WHAT IS DUCTILITY?

Every reinforced concrete element, for example a beam, is composed of two materials: concrete and reinforcing steel. Imagine a beam built of plain concrete (without reinforcing steel), supported at both ends and in the middle. If we load both spans, what happens?

- In the initial stage of loading, the beam deflects a little.
- In the second stage of loading, the beam suddenly collapses.

If we were in a building in an overload situation, for safety’s sake, we would definitely prefer the structure to deform allowing us to evacuate, rather than to undergo a sudden collapse leaving us with no chance to escape in time.

Such overloads could be caused by:
- Explosion
- Impact damage
- Heavy loading on floors designed for light loading
- Flooding of roofs or floors
- Seismic activity
- Foundation movement due to the proximity of construction work, or problems with water infiltration, etc.

On the other hand, if the concrete is now reinforced with steel bars, and loaded in the same way as before, the outcome will be as follows:

- In the initial stage of loading, the beam deflects a little.
- In the second stage of loading, the beam continues to deform.
- In the third stage of loading, the beam deflects some more, and small cracks appear.
- In the fourth stage of loading the beam deflects even more and the cracking becomes more extensive.

Concrete needs steel reinforcing bars to achieve ductility. Reinforcing bars also need certain bond characteristics with concrete, in order to achieve the required composite behaviour with the concrete. Celsa Reassure Grade 500C bars are designed to meet the bond requirements of BS 8110 Type 2 and EC2.

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In general, the higher the steel ductility, the greater the ductility of the beam. The tensile ductility of steel is its ability to deform when loaded above its elastic limit without fracturing.

Ductility is Safety

A ductile structure near collapse warns about its condition, through large deflections and extensive cracking.

“If the structure is brittle, collapse can occur with no warning, with small deflections and much less cracking.”

Ductility from Celsa Steel
A Guarantee of Safety

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STEEL DUCTILITY

We have seen that elongation is a measure of ductility in a material. One factor that affects its ductility is the ratio of the ultimate tensile strength (UTS) to the yield strength (YS).

The higher the values of these parameters (AGT, Ductility Grade), the greater the ductility of the steel.

PARAMETERS THAT DEFINE STEEL DUCTILITY

The parameters which have traditionally defined the level of ductility of a steel are the following:

- The ratio between the ultimate tensile strength and the yield strength (Rm/Re): (The equivalent symbol used in the materials standards BS4449 and EN10080 is Re).

- Elongation to fracture, measured on a gauge length of 5 bar diameters, (A5).

The higher the values of these parameters, the greater the ductility of the steel.

STRESS-STRAIN CURVE FOR A COLD-ROLLED STEEL (GRADE A)

1. Elastic (linear) stage

2. Plastic (non-linear) stage

In a cold-rolled steel, the yield point is not clearly defined, and is close to the ultimate stress.

STRESS-STRAIN CURVE FOR A HOT-ROLLED STEEL (GRADES B AND C)

1. Elastic (linear) stage

2. Plastic (non-linear) stage

In a hot-rolled steel, the yield point is clearly defined, unlike in the case of cold-rolled steel.

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FLATNESS

FATIGUE

Fluctuating tensile loads can cause fracture of steel bars at stress levels below the yield stress. This phenomenon is known as fatigue.

The effect can be important where there are significant dynamic loads, such as on railways, bridges etc.

In BS4449 to which the UK bridge code BS 5400 refers, steel has to survive at least 5,000,000 stress cycles under specified loading conditions.

Steel ductility is related to the area under the plastic portion of the stress-strain curve. This area represents the energy absorbed by the steel in plastic deformation prior to failure.

LOW CYCLE (TENSION & COMPRESSION) LOADING

The effect on steel bars is called repetitively between tension and compression. The simplest example of this type of loading is in a dam or bridge. This type of loading is applied to the structure in the case of vibration, load patterns are very different from those of steel under fatigue loading conditions.

When a static tensile or compressive stress has a characteristic and destructive effect on the steel. Additional ductility greatly improves the capacity of a steel bar to resist this type of loading.