cut and then given to the steer, up stage with semi automatic machine that means part manually and part about this. But fully automatic machines are possible and they look something like this they look something like this, if this is the steer up making machine.

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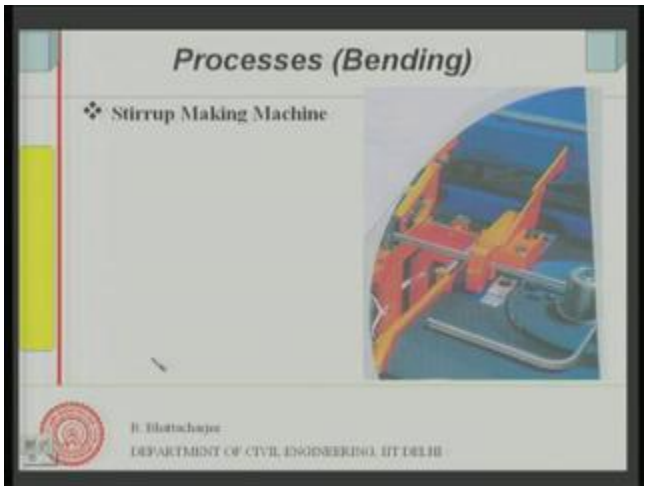

So, this is the steer up making machine like this rotates this comes through this whole thing is movable it rotates and the bending have been fixed the amount that will bend because there are 2 such rollers and through it rolls out and the bending has the fix. So, this is automatic machine automatic steer up making machine and then, cut it as soon as the steer up has informed. So, this automated machine can give you, accurate angle give you accurate angle and process the rebar as you want.

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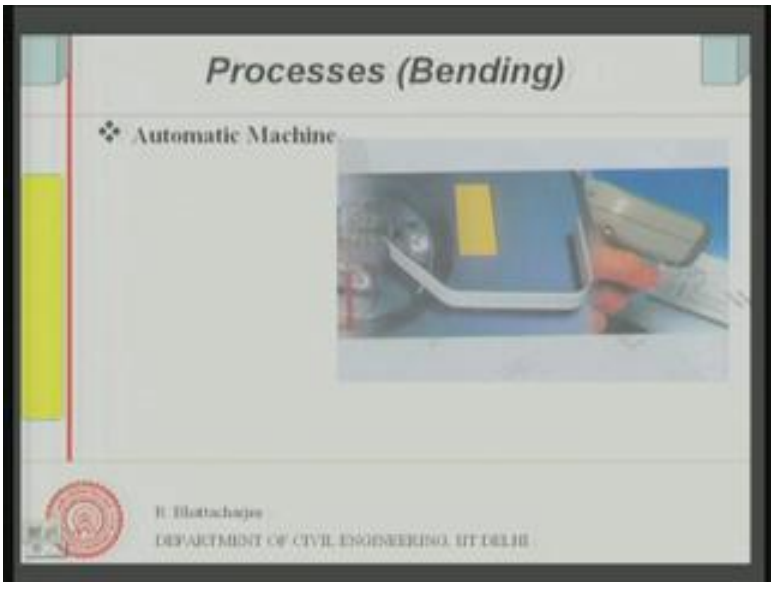

This is the same machine in other view this is the shape that actually it is molding to their several rollers here or spindles through, which it rotates and you can get the complete angle the way you want to completely. Now, this machine is fully automatic machines. What it does it does got you can say the bar code reader and it reads the you know, auto kid diagram of the auto kid diagram of the bar bending schedule.

So, you have just feed the bar bending to give the bar bending schedule which it will read itself and record it because it is complete raised. So, you record the whole thing and accordingly go on producing; you can see that, it produces about 1 2 3 4 bar are ago. So, as many number of them as you require you can produce them. So, produce the large quantity in 1 go that is in 1 issue is obviously not level intensively. So, you have removed out the rebar, but more importantly more you have done is its absolutely accurate it will not be you know, bar dimensions which normally when it is manually bend some bars could be something like when, its manually went the problems comes out something 1 bar could be 1 steer up something like this. You know, 1 steer up be possibly something like this the other would be some where you know some different angle.

So, angles extra different there not exactly same, but in this sort of automatic system this is precise. Therefore, we covered depth would be maintain is like to be maintain use the proper cover block, particularly which is to steer up. And such things and in actual construction practice the major problems of durable to rebar corrosion comes because the cover being not up to the mark, if covers specified in the code is about 20 millimeter.

So, in actual site measurement where manual construction goes on where it is semi engineer not really engineer. You find the possibility varies from may be 5 or 10 to some times 5 to 20 or 20 5 very rarely you get exact or higher cover them. What is being suggested for, various reasons people walk to them the sizes of the steer ups are bending is not proper. But this automatic machine definitely ensures that, you have the kind of steer ups or the bar that is produced.

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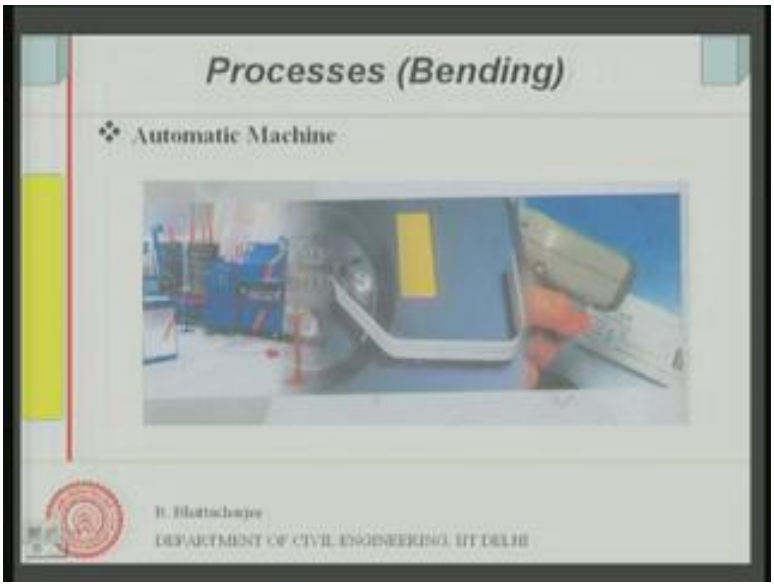

So, this is another view of the same thing the complete machine showing, the location of bar gets bend it actually comes through, it can may know the steel bar comes to this from the role.

So, you can see the roles here the roles are here and from the roles it comes through this and finally; this is a particle sort of a days where this steer up formation takes place, and this shows the bar reading for the bar bending schedule read through bar code reader. And this is used in libraries you must seen in mostly, often use in library sort or in shops various shops, where they can read various high tends pure codes available and trough that, actually here this is the reader this reads. The bending diagram bending schedule I mean bar bending schedule.

So, the bar is like this and then there is a role and from the role it comes and then goes on automatically produce in the bars 31. Such production definitely minimizes the error angles are perfect and also the quality of you know, fabricated bars that is you are getting. Now, it is completely ensured; so this is the process of river material and rebar construction you know rebar production.

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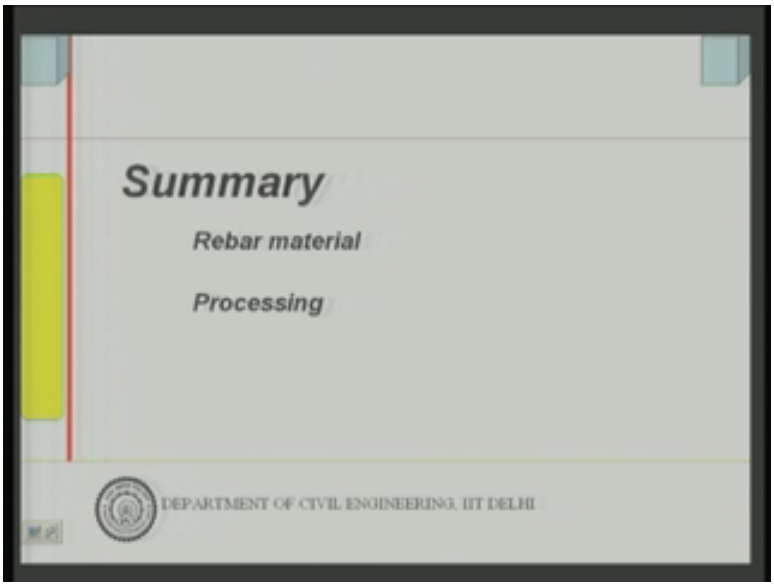

So, if you look at the summary of the overall summary of this module, 11 what you have seen initially you try to look into what is metal basic, you to try to look into what is metal then, we have try to look in to the micro structure of the metal because this micro structure helps us in understanding.

Why what type of steel I can select in my for my particular requirement and then followed by that; you have looked into certain process by which, you know steel and we looked into steel actually certain process what is steel and then, how the steel certain process, how you can modify the steel for various uses. Then looked into the pre stressing steel pre stressing steel what are this requirements and then, you know what kind of steel what properties are required for the steel pre stressing steel also you have looked 1 major steel that, is capable steel required for cable suspension course. Most of the time, you have to devoted or discussion on structural steel. Structural steel which, use directly in construction of building and many other structures.

For example: railway guarders steel bridges or buildings where the plain carbon steel is used its maximum that's what, we looked into then lastly we have looked in to reinforcement in concrete. And we have seen you also discussed out why till date steel is a most suitable reinforcement even though, at terms of India to replace it by various other

kind of polymeric composites, because polymeric composites can be design for the desirable property very easily.

However; steel is not been used able to replace the steel and varieties of steel that we use rebar you talked about 1 point that, I like to mention that we have talked about pre stressing steel. But polymer composites certain fibers for example: paremite cabler fibers have been actually successfully used for pre stressing process, because there the modulus of the velocity not a problem because they do not expand together you know, the elongation takes place. In case of pre stressing, where it takes place separately elongated in the beginning.

So, the modulus of elasticity is not in issue here in post tensions situation also the issue is off course, crisp and relaxation and you should have high tensile strength. So, in some places polymer composition been use successfully as pre stressing, where instead of steel, but reinforcement still it is steel as the dominant material and possibly it is a major place where steel is used in construction. So that's what, we looked into and we have looked into the processing of rebar.

The idea of giving idea about, the processing is that, with large amount of large volume of construction to you having and also, the quality which is lacking many of our manual or semi engine construction. The automatic or mechanical processing can do a much better job in this regard and that is why, the processing is included. So, we have disused the rebar material today and processing today and with this you can summarize all discussion on metal, with special emphasis to steel that is more in level.

So, thank you to close this discussion.