Clay Building Materials

Introduction

Stone and clay are among the oldest of building materials. The use of stone in particular dates back to prehistoric times and many ancient civilisations have appreciated the properties of stone and developed the art of using it. Lack of timber or other materials sometimes forced the use of stone and in other cases, stone was the preferred material because of certain superior properties such as durability or prestige. The natural enduring appearance of stone and its abundance have ensured its continued use as a building material to modern times.

Similarly, clay has endured as a building material and even in early times its use was widespread (e.g. bricks, tiles, pipes and accessories). The shaping of plastic clay and then hardening it by drying and firing, was perhaps humanity’s earliest form of manufacturing but it was not until the late nineteenth century that machines became involved in the manufacturing process.
Clay

Clays are natural materials made up of very small crystalline mineral fragments. The shape, size and type of these fragments give clays their plastic quality which allows them to be moulded and shaped when wet. These mineral fragments are also responsible for the hard, stony nature of clays after they are fired at high temperatures.

Clay products

When clay has been changed by heat (firing), the products are called ceramics. During firing, water is driven off, some recrystallisation of minerals takes place, and glass is formed from quartz sand present in the clay. The result is a hard, insoluble material. The higher the firing temperature, the more recrystallisation occurs and the more glass is formed, resulting in greater hardness and density.

The minerals present in the clay will determine its colour when fired. Ceramics are also coloured by having a specially prepared coating, or slip, applied before firing, which results in a glaze of the required colour or texture.

Different products require different firing temperatures, as shown in Table 1. As temperature may vary, the figures given are only approximate.

<table>
<thead>
<tr>
<th>Ceramic</th>
<th>Approximate firing temperature (°C)</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcelain</td>
<td>1350</td>
<td>electrical insulators</td>
</tr>
<tr>
<td>Vitreous china</td>
<td></td>
<td>sanitary appliances</td>
</tr>
<tr>
<td>Earthenware</td>
<td></td>
<td>glazes; tiles (for internal walls); some sanitary appliances</td>
</tr>
<tr>
<td>Stoneware</td>
<td></td>
<td>drainpipes and fittings</td>
</tr>
<tr>
<td>Fireclay</td>
<td></td>
<td>firebricks; flue liners</td>
</tr>
<tr>
<td>Terracotta</td>
<td>100–1050</td>
<td>floor and roofing tiles; air bricks; chimney pots</td>
</tr>
<tr>
<td>Bricks</td>
<td></td>
<td>structural and decorative brickwork</td>
</tr>
</tbody>
</table>

Uses of ceramics in building

There are five types of ceramics, apart from bricks, that are mainly used in building:

- terracotta
- fireclay
- stoneware
- vitreous china
- porcelain

Table 2 shows how these different ceramics are made and used.
Table 2: Features, firing temperatures and uses of ceramics used in building

<table>
<thead>
<tr>
<th>Type of ceramic</th>
<th>Features</th>
<th>Firing temperature</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terracotta</td>
<td>Yellow to brownish red clays; which may be glazed or unglazed. Terracotta roofing tiles, although brittle, are stable in high climatic temperatures and do not contaminate run-off water</td>
<td>Fairly low temperature</td>
<td>Main use is for floor and roofing tiles and air bricks (ventilators). Over the years, the most common pattern seen in Australia has been the French or Marseilles pattern (see Figure 4.1).</td>
</tr>
<tr>
<td>Fireclay</td>
<td>Usually a creamish colour, it can withstand high temperatures over a period of time without cracking</td>
<td>Filled at a higher temperature than fireclay</td>
<td>Flue liners and firebricks in stoves, fireplaces, kilns and furnaces</td>
</tr>
<tr>
<td>Stoneware</td>
<td>Harder, and less absorbent than fireclay. Contains more glass</td>
<td>Fired at a higher temperature than fireclay</td>
<td>Drainpipes and fittings.</td>
</tr>
<tr>
<td>Vitreous china</td>
<td>High glass content. Even if its glaze should crack, it will not allow moisture to seep in</td>
<td></td>
<td>Very suitable for sanitary fittings such as toilet bowls, basins and sinks</td>
</tr>
<tr>
<td>Porcelain</td>
<td>Similar to vitreous china but is purer.</td>
<td></td>
<td>Special uses, such as for electrical insulators</td>
</tr>
</tbody>
</table>

Figure 1 - French (Marseilles) pattern terracotta roofing tile

Bricks

Bricks used in construction are made from:
- clay or shale
- cement/concrete
- sand and lime (calcium silicate)
Methods of brick manufacture

Bricks are no longer made by hand but these are sometimes available second-hand from demolition sites. They are soft, porous, rather irregular in shape and, if protected from the weather, retain a pleasing warm appearance.

There are, now, two main methods of brick manufacture:

- the dry pressed method
- the plastic or extruded process

Dry pressed method

In this method, almost-dry clay powder is pressed into moulds and then fired. Most dry-pressed bricks have an indentation (called a frog) resulting from the shape of the mould (see Figure 2).

![Figure 2 - A Dry-pressed brick](image)

Plastic or extruded process

With the plastic or extruded process, a soft, moist mix is extruded through a die in the form of a long clay column which is then cut into brick-sized pieces by wires in a frame (see Figure 3). Extruded bricks have a much higher average compressive strength because the proportions between the raw materials are more accurate.
Brick classification

Bricks are graded A, B or C, according to their compressive strength (with grade A being the strongest) and are classified according to type as shown below:

- **Clinkers**: over burnt and very hard but often distorted in shape; usually unsuitable for regular brickwork; often used for feature walling.
- **Callows**: underburnt, light in colour, soft, very absorbent; inferior for most structural purposes.
- **Commons**: general purpose bricks; hard in texture but often with flaws developed during manufacture.
- **Select commons**: best quality commons, with sharp arises and fairly uniform colour; suitable as a substitute for face bricks.
- **Face bricks**: good quality bricks, with smooth or texture faces in a variety of styles and colours.
- **Sandstock**: imitation (mechanically-made) or hand-made bricks.
- **Brickettes**: small-face bricks, with plain and textured faces; often used for fireplace facings and ornamental feature work.
- **Firebricks**: dry-pressed, usually cream in colour, available in a wide range of sizes and shapes; used in furnaces, stoves, fireplaces and areas of intense heat.

The different types of brick can best be illustrated by looking at appropriate product literature.

With modern methods of applying a surface coating to a compatible colour base, bricks are now available in many colour shades, from black, through reds and yellow to white.

There are also purpose-made bricks which are made in special shapes (eg bullnose or squint).
Brick quality and standards

The quality of good bricks is determined by their texture and hardness and their size and shape.

They should have an even, granular texture, be well-fired and free from flaws (e.g. face blisters or shrinkage cracks). Two bricks, when struck together, should give a clear ringing sound.

They should also have regular shaped faces and sharp rises (see Figures 4.2 and 4.3) and fall within a standard size range.

Brick sizes:

Metric modular brick 290x90x90mm
Metric standard brick 230x110x76mm

The long face (called the stretcher) of a standard metric brick measures 230x76 mm, and the short face (called the header) measures 100x76 mm.

A closer (quarter brick) measures 50x76x110 mm (standard metric) and a queen closer (a standard metric brick split lengthways showing a closer face at each end) measures 50x76x230 mm (see Figure 4).

Figure 4 - Non-standard bricks

Laying bricks

Bonding is the way the bricks forming a structure are held together. Good bonding depends on the chemical bond between the bricks and mortar and on the mechanical bond resulting from how the bricks are laid.

The depth of mortar between bricks is usually 10 mm, providing a horizontal joint (called a bed joint) and a vertical joint (called a perpend).

Jointing is the term usually given to the surface finish of the mortar set between bricks. Such finishes vary according to trends. Tuck pointing used to be common about the turn of the
century but has since faded from popularity. The most common forms of jointing in use at present are:

- ironed
- flush jointing
- raked jointing (see Figure 5)

![Examples of different forms of jointing](image)

Figure 5 - Examples of different forms of jointing

Many different methods of laying bricks are used, some more effective than others. Bonding is provided by the way the bricks overlap each other and interlock, and it should:

- distribute the load evenly throughout the mass of brickwork
- tie the mass of brickwork together as an integrated unit
- provide a pleasing arrangement of bricks and joints

Two types of bonding are illustrated in Figures 6 and 7. The stack bond (see Figure 6), for example, provides little mechanical bond between the bricks (because it creates a vertical downward thrust), whereas with stretcher bond (see Figure 7) the load is more evenly distributed throughout the brickwork.

![Stack bond](image)

Figure 6 - Stack bond
Some other bonds, such as the English bond, Flemish bond, colonial bond and garden wall bond, provide an even more effective mechanical integration of the load distribution (see Figure 8).

![Figure 7 - Stretcher bond](image)

![Figure 8 - Some types of brick bonds](image)

**Accessories for brickwork**

There are a number of different accessories which are used with brickwork:

- wall ties
- damp proofing
Let’s look at how they are used.

**Wall ties**

Wall ties tie the two walls of a double brick wall together, so that they do not move apart from each other. In brick veneer construction, they tie the brickwork outer veneer to the timber load-bearing frame.

The most common type is 4 mm or 3.15 gauge galvanised wire bent to shape, with a kink (or drip) which should be positioned pointing down in the cavity between the two walls to prevent moisture passing along the inside wall (see Figure 9).

Wall ties should be spaced no more than 1 m apart and staggered every fourth course in height, with a minimum number of four ties per square metre. The ties should be at least 6 mm higher on the inner walls than on the outer walls. If the cavity width is greater than 75 mm, special length ties are used.

![Figure 9 - A wall tie](image)

**Damp-proof courses**

Damp-proof courses are provided:

- horizontally in walls and on piers to prevent upward seepage of water from the ground or through concrete in contact with the ground
- vertically as vapour barriers to prevent penetration of moisture through a wall
- through walls and across cavities as flashing to control moisture from a roof or parapet or around windows, door heads and sills

**Anti-termite caps**

Anti-termite caps made of galvanised iron are used on all piers under floor timbers. Other forms of termite protection are provided for slab on ground construction.

**Ventilators**

Ventilators made of terracotta or concrete with wire mesh are set into brickwork to provide under-floor ventilation as close as possible to the underside of the floor, or ventilation into the cavity of double brick walls.

**Reinforcement**

Reinforcement should be placed in footings and walls where tension stress is likely to occur, because brickwork is weak in tensile strength. The types of reinforcement available are:
• wire mesh
• welded wire
• fabric mesh
• expanded metal
• steel rods, generally used for vertical reinforcement

![Figure 10 - Reinforcement types](image)

**Lintels**

Lintels are steel bars, steel angles and so on, used over doors, windows, fireplaces or other openings to support the brickwork above (see Figure 11).

![Figure 11 - Lintels](image)

**Piers**

Piers are brick columns which provide above-ground support for other structural members, usually floors. They are of two types, attached and isolated.

Attached and engaged piers are built attached or bonded to a wall. It may be used to stiffen or supply lateral support to the wall and carry a superimposed load by providing an additional bearing area.

An isolated (or sleeper) pier is free-standing and usually carries some structural load but it may also be purely decorative (ie non–load-bearing). In order to maintain stability, attention must be paid to the relationship between the height of the pier and the size of the base dimension. Tables can be obtained to provide guidance in this respect.
Figure 12 - An isolated (sleeper) pier
Dimensional changes in bricks

Thermal expansion
The thermal expansion of bricks varies slightly depending upon their colour and the method of manufacture.

Short-term wetting and drying change
All bricks expand on wetting and contract on drying, but the changes are not sufficient to require consideration in practical brickwork.

Long-term permanent change
The long-term permanent change in dimensions of bricks (growth) depends upon the material from which they are made. All fire-clay products, including bricks, are subject to chemical reactions between water and certain of their constituent minerals that cause them to expand.

Moisture expansion must be considered when designing and constructing a brick structure. If expansion gaps are provided at intervals calculated using the characteristic expansion of the brick used in the structure, stresses due to restraint of further growth are unlikely to cause problems during the practical life of the building.

Initial rate of absorption
The bond between brick and mortar is largely influenced by the tug-of-war between the capacity of the brick to absorb water and the ability of the mortar to retain that water. If the bricks suck the water too quickly from the mortar, the mortar stiffens too quickly and the next course cannot be properly bedded. If the mortar retains too much water the bricks tend to float on the mortar bed, which makes it difficult to lay plumb walls. There will also be poor bond.

The power of a brick to absorb water is measured by the initial rate of absorption test, which is the amount of water absorbed by a brick in one minute. Low suction bricks need a leaner mortar to give good bond, which is done by increasing the proportion of washed sand in the mix. High suction bricks require:

- a mortar with very high water retention
- shortening of the length of the bed joint
- wetting of the bricks

Water absorption
Water may enter brickwork from many sources, fresh mortar or plaster, from rainfall during construction, rising ground water, condensation or leaky plumbing. Bricks play a major role in the water-tightness of a wall.
Soluble salts in bricks

Soluble salts are those which dissolve in water. These sometimes appear on the surface of bricks and mortar and the phenomenon is known as efflorescence. Nearly all the salts which cause efflorescence come from sources outside the brick, such as ground water, sea spray, acidic atmospheric gases, mortar ingredients and other materials in contact with bricks. Soluble salts attack porous materials when the concentration of the salts in the solution gradually increases as the material dries. Crystallisation begins when the volume of water remaining cannot dissolve all the salts present. During crystallisation pressure is applied to the walls of the pore. When this occurs near the surface of the material, the pressure applied on the pore walls may exceed the tensile strength of the material and fretting will take place.

Design for the control of external movement associated with brick growth

The sources of movement in brickwork are:

- foundation and footing movements, dishing and doming
- frame movements
- temperature movements - expansion in hot weather, contraction in cold weather
- vertical shortening - shorten as loads increase during construction and occupation of the building
- horizontal concrete shrinkage - shrinkage of concrete during drying

Design of external control joints will minimise movement by providing:

- vertical gaps for horizontal movements
- horizontal gaps for vertical movements

Horizontal movement

So that disruption to other elements in the wall is avoided, the maximum movement at each gap is limited to 7 to 8 mm from the wall section on each side of the gap; that is, a total movement at the gap of 15 mm and a total gap width of about 20 mm.

Vertical movement

Horizontal gaps to control vertical movement are required only in buildings where the external leaf of brick cladding is non-loadbearing and is supported by a frame or from floor slabs in a loadbearing wall structure.

Expansion joints

In clay brick walls the main movement is a slight expansion which can cause cracking in the brickwork. The correct location of an expansion joint is very important. The first and last expansion joint in a wall should always be placed near the corners of the building as well as near openings.

Failure to ensure that gaps were clean before sealing is the most common cause of brick expansion problems. The use of joint fillers that are too rigid is the second most common cause of brick expansion problems.
Unfired clay or soil construction

Clay in mud and soil has a very long history as a building material. Wet or moist soil or clay is put into forms or moulds and allowed to sun-dry (*cure*). Mud brick (*adobe*), rammed earth (*pisé*), pressed blocks, wattle and daub, and cob are the five most common methods used.

**Table 3** - Advantages and disadvantages of soil based materials in construction

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usually very cheap</td>
<td>Usually very labour-intensive</td>
</tr>
<tr>
<td>Excellent thermal insulation and thermal capacity</td>
<td>Can be unsuitable in very wet areas</td>
</tr>
<tr>
<td>Often capable of sustaining innovative, free-form designs</td>
<td>Resistance to them by some local government authorities and building inspectors, by lending organisations and by prospective purchasers</td>
</tr>
</tbody>
</table>

Mud brick (*adobe*)

Mud brick walls are probably one of the oldest and most popular forms of earth housing. Wet mud is placed in boxes (forms) which are removed shortly after, and the blocks are allowed to cure for about a month before being used. The blocks are bonded with a mortar of the same mud that was used for making the blocks.

Soils suitable for adobe combine the plasticity of clay with the non-shrinking properties of sand and stone. A binder such as straw or hay is often added.

**Table 4** - Advantages and disadvantages of mud brick construction

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple to construct, not a great amount of skill required</td>
<td>Blocks can be rather rough looking and can chip easily</td>
</tr>
<tr>
<td>Strong, relatively crack-free walls</td>
<td>Usually unsuitable for use in areas</td>
</tr>
</tbody>
</table>
can be made with an annual rainfall exceeding 600–750 mm, unless design precautions are taken.

Rammed earth (pisé)
Moist soil is rammed into position between heavy wooden forms. The forms are moved along or up as work progresses. The ramming may be done by hand or with pneumatic tampers.

Table 5 - Advantages and disadvantages of rammed earth construction

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>A well-made rammed earth wall is one of the most durable earth walls that can be made</td>
<td>It is not easy to do well and the heavy wooden forms take time, money and some skill to build</td>
</tr>
<tr>
<td>Ramming can be done by unskilled labour</td>
<td>Careful selection of soil type is essential or the walls will shrink and crack after they dry</td>
</tr>
<tr>
<td>Materials are cheap</td>
<td>Water content must be carefully controlled</td>
</tr>
</tbody>
</table>

Machine-made (pressed earth) blocks
The method involves the use of a hand-operated machine to press the soil into bricks or blocks which are then allowed to sun-cure before being laid in courses like any other brick or block.

Advantages of machine-made blocks are:
- machines are fairly cheap
- the blocks have approximately the same strength and durability as rammed earth
- blocks that have had chemical stabilisers added to them have almost the strength and durability of burnt brick or timber
- laying the blocks is relatively simple
- if the blocks are sun-cured before use, there is little chance of further shrinkage when placed, thus providing essentially crack-free walls

Wattle and daub
With this method, a wall of reeds or branches is woven over a timber frame and mud is plastered on the inside and outside of the weave. Although very cheap and fast to build, the mud often cracks and needs constant maintenance. White ants easily destroy the timber frame, and the buildings are not usually very durable.

Cob
In this method, stiff mud is mounded into large balls, which are piled in layers to form walls and shaped and trimmed after placing. Although little skill is needed to build cob houses, serious shrinkage cracks often occur.

Materials added to stabilise earth
Cement is often used in adobe, pisé, pressed block construction and in soil floors to improve inferior soils. The soil needs to be pulverised first. The cement (5–12% by weight) and water are then added and amounts made must be in smaller batches than for straight mud, since the concrete ‘goes off’.

Bitumen added to soil acts both as a binding and waterproofing agent.
Straw bale construction

It is now widely accepted that straw-bale construction is environmentally beneficial. There are several reasons for this:

- straw is renewable on an annual basis
- it is mainly a waste product
- it has excellent insulation and acoustic properties
- its embodied energy is very low

There are two types of construction used for straw bale construction: load bearing construction and post and beam.

In load bearing construction, the straw walls are built first, and the roof then constructed, with the load bearing on these straw walls. This is the quickest form of construction; however, the disadvantage is that the walls are exposed to weather while waiting for the roof to be constructed.

In post and beam construction, the roof is constructed first using posts and beams as the supporting structure. The straw bale walls are then in-filled, with the advantage of this work being carried out under cover from the roof.

Both these two types of construction require the straw bales themselves to be protected from the weather by the use of a masonry render which is applied to each skin – thus keeping the bales protected from rotting and attracting vermin.
Non-clay bricks and blocks

Concrete bricks and blocks

These are manufactured from graded sand, aggregate, Portland cement and water; fly ash is often used as a cementing agent. They are made in a variety of solid and hollow shapes but in standardised metric sizes, so that a block or half block, with the addition of 10 mm of mortar, measures whole units of 100 mm or 50 mm.

Table 6 - Concrete block and brick sizes

<table>
<thead>
<tr>
<th>Brick type</th>
<th>Length</th>
<th>Height</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard blocks</td>
<td>390</td>
<td>190</td>
<td>290, 190, 140, 90</td>
</tr>
<tr>
<td>Half-high blocks</td>
<td>390</td>
<td>90</td>
<td>190, 140, 90</td>
</tr>
<tr>
<td>Metric modular bricks</td>
<td>290</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Standard bricks (same size as standard clay bricks)</td>
<td>230</td>
<td>76</td>
<td>110</td>
</tr>
</tbody>
</table>

Concrete bricks, blocks and paving are very versatile with the advantage that they are not usually difficult for unskilled workers to use. They come in a variety of textures and colours.

Blocks are usually used hollow and unreinforced. They can easily be reinforced, if required, by using steel reinforcement and filling the central core with concrete.

Concrete blocks shrink and swell with temperature and humidity variations and this has to be allowed for, particularly in external work.

Paving blocks are available in new interlocking systems that make very hard-wearing, attractive roads or footways and which give good access to buried service piping.

Concrete roofing tiles are also available in a range of colours and shapes and are widely used.

Calcium silicate bricks

Calcium silicate or sand-lime bricks are also used, though not in the same quantities as clay bricks.

They are usually whitish or grey in colour, but their physical characteristics are different.
Stone

The use of stone as a building material dates back to the caves and rock shelters of prehistory. Throughout the ages, different peoples—such as the Britons, Vikings, Egyptians, Chinese, Mayans, Incas, Aztecs, Romans, Greeks, Celts and Tibetans—have appreciated the properties of stone and developed the art of using it. In many instances, lack of wood or other options forced the use of stone; in other cases, stone was the preferred material because of certain superior properties, such as durability or prestige.

The main rock groups

Rocks, referred to in building as 'stones', can be divided into three groups, according to how they are formed in nature:

- igneous rocks
- sedimentary rocks
- metamorphic rocks

Igneous rocks

Igneous rocks are all formed from molten rock which has cooled and hardened. For example, rocks such as basalts, volcanic glass and pumice (cooled glassy froth) are formed from volcanic lava. Rocks such as granite are formed from molten rock that has cooled and hardened underground.

Types of igneous rocks

Granite

Granites and granite-like rocks are hard rocks and are made up of a mosaic of fairly large crystals of various minerals easily visible to the naked eye.

Granites are usually light grey or pink in colour but can vary through to quite deep reds. The trade term 'granite' is also used to cover a number of darker rocks including gabbro, a black rock known as 'black granite'.

Examples
- Moruya granite—pale grey (used for the Sydney Harbour Bridge pylons).
- Mudgee granite—deep reds.
- Bathurst granite—reds and pinks, various types from the area around Bathurst.
- Riverina grey—from the Tocumwal area; and pinks from Berrigan.

Trachyte

Trachyte has smaller grains than granite.

Examples:
- Bowral trachyte—dark olive green or dark grey, occasionally streaked with beautiful veins of glassy crystals and quarried at 'The Gib'. Bowral trachyte has been used on a number of Sydney buildings and for the piers of the old Hawkesbury Bridge.
- Canoblas trachyte—a very hard and durable stone, it polishes to a soft grey or buff base colour with small pink and black spots and is from Orange (held in great repute by local builders, it makes a good flagging stone and was used as such on the front of most of the older important buildings in Orange).

**Basalt**

Basalt is a very dark to black, fine-grained igneous rock. Basalts are often called ‘bluestone’ or ‘blue metal’. They have been quarried from Orange, Kiama, Dundas, Stirling (near Inverell) and Uralla and used extensively in Melbourne (e.g. St Patrick’s Cathedral) and other parts of Victoria.

**Dolerite**

This is similar to basalt but coarser grained. It is used extensively as road metal, gravel and aggregate in concrete.

**Sedimentary rocks**

Sedimentary rocks are most often made up of bits of other rocks, usually as a result of erosion. For example, layers of mud and sand (the result of other rocks being worn down) become buried deep in the earth and are compressed and hardened to form shale and sandstone.

**Types of sedimentary rocks**

**Sandstone**

Formed in nature by sand grains which are cemented together, sandstone is a popular building stone when available, as it is fairly easily worked, very attractive in appearance and not very heavy. Many types of sandstone, however, are too soft and crumbly to be useful.

Sandstones are porous, allowing dampness to soak through: so, when used as footings, they must have good damp-proof course. Inadequate or non-existent damp-proofing has resulted in rising damp problems in many old buildings with sandstone footings.

The predominant building stones used around Sydney have been the Sydney and Gosford sandstones. As these two stones are basically identical, descriptions of Sydney sandstone apply equally to Gosford sandstone.

Sydney sandstone is one of the finest building sandstones in Australia. Its colour is usually a pale yellowish or buff colour to pinkish or brownish tones, with colour variations within it. It is easily seen in many road cuttings around the Sydney area, such as the expressways north of Sydney, in the Blue Mountains, and approaches to the Harbour and Gladesville bridges.

Other areas in NSW where sandstone has been quarried include Marulan (used for St Saviour’s Anglican cathedral, Goulburn); Bundanoon, one of the best sandstones in NSW for large buildings, its colour varies from white to pink (used for the base of the soldier’s memorial and town hall in Goulburn and St Michael’s cathedral, Wagga Wagga); Yass; Canberra; Frogshole; Galong; Grong Grong; Milparinka; Mendooran; Newcastle (identical to Sydney sandstone); and Ravensfield.

**Limestone**

Limestones are sedimentary rocks formed from coral, sea shells and deposits of calcite (the mineral of which shells and coral are made).

Limestone as a building stone is worked and sold under the general name ‘marble’. However, limestone is also mined extensively for manufacturing lime and cement.
Metamorphic rocks

Metamorphic rocks are formed as a result of changes which have been usually brought about by heat and/or pressure in the earth’s crust. For example, when shale (a sedimentary rock) is compressed it becomes a metamorphic rock, slate; sandstone, when heated up, perhaps by volcanic lava, turns into quartzite; and limestone becomes marble under pressure.

Types of metamorphic rocks

Slate

Slate is formed by immense pressure in the earth’s crust compressing and altering clay rocks such as shale. Slate splits easily in layers in one direction, like pages of a book. Some coloured shales are marketed for paving as ‘slate’, but a true slate is usually grey, greenish grey, bluish or purplish in colour.

Slate is fairly soft and easily scratched, but has a very pleasing appearance when well laid and cared for. Its softness is obvious when we see how the centre of the tread, in the grey slate steps in old buildings, are often worn away with use.

The high labour cost of cutting and laying slate roofs led to a decline, but its recent popularity for floors, wall facings and fireplace surrounds has renewed interest in it as a marketable product.

In the early days of the colony of NSW, slate was brought out from Britain as ship’s ballast. It was then used to roof many early Sydney buildings (some fine old slate roofs are still to be seen around NSW). Gradually Australian deposits were found and worked—at Chatsbury, Gundagai, Towrang, Black Mountain, Bathurst and Mudgee.

Marble

Limestone, acted on by heat and pressure in the earth’s crust, changes its structure and pattern of colour and becomes marble. Marble and limestone are both quarried for building stone as ‘marble’, so we will look at them together. Their colours vary from almost pure white through nearly every possible shade of greys, greens, yellows, reds and blues to black. They are used for making cement, for ornamental and monumental stones, statues and building stones.

Stone classified for building purposes

In the building industry, special terms are used to describe different types of stone. These terms might indicate the quarry location, the colour, texture, pattern or use of the stone.

Trade terms

Some terms, such as the following, have a different meaning in the building industry to their geological meaning.

- **Granite**
  any medium- or coarse-grained igneous rock used as dimension stone.

- **Sandstone**
  sedimentary rock made of sand-size grains; sandstones with thin, even, regular bedding along which the rock is easily split are termed ‘natural flagstones’; in NSW sandstone which splits with equal ease in any direction is called ‘freestone’.
Marble is any limestone or marble which is able to take a polish and is used decoratively; also includes the metamorphic rock serpentine, termed ‘serpentine marble’.

Dimension stone

This term refers to natural rock used as ‘building stone’, ‘ornamental stone’ and ‘monumental stone’. It is generally quarried in blocks or slabs and marketed in a variety of sizes and finishes according to customers’ needs. The main varieties of dimension stone quarried and used in NSW are granite, marble, sandstone and slate.

Although most varieties of dimension stone are widespread in NSW, economically viable deposits are not common. Suitable sandstone deposits are available fairly close to Sydney, but the other stones are located in isolated areas a long way from major markets. These localities include: Wombeyan (marble); Yass (limestone); Mudgee (granite); Eugowra (granite); Bowral (trachyte); Bundanoon (sandstone); Tumut (marble); Mulyandry (granite); Middle Arm (slate).

Requirements of dimension stone

These may vary from one project to another but, in general, are as follows:

• It must be able to be extracted in large blocks free from joints and imperfections.
• It must be sound and durable.
• It should be uniform in colour and texture.
• It must have aesthetic appeal (difficult to describe, but such things as colour, pattern, texture and finish are important).
• Stones used for certain purposes must be capable of taking and keeping a polish. Only ‘granites’ and ‘serpentine marble’ keep a polish when exposed to weather.
• It must be available in quantity so that sufficient reserves exist of fairly uniform stone to meet large orders and future demands for maintenance or restoration work.

Economic outlook

Dimension stone is a moderate to high-cost material. It is often passed over for cheaper load-bearing materials such as steel and reinforced concrete.

Other dimension stones likely to be in demand include good quality purple and green slate for decorative purposes and good quality white marble, black marble, gabbro and granite.

Construction materials

Construction materials are low-cost minerals and rocks that are extracted in bulk. They require little processing and are used for construction purposes. Such materials include the following:

• Coarse aggregate: Crushed and broken stone, prepared road base and gravel. Usually igneous rocks are used in NSW, though sedimentary sandstones have also been used successfully. The most important deposits are those situated near the larger cities. Much of the coarse aggregate is used in concrete.
• Fine aggregate: Construction sand, which is usually dug from rivers, beaches or dunes and must be clean, with no soil or salt. It is used mostly for concrete, mortar, sand-lime bricks and fillers.
• Unprocessed materials: These include weathered rock, gravel, soil and loam. They are used mainly for road-making and site-filling.
General properties of stone

Most natural stones are very good load-bearers and make good footings, walls and pylons. The amount of thermal expansion is very low for marble and slightly greater for sandstone, slate and granite. However, allowance should be made for thermal movement.

Some stones, especially igneous rocks (such as granites, trachyte and basalt), are not all porous and therefore do not allow moisture penetration. Others, like sandstone, can be very porous.

Most natural stones are very durable—a property which can, however, be adversely affected by certain environmental factors.

Factors causing deterioration in stone

Atmospheric pollution
Sulphur chemicals in the air or soil dissolve in rainwater and form weak sulphuric acid which will slowly dissolve marble, limestone, calcareous sandstones and mortars.

Salt
Salts dissolved in water seep into rocks and dry out, forming crystals. These growing crystals cause pressure in porous rock or in mortar and, as they expand, can cause progressive decay.

Frost
Porous rocks in which water freezes will crack and disintegrate, often very quickly. However, frost action is not a problem in most parts of NSW.

Solubility
Limestone, marble and calcareous sandstone will slowly dissolve in water.

Wetting and drying
Repeated wetting and drying of porous rocks can cause slow surface crumbling and should be guarded against. (This also weakens mortars.)

Corrosion of metals
As iron and steel rust, they swell. Where iron or steel rods, bolts or bars are fitted into or between pieces of masonry and allowed to rust, serious damage is caused in stone structures.

Some metals also form salts as they corrode which can be destructive to surrounding stonework.

Vegetation
Most plants, including lichens and mosses, do little damage to stonework, but they do hold moisture, which may be a problem with mortars and porous rocks. Ivy, however, because of the way its roots penetrate cracks and cavities, can cause serious damage.
Finishes and maintenance of stonework

Surface finishes

Figure 13 gives some idea of the range of tooling that can be done on stone with, usually, a mallet and various chisels. Today, with mechanisation, sawn and polished faces are used fairly frequently, especially with monumental work.

![Figure 13 - Some types of surface finishes and tools](image)

Rubble walling

Walls may be built either as:

- random rubble (uncoursed)
- random rubble (coursed)
- square rubble (uncoursed)
- square rubble (built in courses)
Walls may be built either as:

- random ashlar
- ashlar (regular coursed)
- ashlar (irregular coursed)

**Ashlar walling**

*Figure 14 - Rubble walling*
Maintenance

Outside stonework should be cleaned regularly and defective joints raked out and refilled (reappointed) with a sand-lime mortar, *not* a cement mortar mix.

Methods of cleaning various stones are outlined in Table 7. Note that caustic soda and soda ash are very damaging and must *never* be used on any stone.

**Table 7 - Cleaning methods for stone**

<table>
<thead>
<tr>
<th>Stone</th>
<th>Method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>All types</td>
<td>Hydrofluoric acid (5% concentration)</td>
<td>Risks damage to adjacent materials. Fast method, no staining, very dusty. Sand-</td>
</tr>
<tr>
<td></td>
<td>Sandblasting, dry</td>
<td>blasting and abrasive tools produce a lot of dust</td>
</tr>
<tr>
<td></td>
<td>Mechanical abrasive tools</td>
<td></td>
</tr>
<tr>
<td>Limestone and</td>
<td>Clean water spray, mild detergent, dry and</td>
<td>Slow, not suitable for heavy encrustations</td>
</tr>
<tr>
<td>marble</td>
<td>polish with soft cloth</td>
<td></td>
</tr>
<tr>
<td>Granites</td>
<td>Ammonium bifluoride</td>
<td>Risks damage to adjacent materials</td>
</tr>
</tbody>
</table>

Preservation

Most stone is fairly durable, so fast decay usually occurs from wrong choice of stone, defects in design, or neglect. These errors should be corrected before attempting to ‘preserve’ the stone. For example, salts should not be sealed in, but should be removed by repeated
Alternative materials

Dimension stone faces considerable competition from cheaper materials, in particular exposed aggregate panels and other concrete-based products. Steel and concrete have virtually replaced dimension stone as a major load-bearing construction material.

Artificial stone

Economic reasons, together with the greater range of architectural finishes available, have brought about a greater use of synthetic and artificial stones, such as the following.

Cast synthetic stone

Pure polyester resin or a mixture of polyester resin and acrylic is moulded into stone-like material which can be cast in single pieces. In situations where the use of stone would require a number of separate stone sections to be jointed together (e.g., in panels or columns), this method offers distinct advantages. It is also not as hard or as cold as stone and can be worked with wood tools. It can be produced in a variety of shapes and sizes and is usually used to imitate marble.

Terrazzo

Irregular fragments of marble are set in cement and then rubbed down to a smooth surface (often used as stall partitions in public toilets, older-style sink draining boards and as paving in shopping malls).

Advantages of artificial stone

- It can be moulded to various shapes and sizes.
- Exposed faces can be finished to a described texture and colour.
- It is cheaper than natural rock and it is often used as a facing.
- Moulded or detailed pieces can be produced quickly.

Imitation stone

A few materials have been used to imitate stonework. For example, cement render or plaster grooved and painted to look like ashlar laid stone blocks; pressed metal sheets resembling stonework; or compressed fibrous cement roofing to resemble slate.