

COMPOSITES

Composites are any multiphase material that is artificially made and exhibits a significant proportion of the properties of the constituent phases. The constituent phases of a composite are usually of macro sized portions, differ in form and chemical composition and essentially insoluble in each other. Composites are made by combining two distinct engineering materials. One is called matrix that is continuous and surrounds the other phase – dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and size-and-shape of dispersed phase.

Classification- composites are classified using different criteria like: (a) type of matrix material—metal matrix composites, polymer matrix composites and ceramic matrix composites (b) size-and-shape of dispersed phase e.g particle-reinforced composites, fiber-reinforced composites and structural composites. The properties of composites are improved versions of properties of matrix materials due to presence of dispersed phase. 1. Particle-reinforced composites are widely available and cheap. There are two types: dispersion-strengthened and particulate-reinforced composites. In dispersion-strengthened composites, particles are about $0.01-0.1\mu\text{m}$ in size.

Here the strengthening occurs at atomic / molecular level i.e. mechanism of strengthening is similar to that for precipitation hardening in metals where matrix bears the major portion of an applied load, while dispersed particles hinder/impede the motion of dislocations. Examples: thoria (ThO_2) dispersed Ni-alloys (TD Ni-alloys) with high-temperature strength; SAP (sintered aluminium powder) – where Al matrix is dispersed with extremely small flakes of alumina (Al_2O_3).

2. Particulate reinforced composite contain large amounts of coarse particles. They are designed to produce unusual combinations of properties rather than to improve the strength. Mechanical properties, such as elastic modulus, of particulate composites achievable are in the range defined by rule of mixtures as follows:

$$E_C (U) = E_m V_m + E_p V_p$$

$E_C (I) = E_m E_p / E_p V_m + E_m V_p$, Where E and V are elastic modulus and volume fractions respectively; c, m & p represent composite, matrix and particulate phases. Particulate composites are used with all material types – metals, polymers and ceramics. Cermets contain hard ceramic particles dispersed in a metallic matrix. Eg.: tungsten carbide (WC) or titanium carbide (TiC) used to make cutting tools. Polymers are frequently reinforced with various particulate materials such as carbon black. When added to rubber enhances toughness and abrasion resistance of the rubber. Aluminium alloy castings containing dispersed SiC particles are widely used for automotive applications including pistons and brake applications.

Concrete is the most commonly used particulate composite. It consists of cement as binding medium and finely dispersed particulates of gravel in addition to fine aggregate (sand) and water. Its strength can be increased by additional reinforcement such as steel rods/mesh. The old rule of thumb for mixing concrete is 1 cement: 2 sand : 3 gravel by volume. Water is critical, therefore mix the components thoroughly before adding water. Usual water is about 0.4 to 0.5 of cement. Too little water results in a concrete that is unworkable. Too much water results in weak concrete. Water may separate out (bleed) from the mixture.

Fiber-reinforced composites provide improved strength and other mechanical properties and strength-to-weight ratio by incorporating strong, stiff but brittle fibers into a softer, more ductile matrix. The matrix material acts as a medium to transfer the load to the fibers, which carry most of the applied load. The matrix also provides protection to fibers from external loads and atmosphere. These composites are classified as either continuous or discontinuous.

Generally, the highest strength and stiffness are obtained with continuous reinforcement. Discontinuous fibers are used only when manufacturing economics dictate the use of a process where the fibers must be in this form. The mechanical properties of fiber-reinforced composites depend not only on the properties of the fiber but also on the degree to which an applied load is transmitted to the fibers by the matrix phase.

Their mechanical properties depend on :properties of the fiber, the degree to which an applied load is transmitted to the fibers by the matrix phase, length of fibers, their orientation and volume fraction as well as the direction of external load. Effect of fiber length: Define critical length (l_c), necessary for effective strengthening and stiffening of the composite material, as: $\sigma^* f d / 2\tau_c$ where, $\sigma^* f$ is ultimate/tensile strength of the fiber, d – diameter of the fiber, – τ_c interface bond strength. Fibers for which $l \gg l_c$ (normally $l > 15l_c$) are termed as continuous, discontinuous or short fibers on the other hand.

Effect of fiber orientation and concentration: with respect to orientation, two extreme possibilities are : parallel alignment and random alignment. Continuous fibers are normally aligned, whereas discontinuous fibers are randomly or partially oriented. Two instants of loading are: longitudinal loading and transverse loading. (a) Continuous fiber composites: Under longitudinal loading, by assuming that deformation of both matrix and fiber is the same i.e. isostrain condition, rule-of-mixtures results in the following: $\sigma_c = \sigma_m A_m/A_c + \sigma_f A_f/A_c$, where, A_m/A_c and A_f/A_c are the area fractions of the matrix and fiber phases respectively. In the composite, if matrix and fiber are all of equal length, area fractions will be equal to volume fractions.

In case of transverse loading, it is assumed that both matrix and fiber will experience the equal stress i.e. isostress condition. Longitudinal tensile strength: Here, matrix material is softer i.e. fibers strain less and fail before the matrix. And once the fibers have fractured, majority of the load that was borne by fibers is now transferred to the matrix.

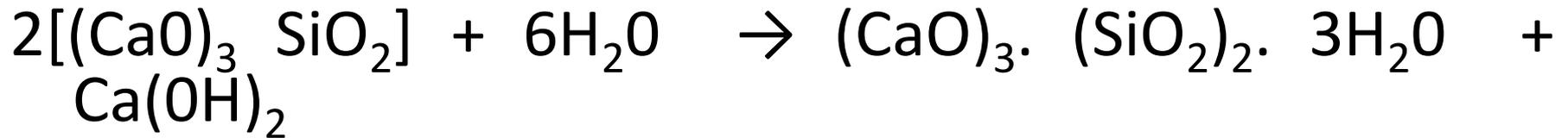
Structural composites: are special class of composites, and consists of both homogeneous and composite materials. Their properties depend on the properties of the constituents as well as the geometrical design of the various structural elements. There are two: laminar composites and sandwich structures. (a) Laminar composites are composed of two-dimensional sheets/layers that have a preferred strength direction.

These layers are stacked and cemented together according to the requirement. Materials used for fabrication are metal sheets, cotton, paper, woven glass fibers embedded in plastic matrix, etc. Examples: thin coatings, thicker protective coatings, claddings, bimetals, laminates. Many laminar composites are designed to increase corrosion resistance while retaining low cost, high strength or light weight. (b) Sandwich structures consist of thin layers of a facing material joined to a light weight filler material. Neither the filler material nor the facing material is strong or rigid, but the composite possesses both properties. Example: corrugated cardboard. The faces bear most of the in-plane loading and also any transverse bending stresses.

Typical face materials include Al-alloys, fiber-reinforced plastics, titanium, steel and plywood. The core serves two functions – it separates the faces and resists deformations perpendicular to the face plane and provides a degree of shear rigidity along planes that are perpendicular to the faces. Typical materials for core are: foamed polymers, synthetic rubbers, inorganic cements, balsa wood. Sandwich structures are found in many applications like roofs, floors, walls of buildings, and in aircraft for wings, fuselage and tail plane skins.

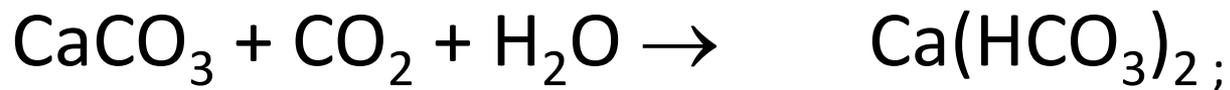
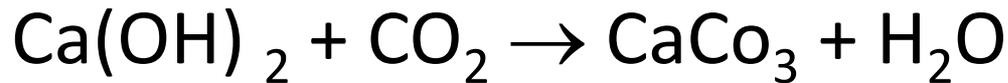
Degradation of concrete and rebar corrosion

One of the important hydration rxns of cement is:



The presence of Ca(OH)_2 is the weakness in cement and thus in concretes. The interactions of concrete with the environment are typified by: a.

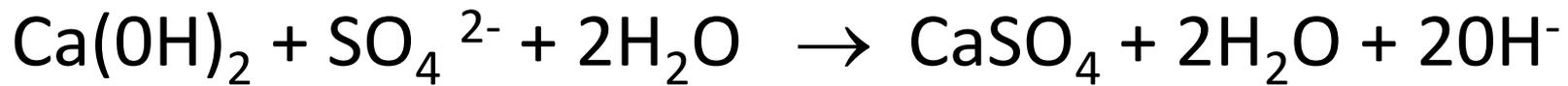
Carbonation



$\text{Ca(HCO}_3)_2$ is very soluble, thus it can be leached from the concrete causing a fall in pH from about 12 to 8. However, if the concrete is of good integrity, the carbonation reactions take place only on the surface.

b. SO₂ can react with Ca(OH)₂ directly.

$2\text{Ca(OH)}_2 + 2\text{SO}_2 \rightarrow \text{CaSO}_3 + \text{CaSO}_4 + \text{H}_2\text{O} + \text{H}_2$ Or SO₂ can react with atmospheric O₂ and H₂O to form H₂SO₄. The SO₄²⁻ then reacts with Ca(OH)₂ thus,



CaSO₄. 2H₂O can then react with tricalcium aluminate in the concrete to form “**ENTTERINGITE**” – calcium sulpho–aluminate hydrate. Its volume is 1.7 times the original volume of calciumaluminate. The formation of this bulky product leads to cracking and consequent erosion of the concrete. To solve the problem, sulphate resisting cement should be employed in making the concrete . Other contaminants like chlorides, oils and organic acids do cause deterioration of concretes based on similar reactions as above.

When prepared initially, concretes are alkaline, thus, the steel will not need protection. However, reinforcement steel corrosion still occurs in practice. This can be traced to factors, such as variation in porosity, permeability and cracks in the concrete. This state of affairs can lead to creation of micro and macro electrochemical cells depending on the distance between the anode and cathode on the steel surface. Other factors include air and water pollution, marine atmosphere, joints, depth of concrete cover, lack of supervision etc. during construction.



Renovation of Concretes: Concretes do flake and spall as a result of general weathering including corrosion caused by airborne pollutants. Prior to painting, cut away patches of weathered, open-textured and spalled concretes up to a predetermined depth, 100mm is usually adequate. Then apply cement grout as binder before filling with a modified repair mortar. After allowing for drying time, the faces of the wall should then be treated with fungicidal wash, followed by wire brushing. Then apply 3 – coats of a polyurethane based paint system. This will provide an effective and long lasting protection against the most extreme environmental conditions. . Recent developments in the coating world have made it possible for the use of water based paints of very high quality and they are also corrosion resistant.

Prevention of Reinforcement bar Corrosion

Use of paint: Prior to implanting the reinforcing steel, the steel bar should be coated with epoxy based coating. Epoxy resists alkaline attack. Also, the exterior of the concrete can be coated with high performance coating to exclude the environment from attacking the surface of the concrete. The use of textured coatings on concrete surfaces is highly recommended for rural and city environments. Textured paints are specially reinforced with silica. Silica is inert, and will not disintegrate on interacting with atmospheric pollutants. However, in heavily industrialized areas, the use of high performance coatings are favoured. Cathodic protection can be applied as well although current demand for the reinforcing bars are usually very high.

ANSWERS

1.c 2.a 3.a 4.b 5.a 6.a 7.c 8.b 9.d 10.a 11.d 12.a