AL- ESRAA COLLEGE UNIVERSITY

Building & Construction Technology Engineering

Concrete Technology (2)

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By

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Elasticity, shrinkage, and creep

This chapter deals with different types of deformation of concrete. Like many other structural materials concrete is to a certain degree elastic.

Stress–strain relation and modulus of elasticity

Figure (1) shows a typical stress–strain diagram for a concrete specimen loaded and unloaded in compression or tension.

It can be seen that the term Young's modulus of elasticity can strictly be applied only to the straight part of the stress–strain curve, or, when no straight portion is present, to the tangent to the curve at the origin. This is the initial tangent modulus, but it is of little practical importance. It is possible to find a tangent modulus at any point on the stress–strain curve, but this modulus applies only to very small changes in load above or below the load at which the tangent modulus is considered.

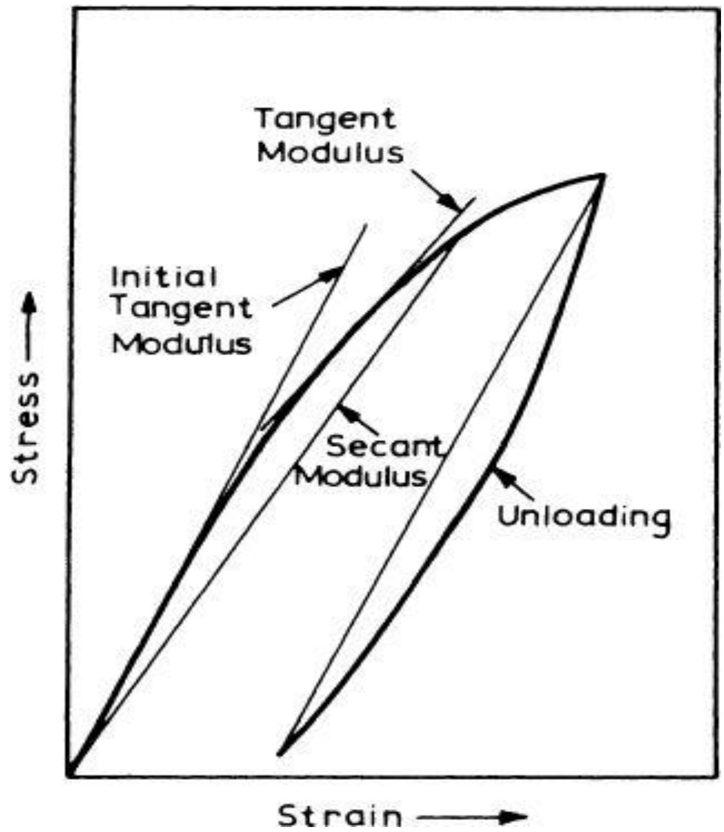

Figure (1): typical stress–strain curve for concrete

For practical purposes, an arbitrary distinction is made: the deformation occurring during loading is considered elastic, and the subsequent increase in strain is regarded as creep. The modulus of elasticity satisfying this requirement is the *secant modulus* of Figure (1). There is no standard method of determining the *secant modulus;* in some laboratories it is measured at stresses ranging from 3 to 14 MPa (400 to 2000 psi) , in others at stresses representing 15,25,33 or 50 per cent of the ultimate strength because the *secant modulus* decrease with an increase in stress.

Table (1): modulus of elasticity of concrete of different strengths given by the British code of practice CP 110:1972 for the structural use of concrete

Compressive strength of works cubes MPa	Mean value of modulus of elasticity GPa
20	25
25	26
30	28
40	31
50	34
60	36

Early volume changes

While the cement paste is plastic it undergoes a volumetric contraction whose magnitude is of the order of one per cent of the absolute volume of dry cement. This contraction is known as plastic shrinkage, since it takes place while the concrete is still in the plastic state. Loss of water by evaporation from the surface of the concrete or by suction by dry concrete below aggravates the plastic shrinkage and can lead to surface cracking, although such cracking is also possible when no evaporation is permitted. However, a complete prevention of evaporation immediately on casting eliminates cracking. Typical plastic shrinkage cracks are usually parallel to one another.

Early shrinkage is greater the larger the cement content of the mix Figure (2) and the earlier the stiffening of the concrete.

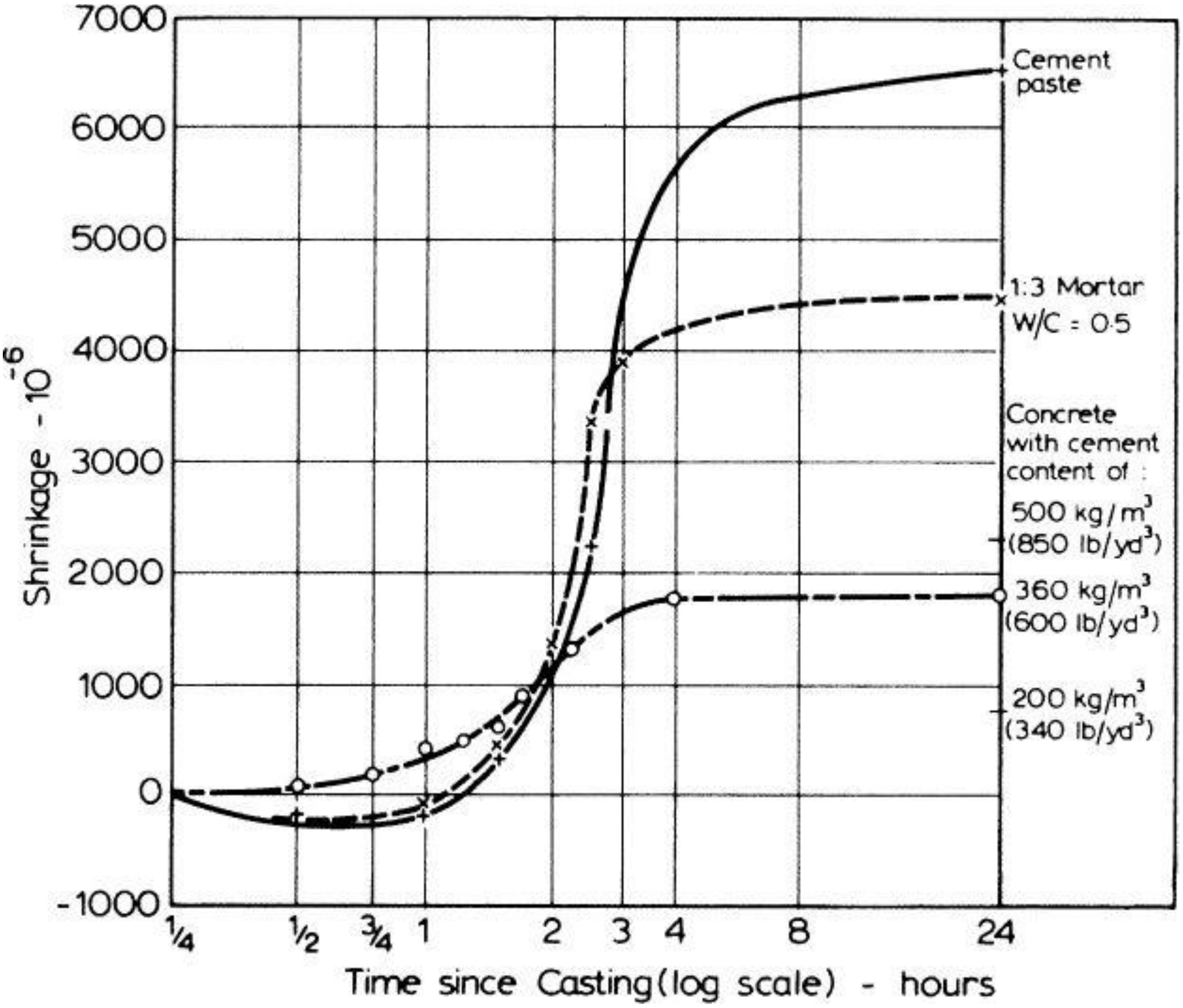

Figure (2): Influence of cement content of the mix on early shrinkage in air at 20 °C (68 °F) and 50 per cent relative humidity with wind velocity of 1.0 m/s (2.25 mph).

Drying shrinkage

Withdrawal of water from concrete stored in unsaturated air causes drying shrinkage. A part of this movement is irreversible.

Mechanism of shrinkage

The change in the volume of drying concrete is not equal to the volume of water removed. The loss of free water, which takes place first, causes little or no shrinkage. As drying continues, adsorbed water is removed and the change in the volume of unrestrained cement paste at that stage is equal approximately to the loss of a water layer one molecule thick from the surface of all gel particles. Since the 'thickness' of a water molecule is about 1 per cent of the gel particle size.

The relation between the weight of water lost and shrinkage is shown in Figure (3) for neat cement pastes, the two quantities are proportional to one another as no capillary water is present and only adsorbed water is removed.

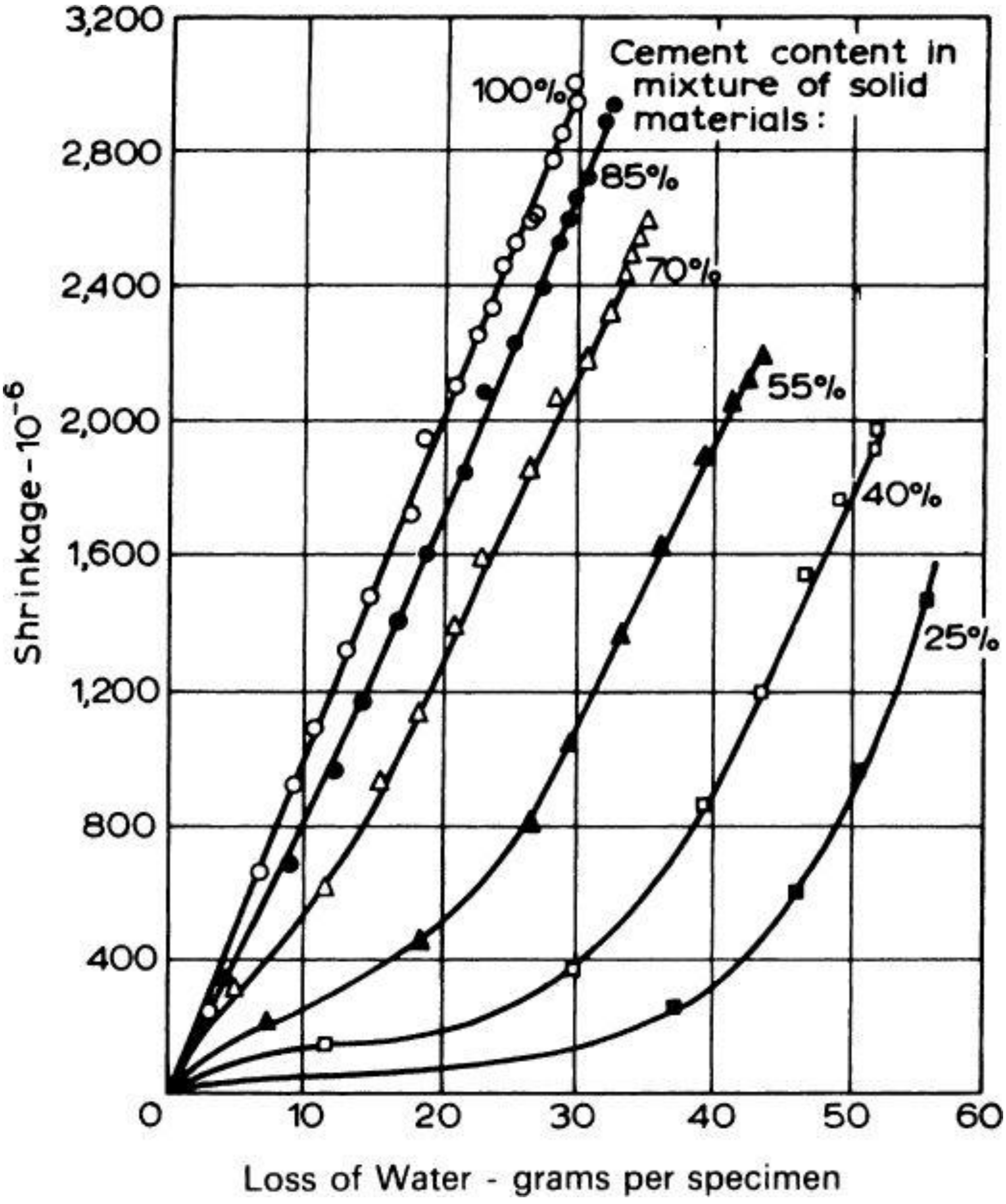

Figure (3): Relation between shrinkage and loss of water from specimens of cement– pulverized silica pastes cured for 7 days at 21 °C (70 °F) and then dried.

Factors Affecting shrinkage

Typical values of drying shrinkage of mortar and concrete specimens, 127mm (5in.) square in cross-section, stored at temperature of 21°C (70°F) and a relative humidity of 50 per cent for six months are given in table (2) but these values are no more than a guide since Shrinkage is influenced by many factors.

Table (2): Typical Values of Shrinkage of Mortar and Concrete Specimens, 5 in. (127 mm) Square in Cross-section, Stored at a Relative Humidity of 50 per cent and 21°C (70°F)

Aggregate/cement ratio	*Shrinkage after six months (10^{-6}) for water/cement ratio of:*			
	0.4	*0.5*	*0.6*	*0.7*
3	800	1200	—	—
4	550	850	1050	—
5	400	600	750	850
6	300	400	550	650
7	200	300	400	500

1- Aggregate content

The most important influence is exerted by aggregate, which restrains the amount of shrinkage that can actually be realized. The ratio of shrinkage of concrete, S_c, to shrinkage of neat cement paste, S_p, depends on the aggregate content in the concrete, a, and is

$$S_c = S_p(1 - a)^n$$

The experimental values of n vary between 1.2 and 1.7. Figure (4) shows typical results and yields a value of n= 1.7.

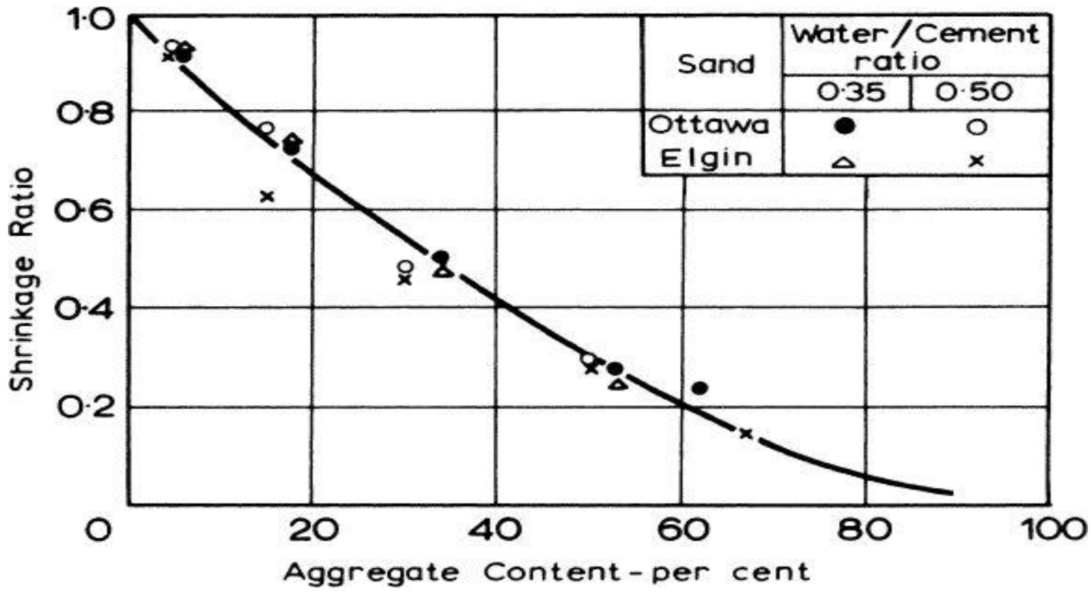

Figure (4): Influence of the aggregate content in concrete (by volume) on the ratio of the shrinkage of concrete to the shrinkage of neat cement paste.

2- Size and grading of aggregate

The size and grading of aggregate *per se* do not influence the magnitude of shrinkage, but a larger aggregate permits the use of a leaner mix and, hence, results in a lower shrinkage. If changing the maximum aggregate size from 6.3 to 152 mm (1/4 in. to 6 in.) means that the aggregate content can rise from 60 to 80 per cent of the total volume of concrete.

3-Water-Cement ratio

The water content of concrete affects shrinkage in so far as it reduces the volume of restraining aggregate. Thus, in general, the water content of a mix would indicate the order of shrinkage to be expected, following the general pattern of Figure (5).

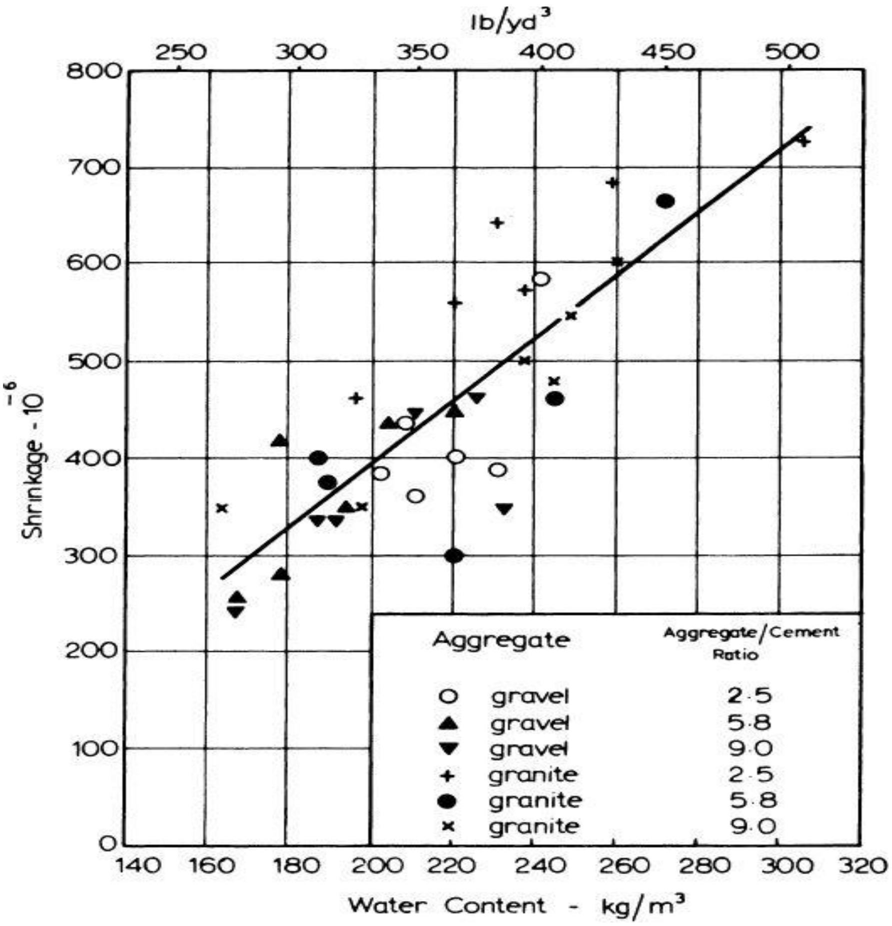

Figure (5): Relation between the water content of fresh concrete and drying shrinkage.

4- Twin influences of water/cement ratio and aggregate content

The twin influences of water/cement ratio and aggregate content (Table 2 and Figure 4) can be combined in one graph; this is done in Figure (6).

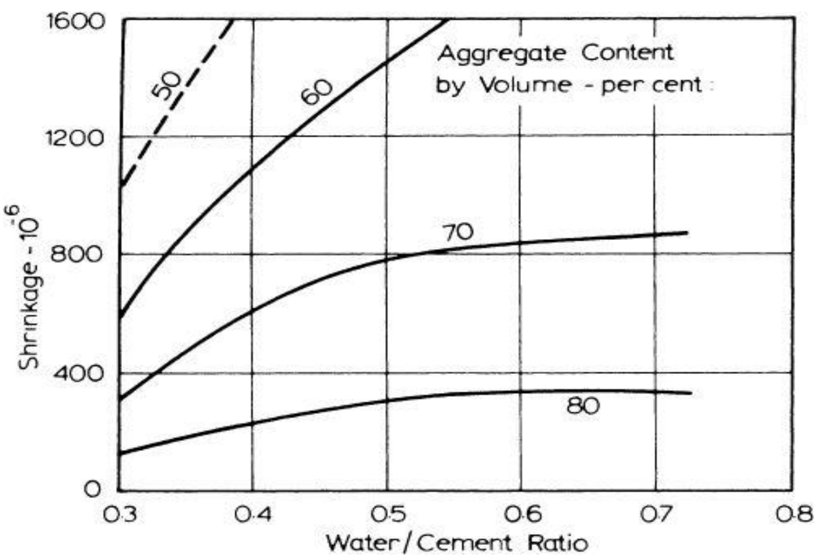

Figure (6): Influence of water/cement ratio and aggregate content on shrinkage

5- Aggregate properties

The elastic properties of aggregate determine the degree of restraint offered; for example, steel aggregate leads to shrinkage one-third less, and expanded shale to one-third more, than ordinary aggregate as shown in Figure (7).

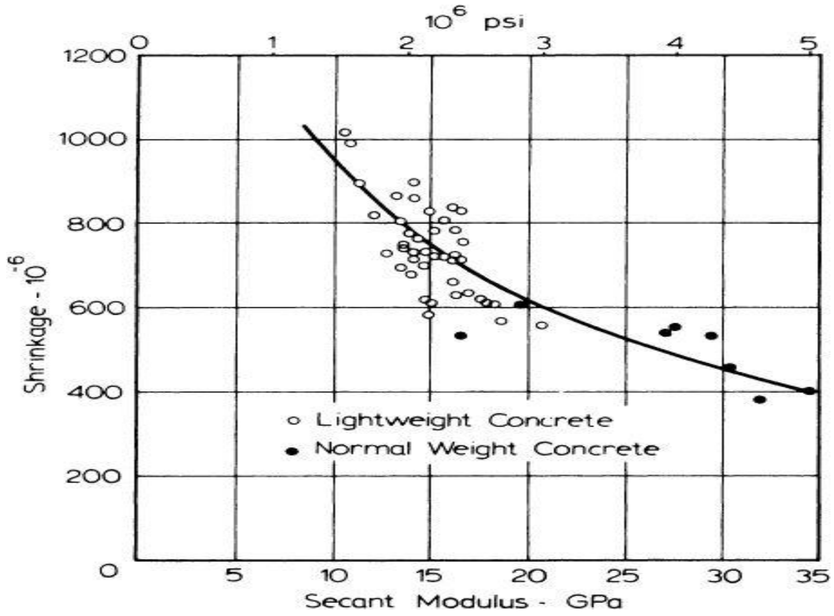

Figure (7): Relation between drying shrinkage after 2 years and secant modulus of elasticity of concrete (at a stress/strength ratio of 0.4) at 28 days.

6- Cement properties

The properties of cement have little influence on the shrinkage of concrete. Fineness of cement is a factor only in so far as particles coarser than, say, 75µm, which hydrate comparatively little, have a restraining effect similar to aggregate.

7- Effect of Age

Shrinkage takes place over long periods: some movement has been observed even after 28 years Figure (8).

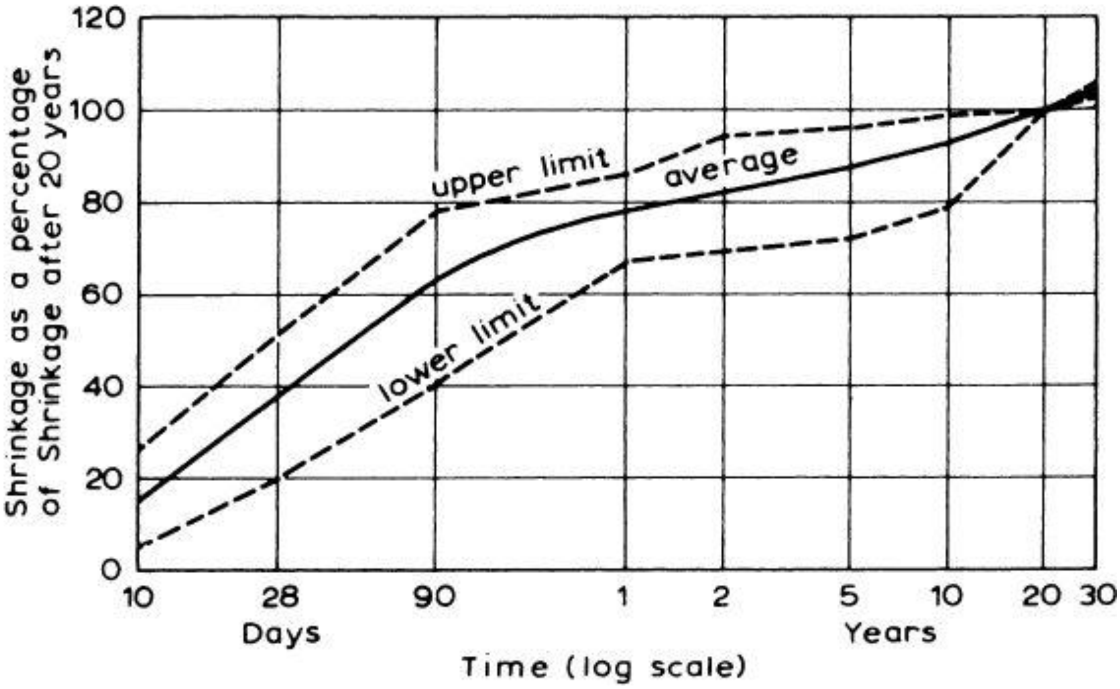

Figure (8): Range of shrinkage–time curves for different concretes stored at relative humidities of 50 and 70 per cent.

The rate of shrinkage decreases rapidly with time:

14 to 34 per cent of the 20-year shrinkage occurs in 2 weeks;

40 to 80 per cent of the 20-year shrinkage occurs in 3 months; and

66 to 85 per cent of the 20-year shrinkage occurs in 1 year.

8- Effect of curing

Prolonged moist curing delays the advent of shrinkage, but the effect of curing on the magnitude of shrinkage is small. The greater the quantity of hydrated cement the smaller is the volume of unhydrated cement particles which restrain the shrinkage.

9- Effect of relative humidity

The relative humidity of the medium surrounding the concrete greatly affects the magnitude of shrinkage, as shown for instance in Figure (9).

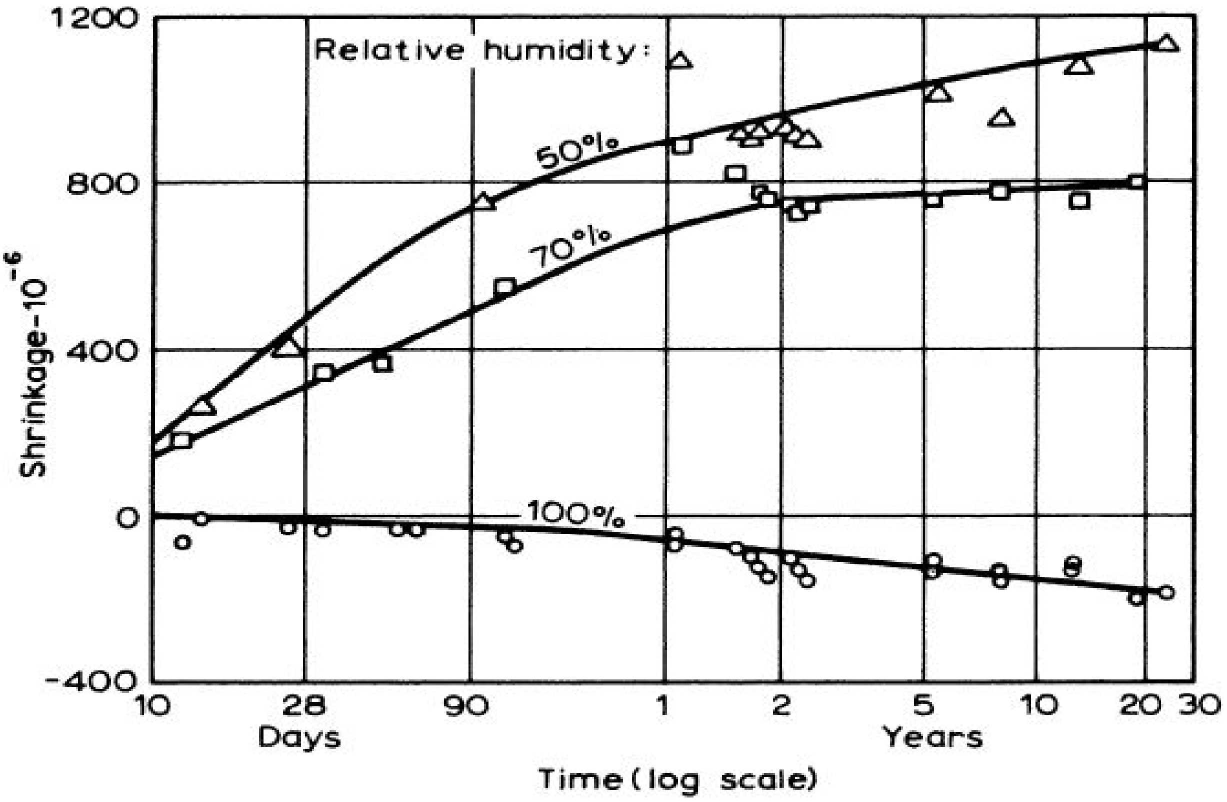

Figure (9): Relation between shrinkage and time for concretes stored at different relative humidities. (Time reckoned since end of wet curing at the age of 28 days)

Creep of concrete

The relation between stress and strain of concrete is a function of time: the gradual increase in strain with time under load is due to creep. Creep can thus be defined as the increase in strain under a sustained stress Figure (10).

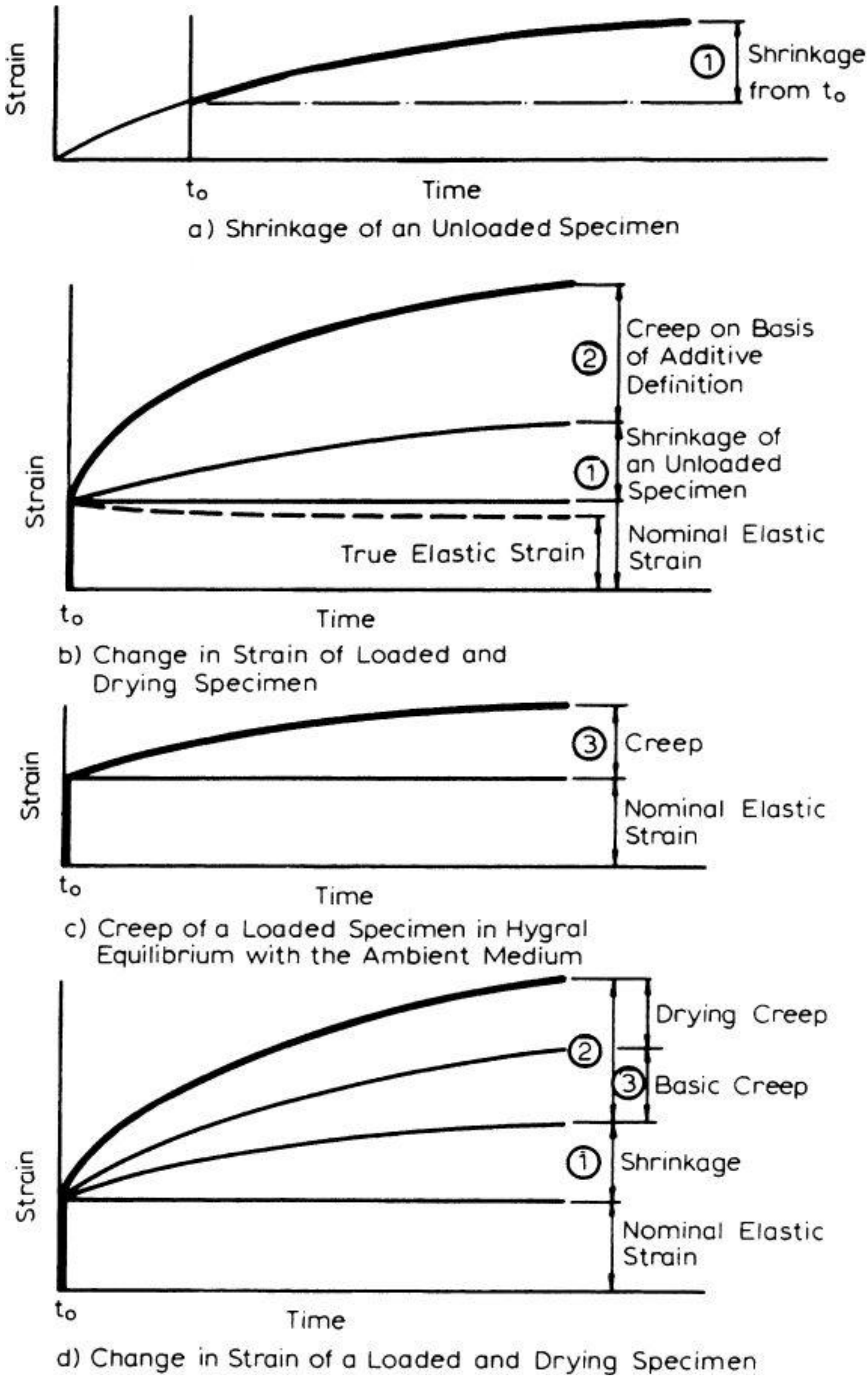

Figure (10): Time-dependent deformations in concrete subjected to a sustained load