Context

- Stress-strain relationship in compression
- Compressive strength
- Tensile strength
- Modulus of elasticity
- Creep
- Shrinkage
- Durability

2.3.1 Stress-strain Relationship in compression.

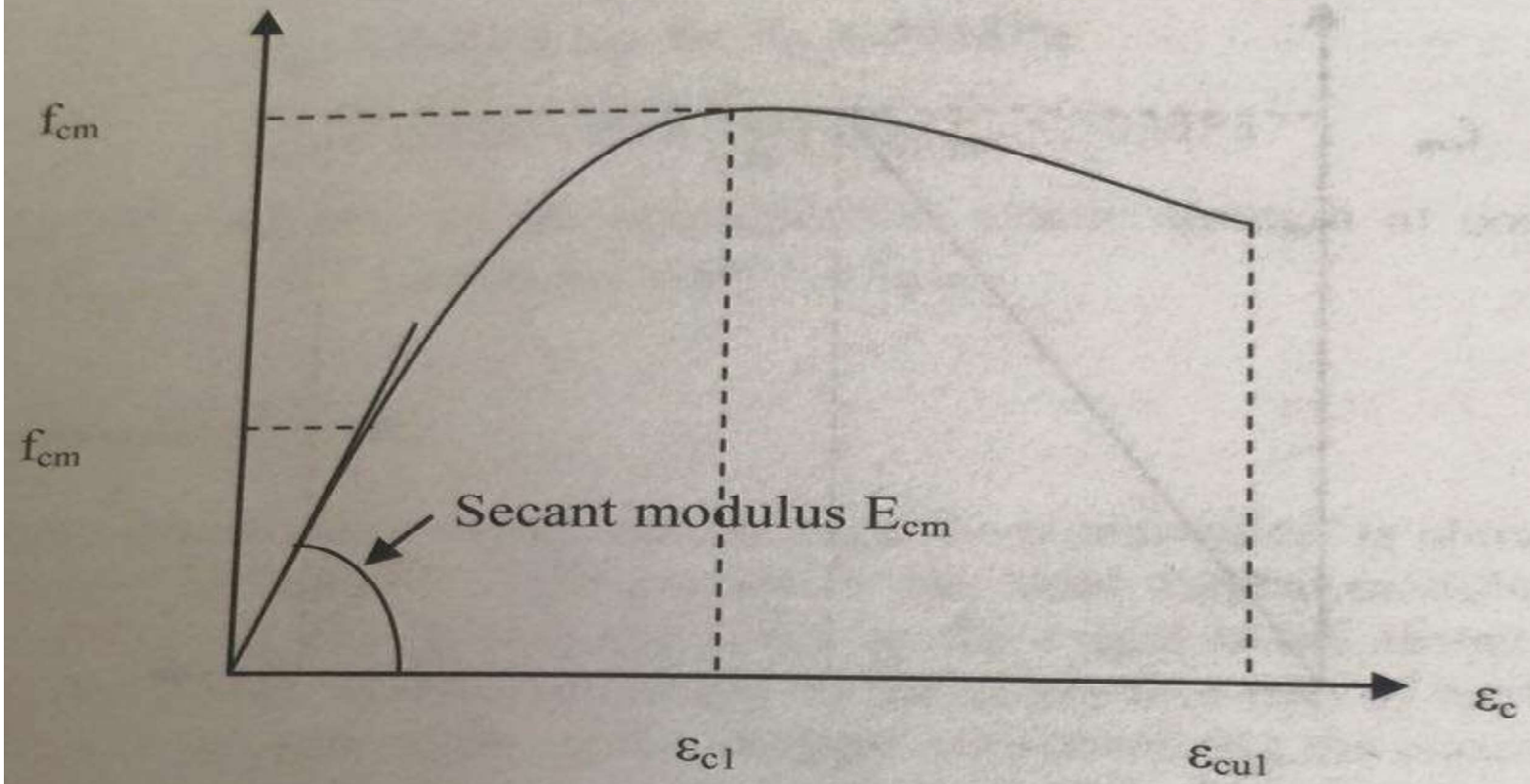


Fig. 2.1 Stress–strain curve for concrete in compression.

- the characteristic compressive strength of cylinder f_{ck} is defined as the strength below which is more than 5% of the results fall.

- the mean compressive strength f_{cm} is related to f_{ck} as $f_{cm} = f_{ck} + 8MPa$

- approximate Relationship between cylinder strength f_{ck} and cube strength f_{ck} cube is $f_{ck} = 0.8\ f_{ck\ cube}$

for design of cross section, two simplified stress-strain relationships are proposed in Euro code 2.

1-a relationship which is the combination of parabola and line

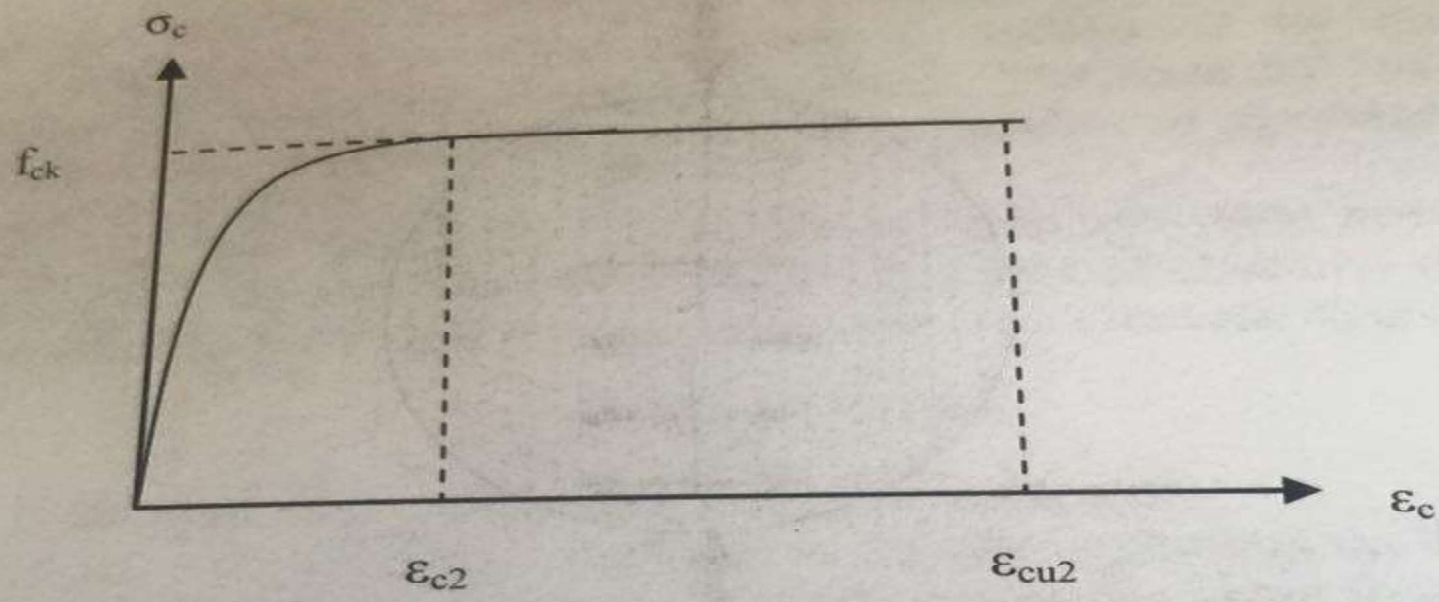


Fig. 2.2 Parabola–rectangle stress–strain relationship for concrete in compression.

2-bilinear stress-strain

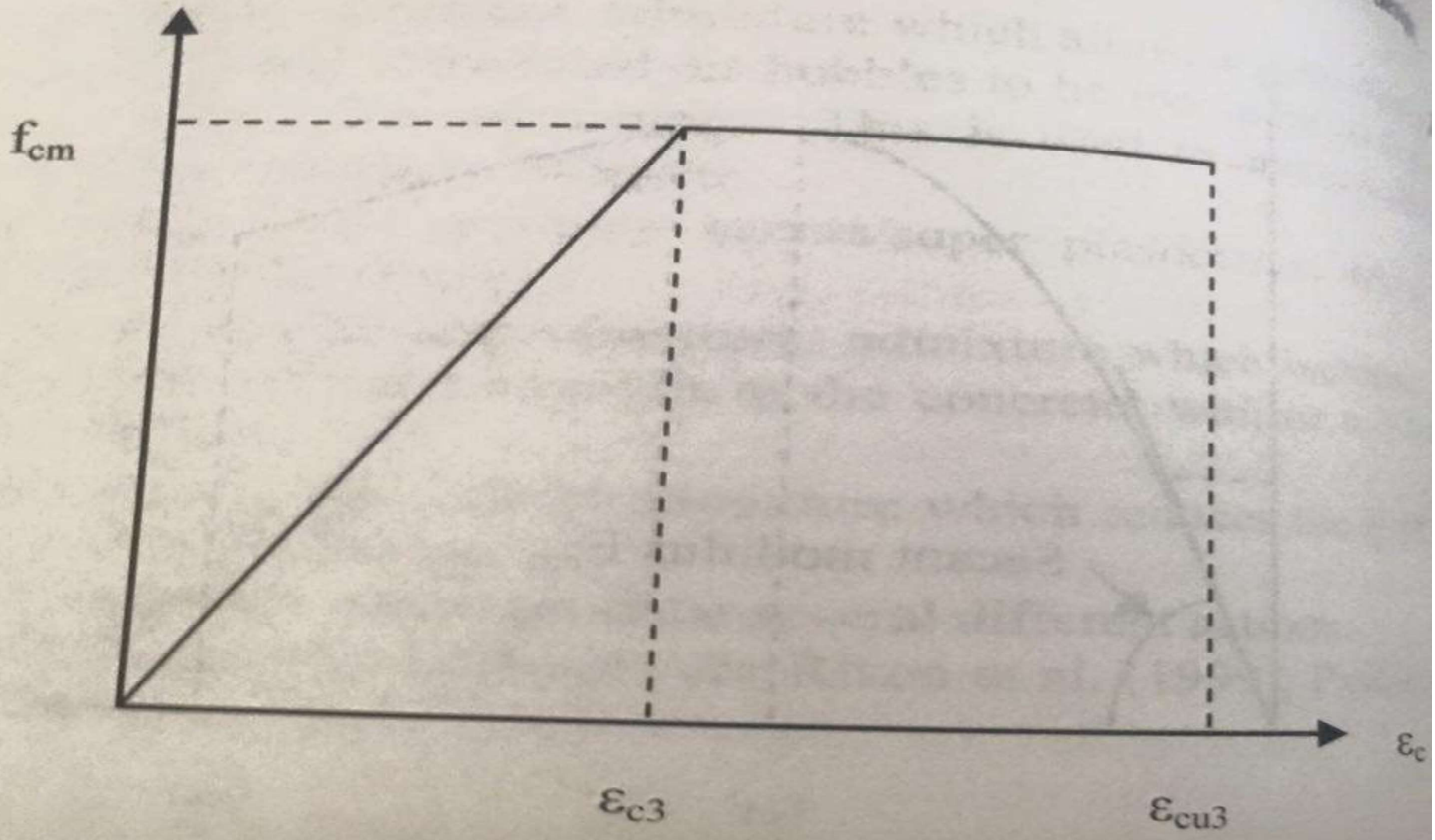


Fig. 2.3 Bilinear stress–strain relationship for concrete in compression.

- mathematical equation for parabola is :

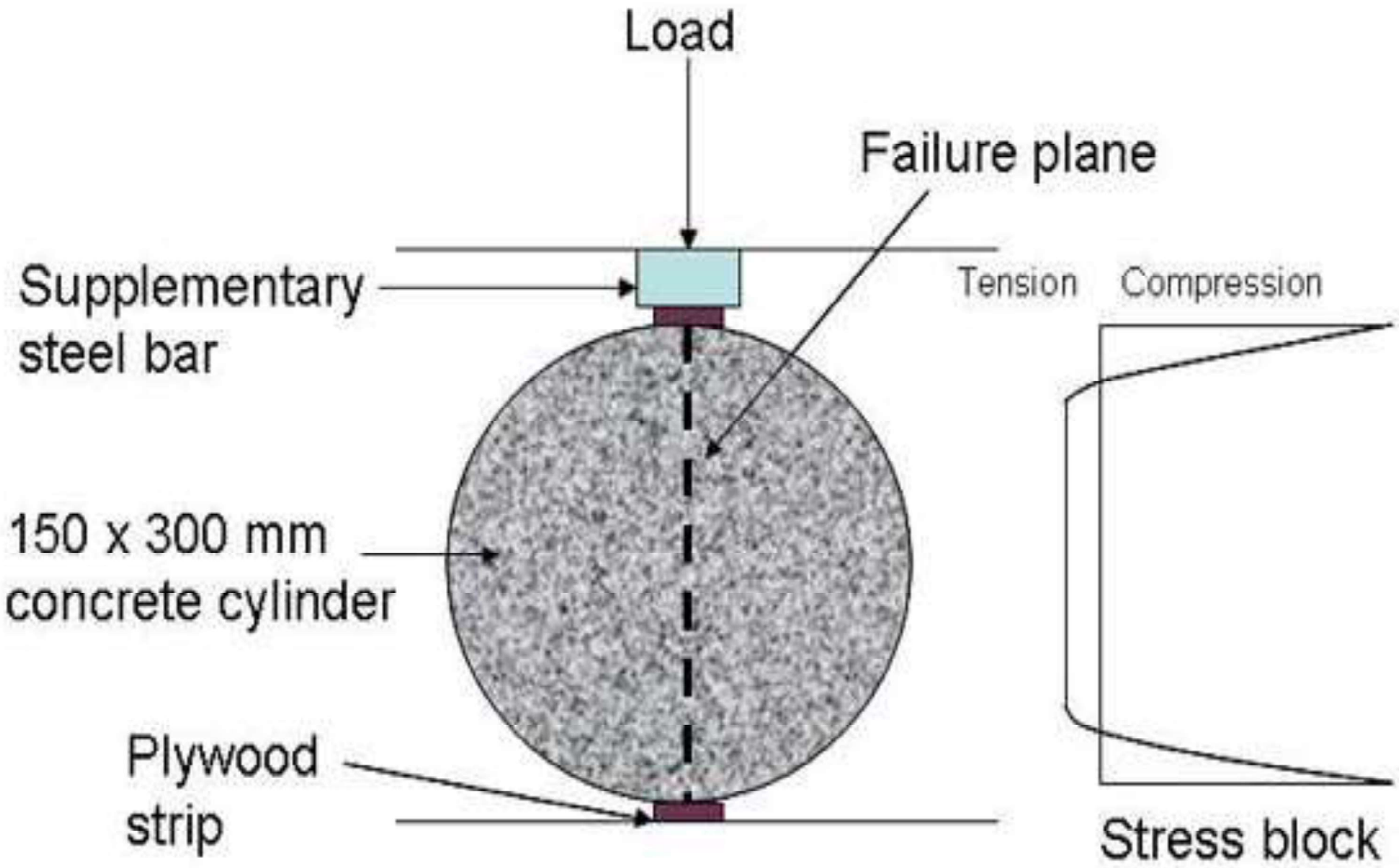
$$\text{stress}, \sigma_c = f_{ck}\left[1-\left(1-\frac{\varepsilon_c}{\varepsilon_{c2}}\right)^n\right] \text{ for } 0 \le \varepsilon_c \le \varepsilon_{c2}$$

$$\text{stress}, \sigma_c = f_{ck} \text{ for } \varepsilon_{c2} \le \varepsilon_c \le \varepsilon_{cu2}$$

Compressive Strength

- Compressive strength of concrete is the most important properties of concrete
- The characteristic strength that is concrete grade is measured by 28-day cylinder/cube strength.
- Standard cylinder 150x300 mm or 150x100 cube with aggregate size of which is not exceeding 25mm is used to determine the strength.

2.3.3 Tensile Strength



- The tensile strength of concrete is about the tenth of compressive strength.

- the mean characteristic tensile strength f_{ctm} is related to mean cylinder compressive strength f_{cm} as follow.

$$f_{ctm} = 0.30 \times f_{ck}^{\frac{2}{3}} \quad \text{for } f_{ck} \leq 50\,\text{MPa}$$

$$f_{ctm} = 2.12 \times \ell n[1 + \frac{f_{cm}}{10}] \quad \text{for } f_{ck} > 50\,\text{MPa}$$

- The 5% and 95% fractals of the characteristic tensile strength of concrete are respectively $f_{ctk,0.05} = 0.7\, f_{ctm}$ and $f_{ctk,0.95} = 1.3\, f_{ctm}$

2.3.4 Modulus of Elasticity

in figure 2.1

- The slope of the initial straight portion is the initial tangent modulus

- The slope of the joining the point to the origin is the secant modulus

- The value of secant modulus depends on the stress and the rate of application of the load

- The dynamic modulus is determined by subjecting a beam specimen to longitudinal vibration. creep is not affecting the value of dynamic modulus and its almost the same as initial tangent modulus.

- Elastic modulus is greatly depend on stiffness of aggregates.

- for limestone and sandstone aggregate the value from equation should be reduced by 10% and 20%

2.3.5 Creeps

creep in concrete is the gradual increase in strain with time in a member subjected to prolonged stress. creep strain is much larger than the elastic strain on loading.

factors affecting creep strain are:

- concrete mix and strength
- type of aggregates
- curing
- ambient relative humidity
- the magnitude and duration of sustained loading
- age of concrete

2.3.5 shrinkage cracks

The term shrinkage is loosely used to describe the various aspects of volume changes in concrete due to loss of moisture at different stages due to different reasons.

Types of Shrinkage in Concrete

To understand this aspect more closely, shrinkage can be classified in the following way:

(a) Plastic Shrinkage
(b) Drying Shrinkage
(c) Autogeneous Shrinkage
(d) Carbonation Shrinkage

- Drying shrinkage: develop slowly due to migration of water and is irreversible but alternate wetting and drying causes expansion and contraction in concrete.

- Autogenous shrinkage: develop very fast during hardening of concrete in early stages.

➢ Plastic Shrinkage

Shrinkage of this type manifests itself soon after the concrete is placed in the forms while the concrete is still in the plastic state. Loss of water by evaporation from the surface of concrete or by the absorption by aggregate or sub grade, is believed to be the reasons of plastic shrinkage. The loss of water results in the reduction of volume. The aggregate particles or the reinforcement

➢Carbonation Shrinkage

Carbon dioxide present in the atmosphere reacts in the presence of water with hydrated cement.
Calcium hydroxide [Ca(OH)2] gets converted to calcium carbonate and also some other cement compounds are decomposed.. Carbonation penetrates beyond the exposed surface of concrete very slowly.
The rate of penetration of carbon dioxide depends also on the moisture content of the concrete and the relative humidity of the ambient medium. ***Carbonation is accompanied by an increase in weight of the concrete and by shrinkage.***

Factors cause shrinkage

- Aggregate types and content
- size of aggregate
- larger size of aggregate is lower in shrinkage
- aggregate that change volume on wetting and drying increase shrinkage (sandsone,Basalt)
- decrease in the ambient relative humidity also increase shrinkage.

2.3.6 Durability

The ability of concrete to withstand the conditions for which it is designed without deterioration for a long period of years is known as durability

or

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties.

Concrete will remain durable if:

- The cement paste structure is dense and of low permeability
- Under extreme condition, it has entrained air to resist freeze-thaw cycle.
- It is made with graded aggregate that are strong and inert
- The ingredients in the mix contain minimum impurities such as alkalis, Chlorides, sulphates and silt

Factors Affecting Durability of Concrete

Durability of Concrete depends upon the following factors:

- **Cement content**

Mix must be designed to ensure cohesion and prevent segregation and bleeding. If cement is reduced, then at fixed w/c ratio the workability will be reduced leading to inadequate compaction. However, if water is added to improve workability, water / cement ratio increases and resulting in highly permeable material.

- **Compaction**

  The concrete as a whole contain voids can be caused by inadequate compaction. Usually it is being governed by the compaction equipments used, type of formworks, and density of the steelwork

- **Curing**

It is very important to permit proper strength development aid moisture retention and to ensure hydration process occur completely

- **Cover**

Thickness of concrete cover must follow the limits set in codes.

- **Permeability**

  It is considered the most important factor for durability. It can be noticed that higher permeability is usually caused by higher porosity .Therefore, a proper curing, sufficient cement, proper compaction and suitable concrete cover could provide a low permeability concrete

Types of Durability of Concrete

There are many types but the major Concrete Durability types are:

- Physical durability
- Chemical durability

Physical Durability

Physical durability is against the following actions
1.Freezing and thawing action
2.Percolation / Permeability of water
3.Temperature stresses i.e. high heat of hydration

Chemical Durability

Chemical durability is against the following actions
1.Alkali Aggregate Reaction
2.Sulphate Attack
3.Chloride Ingress
4.Delay Ettringite Formation
5.Corrosion of reinforcement

Causes for the Lack of Durability in Concrete

1. External Causes:

1.Extreme Weathering Conditions
2.Extreme Temperature
3.Extreme Humidity
4.Abrasion
5.Electrolytic Action
6.Attack by a natural or industrial liquids or gases

2. Internal Causes

a) Physical

- Volume change due to difference in thermal properties of aggregates and cement paste
- Frost Action

b) Chemical

- Alkali Aggregate Reactions

i. Alkali Silica Reaction
ii. Alkali Silicate Reaction
iii. Alkali Carbonate Reaction

- Corrosion of Steel

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