Technical Textiles
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Lecture No- 32
Compression Bandage (contd…)

Hello everyone. So we will continue with compression bandage.

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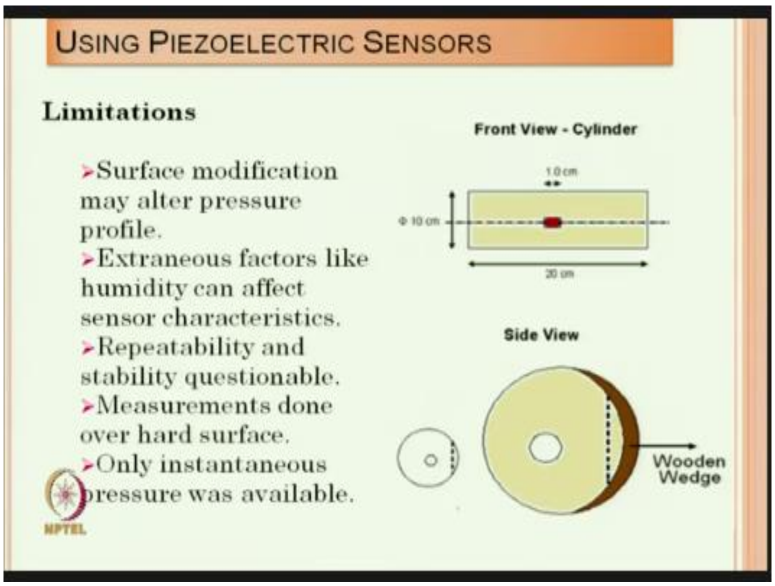

In last class we have discussed, different measurement principles for compression exerted by a bandage and their limitations. Now, we will start with few commercially available instruments.

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Which are used for measurement of compression pressure. The Kikuhime is one of such commercially successful measurement techniques. This is a simple robust and cost effective method which provides accurate measured compression value. So this is one sensor which is on which the bandage is wrapped and the pressure value is sensed with the help of pressure sensor and we can get the pressure value at any time.

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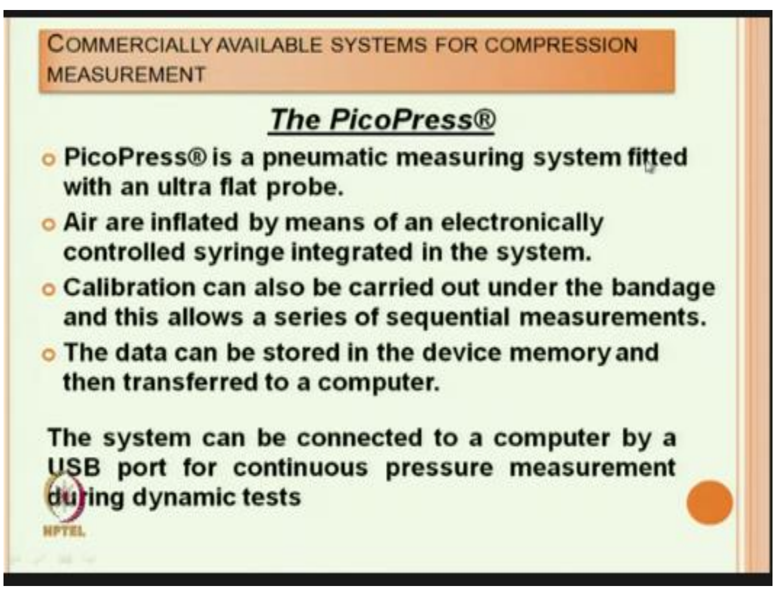

Another system which is known as the PicoPress, the PicoPress is a pneumatic system, which is actually filled with ultra thin, ultra flat probe. Air is electronically inflated that the probe is electronically inflated by a syringe, so electronically controlled syringe which inject air in the probe, calibration can be done and the data of pressure can be stored and this sensor that they can send signal directly to the computer. So this data can be stored in a device memory and then transferred to a computer.

So we will get the total pressure profiling, total pressure during the application of the bandage in real time. So the problem of hard surface is not here, the sensor is actually applied on the body and then bandages wrapped. So actual pressure during the bandage application, we can get.

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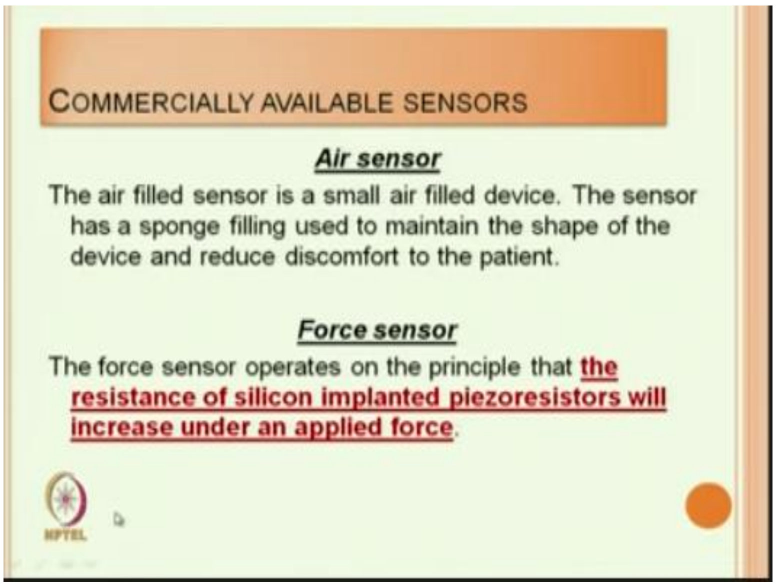

Air sensor is another device works on the air filled system. So the air filled sensor is a small air filled device, it is a it works on the similar principle as that PicoPress or Kikuhime. The sensor has sponge filling use to maintain the shape of the device. So that is us that there will be a sponge filling the shape does not change as it is flexible and also while applying on the patient's surface, there should not be any discomfort sensation. So that is why a soft sponge feeling is there.

Force sensor is another measurement technique which works on the Piezo-electric principle. The force sensor operates on the principle that the resistance of silicon implanted piezoregistors will increase, as we increase the compression load. So after this, commercially available sensors, there are different approaches to develop. The compression measurements systems on soft surface not on actual human limb or leg or hand.

Because the limitation is here that we cannot study, we can get the value of compression, but if you want to study the effect of various parameters, we need to have one instrument and for long time if you want to measure the pressure profiling.

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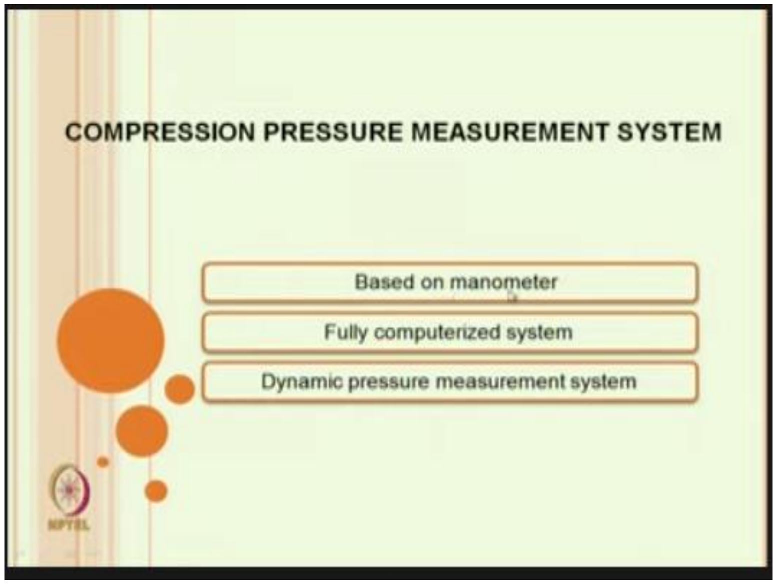

So, there are three approaches in measurement systems. One is that based on manometer, the pressure is measured based on manometer. Next approach was the fully computerized instrument to measure the pressure, the difference between these two are the manometer based system we can measure the instantaneous pressure. But, if we try to study the pressure profiling over long time say one day 24 hours or maybe 48 hours then manometer base system will not give the correct result we will not be able to get data.

Because constantly the pressure will change and monitoring will be difficult. For that if we get the pressure sensor and the sensor is connected with the computer then we will get the value in continuous fashion for long time, so if you want to study the pressure for long time, for longer duration say 24 hours then we need to monitor the pressure continuously and these two systems were basically for static mode, that was there is no movement of limbs.

So during static test we can use both manometer or fully computerized system but if we want to study the dynamic pressure profiling, so then we have to use another system that is dynamic pressure measurement system. In dynamic pressure measurement system we can have different parameters like suppose someone is walking or running, to simulate this walking, so if he is running, walking fast, whether it is walking slow that change in the cycle, rate of cycle.

It should be possible here and also we may find that the different person will have different hardness of the limbs are also during walking or standing there will be expansion and contraction of the muscle that simulation is required. So this dynamic measurement principle we can simulate this, the muscle expansion and contraction and their effect on the actual pressure profiling for longer time.

And sometime it may also happen someone is putting the steps in smaller span, or if you are trying to put the longer span, longer distance that also can be simulated using this equipment. So, I will discuss all three systems separately and the research studies carried on these systems one by one. So let us first we will start with the manometer based principle. So in all these three system the basic principles are that to develop, or to simulate the limbs similar to our body.

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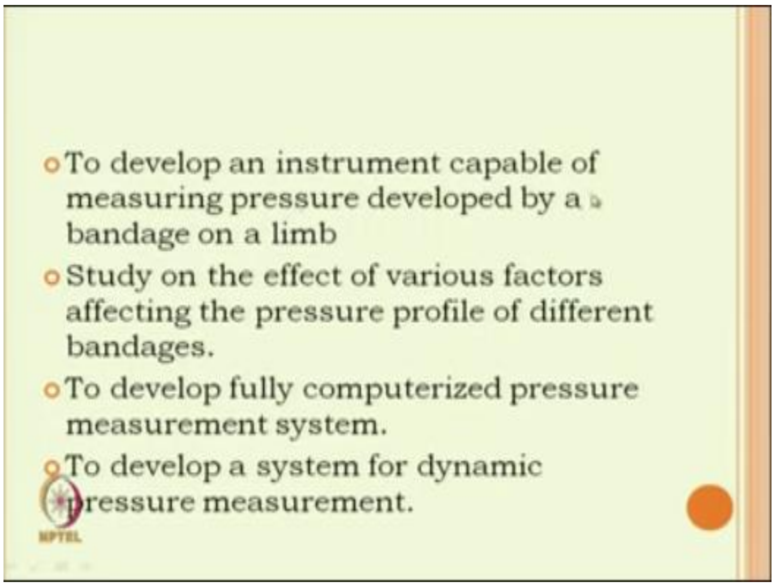

And here to develop an instrument capable of measuring pressure developed by the bandage on the limb and here to study different factors which affect the bandage pressure and then we have developed computerized system and then at dynamic mode we have studied. So all these steps we will discuss here.

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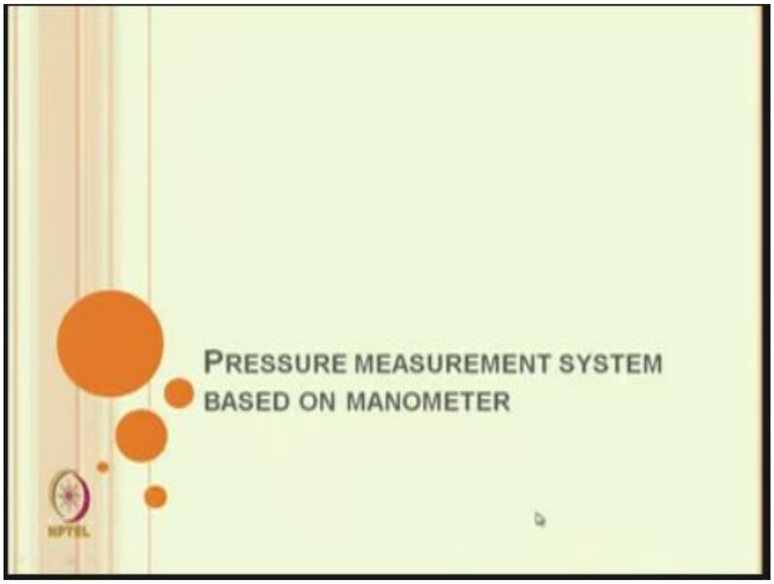

First the pressure measurement system based on manometer.

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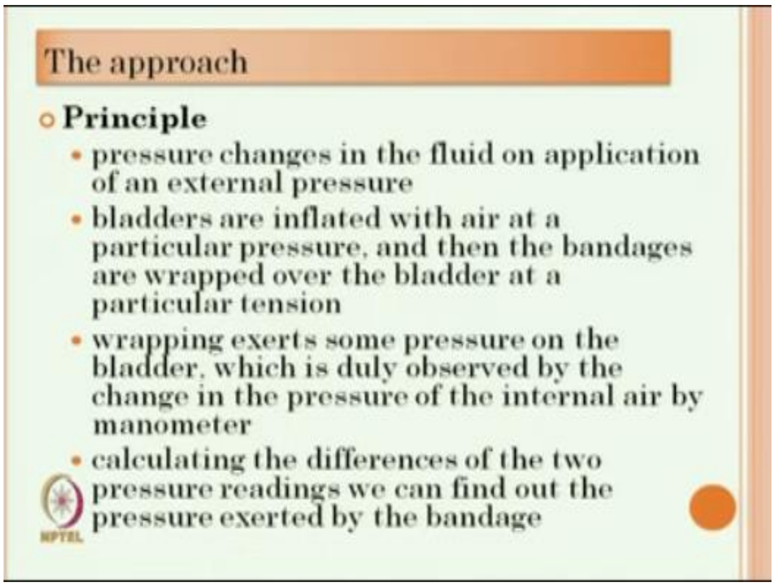

Here the approach, we have actually adopted is that the pressure changes in the fluid on application of an external pressure. Now, the basic approach here was adopted.

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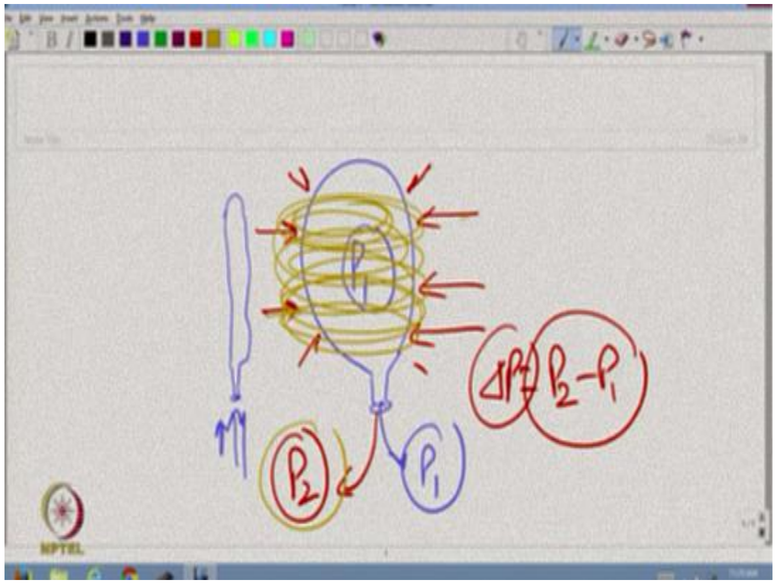

Suppose this is a bladder, bladder. Now, once we fill the bladder with air and if we know the internal pressure P1. P1 we can measure by measuring the air pressure that we can measure that is P1 we are measuring. Now let us try to apply external pressure and after external pressure application the pressure is here it is P2 and the difference between P2 and P1 is actually the pressure which you have applied from outside.

This is the basic principle so delta P is the actual pressure exerted by the bandage if we try to apply pressure using the bandage then what we will do? We will wrap the bandage suppose we are wrapping the bandage. Along this by certain tension the wrapping and that due to the wrapping it will the pressure will increase to P2 and the increased pressure delta P is the actual pressure applied by the bandage. This is the simple principal we have adopted in this equipment. Now here what we have done.

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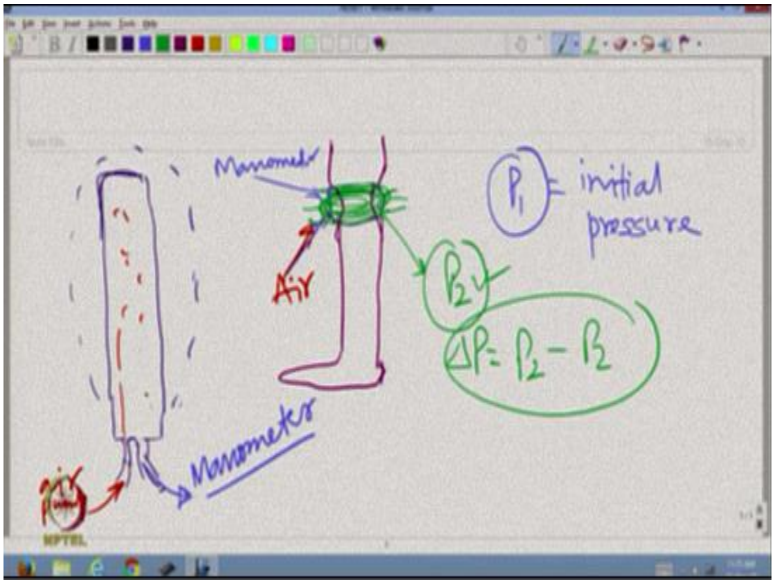

Let us say that we have taken one limb. Here, the wooden limb we have taken and there are some groves are created. This is a similar, then what we have done; we have taken a bladder flat bladder long. This is a bladder one side; it is blocked in another side there will be two openings, two openings are there. Now in one of the openings, this is connected to the pump, air pump. So this will actually fill the bladder with the air that will get expanded like this.

And here this side is connected with a manometer and this will measure the pressure applied. Now in the flat condition this bladder is wrapped here. Wrapped, one single graph was made only single and it is fixed on this surface. Now depending on our, the hardness of our body part we can insert the air. This we will discuss, I am now discussing the principle, the air we are inserting and here the manometer, here measuring the pressure.

And, air is inlet is the air we have pumped in the air and it has generated certain pressure and that P1 pressure. P1 initial pressure, this is initial pressure. Initial pressure P1 which simulates the, our body limb hardness, which is soft. Here it is soft, we are not wrapping on the hard surface. Then we are trying to wrap the actual bandage. The green color bandage we have taken so we are wrapping we may, so we are wrapping the bandage along this.

There are different ways of wrapping, like different overlapping the mode of wrapping from top to bottom or bottom to top this we have studied in detail. So once we are wrapping the bandage, the pressure has increased to P2 because of the extra pressure applied by the bandage. So that manometer is now recording pressure P2. So, to get the value actual value of pressure exerted by the bandage, so P2 – P1 this is called excessive pressure.

Excessive pressure means the pressure exerted actual pressure exerted by the bandage. So here we have actually eliminated different drawbacks with the Piezoelectric sensor or strain gauge or Laplace law because here we are applying pressure on the soft surface and for research purpose for long term data acquisition, we need this type of instrument. The principle we have just discussed the pressure changes in the fluid on application of an external pressure.

Bladders are inflated with air at a particular pressure depending on our body hardness and then the bandages are wrapped over the bladder at a particular tension, required tension. The wrapping exerts some additional pressure on the bladder, which is duly observed by changes in pressure by the manometer. So, the manometer gives that instantaneous value that will give us idea about the pressure applied by the bandage.

So by calculating the difference between two pressures, we can calculate the actual pressure exerted by the bandage as I have just mentioned.

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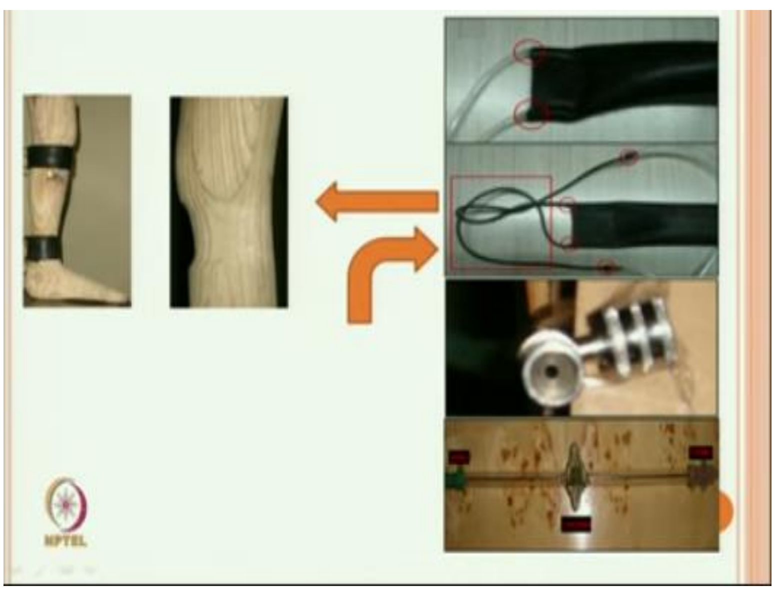

These are the photographs I have just shown that the groove, there are two portions just to simulate the wrapping at the knee and wrapping at ankle portion. Here at knee this is the circumference is high here circumference is low and this is we can see here it is a curved portion the bladder is placed on the curved portion here. So, that the structure of this is not simple cylindrical.

There is a curve also incorporated, that we will see the effect of this curve here, it is a cylindrical portion and we will see that, we can see here one is inlet for pressure another is for the manometer this bladder is wrapped here, this is a flat bladder and then it is wrapped on this groove.

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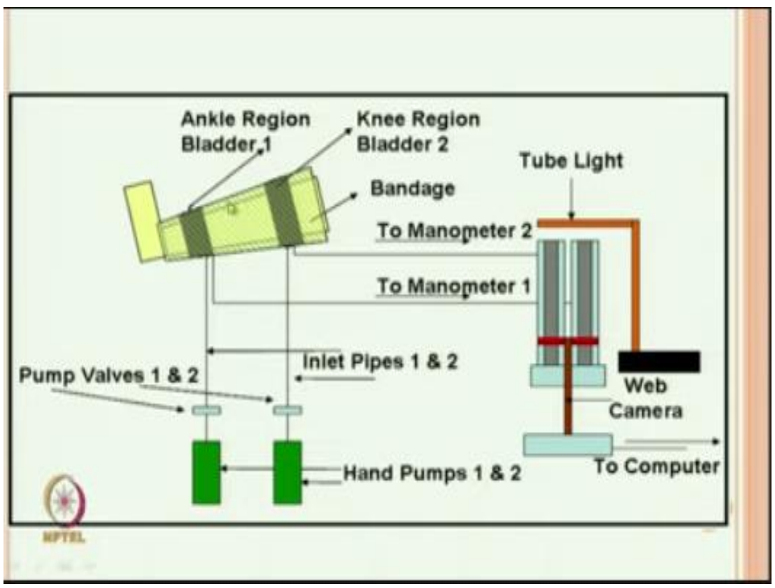

Here we can see here, this is manometer exact at knee zone bladder 2, bladders 1 in ankle zone and hand pump is used here. The hand pump using hand pump we can control the initial pressure. So there are two hand pumps one is for knee another is for ankle. We can use webcam just to know the pressure records of pressure. If we want to do for long time but for longer duration measurement the accuracy is doubtful here, but still we can try and webcam is directly connected with the computer from we can record the pressure.

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These are the actual photographs of the system through manometer we can record the pressure and webcam is mounted here to see the height of this meniscus.

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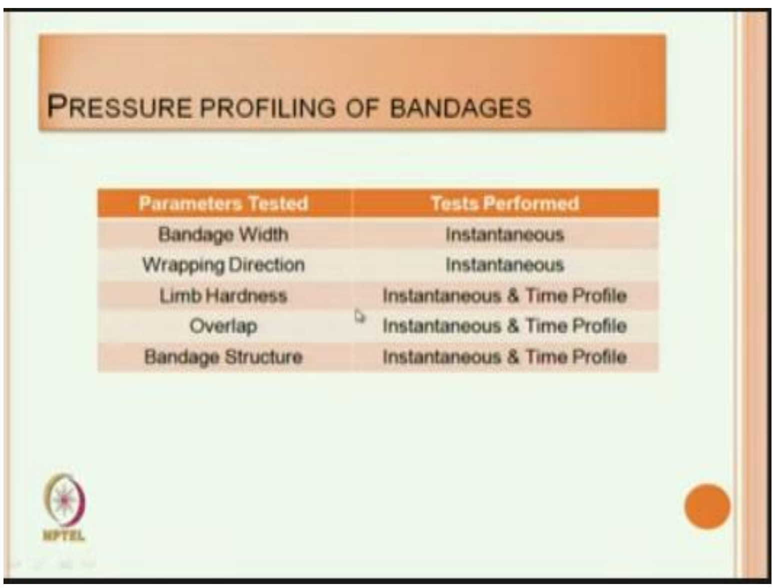

Now pressure profiling here, so parameters which we can measure are the effect of bandage width, we have measured the effect of wrapping direction, limb hardness, effect of overlap, what is the overlap because normally in bandaging the bandage width is smaller than the affected width and if we need, suppose if we apply the 100% overlap, that means we cannot move from one place to another place.

So for that there are different level of overlaps recommended that may be 50%, 75% overlaps are recommended that effect of overlap we have studied and the bandage structure whether the bandage long stretch bandage or short stretch bandage those bandage structures are studied stiff bandage or heavy bandage or light bandage and the test parameters are basically, instantaneous bandage width, effect of bandage width, when we have measured we have measured the instantaneous measurement.

Wrapping direction, it was instantaneous, limb hardness instantaneous and time profiling, overlap also instantaneous and time profiling we have measured, bandage structure we have measured instantaneous and also time profiling.

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In this study we have taken three different bandages with the construction ends per inch, picks per inch is given 24, 22, these bandages are commercially available bandages with mass per unit area and peak load. This is, these are the different, so if we see this bandage it is peak load and here the mass per unit area is less and this bandage was the stretchable bandage and whereas this B bandage is stiffer bandage with the higher mass per unit area. Bandage B is stiffer and bandage C is flexible bandage.

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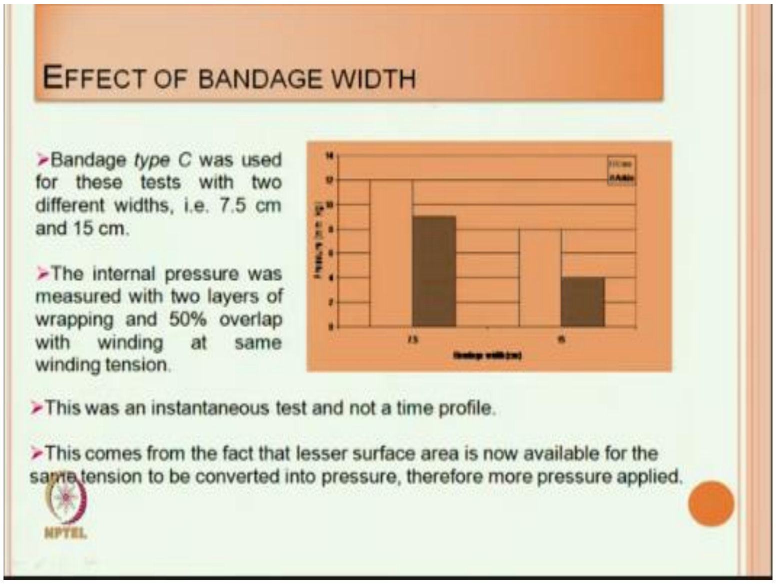

Now try to see here effect of bandage width as has already been discussed if we increase the bandage width, the pressure exerted, instantaneous pressure exerted will reduce. Now we can see here, bandage type C was used here for this test which is flexible one widths 7.5 centimeter and 15 centimeter all other parameters were kept constant, the internal pressure was measured with two layers, so two layers were that layers were fixed.

Two layers of wrapping and 50% overlap during winding, as in bandage width we have measured instantaneous compressional value. So instantaneous test, it is not time profiling. So here from this figure, it is clear that the bandage width 7.5 centimeter width is giving higher pressure, compression pressure than the wider bandage and it is true for both the knee zone and in the ankle zone. This is the knee zone and this is ankle zone.

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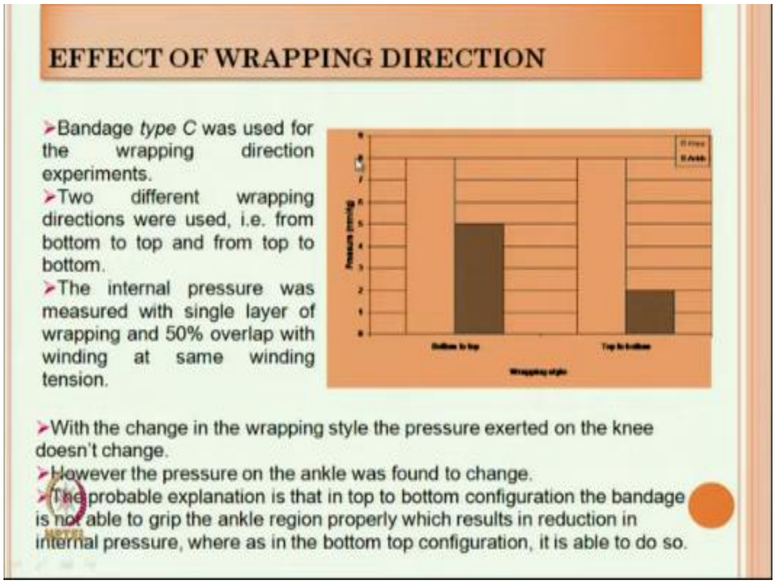

Bandage type C was used for the wrapping direction. So here it is effect of wrapping direction, keeping all other parameters constant, two different wrapping directions were used, from bottom to top and top to bottom. This is bottom to top and here is top to bottom. The internal pressure was measured with single layer. Here we have measured with the single layer and with 50% overlap.

Single layer is because we have only crossed from top to bottom or bottom to top that is a single layer with a 50% overlap. It is basically we can say it is a single wrap, only one we are wrapping. So what we have seen here with the style change pressure exerted at the knee does not change. So whether we change which is knee means it is close to knee, it is not actually at the knee portion which is cylindrical zone simple cylindrical shape.

So whether we apply the bandage from top to bottom or bottom to top that does not affect the instantaneous pressure it remains same but in case of ankle, we can see bottom to top gives higher pressure than top to bottom. The pressure value changes and this change in pressure value mainly due to the complex structure complex structure, it is a curved structure. So for this type of structure in the curved structure, top two bottom means it is a basically close to bottom main portion is at the top.

So from top to bottom if when we see it has dropped suddenly, because at the start we have started with the top as it was going and but when once it is reaching at the curved portion suddenly pressure was reduced. So with the change in wrapping direction pressure exerted on the knee does not change. However, the pressure on ankle was found to change. So the reason as I have mentioned, the probable explanation is that the top to bottom configuration the bandage is not able to grip the ankle.

Top to bottom the bandage is not able to grip the ankle region properly that is why suddenly it has dropped. So while bandaging the complex zone with complex profile, we must be careful in applying the proper tension.

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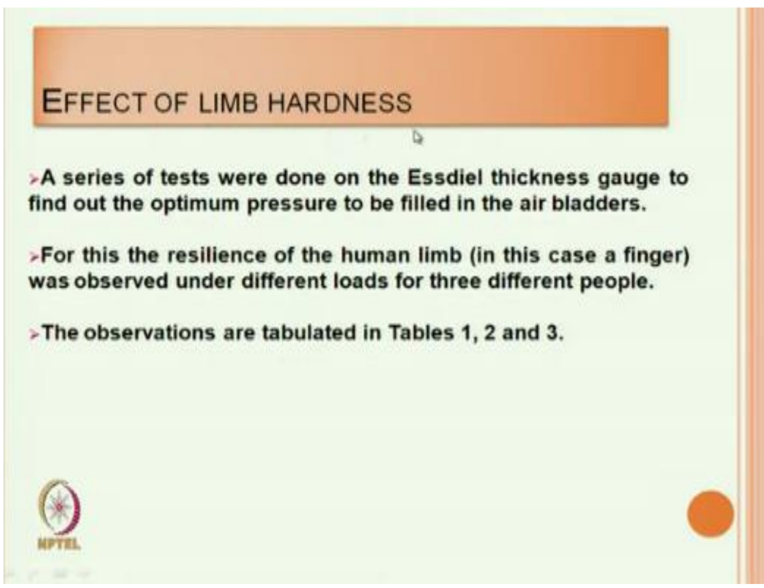

Now coming to effect of limb hardness, limb hardness is it is very difficult to measure we know that someone is with higher limb hardness and other may have softer limb but getting actual value it is very difficult. So what has been tried here, we have taken the thickness at different pressure of the limb, a series of tests to have done on Essdiel thickness gauge to find out the optimum pressure to be filled in the air bladder.

So air bladder pressure initial pressure it is which shows the limb hardness and here just to get idea we have taken finger as the zone. So for this resilience of human limb in this case a finger was observed under different applied pressure.

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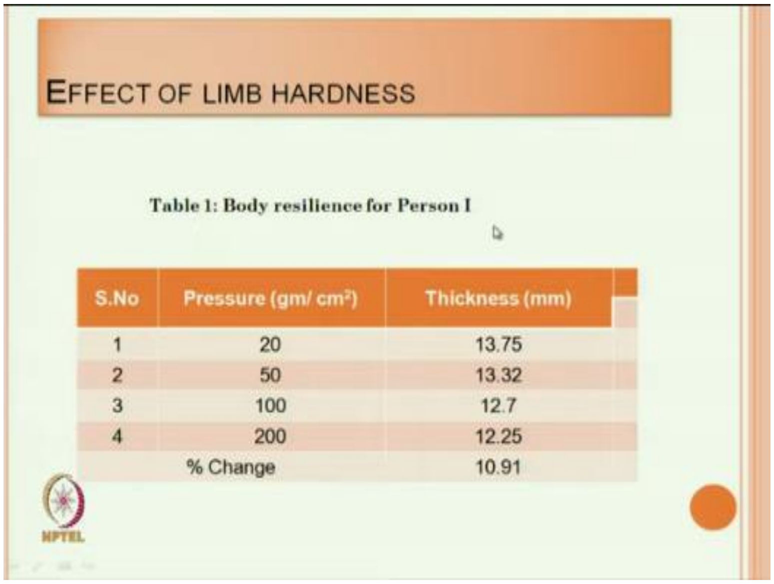

S.No	Pressure (gm/ cm²)	Thickness (mm)
1	20	13.75
2	50	13.32
3	100	12.7
4	200	12.25
	% Change	10.91

So this is the, for a person 1 we have carried out with wide range of the person of different age group among the students even professors. Now, we can see here with the increase in pressure from 20 gram per square centimeter to 200 gram per square centimeter there is a change in pressure here it is 10.91% that change in pressure shows the limb harness how the body parts get compressed with the pressure.

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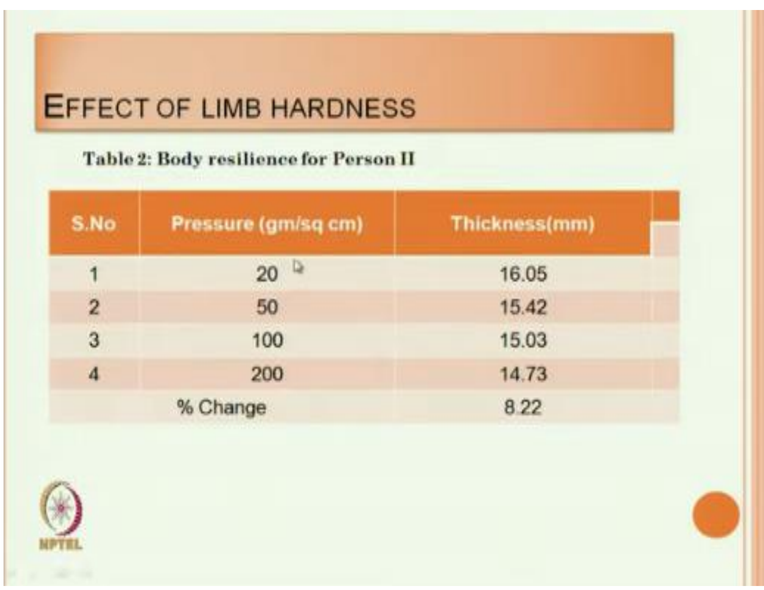

S.No	Pressure (gm/sq cm)	Thickness(mm)
1	20	16.05
2	50	15.42
3	100	15.03
4	200	14.73
	% Change	8.22

A person 2 is giving 8.22% change.

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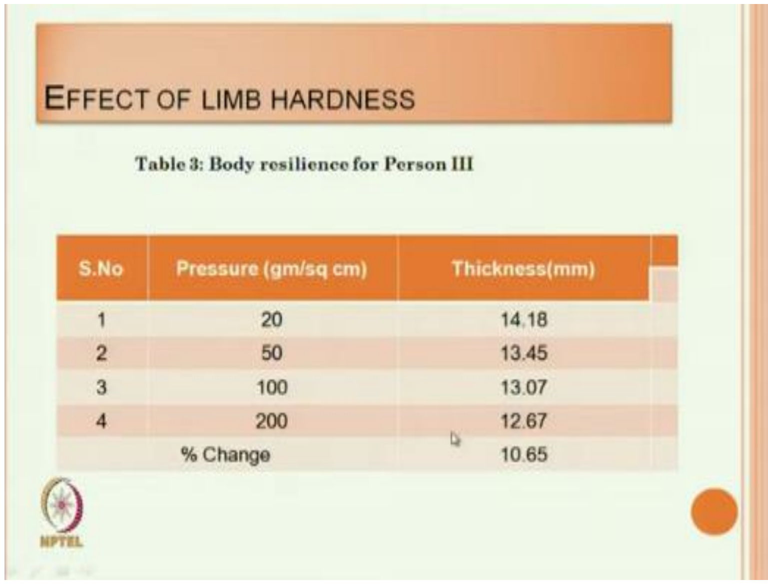

S.No	Pressure (gm/sq cm)	Thickness(mm)
1	20	14.18
2	50	13.45
3	100	13.07
4	200	12.67
	% Change	10.65

Person 3 is 10.65. So we have got so 10.91, 8.22, 10.65, these are the typical values, so from there if we take for three persons.

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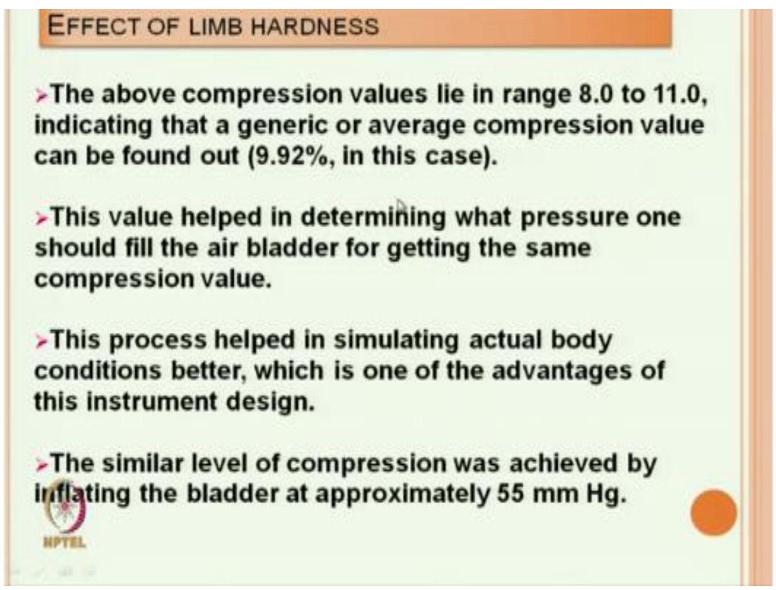

We have got the average of 9.92% in this case if we take the average. Now again, we have carried out study on bladder. We have filled bladder at different pressure manually by hand pump and tested again in Essdiel thickness tester. We found that at pressure internal pressure initial pressure of 55 millimeter Hg the compression is around 9.92%. So in that way we came into conclusion that if we apply the internal pressure of 55 millimeter Hg that will typically simulate our body hardness.

So we have tried to keep that pressure this average values, at least we will get some idea. So, this is the basic assumption on this basis what we have done.

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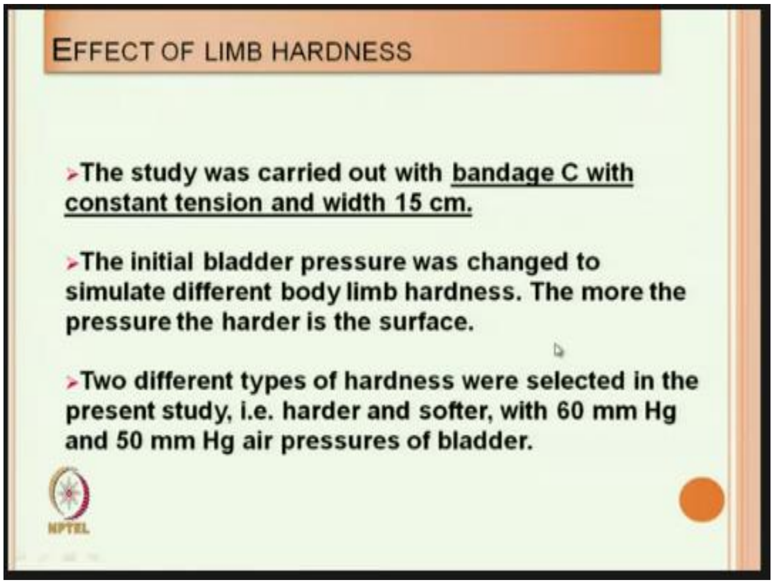

We have used two hardnesses one is softer than that and harder than that, softer than 55 millimeter Hg, that is we have taken 50 millimeter Hg pressure, another we have taken harder for with a 60 millimeter Hg. So within that range, we have kept we wanted to study the limb hardness. So with the 50 and 62 hardnesses we have taken, 55 was assumed it is average. The study was carried out with bandage C at constant tension and with 15 centimeter width.

The initial bladder pressure was changed to suitable value just to simulate the body hardness as I have mentioned it is a 60 millimeter Hg and 50 millimeter Hg pressures were kept.

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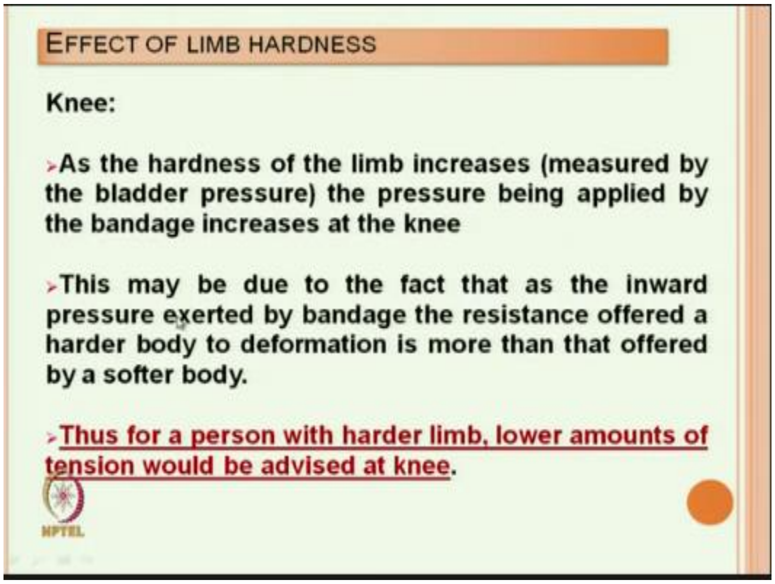

Now effect of Limb hardness at knee and we have measured at ankle also. So, at knee as the hardness of the limb increases that is measured by a bladder pressure, the pressure being applied by the bandage increases at knee, that is important. Keeping the tension and bandage with and all other parameters constant as we keep on increasing the limb hardness, it will start increasing the compression applied compression for same bandage.

Which is due to the fact that the inward pressure exerted by bandage, the resistance offered by harder surface will be more because of the less flexibility for the due to deformation. Than the soft ones, so soft body surface will try to get contracted get deformed that is why it will not apply high pressure, thus a person with hard limb lower amount of tension would be advisable at knee. So we must know the limb hardness otherwise keeping all this parameter for parameter same for hard body muscle we will unnecessarily apply higher pressure.

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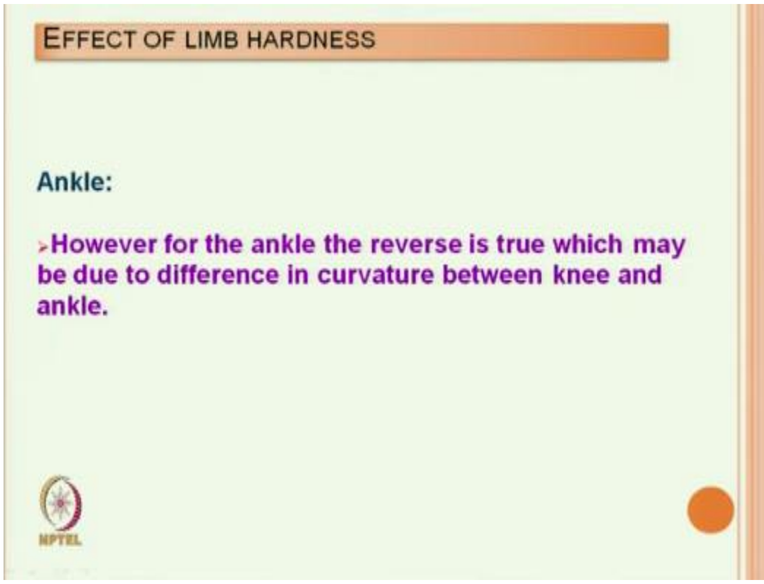

However at the ankle the reverse is true, which may be due to difference in curvature between knee and ankle. So in ankle what has been observed it is the reverse trend and the curvature at ankle is entirely different.

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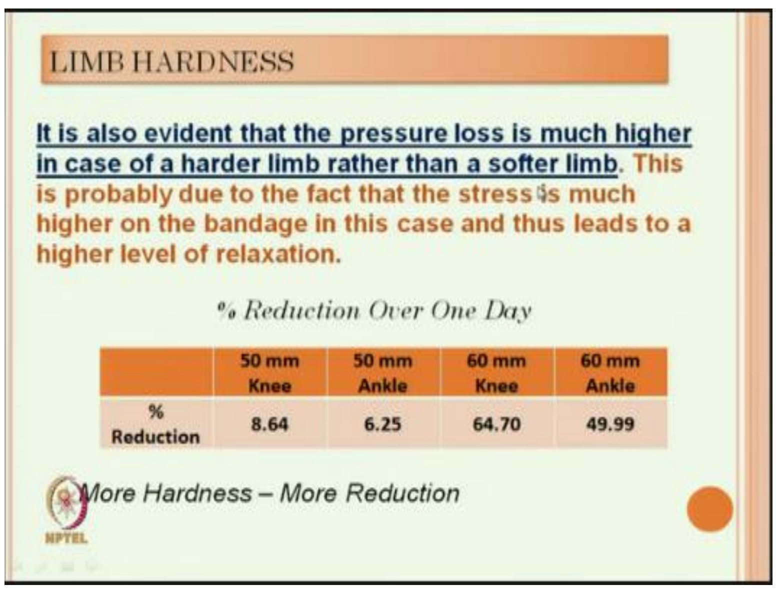

It is also evident that the pressure loss is much higher in case of hard limb than in soft limb, so when we try to monitor the drop in pressure in the hard limb the pressure drop due to relaxation in the structure of compression bandage is more than the soft limb. This is due to the fact that the stress is much at hard limb than the soft limb. So due to stress relaxation in case of hard limb it is more.

So we can see the reduction in pressure for 50 millimeter that will soft limb it is around 8, 6 to 8% whereas for harder limb with 60 millimeter Hg pressure that is both in knee and ankle this is very high, 64% and 49%. From this table, we can also see the level of reduction in pressure is less in case of ankle for both 50 millimeter and 60 millimeter hardness of limb and this is due to the curvature.

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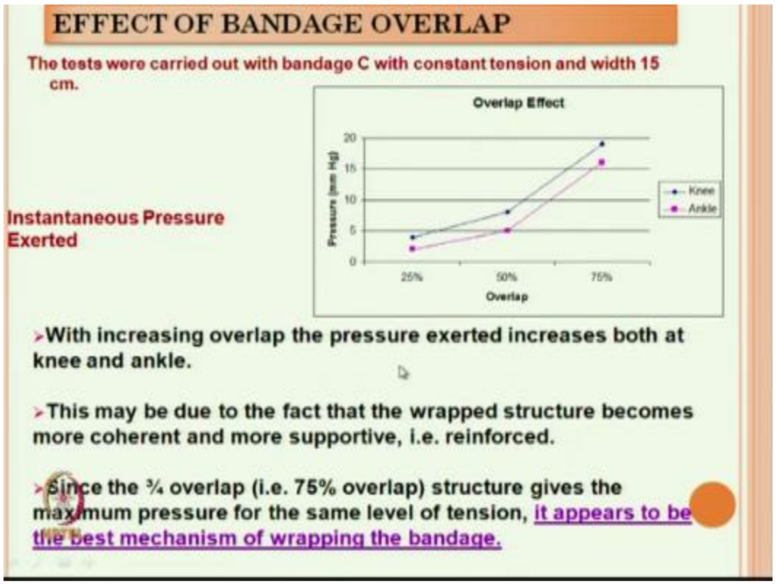

Now, the effects of bandage overlap, so with the increase in overlap the pressure exerted increases in both knee and the angle. So here we can see the overlap is 25%, 50% and 75% overlaps. So as we go on increasing the overlap the pressure exerted becomes high because the increase in overlap the more and more threads are coming into picture. So the fabric layers are coming into picture that is why the pressure exerted increases.

Since the three fourth overlap, there is 75% overlap structure gives a maximum pressure for the same level of tension, it appears to be the best mechanism of wrapping up bandage. Why do we need overlap that I have already explained we cannot have 100 % overlap, then we will not be able to spread the bandage on larger area. So we need overlap but from this experiment it is it appears that the 75% overlap is the best to impart pressure on our limb.

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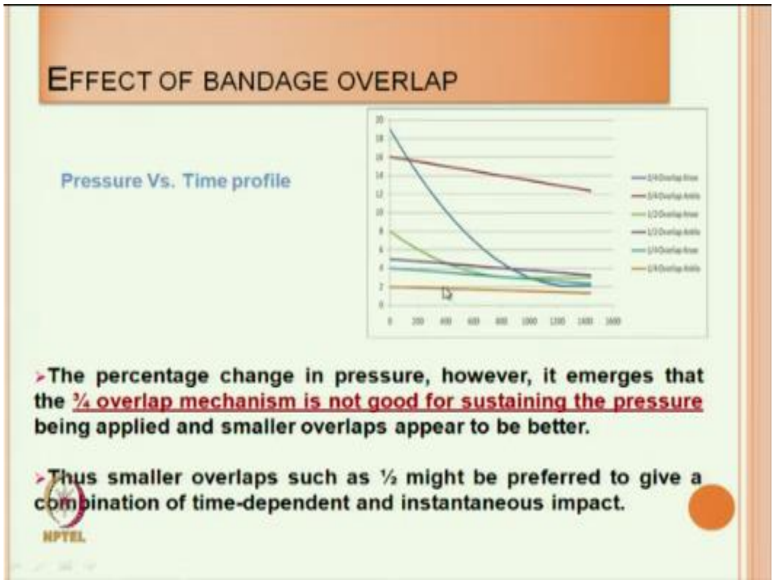

But we can see that time profile, if we see the time profile that means with the time, how the pressure drop, pressure changes that means how the pressure is reduced with the time due to relaxation in the structure. This result it is showing three fourth that means 75% overall. This is at the ankle, this is knee and this one is at the ankle, so at knee and angle, although initial pressure was very high, but pressure retention with three fourth overlap that is 75% overlap is not that good.

Whereas the 50% overlap, although initial pressure was less the pressure retention was better. So initial pressure we can always change by changing the bandage width, changing the tension, but the pressure retention it depends on the overlap here. So that is why the 75 % overlap which earlier it was expected based on instantaneous value it is not recommended on the other hand we can recommend that 50% overlap is good to retain the pressure for long time. That is why it is recommended to have 50% overlap instead of 75% overlap.

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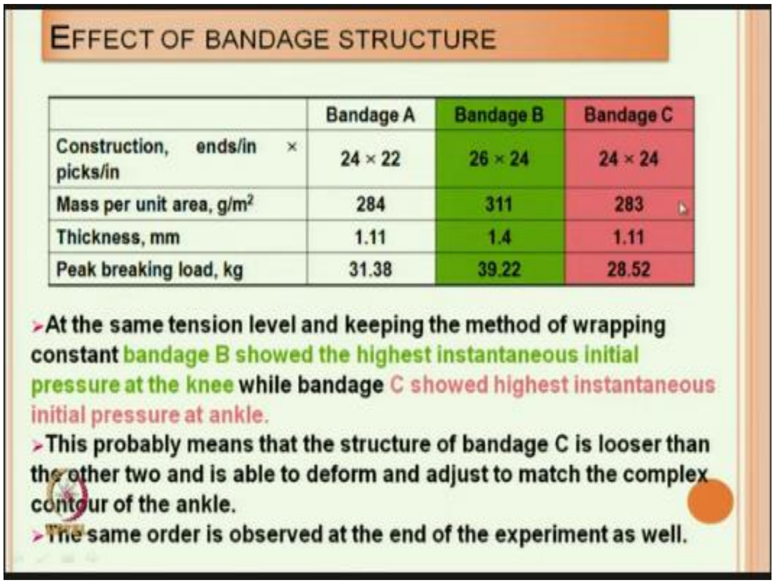

Now coming to the effect of bandage structure, again the same three bandages were used here. The bandage C is having lower peak load, lower mass per unit area, whereas bandage B higher mass per unit area and higher peak load and this is stiffer bandage and bandage C is flexible bandage. So at the same tension level and keeping the method of wrapping same, bandage B shows highest instantaneous initial pressure at the knee.

While bandage C shows highest instantaneous pressure at ankle, this is very important. Bandage B which is stiffer one, keeping all other parameters constant, this is giving highest pressure at ankle at the knee zone where the structure is smooth or uniform structure cylindrical structure. But once we try to wrap at the curved portion the bandage B is not giving that high pressure instead the flexible bandage is giving higher pressure at the ankle.

This is basically due to the flexibility; it can adopt the complex structure of the body part. So complex contour, so that is why if we have to use the compression bandage in the complex contour of our body, we must go for the flexible bandage which will match the complex contour of the ankle or any body part. On the other hand, for the simple body contour we can go for the stiffer bandage.

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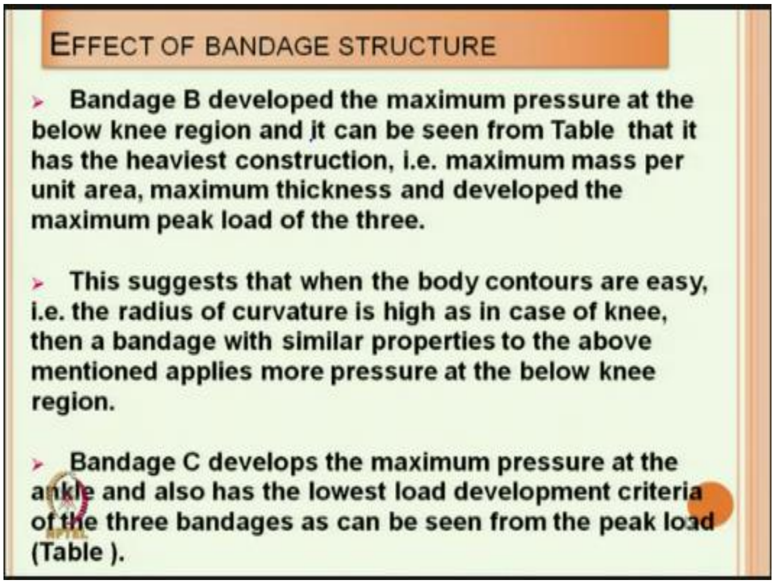

So bandage B developed maximum pressure at the knee zone that is below the knee which is cylindrical zone and it can be seen from the table that it has heaviest construction that is maximum mass per unit area, maximum thickness and developed the maximum peak load. So heavy structure we must use in the simplest construction this suggests that when a body contours are easy that is radius of curvature is high as in case of knee then the bandage with similar profiles that similar properties like heavier and the thicker can be used.

Bandage C develops the maximum pressure at ankle also has the lowest load development criteria and that is why it is giving the highest higher pressure at the complex zone.

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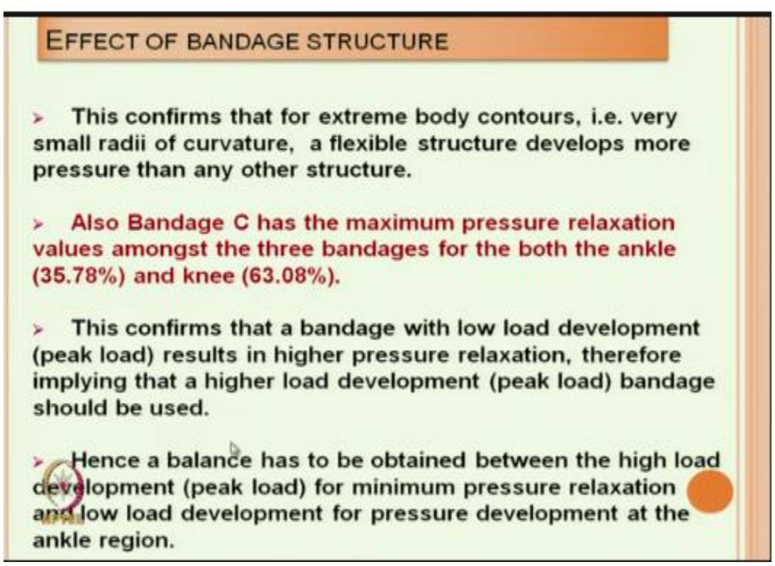

So this confirms that the extreme body control that is complex body contour, very small radii of curvature. A flexible structure develops more pressure than any other structure. Also, the bandage C has the maximum pressure relaxation values among the all three bandages for both ankle and the knee. So, bandage C if we see as it is a flexible one, it actually relaxes. So, pressure drop in bandage C more in case of the ankle, it is 35% and in knee 63%.

This suggests that the stiffer bandage is useful for retaining the pressure. So this confirms that the bandage with low load development, that is peak load results in higher pressure relaxation. Therefore implying that the higher load development that is peak load bandage should be used as far as pressure relaxation is concerned. This the instrument which we have already used discussed, that was based on manometer and typically we can measure.

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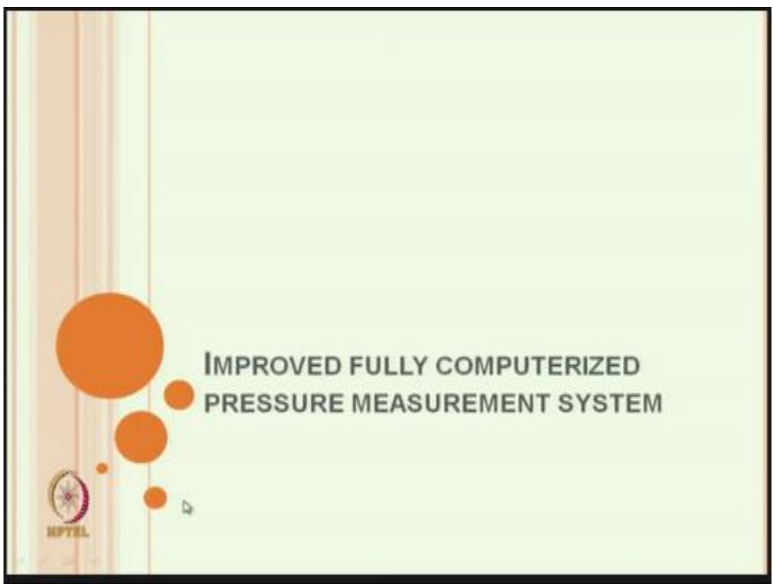

The instantaneous value and discrete value of pressure drop but if we try to measure the pressure profiling constantly then we must use instead of manometer we must use the pressure gauge. So we a pressure gauge is used here.

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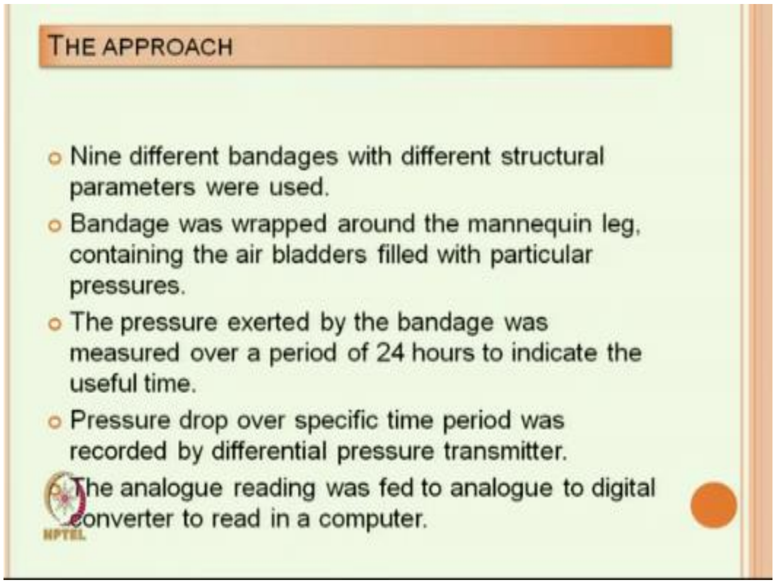

So, 9 different bandages with different structural parameters were used here. Bandages were wrapped around the mannequin leg containing air bladder as similar to earlier study, filled with a particular pressure. Here you can see the pressure exerted by the bandage was measured over a longer period, 24 hours and the pressure drop over specific period was recorded by differential pressure transmitter.

So that pressure drop was recorded here and this analog reading was fed to analogue to digital card converting card and then to the computer, send to the computer for recording the digital data. Now, we will continue with this system and also in next class we will discuss different experimental studies carried out on this instrument, along with another system for measuring the pressure profiling during the movement condition that is the active condition. In dynamical condition that at different level of movement that will discuss, till then thank you.