Technical Textiles
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Lecture No- 33
Compression Bandage (contd…)

Hello everyone, so what we are discussing now, different approaches to measure the compression pressure. In last class, we have discussed one method of measuring the compression pressure based on the manometer principle. Here we will discuss the method.

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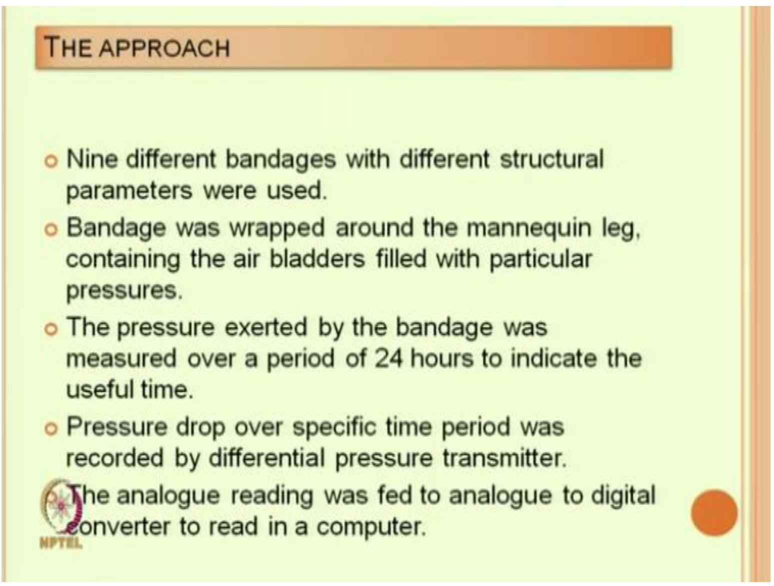

Fully computerized measurement technique in this system again, we use the mannequin leg, and air bladder like earlier, which we have discussed but as the pressure is measured using pressure sensor, we can record the pressure for long duration. Here the pressure was recorded for 24 hours duration and pressure drop for different parameter was recorded over specific time period and we get the analog data.

And it was converted to the analog to digital through analog to digital converter and which is fed to the computer for getting the pressure profile.

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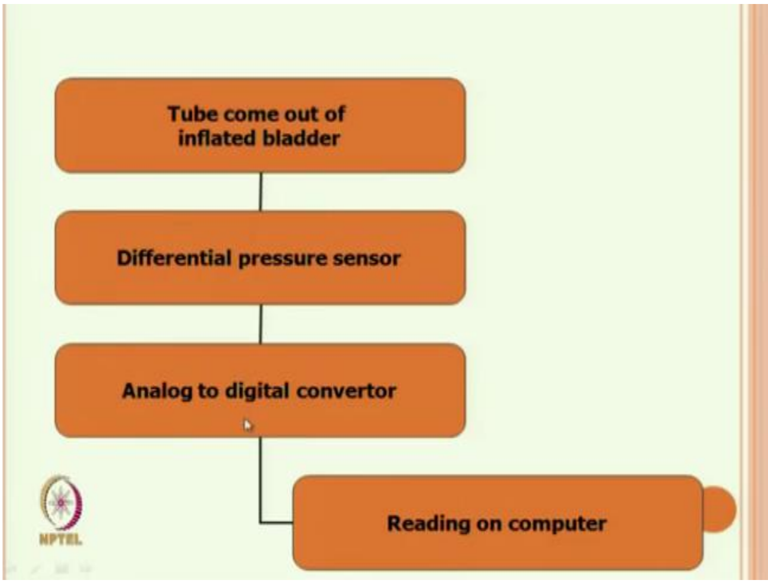

The same tube which I have already mentioned bladder tube, so from bladder there are two tubes one is input tube, that is for pressure exertion the air inlet and another tube is for measuring the bladder pressure. So this tube is connected with the digital pressure sensor and from that the, A to D converter we get the pressure value through the computer, it is connected with the computer.

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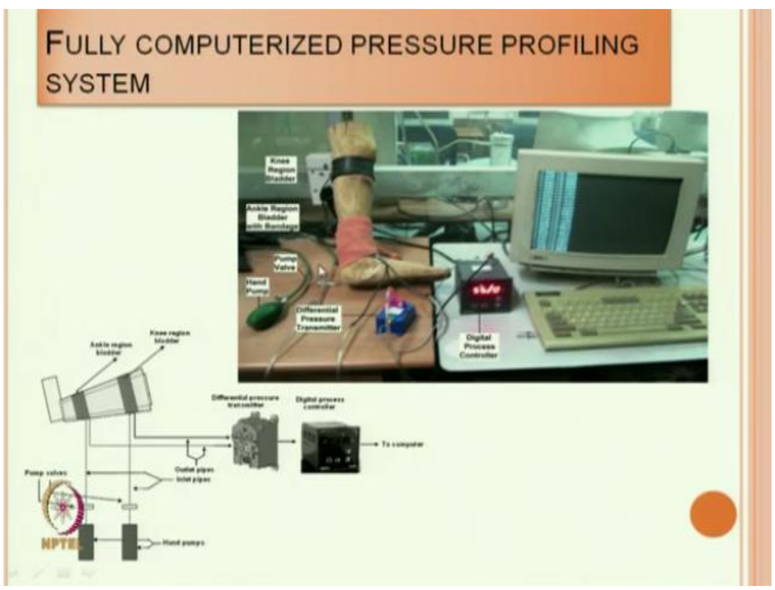

This is the, system photograph and construction wise it is a similar construction air bladder is there but the only change here is that instead of manometer here we are used the pressure sensor and which is connected with the computer. So, this is the same setup and compression bandage here it is showing it is at ankle zone it is wrapped and pressure is monitored here with the time.

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DETAILS OF THE BANDAGES USED

Bandage	Mass per unit area (g/m²)	Thickness (mm)	Breaking load (kg)		Breaking extension (mm)		Initial modulus (kg/mm²)	
			Warp	Weft	Warp	Weft	Warp	Weft
A	362	0.98	22.71	23.28	94.86	10.11	1.07	9.51
B	257	1.24	15.77	29.44	45.07	21.22	0.16	11.03
C	378	1.07	18.48	46.81	95.21	31.44	0.12	14.30
D	397	1.38	15.51	38.91	71.57	20.87	0.05	19.08
E	266	1.52	9.54	10.97	53.77	11.68	0.19	5.14
F	253	1.42	21.88	41.67	78.57	20.89	1.58	14.31
G	264	0.97	16.47	13.64	62.75	12.92	1.58	4.70
H	378	1.18	21.82	30.71	118.65	17.21	0.11	9.78
	456	1.44	20.99	46.17	119.84	23.46	0.07	22.90

In this experiment we have taken the 9 different samples. Bandage samples, commercially available bandage samples, we have done detailed studies on these bandages. But here I will take some specific bandages just to see the trend, where detailed research study is not required at this stage but we will try to see the bandage structure, effect of bandage structure on the compression behavior.

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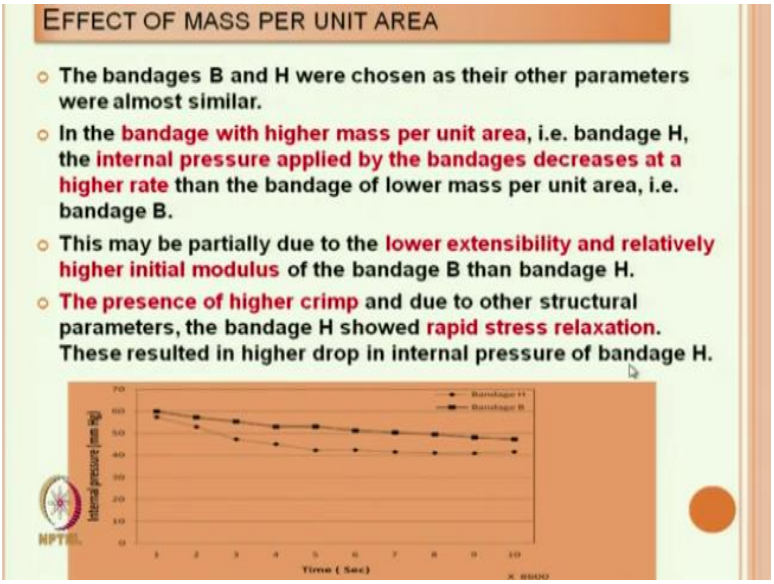

Now effect of mass per unit area of bandage, so what we have done we have taken bandage B and bandage H. So if we see here bandage B is mass per unit area is 257 and bandage 8 is heavier it is 378 and other parameters are almost same except the bandage mass per unit area. So other parameters were almost similar, the bandage with higher mass per unit area that is bandage H, the internal pressure applied by the bandage decreases.

So initial internal pressure was kept constant for both bandage B and bandage H by adjusting the tension, if we see this two graphs the bandage H, this is the bandage H where pressure drop, the internal pressure drop is high. It decreases at higher rate than the bandage with lower mass per unit area. So heavier bandage is showing higher drop in pressure this may be partially due to lower extensibility and relatively higher initial modulus of bandage B than bandage H.

So bandage B's initial modulus was higher than bandage H and extensibility was also lower. So to retain pressure, even if the bandage is lighter, that is the mass per unit area is low, if we use the bandage with higher initial modulus or lower extensibility then also it can retain the pressure, so pressure drop will be less. The presence of higher crimp, so due to other structural parameters the bandage, H shows the rapid stress relaxation.

So if the bandage thickness and mass per unit area is high, in that case the bandages prepared with the higher crimp. So that crimp present in the bandage will have relaxed, will try to relax and immediately the pressure drop will be there.

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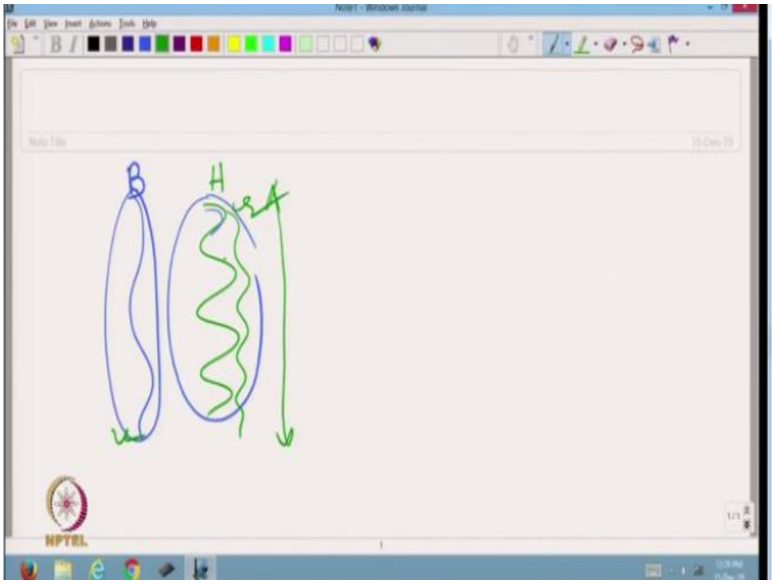

Now, this we can see here this is bandage, say H and bandage B. Now while applying pressure initially, the pressures were same by maintaining the tension, but with the time this crimp will try to get straightened. A bandage dimension will be, it will be stretched the more stretch will be there in bandage H than bandage B due to higher crimp. So stress relaxation will be high in case of bandage H that is why the pressure drop will be high.

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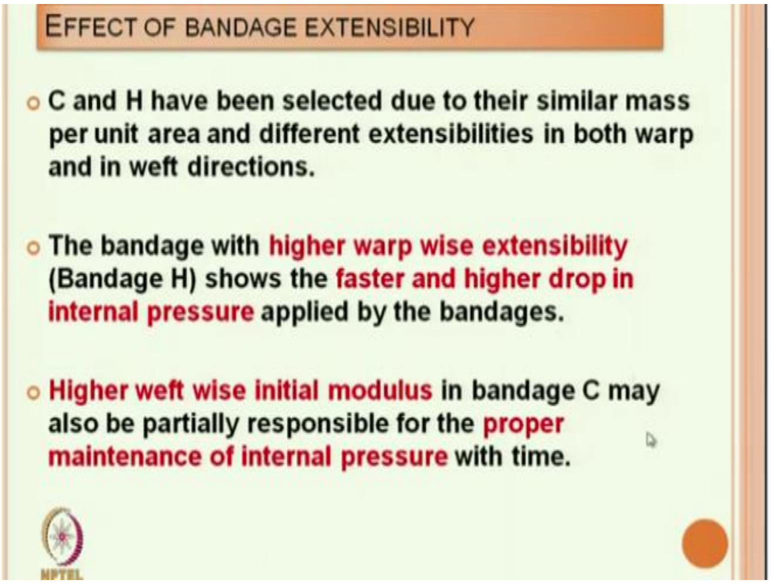

Now if we try to see the bandage extensibility, for that we have taken two different bandages bandage, C and bandage H, their mass per unit area are typically same. So we can see the bandage C and bandage H their mass per unit area are same but bandage C is having much higher extension than bandage H. So bandage C is having higher extensibility bandage with higher warp wise extensibility shows faster and higher drop in initial pressure applied by the bandage.

Now if we see here the warp wise the extensibility in bandage C is higher but bandage H warp wise extension is much higher than bandage C it is 95.21% and here it is a 118.65% warp wise extension is higher, although the weft wise extension in bandage C is higher than bandage H, while wrapping the extensibility in warp is important not in weft. So, this bandage C and bandage H, they are classical example that warp wise the extension of bandage H is higher whereas bandage at the weft wise extension is lower as compared to bandage C.

So, that is why bandage H has got higher extensibility that is why pressure drop is higher in bandage H, higher weft wise initial modulus in bandage C may also be partially responsible for proper maintenance of initial pressure. So weft wise initial pressure initial modulus was high for bandage C. So these two factors are responsible for maintaining the pressure.

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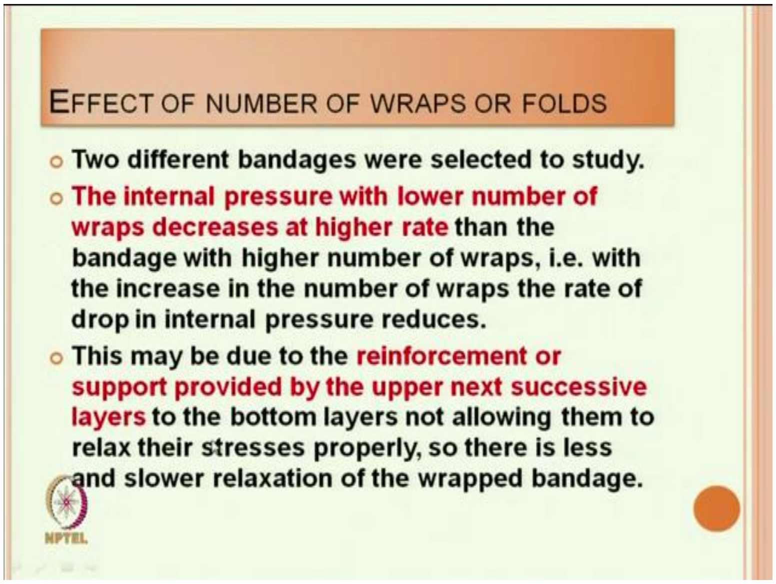

Number of wraps or number of layers or number of folds, we can use different terms here. So different agencies they use different terms. So we have selected two different bandages. The internal pressure with lower number of wraps decreases at higher rate than the bandage with higher number of wraps. So, that is why we have observed here with the increase in number of wraps the effect of drop in the internal pressure reduces.

That means if we increase the number of wrap, that pressure drop during time will reduce. So the integral pressure with lower number of wraps decreases at higher rate. So if we want to retain the pressure we must apply more number of wraps. So this is mainly due to the reinforcement or support provided by the upper next layers of wraps.

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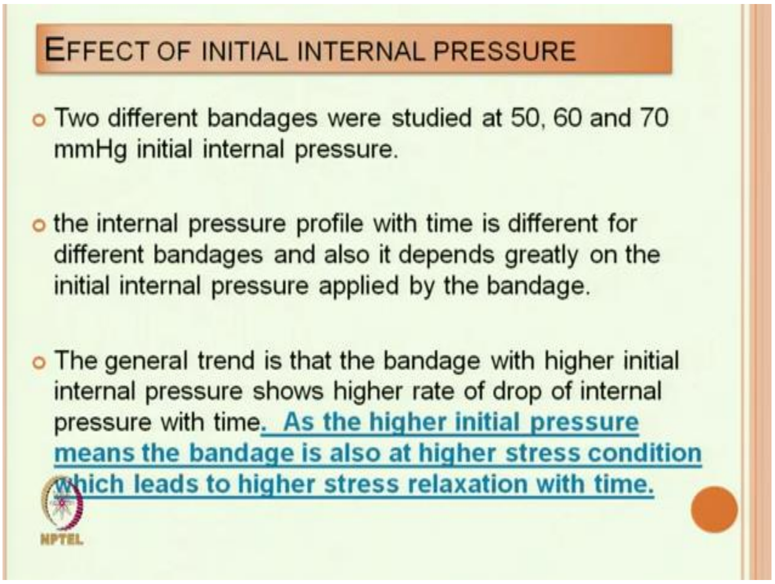

Effect of initial internal pressure that is done by changing the tension, so two different bandages were studied at 50, 60, and 70 millimeter of internal pressure. So, internal pressure means the, it shows the limb hardness; 50, 60 and 70 millimeter of internal pressure the internal pressure profile with the time is different for different bandages and also depend on the initial pressure. Initial pressure that means 50, 60 and 70 millimeter initial pressure means by changing the wrapping tension we can change this pressure.

The general trend is that the bandage with higher initial internal pressure that means when we wrap the bandage at higher tension, so initial internal pressure if it is high it shows higher rate of pressure drop. So that means if we apply the higher tension during the wrapping that will result higher stress relaxation. So when we wrap at the tension to get the 50 millimeter pressure, that means we are wrapping at lower tension than when we are applying 70 millimeter Hg pressure.

So the bandage was initially under stressed condition for 70 millimeter Hg. So as it is under high stress condition the stress relaxation will also be high, as the higher initial pressure means the bandage also at higher stress condition which leads to higher stress relaxation with the time. So to maintain the pressure at certain level, internal pressure at certain level we should not go for higher initial internal pressure.

So, moderate internal pressure is required so that we can maintain the pressure. Now our next study is that the dynamic measurement.

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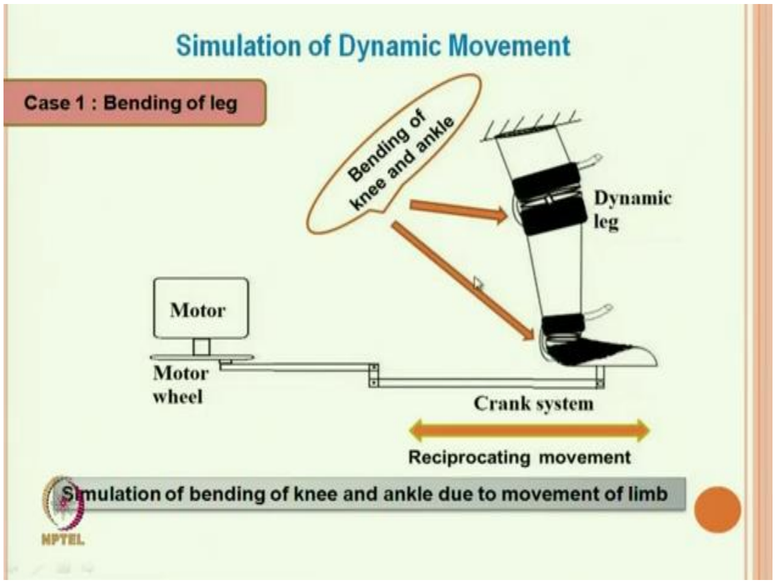

In this study, we try to simulate different practical aspects. So case 1 is bending of leg, so bending of leg at knee as well as at the ankle portion. Here, the mannequin is developed in such a percent this knee and ankle can be bent and this is done by using one motor with the crank arrangement and this crank system reciprocates, it will generate a reciprocating movement and such that the, leg and knee portion there will be bent created.

This simulates the bending of knee and ankle due to due to the limb movement due to walking or running or jogging. So it is very important that someone is putting band on ankle and knee during use with a time how the pressure is getting changed, we must study this characteristics.

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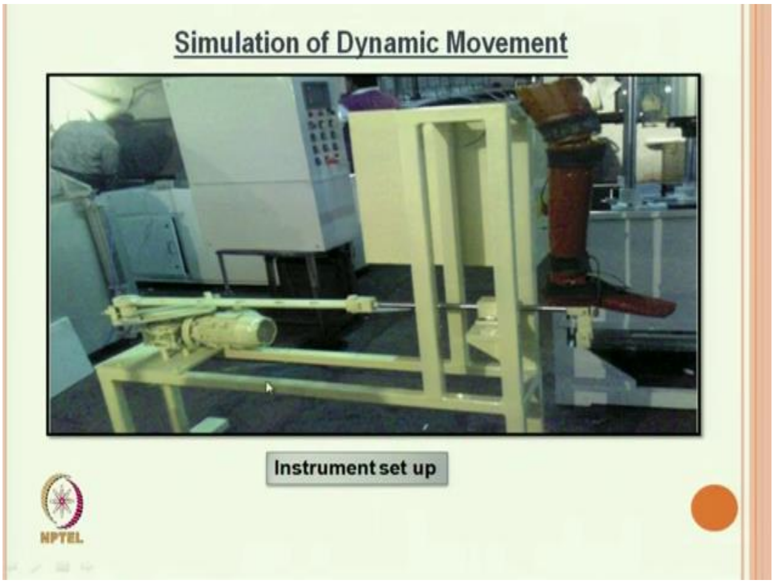

Here is the system, we can see this is a motor system here and it is linked with the crank arrangement, this is a crank arrangement which makes the, two and fro reciprocating movement. Now, you can see the Video here.

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This is the crank arrangement and another you can see here this is the one pneumatic cylinder this moves at slow rate. Here, this is the crank arrangement, which is moving at faster rate. Now, you can see here, this is a type of movement created. Now, this is actually simulating, the bending of knee as well as the angle zone

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And this pneumatic cylinder, the main function of the pneumatic cylinder is to change the pressure of air inside the bladder in dynamic condition as we have discussed earlier.

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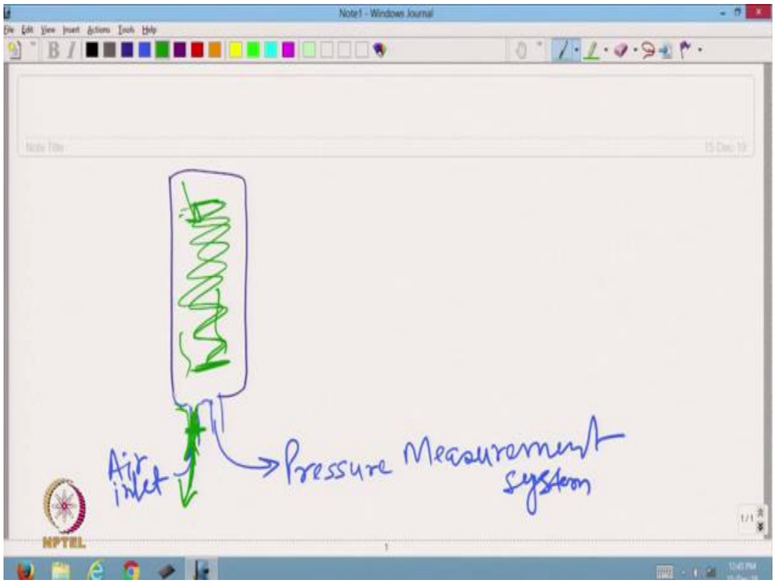

In the bladder, this is a bladder so black color we can see this is to pressure measurement and this is for pressure measurement system and here it is air inlet. Earlier we have seen this and, whatever the air inside the internal pressures it show the limb hardness, muscle hardness. Now earlier what we have tried we have seen that the air at constant amount of air is first entered and so that the pressure initial pressure was fixed.

And then this is the inlet was stopped and on that we have done experiment. Now here the idea is to change the limb hardness because while walking or moving the muscle, the hardness of muscle keep on changing just to simulate this the air inlet with the use by using one piston and the cylinder it goes keep on changing it enters when we need a higher pressure and it comes back to reduce the pressure. So in this way the cyclic motion takes place here, you can see here this by this video, once again.

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This is for there are two reciprocating movement this movement, it is for the steps it shows the movement of leg. Another movement is here and this movement which is slower this piston this movement, which is showing it is going connected with the air this is the syringe and it is going to the bladder, so which is simulating the cyclic change in the hardness of muscle.

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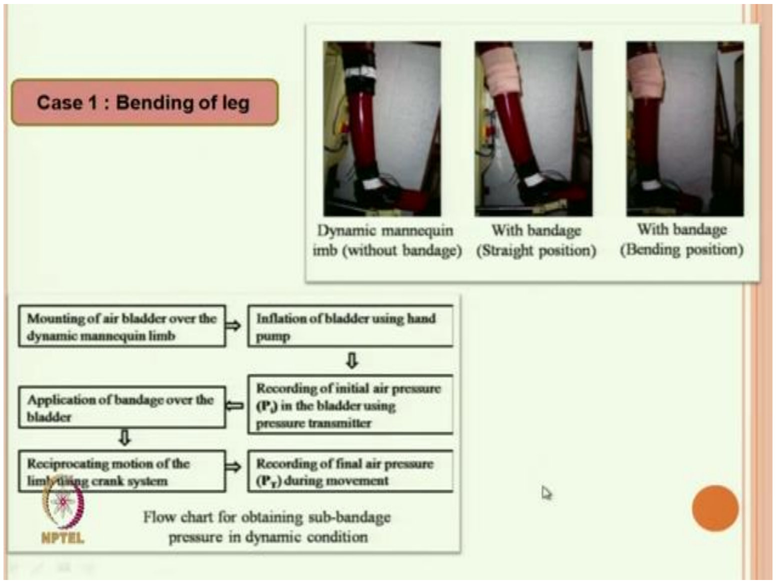

So bending of leg we have seen, so monitoring of air bladder over dynamic mannequin leg, this is mounting the air bladder on the mannequin leg then inflation of bladder using hand pump. We can use hand pump also here if we want a static mode, the recording of internal pressure we can record then we apply bandage. Due to the bandage application the pressure increases, that difference we can measure.

And then under reciprocation we can record the change in pressure in each and every cycle. So with the, different cycle, the pressure will constantly change, it will change and we can measure the pressure with the time.

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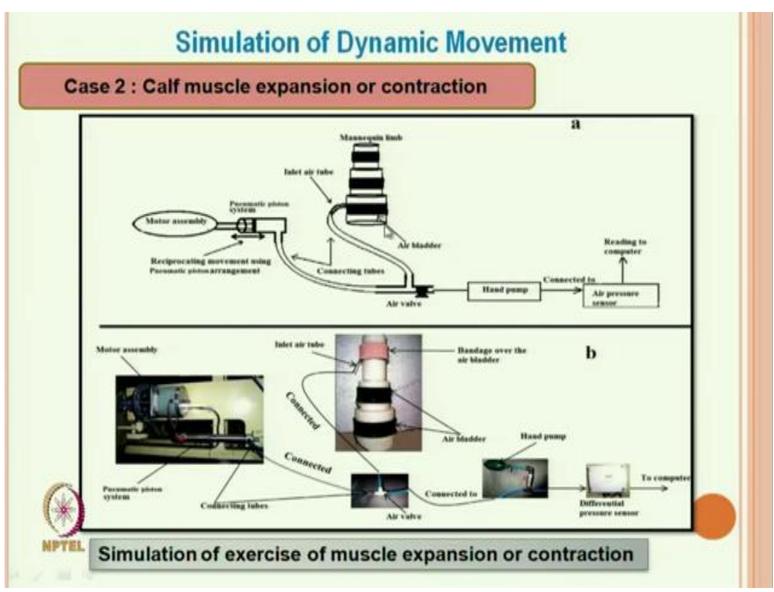

We can see here calf muscle expansion or contraction system, suppose this is a muscle. Now here the piston is there cylinder and piston the movement of this piston will lead to change in calf muscle expansion or contraction, that is how we get the change in hardness and that is measured by the, this air pressure sensor.

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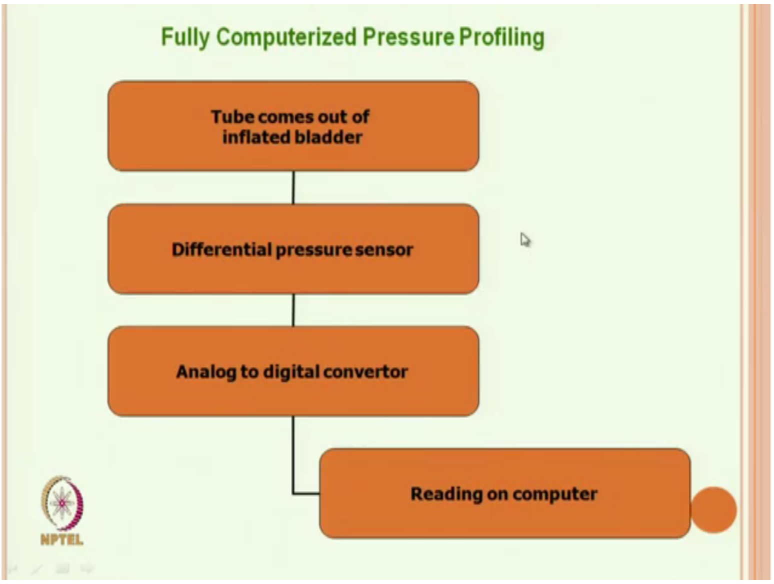

This instrument the flowchart is that, the tube comes out of the inflated bladder and it is going to the differential pressure sensor through analog to digital converter were we can record the data in the computer.

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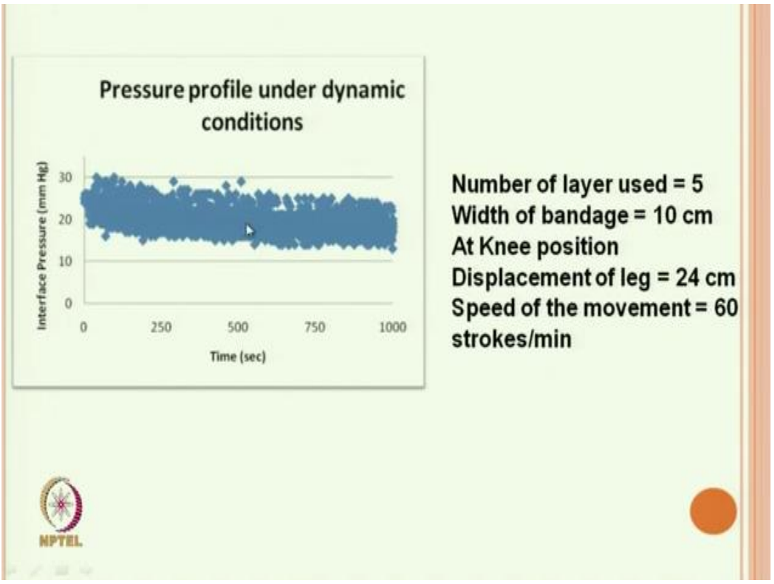

This is a type of profile we get in the instrument where the number of layers used is 5, that is bandage layers were kept 5 width of bandage was 10 centimeter at knee position and displacement of leg that is while walking it will simulate the steps length. The displacement of leg was 24 centimeter and speed of movement that is the how fast his putting steps it is a 60 strokes per minute.

That is the, these are the parameters with which we are getting this type of profile, that is higher values that means maximum pressure and it is a lower pressure and this is carried out up to say 1000 second. For certain, so we can see the mean pressure that is an internal pressure gradually reduces this is mainly due to the relaxation of the bandage.

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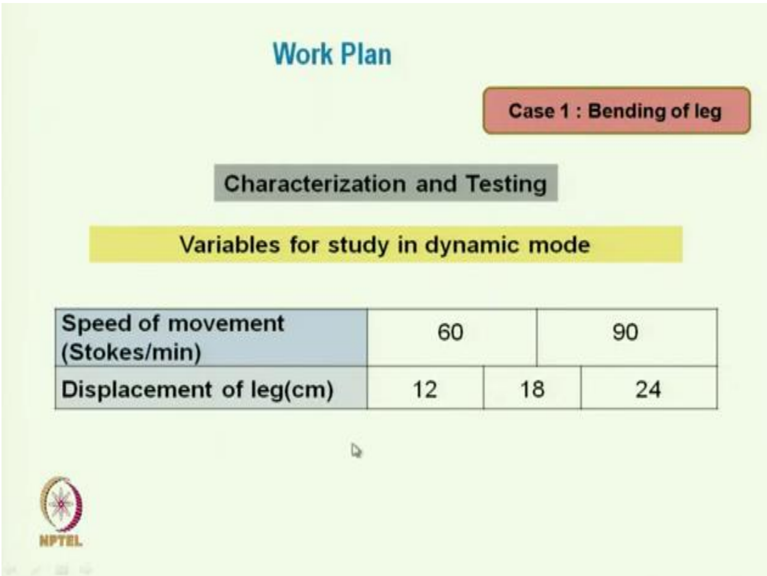

Now in the work plan the study what we have carried out the effect of bending of leg the variables what we have done here, it is a stroke movement that strokes per minute. That is when a, suppose it is moving at slow speed at 60 strokes per minute and to simulate high speed it is a 90 strokes per minute and thus displacement of leg is 12 centimeter, 18 centimeter and 24 centimeter these are the two variables you have used here.

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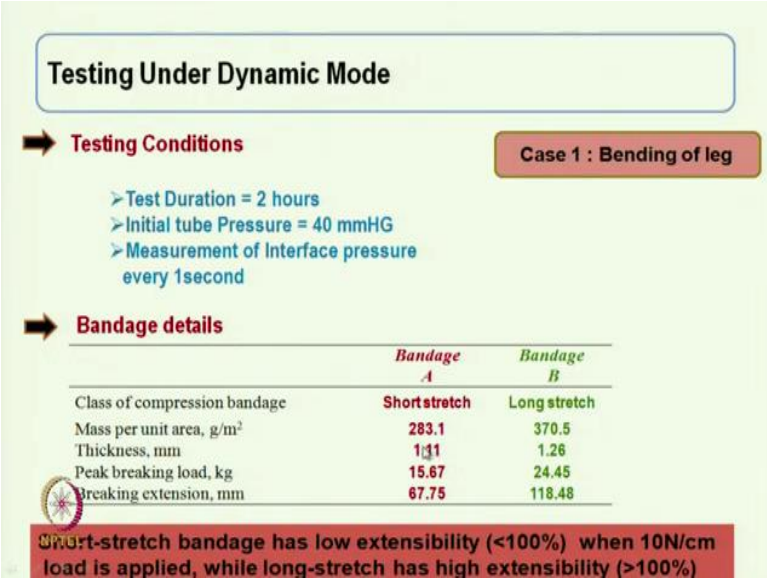

	Bandage A	*Bandage B*
Class of compression bandage	Short stretch	Long stretch
Mass per unit area, g/m^2	283.1	370.5
Thickness, mm	1.11	1.26
Peak breaking load, kg	15.67	24.45
Breaking extension, mm	67.75	118.48

Tests were carried out for 2 hours continuously; it was recorded initial tube pressure that is initial internal pressure which simulates the hardness it was kept 40 millimeter here. Like we have seen earlier it was from 50 and 60 was carried out but here initial pressure was kept 40 millimeter Hg and measurement of interface pressure was carried out after each second, after one second we get the value, two bandages were taken one is called it is a short bandage.

And this is the long bandage, short stretch and long stretch bandage. The short stretch bandage are those where the extensibility is less than 100% and long stretch bandage is are those where extensibilities are more than 100%. So based on that the bandages are characterized in two categories short stretch and long stretch; short stretch and long stretch bandage mass per unit area for short stretch was less 283 and 370 for long stretch thickness was given.

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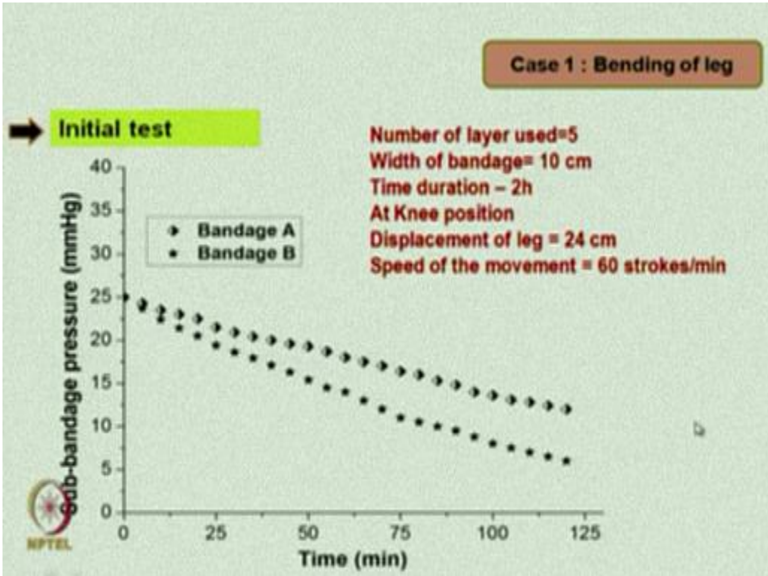

Now we can see with all these parameters; like number of layers, 5 layer10 centimeter width for 2 hours to duration at knee position. So the position measured was at knee position displacement with the 24 centimeter and 60 strokes per minute the speed of the movement. What has been observed bandage A; bandage A was with the short stretch, short stretch bandage and this is long stretch bandage, bandage B was long stretch.

So in case of bandage B, the sub bandage pressure drop was higher than the short stretch bandage. So keeping the initial pressure same which is this is the pressure initial pressure of the bandage that means the bandage with the long stretch bandage, they are responsible for the drop in pressure that we have seen earlier also. So to retain the pressure we must use the short stretch bandage.

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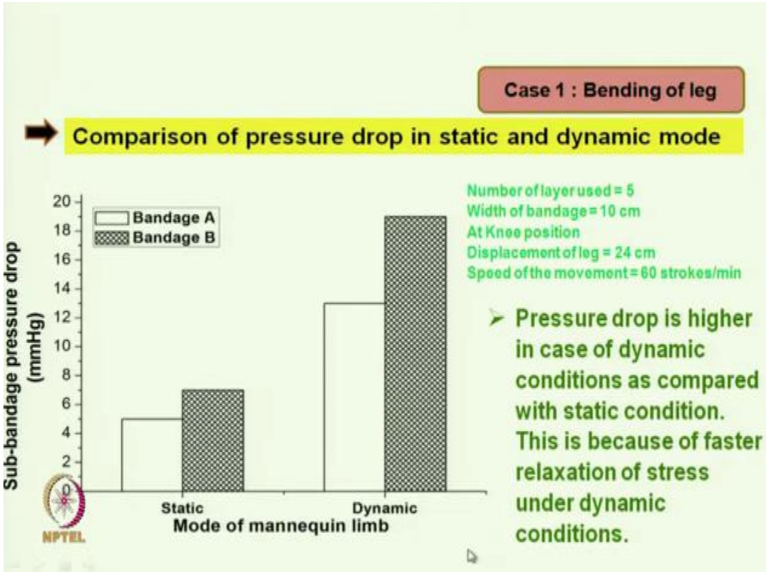

At least for knee zone where the profile is the simple profile with higher the radius of curvature. Now try to see the pressure drop in static mode and in dynamic mode. Suppose we are applying bandage at knee position and the patent is stationary, he is is not moving, static, in that case for both the bandages, the pressure drop will be low, lower than at the dynamic stage. So in dynamic stage pressure drop is very high.

And here again, we can see the pressure drop in long stretch bandage is higher than the short stretch bandage both in static and dynamic mode. So pressure drop is higher in case of dynamic condition as compared to the static condition. This is because the faster relaxation of stress under dynamic condition is taking place. So if it is in dynamic condition, so stress relaxation will take place at faster rate.

There is when structural reorientation will also be there, so that will also take part in stress relaxation.

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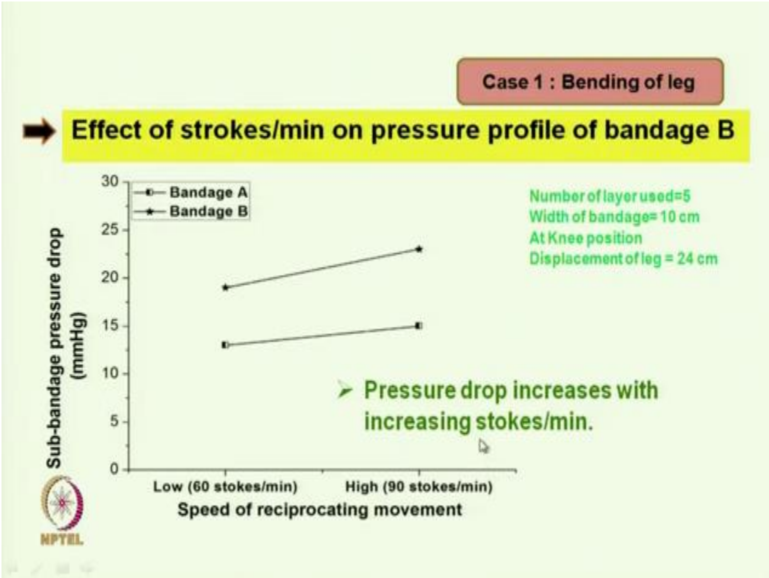

Now effects of stroke per minute on pressure profiling of bandage B, here bandage B is taken with the long stretch. So B and this is for A, now sub bandage pressure if we can see that with the low stroke per minute the sub bandage pressure drop is low, so as we increase the stroke per minute, stroke frequency, the pressure drop will be high so pressure drop increases with the increasing stroke per minute.

That means a person with a bandage, if he is moving at higher speed, higher rate of stepping, so he will lose the pressure at higher rate. This is basically due to the fact that the higher stroke rate means with the time so at it is done for 2 hour, so for two in 2 hours with the stroke per minute of say here 90 stroke per minute. So 2 hours there will be 90 into 60 into 2 that many strokes will be there but on the other end for 60 strokes per minute.

So number of cycle number of stress relaxation cycle is more for higher stroke per minute, that is why the stress relaxation pressure drop will be high for higher stroke per minute, so this is basically it is a number of cycles.

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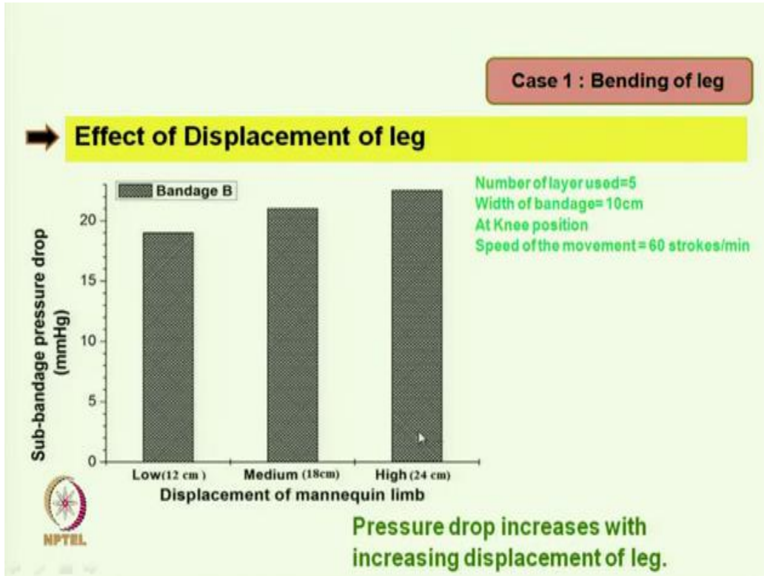

Again effect of deflection if you can see the leg deflection 12 centimeter, 18 centimeter, and 24 centimeter the pressure drop is higher for 24 centimeter. That is reduction in pressure after 2 hours, so that means if we have higher stretch, higher displacement of limb, that means the stretch in the bandage will be high. That will reflect on pressure drop, there will be higher stretch, higher permanent deformation in bandage and effectively the pressure will reduce.

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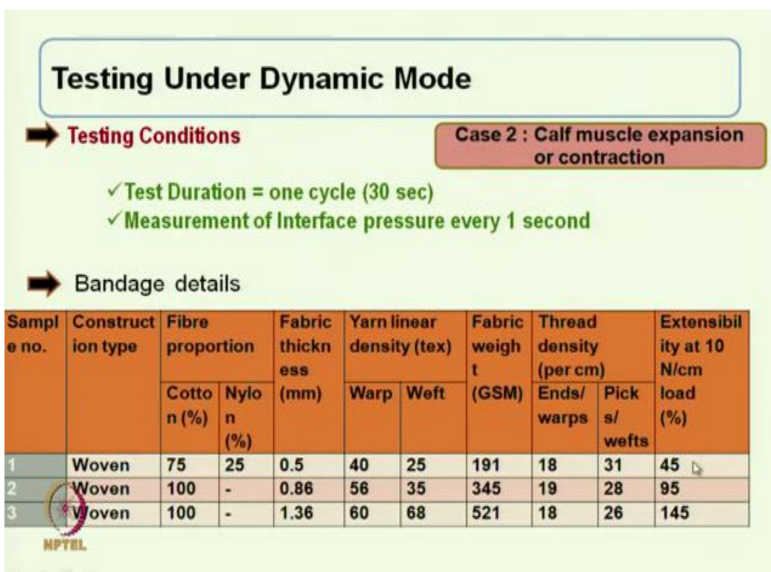

Sample no.	Construction type	Fibre proportion		Fabric thickness (mm)	Yarn linear density (tex)		Fabric weight (GSM)	Thread density (per cm)		Extensibility at 10 N/cm load (%)
		Cotton (%)	Nylon (%)		Warp	Weft		Ends/ warps	Picks/ wefts	
1	Woven	75	25	0.5	40	25	191	18	31	45
2	Woven	100	-	0.86	56	35	345	19	28	95
3	Woven	100	-	1.36	60	68	521	18	26	145

Now, here in under dynamic condition the effect of calf muscle expansion or contraction, we have studied, three different samples who are taken, the test duration one cycle that is 30 seconds cycle, that is in one cycle. In 30 second there will be one cycle completed that means expansion and contraction; the complete cycle will take 30 second measurement of interface pressure is at every one second that we have already mentioned.

So, 3 bandages were taken, woven structure with different combinations. Here we can see the extensibility, here three different extensibility 2 long stretch and one the short stretch two samples and one long stretch 145%. So these are extension the low extension medium extension and high extension, you can say and what we have coded this value this E -1, E 0 and E +1 three levels;-1 level, 0 level and it is a +1 level, so stretchability is taken here.

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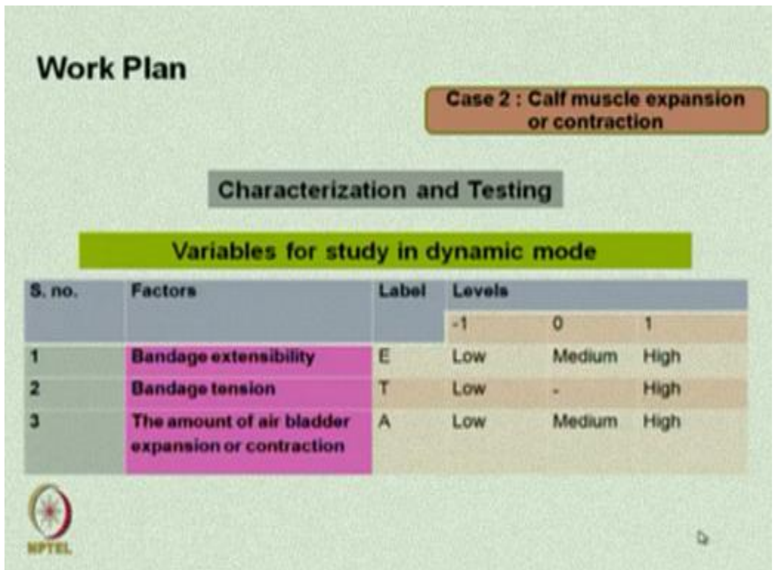

You can see bandage stretchability it is low, medium, high, low means 45%, medium 95%, and high is 145%, - 1, 0, 1, bandage tension, we have kept 2 level one is low that means T-1 and T+1. E-1 means bandage with low extensibility, E0 bandage with media medium extensibility, E1 bandage with high extensibility. Similarly amount of air bladder expansion and contraction, we have taken 3 different levels.

Amount of air that means amount of air expansion means that the pressure inserted in the, there is it shows the hardness of the bladder. So amount of air bladder expansion and contraction; the low level, medium level, and high level, so for a particular experiment if we see E-, T-, E-1, T-1, A-1, that will mean that we have taken the bandage with lower stretchability, the bandage tension we have kept at lower level and amount of air bladder expansion at lower level. So this is the notation we have used here.

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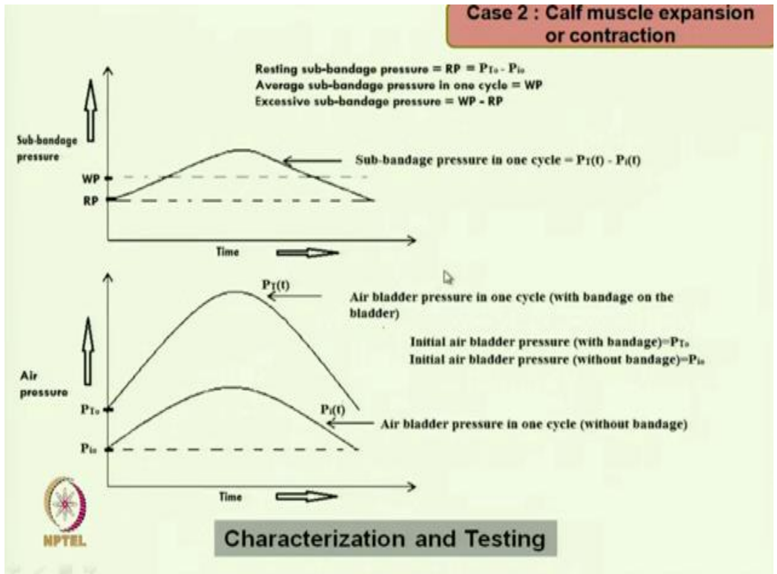

Now here it is the one cycle where it shows the time within one cycle. Here this one is the air bladder pressure in one cycle without bandage, this is without bandage and initially the when the piston moves from left to right the air inlet in the bladder, bladder will get expanded. So bladder pressure will increase and then while reverse movement the bladder pressure will decrease, so this is the initial pressure.

And here it is a pressure the extra pressure due to bladder movement, which shows the calf muscle expansion and contraction and this is the pressure profiling after bandage application, in the bandage condition. Now if we keep on taking the difference with this is the difference, this difference shows the excessive pressure due to the bandage. So this is excessive pressure that excessive pressure is changing with the cycle due to the expansion and contraction of the muscle. Now coming to the experimental results;

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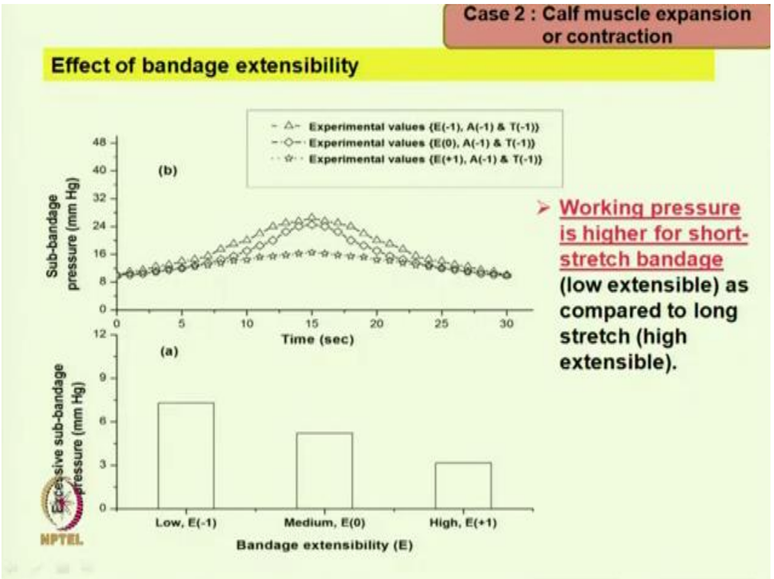

Here, we can see the effect of bandage extensibility, so bandage extensibility E-1, E0, E+1, so y axis it excessive bandage pressure. So this is the excessive pressure for low stretch keeping all other parameters constant low stretch bandage will insert that will impart higher pressure and high stretch bandage will impart lower pressure that we have already seen earlier, but in dynamic condition we can see this curve at the top where combination is that E-1.

That means it is the lowest extensibility and other two parameters were kept constant, so here bandage extensibility, is there other two parameters A-1 the amount of air at the lowest level and T-1, tension is at lowest level. Only variable is that bandage extensibility this curve shows that the bandage with lower extensibility will impart higher pressure, the sub bandage pressure. So as the extensibility increases the pressure, the sub bandage pressure reduces.

And this is true for the total cycle that is at different at every level, we can see this is true but this is prominent when the bandage expansion is maximum. The working pressure is higher for short stretch bandage that we have seen for short stretch bandage if we use this is always during walking during movement it will keep on imparting pressure on the body, but in case of short stretch bandage this pressure extra pressure will be low. So we must decide which we have to use depending on our comfort requirement.

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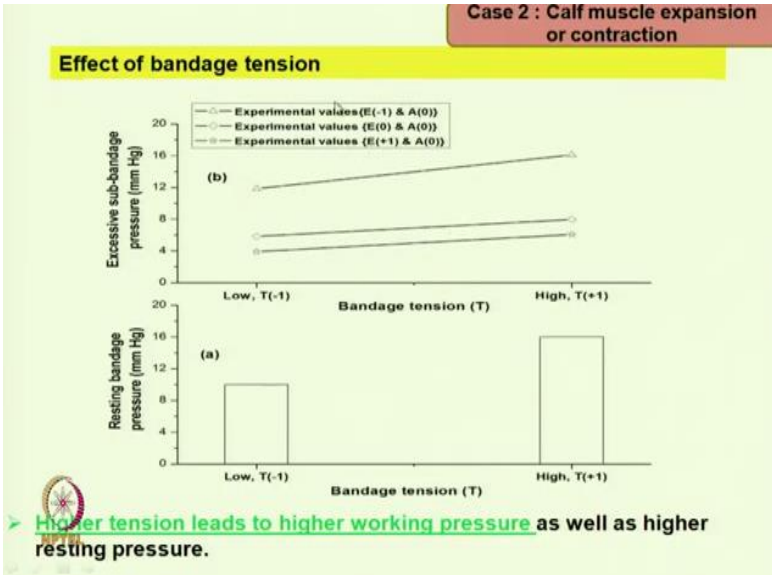

Next is that effect of bandage tension. Here the bandage tension if we increase this is the lower tension and it is a higher tension as we have seen already. The bandage pressure resting bandwidth pressure will be high when we impart the higher pressure and here we can see from these 3 curves with the increase in tension, bandage tension and the bandage pressure excessive pressure sub bandage pressure increases.

But for the low stretch bandage where extensibility is low, the pressure is high, so that we have already seen.

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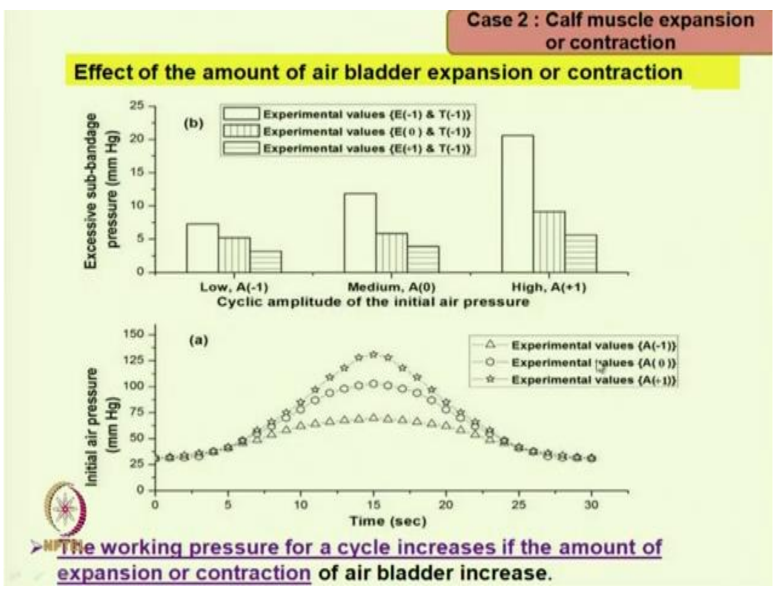

And now the effect of the amount of air bladder expansion or contraction, so depending on our posture the muscle get expanded at different level. So we can see here, this diagram, this figure source that with the lower expansion the initial pressure, the initial air pressure will be low but as we increase the pressure that amount of air, as we increase the amount of air at say +1 level, this is the initial pressure will be high.

The same trend is followed but at the, maximum level the mid level of the cycle this difference is maximum. Now, coming to the excessive sub bandage pressure that means additional sub bandage pressure here, additional sub bandage pressure is highest when we impart we actually the amount of air for bladder expansion is high. So for higher expansion higher muscle expansion, the excessive pressure, pressure sub bandage pressure is highest.

And in case of low muscle expansion the excessive sub bandage pressure will be low and this trend shows that for short stretch bandage with a low extensibility, the increase is high, highest followed by the medium stretch and low stretch. That means the working pressure for a cycle increases if the amount of expansion or contraction of bladder increases. So this working pressure is increasing.

So after this this study, now we will try to see some smart compression bandage which are available.

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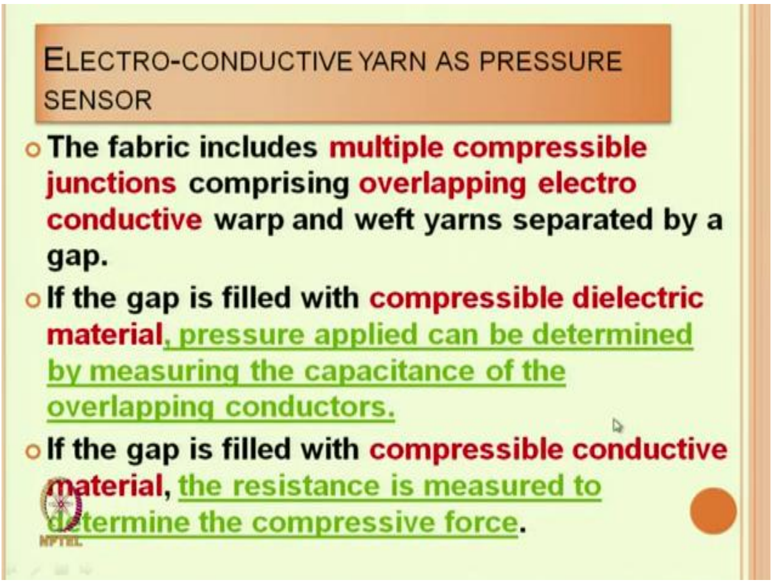

So, one of these is that electro-conductive yarn used as pressure sensor; so here we do not need any additional pressure measurement technique. The bandage itself will show what is the pressure applied on our body surface. The fabric includes multiple compressible junctions, comprising of overlapping electro-conductive work and weft yarns separated by gaps. So there will be gap created, if the gap is filled with compressible dielectric material. Now try to see here.

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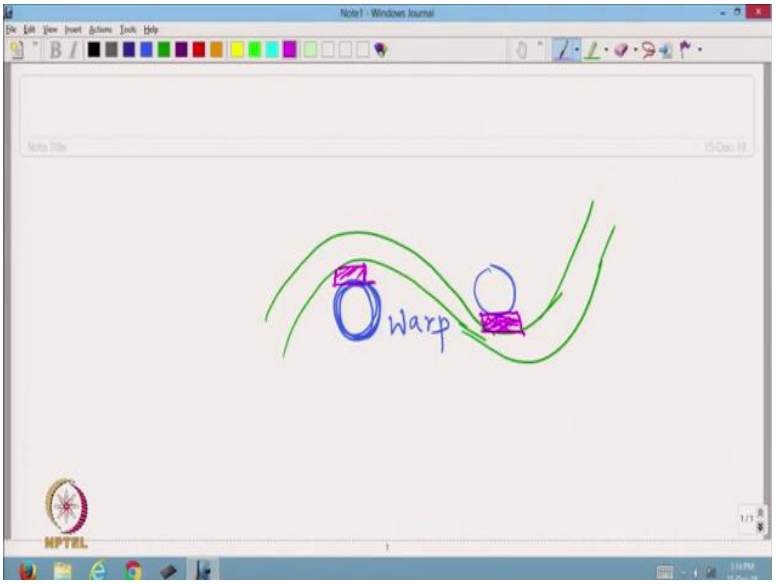

Suppose, this is warp yarn, this is a warp yarn and here we have weft yarn. Now at this junction if we can use some compressible material, one compressible material dielectric material. Depending on the tension as it is compressible its thickness will change. So, the capacitance value will change and if we can record that capacitance value that will give us the inbuilt continuous measurement of the compression pressure we can measure.

So if the gap is filled with compressible dielectric material pressure applied can be determined by measuring the capacitance of the over lapping conductors. So that we can see, so electro-conductive yarns will be that this warp and wefts yarns are electro-conductive yarns and in between the compressible dielectric materials are kept. So depending on the pressure applied this compressive material will, capacitance will change and due to conductive threads warp and weft threads.

This can be this pressure value can be measured. If the gap is filled with compressible conductive material so one is compressible dielectric material then we can measure the capacitance value and if we fill the gap with the compressible conductive material then resistance will be measured. So the resistance is measure of the compressive load so both ways we can measure.

So this type of smart compression bandage measures the compression, so the sensor is inbuilt within the structure.

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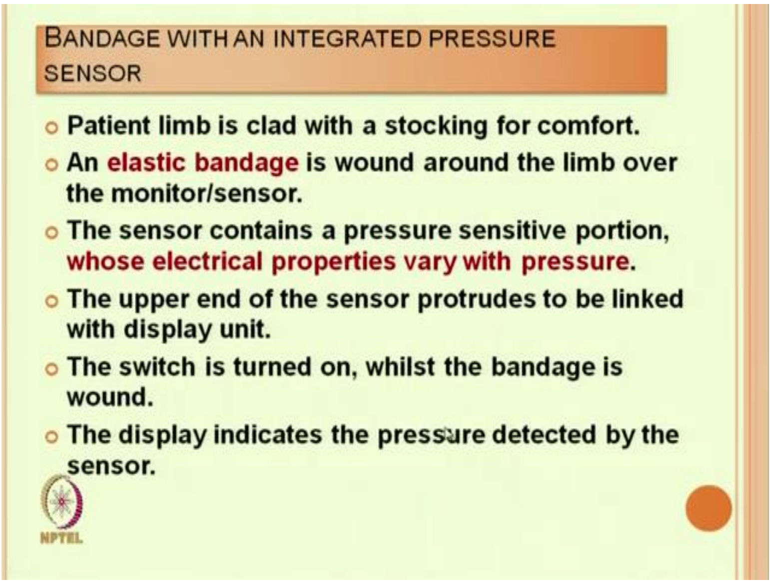

So, another bandage where pressure sensor is inbuilt within the sensor within the bandage itself, present limb is clad with us stocking for comfort an elastic bandage is wound around the limb over the monitor sensor. The sensor contains a pressure sensitive portion whose electrical properties vary with pressure that sensor that process sensitive sensors are there, the upper end of the sensor which is protruding which can be connected with the display unit.

And once the switch is turned on and we will get the data and display indicates the pressure detected by the sensor. So this is another technique.

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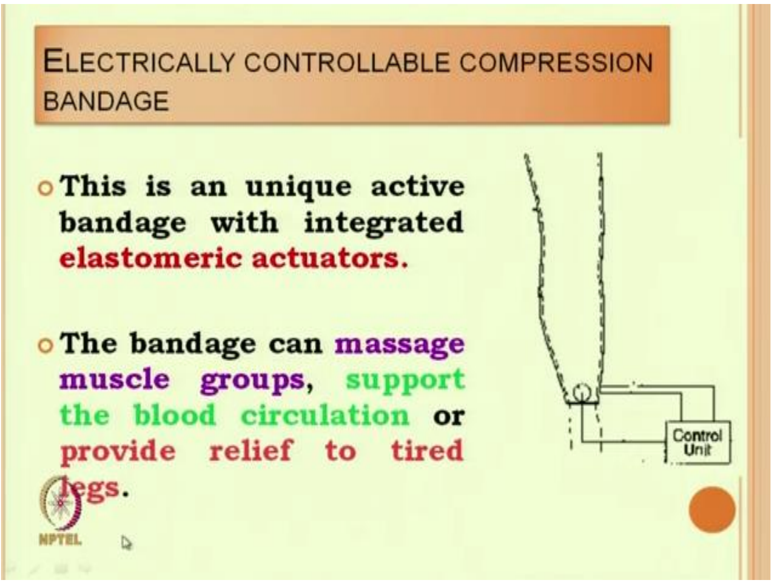

Another bandage which is electrically controlled compression bandage, so this will change the compression pressure automatically. This is a unique active bandage this is called active bandage because it has got integrated elastomeric actuator, this will automatically compress and expand. The bandage can massage the muscle group, massaging will be there. Support the blood circulation or provide relief too tired limb. So automatic messaging will be there due to electromagnetic actuators.

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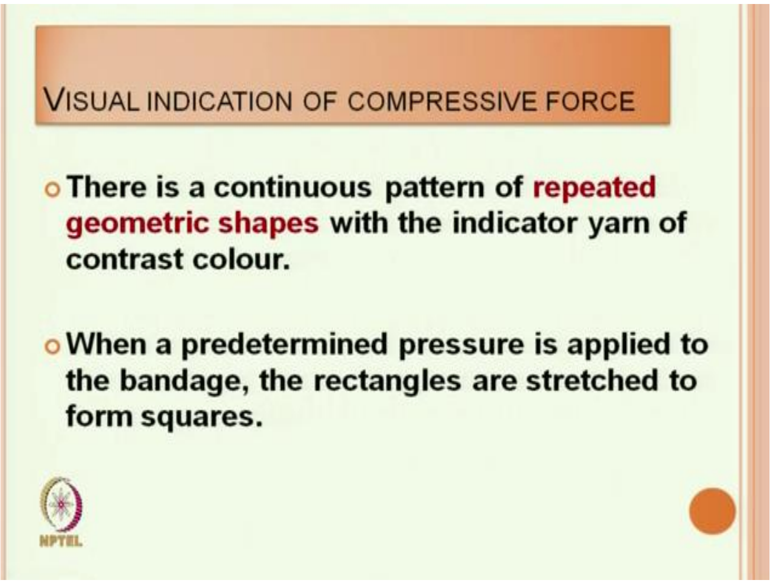

Another measurement technique here, which is very simple one the bandage is actually printed with the geometrical shape depending on the tension or stretch the shape will change like the geometrical shape you say square, depending on the stretch, it will become a rectangle. So from there we can if we know the stress strain characteristics, we can predict the amount of pressure it is apply.

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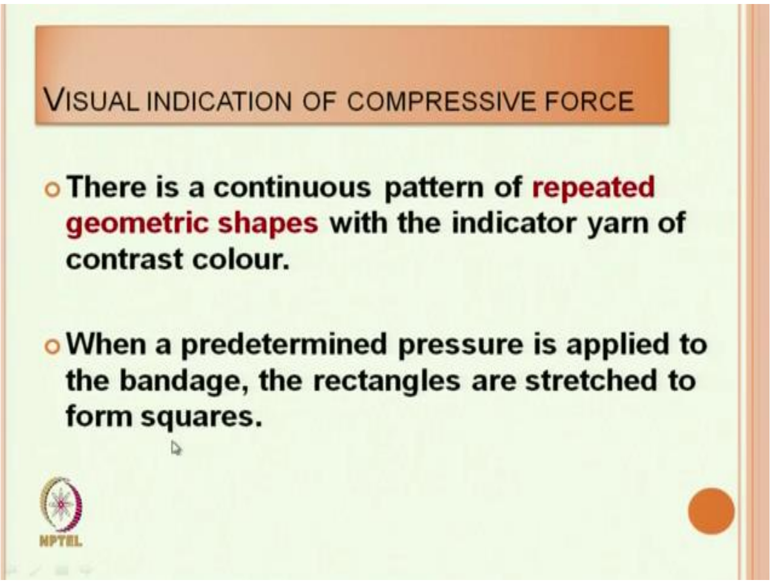

Suppose this is one bandage;

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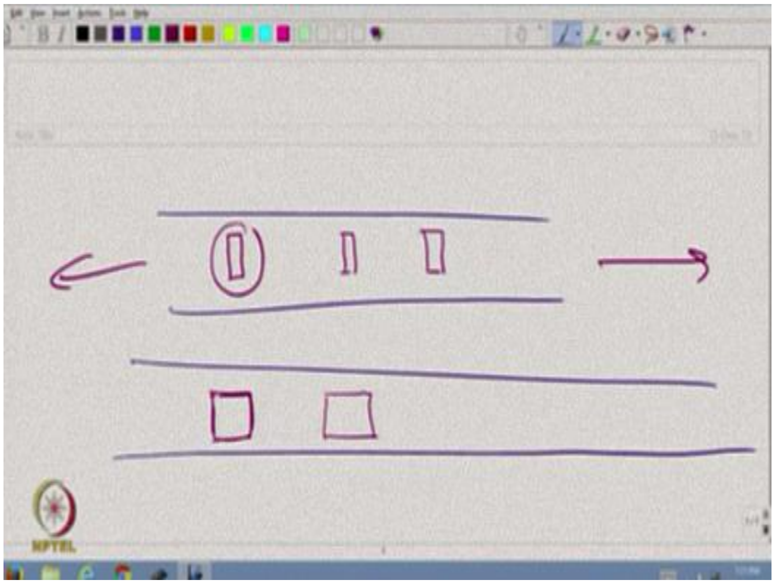

This is a bandage length wise and here one. Say rectangle is there, these are the rectangles. Now after stretching so when we, during application after application of load when it is stretched and this rectangle becomes a square, this will indirectly show that level of stretch and if we know the stress-strain characteristics we can calculate we can predict the amount of the stress. So the manufacturer themselves put this rectangular shape and the level of pressure required pressure will be achieved when it will become square.

So we only have to see that whether the shape required shape has reached and then we will know that it has reached it is applying or in setting required pressure. So when the predetermined pressure is applied to the bandage, the rectangles are stretched to form square. So this is one development available so these are the developments so apart from this we can see there are many other developments.

So in this class one this course, it is not possible to incorporate everything. If one is interested it is available in the literature, so we will end this compression bandage session here, thank you.