The Test for Quality and Reliability

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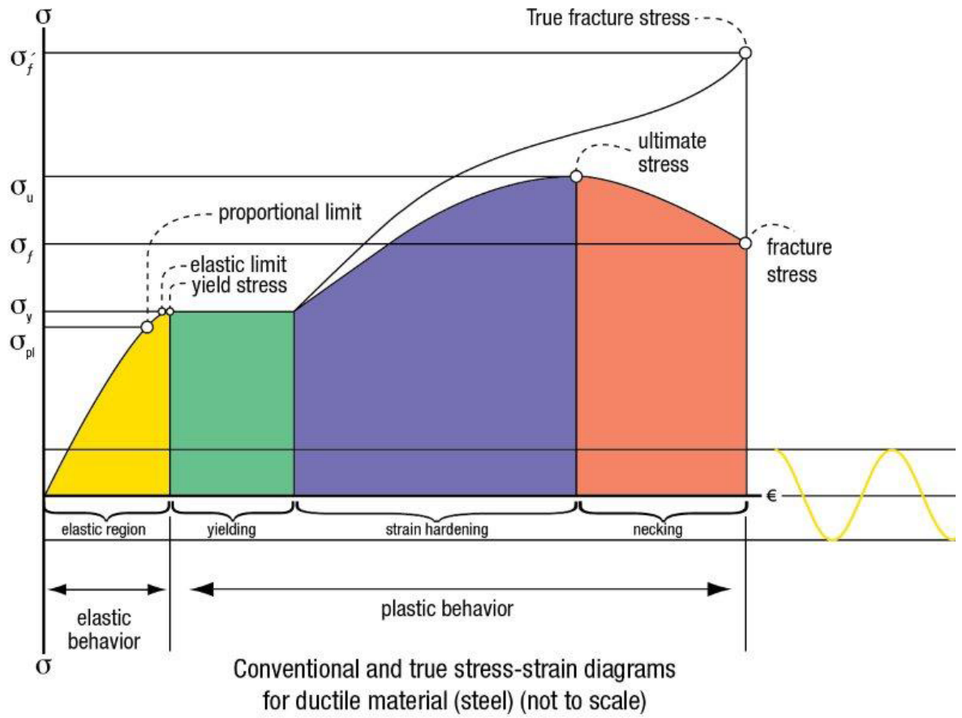
As engineers, we are all familiar with the Tensile Test of steel. The BUET SM Lab test in the Civil Engr. Dept. is well known and widely accepted as the benchmark in Quality Assurance for materials in the construction industry.

The familiar stress-strain graph in the diagram below, describes the behavior of ductile steel subjected to a gradually incremental axial load till the material ruptures. Engineers are very familiar with the yield strength and elongation of steel and are concerned with these 2 values in their design and construction work.



Conventional and true stress-strain diagrams for ductile material (steel) (not to scale)

In recent years the approach to materials quality has undergone a major shift from the simple mechanistic model to a more sophisticated probabilistic model. In fact the European standards for construction steels no longer specify Yield strength of steel but emphasize Characteristic strength. It is defined as the 90% probability that 95% of the values are at or over the desired value. This is the long term quality attribute of a steel manufacturing plant. European construction regulatory authorities certify and license individual steel rolling mills rather than relying on site extracted samples.

Traditionally elongation was measured by measuring the set gauge marks on the steel specimen before and after rupture. The European standards, since the last 10 years has stopped specifying elongation values after the steel has crossed the Ultimate Strength. Any elongation beyond this value, in the necking zone, is considered useless for structural design purposes. For example, a beam will attain its maximum moment capacity at the ultimate stress in steel, not at the fracture stress.

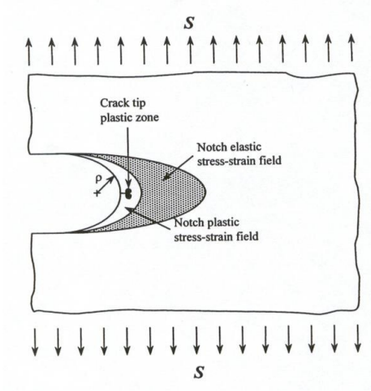
In analyzing the failure of structures and machines it has been found failures have occurred at stresses much below the yield strength of the material. Such failures have been attributed to cyclic loading of structural materials. Cyclic loading is characterized by load reversals; a material under tensile load is subjected to compression loading and vice versa. The Endurance test of materials is very relevant for structures, such as multi-story industrial buildings and bridges which are subjected to fluctuating and reversing load patterns.

Along the familiar stress-strain graph an axial cyclic load of reinforcing steel is shown to compare the relative loading patterns in both the tests. While in a Tensile test the specimen is loaded till rupture, in an Endurance test cyclic loading of the specimen is within the elastic limit of the material. The fact that steel can fail in a brittle manner, much below its yield strength is highly ominous as the consequence of a failure can be catastrophic.

A 32mm 500 MPa reinforcing bar subjected to 160 MPa tension-compression load at 130 Hz cycle. The test is considered a success if the bar survives 5 million load reversals. A copy of BSRM's 32mm Grade 500 reinforcing steel tested in a U.K. Lab is enclosed. This is the prescribed Fatigue test procedure for reinforcing steels as per ISO and Euro Norm and Euro Code 2 standards. Unfortunately, there is no laboratory in the country, to perform the axial cyclic load tests on reinforcing steel. It takes over 10 hours to test a single rebar specimen.

The value of a FatigueTest of steel comes from the fact that steel samples which pass the traditional Tensile Test can fail in a FatigueTest due to the presence of internal defects and surface geometry irregularities. The Endurance test is the 'acid test' for steel quality. It is the test of integrity of steel, as any defects in the steel not detected in the tensile test will be detected in an Endurance test. The failure of a ductile material in an endurance test is known as fatigue failure. Endurance testing ensures a higher assurance of safety and reliability of materials.

All of us take the rebar deformations for granted and do not pay any attention to it. Sharp edges and discontinuities can give rise to stress raisers. Stress concentrations in sharp edges, can exceed the yield strength of the steel at axial loads much below the yield strength. Under repeated reversed loading localized fine microscopic cracks can develop in a bar which propagates initially very slowly from the surface to deep within the core of the bar. At a critical depth the cross-section of the rebar is no longer able to take the design stress of the structure and catastrophic collapse ensues. An example of discontinuity is illustrated below



QUALITY is the standard of something as measured against other things. It means conforming to specifications. RELIABILITY has two related definitions. One is the state of being dependable. The other is consistency – that is, the degree to which something yields the same or compatible result time after time. RELIABILITY is a function of the design; QUALITY is a result of the manufacturing.

Therefore, we can assert while the Tensile Test is the measure of Quality of the steel, the Fatigue Test is the measure of Reliability of steel.