Testing Functional & Technical Textiles

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Lecture – 23
Testing of Compression Bandages

Hello everyone. So, we will discuss today new topic on the course Testing of Functional and Technical Textiles.

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So, till now we have completed functional textile then in testing of technical textiles, we have discussed testing of fibre reinforced composite material, then testing of filter fabrics, then we have discussed testing of geotextiles, after that testing of ballistic protective clothing, then we have discussed testing of UV radiation protective textiles.

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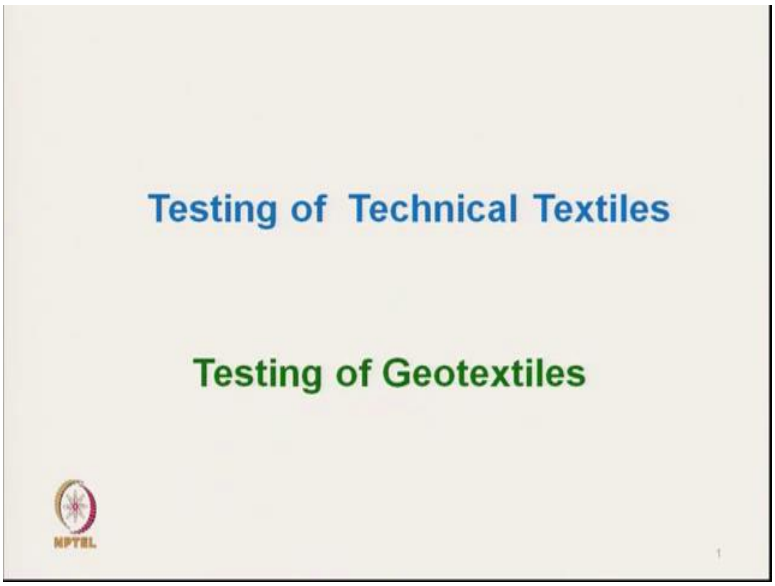

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Today we will discuss one new topic which is Testing of Compression Bandage. Why do we need compression bandage? What is compression bandage? Before we understand, before we discuss the testing methods of compression bandage we must understand the need of compression bandage. So, the need comes from the fact which is known as compression therapy.

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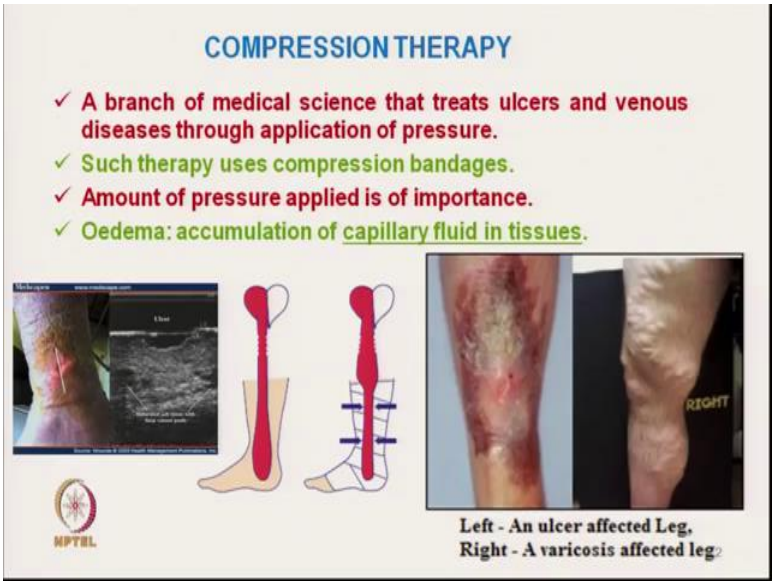

So, what is compression therapy? It is a branch of medical science that treats the ulcers and venous diseases through application of pressure. So, here compression bandage comes

into picture. So, such therapy uses compression bandage which is used to exert external pressure on the body. So, the pressure is maintained and which helps in healing this type of disease.

So, amount of pressure applied is very important. Oedema is one such disease which is accumulation of capillary fluid in the tissues; this capillary fluid should flow through vein instead they have been accumulated in the tissues which causes this type of diseases. Also the skin ulcers are also created in right side it is a varicosis affected leg and here its a skin ulcer. So, for treatment of this type of disease, compression therapy is extremely important and where we can use the compression bandage.

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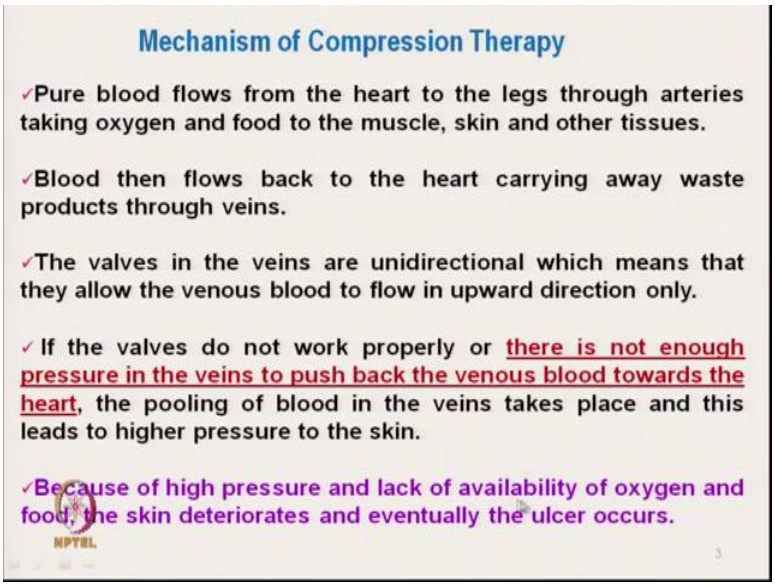

So, to understand the mechanism of compression therapy, we can use the compression bandage. So, pure blood flows from heart to the legs which is furthest point from the heart through arteries which takes the oxygenated blood; so, taking oxygen and food for the muscles, skin and other tissues. And blood then flows back to the heart carrying away the waste product through the vein and the problem comes here which actually is having problem with flowing back to the heart. The valves in the veins are unidirectional which means that they allow the venous blood to flow upward direction only.

So, if the valves work properly, they will only allow the blood flow from leg to the heart, it will not allow the blood flow backward. So, for that we need certain pressure, so that the blood flows from leg to the heart through veins. If the valves do not work properly; so,

valves if they do not work properly or there is not enough pressure in the veins to push back the venous blood towards the heart.

So, there maybe two situations; one is that the valve does not work properly or there is not enough pressure. In that case, what will happen? The pooling of blood in the veins takes place and this leads to high pressure in the skin. So, this happens in the particular in the lower part of the body mainly in the leg zone, because of high pressure and lack of availability of oxygen, because those bloods they are having lack of oxygen and food. So, those bloods are accumulated there, they are not coming back, not get purified, the skin deteriorates eventually the ulcer occurs, so this deoxygenated blood should come back to the heart.

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So, this is the bandage is wrapped on the body part. The compression therapy, its a principle treatment for leg ulcer; for leg ulcer, we use compression therapy. Sustainability and uniformity of bandage pressure determines the speed of recovery of element, we apply the pressure through the bandage, but it is very important to understand the sustainability of pressure. The pressure should be maintained, but due to creep or other relaxation characteristics, this pressure sometime gets reduced gradually that is called pressure drop.

So, if pressure reduces due to reduction of the structure; so, the effectivity of the compression therapy is reduced. So, the pressure applied should be in the desirable range, we should know the level of pressure during compression therapy.

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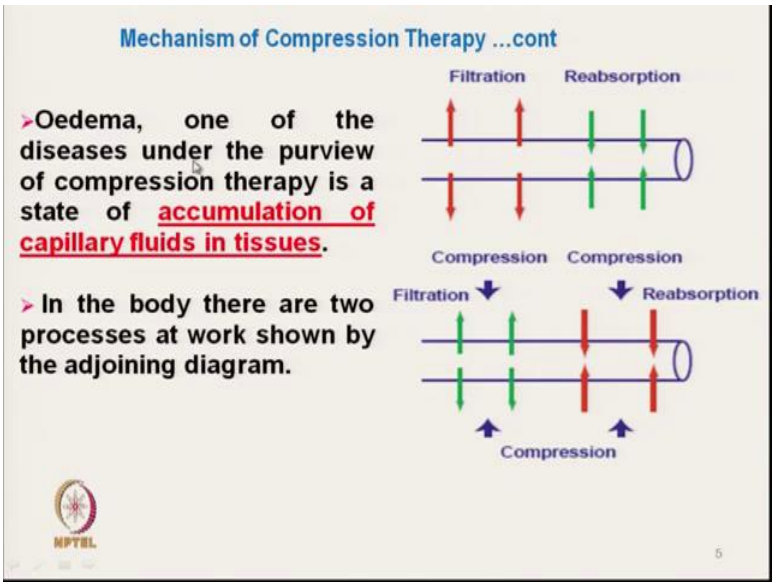

Now, continuing with the mechanism of compression therapy, this oedema one of the diseases under the purview of compression therapy is a state of accumulation of capillary fluid in tissues that I have mentioned already. In the body there are two processes, one is filtration process another is reabsorption process.

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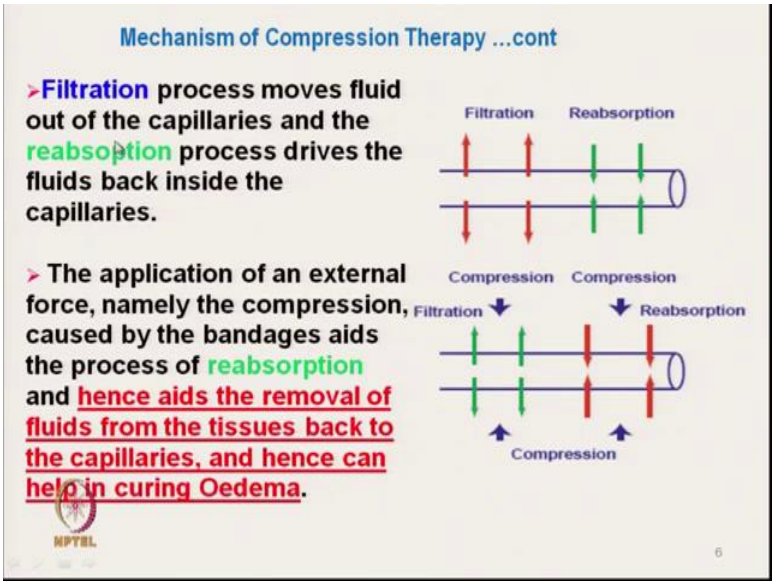

So, the filtration process is that, it moves the fluid out of the capillary, the fluid which is coming here, it moves out of the capillary and reabsorption process drives the fluid inside

the capillary. So, if pressure in outside, in the tissue is high, then reabsorption will take place and that fluid will go to the heart for purification.

So, the application of external force, namely the compression caused by the bandage which helps the process of reabsorption, the reabsorption will increase. Hence, aids the removal of fluid from the tissues back to the capillary hence, can help curing the oedema. So, whatever excess fluids are there in the tissue, if we use the compression and use the pressure, compression bandage that will push the fluid back to the capillary and we will help in curing the oedema process, oedema the disease ok.

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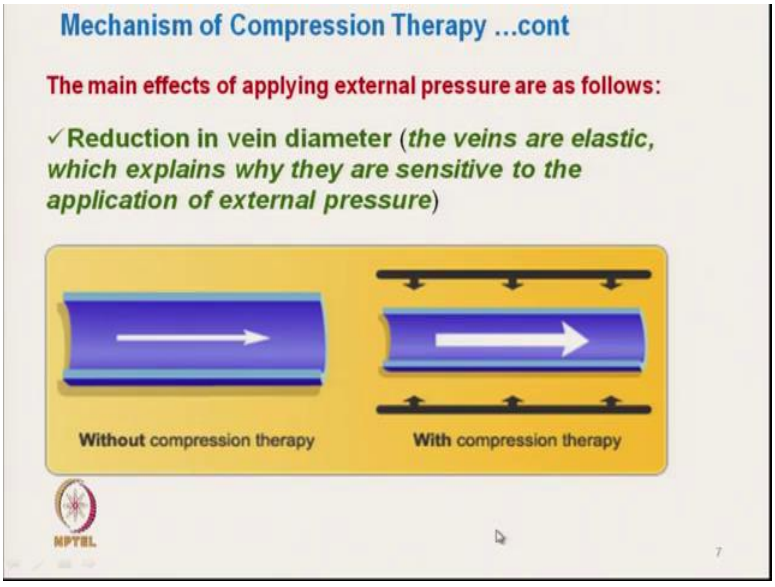

And this is the schematic diagram; the main effects of applying external pressures are reduction in vein diameter. So, this is without any compression therapy, the diameter of vein is more and once we use the compression by the compression bandage it reduces the diameter of veins, the veins are elastic which explains why they are sensitive to application of external pressure. So, if we apply as these are elastic in nature, they will get compressed and diameter of the veins will reduce.

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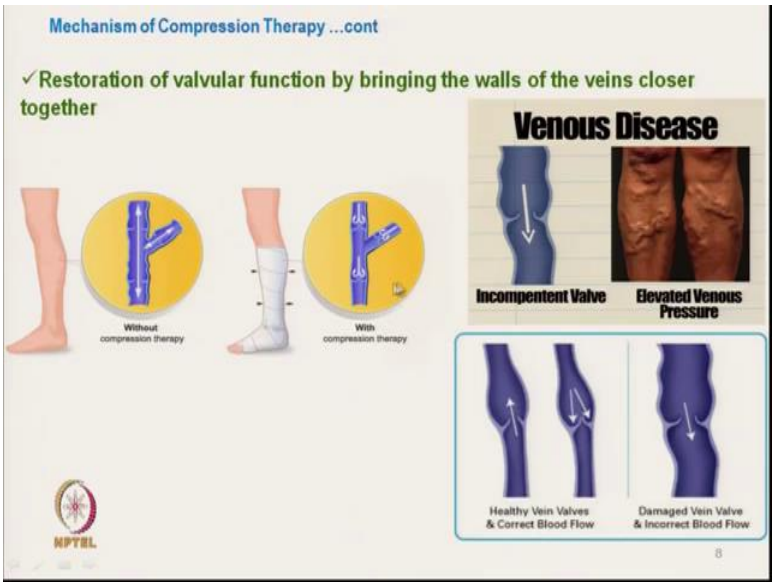

So, this is the process, once the diameter of veins reduces the functioning of the this valves will be perfect. So, here its with disease and the damaged vein valves incorrect blood flow, blood should not flow in other side. So, this is the damaged vein ok, healthy vein it is unidirectional, it is blood flow is there, but in other direction it will be stopped here.

So, restoration of valvular function by bringing the walls of the veins closer together, that is very important. Here the valves are wide apart; so, valve functioning is not proper. So, once valve functioning is not proper, if we can by compression, if we can bring this valve closer so, the valve will start functioning again properly. So, that will actually reduce this venous diseases, this is these are the diseases due to venous disorder ok, accumulation of fluid in the tissues.

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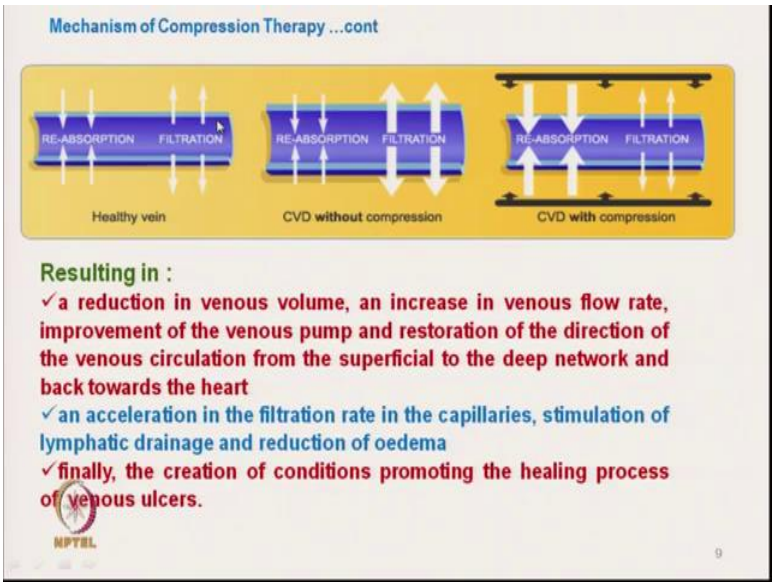

So, this reduction in diameter results in reduction in venous volume and increase in venous flow rate. So, venous flow rate will increase so as we increase the pressure so, venous flow rate will increase improvement of venous pump and restoration of direction of venous circulation; so, venous circulation will improve and from the superficial in the deep network and back to the heart. So, from this tissues, the fluid will go back to the heart properly.

And acceleration in the filtration rate in the capillaries, stimulation of lymphatic drainage and reduction in oedema; so, that will reduce the occurrence of oedema, finally, the creation of condition promoting the healing process of venous ulcer. So, gradually if we can increase the blood flow, if we can reduce the venous diameter gradually, the venous ulcers will improve ok, it will start healing.

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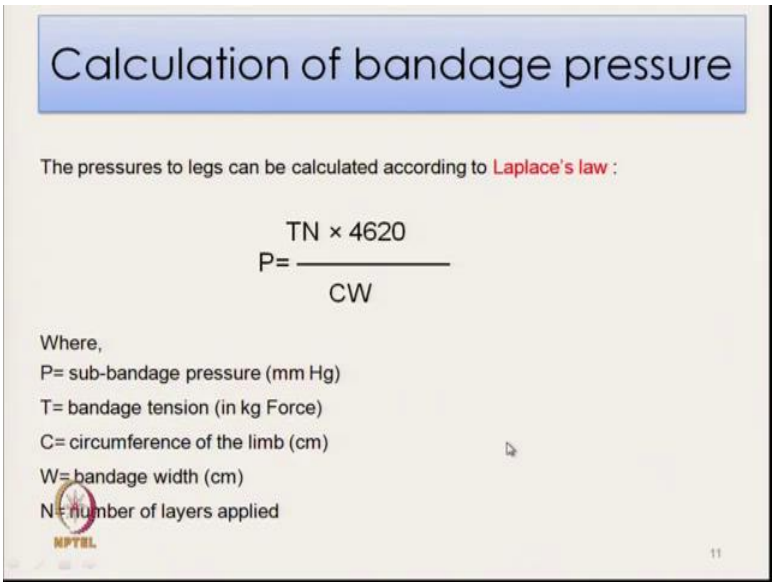

Now, coming to the compression bandage, how to calculate the pressure? So, we normally calculate the pressure using Laplace's law which says, the P is the sub bandage pressure equal to, T is the bandage tension in kg force, C is the circumference in centimetre, W is width in centimetre, N is number of layers and this is the constant for unit conversion. So, this millimetre Hg is the pressure, so, using this formula we can calculate the pressure exerted by the compression bandage, if we know the tension of bandage during wrapping, if we know the circumference of the limb and number of wraps and width of bandage.

The pressures to legs can be calculated according to Laplace's law :

$$P = \frac{TN \times 4620}{CW}$$

Where,

P= sub-bandage pressure (mm Hg)

T= bandage tension (in kg Force)

C= circumference of the limb (cm)

W= bandage width (cm)

N= number of layers applied

So, from this equation we can see, if we use higher tension then pressure will be increased, higher number of wrap pressure will increase and its inversely proportional to the circumference of the limb; that means, the circumference of the limb if it is more, that for same tension or same number of wrap or same width the pressure will be less and with the higher width of bandage the pressure is less. So, by knowing all this fact, we can control the sub bandage pressure.

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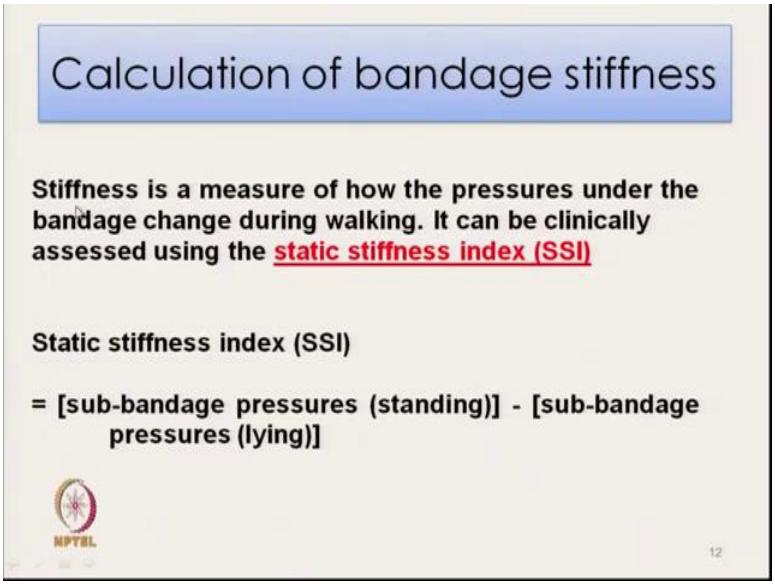

So, stiffness is another parameter, so, calculation of bandage stiffness is that, it is a measure of how the pressure under the bandage changes during walking. So, if a person is say lying and once he stand, there will be change in pressure, so that change in pressure is expressed in static stiffness index. So, it is clinically assessed by using static stiffness index which is the difference between sub bandage pressure when a person is standing with the sub bandage pressure, when a person is lying, so, that difference is known as static stiffness index.

Static stiffness index (SSI)

= [sub-bandage pressures (standing)] - [sub-bandage pressures (lying)]

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So, principles are there ok, different principles of measurements are there. So, Laplace law we can use the Laplace law principle, but the limitations are so validity is doubtful ok. We can use strain gauge principle for measurement of compression pressure, but there we cannot have smooth surface like our limb our body part, the surface profile has to alter, then we can use the strain gauge.

Piezo electric sensor repeatability is doubtful and stability is are questionable and all this principles, the main common problems are they use hard surface for all this principles we need hard surface, but actual application, if we see the in actual application of compression bandage, we do not apply compression bandage on hard surface. In all this principle they need calibration which is important and surface profile like strain gauge, piezo electric sensor, they change the surface profile which is not desirable.

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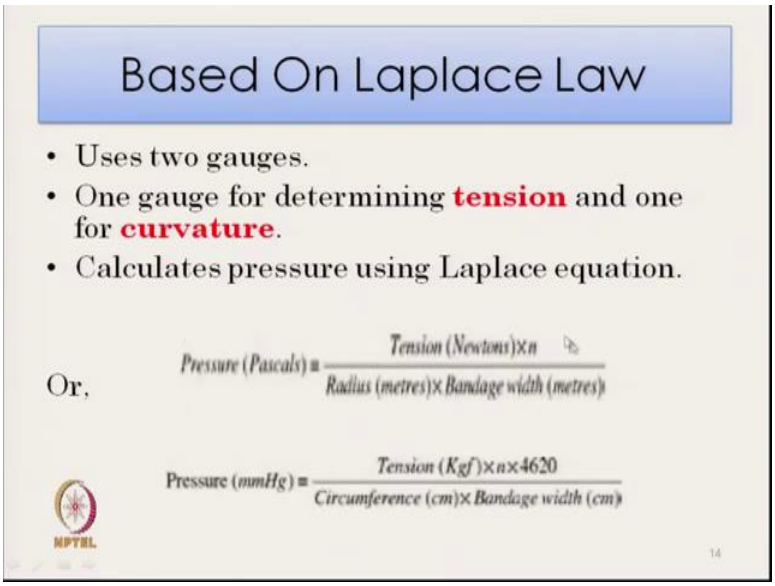

So, based on Laplace law there are instrument where we use two gauges; one gauge is required for measuring the tension another gauge is required to measuring the curvature. So, these two factors are required to calculate the pressure using Laplace law. So, this is the pressure required in Pascal tension in Newton multiplied by n is the number of layers divided by radius of curvature and the bandage width.

So, this is the typical formula equation where the number is known from the wrapping and the bandage width is known as we know the bandage when we are wrapping, but tension and radius or say curvature, we can get from two gauges. Using this formula we can calculate the pressure exerted during compression.

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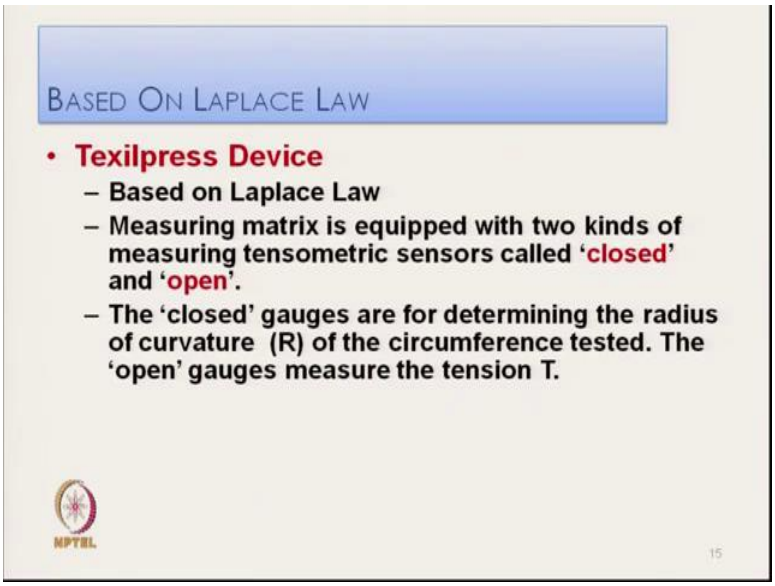

Another method based on Laplace law which is texilpress device which works on Laplace law. Here again, so measuring matrix is equipped with two kinds of measuring tensometric sensors; one is called closed, another is called opened. The closed gauges are for determining the radius of curvature of the circumference tested and open gauges are to measure the tension. So, if we measure the radius of curvature and tension, then we can calculate the pressure exerted by the compression bandage using Laplace law.

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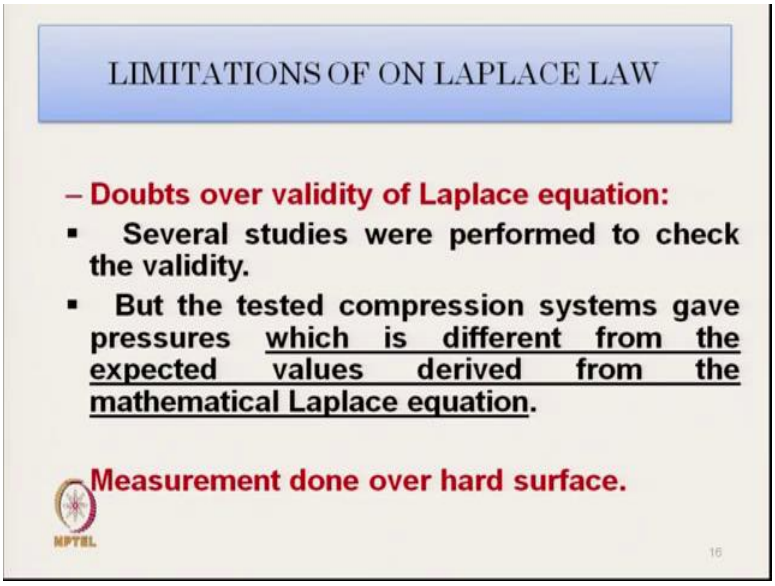

The main limitations of Laplace law are doubts over validity of Laplace equation. There are several studies which were performed to check the validity, but the tests the tested compression system gave pressures which is different from the expected value derived from the mathematical Laplace equation so, the values are not matching. And another problem here is that, the measurements are done over hard surfaces for Laplace equation so, if we use Laplace equation for such equipments we need hard surface, but in actual practice its a our body parts are soft surface.

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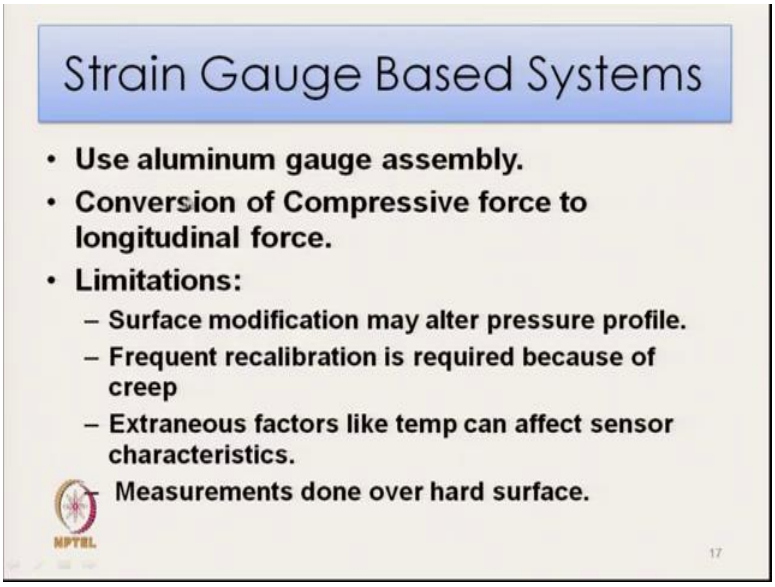

Next principle of measurement of compression bandage is strain gauge based principle where aluminium gauge assembly is used and the conversion of compressive force to longitudinal force is required and the limitation is that the surface modification may alter the pressure profile. So, we need surface modification because we have to place the strain gauge on the surface and that total profile of the bandage also changes which also alter pressure profile.

Here frequent recalibration is required due to creep effect of the strain gauge because in compression bandage, the pressure is kept for long time that may result the creep of the strain gauge, some external factors like temperature or humidity affect the sensor characteristics and here again the measurement is done over hard surface.

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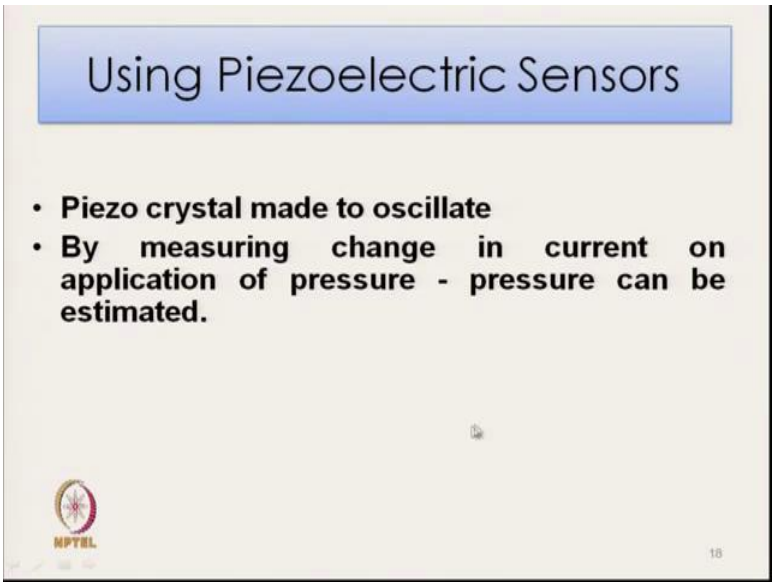

Another method which is piezo crystal based method; piezo electric sensors are used and piezo crystals are made to oscillate by measuring the change in current on application of pressure, pressure can be estimated.

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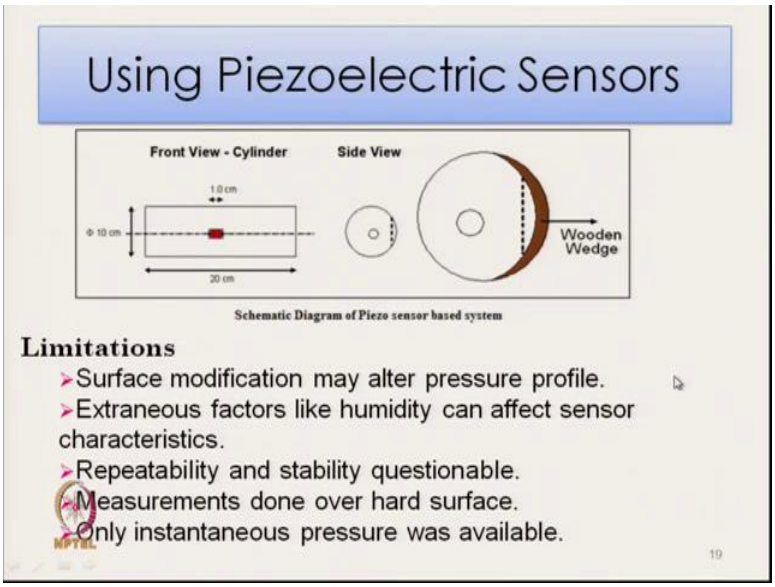

So, here the limitations are same as that we have discussed earlier. Surface modification is required which may alter the pressure profile, external factors are the affecting factors like humidity temperature, repeatability and stability is questionable, measurements done

over hard surface and here one most important limitation only instantaneous pressure was available so, continuous pressure profiling is a problem.

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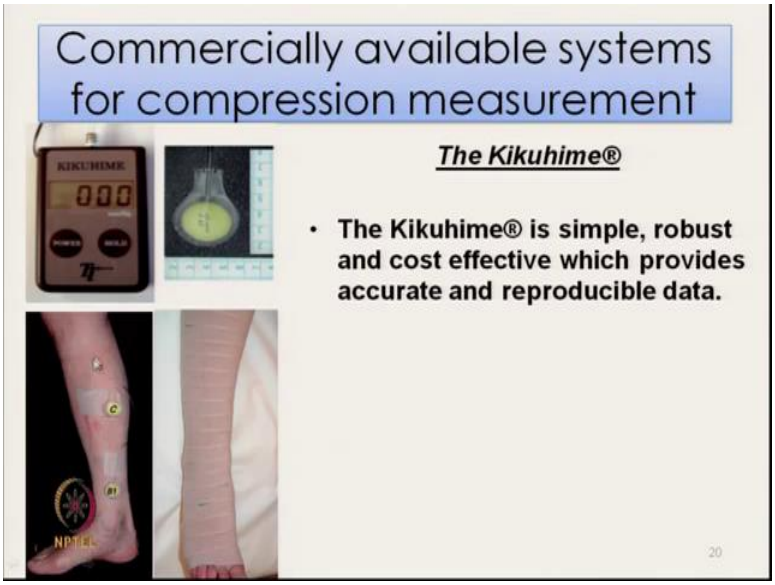

There are some commercially available systems one of them is the Kikuhime method. It is a simple method, robust and cost effective which provides accurate and reproducible data. This is the system which we place during the wrapping and it gives the pressure value.

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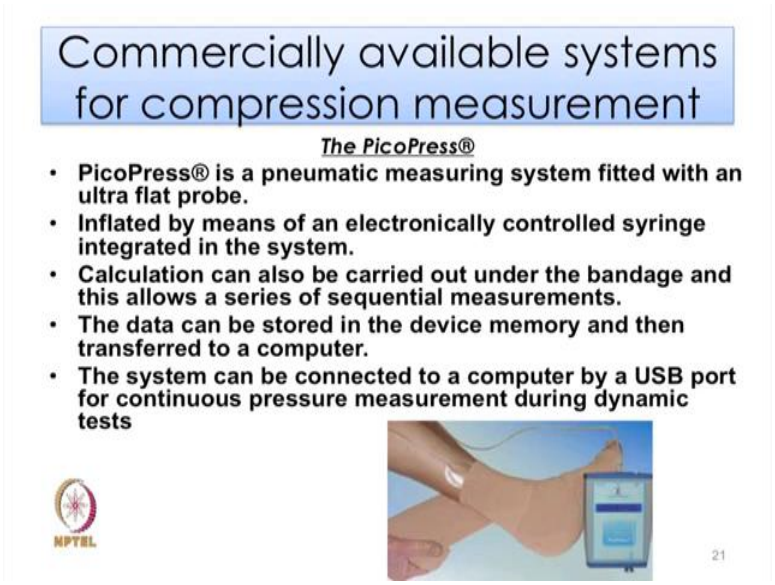

Another commercially available system is it is a PicoPress, it is a pneumatic measuring system fitted with ultra flat probe. So, here its ultra flat probes are there which is pneumatic

principle which works on pneumatic principle and after wrapping, we have to inflate by and electronically controlled syringe ok, integrated in the system it will be inflated.

And calculations can also be carried out by the this sensor during the wrapping and also under the bandage and this allows a series of sequential measurement. So, during wrapping, we can measure and also under the bandage cover, we can measure the pressure value. This data can be stored in the computer and also we can take in the connect with the computer by USB port and take continuous value of pressure. This PicoPress measurement system is very close to actual system of measurement due to ultra thin probe.

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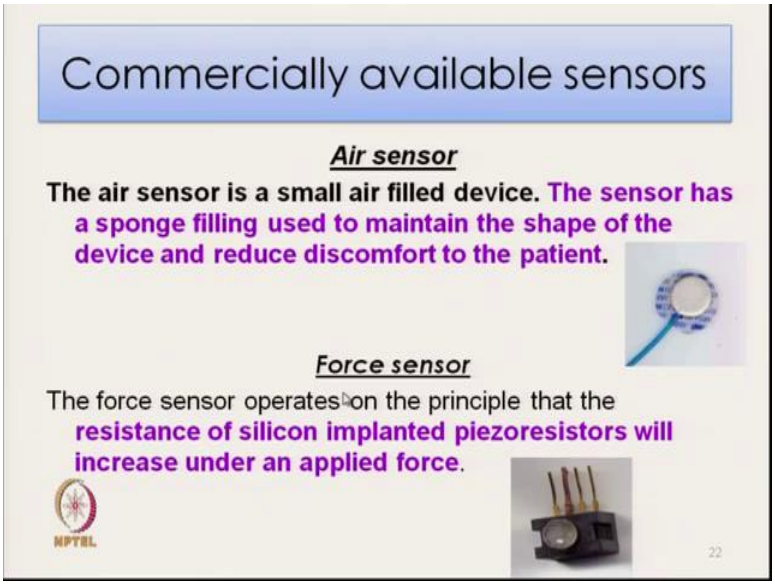

There are other methods like air sensor, it is a small air filled device. The sensor has a sponge field used to maintain the this sponge filling it is to maintain the comfort level of the patient. Force sensor can also be used here.

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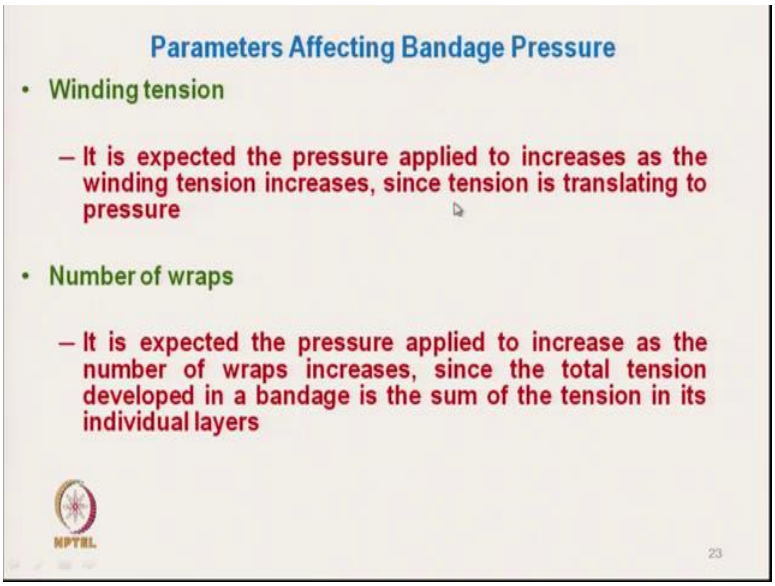

And the parameters which has already been discussed, this parameters are winding tension, number of wraps, width of the bandage, time elapsed after bandaging.

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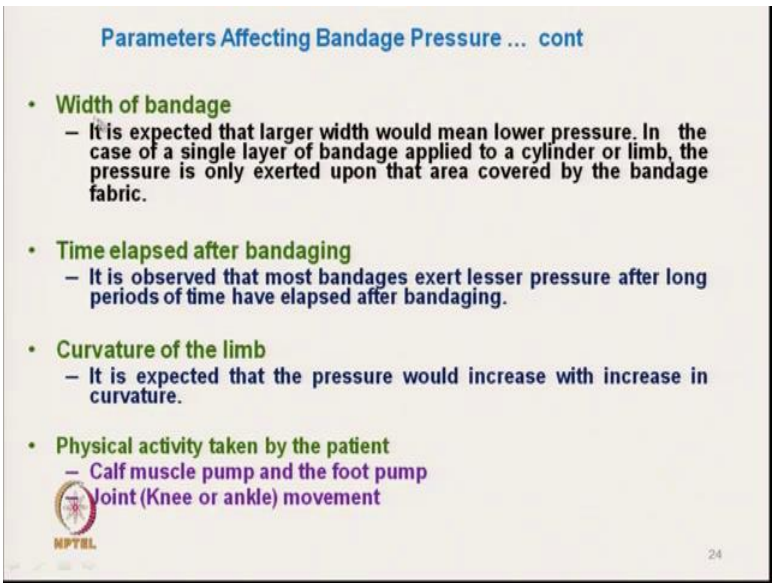

This is one important parameter because, when we start recording the pressure just after bandaging, the pressure is high, but as the time elapsed after bandaging. It is observed that most bandages exert less lesser pressure after long period due to creep effective stress.

Stress relaxation effect that needs to be studied carefully also curvature of the limb and most important is that, the physical activity taken by the patient. Once we apply bandage,

it does not mean the patient will be stationary they will try to walk or move ok. So, calf muscle pump and the foot pump joint that is knee and ankle movement so, these physical activities affect the pressure profiling. So, we have studied detailed I will just show the result so, to study all these one instrument has been developed. So, these are the factors as we have already discussed here.

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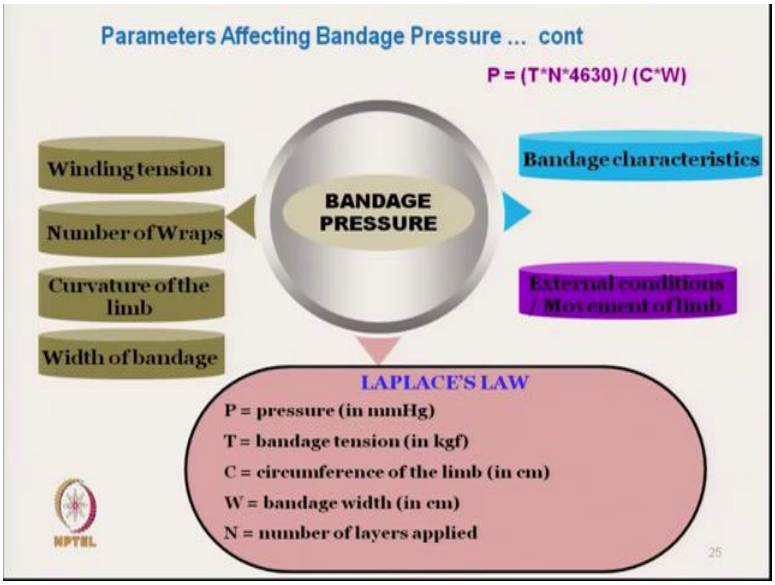

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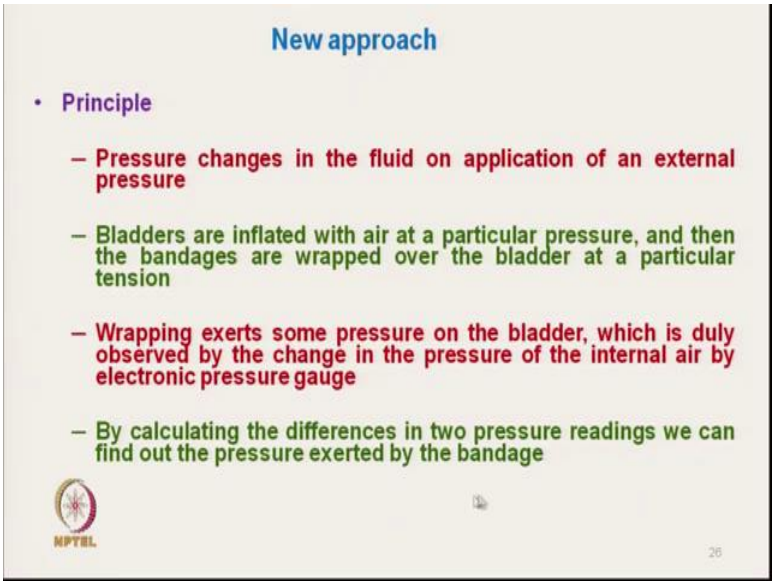

Now, the principle of the new instruments is that pressure changes in the fluid on application of external pressure that is the basic principle. Suppose, we inject some air in

a bladder so, bladder is filled with some air of certain pressure. If we apply external pressure on bladder, the pressure will increase. So, that principle is being used here to develop new instrument. The bladders are inflated with air at a particular pressure, then the bandages are wrapped over the bladder at a particular tension.

Wrapping of the bandage exerts some pressure on the bladder which is additional pressure on the bladder, which is duly observed by the change in pressure in the internal air by electronic pressure gauge. So, internal air pressure is changed the level of change is being observed and that is recorded. By calculating the difference in two pressure readings we can find out the pressure exerted by the compression bandage.

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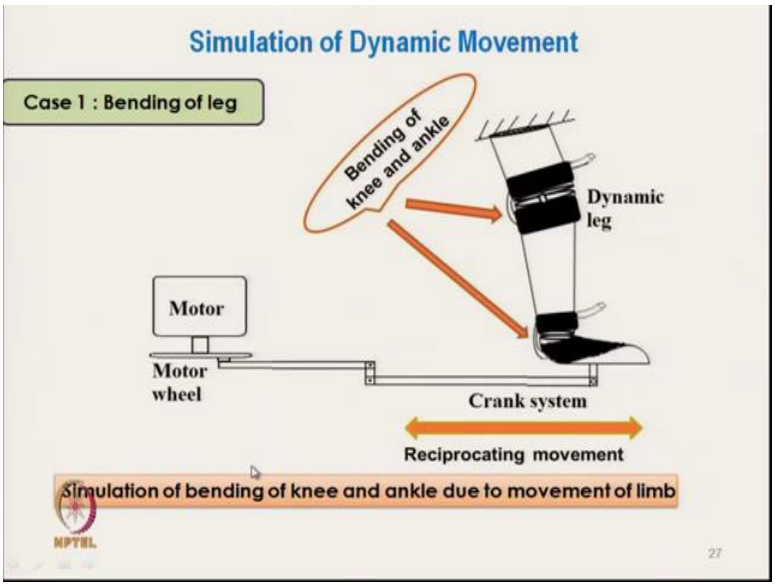

Now, this is one equipment, the schematic diagram of the equipment here as we have discussed we will consider here two situations; one is bending of leg, so, this is the leg mannequin and motor, it is attached with the motor and the bending level and the rate of stroke can be changed.

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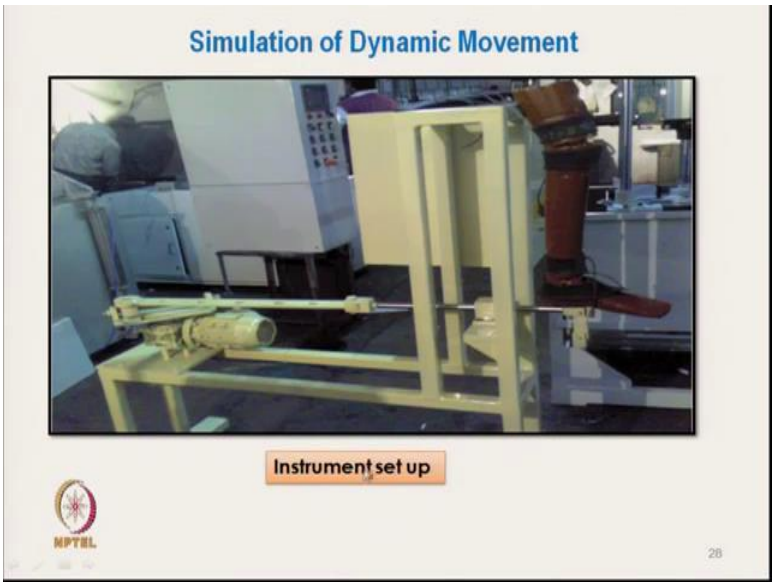

This is the picture of the instrument setup.

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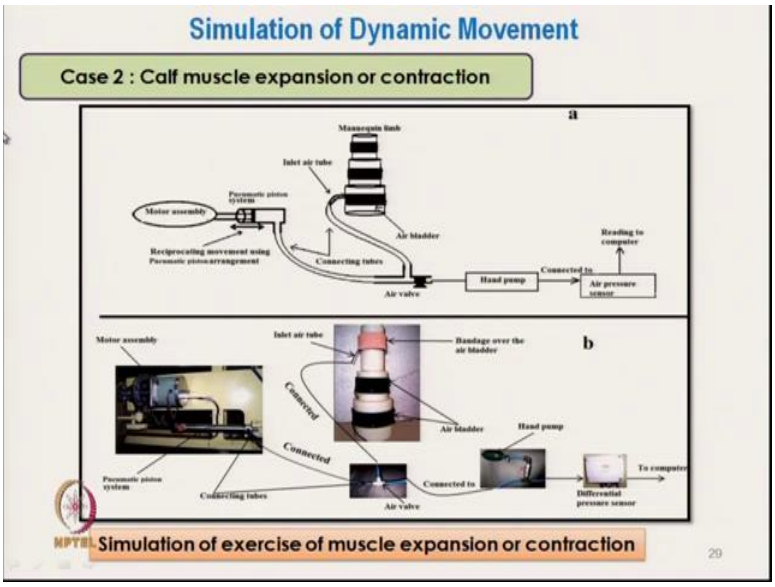

And in case 2, where the calf muscle expansion or contraction have been reported like this is, these are the different diameters of calf muscles and the black colour these are the bladders which are inflated by using pump and this pump are inflated and deflated cyclically to simulate the calf muscle expansion. And over this bladder the compression bandage is wrapped.

So, initial pressure is recorded by the pressure sensor and after bandage is wrapped, the pressure sensor record the pressure again as the difference is the effective pressure by the compression bandage.

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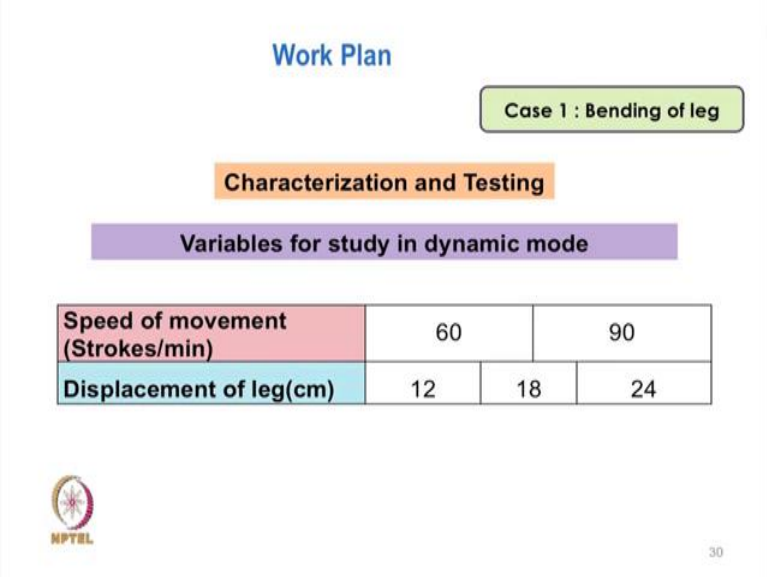

Now, here in case 1, when we study the bending of leg, the stroke speed; the speed of movement, the stroke per minute has been changed one is 90 and another is 60; that means, a person once he is walking, it simulates the speed of walking and the pressure drop for a particular bandage is studied. And displacement of leg; that means, stretch of leg a person moving or walking with the smaller step or with the longer step that simulates here, the level of bending of leg are simulated with the displacement at 12, 18 and 24 centimetre.

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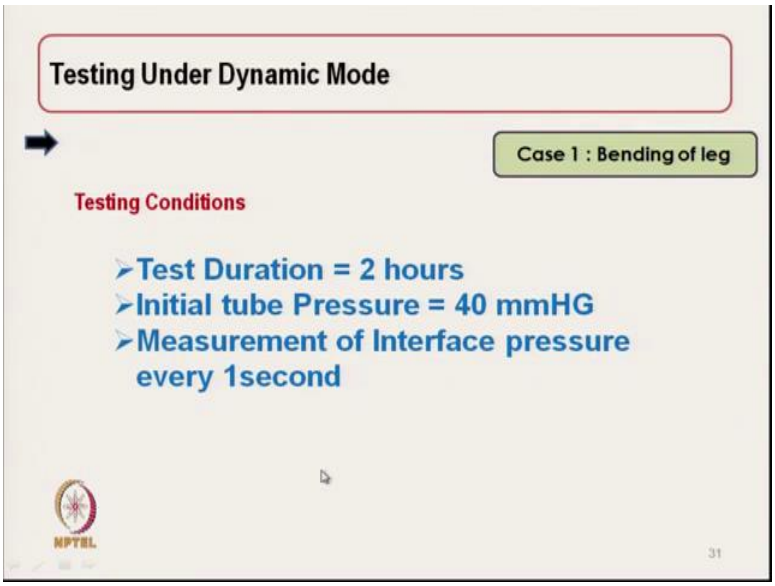

And test duration is 2 hour, initial pressure is 40 millimetre HG, initial pressure actually shows the limb hardness, measurement of interface pressure is done after every 1 second and this is the result here.

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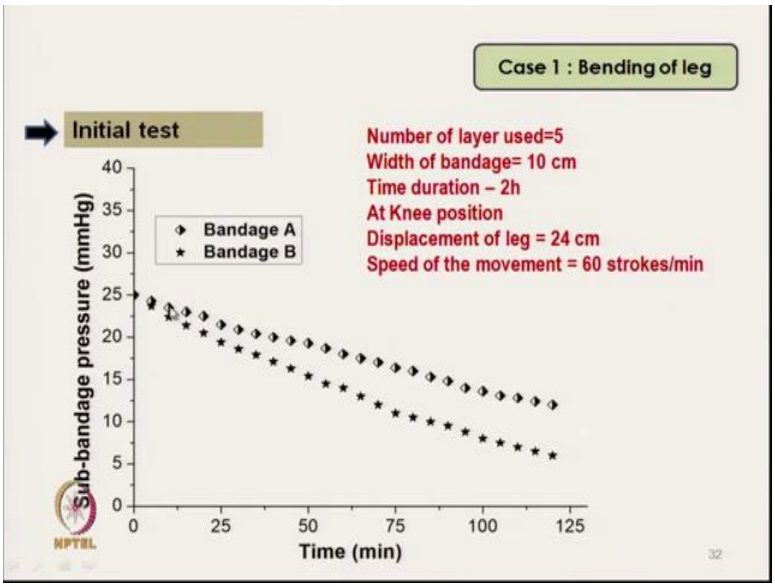

Which shows the sub bandage pressure, it reduces as time elapse with the time sub bandage pressure reduces gradually; that means, there is stress relaxation for both bandage A and bandage B, but the ideal bandage should be that there should not be reduction in sub

bandage pressure. We have to decide, we have to select the bandage where the pressure drop is least with the time.

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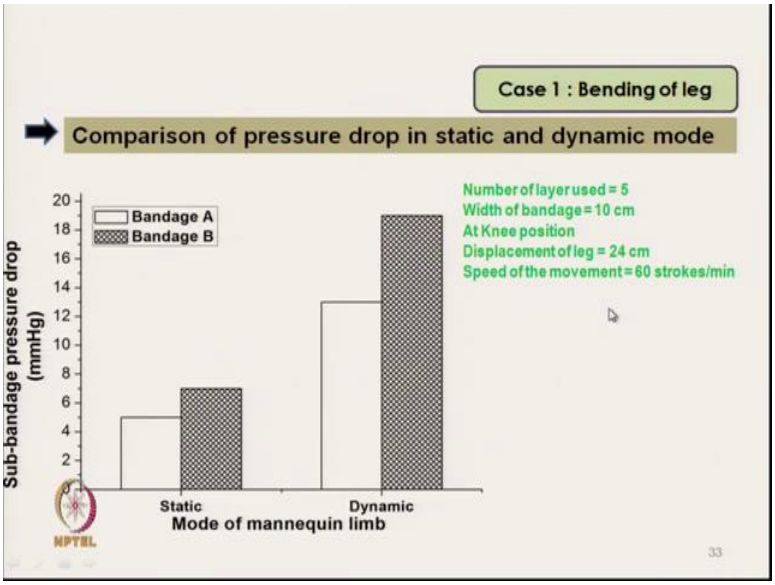

And this picture shown, this figure showing the sub bandage pressure with a static mode and the dynamic mode, this is the drop in pressure. So, if you see in static mode both for bandage A and B, the pressure drop is least so, which is required, but once the person is dynamic, the pressure drop is much higher than that; the which means, after putting bandage a person if he moves, the pressure drop will be high; that means, reduction in pressure of compression bandage will be high.

So, after certain time the pressure will be reduced so, in that case what will happen, the effectivity of the treatment will be lost and we have to either replace the bandage or rewrap the bandage.

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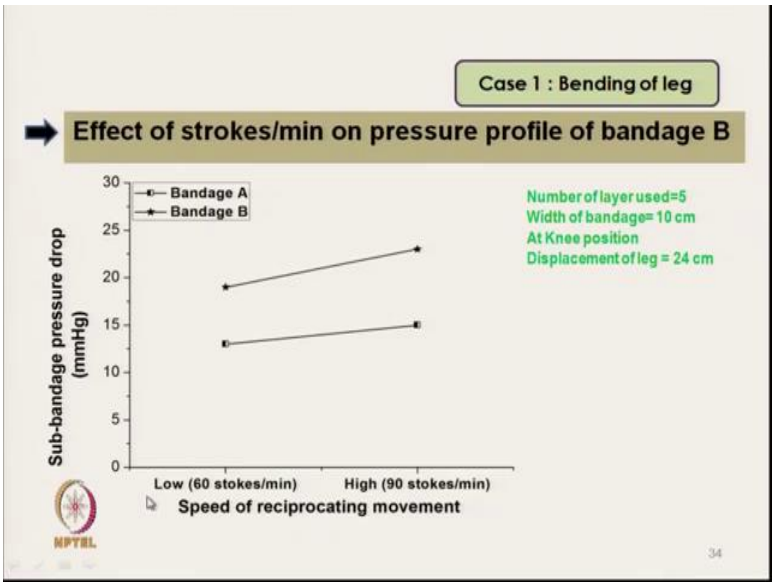

This figure shows the speed of reciprocating movement. Once, the person moves at slower speed the pressure drop is less, but with the increase in speed the pressure drop is high, this is due to structural change of the bandage.

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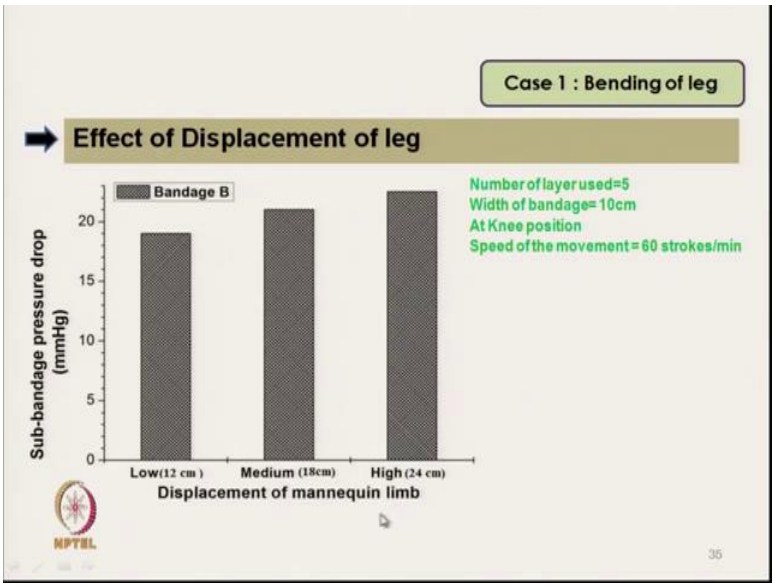

Here this picture shows that, the displacement of mannequin limb as the displacement increases from 12 centimetre to 24 centimetre, the pressure drop increases; that means, if the bending of the limb, bend is there it is more or if the step length is more, if he is walking

with the longer step, in that case pressure drop will be high. So, higher pressure drop means, the lower effectivity of the compression therapy.

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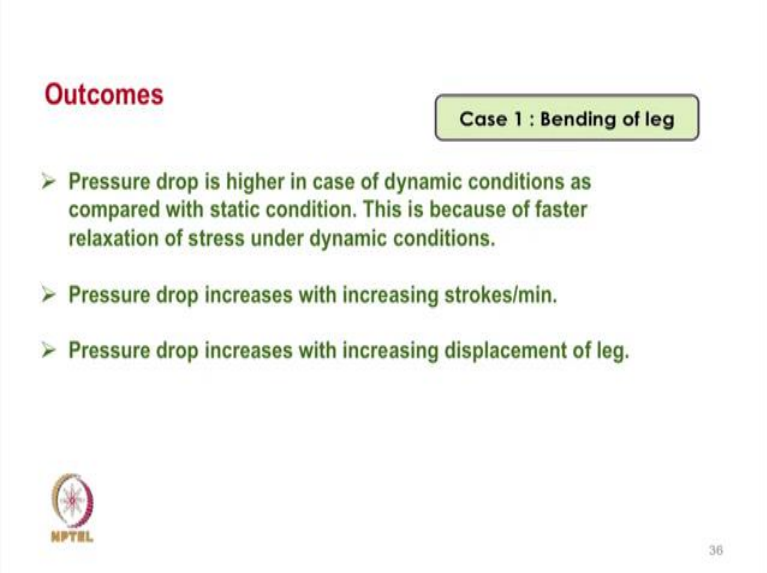

So, the outcome of case 1 is that, pressure drop is high in case of dynamic condition as compared with the static condition. This is because of faster relaxation of stress under dynamic condition, pressure drop increases with the increase in stroke per minute and pressure drop increases with increasing displacement of leg.

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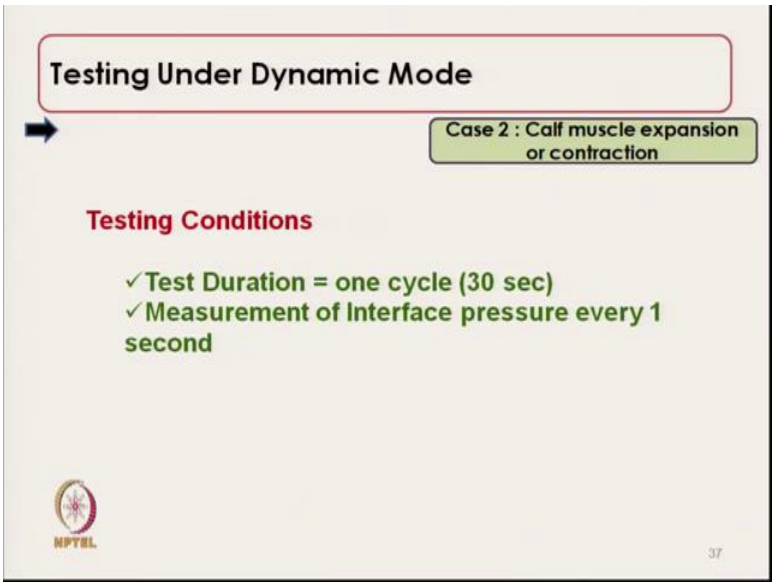

And in next study; case 2, where calf muscles is expanded and contracted. This type of situation we normally come across, when we try to stand up or try to move, try to fold our legs, in those cases the muscles will get expanded and contracted, but if we do not move, if we lay stationary condition; in that case, calf muscle movement will not be there. But in actual practice the calf muscle expansion and contraction take place because the person will definitely move. This result will show how this calf muscle expansion and contraction affect the pressure drop characteristics.

The test duration here is a 30 second and the calf muscle expansion and contraction is simulated using one piston. So, where air is being pumped and it is taken away so, measurement of interfacial pressure is done in every 1 second.

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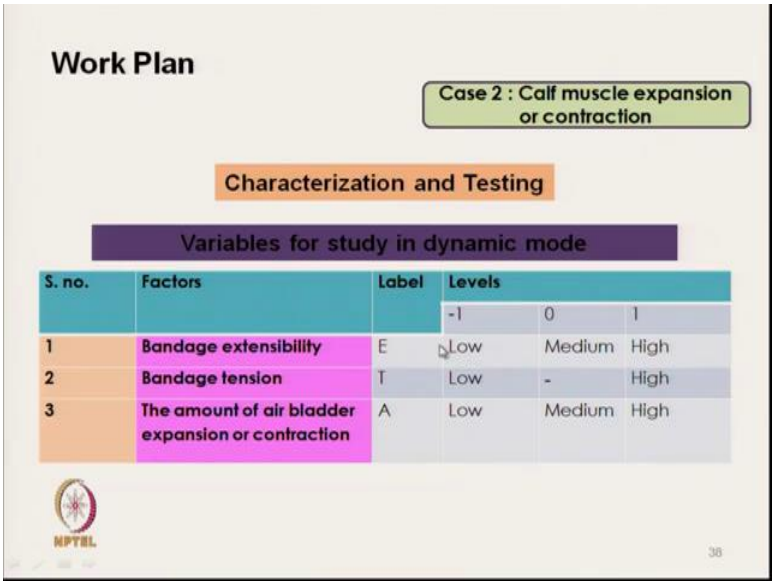

So, along with the bandage extensibility and bandage tension here the amount of air bladder expansion and contraction there are three levels, expansion and contraction in lower level, medium level and higher level. So, this is showing with the term A.

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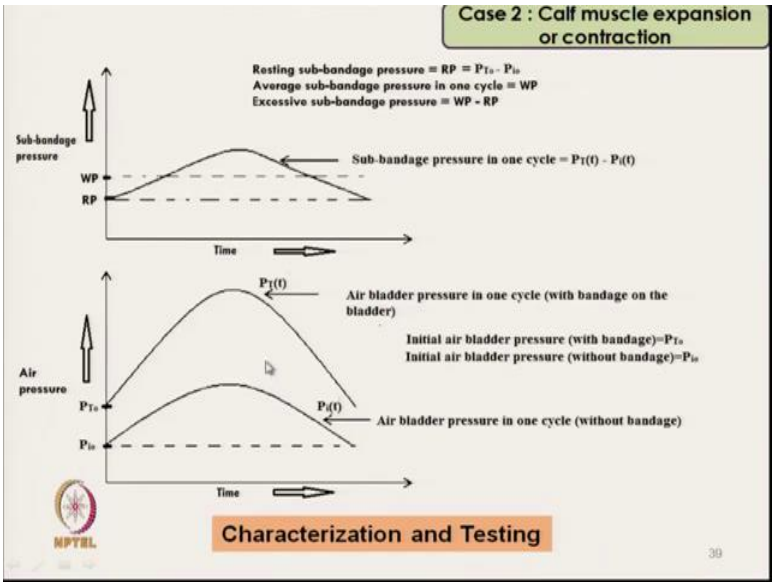

So, this result it shows the with time that is the cycle time is 30 second, this is 30 second cycle time; as we increase this is air bladder pressure one cycle without bandage as we increase the pressure; the calf muscle expansion, its simulating the calf muscle expansion, the air pressure is increased and then it is decrease.

And once we apply the bandage, wrap the bandage over the bladder, the pressure is increasing and then its decreasing. The difference between these two are actually the pressure; pressure exerted by the bandage which is shown here, the rest resting sub bandage pressure that is the, this is the sub bandage pressure ok.

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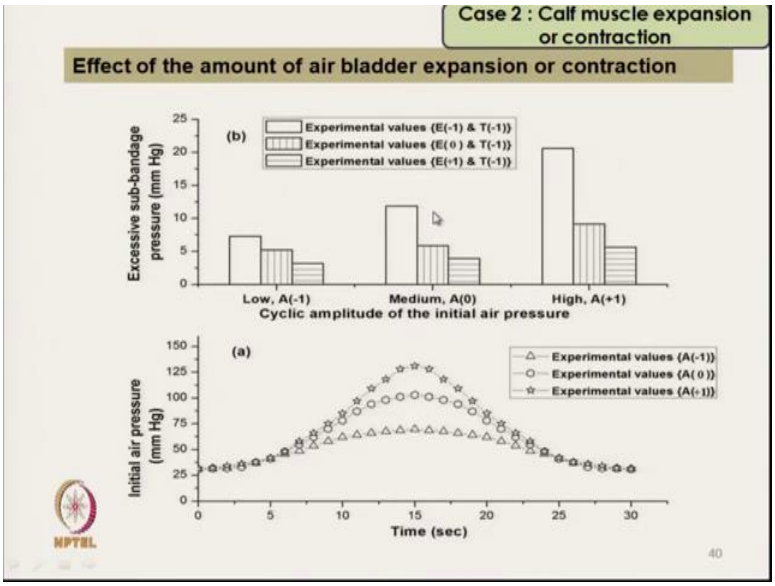

Now, this picture shows here, this is the cyclic amplitude of initial air pressure, the excessive sub bandage pressure here that is the pressure drop here at low level; low level of expansion contraction the pressure drop is low, but whereas, at higher level of expansion contraction, the pressure drop is very high. So, this is the initial pressure drop here at lower level, this is at lower level, initial pressure at higher level and it this is at medium level. This is with the time and 30 second is the cycle time.

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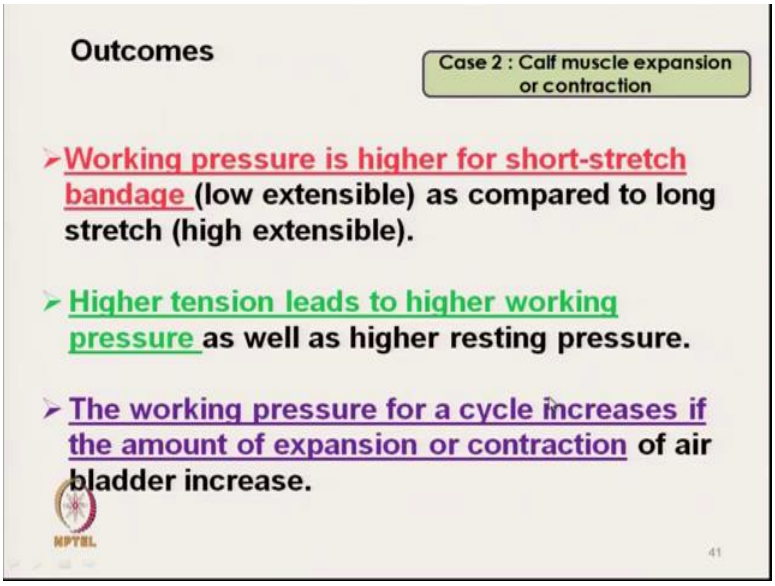

And this we have discussed here and the outcome here, the result here, the working pressure is higher for short-stretch bandage, that we have used two types of bandage, short-stretch bandage and long-stretch bandage. Short-stretch bandage is low extensible bandage and long stretch bandage is highly extensible bandage so, pressure is high if we can develop a short stretch bandage.

Higher tension leads to higher working pressure, that is obvious that we have already discussed using Laplace equation also, the working pressure for a cycle increases if the amount of expansion and contraction of air bladder increases that we have already seen and we have come to the end of this session.

Thank you.