



# **NATIONAL DIPLOMA IN QUANTITY SURVEYING**



## **BUILDING SCIENCE AND PROPERTIES OF MATERIALS**

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## WEEK 1

### TIMBER

Timber is valuable as a building material for number reasons. It is structurally useful because of its high strength in relation to its density. It is comparatively easy to work to a variety of shapes either by hand or by machine, is durable under appropriate conditions, and can give a good finished appearance at reasonable total cost. However, as it is a product of nature which comes to us in countless varieties of species and qualities, it must be properly processed and selected to suit the work in hand.

Timber is an organic material (i.e. of carbon compounds) produced in the growth processes of living tree. The main source of timber is used in the building industry is the trunk (main stem) of the tree. The girth (circumference) of the trunk increases as tree develops, and the tree is thought to have reached maturity it is felled and the raw timber is converted (cut to baulks and planks) and seasoned (partially dried) for use.

### GROWTH, COMPOSITION AND STRUCTURE

The growth and structure of timber is the most clearly illustrated by the three principal trunk Section (Fig 44) – the cross section (or transverses section), Radial section and tangential section. The annotations To (fig 44) will be now explained.

#### Growth

Growth takes place outwards from the centre of the trunk (except in bamboo and palm tree types, with which we are not concerned) and a new outer sheath of wood tissue is deposited during each growth period, or season. Each sheath, or layer, is termed a growth ring, and these concentric rings are in some cases clearly visible on inspection of the cross-section.

In temperate climate, as in the British Isles, growth takes places mainly in the spring and summer months, so that each growth ring normally represents one year's growth, and may then be referred to as an annual ring. In some tropical climates, however the growing season is almost continuous and it is possible to have more than one growth during a year. Trees of rapid growth will tend to have wide growth rings, whereas slow growth is associated with narrow growth rings.

Growth in summer is slower than it is in spring, and this result in the summer wood (also called late wood). Being stronger, and usually darker in spring wood (early wood). This variation in colour, or texture, is one means by which the growth rings are rendered distinguishable.

The pith, or heart centre, is a fibrous core of woody tissue forming the core of the trunk, which decays as the living tree gets older, and then has no practical value.

The sapwood is the more recently formed wood tissue comprising the outer growth rings. It contains a large amount of sap (aqueous solution) and nutriment (food) for the growing tissue, and furnishes timber which has a somewhat lower natural durability than heartwood.



## Wood

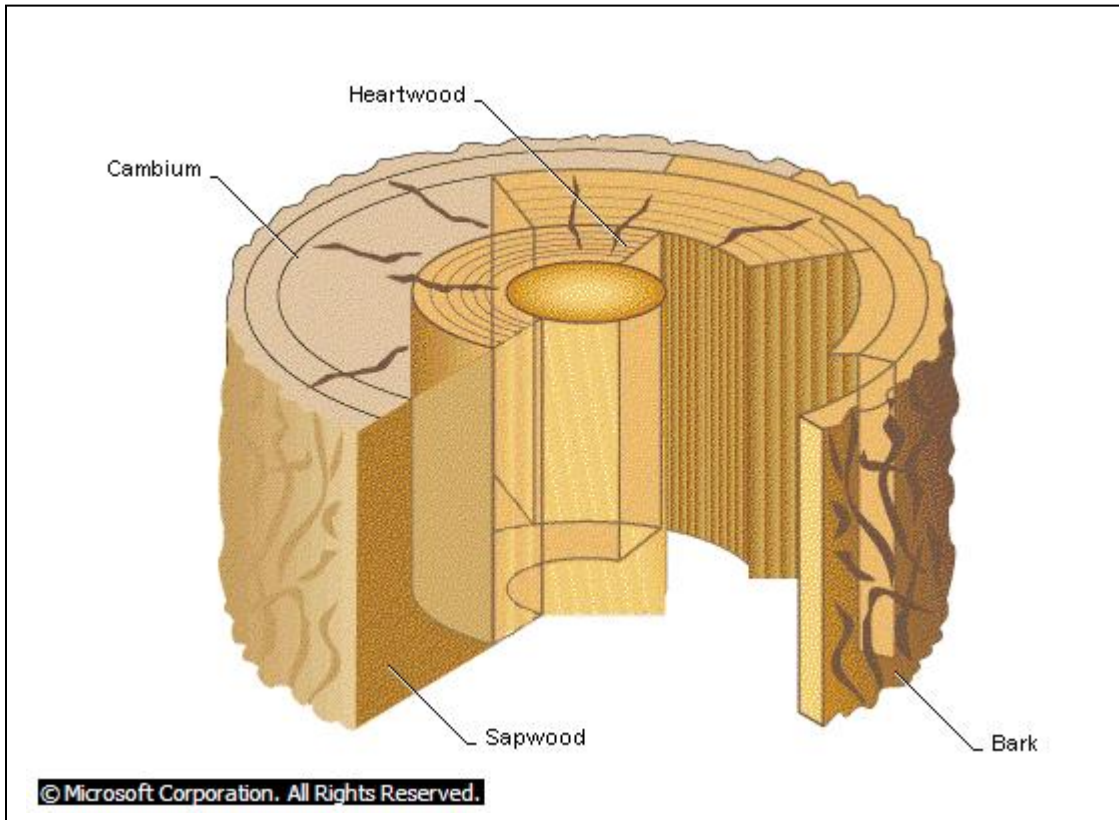
### I INTRODUCTION



Wood, hard, tough substance that forms the trunks of trees, and that has been used for thousands of years as a fuel and as a material of construction (*see* Building Construction). Technically, the term *wood* includes similar materials in other parts of the plant, including even the so-called veins in leaves, but only those portions of wood which have commercial importance are discussed in this article.

For the botanical aspects of wood, including its structure and growth, *see* Tree; Xylem. For growth and distribution, *see* Forest. For the cultivation of trees for wood, *see* Forestry. For the cutting of trees and the manufacture of lumber, *see* Lumber Industry.

## II GRAIN AND STRUCTURE



### Heartwood and Sapwood

This diagram shows the types of wood found in a typical tree trunk. The wood at the center of the trunk, the heartwood, is older, darker, and more durable than the younger wood surrounding it. As a tree grows, a thin layer of cells called the cambium generates new wood, called sapwood, just under the bark. Sapwood is softer and tends to be lighter in color than heartwood. As the sapwood ages, natural substances called extractives invade the sapwood and gradually convert it to heartwood.

The typical markings, called grain, that are found on all types of natural wood are due to the structure of the wood. Wood consists essentially of fine cellular ducts or tubes, which carry water and

dissolved minerals from the roots to the leaves, and which are thus arranged more or less vertically within the trunk. When the wood is cut parallel to the axis of the trunk, straight-grained lumber is usually produced. In some trees, however, the ducts are helical; that is, they twist around the trunk as they ascend. Such trees produce cross-grained lumber, which is also obtained from ordinary trees when the cut is not parallel to the axis of the trunk.

Many woods have prominent annual rings. The trunk of a tree does not grow in length, except at its tip, but does grow in width. The only portion of the trunk that is engaged in active growth is the cambium, a thin layer entirely surrounding the trunk. In trees of the Temperate Zone, the cambium lays down new wood during the spring and summer, and in most trees the early wood is more porous and therefore lighter in color than the wood produced later in the season. The trunk of a tree is thus surrounded each year by a new pair of concentric sheaths, one darker than the other.

Although the thin layer of cambium is the only part of the trunk that is alive in the sense that it is engaged in active growth, living cells are also interspersed among the xylem cells of the sapwood. As the tree grows older, however, the central portion of the trunk dies completely; the ducts become plugged with gums or resins, or merely air (*see Gum*). This central part of the trunk is called heartwood. The internal changes are accompanied by changes in color typical of the species of trees, so that the heartwood is usually darker than the sapwood.

### III CLASSIFICATION

Woods are classified as softwood or hardwood, depending on the tree from which they come. Woods from broad-leaved trees are called hardwoods, and woods from coniferous trees are called softwoods, regardless of their actual hardness. Thus many softwoods are actually harder than some of the so-called hardwoods. The hardwoods have long, continuous ducts leading through the trunk; the softwoods do not have such ducts, and the fluids are transported from cell to cell. Many softwoods have resin ducts running parallel to the grain, and softwoods in general contain considerable resin, whereas few hardwoods have any such material in the wood. Most lumber in the

U.S. is softwood; the hardwood is generally employed for furniture and high-grade flooring.

Knots are areas of the trunk in which the base of a branch has become embedded in the body of the wood. When the wood is sawed into planks, the knot becomes evident as a roughly circular discontinuity or irregularity in the grain structure. Where the branch begins within the tree, the rings of the knot are continuous with the grain of the wood, producing an intergrown knot; farther out toward the surface, the grain of the trunk has grown around the branch, producing an encased knot.

During seasoning (see below), when the shrinkage in a board varies with the direction of the grain, the knots shrink at a faster rate than the remainder of the wood. An encased knot may thus fall completely out of the plank, forming a knothole. An intergrown knot cannot fall out, but the wood around the knot is distorted by the uneven shrinking, and the board may be weakened even more than by the presence of a knothole. Knots are generally undesirable in lumber from the standpoint of appearance, apart from consideration of their effect on the strength of the wood. In some cases, however, knotty pine and similar types of lumber are desired for paneling interiors, because of the patterns in the grain formed by the knots.



#### Types of Wood

Wood types differ considerably in properties such as color, density, and hardness, making timber a resource that is valuable in a wide variety of contexts. Each of the samples of commonly used woods shown here has distinctive characteristics. Mahogany is a tropical tree prized for its heavy, strong, easily worked wood. Hickory is a tough, hard wood used for tool handles, furniture, and smoke wood for meat. Instrument makers favor the strong, richly colored wood of the cherry tree. Yew is strong, fine-grained wood used for cabinetmaking and archery bows. Like mahogany, the wood of the iroko is resistant to both rot and insects and bears the "interlocked" grain of many tropical trees. Oak is one of the world's most durable woods. It is used in barrel-making, veneers, and flooring. A rich color and swirling grain makes walnut a popular wood for cabinets and gunstocks. Larch is a tough, relatively cheap wood used in construction and frequently made into pulp for paper.

The wood's appearance is one of the most important properties when the wood is being considered for some interior use such as furniture or paneling. Certain woods, such as walnut, have straight, parallel graining, which, when combined with dark, attractive color and great hardness, makes them highly desirable for veneer (see also Plywood below). Irregularities of grain may make attractive patterns, or lumber may purposely be cut from a crotch to yield wavy, interlocking patterns. Many veneers are made by peeling a thin layer circumferentially from around the trunk, so that the knife cuts across the annual ring marks only at considerable distances, producing the large, irregular patterns typical of many plywoods.

#### IV PHYSICAL PROPERTIES

The principal physical properties of wood are strength, hardness, stiffness, and density. Density is generally an indication of the mechanical properties, inasmuch as dense woods are usually hard and strong (*see* Ironwood). The term strength covers a number of essentially different properties; a wood that is high in one kind of strength is not necessarily high in others. Moreover, the strength varies greatly with the state of seasoning, or dryness, of the wood, and with the direction of the grain; wood is always much stronger when cut along the grain rather than across it, and for this reason planks and such articles as poles and handles are always cut with the grain running the long way. Wood has high compression strength, in some cases higher in proportion to its weight than steel; it has low tensile strength and moderate shear strength. *See* Materials Science and Technology: *Mechanical Properties of Materials*.

High compression strength is required for foundations, and for the main supports of buildings. Bending strength is essential for most structural wooden members, including joists, studding, and beams of all sorts. Many woods that are commonly used for high bending strength have high compression strength, and vice versa; but oak, for example, is very strong in bending and comparatively weak in compression, whereas redwood is strong in compression and comparatively weak in bending.

Toughness is a measure of strength against sudden and repeated stress. Hickory and ash are outstanding for their toughness and are used in wagon spokes, baseball bats, and ax handles; because hickory is stiffer than ash, it is preferred for thin handles, such as those of golf clubs.

Other less important mechanical properties may be critical for a particular use; for example, the elasticity and resonance of spruce render it the only material suitable for the sounding board of a fine piano.



## V DURABILITY

Wood is naturally a very durable substance. If not attacked by living organisms, it will last for hundreds or even thousands of years. Samples of wood used by the ancient Romans have been found virtually in their original condition when a combination of circumstances protected them against attack. The most important of the organisms attacking wood are the fungi that cause so-called dry rot, which actually occurs only when the wood is damp. The sapwood of all trees is susceptible to this type of decay, but the heartwood of a few species is naturally resistant to these fungi. Walnut, redwood, cedar, mahogany, and teak are among the well-known woods that are extremely durable. Other woods are resistant to various types of attack. Greenheart and teak are particularly resistant to the attack of marine borers, and so are often used for underwater construction for wharves. A number of woods are comparatively resistant to termites, including redwood, black walnut, mahogany, and several types of cedar (*see* Termite). In most of these cases, the woods are aromatic, and the resistance is probably due to the resins and similar chemicals they contain.

Wood may be preserved by protecting it chemically against deterioration. The most important method of treatment has long been impregnation with creosote or zinc chloride. This method is still one of the best, although a number of newer chemicals, notably several containing copper compounds, have been introduced for the same purpose. Wood can be protected against weathering by suitable surface coatings, applied by brushing, spraying, or dipping. Surface applications yield little penetration, however, and therefore do not prevent deterioration under attack by insects, fungi, or borers.

## VI SEASONING

Freshly cut wood contains considerable water, which amounts to from one-third to more than one-half of the total weight. The drying of wood before it is processed into lumber is called seasoning, and is done for a number of reasons. Seasoned wood is far more resistant to decay than fresh wood; it is much lighter and therefore less expensive to ship; it has much higher heating value, which is important if it is to be used as fuel; and, most important, wood changes in shape during drying, and this change in shape should be completed before the wood is sawed.

Wood may be seasoned either by air-drying or kiln-drying. Air-drying takes several months, whereas kiln-drying takes a few days. In both cases, the wood must be carefully stacked to prevent warping, and the rate of drying must be carefully controlled.

## VII PLYWOOD

Plywood consists of several layers, or plies, of wood thoroughly bonded to one another by glue or synthetic resins (*see* Adhesive). The layers are laid with the grain in different directions, generally perpendicular to one another, so that the resultant sheet of plywood is equally strong in all directions. The bonded joint is at least as strong as the wood itself, and moisture-resistant glues can be used if necessary, so that plywood is as durable as the wood of which it is made. So-called laminated wood is a similar product, made by bonding layers of wood with the grain all running in one direction. This procedure results in a product that, like ordinary lumber, is extremely strong in the direction of the grain and weak in other directions.

Only the layers on the outside of the plywood need have hardness and good appearance; the inner layers need only be strong. In some cases, only one side of the plywood is a high-grade layer; such plywoods are used, for example, in making cabinets of which the inside will not be visible. Fine and expensive woods, such as mahogany, satinwood, ebony, and zebrawood, are now commonly used in the form of plywood, with a thin layer of expensive wood covering several layers of strong but inexpensive ordinary wood such as Douglas fir. In this way, the expense of the wood is greatly reduced, the appearance is in no way changed, and the strength and resistance to warping is greatly increased. Plywoods made of less expensive wood have been used to substitute for metals.

## VIII CHEMICAL WOOD PRODUCTS

Wood is an important raw material in the chemical industry. Each year an enormous quantity of wood is reduced to pulp and reconstituted mechanically to form paper. Some modern industries are based on extracting from wood its minor chemical constituents, such as tannins, pigments (*see* Paint and Varnish), gums, resins, and oils, and further modifying these constituents.



In addition to water, the principal constituent of wood is cellulose. Much of the large quantity of cellulose used today in making rayon and nitrocellulose is obtained from such comparatively pure sources as cotton, but an increasing quantity is being obtained from wood. The chief difficulty in using cellulose from wood lies in separating it from its impurities, the most important of which is lignin, a carbohydrate. Formerly, the lignin was discarded, but it was found to be a raw material for the manufacture of plastics and a suitable medium for the cultivation of yeast, which is an important livestock and poultry feed.

Wood may be used as a chemical raw material, without separating the cellulose from the lignin, by several different processes. In the Bergius process, wood is treated with hydrochloric acid in order to produce sugars, which are either used as cattle feed or fermented to produce alcohol. Wood may be converted into liquid fuels by hydrogenation. Wood has long been used also as a source of chemicals by destructive distillation. Most of these chemicals, however, including acetic acid, methyl alcohol, and acetone, are now made synthetically.

Certain new products consist essentially of a mixture of wood with certain chemicals; such a mixture will have mechanical properties similar to those of wood, but will be stronger and more resistant chemically. The most important methods of making these mixtures consist of impregnating the wood with certain chemicals, such as a mixture of phenol and formaldehyde, and then heating the impregnated wood so that the chemicals react within the cells of the wood to form a plastic. Wood treated with such resins is known as impreg. It has great resistance to decay and to insect and borer attack; its specific gravity is increased, but its strength is increased only slightly, if at all. A different product, called compreg, is made by compressing the impregnated wood in a hydraulic press at pressures of about 70 kg/sq cm (about 1000 lb/sq in) while the chemical reaction which forms the plastic is progressing. Such compressed impregnated wood may have a specific gravity up to about 1.35. The hardness is many times as great as that of the original wood, and the strength is somewhat greater, although the toughness may be less.

The heartwood is the inner part of the trunk, which provides the main strength to support the living tree, and which is substantially free from both sap and nutriment. Heartwood is often darker in colour than the surrounding sapwood, due to chemical changes in certain substances (e.g. starch) present

in the wood. In the growing tree, heartwood has ceased to contain living cells.

The cambium is an extremely thin, glutinous layer which forms a film at the outer surface of the sapwood, beneath the bark. It is the cambium which produces the wood tissue of the new growth ring, in addition to the much smaller proportion of bark. Required.

The bark is a protective outer layer of the woody fiber, which periodically scales off as the trunk increases in girth, being renewed from its inside surface by the cambium.

## Wood composition

Wood tissue is composed of various types of cell, the units of which living matter is composed. These cells have various shapes, but all consist of a wall enclosing a cavity. In the living cell of the cambium are filled with a watery liquid matter. The living called protoplasm. Cells produced by the cambium undergo a process known as lignifications to form wood, in which the cell walls thicken.

These are essentially three functions to be performed by the various types of wood cell. These are to conduct the sap, to provide storage space for food, and to provide the mechanical strength necessary for the support of the tree. To produce the substance of which the cell and foodstuffs are composed, the tree must first of all manufacture its own organic matter, the stuff of which all living tissues is made, and it achieves this by rather fascinating means in the spring, sap, which is water containing various mineral salt in solution, is taken up from the soil from the roots of the tree and passes up through the sapwood into the leaves, where it is converted into carbohydrates, organic compounds of carbon, hydrogen and oxygen which are the tree's raw materials for foodstuffs, by a process, carbon dioxide is absorbed from the atmosphere and undergoes chemical action with the sap, using the sun's light as energy and the green colouring matter of the leaves (chlorophyll) as a catalyst (activator). Food material in solution then passes from the leaves back down the trunk through an inner layer of bark (the bast) next to the cambium. Part of the food material will be consumed in the form of sugars, some being converted to cellulose-the important structure component of wood tissue, and part will be held in reserve as starch, for conversion to sugars when required.

## Week 3

### Chemical nature of wood

The cell walls of wood are composed of cellulose, which, like starch and sugars, is a carbohydrate, and a substance called lignin (the non-carbohydrate constituent). The lignin acts as cement, binding together the cellulose material in the cell walls to give the wood its strength and rigidity.

### Softwoods and hardwoods

These are the two broad classes, into which timbers are divided commercially, according to whether they are from conifers (pine trees or firs), or from broadleaf trees. A botanist would call these 'gymnosperms' and 'angiosperms' respectively.

The conifers furnish softwood timbers which have needle-like leaves and are cone-bearing. The cones are exposed seeds. Hardwoods are furnished by broadleaved trees which have covered seeds.

Their name is descriptive, and distinguishes them from the conifers as previously defined. The two terms can be misleading, since although most hardwoods are in fact mechanically harder than most softwood; this is not invariably the case. For example, pitch pine, although classified as softwood, is mechanically harder than some hardwoods, whereas balsa and willow are notable examples of very soft hardwoods. Another distinction is that the hardwoods are mainly deciduous (lose their leaves in winter) whereas softwoods are mainly evergreens.

Apart from the differences mentioned in defining softwoods and hardwoods, there are important differences in the cellular structure of the groups.

### Softwoods structure

The softwoods have the more primitive structure,  
With only two types of cell, tracheids and parenchyma  
Cells, enlarged sections of these are shown at figs 45  
And 46. The tracheids are pod-like, from the bulk of  
The timber, and are longitudinally arranged in the trunk  
And radially distributed about the pith. They have the dual  
Role of conducting the sap and providing the tree's mechanical  
Strength, for which purpose the cells develop thicker walls.  
Parenchyma cells provide storage space for foodstuffs. They  
Are brick-shaped and butt against one another to form chains,  
Which are mainly horizontal and lie radially about the pith and  
Are therefore called rays. However, they may also be in vertical  
Chains, known as wood, or strand, parenchyma, tracheids some

Time occur lying horizontally, association with rays, and are  
Then called ray tracheids.

Fig 45 A trachied (section)

Conduction between the different cells takes place  
Through pits, which are areas of the cell walls which,  
Because they have not undergone thickening  
During the process of lignification, are permeable  
To fluids. The two basic forms of pitting are the  
Simple pit and the bordered pit. Fig 47 shows these  
As a section through the cell wall. They are seen in  
Elevation at smaller scale in Figs 45 and 46.

Fig46 A parenchyma cell (section)

The simple pit has difference shapes according to the species of timber in which it occurs and it is these features which allow the positive identification of a particular species under microscopic examination. Bordered pits, which occur only in tracheids, can act as a valve controlling the flow of sap or foodstuffs by movement of the disc-shaped thickened central region (the torus) in response to pressure.

### Hardwood structure

There are four types of cell in hardwoods and they  
Include fibers and vessels, in addition to parenchyma  
And tracheids.

The fibres, which are needle-like in form (Fig 48) make  
Up the bulk of the timber, and act as mechanical tissue.

The vessels are cylindrical tubes (Fig 49) forming continous  
vertical chains in the trunk to provide for sap conduction.

The circular or oval section of a vessel as seen at a  
Cross-section is termed a pore.

The parenchyma cells are of the same type as those in  
Softwoods, with the same function of providing food storage.

Tracheids are only occasionally present in hardwoods  
And are distinguished by their bordered pits.

Fig 49 a vessels

### Identification

Since the structure and composition of a particular timber will determine its properties and uses, identification of species can be important. A part from the commercial classification into softwoods and hardwoods, there is a botanical name of classification, in which each timber, or rather the tree from which it comes, belongs to a family, and within each family to genus. Finally, each genus may give rise to a number of different species, which may be given a common, or local, commercial name.

For example, within the pine family (pinaceae), there are a number of different genera (plural of genus), including each *pinus* (the 'true' pines) and *picea* (the spruces). Within each genus are number of different species, such as *pinus sylvestris* (Scot pine), *pinus strobus* (Canadian yellow pine) and *pinus palustris* (American long-leaf pitch pine). Similarly, there are *picea abies* (European spruce or whitewood), *picea glauca* (Canadian spruce) and *picea sitchensis* (Sitka spruce).

To take a further example, this time from hardwoods, in the beach family (fagaceae), are found the genera *fagus* (the 'true' beeches), *Quercus* (the oaks) and *Castanea* (the chestnuts), as well as the genus *Nothofagus*. Again, there are different species, e.g. *fagus sylvatica* (European beech), *fagus grandifolia* (North American beech), *Quercus* (the oaks) and *robur* (a European oak), *Quercus rubra* (American red oak) and *Quercus cerris* (Turkey oak), *Castanea sativa* (European chestnuts) and *Castanea dentata* (American chestnuts). Examples of species belonging to *Nothofagus* genera are *Nothofagus dombeyi* (coigue beech) and *Nothofagus procera* (rauli).

The botanical method of classification is useful because it is used throughout the world, and is a practical value in that timbers within the same family will have a certain common features, and those within the same genera may have or even very similar properties, and therefore, similar uses.

Timber species may sometimes be identified by their general features; for example, by colour, density, smell, the appearance of their growth rings or rays when visible, or the shape and distribution of their pores, if present. However, more detailed examination is often needed, such as by magnification under a hand lens or microscope.

The hand lens is most useful for examining hardwoods, and one giving a magnification of ten (x10) is often used. In the case of softwoods, there is usually little to be gained by hands lens examination beyond what is already visible to the naked eye, and are invaluable.

## EXPERIMENT 28 (Fig 50) Examination of hardwoods and softwoods by hand lens

Apparatus Hand lens (x10)

Week 4

## PRACTICAL



Fig 50 Timber examination by hand lens (Experiment 28)

Specimens Hardwood and softwood samples, size approximately 100 x 50 x 10mm with 50 x 10mm edge showing a cross-section (fig 50)

Preparation cut a small area of end grain of each specimen cleanly by paring it with a very sharp cutting edge such as a chisel or wedge-shaped cutter

### Method

1. Hold the lens near one eye and bring the cut end of the specimen towards it until clear focus is obtained. It should not be necessary to close the other eye
2. Examine the section, observing the main features (see note below), and sketch, in pencil, what you see. Do not attempt to reproduce exact detail; a likeness is all you need. This is shown in Fig 51, where typical distinguishing features are illustrated
3. Repeat the procedure (Section 1 and 2) for the remaining specimens

Note A cross-section should always be held and drawn with the growth rings horizontal, when it is being examined and sketched. The rays should be vertical with the top and bottom edges of the

Fig 51 Typical cross-section Illustrated

Section facing the outer and inner parts of the trunk respectively, as shown in fig 52.

Whereas the rays, or other features, may, in fact, be lighter in colour than the surrounding areas, in a line drawing they are usually shown as dark lines

Results: Recognising and interpreting the main features of a specimen requires some practice and experience, and a summary of the main diagnostic features to look for, some only visible under a microscope, follows



## CEMENT

### I INTRODUCTION

Cement, any material that hardens and becomes strongly adhesive after application in plastic form. The term *cement* is often used interchangeably with *glue* and *adhesive* (*see* Adhesive); in engineering and building construction the term usually refers to a finely powdered, manufactured substance consisting of gypsum plaster or portland cement that hardens and adheres after being mixed with water.

Cements are used for various purposes, such as binding sand and gravel together with portland cement to form concrete, for uniting the surfaces of various materials, or for coating surfaces to protect them from chemical attack. Cements are made in a wide variety of compositions for a wide variety of uses. They may be named for the principal constituents, such as calcareous cement, which contains silica, and epoxy cement, which contains epoxy resins (*see* Resins); for the materials they join, such as glass or vinyl cement; for the object to which they are applied, such as boiler cement, or for their characteristic property, such as hydraulic cement, which hardens underwater, or acid-resisting cement, or quick-setting cement.

Cements used in construction are sometimes named for their commonly reported place of origin, like Roman cement, or for their resemblance to other materials, such as portland cement, which produces a concrete resembling the Portland stone used for building in England. Cements that resist high temperatures are called refractory cements.

Cements set, or harden, by the evaporation of the plasticizing liquid such as water, alcohol, or oil, by internal chemical change, by hydration, or by the growth of interlacing sets of crystals. Other cements harden as they react with the oxygen or carbon dioxide in the atmosphere.

## II PORTLAND CEMENT

Typical portland cements are mixtures of tricalcium silicate ( $3\text{CaO} \cdot \text{SiO}_2$ ), tricalcium aluminate ( $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ ), and dicalcium silicate ( $2\text{CaO} \cdot \text{SiO}_2$ ), in varying proportions, together with small amounts of magnesium and iron compounds. Gypsum is often added to slow the hardening process.

These active compounds in cement are unstable, and when water is added they rearrange their structure. The initial hardening of the cement is caused by the hydration of tricalcium silicate, which forms jellylike hydrated silica and calcium hydroxide. These substances ultimately crystallize and bind together the particles of sand or stone, which are always included in a mortar or concrete mixture, into a hard mass. Tricalcium aluminate acts in the same way to produce the initial set, but does not contribute to the ultimate hardening of the mixture. The hydration of dicalcium silicate proceeds similarly but far more slowly, hardening gradually over a period of years. The process of hydration and setting of a cement mixture is known as curing; during this period heat is evolved.

Portland cement is manufactured from lime-bearing materials, usually limestone, together with clays, shales, or blast-furnace slag containing alumina and silica, in the approximate proportions of 60 percent lime, 19 percent silica, and 8 percent alumina, 5 percent iron, 5 percent magnesia, and 3 percent sulfur trioxide. Some rocks, called cement rocks, are naturally composed of these elements in approximately suitable proportions and can be made into cement without the use of large quantities of other raw materials. In general, however, cement plants rely on mixed materials.

In the manufacture of cement the raw materials are ground together, the mixture is heated until it fuses into a clinker, and the clinker is ground into a fine powder. The heating is usually accomplished in rotary kilns more than 150 m (500 ft) long and 3.7 m (12 ft) or more in diameter. The kilns are slightly tilted from the horizontal, and the raw material is introduced at the upper end, either in the form of a dry rock powder or as a wet paste composed of ground-up rock and water. As the charge progresses down through the kiln, it is dried and heated by the hot gases from a flame at the lower end. As it comes nearer the flame, carbon dioxide is driven off, and in the area of the flame itself the charge is fused at temperatures between  $1540^\circ$  and  $1600^\circ\text{C}$  ( $2800^\circ$  and  $2900^\circ\text{F}$ ). The material takes approximately 6 hours to

pass from one end of the kiln to the other. After it leaves the kiln, the clinker is cooled quickly and ground, and then conveyed by a blower to packing machinery or storage silos. The amount thus produced is so fine in texture that 90 percent or more of its particles will pass through a sieve with 6200 openings per sq cm (40,000 per sq in).

In a modern kiln, 45 kg (about 100 lb) of raw material will make 27 to 30 kg (about 59 to 66 lb) of cement. The weight lost is largely carbon dioxide and water. Kilns usually burn coal in the form of powder and consume about 450 g (about 1 lb) of coal for about every 900 g (about 2 lb) of cement produced. Oil and gas are also used.

A number of tests are used to check the quality of the cement. A common one is to use a mortar specimen of one part cement and three parts of sand and measure its tensile strength after a week in air and underwater. A good cement will show a tensile strength of 19.4 kg per sq cm (275 lb per sq in) under these conditions.

### III SPECIAL CEMENTS

By varying the percentage of its normal components or adding others, portland cement can be given various desirable characteristics, such as rapid hardening, low heat during hydration, and resistance to alkalis. Rapid-hardening cements, sometimes called high-early-strength cements, are made by increasing the proportion of tricalcium silicate or by finer grinding, so that up to 99.5 percent will pass through a screen with 16,370 openings per sq cm (105,625 per sq in). Some of these cements will harden as much in a day as ordinary cement does in a month. They produce much heat during hydration, however, which makes them unsuitable for large structures where such heat may cause cracks. Special low-heat cements, which usually have a large proportion of dicalcium silicate, are generally used for massive pourings. Where concrete work must be exposed to alkaline conditions, which attack concretes made with ordinary portland cement, resistant cements with a low aluminum content are generally employed. Cements for use under salt water may contain as much as 5 percent iron oxide, and those with as much as 40 percent aluminum oxide are used to resist the action of sulfate-bearing waters.

## IV PRODUCTION

It was not until the 20th century that the United States produced portland cement in any great quantity. In 1910, 13 million metric tons were manufactured. After 1910 production rose steadily until 1928, when 30 million metric tons were made. Production dropped sharply in the early 1930s, then began to rise again. In the late 1980s the U.S. cement industry annually produced about 70 million metric tons, or about 6.6 percent of the world total.

## V HISTORY

Although various types of mineral-based hydraulic cement are of ancient origin, hydraulic cements have been used only since the middle of the 18th century. The term *portland cement* was first used in 1824 by Joseph Aspdin, a British cement maker, because of the resemblance between concrete made from his cement and Portland stone, which was much used in building in England. The first modern portland cement, made from lime and clay or shale materials heated until they formed cinders (or clinkers) and then ground, was produced in England in 1845. At that time cements were usually made in upright kilns where the raw materials were spread between layers of coke, which was then burned. The first rotary kilns were introduced about 1880. Portland cement is now almost universally used for structural concrete.



### Driving Concrete Pilings

Portland cement, mixed with water and sand or gravel, forms concrete, a common building material. Here, a pile driver pushes concrete pilings into the earth to help support an office building in Boston.

By far the commonest type of cement used in the building industry in the Great Britain is the cement known as ordinary Portland, which got its name originally because of its resemblance, when set to the natural Portland limestone from Dorset. The principal raw materials for making this cement are chalk (or limestone) and clay, both deposits in Great Britain.

The essential property of Portland cement is that it hardens by a chemical action when mixed with water. This process is known as hydration. A paste of cement and water first undergoes gradual stiffening called setting, but the hydration continues long after the paste has become rigid, resulting in a progressive increase in strength, called hardening.

In addition to ordinary Portland cement there are other types. Some are made from the same raw materials but manufactured to give slightly different properties, such as different rate setting or hardening, or great resistance to chemical attack. This modified forms of cement, and ordinary Portland, together make up the Portland group of cements. There are also numbers of special cements, including blends of Portland with other cementitious materials, as well as cement made from different raw materials. We shall first consider the Portland cements.

## Manufacture

There are two methods of manufacture in use for Portland cements, the wet process and the dry process. The wet process was developed for the softer clays and the dry process was developed for harder clay and shales.

For the wet process the materials are chalk and clay, the proportions being roughly three parts of chalk (or limestone) to one part of clay; water is added and the substance is then reduced to slurry. First by crushing then by grinding in wash mills. The slurry then passes to storage tanks, where it's kept agitated to prevent settlement from there the slurry is pumped to the inlet end of a rotary kiln, which is large steel cylinder, lined with refractory blocks. The kiln revolves slowly on an axis slightly inclined to the horizontal, causing the contents to gravitate towards the lower end. The complete process takes several hours. Pulverised coal (or oil fuel) is blown in at lower end of the kiln and burns continuously, causing the materials in the slurry to combine chemically. For this to occur a temperature of about 1250 degrees centigrade must be reached at the hottest part of the kiln (near its lower end). During the kilning the slurry first loses its free content, then becomes dehydrated. The calcium carbonate decomposes calcium oxide (quicklime), and finally there is chemical combination between the quicklime and compounds in the clay to form cement. The cement leaves the kiln in the form of small nodules, cement clinker. The clinker is cooled by being passed through a ventilated rotating cylinder, similar to the kiln itself but of shorter length and is finally ground in a tube mill to form the familiar grey powder, ordinary Portland cement. During the final grinding process a small quantity of gypsum (2-5%) is added to prevent the cement from setting too quickly after water has been added.

In the process the materials are crushed, dried, then ground in a tube mill to form a powdered mixture which is then burnt from the dry state. This method uses less fuel than the wet process.

## Composition

Ordinary Portland cements are variable composition, but a typical chemical analysis would show roughly 60% of lime ( $\text{CaO}$ ), 20% of silica ( $\text{SiO}_2$ ), 10% alumina ( $\text{Al}_2\text{O}_3$ ), 3% oxides of iron and small amounts of other materials. These materials are present mainly in chemical combination, the most important compound being the silicates and aluminates of calcium. This is further illustrated in fig I.

ORDINARY PORTLAND CEMENT			
A- RAW MATERIALS			
ARGILLACEOUS CALCAREOUS (Clay, shales)	I PART	3 PARTS	
<div>Or MARL</div> <div>(Chalk, limestone)</div>			
Note: only gypsum and water may be added after burning			
B-CHIEF CHEMICAL CONSTITUENTS IN RAW MATERIALS			
LIME 65% High lime content increases setting time but gives high early strength. Excess if hard burnt causes unsoundness	SILICA 20% High silica content increases setting time and strength.	ALUMINA 5% High alumina content reduces setting time and increases strength.	IRON OXIDE 3% Imparts grey colour.
C- CHIEF COMPOUND IN FINISHED PRODUCT (POWDER)			
CALCIUM SILICATE 75% ALUMINATES 25%		CALCIUM	
Tricalcium silicate C3S Early strength high heat more in R H less in L H	Dicalcium silicate C2S Later strength Little heat	Tricalcium aluminate C3A Little strength Great heat Unstable, decomposing to lime in the presence of air or water. Attack by sulphates to form calcium sulpoaluminate. Less in S R and L H	Tetra-calcium alumina ferrite C4AF Little strength Little heat
D- COMPOUND IN SET CEMENT			
Their precise nature has not yet been confirmed. They are believed to consist of interlacing needles of the hydrated crystals of silicates and aluminates, together with hydrated forms of the iron compounds and free hydrated lime.			
Note: all proportions are variable and typical values only are given here			
H			
R H- Rapid Hardening Portland cement			
L H- Low Heat Portland cement			
S R- Sulphate Resisting Portland cement			

Fig I The chemistry of ordinary Portland cement



### Hydration

When Portland cement is mixed with water the two combine in the chemical process known as hydration, and a crystalline structure develops. It is the growth of the various compounds which causes the setting and hardening of the cement paste. Hydration is accompanied by the release of small amounts of uncombined calcium hydroxide –  $\text{Ca(OH)}_2$  – known as the free lime content of hardened cement. Provided that the necessary water is available, hydration, and therefore strength gain, continues indefinitely, although at a progressively reducing rate. This explains the need to keep concrete damp for a time after placing, a procedure known as curing, during hydration, heat is given off.

### Rapid-hardening Portland cement

If Portland cement is ground finer, than normal in the final manufacturing stage, the rate at which hydration will occur is speeded up, and the cement paste hardens more rapidly. This finer grinding is the principal feature of rapid-hardening Portland cement, which is the same as ordinary Portland, except for a very minor adjustment of its composition made after chemical analysis at the slurry stage if found necessary.

### TEST FOR ORDINARY AND RAPID-HARDENING CEMENTS

Full requirements and test for both these cements are given in British Standard 12 (usually written as 'BS 12') 'Portland cement (ordinary and rapid-hardening)'.

The test are for fineness and chemical composition of the cement powder, strength and soundness of hardened specimens, and setting time of cement paste. A summary of the testing methods follows, and current BS requirements are given in Table I, page 301.

### MODIFIED PORTLAND CEMENT

A number of different types of Portland cement with modified properties to suit particular circumstances are available. While these may have different rates of gain, it is useful to remember that they will all in time eventually reach about the same strength.

### Rapid –hardening cement

You have already seen that the main feature of the cement is its finer grinding than ordinary Portland, and its main use is in concrete work where greater early strengths are required than would be obtained with ordinary Portland.

### Extra rapid-hardening cement

The rate of hardening of this cement is increased even further by adding an accelerator to rapid hardening cement. The usual method is to add 2% of chloride to the cement during its final grinding in manufacture. Alternatively, the same effect is obtained by adding the calcium chloride to rapid-hardening cement at the time of mixing, preferably in solution and added to the mixing water, for good dispersion in the mix. This cement is used mainly for concreting work in winter conditions to counteract the reduced rate of hydration at low temperatures, the cement is also quick-setting, so the concrete normally be placed in its final position within 20 minutes of leaving the mixer.



An increase in the rate of setting and hardening of cement is accompanied by an increase in the rate at which the heat of hydration is given off in cold weather this lessens the likelihood of frost damage to new work. On the other hand, in mass concrete structures like dams, the heat of hydration is not easily lost and can cause over-heating internally, resulting in cracking and even disintegration. For such cases, a low-heat Portland cement can be used.

### **Low-heat Portland cement**

This cement is modified composition to give rate of heat evolution. BS 1370:1958 limits the heat of hydration of this cement to not more than 60 calories per gram at 7 days, nor more than 70 calories per gram at 28 days. A typical ordinary Portland cement evolves about 100 calories per gram in 28 days.

### **Sulphate resisting cement**

This is modified Portland cement with improved resistance to chemical attack by sulphates which are salt found in sea-water, certain ground water, and (as impurities) in some building materials. Sulphates in solution can cause softening, and considerable expansion of cement-based materials.

### **White cement**

This is made by using china clay (kaolin), which is pure clay, free of iron oxides. Iron oxides give ordinary Portland cement its grey colour.

### **Coloured cements**

These are made by blending inert pigment powders with white, or grey cement, depending on the colour required. The pigments may be added at the works, or alternatively, by the user.

### **Water-repellent cement**

This is produce by intergrinding the Portland cement clinker with a small proportion of a water-repellent, such as gypsum with tannic acid, or certain metallic soaps. These cement are used in water-repellent renderings and in base-coats where the background is of uneven suction (e.g. no-fines concrete), especially where a coloured finish coat is to be applied, in order to avoid patchiness, as well as in dense concrete.

### **Hydrophonic cement**

These are treated in manufacture so that the cement powder does not readily absorb moisture, and can be stored for considerable periods in damp or humid conditions without deteriorating.

## **CEMENT OTHER THAN PORTLAND**

These include Portland blast-furnace cement, masonry cement, Supersulphated cement, and high alumina cement.

### **Portland blast-furnace**

cement to BS 146 is an interground mixture of up to 65% of basic blast-furnace slag and ordinary Portland cement. It is low-heat cement, slower in its early hardening than ordinary Portland, but can in the long term be of equal or greater strength. Its high resistance to sulphates makes it popular for marine construction.

### **Masonry cement**

This is produce especially to give the high workability desirable in mortars for masonry, brickwork and rendering without the addition of lime or other plasticiser by the user. It consists usually of a blend of ordinary Portland cement and finely powdered chalk or silica, possibly with the addition of plasticising chemical.

### **Superulphated cement**

This is an interground mixture of 80 to 85% of basic blast-furnace slag and 10 to 15% of gypsum, with about 5% of Portland cement clinker as an activator. It is lo-heat cement and has a high resistance to sulphates, peaty soils and oils.

### **High-alumina cement (Aluminous cement)**

This cement is made by heating a mixture of bauxite (aluminum ore) and limestone. The mixture melts at about 1600 degrees centigrade and is cast into 'pigs', then ground to a powder.

This cement (to BS 915) has a high resistance to most chemicals (particularly sulphates), except alkalis. It very rapidly gains strength and reaches about 80% of its full strength in only 24 hours. Continuous wet curing is essential during this period owing to the great heat generated. It must always be remembered that concrete which is made with this cement will permanently lose up to 50% or more of its maximum strength if subjected, when moist, to temperatures above 30 degrees centigrade at any time during its life due to change occurring in the chemical nature of the bond, called reversion. This must be taken into account structurally. High-alumina cement should only be in thin section to prevent cracking from thermal expansion where the heat of hydration cannot easily disperse. The cement is widely used in refractory concrete, since it remains stable well above 1000 degrees centigrade, whereas Portland cement concrete are unlikely to withstand prolonged heating much above 500 degrees centigrade.



## AGGREGATES

An aggregate is a material in granular or particle form such as sand or gravel, which is added to the class of materials known as binders (e.g. cement, hydraulic limes, plasters and bitumen) to produce a solid mass on hardening. Since most aggregates are inert and undergo no chemical action with the binder, the strength of the combined mass depends on:

- a) The specific adhesion or bond which develops between aggregate and binder.
- b) The mechanical key or particles interlock which develops between the constituents particles in virtue of their shapes, size and surface texture.
- c) The strength of the aggregate and binder respectively.

Aggregate materials can be classified as fine or coarse, natural or artificial dense or light weight and so on, according to the requirements of the user.

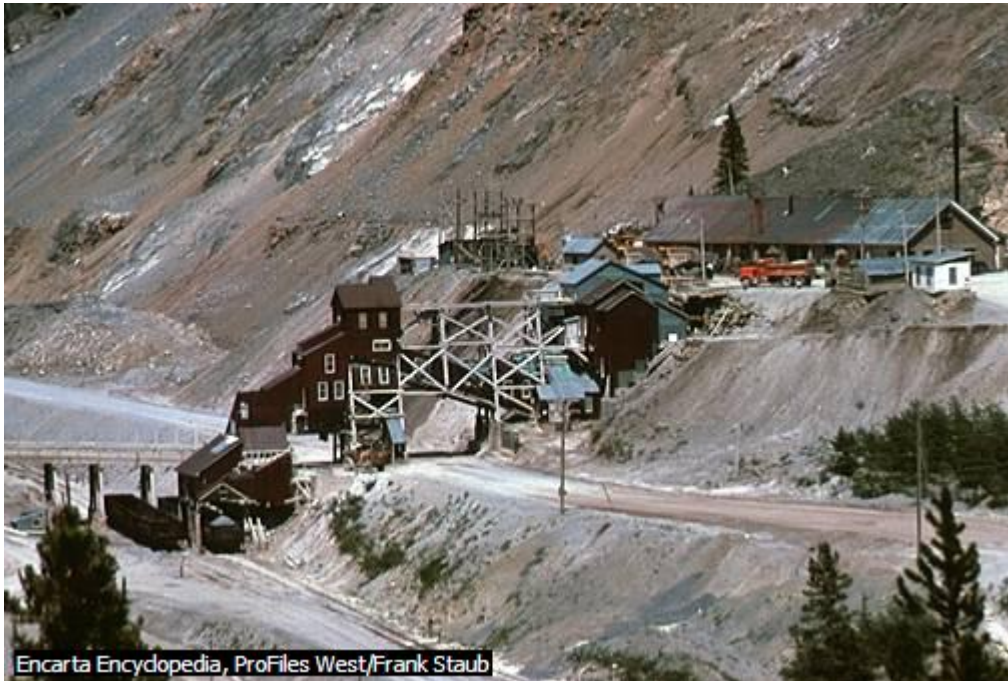
The description fine or coarse refers to the largest size of particle present in substantial amounts. For general building purposes, a fine aggregate is one mainly pass in 4.76mm square mesh sieve and a coarse aggregate is the one which will be mainly retained on that sieve. An aggregate which has substantial amounts of both fine and coarse particles is termed an all-in aggregate.

Aggregate from natural sources include crushed or uncrushed stone or gravel, and sand including crushed stone sand and crushed gravel sand. The crushing is done by machinery usually at the pit or quarry. Artificial aggregates include crushed bricks, blast-furnace slag and numerous light weight and special aggregate.

Fine aggregate are used, together with appropriate binder, to produce material for such purposes as rendering, plastering, floor topping, and road surfacing. In addition to this, aggregates are used with a cement binder as jointing materials for pipes, bedding for tiles, and mortar for brickwork and block work.

#### ACQUISITION:-

Quarrying; Excavation degrading, grading porosity, Absorption; All-in aggregate.



**Quarrying:** - The methods adopted in quarrying stone vary and depends upon the type and its depth below the surface. Most stones are obtained from open quarries, but where it is very deep underground mining is used.





Blasting is sometimes needed in sandstone quarries because of the hardness of the stone. Briefly, a series of deep holes (about 25mm in diameter) is formed by a drilling machine at the required distance from and parallel to the face of the quarry. A small charge of block powder and a fuse are placed in each hole and the hole is partially paused or tamped with sand; the fuses are connected to a battery and the charge fired; this explosion is sufficient to shake the mass of stone; the holes are now cleared of tamping and the second or main charge inserted and again fired simultaneously. This removes a large bulk of stone which is only slightly shattered because of the two blasts. There is little overburden in many of the sand stone quarries. Thus in the stone differ quarry it does not exceed 2m in depth; the depth of the present working face is 50m although some of the best stone is obtained at a depth of from 2 to 3m.

**Grading:** - In practice we are concerned not only with the maximum particle size of an aggregate, but with the amounts of the various sizes present. This is known as the grading of an aggregate found by shaking a sample through a series of sieves of different standard mesh sizes. The amount retained on each sieve is weighed and expressed as a percentage of the sample. Grading requirements depend on the proposed use of the aggregate and in this note they are referred to in the various sections which deal with the types of work concerned.

## **ABSORPTION AND SURFACE MOISTURE**

The following explanations of certain terms used should be clearly understood:-

1. Oven dry – completely dry for practical purpose
2. Air dry- dry at the surface though containing some interior moisture, but less than the amount required to saturate the particles.
3. Saturated and surface dry- This is an idealized condition, the aggregate absorbed no more water without a film of water forming on the surface.
4. Wet- The aggregate is itself saturated and carries an excess of moisture forming a film on the surface of the particles.

The absorption of an aggregate is often a useful guide to the permeability and frost resistance of concrete made with it.

**Marine dredged aggregate:-** materials is however usually quite clean apart from the presence of shells and salts, washing with frequently changed fresh water will reduce the salt content but the disposal of such water can present plant.

One method used for obtaining aggregates from the bed of the North-sea, 8km from the coast in depth up to 30m, by the use of steel suction tube about 600mm diameter. The steel tube is pivoted over the side of the ship until the lower end rest on the sea bed. The aggregate is then pump up the tube through a large impellent and into the open hold of the ship.

**Porosity: -** In hot desert countries, such as those in the Middle East, aggregate supplies are usually serious problem. Apart from the storage of good quality natural materials in most areas, many of the available sources are contaminated by the presence of deleterious salts. This applies to both sand, which is usually in abundant but with poor grading and particle shape, and to sources of limestone, which in addition may also be of friable and porous nature.

## Week 8



### Concrete Bridge

Modern bridge construction for the Gateway Bridge over the Brisbane River in Australia uses lightweight and durable concrete reinforced with steel bars or mesh. Concrete is made from three components: an aggregate material such as sand or gravel, water, and the binding agent, portland cement.

## CONCRETE

This is an artificial material similar in appearance and properties to some natural limestone rock. It is formed by binding together particles of natural or artificial stone, bricks or other aggregate with cement. One of the important properties of concrete is the case with which can be moulded to any shape before hardening occurs. Concrete made with normal density fine and coarse aggregates, cement and water. It is classified as dense concrete.

## DENSE CONCRETE

### WATER CONTENT AND VOIDS.

The presence of the coarse aggregate in concrete results in hardened materials which is far stronger than can be obtained using a mortar mix of the same cement content. This aspect is achieved indirectly because less water is needed to produce a workable mix when coarse aggregate is added.

The setting and hardening of concrete is due to the hydration of the cement binder. This is a crystallization process, and the aggregate can normally be considered as an inert constituents. The amount of water necessary for the complete hydration of 1kg ordinary Portland cement is roughly 0.25kg, but if these amount of cement and water are mixed together, the resulting cement paste is barely workable. Evidently, if any aggregate were added to this mix, additional water would be needed to make it workable. This extra water, above that needed for hydration, acts as an extender of the cement paste, allowing it to coat the surface of all particles of an aggregate and thereby to function as a lubricant providing the workability necessary for handling and placing the mix. Unfortunately the effect of this 'excess' water for workability is to form voids, or pores, in the hardened mortar or concrete as the materials dries out. These pores (water voids) cause a reduction in density, strength and durability of concrete. It follows that water content of mixes should normally be kept as low as possible, consistence of providing adequate workability to allow placing and full compaction. Compression entails the removal of air from concrete by vibration or punning (rodding), a particle made necessary because air-voids will equally reduce the strength of concrete. Remember, as a guide, that every 1% of avoids left in the concrete whether water voids or air voids results in a strength loss of about 5%. For example, 4% of voids would cause a strength loss of 20%. Another draw back to a high water content is that it leads to increased drying shrinkage.

## WATER: CEMENT RATIO

It is usual to express the amount of water in any mix as a ratio of the weight of cement present. If this rule is applied to the case where a cement paste with the minimum water was used to fully hydrate the cement, the equation will be:

$$\begin{aligned}\text{Water: cement ratio} &= \frac{\text{weight of water in mix}}{\text{Weight of cement in mix}} \\ &= \frac{0.25\text{kg/f}}{1\text{kgf}} = 0.25\end{aligned}$$



The range of water: cement ratio used in practice for ordinary dense concrete is between about 0.40 and 0.80.

Example: find the total water required in a concrete mix specified to contain 100kg of cement with water: cement ratio of 0.50

Re-arranging the water: cement ratio formula:

$$\begin{aligned}\text{Weight of water in mix} &= \text{water: cement ratio} \times \text{weight of cement} \\ &= 0.50 \times 100 \\ &= 50\text{kgf} \quad (0.50\text{L})\end{aligned}$$

An important relationship called the water: cement ratio 'law' is that the compressive strength of fully compacted concrete is generated by the water: cement ratio, irrespective of the mix proportions.

### **AGGREGATE: CEMENT RATIO**

Returning to our example of a mix containing 100kg of cement with water: cement ratio 0.50, consider the effect by adding different amounts of an aggregate say 100kg, 200kg, 300kg and so on. This would be referred to as using aggregate cement ratios of 1, 2, 3 respectively, remember that the water: cement ratio 'law' tells us that the strength of hardened concrete made using these mixed, when fully compacted, will be the same. Unfortunately, we cannot go on extending our cement paste indefinitely in this way, since the mix becomes less workable (drier) as more aggregate is added and eventually it could not be properly placed and compacted. In practice, the limiting factors are the methods of compaction available, the size and shape of section to be cast and the congestion of reinforcement. Remember that drier mixes can be compacted better mechanically than is possible manually and that small, intricate shapes require greater workability.

### **WORKABILITY AND STRENGTH**

Considering again our concrete with mix 100kg of cement with water: cement ratio of 0.50, suppose that we have decided that our aggregate: cement is to be 4 and we use 400kg of aggregate. This will fix the workability of the mix, but only relative to a particular aggregate, since the aggregate grading, particle shape and surface texture all influence the workability. The finer our aggregate the greater its specific surface (the total surface area of all its particles per unit weight), and consequently the further must our cement paste be spread, with corresponding reduction in its lubricating efficiency, that is less workability. This accounts for the use of proportion of coarse aggregate in dense concrete. The larger particles give better workability for a given water: cement ratio and aggregate: cement ratio; alternatively, they allow higher strength (by reduced water: cement ratio) for a fixed aggregate: cement ratio and a given workability.

## **WORKABILITY TESTS**

Workability refers to the ease with which concrete can be placed and compacted, and various tests are used to assess this.

### **SLUMP TEST**

The most commonly used site method of assessing workability is the slump test. The test entails filling an open-ended conical mould with concrete and measuring the slump or drop in level of the concrete when the mould is lifted clear. Since the workability of a given concrete increases with the amount of water added, the slump test also provides a means of controlling the water content of successive batches of the same mix, provided there is no substantial change in the aggregate grading. Remember that an increased water content causes a reduction in strength and durability. But that workability must be sufficient to allow full compaction.

## PAINTS

Paint is a liquid coating that is applied to the various surfaces and components. It dries as a film and gives protection and decoration.

### PURPOSE OF USING PAINTS

1. To protect the underlying surface by exclusion of the atmosphere, moisture, fungi and insects.
2. To provide a decorative easily maintained surface.
3. To provide light and heat-reflecting properties.
4. To give special effects, for example, inhibitive paints for protection of metals, electrically conducting paints as a source of heat condensation resisting paints.

### PAINTS APPLICATION IN STAGES OR SYSTEM.

There are usually three stages in a painting application; primer, undercoat and finishing.

#### PRIMING COAT

The first coat of paint applied to a raw surface. The priming coat is usually designed to seal the surface, to help prevent corrosion, and to be a suitable base for the next coat such as the undercoat.

#### UNDERCOAT

A coat of paint or varnish applied after preparation of the surface and before the final coat is used to build up the surface and give opacity together with a smooth surface which provides a good key for the finishing coat.

#### FINISHING COAT

Must be durable layer of the required colour or texture. Traditionally most finishing coats were gloss finish and these tend to have the best resistance to direct since they provide very smooth surface.

### THE MAIN COMPONENTS OF PAINT ARE THE VEHICLE OR BINDER, THE PIGMENT AND THE EXTENDER

#### VEHICLE OR BINDER

This is the fluid material in the paint which must harden after application. The hardening process may be due to one of the following:-

- a. Polymerization: - The joining of monomers to make polymers in a chemical process that usually involves the use of heat and pressure.

- b. Coalenscence of an emulsion: - Emulsions are pro-polymerised into very small particle which are prevented from coalescing by an emulsifying agent. They set by water loss leading to breaking of the emulsion.
- c. Evaporation of a solvent:-Solvents need to be volatile, hence they are often flammable.

## PIGMENTS

These are fine insoluble particles which give the colouring ability and body to the paint. Primers and undercoats tend to have large proportions of pigments to produce opacity, while finish coats have low proportion since to produce a gloss, the pigment should be beneath the surface.

## EXTENDERS (SOLVENTS & THINNERS)

These can be added to control the flow characteristics and gloss of the paint with added advantage of reducing the cost. Because they are not involved in the colouring process they have particle size larger than that of the pigment.

## SOME COMMON TYPES OF PAINT

### OIL (ALKYD RESIN) PAINTS AND VARNISHES

These are well established and are still the most widely used paints for general purposes including painting of wood and metals. They were traditionally based on linseed oil but modern oil paints are manufactured from alkyd, polyurethane, as other synthetic resins, which allow greater control over flow characteristics, hardening time and hardness/feasibility of dried film.

### EMULSION PAINTS

These are now very widely used in interior decorations. Example is polyvinyl acetate (PVA) emulsion which is suitable for application to new cement or plaster. The molecule are very large but are dispersed in water by colloids to give particles of approximately 1ohms in size. Hence, this paints have advantage of being water miscible, although on drying coalescence of polymer particles occurs, resulting in a coherent film with moderate resistance to water.

### CELLULOSE PAINTS

These are solvent-based paints. The cellulose constituent is in the form of nitrocellulose dissolves in a solvent as acetone. Plasticizers are added to give elasticity and synthetic resins are added to give a gloss, since pure cellulose gives little gloss.

Drying usually occurs rapidly but well ventilated areas are essential and the paint is highly flammable. Cellulose paints are the most suited spray applications (though retained varieties for brushing are avoidable). These properties, together with the fact that the paints give off a penetrating odour, tend to restrict the use of cellulose paints to factory applications. In these conditions, high quality finishes can be obtained and the resulting coat has good resistance to fungal attack and to chemicals including alkalis.

## BITUMINOUS PAINTS

These are intended primarily for protection of metal used externally and have poor gloss-retention properties. They are amenable to application in thin coats therefore cause lifting if applied oil-based coats. Sunlight softens the paint, though resistance can be improved by use of aluminum in the final coat.

## PAINTS APPLICATION

The main tools of a painter are brushes, rollers and spray equipment.

**BRUSHES:** - Most paints is applied be brushes in the decorations of buildings than by any other method because a brush will reach into corners and intricacies inaccessible to other tools. Best-quality paint and varnish brushes are made of pure hog bristle which has a natural curve, taper and flag to hold the paint well and to enable a high standard of finish to be achieved. Cheaper brushes include short bristle or a mixture of hog bristles and other filling materials. After use wash it thoroughly with water and allow it to dry before keeping it in a more proper place.

**ROLLERS:** - The use of rollers for paint application saves a great deal of times they are made in sizes from about 50 – 350mm wide and apart from the usual cylindrical type they can be designed in different shapes, convex, concave or corrugated to suit unusual contours, to maintain it after use a clean water is used for emulsion paint and for texcote or oil paint kerosene is used to move easier when washing and keep to dry off before keeping it in a store or place.

**SPRAYING GUN:** - Is economical poly where large areas are involved. So called 'airless' spraying employs compressed air to drive a reciprocal ram pump, which lifts the paint from a container under pressure. The paint under pressure is passed through a metal reinforced lose to the gun, the control of which consists of a needle or ball type cut off valve, allowing the paint to pass out when the trigger is squeezed. When correctly used, airless spraying does not result in too much overspray. It is fast, covering up to 10m<sup>2</sup> a minute and the spray will take high-solids materials such as rust-preventative compounds. After usage the gun is washed thoroughly with kerosene or thinner so that all the paint that holds on the body will go off, when used next time it will be easier and it will not waste time and the life span of the gun will last because of maintaining it after used.

## PLASTICS

Plastics are substances formed as a result of polymerization of organic compounds. The main element that constitute organic compound is carbon.

Carbon is unique in a chemical sense. It is in the centre of the first short period of the periodic table and contains four electrons in the outer shell. Furthermore, carbon atoms form chain (sometimes of very great length) and rings. Sometimes both chains and rings are included in the same molecule. In addition, carbon can form multiple of bonds, that is, double or triple bond.



Tony Stone Images/Mitch Kezar  
**Plastics Manufacturing**

Ontario's plastics industry produces a range of goods, as in this Toronto plastics manufacturing plant. The richest province in Canada, Ontario leads the nation in manufacturing. Its economic leadership comes from vast natural resources, cheap electric power, plentiful skilled labor, and convenient transportation links to the rest of Canada and the United States.

**POLYMERISATION;** The formation of very large molecules by repeated combination of simple molecules is known as polymerization.

A unit of the simple molecule is known as monomers and the large molecule formed the polymer.

Copolymer is formed when two or more types of monomer combined to form very large molecules

### **THERMOPLASTIC RESINS**

The material that are viscoelastic at intermediate temperature and fluid at higher temperatures are called thermoplastic resins. Viscoelastic strain is an exhibition of gradual deformation of material to a limited extent under a given load and on removal of the load they recover their original shape after a time.

The temperature below which this viscoelastic is insignificant is the glass transition temperature. At still higher temperature, the material will also undergo irreversible deformation under applied load i.e. they flow. This mechanism becomes significant at the temperature.

Article to be made from thermoplastic resins can be shaped by mechanically deforming material above the flow temperature and cooling before removal of the restraining forces. Thermoplastic can be joined by welding i.e. heating the contact area and then mechanically pressing the parts together when they cool.

### **THERMOSETTING PLASTIC RESINS**

Some polymers can have more than two linkages for molecule and so build up to three dimensional networks which are continuous structures of covalent bonds. When completely polymerized, such materials will not undergo any irrecoverable plastic deformation, even at high temperatures and will fracture only in a brittle manner. They can be used at higher temperature than most thermoplastic resins, the unit being the temperature at which decomposition or charring occurs. Articles of those resins are usually manufactured from partially polymerized material which is pressed into moulds and heated to complete polymerization. They are known as thermosetting plastic resins, with so many variations possible on the shape and size of polymer molecules a wide range of mechanical properties are obtained.

Thermoplastics can be softened any number of times by heat and pressure which thermosetting plastics are softened the first time, but the heat and pressures produce chemical change and the resulting hard mass cannot be resoftened.

### **BUILDING USES OF PLASTICS**

The use of plastics in building is confined to small fittings, such as door furniture, air vent covers, lighting, fittings, W.C seats, drawing boards and so on.



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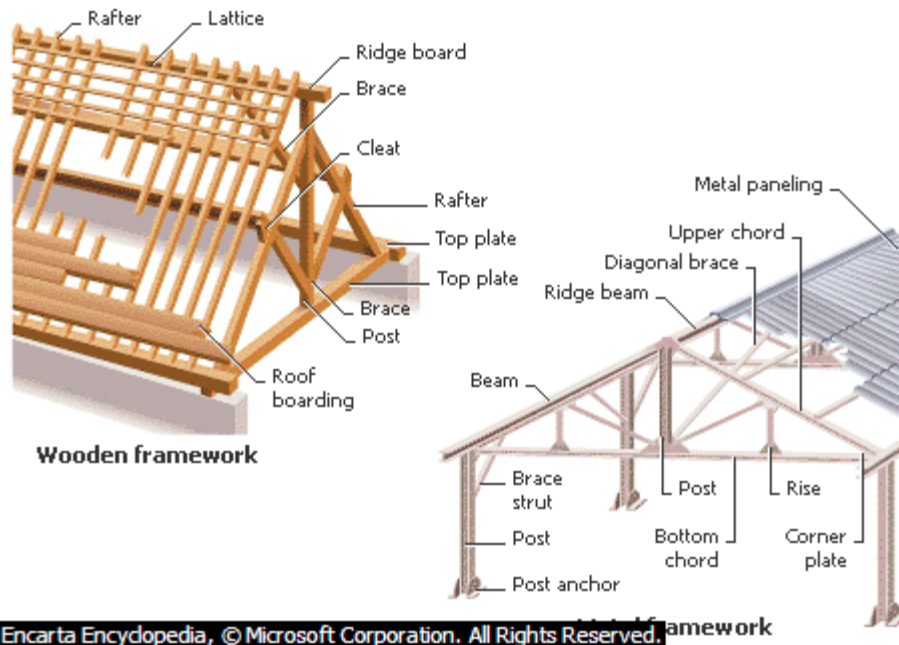
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## Week 12

### METALS



Metals can be divided into ferrous metal and non ferrous metals.

Ferrous metals;- properties-

- 1) Contain iron
- 2) They are magnetic
- 3) Good thermal conductors

Example;- steel and iron

Non-ferrous metals;- properties-

- 1) Do not contain iron.
- 2) They are not magnetic.
- 3) Poor conductors.

### APPROXIMATE PERCENTAGE CONSTITUENT OF STEEL

- 1) Low carbon mild steel  $-0.04-0.3c +0.8mn$
- 2) Medium carbon steel  $0.3-0.7c +0.8mn$
- 3) High carbon steel  $0.7-1.7c +0.8mn$
- 4) Low alloy steel  $0.2c +0.8mn +1.0cr +2.0nr$
- 5) High alloy steel ( stainless steel  $-0.1c = 0.5mn + 18.0cr + 8.0nr$
- 6) Cast iron-  $1.8-4.4c +0.9mn +2.0$

## ALLOYS

An alloy is a combination of two or more metals, or of metals and a non-metal such as carbon, silicon, nitrogen or phosphorus, to form what is often referred to as a solid solution. Alloys are generally prepared by melting the metals (or metal) and non-metal together and allowing the molten mixture to cool.

Formation of alloys is possible because metals have a crystal structure with interstices or voids which can be filled with different metallic atoms, the number of these atoms present and the conditions under which alloying occurs (e.g. extent of heat treatment)

Examples of alloys

- 1) Steel; Consists of iron and between 0.1-1.5% carbon, plus small amount of sulphur and phosphorus.
- 2) Aluminium alloys include
  - a) Duralumin (Aluminium, magnesium, copper and manganese)
  - b) Magnalium (contains aluminium and magnesium)
  - c) Aluminium bronze (contains aluminium and copper)These aluminium alloys are noted for their high tensile strength, extreme lightness

And resistance to corrosion, and have been used extensively in aircraft construction.

## APPLICATION OF THE VARIOUS STEELS



Steel Production

Molten pig iron is poured into a basic oxygen furnace (BOF) for conversion to steel. Steel is a form of iron produced from iron ore, coke, and limestone in a blast furnace. Excess carbon and other impurities are removed to make a strong steel.

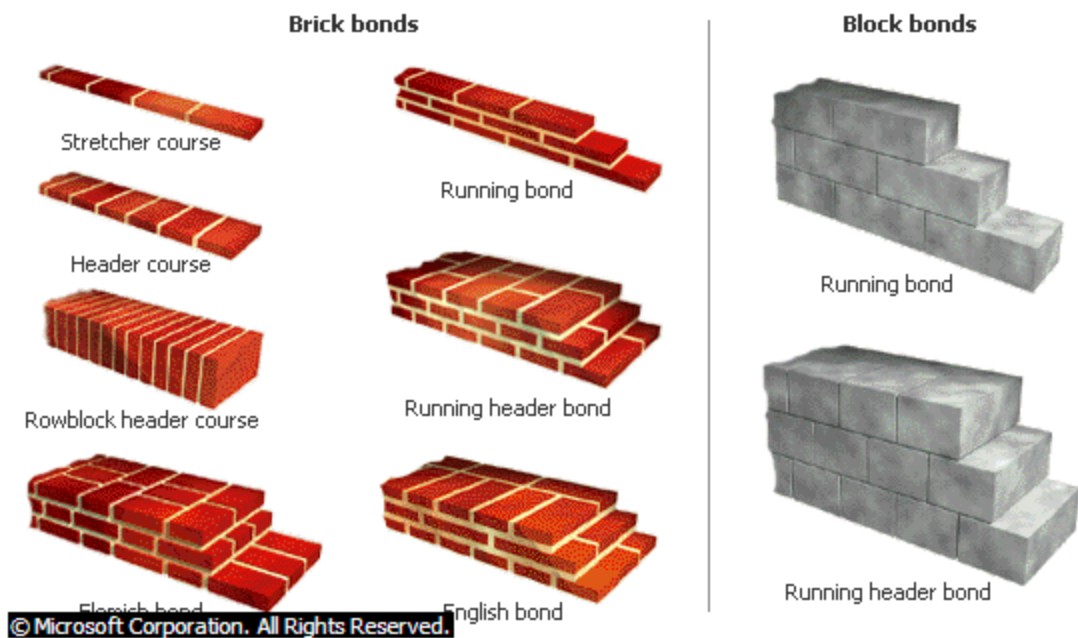
1. Low carbon mild steel- Low stress constructional steel suitable for welding.
2. Medium carbon steel - Medium stress uses , machinery etc
3. High carbon steel - High stress, uses, springs, cutting tools
4. Low alloy steel - High stress uses pressure vessels, aircraft parts
5. High alloy steel- High temperature or anti –corrosion use
6. Cast iron- Low stress uses, cylinder blocks rain pipes.

## Brick

Brick, block of clay or other ceramic used for construction and decorative facing. Bricks may be dried in the sun but are more usually baked in a kiln. They cost relatively little, resist dampness and heat, and can last longer than stone. The color varies according to the clay used and in proportions according to architectural tradition. Some bricks are made of special fireclays for use in fireplaces or ovens. Others may be made of glass or they may be textured or glazed. Bricks may be arranged in various patterns, called bonds, according to the way the long sides (stretchers) or short sides (headers) are placed.

Brick was the chief building material of ancient Mesopotamia and Palestine, which had little wood or stone. The inhabitants of Jericho in Palestine were building in brick about 9000 years ago. Sumerian and Babylonian builders constructed ziggurats, palaces, and city walls of sun-dried brick and covered them with more durable kiln-baked, often brilliantly glazed brick, arranged in decorative pictorial friezes. Later the Persians and the Chinese built in brick, for example, the Great Wall of China. The Romans built such large structures as baths, amphitheaters, and aqueducts in brick, which they often covered with marble facing.

During the Middle Ages, in the Byzantine Empire and in northern Italy, in the Low Countries, and in Germany, wherever stone was scarce, builders valued brick for its decorative and structural qualities. They made handsome use of warm, red, unglazed brick laid in a variety of intricate patterns, such as checker, herringbone, basket weave, or Flemish bond. Such traditions continued in the Renaissance and in English Georgian architecture, and were brought by colonists to North America. Brick was already known to the Native Americans of pre-Columbian civilizations. In dry regions they made houses of sun-dried adobe brick. The great pyramids of the Olmec, Maya, and other groups were made of brick faced with stone. Brick, factory made in vast quantities, has continued to be a versatile building material.



#### Brick and Block Bonds

Brick and concrete block are common building materials. Brick and block are stacked together to create walls and other structures. The individual bricks are held in place by mortar, a type of cement. Bricks can be stacked in various patterns called bonds. Each bond is made up of individual rows of bricks called courses. By alternating or repeating various courses, different bonds are created. Blocks are also stacked in bonds.

#### CLAY BRICKS;

Are chiefly made from clay or shale moulded by either hand or machinery. The principal element of clay suitable for brick making are Alumina and Silica. Brick clays also contain varying proportions of limestone, iron, magnesium and salts.

#### MANUFACTURING PROCESS:

Bricks are made by getting the clay from the ground all dirt/impurities are removed before the clay is mixed with water. The bricks are then produced either manually or mechanically. The bricks are then put in a kiln and subjected to heat to harden and strengthen them.

## CHARACTERISTICS OF BRICKS.

Bricks are of two characteristics.

Good Bricks;

1. Should be thoroughly burnt, it makes them hard and durable.
2. A hard ringing sound emitted when two bricks are struck together indicates that they have been burnt satisfactory.

Bad Bricks;

Inferior(bad)bricks are generally under burnt and as a consequence are easily broken and are very porous. These are neither hard nor durable and are incapable of withstanding heavy load.



**Brick Wall**

Bricks, blocks of baked clay, have been used in construction for thousands of years. Bricks are stacked and bonded together with mortar to form a wall.

The Image Works/Antman

## CALCIUM SILICATE BRICKS.

They are generally known as sand lime bricks. Sand lime bricks have mainly been used as commons. The bricks are made from a carefully controlled mixture of clean sand and Hydrated lime which is mixed together water and moulded to bricks shaped in a steam oven. The resulting bricks are very uniform in shape and colour and are normally a dull white.

## TYPES OF BRICKS

1. Common Bricks; Are used for general building work where appearance is not vital.
2. Facing Bricks; Are used for appearance, durability and capable of withstanding the effect of rain, wind and frost without breaking up.

3.Engineering Bricks; Are used for position in buildings where strength is required or damp penetrations is to be resisted.

4.Solid Perporated Bricks; Cellular and perporated bricks are lighter in weight than solid bricks and the cells and perforation facilities drying and burning.

### **BUILDING BLOCKS.**

Are made up of cement,sand and water to facilitate the mix.

Blocks can be classified as;

1.Solid Blocks; The thinner the thickness of the block,the better for it to be solid.

2.Hollow/Cellular Blocks; The thinner then block, the better it should be manufactureas either hollow or cellular to reduce the weight of the blocks.



## GYPSUM PLASTER

# Gypsum

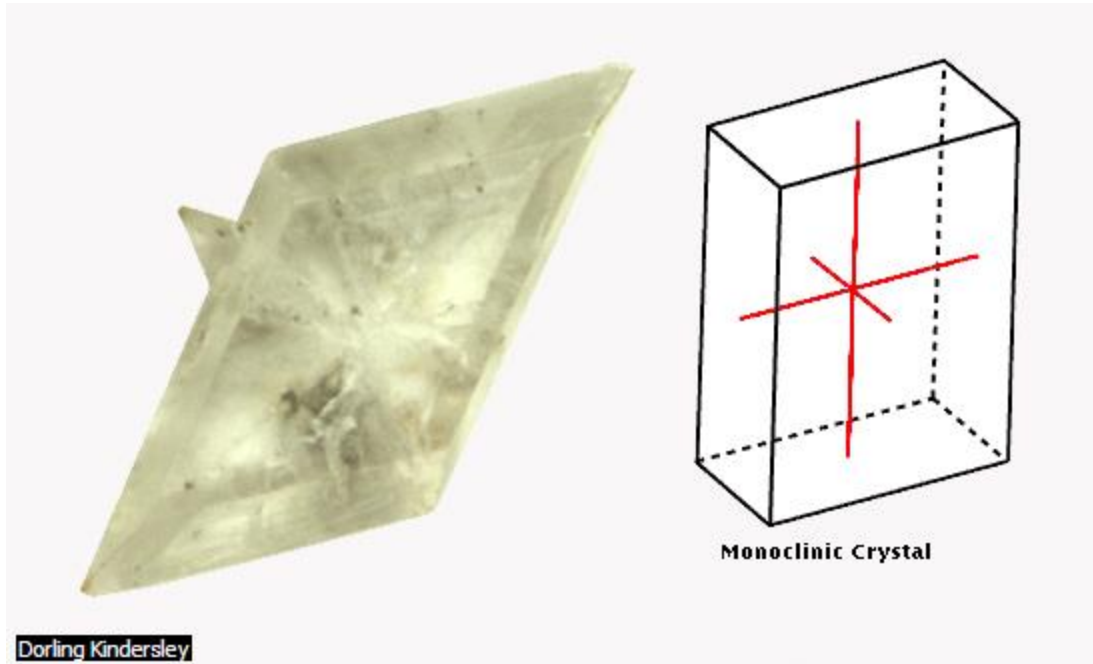
Gypsum, common mineral consisting of hydrated calcium sulfate ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ). It is a widely distributed form of sedimentary rock, formed by the precipitation of calcium sulfate from seawater, and is frequently associated with other saline deposits, such as halite and anhydrite, as well as with limestone and shale. Gypsum is produced in volcanic regions by the action of sulfuric acid on calcium-containing minerals; it is also found in most clays as a product of the action of sulfuric acid on limestone. It occurs in all parts of the world; some of the best workable deposits are in France, Switzerland, and Mexico, as well as in California, Ohio, Michigan, and Utah in the United States. Alabaster, selenite, and satin spar are varieties of gypsum.

Artificial gypsum is obtained as a by-product in an old method for the manufacture of phosphoric acid. Phosphate rock, the essential constituent of which is tricalcium phosphate, is treated with sulfuric acid, producing phosphoric acid and gypsum. The gypsum is compacted into blocks and used for the construction of nonsupporting walls in buildings. By properly controlling the concentration and temperature of sulfuric acid added to phosphate rock, a mixture of monocalcium phosphate, dicalcium phosphate, and gypsum may be obtained. This mixture is a valuable fertilizer, superphosphate.

Gypsum crystallizes in the monoclinic system in white or colorless crystals, massive or foliated in formation. Many specimens are colored green, yellow, or black by impurities. With a hardness ranging from 1.5 to 2, it is soft enough to scratch with a fingernail and has a specific gravity of 2.3. When heated to  $128^\circ \text{C}$  ( $262.4^\circ \text{F}$ ), it loses part of its water of hydration and is converted into plaster of Paris,  $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$ . Finely ground plaster of Paris, when moistened with water, sets in a short time into a hard mass of gypsum, the rehydrated crystals forming and interlocking in such a way as to cause expansion in volume.

Because of its property of swelling and filling all interstices upon drying, plaster of Paris is used extensively in making casts for

statuary, ceramics, dental plates, fine metal parts for precision instruments, and surgical splints. Uncalcined gypsum is used as a fertilizer in the form of land plaster for arid, alkaline soil. It is also used as a bed for polishing plate glass and as a basis for paint pigments. Large amounts of gypsum are used as a retarder in portland cement.



Dorling Kindersley  
Gypsum and Crystal Structure

A common sedimentary mineral, gypsum is soft enough to be scratched by a fingernail. The crystals are formed by the evaporation of saline waters. Therefore, rich deposits of gypsum are frequently found near the sea. Gypsum has a monoclinic crystal structure, which means it has three axes of unequal length, two of which are perpendicular to the third axis, but not to each other.

Dorling Kindersley

**GYP SUM;** \Is a rock consisting of calcium sulphate.( $\text{CASO}_4 \cdot 2\text{H}_2\text{O}$ ). It is ground and heated in a kiln which drives off most of the moisture.

When gypsum is heated, water is expelled and a white, grey or pink powder is obtained. This is **CLASS A Plaster** and is known as plaster of paris.

**ADDITIVE**(a retarder)chemical substance added to delay it's setting time.**CLASS B.**

**CLASS C AND D.;** Are based on chemically anhydrous calcium sulphate ( $\text{CASO}_4$ )obtained as a by-product or by heating the gypsum to a higher temperature than for group one.

## Paint and Varnish

### I INTRODUCTION

Paint and Varnish, liquids that solidify when exposed to air, and are used to cover surfaces for decorative and protective purposes. Paints are formed by mixing a pigment (the substance that provides color) and a binder, a fluid vehicle, such as linseed oil, that solidifies when exposed to air. A varnish is a transparent solution that solidifies into a protective coating. Opaque and colored varnishes are called lacquers.

### II HISTORY

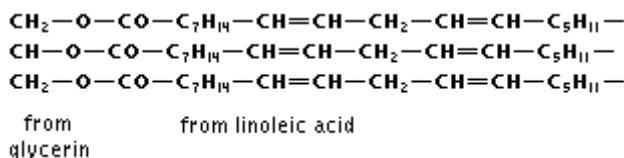
The first uses of paint were entirely decorative. Thus, paint without a binder, consisting of iron oxide, was used for cave paintings about the 15th millennium BC. In Asia, several pigments made from ores, prepared mixtures, and organic compounds were known about 6000 BC. Indigo, a pigment extracted from the indigo plant, was known to the ancient Egyptians, Greeks, Romans, and Inca. Gum arabic, egg white, gelatin, and beeswax were the first vehicles used for these pigments. Lacquers were used to paint buildings in China about the 2nd century BC; in Europe, protective painting began about the 12th century AD. Linseed oil, although known as a paint vehicle by the Romans, appeared in artistic painting only in the 15th century. White lead, a white pigment, became widely used in the 17th century, and paint consisting of prepared mixtures of pigments and vehicles first became commercially available in the 19th century.

### III CHEMICAL COMPOSITION OF PAINTS

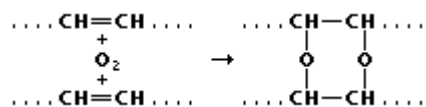
A modern paint formulation consists of several different categories of chemical compounds. The vehicle forms the adherent, skinlike coating; the pigment is dispersed in the vehicle and gives the final film its color and hiding power; and the solvent, or thinner, evaporates shortly after the coating has been laid. The vehicle can be an unsaturated, or drying, oil, which is an ester formed from the reaction of a long-chain carboxylic acid, such as linoleic acid, with a viscous alcohol, such as glycerine; or it can be a polymer. A filler, containing powdered components such as kaolin (*see* Clay) or barium sulfate, enhances the strength of the dried film of paint.

## A Vehicles

The molecular structure of a typical drying oil, linseed oil, is as follows:



If this substance is exposed to the oxygen in the air, the unsaturated ends on the hydrocarbon chain, shown above at the locations of the double bond,  $-\text{CH}=\text{CH}-$ , are attacked, and an oxide, or ether, is formed, thereby cross-linking one molecule to another, to yield a tough, insoluble macromolecule with high molecular weight, as follows:



The drying oil, therefore, is a monomer when it is in the can and becomes a polymer after being applied to an exposed surface.

If the vehicle is a synthetic polymer, it is dispersed in a suitable solvent, so that as the solvent evaporates the individual macromolecules come into contact and become enmeshed with one another. The solidification is improved by the presence in the solvent of a polymerization catalyst, called a drier. The types of synthetic polymers most widely employed as paint vehicles are alkyd resins, which are polyesters of a polyhydric alcohol, such as glycerol, with a polybasic acid, such as phthalic acid,  $\text{C}_6\text{H}_4(\text{COOH})_2$ ; nitrocellulose, in which cellulose is depolymerized, the small molecules are nitrated, and the substance is then repolymerized (*see* Rayon); phenolic resins; acrylic resins; epoxy resins; polyvinyl acetate resins; and polyurethanes.

## B Pigments



### Colorful Minerals

Today most pigments for paint and dye are produced synthetically, but in ancient times people used local minerals. The minerals were crushed into a powder and mixed with animal fats to produce a wide range of usable colors. Here, several minerals are shown in original and powdered form alongside paint pigment samples. Clockwise from top right, the minerals are: hematite (also known as jewelers' rouge), malachite (a green copper compound), azurite ("royal" blue), cinnabar (vermillion red), lapis lazuli (ultramarine blue), realgar (an arsenic compound), and orpiment (shown center; a form of "fool's gold").  
Dorling Kindersley

A paint pigment is a fine powder that either strongly scatters light, to yield a white effect, or absorbs certain wavelengths of light, producing a colored effect. Typical white pigments are inorganic oxides such as titanium dioxide,  $\text{TiO}_2$ ; antimony oxide,  $\text{Sb}_2\text{O}_3$ ; and zinc oxide,  $\text{ZnO}$ . Other white, insoluble, inorganic compounds are also frequently used, including zinc sulfide,  $\text{ZnS}$ ; white lead (the hydroxycarbonate, hydroxysulfate, hydroxyphosphite, or hydroxysilicate of lead); and barium sulfate,  $\text{BaSO}_4$ . The following inorganic oxides are typical

colored pigments: iron oxide,  $\text{Fe}_2\text{O}_3$  (yellow, red, or brown colors); chromium oxide,  $\text{Cr}_2\text{O}_3$  (green); lead oxide,  $\text{Pb}_3\text{O}_4$  (red). The chromates of lead, zinc, strontium, and nickel produce various shades of yellow and orange. A variety of organic solids is used for other colors.

## C Solvents

The solvent or thinner for drying oil paints is generally turpentine, which is a mixture of cyclic hydrocarbons containing ten carbon atoms, or the thinner may be a mixture of suitably volatile hydrocarbons derived from petroleum distillates. The solvent for most synthetic vehicles is an alcohol, a ketone, or an ester.

## D Special Paints

Enamel paints consist of zinc oxide and lithopone in brown linseed oil and high-grade varnish (*see* Enamel). Luminous paints contain various phosphorescent sulfides of barium, strontium, and calcium. Watercolors for artists are finished either in dry cake or moist condition. In both cases, they contain the finest pigments ground in gum arabic or dextrin. For the moist form, glycerol is added.

Another kind of paint, the water-thinned latex paint, was introduced in 1949. The synthetic vehicle is emulsified, that is, suspended as very tiny droplets in the water; when the paint dries, the water evaporates and the pigment and vehicle particles become bonded together, forming a relatively strong film. The film is porous enough to permit the passage of moisture, thus increasing its resistance to blistering. Most latex paints are limited to interior use and are popular because they are odorless and easy to apply.

In some applications so-called solid-emulsion paints, or powder coatings, replace liquid paints. They are sprayed onto a metal surface, as in the production of machinery or window frames, and adhere by electrostatic attraction. Heat causes the powder to flow and form a film.

## IV VARNISH AND LACQUER

Varnishes are transparent solutions produced by heating a drying oil, resin, drier, and solvent together. If applied as a thin film, varnish gives a hard transparent coating upon evaporation, oxidation, and polymerization of the solvent. The numerous variations in composition and preparation of varnish make its classification difficult. The so-called spirit varnish, for example, is a resin dissolved in a volatile solvent that contains no drying oil, and asphalt varnish is a solution of asphalt and a solvent that gives opaque, black coatings. (*See also* Lac).

Lacquers are certain natural and synthetic varnishes, particularly those obtained from the sap of the varnish tree, *Rhus verniciflua*, a Japanese sumac, containing the phenolic resin urushiol. The sap is heated to drive off moisture, leaving a brown syrup. Pigments are added and, sometimes, diluting agents. The resulting material is applied as a thin coating to wood, metal, or ceramic articles; when hard, the lacquer coat is polished smooth with an abrasive, and another coat is applied over it. Often, more than 30 coats are used on a fine piece of lacquerwork. Commercial lacquers used in the U.S. for painting metallic objects usually have a pyroxylin base.

**PAINTS;** Is a liquid coating that is applied to various surfaces and component. It dries as a hard film and gives protection and decoration.

### PURPOSE OF USING PAINTS

1. To protect the underlying surface by exclusion of the atmosphere, moisture, fungi and insects.
2. To provide a decorative easily maintained surface .
- 3 To provide light and heat-reflecting properties.
4. To give special effects.

### PAINT APPLICATION IN STAGES

**PRIMING COAT** ; - Is applied to a raw surface , is usually designed to seal the surface, to prevent corrosion.

**UNDER COAT**;-Is used to build up the surface and give opacity together with a smooth surface which provides a good key for the finishing coat.

**FINISHING COAT**;- Must be durable layer of the required colour or texture. Traditionally most finishing coats were gloss finish.

### THE MAIN COMPONENT OF A PAINT.

**VEHICLE OR BINDER**;- Is the fluid material in the paint which must harden after application . The hardening process may be due to one of the following;-

- a) Polymerisation;- The joining of monomers to make polymers in a chemical process that usually involves the use of heat and pressure.
- b) Coalescence;- The set by water loss leading to breaking of the emulsion.
- c) Evaporation;- Solvents need to be volatile, hence they are often flammable.

**PIGMENTS**;-These are fine insoluble particles which give the colouring ability and body to the paint.

**EXTENDERS**;- These can be added to control the flow characteristics and gloss of the paint with the added advantage of reducing the cost.

### COMMON TYPES OF PAINT

#### OIL (ALKYD RESINS) PAINTS AND VARNISHES.

These are used for general purposes including painting of wood and metals. They were traditionally based on linseed oil but modern oil paints are manufactured from alkyd, polyurethane, or other synthetic resins.

#### EMULSION PAINTS.

These are now very widely used in interior decorating. e.g. are polyvinyl acetate(PVA) emulsion which are suitable for application to new cement or plaster.



## WEEK 15

### 13.0 CORROSION

#### 13.1 Definition of Corrosion

Corrosion is the destruction of a material by chemical attack resulting from its environment for metals. It involves a gradual reversion to the more stable state such as the oxide, sulphide or carbonate.



**Oxidation: A Chemical Reaction** fig 13.1

Iron, in the presence of water, combines with atmospheric oxygen to form a hydrated iron oxide, commonly called rust. This process has slowly been corroding these old Pontiacs in New Mexico.

### 13.2 Corrosion Mechanism

- (1) **Direct Chemical Combination:** Metal combine directly with gases such as oxygen, chlorine, sulphuric gases, carbon-dioxide etc to form a surface film to form chlorine sulphides, carbonates etc.

This type of corrosion is most serious in highly polluted atmosphere, although in a few cases the corrosion can be self suppressed by the formation of a thin protective layer of surface film (e.g. in aluminum and chromium)

- (2) **Electrochemical Corrosion:** This is the corrosion in aqueous environments, the result of electrochemical reaction in which water acts as a conducting liquid (electrolyte).

The diagram below shows Corrosion Mechanism in Soil environment.

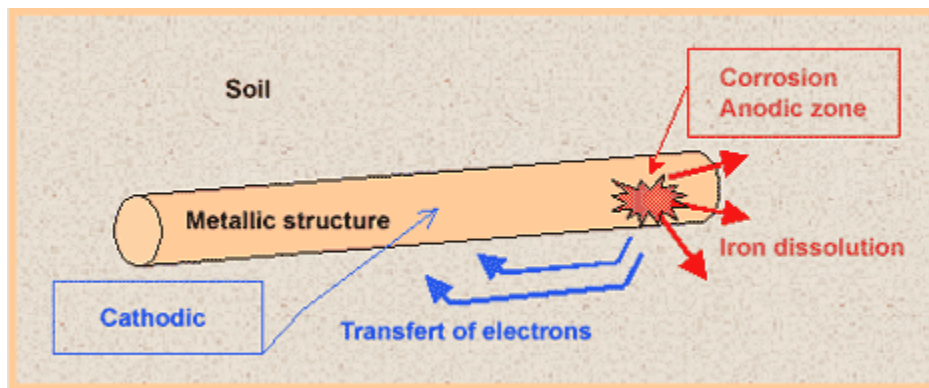


Fig.13.2

### 13.3 Factors Influencing Corrosion

Oxygen and moisture (water) are essential for corrosion to occur, but under certain circumstances corrosion can take place in the absence of oxygen (anaerobic corrosion).

### 13.4 Rusting

Rusting is just the oxidation of iron at the surface. This process is activated by the presence of moisture and carbon-dioxide. On oxidation, initially iron changes to ferrous, bicarbonate, then to ferric-bicarbonate and finally to hydrated ferric oxide.

Atmospheric pollution too accelerates rust formation. Corrosion is slow but steady eating away the metal and is a consequence of rusting.

### 13.5 Protection of Metals against Corrosion

- 1) **Tarring:** Iron is dipped in hot coal tar so that a film of it sticks to be surface which protects the surface from rusting and corrosion.

Pipes or ends of poles to be embedded in earth are usually given this protective treatment.

- 2) **Painting:** Paints, usually the lead paints are applied on the surface to be protected. Exposed metal surface as in the case of roof trusses and bridge structure are given this treatment which has to be invariable repeated after regular interval of time.

- 3) **Enameling:** Enamel provides better and long lasting protection as compared to painting.

This treatment is given only to smaller surface (enamel consist of high grade bases like zinc oxide or lead oxides ground in oil or vanish, they dry slowly leaving a hard tough and elastic film which is smooth and durable. Enamel painted surface and washable and are not affected by acids, alkalis, gases or steams.

- 4) **Galvanizing:** Depositing a fine film of zinc on the iron/steel surface is termed as galvanizing. The surface to be galvanized is first cleared of all foreign matter by giving it an acid wash to be followed by a wash of clean water. The surface is then dried and dipped in molten zinc. The fine film of zinc that gets deposited protects the surface from contact with atmosphere and consequent oxidation. Removal of the zinc film caused by wear or scratches lane exposes the surface to rust and corrode.

- 5) **Sheradising:** Surface to be treated is cleaned of all foreign deposits by washing it with acid solution and then the clean water. It is then dried covered with in dust and enclosed in steel box to be heated in furnace under controlled temperature. Molten zinc spread over the whole surface and on cooling from thin protective layers. Sheradising gives better protection than galvanizing.

- 6) ***Tin Planting***: After cleaning the surface with acid wash followed by washing with plain water and drying. It is dipped into both of molten tin. A protective covering of tin layer is left on the surface.
- 7) ***Electroplating***: By the process of electrolysis a thin film of nickel chromium, cadmium, copper zinc is deposited on the surface to be protected. The surface to be protected is made the cathode and the metal to be deposited is made the anode.

### 13.6 Effect of Corrosion on Metals

#### Corrosion Process

The Corrosion is the result of a chemical or electrochemical reaction between a metal and its environment, which produces a deterioration of the metal and its properties. The identity of a metal is determined by its corrosion potential and is measured in millivolts. This measurement may vary from one zone to another depending on the surrounding medium.

The zone where the corrosion process may be initiated is known as the anodic zone. An anodic zone is defined by the most negative potential. The corrosion of a metal is an oxidation process called an anodic reaction. A cathodic zone creates a secondary process known as the cathodic reaction. This is a reduction process by which the electrons created by the anodic reaction is consumed, resulting in the two processes balancing their charges:



In order for the corrosion process to occur, there must be an anodic zone and a cathodic zone. Depending on the circumstances, these two zones can be positioned close together on a metal's surface, or far apart. The two zones co-exist creating an electrochemical process in which the surrounding medium acts as a transport system for ions. This pathway is defined as the electrolyte.

One of the key elements for the corrosion process is the soil surrounding the metal surface. In addition to the soil being an electrolyte, the properties of the soil may inhibit or enhance the corrosion. Such processes including soil resistivity (velocity of the current traveling through the ground), directly effect the formation, rate and placement of corrosion on the metal surface. A less resistive soil, results in an accelerated corrosion reaction.

Furthermore, soils with the following parameters may also influence the location and formation of the anodic zones:

- Low oxygenated soil
- Ground of low resistivity
- Presence of sulphate-reducing bacteria
- Soil saturated with water
- Organic contamination (compost, refuse, ...)
- Contact with highly conductive materials (ashes, coal, salts, ...)
- Dissimilar materials.

On a metal structure placed in a soil environment, localized corrosion attacks are a particular concern. The metal structure may go through numerous layers of soil. With every layer there is a transition in soil composition, shifting aggressiveness with varying layers of resistivity. These resistive regions (both anodic and cathodic) typically decrease with incremental depth; however the corrosion process will be amplified on the metal structure where the various layers of soil intersect.

In understanding the corrosion process and the various elements involved that directly effect this electrochemical reaction, it is evident that the lifespan of a metal structure may be strongly influenced by one or several factors. The placement and rate of corrosion on a metal structure affects not only the metal internally but the lifespan structurally.

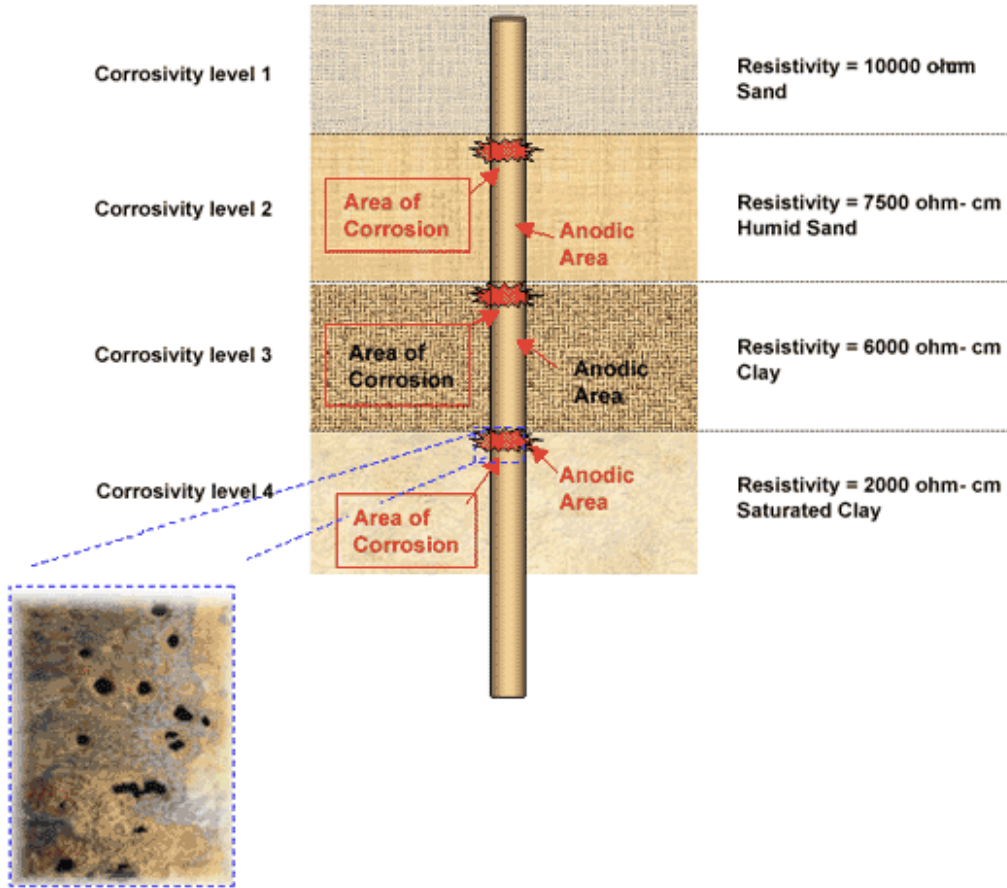


Fig.13.3

Techno Protection offers two corrosion protection applications, based on the cathodic protection principle. With the introduction of an external anodic area, the natural corrosion process can be manipulated to secure it efficiently against the degradation related to corrosion.