Civil engineering materials

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Abstract

For any construction project to prove satisfactory, it is essential to understand the properties of materials during both the design and construction phases. It is crucial to consider the economic viability and sociological and environmental impact of a project. During this initial design phase, possible alternative locations and a preliminary assessment of suitable construction materials are taken into account. The decision of which structural form and material choice is most appropriate depends on a number of factors including cost, physical properties, durability and availability of materials. Buildings can contain wood, metals, concrete, bituminous materials, polymers, and bricks and blocks. Some of these can only be used in non-structural elements, while others can be used alone or in combination with structural elements. The actual materials used in the structural members will depend on both the structural form and other factors mentioned earlier. In this study, various materials such as metal, timber, concrete floor and polymer used in civil engineering were examined, the properties and usage areas of these materials were examined.

Keywords: Building, Steel, Polymer, Concrete, Timber

1. Introduction

To prove that any civil engineering or construction project is satisfactory for its intended purpose, it is essential to understand the properties of materials during both the design and construction phases.

During the initial planning and design stages of a project, the key factors on which any subsequent continuation decision will be based include its economic viability and its sociological and environmental impact.

During this initial or conceptual design phase, possible alternative locations and/or placements of relevant works and a preliminary assessment of suitable construction materials are taken into account.

Alternative layouts and building forms for building structures are examined together with the suitability of different materials for use in building elements for each of them. The decision of which structural form and material choice is most appropriate depends on a number of factors including but not limited to cost, physical properties, durability and availability of materials.

The ease and speed of construction affect the initial cost (construction) and/or subsequent costs (maintenance) over the design life of the structure; both of these are important considerations when evaluating the economic viability of any project.

Buildings can contain timber, metals, concrete, bituminous materials, polymers, and bricks and blocks. Some of these can only be used in non-structural elements, while others can be used in structural elements on their own or in combination with others. The actual materials used in the structural members will depend on both

the structural form and other factors mentioned earlier.

Metals, concrete, lumber and masonry find their place as structural elements where appropriate, building structures often allowing for greater selection of structural forms and construction materials than in the example above. A sound decision about whether a situation is appropriate a particular material will depend, among other things, on the engineer having a thorough understanding of the material's behavior and properties. Some of these characteristics can be quantified for general comparison purposes (Table 1), but all require in-depth knowledge of the key factors that may affect them.

The use of composite materials such as clay mixed with the fibrous materials mentioned above acknowledges the inability of some materials to resist all the forces to which they will be subjected. An example of these in use today is reinforced concrete (where the steel reinforcement is positioned to resist tensile forces and glass fiber reinforced plastic (GRP). Another notable example is the use of soil reinforcement systems in earthen structures, where steel (galvanized, stainless, or plated steel), aluminum alloys, polymers, and other materials are used as soil reinforcement in a variety of ways [1].

In this study, various materials such as metal, timber, concrete soil and polymer used in civil engineering were reviewed, and the properties and usage areas of these materials were examined.

Table 1. Properties of some engineering materials [2]

	Density (kg m^{-3})	Tensile modulus of elasticity, E (kN mm^{-2})	Tensile strength, f_t (N mm^{-2})	Coeff. of thermal expansion α ($\times 10^{-6}$ K^{-1})	Thermal conductivity, k (W m^{-1} K^{-1})
Cast irons	7 200	170	300–1000	12–13.5	33–45
Structural steels	7 850	210	350–700	12	52
Aluminium alloys	2 750	70	70–600	21–23	95–165
Lead	11 350	13	—	29	35
Scots pine (parallel to grain)	510	10	90–120	4	0.38
Concrete	2 400–2 500	20–50*	20–100* (3–15)**	9–12	1.8–2.5
Autoclaved aerated concrete (AAC – medium strength)	300–600	0.9–2.5*	1.8–4.0* (0.6–1.1)**	5–8	0.06–0.14
PVC	1 400	2.4–3.0	40–60	70	0.16
GRP: polyester	1 400–2 000	6–50	60–1000	10–30	0.2–0.4
Fired clay bricks	1 600–2 400	5–30*	5–100*	5–7	0.4–2.8
Concrete blocks	500–2 100	—	3–35*	8–12	0.1–2.3

* Compressive values.
** Modulus of rupture.

Note: All properties in table 1.1 are indicative of the probable range of values for each class of material. The mechanical properties (strength and E values) given are for short-term loading conditions. The properties of specific materials will be dependent on their composition, that is on the properties and proportions of their constituent materials, including moisture content. Their mechanical properties may additionally be dependent on their temperature and age and the rate of loading.

2. Metals

Atoms of chemical elements consist of a very dense and compact nucleus surrounded by electrons. The nucleus consists of two types of subatomic particles, protons and neutrons, each carrying a positive electrical charge. An electron has a negative electric charge of equal magnitude to the charge.

Orbiting electrons occupy separate concentric shells, or energy levels, around a nucleus, with electrons in the inner shells more tightly bound to the nucleus than those in the outer shell. The number of electrons in the outermost electron shell has a significant effect on the properties of an element. The outermost shell electrons responsible for the chemical reactivity of the elements are the valence electrons.

Interatomic bonds involving the interaction between valence electrons can be formed in a variety of ways, the three main types being covalent bonds, ionic bonds, and metallic bonds. These are called primary bonds and are relatively strong. In metals, atoms are connected to each other by metallic bonds. In addition, there are weaker secondary bonds that can exist between them.

All substances familiar to us, both solid and liquid, are made up of very large clusters of atoms, and the properties of these materials are partly due to the type of bond formed and the strength of the bonds.

2.1. Elastic deformation

The importance of metals as building materials is almost invariably related to their load-carrying capacity in tension, compression or shear and their ability to withstand limited deformation without fracture. The application of an external load causes a balancing force to be established within the material, and this internally acting force is called a stress. The stress acting on a material is defined as the force applied per unit area.

Normally accepted stress types are tensile, compressive and shear stresses; The previous two types are called direct stresses. When a material is in a state of stress, its dimensions will change. A tensile stress will cause the material to lengthen, while a compressive stress will shorten the material's length. A shear stress gives the material a bend. The dimensional change caused by a stress is called strain. In direct tension or compression, strain is the ratio of the change in length to the original length. As a ratio, it has no strain unit and is just a numerical value. In elastic behavior, the strain that occurs in a material is fully recovered as soon as the stress is removed when the material is subjected to a stress. In metallic materials, when the applied stress exceeds a critical level, elastic limit, or yield stress, the deformation behavior of the material changes from elasticity to plasticity (Table 2). The plastic strain is not recoverable and when the deforming stress is removed, only the elastic portion of the strain is recovered and the plastic strain, which is a permanent change in dimensions, remains in the material.

Table 2. Modulus and density values for some metals [2]

Metal	E ($kN\ mm^{-2}$)	Density ($kg\ m^{-3} \times 10^{-3}$)	Specific modulus ($Nm\ kg^{-1} \times 10^{-6}$)
Aluminium	70	2.7	25.9
Chromium	238	7.1	33.5
Cobalt	203	8.7	23.3
Copper	122	8.9	13.7
Iron	215	7.87	27.3
Magnesium	44	1.74	25.3
Nickel	208	8.9	23.4
Titanium	106	4.51	23.5
Zinc	92	7.14	12.9

2.2. Plastic deformation

When stretched to a level beyond the elastic limit, metals will stretch plastically. Some metals will begin to deform plastically at low stress values and will yield very significantly before fracture occurs. These are called ductile. Other metals and alloys show little plastic yielding before fracture and are called brittle materials.

2.3. Reinforcement mechanisms

Metallic materials used for structural work are not pure metals but alloys containing two or more elements. There will be various interacting effects that affect both the number of phases present and the temperature at which phase changes occur. These can be represented by means of a phase diagram, which is simply a map of a system and shows the phases that should be in equilibrium. Phase diagrams are important for understanding alloy systems because alloy structures and thus alloy properties will depend on the nature of the solid phase or phases formed.

Structural engineering materials need to be both hard and strong and also have a measure of ductility to avoid brittle fracture. The stiffness is directly related to the modulus of elasticity, E, and the cross-sectional shape of the element. The modulus of elasticity is an inherent property of a metal and is only marginally modified by machining operations or alloying. However, metals and their shear strength can be significantly altered by mechanical and heat treatments and the addition of alloying elements. Anything that disturbs the smoothness of the slip planes will complicate the movement of the dislocations and therefore increase the strength of the material.

Generally, an increase in strength will be accompanied by a decrease in ductility, but this is not always the case. The main methods of strengthening metals are strain hardening, solution strengthening and dispersion hardening. These methods can be used alone or in combination to produce strong materials.

2.4. Behavior in service

A material, component, or structure is considered to have failed when its ability to fully perform its original design function has ceased. This could be the result of a variety of reasons. Failure may result from partial or complete breakage, plastic buckling, dimensional change over time, loss of material due to corrosion, erosion or abrasive wear, or change in properties and properties over time.

These various failure modes can be due to stress, time, temperature, environment, or a combination of any of these. Most civil engineering structures need to have a long life and it is important for the designer to be aware of the possible modes of deterioration of materials and the effects of various stresses and environmental factors on behavior [2].

2.5. Failure by yielding

Metals show both elastic and plastic behavior. As the stress level increases, the amount of elastic strain also increases in direct proportion to the applied stress up to a certain limit, that is, the elastic limit. Permanent plastic yielding occurs when the elastic limit is exceeded. Many steels have a specific yield point indicated by a sharp discontinuity in a tensile-strain curve, but in most metals there is a gradual transition from elastic to plastic deformation modes. Some metals have low elastic limits and are highly ductile with significant plastic deformation before fracture. Most high-strength materials have high yield strengths and show little plastic deformation; slightly higher than the yield strength. In order to minimize the possibility of excessive deformation or failure by yielding in service, it is usual in design to limit the maximum stress under service load to yield or toughness strength divided by a factor of safety.

The tensile properties of metals can be determined with comparative ease in the laboratory, and the results of standard tensile tests are very useful to the designer.

2.6. Tensile test

There are standard procedures for tensile testing of metals and these are contained in BS EN 10002-1 with recommended dimensions for tensile test pieces.

2.7. Fatigue of metals

When a metal component or structure is subjected to repeated or cyclic stresses, it may eventually fail, even if the maximum stress in any stress cycle is significantly less than the breaking stress of the material. This type of failure is called fatigue failure. Failure due to fatigue is a fairly common occurrence. Components are subjected to varying or fluctuating loads throughout their service life. Fatigue failure is the result of crack nucleation and growth processes or only growth for components that may include cracks introduced during manufacturing.

2.8. Corrosion

Corrosion of metals can be broadly classified as dry corrosion and wet corrosion. Usually, the former is a direct reaction between the surface metal and atmospheric oxygen, while the latter involves a series of electrochemical reactions in the presence of an aqueous electrolyte. Direct oxidation is not a problem for most metals, except at high temperatures where oxidation rates are very high.

At normal temperatures, most metals have a low rate of oxidation and can often be protective when an oxide layer is formed. For example, aluminum and chromium have a high affinity for oxygen, but the oxide layer formed on the surface of the metal is compact and impermeable and provides protection by preventing more oxygen from reaching the metal. In the case of aluminum, the degree of protection can be improved by increasing the thickness of the aluminum oxide layer by anodizing, an electrolytic oxidation process. When an alloy steel contains more than 12 percent chromium, a continuous film of chromic oxide is formed that quickly covers the entire steel surface. Steels protected by a self-healing passive film containing more than 12% chromium chromic oxide is therefore corrosion resistant or stainless.

2.9. Corrosion protection

Corrosion can never be completely eliminated, but it is important to take all necessary steps to minimize the occurrence of corrosion. Therefore, it is vital to take adequate preventive measures and this means careful material selection, no direct contact of dissimilar metals, careful attention to design details to prevent cracks from forming and water pooling in parts of a structure. Many methods are used to minimize the risk of

corrosion and these can be grouped into the following categories: (a) protective coatings, (b) cathodic protection; and (c) use of inhibitors.

2.10.   Metallic materials in construction

It is customary to refer to two main categories of metals and alloys - ferrous and non-ferrous. The term iron covers iron and its alloys, while the other 70 or so metals are all classified as non-ferrous. The element iron occupies a very special position because of its availability, relatively low cost, and the wide range of very useful alloys obtained from alloying iron with carbon and other elements.

In fact, over 70 percent of total world metal consumption is in the form of steel and cast iron. Only a small number of non-ferrous metals are produced in large quantities. Although many metallic alloys have been developed for use in engineering, we can mention aluminum and its alloys, copper and its alloys, zinc and lead among the alloys used in the construction industry. (Lead is no longer used as it is harmful to health) [2].

2.11.   Steels

Steels are essentially alloys of iron and carbon, but they always contain other elements, either as impurities or as alloying elements. The iron obtained from the smelting of iron ore in the blast furnace is impure, and impurities in the blast furnace iron are removed by oxidation in steelmaking processes. At the end of the refining process, the melt will have only small amounts of carbon, silicon, manganese, sulfur and phosphorus, usually less than 0.05 percent each, but in a highly oxidized state. Except for low carbon rimming steels that are not used as structural material, liquid steel must be deoxidized. Silicon and manganese are often used as deoxidizers and are added in sufficient quantities to give the steel a residual content of these elements because they help provide increased strength. Aluminum, an element with a very high affinity for oxygen, is also used for the deoxidation of liquid steel, and this element promotes a fine-grained structure. Steels can be divided into plain carbon steels and alloy steels. While alloy elements cannot be included in plain carbon steels, alloy elements are more than 5% in high alloy steels [3, 4].

Fusion welding is used in steel construction and possible defects are checked by non-destructive inspection. Of course weld design and the weldability of the steels are important in steel construction (Figure 1). A good weld is one in which there is complete fusion of the filler with the base metal, the filler fully penetrates the joint gap, and is free of porosity, slag inclusions, and cracking. With the right choice of welding method and good welding practice, defects should not occur in the welds.
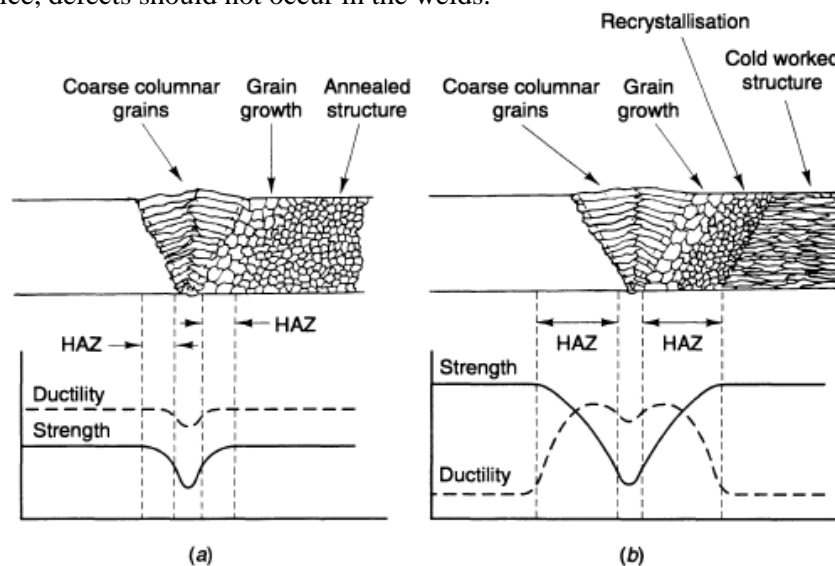

Figure 1. Variation of structure and properties across a weld in a single-phase metal: (a) annealed; (b) work hardened [2]

3.   Timber

Trees cover about 30 percent of the earth's land surface [5]. Timber as a building material has a long history, is probably still associated with stone as the oldest widely used building material, and is easily ranked first in world annual consumption [6]. The versatility of wood is part of its continued appeal. It can be processed

equally easily using simple hand tools. It is light but strong and sturdy, has excellent thermal insulation properties and is more fire resistant than steel or concrete, and has a warm and attractive appearance.

The variability of wood, derived from its natural origin, is both an advantage and a disadvantage. Whatever the requirement, it's probably worthwhile to have lumber to meet it, but one downside is that specifications vary from tree to tree, even for a single species.

3.1. Structure of wood

To use any structural material for optimum effect, it is necessary to understand its composition and structure, as these can have a major impact on the material's properties. For timber, this requires knowledge of the nature and growth patterns of trees, as the composition and structure of wood is driven by the needs of the growing tree rather than the needs of the timber user. With this information and the assessment of variations occurring between and within species, it should be possible to accurately identify the timber for any performance requirement.

All commercial woods can be divided into two broad groups: softwoods and hardwoods. When used for the first time in the Middle Ages, these terms could indicate the relative hardness, density, or ease of processing of the timber types commonly used at the time, possibly comparing, for example, imported spruce with natural oak [7]. However, nowadays, the terms hardwood and softwood are used. It is quite misleading: balsa is a hardwood but softer and less dense than any softwood, while pitch pine is a softwood that is harder and denser than many hardwoods.

The actual distinction between the two timber groups is botanical as follows:

1. Softwood is produced from gymnosperms, which are coniferous trees such as pine and spruce, with characteristic needle-like leaves. These trees are usually evergreen, but the group includes some species, such as larch, which loses all its needles in the fall.

2. Hardwood is produced from a group of angiosperms known as dicotyledons, which are broad-leaved trees such as oak, beech and ash. Warmth zone hardwoods are generally deciduous, while most tropical hardwoods retain their leaves all year.

3.2. Solid wood production

The conversion from living forest wood to the finished building section involves four basic processing steps: cutting, transforming, seasoning, and grading. First, logging is part of the entire forestry process [5]. Whether a log comes from a clear cut of a plantation crop with a mechanical harvester from the selected cut with a chainsaw in an old growth forest does not affect the quality of the timber. Quality can vary, but it's more about changing growing conditions and cutting age than cutting method. However, one aspect of forestry that interests all construction users is the importance of sourcing their timber from well-managed, sustainable sources.

3.3. Converting timber

Conversion is the term used to describe the processes in which the sawn trunk is cut into marketable sized timber. The vast majority of construction timber is converted. The log is first cut to the appropriate length in the log in the woods or mill and then the bark is removed, which gives a cleaner log for the saw and increases the value of the cuts that can be cut. The logs are then cut lengthwise into the required sections.

3.4. Wood's durability

Timber is biodegradable and the concept of timber's durability can therefore be seen as a contradiction. However, it must be recognized that, as with any structural material, degradation requires certain environmental conditions and even under these conditions different grades of material, meaning different species for timber, will degrade simultaneously. Some woods are naturally durable and can be long-lasting even in highly adverse conditions. Others are very susceptible to spoilage, but can still be used successfully provided they are treated in some way to increase their resistance to fungal rot and insect attack; these are the two most serious problems for timber in service. As with all materials, if a timber structure is to achieve its purpose, a proper assessment of the service environment must be made to select the design life and the most appropriate type or treatment. The design and, more importantly, the detailing must be carefully considered and implemented to avoid the building problems such as moisture traps and a planned maintenance program must be maintained throughout the life of the structure.

The chemical composition of timber includes not only the basic cell building blocks of cellulose and lignin, but also varying amounts of extractives. These are substances such as oils, gums, resins, tannins and other

phenolic compounds that accumulate in the heartwood of the growing tree, and due to their color, odor and toxicity, the durability of the timber. Since the content and composition of extractives vary by species, natural strength also varies. In the UK the durability of timber is evaluated from 50 mm square heartwood piles in contact with the ground. As with all timber characteristics, there is great variability even within species, and data from soil burial tests are therefore used to classify commonly used timbers into five broad categories. These categories range from perishable (speeds survive less than 5 years) to very durable (lasting more than 25 years). Very durable woods are all hardwoods and include greenheart, iroko, jarrah, opepe and teak. The best softwoods are western red cedar and pitch pine (surviving in contact with soil for 20-25 years), both of which achieve the hardy classification. Most softwoods, which make up the bulk of all timber used in construction, are classified as perishable (average survival of 5-10 years).

3.5. Properties of solid timber

The properties of the wood are important depending on the particular application considered. For some it may be durability, others may accentuate the appearance, but for structural applications the basic requirements are normally strength and deformation. While what makes the most attractive wood for decorative uses is a subjective aesthetic judgment and durability.

3.6. Density

The density of the solid cell wall material in wood is effectively constant regardless of the species, the usually stated value is 1500 kg m^{-3} [8]. The difference between this value and the densities of commercial timber species is below 400 kg m-3 for dry timber and above 1000 kg m^{-3} for hardwood Ekki [9] for softwood Sitka spruce. The variation from species to species due to the cellular structure of wood is mainly due to differences in the ratio of cell space (air) to the cell wall. However, even within a given species, there can be quite large variations in density between samples from different trees or even different parts of the same tree.

Differences in density from tree to tree are often the result of differences in growth rate under the influence of latitude, climate, soil conditions, or even a tree's location at the edge or inside of a forest. The effect of increased growth rate is to decrease density in softwoods and increase density in ring-pore hardwoods due to the increased amount of lighter early wood tracheids.

3.7. Strength properties

The strength of wood is affected by density and a wide variety of naturally occurring defects, and their consideration forms the basis of the grading system. It should also be noted that wood is anisotropic and its strength properties must be considered in relation to the loading direction with respect to the grain direction.

In addition to all the parameters previously described, timber strength is also affected by moisture content, application speed and loading time, and temperature. The effect of moisture content is known to be up to 50 percent less than dry strengths in flexural wet strengths.

The effect of moisture content on strength is generally thought to be related to the strengthening of secondary bonds between microfibrils in the cell walls as they approach each other due to the removal of intervening water during drying [8]. This is supported by the general pattern of the relationship between strength and moisture content, the fiber shows a gradual decrease in strength with the increase in moisture content up to the saturation point, after which the strength remains constant.

The strength properties of wood are normally evaluated by relatively short-term tests, typically on the order of five minutes to fracture. In reality, timber structures can experience load applications ranging from the very short term (wind gusts) to the long term (its own weight plus permanently applied load). Since timber is essentially a viscoelastic material, it undergoes increasing deformation under load with increasing load application time, the effect of which varies with the apparent strength, duration of the load. While the form of this curve has been criticized by [10], who suggested that it should be downwardly concave rather than upwardly concave for structural dimensions, the general agreement is that wood strength is time dependent.

The strength of wood is also affected by temperature; the overall effect is a linear decrease in strength with an increase in temperature. This effect is very dependent on moisture content, dry timber undergoes a much less reduction in strength per °C increase in temperature than wet timber [11], and the effect also varies with the particular strength characteristic considered.

3.8. Timber products

While solid wood is undoubtedly a successful building material, it is possible to point out some disadvantages. These include its natural anisotropy, the many inherent defects it is exposed to and reduce its strength, the

limited sizes (in cross-section and length) available commercially, and the difficulty of drying large sections even when present. A number of processed products are available that can, to some extent, overcome these defects; these are typically various sheet materials and glued-laminated structural members.

3.9. Sheet materials

The board, board or panel product range includes veneer and core plywood, particle board and particle board, and various fiberboards. The concept behind these products is that by rearranging the wood material in various ways, imperfections and anisotropy can be reduced or eliminated.

3.10. Glued laminated sections

Glue-lam sections are assembled from unaltered solid wood sections that are glued together to form a single structural element, unlike panel products, where the wood structure is disassembled and reassembled in various ways to improve properties. Usually the sections are laminated horizontally, that is, the glue lines are parallel to the neutral axis of the element, but vertical lamination is possible and the finished sections can be straight or curved.

4. Concrete

Concrete is a man-made composite whose main component is natural aggregate such as gravel, sand or crushed rock. Alternatively, artificial aggregates such as blast furnace slag, expanded clay, broken brick and steel shot can be used where appropriate. The other essential component of concrete is the binding medium used to bind the aggregate particles together to form a rigid composite material [12]. The most commonly used binding medium is the product formed as a result of the chemical reaction between cement and water. Other binder media are used on a much smaller scale for special concretes where the cement and water of normal concretes are wholly or partially replaced by epoxide or polyester resins. Known as resin-based or resin-added concretes, these polymer concretes respectively are costly and generally unsuitable for use where fire resistance properties are required, but are useful for repair work and other specialty applications. Resin-based concretes have been used, for example, for prefabricated chemical resistant pipes and lightweight drainage channels.

4.1. Component ingredients

Concrete is mainly composed of three materials, cement, water and aggregate, and an additional material, sometimes known as an admixture, is added to change some of its properties. Cement is the chemically active ingredient, but its reactivity is only activated when mixed with water. It takes part in chemical reactions, but its usefulness is due to the fact that it is an economical filling material that resists volume changes in the concrete after mixing and increases the durability of the concrete.

A typical structure of hardened concrete and the proportions of constituent materials encountered in most concrete mixes are shown in Figure 2. In a properly proportioned and compacted concrete, voids are usually less than 2 percent. The properties of concrete in its fresh and hardened state can vary greatly depending on the type, quality, and proportions of the components, and following the discussion, students should try to appreciate the importance of these properties of component materials influencing concrete behavior.
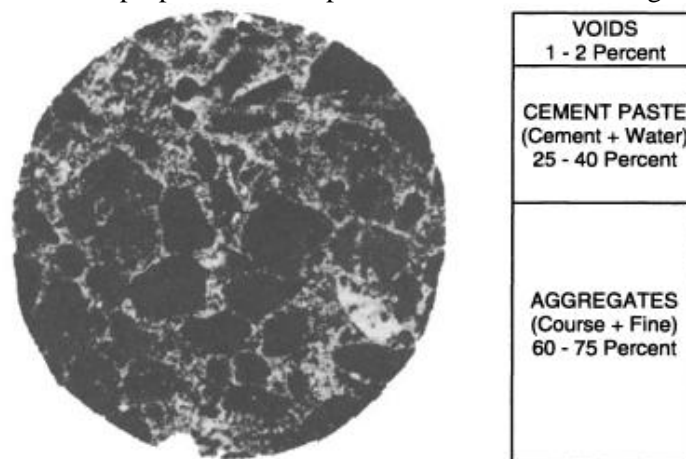

Figure 2. Composition of concrete [2]

The different cements used to make concrete are finely ground powders and the important feature of all is that when mixed with water, a chemical reaction (hydration) occurs, which creates a very hard and strong binding environment for the aggregate particles over time. In the early stages of hydration, while the cement mortar is in the plastic stage, it imparts cohesion to fresh concrete.

4.2. Properties of fresh concrete

Fresh concrete is a mixture of water, cement, aggregate and additives that can be used in certain situations to control rheology, setting and setting rate and durability. After mixing these components to achieve a homogeneous mixture, operations such as transporting, placing, compacting and finishing fresh concrete can all significantly affect the properties of the hardened concrete. It is important that the carrier materials remain homogeneously dispersed in the concrete mass at various stages of transportation and that full compaction is ensured. When any of these conditions are not met, the properties of the hardened concrete, such as strength and durability, are adversely affected.

The properties of fresh concrete that affect full compaction are its consistency, mobility and compressibility. In concrete practice these are often known collectively as workability. Concrete's ability to maintain its homogeneity is governed by its stability, which depends on its consistency and stickiness. The methods used for transporting, placing and consolidating concrete, as well as the nature of the mix and the part to be poured, may vary from job to job, followed by the relevant workability and stability requirements. Evaluating the suitability of fresh concrete for a particular job will always remain a matter of personal judgment to some extent.

4.3. Properties of hardened concrete

The properties of fresh concrete are important only in the first few hours of its history, whereas the properties of hardened concrete acquire a retained significance throughout the remaining life of the concrete. Important properties of hardened concrete; strength, deformation under load, durability, permeability and shrinkage. Generally, strength is considered the most important property, and the quality of concrete is often judged by its strength. However, there are many cases where other properties such as low permeability and low shrinkage are more important for water-retaining structures. Although in most cases an improvement in strength results in an improvement in another, there are exceptions to the properties of concrete. For example, increasing the cement content of a mix increases strength but results in higher shrinkage, which in extreme cases can adversely affect durability and permeability [2].

4.4. Strength

The strength of concrete is defined as the maximum load (tensile) it can bear. As the strength of concrete increases, its other properties generally improve, and because strength tests, especially in compression, are relatively simple to perform, concrete compressive strength is widely used in the construction industry for specification and quality control purposes. Concrete is a relatively brittle material that is relatively weak in tensile.

The compressive strength of concrete is taken as the maximum compressive load it can carry per unit area. Concrete strengths up to 80 N mm^{-2} can be achieved by selective use of cement type, mixing ratios, compaction methods and curing conditions.

4.5. Concrete durability

In addition to being able to withstand loads, concrete must also be durable throughout its service life. The durability of concrete can be defined as its resistance to deterioration processes that may occur between its environment (external) or its constituent materials or as a result of their reaction with pollutants. Generally speaking, premature deterioration is the result of physical or chemical events that occur on or within the concrete surface.

The quality of concrete in the near-surface or cover zone plays an important role in influencing concrete durability. This interfaces with the environment and provides the first line of defense against external physical and chemical attack and provides protection to embedded steel in the case of reinforced concrete or pre-stressed concrete. Ensuring concrete quality in this region and providing building materials with the necessary chemical resistance according to environmental conditions are critical factors in terms of ensuring concrete durability in buildings.

4.6. Permeability properties of concrete

Many processes that lead to concrete deterioration involve the introduction of aggressive liquids from the surrounding environment into the concrete, followed by physical or chemical processes that attack the concrete texture or reinforcement, often leading to the build-up of expansion forces and failure. Similarly, damage that occurs internally within concrete is mainly affected by moisture. Obviously, concrete's ability to limit these processes affects durability and degradation rate.

4.7. Concrete quality evaluation

Concrete structures may need to be tested in situ when data is needed to allow engineering decisions to be based on the condition of a structure. Also, testing can often accompany a building's change of ownership and is required to evaluate the structural capacity of concrete after fire damage.

4.8. Test program planning

The first step in any structural assessment should be to consider all available documented records from the time of construction, particularly concrete mix ratios, material sources, cube test results, and temperature and humidity at the time of casting. Obtaining such information can be difficult. For older buildings and such cases, although word of mouth information is highly unreliable and contradictory, people involved in the original design or construction can help.

Before designating or performing any tests, a thorough visual inspection of the structure must be completed to determine which areas need to be tested and to identify appropriate tests [13]. Difficulties with accessing the structure and hazards associated with certain test methods should also be evaluated at this time.

Consider current health and safety regulations. Many important concrete details regarding workmanship quality, structural integrity and material failure or shortage can also be determined at this stage. The main visual features that are indicative of specific problems are as follows:

1. separation/bleeding of shutter joints (mixture component problems);
2. plastic shrinkage cracking (mixture component problems);
3. honeycomb (low labor standards);
4. excessive bending or bending cracking (structural insufficiency);
5. deterioration of doors or windows (prolonged deviations caused by creep, thermal or structural movement);
6. surface cracking, chipping or staining (material deterioration due to reinforcement corrosion, sulfate attack, freezing action or alkali-aggregate reaction).

Information from these symptoms helps to choose the right type of test for further investigation. The inspection engineer should note the location, frequency, and severity of deviations, cracks, and surface defects such as splintering and discoloration, and evaluate potential difficulties in accessing for testing or repair. Therefore, it is important for the engineer to be able to identify the causes of different cracks, and it is important for the reader to refer to a publication by [14] for further guidance.

4.9. Concrete mix design and quality control

Concrete mix design can be defined as the procedure in which the proportions of component materials are selected so as to produce concrete with all the required properties at minimum cost for any given set of conditions. In this regard, the cost of any concrete includes, in addition to the materials themselves, the cost of mix design, hatching, mixing and placing the concrete.

Quality control primarily refers to the inspection carried out on site to ensure that the materials used in the production of concrete are of the required quality and that the specified mixing ratios are complied with as closely as possible with the available site possibilities. It also refers to the testing of controls to ensure that the properties of the concrete, both in the fresh and hardened state, conform to the design requirements, and to take the necessary corrective action when there are significant deviations from this. Compliance with concrete specification, or otherwise, analysis of the results of such tests depends on the specific contractual terms governing compliance. Different standards and codes of practice have slightly different requirements in this regard. The specific details of these and the different manufacturer and buyer risks associated with each are beyond the scope of this text.

Mix design, quality control, and the total cost of the finished concrete product are interlinked and this will become increasingly evident as factors influencing mix design are discussed.

5. Polymers

Polymers are now well established as one of the main classes of manufactured materials alongside metals and ceramics. A wide variety of such materials have been developed over the past three decades, based on about fifty separate synthetic polymers. They are widely used in industry and engineering. These materials have engineering properties very different from metals and ceramics, and a separate manufacturing and processing technology largely focused on molding, extrusion and fiber forming. The relatively low elastic modulus and allowable high stresses of many polymers often allow for a 'softer' approach to design and product fabrication. However, at the other extreme are high-performance polymer fibers that are tougher and stronger than steel wire.

Building construction is one of the main volume markets for polymers, taking about one-fifth of total production in the US and Western Europe. However, the use of polymers in civil engineering is less conspicuous because these materials generally do not directly compete with traditional load-bearing materials, structural metals, concrete and masonry. However, a number of polymers have important and established civil engineering uses. One of the simplest and most noticeable applications is in piping, where longer-established materials such as ductile iron, heavy clay and concrete face serious competition with various polymer materials. Polymers also play important supporting roles as surface coatings, membranes, adhesives and bonding compounds, roofing materials, coatings and thermal insulation. Fiber reinforced plastics have a limited role in lightweight structures. Also, new uses are emerging in various types of polymer concrete and textiles, both in fabric structures and in flooring engineering. Some polymer fibers are now used as a reinforcement for cementitious materials.

Table 3. The main polymer materials used in civil engineering [2]

Hydrocarbon polymers		
	PE	polyethylene
	PP	polypropylene
	PB	polybutylene
	NR	natural rubber
	PS	polystyrene
	IR	polyisoprene rubber
Other carbon chain polymers		
	PVC	poly(vinyl chloride)
	CPVC	chlorinated poly(vinyl chloride)
	PTFE	polytetrafluoroethylene
	PVDF	poly(vinylidene fluoride)
	PMMA	poly(methyl methacrylate), *acrylic*
	PAN	polyacrylonitrile
	PVAC	poly(vinyl acetate)
	CR	polychloroprene rubber, *neoprene*
	CM, CSM	chlorinated, chlorosulphonated polyethylene rubbers
Heterochain polymers		
	PA	polyamide, *nylon* (aromatic polyamide, *aramid*)
	PETP	poly(ethylene terephthalate), *polyester*
	PBTP	poly(butylene terephthalate)
	PC	polycarbonate
	POM	polyoxymethylene, *acetal*
	PPO	polyphenylene oxide
Network polymers		
	PF	phenol–formaldehyde resins
	UF	urea–formaldehyde resins
	MF	melamine–formaldehyde resins
	EP	epoxy (epoxide) resins
	UP	unsaturated polyester resins
	PUR	polyurethanes
Copolymers, alloys and hybrids		
	EPDM	ethylene–propylene–diene rubber
	ABS	acrylonitrile–butadiene–styrene copolymer
	NBR	acrylonitrile–butadiene rubber, *nitrile*
	SBR	styrene–butadiene rubber
	IIR	isobutene–isoprene rubber, *butyl*
	TPE	thermoplastic elastomer
	HIPS	high impact polystyrene
	FEP	fluorinated ethylene–propylene copolymer
	PPO/PS	poly(phenylene oxide)/polystyrene alloy

A polymer is a large molecule containing hundreds or thousands of atoms formed by joining one, two or sometimes more types of small molecules (monomers) in chain or network structures. Polymer materials are a group of carbon-containing (organic) materials with such macromolecular structures. Polyethylene, polystyrene and epoxy resins are well-known examples. Table 3 lists the major polymer materials used in civil engineering. The table contains internationally accepted standard abbreviations, the use of which greatly reduces the difficulties of polymer terminology.

Linear chain thermoplastics are divided into two main groups. First, there are those such as PE, PP, PA, PC, and PETP that are crystalline and are used well below or above glass transition temperatures. They are generally tough, versatile materials, and many have important uses as solid polymers, films, and fibers. Second, purely amorphous and used below glass transition temperatures. They are usually hard, transparent and brittle. Rubber-modified thermoplastics and most polymer alloys have two-phase microstructures, each with different physical properties (Figure 3). Alloys and blends are made from both crystalline and amorphous polymers.

Elastomers are network polymers based on linear chains above glass transition temperatures and are slightly crosslinked to improve rubber flexibility. Thermosets are densely cross-linked or random network polymers. Its mechanical properties are much less sensitive to temperature changes than thermos plastics or elastomers. They are generally hard and strong, but are often brittle and are widely used in fiber-reinforced composites, adhesives and surface coatings.
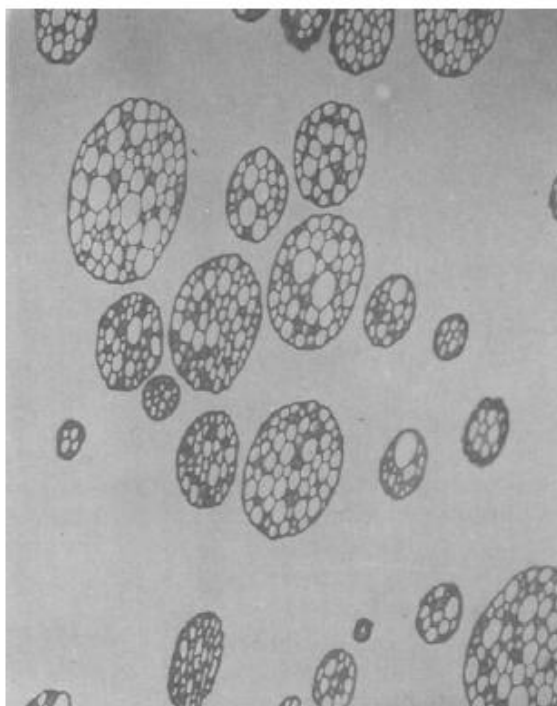

Figure 3. Rubber-modified high-impact polystyrene (HIPS): electron micrograph showing dispersed SBR elastomer particles, each about 2 μm in diameter, in a PS matrix [2]

5.1. Polymerization reactions

The polymerization reactions with which solid thermoplastics are produced are often special topics for chemists and chemical engineers. These materials are produced by the polymer sector of the petrochemical industry from hydrocarbon raw materials away from the processor and the consumer.

On the other hand, the reactions in which thermoset resins (and adhesives, surface coatings and composites based on them) cure are somewhat important to the civil engineer. The polymerization of these materials should be postponed to the final stages of fabrication or construction and therefore may occur in the workshop or in the field.

The chemistry of these reactions is complex; in most cases, the precursor to the final polymer material is provided in the form of a liquid resin. The polymerization is usually completed by the addition of one or more reactive chemicals known as catalysts, hardeners, or hardeners.

5.2. Properties of polymer materials

Civil engineer is mainly concerned with mechanical properties and physicochemical properties that determine durability. Electrical and optical properties are usually much less important.

5.3. Density

Polymers are materials composed mostly of light elements, and solid polymers have low densities. Polymethylpentene (830 kg m^{-3}) and polypropylene (PP) (905 kg m^{-3}) have the lowest densities of commercial solid polymers; The density of PTFE is abnormally high (2150 kg m^{-3}), due to its high fluorine content. By comparison, the densities of steels are about 7900 kg m^{-3}. Where appropriate, a comparison of the mechanical properties of Polymers with other material classes can be made for the large density factor.

5.4. Mechanical behavior of polymers

Because one grade polymer materials exhibit a wide range of mechanical properties, and the mechanical response in a single material can vary significantly over a relatively small temperature range.
Some polymers (amorphous thermoplastics and thermosets) are hard materials and fail with brittle fracture at relatively small stresses (2 to 5 percent) (Figure 4). They show a reasonably elastic response to stresses below failure stress.
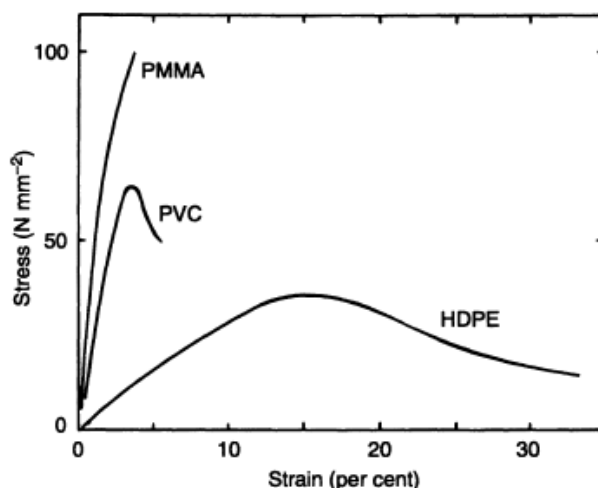

Figure 4. Conventional short-term stress-strain curves of three polymer materials [2]

Crystalline thermoplastics are harder; they have lower elastic modulus and higher breaking stresses. The stress-strain curve may or may not have a well-defined yield point. With increasing temperature, the modulus decreases and there is a fairly well-defined melting temperature at which the polymer is a viscous liquid. At lower temperatures, materials are harder and eventually become brittle.
Elastomers exhibit uniquely low tensile and shear modulus and can support very large stresses (up to 500 percent) fully recoverable. Crosslinking greatly inhibits viscous flow, but at low temperatures elasticity can become heavier and delayed.

5.5. Toxicity

Some organic monomers from which polymers are synthesized are considered toxic and strict controls are applied to the use of these substances. Residual levels of free monomers in thermoplastics are usually extremely low and these materials are not normally considered hazardous. However, if exposed to abnormally high temperatures, partial pyrolytic decomposition may occur which releases monomers or other volatile and toxic substances. There is no doubt that polymer materials contribute to rapid toxic gas production in the early stages of building fires.
Non-polymerized materials should be used with extreme caution. Materials in this category include thermosets, epoxy and polyester compounds for adhesives and coatings, acrylamide mortars for chemical soil stabilization, and formaldehyde for PF and UF foams.
Other toxicity problems arise with some polymer additives and additives allowed in formulations for contact with drinking water must be strictly controlled.

5.6. Polymers in civil engineering

This section discusses the main uses of polymers in civil engineering from a materials expert's point of view. The large components of unreinforced solid polymers, with the exception of pipe, are unusual due to the relatively low stiffness of these materials. PMMA, PVC and PC are used for glazing, roofing and cladding panels where loads are generally low and component stiffness is achieved by vacuum forming or adding webs, ribs or pleats to a domed profile. PP and PE tanks are produced up to a few meters. Innovative uses of thermoplastics benefit from extrusions or molds of complex shapes, including numerous building components, from window frames to reinforcement spacers.

Glass-reinforced plastics, general polyesters, more commonly used for large tanks, ducts and building panels [15], the latter is usually sandwich structure with a polyurethane or other cellular polymer core. In all applications of structural plastics, fire performance is paramount.

5.7. Ropes, gratings and rebars for structural concrete

A potentially important structural application of high-performance polymers is the use of continuous fibers as structural reinforcement and prestress tendons. Aramid and carbon fiber have hardness and strength comparable to conventional steel materials and are beginning to find valuable applications where steel is subject to corrosion. Figure 5 compares the mechanical properties of such systems and shows that the polymer element can act in a fully load-bearing manner. A number of approaches are currently being developed [16]. These include various combinations of polymer and non-polymer fiber and polymer matrix. Among them:

(1) using unbonded aramid fiber bundles as prestress tendons;

(2) the use of aramid, carbon or glass fiber bonded to epoxy resin matrix and pultrusion treated solid rods to form a polymer version of a rebar;

(3) the use of epoxy-bonded carbon, glass and aramid fibers to form two- and three-dimensional grids.

In addition, polymers can also be used in other applications in civil engineering such as; pipes, polymer membranes, coatings, adhesives and polymer concretes.
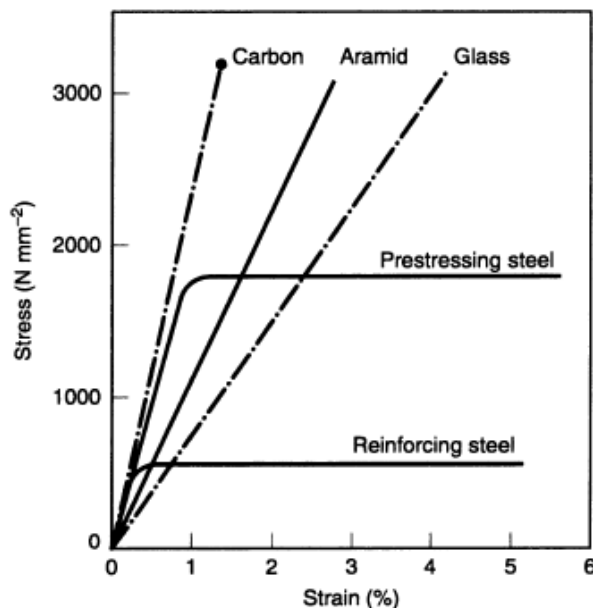

Figure 5. Stress-strain relations for engineering fibers and reinforcements [2]

5.8. Polymer concretes

Polymers can be combined with concrete in various ways to change the properties of concrete, especially to increase its strength and decrease its permeability, thereby increasing durability. On the other hand, polymer cement concrete (PCC) is produced by mixing organic and inorganic components during hydration. The organic component can be polymerized during curing of the cement as a polymer emulsion, a monomer dispersion or a resin/hardener dispersion.

In general, polymer impregnated concrete (PIC) has superior properties because the pore system in the concrete is more or less completely filled by the polymeric impregnation agent. However, PIC production requires more elaborate facilities and currently has little regular use. PCCs show reduced permeability and may have somewhat increased potency. Changes in the properties of fresh wet material are equally important:

changes in flow and slump and better adhesion to old concrete. Industrial flooring, concrete repair and grouting are prominent uses. Polymeric MF additives are used as superplasticizers for high strength or high slump concrete. Polymers are also added to concrete in the form of fibers. Chopped fibrillated PP improves impact resistance, and high modulus aramid fibers and carbon fibers are mainly used as reinforcement to some extent, to achieve better load distribution and increase toughness. The fibers used are typically about 25 mm long.

6. Bricks and block

Bricks and blocks differ in this respect as they always have an approximately cubic shape, and indeed the words brick and block are associated in many minds with a shape rather than a material. However, it is important to examine the material properties because they are widely used in the construction industry.

Largely mechanized processes are used in the brick and block making industries today, but clay bricks are still made by hand in many parts of the world.

Clay, calcium silicate and concrete products all include both bricks and blocks, the difference between the two is mainly in one size and the blocks are larger than bricks. Clay and calcium silicate bricks and concrete blocks, whose production and properties are discussed here, are the most commonly used form for each material in this context.

All bricks and blocks have similar uses in general, although their properties differ in some important respects depending on the raw materials used and the method of manufacture. Understanding these properties is crucial for the effective use of bricks and blocks, as these properties have a significant impact on the actions that must be taken to ensure the proper implementation of each product and its satisfactory behavior in service.

6.1. Calcium silicate brick

The raw materials used in the production of calcium silicate bricks are siliceous aggregate, high calcium lime and water. Generally, a very fine aggregate is used, most of which passes through a 1.15 mm sieve, the ratio of aggregate to lime by weight is between 10 and 20. When different colored bricks are required, inert and stable inorganic pigments are also added. The materials are first thoroughly mixed in the required proportions and then transported in an automatic press where they are molded to the required size and shape. At normal temperatures, slaked lime does not harden when mixed with water, unlike Portland cement, and therefore dry mixes and high molding pressures are required to ensure that newly molded bricks have enough strength to allow immediate use without damage.

From the press, the bricks are transferred to an autoclave; wherein high pressure steam curing for several hours produces an aqueous calcium silicate (Tobermorite) as the lime combines with some of the silica aggregate, which creates the binder medium.

6.2. Properties of calcium silicate brick

The size, strength and drying shrinkage of calcium silicate brick are among the specifications specified in BS 187. Some of these and other features are discussed here.

6.3. Size

Standard brick dimensions are 215 X 102.5 X 65 mm, these are the length, thickness and height of the brick, respectively. Not commonly used metric modular sizes are 190 X 90 X 90 or 65 mm and 290 X 90 X 90 or 65 mm.

6.4. Absorption

The water absorption of calcium silicate brick ranges from about 6 to 16 percent by weight.

6.5. Density

This ranges from about 1700 kg m^{-3} to 2100 kg m^{-3} depending on the composition of the brick and the manufacturer. Where the brick density using a particular brick is critical, for example for soundproofing, this information should be obtained from the manufacturer.

6.6. Strength

Compressive strength is the general criterion for brick, but as with other engineering materials, the strength of calcium silicate brick is not a property that can be determined without fully recognizing the strength

variability between nominally identical brick samples. Typically, the average range of compressive strengths for bricks in general use is 14-27.5 N mm^{-2}, depending on the quality of the brick produced, although strengths greater than 48.5 N mm^{-2} can be obtained by some manufacturers.

6.7. Drying shrinkage

Calcium silicate brick shrinks when dry in a similar way to concrete products, but the magnitude of this drying shrinkage is 0.01-0.04 percent, about half that associated with the latter.

6.8. Modulus of elasticity

The modulus of elasticity of the calcium silicate brick is related to the compressive strength, with values generally in the range of 14-18 kN mm^{-2}.

6.9. Concrete block components

The materials needed to make concrete blocks are a hydraulic binder, water and aggregate, and only in the case of aerated concrete blocks, a reactive foaming agent to create their characteristic cellular structure. Additives and/or additives are also sometimes used to expand the product range.

The binder is Portland cement, either alone or mixed with lime, pulverized fuel ash, or ground powdered smoke slag. Portland cement is generally N or R class; others are used only when specific applications require special features. A wide range of aggregates are used; They may be of the dense or light type, normally not exceeding 10 mm in maximum size. The most common additives are pigments used to impart different colors; Additives such as retarders, accelerators and water reducing agents are used to facilitate block manufacturing processes or to impart certain special properties to the finished product.

6.10. Manufacturing of aggregate concrete block

The manufacturing process involves compacting the newly mixed component materials (binder, water and aggregate) in a mold and then immediately extruding the pressed block so that the mold can be used repeatedly.

Because the finished blocks must be self-supporting and able to withstand any movement and vibration from the moment they are extruded, much drier, higher fine aggregate content and weaker mixes are used than in normal concrete work.

The two basic types of block making machines commonly used are known as spawning and static machines. In the first case, the blocks are produced directly on a horizontal surface while the machine is moving; The blocks are left in this position to harden sufficiently before being stacked for final air curing for up to 28 days, depending on climatic conditions. In the latter case, the blocks are stamped and either deposited directly onto the pallets or manually loaded onto pallets, which are immediately transferred to the curing chambers where the blocks are normally steam-cured at atmospheric temperature. It is held under pressure for about 12 hours and then stacked outside for final curing, usually until 7 days old. Autoclaving is sometimes used, in which case the blocks are ready for use immediately after they are removed from the curing chamber.

6.11. Brick and block works

The individual bricks and blocks when combined with mortar are collectively referred to as brick and block work or alternatively brick and block masonry.
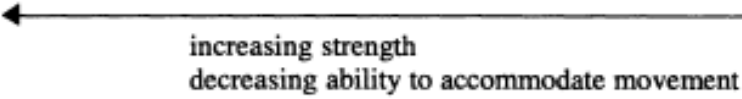
6.12. Mortars

Typical mortars used in both brick and block works are given in Table 4. Relevant standards are BS 12, BS 146, BS 890, BS1199, BS1200, BS 4027, BS 4248 and BS 4887.

Masonry cement contains Portland cement, a very fine mixture of mineral fillers and an air entraining agent, and it is the plasticizing effects of the filler and entrained air that give masonry cement mortars their exceptionally good working qualities.

Sand-cement mortars with an air-entraining agent (mortar softener) have both improved running properties and greater resistance to damage from the freezing effect due to the presence of entrained air.

Table 4. Recommended mortar mixes [2]

Type of mortar	Mix proportions by volume			
Cement : lime : sand	$1:0$ to $\frac{1}{4}:3$	$1:\frac{1}{2}:4$ to $4\frac{1}{2}$	$1:1:5$ to 6	$1:2:8$ to 9
Masonry cement : sand	–	$1:2\frac{1}{2}$ to $3\frac{1}{2}$	$1:4$ to 5	$1:5\frac{1}{2}$ to $6\frac{1}{2}$
Cement : sand with plasticiser	–	$1:3$ to 4	$1:5$ to 6	$1:7$ to 8
Mortar designation	(i)	(ii)	(iii)	(iv)

← increasing strength
decreasing ability to accommodate movement

The mixing ratios shown in a single mortar definition for different mortar types in Table 4 will generally yield mortars with similar compressive strengths, but especially for higher strength mortars, those containing entrained air will tend to have lower strengths than their equivalent. cement-lime-sand mortars. Although mortar definitions are primarily related to mortar strength, mortar strength is the most important consideration in mortar selection, only applicable to heavily loaded bricks in load-bearing structures. Due to the tendency of air-entrained mortars to have slightly lower strength than cement-lime-sand mortars, their use in calculated load-bearing masonry is normally only permitted when a high degree of quality control has been exercised and full information provided. their strength properties are available.

More generally, the definition of mortar and the choice of mortar type will be mainly influenced by durability requirements. Cement-sand mortars with plasticizers, masonry cement mortars and cement-lime-sand mortars, respectively, have a reduced resistance to damage from freezing and have increasingly improved bonding properties and therefore resistance to rain penetration from the mortar joints in the masonry. Generally recommended mortars are weaker than the bricks or blocks they are associated with. This is desirable so that minor movements associated with humidity and temperature changes, as well as the differential settlement of foundations normally expected, can be accommodated within the mortar joints.

6.13. Applications of brick and block works

Today, masonry is mainly used for non-bearing and load-bearing walls; the difference between them is that the latter carries vertical roof and/or floor loads, as in cross wall construction, while the former carries only its own weight. Both can be subjected to wind load. Masonry can be prestressed, reinforced or unreinforced, and many applications include retaining walls, parapets and sewer work.

The selection and construction method of a particular brick or block type for a particular application will largely depend on the brick or block construction characteristics involved. These properties relate to the properties of its components, namely the individual bricks or blocks (units) and the mortar used to bind the units together.

7. Conclusions

Traditional construction materials, such as timber, steel, asphalt and cement concrete are often used in many construction projects. Modern materials, such as polymers and composites are making headway into the construction industry. The following conclusions can be drawn from the present investigation:

a. Materials from two main metal and alloy categories, ferrous and non-ferrous, are used in construction. While iron and steel are commonly used from ferrous materials, aluminum and its alloys, copper and its alloys and zinc can be counted from non-ferrous materials. (Lead is no longer used because it is harmful to health).

b. Timber as a building material has been used for a long time. The versatility of wood is part of its continued appeal. It can be processed with equal ease using simple hand tools. It is light but strong and sturdy, has excellent thermal insulation properties and is more fire resistant than steel or concrete and has a warm and attractive appearance.

c. Concrete is a man-made composite whose main component is natural aggregate such as gravel, sand or crushed rock. Alternatively, artificial aggregates such as blast furnace slag, expanded clay, broken brick and steel shot can be used where appropriate. The other essential component of concrete is the binding medium used to bind the aggregate particles together to form a rigid composite material. The

most commonly used binding medium is the product formed as a result of the chemical reaction between cement and water.

d. Polymers are widely used in industry and engineering. However, the use of polymers in civil engineering is less remarkable because these materials often do not directly compete with traditional load-bearing materials, structural metals, concrete and masonry. However, a number of polymers have important and established civil engineering uses. One of the simplest and most remarkable applications is in pipes, where more established materials such as ductile iron, heavy clay and concrete face serious competition with various polymer materials. Polymers also play important supporting roles as surface coatings, membranes, adhesives and bonding compounds, roofing materials, coatings and thermal insulation.

e. Polymers can be combined with concrete in various ways to change the properties of concrete, in particular to increase its strength and decrease its permeability, thereby increasing durability. On the other hand, polymer cement concrete (PCC) is produced by mixing organic and inorganic components during hydration. The organic component may be polymerized during curing of the cement as a polymer emulsion, a monomer dispersion or a resin/hardener dispersion.

f. Bricks and blocks differ in this respect as they always have an approximately cubic shape, and indeed the words brick and block are associated in many minds with a shape rather than a material. However, it is important to examine the material properties as it is widely used in the construction industry. Today, the brick and block making industries use largely mechanized processes, but clay bricks are still made by hand in many parts of the world.

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