Marine Construction and Welding

Prof. Dr. N. R. Mandal

Department of Ocean Engineering & Naval Architecture

Indian Institute of Technology, Kharagpur

Lecture No. # 41

Welding Sequence

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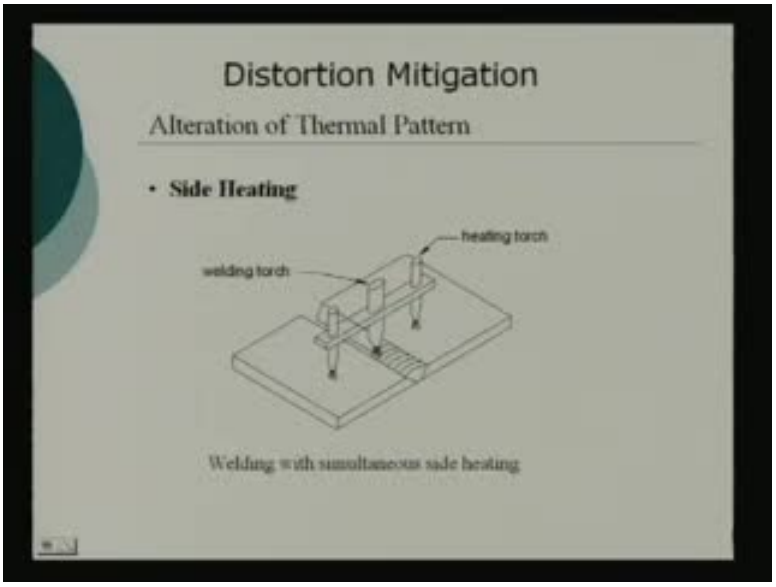

Anyway, so, continuing with Distortion Mitigation - Distortion Mitigation techniques - we just go back; and here, the point was alteration of thermal pattern that was the primary source or the primary sort of starting point, through which we attempted mitigating the effect of heat flow in the structure due to welding. Because, all is because of heat flow; so, if you can change the pattern of heat flow that was done inside heating; try to change the pattern of heat flow, such that the effect is nullified; effect of the welding heat is nullified. Second, was heat sinking; that means, it is kind of taking away the heat. Third was thermal tensioning; it is essentially by altering the heating pattern, such that, you stimulate a situation, whereby the structure is under tension, such that the compressive forces are nullified or neutralized, thereby we prevent the structure from buckling.

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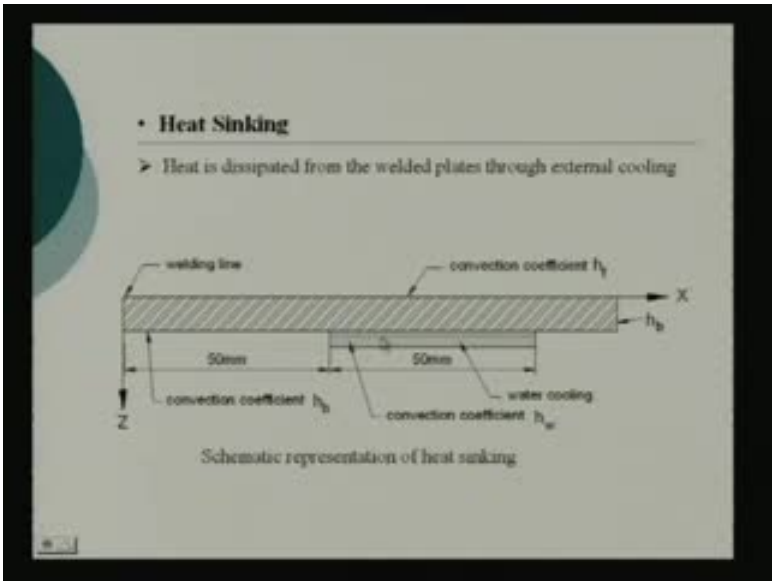

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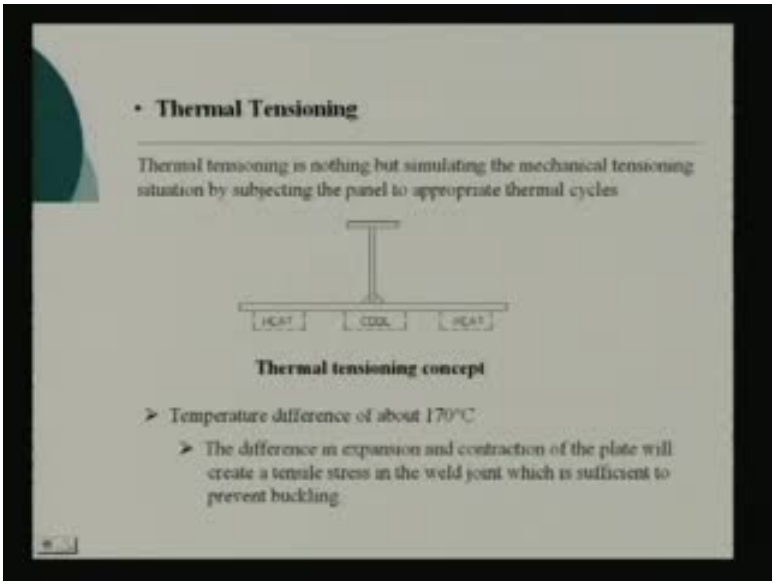

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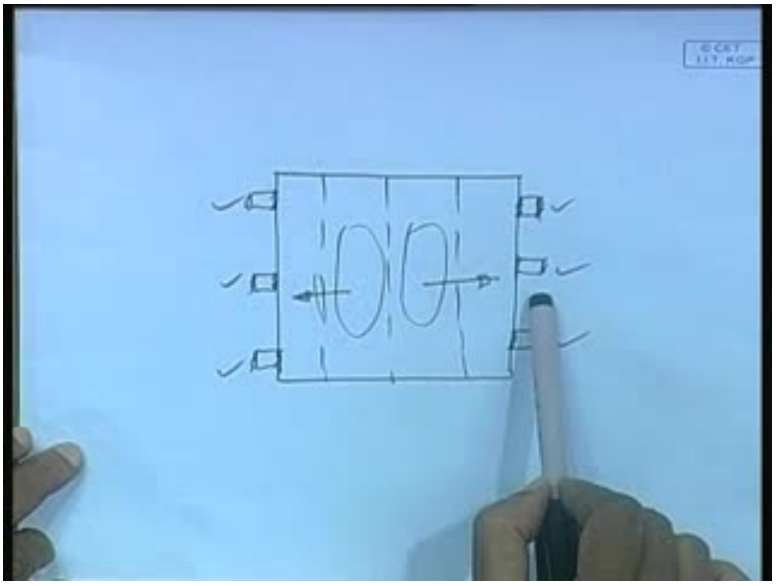

And then, we talked about a tensioning method by providing by clamping the plates in such a fashion, that the plate comes under tension when the welding is being done; plate is already is tension, how is that achieved? That is achieved by suitably welding the clamp; how the clamping is being done? Just by welding lugs; so, one side, the lugs are welded; on the other side, lugs are welded; prior to welding, the lugs are heated up, they are heated up to a elevated temperature and then welded. The result is, the moment they are getting cooled down, they are contracting and putting the plate in tension. It is a very simple, but quite effective method, quite an effective method and very easy to implement. So, thereby, one can do away with the problems of buckling distortions because of the welding of the stiffness.

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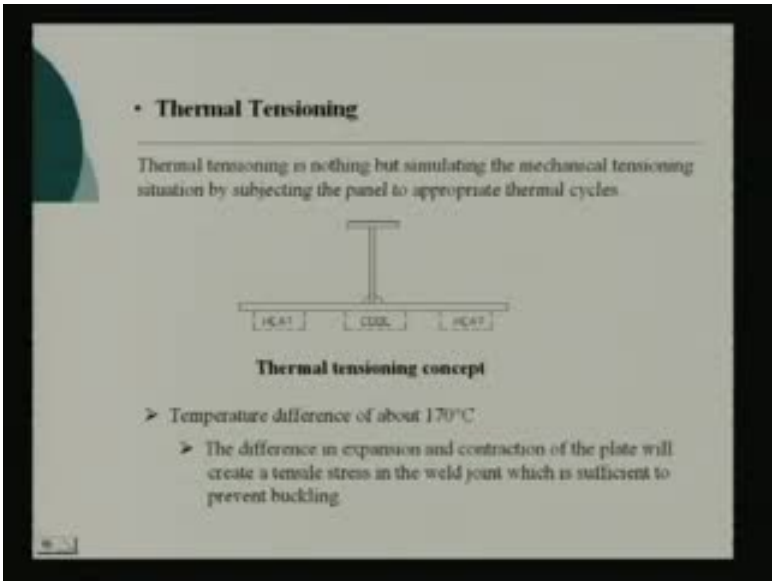

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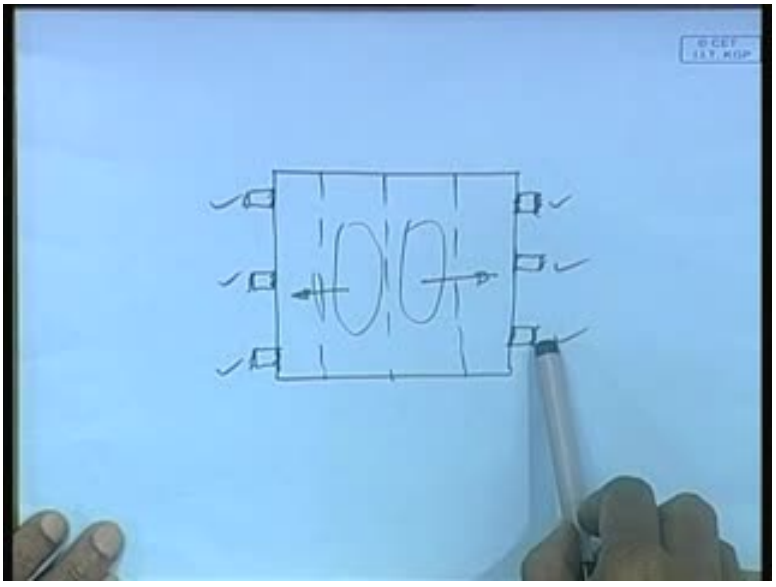

So, these are all by... of course, this is a kind of a mechanical, means, of putting, simulating, well, simulating the tension; I would not say mechanical by again actually thermal process; but here, I am not altering the thermal pattern of the welding process. In all the previous methods, we have altered the thermal pattern which was created by welding. Here, we are using the phenomena of expansion and contraction to create a mechanical tension in the plate, right?

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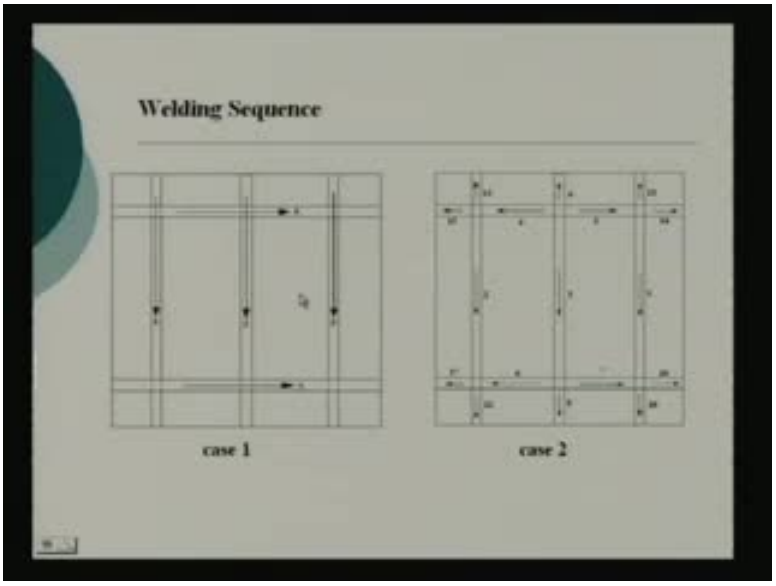

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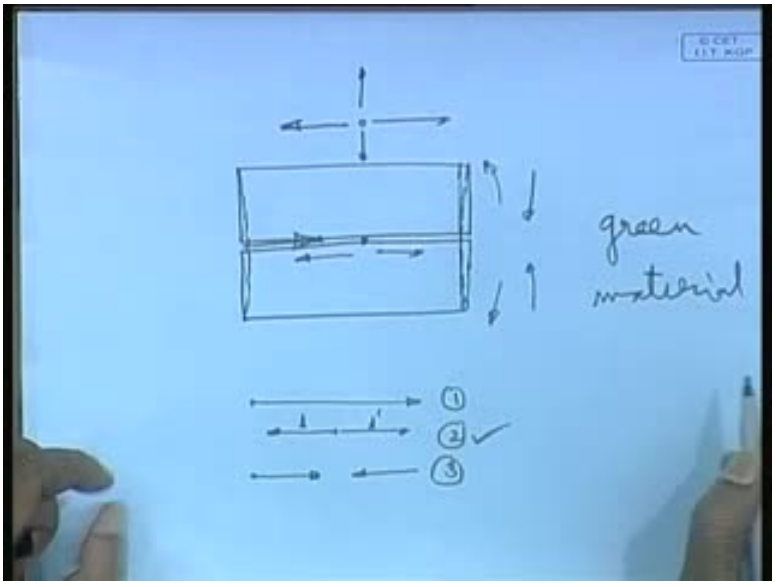

Next method is welding sequence; that means, by judicious sequencing of welding, we can do we can mitigate distortion. The simplest case is this one; that we have already talked about that, let us once again recall that; when we have been talking about rotational distortion, we have seen, depending on the speed of the welding, the plate may either rotate in this direction or in the opposite direction. If the speed is slow, they may close; if the speed is fast, they may open up, right? So, that was rotational distortion. So, what was the solution given? Solution is, start welding from the center, simultaneously outwards; this is what is welding sequence; that means, a sequencing of welding is done

such that effect of one welding nullifies the effect of the other welding, that means, in such a, instead of starting the welding from one part and go out to the end or starting both from end and coming at the center, you start from the center and go towards the end. Because here, three possible sequence are possible: one is from the end going towards the other end, another would be from center going outwards, another would be simultaneously going inside from outside. They are the three sequences essentially for this simple case of butt welding, of which this is ideal, why? Because here, the welding run number-1 and welding run number-1 dashed, they are going simultaneously; they are not 1 and 2, they are 1 and 1 dash; by 1 dash, I mean they are simultaneously, so, what is happening? The effect of 1 is being nullified by the effect of 2; that is what essentially is the, I mean, that is the essence of sequencing of welding where we will take advantage of. Here, we are not mitigating anything; they are self mitigating, they are self canceling. In the previous, all the methods, we have implemented some external agencies through which the effect was mitigated effect was cancelled. The heat flow pattern was changed, some tensioning has been applied, but here, same welding is being done; but, I am changing my sequence of welding, right? Such that, the effect produced by one particular weld is nullified by the other, so, that is what is sequencing of welding, so, this is a very simple case for a case of butt welding.

And the general rule is weld outwards, always welding should start from the center and go outward; that that was is the general thumb rule, if you say; while designing a sequence of weld, welding, the sequence should should be such that the welding process should start from the near-middle of the structure and go outwards.

Why go outwards? The idea is, as you are welding, the plates are getting rigid and rigid, getting stiffer and stiffer; because, they are getting welded to some other structures, some panel or butt welding or whatever; they are no more free to move, so as I go outward, whatever movement, the free edges can take; but, think of the opposite, it cannot take.

Just as in this case, if I see the welding sequence number-3 if I do, what will happen? I am start welding from this side and also from this side; the stresses are getting, kind of, as if accumulated that in the middle, it may get bulged, right? This is a simple case; but still, the ideal is the number-2 when I go outside. So, any kind of shrinkage or whatever, essentially, it will do, it will cause shrinkage; so, shrinkage, it can the edges are free, so edges will shrink, rest part will remain flat. But, if I do the opposite, then it may, full

thing may buckle; that will be more severe. Because, when something happens at the edge, I have some other means to take care of that. I can provide some allowance, whatever, as shrinkage; it comes to the design dimension or I can cut it off. I have an additional material at the edges which are which is called green materia. It refers to as green material.

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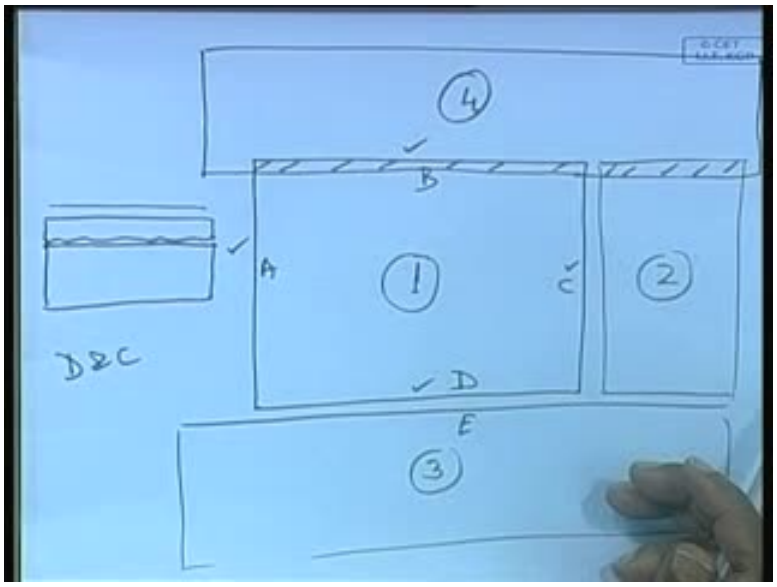

You see, in shipbuilding, whenever a panel is fabricated, right? Say, the panel dimension is like this, so, you know, all the edges are previously marked, I mean, they have their frame of reference everything. So essentially, to this panel, there will be other panels will be welded; this will be connected to some other structure, that side also some connection; all sides will be connected to something or other, right? That is always like that.

So, when you are talking about this panel number-1 say, so, it will have to have... This is my one of the finished edge; this is another finished; these all four are to be so called finished edge, such that, they match with the adjacent, say structures, will be something; here something there, right? So, how, how is it done? Whether, when the panel, panel number-1, you are fabricated whether all the edges are finished? No, it is not like that. Say these are my edges A,B,C,D; the general practice is you keep any of the two edges finished; by finish means to the right design dimension. Say, my D and C are finished; finish means, they can, right across, it can be aligned with the structure panel number-3, whose again the edge number, E is ready; they are aligned, similarly this is aligned,

right? Now, this side say, another some structure is coming. What I have drawn is, you see there is an overlap, means what? This much is green material in panel 1, extra material is being kept. So, now, after you align this panel 4 or the structure or the component, structural component 4 properly aligned and you mark it and cut it off. Similarly, from panel 2, you cut it off. How do you cut? Manually, cannot help; that means, this is what is referred to as - cut at site - the structure is there, the another structure comes it is aligned and you see so much overlap is there; that was purposely kept, extra green material was kept, why? Because, I am not sure how much the panel will shrink this way, that way, all the structures. Because, worst will be when I put this panel number-4 and there is a big gap between panel 1 and panel 1; you are helpless. Putting a small strip there will be a terrible job; instead I have it overlapping, and then the excess material cut it of, that is easier; well, that is the practice, why?

To take care of these possible deformations, shrinkages, etcetera, to, sort of, account for all those, I mean, uncertainties in the alignment. But obviously, what does that mean? That means quite a huge amount of additional work; you align, then you cut it manually; so, manual cutting means, what? The cut edges will not be a very nicely cut like a machine cut; it will be like this, the moment like this; then, when? Because, this is the edge of the plate, so, to this a finished edge is being welded.

So, you see the root gap; this will be the root gap. Because, you have cut it manually; manually means what? With a gas torch holding it in hand, you have to cut; there is no other way, so, that cutting is extra additional work. This welding will be again manual and also, since this is not very uniform, you have to continuously manipulate. Fill up the gaps properly, do the welding, so, time taken is more; weld quality also would not be that good. This extra green material is wastage, so, many things are coupled with this.

But, think of a situation which is referred to as zero tolerance fabrication; means, I do not keep any tolerance, I do not keep any green material. Each panel I make, it’s all four sides are finished; finished means, to the design dimension, I bring it I am sure that it will match. But, that is possible only if one can implement properly, one is accurate control systems that means, you have a system in place which will guarantee, you on the accuracy of the dimension, dimensional accuracy, dimension of the structure, right? You have your distortion control and mitigation techniques in place, then only you can assure dimensional accuracy; anyway, so, that is one aspect other side of it. Otherwise, globally

this is the practice, that is very easy to say again, but, not very easy to implement; but, well, objective should be there; so, as to I may, I can maximize that and minimize this aspect of keeping green material, right? Because that is also another aspect; this green material, that means, additional material what I am keeping, how much to keep 25 millimeter, 50 millimeter, 100 millimeter, 150 millimeter? It all matters; if I keep its better, if I keep it is 0, right? But, well tolerable if I keep it 25, the work content become same, whether 25 or 200; but the cost of the scrap reduces; material utilizes and increases if I can keep 25. But, by keeping 25, if somewhere I fall short, there is a gap then what? So, all these aspects are there; they are all basically stems from, essentially welding, weld-induced distortions; because, there is unprecedented shrinkage, unaccounted deformations, so, you land up in a problem, other is - why should there be any problem? Because, every piece is properly measured and cut, right? So, while cutting, there can be thermal shrinkages taking place, while welding definitely a thermal shrinkage has taken place and material is falling short.

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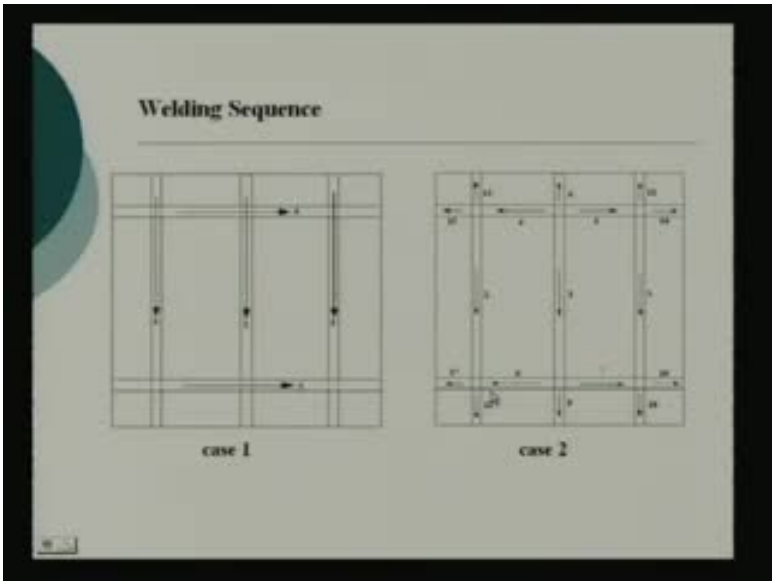

Anyway, so, next mitigation technique is by proper sequencing of welding. So, a simple case of welding sequence what we have seen; here, the essence is to, kind of, nullify the effect of one particular weld by the other weld; and, when you go for a somewhat little more complex structures like this; complex, means, here it is again that a standard case of a stiffened panel, wherein, let us consider that these are the 3 longitudinals and these are the 2 transverses. This is a very simple case of a stiffened panel. Obviously, in actual stiffened panel, there will not be only 3 longitudinal and 2 transverse, they will be probably 20 longitudinals and 5 transverses like that, right? But, just to study the effect, we have taken, simple this thing. So, here as you can see, we have shown two cases, and this is the third case. There the three possible sequences of welding; if you take a look at it, say the case-1, what is being done is, as if we have positioned the stiffeners, there are 5 stiffeners, 3 longitudinal, 2 transverses; so, I have, we have positioned the stiffness and the first stiffener is welded, right? Then, the second stiffener is welded, then the third stiffener is welded; once all the 3 stiffeners welded, then I go and weld the fourth transverse and the fifth one.

So, here, what is happening? Right from one end, I am starting, finishing at the other end of individual stiffeners; and I am starting from one end, right? First these arrows, they show the sequence of welding; here, I am assuming that both the side of the stiffeners are I am welding simultaneously; that is possible. I can have a gantry mounted welding heads, two welding head; they will move simultaneously. So, the entire length of the

stiffener is welded in one go; that is possible, so, that is how. Let us assume that the stiffeners are being welded, so this is one sequence.

In the second sequence, what have we done? We have welded the middle stiffener first; that too, not right from the end to end, but from the transverse to the other transverse. You see, in the first case, it was from end to end; from one end, one edge of the plate we have started and went over to the other edge; each stiffener, from end to end we welded. Here what are we doing? We are starting from the middle, right? There are various combination are possible; I have just arbitrarily taken three combinations; not very arbitrarily, from, because you see, these are because, no point going by theory of permutation and combinations, there will be huge number of combinations; that is not feasible. When you work on such problems, they are very, kind of, there are various practical aspects linked to it. We will have to see very complicated sequencing will not work; they are feasible in the drawing board, but in practice, you cannot implement that also has to be seen.

So, very logical from the tactics point of view, is the first case; that means, I put the stiffener, align it and weld it from one end to the other end; very simple, from practical point of view, one who does not realize the effect of welding sequence, he will do the follow, follow the case-1. You give it to just a welder, give him the plate and the stiffeners and the drawing and do not tell him about sequencing he will start from one end and go on welding it; and obviously, you start from here end there, it's easy. So, that way, the 3 stiffeners are welded, then bring the transverse members, put them in place, and again from one end you start, you weld, cross over the longitudinal, again you weld and and finish, right?

So, from the practical point of view, it is easy to implement; you start the welding, you progress to till the end. But, when I do this sequence, here one, what logic? Because, I said, we are assuming that the thumb rule we know; thumb rule says that the start from the middle go outwards. In the first case, we flouted that; we started from the edge and went over to the other edge, so, here I am starting from the middle. So, the middle stiffener, and literally I am starting from the middle; I am not starting from the end. But, at some point, where, where this, it is crossing the transverse.

So, here, the first difference is, I am first putting all the stiffeners in place; means, all the longitudinals are aligned put in place tack welded; by tack welding means, small, small at intervals small, small weld beads are provided, just to hold it in position. And then, put the two transverses, tack weld them; so, the whole structure is in place. Then, welding starts from the middle, from the one transverse to the other transverse; one - then I go to the other longitudinal - two, right? Then again, I come over to the third longitudinal - 3; then I go the transverse, again from the middle outward 4, middle outward , again the other transverse 6, 7 and so on; gradually, as if we started from the middle and gradually spreading out, right? But, here what we did? We first welded the middle part of the longitudinal, then the middle part of the other longitudinals, and then the transverses; that was the sequence.

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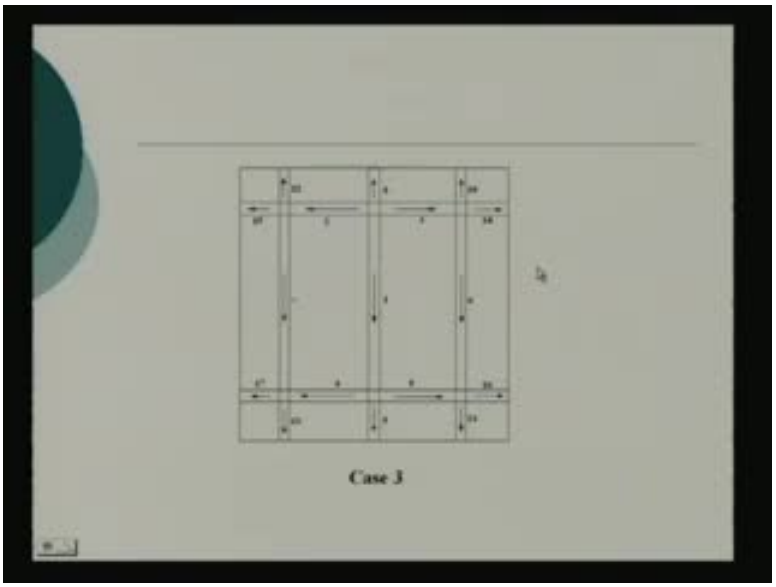

Next in case-3, what do you see is, something we start with the middle part of the longitudinal, right? And then, instead of jumping to the other longitudinals, we start for the transverses; again, from the middle, going outwards; this is number-2, and then the other half number-2, number-3; then, come to the next transverse number-4 number-5.

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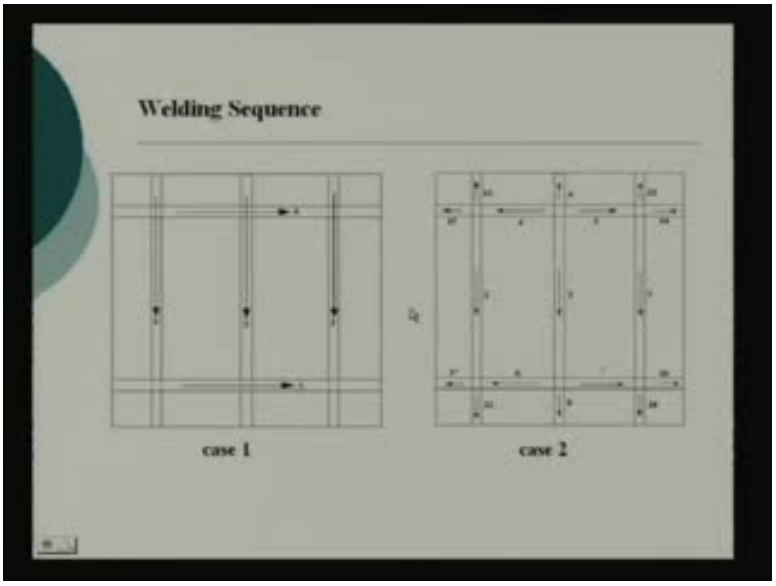

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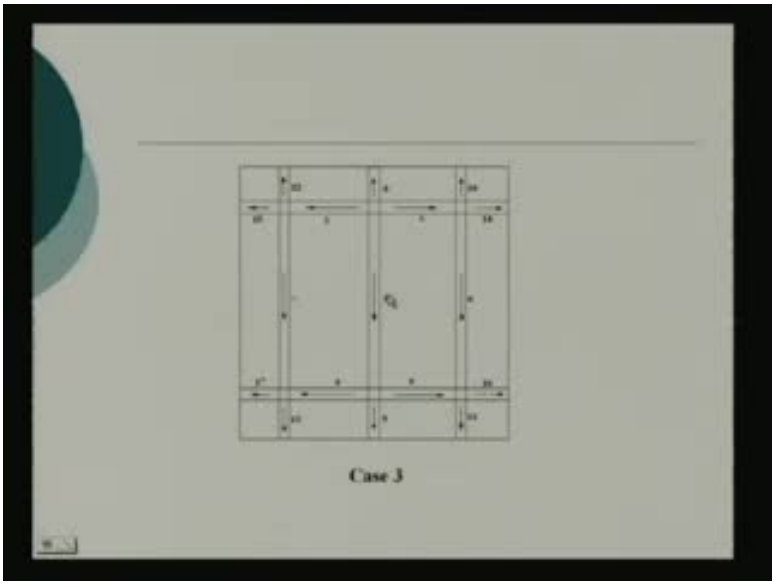

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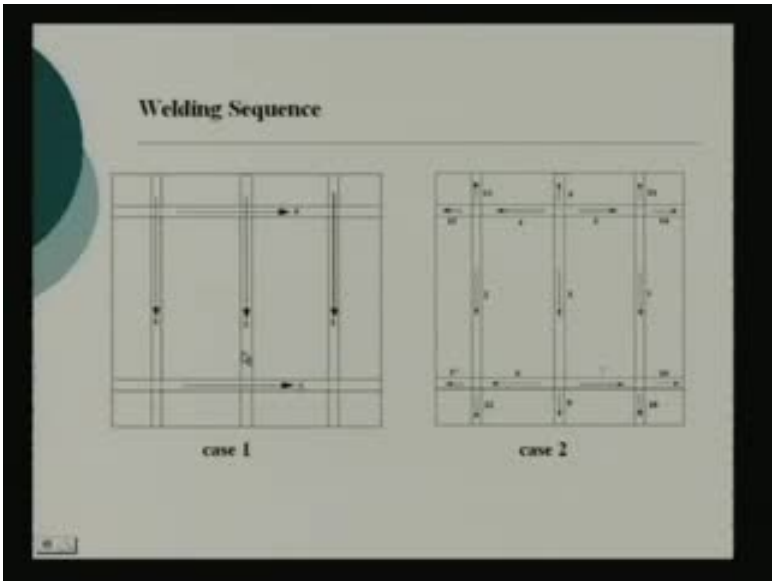

So, what is the difference? Here, you see, if I can compare only think of these four welding sequences 1, 2, 3, 4, 5, sorry 5; you see, in the case-1, when I have done all the five sequences, I have completed the welding. They are straight cases of five runs; well, in case-2, when I have done five welding, it was the middle part of the central longitudinal, then the outside longitudinal, both, and a part of the here transverse; so what happened? In this case, well, the stiffening, you see how the stiffening progressed. Because, in welding sequence, one has the idea of one welding you do, the next welding nullifies the effect of this; that is the whole idea; that means, essentially balancing of thermal stresses. Now, well, how do you balance? There are so many weldings are there.

So, based on that, logic one tries to go; I mean, work out what should be the sequence, how I am... one welding, like here, you see, I have done this 4, then I do the 5; I balance them. They are just opposite; the vectors are just opposite, so, each is cancelling other. But, when I do one, there is nothing to balance this; so, that is, at the same time refers to, right? But, that is one aspect. Other aspect is, I will have to see how the plate is getting stiffened. As I am welding it, I am producing a stiffened panel, so, progressively it is getting stiffened; welding is progressing, so, the plate is also progressively getting stiffened. So, if it is getting progressively stiffened, its rigidity is increasing; that means, rigidity against distortion is also increasing. A flat simple panel plate will much easily buckle, but when it has the stiffeners, it will not easily buckle, because lot of the load will be taken by the stiffener also, right?

So, that also has to be seen. Here the stiffeners by virtue of putting the stiffeners is adding stiffness to the structure; at the same time, because of putting the stiffeners is putting thermal stresses in the structure. So, stiffeners should negate the thermal stresses; its own thermal stresses is generating because of the welding. So, the process of stiffening of the plate has to be seen that it is progressively going outwards; it is getting stiffened. As I am progressing going outwards means what? Stresses are as if developing away, and gradually I am strengthening my plate and going outwards; so, it is expected that in such a mode, deformations will be less. So, that was the basis of choosing these three sequences; otherwise, I said on what basis you first start. Analysis is one aspect, but analysis, we will do of a given system first. You will have to first think of the system; and now, here hardly this few longitudinals, how many? Only five; you have so many possibilities of sequencing.

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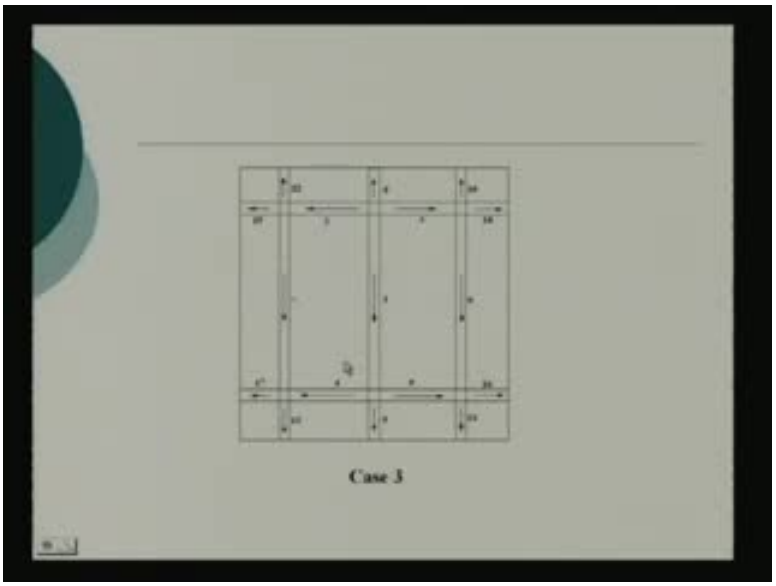

So, this was the logic. That first logic was, simple to fabricate case-1, right? Case-2m we thought of implementing that aspect of, first start from the center, but also, keep the simplicity in mind; that means, number-1, then this number-2, then number-3, and then go about 5, 4, 5, 6, 7; but, in the third one, we thought of middle, first, and then 2, 3, 4, 5; that means, what? This is this part is getting stiffened; you see, the central is welded and two transverses are welded; so, central part is getting rigid, that is that; and gradually, that is progressing outwards, so, that has been done. This is 1, 2, 3, 4, 5, and then we went to 6; then, went this side, then came here.

So, you see, after the seventh welding, this entire central part of the plate has become rigid; and then, we again came back to the middle 8 just opposite 9, right? Then here, 10; again, the opposite 11, 12, 13; they are the three things. Well, so, on this logic, these three sequences we thought of.

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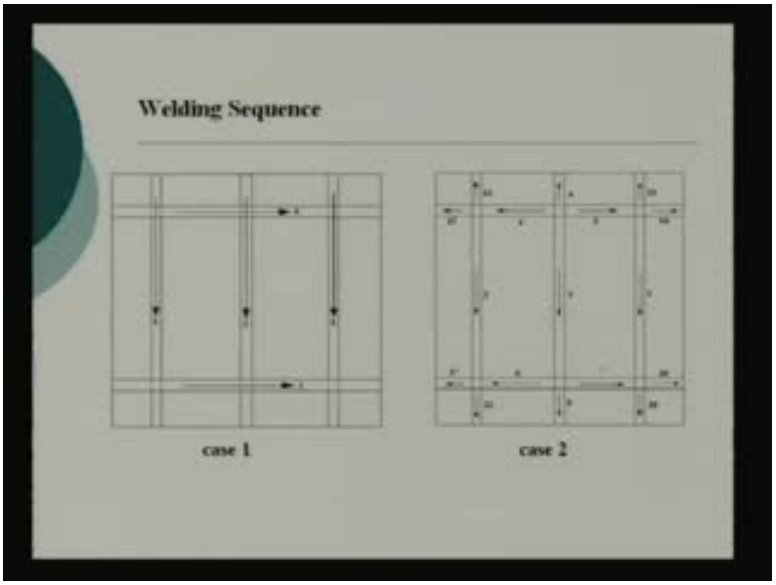

From the fabrication point of view, this is very easy; one welder sits, starts from here, goes up to the end; say, two welders are, if one welder is working, this case-1 is ideal, so give it, leave it to the welder; do not talk about sequence, he will inferably follow this welding sequence of case-1, because it is easy for him. The stiffeners are aligned, he sits, starts welding. I am assuming, well, whether it is a manual or automatic welding, he fixes it, it does at one stretch. Once it is aligned, it does the entire welding; if it is a manual welding, he sits and does in one go.

But here, what is happening? In the second case, you see he starts from here, completes. Then, comes here, does the two; then, again all the way goes there,3; then, again come here, 4; again, move over there, 5, too much of movement. But still, not that bad; at one go 1, 2, 3 he has done; then here, 4, 5, again comes here 6, 7.

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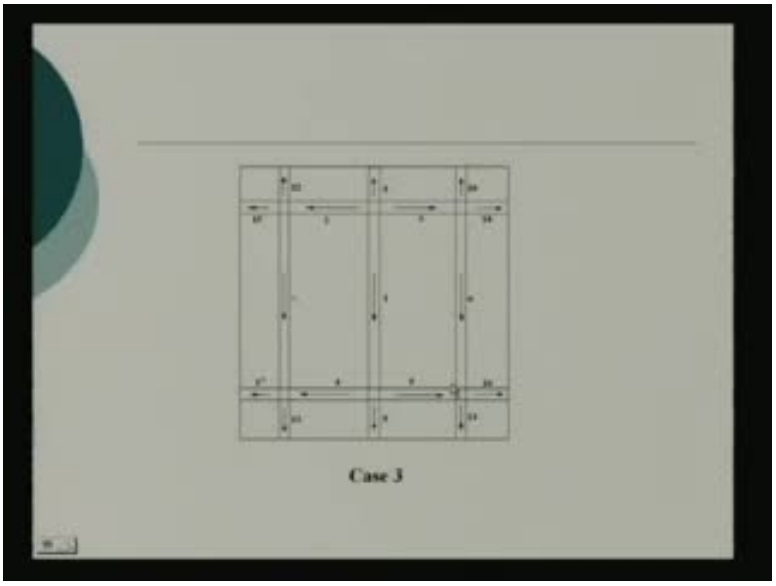

Case-3 is worst from the welder's point of view. He does here, then all the way goes back and does only this much, a small one; again goes back here 3, again all the way comes to the other side 4, 5, a welder will not do; unless, he is totally convinced of why he should do, which very often we ourselves we behave; many things we know we should not do, but possibly in the bottom of our heart we are not very convinced that we should not go he should do so, you do not act accordingly. So, why do blame the welders? Unfortunately they also are human beings; they will see their convenience. So, that is the problem, right? They will not do, he will not do, like to do.

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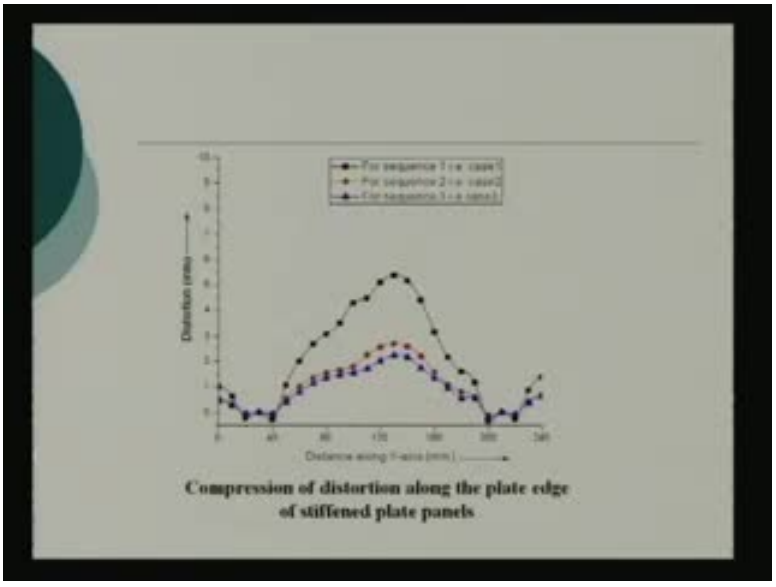

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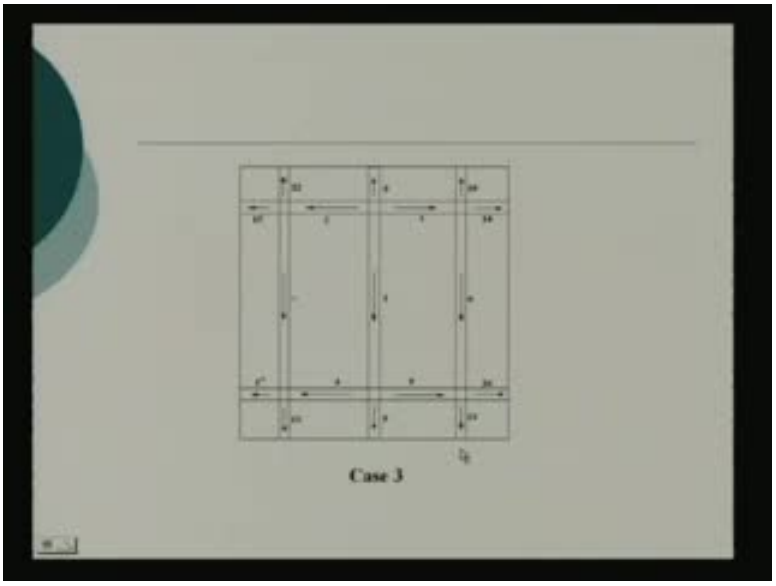

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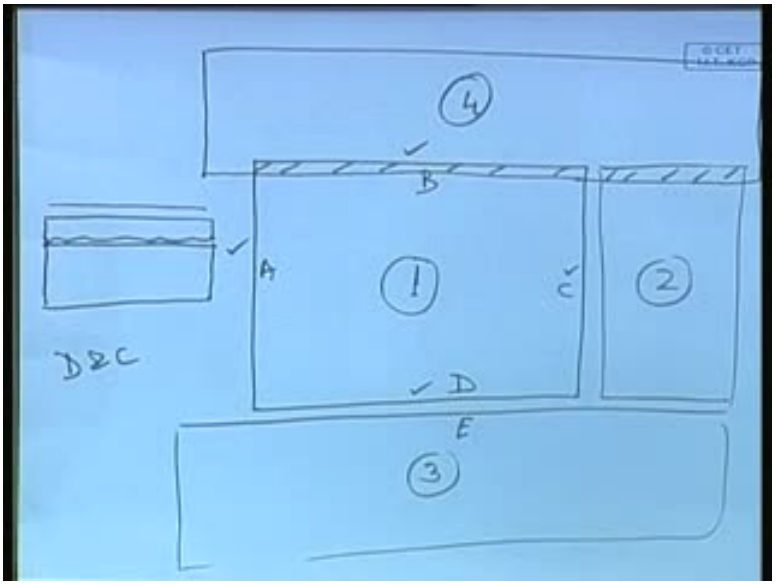

Now, let us see what are the results of these three. This is the this of course, is theoretical analysis from that, we are getting; and this theoretical analysis is already tested, so, you can fairly sort of believe the facts the results is giving. You see, the black one; here, the well here, the plot is compression of sorry, sorry; it is not compression, comparison; comparison of distortion along the plate edge of stiffened plate panels; along the plate edge means, (this we have taken 40 to 40) along this edge; the what what has been plotted there is the distortion along this edge, because we are... I mean, well, one can find out distortion anywhere, but, for the time being, we are interested along this edge, why?

Because. that edge will be... I will have to align it with some other structure, so, I would like to know what will, what is that has happened to that edge.

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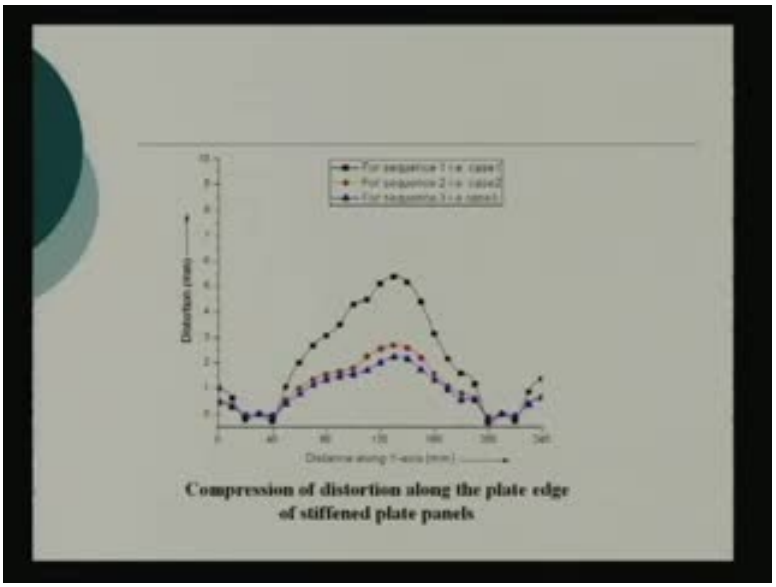

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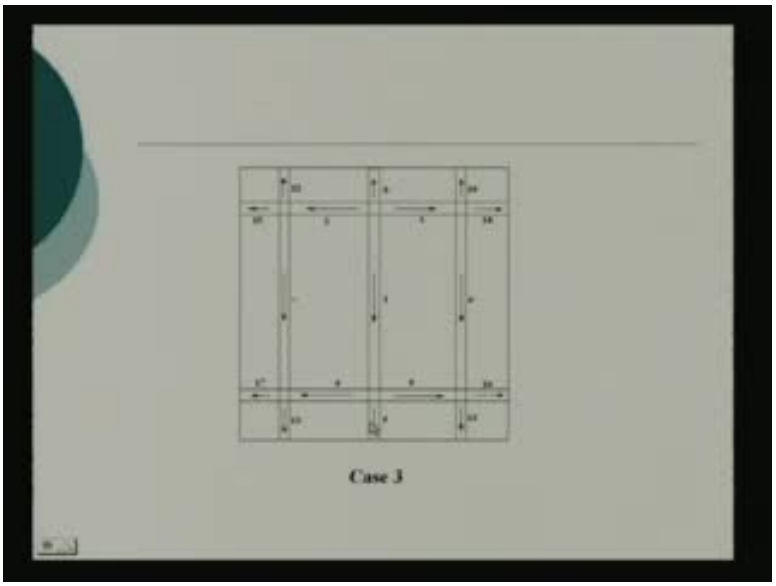

So, what you see is actually these two points, these are the points where you have the transverses; you see, the transverses are there at the fortieth location and at the two hundredth location, these two transverses; so, from here, it is 40, and then here, it is 200. So, these two locations have transverses, so there, that obviously, deformations are less; here, it is much more.

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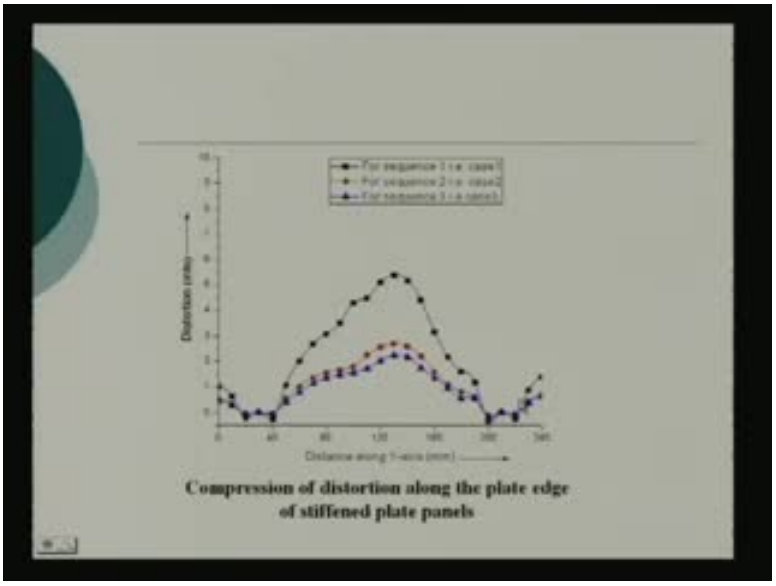

So, what we see is, the case-1 the deformation level, well, it is in a model scale it has been done, the plate size is small, everything is small. So here, we seen that over a distance of this 40 to 200 millimeter, the deformation of around 6 millimeter, right, or six units; whatever you take.

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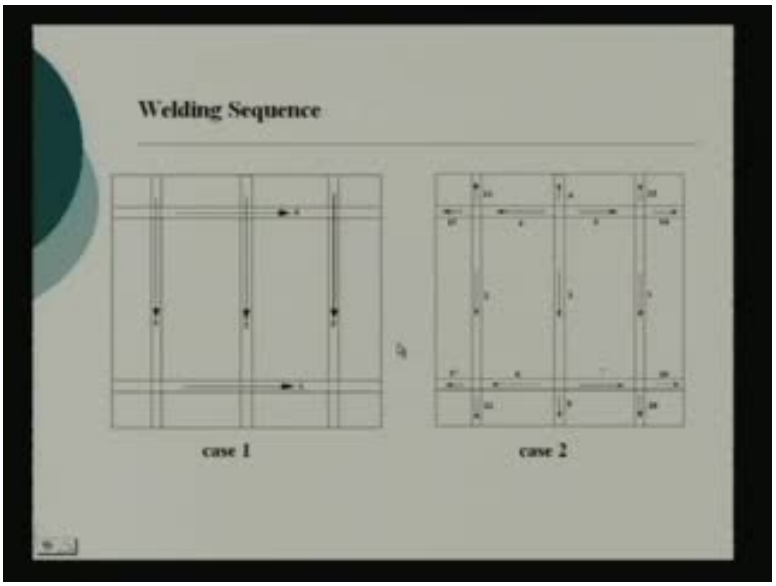

In case of sequence-2, if we recall those sequences, it is here; it is drastically reduced. Simply by changing from here, the basic difference is started from one edge and went over to the other edge; and here. It started from the middle, did this, again did that; so,

when I am doing the middle, it is rather neutral. Because, if you weld along the neutral axis, there is no deformation, you know. So, it is like that. One is welded, it will give rise to stresses definitely, then I do this, then I do the other one; so, this is canceled by that one. Whereas, in the first case, there is no cancellation; it is only adding up, right? But here, there is a case of some cancellation.

So, that is immediately reflected in the drastic reduction of distortion; it was around say 6, it has come down to around 2, 2.5 something like that. And, well, the blue one is the case-3, further refined; it is essentially what it shows, that this is further refined; I mean, it is good enough.

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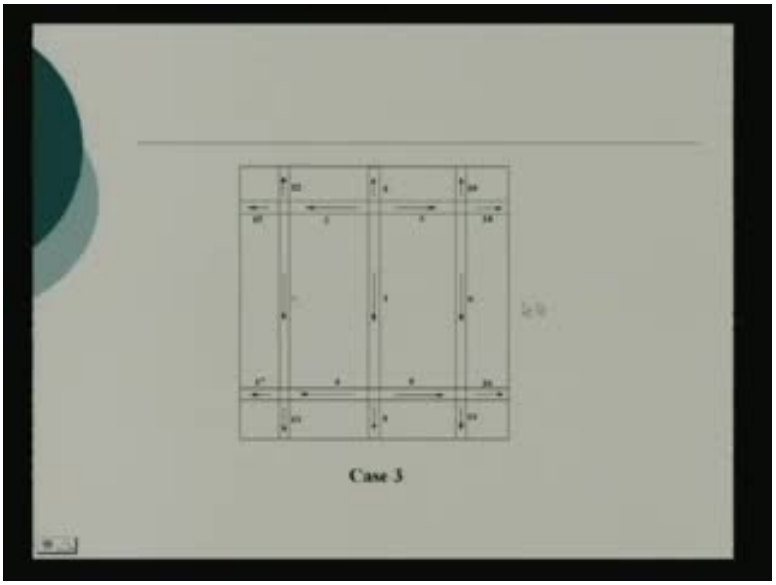

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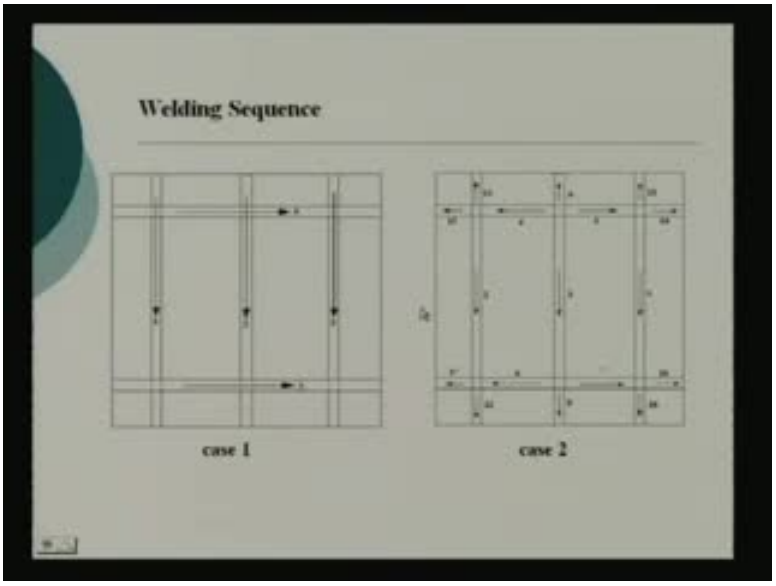

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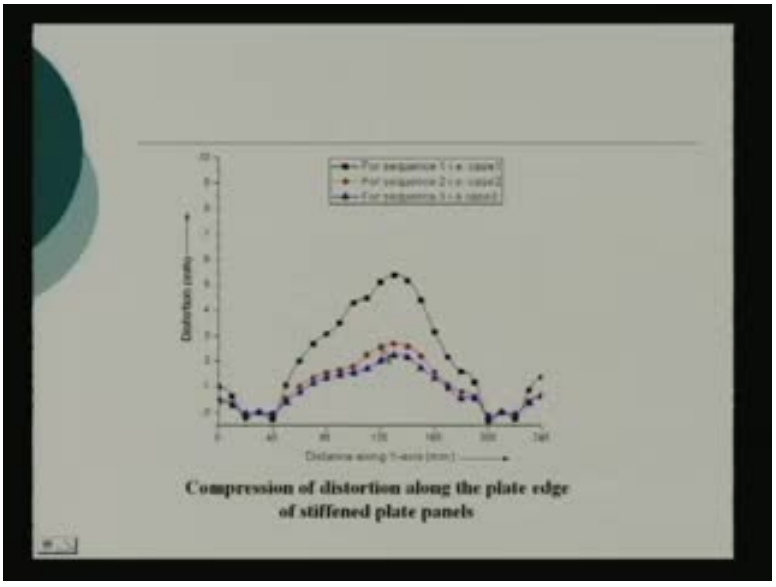

So, if you welder does not like this, at least you can convince him to do this; that itself will be difficult. So, that is how you see the effect of sequence, how drastically it works, how drastically it effects. But, as you have seen in the from the practical point of view, it is difficult if it is a manual welding; it is difficult to convince the welder to follow either case-2 or case-3, because, he will have to frequently get up and sit down for doing the welding; that a person would not like to do that. And, in reality, we have experienced, we have tried some of these sequences in gaudy shipbuilders. So, there the moment the problem is, the moment we talk about, immediately people will say, we know what is to

be done. They know that welding has to start from center and go outward, but, what does that mean? This case-2 is center go outward, this is also center go outward, but there is a difference. Because, this small difference can be substantial for bigger panels, right? So, that is one aspect; and second aspect is, well, these are some of the application aspects, that means, no point blaming that he is not listening.

When an engineering drawing is produced, there it is not enough to just to show the structural components, but you also should, but it should also contain all the fabrication details, it is like a novel; a novel it is not enough only to give the names of the characters and brief description about them. See, you do not get the essence of the novel what the author wanted to write; engineering drawing is also same thing. Unless all the details the engineer and the designer have put in, the fellow who is fabricated, he is just the reader of the novel; he only reads. Here, no scope of imagining, in case of a novel, well, something is left to the reader, so that he can imagine things and enjoy more, he draws a picture of his own; here is no chance, it has to be given to him, everything in detail; that means, what should be the welding procedure, what should be the welding sequence, the welding details, the edge preparation details, everything. If you see a proper drawing of a proper shipyard, all these are given. But this if this is not followed, then how the welder will know?

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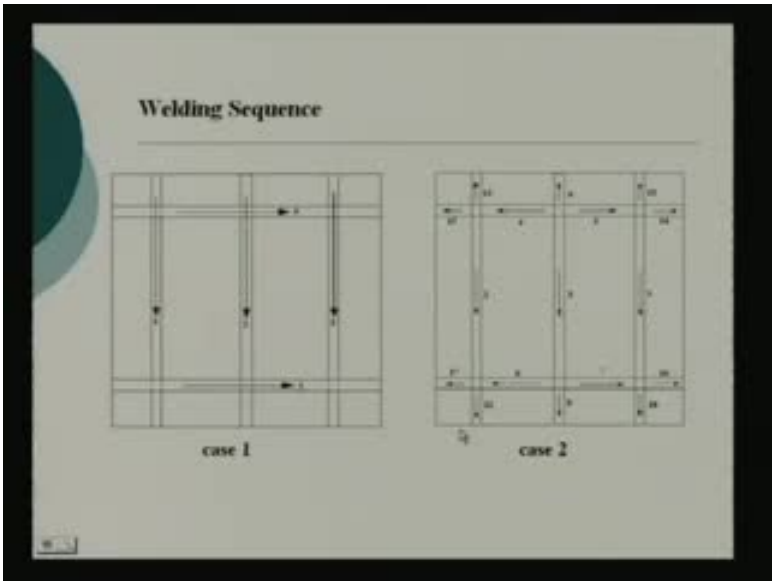

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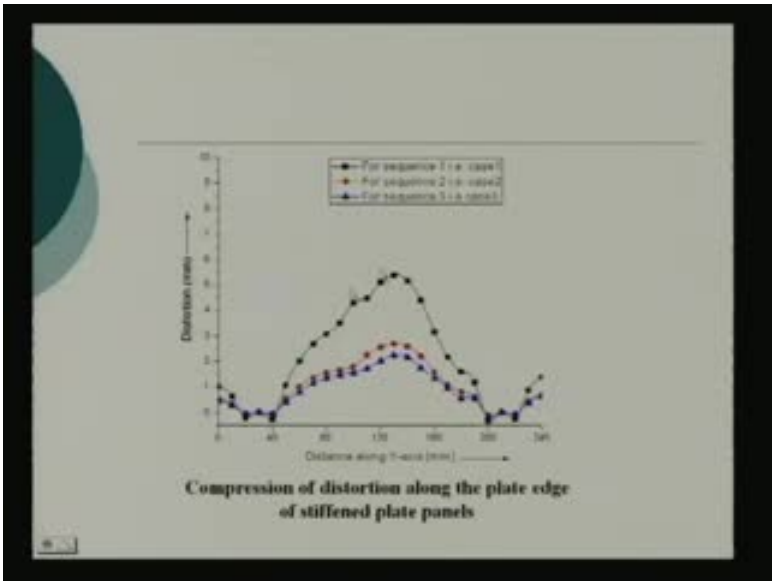

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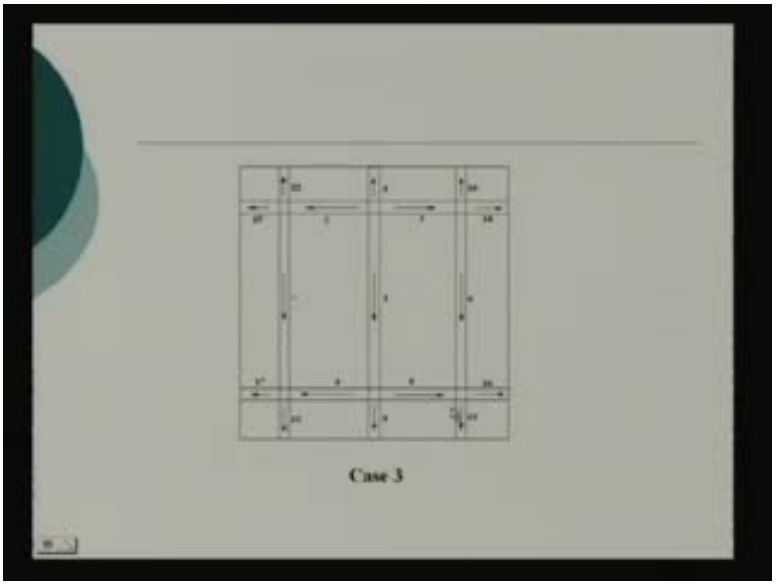

If it is said that welder knows the sequence, then well, case to case it may vary; so, why leave it to chance, leave it to his own imagination; no, should not be left; that is another that that is another thing. This, I am saying just its not only enough to know how the sequencing is to be done, on what basis; and also, as you can see this is a difficult aspect; difficult means, in shipyard it is not feasible that, well, for a given particular case, you start working out different cases, analyze it and then say go for case-2 or case-3 or whatever. No, no, that way you cannot cannot work; because, this analysis is very, very tedious; and for real life structures, it is nearly impossible; then again, you will have to

have implemented different methods. So, at least, logical sequencing one should understand; that is, what we have tried to do here, the case-1, case-2 and case-3; on what logic they are met? So, this logic seems to be better.

Now, so, whenever a complicated drawing comes where you have 20 longitudinal members and 10 transverse members or whatever; so, there based on this, you show the sequence; it is to be shown. Then only the welder will follow and the deformations; then then only you can expect the welder to follow, because it is told so well, then it depends slowly to motivate them to work accordingly though it makes things little difficult. So, what is the procedure, what is followed is, the sequences given in the drawing sheet, so, sequences drawn on the plate; it is just marked 1, 2, 3, 4, 5, so, he knows from where he should jump to which place and do the welding like that.

Anyway, so that is all as far as distortion mitigation control and mitigation is concerned. Well, so, with that we conclude this course of main construction and welding fine.