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SANS 10400-H: THE APPLICATION OF THE NATIONAL BUILDING REGULATIONS — PART H: FOUNDATIONS

Remarks:

PLEASE NOTE:

- **The technical committee, SABS SC 59P:** *Construction standards – Geotechnical standards* **responsible for the preparation of this standard has reached consensus that the attached document should become a South African standard. It is now made available by way of public enquiry to all interested and affected parties for public comment, and to the technical committee members for record purposes. Any comments should be sent by the indicated closing date, either by mail, or by fax, or by e-mail to**

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Any comment on the draft must contain in its heading the number of the clause/subclause to which it refers. A comment shall be well motivated and, where applicable, contain the proposed amended text.

- **The public enquiry stage will be repeated if the technical committee agrees to significant technical changes to the document as a result of public comment. Less urgent technical comments will be considered at the time of the next amendment.**

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Edition 3

SOUTH AFRICAN NATIONAL STANDARD

The application of the National Building Regulations

Part H: Foundations

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Edition 3

Table of changes

Change No.	Date	Scope

Acknowledgement

The SABS Standards Division wishes to acknowledge the work of the South African Institution of Civil Engineering, the South African Institute of Engineering and Environmental Geologists, and the National Home Builders Registration Council in updating this document.

Foreword

This South African standard was approved by National Committee SABS SC 59P, *Construction standards – Geotechnical standards*, in accordance with procedures of the SABS Standards Division, in compliance with annex 3 of the WTO/TBT agreement.

This document was published in xxxx 2012.

This document supersedes the corresponding parts of SABS 0400:1990 (first revision).

Compliance with the requirements of this part of SANS 10400 will be deemed to be compliance with the requirements of part H of the National Building Regulations, issued in terms of the National Building Regulations and Building Standards Act, 1977 (Act No. 103 of 1977).

SANS 10400 consists of the following parts, under the general title *The application of the National Building Regulations:*

Part A: General principles and requirements.

Part B: Structural design.

Part C: Dimensions.

Part D: Public safety.

Part F: Site operations.

Part G: Excavations.

Part H: Foundations.

Part J: Floors.

Part K: Walls.

Part L: Roofs.

Part M: Stairways.

Part N: Glazing.

Part O: Lighting and ventilation.

Foreword (*concluded*)

Part P: Drainage.

Part Q: Non-water-borne means of sanitary disposal.

Part R: Stormwater disposal.

Part S: Facilities for persons with disabilities.

Part T: Fire protection.

Part V: Space heating.

Part W: Fire installation.

Part X: Environmental sustainability.

Part XA: Energy usage in buildings.

This document should be read in conjunction with SANS 10400-A.

Annex A forms an integral part of this document. Annexes B, C, and D are for information only.

Contents

The application of the National Building Regulations

Part H:
Foundations

1 Scope

This part of SANS 10400 provides deemed-to-satisfy requirements for compliance with part H (Foundations) of the National Building Regulations.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from the SABS Standards Division.

SANS 1936-1:2012, *Development of dolomite land – Part 1: General principles and requirements*.

SANS 1936-2, *Development of dolomite land – Part 2: Geotechnical investigations and determinations*.

SANS 1936-3, *Development of dolomite land – Part 3: Design and construction of buildings, structures and infrastructure*.

SANS 2001-CM2, *Construction works – Part CM2: Strip footings, pad footings and slab-on-the-ground foundations for masonry walling.*

SANS 10400-A, *The application of the National Building Regulations – Part A: General principles and requirements.*

SANS 10400-B:2012, *The application of the National Building Regulations – Part B: Structural design.*

SANS 10400-J, *The application of the National Building Regulations – Part J: Floors.*

SANS 10400-K, *The application of the National Building Regulations – Part K: Walls.*

3 Definitions

For the purposes of this document, the definitions given in SANS 10400-A (some of which are repeated for convenience) and the following apply.

3.1
action

3.1.1
direct action
assembly of concentrated or distributed forces acting on a structure, or set of forces (loads) applied to a structure

3.1.2
imposed action
variable action
action for which the variation in magnitude with time is neither negligible in relation to the mean value nor monotonic

3.1.3
indirect action
cause of deformations imposed on a structure or constrained in it, or set of imposed deformations or accelerations

3.1.4
permanent action
action that is likely to occur continuously throughout a given reference period and for which the variations in magnitude with time are small compared with the mean value, or for which the variation is always in the same direction (monotonic) until the action attains a certain limit value

3.2
articulation joint
joint in masonry provided at suitable locations and intervals, that takes cognizance of the lateral stability and structural integrity of individual panels, and that enables wall panels to move in harmony with their supports without developing significant damage

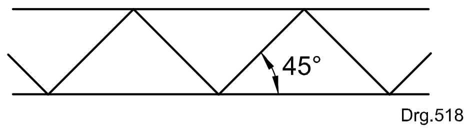
3.3
bed joint
horizontal mortared joint between courses of masonry

3.4
brickforce
light, welded steel fabric that comprises two hard-drawn wires of diameter not less than 2,8 mm and not more than 3,55 mm, held apart by either perpendicular (ladder-type) or diagonal (truss-type) cross wires (see figure 1*)*

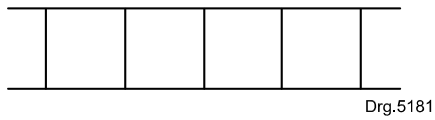
NOTE Ladder-type brickforce usually has a main wire diameter that does not exceed 3,15 mm and is supplied in rolls. Truss-type brickforce usually has a diameter of 3,55 mm and is supplied flat.

3.5
cavity
void in a masonry member formed by or between the individual masonry units that comprise that member

3.6
cavity wall
wall that consists of two parallel walls (called leaves) of either solid or hollow units, that are built side by side and tied to each other with wall ties so that there is a cavity of width at least 50 mm between the leaves



a) Truss type



b) Ladder type

Figure 1 — Brickforce types

3.7
collapsible soil
soil with a high void ratio and with a low density that, when subjected to a combination of direct actions and an increase in soil moisture content, experiences sudden or rapid settlement

3.8
competent person
person who is qualified by virtue of his education, training, experience and contextual knowledge to make a determination regarding the performance of a building or part thereof in relation to a functional regulation or to undertake such duties as may be assigned to him in terms of the National Building Regulations

NOTE This is a generic definition, to be used where no other definition is given, or no references are made to other standards. Other parts of SANS 10400 contain definitions of a more specific nature relevant to their disciplines.

3.9
competent person (civil engineering)
person who

a) is registered in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000), as either a Professional Engineer or a Professional Engineering Technologist,

b) has a tertiary qualification (degree or diploma) in civil engineering, and

c) is generally recognized as having the necessary experience and training to undertake rational assessments or rational designs in the field of civil engineering

3.10
competent person (geotechnical)
person who

a) is registered in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000), as either a Professional Engineer or a Professional Engineering Technologist and has a tertiary qualification (degree or diploma) in civil engineering, or

b) is registered as a Professional Natural Scientist in terms of the Natural Scientific Professions Act, 2003 (Act No. 27 of 2003), and has a BSc (Hons) degree or higher qualification in engineering geology, and

c) has suitable experience in geotechnical site investigations or foundation designs (or both)

3.11
compressible soil
soil that, when subjected to direct actions, undergoes a gradual settlement as volume changes occur

3.12
core
void within the cross section of a hollow masonry unit

3.13
deemed-to-satisfy requirement
non-mandatory requirement, the compliance with which ensures compliance with a functional regulation

3.14
dolomite land
land underlain by dolomite or limestone residuum or bedrock (or both), within the Malmani Subgroup and Campbell Rand Subgroup, typically at depths of no more than

a) 60 m in areas where no de-watering has taken place and the local authority has jurisdiction, is monitoring and has control over the groundwater levels in the areas under consideration; or

b) 100 m in areas where de-watering has taken place or where the local authority has no jurisdiction or control over groundwater levels

NOTE For more information on dolomite land in South Africa, see annex B of SANS 1936-1:2012.

3.15
expansive soil
fine-grained soil the clay mineralogy of which is such that it changes in volume to varying degrees in response to changes in moisture content, i.e. the soil increases in volume (heaves or swells) upon wetting up and decreases in volume (shrinks) upon drying out

3.16
expected damage
approximation of the probable damage that might occur in walls and floors

3.17
fabric reinforcement
steel fabric of hard-drawn mild steel wire, that consists of longitudinal and cross wires welded together, and is intended for use as a form of reinforcement for concrete slabs

3.18
factual data
materials, statistics and properties that can be seen, measured or identified by means of accepted or standardized criteria, classifications and tests

3.19
foundation
that part of a building which is in direct contact with, and is intended to transmit loads to, the ground

3.20
foundation wall
that portion of a wall between the foundation and the lowest floor above such foundation

3.21
free-standing wall
wall (that is not a retaining wall) without lateral support

3.22
functional regulation
regulation that sets out in qualitative terms what is required of a building or building element or building component in respect of a particular characteristic, without specifying the method of construction, dimensions or materials to be used

3.23
geotechnical site investigation
process of evaluating the geotechnical character of a site in the context of existing or proposed works or land usage, which may include one or more of the following:

a) evaluation of the geology and hydrogeology of the site;

b) examination of existing geotechnical information pertaining to the site;

c) excavating or boring in soil or rock and systematic description of the soil and rock profiles;

d) determining the depth of any fill that might be present;

e) in-situ assessment of geotechnical properties of materials;

f) recovery of samples of soil or rock for examination, identification, recording, testing or display;

g) testing of soil or rock samples to quantify properties relevant to the purpose of the investigation;

h) evaluation of geotechnical properties of tested soils;

i) reporting of the results; and

j) providing solutions (where relevant) and conclusions

3.24
ground movement
displacement in any direction of the founding stratum that is not solely dependent on the loads applied by the structure

3.25
grouted cavity wall
cavity wall with the space between the leaves filled with infill concrete, and which may be reinforced

3.26
infill concrete
highly workable concrete placed in cores, cavities or pockets to produce grouted and reinforced masonry

3.27
inherent hazard class
IHC
classification system whereby a site is characterized in terms of eight standard inherent hazard classes denoting the likelihood of an event (sinkhole or subsidence) occurring, as well as its predicted size (diameter)

3.28
inspection
general inspection by a competent person of a system or measure or installation during the erection or installation of a building, or part thereof, at such intervals as might be necessary in accordance

with accepted professional practice, to enable such competent person to be satisfied that the design assumptions are valid, the design is being correctly interpreted and that the work is being executed generally in accordance with the approved designs, appropriate construction techniques and good engineering practice, but excludes detailed supervision and day-to-day inspection

3.29
interpretative data
information derived from factual data using accepted and proven techniques, or from reasonable judgment exercised in the assessment of geological and geotechnical conditions or processes evident at the site

3.30
lintel
beam that spans an opening in a wall

3.31
load
value of a force corresponding to an action

3.32
masonry unit
rectangular unit that is intended for use in the construction of bonded masonry walling

3.32.1
hollow masonry unit
masonry unit that contains cores that exceed 25 %, but that do not exceed 60 %, of the gross volume of the unit

3.32.2
solid masonry unit
masonry unit that either contains no cores or contains cores that do not exceed 25 % of the gross volume of the unit

3.33
masonry wall
assemblage of masonry units that are joined together with mortar or grout

3.34
opinion
conclusions or recommendations derived by a competent person from consideration of factual and interpretative data, and from the exercise of judgment

3.35
problem soil horizon
soil horizon that gives rise to movements outside of the range that a type 1 masonry building can tolerate without distress

3.36
rational design
design by a competent person involving a process of reasoning and calculation and which may include a design based on the use of a standard or other suitable document

3.37
retaining wall
wall intended to resist the lateral displacement of materials

3.38
rod reinforcement
bed joint reinforcement in masonry that comprises hard-drawn wires that have a diameter of not less than 4,0 mm and not greater than 6,0 mm, and which are pre-straightened at the point of manufacture

3.39
settlement
downward movement of the foundations caused by the application of a load to the founding stratum by the structure

3.40
sinkhole
feature that occurs suddenly and manifests itself as a hole in the ground

3.41
slab-on-the-ground foundation
concrete floor that is supported on the ground, and that incorporates lightly reinforced integral edge and internal beams

3.42
soil horizon
layer of soil that has similar geotechnical properties

3.43
strength
capability of a body to resist the loads applied to it

3.44
strip foundation
rectangular unreinforced or lightly reinforced concrete foundation that supports masonry walls

3.45
structural
relating to or forming part of any structural system

3.46
structural system
system of constructional elements and components of a building which is provided to resist the loads acting upon it and to transfer such loads to the ground upon which such building is founded

3.47
subsidence
shallow, enclosed depression

NOTE Most South African literature previously used the term “doline” when referring to a subsidence as defined above. The use of the term “subsidence” is in line with international literature and practice.

3.48
type 1 masonry building
building not used for storage or industrial purposes, and with masonry walls that are not supported by steel, concrete or reinforced masonry columns

NOTE Masonry walls in a type 1 masonry building rely on returns and cross walls for their stability, i.e. a cellular construction.

4 Requirements

4.1 General

4.1.1 The functional regulation **H1(1)** contained in part H of the National Building Regulations shall be deemed to be satisfied where a geotechnical site investigation has been carried out in accordance with the requirements of 4.2, and the foundations of a building are in accordance with the relevant requirements of

a) SANS 10400-B, and such foundations are designed to suit site conditions by taking into account

   1) all the information contained in the geotechnical site investigations conducted in accordance with the requirements of 4.2,

   2) the shape, size and construction of the buildings, as well as the layout and topography of the site,

   3) the existing, previous and future vegetation,

   4) differential movements,

   5) the location of services, and

   6) erosion,

   provided that the occupancies classified as E4, H3, H4 and H5 (see Regulation **A20** in SANS 10400-A) also comply with the requirements of annex A;

b) 4.3 in the case of single-storey and double-storey type 1 masonry buildings, provided that in the case of dolomite land, the inherent hazard class determined in accordance with SANS 1936-2 and dolomite area designation, determined in accordance with the requirements of SANS 1936-1, are such that precautionary measures in addition to those pertaining to the prevention of the concentrated ingress of water into the ground are not required to permit the construction of buildings; or

c) 4.4 in the case of free-standing walls and retaining walls, subject to any soil improvements, by chemical or mechanical means (or both) undertaken to improve the properties of soils under the building, executed under the direction and inspection of a competent person (geotechnical).

NOTE SANS 634 establishes a detailed scope of work for a preliminary and two-phase detailed geotechnical site investigations in townships that might be underlain by dolomites, limestone or undermined land, where unoccupied land or undeveloped parcels of land will be utilized for township development purposes.

4.1.2 In the case of type 1 masonry buildings, the following information shall be stated immediately above the title block in the drawings submitted to local authorities in terms of SANS 10400-A (see Regulations **A2** and **A7** in SANS 10400-A):

a) the site class designation, determined in accordance with the requirements of 4.2; and

b) the category of expected damage (see SANS 10400-B), if the design is based on category 2 expected damage.

4.2 Geotechnical site investigations

4.2.1 Geotechnical site investigations shall be undertaken under the direction of a competent person (geotechnical), who shall document and formulate an opinion regarding the parameters upon which the design of the foundations is to be based and, in the case of single-storey or double-storey type 1 masonry buildings, shall classify the site in accordance with the descriptors contained in column 5 of table 1 and the requirements of 4.2.3.

Table 1 — Site class designations of single-storey and double-storey type 1 masonry buildings

1	2	3	4	5
Typical founding material	**Nature of founding material**	**Expected range of total soil movements** mm	**Assumed differential movement** % of total	**Site class designation**
Rock (excluding mud rocks which might exhibit swelling to some depth)	Stable	Negligible	–	R
Fine-grained soils with moderate to very high plasticity (clays, silty clays, clayey silts and sandy clays)	Expansive soils	< 7,5 7,5 to 15 15 to 30 > 30	50 50 50 50	H H1 H2 H3
Silty sands, clayey sands, sands, sandy and gravelly soils	Compressible and potentially collapsible soils	< 5 5 to 10 > 10	75 75 75	C C1 C2
Fine-grained soils (clayey silts and clayey sands of low plasticity), sands, sandy and gravelly soils	Compressible soils	< 10 10 to 20 > 20	50 50 50	S S1 S2
Contaminated soils[a], controlled fill, dolomite land, landslip, landfill, marshy areas, mine waste fill, mining subsidence reclaimed areas, uncontrolled fill, very soft silts/silty clays	Variable	Variable	–	P[b]

NOTE 1 A composite description is more appropriate to describe a site more fully, for example, C1/H2 or S1 or H2 (or both). Composite site classes might lead to higher differential movements and result in design solutions appropriate to a higher range of differential movement, for example, a class R/S1 may be described as a class S2 site. Alternatively, a further site investigation might be necessary as the final design solution might depend on the location of the housing unit on a particular site.

NOTE 2 Where it is not possible to provide a single site designation and a composite description is inappropriate, sites may be given multiple descriptions to indicate the range of possible conditions, for example, H1-H2 or C1-C2.

NOTE 3 Soft silts and clays usually exhibit high consolidation and low bearing characteristics. Structures founded on these horizons might experience high settlements and such sites should be designated as class S1 or S2, as relevant and appropriate.

[a] Sites that contain contaminated soils include those associated with reclaimed mine land, land down the slopes of mine tailings, and old landfills.

[b] Where sites are designated as class P, the reason for such classification should be placed in brackets immediately after the suffix, i.e. P (contaminated soils). Dolomite land should be designated as class P (dolomite-D2/H2) or class P (limestone-D2/H2) where the first designation after dolomite/limestone is the designation obtained from SANS 1936-1.

4.2.2 The competent person (geotechnical) shall document and formulate all opinions in such a manner that a peer review, if conducted on the same basic data, will arrive at a substantially similar opinion.

4.2.3 Site class designations shall be derived from an estimation of the expected range of total soil movements experienced by single-storey and double-storey type 1 masonry buildings, where the foundation load on a foundation that has a width that does not exceed 0,6 m in respect of single-storey buildings and 0,8 m in respect of double-storey buildings, does not cause the soil bearing pressure to exceed 50 kPa.

For the purposes of this subclause, it may be assumed that total soil movements are approximately equal to 50 % for soils that exhibit expansive or compressive characteristics and 75 % for soils that exhibit both compressive and collapse characteristics. Where this assumption is incorrect or inappropriate, the total soil movements shall be adjusted so that the resultant differential movement implied by table 1 is equal to that which is to be expected in the field.

4.2.4 The competent person (geotechnical) shall investigate and advise on the necessity of installing subsurface drains on sites

a) in marshy areas,

b) that have shallow water tables, and

c) that are to be terraced to the extent that the depth of cut below original ground level exceeds 0,75 m.

NOTE 1 The SAICE *Site investigation code of practice* gives guidelines on acceptable engineering practice to assist the construction industry in the planning, design and execution of geotechnical site investigations.

NOTE 2 Annex B outlines the typical geotechnical and structural solutions associated with the site class designations contained in column 5 of table 1.

4.3 Standard foundation solutions for single-storey and double-storey type 1 masonry buildings

NOTE 1 The requirements of 4.3 apply only to dolomite land that is designated as D1 and D2 (see SANS 1936-1).

NOTE 2 On sites with composite classifications, the design should be based on the requirements for the most severe designation.

NOTE 3 Annex C provides information on the protection of single-storey type 1 masonry buildings against damage due to ground movements. It outlines the nature of ground movements in problem soil horizons, and tendencies in damage. It also discusses the repair of significant damage.

4.3.1 Geotechnical solutions

4.3.1.1 Geotechnical solutions shall be designed by a competent person (geotechnical) to reduce total soil movements by, for example,

a) removing the soil horizon that gives rise to movements outside of the range that a building can tolerate without distress, and replacing this horizon with adequately compacted inert material, or reusing the excavated material in a compacted condition;

b) founding the foundations at a greater depth than is commonly associated with normal construction, i.e. on a suitable soil horizon situated below the problem soil horizon; or

c) in-situ compaction.

4.3.1.2 The competent person (geotechnical) shall take into account the impact of a geotechnical solution on the stormwater drainage of the site.

NOTE Impact rolling, if opted for, is frequently undertaken after the roads have been constructed and results in a lowering of the site. Unless the roads are sufficiently low, however, this might cause stormwater to pond.

4.3.1.3 The competent person (geotechnical) shall inspect the works during the implementation of the solution.

4.3.1.4 A competent person (civil engineering) or competent person (geotechnical) shall, in the case of deep strip foundations for masonry walls (see annex B) on class C1, C2, S1 and S2 sites,

a) specify any reinforcing of walls, foundations and floors and precautionary measures that might be required to minimize the cracking of the walls and floors; and

b) inspect and approve the founding horizon.

4.3.1.5 A competent person (civil engineering) or competent person (geotechnical) shall, in the case of soil rafts on class H1, H2, H3, C1, C2, S1 and S2 sites and the compaction of in-situ soils below individual footings on class C1, C2, S1 and S2 sites (see annex B),

a) ensure, in the case of heaving soils, that the entire active profile is removed, or that the remaining profile does not produce surface heave movements in excess of those that can be accommodated by the design solution adopted;

b) approve the founding material or, in the case of compressible and collapsible soils, ensure that sufficient material is removed to permit the use of the design solution specified;

c) approve the backfill material and institute and review appropriate quality control checks on the compaction thereof; and

d) specify any reinforcing of walls, foundations and floors and precautionary measures that might be required to minimize the cracking of the walls and floors.

4.3.2 Structural solutions

4.3.2.1 General

4.3.2.1.1 The requirements of 4.3.2 apply only in respect of single-storey type 1 masonry buildings that comply with the requirements of SANS 10400-K where

a) the height of the wall from the floor level to the top of an external gable does not exceed 5,0 m;

b) the span of roof trusses or rafters (or both) between supporting walls does not exceed 8,0 m;

c) the span of concrete roof slabs between supporting walls does not exceed the dimensions given in figure 2;

d) the dead load (self-weight) of the roof covering of roofs other than concrete slabs does not exceed 80 kg/m^2;

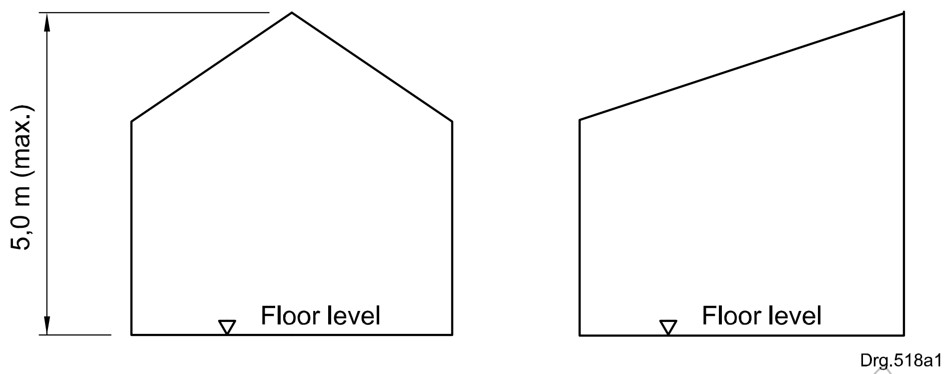
e) the thickness of concrete roof slabs does not exceed 225 mm if of solid construction, or the equivalent mass if of voided construction;

f) the height of foundation walls does not exceed 1,5 m; and

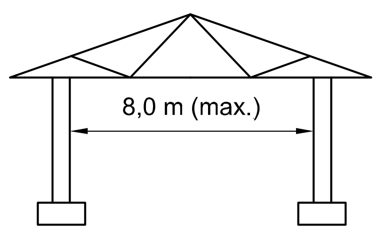
g) the height of fill beneath floor slabs does not exceed 1,0 m.

NOTE The requirements of SANS 10400-B apply where the parameters associated with single-storey type 1 masonry buildings fall outside of the requirements of this subclause.

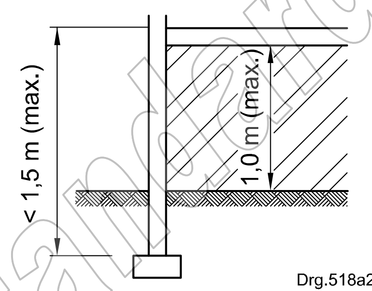
4.3.2.1.2 Foundations shall be constructed in accordance with the requirements of SANS 2001-CM2 and in such a manner that the bed joint thickness of the first masonry course above the foundation is not less than 5 mm and not greater than 40 mm.



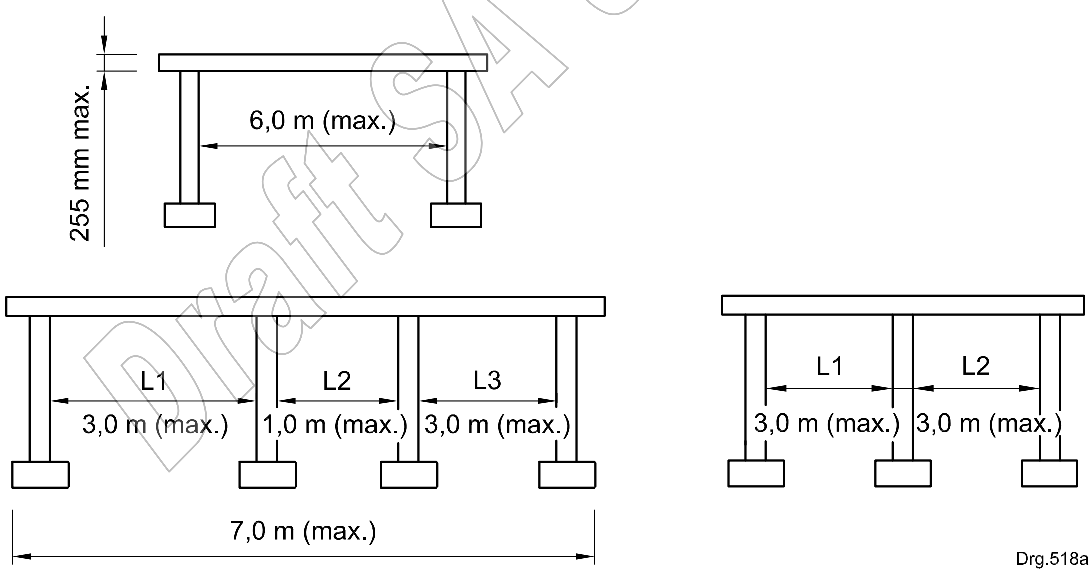
a) Wall height to top of external gable



b) Walls supporting timber or steel roof trusses



c) Maximum heights of fill and foundation wall



d) Walls supporting concrete roofs

Figure 2 — Limiting dimensions applicable to the design by rule of foundations

4.3.2.1.3 Floor slabs and related fills shall be in accordance with the relevant requirements of SANS 10400-J.

NOTE A competent person (civil engineering) is required in terms of SANS 10400-J to design and inspect fills where the maximum height of fill beneath floors measured at any point, exceeds 400 mm.

4.3.2.1.4 Masonry walls shall be so located that the distances between the walls and the centre(s) of any existing shrubs or tree trunks are not closer than those set out in table 2. On sites designated as H1 in accordance with the requirements of 4.2, such distance shall not be less than 0,75 × mature height of a tree. It shall not be less than 1,0 × mature height of a tree on H2 sites, and 1,5 × mature height of a tree on H3 sites.

NOTE Annex D provides information on the cracking of masonry walls, and advice on foundation maintenance and tree or shrub planting to minimize the risk of cracking.

4.3.2.1.5 On sloping sites steeper than 1:4 where landslip is not a consideration, the site shall be cut or backfilled (or both) and compacted to not less than 93 % MOD AASHTO density at −1 % to +2 % of optimum moisture content and benched into the in-situ material, under the supervision of a competent person (civil engineering) such that the fill (see figures 3 and 4):

a) extends at least 1 m beyond the face of the structure and has a side slope not steeper than 1:1 with respect to the horizontal, and the slope of the fill is covered with a lightly compacted material to reduce the external slope to 1:2 or flatter; or

b) is retained by either a deepened reinforced concrete beam which forms an integral part of the slab, or by a masonry foundation wall in accordance with the requirements of SANS 10400-B or SANS 10400-K, as relevant.

4.3.2.1.6 The foundation may be stepped in conjunction with the requirements of 4.3.2.1.5 in order to reduce the extent of the excavation or fill, provided that at the change of elevation, the ground behind any step is adequately drained and the step waterproofed.

4.3.2.1.7 A competent person (civil engineering) shall design and inspect the installation of sub-surface drains that might be required to prevent the passage of moisture into the interior of the building footprint.

Table 2 — Minimum distance between perimeter walls of buildings and free-standing masonry walls and the centre of tree trunks or shrubs

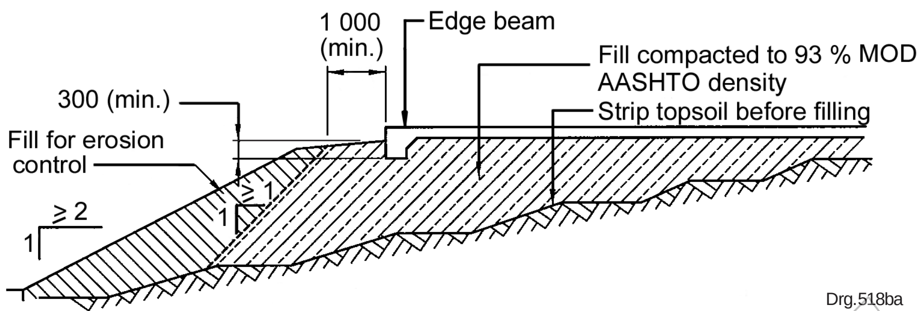
1	2	3	4
Description	**Minimum distance between walls and trees or shrubs** m		
	Mature height of tree		
	< 8 m	**8 m to 15 m**	**> 15 m**
Buildings	–	0,5	1,2
Free-standing masonry walls:			
a) category 1 expected damage[a]	–	1,0	2,0
b) category 2 expected damage[a]	–	0,5	1,0

NOTE 1 This table establishes requirements for the proximity of young trees or new planting to buildings and allows for future growth. This should not be taken to imply that construction work can occur at the specified distances from existing trees, as such work might damage the tree, or render it dangerous, but refers to the potential for future growth, either of a young tree or of planting occurring subsequent to construction.

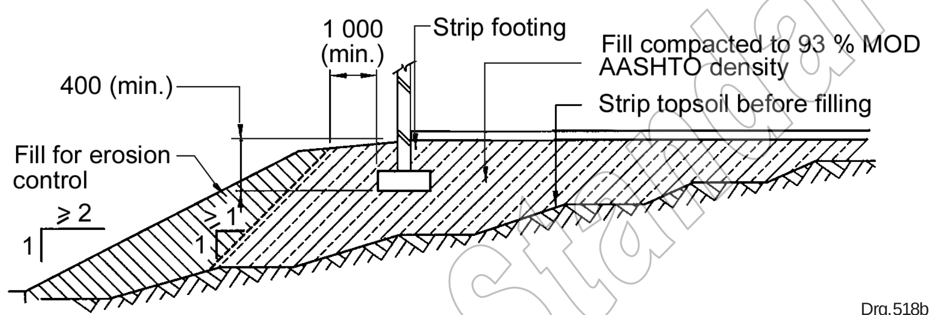
NOTE 2 Annex D provides information on tree planting and the maintenance of sites to minimize the risk of cracking due to changes in moisture content or saturation of the near surface soil horizons.

[a] See table 4 of SANS 10400-B:2012.

Dimensions in millimetres



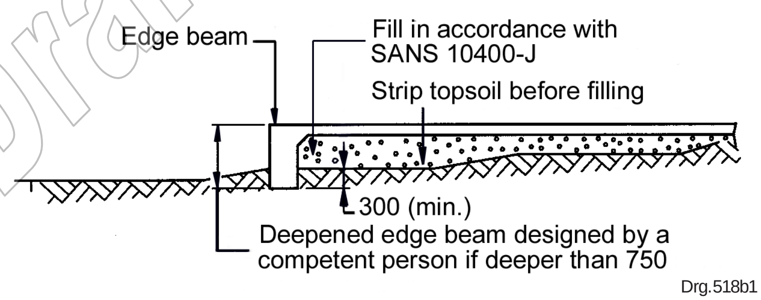
a) Slab-on-the-ground foundation founded on engineered fill



b) Strip footing foundation founded on engineered fill

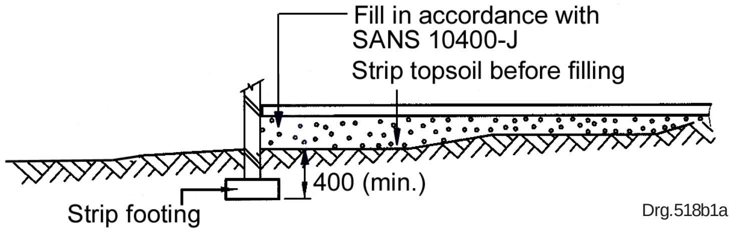
Figure 3 — Fill and foundation options for low side of sloped sites on engineered fill

Dimensions in millimetres



a) Fill under slab-on-the-ground foundation

Figure 4 — Fill and foundation options for low side of slope sited on in-situ material



b) Fill under slab (strip footing)

Figure 4 — Fill and foundation options for low side of slope sited on in-situ material *(concluded)*

4.3.2.2 Strip foundations on class C, H, R and S sites

4.3.2.2.1 Strip foundations for single-storey buildings on class C, H, R and S sites shall

a) have a width as given in table 3,

b) be in accordance with figure 5, subject to the slab not exceeding 200 m^2 where the alternative detail using thickened slabs is used, and

c) have a thickness of not less than 200 mm, except in the case of bearing onto solid rock, where the thickness shall be sufficient to achieve a level surface.

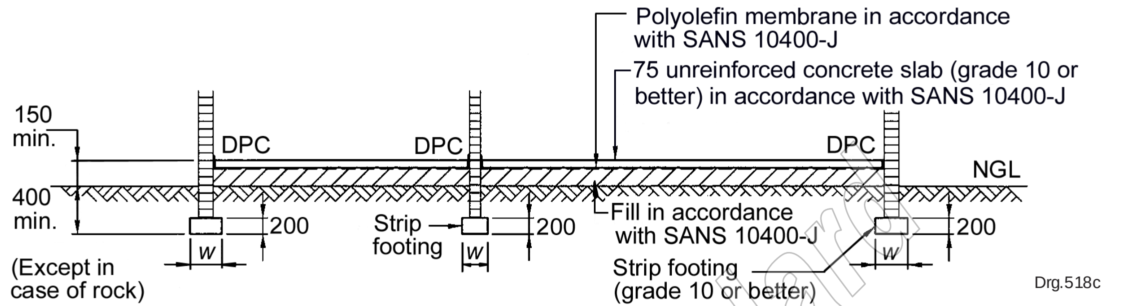
4.3.2.2.2 Service trenches shall, as far as is practicable, not be excavated parallel to buildings within 1 500 mm of the building perimeter.

4.3.2.2.3 Steps in foundations greater than 400 mm shall be designed in accordance with the requirements of 4.1.1(a).

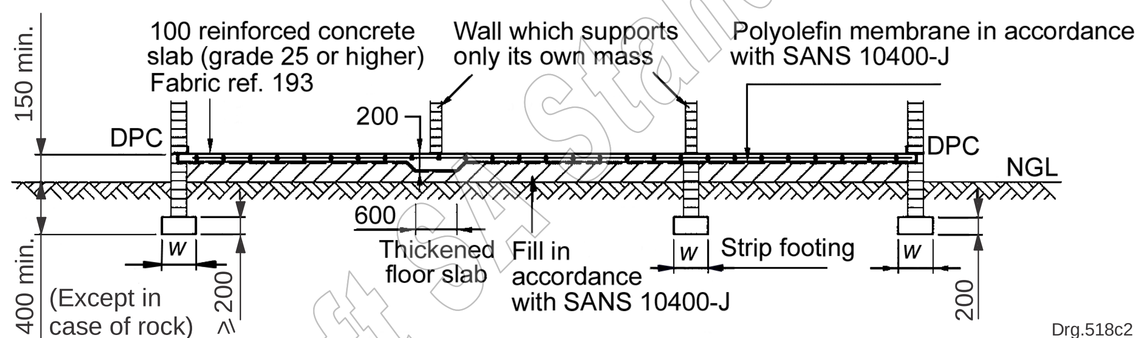
Table 3 — Minimum width (*w*) of strip foundations in single-storey buildings

1	2	3	4	5
Type of founding material	**Minimum width of strip foundations** mm			
	Tiled or sheeted roof		**Reinforced concrete roof**	
	Internal wall	**External wall**	**Internal wall**	**External wall**
Rock	400	400	400	400
Soil	400	500	750	600
NOTE Foundations for internal walls upon which reinforced concrete roofs do not have any bearing may have a width of 400 mm.				

Dimensions in millimetres



a) Strip foundations



b) Strip foundations with thickened footings

DPC = damp-proof course
NGL = natural ground level

NOTE 1 *w* is the width of the foundation derived from table 3.

NOTE 2 Fabric ref. 193 has 5,6 mm diameter bars at 200 mm centres in both directions.

NOTE 3 Concrete grade 10 is permitted in unreinforced members subject to it being cured. Grade 15 and grade 20 concrete should be used in strip footings and floor slabs, respectively.

Figure 5 — Strip footing details (class C, H, R and S sites)

4.3.2.3 Slab-on-the-ground foundations on class C, H, R and S sites

4.3.2.3.1 Slab-on-the-ground foundations for single-storey buildings on class C, H, R and S sites shall be in accordance with figure 6 where such foundations

a) have a surface area that does not exceed 200 m^2,

b) are free of joints,

c) do not contain any changes in surface levels with steps that exceed 400 mm, and

d) do not support any chimneys or walls which support concrete roofs.

NOTE The requirements of SANS 10400-B apply where the parameters associated with the foundations fall outside of the requirements of this subclause.

4.3.2.3.2 Edge beams that have a depth greater than 750 mm and steps in the floor at any change in level of slab-on-the-ground foundations in excess of 400 mm shall be designed and constructed in accordance with the requirements of 4.1.1(a).

4.3.2.3.3 Service trenches shall, as far as is practicable, not be excavated parallel to buildings within 1 500 mm of the building perimeter.

4.3.2.3.4 Steps in foundations greater than 400 mm shall be designed in accordance with the requirements of 4.1.1(a).

NOTE 1 Research has shown that unreinforced concrete floors that are not connected to foundations crack when

a) the joint spacing exceeds 30 times the slab thickness, or 4,5 m, whichever is the lesser;

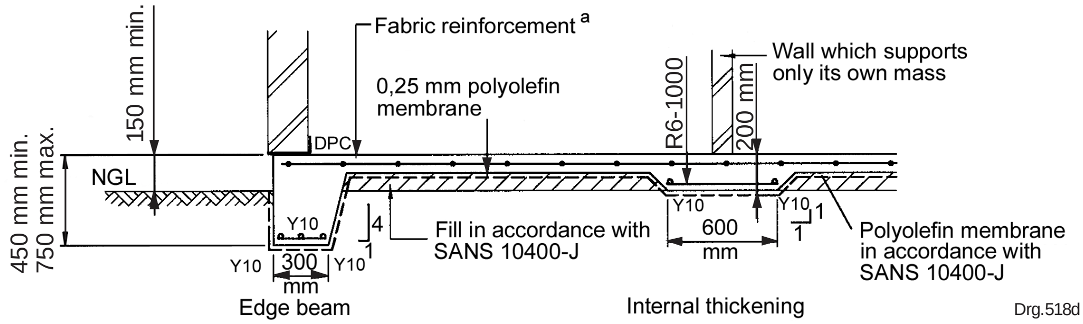
b) panels are of irregular shape;

c) panels contain re-entrant angles in their edges; or

d) ground movements occur.

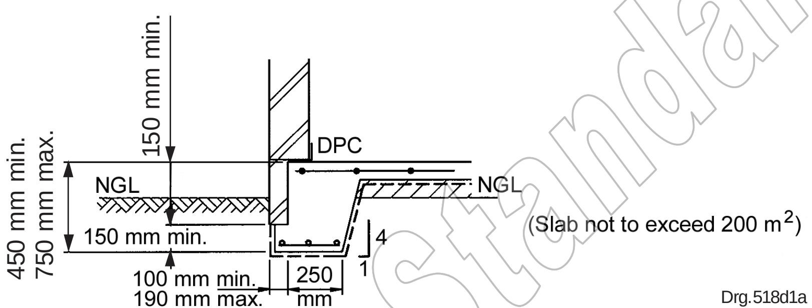
Slab-on-the-ground foundations are restrained from shrinking freely by the internal beam thickenings and edge beams. They are therefore more susceptible to cracking than unrestrained concrete floor slabs. As a result, early shrinkage cracking should be taken into account in the design.

NOTE 2 The performance requirements set out in SANS 10400-B are that the expected damage to slabs should not be more severe than category 1 or 2, depending upon the selected user performance level, namely fine but noticeable cracks that have an approximate width of less than 1,0 mm or 2,0 mm, respectively. The fabric reinforcement ensures that cracking is within these limits. Specialist advice from a competent person should be sought if crack widths less than 1,0 mm are desired. Guidance in this regard is provided in SANS 10109-1.



[a] Ref. 100 for slabs up to 50 m^2
Ref. 193 for slabs of 50,1 m^2 to 125 m^2
Ref. 245 for slabs of 125,1 m^2 to 200 m^2

a) Section through foundation



b) Deepened edge rebate detail

DPC = damp-proof course
NGL = natural ground level

Fabric ref. 100 has 4,5 mm diameter bars at 200 mm centres in both directions.
Fabric ref. 193 has 5,6 mm diameter bars at 200 mm centres in both directions.
Fabric ref. 245 has 6,3 mm diameter bars at 200 mm centres in both directions.

NOTE Where justified by satisfactory local experience, the polyolefin underfloor membrane may be terminated at the face or edge of the internal beams.

Figure 6 — Slab-on-the-ground details (class C, H and S sites)

4.3.2.4 Modified normal construction on class C1, H1 and S1 sites

4.3.2.4.1 Modified normal construction for single-storey buildings on class C1, H1 and S1 sites shall be in accordance with table 4 and the relevant requirements of figures 7 to 10 where such buildings

a) contain no concrete roofs,

b) contain no arches, and

c) have lintels over openings in accordance with the requirements of SANS 10400-K.

NOTE 1 The use of articulation joints will replace the requirements in SANS 10400-K for control joints.

NOTE 2 Compliance with the requirements of this subclause will limit expected damage to that of category 1 (see SANS 10400-B) provided that

a) no water ponds within 1,5 m of walls,

b) trees and shrubs are no closer than the distance stated in 4.3.2.1.4,

c) leaks in all plumbing and drainage are repaired promptly.

Table 4 — Requirements for modified normal construction for different site classes or categories of expected damage (or both)

1	2	3
Site class designation (see table 1)	**Requirements**	
	No.	**Description**
H1	1	Articulation joints provided at all internal and external doors and openings (see figure 7).
	2	Where the overall length of a wall between free ends, returns or articulation joints at doors or openings exceeds 7,5 m in any direction, articulation joints shall be incorporated.
	3	Guttering not permitted.
	4	Apron slabs provided.
	5	Foundation details in accordance with figure 8.
	6	Walls lightly reinforced in accordance with the requirements of SANS 10400-K.
C1 and S1	1	Articulation joints provided at all internal and external doors (see figure 9).
	2	Where the overall length of a wall between free ends, returns or articulation joints at doors or openings exceeds 7,5 m in any direction, articulation joints shall be incorporated.
	3	Guttering not permitted.
	4	Apron slabs provided.
	5	Foundation details for walls in accordance with figure 10 (subject to the replacement of the details for the floors and internal footings with the alternative foundation detail contained in figure 5 being permitted).
	6	Walls lightly reinforced in accordance with the requirements of SANS 10400-K.

4.3.2.4.2 Steps in foundations greater than 400 mm shall be designed in accordance with the requirements of 4.1.1(a).

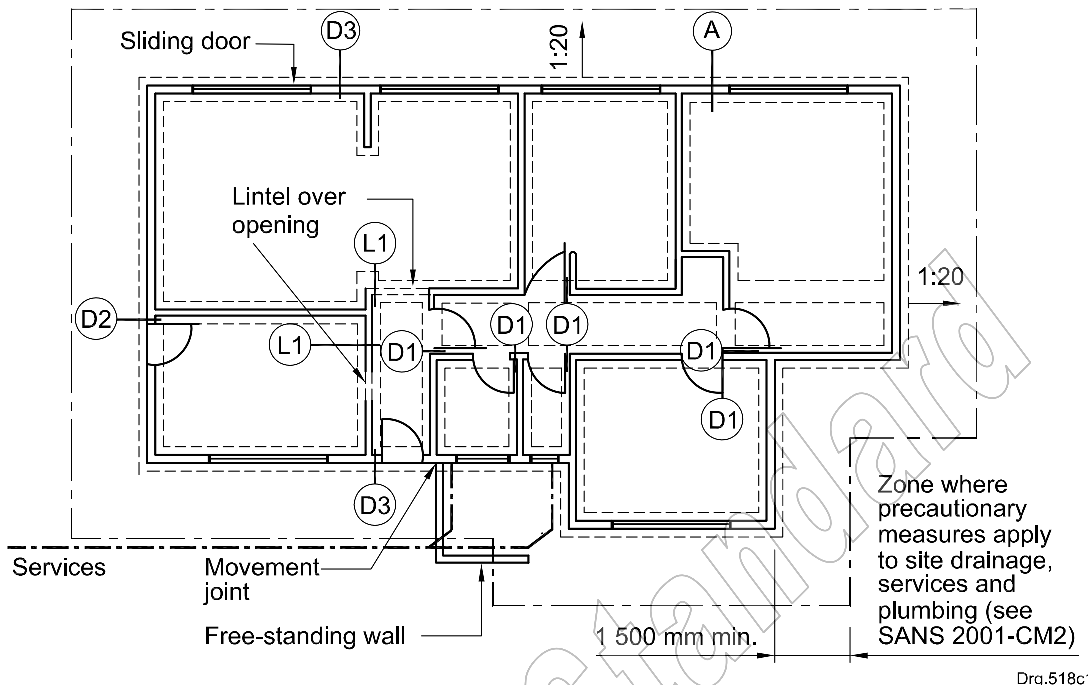
4.3.2.4.3 Apron slabs, where required, shall comprise concrete slabs cast to falls, that have a width not less than the greater of 1 000 mm and the roof overhang plus 600 mm. Such slabs shall either be 75 mm thick and be provided with joints at centres that do not exceed 2,0 m, or be 100 mm thick and be centrally reinforced with fabric reinforcement ref. 100.

4.3.2.4.4 Articulation joints shall be in accordance with the requirements of SANS 10400-K.

NOTE 1 Articulation joints should be located at positions where concentrations or variations in the potential development of stress might occur, such as at changes in wall height, changes in wall thicknesses, and deep chases or rebates for service pipes.

NOTE 2 When planning the position of internal wall joints, returns (i.e. wall elements forming an L-shape, Z-shape or T-shape on plan) should be positioned in such a manner that the lateral stability of the walls is ensured (see SANS 10400-K).

4.3.2.4.5 The interface at the extension between new and existing buildings shall be in accordance with figure 11.



Plan

A = articulation joint in the wall

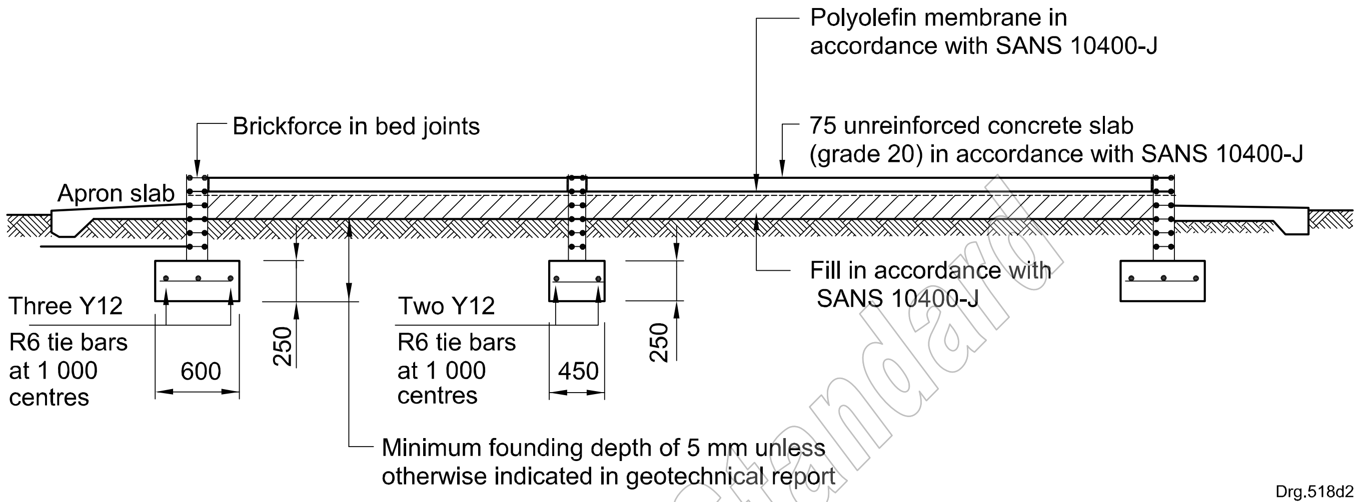
D1, D2, D3 = articulation joints above the doors

L1 = articulation joint above openings

NOTE For joint details, refer to the SAICE *Code of practice for foundations and superstructures for single storey residential buildings of masonry construction*.

Figure 7 — Modified normal construction — Location of articulation joints — Class H1 sites

Dimensions in millimetres

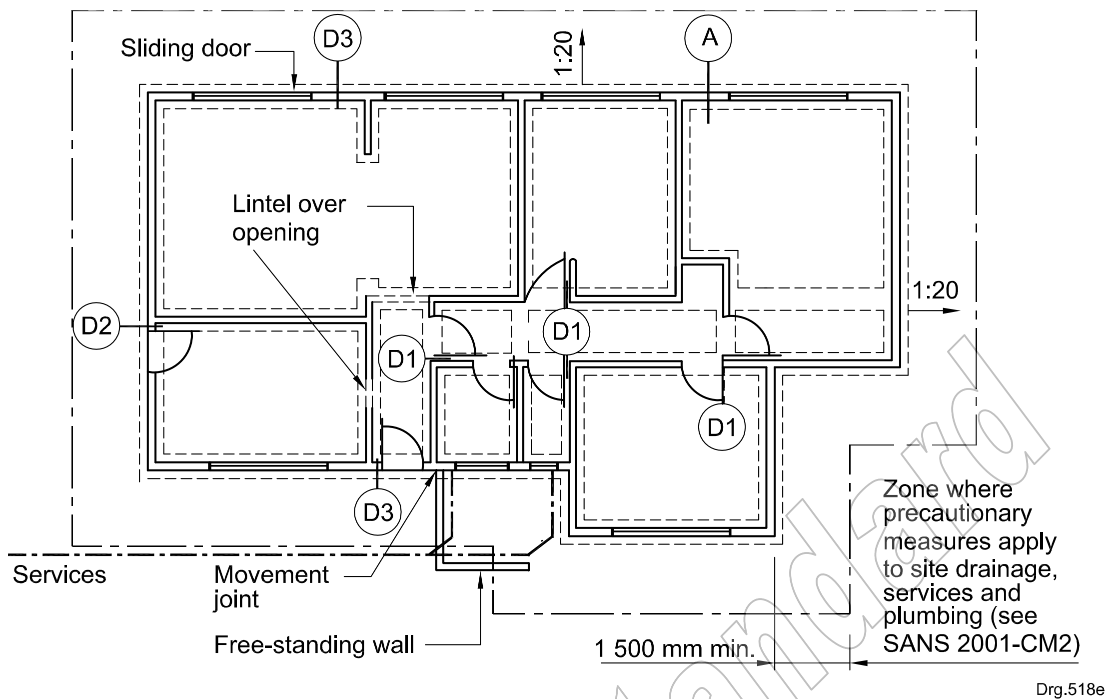


Brickforce shall be provided in every course in foundation brickwork.

Walls above the damp-proof course shall be lightly reinforced in accordance with SANS 10400-K.

Strip footings shall be grade 20 concrete.

Figure 8 — Modified normal construction — External solid or hollow unit walls of width 100 mm or less — Class H1 sites



Plan

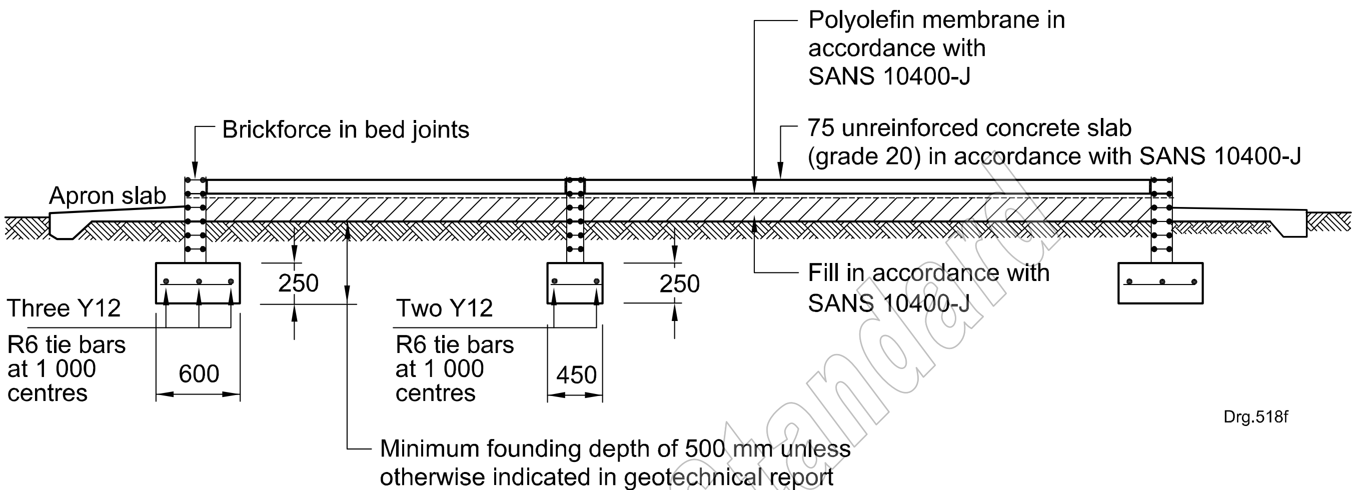
A = articulation joint in the wall

D1, D2, D3 = articulation joints above the doors

NOTE For joint details, refer to the SAICE *Code of practice for foundations and superstructures for single storey residential buildings of masonry construction*.

Figure 9 — Modified normal construction — Location of articulation joints — Class C1 and S1 sites

Dimensions in millimetres

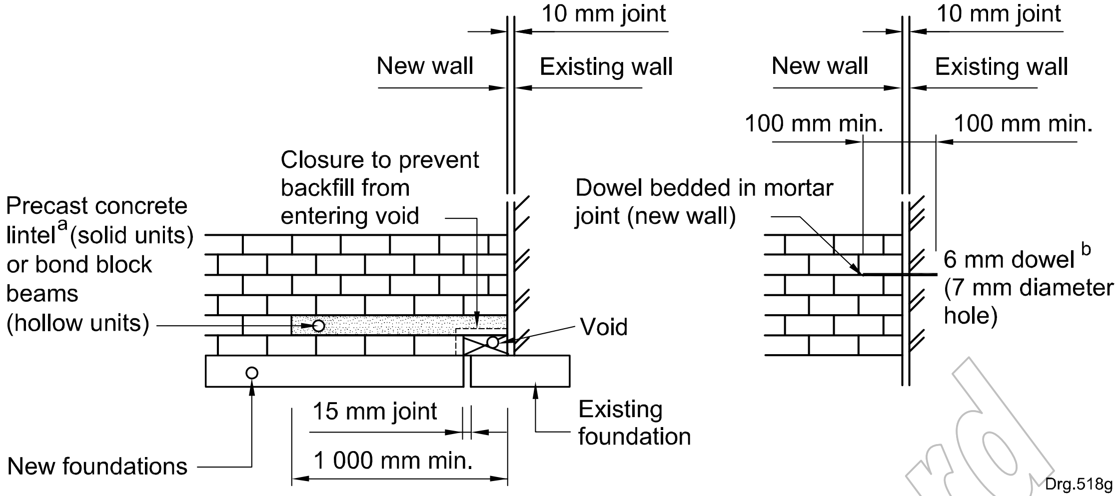


Brickforce shall be provided in every course in foundation brickwork.

Walls above the damp-proof course shall be lightly reinforced in accordance with the requirements of SANS 10400-K.

Strip footings shall be grade 20 concrete.

Figure 10 — Modified normal construction — External solid or hollow unit walls of width 100 mm or less — Class C1 and S1 sites



a) Foundation detail **b) Dowel detail**

NOTE Dowels are only required if a return is not provided in the new wall at the interface with the existing building.

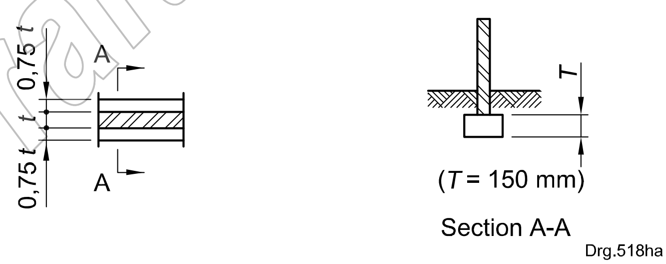
[a] Lintel shall be built into masonry and shall cantilever over existing foundation to form a gap.

[b] Dowel shall be free to move in existing wall.

Figure 11 — Details at interface of new and existing walls — Modified normal construction — Class C1, H1 and S1 sites

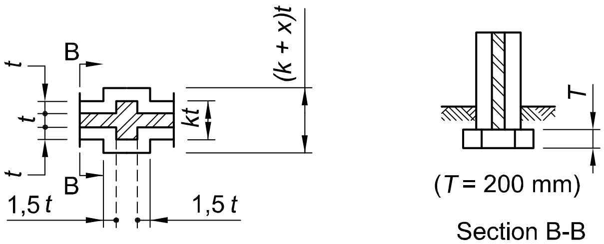
4.4 Foundations for free-standing walls and retaining walls

Foundations for free-standing walls and retaining walls that comply with the requirements of SANS 10400-K shall be in accordance with figures 12 and 13, respectively.



a) No piers

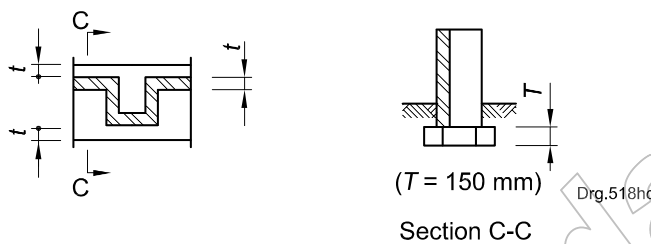
Figure 12 — Foundation details for free-standing walls



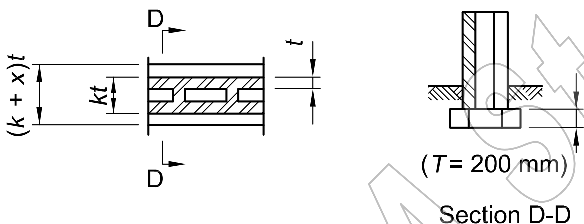
k	x	
	Hollow units	Solid units
3	3	4
5	4	6

Drg.518hb

b) Piers projecting on both sides



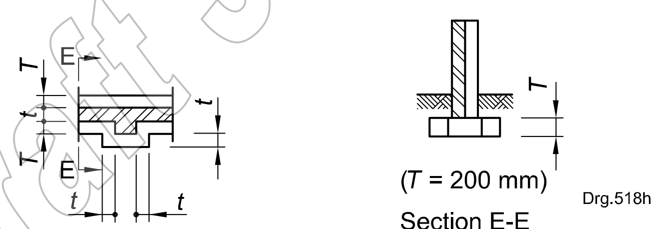
c) Z-shaped



k	x	
	Hollow units	Solid units
3		4
4	3	4,5

Drg.518hd

d) Diaphragm



e) Piers projecting on one side only

k = multiplier of the wall thickness used to determine the depth of the pier

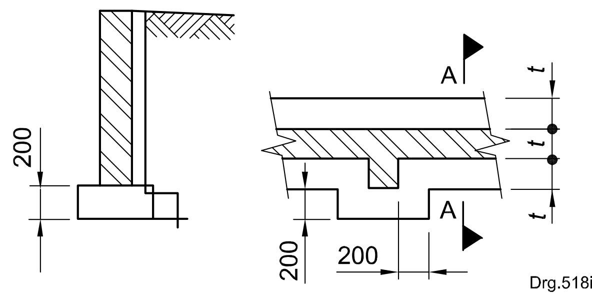
t = wall thickness

T = foundation thickness

X = parameter used to determine the width of a foundation at a pier

Figure 12 — Foundation details for free-standing walls *(concluded)*

Dimensions in millimetres



Section A-A

Plan

Figure 13 — Foundation details for retaining walls

Annex A
(normative)

Design of foundations for single-storey and double-storey domestic residences and dwelling houses

NOTE The design of masonry walls to satisfy serviceability criteria is addressed in annex C of SANS 10400-B:2012.

A.1 General

A.1.1 Structural solutions shall improve the flexibility and strength of the structure to enable the building to tolerate potential soil movements so that the resulting response to actions is within the limits specified in SANS 10400-B.

NOTE The selection of either a geotechnical or a structural solution (or a combination of both) depends on the feasibility and the economic merits of the respective solutions.

A.1.2 Foundation design, building procedures and precautionary measures shall generally be based on one or more of the following:

a) well-documented case studies of building and design procedures in South Africa;

b) rational design methods in accordance with recognized engineering principles and practices; and

c) published research findings that have been successfully applied in the design of foundations on South African soil profiles.

A.1.3 The foundation design shall prevent the passage of moisture to the inside of the building. The excavation for foundations shall take account of the design and shall be suitable to receive concrete. The upper surface of floor slabs at any point shall not be less than 150 mm above the surrounding finished surface levels.

A.2 Floor slabs

Floor slabs shall be designed in accordance with the requirements of SANS 10400-J.

A.3 Strip footings

A.3.1 Strip footings shall be continuous throughout the structure and shall be of sufficient width so as to avoid overstressing of the founding horizon, especially where it is required to support isolated piers or columns.

A.3.2 On sloping sites with backfilling of varying depth and where the bearing capacity of the soil is low, the width of the footing shall be determined by taking the vertical and horizontal loads exerted by the backfill into account.

A.3.3 The foundations of masonry walling that is sloped to suit site levels shall be such that the bed joint thickness of the first masonry course above the foundation is not less than 5 mm and not greater than 40 mm.

A.3.4 Slabs that pass over or are supported on foundation walls shall be designed as suspended floor slabs or partially suspended floors, as relevant and appropriate.

A.3.5 Steps greater than 400 mm in height shall only be permitted should the increase in the bearing pressure on the founding horizon arising from surcharge loading not cause the allowable bearing pressure to be exceeded, and the arrangements to drain the fill behind such walls do not increase the risk of movements occurring.

A.4 Slab-on-the-ground foundations

The general procedures for the design of a slab-on-the-ground foundation supported on stable founding horizons shall take account of

a) the nature and bearing capacity of the fill material to be placed under the slab or the founding horizon,

b) the need for adequate stiffness to ensure that deformation of the slab will not adversely affect the masonry superstructure,

c) erosion of the material beneath the edge beams of the slab, and

d) shrinkage of the floor slab, taking cognizance of the restraining effect of the edge beams and thickened slab elements.

A.5 Solution for composite site classes

Where the site class has a composite designation, for example, class C1 or H2, the design solution shall address the different types of soil movement.

A.6 Piled foundations on heaving clay sites

A.6.1 In the case of class H2 and class H3 sites, piles shall generally be sufficiently anchored within a stable stratum to withstand the nett heave uplift forces exerted on the pile shaft by the heaving soil horizons. Where it is uneconomical or practically impossible to accommodate these heave uplift forces, the pile shaft shall be permanently isolated from the heaving horizons over a portion of the full depth of the heaving zone.

A.6.2 The suspended floor structure supported by the piles shall be fully isolated from the heaving soil by

a) class H2 sites: 150 mm

b) class H3 sites: the lesser of 200 mm and three times the estimated total heave.

A.6.3 Measures shall be taken to ensure the maintenance of the isolation space referred to in A.6.2 over the life span of the building.

A.6.4 The piles referred to in A.6.1 shall be

a) adequately reinforced to resist all applied forces and in particular nett heave uplift forces,

b) reinforced over their full length, and

c) anchored within the stable horizon by means of straight side sockets or base enlargements within such a horizon.

A.7 Buildings founded on class P sites

A.7.1 Mining subsidence sites

The design shall take into account movements associated with lateral strain, settlement, slope and curvature.

NOTE 1 Where possible, walls should be of uniform structural stiffness and control joints should be introduced between components of different stiffness to isolate brittle elements. Articulation of both the superstructure and foundation system should be considered where large curvatures are expected.

NOTE 2 Slab-on-the-ground foundations or stiffened or cellular rafts (or both) are recommended. Deep beams or piers should be avoided unless slip joints are provided between the beam and supporting piers. Additional steel reinforcement should be provided to resist tensile and compressive forces arising from ground strains.

NOTE 3 Except on active clays, frictional forces should be reduced by over-excavating the trenches and introducing a layer of compacted sand beneath the footing and compressible material along the sides of edge beams. The lateral strength should be increased by designing footings to withstand lateral earth pressure, and by decreasing beam spacing.

A.7.2 Fill sites

The design shall take account of the potential settlement and reactive movements of both the fill and underlying soils.

NOTE Normal construction with lightly reinforced strip footings and light reinforcement in masonry may be used if this assessment indicates that the movements are no more severe than those in respect of class C, H and S sites.

A.7.3 Dolomite areas designated as D3

A.7.3.1 General

Risk shall be managed on areas designated as dolomite area designation D3 as follows:

a) The site shall be classified in terms of inherent hazard classes in the first instance and thereafter in terms of dolomite area designations by a competent person to ensure that appropriate development takes place (see SANS 1936-1 and SANS 1936-2).

b) The township services shall be installed in accordance with minimum specified requirements and mandatory precautionary measures to minimize concentrations of services provided in SANS 1936-3.

c) Minimum site precautions shall be observed when a building is constructed to ensure that water does not pond on the site. Plumbing requirements shall be observed to minimize the risk of service pipes rupturing or leaking (see SANS 1936-3).

d) A soil mattress or reinforced concrete foundation shall be provided on sites designated as D3 to allow occupants to safely evacuate buildings in the event of a sinkhole occurring.

NOTE 1 The requirements for dolomite area designations and general requirements for buildings in dolomite land are established in SANS 10400-B.

NOTE 2 Precautionary measures required on dolomite sites D1 to D4 are given in SANS 1936-1 and SANS 1936-2.

A.7.3.2 Performance requirements

A.7.3.2.1 The design of a building in areas underlain by dolomites with a dolomite area designation of D3 shall be such that

a) a sinkhole that has a nominal diameter of 2,0 m on inherent hazard class 5 sites and 5,0 m on inherent hazard class 3 and 4 sites, occurring anywhere on, beneath or adjacent to the building (see figure A.1), will not envelop the building, or result in the toppling or sliding failure of the building or a portion thereof into such a hole,

b) there is sufficient time for occupants to safely escape from the structure after the occurrence of the sinkhole referred to in (a), and

c) the level of expected damage associated with soil movements unrelated to sinkhole and subsidence formation in the near surface horizons is within the limits set out in SANS 10400-B.

A.7.3.2.2 The requirements of A.7.3.2.1 may be complied with by providing an engineered soil mattress in accordance with the requirements of A.7.3.3 on inherent hazard class 5 sites, or a reinforced concrete foundation in accordance with the requirements of A.7.3.4 on inherent hazard class 3, 4 and 5 sites.

NOTE 1 Sinkholes can occur at any point under or adjacent to the footprint of a building (see figure A.1). Apron slabs, which are commonly used to mitigate the effects of differential heave on structures and to move collapse settlements away from the footprint of the structure, have little effect on the location of a sinkhole.

NOTE 2 Subsidences occur where the premature termination of sinkhole formation occurs or where the overburden material consolidates due to de-watering or significant seasonal fluctuations. Subsidences that are caused by the premature termination of sinkhole formation may be dealt with in the same manner as sinkholes. Subsidences may also be associated with de-watering where the original ground water level (and fluctuations thereof) is located above the dolomite bedrock in soil material with a low dry density, high void ratio and high compression index. In such circumstances, buildings straddling the perimeter of the subsidence will be subject to differential settlements.

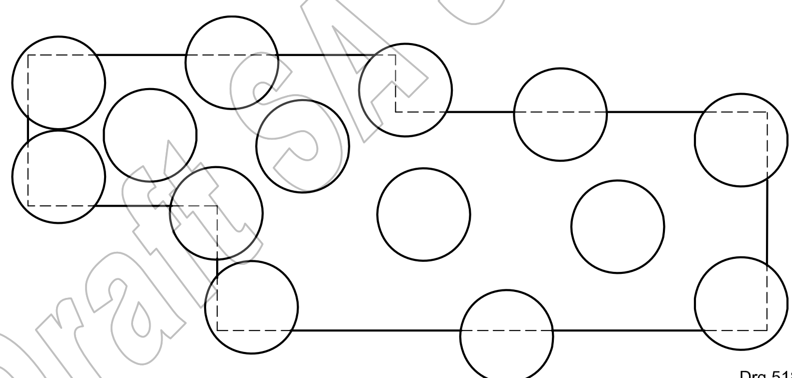


Figure A.1 — Critical locations of sinkholes under the footprint of a building

A.7.3.3 Soil mattress construction on inherent hazard class 5 sites

Where the soil mattress solution is adopted, the material on the entire plan area of the building plus a perimeter area on inherent hazard class 5 sites shall be removed and returned with compaction, or compacted in situ, to 95 % MOD AASHTO density at −1 % to +2 % of optimum moisture content, to form an engineered soil mattress or platform of appropriate material, known strength and suitable thickness below the building so that

a) the risk of sinkhole formation is reduced by improving the infiltration characteristics of the material overlying the dolomite;

b) uniform support to the foundation system is provided so that differential settlements are reduced to within limits that the building can tolerate without distress; and

c) a roof is formed over any cavities of a 2,0 m diameter that might develop below the building, so that in the event of sinkhole formation, the building complies with the performance requirements established in A.7.3.2.

NOTE 1 The thickness of the mattress will depend on a number of factors (see figures A.2 and A.3), the most important being

a) the thickness and properties of the soil overlying pinnacles and boulders,

b) the properties of the in-situ soil below the mattress, and

c) the sensitivity of the proposed building to settlement.

NOTE 2 The mattress may be constructed using conventional equipment to excavate material and compact the fill. Alternatively, where the geotechnical conditions and the proximity of other buildings lend itself thereto, dynamic consolidation may be used, provided that the safety of the operator and equipment is considered. The method of mattress construction is best determined after a number of trenches (3 m to 4 m deep or to bedrock head, whichever is the lesser) have been excavated and profiled to determine the thickness of soil cover over pinnacles and boulders as well as the nature of the material.

NOTE 3 On sites where the overburden above the pinnacle and boulder dolomite formation is less than the thickness of the mattress and where rockfill is available, the material is typically removed to a depth of about 1 m below the tops of pinnacles and large boulders, and is backfilled with rockfill to about 200 mm above the pinnacles. Alternatively, the pinnacles may be trimmed using pneumatic tools suitable for work in dolomite land, or by blasting. Thereafter, the remainder of the soil mattress is constructed with selected chert gravel or other suitable granular material placed under controlled conditions. On sites where the overburden above the pinnacle and boulder dolomite formation exceeds 3 m, the thickness of the mattress is typically between 1,5 m and 2,5 m below the underside of foundations (see figure A.3).

NOTE 4 Slab-on-the-ground foundations are most appropriate where mattresses are constructed as they are relatively shallow and distribute loads effectively. There is no point in providing a mattress and then excavating through it, to found the building.

NOTE 5 It is difficult to construct mattresses on steeply sloping sites or for a building with the ground floor on different levels as the continuity of the mattress is compromised. In these instances consideration should be given to reinforced concrete foundations.

NOTE 6 Mattresses may require some tension reinforcement to span potential sinkholes or between unyielding points of support.

A.7.3.4 Reinforced concrete foundations

A.7.3.4.1 Reinforced concrete foundations shall be designed and constructed in such a manner that the building complies with the performance requirements established in A.7.3.2.

A.7.3.4.2 The walls and floors of buildings shall withstand a loss of support, without collapse into the sinkhole, occurring anywhere within the footprint of the building over an area that has a diameter of (see figure A.1)

a) inherent hazard class 5 sites: 2,0 m

b) inherent hazard class 3 and 4 sites: 5,0 m

A.7.3.4.3 The wall foundations shall be founded

a) within the near surface horizons,

b) on piles that have been proof-drilled for a minimum of 6 m of solid rock in order to confirm that piles are socketed into pinnacles or bedrock, as opposed to floaters,

c) on stub columns founded on bedrock, or

d) on pinnacles occurring in close proximity to the surface provided that it is established that these pinnacles are attached to the bedrock.

NOTE Suitable forms of construction include:

a) stiffened raft foundations (grid of reinforced or post-tensioned concrete beams cast integrally with the floor slab);

b) stiffened strip footings (reinforced grouted cavity wall construction with interconnected floor slabs); or

c) cellular raft foundations (two horizontal reinforced concrete slabs interconnected by a series of webs).

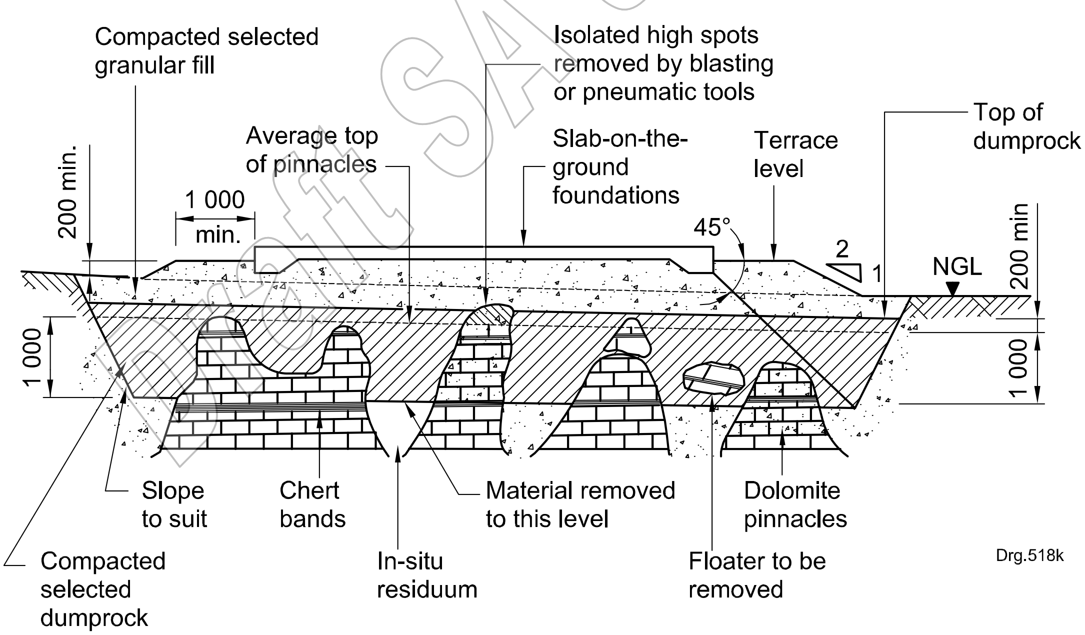
A.7.3.4.4 Beams may extend beyond the perimeter of the external walls to reduce the span that the building has to cantilever over or eliminate the cantilever resulting from the development of a sinkhole at the corner or perimeter of a building. Such beams shall extend beyond the assumed edge of the loss of support for a minimum length of 1,5 m and have a bearing pressure of less than 50 kPa.

A.7.3.4.5 Floor slabs shall be reinforced and positively connected to all edge and stiffening beams.

A.7.3.4.6 Reinforced concrete foundations, when subjected to a loss of support in accordance with the requirements of A.7.3.4.2 and subjected to a load combination of (1,0 × permanent actions) + (0,5 × imposed or variable actions), shall have deflection limits not more severe than 1:250.

A.7.3.4.7 Apron slabs shall be provided around all the perimeters of buildings and shall comprise 75 mm concrete slabs, not less than 1,5 m wide, cast to not less than 75 mm falls away from walls. Such slabs, unless appropriately reinforced, shall be provided with control joints at centres that do not exceed 2 000 mm to minimize the effect of shrinkage cracks and shall be suitably sealed against the buildings.

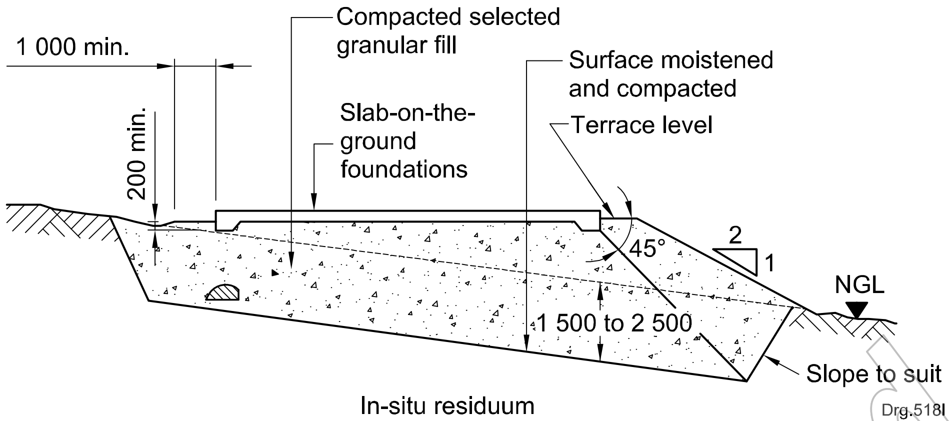
Dimensions in millimetres



NGL = natural ground level

Figure A.2 — Typical mattress on a site with shallow pinnacles and boulders

Dimensions in millimetres



NGL = natural ground level

Figure A.3 — Typical mattress on sites where the overburden above the pinnacle and boulder dolomite formation exceeds 3 m

A.8 Design procedure for stiffened or cellular rafts

A.8.1 The general procedures for the design of a stiffened raft or cellular raft on expansive, collapsible or compressible soil horizons, shall take into account

a) the characteristic surface ground movements,

b) a design value in respect of differential movement,

c) the live loads and the dead loads, including the self-weight of the slab as determined in accordance with the requirements of SANS 10400-B,

d) a load combination of (1,0 × permanent actions) + (0,5 × imposed or variable actions), and

e) the tolerable limits for relative differential movement depending on the surface finishes and the actual detailing of the superstructure, which in the absence of more specific information may be taken from table C.1 of SANS 10400-B:2012.

A.8.2 The design method in respect of rafts founded on heaving profiles shall be based on a ‘plate-on-mound’ or a ‘swell-under-load’ approach that has been proven in South Africa, such as that incorporated in

a) the finite element programme FOCALS,

b) Lytton’s method, and

c) other established methods of raft design for expansive clays that, as a minimum, take account of the size of the raft, the thickness and stiffness of the expansive soil profile and the potential magnitude of the differential heave.

A.8.3 Where rafts are founded on profiles that exhibit collapse settlement or settlement characteristics, the design procedure shall be based on the concept of the development of soft spots (localized loss of support) occurring beneath the structure in the most adverse location. The minimum dimensions of such spots on profiles that exhibit a collapse potential should typically not be less than 1,5 m.

A.8.4 Rafts founded on profiles that exhibit settlement characteristics may typically be designed on the basis that walls cantilever for one-third of each horizontal dimension and span supports for two-thirds of such dimensions.

A.8.5 Particular attention shall be paid to forms of construction involving heavy structural columns, highly brittle features or elements that are prone to cracking.

NOTE Unreinforced masonry arches should be avoided as they are prone to cracking. Special measures in floor slabs might be required where brittle floor coverings are provided.

A.8.6 The structural proportions of the slab and stiffening beams shall be determined to achieve the required stiffness and moment capacity. To ensure adequate ductility, the cross section should be reinforced so that the ultimate strength as a reinforced section M_u is at least 20 % greater than the cracking strength M_{cr}, where M_{cr} may be determined for both hogging and sagging moments for 25 MPa concrete using an allowable flexural tensile strength of 1,7 MPa.

A.8.7 The effective total width of the flange in both tension and compression can be taken as follows:

a) edge beams: beam width + (slab length/10), subject to a maximum of half the clear distance between beams

b) internal beams: beam width + (slab length/5), subject to a maximum of the clear distance between beams

A.8.8 Shear reinforcement shall be provided in raft beams where the calculated shear force exceeds the design strength of the unreinforced section. Side face reinforcement may be omitted in deep raft beams.

A.8.9 Particular care should be exercised in the selection of aggregates in the mix design and the curing of concrete so as to minimize concrete creep. The lower the creep coefficient, the higher the long term concrete modulus, and, by implication, the stiffer the slab. In the absence of more specific information, the elastic modulus of the concrete should be taken as the long-term value, which may be assumed to be 50 % of the short-term value.

A.8.10 Irregular-shaped rafts should be regarded as a series of overlapping rectangles (see figure A.4). Such rectangles should be designed separately. Alternatively, rafts may be modelled as a grillage or using finite elements with appropriate support conditions. Additional reinforcement should be provided in the segments of the beams incident on the re-entrant corners of rafts with T-shaped and L-shaped plans. There should be minimum torsional reinforcement in the vicinity of external corners of the raft.

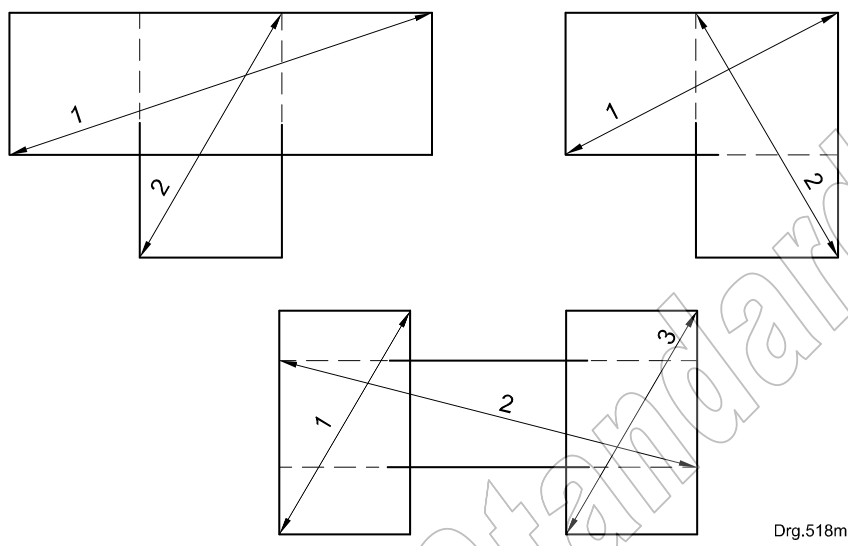
A.8.11 The beams in rafts provide the double function of load support and stiffness against foundation movements. Slabs are usually considered to be capable of transferring loads to the beam if the centre line of the wall is within 750 mm to 1 000 mm of the centre line of the beam. In multi-storey construction or where walls support heavy roof structures, detailed design checks should be performed.

A.8.12 The following should be observed in the arrangement of internal beams:

a) The beams should be continuous in a straight line from edge to edge of the slab as this is more important than placing beams directly below walls. When beams cannot be placed in a straight line, a deviation should not exceed the limits shown in figure A.5(a).

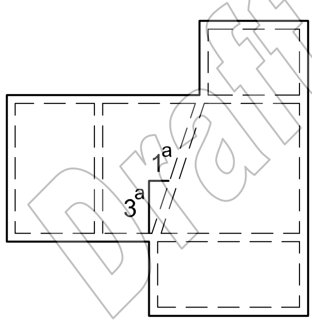
b) For L-shaped and T-shaped buildings, the beams should be located to continue the edge beams at the corners (see figure A.5(b)). Re-entrant corners need not be provided at minor changes in the plan, such as at doorways and small protrusions.

A.8.13 Polyolefin membranes should be provided to limit down drag, caused by shrinkage of clay, on beams that have an overall depth of 1 000 mm or greater.



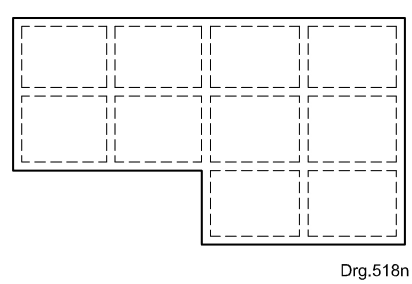
Numbers identify the rectangles that shall be separately designed.

Figure A.4 — Design of irregular-shaped rafts



a Ratio of the vertical deviation to the horizontal deviation

a) Typical deviation of stiffening beams



b) Typical layout of stiffening beams

Figure A.5 — Arrangement of stiffening beams

A.9 Design of movement and articulation joints in masonry walls

A.9.1 Butt joints (see SANS 10400-K) may be used to form control, articulation and full movement joints providing that they do not compromise the lateral stability of the wall. Tied butt joints may be used to form articulation joints, but not full movement joints.

NOTE Butt joints change the support conditions in wall panels, typically from support along three sides to support along two adjacent sides. However, should concertina ties be used in these joints to provide lateral stability while permitting some in-plane movements between panels, wall panels may be designed as being supported on three sides. The joint details shown in SANS 10400-K, however, only allow limited movement and are therefore not suitable for use in full movement joints.

A.9.2 Articulation and full movement joints shall be constructed so that they are free of obstructions. Particular care shall be taken during construction to ensure that mortar droppings or other such intrusions, electrical conduits or water pipes or applied finishes do not restrict the movement of such joints. Brickforce and rod reinforcement in bed joints should be discontinuous at these joints.

A.9.3 Articulation joints shall be capable of expanding or contracting to cater for the rigid body displacements of the walls as they rotate with the foundations, and may be used in place of control joints. Such joints shall, in respect of unreinforced walls, be provided at spacings that do not exceed those set out in table A.1. Joints shall be free of mortar droppings or other obstructions which might impede the function of the joints, and where required shall be filled with a compressible filler and sealed with a sealant which is capable of withstanding the range of movements which are expected to take place.

Table A.1 — Maximum spacing of articulation joints in unreinforced wall panels 2,4 m to 2,7 m high

1	2	3
Site class designation (see table 1)	**Wall construction**	**Joint spacing** m
H1	Face masonry Rendered masonry	6,5 5,5
H2 and H3	Face masonry Rendered masonry	5,5 5,0

A.9.4 Articulation joints should be located at positions where concentrations or variations in the potential development of stress might occur, such as at

a) changes in wall height,

b) joints in foundations,

c) changes in wall thicknesses,

d) junctions of walls of different masonry materials, and

e) deep chases or rebates for service pipes.

A.9.5 In cavity wall construction, cavity wall ties shall be provided on either side of articulation joints at vertical centres that do not exceed 400 mm. Where required, flexible or sliding anchors in accordance with the requirements of SANS 10400-K shall be provided to provide lateral stability to walls.

A.9.6 Articulation joints may be formed at door openings in accordance with the requirements of SANS 10400-K. When planning the position of internal wall joints, returns (i.e. wall elements forming an L-shape, Z-shape or T-shape on plan) should be provided to ensure lateral stability of the walls. Where possible, articulation joints should be formed in the corners of rooms, where they will be less prominent.

A.9.7 Full movement joints may be designed along similar lines as articulation joints, subject to the joints being designed to accommodate larger movements (see figures A.6 and A.7).

The following factors should be taken into account in the sealing of joints:

a) the total theoretical amplitude and direction of joint movement;

b) the design joint width;

c) the actual joint width;

d) the movement capacity of the sealant;

e) the surface preparations and primers;

f) the backing medium;

g) the curing times;

h) the life expectancy of the sealant;

i) the appearance of the sealant;

j) the maintenance or replacement during the lifetime of the structure; and

k) exposure to the weather.

A.9.8 Sealants should be such that there is good adhesion between the sealant and the material on either side of the joint. Backing material should be resilient and should not adversely affect the sealant by adhering to it.

In order to achieve satisfactory performance of the sealed joint, careful consideration shall be given to the geometry of the sealant in the joint. The joint geometry, expressed as a ratio of the width to depth of the sealant cross section, is related to the deformation characteristics of the sealant and should be designed with the object of minimizing the stresses induced in the sealant as a result of deformations caused by movement of the joint.

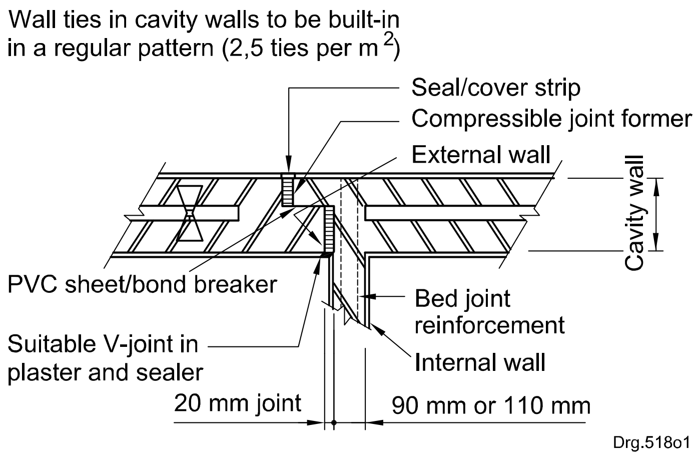
The preferred width-to-depth ratios for different sealant types are

a) elastic sealants	2:1
b) plastic sealants	1:1 to 1:3
c) elasto-plastic sealants	2:1 to 1:1
d) plasto-elastic sealants	1:1 to 1:2

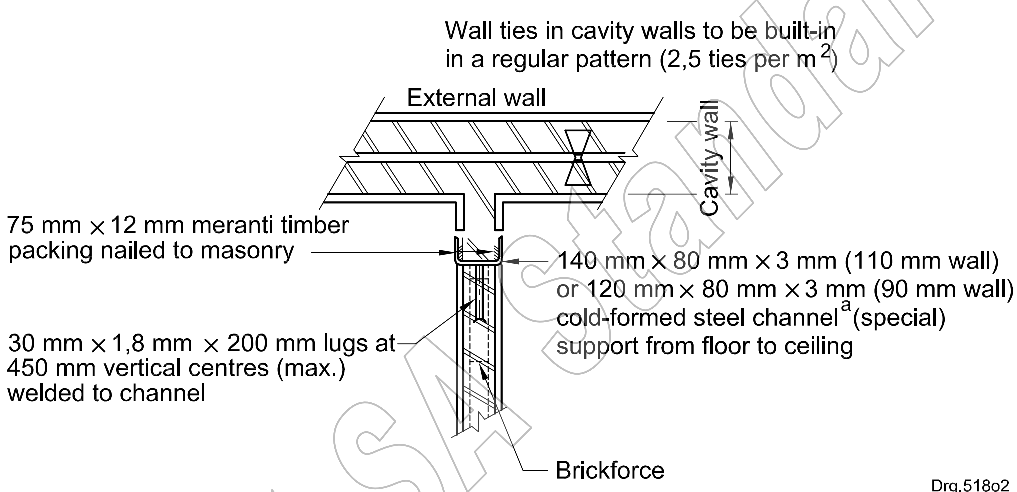
The manufacturer of the sealant should be consulted to obtain the preferred ratio.

Despite these ratios, care should be taken in narrow joints to ensure that the depth of the sealant is adequate. In the case of a porous substrate, a minimum depth of 10 mm is recommended, and in the case of a non-porous substrate, 6 mm.

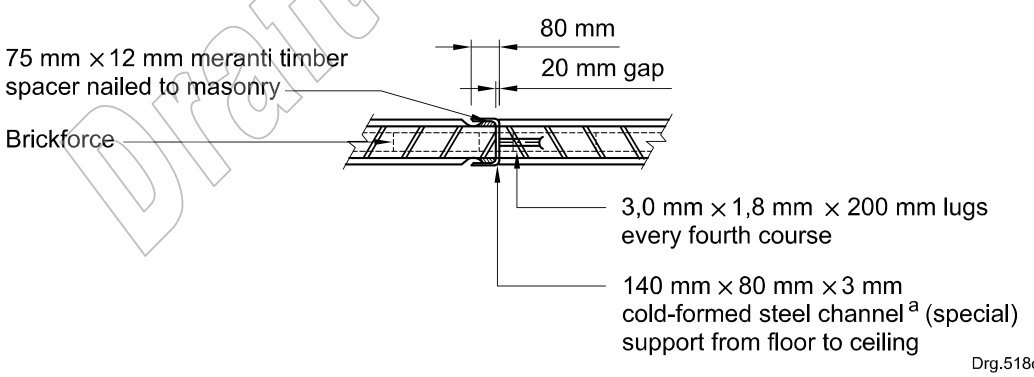
A.9.9 The sealant should be applied against a firm backing material in a manner which will ensure that it is forced against the sides of the joint under sufficient pressure to obtain good adhesion. The backing material should be firm but resilient, and should not adhere to, or react with, the sealant. The compressibility of the backing material or joint filler (or both) is the most critical factor in the design of an adequate joint. Flexible cellular polyethylene, cellular polyurethane or foam rubber are the most satisfactory materials. Hemp, soft (fibre) board, cork, semi-rigid foams and similar materials are not suitable and should not be used. Alternatively, a temporary filler may be used to keep the joint clean and true, and a permanent backing material (for example, polyethylene cord) may be forced into the formed joint to provide a backing for the sealant.



a) Joint type "M1"



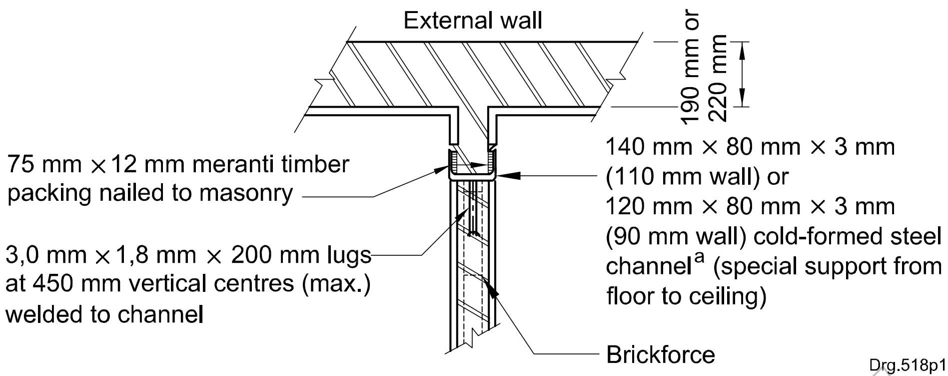
b) Joint type "M2"



c) Joint in internal wall

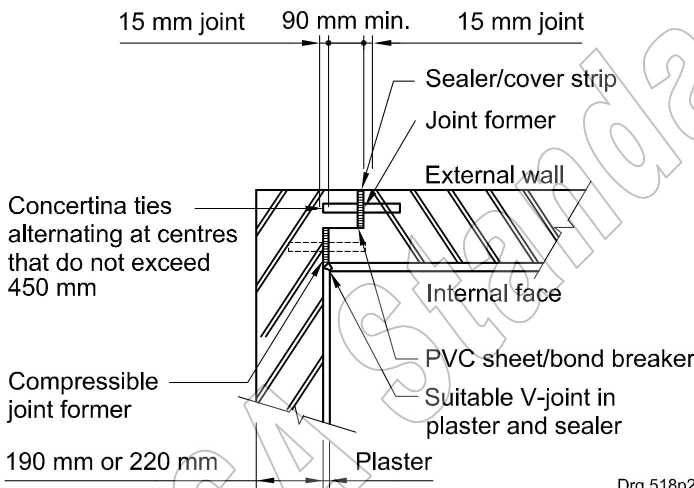
[a] Channel shall be painted with one coat zinc chromate primer before being built into the wall.

Figure A.6 — Full movement joint details for buildings with external cavity walls

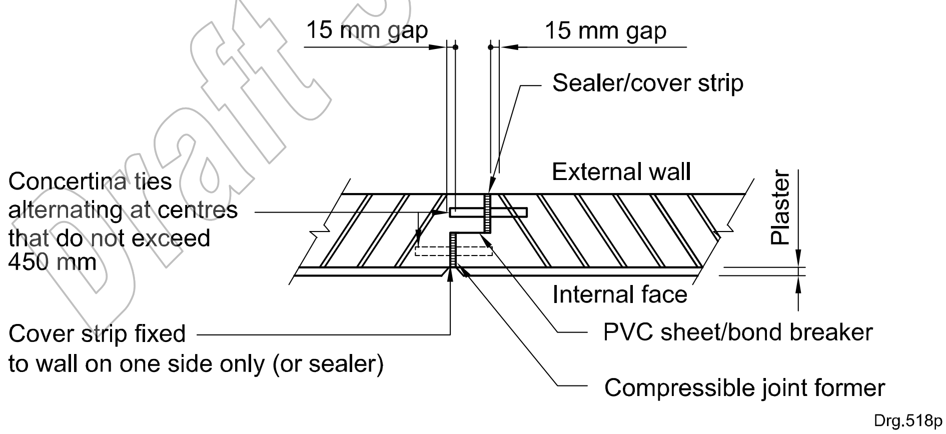


[a] Channel shall be painted with one-coat zinc chromate primer before being built into the wall.

a) Joint type "A1"



b) Joint type "A2"



c) Joint type "A3"

Figure A.7 — Full movement joint details for collar-jointed walls (190/220 solid masonry units)

Annex B
(informative)

Typical geotechnical and structural solutions associated with the site class designations for single-storey type 1 masonry buildings

B.1 General

B.1.1 Table 1 provides a site class designation system for single-storey type 1 masonry buildings where the founding horizons may be described as being stable, expansive, compressible or potentially collapsible in character, where the stability of the dolomite formation or shallow mine workings, if any, has been verified. The site class designation is based on the assumption that the magnitude of the differential movements experienced by single-storey type 1 buildings, expressed as a percentage of the total soil movements, is approximately 50 % in the case of soils that exhibit expansive or compressive characteristics and 75 % in the case of soils that exhibit both compressive and collapse characteristics.

B.1.2 These site class designations permit sites to be classified in terms of building practice.

B.2 Construction descriptors

The common terms associated with type 1 masonry buildings are described in table B.1.

B.3 Linking the site class designations to building practice

B.3.1 Tables B.2 to B.4 outline foundation design, building procedures and precautionary measures commonly encountered in respect of single-storey type 1 masonry buildings located on sites classified in accordance with table 1 where the category of expected damage is 1 (see tables 4 to 6 of SANS 10400-B:2012).

NOTE 1 The construction solutions proposed in these tables may be divided into two categories, namely structural and geotechnical solutions.

NOTE 2 Solutions for category 2 of expected damage will generally involve less stiff foundations and less reinforcement or articulation joints in walls.

B.3.2 Geotechnical solutions generally eliminate or reduce the total soil movements to within limits which can be tolerated by buildings without distress by means of one of the following:

a) removal of the soil horizons that cause unacceptable differential movements and replacement of these horizons with inert material suitably compacted or the reuse of the excavated material as founding material in a compacted form;

b) founding of the wall footings at a deeper level than is commonly associated with normal construction, i.e. a suitable founding horizon below the horizons within which relatively large movements might take place; and

c) densification of the soil horizons that cause unacceptable differential movement by means of surface compaction.

B.3.3 Structural solutions employ techniques to improve flexibility or stiffness and strength, which reduce the effects of differential soil movements to a level that can be tolerated by a building without significant damage.

NOTE The selection of either a geotechnical or structural solution depends upon the practicality and economy of the solution in question.

Table B.1 — Descriptors of typical solutions for single-storey type 1 masonry buildings

1	2
Term	**Description**
Cellular raft	A foundation system that comprises two horizontal reinforced concrete slabs interconnected by a series of web beams and that, by virtue of its stiffness, a) enables a structure to tolerate differential movements or localized loss of support (soft spots), or b) reduces the differential movements due to heaving or collapsible soils to a level that can be tolerated by the superstructure without significant damage occurring.
Deep strip foundation	Normal construction where the foundations are founded at a greater depth than normal, on a suitable soil horizon below the problem soil horizon, which exhibits compressive or collapse characteristics.
Modified normal construction	Normal construction with precautions, including articulation joints at doors and openings, light reinforcement in masonry and reinforcement in concrete strip footings.
Normal construction	Unreinforced concrete strip or lightly reinforced slab-on-the-ground foundation with unreinforced masonry superstructures.
Normal construction with precautions	Normal construction, excluding the use of thickened floor slab foundations under internal walls, with specific site drainage and plumbing installation precautions.
Pier foundation	Masonry, reinforced concrete or mass concrete column with or without a pad footing, designed to transfer structural loads to a suitable founding horizon.
Pile	A reinforced concrete or steel column-shaped member in the ground designed to transfer structural loads to a suitable soil horizon
Slab-on-the-ground foundation	Concrete floor supported on the ground, incorporating lightly reinforced integral edge and internal beams.
Split construction	A construction technique, in which the structure of the building is provided with sufficient flexibility to accommodate the differential movements of the founding horizon, by means of a combination of full movement joints, reinforced masonry, stiffened strip footings and floating/suspended floors, without significant damage occurring.
Stiffened raft	A foundation system that comprises a grid of reinforced/post-tensioned concrete beams cast integrally with the floor slab and that, by virtue of its stiffness, a) enables a structure to tolerate differential movements or localized loss of support (soft spots), or b) reduces the differential movements due to heaving to a level that can be tolerated by the superstructure without significant damage occurring
Stiffened strip footing	A foundation system which, by means of reinforced stiffening beam elements, enables a structure to tolerate differential movements or localized loss of foundation support (soft spots) without significant damage occurring.
Strip footing	A rectangular unreinforced or lightly reinforced concrete foundation which supports masonry walls.

Table B.2 — Foundation design, building procedures and precautionary measures for single-storey type 1 masonry buildings founded on expansive soil horizons

1	2	3	4
Site class (see table 1)	**Estimated total heave** mm	**Construction type**	**Foundation design and building procedures** (expected damage limited to category 1 of expected damage[a])
H	< 7,5	Normal	• Normal construction (strip footing or slab-on-the-ground) foundation • Site drainage and service and plumbing precautions recommended
H1	7,5 to 15	Modified normal	• Lightly reinforced strip footings • Articulation joints at all internal and external doors and openings • Light reinforcement in masonry • Site drainage and plumbing and service precautions
		Soil raft	• Remove all or necessary parts of expansive horizon to 1,0 m beyond the perimeter of the building and replace with inert backfill compacted to 93 % MOD AASHTO density at −1 % to +2 % of optimum moisture content • Normal construction with lightly reinforced strip footings and light reinforcement in masonry if residual movements are < 7,5 mm, or construction type is appropriate to residual movements • Site drainage and plumbing and service precautions
H2	15 to 30	Stiffened or cellular raft	• Stiffened or cellular raft of articulated lightly reinforced masonry • Site drainage and plumbing and service precautions
		Piled construction	• Piled foundations with suspended floor slabs with or without ground beams • Site drainage and plumbing and service precautions
		Split construction	• Combination of reinforced masonry and full movement joints • Suspended floors or fabric reinforced ground slabs acting independently from the building • Site drainage and plumbing and service precautions
		Soil raft	• As for H1
H3	> 30	Stiffened or cellular raft	• As for H2
		Piled construction	• As for H2
		Soil raft	• As for H1

NOTE 1 Differential heave equals 50 % of total heave.

NOTE 2 The relaxation of some of these requirements, for example, the reduction or omission of reinforcement or articulation joints, might result in category 2 of expected damage.

[a] Fine internal cracks which can easily be treated during normal decoration (see table 4 of SANS 10400-B:2012).

Table B.3 — Foundation design, building procedures and precautionary measures for single-storey type 1 buildings founded on soil horizons subject to both consolidation and collapse settlement

1	2	3	4
Site class (see table 1)	**Estimated total settlement** mm	**Construction type**	**Foundation design and building procedures** (expected damage limited to category 1 of expected damage[a])
C	< 5	Normal	• Normal construction (strip footing or slab-on-the-ground) foundations • Good site drainage
C1	5 to 10	Modified normal	• Reinforced strip footings • Articulation joints at some internal and all external doors • Light reinforcement in masonry • Site drainage and service and plumbing precautions • Foundation pressure not to exceed 50 kPa
		Compaction of in-situ soils below individual footings	• Remove in-situ material below foundations to a depth and width of 1,5 times the foundation width or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at –1 % to +2 % of optimum moisture content • Normal construction with light reinforcement in masonry
		Deep strip foundations	• Normal construction with drainage precautions • Founding on a suitable founding horizon below the horizons within which relatively large movements might take place
		Soil raft	• Remove in-situ material to 1,0 m beyond the perimeter of the building to a depth of 1,5 times the widest foundation or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at –1 % to +2 % of optimum moisture content • Normal construction with lightly reinforced strip footings and light reinforcement in masonry
C2	> 10	Stiffened strip footings, stiffened or cellular raft	• Stiffened strip footings or stiffened or cellular raft with lightly reinforced or articulated masonry • Bearing pressure not to exceed 50 kPa • Fabric reinforcement in floor slabs • Site drainage and service and plumbing precautions
		Deep strip foundations compaction of in-situ soils below individual footings	• As for C1 but with fabric reinforcement in floor slabs
		Piled or pier foundations	• As for C1
		Soil raft	• Reinforced concrete ground beams or solid slabs on piled pier foundations • Ground slabs with fabric reinforcement • Good site drainage • As for C1
NOTE 1 Differential settlement equals 75 % of total settlement. NOTE 2 The relaxation of some of these requirements, for example, the reduction or omission of reinforcement or articulation joints, might result in a category 2 of expected damage.			
[a] Fine internal cracks which can easily be treated during normal decoration (see table 4 of SANS 10400-B:2012).			

Table B.4 — Foundation design, building procedures and precautionary measures for single-storey type 1 buildings founded on soil horizons subject to consolidation settlement

1	2	3	4
Site class (see table 1)	**Estimated total settlement** mm	**Construction type**	**Foundation design and building procedures** (expected damage limited to category 1 of expected damage[a])
S	< 10	Normal	• Normal construction (strip footing or slab-on-the-ground) foundation • Foundation bearing pressure not to exceed 50 kPa • Good site drainage
S1	10 to 20	Modified normal	• Reinforced strip footings • Articulation joints at some internal doors and all external doors • Light reinforcement in masonry • Site drainage and service and plumbing precautions • Foundation pressure not to exceed 50 kPa
		Compaction of in-situ soils below individual footings	• Remove in-situ material below foundations to a depth and width of 1,5 times the foundation width or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at −1 % to +2 % of optimum moisture content • Normal construction with lightly reinforced strip foundations and light reinforcement in masonry
		Deep strip foundations	• Normal construction with drainage precautions. Founding on a suitable soil horizon below the problem soil horizon
		Soil raft	• Remove in-situ material to 1,0 m beyond the perimeter of the building to a depth of 1,5 times the widest foundation or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at −1 % to +2 % of optimum moisture content • Normal construction with lightly reinforced strip footings and light reinforcement in masonry
S2	> 20	Stiffened strip footings, stiffened or cellular raft	• Stiffened strip footings or stiffened or cellular raft with lightly reinforced or articulated masonry • Bearing pressure not to exceed 50 kPa • Mesh reinforcement in floor slabs • Site drainage and service and plumbing precautions
		Deep strip foundations – Compaction of in-situ soils below individual footings	• As for S1 but with mesh reinforcement in floor slabs
		Piled or pier foundations	• Reinforced concrete ground beams or solid slabs on piled or pier foundations • Ground slabs with fabric reinforcement • Good site drainage
		Soil raft	• As for S1

NOTE 1 Differential settlement equals 50 % of total settlement.

NOTE 2 The relaxation of some of these requirements, for example, the reduction or omission of reinforcement or articulation joints, might result in a category 2 of expected damage.

NOTE 3 Account should be taken of sloping sites where differential fill heights might lead to greater differential settlements.

NOTE 4 Settlements induced by loads imposed by deep filling beneath surface beds might necessitate the adoption of a construction type appropriate to a more severe site class.

[a] Fine internal cracks which can easily be treated during normal decoration (see table 4 of SANS 10400-B:2012).

Annex C
(informative)

The protection of single-storey type 1 masonry buildings against damage due to ground movements

C.1 The nature of foundation movements in problem soil horizons

C.1.1 Foundation movements in problem soils are normally associated with the following changes in moisture content:

a) Expansive soils are soils that undergo changes in volume due to changes in moisture content, swelling when the moisture content increases and shrinking when the moisture content decreases.

b) The natural wetting up of the soil profile below the central portions of a structure typically leads to the development of a domed profile under the building in the long term, known as the "central doming" mode of deformation. In the short term, ingress of water into the soil around the perimeter of the structure can lead to heave around the perimeter of the building resulting in the "edge heave" mode of deformation.

c) Compressible soils are soils of low stiffness that settle significantly when loaded. In free-draining soils (e.g. sands), this settlement occurs during and shortly after loading. In low permeability soils (e.g. clays), this settlement occurs over a period of time as the pore pressures set up during loading dissipate.

d) Collapsible soils are open-textured (high void ratio) soils that are stiff when dry but lose their stiffness when they become wet. This can lead to sudden, large settlements taking place when the moisture content of the soil below a foundation increases, even many years after construction.

C.1.2 Uniform heave, shrinkage, collapse settlements or consolidation settlements generally do not cause damage to structures, but might detrimentally affect service (water and sewer) pipe entries at the perimeter of structures. Non-uniform or differential movements can cause structural distress, deformations and overstressing of structural components, resulting in damage to the building.

C.1.3 Ground movements should be evaluated and predicted on the basis of geotechnical investigations. These potential movements are expressed as total movements in table C.1. The differential movements (percentage of total movements) that a building would experience, if subjected to such potential movements, can accordingly be ascertained. The predicted movements are required to be taken into account in the design of buildings founded on soil that exhibits collapse, heave or shrinkage (or both), consolidation or compressive characteristics.

C.2 Tendencies in damage

Damage caused by heave or shrinkage movements (or both) differs from that due to collapse or consolidation settlements. Generally, if no precautions are taken to reduce differential movements or to prevent conditions that promote potential movement from occurring, foundation movements will have the following results:

a) on expansive soils:

1) damage occurs throughout the building, the severity of the damage is greatest in the external walls or internally in the central portions of the structure, depending on the moisture content of the soil preceding construction; and

2) cracks alternately open and close as a result of seasonal and climatic changes in the water content of the founding material.

b) on compressible soils:

1) damage manifests itself in a particular portion of the building, for example, along a line through the building; and

2) cracks open in time, as subsequent settlement occurs; and

c) on collapsible soils: damage is localized in portions of the building as and when collapse settlement occurs, for example, beneath foundations adjacent to leaking water pipes or adjacent to areas of poor drainage where surface ponding of rainwater occurs.

C.3 Repair of significant damage

C.3.1 General

The techniques employed in repairing buildings where significant damage has occurred differ depending on whether movements were caused by heave or settlement, and whether any further movements are possible.

Typical ranges of repair costs for repairing buildings built without precautions on normal strip footings (normal construction) are given in table C.1.

Table C.1 — Typical repair costs of single-storey type 1 buildings founded on problem soil horizons with normal construction and no precautions

1	2	3	4
Site class designation	**Differential movements** mm	**Type of movement**	**Approximate range of repair costs** [a] %
H1	2,5 to 7,5	Shrinkage/heave	5 to 10
H2	7,5 to 15		10 to 20
H3	> 15		20 to 50
C1 or S1	2,5 to 7,5	Settlement	up to 10
C2 or S2	> 7,5		up to 15
[a] Given as a percentage of initial construction cost of the building.			

C.3.2 Heave

Earlier attempts at repairing structures consisted of breaking out and replacing sections of walls, especially over doorways and windows. Frequently, dry wall panels were provided above door frames. In some extreme instances, demolition was considered more appropriate than attempting repairs.

In the case of severe heave profiles, successive repair operations, although not as costly and extensive as the initial repairs, were required at intervals of approximately 10 years.

Current techniques include the construction of a moisture trench around the structure to stabilize the moisture content of the heave profile under the structure, and the cutting of articulation joints through the masonry after sections of the wall have been rebuilt and repaired. Generally, conventional ceiling cornices are replaced with cornices nailed to walls only, and dry wall panels are provided above doorways where it would be impractical to cut joints. Provided the moisture equilibrium in the moisture trench is maintained and the foundation maintenance procedures are observed, extraordinary remedial measures would normally not be required.

C.3.3 Collapse settlements

Before undertaking any repair of damage caused by collapse settlement, the source of water ingress should be remedied. If the movement stabilizes, wall cracks can be repaired. If necessary, underpinning of the foundations may be undertaken. Mass concrete underpins may be considered where a stable stratum is present at shallow depth below the foundations. If not, jacked, driven or drilled underpinning piles may be used in conjunction with a suitably designed connection between the pile and the existing foundation. Some underpinning solutions allow the building to be jacked back into its original position.

Repair techniques, such as underpinning by means of mass concrete piers, have provided a measure of relief, but have proved to be expensive. A more economical technique has been developed whereby steel piles are inserted under strip footings that have subsided. The pile is then jacked into the soil until it resists further movement. At this point, the foundations move upwards to their initial level, thereby closing the cracks in the superstructure. A series of closely spaced piles would permanently restore the building to its original condition. Wall cracks would then be repaired upon completion of the underpinning operation.

C.3.4 Consolidation settlement

Repair techniques might entail the cutting of articulation joints in the affected masonry, and the repair of the damaged masonry walls using a variety of techniques.

Underpinning, as described in C.3.3, may also be considered.

C.4 Prevention versus repair

C.4.1 The National Building Regulations contain mandatory requirements for the design of foundations on problem soils, but do not state whether or not prevention of cracking is preferable to remedial measures. The following factors should be taken into account when considering whether or not it is more economical to prevent or repair cracks in a design:

a) the initial construction cost (see table C.2 for estimates);

b) the costs of repair or abnormal maintenance (see table C.1 for orders of magnitude);

c) the impact of structural damage on the resale value of the structure;

d) the cost of inconvenience associated with repairs;

e) engineering factors, such as stability, safety and structural integrity;

f) environmental factors, such as whether or not the building is habitable;

g) the risk of the predicted potential movement being realized; and

h) emotional effects.

C.4.2 In general, it may be stated that a policy requiring the complete prevention of cracking would prove to be uneconomical; the developer or the owner (or both) should make a decision as to the severity of cracking which, in light of the above-mentioned factors, would be tolerable and economical, namely (as set out in tables 4, 5 and 6 of SANS 10400-B:2012):

a) Negligible cracking – category 0 of expected damage

b) Very slight cracking – category 1 of expected damage

c) Slight cracking – category 2 of expected damage

Such decision should be conveyed to the competent person (structures) (see SANS 10400-B), who is responsible for the design, for adoption as a basic criterion of the design of the structure in question.

In view of the nature of the expected cracking (i.e. recurring cracks in the case of expansive soils and relatively stable cracks in the case of compressible and collapsible soils), it is considered to be reasonable and economical to specify a category 1 of expected damage in respect of expansive soils, and a category 1 or 2 of expected damage in the case of compressible and collapsible soils.

Table C.2 — Typical initial costs of structural solutions for single-storey type 1 buildings founded on different soil horizons

1	2	3	4	5
Site class designation	**Differential movements** mm	**Type of movement**	**Construction type** (see table B.1)	**Estimated additional cost** [a] %
C, H, R and S	< 2,5	–	Normal construction (internal walls founded on strip footings)	0
H1	2,5 to 7,5	Heave/ shrinkage	Modified normal construction	1 to 3
H2	7,5 to 15		Split construction	3 to 15
H2 and H3	> 15		Stiffened raft	7 to 15
H2 and H3	> 15		Piled construction	8 to 25
C1 and S1	2,5 to 7,5	Settlement	Modified normal construction	1 to 3
C2 and S2	> 7,5		Piled or pier construction	5 to 15
C2 and S2	> 7,5		Stiffened strip footing or stiffened raft	5 to 10

[a] Given as a percentage of initial construction cost of the building.

Annex D
(informative)

Cracking of masonry walls, foundation maintenance and tree planting

D.1 General

Cracking in masonry structures is a common occurrence but can be minimized by correct detailing and design. Often minor cracking is of little consequence from either an aesthetic or a structural perspective. However, in some cases the cracking can be significant, and even if the structural integrity of the structure is not threatened it can be of major concern to the owner. The standard solutions provided in this part of SANS 10400 assume that the site is properly maintained in a manner which will afford adequate protection to the foundations.

D.2 Cracking in masonry

It is virtually impossible and certainly uneconomical to design and construct a completely crack-free structure even under the most favourable founding conditions. Some minor cracking and movement can be expected to take place. However, the severity of cracking and structural distress of structures can be contained within nominated limits (see table 4 of SANS 10400-B:2012).

D.3 Cracking in masonry due to causes other than ground movement

Not all cracking in masonry is caused by foundation movements and differential settlements. Masonry is a brittle construction material and, as such, is susceptible to cracking. Cracking in residential structures might arise from one or a combination of the following causes:

a) the use of sands that do not comply with SANS 1090, and which have a high water demand;

b) thermal movements (expansion and contraction);

c) moisture movements in the masonry units (wetting and drying; shrinkage in concrete units);

d) absorption of water vapour on a molecular level in burnt clay units (moisture expansion);

e) excessive shrinkage of plaster associated with deficiencies in materials and workmanship; and

f) movement of supported structures, such as concrete slabs, timber roofs, etc.

After construction, masonry experiences small dimensional changes, many of which are irreversible. Generally, masonry is not free to expand or contract as restraints are often present. Thus tensile and compressive forces might be induced within the walling itself, which result in the formation of cracks as the build-up of stresses is relieved. Generally, these cracks will be found in areas of high tensile stress concentrations, such as at openings or changes in height, thickness or dimensions of the wall.

D.4 Foundation maintenance

All soils are affected by water. Water can weaken the structure of some soils causing gradual or sudden (collapse) settlements to take place. Expansive soils shrink or swell in response to changes in moisture content resulting in heave movements. The owner should therefore

a) pay attention to the drainage of the site. Stormwater and garden irrigation water should not be permitted to pond within 1,5 m of masonry walls;

b) ensure that shrubs are not planted closer than the following distances from masonry walls:

   1) class H sites: 1,2 m;

   2) class C1, H1 and S1 sites: 1,5 m;

c) ensure that trees are not planted closer to masonry walls than the distance stated in D.5; and

d) ensure the prompt repair of leaks in all plumbing and drainage.

D.5 Trees

D.5.1 General

Many structures are likely to be located in close proximity to planted or self-sown trees during their useful life. In some situations, trees can adversely affect structures and induce damage.

All trees should be regarded as a potential source of damage. The following varieties are, however, particularly prone to causing damage:

a) all eucalyptus varieties;

b) Lombardy (Free State) poplars;

c) London planes;

d) willows (Salix) of any type; and

e) jacarandas.

D.5.2 Damage due to direct action

D.5.2.1 Trees can cause direct damage by

a) the growth of roots or the base of the trunk lifting or distorting structures,

b) the disruption of underground services and pipelines,

c) the direct contact of branches with the superstructure, or

d) being blown over.

The growth of the base of the trunk or of roots near the surface exerts comparatively small forces. Paving slabs or low boundary walls can be lifted or pushed aside very easily, but heavier structures or stronger structures are more likely to withstand these forces without damage.

The greatest risk of direct damage occurs close to the tree from the growth of the main trunk and roots, and diminishes rapidly with distance. The risk of damage can be minimized should precautions be taken when the distance from trees is less than that given in table D.1. New trees should not be planted closer than indicated in table D.1. Where these distances are not observed, precautions, such as the reinforcement of foundations to resist lateral thrusts and the bridging over of roots to allow for future growth, should be adopted.

D.5.2.2 Water leaking from damaged drains, sewers or water mains will encourage localized root growth. Roots are then likely to enter a drain or sewer through the defect and proliferate, causing blockages and so aggravating the initial defect. Intact drains, provided they are further from trees than the distances stipulated in table D.1, should not suffer direct damage and will not attract roots.

Damage can be avoided by

a) routing services in accordance with table D.1;

b) ensuring watertight joints; and

c) in clay soils, the use of flexible materials or joints (or both) to accommodate movement.

Table D.1 — Minimum distance between buildings and the centre of trunks of young trees or position of new planting, to avoid direct damage to a structure from future growth of the base of the trunk and roots

1	2	3	4
Description	**Minimum distance between buildings and trees** m		
	Mature height of tree		
	< 8 m	**8 m to 15 m**	**> 15 m**
Buildings other than single-storey buildings of lightweight construction (for example, timber framed)	–	0,5	1,2
Single-storey buildings of lightweight construction (for example, timber framed)	–	0,7	1,5
Free-standing masonry walls:			
– distance for prevention of all direct damage	–	1,0	–
– distance which permits some movement and minor damage which might be tolerable	–	–	2,0
Drains and underground services:			
– distance which permits some movement and minor damage which might be tolerable	–	0,5	1,0
– less than 1 m deep	0,5	1,5	3,0
– more than 1 m deep	–	1,0	2,0
In-situ concrete paths and driveways:			
– distance for prevention of all direct damage	0,5	1,0	2,5
– distance which permits some movement and minor damage which might be tolerable	–	0,5	1,5
Paths and driveways with flexible surfaces, such as asphalt, shale or paving slabs:			
– distance for prevention of all direct damage	0,7	1,5	3,0
– distance which permits some movement and minor damage which might be tolerable	–	0,5	1,0
NOTE This table provides guidance on the proximity of young trees or new planting to allow for future growth. This should not be taken to imply that construction work can occur at the specified distances from existing trees, as such work might damage the tree, or render it dangerous, but refers to the potential for future growth, either of a young tree or of planting occurring subsequent to construction.			

D.5.3 Damage due to indirect action

More than 99 % of water absorbed by trees is transpired through its leaves into the atmosphere. This causes the soil to dry out and, in the case of clay soils, to shrink. Any subsequent wetting up of the clay will induce swelling. In this manner trees and large shrubs can induce movement on clay founding horizons resulting in damage to structures. The severity of movements so induced depends on the percentage of clay content and the mineralogy of the clay, the depth and extent of the root system of a tree and the efficiency of a particular type of tree to extract moisture from the soil.

To avoid damage caused by these movements, it might be necessary to adopt one or more of the following actions:

a) design structures to tolerate soil movements associated with trees;

b) found structures on a horizon below the level of moisture content change;

c) remove the offending trees and shrubs;

d) provide a moisture barrier as shown in figure D.1 so that roots cannot pass through, below or around them; or

e) site structures or plant large trees and shrubs not closer than (see figure D.2):

    1) H1 sites: 0,75 × mature height

    2) H2 sites: 1,0 × mature height

    3) H3 sites: 1,5 × mature height

The effects of the removal of trees on clay sites should also be considered, as such removal might induce large swelling movements as soil profiles wet up, particularly where trees have depressed the water table over a period of time.

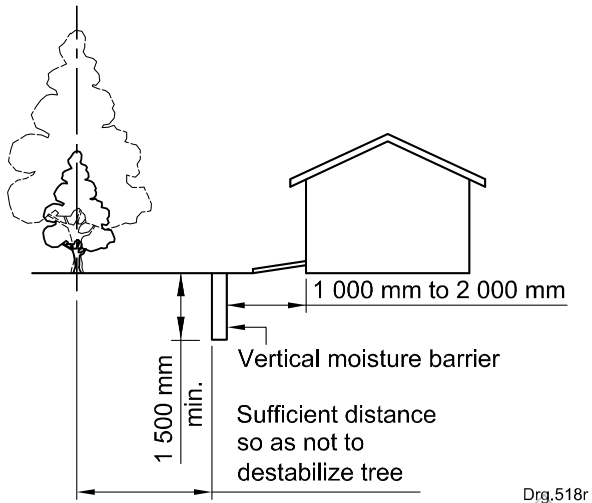


Figure D.1 — Vertical moisture barrier

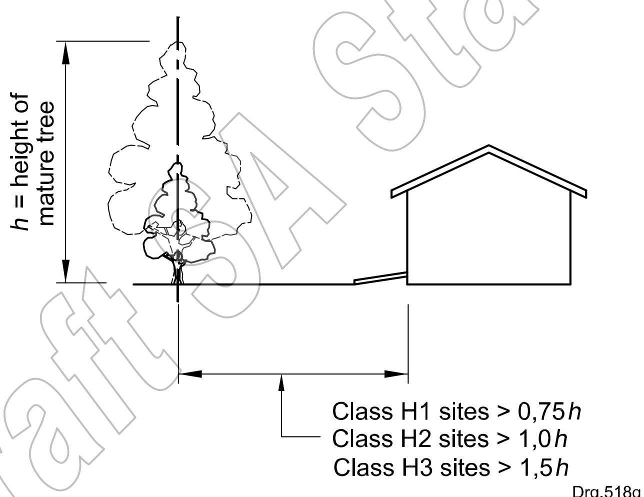


Figure D.2 — Location of trees on sites with expansive soil horizons

Bibliography

Standards

SANS 634, *Geotechnical investigations for township development.*

SANS 1090, *Aggregates from natural sources – Fine aggregates for plaster and mortar.*

SANS 10109-1, *Concrete floors – Part 1: Bases to concrete floors.*

Other publications

Buttrick DB, van Schalkwyk A, Kleywegt RJ and Watermeyer RB. *Discussion on proposed method for dolomite land hazard and risk assessment in South Africa*. Journal of the South African Institution of Civil Engineering, No. 44, November 2002.

Joint Structural Division of the South African Institution of Civil Engineering and the Institution of Structural Engineers*. Code of practice for foundations and superstructures for single storey residential buildings of masonry construction*. 1995.

Joint Structural Division of the South African Institution of Civil Engineering and Institution of Structural Engineers. *Code of practice for the assessment of housing units in South Africa*. 2000.

Pellissier JP, Williams AAB and Lunt BG. *Predicting and assessing undermining-induced distress in typical South African buildings*. Symposium on Construction Over Mined Areas, Pretoria, May 1992.

Pidgeon JT. *A comparison of existing methods for the design of stiffened raft foundations on expansive soils*. 7th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Accra, June 1980.

Pidgeon JT. *The interaction of expansive soils of stiffened raft foundation*. Proceedings of the South African Geotechnical Conference, Silverton, November 1980.

Pidgeon JT. *The results of a large scale field experiment aimed at studying the interaction of raft foundations and expansive soils*. International Conference on Soil Structure Interactions. Paris, May 1987.

Schwartz K. *Collapsible soils*. Civil Engineer in South Africa. Vol. 7, July 1985.

South African Institution of Civil Engineering (SAICE) – Geotechnical Division. *Site investigation code of practice.* 1st Ed, 2009.

Wagener F. *Dolomites*. Civil Engineer in South Africa. Vol. 7, July 1985.

Watermeyer RB and Tromp BE. *A systematic approach to the design and construction of single-storey residential masonry structures on problem soils*. Civil Engineer in South Africa. March 1992.

Williams AAB, Pidgeon JT and Day PW. *Expansive soils*. Civil Engineer in South Africa. Vol. 27, No. 7, July 1985.