CHAPTER 2

MATERIALS

2.1 Introduction

This chapter discusses the properties of concrete and steel which affect the behaviour of the composite lipped channel sections. Each property is discussed briefly with reference to its relevance to the composite section.

2.2 Properties of Concrete

2.2.1 Compressive Strength

The characteristic strength of concrete either based on the 28-day cube strength ; that is, the crushing strength of a standard 100mm concrete cubes, or the 28-day cylinder strength, which is the crushing strength of a 150mm diameter x 300mm long concrete cylinder. Generally the cylinder strength is approximately 70 – 90 % of the cube strength, the difference being caused by the frictional forces which arise between the testing apparatus and the concrete specimen and the cross-sectional shape.

A uniaxial compressive strength test gives rise to a typical stress-strain relationship which is in Fig. 2.1 for constant rate of strain. The peak of the stress-strain graph is known as the ultimate strength of the specimen. The graph also shows the post-peak behaviour of the concrete which represents the strain softening. If we refer to Fig 2.2 which depicts the stress-strain relationship for various strengths of concrete, we see that the higher the concrete strength, the more brittle its behaviour after the peak stress has been reached.

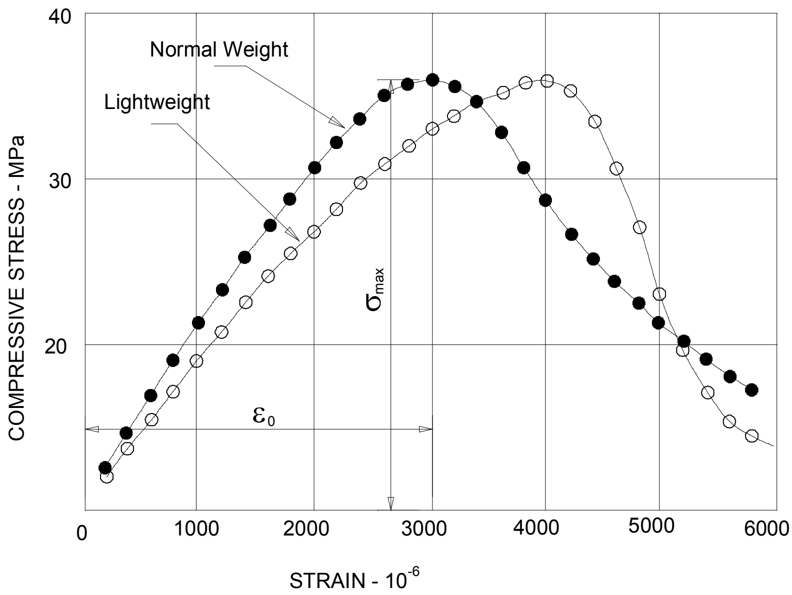

Fig 2.1 Stress-Strain Relationship of Concrete Tested in Comprassion

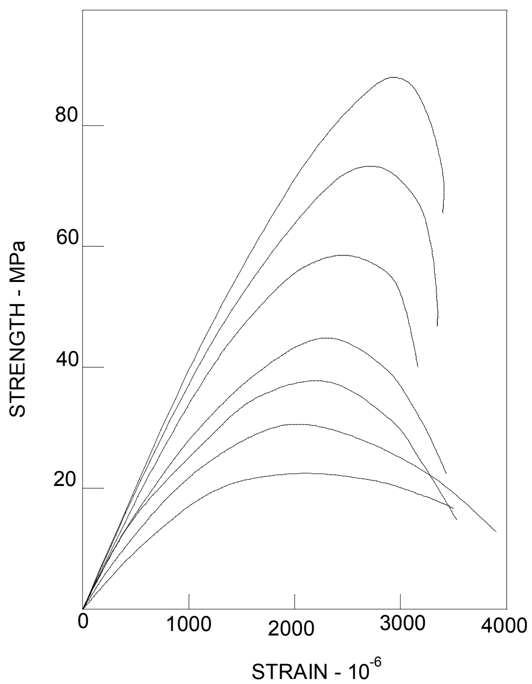

Fig 2.2 Stress-Strain Relationships in Compression for Various Concrete Strengths.

2.2.2 Tensile Strength

The stress-strain curve for tension is similar to the one for compression and is shown in Fig 2.3. These test require a special apparatus for carrying out the test, because of the difficulty of carrying out a concentric pull. The indirect tensile strength, also referred to as the splitting tensile strength, can be determined using a standard 300m x 150mm diameter concrete cylinder. The cylinder is loaded across a diameter until failure occurs by splitting across a vertical plane. A description of the test is described in BS 1881 and ASTM Standard C496. The values obtained from the splitting test are usually between 10.0% to 15.0% of the concrete compressive cylinder strength.

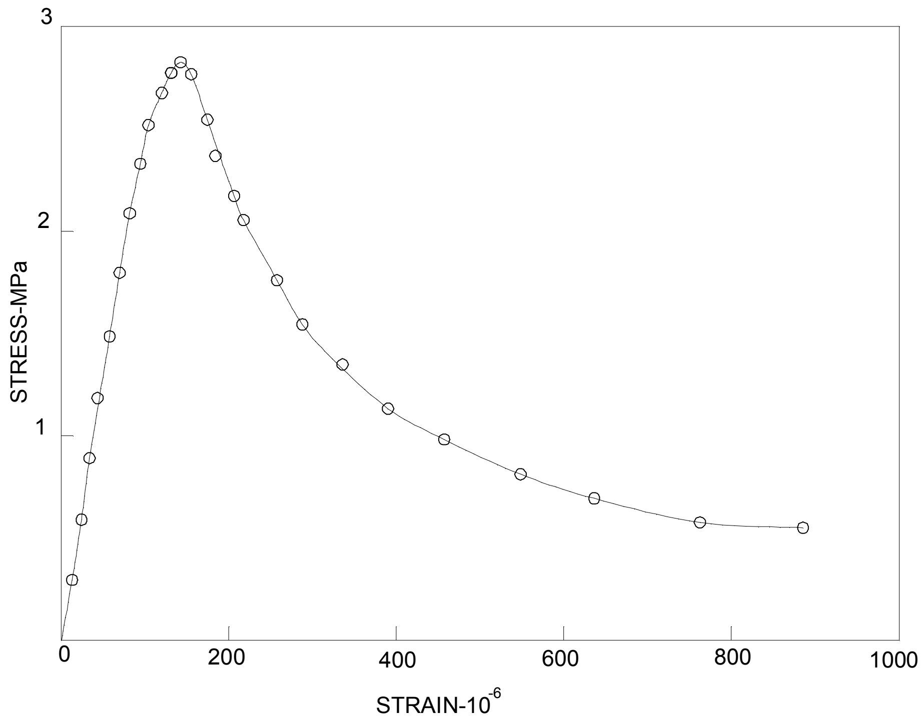

Fig 2.3 Typical Stress-Strain Curve Relation in Direst Tension

2.2.3 Flexural Strength

The flexural strength of concrete is determined by testing an unreinforced concrete beam under symmetrical two-point loading applied at one-third load points. The flexural strength is determined by the following equation:

$$f_b = \frac{M}{Z} \tag{2.1}$$

where M = maximum bending moment in beam where rupture occurs.
Z = elastic section modulus of the beam.

The above value is also referred to as the modulus of rupture and is used in determining the cracked moment of inertia when assessing the deflection of the composite beams.

2.2.4 Modulus of Elasticity

Fig 2.4 shows a diagrammatic representation of a stress-strain relationship for concrete loaded and unloaded to well below its ultimate strength. Generally, the curve has a sharp incline up to one-third of the maximum stress. The term Young's modulus of elasticity can only be applied to this part of the curve, and more correctly, it is applied to the initial slope at the origin. At this point the slope of the curve is called the initial tangent modulus. The curvature of the stress strain curve depends to a large extent on the rate of application of stress. For this reason, the modulus of elasticity, also referred to as the secant modulus of elasticity, is based on a position on the stress strain curve corresponding to a stress equal to one-third of the cylinder strength. This has been chosen to yield a value which is of practical use in the design office.

An expression for the modulus of elasticity is :

$$E_c = 4.73\sqrt{f_c^{'}} \tag{2.2}$$

where E_c = modulus of elasticity in GPa

$f_c^{'}$ = cylinder strength in MPa

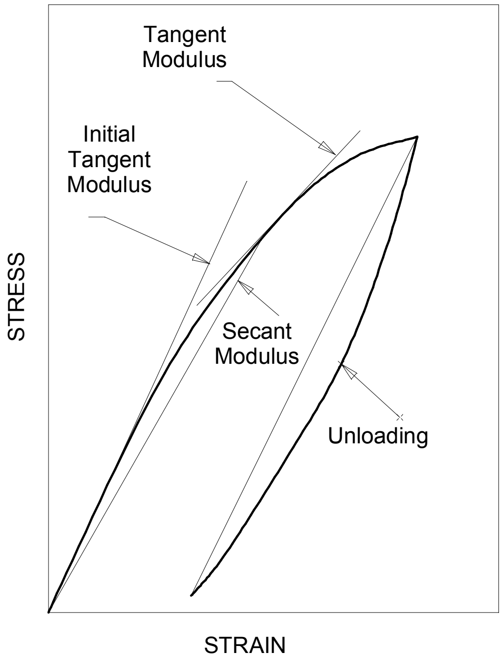

Fig 2.4 Diagrammatic Representation of the Stress Strain Curve for Concrete

2.2.5 Poisson’s Ratio

Poisson’s ration lies in the region of 0.1 to 0.2. For design purposes a practical value of 0.2 is used.

2.3 Structural Steel

2.3.1 Stress-Strain Curve

Fig 2.5 gives a typical stress-strain curve for a structural steel in tension. The important aspects of the curve relative to the study are :

- Line OA which is the linear elastic region of the curve. The slope of OA gives the modulus of elasticity.
- Line BC which defines the yield point of the material. The material behaves perfectly plastic over this portion of the curve.
- Line CD which indicates the strain hardening of the material.
- Point D which defines the ultimate stress of the material.

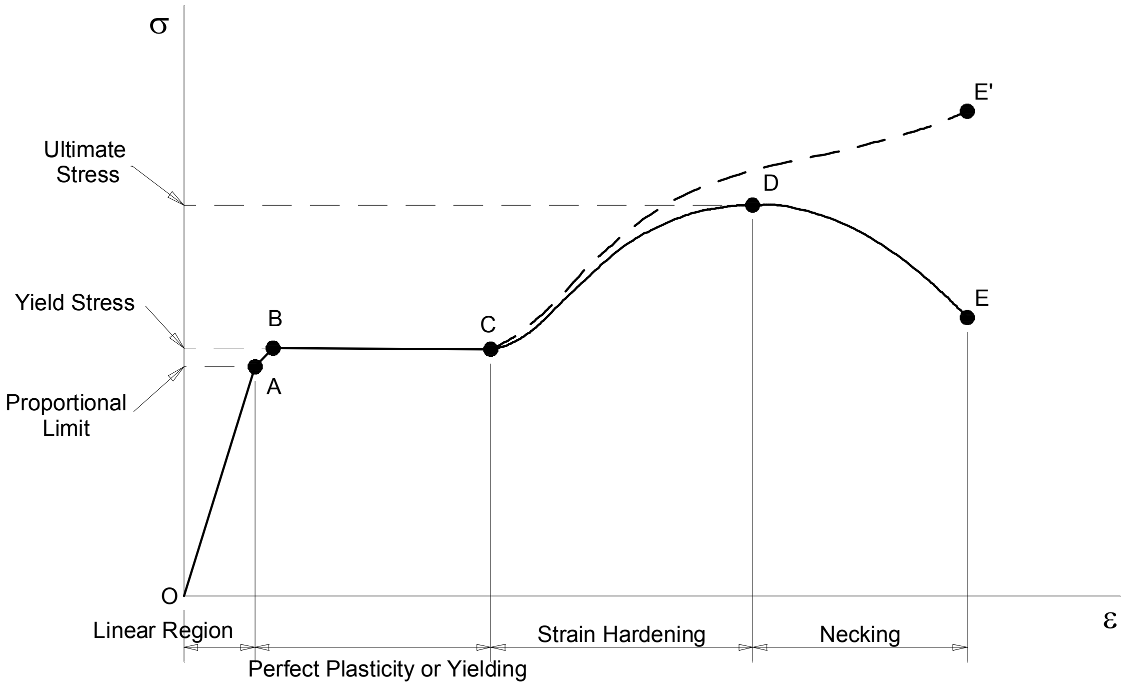

Fig 2.5 Diagrammatic Representation of the Stress Strain Curve for Structural Steel

Typical values for the various points on the curve for the South African market are given in Table 2.1.

Grade	Ultimate Tensile Strength	Yield Stress f_y (minimum) for thickness, t(mm)					Minimum elongation on gauge length of		Charpy V notch impact test (10 mm x 10 mm test piece)		
	f_u (Mpa)	t ≤ 16 (Mpa)	16< t ≤ 25 (Mpa)	25< t ≤ 40 (Mpa)	40< t ≤ 63 (Mpa)	63< t≤100 (Mpa)	200mm (%)	5,65 $\sqrt{S_o}$ (%)	Min. Average energy absorbed (J)	Temperature (^oC)	Maximum thickness (mm)
300WA	450/620	300	300	300	290	280	20	22	-	-	-
300WC	450/620	300	300	300	290	280	20	22	27	0	50
300WDD	450/620	300	300	300	290	280	20	22	27	-30	50
350WA	480/650	350	345	345	340	325	18	20	-	-	-
350WC	480/650	350	345	345	340	325	18	20	27	0	40
350WDD	480/650	350	345	345	340	325	18	20	27	-30	40
450WA	550/700	450	430	415	-	-	17	19	-	-	-
450WC	550/700	450	430	415	400	-	17	19	27	0	19
450WDD	550/700	450	430	415	400	-	17	19	27	-30	19

Table 2.1 Mechanical Properties of Structural Steel

2.3.2 Modulus of Elasticity

The modulus of elasticity used in the test series is 200 GPa.