Green Building Handbook for South Africa

Chapter: Materials

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The construction industry is a multi-billion dollar industry, and the production and harvesting of raw materials for building purposes occurs on a world-wide scale. Environmental issues are becoming a major world topic, and the construction industry is increasingly its environmental performance is coming under close scrutiny particularly with regard to the availability and sustainability of certain materials, and the extraction of the large qualities needed to meet the needs and aspirations of the global community.

The construction industry is a significant consumer of materials, using 50 per cent of all products produced globally[1]. Building material is any material which is used for a construction purpose. Many of these materials are sourced from natural occurring substances such as clay, sand, wood and rocks. Other materials are man-made products, some more and some less synthetic.

Natural materials

Building materials can be generally categorised into two sources, natural and synthetic. Natural building materials are those that are unprocessed or require minimal processing by an industry, such as timber or glass.

Mud and clay

The amount of mud and clay used leads to different construction approaches to building with the quality of the soil used being the determining factor. A high clay content generally results in the adobe style of building, while low clay soils result in building with sods. Ingredients may be added to mud and clay and these generally include sand and gravel, and straw and grass.

Rammed earth walls may be a combination of the above, and the mixture can either be compressed by hand, or by mechanical pneumatic compressors.

Wattle and daub is a method of wall construction whereby wattles made of vertical timber stakes are interwoven with horizontal branches and daubed with clay.

Mud and clay are good thermal mass materials and maintain temperatures at a constant level. Clay holds heat or cold, releasing it over a period of time, much like stone. Earthen walls will thus require more heat to warm up, but will retain the heat (or coolness) longer.

Stone

Stone has been used as a building material from the earliest of times as it is generally readily available, and is extremely long lasting. Circular huts were constructed from loose granite rocks throughout the Neolithic and Early Bronze Age, and the remains of an estimated 5,000 can still be seen today. Some civilizations are known for their stone buildings, including the Egyptians, Aztecs and Inca's.

As stone is a very dense material it requires intensive heating to become warm. Rocks were generally stacked dry but mud, and later cement, can be used as a mortar to hold the rocks together.

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[1] Edwards, B., (2002). *Rough guide to sustainability*, RIBA, London.

Granite is still used extensively today, as is slate. The compressive strength of stone may sometimes be important, but most stones used in buildings are understressed. The weakest sandstones can carry 1,290 tons/sq.m while some granites can support 8,600 tons/sq.m[2].

Other important factors that guide stone selection are appearance, which may be the overriding consideration where colour, texture, patterning, and grain are important, and weight.

Thatch

Thatch is also one of the oldest materials used in construction, especially in Africa. Grass is a goof insulator, and is easily harvested, making it one of the truly renewable materials that can be used in buildings. In many parts of the world grass is also used as a roofing material.

Wood

Wood is a generic building material and is used for building just about any structure in most climates. Wood is a product of fibrous plants and trees and is used as a construction material when cut or pressed into timber such as boards, planks and similar materials. Wood is also a truly renewable material, although the rate of harvesting is threatening the continued existence of certain species.

Wood can be very flexible under loads, keeping strength while bending, and is strong in compression. Historically wood for building structures was used as unprocessed logs, cut to the required length and notched into place. The development of tools, and during the industrial age, mechanised tools, enabled the logs to be cut into varying dimensions, resulting in easier and quicker construction[3].

The gluing of strips of wood yielded even stronger timber sections (laminated beams and boards) and the compression of wood dust and chips with a binding agent (glue) produced compressed boards of greater strength and in greater lengths and widths than would otherwise be possible.

Brick and Block

Brick is a block made of a kiln-fired material, usually clay or shale, but also may be of lower quality mud. Clay bricks are formed in a mould – the soft mud method – or in a commercially manufactured process using an extrusion method and wire cutters. Kilns were traditionally fired by the burning of timber or straw, and later from the use of electricity. More recently brick makers have been switching to gas-fired kilns to reduce their dependence on electricity, and to reduce their carbon emissions.

Bricks were used in some of the earliest known cities, going back some 5,000 years ago. More recently, blocks are being made from cement rather than clay, and in some instances, fly ash or bottom ash – a waste material from coal-fired power stations.

Concrete

The invention of concrete is generally associated with the Romans who revolutionized building by its use.

Concrete is a composite building material made from a combination of aggregates and a binder such as cement. The most common form of concrete is Portland cement concrete, consisting of mineral aggregate such as stones, gravel and sand, Portland

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[2] Guedes, P., (1979). *The Macmillan Encyclopaedia of Architecture and Technology*, The Macmillan Press, London.

[3] Guedes, P., (1979). The Macmillan Encyclopaedia of Architecture and Technological Change, The Macmillan Press, London.

cement and water. The cement hydrates after mixing and hardens into a stone-like material. Concrete has a low tensile strength and is generally strengthened by the addition of steel reinforcing bars: this is commonly referred to as reinforced concrete. Research is underway to supplement the bars with steel fibres, preferably obtained from recycled steel. Fly ash and bottom ash can also be added to concrete to reduce the cement content, and thereby to reduce the carbon dioxide emissions.

In the early part of the 20th Century research was carried out by Stussi and Whitney[4], among others, on the properties of reinforced concrete under load. This led to the evolution of ultimate load theory by which it was possible to design beams and other structural elements in which the steel and the concrete would begin to fail together at the same load. High-tensile steels became available, capable of taking up many times the tensile stresses permitted for mild steel, but even with special precautions it was difficult to control the cracks that develop with concrete under heavy loading. Since 1945 there have been significant strides made in the concrete-mix design, making it possible to achieve much higher compressive strengths.

Aggregates can be used to give concrete special properties: lightweight aggregates made from foamed blast-furnace slag, expanded clay, sintered pulverized fuel ash, and pumice, can reduce the weight of concrete and increase their thermal insulation. No-fines concrete, which uses specially graded aggregates without employing sand in the mix, makes it possible to use less cement and very much lighter formwork comprised of frames supporting wire mesh panels. Aerated concrete, made by including additives which evolve gases during setting, are useful for blocks and other building elements where good insulating properties are required[5].

Concrete is the predominant building material of our age due to its plasticity, longevity, formability, and ease of transport.

Metal

Metal is most often used as a structural frame for larger structures, such as skyscrapers. There are various types of metals: steel is a metal alloy whose major component is iron, and is the general choice for metal structural building materials.

The properties of steel can be carefully controlled: it can be made highly elastic and ductile, or it can be made of great hardness and durability. Steel is strong, flexible, and durable, especially if corrosion is dealt with adequately. Developments in metallurgy and structural theory have imposed stricter demands on the performance of iron and steel alloys, and have led to advances in structural design; special high-tensile steels are available which have a permissible tensile stress much higher than normal mild steel[6].

Stainless steel was developed accidently in 1912. This alloy, which does not corrode, normally contains about 10-14% chromium. Other steel alloys such as “Weathering,” also known as “Cor-ten,” have been adopted for their special properties. “Cor-ten”, which is a copper-steel alloy, develops a tenacious oxide coating which obviates the necessity of painting. Steel may also be stove-enamelled, which gives a resistant and smooth vitreous coating which can be readily cleaned.

Aluminium alloys and tin have better corrosion resistance and have a lower density which overcomes their greater cost. Brass and copper were used quite extensively in the past but is now generally restricted to specific uses or speciality items.

Other metals include titanium, chrome, gold and silver. Titanium can be used for structural purposes but is far more expensive than steel.

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[4] Guedes, P., (1979). *The Macmillan Encyclopaedia of Architecture and Technological Change*, The Macmillan Press, London.
[5] Ibid.
[6] Ibid.

Glass

The manufacture of glass is of considerable age, having been invented about 2000 BC. Glass has been used since Roman times to cover openings in buildings: development in glass technology have enabled the size of the openings to become progressively larger to the extent that glass can now be a ‘curtain’ wall that covers the entire façade or roof of a building.

Glass is generally made from mixtures of sand and silicates, but is unfortunately very brittle.

Plate glass was first made in Britain in 1773 although it only became truly commercialised by the mid-1800s. Glass bricks and blocks appeared at the turn of the 20th century, and became part of the signature of the modern movement in architecture. In the 1900s Germany began making what was referred to as “glass silk”, or glass fibre, now used extensively for thermal, acoustic, and electrical insulation. It can be produced as a “wool,” or it may be woven into a fabric[7].

Toughened or annealed glass is a 20th-century product which greatly extended the range of uses to which glass can be put. Laminated glass is another form that is resistant to breakage: two sheets are cemented with an interlayer of polyvinyl butyral[8].

Suspended assemblies of toughened glass have made it possible to glaze very large apertures in buildings without the use of frames or glazing bars. In this application the glass is stiffened by glass fins that are fixed to the frame of the building, and the gaps between the sheets are filled with a transparent polysulfide or silicone sealing compound.

Special types of glass have also been manufactured for glass-clad buildings in order to improve the indoor environment, and to reduce the costs of HVAC. Solar control glass is specially manufactured to reduce solar heat gain either by absorption, re-radiation, or by reflection, while still allowing a high proportion of visible light to be transmitted. Photosensitive glass is also possible where the glass changes its transparency with the amount of light falling on it.

Double glazing, with clear or tinted glass, can reduce energy costs considerably by increasing insulation. Factory-sealed, double-glazed windows are manufactured in many forms, either with the edges closed, by the lanes being fused together, or by the use of another material as a separator[9].

Ceramics

Ceramics are used extensively for tiles and other fixtures. Ceramics used to be a specialised form of clay-pottery firing in kilns, but it has evolved into more technical areas.

Synthetic materials

Plastic

The term plastic covers a range of synthetic or semi-synthetic organic condensation or polymerization products that can be moulded or extruded into objects, films or fibres. The name is derived from malleable nature when in a semi-liquid state.

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[7] Guedes, P., (1979). *The Macmillan Encyclopaedia of Architecture and Technological Change*, The Macmillan Press, London.
[8] Ibid.
[9] Ibid.

Plastics vary immensely in heat tolerance, hardness, and resiliency. Combined with this adaptability, their general uniformity of composition and lightness of plastics ensures their use in almost all industrial applications.

Foam

Recently synthetic polystyrene or polyurethane foam has been sued in a limited scale. It is lightweight, easily shaped and excellent insulator. It is generally included as part of a structurally insulated panel (SIP) where the foam is sandwiched between external skins of steel, wood or cement.

Cement composites

Cement bonded composites are an important class of building materials. These products are made of hydrated cement paste that binds wood or alike particles or fibres to make pre-cast building components. Fibrous materials including paper and fibreglass are used as binders.

Wood and natural fibres are composed of various soluble organic compounds like carbohydrates, glycosides and phenolics. Those compounds are known to retard cement setting. It is therefore necessary to assess the compatibility of a wood with cement bonded composites. Wood-cement compatibility is the ratio of a parameter related to the property of a wood-cement composite to that of a neat cement paste. The compatibility is often expressed as a percentage value. To determine wood-cement compatibility, methods based on different properties are used, such as hydration characteristics, strength, interfacial bond and morphology[10]

Natural fibre composites

As stated above, composite building materials have been used by mankind for their housing and building needs for centuries. These composites were based on timber, bamboo, jute and a large variety of vegetable fibres such as reinforced mud-blocks for walls, panels for partitioning and roofing.

With the development of cast iron and steel in the Industrial Period construction products underwent a significant transformation in materials science and technology. The focus on the behaviour of metals and other alloys sparked an interest in metallurgy and materials engineering resulting the use of a multitude of metal composites in complex structures.

Later developments lead to the discovery of very stiff fibres such as glass, carbon, boron and more lately Kevlar and enabled the use of several high performance composites with matrices of synthetic resins such as polyesters, phenolics and epoxies in applications as diverse as aircraft, space ships, machine tools, electronics and biomedical materials.

The more recent search for stronger and stiffer fibres and the desire to utilise widespread organic by-products have enabled the production and use of vegetable fibres, such as coir, banana, sunhemp, jute, sisal, etc., as quite inexpensive and effective reinforcing fibres, and organic binders as an alternative to cements.

There can be little doubt that research and development in this field will lead to a new generation of building materials that will substantially reduce the environmental burden of resource consumption by the construction industry while yielding materials that are lighter, stronger, stiffer, and more adaptable to numerous applications.

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[10] Karade, S., Irle, M., and Maher, K., 2003. *Assessment of wood-cement compatibility: A new approach*. Holzforschung, 57:672-680.