Part 5
STRUCTURAL MASONRY WITH CLAY BRICK

5.1 STRUCTURAL DESIGN REQUIREMENTS

Any building should be designed to provide strength, stability, serviceability and durability in accordance with accepted principles of structural design. The design of the structural system of any building should be carried out in accordance with SABS 0160 (for loads) and SABS 0164 (for structural masonry).

However, "deemed-to-satisfy rules" for single and double-storey buildings (with certain limitations) are covered in:

- SABS 0400: *The Application of the National Building Regulations*
- *National Home Builders Registration Council's Home Building Manual,* parts 1, 2 and 3.

The design and construction of all buildings must comply with the statutory requirements of the National Building Regulations (SABS 0400) and the National Home Builders Registration Council Warranty Scheme, with their *Home Building Manuals*.

This Clay Masonry Manual covers only the "deemed-to-satisfy rules" in SABS 0400. SABS 0400 is currently being revised.

5.2 EMPIRICAL DESIGN (SABS 0400)

5.2.1 Building limitations

The building shall not exceed two storeys in height and shall be subject to the following limitations:

- The building plan-form and the layout of the intersecting, mutually stabilising walls that form part of such a building, shall provide a structure that is stable against the action of horizontal forces from any direction and shall consist of rectangular, polygonal or circular cells, or a series of contiguous or intersecting cells.
- The span between supporting walls of a timber or metal roof truss, roof rafter or roof beam shall not exceed 10 m and the span between supporting walls of any first floor or roof slab shall not exceed 6 m.
- The dead load of the roof covering material shall not exceed 800 N/m^2 of slope area for roofs other than concrete slabs. Concrete roof slabs shall not exceed 175 mm in thickness if of solid construction, or the equivalent mass if of voided construction.
- Concrete first floor slabs shall not exceed 175 mm in thickness if of solid construction, or the equivalent mass if of voided construction.
- In order to limit floor loading on first floor space or on suspended ground floor slabs, the use of such floors shall be restricted to:
  - detached dwelling houses and dwelling units;

- bedrooms, wards, dormitories, bathrooms containing soil fixtures, kitchens, dining rooms, lounges and corridors, in educational buildings, hospitals, hotels and other institutional occupancies;
- classrooms;
- offices; and
- cafes and restaurants.

Note: SABS 0400 does not cover the construction of buildings in areas of seismic activity (earthquakes). In the code of practice of the Joint Structural Division of the South African Institution of Civil Engineering and the Institution of Structural Engineers on the assessment of the performance of housing units in South Africa, details are given of seismic hazard zones in the country and values of peak ground acceleration to be used in design.

5.2.2 Strength requirements for masonry units and mortar (SABS 0400 Table 1 – Part KK4)

Table 6: Strength requirements for masonry units and mortar

Wall Type	Position	Minimum average compressive strength, MPa		Class* of mortar required
		Solid units	Hollow units	
Structural other than foundation and retaining walls	Single storey building – internal or external	7,0	3,5	II
	Double-storey building – internal or external	10,5 or **14,0	7,0	II
Non-structural other than parapet, balustrade and free-standing walls	External	7,0	3,5	II
	Internal	7,0	3,5	III
Free-standing	External or internal	10,5	7,0	II
Foundation	Supporting single storey	7,0	3,5	II
Foundation	Supporting double-storey	10,5 or 14,0	7,0	II
Parapet	—	7,0	3,5	II
Balustrade	—	7,0	3,5	II
Retaining	—	10,5	7,0	II

* Lime may be added to the mortar mix

SABS 0164-1 specifies the method of test for the compressive strength of mortar and gives details of the compressive strength required of the various classes of mortar and approximate mix proportions used to attain the required strengths.

** See table 7

5.2.3 Dimensions of masonry walls in buildings (SABS 0400 Table 2 – Part KK5)

Table 7: Permissible dimensions of masonry walls in buildings

Nominal wall thickness (mm)	Use of wall in a building	Maximum storey height (m) [1, 5]	Maximum height, ground floor to top of external gable, (m)	Maximum unsupported length, (m)[2]	Minimum average compressive strength (MPa)		Minimum class of mortar [4]
					Solid units	Hollow units	
90	Non-structural internal wall in any storey	3,0	n/a	6,0	7,0	3,5	III
	External infilling and cladding to framed building to height of 25 m	3,3	n/a	note (3)	7,0	n/p	II
	Wall providing lateral support in single storey building but carrying no gravity load other than its own weight	3,0	n/a	6,0	7,0	3.5	II
110	Non-structural internal wall in any storey	3,3	n/a	7,0	7,0	3,5	III
	External infilling and cladding to framed building to height of 25 m	3,3	n/a	note (3)	7,0	3,5	II
	Structural wall in single storey building	2,6	4,0	6,0	7,0	3,5	II
	Wall providing lateral support in single or double-storey building but carrying no gravity load other than its own weight	3,3	n/a	7,0	7,0	3,5	II
140	Non-structural internal wall in any storey	3,0	n/a	7,0	7,0	3,5	III
	External infilling and cladding to framed building to height of 25 m	3,0	n/a	5,0	7,0	3,5	II
	Structural wall in single storey building	3,3	5,0	6,0	7,0	3,5	II
	Structural wall in double-storey building	3,0	7,5	6,0	10,5	7,0	II
190	Non-structural internal wall in any storey	3,5	n/a	9,0	7,0	3,5	III
	External infilling and cladding to framed building to height of 25 m	3,3	n/a	7,0	7,0	3,5	II
	Structural wall in single storey building	3,5	5,5	8,0	7,0	3,5	II
	Structural wall in double-storey building	3,3	8,5	8,0	10,5	7,0	II
230	Non-structural internal wall in any storey	4,0	n/a	9,0	7,0	3,5	III
	External infilling and cladding to framed building to height of 25 m	3,3	n/a	8,0	7,0	3,5	II
	Structural wall in single storey building	4,0	6,0	9,0	7,0	3,5	II
	Structural wall in double-storey building	3,3	8,5	9,0	10,5	7,0	II
90-50-90 to 90-110-90 cavity wall	External infilling and cladding to framed building to height of 25 m	3,3	n/a	5,0	7,0	3,5	II
	Structural wall in single storey building	3,0	4,5	8,0	7,0	3,5	II
	Structural wall in double-storey dwelling unit without concrete slab roof	2,8	7,5	8,0	14,0	n/p	II
110-50-110 to 110-110-110 cavity wall	External infilling and cladding to framed building to height of 25 m	3,3	n/a	6,0	7,0	3,5	II
	Structural wall in single storey building	3,0	5,0	9,0	7,0	3,5	II
	Structural wall in double-storey building	3,0	8,0	9,0	14,0	7,0	II

Note: n/a = not applicable, n/p = not permitted.

1) Measured from floor level to floor level or from floor level to eaves in case of top storey.
2) Distance between intersecting walls, concrete columns or other members providing effective lateral support to wall and to which it is securely bonded or anchored. Where wall panel is supported at one end only, the unsupported length shall not exceed one-half of the tabulated length.
3) Only permitted as exterior leaf of cavity wall in which internal leaf is a structural concrete wall to which a masonry wall is tied as required for cavity walls by rule (KK8 SABS 0400).
4) See Table 6.
5) A parapet wall of 500 mm in height added to storey height is permitted.

5.2.4 Empirical rules for foundations (SABS 0400 Part H)

Empirical rules apply to buildings not exceeding two storeys in height and with loadings not exceeding those detailed in building limitations for empirical design, except in cases where the founding material is heavy soil, or shrinkable clay or a soil with collapsible fabric. These rules include that:

- Walls are to be placed centrally on foundations.
- Concrete should have a compressive strength of at least 10 MPa or be mixed in proportions (by volume) not weaker than 1 part of cement to 4 parts of sand to 5 parts of coarse aggregate.
- Any continuous strip foundation shall have a thickness of not less than 200 mm.
- The minimum width of any continuous strip foundation shall not be less than 600 mm for a wall supporting a roof covered with concrete tiles, clay tiles or thatch; 400 mm for a wall supporting a roof covered with metal or fibre-cement sheets or metal roof tiles.

SABS 0161: *The design of foundations for buildings* contains recommendations with regard to site investigations and inspections, materials, design considerations, earthworks and excavations, and foundation types.

5.2.4.1 Foundation preparation

- Top soil containing grass roots must be removed from the area where unreinforced or reinforced slabs are to rest. Loose or disturbed ground must be compacted.
- The accuracy of the setting out shall be achieved through positive control measures: their relative location to site boundaries and adjacent structures shall be verified. Regular checks on the trench widths, trench lengths and the length of diagonals across external corners must be carried out.
- On sloping ground, foundation trenches for strip footings may be stepped so that the required foundation depth is attained as shown in Figure 6.
- Sites to receive 'slab-on-the-ground' foundations shall be levelled. All necessary filling shall comply with the requirements of compaction provided below. The bases of edge beams shall be sloped not more than 1:10. Steps in slabs in excess of 400 mm shall only be permissible if approved by a competent person.
- Steps in foundations shall not be provided within 1,0 m from corners.
- Excavations shall be deepened locally to remove soft spots where necessary. Hard spots shall be removed wherever practicable. Where soft spots/isolated boulders do not exceed 1 500 mm in diameter, unreinforced strip foundations may be centrally reinforced with two No Y12 bars, extending a distance of not less than 1 500 mm beyond the face of such soft spots as shown in Figure 7.

Excavations should be prodded with a 10 to 12 mm diameter bar prior to the casting of concrete. Uniform penetration should be obtained. Where this is not the case, the soft spots (where penetration is greater than in the surrounding areas), should be dealt with as shown in Figure 7.

- Excessive foundation excavations shall be avoided.
- Any fill upon which edge beams of 'slab-on-the-ground' foundations and strip footings are to be founded, shall be placed under the supervision of a competent person or shall be deepened to be founded on *in situ* material. The controlled fill shall continue past the edge of the foundation and at least 1 000 mm shall be retained or battered beyond this point by a slope not steeper than 1:2 (vertical:horizontal).
- Trenches shall be kept free of surface water.
- Where the bottom of foundations has dried out excessively due to exposure or has softened due to rain or ground water, the excavation shall be rebottomed prior to concreting.

Figure 6: Acceptable method of stepping strip foundations and 'slab-on-the-ground' foundations

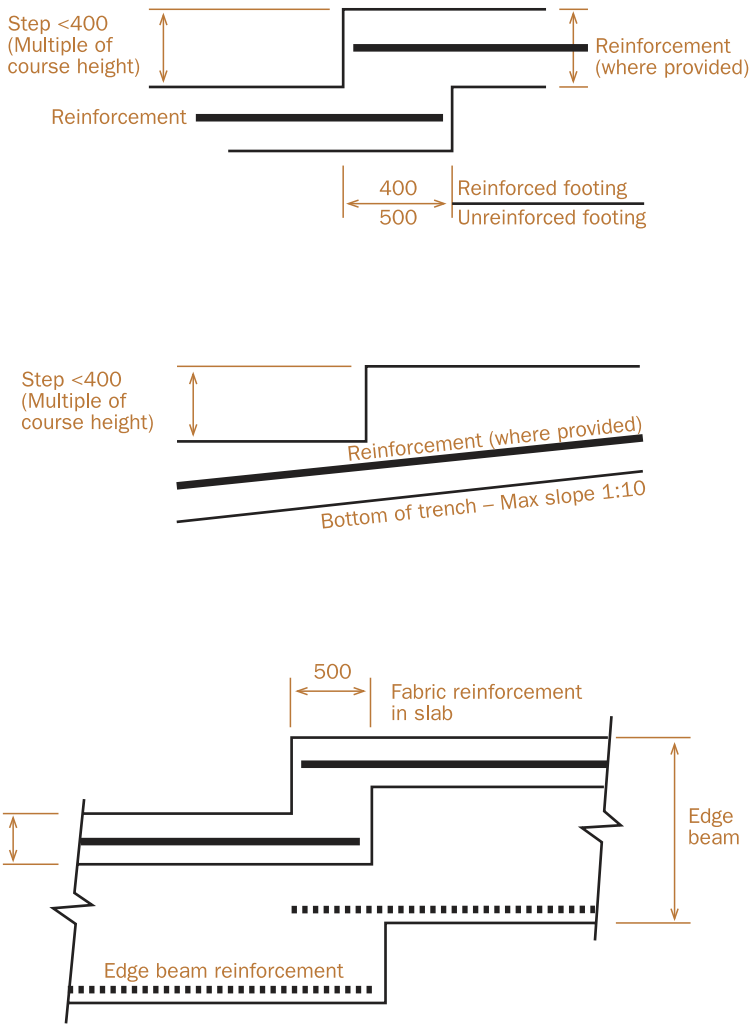
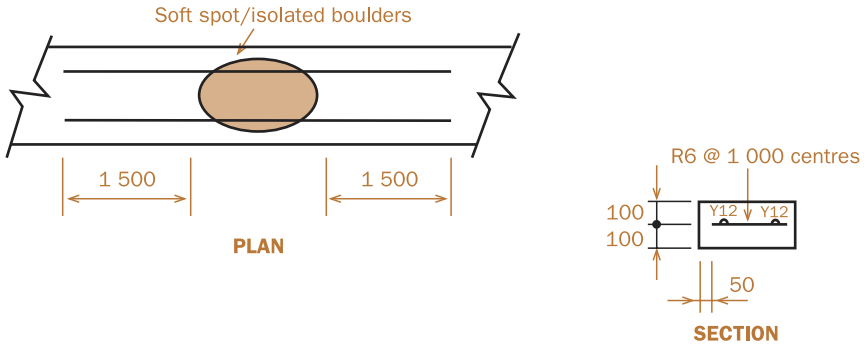


Figure 7: Reinforcement in strip footings at soft/hard spots



5.2.4.2 *Minimum width of strip foundations in single storey structures (SABS 0161: Part 4, Section 2, Table 2)*

Table 8: Minimum width of strip foundations in single storey structures

Type of founding material	Tiled or sheeted roof		Reinforced concrete roof	
	Internal wall (mm)	External wall (mm)	Internal wall (mm)	External wall (mm)
Rock	400	400	400	400
Soil	400	500	600	750

Note: Internal walls upon which reinforced concrete roofs do not bear may have a foundation width of 400 mm.

5.2.4.3 *Compaction*

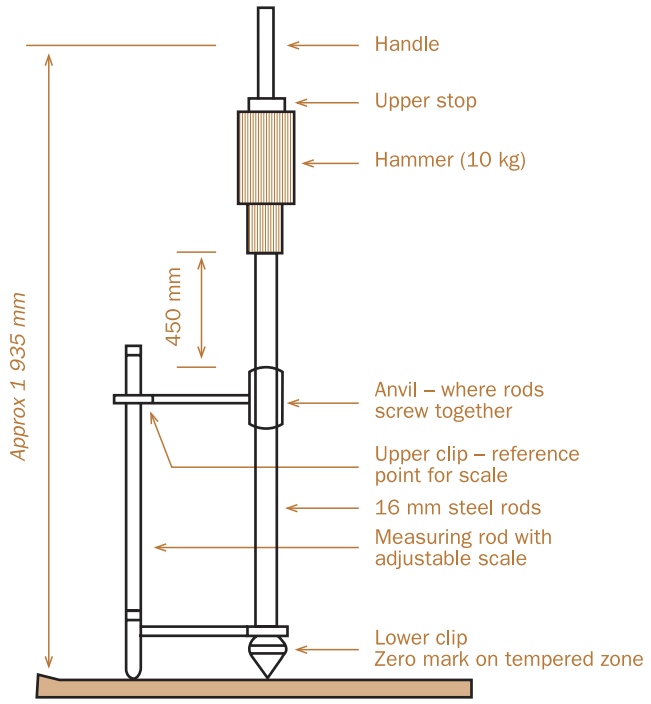
The maximum height of fill beneath floor slabs and 'slab-on-the-ground' foundations, measured at the lowest point, shall not exceed 400 mm unless certified by a competent person.

Fill shall be moistened prior to compaction so that a handful squeezed in the hand is firm, but does not show signs of moisture. Fill shall be placed in uncompacted layers not exceeding 100 mm in respect of hand compaction, or 150 mm in respect of compaction by mechanical means.

Each uncompacted layer shall be well compacted before additional fill material is added.

Compaction in excess of 3 blows of a dynamic cone penetrometer (see Figure 8) is required to penetrate 100 mm of the fill, provided that fills do not comprise more than 10% gravel of size less than 10 mm and contain no isolated boulders.

Figure 8: Dynamic cone penetrometer



5.2.5 Minimum thickness of foundation walls (SABS 0400 Table 4 – Part KK9)

- The height of any foundation wall not acting as a retaining wall shall not exceed 1,5 m.
- Where a difference in ground level, including backfill, exists between the two foundation walls, such difference shall not exceed 1,0 m.
- No foundation wall shall have a thickness less than the relevant value given in Table 9; provided that such thickness shall not be less than:
  - the thickness of the wall carried by such foundation wall; or
  - if it is the wall carried by the foundation wall, the sum of the thicknesses of the leaves of such a cavity wall.

Table 9: Minimum thickness of foundation walls

Type of foundation wall	Minimum thickness of wall (mm)						
	Acting as a retaining wall			Not acting as a retaining wall			
	*Difference in ground level (mm)			Height (mm)			
	Less than 500	500 to 750	750 to 1 000	Less than 300	300 to 500	500 to 1 000	1 000 to 1 500
Single leaf brick							
External	140	190	230	140	140	140	190
Internal	—	190	230	90	140	140	190
Single leaf hollow block (cavities filled with concrete)							
External	140	190	230	140	140	140	190
Internal	140	190	230	90	140	140	190
Cavity walls							
External (cavity filled to 150 mm below damp-proof course level)	190	190	230	190	190	190	190

* For difference in ground level of more than 1 000 mm, see table 10.

5.2.6 Free-standing walls (SABS 0400 Table 5 – Part KK11)

- Where any free-standing wall is a masonry wall, the height, thickness and pier size of such a wall shall conform to the relevant values given in Table 10. Any cavities in piers in a wall constructed of hollow units shall be filled with concrete.

Table 10: Free-standing walls

Nominal wall thickness (mm)	Maximum height of wall above finished ground (m)		Piers	
	Without piers	With piers	Nominal (projection x width) (mm)	Maximum spacing (centre to centre) (m)
90	0,8	1,2	200 x 290	1,8
110	1,0	1,4	240 x 230	1,8
140	1,3	1,6	300 x 290	2,0
190	1,5	2,0	400 x 290	2,5
230	1,8	2,3	480 x 350	3,5
290	2,2	2,6	400 x 290	4,5

- A damp-proof course shall not be installed in any free-standing wall.
- Where moisture is likely to be encountered from ground water, high density bricks with a water absorption not exceeding 7% shall be used up to 150 mm above ground level in any free-standing wall.

Where any wall consists of sections of two or more different thicknesses, the maximum height of any such section shall not be greater than the value given in Table 10 for the thickness in question. The sum of the heights of the various sections of such a wall shall not be greater than the value of the maximum height given in Table 10 for the thickest section of such a wall.

5.2.7 Retaining walls (SABS 0400 Table 6 – Part KK 12)

A masonry retaining wall, excluding basement or foundation walls of buildings, constructed in accordance with these rules, shall not be erected in a position where the ground or fill which it retains may be subjected to superimposed loads, other than that from pedestrian traffic, within a distance equal to the height of the fill retained by such a wall.

Where any structure is to be erected on top of such a wall, it shall be designed for structural adequacy, provided that a wire fence not greater in height than 1,5 m shall not be regarded as a structure.

There shall be no excess of fill behind such a wall within a distance equal to the height of the wall.

Movement joints shall be provided at distances not exceeding 10 m (moisture expansion) apart.

Subsoil drainage shall be provided behind such a wall, together with sufficient weepholes to prevent the accumulation of water.

No horizontal damp-proof course of sheet material shall be used in any such retaining wall.

No height, wall thickness and pier size for any masonry retaining wall shall exceed the limits contained in Table 11. Where piers are indicated in the Table, any length of wall shall be supported at each end by such a pier and all piers in the wall shall project from the face of the wall that is not in contact with the fill, shall be bonded into the wall and shall extend to the full height of the wall.

TABLE 11: RETAINING WALLS

Nominal wall thickness (mm)	Maximum height of fill to be retained (m)	Piers	
		Nominal dimensions (projection x width) (mm)	Maximum spacing (centre to centre) (m)
190	0,8	No piers required	
	1,1	300 x 190	2,0
	1,3	400 x 190	2,4
230	0,9	No piers required	
	1,4	360 x 230	2,5
	1,5	480 x 230	2,7
290	1,1	No piers required	
	1,5	300 x 290	3,0
390	1,4	No piers required	

5.3 RAIN PENETRATION REQUIREMENTS (SABS 0400 – PART KK14)

A cavity wall built of masonry is a “deemed-to-satisfy” form of construction to resist the penetration of rain through a wall.

Cavity walls

A cavity wall consists of two parallel walls (leaves) of masonry units built side-by-side and tied to each other with wall ties, with a cavity of width not less than 50 mm and not more than 110 mm.

Weepholes shall be formed in the outer leaf of walling, at intervals not exceeding 1 000 mm and immediately above the damp-proof courses, by leaving perpend joints open for a height of approximately 50 mm, or providing openings approximately 30 mm wide in the shell bedding of hollow units.

Where ducts, sleeves or pipes are laid across a cavity, the construction shall prevent the transmission of moisture. The cavity in cavity wall construction shall be kept free of mortar and debris as the work proceeds. Ties shall be cleaned of mortar droppings. Mortar droppings reaching the base of the cavity shall be removed daily through temporary openings. Care shall be taken not to damage the damp-proof course membrane while cleaning the cavity.

Timber battens spread across the uppermost layer of wall ties may be used to prevent excess mortar being spilt into cavities.

Stainless steel (Grade 816) ties shall be used in the following areas:

- sea spray zones; and
- tidal and splash zones.

Coastal areas are situated between the coastline and an imaginary line 30 km inland, parallel with the coastline, or the top of the escarpment or watershed of the first mountain range inland, if these are less than 30 km from the coastline. The entire area of jurisdiction of any local authority whose area is cut by the line demarcating these coastal areas is taken as falling within the coastal area.

Figure 9 illustrates the shapes of ties that are commonly used. Crimp wire ties must not be used in cavity wall construction. They may be used in collar jointed walls. Butterfly and modified PWD wall ties are suitable for use in cavity wall construction where the cavity width does not exceed 110 mm.

5.4 MORTAR

Four types of building mortar are detailed in SABS specifications (SABS 0164-1 and SABS 0249):

- Common cement: sand
- Common cement: lime: sand
- Common cement: sand plus mortar plasticiser
- Masonry cement: sand.

5.4.1 Mix proportions

The approximate limiting proportions of these mortars are detailed in Table 12.

Table 12: Proportions of mortar

Mortar class	Common cement (kg)	Lime (litres)	Sand (measured loose and damp) (litres) maximum	Masonry cement: sand or common cement: sand with mortar, plasticiser	
				kg	litres, max
I	50	0-10	130	50	100
II	50	0-40	200	50	170
III	50	0-80	300	50	200

Class II mortar is the general purpose mortar for all brickwork. Concrete wheelbarrows have a capacity of 65 *litres* and a sand volume of 200 *litres* is achieved by using three wheelbarrows of sand.

50 kg common cement:	0-40 litres lime:	200 litres (max) of sand measured loose and damp
2 bags		6 wheelbarrows

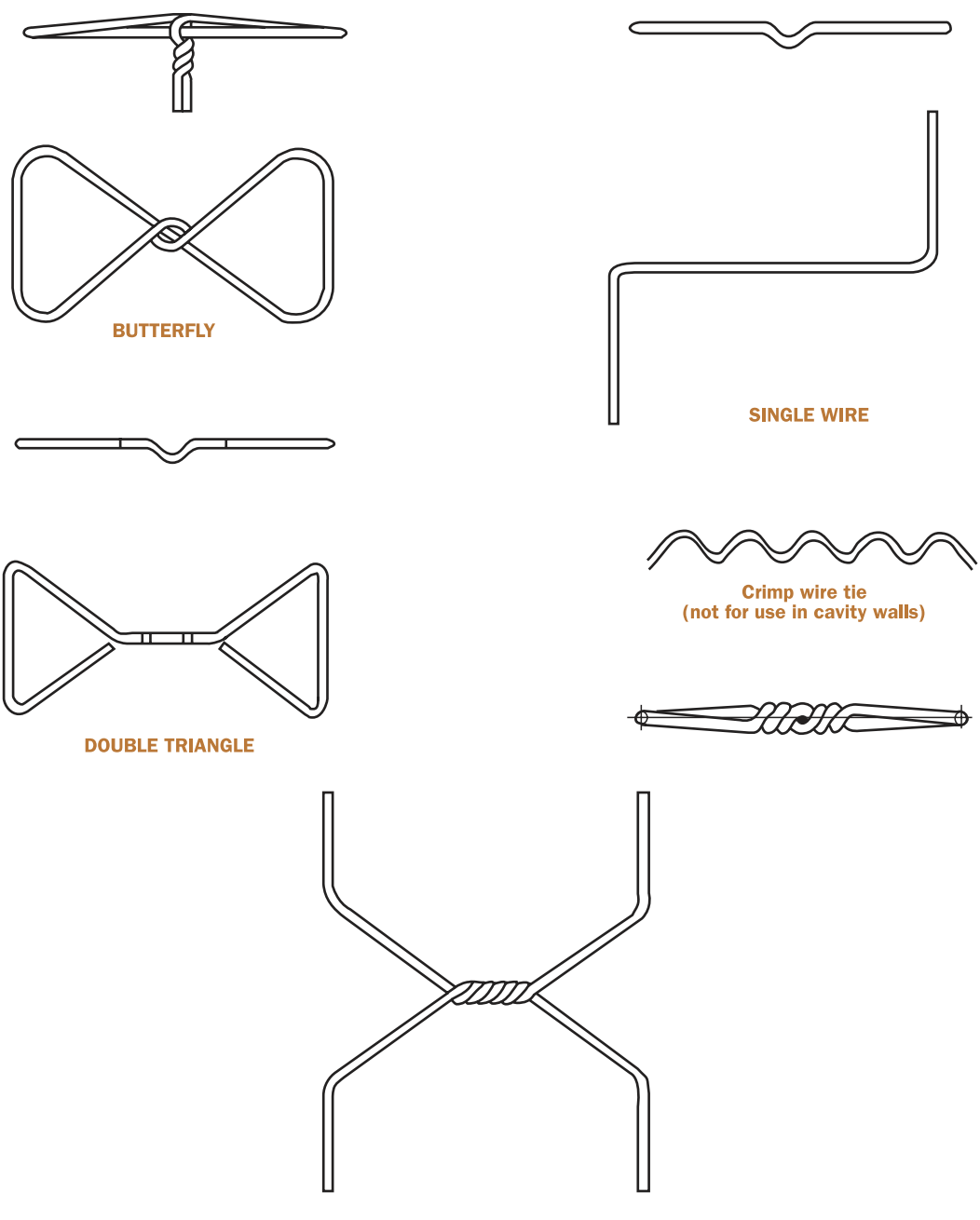
The addition of lime is optional. A maximum of 40 litres is permitted per 50 kg unit of common cement.

Mortars made with Masonry Cements carrying the NHBRC logo and the words "Cement type and applications may be used in accordance with the NHBRC Home Building Manual" and designated as being 12,5:

50 kg masonry cement:	170 litres (max) of sand measured loose and damp
2 bags	5 wheelbarrows

A competent person is required to design mixes for mortars which use materials or mix proportions other than those described above to satisfy the requirements of 5.4.1.

Figure 9: Wall ties



Note: For dimensions of wall tiles refer to SABS 28

5.4.2 Cement

Cements for use in mortar shall be common cements complying with SABS EN 197-1, and masonry cements complying with SABS ENV 413-1.

Cement designation	Strength grade
CEM I	42,5N
CEM II A-L	32,5N or higher
CEM II A-M	42,5N
CEM II A-S	32,5N or higher
CEM II A-V	32,5N or higher
CEM II B-S	32,5N or higher
CEM II B V	32,5N or higher
CEM III A	32,5N or higher

5.4.3 Lime

The use of lime in mortar mixes is optional. Lime imparts the properties of plasticity and water retention to mortar. The latter property is important as it prevents mortar drying out, resulting in the incomplete hydration of the common cement.

Lime used in mortar is hydrated lime (commercial bedding lime) and not quicklime or agricultural lime. Lime gives the best results when used with coarse sands. Lime with clayey sands can make the mortar over-cohesive and difficult to use. Lime should not be used with masonry cement.

5.4.4 Sand

Table 13: Grading requirements of sands for mortar
(extract from SABS 1090: Aggregates from natural sources – fine aggregate for plaster and mortar)

Size of square apertures (mm)	Percentage by mass passing	
	Fine aggregate for plaster	Fine aggregate for mortar
4,750	100	100
2,360	90-100	90-100
1,180	70-100	70-100
0,600	40-90	40-100
0,300	5-65	5-85
0,150	0-20	0-35
0,075	0-7,5	0-12,5

Sand for mortar should comply with SABS 1090 and must be well graded from 5 mm downwards, in accordance with Table 13.

In the assessment of mortar sands, grading is only one factor to be considered, with shape, surface area, character of fines and average particle size of the sand also being important. A simple practical field test that includes these factors is the Cement and Concrete Institute test.

Provided that a sand yields a smooth, plastic and cohesive mix, its quality, based on "water demand" can be determined by the following test.

The quantities used should be weighed on a kitchen scale that is accurate, and the test should be carried out on a smooth impervious surface. It is also important that the sample used is fairly representative of the bulk supply.

Procedure:

- Dry out a wheelbarrow full of sand to be tested.
- Weigh 5 kg cement and 25 kg of dry sand. Measure 5 *litres,* 1 *litre* and 1,5 *litres* water into separate containers.
- Mix the cement and sand until the colour is uniform.
- In succession, mix in each of the volumes of water (5 *litres*, 1 *litre* and 1,5 *litres*) until the mix reaches a consistency suitable for plastering.

Then:

- If 5 *litres* is enough – the sand is of "good" quality
- If 5 *litres* + 1 *litre* is enough – the sand is of "average" quality
- If 5 *litres* + 1 *litre* + 1,5 *litres* is enough – the sand is "poor"
- If more than 7,5 *litres* is needed – the sand is "very poor".

A "good" or "average" sand should be used for mortar in walling below the damp-proof course.

5.4.5 Mortar plasticisers

Mortar plasticisers exercise a desirable effect on the workability and plasticity of the mortar in which they are used. Generally, the admixtures have no effect on setting time (they do not accelerate or retard the mortar setting) but may cause air entrainment.

The use of mortar plasticisers is optional. Their effectiveness varies with the quality of sand, the composition of the cement, its fineness, the water-cement ratio, temperature of the mortar, volume of plasticiser and other factors or site conditions.

5.4.6 Pigments

Pigments may be used to colour mortar, with the dosage depending on the specific colour required. The recommended limit on mineral oxide content is 7% of common cement content. Pigmented mortar with face brickwork can change the appearance of a building dramatically.

5.4.7 Ready-mixed mortar

Ready-mixed mortar with an extended board life has been successfully used over a number of years.

Ready-mixed mortar has advantages of convenience on site as it is delivered at a consistency ready for use. Usually it is delivered in ready-mix trucks or containers. It is stored in containers on site in a protective manner that minimises loss due to evaporation and protects the mortar from freezing in cold weather. No other materials or admixtures are added on the site.

The mortar contains a regulator, which is a retarding type admixture, that controls the initial hydration period of the cement. This allows the mortar to remain plastic and workable for a period, generally between 24 and 36 hours, but sometimes as long as 72 hours. At any time during this period when the mortar is used, suction by the masonry units will occur and initial set takes place in a normal manner. The early strength that develops is satisfactory for the walls to be constructed at a normal rate and the mortar will retain enough water to ensure long-term strength development.