Work System Design
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Lecture – 57
Case Study: Tower Crane Cabin

Namaskar friends, welcome to session 57 of our course on work system design and as all of you are well aware that we are in the last week of our discussion for this course, in the last week our focus is primarily to understand the applications of the concepts that we have already understood or that we have discussed in the course and in the previous session that was session number 56 in week number 12, we have discussed the design of an office chair or the ergonomic design of an office chair.

And what has to be taken into account or what are the parameters to be considered or what are the components of the chair which need to be designed as per the specific requirements or the purpose for which the chair is being designed, so we have seen that once we are designing a particular physical object or equipment or a device with which a person has to interact or an operator has to interact we have to see we have to make that interaction much more enjoyable for the person who is interacting with the device.

Now, in the chair, when a person has to sit on the chair for a very long period that is for maybe 8 to 10 hours in a day, the interaction; the interface between the chair and the operator or the worker or the professional has to be very, very, very, very good or the person must enjoy sitting on the chair, so the feel that he gets while sitting on the chair physically or I am not saying the emotional feel but the physical feel that a person gets after sitting on a chair has to be very, very pleasant.

So, similarly in that series only today, we are going to see the design of a tower crane cabin and we will see that what are the important parameters to be taken care of and this is available, this PPT or presentation is available on the Internet, we are just reproducing it and trying to connect it to what we have tried to discussed in this course, so the source is given, you can refer to the complete PowerPoint presentation using the source.

But the important point is that here also the person or an operator or a tower crane operator is interacting with the cabin, he is trying to manipulate the controls, he is able to see the displays, he is able to perform his task with interaction with the cabin, so how the cabin must be designed so that the worker feels comfortable, the worker is able to perform his task efficiently, he feels safe, all kinds of accidents are avoided.

So, there are certain criteria under which we have to design this interaction between the cabin operator as well as the cabin controls and displays and the seating arrangement and the we can say the visibility or the windows or the ventilation system, so all these things have to be designed properly if we have to ensure that the operator or the cabin operator is able to perform his task to the satisfaction of his superiors.

As well as there are no accidents or he feels safe while doing the work, so that is the basic idea behind this thing, so this is consist; the overall picture consists of a work system in which there is an operator one element of the work system, then there is in an environment with which the worker is interacting and the output is that he is producing some work, so that is a work system and we will see that for this specific case, where the tower crane cabin has to be designed how this interaction or how this system has to be designed.

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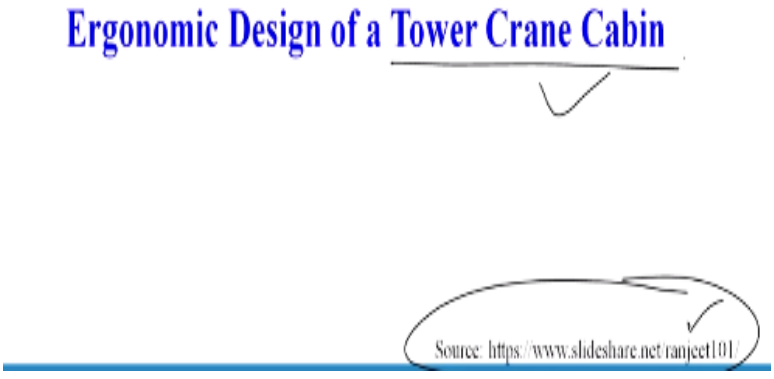

So that the work is effective and efficient, as well as productive, so let us just try to understand the source is already given from where this idea has been taken or the pictures have been taken, so the ergonomic design of a tower crane cabin, this is the title, so tower crane cabin will be clear to you when you see the picture.

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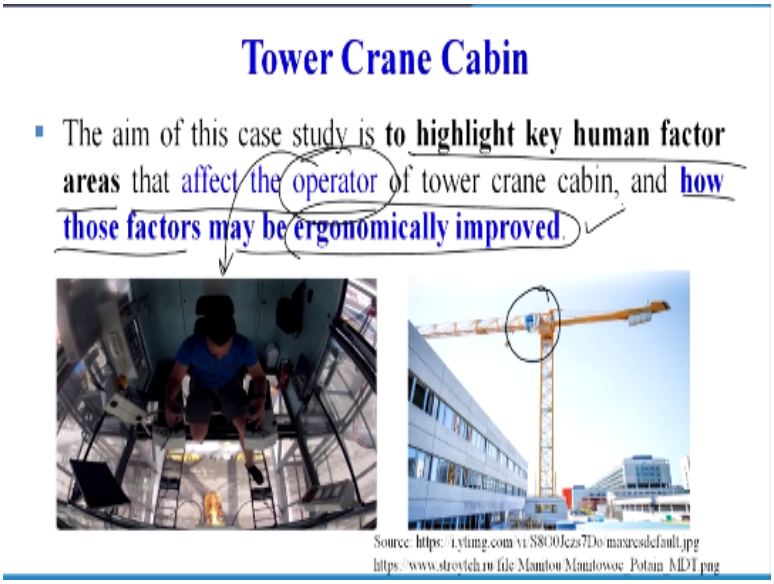

So, this is you can see the tower crane cabin, where our operator is sitting and he is operating the crane from there, so this is a tower crane cabin. The aim of this case study is to highlight the key human factor areas that affect the operator, so this is one important element, the operator who is shown here of the tower crane cabin and how these factors may be ergonomically improved, so we have to improve the factors.

First is; we have to highlight or we have to identify the key factors or the areas which need improvement and then we have to work on those areas based on the scientific knowledge that we have, based on the information, the data, the anthropometric data, the guidelines of occupational and health safety, so basically based on the guidelines, based on the acts, based on anthropometric data, based on the ergonomic principles, we have to design the system.

So that the worker feels comfortable and he is able to perform his task more efficiently and effectively, there will be certain problems if we are not able to design the system properly. What are those problem and how they can be overcome that we can see in our subsequent slide, so here

we can see a person is sitting inside the cabin and we can easily observe that he is able to see down because we have a transparent body through which the worker can see what he is doing or what is the view of the ground?

So that ground view also he can have, while sitting here and here we can see his hands have easy access to the controls, he can see sideways also, as well as the displays are also there, this is one display on the side, so we have already seen in our discussion in week 11, where controls and displays also different types of displays and different types of controls we have already understood, so we need to design the displays and controls also with utmost care.

Because they are also going to affect the performance of the operator who is operating a particular system, where controls and displays are being used, so that is the point that we will come to discussion, today also that will come for discussion, today also that how the controls and displays have to be placed inside a tower crane cabin in order to ensure that the worker is able to perform his task in the most efficient manner.

So, this is the basic problem, this is the person is sitting at a height, this is a tower crane cabin and this is the inside view of this tower crane cabin, so let us see now what are the issues to be looked into, so we have to identify the key human factors or the areas and try to improve them based on the ergonomic principles of work system design.

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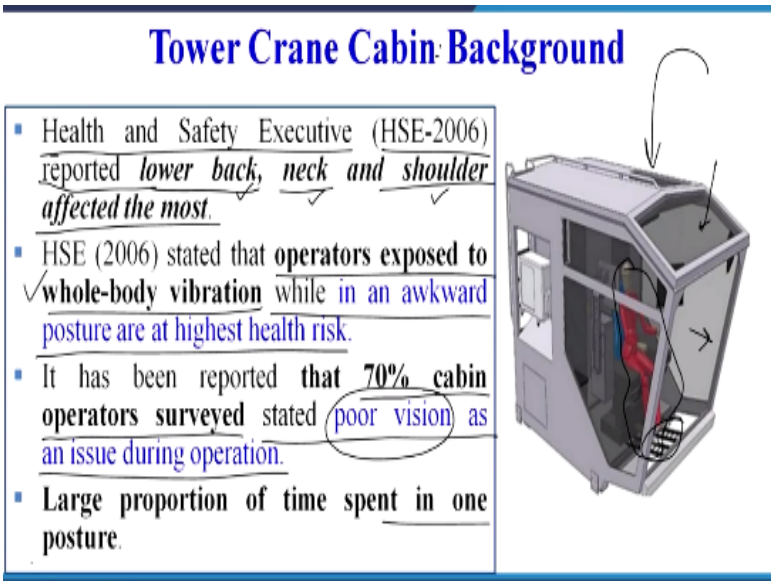

Now, this is just one schematic view of a person operating the cabin, we can see here there are foot rest, this is the front screen, top screen, this is a person in the red outfit who is shown here, so let us see now, what are the exact guidelines, what they suggest, tower crane cabin, so we are just trying to see the background. The health and safety executive HSE 2006 reported lower back neck and shoulder affected the most.

So, it is already reported that in such type of tower crane cabins, lower back, neck and shoulder are affected the most, now why; just you can have a quick thought over it why the lower back, neck and shoulder because the person who is sitting on the chair, if he has to manipulate the crane and he has to manipulate the different controls and if the controls are not properly aligned or not properly placed or not properly put into the minimum or the maximum working area for the person he may have to bend number of time to reach to the controls.

Other thing can be; he has to look down numerous time in a day, so the lower back will certainly, he may have to turn his torso number of times, so that also can create a problem, so lower back, neck also, because he may have to look left or right maybe number of times, so that can also be a problem, shoulder also because he has to reach to the controls may be number of times in a day, so when you do these tasks in a repetitive manner again and again over and over again, maybe after every 10 minutes, you have to reach to a particular control.

Definitely, it will add to may be injuries to your muscles or tendons, so that is an important point to be taken care of, so this is already established, it is reported that lower back, neck and shoulder affected the most. Then, operators exposed to whole body vibration while in an awkward posture are at highest health risk, so this whole body vibration is another culprit which is going to affect the health of the workers who are working such type of systems where the vibrations are beyond the critical limit or higher than the critical limit.

And on top of that there is a whole body vibration and top of that working in awkward postures, their risk becomes even higher, it has also been reported that 70% cabin operators who were surveyed stated poor vision as an issue during operation. So, when they are operating the crane, they have reported that poor vision is one important area, which needs to be improved. So, large proportion of the time spent in one posture only.

Because they have to sit on the chair, so that is also one of the important may be drawbacks or one of the important areas where the efforts can be put that the posture can be changed maybe after specific periods of time or the seating arrangement for the cabin operator be designed in such a way that he can tilt the seat, he can stand or may be tilt the seat forward to look down or to have a better view of the ground situation.

So, the seat can be made slightly flexible, so that he is not in the same posture for 8 hours in a day, so now this particular slide has given us just a hint that how we can design a cabin in a much better manner, so we can see there are physical problems, whole body vibrations are there, vision or site problems are there, then posture problems are there, so we have to ensure a normal posture for the worker.

So, we can see with these guidelines now, with these problems we have to see that how to modify the design of our current tower crane cabins, so that it becomes ergonomically suited for the workers or for the cabin operators. Now, let us see, now what are the key area from the previous slide if we come to this slide, what are the key areas?

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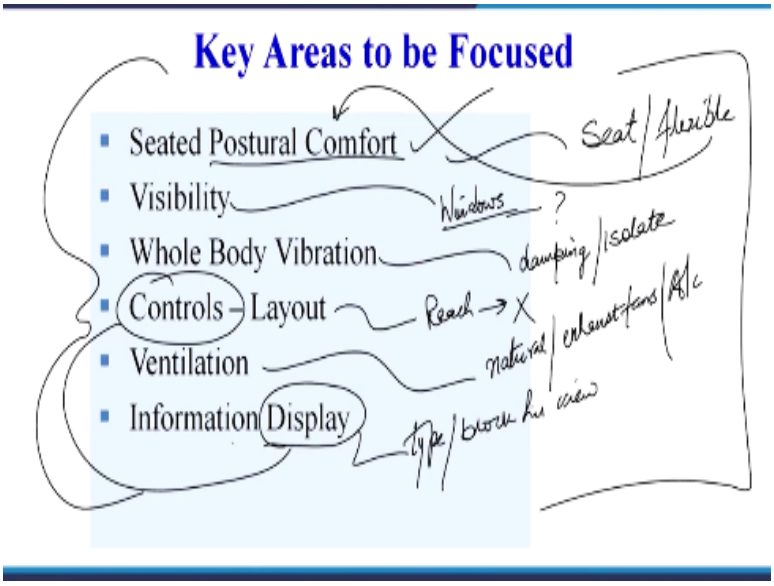

We must ensure the comfortable posture for the worker, which will help us to design the seat or it must be flexible, the seat has to be flexible to ensure the posture comfort. Visibility; this will depend upon the windows because through windows, the operator has to look down, so we need to work on the windows, what should be the material and what can be the visibility range through the window.

Whether, they have to be completely transparent or translucent or opaque something means, we have to work on these windows in order to ensure good visibility for the cabin crew operator, then whole body vibration maybe, we have to look for damping these vibrations that how the vibrations can be controlled or how to isolate the worker from this vibration that we can look into.

Then, the controls layout must be such that he need not have to reach to the controls that has to be avoided, then he must be able; controls must be within his working area, so that the operator is able to control the; control the crane with minimum possible effort, then the ventilation is very, very important, so that we have to see whether we can provide the natural ventilation or it can be with the help of exhaust fans or we can provide an air conditioning equipment.

So, all that has to be seen from ventilation point of view, then the displays; already I have highlighted the importance of displays and controls in one of our previous sessions, so the type

of display, it must not maybe block his view for the ground that he has working and there is a; may we can say a display panel here through which; may be beyond which he is not able to see, so that display must be so designed that the operator is able to see all the ground or the field at which he is working.

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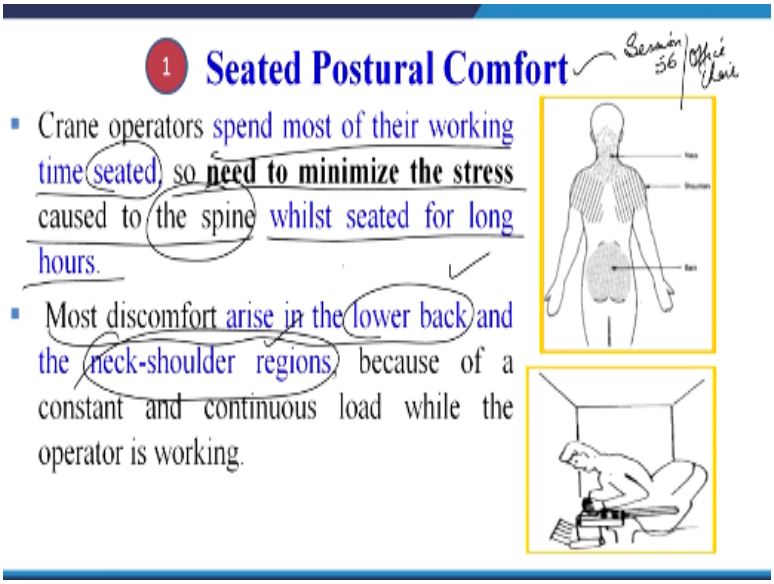

So, these are few may be suggestions which can help us to ensure all these key areas are taken into account. Now, let us see now one by one, so seated postural comfort; already some of the things we have seen in our session number 56 in which we have seen office chair, so that some of the guidelines may remain the same but we will let us see that what can be the guidelines for designing a chair or the seat which has to be used by a tower crane operator.

So, let us see crane operators spend most of their working time in the seated position only, so need to minimise the stress caused to the spine while seated for long hour, so first thing is we have to focus on the spine that we must ensure that there are no injuries or the spine is relaxed when he is working for long duration. So, one thing is he is working; he is working in a sitting position.

On top of that there are whole body vibrations also, so we have to ensure that the worker is not prone to injuries, most discomfort arise in the lower back which we have already seen and the neck shoulder regions which will also we have already seen because of a constant and

continuous load while the operator is working, so these are the important areas or key areas which need some solution.

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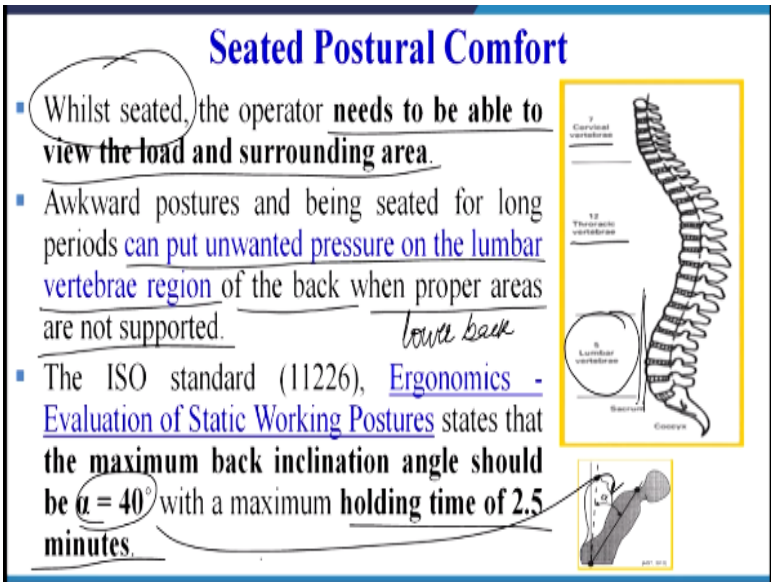

While seated, the operator needs to be able to view the load and the surrounding area, so this is related to the problem of visibility which 70% of the operators have already highlighted in the survey that the 70%; 70% operators who feel that visibility or the vision is an important criteria which affects their performance, so we need to be able to view the load and surrounding area, so while seated the person must be able to have a good vision of the work area in which he is operating.

So, awkward postures and being seated for long periods can put unwanted pressure on the lumbar vertebrae region of the back when proper areas are not supported, a little bit of a medical language, so lower it is given, put an awkward pressure on the lumbar vertebrae region, so it is given here, lumbar vertebrae region, so this is the region, this is thoracic vertebrae, this is cervical vertebrae.

So, we are focusing on this particular region that seating for long posture, awkward postures can put unwanted pressure on the lumbar vertebrae region of the back, when proper areas are not supported, so this is also related to as far as I understand maybe the lower back region only which we have already established in the first slide. So, the ISO standard 11226, Ergonomics

evaluation of static working posture states that the maximum back inclination angle should be alpha is = 40 degree, which is given in this diagram.

This is alpha with a maximum holding time of 2.5 minutes, so we can just; we must ensure that the holding time or when we are in a tilted position over at a back inclination angle of maybe 40 degree, we must not stay in that position beyond 2.5 minutes in order to be safe in order to be healthy. Healthy means that we once we are doing it, we may feel safe but if we are doing it on a regular basis or prolonged exposure we are doing to such type of awkward postures at a later stage it may cause a problem.

For example, this is a common example sometimes, the speed breakers on which we drive are not well designed, so if once you are crossing the speed breaker nothing may happen to you but if continuously you are; you are crossing that speed breaker, number of times may be 100 time, 200 times in a day, similar types of speed breaker it may affect your back, so it may affect, it may have a severe effect on your back support system.

So, therefore it is very, very important that once or twice you may tend to bend beyond that inclination angle as suggested but a regular movement or regular we can say body movement in that direction and that also beyond a holding time of 2 1/2 minutes may lead to certain problems, so seated postural comfort, how we can ensure? So, discomfort of crane cabin seats can be minimised by.

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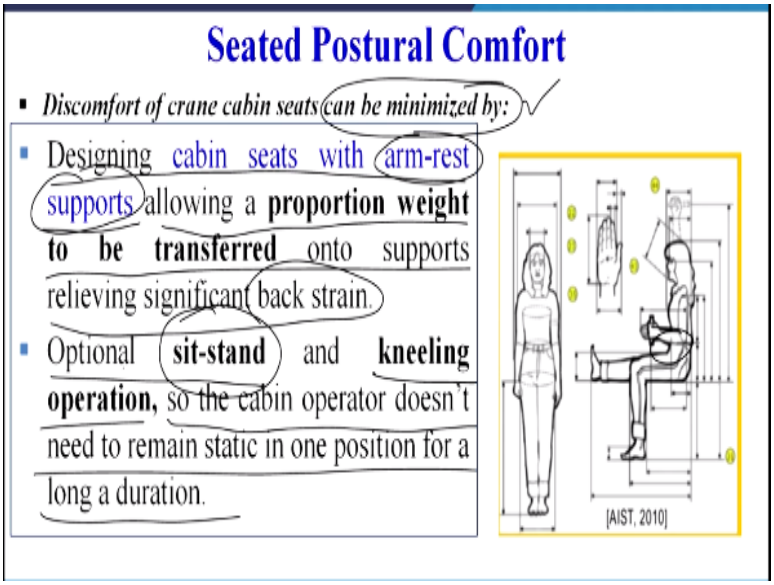

So, now we are trying to see how it can be minimise, lower back is a problem, shoulder neck region is a problem because we are looking at different directions through the crane cabin, so these are the 2 issues that have to be resolved, so we have to design the crane cabin seats with armrests supports, very, very important armrests support; here, we will have armrests supports allowing a proportion of weight to be transferred onto the supports relieving the significant back strain.

So, when you have armrests, some of the; or proportion of the weight will be shared by the armrests, so allowing a proportion of weight to be transferred onto the supports relieving the significant back strain. Optional sit stands and kneeling operation, so the cabin operator does not need to remain static in one position for a long duration of time, so we must ensure sit stand flexibility for the cabin operator.

So, he may sit and he may stand also during maybe 8 or 9 hours of the operation for some period of time he may like to sit and operate the crane and for some period of time, he may like to stand and operate the crane but that flexibility has to be ensured while we are designing the crane cabin because this height will come into picture suppose, we; while designing we only consider that the person will be sitting and operating the crane.

Then, the person because of the height constraint may not be able to get up and operate the crane, so while designing we must ensure that option is available to him, he can work while in sitting position as well as in standing position also moreover in the kneeling position also, so for that if we are able to provide this, then the worker may not sit on the seat provided to him for a long duration of time.

Thus, his backbone or sorry the lower back will be okay as well as the other issues related to the pressure points under the thighs and what that; what we have already covered in our work session number 56 regarding the design of a chair, other issues will also be taken care of.

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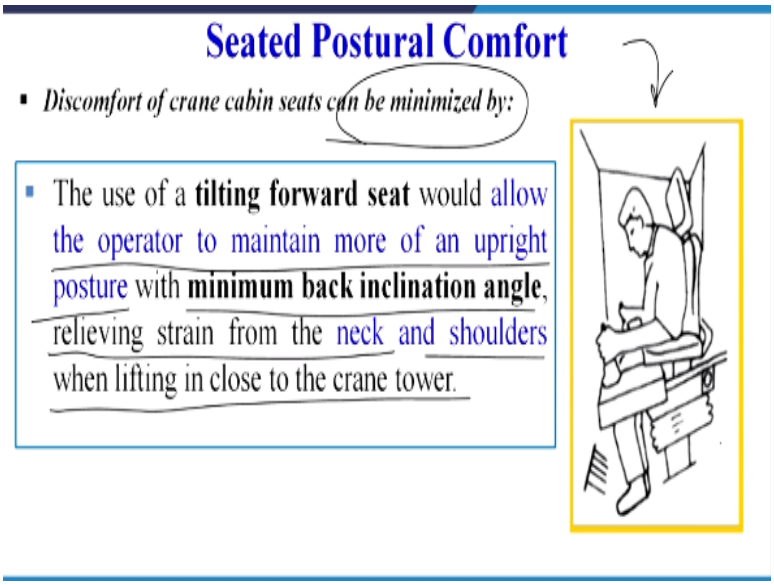

Now, discomfort of crane cabin seats can be minimised by first thing we have already seen in the previous slide that we must ensure sit stand position, we must ensure we can see the first that armrest must be provided, sit stand option must be available with the worker, the use of a tilting forward seat would allow the operator to maintain more of an upright posture with minimum back inclination angle relieving strain from the neck and the shoulders when lifting in close to the crane tower.

So, this is the example which is shown, the tilting forward seat arrangement can be there which will minimise or which will lead to minimum back inclination angle and relieving strain from the neck and shoulder, when he is operating at a nearby position, so nearby means, when the load

that the person is picking up or dropping is near to the crane cabin. Though this is; these are the guidelines or we can say some parameters which can help us to ensure that the worker feel comfortable sitting on the chair at which he is operating or through which he is operating the crane.

Now, let us see about visibility which is a very, very important parameter, so if the visibility is not proper or if the operator is not able to see the working area clearly, it can lead to catastrophic accidents also, so in order to ensure that the operator works properly or he works without any accidents or an incident, we must ensure good visibility. How it can be ensured? Quickly, we can see.

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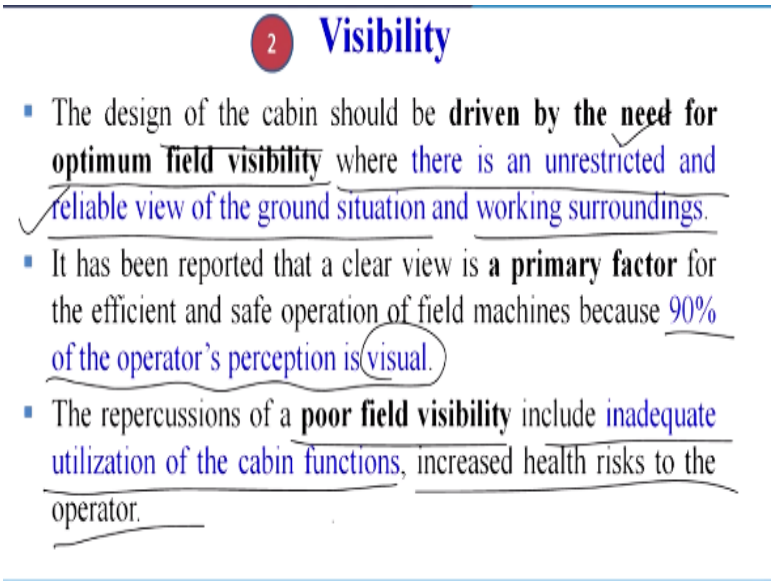

The design of the cabin should be driven by the need for optimum field visibility, the area in which the operator is operating where there is an unrestricted and reliable view of the ground situation and working surroundings, so the we must ensure that the operator has a unrestricted and reliable view of the ground situation, he must not be able to may be making a guess that this may be there, he must be able to take his decisions based on the direct view of what he is able to; what he has to do, so it must not be a guesswork.

But it must be based on the view that he has of the field or the ground, it has been reported that the clear view is a primary factor for the efficient and safe operation of field machines because

90% of the operator's perception is visual, same thing I have told, 90% of the operator's perception is visual only, so the visibility has to be ensured, there has to be no obstruction whatsoever which is affecting the visibility of the operator specially in case of a tower crane cabin.

The repercussions of a poor field visibility include inadequate utilisation of the cabin functions, increased health risks to the operator, so maybe he may not be able to utilise all the functions which are available with him, if the visibility is not adequate.

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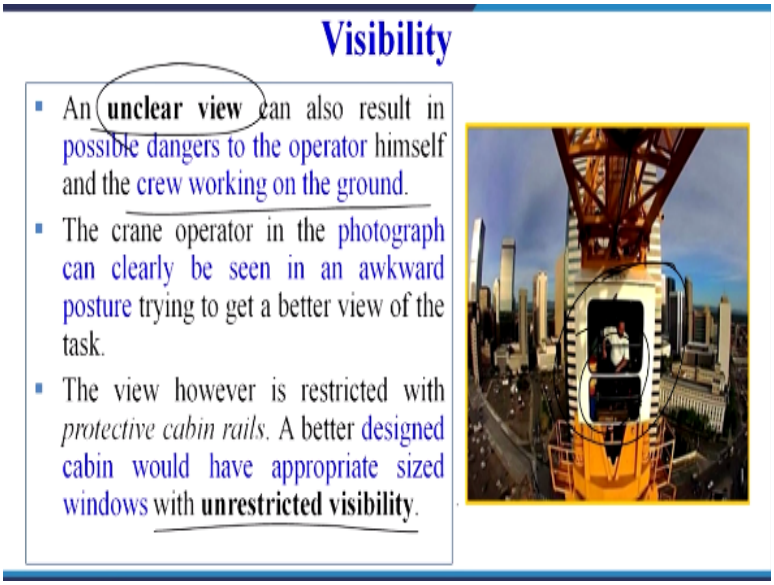

Now, this is another example of a tower crane cabin; an unclear view can also result in possible dangers to the operator himself and the crew working on the ground, so an unclear view can lead to catastrophic accidents, the crane operator in the photograph can clearly be seen in an awkward posture trying to get a better view of the task. Now, you can see he is in an awkward position while he is trying to have a better view of the ground.

The view however is restricted with protective cabin rails, so these are the protective cabin rails, a better designed cabin would have appropriate sized windows with unrestricted visibility, so I have already told a better designed cabin would have appropriate sized windows with unrestricted visibility, so we have to ensure unrestricted visibility for the cabin crew, sorry for the cabin operator.

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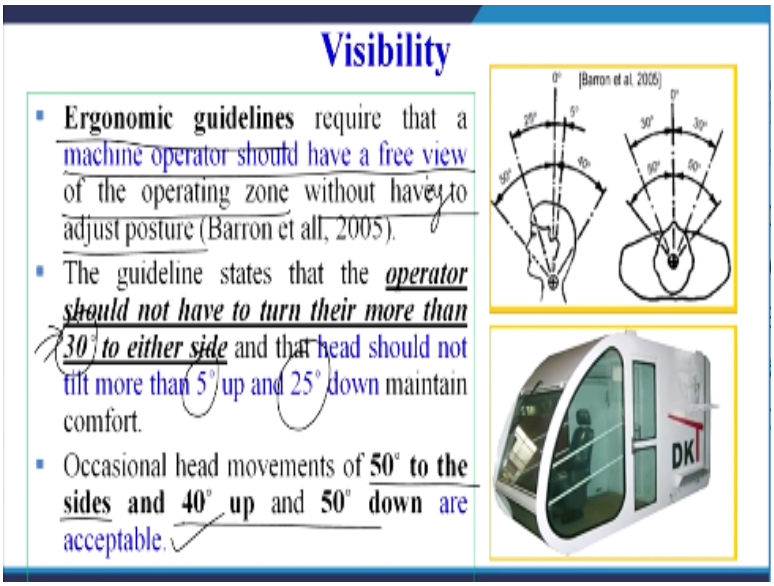

Now, this is a visibility some guidelines, so the ergonomics guidelines require that a machine operator must have a free view of the operating zone without having to adjust to the posture, so as per the ergonomic guidelines, the machine operator must have a free view of the operating zone without have to; without having to adjust the posture, so without changing the posture the worker must be able to have a clear view of what he is operating or the jobs on which he is operating through the crane controls.

So, the guideline states that the operator should have; should not have to turn their more than 30% to either side and that head should not tilt more than 5%; 5 degree sorry, more than 30 degree, I think by mistake I have said percent, so the guideline states that the operator must not have to turn their more than 30 degree or to either side and that head should not tilt more than 5 degree up and 25 degree down to maintain the comfortable working position.

So, even the head movement in terms of degrees is also stated and clearly defined, so body movement is also restricted by 30 degree, so we can see he must not have to moved too much, not up and down for the head motion, so that also is restricted, so once or twice we can do, there is no problem but maybe every 10 seconds or every maybe 10 minutes if you have to do again and again the same thing, the neck and the shoulder as well as the back may get affected.

So, occasional head movements of 50 degree to sides and 40 degree up and 50 degree down are acceptable, so the range is given in which the head movements are acceptable, so this is again another design of a cabin for tower crane.

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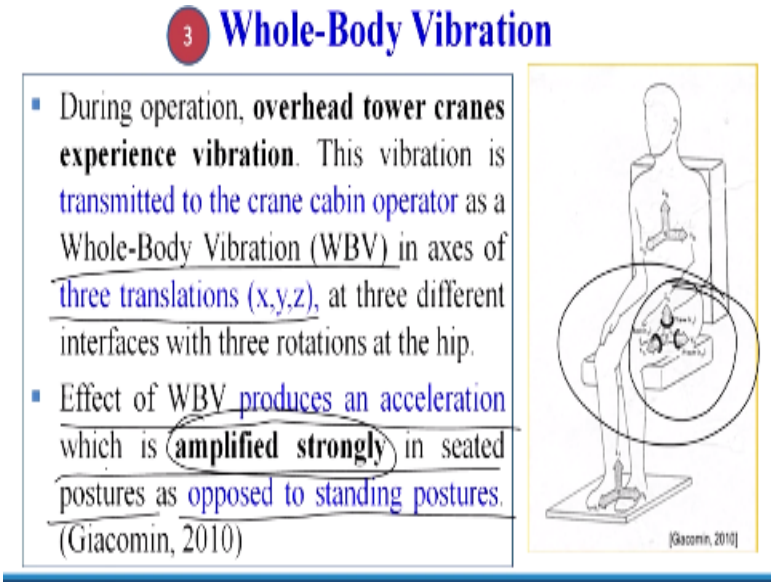

So, whole body vibration we can see during operation overhead tower cranes experience vibration, this vibration is transmitted to the crane cabin operator as a whole body vibration in the axes of 3 translations x, y and z, it is given here, x, y and z at 3 different interfaces with 3 rotations of the hip, so maybe in this zone, he experiences the whole body vibration. So, if you can get the similar type of feel, when you are get may be travelling by a bus or a car or automobile some body vibration is there.

So, the effect of whole body vibration produces an acceleration which is amplified strongly in a seated posture as opposed to the standing postures, so especially when you are seating, so when you are seated, the amplitude; sorry, the vibrations are, they produce acceleration, the effect of WBV a whole body vibration produces an acceleration which is amplified strongly in seated postures as compared to the standing postures.

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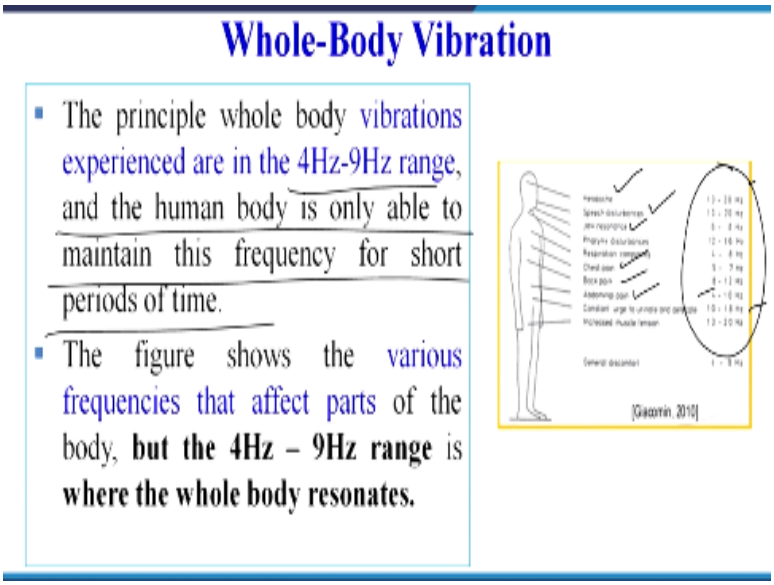

So, this is something as we have seen in the body movement 30 degree left and right and maybe head movement up and down the critical limits are given similarly for whole body vibration also the principal whole body vibration experienced are in the 4 Hz to 9 Hz range and the human body is only able to maintain this frequency for a short periods of time. The figure shows the various frequencies that affect the parts of the body but the 4 Hz o 9 Hz range is where the whole body resonate.

So, this is giving the different frequencies if the body is exposed to different types of vibration it may lead to headache, it may lead to speech disturbances, jaw resonance, abdominal pain, chest pain, back pain so that the range is also given 30 to 20 Hz, 4 to 10 Hz, 10 to 18 Hz, so if you are constantly exposed to the whole body vibration, you may experience these symptoms if you are exposed for longer durations of time.

And you can see a tower crane operator will be there in the cabin for maybe 8 hours in a day and maybe 5 days in a week, so therefore he is prone to; he is may be subjected to continuous whole body vibration and may have these symptoms over a period of time, so then we have to see the controls layout also.

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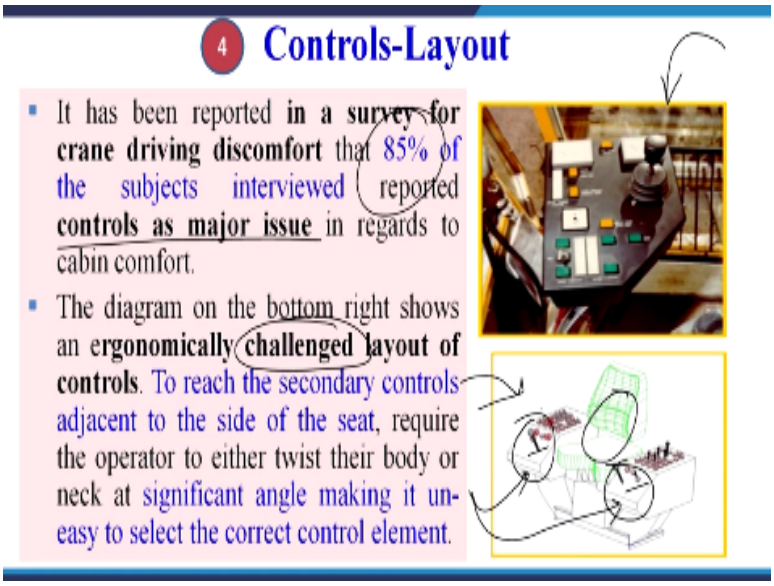

So, this is one example of the control, so here also this is something which is shown here, these are the controls which may be avoided, so let us see now. It has been reported in a survey for crane driving discomfort that 85% of the subjects interviewed reported controls as a major issue in regards to cabin comfort, so 85% is a big number, people or the cabin operators, crane cabin operators have reported that this is an issue 85% that controls are not proper.

So, the diagram on the bottom right, this is the diagram shows an ergonomically challenged, it is not ergonomically designed, it is ergonomically challenged layout of controls to reach the secondary controls which I have already highlighted, to reach the secondary controls adjacent to the side of the seat require the operator to either twist their body or neck at significant angle making it uneasy to select the correct control elements.

So, these 2 are difficult to control by a person who was sitting here, so these control elements or controls may be designed in such a way that the operator is able to perform the task in a much comfortable manner.

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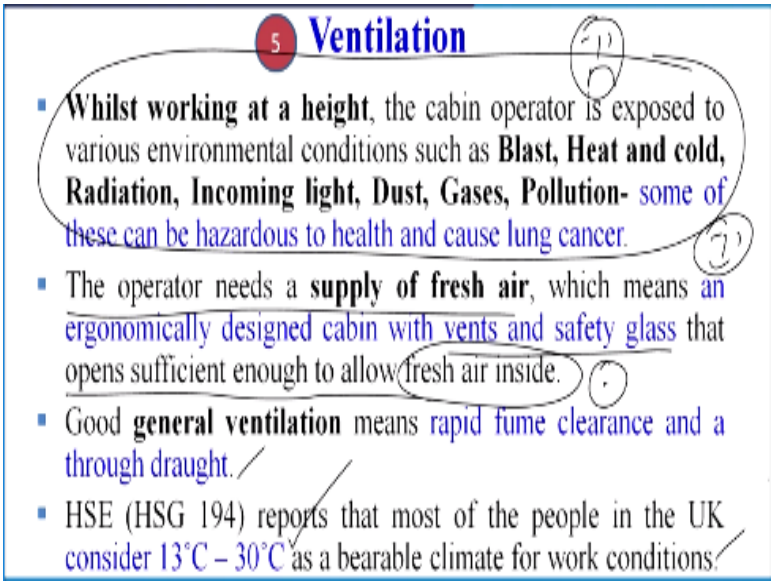

Then, ventilation is also very, very important, whilst working at a height, the cabin operator is exposed to various environmental conditions such as blast, heat, cold radiation, incoming light, dust, gases, pollution, some of these can be hazardous to health and cause different types of diseases. The operator needs a supply of fresh air, this is very, very important, these are all negative points, these are the problem areas, these problem areas need to be; need to be taken care of, so that the operator feels happy.

So, the operator needs a supply of fresh air, which means an ergonomically designed cabin with vents and safety glass that opens sufficient enough to allow the fresh air inside, so we have to allow the fresh air inside the cabin, so that the worker feels comfortable. Good general ventilation means rapid fume clearance and a through draught, so that is may be slightly technical terms; term from the ventilation and air conditioning point of view.

But we can just as a layman, we can try to understand that that supply of fresh air must be ensured inside the cabin. HSC, as we have already seen reports that most of the people in the UK consider this is one data, 13 degree centigrade to 30 degree centigrade as a bearable climate for the working condition, so just one range is given, the temperature must be maintained within this range in order to ensure good working conditions.

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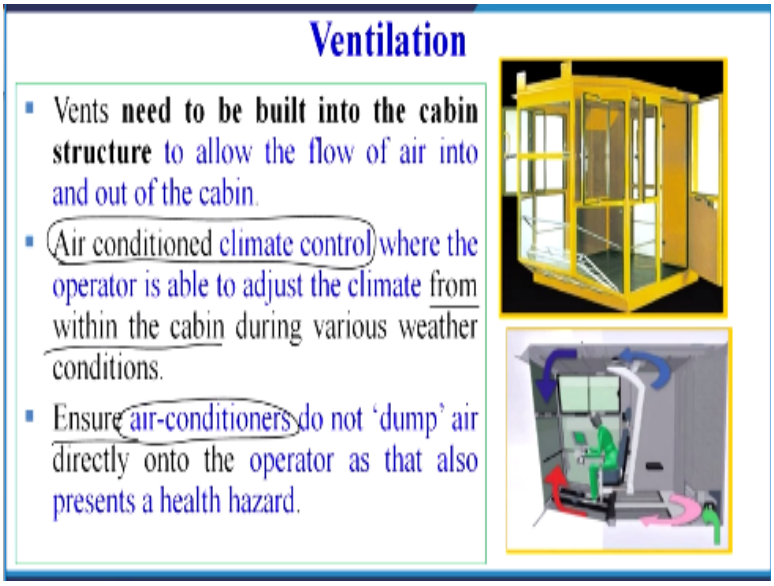

So, ventilation; vents need to be built into the cabin structure to allow the flow of air into and out of the cabin, air conditioned climate control where the operator is able to adjust to the climate from the within the cabin from within the cabin during various weather conditions, so that is climate controlled can be given to the worker, he can control the temperature or the humidity levels inside the cabin.

Ensure air conditioners do not dump air directly onto the operator as that also presents a health hazard, so the selection of air conditioners is also very, very important, so this is just one blue arrow showing the circulation of the air.

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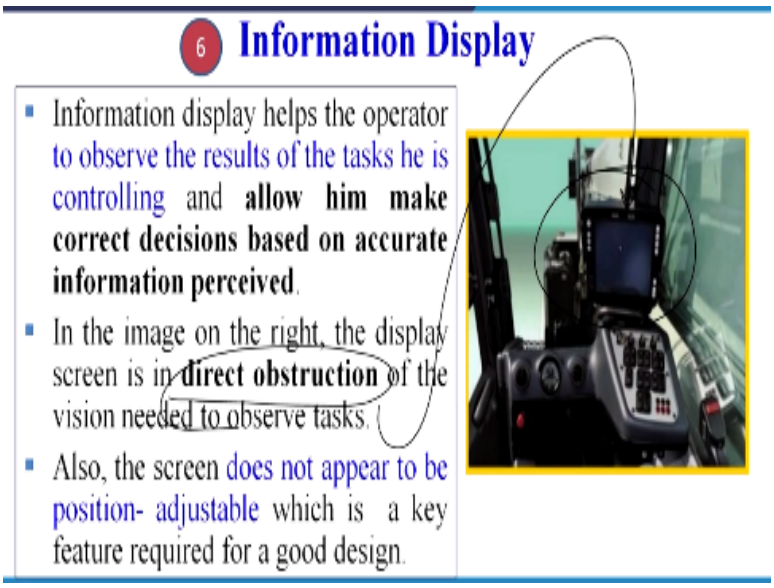

Then, the information displays here you can see, this is one display which is shown here, information display helps the operator to observe the results of the tasks, he is controlling and allow him to make correct decisions based on accurate information perceived, so we cannot do away with the displays because displays are important, which are giving him the information how he is performing the task or he is getting a feedback or he is able to monitor the type of work he is doing through the information display.

So, we cannot do away with the display but in the image on the right, the display screen is in direct obstruction of the vision needed to observe tasks, so this is direct obstruction which is shown here, so definitely we would try to redesign this display in such a way that it does not obstruct the vision of the operator because visibility is an important parameter, which we have already discussed.

Also the screen does not appear to be position adjustable which is a key feature required for a good design, so the screen is fixed, it is not position adjustable which is a key design parameter, if it is possible to adjust the location of the screen, it will be easier for the operator to ensure good visibility.

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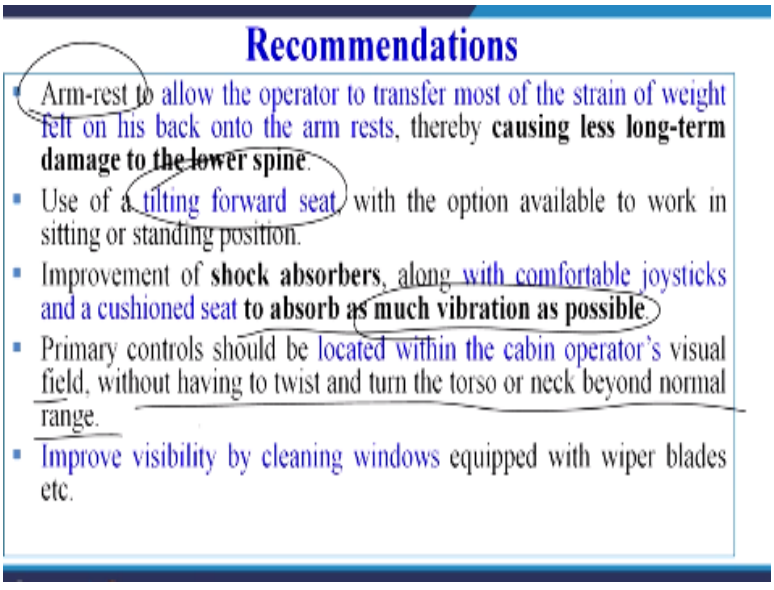

Now, what are the recommendations? Quickly, I will read the recommendations already, we have understood various factors that have to be taken into account, so let us see, armrest to allow the

operator to transfer most of the strain of weight felt on his back onto the armrest thereby causing less long term damage to the lower spine, so first thing is arm rests may be provided, use of tilting forward seat with the option available to work in sitting or standing position, second; regarding the seating comfort.

Improvement of shock absorbers along with comfortable joysticks and a cushioned seat to absorb as much vibrations as possible because we have seen if the human body is exposed to continuous whole body vibrations for a; maybe for a long exposure periods or time, it may cause different types of physical problems, primary controls must be located within the cabin operators visual field, without having to twist and turn the torso or neck beyond the normal range.

And the normal ranges are also specified as per the various guidelines, improve visibility by cleaning windows equipped with wiper blades etc., so we have to ensure a clear vision for the operator and if we have maybe glass windows or if we have transparent windows, we must ensure that they are cleaned at regular intervals because in such type of construction activity going on there may be lot of dust which may affect the visibility, of the dirt get or the dust get deposited on the windows which are transparent in nature.

So, I think with this I will conclude the today's session, with this understanding that this one; this is one system that we have try to understand and we have seen that there are certain acts, certain guidelines available for the design of such type of system, so when we are designing a system we must look for guidelines and recommendations which will help us to design a system in a much better manner.

In our subsequent session, in the next session, we will try to see some other very common problem or one very common design which all of us are using and how it has to be designed taking into account the ergonomic principles of work system design, thank you.