Basics of Mechanical Engineering-1

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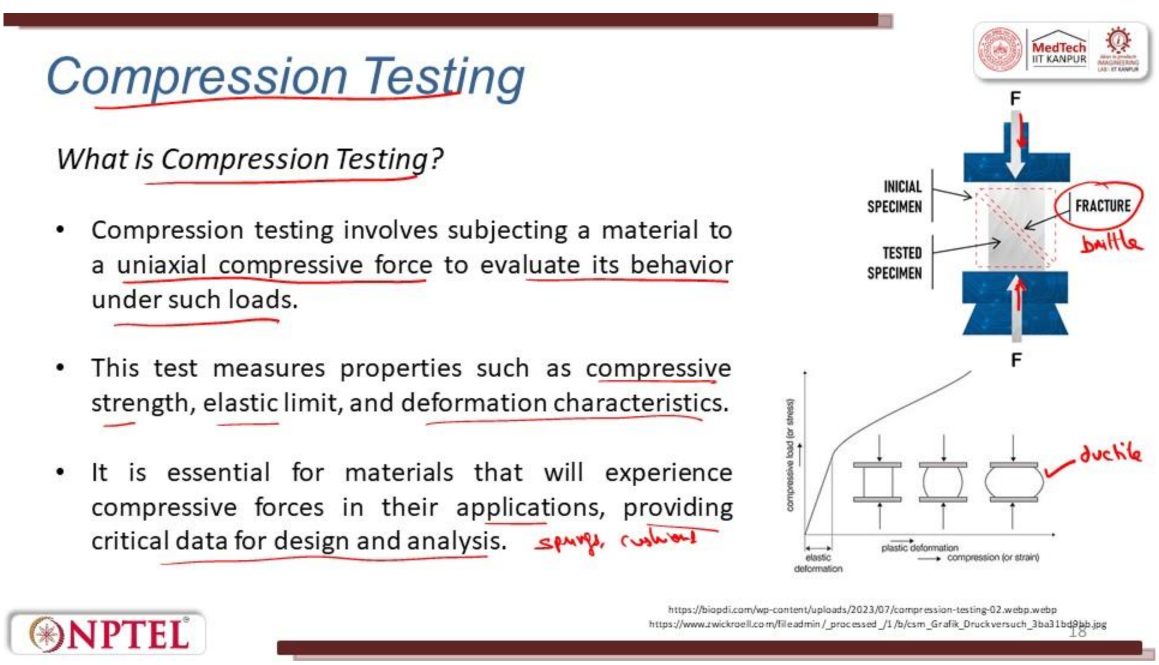
Week 09

Lecture 36

Testing for Compression

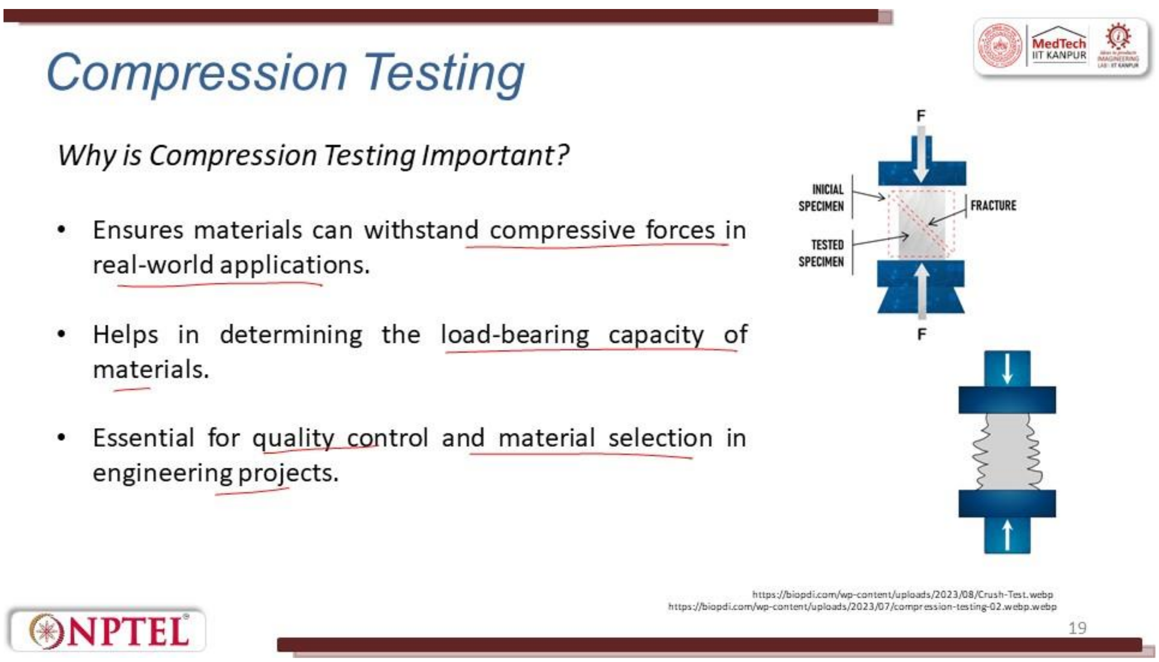
Welcome to the second part of the lecture on the Testing of the Strength of the Materials. We have discussed about the Tensile Test in the first part of this lecture. We are in the course Basics of Mechanical Engineering 1. This course is co-taught by Professor J. Ramkumar and Dr. Amandeep Singh from IIT Kanpur. I am Amandeep.



In this lecture, I will discuss about Compression testing, what is Compression Testing? We will go through and also I will walk you through the virtual simulation setup that is virtual about a setup for the compression testing like we did for the tensile test. So compression testing involves subjecting a material to uniaxial compressive force to evaluate its behavior under such loads. That is a uniaxial load along a single axis and in the opposite directions towards the specimen. So, there is a fracture in the specimen depending upon the property of the material.

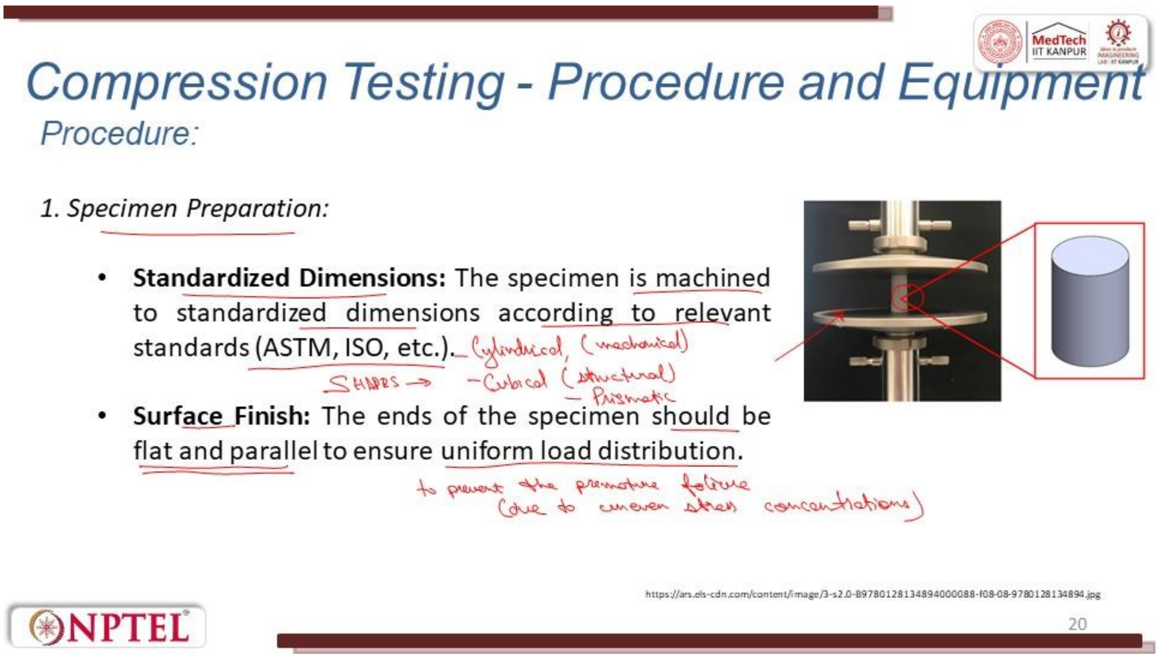
Like for example, this is a ductile material. For ductile material, there will be compression. For brittle material, there will be fracture. This is for brittle material. This test measures the properties such as compressive strength, elastic limit and deformation characteristics.

It is essential for materials that will experience compressive forces in their applications providing critical data for design analysis. These materials could be springs, could be cushions or soil. I will talk about the applications at the end of this lecture.



Why is Compression Testing important? Compression Testing ensures materials can withstand compressive forces in real world applications.

And it helps in determining the load bearing capacity of the material which is essential for quality control and material selection; this is what is similar to what is there for the tensile test there are specimen preparation methods.



So we have the steps or the procedure here the first step is the Specimen Preparation that is standardized dimensions are there again these are given by a certain standard which could be ASTM, which could be ISO standard or so the specimen is machined to standardize dimensions according to relevant standards and this is a specimen that is kept for the compression testing and this is kept between platens, we do not have grips here only between the platens it is compressed surface finish.

The ends of the specimen should be flat and parallel to ensure uniform load distribution. This is to prevent the premature failure. To prevent premature failure, so this premature failure could be due to uneven stress concentrations.

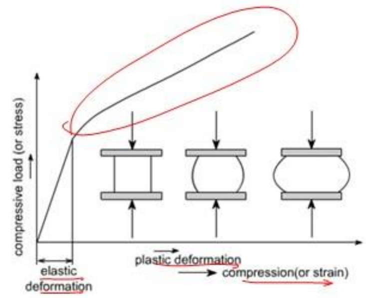
So, it is important to have the flat and parallel surfaces and these specimens could be of multiple shapes that is it could be cylindrical, it could be cubical generally the structural applications that is in the civil structure which are there those are cubical here and generally the mechanical and it could also be prismatic these are shapes of the specimens.

Compression Testing - Procedure and Equipment

3. Data Collection:

- **Stress-Strain Curve:** The recorded data is used to plot a stress-strain curve. Stress is calculated as the applied force divided by the original cross-sectional area, and strain is the change in length divided by the original length.

- **Elastic and Plastic Deformation:** The curve shows the elastic region (linear part) where the material deforms but returns to its original shape when the load is removed, and the plastic region (non-linear part) where permanent deformation occurs.



https://sm-nitk.vlabs.ac.in/exp/compression-test-mild-steel/images/compms1.png

Next is Mounting of the Specimen Alignment. Proper alignment of the specimen in the testing machine is crucial to avoid introducing bending stresses. The specimen should be placed between the machine's compression platens, ensuring that the load is applied along the specimen's central axis. The different platens are there, they could be platen depending upon the size of the specimen, depending upon the strength that is there, depending upon the type of the specimen whether it is concrete, whether it is metal, whether it is an alloy or so, different platens are there.

So, I will show you the virtual laboratory setup for mild steel and cast strain. Let me go through the procedure.

Compression Testing - Procedure and Equipment

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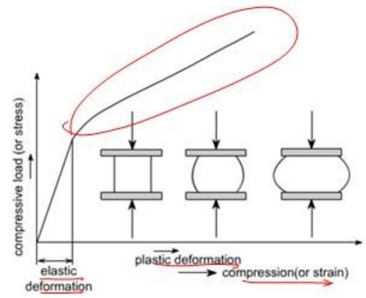

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NPTEL

Data collection, stress strain curve just like we have discussed in the tensile test, a recorded data that is used to plot a stress strain curve stress is again applied load by the cross section area and strain is the change in length by its original length.

Elastic and Plastic Deformation here the curve shows the elastic region here that is linear part, so this is elastic deformation that you can see here where the material reforms but returns to its original shape when the load is removed. And the plastic region that is non-linear part that is there where permanent deformation occurs, this is the plastic deformation region.

Complete. So, this is plastic deformation that is going in this direction and this is compression or strain that is shown here in the curve.

Compression Testing - Procedure and Equipment

4. Fracture and Analysis:

- **Compressive Strength:** The maximum stress the material can withstand before failure.
- **Modulus of Elasticity:** The slope of the linear portion of the stress-strain curve, indicating the material's stiffness.
- **Yield Strength:** The stress at which the material begins to deform plastically.
- **Deformation Characteristics:** Evaluation of how the material deforms, including any buckling or fracturing behavior.

Now, Fracture and Analysis. Compressive Strength. Maximum stress the material can withstand before failure is compressive strength.

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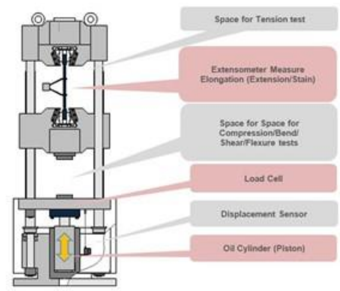
Compression Testing - Procedure and Equipment

Equipment:

1. Universal Testing Machine (UTM):

- **Load Frame:** The main structure that supports the specimen and the loading mechanism.
- **Crosshead:** The movable component that applies the compressive load to the specimen.
- **Load Cell:** A device that measures the force applied to the specimen with high accuracy.
- **Platen:** Flat, parallel plates that apply the compressive force to the specimen.



https://torontech.com/servo-hydraulic-universal-testing-machine/

These are all obtained while we conduct the compression test on the equipment which is same universal testing machine which again the systems, which I have explained in the previous lecture it has a load frame, it has a cross head, it has a load cell, it has a platen it does not have a grip. So, these are you can see in the figure there are platen, but grip is not there. So, cross head, load frame, load cell are already there.

Compression Testing - Procedure and Equipment

2. Extensometers or Displacement Sensors: (dial gauge)

- **Contact Extensometers:** Measure the change in length directly on the specimen.
- **Non-Contact Extensometers:** Use optical or laser methods to measure deformation without physical contact.

3. Data Acquisition System:

- **Computer Software:** Modern UTMs are equipped with software that records and processes the test data, generating stress-strain curves and calculating key mechanical properties automatically.

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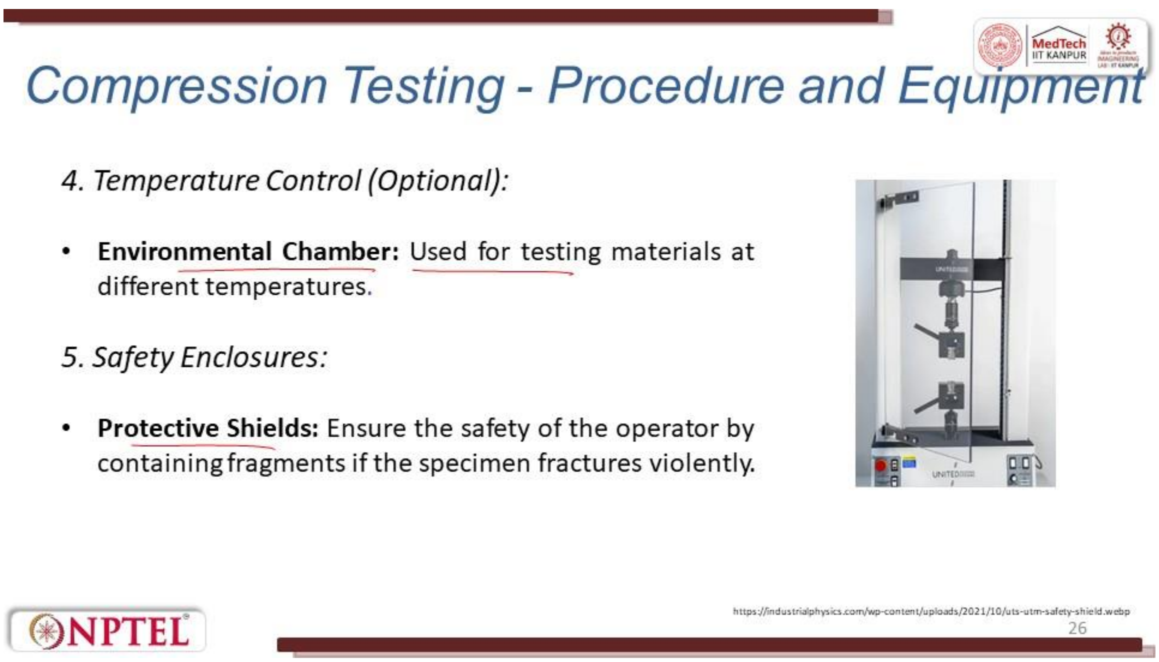
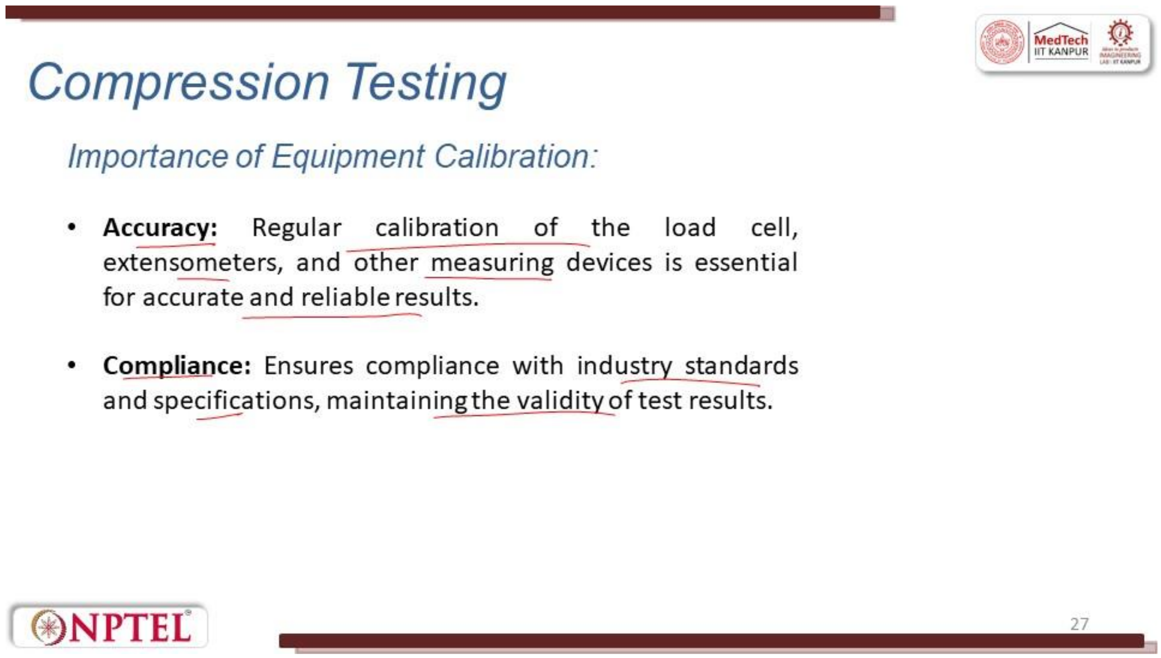
Next comes the Extensometer or Displacement sensors. We can also use dial gauge. Contact extensometers, that is they measure the change in length directly on the specimen. There could be non-contact extensometers, that is they use optical or laser methods to measure deformation without physical contact.

Then data acquisition system similar to the systems which were shown there for the tensile test. So, there are data acquisition systems in the modern UTM which are equipped with software records and these calculate the curves and key mechanical properties automatically.



So, temperature control similar to the tensile test because UTM is same machine environmental chamber is there, protective shields are there. So, that we simulate to the real world conditions and we try to get the specimen tested.



Accuracy and compliance is also same. Regular calibration of load cell extensometers, other measuring device is essential for accurate and reliable results and this ensures compliance with industry standards and specifications, maintaining the validity of the test results.

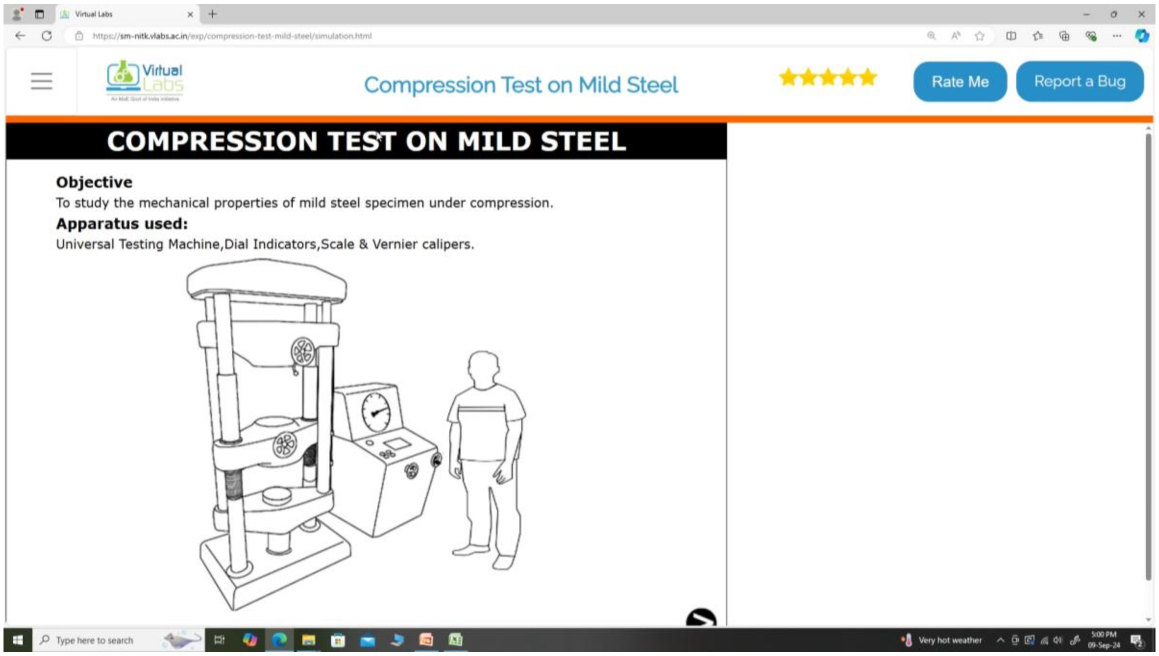
Now, let us go through a video on compression test where a complete setup is there. This is also developed by a center for design NITK that is NIT Suratkal. So, this is a video on compression test.

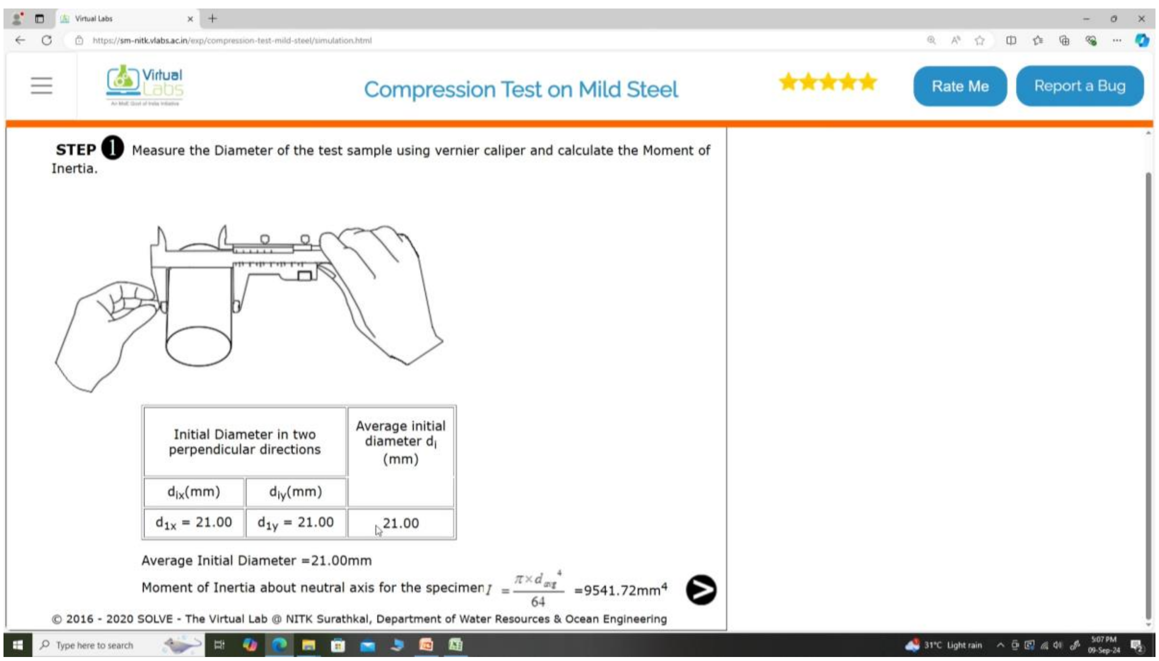
So, in this video, let me just play the video. This is a universal testing machine and they will conduct a compression test on mild steel. The objective is to study the properties of or compression properties of mild steel specimen. So, this is a mild steel specimen. This is used for the experiment.

We measure the diameter at two places. Then we calculate the average diameter and the moment of inertia for the neutral axis. And then we measure the length of the specimen and dial gauge is inserted here so that we measure the change in the length. Specimen is placed here on a platen that is it is a mild steel specimen we reload the cross hatch to just touch the specimen and the friction determines what kind of shape would it get because it is a ductile material and we know that a barrel shape would be produced. We will start the machine.

So, we will keep on applying the load. So, this dial indicator shows that load is being applied here while applying the load the deflection is there, the load is there, it is going on. So, test is continued till the specimen takes a barrel shape when it is a ductile material. If it is a non-ductile material, it will be fractured. So, we measure the new length and diameter, then the graph of load versus dial gauge reading is plotted, then we calculate the proof step, compressive strength, secant modulus, tangent modulus, modulus of elasticity.

Now, I will walk you through the simulation, so that we try to conduct this test completely and the whole experiments set up that we have seen, we will try to see that in a simulator environment developed by the VLAB and it is called itself.





This is a virtual lab set up for mild steel and this is compression test on mild steel. The machine is same. And you can see I can look at the aim to study the mechanical properties of mild steel specimen under compression. The theory is the elastic deformation would be there, plastic deformation would be there, law that is used here is Hooke's law again where E is equal to stress by strain that is Young's modulus and you can see different specimens behave differently depending upon the length by diameter ratio.

If L/D is more than 5, it is buckling, you can see here if L/D is more than 2.5 it is shearing, you can see specimen here and if it is gave more than 2 and friction is present at the contact surfaces, it is double barreling is this C part that you could see here. When L/D is less than 2 and friction is present at the contact services, it is barreling single, barrel is produced that is figure number D.

When L/D ratio is less than 2 and no friction is present at the contact services then we have homogeneous compression that is the affinity between the surface of the platen and the test specimen is not there and it completely flattens just like as shown in figure E. Then comes the compressive instability due to work softening material. So F like condition could also happen.

So there are different specimen forces applied in this direction. There could be buckling, there could be barreling, there could be shearing depending upon the kind of the specimen. The shearing would happen in brittle material. The barreling would happen in a ductile material.

The procedure, I will walk you through the procedure when we go to the simulation and it is just the same steps, we hold the experiment, we measure the diameter and we try to hold the experiment and we try to hold the specimen on the machine, we try to conduct a test and we obtain the reading.

So, there is a single barreling because this is mild steel and we obtain the graph. So, I will walk you through that step by step. So, let me try to go through the pre-test questions that is the self-evaluation that are we ready or do we have the theoretical information with us to conduct a test. So, there are certain questions here that is first is tactile nature of material: in compression testing is indicated by as I discussed, tactile nature would mean a barrel shape would be there, there will be no fracture.

Answer is a formation of barrel shape, neck formation is not there in compression test that is there in tensile test. Second question is compression test is preferred to tension test for determining the modulus of elasticity, say true or false; it is false modulus phase elasticity is more closely determined using the Tension test.

Next question is in compression testing increasing in buckling is due to why the buckling is there because L/D is high that is length is high and diameter is small when the more and more length is there more buckling would happen. So, that is A is increasing length to diameter ratio this seems to be the answer let me try to go through others.

Decrease in length due to diameter ratio does not depend on length to diameter ratio no buckling. Answer is A, increase in length to diameter ratio. I will check the answers when I submit the final free test assignment.

So, which of the following has no unit? Modulus of rigidity, compressive strength, modulus of elasticity, strain, all of them have units. Strain does not have a unit because it is change in length per unit original length. Now, deformation per unit length in direction of force is known as, so it is per unit length in the direction of force interaction of force that means it is linear strain obviously.

So linear strain is there then which IS core is used for compression test on hard metals, there are different IS cores which are used, for specimen for the compression test and for the hard metals it is IS 13780, 1993; I have submitted the quiz I have gotten 6 out of 6 that means all the answers are correct.

So, after that we come to the simulation and after the simulation as well you can see here post simulation assignment is also there which I will not submit. These are the certain questions that you should answer. And there are videos, there are quiz available, these questions, there are videos available for that, for demonstration videos, for compression test or so.

So, I will only go through the simulation part. So, this is the universal testing machine, the objective is to study the mechanical properties of mild steel specimen under compression, apparatus is universal test machine, dial indicators, scale and vernier calipers.

First step, let me measure the diameter of this test sample using vernier caliper and calculate the moment of inertia. I will measure the diameter. So, D in one direction is 21 millimeters. Then again I try to measure it at another point. So, diameter is measured at two points along the length of the specimen.

dix, diy is measured which is 21 millimetres and average is again 21 millimetres. Then movement of inertia about neutral axis of the specimen $I = \frac{\pi \times d_{avg}^4}{64}$ which is 954 1.72 millimetre to the fourth degree. Now let us measure this specimen length. The length of the specimen is 45 millimetres. Now, we will place a specimen in the universal testing machine.

So, it does not go inside any grips. It is just placed on the platens here and we rotate the wheel here. Now, specimen is tightened and we use the dial gauge and we try to set the dial gauge to 0. It is now set to 0 here. Now, we will start our compression testing while pressing green button.

Now, this has slowly started applying load and we are getting the readings here. You can see readings are being added one by one the load is being applied. You can see in this ivory scale as well that load is being applied here and the specimen is getting into a barrel shape. Now the specimen is now completely turned into a single barrel shape and the experiment is completed. This is how the specimen shape is changing and they are indicating to stop the machine.

Red button is pressed and the machine is stopped. We can download the data in a similar fashion as we did for the tension test here. So this is the compression test data in which we have caught on the load that is applied in kilograms and dial gauge readings that is what is the compression that is happening here.

Now next we can move to the step 5 that is we can see the graph where load versus dial reading two columns which were obtained, those are plotted against each other and we can also look at the slope that how the slope is showing load versus dial reading and this is the elastic region.

Then we also can look at the graph again and we go to the next step, we can put the values calculated using the observations which are obtained at the initial diameter 21, the length of the specimen 45 both in millimeters, original area is 346 millimeter square slope in kilonewton but unit division is 159.09, slope in kilo Newton per division is 71.43, slope 3 in kilo Newton per division is 208.33, least count is 0.01, putting all those values or using all those values and using the relations to calculate the proof stress to calculate the compressive strength, secant modulus, tangent modulus, modulus of elasticity.

We can put the values here and check our values using this simulation interface. This is a simulation for the mild steel. Let me also try to check it for the cast iron. So this is the link for the cast iron that is provided to you in the notes itself.

So for cast iron, let me try to open. So, this is the test for the cast iron where the aim is to study the mechanical properties of cast iron specimen under compression. Theory for the cast iron test all is almost same only you will see because this is a brittle material. So, in compression the fracture would be there. So, this fracture when the load is applied at a single line that is along the axis this angle will be 45 degrees.

You can see this is shear plane where the So now procedure is similar to what we discussed. Now let me try to first go through the questions so that we test our readiness for conducting the test. So there are five questions here. First question is in compression test. Fracture in castor and specimen would occur along, in which plane the fracture would occur?

Would it occur along the axis, perpendicular to the axis or at a shear plane that is oblique? So, it is right angle to the axis of the specimen, axis of the load and oblique plane. C is the answer which is an oblique plane. In compression testing, increasing in buckling is what is the reason? So, there could be multiple reasons here one of the option it is given is increase in length to diameter ratio.

Decrease in length to diameter ratio does not depend on length to diameter ratio, no buckling. So, increase in buckling is always due to increase in length to diameter ratio. So, brittle materials are generally, that means weak compression, strong tension, no weak tension, strong compression.

Have weak tension and strong compression. Strong in both tension and compression, weak in both tension and compression, no brittle materials are comparatively weak in tension and strong in compression.

So, gold, cast iron, copper are ductile materials, silver, concrete are brittle materials. I think this is completely false because we cannot compare cast iron is brittle, copper is ductile, similarly silver is ductile, concrete is brittle, so this is false. The shape of the specimen used in compression test is, it could be cube, cylinder, cuboid, prism. So, I think I need to put here the more closer shapes which I have mentioned are cube and cylinder. 1 and 2.

For mild strain and for the metal testing generally these shapes are there. Prisoner could also be used at certain places but majorly I will answer it as the cube and cylinder only. Submit the quiz 5 out of 5. So, we are ready for the test simulation. It will keep asking the steps and we will keep going through them.

Measure the diameter of the sample using Van Eyck helper and calculate the moment of inertia similar to what we did for the mild steel, we will measure diameter at one place and along the length at another place, we will also again measure the diameter. So, both the diameters which are coming are 22 millimeter and we calculate the moment of inertia which comes to 11493.19 mm^4. Then we measure the length of the specimen. To measure the length, we click here and length of the specimen is 41.06 millimeters. Then we drag the specimen to put it on the platen, this cap.

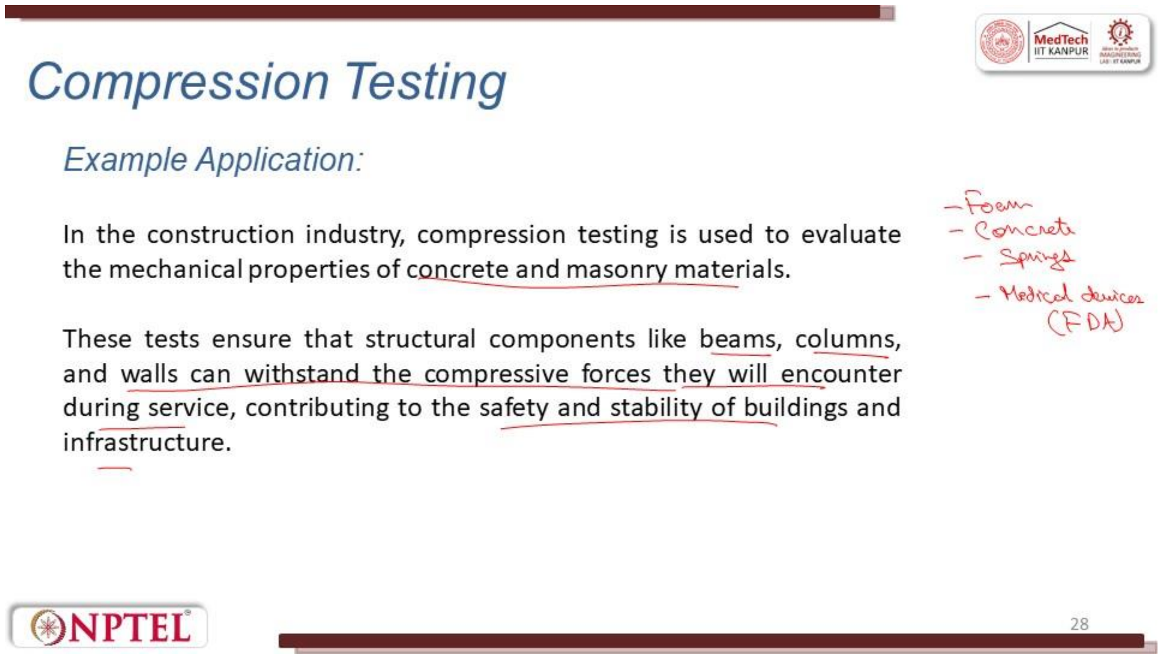
We rotate the wheel so that the crosshead and the platen comes in contact with the specimen. Then we mount the dial gauge and set the dial gauge reading to zero. Then, we start our machine and gradual load is applied. So, a load in kilo Newton, you can see previously the load was in kilograms only. So, this is bitter material, dial gauge reading is going on.

So, it has completed reading and the fracture has happened here at 45 degree. It is shear plane which is an oblique plane. We stop the machine while pressing the red button. We go to the next step, this is the load versus style reading VD data, you can see at any point; let me see as a dial gauge reading 10, the load is 25 kilometer, let me confirm this through graph so at the 10 reading, it is 25 years, so on, it is continuing till almost up to more than 400. So again, let me try to view the data at around 406, it is 270.

At around 406, it is 270. This is how it is plotted. We can also view the slope. Slope 1 is 1.16. Slope 2 is 0.85.

Slope 3 is 1.37. Then we will view the graph once again can view the graph at any point. And we now test our calculations while putting all the observations which have been gotten through the experiments. Initial diameter, the length of the specimen between grips is 22 mm and 41.06 mm respectively. The area is calculated in millimeter square that is 379.94 millimeter square.

Slope one, slope two, slope three is given. Least count is given using this calculation. We can put the values here and we can check the values once we put it here.



Now let me come to the applications of the compression testing. In the construction industry, compression testing is used to evaluate the mechanical properties of concrete and visionary materials.

These tests ensure that structural components like beams, columns and walls can withstand the compressive forces they will encounter during surveys. This contributes to the safety and stability of buildings and infrastructure. Other than this, the compression testing is conducted for various materials. It is a basic form of mechanical testing that is implied to assess the response of a material under crushing loads. It is done on the universal testing machine as we discussed.

So, concretes, composites, corrugated materials such as cardboard are commonly employed in load-bearing applications with their ability to withstand compressive stress that is of utmost importance there. So, some materials such as foam, concrete we have already talked about, springs. These generally go through the compression testing. Springs are ubiquitous in nearly all mechanical devices. They are majorly used.

So the consumer electronic components undergo routine testing prior to the final assembly. So in medical devices as well. So there are certain medical devices that have to go through the stringent compliances. which are given by FDA or other agencies. They rigorously control the medical injectable devices to guarantee that they operate under the suitable compressive load. So, compression testing can be conducted by utilizing diverse selection of the platens specifically engineered for different types and sizes of the specimen.

So, this is a method that is employed to a certain characteristics values including elastic and proportional limits. We calculate the yield point, yield strength, compressive strength and we obtain further mechanical details in the testing so that we try to employ or apply the material to the actual use. So, this was regarding the compression test. Next, I will go through bending test, hardness test, impact and other testing systems which are there that we have discussed in the theoretical part of the course. I will also go through the laboratory demonstration.

I will show you the videos. I will show you the virtual laboratory setups. And we will go through the details of how the testing is conducted for the different kinds of the characteristics of the materials. And this was the compression test in this lecture. We will meet in the next lecture where I will further talk about the material testing.

Thank you.