TECHNICAL NOTE #36

Durable clay brick – protecting property from fire and flood

Clay bricks are ceramic products – they are fired in a kiln rather than just dried in the sun. Clay masonry is incombustible - it cannot conduct electricity or contribute to the spread of fires. Clay brick walls withstand saturation from flood water.

This technical note looks at how contractors and property owners can maximise the inherent durability of clay brick through correct building design and bricklaying techniques.

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CLAYBRICK for good – THE VOICE OF THE CLAY BRICK INDUSTRY

SECURE SAVE SUSTAIN STYLE

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Executive Summary

Maximising the inherent long-term durability of brickwork in modern buildings requires an understanding of physical properties of the bricks and mortars, as well as the best bricklaying techniques.

The buildings degree of exposure to water, wind and weather influences what type of bricks and methods should be used. The Clay Brick Association of Southern Africa provides a wealth of knowledge of local masonry products and building methods on it's website to supplement the experience of building contractors.

Common enemies of masonry brickwork are:

- Fire
- Water saturation (including rain and flooding)
- Frost (exacerbated by water saturation)
- Sea Salts and chemicals

Clay bricks are a dense, ceramic product, fired at high temperatures. They are virtually indestructible on their own.

Fire Resistance

Well-constructed houses and buildings can help prevent fire tragedies by using materials that are relatively fire-resistant. In engineering terms, no practical building material is truly fireproof – it's not a question of whether a fire can damage a structure, but a question of when. It simply takes longer for fire to affect fire-resistant materials.

The key is to construct a building in which a fire would take effect slowly, allowing the occupants plenty of time to escape. This is also why materials themselves are rated in respect to how long it would take fire to affect its structural abilities.

SANS10400-Part T

There are very strict regulations when it comes to fire safety and protection against fire in any building in South Africa. The design, construction and equipment of buildings must comply with SANS 10400 Part T, and satisfy the local authority. The regulations for Fire Protection are contained in a 91 page document published by the SABS. This document includes information on compliance and fire resistance of building materials and components for both structural and non-structural walls.

Terminology: Combustible vs Ignition-resistant vs fire-resistant

Combustible materials are those that readily ignite and burn. Many common construction materials are combustible, including wood and wood-plastic composite and plastic products (commonly used for decking and siding). These actively contribute to the spread of the fire.

A noncombustible material is one that is not capable of undergoing combustion under specified conditions (ASTM E 176).

Noncombustible roof coverings include:

- Clay or concrete roofing tiles
- Cement shingles or sheets
- Exposed concrete slab roof
- Ferrous or copper shingles or sheets
- Slate shingles

Heavy timber is combustible, but is considered fire-resistant because it burns so slowly.

Metals like aluminium or steel aren't combustible but are not considered fire-resistant because they tend to buckle under intense heat. The building collapses quickly, even though the metal hasn't melted. Materials that contain large quantities of combined water or other gaseous components might be non-combustible, but the density loss that occurs during a fire might still make the material unstable.

Ignition-resistant

The duration of "ignition resistant" test is 30 minutes. Wood and wood-based products that qualify as an ignition resistant material have been treated with a fire retardant. However weathering may leach fire retardant chemicals from the product over time.

Fire Resistant

The Fire Resistance Rating is a measure of the length of time a walling element will resist a fully developed fire. Failure occurs in an element when its resistance is overcome in ANY way:

1. if it collapses or its structural ability is impaired.
2. if it develops cracks and fissures through which hot gas or flame can pass
3. if the temperature on the side away from the fire exceeds a certain level

Fire resistance ratings and tests are designed to evaluate the capability of an **assembly** (such as a masonry wall that has bricks, mortar, metal ties and possibly insulation, or a roof that combines timber, clay tiles and metal struts.) The objective of a high fire resistance rating is to prevent the spread of the fire to adjoining structures (Beitel 1995) and to ensure that there is enough time for people to exit a burning building before it collapses (Kruppa 1997).

Fire Resistance Values for Clay Brick

If we learned anything from the popular children's tale of the "Three Little Pigs," it's that you should make your house out of brick. Brick is not only resistant to a big bad wolf's huffing and puffing - it's also resistant to fire.

As bricks are fired in a kiln at temperatures up to 1 200°C, they're already highly resistant to fire. Although individual bricks are extremely fire-resistant, a brick wall is held together with mortar, which is less fire-resistant. Nevertheless, brick is among the best building materials for fire protection.

Depending on the construction and thickness of the wall, a brick wall can achieve a 1-4 hour fire-resistance rating when tested in accordance to SANS10177 Part Z "Fire Resistance Test for Building Elements". The fire resistance rating of 220 mm external clay brick masonry is 4 hours.

- **Single leaf wall (90 - 140mm)**
  - Structural: 30 minutes
  - Non-structural 60 minutes

- **Double leaf clay brick wall (140 - 280mm)**
  - Structural: 120 minutes
  - Non-structural: 240 minutes (maximum)

ACTUAL PERFORMANCE OF CLAY BRICK UNDER "VELD FIRE" CONDITIONS

In June 2017, Knysna / Plettenberg bay experienced the biggest fire disaster in South Africa in modern times, with over 1 000 fire-fighting personnel deployed from all over the country.

What is clear from many photographs, is that for most properties, only the masonry walls have been left standing (although clearly damaged). For those houses on the periphery of the blaze, what is the probability that brick walls that survived the blaze remain structurally sound?*

Properties damaged by the Knysna fire in 2017

Most clay bricks are fired to at least 1000 degree Celsius, and even if higher external temperatures were to occur, the clay bricks would not lose their integrity. A more important factor in assessing the likelihood of structural damage is the rate of travel of the fire. The speed of the recent Knysna fires was estimated at 60 km/h – or 1 km per minute – due to severe wind driven conditions.

This gives a fire transit time of 10-15 minutes. The inherent high thermal resistance of clay brick and mortar masonry would significantly retard the flow of heat into the body of both bricks and mortar. This will have helped to reduce the rate of temperature build up to below that which damage may occur.

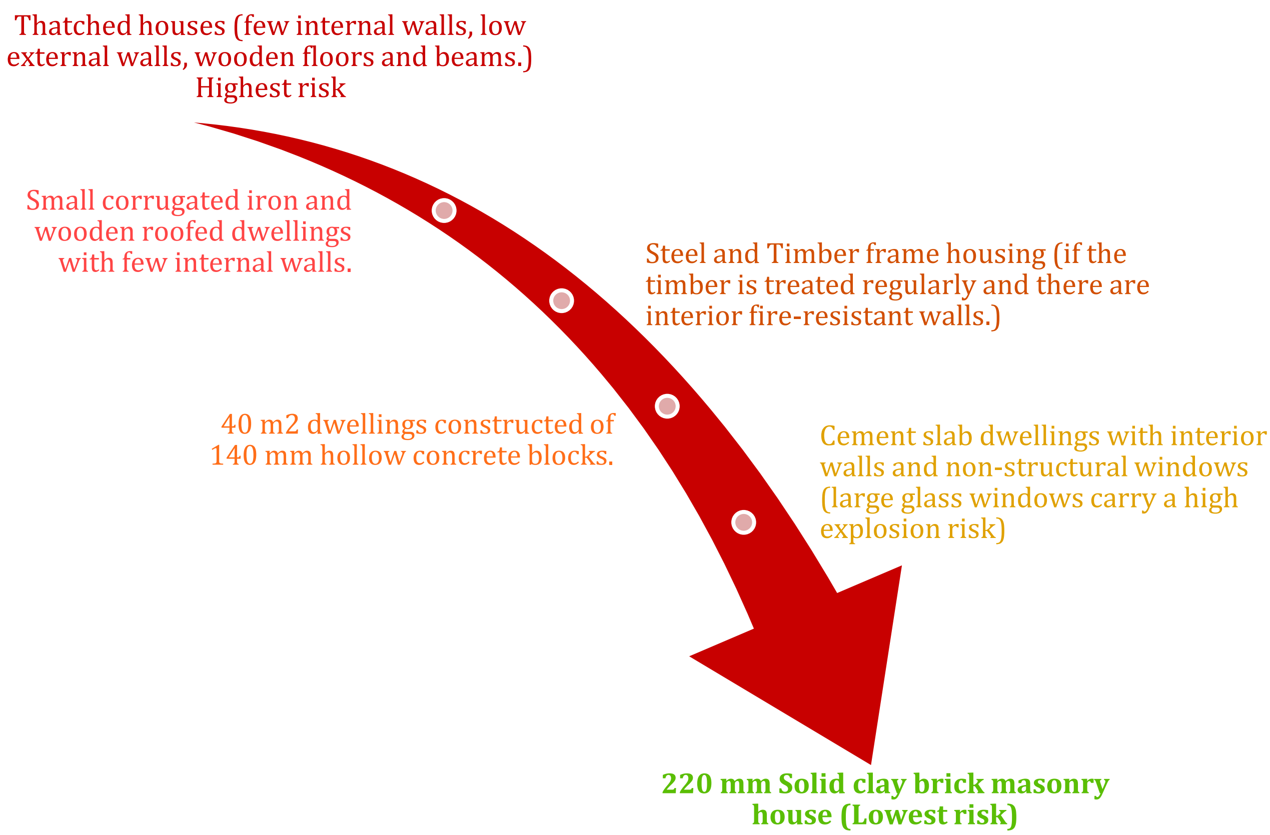
Consequently, it is unlikely that significant reductions in the structural strength of the clay brick masonry will have occurred. The reduced rate of heat penetration is also unlikely to have caused significant reductions in the strength of steel ties or brick force.

After any fire, if the resident sees any visible signs of masonry cracking, wracking of the brick work or separation between adjoining wall elevations, the services of a structural engineer should be sought.

Fire resistance of other materials

Concrete is also a fire-resistant material - it is noncombustible with low thermal conductivity. It takes a long time for fire to affect its structural, load-bearing ability, and it protects from the spread of fire. It's significantly more fire-resistant than steel, and often protects steel from fire.

However, it's important to note that concrete contains aggregate that can make up 60 to 80 percent of the concrete's volume. Natural aggregates tend not to perform as well. Moisture in the aggregate can expand when heated, causing concrete to sinter after long exposure.



WATER SATURATION

If brickwork remains saturated for long periods, sulfate attack may disrupt the joints unless a sulphate-resistant mortar is used. Both bricks and mortar may be susceptible to damage by freezing when saturated.

The following are locations where brickwork is likely to remain saturated for long periods:

- Near ground level below the damp proof course and in foundations.
- In free-standing walls, retaining walls and parapets.
- In cappings, copings and sills around windows and doors
- At terminal points where brick joins other materials s (e.g. where wooden or concrete floors or beams penetrate the brickwork)

The presence of sulfates in soils and ground-waters can significantly affect the durability of brickwork below ground-level dpcs unless care is taken in specification.

PROTECTION FROM SATURATION

The quality of workmanship, both in the preparation of the mortar as well as in bricklaying, is a vital factor in achieving the long-term durability of brickwork. Waterproofing treatments are advisable on the soil- retaining surfaces of planters and other forms of retaining wall.

The design of the structure should allow for protective features. Brickwork is unlikely to become saturated where projecting features shed run-off water clear of the walling below. Roof overhangs or copings, projecting and throated sills at openings, bellmouths to renderings and similar features at the bottom of tile hanging and other claddings may provide such protection to wall heads. Protection is also afforded to brickwork by damp- proof courses and flashings.

The frequency and extent of saturation of brickwork also depends on the degree of exposure to the weather. In areas of high exposure to driving rain, it is particularly important to give consideration to architectural features that minimise saturation.

If, for functional or aesthetic reasons, protective features are omitted, particular attention should be paid to the choice of bricks and mortar.

Although use of reclaimed/recycled bricks is excellent from a sustainability point of view it is possible for NFP plaster bricks, originally used for internal brickwork, to end up being used externally. Therefore it is recommended that reclaimed/recycled bricks be used with caution.

Frost exacerbated by Saturation

The destructive effect of frost is due to the 9% increase in volume that occurs when water at 0oC is converted into ice. When bricks and mortar are saturated and frozen, expansion within the pore spaces may set up stresses that cannot be withstood. With some bricks and mortars, accessible space within the pore structure, in which expansion can take place, greatly reduces the risk of frost damage.

It is not necessarily the coldest or wettest winters that lead to frost failure, but rather recurring freeze/thaw cycles of saturated brickwork. When failure occurs, brick surfaces may flake or spall, while the mortar joints may crumble.

Brickwork is particularly at risk during winter construction. As night frosts are common, even in mild winters, it is important that bricks stored on site, as well as uncompleted and new brickwork, are adequately protected from both saturation and frost. Even correctly proportioned mortar may be damaged by frost before it has fully hardened. Most clay bricks are resistant to the levels of frost experienced in South Africa.

Sulfate Attack exacerbated by Saturation

Sulfates disolved in water include salt water at the coast and ground water contaminated by industrial or agricultural chemicals. Sulfates enter the masonry disolved in water, and then crystallise in the pore structure of the brick, exerting significant expansive force as the masonry dries out. Cycles of saturation and drying re-crystalise the sulphates and the result over time is crumbling and erosion of the mortar joint (or in severe cases expansion and bowing). Where conditions for sulfate attack are present, it may take several years before it becomes apparent.

Protection from sulphate attack

Sulfate attack on brickwork mortars is principally caused by the reaction between sulfate in solution and the tricalcium aluminate (C_3A) constituent of Portland cement, which forms calcium sulfoaluminate (ettringite). This reaction only occurs if there is an appreciable C_3A content. The risk is greatly reduced by the use of sulfate-resisting Portland cement where the C_3A content is limited to a maximum of 3.5%.

Sulfate attack occurs only if there is a considerable amount of water movement through the brickwork. Diffusion alone will not carry sufficient amounts of sulfate to the hydrated cement in the mortar. Water movement may occur by percolation of water through the brickwork under the action of gravity, such as in free- standing walls, or below brick sills where effective damp proof courses have not been provided. Movement of water may also be brought about by evaporation and capillary action, for example through retaining walls that are not waterproofed on the retaining face, or in external walls between ground level and the dpc.

Sulfates may be derived from ground-waters, from the soil, or from make-up fill adjacent to the brickwork. Where soil or ground-water sulfate levels are appreciable, the use of strong mortar mixes containing sulfate-resisting Portland cement should be considered.

Sulfate attack can only occur when sulfate solutions can readily penetrate the mortar itself. Strong, dense mortars are relatively resistant to sulfate attack, despite their higher C3A content. The permeability of the mortar is also affected by the grading and clay content of the sand.

Vulnerable situations

Parapets and free-standing walls without effective copings and other exposed brickwork, may remain wet long enough for sulfate attack to occur if the other conditions are present.

If dense rendering on brickwork becomes cracked, rainwater may penetrate it. Drying-out will be restricted by the render and the brickwork may remain wet long enough for severe sulfate attack and expansion to occur in the mortar joints. In all such cases, protective detailing and good specification and workmanship will minimise saturation. Additionally, the use of sulfate-resistant cement should be considered for the jointing mortar and the base coat of the render, particularly if NFP clay bricks are to be used.

Copings

Copings provided at the top of parapet walls, free-standing walls and retaining walls will minimise the risk of saturation of the brickwork. A coping sheds rainwater falling on it clear of all exposed faces of the walling it is designed to protect. The drip edge of the throating should be at least 40mm from the face of the wall.

A continuous sheet of damp proof course should be provided immediately beneath jointed copings and cappings (which do not extend), in order to prevent downwards percolation of water into the wall should the joints fail.

Mortars

Modern mortars made from suitable materials can be designed and mixed to provide a level of durability to match the bricks. The durability of mortar will be enhanced as the cement content is increased. Because the cement content of mortar is very important, accuracy in the proportioning of mortar mixes is essential. It is recommended that use is made of a gauge box or bucket, carefully filled without compaction and struck off level.

It should be noted that damp sand is cohesive and will normally stand up on the shovel. On the other hand, cement, being a free-flowing dry powder, will occupy a considerably smaller volume on the shovel. When the batching of mortar mixes is based on shovelfuls, the resultant mix is often considerably leaner than intended, resulting in subsequent deterioration and the need for repointing or even rebuilding.

It should be remembered that Portland cement may hydrate with loss of strength on prolonged exposure to the atmosphere, and therefore relatively fresh material should be used.

Excessive clay mineral content in the sand may interfere with the development of strength in the mortar. Sands with fine and relatively single-sized particle size grading may produce rather porous and permeable mortars. In either case, durability will be impaired.

Mortar joints

Bucket-handle or struck and weathered joints contribute to brickwork durability, as the tooling of the joints reduces the permeability of the mortar surface and improves the seal between the bricks and the mortar, thereby enhancing the wall's resistance to rain penetration.

Recessed joint profiles in external brickwork will increase the level of saturation along the upper arrises of the bricks, with a consequent risk of water penetration. The depth of the recess should take into account the proximity to the exposed face of the brickwork of perforations in the brick. All joints should be properly formed.

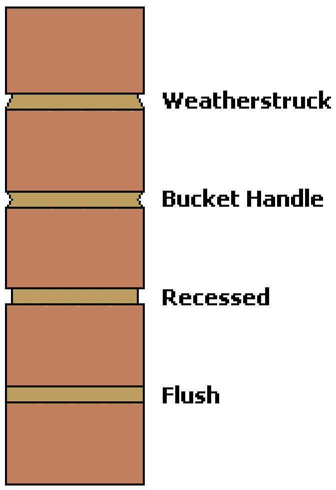


Figure 2: Types of mortar joints

Although bed joints are usually adequately filled, the common practice of 'topping and tailing' headers can lead to insufficiently filled perpendicular joints and an increased risk of water penetration.

Earth-retaining walls (excluding the coping or capping)

Because of the possibility of contamination from the ground and saturation by ground waters, in addition to severe climatic exposure, these walls are particularly prone to frost and sulfate attack, if not protected as previously described. It is strongly recommended that such walls are back-filled with free-draining material to prevent a build–up of water pressure, and are water- proofed on the retaining face.

Free flowing drainage holes must be provided every 2 brick lengths along the lower course of brickwork retaining walls.

For further information:
The Clay Brick Association of South Africa
Website: www.claybrick.org