Structural Integrity: Materials Testing
Testing Materials

Many tests on materials and structures involve measuring the response of the material or component to an applied load. This might be to mimic the loads experienced in service, or to see just how much load-bearing capability a particular design has in practice.

Such tests may involve monitoring the evolution of damage, perhaps by fatigue, when a component like this large steel I-beam is subjected to cyclic loads for a period of many days or weeks.
Other tests could look at the deformation and failure of a new joint design for steel girders in large buildings.

This is a, a structural test. It's the sort of component we'd normally find in a, a building. We've got a column here that would normally go vertically and a beam here that would normally go horizontally, we've got floor surface sat on this part here. There are various ways we can connect these up, either by a bolting or, in this particular case, by welding. So we've got a weld running all the way around there. But we can monitor the strains during the test using strain gauges. We've got various positions; we've got one there and we've got various ones around the weld.

This actual test is conducted at 5°C, so we use cooling fans like this, and which will blow liquid nitrogen through. And we monitor that by thermocouples. What we'll do is apply a rising load at this point here and monitor the strains throughout the test. And what we'd expect, around 200 kN, we'd get some ductile yielding, and then as we push it beyond that, well hopefully we'll get some ductile tearing. And the ram, we'll push to about 200 millimetres, so we'll either push it until we get tearing or we run out of ram movement. We'll use these results to compare to results we've done in the past with bolted connections and look how the two compare.

Other tests are much simpler, and aim to determine the properties of materials so that these properties can be used in design calculations.

This is a test to determine the properties of an aluminium alloy.
Specimens like this are machined from a plate of the material. It will be tested by applying an increasing force and measuring the sample's response until it fails.
The samples have wide areas at each end which are clamped by the grips of the testing machine. The central region, or gauge, is narrower. As a result, the stress in the sample is highest in the gauge. This ensures that the sample will not fail in the grips, and that the properties can be determined accurately in the gauge length.

An accurate extensometer is connected to the sample, within the gauge length.This test machine applies a force by slowly raising the upper grip assembly. A load cell records the force applied to the sample, and the extensometer records its extension. The cross-sectional area of the sample in the gauge is used to calculate stress, and the strain is calculated by comparing the extension relative to the original separation of the extensometer arms. Initial test with low loads and a straight-line response. The sample initially extends elastically. Removing the load at this point would allow the sample to relax back to its original length with no permanent deformation. Eventually a point is reached where the sample begins to deform plastically. Small increments in load now cause much larger extensions. The sample then begins to neck as plastic instability sets in, and failure occurs shortly afterwards.

If we look again at a slower speed, we can see the neck forming just before fracture.If we then compare the fractured sample to an untested sample, we can see firstly how much plastic elongation there has been. By looking at the fracture, we can see the reduction in width caused by the necking just before failure. That reduction in width becomes even more apparent when compared to the untested sample. The data from the test can be used to measure the mechanical properties of the material tested.

Here is another plot of the data that were recorded.
The initial elastic slope of the stress-strain response tells us about the Young's modulus – the elastic modulus – of the material. In this case around 70 Giga Pascals.
The yield stress may be difficult to determine precisely, so it is usually expressed as a proof stress: the stress which would cause a certain level of plastic deformation.

In this case we will choose a proof stress at 0.5% strain. A line drawn parallel to the initial elastic loading line intersects the test data at 520 megapascals: this is our 0.5% proof stress.
Finally, the ultimate tensile strength is found from the maximum stress reached during the test, which in this case is about 560 megapascals.