ISBN 978-0-626-27630-0

SANS 10400-B:2012

Edition 3

SOUTH AFRICAN NATIONAL STANDARD

The application of the National Building Regulations

Part B: Structural design

Published by SABS Standards Division
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SABS

SANS 10400-B:2012
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, Agrément South Africa and the National Home Builders Registration Council's Technical Advisory Committee in reinterpreting functional regulations relating to structural performance.

Foreword

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

This document was published in August 2012.

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

Compliance with the requirements of this document will be deemed to be compliance with the requirements of part B 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.

Foreword (*concluded*)

Part O: Lighting and ventilation.

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

Contents

The application of the National Building Regulations

Part B:
Structural design

1 Scope

This part of SANS 10400 provides deemed-to-satisfy requirements for compliance with part B (Structural Design) 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 1936-4, *Development of dolomite land – Part 4: Risk management*.

SANS 2001-CM1, *Construction works – Part CM1: Masonry walling*.

SANS 2394/ISO 2394, *General principles on reliability for structures*.

SANS 10082, *Timber frame buildings*.

SANS 10100-1 (SABS 0100-1), *The structural use of concrete – Part 1: Design*.

SANS 10100-2 (SABS 0100-2), *The structural use of concrete – Part 2: Materials and execution of work*.

SANS 10104 (SABS 0104), *Handrailing and balustrading (safety aspects)*.

SANS 10160 (all parts), *Basis of structural design and actions for buildings and industrial structures.*

SANS 10162-1, *The structural use of steel – Part 1: Limit-states design of hot-rolled steelwork*.

SANS 10162-2, *The structural use of steel – Part 2: Cold-formed steel structures*.

SANS 10162-4 (SABS 0162-4), *Structural use of steel – Part 4: The design of cold-formed stainless steel structural members*.

SANS 10163-1, *The structural use of timber – Part 1: Limit-states design*.

SANS 10163-2 (SABS 0163-2), *The structural use of timber – Part 2: Allowable stress design*.

SANS 10164-1 (SABS 0164-1), *The structural use of masonry – Part 1: Unreinforced masonry walling*.

SANS 10164-2, *The structural use of masonry – Part 2: Structural design and requirements for reinforced and prestressed masonry*.

SANS 10400-A:2010, *The application of the National Building Regulations – Part A: General principles and requirements*.

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

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*.

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

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

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

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
agent
physical event, object or action that has an effect on a building or parts of a building

3.3
Agrément certificate
certificate that confirms fitness-for-purpose of a non-standardized product, material or component or the acceptability of the related non-standardized design and the conditions pertaining thereto (or both) issued by the Board of Agrément South Africa

3.4
Board of Agrément South Africa
body that operates under the delegation of authority of the Minister of Public Works

3.5
category 1 building
building which

a) is designated as being of class A3, A4, F2, G1, H2, H3, or H4 occupancy (see Regulation **A20** in SANS 10400-A),

b) has no basements,

c) has a maximum length of 6,0 m between intersecting walls or members providing lateral support, and

d) has a floor area that does not exceed 80 m^2

NOTE 1 Table C.1 of SANS 10400-A:2010 outlines the difference in performance between category 1 buildings and other buildings that have the same occupancy designation in respect of a number of building attributes.

NOTE 2 A building may be classified as a category 1 building for the purposes of one or more parts of SANS 10400. Additional limitations may accordingly be imposed on category 1 buildings. For example, a category 1 building in terms of SANS 10400-T (Fire protection) will be restricted to a single storey.

NOTE 3 Fire requirements for category 1 buildings are based on occupants escaping quickly from buildings. The design population for occupancies as set out in table 2 of part A of the Regulations (see SANS 10400-A) should therefore not be exceeded.

3.6
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.

3.7
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

3.8
competent person (dolomite land)
person who

a) is registered as a Professional Engineer in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000), or a person who has a BSc degree, or higher, in geology or engineering geology and is registered in terms of section 11 of the Natural Scientific Professions Act, 2003 (Act No. 27 of 2003), and

b) is generally recognized as having the necessary experience and training to undertake rational assessments or rational designs in the context of dolomite areas

3.9
competent person (structures)
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

b) is generally recognized as having the necessary experience and training to undertake rational assessments or rational designs in the field of structural systems

3.10
deemed-to-satisfy requirement
non-mandatory requirement, the compliance with which ensures compliance with a functional regulation

3.11
deflection
movement under the actions of a defined point in a structure, in a defined direction

3.12
design working life
assumed period for which a structure, or a structural element or a structural component is to be used for its intended purpose, without substantial additions and alterations, severe abuse or poor maintenance, and without major repair being necessary

3.13
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.

3.14
durability
retention of performance and appearance of a building and its various structural elements or components over time, when reasonably maintained at regular intervals in a particular environment

3.15
dwelling house
single dwelling unit and any garage and other domestic outbuildings thereto, situated on its own site

3.16
dwelling unit
unit containing one or more habitable rooms and provided with sanitary and cooking facilities

3.17
expected damage
approximation of the probable damage that might occur in walls and floors

3.18
free-standing wall
wall (that is not a retaining wall) without lateral support

3.19
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

3.20
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

3.21
ground movement
displacement in any direction of the founding stratum that is not solely dependent on the loads applied by the structure

3.22
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

3.23
lifetime
period for which the structure, as built, is used for its original intended purpose and occupancy, without substantial additions and alterations, severe abuse or poor maintenance, all of which might have a significant effect on the structural safety and structural serviceability performance of the structure

3.24
load
value of a force corresponding to an action

3.25
maintenance
total set of activities performed during the design working life of a structure or a structural element to enable it to fulfil the intended requirements

3.26
minor damage
expected damage that can readily be attended to in the course of normal redecoration and that requires only remedial work of a very minor nature to reinstate functional efficiency

3.27
performance
behaviour of a building as a whole or any part of it related to use

3.28
rational assessment
assessment by a competent person of the adequacy of the performance of a solution in relation to requirements including as necessary, a process of reasoning, calculation and consideration of accepted analytical principles, based on a combination of deductions from available information, research and data, appropriate testing and service experience

3.29
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

3.30
reliability
ability of a structure or structural element to fulfil the specified requirements, including the design working life, for which it has been designed

3.31
serviceability
ability of a structure or structural element to perform adequately under normal use and under all expected actions

3.32
settlement
downward movement of the foundations caused by the application of a load to the founding stratum by the structure

3.33
stability
ability of a structure to maintain equilibrium and to resist displacement or overbalancing

3.34
storey
that part of a building which is situated between the top of any floor and the top of the floor next above it or, if there is no floor above it, that portion between such floor and the ceiling above it (any open work floor, catwalk or gallery being taken to be part of the storey in which it is situated); and in relation to a building

a) the ground storey is taken as the storey in which there is situated an entrance to the building from the level of the adjoining ground or, if there is more than one such storey, the lower or lowest of these,

b) a basement is taken to be any part of the building which is below the level of the ground storey,

c) an upper storey is taken to be a storey of the building which is above the level of the ground storey, and

d) the height expressed in storeys is taken to be that number of storeys which includes all storeys other than a basement

3.35
strength
capability of a body to resist the loads applied to it

3.36
structural
relating to or forming part of any structural system

3.37
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

3.38
structure
organized combination of connected parts designed to provide some measure of rigidity, or construction works that have such an arrangement

3.39
wind load
force exerted by wind action

4 Requirements

4.1 General

The functional regulations pertaining to structural design contained in part B of the National Building Regulations shall be deemed to be satisfied, subject to buildings in dolomite land complying with the requirements of 4.4, where the structural system of the building (see figure 1)

a) complies with the requirements of parts H, J, K, L, M and N of SANS 10400 and, in the case of timber buildings, with the requirements of SANS 10082;

b) is the subject of a rational design or a rational assessment prepared by a competent person (structures) in accordance with the requirements of 4.2;

c) is the subject of an Agrément certificate in accordance with the requirements of 4.3; or

d) is in accordance with a combination of (a) to (c) above.

NOTE 1 Compliance with the requirements of subregulation **B1(1)** and **B1(2)** can be demonstrated in several ways. These include applying prescribed rules to structural elements, engaging a competent person (structures) to prepare rational designs in accordance with relevant South African national standards for elements which fall within the scope of such standards, engaging a competent person (structures) to prepare a rational assessment which may incorporate tests that prove the fitness for purpose of the building component, or obtaining Agrément certification for the building system or component thereof (see figure 1).

NOTE 2 The performance of a building as a whole should be considered first. Thereafter, the performance of each subsystem or component should be considered. Different deemed-to-satisfy requirements may be utilized to demonstrate compliance of a subsystem with functional requirements.

NOTE 3 Qualification, experience and engineering common sense should enable engineers to identify the relevant risks (including naturally occurring and man-made risks associated with design, assessment, construction and maintenance processes), decide on the structural concept, and design the structural system as a whole so that the structure will be safe over its specified design life.

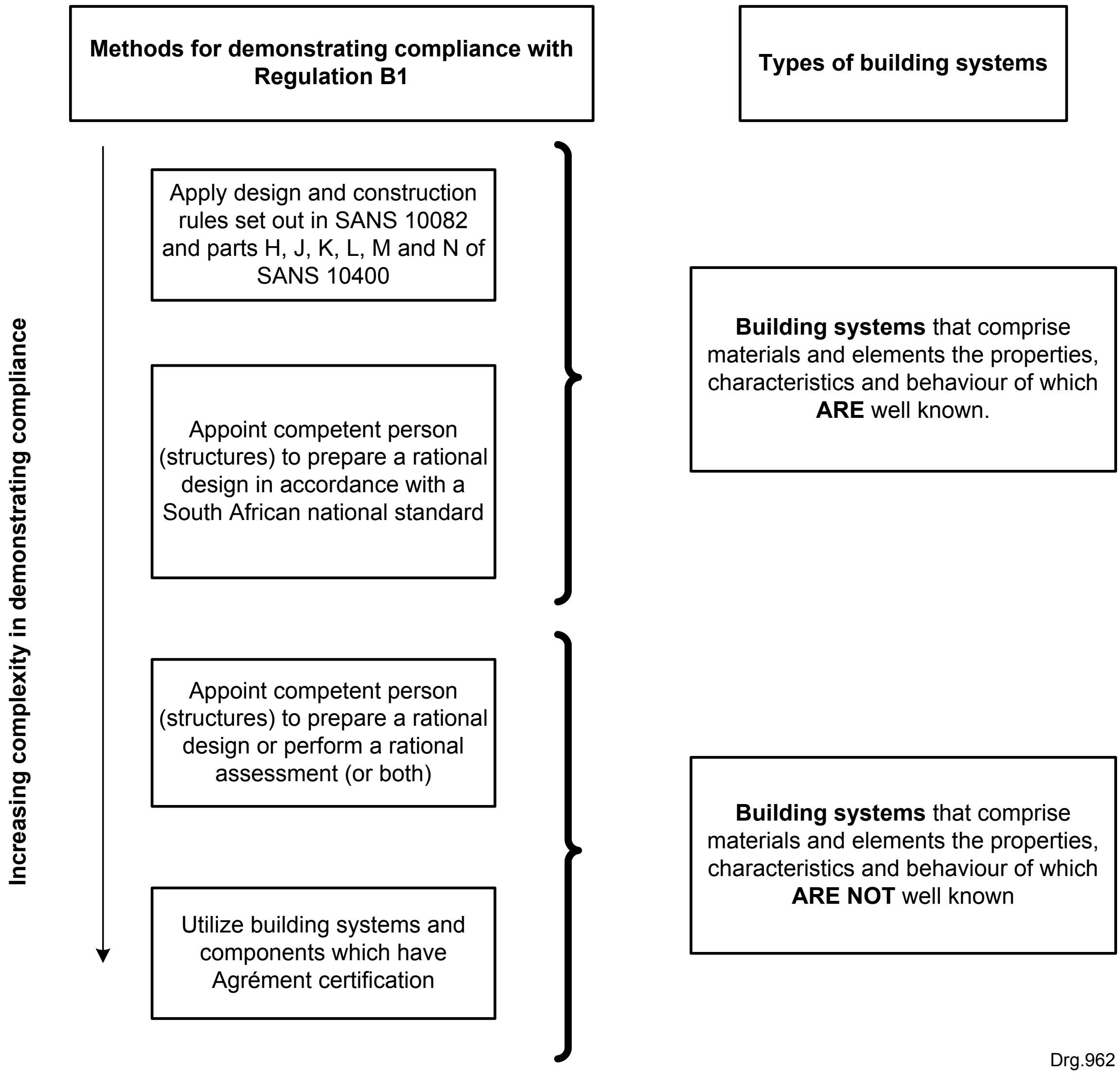


Figure 1 — Methods for demonstrating compliance with Regulation B1

4.2 Rational design and rational assessment

4.2.1 General

4.2.1.1 The design working life of a building other than a category 1 building shall be not less than 30 years in respect of the structural system and non-accessible components, and 15 years for repairable or replaceable components and materials, such as claddings, roofing materials, exterior trims, and integrated components, such as windows and doors. Category 1 buildings may have a design life of not less than 10 years in respect of repairable or replaceable components, provided that provision for upgrading is made at the design stage and such upgrading does not require the removal or dismantling of the existing structure and does not require highly specialized skills to be applied.

4.2.1.2 The representative permanent, imposed and seismic loads and impact sources applied to the structure and structural elements shall be in accordance with the requirements of the relevant part of SANS 10160.

4.2.1.3 The representative free stream velocity pressure on buildings shall be determined and converted into a wind load in accordance with the requirements of the relevant part of SANS 10160, provided that

a) the free stream velocity pressure applied to the structural system as a whole and to structural elements of dwelling houses is not less than 0,37 kPa and 0,45 kPa, respectively, and the minimum wind load applied to structural elements is not less than that given in table 1; and

b) the minimum service wind load applied to free-standing walls is at least

   1) 0,58 kPa within a distance equal to four times the height of the wall from a free end or an end with return adjacent to an opening or discontinuity in the wall, and

   2) 0,41 kPa elsewhere.

4.2.1.4 Buildings shall suffer no more than minor damage when subjected to winds associated with a 25-year mean recurrence interval. Damage from winds associated with a 50-year recurrence interval shall not prevent the buildings from fulfilling their intended purpose, except for the possible loss of roof covering material and cladding, nor shall such damage pose a threat to the inhabitants. In the case of severe or extreme winds, damage to the building shall not be disproportionate to the severity of the cause.

4.2.1.5 The resistance of the structure under the effects of all actions shall be assessed in terms of limit-state criteria or allowable stress criteria in accordance with the requirements of the relevant part of SANS 10160, or those specified in SANS 10100, SANS 10162, SANS 10163 or SANS 10164.

NOTE Actions include movements arising from shrinkage and creep of materials such as concrete, thermal movements, movement due to moisture changes, deflection of structural components and moisture expansion of burnt clay masonry units.

4.2.1.6 The response of the structure and structural elements to representative actions and impacts shall, where appropriate, be within the limits established in table 2.

4.2.1.7 The maintenance required to maintain, with an appropriate degree of reliability, the structural safety and serviceability performance of the structural system in the environment in which it is located, when subjected to normal use, shall not be excessive. The normal preventative maintenance cycle in respect of buildings other than category 1 buildings shall not be more frequent than five years.

4.2.1.8 Construction materials used in the structural system shall be resistant to, or made resistant to,

a) insect and rodent attack,

b) abrasion owing to wind-blown sand,

c) corrosive attack by groundwater, surface water, rainwater, atmospheric pollutants and any subsurface or atmospheric gases to which such materials might reasonably be exposed,

d) solar radiation, and

e) condensation,

to the extent that any changes in sectional form or mechanical properties, subject to appropriate preventative maintenance being undertaken, do not reduce the structural safety and structural serviceability performance requirements throughout the design working life.

NOTE Condensation is a problem in the Southern Coastal Condensation Problem Area (see annex A). Adequate preventative measures, such as the provision of vapour barriers or the use of impervious materials, might need to be taken to ensure that moisture from condensation that might occur on the underside of metal roofing sheets, at ceiling level or interstitially, does not have a deleterious effect on structural elements over the lifetime of the structure. An alternative solution is to improve the thermal performance such that no significant condensation occurs.

4.2.1.9 The manufacture of components and the construction or erection of structural elements (or both) shall be such that the structural safety and structural serviceability performance requirements, appropriate to the type of building, throughout the design working life, are not reduced by variations and inconsistencies in quality.

4.2.1.10 Testing in accordance with the requirements of annex B shall be used to demonstrate that specific requirements are complied with in relation to tables 1 to 3, as appropriate.

NOTE 1 Suitable tests are described in Agrément South Africa's *Performance criteria: Building and walling systems – Structural strength and stability*, for example,

Test 1: Transverse flexure of walls

Test 2: Horizontal load resistance/vertical spanning

Test 3: Racking

Test 4: Horizontal load on doors, windows and their immediate surround

Test 5: Strength of L-connections between walls

Test 6: Strength of T-connections between walls

Test 7: Anchorage of roof trusses to walls

Test 8: Ability of the walls to resist vertical loads

Test 9: Ability of gable walls to resist wind loading.

NOTE 2 Suitable tests, complete with acceptance criteria, are described in Agrément South Africa's *Performance criteria: Building and walling systems – Structural assessment of dry-stack masonry building systems*, for example,

Test 1: Vertical load-bearing capacity of walls

Test 2: Transverse flexure of walls

Test 3: Horizontal load resistance/vertical spanning

Test 4: Horizontal line load resistance

Test 5: Racking load resistance

Test 6: Response of buildings to simulated wind loading

Test 7: Horizontal load on doors and windows and their immediate surround

Test 8: Transverse flexure of gable walls

Test 9: Soft body impact test

Test 10: Steel tool impact test (hard body impact test).

Table 1 — Minimum service wind actions for roofing and wall elements in dwelling houses

1	2
Component	**Minimum service wind load to be applied** kPa
Roofing elements	
Wind uplift on roof	0,59
Local effects on eaves overhangs	0,78
External wall elements	
Outward pressure on doors and windows	0,51
Inward pressure on doors and windows	0,45
Outward pressure on walls	0,52
Inward pressure on all walls	0,37
Horizontal pressure on the side of a building[a]	0,37
Internal wall elements	
Pressure on either face	0,20
[a] This is the pressure which causes “racking”.	

Table 2 — Structural response of buildings to representative actions and impacts

1	2
Agent	**Performance parameter**
Building structure	
Ground conditions and movements	**Tilt** Rotation of any part of the structure or the structure as a whole from its intended line or level as a result of settlement or ground movement shall not be more severe than – Buildings other than category 1 buildings: 1:200 – Category 1 buildings: 1:100 **Total settlement** Buildings other than category 1 buildings: 10 mm after building has been completed. Category 1 buildings: 20 mm after the building has been completed, unless special precautions have been taken to adequately accommodate movements in excess of this value.

Table 2 (*concluded*)

1	2
Agent	**Performance parameter**
Structural element: roof	
Direct and indirect actions	**Deflection** Deflection ratio (ratio of maximum deflection from the horizontal to the span of the roof) arising from permanent, imposed and wind actions at the ceiling level shall not be more severe than – Buildings other than category 1 buildings: 1:250 – Category 1 buildings: 1:175 **Cracking** Irreversible damage in the load deflection curve, even if cracks or other damage is not visible. Cracks in roofing substrates (decking) that might impair the normal function of the roof or coverings.
Hail impact	After being tested in accordance with the relevant provisions of annex B, the test specimen shall be acceptably free from visible defects when viewed from a distance of 2,0 m.
Structural element: walls	
Direct actions	Deflection ratio (ratio of maximum deflection from the vertical to the length or the height of the wall panel) arising from permanent, imposed and wind actions shall not be more severe than – Buildings other than category 1 buildings: 1:250 – Category 1 buildings: 1:175
Indirect actions	Minor damage that is not more severe than that of category 1 expected damage (see table 4), or the equivalent thereof.
Ground movements[a]	Minor damage that is not more severe than category 2 expected damage (see table 4), or the equivalent thereof.
Soft body impacts	**Collapse impacts** Walls shall not collapse or be permanently deformed. **Service impacts** Walls when struck shall not be displaced by more than 1/600th of their height or have cracks, which cannot be readily repaired, of aggregate length exceeding 300 mm and width exceeding 0,5 mm.
Sharp body impacts	Walls shall not be punctured nor, in the case of materials of a non-fibrous nature, be indented or locally displaced by more than 3 mm. In addition, there shall be no readily visible cracks (i.e. wider than 0,25 mm) and the aggregate length of such cracks shall not exceed 300 mm.
Door slamming	The slamming of the test door shall not cause damage to the wall or cause the frame to detach from the wall.
Fittings	The loosening and withdrawal of the fixing devices shall not cause more than minor, readily repairable damage to the wall.
Structural element: floor	
Direct actions	Deflection ratio (ratio of maximum deflection from the horizontal to the span of the floor) arising from permanent, imposed and wind actions shall not be more severe than: – Buildings other than category 1 buildings: 1:250 – Category 1 buildings: 1:175
Indirect actions (slab-on-the-ground foundations)	**Floors covered with carpets and flexible floor coverings** Minor damage that is not more severe than category 2 expected damage (see table 5), or the equivalent thereof, as nominated by the user. **Floors covered with semi-flexible or rigid tiles** Minor damage that is not more severe than category 1 expected damage (see table 5), or the equivalent thereof.
Ground movement and conditions[a]	Minor damage that is not more severe than category 2 expected damage (see tables 5 and 6), or the equivalent thereof.
[a] Owners may specify a different category of expected damage, particularly on heaving clay profiles. Competent persons (structures) should ascertain from owners which category of expected damage should apply, provided that such damage is not more severe than that of category 2 expected damage.	

Table 3 — Representative actions and impacts applied to the building structure and structural elements

1	2
Agent	**Performance parameter**
	Building structure
Wind actions[a]	In accordance with the requirements of the relevant part of SANS 10160 and 4.2.1.3
Seismic actions	In accordance with the requirements of the relevant part of SANS 10160
Ground conditions and movements	In accordance with the expected range of ground movements associated with the site
	Structural element: roof
Permanent actions	Self-weight of covering, ceilings, structure and geysers, if any (see SANS 10160 and specialist literature)
Imposed or variable actions[b]	In accordance with the requirements of the relevant part of SANS 10160
Wind actions	In accordance with the requirements of the relevant part of SANS 10160 and 4.2.1.3
Snow action	A uniformly distributed load corresponding to the expected depth of snow where a snow depth exceeding 250 mm can be expected to accumulate
Hail impact	Impacts of up to 10 J or, where the building is located in areas where severe hail storms are known to occur, 20 J[b]
	Structural element: walls
Wind actions	In accordance with the requirements of the relevant part of SANS 10160 and 4.2.1.3
Permanent actions	Self-weight of wall (see SANS 10160 and specialist literature)
Imposed or variable actions	In accordance with the requirements of the relevant part of SANS 10160
Soft body impacts	Two soft body impacts each generating an impact of:

Category 1 buildings

Type of wall	**Internal walls and external walls (impact from the inside)**		**External walls (impact from the outside)**	
	Service	**Collapse**	**Service**	**Collapse**
Heavyweight construction	130 J	265 J	265 J	410 J
Lightweight construction	130 J (framing) 90 J (cladding)	265 J	265 J	410 J

Buildings other than category 1 buildings

Type of wall	**Internal walls, external walls at ground floor (impact from the inside) and external walls at first floor and higher (impact from the outside)**		**Internal walls around stairways, external walls at first floor and higher (impact from the inside) and external walls at ground level (impact from the outside)**	
	Service	**Collapse**	**Service**	**Collapse**
Lightweight construction	130 J (framing) 90 J (cladding)	265 J	265 J	410 J

[a] Value required to determine overall stability (overturning, wind uplift, raking).

[b] The requirement for a hail impact resistance of 10 J ensures that roofing material is resistant to mild hail storms. For roof sheeting to be hail resistant, such sheets should have a hail resistance of 20 J (A 45 mm diameter hailstone at terminal velocity in still air has a kinetic energy of approximately 15 J.). Hailstorms tend to be more severe at higher altitudes and in the Summer Rainfall Areas. Buildings should generally be designed for the 10 J requirement, unless they are located in areas where severe hailstorms are a common occurrence (such as high altitude mountainous areas).

Table 3 (*concluded)*

<table>
<tr><td>1</td><td>2</td></tr>
<tr><td>Agent</td><td>Performance parameter</td></tr>
<tr><td>Sharp body impacts</td><td>Category 1 buildings
Two blows generating an impact of 4,2 J
Buildings other than category 1 buildings
Two blows generating an impact of:
<table>
<tr><td colspan="2">External walls</td><td colspan="2">Internal walls</td></tr>
<tr><td>At ground floor (impact from the inside)</td><td>5,3 J</td><td rowspan="2">Non-load-bearing walls</td><td rowspan="2">5,3 J</td></tr>
<tr><td>At ground floor (impact from the outside)</td><td>7,9 J</td></tr>
<tr><td>At first floor and higher (impact from the inside)</td><td>5,3 J</td><td>Load-bearing walls</td><td>7,9 J</td></tr>
<tr><td>At first floor and higher (impact from the outside)</td><td>7,9 J</td><td>Around stairwells</td><td>7,9 J</td></tr>
</table></td></tr>
<tr><td>Hail impact</td><td>Impacts of 10 J on components other than glazing</td></tr>
<tr><td>Door slamming</td><td>25 kg door slammed ten times from a position of 60° open, with a force of 150 N applied at the handle position in the direction of closure, such force being applied until the door makes contact with the frame</td></tr>
<tr><td>Fittings</td><td>Lightweight fittings (e.g. coat hooks, towel rails and medicine cabinets) that have a mass of 8 kg suspended 45 mm away from the wall at any location
Medium-weight fittings (e.g. hand basins, cisterns, medium-sized cupboards and 9 kg fire extinguishers) that have a mass of 25 kg suspended 45 mm away from the wall, at designated locations on the wall
Heavyweight fittings (required where there is a high probability that people will stand upon the fittings, e.g. wash troughs, sanitaryware basins, geysers and fire hose reels) that have a mass of 135 kg suspended 345 mm away from the wall for a period of 5 min
Shelving: safe load nominated by the owner</td></tr>
<tr><td colspan="2">Structural element: floor</td></tr>
<tr><td>Permanent actions</td><td>Self-weight of flooring system (as determined by the supplier)
Finishes (as determined by the supplier)</td></tr>
<tr><td>Imposed or variable actions</td><td>In accordance with the requirements of the relevant part of SANS 10160</td></tr>
<tr><td>Vibrations</td><td>Where relevant, in accordance with the requirements of the relevant part of SANS 10160</td></tr>
<tr><td colspan="2">[a] Value required to determine overall stability (overturning, wind uplift, raking).
[b] The requirement for a hail impact resistance of 10 J ensures that roofing material is resistant to mild hail storms. For roof sheeting to be hail resistant, such sheets should have a hail resistance of 20 J (A 45 mm diameter hailstone at terminal velocity in still air has a kinetic energy of approximately 15 J.). Hailstorms tend to be more severe at higher altitudes and in the Summer Rainfall Areas. Buildings should generally be designed for the 10 J requirement, unless they are located in areas where severe hailstorms are a common occurrence (such as high altitude mountainous areas).</td></tr>
</table>

Table 4 — Classification of damage in masonry walls

1	2	3
Description of damage in terms of ease of repair and typical effects	**Approximate maximum crack width[a] in walls** mm	**Category of expected damage[b]**
Hairline cracks less than 0,25 mm wide, classified as negligible.	< 0,25	0 Negligible
Fine internal cracks which can easily be treated during normal decoration. Cracks rarely visible in external masonry.	< 1 (isolated; localized)	1 Very slight
Internal cracks that are easily filled. Redecoration probably required. Recurrent cracks can be masked by suitable linings. Cracks not necessarily visible externally. Doors and windows might stick slightly.	< 5	2 Slight

NOTE 1 Where cracks less than 1 mm are widespread throughout the building, the damage may be regarded as being category 2 expected damage.

NOTE 2 Annex C provides guidance on the limiting movements of masonry walls.

[a] Crack width is only one factor in assessing damage and should not be used on its own as a direct measure of damage. In assessing the degree of severity of damage, account should be taken of its location in the house.

[b] This classification is based on the ease of repair which may be considered under three headings representing a progression in difficulty of repair, namely, redecoration due to wear and tear, remedial work to reinstate functional efficiency, and structural repair.

Table 5 — Classification of damage with reference to concrete surface beds

1	2	3	4
Description of typical damage	**Approximate maximum crack width in floor** mm	**Maximum deviation of any point from a 3 m straight edge** mm	**Category of expected damage**
Hairline cracks Insignificant tilt of floor or change in level	< 0,3	< 5	0 Negligible
Fine but noticeable cracks Floor reasonably level	< 1,0	< 8	1 Very slight
Distinct cracks Floor noticeably curved or changed in level	< 2,0	< 10	2 Slight

Table 6 — Classification of damage caused by ground-floor slab settlement and ground movements

1	2	3	4
Description of typical damage	**Approximate crack width in floor** mm	**Approximate gap** mm	**Category of expected damage**
Hairline cracks between the floor and skirting.	–	< 1	0 Negligible
Settlement of the floor slab, either at a corner or along a short wall, or possibly uniformly, such that a gap opens up below the skirting boards, where provided, but which can be masked by resetting the skirting boards. No cracks in floor slabs, although there might be negligible cracks in the floor screed and finish. Slab reasonably level.	–	< 5	1 Very slight
Larger gaps below skirting boards; some obvious, but limited local settlement leading to slight slope of the floor slab. Gaps can be masked by resetting skirting boards and some local re-screeding might be necessary. Fine cracks appear in internal walls which might require some redecoration; slight distortion in door frames which might result in sticking of the doors. No cracks in the floor slab although there might be very slight cracks in the floor screed and finish. Slab reasonably level.	< 1	< 15	2 Slight
NOTE Gap refers to the space, usually between the skirting and finished floor, caused by settlement after making appropriate allowance for discrepancy in building construction, shrinkage, normal bedding down, etc.			

4.2.2 Rational designs in respect of building systems comprising materials and elements the properties, characteristics and behaviour of which are well known

4.2.2.1 The competent person (structures), in order to demonstrate that the functional regulations contained in part B of the National Building Regulations pertaining to the structural system or part thereof are satisfied, shall undertake a rational design in accordance with the following South African national standards, international standards, or in accordance with recognized engineering principles, as applicable:

a) SANS 10100, for the structural use of concrete;

b) SANS 10104, for safety aspects of the handrailing and balustrading;

c) SANS 10160, for the general procedures and loading to be adopted in the design of a building;

d) SANS 10162, for the structural use of steel;

e) SANS 10163, for the structural use of timber; and

f) SANS 10164, for the structural use of masonry.

4.2.2.2 The competent person (structures) responsible for the preparation of the rational design of a structural system or part thereof, shall document the form and size of principal structural elements for a proposed system, detail all connections associated therewith and determine the construction and material specifications necessary to achieve the design intent.

4.2.2.3 The competent person (structures) responsible for the rational design shall, if called upon by an owner of a building constructed in accordance with the rational design, or by a local authority within a period of 10 years after completion of the building system or part thereof, produce documentation (including assumptions made, loads applied and calculations) that demonstrates that the building system complies with part B of the National Building Regulations for the performance parameters contained in table 3.

4.2.2.4 The competent person (structures) shall carry out an inspection of the building and shall furnish the local authority with a certificate to this effect on completion of the system.

NOTE 1 SANS 2001-CC1, SANS 2001-CC2, SANS 2001-CG1, SANS 2001-CM1, SANS 2001-CM2, SANS 2001-CS1, and SANS 2001-CT1 may be used to specify construction requirements.

NOTE 2 The Rules of Conduct for Registered Persons issued in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000) state that a registered person may not, without satisfactory reasons, destroy or dispose of or knowingly allow any other person to destroy or dispose of information (drawings, designs, records, reports, specifications, contract documents, built records or plans, or electronic data that form part of the records relating to the work) within a period of 10 years after completion of the work concerned.

NOTE 3 Local authorities and competent persons may, in terms of the Promotion of Administrative Justice Act, 2000 (Act No. 3 of 2000), be called upon to give reasons for their decisions made in terms of the National Building Regulations and Building Standards Act, 1977 (Act No. 103 of 1977). Furthermore they may, in terms of the Promotion of Access to Information Act, 2000 (Act No. 2 of 2000), be compelled to make available certain records relating to work done in connection with the said National Building Regulations and Building Standards Act, particularly where such records are likely to reveal evidence of imminent and serious public safety or environmental risk. (See B.9 of SANS 10400-A:2010.)

4.2.3 Rational designs in respect of building systems comprising materials and elements the properties, characteristics and behaviour of which are not well known

4.2.3.1 The competent person (structures) shall undertake a rational design or a rational assessment (or both) in order to demonstrate by way of one or more of the following that the performance of the building system or part thereof in accordance with the requirements of SANS 2394 is such that the functional regulations contained in part B of the National Building Regulations are satisfied:

a) engineering first principles;

b) relevant research;

c) applicable standards and authoritative publications;

d) verifiable experience; and

e) suitable and appropriate test results and analysis.

The assumptions made and the level of reliability of rational designs or rational assessments (or both) shall be such that a peer review of the structural system or part thereof would arrive at a similar conclusion.

4.2.3.2 The robustness of walls, doors and window frames shall be established by means of one or more of the tests described in annex B.

4.2.3.3 The competent person (structures) responsible for the preparation of the rational design or rational assessment (or both) of a structural system or part thereof shall, as relevant, document all assumptions made and the form and size of principal structural elements for a proposed system, detail all connections associated therewith and determine the construction and material specifications necessary to achieve the design intent.

4.2.3.4 The competent person (structures) responsible for the rational design or rational assessment (or both) shall, if called upon by an owner of a building constructed in accordance with the rational design or rational assessment (or both) or by a local authority, within a period of 10 years after completion of the building system or part thereof, produce documentation (including all assumptions made, loads applied, tests conducted, studies undertaken, calculations, etc.) that demonstrates that the structural system complies with part B of the National Building Regulations.

4.2.3.5 The competent person (structures) shall carry out an inspection of the building and shall furnish the local authority with a certificate to this effect on completion of the structural system.

NOTE 1 The competent person should demonstrate that the building system will provide the required level of performance. This may be done on a factual and technical basis which can be substantiated and verified by means of, inter alia, tests performed by a recognized competent authority or organization as defined in Regulation **AZ4** (see SANS 10400-A), by way of calculations performed in terms of appropriate South African structural standards, appropriate and applicable international standards or from first principles, or by applying research findings.

NOTE 2 The Rules of Conduct for Registered Persons issued in terms of the Engineering Profession Act, 2000 (Act No. 46 of 2000), state that a registered person may not, without satisfactory reasons, destroy or dispose of or knowingly allow any other person to destroy or dispose of information (drawings, designs, records, reports, specifications, contract documents, built records or plans, or electronic data that form part of the records relating to the work) within a period of 10 years after completion of the work concerned.

NOTE 3 Local authorities and competent persons may, in terms of the Promotion of Administrative Justice Act, 2000 (Act No. 3 of 2000), be called upon to give reasons for their decisions made in terms of the National Building Regulations and Standards Act, 1977 (Act No. 103 of 1977). Furthermore they may, in terms of the Promotion of Access to Information Act, 2000 (Act No. 2 of 2000), be compelled to make available certain records relating to work done in connection with the said National Building Regulations and Standards Act, particularly where such records are likely to reveal evidence of imminent and serious public safety or environmental risk. (See B.9 of SANS 10400-A:2010.)

4.3 Agrément certification

The requirements of Regulation **B1** shall be deemed to be satisfied where the building system or part thereof is the subject of an Agrément certificate, provided that

a) the building element or building component is used within the scope, conditions and limitations prescribed in the certificate, and

b) the building element or building component is compatible with other elements or components of the building or building system.

4.4 Buildings in dolomite land

Buildings shall not be constructed on dolomite land unless such sites are developed in accordance with the requirements of SANS 1936-1 and

a) competent persons (dolomite land) plan and conduct geotechnical site investigations for such land, evaluate factual data, establish interpretative data and formulate an opinion relating to the outcomes of such investigations in accordance with the relevant requirements of SANS 1936-2;

b) competent persons (structures), as relevant, design buildings in accordance with the relevant requirements of SANS 1936-3;

c) competent persons (civil engineering) design and inspect for design intent the necessary precautionary measures required on dolomite land to enable safe developments to take place; and

d) competent persons (dolomite land), where relevant, develop dolomite risk management strategies in accordance with the requirements of SANS 1936-4.

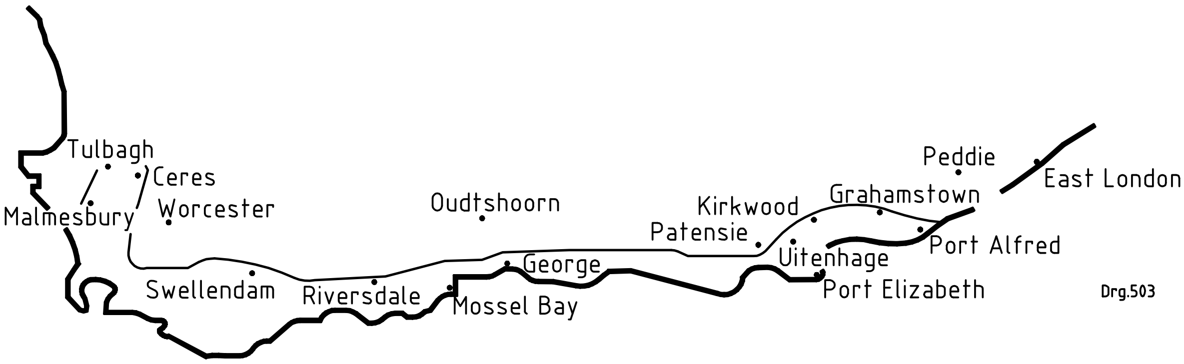
Annex A
(informative)

Condensation

Under severe climatic conditions, such as occur in the Southern Coastal Condensation Problem Area (see figure A.1), condensation in building cavities such as cavity walls or in roof spaces, can, if occurring over a prolonged period, be detrimental to the structural system unless appropriate protective measures are taken.

The factors that give rise to such condensation in dwellings include overcrowding, poor thermal performance of the wall and roof construction, inadequate ventilation, the use of paraffin or gas (or both) heating for cooking and the indoor washing and drying of laundry. All of these factors contribute to the generation of excessive water vapour in the indoor atmosphere, which condenses on walls and ceilings when the surface temperature falls below the dew point. Such moisture might also be transferred into building cavities by air movement where, in turn, it would condense on cold surfaces.

Preventative measures that can be taken include improving the thermal performance of the building and the provision of effective vapour barriers in appropriate positions so as to prevent rotting of timber studs or timber roof truss components, or corrosion of steel studs and wall ties.



The SCCP area is readily identified by combining the following environmental features:

a) It lies south of the major mountain ranges in the Southern Cape.

b) It includes the area that receives winter and all-year-round rainfall.

c) It receives an annual rainfall of between 250 mm and 500 mm per year.

Towns that lie on the SCCP boundary

Albertinia	Gouda	Katara	Prince Alfred	Swellendam
Alicedale	Grahamstown	Kirkwood	Riebeek East	Tulbagh
Barrington	Greyton	Langholm	Riebeek West	Uitenhage
Bathurst	Hamlet	Lindeshof	Riversdale	Villiersdorp
Blanco	Hankey	Louterwater	Riviersonderend	Wellington
Bluecliff	Heidelberg	Malmesbury	Ruiterbos	Wolseley
Ceres	Herbertsdale	Mamre	Stormsvlei	
Franschhoek	Joubertina	Paarl	Suurberg	
Genadendal	Kammiebos	Port Alfred	Suurbraak	

Towns that lie within the SCCP area

Addo	Dana Bay	Kalbaskraal	Papiesvlei	Stellenbosch
Alexandria	Despatch	Kareedouw	Paradise Beach	St Francis Bay
Amsterdamhoek	Droë Vlakte	Kariega	Paterson	Still Bay
Askraal	Elgin	Kasuka	Pearly Beach	Storms River
Aston Bay	Elim	Kenton on Sea	Philadelphia	Strand
Atlantis	Fairfield	Kleinmond	Plettenberg Bay	Struis Bay
Baardskeerdersbos	Firgrove	Klipdale	Pniel	Sunland
Bellevue	Fish Hoek	Knysna	Port Beaufort	Swartkops
Bethelsdorp	Gans Bay	Kommetjie	Port Elizabeth	The Crags
Betty's Bay	George	Kruisfontein	Protem	Vermaaklikheid
Bloubergstrand	Gordon's Bay	Kuilsrivier	Riethuiskraal	Viljoenskroon
Bluecliff	Gouritsmond	Kylemore	Rietpoel	Vlees Bay
Boesmansrivier-	Grabouw	Loerie	Rondevlei	Waenhuiskrans
mond	Groot Brakrivier	Malgas	Salem	Wilderness
Boknesstrand	Groot	Melkbosstrand	Scarborough	Windmill
Botrivier	Jongensfontein	Milnerton	Sea View	Witsand
Brandwag	Hartenbos	Mossel Bay	Sedgefield	Wittedrif
Bredasdorp	Hawston	Muizenberg	Simon's Town	Witteklip
Caledon	Hermanus	Napier	Sinksabrug	Woodlands
Cape Town	Hermon	Noanaha	Skipskop	Wydgeleë
Clarkson	Herold's Bay	Onrus	Slangrivier	
Coega	Hout Bay	Oukraal	Somerset West	
Coerney	Humansdorp	Oyster Bay	Southwell	
Colchester	Jeffreys Bay	Pacaltsdorp	Stanford	

Figure A.1 — The Southern Coastal Condensation Problem (SCCP) area

Annex B
(normative)

Performance tests pertaining to structural safety, serviceability and durability

B.1 General

The effects of actions on individual structural members shall be determined by methods of structural analysis that take into account equilibrium, general stability, geometric compatibility, and both short-term and long-term material properties. Members that tend to accumulate residual deformations under repeated service loads shall have included in their analysis the added eccentricities expected to occur during the design working life.

The assessment of distortions of individual structural members shall be determined by methods of structural analysis that take into account equilibrium, general stability, geometric compatibility, and both short-term and long-term material properties.

Structural durability may be established by using methods that simulate predictable future degradation of the product, such as tests which accelerate mechanical wear, or other forms of degradation by agents such as solar radiation, heat frost, thermal shock, air humidity, condensation, salty fog, chemical agents and biological agents.

B.2 Performance tests

B.2.1 Sandbag impact test (soft body impacts)

Carry out the test on a representative wall specimen, approximately 4 m long and of storey height (see figure B.1). The wall includes a standard door opening positioned between 300 mm and 450 mm from one end of the wall. The top and bottom of the wall are fixed and both ends supported as in practice; end returns may be provided for this purpose, if necessary.

Suspend a 250 mm diameter leather or fabric bag containing 30 kg of sand by a rope from a convenient point above the top of the wall (see figure B.1). The bag should touch the surface of the wall lightly and its centre of mass should be within 1 000 mm above floor level or ground level, as appropriate for internal and external faces, respectively, when it is hanging freely at rest. The bag may impact any other point deemed necessary by the evaluator.

Draw the bag away, pendulum fashion, from the wall at right angles to the face of the wall until its centre of mass is at the required height of swing above its initial free-hanging position. Then release the bag and allow it to swing pendulum-wise and strike the wall. Make two impacts from each height of swing on each point tested.

When the test structure is of unframed construction, carry out this operation as near as possible to a point midway in the length of the wall. Repeat the operation near the end of the wall farthest from the door. If the wall is of framed construction, choose points of impact that are both between and on the line of the framing and joints (if applicable).

The height of swing that provides the required level of impact energy is set out in table B.1.

Check for compliance with the provisions of tables 2 and 3.

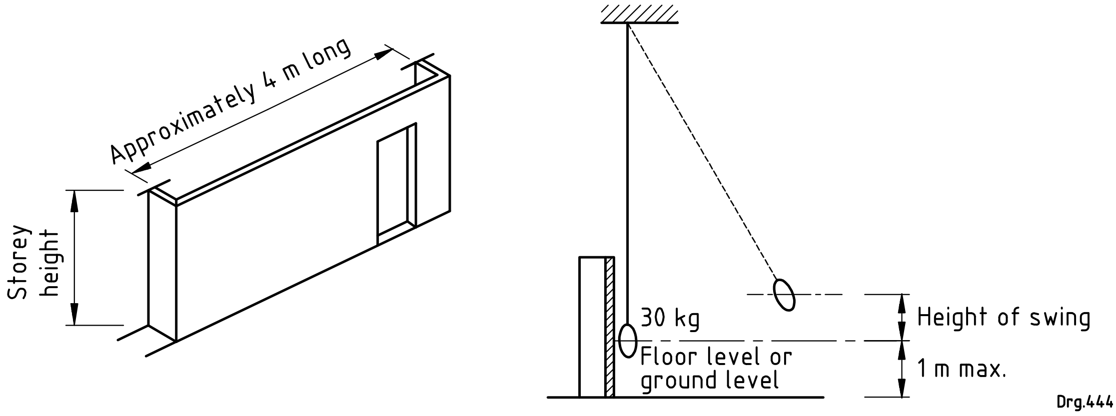


Figure B.1 — Sandbag impact test

Table B.1 — Height of swing in sandbag test required to simulate a range of impacts on walls

1	2
Height of swing mm	**Impact** J
300	90
450	130
600	175
900	265
1 400	410
1 800	530

B.2.2 Steel tool test (hard-body impacts)

Carry out the test on the same structure that is used for the sandbag test or on a separate wall specimen at least 1,0 m wide. Use a 38 mm diameter steel impact tool with a mass of 1,8 kg, shaped like a chisel with a hardened edge 38 mm wide, rounded to a 2,5 mm radius and attached to a rigid pendulum which pivots in a metal frame (see figure B.2).

Position the tool so that when it is hanging freely at rest, the chisel edge lightly touches the surface of the wall with the tool's long axis at right angles to the wall and the chisel edge horizontal. Draw the tool away from the wall, pendulum fashion, until its centre of mass is at the required height of swing above its initial free-hanging position. Release the tool to swing back and strike the wall with the full width of its edge. Make two impacts on each point tested from each height of swing.

If the wall is of framed construction, then perform the test

a) on the line of the framing,

b) close to, but not on the line of the framing, and

c) midway between the lines of the framing.

The height of swing that provides the required level of energy is set out in table B.2.

Check for compliance with the provisions of tables 2 and 3.

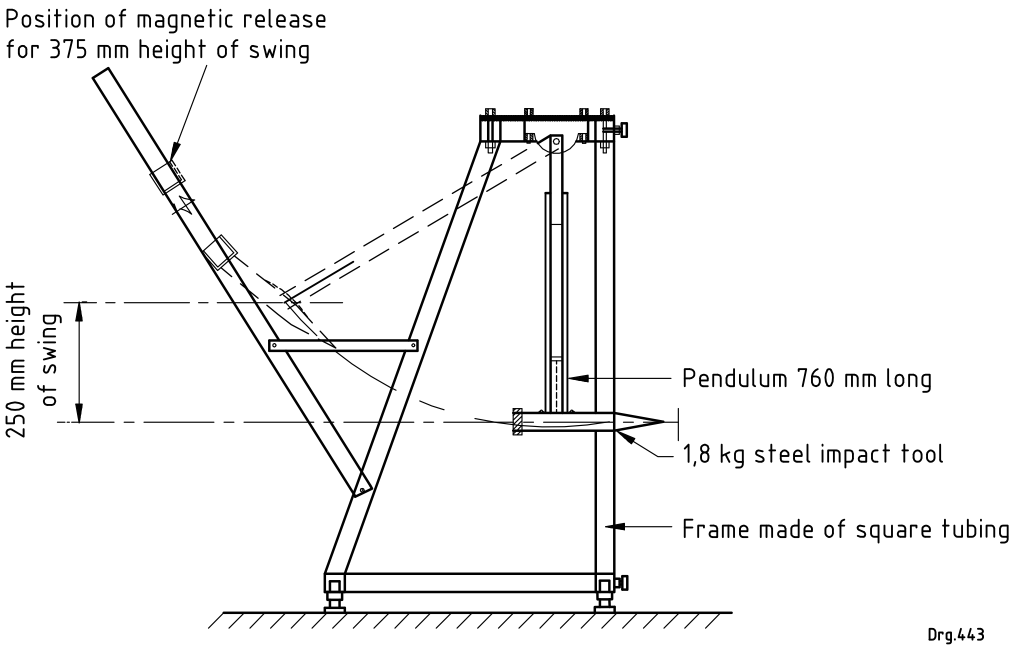


Figure B.2 — Steel tool impact resistance test apparatus

Table B.2 — Height of swing to simulate a range of impacts in the steel tool impact resistance test

1	2
Height of swing mm	**Impact** J
200 250 375	4,2 5,3 7,9

B.2.3 Test for lightweight and medium-weight fittings

Use a wall specimen similar to that used for the sandbag impact test.

Fix a test fitting, fabricated from steel as shown in figure B.3, to the wall with four screws or such other suitable fixing devices as might be used in practice. Suspend an initial test load of 2,3 kg at the position shown for 1 min and increase the load thereafter in 2,3 kg increments at 1 min intervals until failure or maximum loads of 11,5 kg (lightweight fittings) or 23 kg (medium-weight fittings) are attained.

Carry out this test at four different positions on the wall if it is of framed construction. Choose the positions to avoid the lines of the framing and the joints, unless the fittings are to be fixed only to the framing members or to other additional members specially provided for that purpose.

Check for compliance with the provisions of tables 2 and 3.

B.2.4 Test for heavyweight fittings

Fix a test fitting, fabricated from steel and which simulates a pair of wash-hand basin brackets, to the wall with screws or such other suitable fixing devices as might be used in practice (see figure B.4). The test fitting is located about midway between the end of the wall and the door opening. Suspend a test load of 136 kg at the position shown on the angle iron for 5 min. Carry out this test only once for a particular wall.

Check for compliance with the provisions of tables 2 and 3.

Dimensions in millimetres

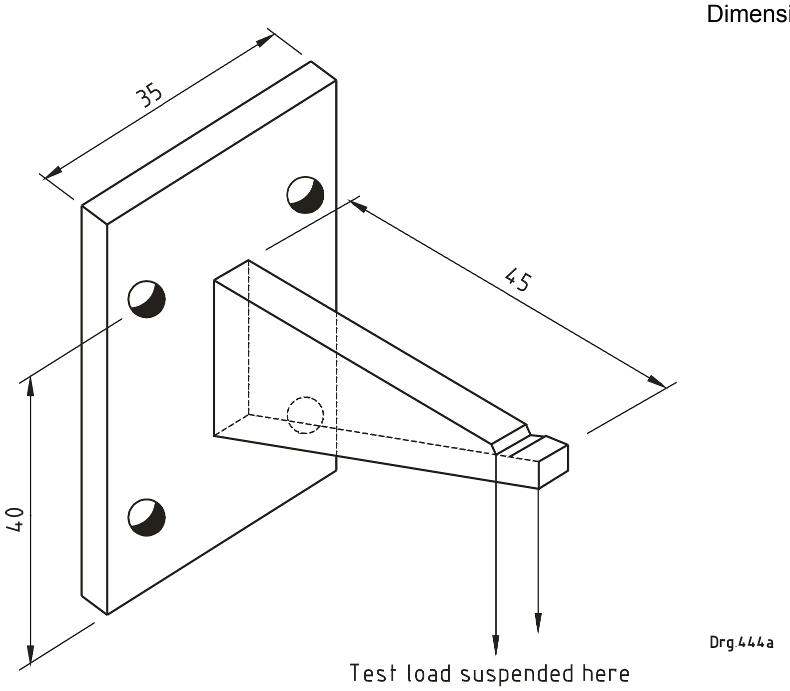


Figure B.3 — Test fitting for lightweight and medium-weight fittings

Dimensions in millimetres

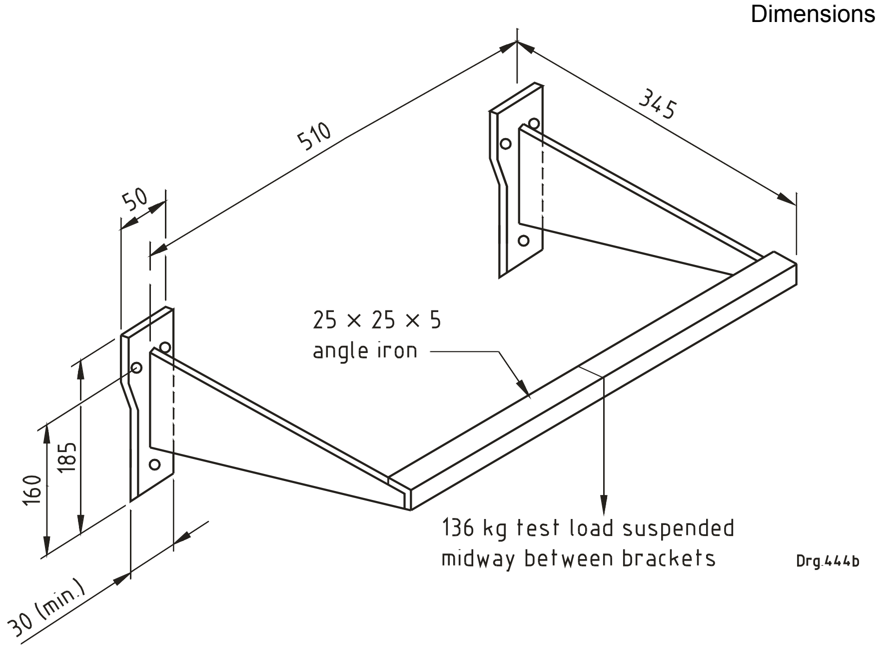


Figure B.4 — Test fitting for heavyweight fittings

B.2.5 Test for shelving

Fix four test fittings, which simulate shelf brackets and which are fabricated from steel, to the wall in a vertical row with screws or such other suitable fixing devices as might be used in practice (see figure B.5). The top of the upper bracket is 2,3 m above floor level and the remaining brackets are spaced at 0,45 centres below it. Suspend an initial test load of 2,3 kg for 1 min from each bracket at the position shown and increase the load thereafter simultaneously on each bracket in 2,3 kg increments at 1 min intervals until failure occurs.

In the case of walls of framed construction, fix the brackets to a vertical member located about midway between the end of the wall and the door opening, or at other specified positions.

The safe load allowed per shelf bracket is one-half of the test load which caused either damage to the wall, or any loosening of a bracket or detachment thereof, or which resulted in a lateral deflection or movement of the wall of more than 1/600th of its height.

Check for compliance with the provisions of tables 2 and 3.

Dimensions in millimetres

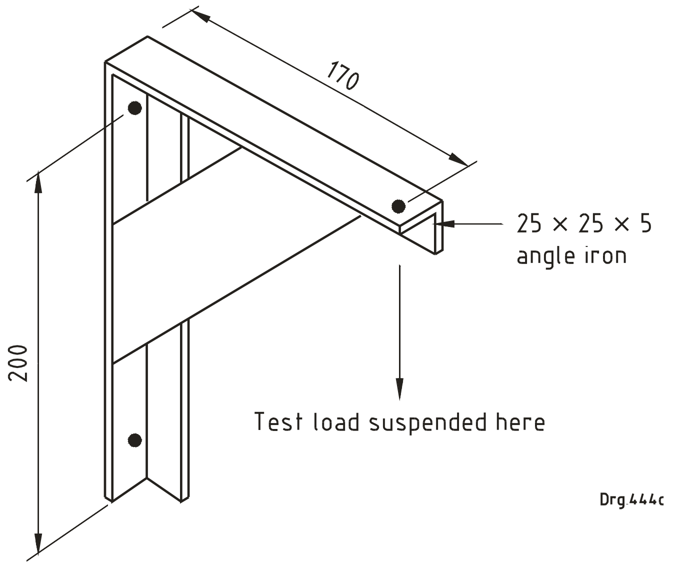


Figure B.5 — Test fitting for shelving

B.2.6 Resistance to door slamming

Use a wall specimen similar to that used for the sandbag impact test, with a door frame fitted in the opening as it is done in practice. Hang a door with a mass of 25 kg in the door frame. Slam the door from a position of 60° open, with a force of 150 N applied at the handle position in the direction of closure. Apply such force until the door makes contact with the frame. Slam the door another 10 times.

Check for compliance with the provisions of tables 2 and 3.

B.2.7 Hail resistance test

Use a specially developed hail gun to fire spherical ice missiles (artificial hailstones) vertically downwards onto the test specimen (portion of roof or wall specimen). Secure the test specimen in a horizontal position in a suitable frame below the hail gun. Set the hail gun so that the kinetic energy of the artificial hailstones at impact with the surface of the test specimen is as required (see tables 2 and 3).

Subject the test specimen to 12 impacts, or a lesser number in the event of failure occurring before 12 impacts. Deliver the impacts normal to the surface of the test specimen at evenly distributed points.

Check for compliance with the provisions of tables 2 and 3.

Annex C
(informative)

The design of masonry walls to satisfy serviceability criteria

C.1 Introduction

The parameters that have a major influence over wall behaviour are the strength, quality of the masonry itself, and the material used to manufacture masonry units (see table C.1 and annex C of SANS 10249:2012). Another important parameter is the influence of the horizontal damp-proof course (DPC) which is located at the base of walls and which has the potential to act as a horizontal control joint. Separation of the wall from the DPC will occur along the DPC with hogging or sagging of the foundation system (see figure C.1).

Masonry will span or, in the case of sagging (dishing) movements, tend to arch across the separation, provided that it has adequate strength to resist the induced tensile stresses. Provided that the masonry walling does not crack, the flexibility of the foundation structure is relatively unimportant, as it is the separation of the wall rather than the magnitude of the separation that governs the wall performance. However, if the masonry cracks under induced stresses, the magnitude of the wall in plane deflection becomes relevant since the crack formed in the masonry will act as a control joint. Crack size will then be governed by the deflection, as the newly formed segments of wall deform to follow the deflected profile.

Under in-plane bending, a masonry wall, acting as a beam, tends to fail in tension (vertical flexural cracking, usually through the perpend units), or in shear (stepped flexural shear crack). Both these modes of failure are initiated by the failure of masonry units or joints at the outer extremity of walls. The mode of failure (cracking pattern) is dependent on the tensile strength of the masonry units and the shear bond strength of the mortar/unit interface.

Table C.1 — Summary of potential movements of masonry units

1	2	3
Unit type	**Movement type**	**Potential movement** mm/m wall length
Burnt clay	Thermal	0,12 to 0,24[a, b]
	Moisture expansion category 1	0 to 0,5
	Moisture expansion category 2	0,5 to 1,0
	Moisture expansion category 3	1,0 to 2,0
	Moisture movement	0,1 to 0,2[a]
Calcium silicate	Thermal	0,33 to 0,45[a, b]
	Drying shrinkage	0,45
	Moisture movement	0,12 to 0,18[a]
Concrete	Thermal	0,21 to 0,42[a, b]
	Drying shrinkage	0,6
	Moisture movement	0,12 to 0,18[a]
	Carbonation (shrinkage)	0,1 to 0,2

[a] Reversible movements
[b] 30 °C temperature change

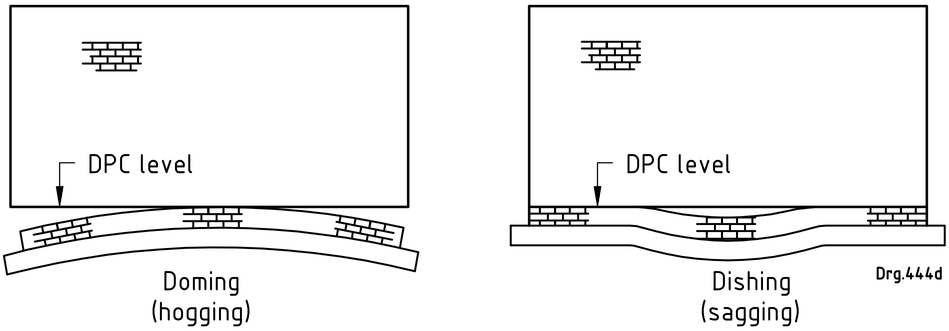


Figure C.1 — Hogging and sagging movements

C.2 Estimation of total movement within a wall

In order to determine the movement likely to take place within a wall, the individual effective movements owing to thermal, moisture and other effects shall be combined. However, the effective thermal and moisture movements should not simply be the sum of the maximum movements since a wall is unlikely to be at both its maximum temperature and its saturated condition at the same time. Therefore, to estimate the possible maximum movement it is necessary to consider carefully the temperature range over which the moisture movement occurs and make some attempt to combine the thermal and moisture movements on a rational basis rather than just considering the extremes. Walls are also restrained to varying degrees at their supports and as such are not able to move freely. Furthermore, the temperature of a wall at the time of construction determines the range of movement that the wall will experience in response to temperature changes.

There is no proven mathematical method for determining movements within a wall. Since there are so many variables involved, it is extremely difficult to determine with any degree of certainty the actual movement that will occur. In general, it is simpler to adopt standard rules rather than to try to estimate movement. Recommendations on the spacing of control joints to accommodate movement are given in SANS 10400-K.

C.3 Accommodation of movement by use of control joints

C.3.1 General

One of the best ways of ensuring that the masonry is able to accommodate small seasonal movements due to temperature and moisture changes is to design the building so that the masonry is separated into discrete panels by the provision of control (movement) joints, i.e. to reduce stresses by reducing restraint.

Control joints may be orientated horizontally or vertically and can also be classified as movement joints. Alternatively, a control joint may be provided in the form of a slip joint separating dissimilar materials to prevent excessive shear forces being generated between the dissimilar materials.

Control joints should be designed so that movement can take place without transferring stresses across the joint. Their design and location should be such that the structural and functional (i.e. impermeability, sound insulation, fire resistance and lateral stability) integrity of the walling is not impaired. Caulks and sealants to these joints should be able to seal the joint adequately against moisture penetration and to accommodate any deformations to which the joint might be subjected. A caulk refers to a material suitable for filling stable (no further movement anticipated) joints, whereas a sealant refers to a material suitable for sealing joints which might experience reversible strains.

Where necessary, dowels, angles or channels strong enough to provide lateral stability should be incorporated. The dowels, which are usually metal rods or flat strips, should be anchored into the masonry in such a way that longitudinal movement is not restrained. Angles or channels fixed on to one side of the control joint should project into grooves and recesses so as not to restrict longitudinal movement.

Vertical control joints are generally provided at regular intervals in long lengths of walls, whereas horizontal joints are usually provided beneath horizontal concrete members in framed structures.

C.3.2 Location of vertical control joints

C.3.2.1 Vertical control joints in unreinforced masonry should generally be positioned where concentrations or changes in stress occur, i.e.

a) at openings,

b) where there are major changes in wall height,

c) where there are changes in wall thickness,

d) where there are control joints in foundations, floors and roofs,

e) near wall intersections, and

f) near return angles in L-shaped, T-shaped and U-shaped structures.

C.3.2.2 In reinforced masonry, vertical control joints should be considered

a) where there are changes in wall thickness,

b) where there are major changes in wall height,

c) at control joints in foundations, in floors and in roofs, and

d) at wall openings.

C.3.2.3 Generally, vertical control joints are not located at the extreme corner of wall returns for stability reasons. They do not usually continue below ground floor damp-proof courses, where changes in temperature and moisture content are minimal, and are not normally required in interior walls of dwellings where the effects of thermal expansion may be disregarded.

Control joints should be built into the wall during construction and run the full height of the masonry. Sawn joints are generally more expensive, require great care in cutting and are not normally as effective as built-in joints.

The position of control joints, bond beams and joint reinforcement should be clearly shown on the plans.

C.3.3 Location of horizontal control joints

Horizontal control joints are normally provided at every storey height in reinforced concrete framed buildings where the cladding comprises burnt clay units or where the shortening of columns can result in excessive loads being transferred from structural members onto masonry walls.

Horizontal control joints may also be provided to separate dissimilar materials.

C.4 Designing walls to distribute cracking

C.4.1 Hogging and sagging movements

Hogging movements generally cause more damage in walls than sagging movements. The reasons for this phenomenon are as follows:

a) The tensile restraint offered by the foundation or supporting members effectively restricts the propagation of cracks from the extremity of walls.

b) Walls tend to arch across separations along the DPC.

c) A certain amount of shear transfer takes place along the DPC at the base of the wall, permitting some composite action to occur. This shifts the neutral axis of the wall from the centre towards the base, resulting in the magnitude of hogging moments being greater than that of sagging moments, for a given wall configuration.

In framed buildings, depending upon the spacing of the columns and the detailing at the connection, hogging movements might not occur. For example, where the length of the wall is less than twice its height and it is built hard up against the columns, the wall will tend to arch and only the material below the arch will be subjected to sagging movements. Where the spans are in excess of twice the height (e.g. in post-tensioned flat slab construction) and the outer leaf is continuous past the face of the column, the wall will be subjected to hogging movements. Alternatively, where such walls are built hard up against the columns, and windows are provided within the wall, it is possible for the upper portion of the wall to arch between the columns and the lower portion of the wall to separate and follow the curvature of the sagging support.

C.4.2 Bed joint reinforcement

Experimental evidence suggests that the provision of bed joint reinforcement, if correctly installed, might be effective in resisting shear as well as tensile failure. Full-scale wall tests have demonstrated that bed joint reinforcement produces a marked increase in the load-carrying capabilities of a wall, and as such permits walls to span increased unsupported lengths.

The onset of visible cracking does not necessarily represent a limit of serviceability. Provided that the width of cracking is controlled by some form of tensile restraint (e.g. reinforcement or concrete foundations), it is possible that significantly larger deformations of masonry can be tolerated than those giving rise to initial cracking. Reinforced concrete beams and slabs are good examples where cracking of a limited width is regarded as normal, and guidelines are laid down for the maximum acceptable width of a crack in various circumstances.

Bed joint reinforcement also imparts ductility to walls and in so doing distributes the total vertical crack width between several cracks. This results in a series of fine cracks as opposed to a single large crack being formed.

Uncontrolled cracking due to hogging of walls should be prevented. Once a crack forms at the top of a wall, there is nothing to stop it propagating downwards. It is for this reason that bed joint reinforcement is usually provided within the joint immediately above windows and openings and also in the uppermost joint in a continuous band around the structure, both in the internal and external walls. SANS 10164-2 recommends that the maximum size of bar in bed joints should not exceed 6 mm. In practice, 5,6 mm and 6,0 mm diameter prestraightened, hard-drawn wire (obtainable from a welded steel fabric reinforcement manufacturer) is well suited for South African structures and offers considerable restraint.

C.4.3 Designing walls to minimize cracking

Cracking can be avoided or minimized by ensuring that induced tensile stresses are kept as low as possible, and that the tensile strength of masonry is as high as possible. These objectives can be achieved by paying particular attention to the design and detailing of the building and by maximizing the masonry bond strength through the selection of sands for mortar and the achievement of good workmanship.

The tolerable limits for relative differential movement depending on the surface finishes and the actual detailing of the superstructure may, in the absence of more specific information, be taken from table C.2.

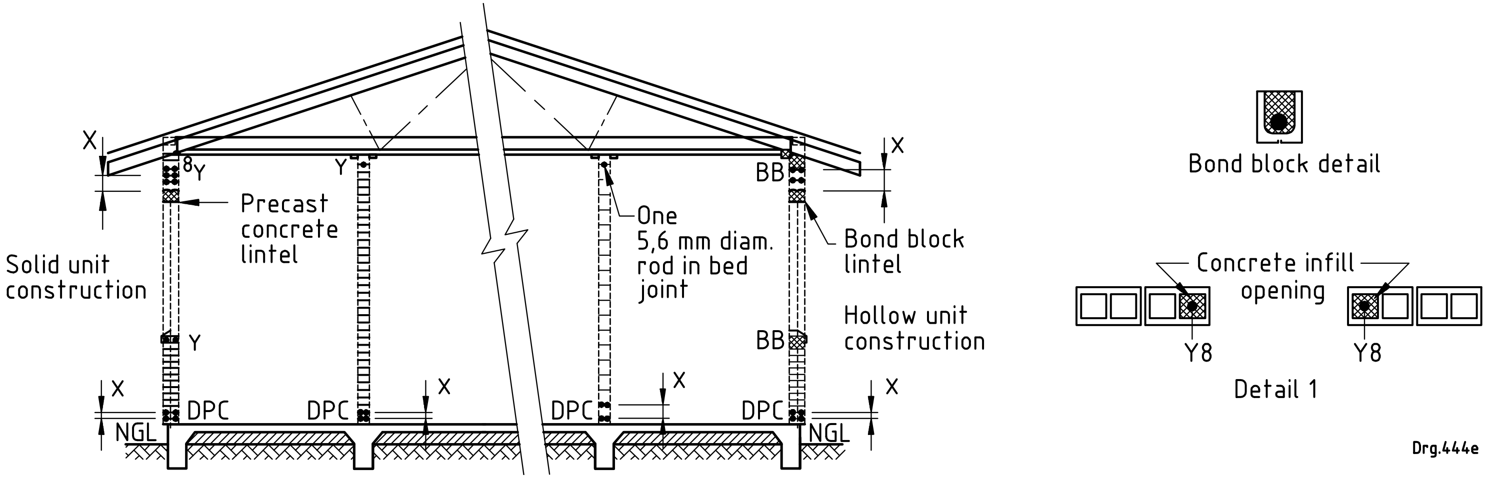
Table C.2 — Allowable deflection ratios to limit expected damage to category 1 buildings

1	2	3
Type of masonry	**Allowable deflection ratio (deflection:span)**	
	Unreinforced	**Lightly reinforced**[a]
Hogging movements		
Articulated masonry		
– plastered	1:800	1:600
– face	1:650	1:500
Full masonry		
– plastered	1:2000	1:1250
– face	1:1500	1:1000
Sagging movements		
Articulated masonry		
– plastered	1:500	1:500
– face	1:350	1:300
Full masonry		
– plastered	1:1000	1:500
– face	1:500	1:300

NOTE 1 A factor of approximately 1,5 should be applied to the tabulated values to upgrade the level of expected damage to that of category 0.

NOTE 2 More severe deflection ratios should be adopted where brittle finishes, such as ceramic tiles, are fixed to walls.

[a] Reinforcement in accordance with figure C.2 should be provided in walls to enable a wall to be regarded as being lightly reinforced.



Solid unit construction

Brickforce shall be provided at vertical centres that do not exceed 425 mm in superstructure walls with additional layers (marked X) as follows:

– in two courses immediately above the floor slab;
– in every course above all lintels to extend 600 mm beyond openings.

5,6 mm diameter rod reinforcement (marked Y) shall be provided as follows:

– two in the course immediately below windows to extend 600 mm beyond openings;
– two (continuous) in uppermost bed joints of external walls;
– one (continuous) in uppermost bed joint of internal walls.

Hollow unit construction

Brickforce shall be provided at vertical centres that do not exceed 400 mm in superstructure walls with additional layers (marked X) as follows:

– in two courses immediately above the floor slab;
– in every course above lintels to extend 600 mm beyond openings.

Bond blocks reinforced with a single Y8 bar (marked BB) shall be provided as follows:

– below openings to extend 600 mm beyond openings;
– in the uppermost course (continuous) of external walls.

All cores adjacent to openings shall have a Y8 bar placed vertically in infill concrete (see detail 1) extending from floor to wall plate level.

Truss-type brickforce shall be used in 140 mm and 190 mm walls.

All reinforcement, including brickforce, shall be discontinuous at articulation joints.

Corrosion protection of reinforcement shall be in accordance with SANS 2001-CM1.

Hollow unit construction of width less than 140 mm shall be reinforced as for solid unit construction.

The minimum lap lengths shall be 500 mm for rods and bars, and 300 mm for brickforce.

Figure C.2 — Lightly reinforced masonry

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