



# JSD

Joint Structural Division

## Checklist Guide for **Structural Engineering Design**

**Joint Structural Division**

**Second Edition**

**June 2016**

## Preface

This publication, which was developed by members of the Joint Structural Division's (JSD) Committee and others, provides a checklist for those involved in structural engineering design, irrespective of the level at which they practice. It is not exhaustive but rather a work in progress. It highlights common design considerations for foundations and the primary structural materials (concrete, steel, masonry and timber) and identifies reference standards for design, materials and construction.

Practicing and aspirant structural engineering professionals applying this checklist guide need to be aware of their responsibilities and obligations with reference to the following Joint Structural Division's publications:

- ***Good Practice Guide for Structural Engineering*** which
  - establishes ethical values for those engaged in the practice of structural engineering;
  - identifies the work performed by structural engineering practitioners;
  - suggests that structural engineering practitioners function at one of four distinct levels of practice;
  - categorises structural engineering work in terms of levels of risk;
  - outlines the levels of competence required to practice structural engineering, based on level of risk and type of work; and
  - makes recommendations for the practice of structural engineering work.
- ***Standard for Structural Engineering Services*** which establishes requirements for those responsible for determining or confirming the structural safety and serviceability performance of structures. It covers the design of structures, the checking of another structural engineer's design, condition assessments, the use of structural engineering software and the certification of structures.

**Marelize Visser**

Chairperson  
Joint Structural Division

# Checklist Guide for Structural Engineering Design

## Contents

1	GENERAL CONSIDERATIONS .....	1
1.1	Statutory requirements .....	1
1.2	Developing the brief .....	1
1.3	Standards which influence the design of a structure.....	1
2	FOUNDATIONS.....	3
2.1	Geotechnical information.....	3
2.2	Site consideration .....	3
2.3	Founding conditions .....	3
2.4	Useful evaluation guidelines.....	3
2.5	Standards for geotechnical investigations.....	4
2.6	Standards for design and construction .....	4
2.7	Useful publications.....	5
2.8	Other older publications/ not in print.....	5
3	REINFORCED CONCRETE DESIGN .....	6
3.1	Concrete properties .....	6
3.2	Building construction.....	7
3.3	Design considerations .....	7
3.4	Site works .....	8
3.5	Reference standards for design, materials and construction .....	10
4	STRUCTURAL STEEL DESIGN .....	12
4.1	Grade of steel .....	12
4.2	Type of sections (to determine design code to be used) .....	12
4.3	Connection method - bolts or welds .....	12
4.4	Method of analysis.....	12
4.5	Loadings .....	12
4.6	Tension members.....	13
4.7	Gussets .....	13
4.8	Connections in general.....	13
4.9	Compression members .....	13
4.10	Base details .....	13
4.11	Beams rolled sections or plate girders .....	13
4.12	Beam-columns.....	14
4.13	Composite construction.....	14

4.14	Crane buildings.....	14
4.15	Serviceability .....	14
4.16	Corrosion protection .....	14
4.17	Erection .....	15
4.18	Quality assurance.....	15
4.19	Economics .....	15
4.20	Passive fire protection .....	15
4.21	Reference standards for design, materials and construction.....	16
4.22	Useful publications .....	18
5	UNREINFORCED AND REINFORCED STRUCTURAL MASONRY .....	19
5.1	General principles that govern all design stages.....	19
5.2	Initial design .....	21
5.3	Structural design.....	21
5.4	Drawings .....	24
5.5	Reference standards for design, materials and construction .....	25
5.6	Useful publications.....	26
6	STRUCTURAL TIMBER DESIGN .....	27
6.1	Introduction .....	27
6.2	Application to roof trusses .....	27
6.3	Reference standards for design, materials and construction .....	29
6.4	Useful publications.....	29

# 1 GENERAL CONSIDERATIONS

## 1.1 Statutory requirements

- Construction Regulations issued in terms of the Occupational Health and Safety Act (Latest Version as Amended).
- National Building Regulations issued in terms of the National Building Regulations and Building Standards Act of 1977.
- National Home Builders Registration Council (NHBRC) Technical Requirements included in the Home Building Manual issued in terms of the Housing Consumer Protection Measures Act of 1998.

## 1.2 Developing the brief

- Inform the client of his/her responsibilities in terms of the Construction Regulations issued in terms of the Occupational Health and Safety Act of 1993 and, if relevant, the National Building Regulations issued in terms of the National Building Regulations and Building Standards Act of 1977 and the Home Building Manual issued in terms of the Housing Consumer Protection Measures Act of 1998.
- Approval stages and requirements.
- Classification of building required e.g. offices, factories, warehouses, residential
- Live loads: future flexibility in service.
- Storage areas, e.g. books, papers, bulk machinery.
- Influence of vibration, e.g. precision measurement.
- Walls and partitions: variation in type and mass.
- Column centres, e.g. parking needs multiple bays widths.
- Floor to floor height: allowance for services and loads.
- Service ducts, through beams and floors.
- Machines and cooling towers: location and duct requirements.
- Elevators: motor rooms, floor details and pits.
- Escalators: supports and motor spaces.
- External cladding, e.g. brick, precast, window wall - design required by façade engineer.
- Lifting beams: loads and position.
- Height of building and exposure: wind loading and environmental considerations
- Seismic area: code application.
- Corrosion conditions: required service life and coating specification.

## 1.3 Standards which influence the design of a structure

Standards relating to foundations and structural materials (concrete, steel, masonry and timber are dealt with in chapters 2 to 6.

### 1.3.1 *Basis of structural design*

- SANS 2394:2003/ ISO 2394:1998, *General principles on reliability for structures*
- SANS 10160-1:2010, *Basis of structural design and actions for buildings and industrial structures Part 1: Basis of structural design*

- SANS 10160-2:2010, *Basis of structural design and actions for buildings and industrial structures Part 2: Self-weight and imposed loads*
- SANS 10160-3:2010, *Basis of structural design and actions for buildings and industrial structures Part 3: Wind actions*
- SANS 10160-4:2010, *Basis of structural design and actions for buildings and industrial structures Part 4: Seismic actions and general requirements for buildings*
- SANS 10160-5:2010, *Basis of structural design and actions for buildings and industrial structures Part 5: Basis for geotechnical design and actions*
- SANS 10160-6:2010, *Basis of structural design and actions for buildings and industrial structures Part 6: Actions induced by cranes and machinery*
- SANS 10160-7:2010, *Basis of structural design and actions for buildings and industrial structures Part 7: Thermal actions*
- SANS 10160-8:2010, *Basis of structural design and actions for buildings and industrial structures Part 8: Actions during execution*
- SANS 10400-B:2012, *The application of the National Building Regulations Part B: Structural design*
- National Home Builders Registration Council's Home Building Manual, 2015

### **1.3.2 Glazing**

- SANS 2001-CG1:2007, *Construction works Part CG1: Installation of glazing in window and door frames*
- SANS 10137:2011, *The installation of glazing in buildings*
- SANS 10400-N:2012, *The application of the National Building Regulations Part N: Glazing*

### **1.3.3 Miscellaneous**

- SANS 993:2010, *Modular co-ordination in building*
- SANS 1169:2008, *Temporary stands*
- SANS 1936-1: 2012, *Development of dolomite land Part 1: General principles and requirements*
- SANS 1936-3:2012, *Development of dolomite land Part 3: Design and construction of buildings, structures and services*
- SANS 1936-4: 2012, *Development of dolomite land Part 4: Risk management*
- SANS 10021:2012, *The waterproofing of buildings (including damp-proofing and vapour barrier installation)*
- SANS 10155:2009, *Accuracy in buildings*
- SANS 10209:2003, *The design and construction of private swimming pools*
- SANS 10400-A:2010, *The application of the National Building Regulations Part A: General principles and requirements*
- SANS 10400-C:2010, *The application of the National Building Regulations Part C: Dimensions*
- SANS 10400-D:2011, *The application of the National Building Regulations Part D: Public safety*
- SANS 10400-F:2010, *The application of the National Building Regulations Part F: Site operations*
- SANS 10400-R:2012, *The application of the National Building Regulations Part R: Stormwater disposal*
- SANS 10400-T:2011, *The application of the National Building Regulations Part T: Fire protection*

## 2 FOUNDATIONS

For all sites other than where there is a reliable history of geotechnical information, a competent geotechnical engineer or engineering geologist should be appointed and an appropriate geotechnical investigation be undertaken.

### 2.1 Geotechnical information

- Investigation for suitable foundation types e.g. piling option.
- Collapsing soils, e.g. aeolian sand and decomposed granite.
- Heaving clays.
- Potential differential settlement.
- Dolomite: sinkholes.
- Mining ground.
- Rock and blasting.
- Water table, sub surface water conditions, e.g. springs.
- Trees and desiccation, e.g. blue gum and fig trees.
- Planting next to building.

### 2.2 Site consideration

- Excavation: has a responsible person been identified to evaluate and supervise all excavation work in terms of the Construction Regulations?
- Basement requirement.
- Lateral support, e.g. anchors under adjacent stands required.
- Survey of adjacent properties.
- Letter to adjacent owners.
- Eccentric footings at boundary, e.g. strap beams, piles.
- Structure designed for a notional horizontal load of 1,5% of its weight, if this is greater than wind load.

### 2.3 Founding conditions

- Required depth, e.g. consider services above.
- Soil type at founding depth and presence of vegetation, ant holes, etc.
- Excavation clean and free of mud and water, e.g. dewatering requirement.
- If auger piling required-depth to the determined.
- Support to foundation sides required if loose material.
- If driven piles-specification required.
- Access and space for piling rigs.
- Blinding required for sandy soils.
- Lateral support to excavation.

### 2.4 Useful evaluation guidelines

A guideline to bearing pressures for different soils is given in the tabulation below from SANS 10161:1980, *The design of foundations for buildings*.



Type of supporting ground	Description of rock, soils and fills	Presumed safe bearing capacity (kN/m <sup>2</sup> )	
		Dry	Submerged
Rock	Fresh rock, massively bedded, intact (igneous, metamorphic, or sedimentary) and requiring blasting for excavation	5 000	5 000
	Fresh rock, fractured or jointed, which can be excavated with difficulty by pneumatic picks, but which normally requires light blasting	1 000	1 000
	Shale, of hard rock consistency	200 - 400	200 - 400
	Decomposed rock, to be assessed as a soil as below	-	-
Non-cohesive	Compact, well graded gravels, very dense silty sand, sands, gravel-sand mixtures	400 - 600	200 - 300
	Compact but poorly graded gravels, gravel-sand, dense sands, silty sands, sandy silt, silt mixtures	200 - 400	100 - 200
	Medium dense sands, silty sands, sandy silts, and silts, clayey sands, clayey silts	100 - 150	50 - 75
	Loose and very loose sand, silty sands, sandy silts, clayey sands, clayey silts	By test only	By test only
Cemented soils	Cemented gravel, hard 'ouklip' (ferricrete), hard calcrete, and hard silcrete	400 - 600	400 - 600
	Weakly cemented soils of medium and low (loose) density	100 - 150	By test only
Cohesive soils	Very stiff sandy or silty clays	400 - 500	300 - 400
	Stiff clays, sandy clays, silty clays	200 - 400	150 - 200
	Firm clays, sandy clays, silty clays	100 - 200	75 - 150
	Soft clays, sandy clays, silty clays	50 - 100	50 - 100
	Compacted fill or selected material	0 - 50	0 - 50
Compacted selected fill	Compacted fill or selected material	By test only	By test only
Random fills	Made-up ground, waste dumps, and other uncompacted fills	By test only	-

Note: Most foundation loads in buildings are applied vertically to the centre of the foundation. However, where the load is applied eccentrically or inclined from the vertical or both, the safe bearing capacity will require modification. The presumed safe bearing capacities should be taken at a depth of not less than 600 mm below the top of natural supporting ground.

## 2.5 Standards for geotechnical investigations

- SANS 633:2012, *Soil profiling and rotary percussion borehole logging on dolomite land in Southern Africa for engineering purposes*
- SANS 634:2012, *Geotechnical investigations for township development*
- SANS 1936-2:2012, *Development of dolomite land Part 2: Geotechnical investigations and determinations*
- SANS 10161:1980, *The design of foundations for buildings*
- SANS 10400:H, *The application of the National Building Regulations Part H: Foundations*
- National Home Builders Registration Council's Home Building Manual, 2015
- South African Institution of Civil Engineers Geotechnical Division, Code of Practice for the safety of persons working in small diameter shafts and test pits for geotechnical engineering purpose, 2007
- South African Institution of Civil Engineers, Geotechnical Division Lateral support in surface excavation. Code of Practice, 1989

## 2.6 Standards for design and construction

- SANS 207:2011, *The design and construction of reinforced soils and fills*

- SANS 2001-BE1:2008, *Construction standards, Part BE1: Earthworks (general)*
- SANS 2001-BE3:2012, *Construction works Part BE3: Repair of sinkholes and subsidences in dolomite land*
- SANS 2001-CM2:2011, *Construction works Part CM2: Strip footings, pad footings and slab-on-the-ground foundations for masonry walling*
- SANS 10161: 1980, *The Design of foundations for buildings*
- SANS 10400-G:2011, *The application of the National Building Regulations Part G: Excavations*
- SANS 10400-H:2012, *The application of the National Building Regulations Part H: Foundations*
- SANS 10400-J:2010, *The application of the National Building Regulations Part J: Floors*
- Joint Structural Division of the South African Institution of Civil Engineering and Institution of Structural Engineers, *Code of Practice for Foundations and Superstructures for Single Storey Residential Buildings of Masonry Construction*, 1995
- National Home Builders Registration Council's Home Building Manual, 2015
- SANS 10160-5:2011, *Basis Of Structural Design And Actions For Buildings And Industrial Structures*

## 2.7 Useful publications

- Brink. ABA. *Engineering Geology of Southern Africa*, Volume 1- 1979; Volume 2- 1981; Volume 3 - 1983; Volume 4 – 1985, Building Publications Pretoria
- Buttrick, D.B, Trollip, N.Y.G, Watermeyer, R.B, Pieterse, ND and Gerber, A.A. (2011) A performance based approach to dolomite risk management. *Environmental Earth Science* 64:1127-1138
- Franki Africa. *A Guide To Practical Geotechnical Engineering in Southern Africa - Fourth Edition* 2008
- South African Institution of Civil Engineers Geotechnical Division, *Commemorative Journal of the Geotechnical Division of SAICE*, 2006
- Watermeyer, R.B. and Tromp, B.E. (1992) A systematic approach to the design and construction of single-storey residential masonry structures on problem soils, *The Civil Engineer in South Africa*, March, pp.83-96

## 2.8 Other older publications/ not in print

- SAIEG - *Guidelines for Soil and Rock Logging in South Africa*
- SAICE - *Code of Practice 1989 - Lateral support in surface excavations*
- SAICE - *Site-Investigation-Code-of-Practice*
- SAICE - *The Safety Of Persons Working In Small Diameter Shafts And Test Pits For Geotechnical Engineering Purposes.*

### **3 REINFORCED CONCRETE DESIGN**

Structural properties of concrete are frequently left to the contractor to determine and defects often form the basis of disputes due to incomplete specification. The following checklist is intended to guide structural designers in the selection of highly variable reinforced concrete materials in the best interests of good structural performance and not solely on the basis of cost.

#### **3.1 Concrete properties**

##### **3.1.1 Compressive strength**

- Specify strength by 28 day cube strength.
- Assessment of strength by cores e.g. South African National Standard method with adjustments.
- Assessment of strength by cubes e.g. statistical or simplified.
- Use of independent testing laboratories.

##### **3.1.2 Flexural strength**

- Modulus of rupture.
- Used in unreinforced concrete e.g. surface beds.

##### **3.1.3 Elastic modulus**

- Deflection of beams and slabs.
- Shortening of columns e.g. shedding of load to steel reinforcement.
- Influence of creep under age loading.

##### **3.1.4 Shrinkage and thermal movement**

- Consider plastic shrinkage, settlement and drying.
- Grading of fine and coarse aggregates.
- Maximum limit allowable in structure.
- Proportion of water in fresh state.
- Shrinkage of coarse aggregates.
- Thermal shrinkage due to heat of hydration e.g. choice of cement, type of formwork, placement temperature, weather.
- Type and location of joints to accommodate shrinkage and thermal movement.

##### **3.1.5 Concrete durability**

- Compaction of concrete e.g. method, temperature, workability.
- Correct choice of cement content.
- Risk of alkali aggregate reaction.
- Impermeability to liquids and gasses.
- Resistance to ingress of chlorides, acidic gasses and moisture.
- Thickness of cover to reinforcing.

### **3.1.6 Abrasion resistance**

- Subjective but vital assessment e.g. abrading and dusting related to finishing of slabs.

### **3.1.7 Bleeding**

- Creation of channels and voids e.g. ingress of aggressive materials.
- Finishing of horizontal surfaces.

## **3.2 Building construction**

- Temperature stress-exposure to sun or hot processes.
- Protection against fire – fire consultant may be required.
- Drips in slabs and nibs for masonry cladding.
- Cast-in items for steel, machinery, precast fixings and pockets.
- Non-structural items, e.g. architectural “furniture”.
- Drainage-weep holes, drainage layer.
- Tolerances – particularly for structural steel connections and bearings.
- Columns – detail special reinforcement at openings for rainwater pipes.
- Partitions specially sensitive to deflection identified.
- Structure sensitive to vibration may be a serviceability issue.
- Stability of building as a whole - lift shaft, cores, shear walls.
- Skill of contractor and level of construction monitoring should be adequate for complex structures.
- Design for robustness, accidental loads, effects of impact or explosions and construction method.
- Structure need to be able to withstand the loss of critical members due to accident.
- Settlement or movement influences on services.
- Take into account possible change in function of structure.
- Basement method of construction e.g. top-down, anchors, props.
- Foundations to suit soils – piles, raft slabs or pad bases.
- Location of construction joints e.g. points of contra flexure shown on drawings.
- Spacing of columns and movement joints to reduce floor cracking.

## **3.3 Design considerations**

### **3.3.1 General**

- Deflections influenced by - span/depth ratios, elastic modulus of concrete, long term shrinkage and creep under loading.
- Cover to reinforcement and quality of cover concrete e.g. durability and life-span.
- Cut off points for steel - pull out forces.
- Distribution steel - front face, back face, in front of main bars, cross-sectional area.
- Main steel bars in correct orientation and location.
- Moments in combined footings.
- Slenderness ratio of columns, Euler load, moment of inertia and biaxial bending.
- Unforeseen Impact loading and loss of stability, influenced by robustness of structure.

### 3.3.2 Analysis

#### a) Bending Resistance

- The concrete moment of resistance of a continuous rectangular reinforced concrete beam is influenced by the degree of elastic moment re-distribution.
- If the applied ultimate moment is exceeded, the beam size needs to be increased, the grade of concrete increased or compression steel provided.
- Where the re-distribution of ultimate moments reduces a moment, that moment of resistance could require adjustment by re-distribution factors.
- For a T beam, the moment of resistance needs to incorporate the slab flange.
- The amount of reinforcement is calculated from the applied ultimate bending moment equated to the ultimate resistance moment of the section.
- The ultimate resistance moment is calculated from the specified concrete quality and reinforcement stress and bar area, considering the dimensions of the section and location of reinforcement within the section.
- The steel stress is given by dividing the specified ultimate strength of the reinforcement by 1,15, and is thus 391 MPa for 450 steel, and 217 MPa for 250 steel. It should be noted that many text books give tables for steel with a strength of 460 MPa, which is not normally available locally.

#### b) Shear Resistance

- The permissible shear stress on a beam or slab needs to be calculated and designed for.
- Check punching in flat slabs over columns-common cause of failure.

#### c) Torsion Resistance

- The shear stress due to torsion in a rectangular section needs to be calculated and designed for.

## 3.4 Site works

### 3.4.1 Mix proportions

- Mix design to be submitted for filing, comment and approval.
- Cement type suitable for environment e.g. coastal, inland, hot or cold weather.
- Concrete grade to satisfy durability or structural strength.
- Correct use and application of admixtures.
- Temperature of concrete at the point of delivery.
- Water requirement of fresh concrete.
- Alkali/aggregate reaction.
- Sand and stone grading approved.
- Rate of strength gain – cement types vary and influence cube test results.
- Mixing method – mass batching, ready mix or hand mix.
- Placement of concrete e.g. pump, crane, hoist.
- Slump specification.

### **3.4.2 Formwork and falsework**

- Off shutter finish required – steel / timber face.
- Adequate props and bracing.
- Shutters cleaned and oiled.
- Design loads should be adequately indicated on design drawings to enable a competent person (to be appointed by the Contractor) to adequately design the temporary works as outlined in the Construction Regulations of the Occupational Health and Safety Act.

### **3.4.3 Reinforcement and post tensioning strands**

- Lap lengths, diameters, spacing.
- Protection for strands at joints.
- Bursting reinforcement at anchorages.
- Anchorages protection around openings.
- Lateral deflection around openings.
- Cover spacers, stools or chairs especially for cantilevers and top steel.
- Protection against displacement during concreting.
- Oil on reinforcement.
- Conduits interfering with placing or compacting concrete.
- Openings required for services – framed with reinforcement.
- Check plumber or electrician does not cut reinforcement and places conduits in the correct position e.g. centrally within slab.

### **3.4.4 Placing concrete**

- Vibrators adequate and spares and backup available.
- Test cubes to be taken, check slump.
- Shutters clean and walkways in position.
- Temperature- excessively hot or cold conditions influence strength.
- If cold, appropriate heating or insulation should be provided.
- Re-vibration required at tops of columns or capitals, joints and stop ends, prior to initial set.
- Use of temporary shuttering or mesh.
- Power-floating required – screed level control necessary.
- Lighting required to facilitate work at night.
- Control / restrictions on personnel movement during and after concreting.

### **3.4.5 Curing and stripping**

- Method of curing – sand, water, chemical, spray.
- Protection against wind, sun or frost.
- When are side shutters stripped? Concrete may be rubbed down.
- When are soffit shutters stripped structure? May require to be re-propped.
- Check if shutters moved during concreting.
- Requirements for back-propping for additional floors.
- Application of floor hardeners.
- Duration of compaction to avoid air entrapment.

- Making and transporting of cubes.
- Making of flexural strength specimens.
- Method of placement e.g. loss of fines and segregation.
- Power-floating while bleeding.
- Slump test on concrete.
- Remedial measures.

### 3.5 Reference standards for design, materials and construction

#### 3.5.1 Design standards

- SANS 10100-1:2000, *The structural use of concrete Part 1: Design*
- SANS 10109-1:2012, *Concrete floors Part 1: Bases to concrete floors*
- SANS 10109-2:2013, *Concrete floors Part 2: Finishes to concrete floors*
- SANS 10144:2012, *Detailing of steel reinforcement for concrete*
- EN 1992-1-1:2004, *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*
- EN 1992-1-2:2004, *Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design*
- EN 1992-2:2005, *Eurocode 2 - Design of concrete structures - Concrete bridges - Design and detailing rules*
- EN 1992-3:2006, *Eurocode 2 - Design of concrete structures - Part 3: Liquid retaining and containment structures*

#### 3.5.2 Materials

- |                    |   |
|--------------------|---|
| Aggregates         | <ul style="list-style-type: none"> <li>• SANS 794:2009, <i>Aggregates of low density</i></li> <li>• SANS 1083:2014, <i>Aggregates from natural sources - Aggregates for concrete</i></li> </ul>   |
| Cement             | <ul style="list-style-type: none"> <li>• SANS 50197-1:2013 / EN 197-1:2011, <i>Cement Part 1: Composition, specifications and conformity criteria for common cements</i></li> <li>• SANS 1491-1:2005, <i>Portland cement extenders. Part 1, Ground granulated blast-furnace slag</i></li> <li>• SANS 1491-2:2005, <i>Portland cement extenders. Part 2, Fly ash</i></li> <li>• BS 1014-1975 (1992), <i>Pigments for Portland cement and Portland cement products</i></li> </ul> |
| Reinforcement      | <ul style="list-style-type: none"> <li>• SANS 282:2011, <i>Bending dimensions and scheduling of steel reinforcement for concrete</i></li> <li>• SANS 920:2011, <i>Steel bars for concrete reinforcement.</i></li> <li>• SANS 1024:2012, <i>Welded steel fabric for reinforcement of concrete</i></li> <li>• SANS 190-2:2008, <i>Expanded metal Part 2: Building products</i></li> </ul>   |
| Ready mix concrete | <ul style="list-style-type: none"> <li>• SANS 878:2012, <i>Ready-mixed concrete.</i></li> </ul>   |

#### 3.5.3 Construction

- SANS 10100-2:2014, *The structural use of concrete Part 2: Materials and execution of work*
- SANS 2001-CC1:2012, *Construction works Part CC1: Concrete works (structural)*

- SANS 2001-CC2:2007, *Construction works Part CC2: Concrete works (minor works)*

### **3.6 Useful publications**

- Cement and Concrete Institute, *Fulton's Concrete Technology*, 9th Edition, 2009
- Marais, LR and Perrie, BD. *Concrete Industrial floors on the ground*, Portland Cement Institute, 2009
- Parrot G, *Reinforced Concrete - Design to SANS 10100*, 2008
- Reynolds, CE, James C. Steedman, JC and Threlfall, AJ. *Reinforced Concrete Designer's Handbook*, Eleventh Edition, CRC Press, 2007
- The Institution of Structural Engineers, *Manual for the design of concrete building structures to Eurocode 2*, 2006



## 4 STRUCTURAL STEEL DESIGN

### 4.1 Grade of steel

- Hot-rolled sections and plate: usually Grade S355JR.
- Cold-rolled sections: Commercial quality (see clause 5.2.2 of SANS 10162-2:2011, *The structural use of steel Part 2: Cold-formed steel structures*) or Grade 355 on special order and thickness dependent.
- Hollow sections: Grade 355 equivalent for thickness greater than 2.5mm and perimeter bigger than a 60 diameter tube.

### 4.2 Type of sections (to determine design code to be used)

- Hot –rolled.
- Cold-rolled.
- Class of section – Class 4 subjected to local buckling.

### 4.3 Connection method - bolts or welds

- Bolts – consider grades of bolts 4.8, 8.8 or 10.9.  
Although with great care it is possible to safely hot dip galvanize bolts, so many things can go wrong and it is strongly recommended not to galvanize class grade 10.9 bolts.  
Bearing / shear connections.  
Tension / shear connections.  
Combined shear and tension.  
Friction grip connections (serviceability condition!) 10.9HR bolts.
- Welds – electrode grade for 355 steel is E70xx or equivalent (70 kips ultimate tensile stress equates to 470 MPa UTS).  
Welding Code – AWS D1.1, American Welding Society – Structural welding code – Steel which is referenced in SANS10162-1:2011, *The structural use of steel Part 1: Limit-states design of hot-rolled steelwork* and SANS 10162-2.  
Welds - Weld Procedure Specifications (WPS) required.  
Welder qualifications to do the weld procedures required.  
Do not over-specify weld sizes.

### 4.4 Method of analysis

- Simple (elastic) analysis.
- Plastic analysis.
- 2<sup>nd</sup> order effects – see Clause 8 of SANS 10162-1.
- Stability of structures Clause 9 of SANS 10162-1.

### 4.5 Loadings

- Load combinations refer SANS10160-1:2011, *Basis of structural design and actions for buildings and industrial structures Part 1: Basis of structural design*.  
Ultimate limit-states design.  
Serviceability-limits design.  
Pay particular attention to wind loads, especially localised conditions on roofs etc.

## 4.6 Tension members

- Overall strength.
- Strength at the connection – rupture (tear out) strength.
- Strength of connectors – welds or bolts-shear lag.
- In uplift situations on light roofs (reversal of forces due to wind) tension members can become compression members and should be designed for this case.

## 4.7 Gussets

- Overall strength.  
Check the rupture (tear out) strength.  
Check for buckling strength.
- Check effect of overlapping gussets in Tee connections for tubular members.

## 4.8 Connections in general

- Look for the “load path” and cater for shear, bearing, tension and compression.
- Refer to Southern African Institute of Steel Construction (SAISC) Green Book Structural steel connections and e-digitized version.
- Cater for eccentricities i.e. when centres of gravity of loads do not meet in a common centroid.

## 4.9 Compression members

- Class of section.
- Slenderness ratios about principle axes.
- Out of plane buckling.
- Eccentrically connected single angle struts.

## 4.10 Base details

- Uplift force combination checked.
- Holding bolt tension catered for.
- Do not use high tensile HD bolts where possible, preferably commercial grade round bar for lightly loaded bolts, Grade S355JR for moderately loaded bolts.
- Do not weld to any high tensile HD bolts (rather bolt “pull out” plates between 2 nuts at bottom of bolts and clamp on location templates using 2 nuts near the top of the bolts).
- Do not call up bolt grade strengths for HD bolts as suitable materials are difficult to source and weld.

## 4.11 Beams rolled sections or plate girders

- Class of section.
- Is the compression flange restrained?
- Consider the benefit of bending moment gradient.
- Do not ignore shear considerations.  
Web crippling and/or yielding – concentrated loads.

Tension field action in plate girders.

#### **4.12 Beam-columns**

- Class of web-combined bending and compression.
- Consider the benefit of bending moment gradient.
- Slenderness ratios in and out of plane.
- Consider fly bracing for stability.

#### **4.13 Composite construction**

- Chapter 17 SANS 10162-1.
- The Southern African Institute of Steel Construction (SAISC) Red Book and their digitized version makes life simple.
- Shear stud requirements refer to AWS D 1.1 chapter 7.
- Permanent slab shutters speed up the process.
- Ensure contractors do not overload shuttering when pumping concrete.

#### **4.14 Crane buildings**

- Load combinations.
- Lateral stability of crane beams and building.
- Good practise is to design crane beams as simply supported.
- The attachment method for crane rails should provide for re-alignment.  
The crane manufacturer may have his own requirements for rail shape, size, attachment and sometimes welding into a continuous rail.
- Fatigue maybe a likely problem - is influenced by class of crane and detailing.
- Tension field action not permitted in crane beams/girders.
- Take care with welds.
- Full penetration welds required for top flange to web if plate girders are used.
- For materials 20 mm and thicker, beware of potential for laminations/ lamellar tearing.
- Consider possible changes of use during structure's life e.g. addition of second crane/upgrade.

#### **4.15 Serviceability**

- Deflections refer SANS 10160-1 for basic rules.  
Span to depth ratios are a guideline.
- Floor vibrations and response to dynamic loads.

#### **4.16 Corrosion protection**

- Refer SANS 1200 HC: 1988, Standardized specification for civil engineering construction Section HC: Corrosion protection of structural steelwork
- Take care with details to reduce corrosion problems.
- Do not use double angle construction in corrosive areas.
- Detail breather/ drain holes for galvanised structures (Refer to guidelines issues by the Hot Dip Galvanizers Association Southern Africa).

## 4.17 Erection

- Safe erection method statement is a requirement in terms of Occupational Health and Safety Act. Consider the erection method and how it may impact on the design concept.
- Stability of slender members, especially considering how slinging will be done.
- Consider the use of lifting beams.
- Safe working at heights requirements of Occupational Health and Safety Act to be taken into account.
- Temporary erection bracing.
- Crane capacity, hard standings.
- Tandem crane lifts are especially dangerous and need to be carefully assessed.
- Line, level and general tolerances in accordance with SANS2001-CS1, *Construction works Part CS1: Structural steelwork*.
- Responsibility for grouting, which should be completed before loading the structure.

## 4.18 Quality assurance

- The design engineer, who needs to sign off the design as having been built to requirements, cannot watch every aspect of the fabrication and erection but can:
  - insist on a Quality Control Plan (QCP) drawn up and signed off by the contractor(s) covering each and every aspect of the manufacturing and erection process as called up on the structural engineer's drawings and required by the various codes and specifications;
  - call up any hold points for inspection e.g. groove preparation and fit up for full penetration welds; and
  - expect a signed off data file covering reports, material certificates and signed off Quality Control Plan.

## 4.19 Economics

- Lightest is not necessarily cheapest.  
Minimum weight is not always the most economical because of the high labour input. It is necessary to do preliminary designs and pricing to cost compare solid web solutions with latticed solutions.  
Keep it simple - a heavier member may be cheaper than a lighter built up member.
- Don't over specify any of the following:
  - welding-check distortion effect;
  - weld inspection - call for sufficient non-destructive testing (NDT) to get confidence in the welding team; and
  - number of bolts.
- Paint specification, inspection and record keeping
- Do not shape gussets unless there is an architectural reason.
- Rectangular gussets do the job just fine - it costs money to shape those bits

## 4.20 Passive fire protection

- Check requirement rating where needed, can be expensive.

- Consider the various alternative forms of passive fire protection including extra reinforcing in the slab resulting in a catenary action and no fire protection to some of the secondary beams.
- The Yellow Book on the Fire Protection Association' web site [www.asfp.org.uk](http://www.asfp.org.uk) .

## 4.21 Reference standards for design, materials and construction

### 4.21.1 Design standards

- SANS 10094:2005, *The use of high-strength friction-grip bolts.*
- SANS10162.-1:2011, *The structural use of steel Part 1: Limit-states design of hot-rolled steelwork*
- SANS 10162-2:2011, *The structural use of steel Part 2: Cold-formed steel structures*
- SANS 10162-4:1997, *Structural use of steel Part 4: The design of cold-formed stainless steel structural members*
- SANS 10208-1:2008, *Design of structures for the mining industry Part 1: Headgear structures*
- SANS 10208-2:2011, *Design of structures for the mining industry Part 2: Sinking stages*
- SANS 10208-3:2012, *Design of structures for the mining industry Part 3: Conveyances*
- SANS 10208-4:2011, *Design of structures for the mining industry Part 4: Shaft system structures*
- SANS 10237:1991, *Roof and side cladding Roof and side cladding*
- EN1993-1-1:2005, *Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings*
- EN 1993-1-2:2005, *Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design*
- EN1993-1-3:2006, *Eurocode 3 - Design of steel structures - Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting*
- EN 1993-1-4:2006, *Eurocode 3 - Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels*
- EN 1993-1-5:2006, *Eurocode 3 - Design of steel structures - Part 1-5: Plated structural elements*
- EN 1993-1-6:2007, *Eurocode 3 - Design of steel structures - Part 1-6: Strength and Stability of Shell Structures*
- EN 1993-1-7:2007, *Eurocode 3 - Design of steel structures - Part 1-7: Plated structures subject to out of plane loading*
- EN 1993-1-8:2005, *Eurocode 3: Design of steel structures - Part 1-8: Design of joints*
- EN 1993-1-9:2005, *Eurocode 3: Design of steel structures - Part 1-9: Fatigue*
- EN 1993-1-10:2009, *Eurocode 3: Design of steel structures - Part 1-10: Material toughness and through-thickness properties*
- EN 1993-1-11, 2006, *Eurocode 3 - Design of steel structures - Part 1-11: Design of structures with tension components.*
- EN 1993-1-12, *Eurocode 3 - Design of steel structures - Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S 700*
- EN 1993-2:2006, *Eurocode 3 - Design of steel structures - Part 2: Steel Bridges*
- EN 1993-3-1:2006, *Eurocode 3 - Design of steel structures - Part 3-1: Towers, masts and chimneys - Towers and masts*
- EN 1993-3-2:2006, *Eurocode 3 - Design of steel structures - Part 3-2: Towers, masts and chimneys – Chimneys*

- EN 1993-4-1:2007, *Eurocode 3 - Design of steel structures - Part 4-1: Silos*
- EN 1993-4-2:2007, *Eurocode 3 - Design of steel structures - Part 4-2: Tanks*
- EN 1993-4-3:2007, *Eurocode 3 - Design of steel structures - Part 4-3: Pipelines*
- EN1993-5:2007, *Eurocode 3 - Design of steel structures - Part 5: Piling*
- EN1993-6: 2007, *Eurocode 3 - Design of steel structures - Part 6: Crane supporting structures*
- EN1994-1-1:2004, *Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings*
- EN 1994-1-2:2005, *Eurocode 4 - Design of composite steel and concrete structures - Part 1-2: General rules - Structural fire design*
- BS2853: 2011, *Specification for the testing of steel overhead runway beams for hoist blocks*
- BS 5950: Part 1-9 (withdrawn), *Structural use of steelwork in building*
- AS 1538 – 1988, *The use of cold-formed steel in structures*
- AS 4100: 1998, *Steel structures*
- AWS DI.1 10:2015, *Structural welding code - steel*
- CSA S16.9:2014, *Design of steel structures*

#### **4.21.2 Material standards**

- SANS 50025-1:2009 / EN 10025-1:2004, *Hot rolled products of structural steels Part 1: General technical delivery conditions*
- SANS 50025-2:2009 / EN 10025-2:2004, *Hot rolled products of structural steels Part 2: Technical delivery conditions for non-alloy structural steels*
- SANS 50025-3:2009 / EN 10025-3:2004, *Hot rolled products of structural steels Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels*
- SANS 50025-4:2009 / EN 10025-4:2004, *Hot rolled products of structural steels Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels*
- SANS 50025-5:2009 / EN 10025-5:2004, *Hot rolled products of structural steels Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance*
- SANS 50025-6:2009 / EN 10025-6:2004, *Hot rolled products of structural steels Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition*
- ISO 898-1:2013, *Mechanical properties of fasteners made of carbon steel and alloy steel - Part 1: Bolts, screws and studs with specified property classes - Coarse thread and fine pitch thread*
- ISO 898-2: 2012, *Mechanical properties of fasteners made of carbon steel and alloy steel - Part 2: Nuts with specified property classes - Coarse thread and fine pitch thread*
- ISO 4014:2011, *Hexagon head bolts - Product grades A and B*
- ISO 4016:2011, *Hexagon head bolts - Product grade C*
- ISO 4017:2014, *Fasteners - Hexagon head screws - Product grades A and B*
- ISO 4018:2011, *Hexagon head screws - Product grade C*
- ISO 4032:2012, *Hexagon regular nuts (style 1) - Product grades A and B*
- ISO 4034:2012, *Hexagon regular nuts (style 1) - Product grade C*
- ISO 7091:2000, *Plain washers - Normal series - Product grade C*
- ISO 14399 (9 parts), *High strength bolting for preloading*
- BS 4360 – 1990 (withdrawn), *Weldable structural steels*

### 4.21.3 Construction standards

- SANS 1921-3: 2004, *Construction and management requirements for works contracts Part 3: Structural steelwork*
- SANS 2001 -CS1:2012, *Construction works Part CS1: Structural steelwork*
- AWS DI.1 10:2015, *Structural welding code – steel*
- EN 1090-2:2008, *Execution of steel structures and aluminium structures - Part 2: Technical requirements for steel structures*

### 4.22 Useful publications

- American Institute of Steel Construction, *Steel Construction Manual*, 14th Ed.
- Blodgett, O.W. *Design of Welded Structures*, Lincoln Arc Welding Foundation, July 1966
- Canadian Institute of Steel Construction, *Handbook of Steel Construction – 10th Edition*
- Davison, B and Owens, G (editor). *Steel Designers' Manual*, 7th Edition. SCI (Steel Construction Institute), Wiley-Blackwell, 2012
- Gilmor, M.I, Kulak, G and Adams, P.F. *Limit States Design in Structural Steel* Hardcover, Canadian Institute of Construction, 6<sup>th</sup> Edition, 1998
- Mahachi, J. *Design of Structural Steelwork to SANS 10162*, Third edition, Xsi-tek, 2013
- Parrot G, *Structural Steel Design to SANS 10162-1*, 2005
- Salmon, CG, Johnson JE and Malhas, FA. *Steel Structures: Design and Behavior*, 5th Edition, Harper & Row, New York, 2008
- Southern African Institute of Steel Construction, *Measuring Quantities for Structural Steelwork*, 2006
- Southern African Institute of Steel Construction , *Southern African Structural Steelwork Detailing Manual (Yellow Book)*, 2008
- Southern African Institute of Steel Construction, *Southern African Steel Construction Handbook - 8th Edition (Red Book)*, 2013
- Southern African Institute of Steel Construction, *Structural Steelwork Connections Limit State Design (Green Book)*, 2013
- Young, W, Budynas, R and Sadegh, A. *Roark's Formulas for Stress and Strain*, 8th Edition
- Timoshenko, S. *The Theory of Plates and Shells (McGraw-Hill Classic Textbook Reissue Series)*
- Zieman, R.D (editor). *Guide to Stability Design Criteria for Metal Structures*, 6th Edition, Wiley, 2010

## **5 UNREINFORCED AND REINFORCED STRUCTURAL MASONRY**

A structural masonry building is unique in that the masonry not only gives the building strength and stability, but provides the envelope that encloses the building. This Check List accordingly provides general principles of design as well as a structural design aide-memoiré.

### **5.1 General principles that govern all design stages**

#### **5.1.1 Overall stability**

- Consider compatibility of design and details of parts and components – one designer responsible for overall design and stability.

#### **5.1.2 Robustness**

- All members of the structure should be effectively tied together in the longitudinal, transverse and vertical directions. This involves the layout of the structure on plan, the interaction of the masonry elements and their interaction with other parts of the structure.
- Check details of intersecting of walls, piers and position of control joints that they do not affect lateral stability. When bed joints are to be raked out for pointing, the designer should allow for the resulting loss of strength.
- Check damp proof course on possible reduction of bending and shear strengths of the masonry. Check that the provision of services (in particular horizontal chasing) and fittings does not impair the performance of the wall.

#### **5.1.3 Accidental forces**

- Consider the effect of misuse, an accident or a particular hazard and ensure that there is an acceptable probability of the structure remaining after the event, even if in a damaged condition. Where there is a possibility of vehicles running into and damaging or removing vital load-bearing masonry members of the structure in the ground floor, the provision of bollards, walls, etc. should be considered.
- Buildings of five storeys and above to be designed for a notional horizontal load of 1,5% its weight if this is greater than the wind loading.
- Check whether special precautions or temporary propping is necessary during construction to ensure overall stability of the structure or of individual elements.

#### **5.1.4 Accommodation of movement in masonry**

- Provide control joints (vertical) to minimise the effects of movements caused by, for example changes in temperature, changes in moisture content, absorption of water vapour, chemical action, deflection under load and ground movement and differential settlement.
- Avoid using dissimilar masonry material indiscriminately in the same wall.
- Locate control joints in unreinforced masonry where concentrations or changes in stress occur i.e. at openings, major changes in wall height, changes in wall thickness, in foundations, floors and roofs, and near wall intersections and near return angles in L, T and U shaped structures.



- Locate control joints in reinforced masonry at changes in wall thickness, major changes in wall in foundations, floors and roofs, and wall openings.
- Avoid locating control joints at the extreme corner of external wall returns.

### **5.1.5 Accommodation of movement in adjoining structural members:**

#### **5.1.5.1 Non load-bearing walls supported by structural members**

- Consider reinforcing lower bed joints and increasing the floor slab thickness where walls are supported on a relatively flexible floor or wall.
- Avoid spans exceeding 7m and consider slip planes under bearings.
- Provide control joints (horizontal) in framed structures where masonry walls are infill panels, that are located at every storey height, and in outer leaf of cavity wall every third storey or 9m whichever is the lesser.

#### **5.1.5.2 Load-bearing walls**

- Suspended reinforced concrete floor and roof slabs can cause cracking in supporting masonry elements due to drying shrinkage, creep, moisture and thermal movement, rotation at support, eccentric transference of reactions of slab into walls and vertical lift of slab corners. Detail to allow for these movements – avoid long spans and use slip joints at wall bearing.

### **5.1.6 Exclusion of moisture**

- Resistance to wind driven rain penetration involves:
  - design, specification, detailing and workmanship, significant design factors being cross-section of wall (cavity walls best);
  - joint profile (recessed joints worst);
  - applied external surface finishes (rendering best);
  - protection or exposure of wall (particularly top of wall); and
  - provision of weep holes and damp proof courses.
- Retaining walls and basement walls where exclusion of water is important, attention is to be given to vertical waterproofing and subsoil drainage.
- Rendered and coated foundation walls need to be water proofed vertically where abutting soil.

### **5.1.7 Durability**

- Durability is primarily related to specification of adequate materials (masonry units, mortar, mortar ingredients, reinforcement, wall ties and joint sealants) and the protection of steel reinforcement, metal wire ties, fixing, accessories etc., from corrosion with satisfactory workmanship and adequate cover. (Particularly important in coastal regions).
- Consideration needs to be given to vertical waterproofing of foundation walls where soil abuts the masonry even when high strength, low water absorption masonry units are used.

### **5.1.8 Fire resistance**

- Masonry walls should be designed to have a fire resistance that is stated in SANS 10400-T, *The application of the National Building Regulations Part T: Fire protection*.

## 5.2 Initial design

- In the initial stages of design of buildings, it is necessary, often at short notice, to produce alternative schemes that can be assessed for architectural and functional suitability and which can be compared for cost. They will usually be based on vague and limited information on matters affecting the structure such as imposed loads, load-bearing wall positions, external appearance and nature of finishes, but it is nevertheless expected that viable schemes be produced on which reliable cost estimates can be based. Accordingly, initial design methods need to be simple, quick, conservative and reliable.
- Sizing of structural masonry walls should be based on the greatest height of wall, with the largest slenderness ratio supporting the longest slab span with the greatest eccentric loading on the wall. Consider un-reinforced and reinforced masonry walls.
- Reference should be made to this Check List for concrete slab and beam thicknesses and steel and timber roof trusses for determining dead loads. Loads should be carried to the foundations by the shortest and most direct routes. Allow in loading for special finishes to masonry walls.
- Standard construction details should be used which may subsequently be modified. Masonry units of dimensions, surface appearance etc., that are in day to day production should be considered in estimates, with a possible extra over cost for masonry units that might have to be specially made or sourced elsewhere.
- The position of structural walls significantly affects costs and the client needs to be aware that these walls are permanent – an imposition of rigidity and limitation for possible subsequent changes.

## 5.3 Structural design

### 5.3.1 *Materials*

#### 5.3.1.1 **Masonry units**

- Fired clay, calcium silicate or concrete.
- Hollow or solid.
- Dimensions and modular layout to minimise cutting of units; this may require purpose made window and door frames.
- Compressive strength.
- Architectural features - texture, colour, profile, aspect ratio and dimensions.
- Specific units - lintel, U blocks, sills, copings, brick slips, corners, closure units, texture and colour, etc.
- Drying shrinkage and expansion on rewetting limits - concrete units.
- Moisture absorption and expansion and initial rate of absorption - fired clay units.
- Obtain samples before commencing design - check continuity of supply over duration of construction. Check if sample panels are to be constructed to check on visual appearance and any special structural requirements of viz. placing of infill concrete around reinforcement etc.

#### **5.3.1.2 Mortar**

- Availability of satisfactory sands for site mixing, or availability of ready mixed mortar (are retarded mortars acceptable?) - mortar mixes - use of masonry cement, lime and mortar.
- Plasticisers.
- Is mortar to be coloured – use of pigments?

#### **5.1.3.3 Cement**

- Common cements, Portland cement extenders, or masonry cement and effect on flexural strength;

#### **5.1.3.4 Reinforcement**

- Mild, high tensile, galvanised or stainless steel.
- Bedding joint reinforcement in rolls or flat strips.
- Wall ties - metal, mild steel, galvanised, stainless steel, copper, copper-zinc alloy or plastic.

#### **5.1.3.5 Masonry accessories**

- Availability and type of brackets, shelf angles, special reinforcement, etc.

#### **5.1.3.6 Infill concrete and grout**

- Size of aggregate.

### **5.3.2 *Design codes of practice***

#### **5.3.2.1 Empirical design**

- SANS 10400-K:2015, *The application of the National Building Regulations Part K: Walls*
- Joint Structural Division of the South African Institution of Civil Engineering and Institution of Structural Engineers, Code of Practice for Foundations and Superstructures for Single Storey Residential Buildings of Masonry Construction, 1995.

#### **5.3.2.2 Engineering design**

- SANS 10164-1:1980, *The structural use of masonry Part 1: Unreinforced masonry walling*
- SANS 10164-2:2008, *The structural use of masonry Part 2: Structural design and requirements for reinforced and prestressed masonry*

#### **5.3.2.3 Overall design**

- SANS 10249:2012, *Masonry walling*

### 5.3.3 **Design sequence**

- Decide whether design based on cracked section (dpc present) or flexural design.
- Calculate characteristic loads and applied load factors.
- Estimate wall thickness or pier size.
- Calculate design strength required.
- Amend wall thickness if necessary and determine required brick/block and mortar strength.

### 5.3.4 **Ultimate limit state**

- Design strength  $\geq$  design load.
- Design load = characteristic load x (Partial Safety Factor Loads).
- Design strength = characteristic strength / (Partial Safety Factor Materials).

### 5.3.5 **Serviceability limit states (reinforced masonry only)**

- Deflection: cantilevers span/125  
general span/250  
partitions and finishes lessor of span/500 or 20 mm
- Cracking: not affecting appearance or durability
- Use serviceability load factors as in SANS 10160-1:2010, *Basis of structural design and actions for buildings and industrial structures Part 1: Basis of structural design.*

### 5.3.6 **Calculate and determine**

#### 5.3.6.1 **Unreinforced masonry**

- Design loads.
- Characteristic compressive strength.
- Characteristic flexural strength.
- Characteristic shear strength.
- Partial safety factor for materials,  $X_m$ .
- Detailed design considerations.
- Slenderness ratio.
- Lateral supports.
- Special types of walls /cavity walls / faced walls / veneered walls.
- Small plan areas.
- Double leaf walls. Cross-bonding or use of collar-jointed double leaf wall with crimp ties.
- Eccentricity of concentrated loads – if cavity, check load on inner or both leaves.
- Analysis of section.
- Walls subjected to lateral load.
- Testing if required.

#### 5.3.6.2 **Reinforced masonry**

- Limit states design.
- Serviceability limit state.

- Loads and strength of materials.
- Design loads.
- Characteristic compressive strength.
- Characteristic shear strength of reinforcing steel.
- Characteristic anchorage bond strength.
- Elastic moduli.
- Analysis of section.
- Partial safety factors for materials.
- Construction control.
- Serviceability limit state.
- Ultimate limit state.
- Detailed design considerations.
- Subject to bending.
- Effective span of elements.
- Limiting dimensions.
- Resistance moments of elements.
- Shear resistance of elements.
- Combination of vertical loading and bending.
- Slenderness ratios of walls and columns.
- Design check for deflection and cracking.
- Axial compressive loading.
- Horizontal forces in the plane of the element.
- Racking shear.
- Bending.
- Detail reinforced masonry.
- Reinforcement area, maximum size, spacing etc.

## 5.4 Drawings

In checking drawings examine from foundations upwards (vertical check) and from left to right (horizontal check). Consider the following details:

### 5.4.1 *Vertical check*

- Foundations.
- Waterproofing below concrete slab on ground, dpc – gap between slab and wall.
- Waterproofing if basement involved.
- Position of weep holes.
- Wall ties – intersecting walls, collar-jointed double leaf walls, and in cavity walls.
- Sills.
- Fixing of door and window frames – if special.
- Lintels and bearing length at supports.
- Bond beams.
- Position of horizontal reinforcement – cover.
- Fixing of concrete floors and roofs to wall.
- Fixing timber/steel roof trusses – anchorage of trusses.
- Position of services.
- Control joints – horizontal – infill panel.
- Control joints – horizontal – outer leaf cavity wall above 3 storeys.

#### **5.4.2 Horizontal check**

- Position of openings – vertical reinforcement in adjoining masonry.
- Position of weep holes.
- Lateral supports – intersecting walls – masonry bond or steel tie bonding.
- Cavities wall ties.
- Position of reinforcement in cores or cavities.
- Cover to reinforcement.
- Position of bedding joint reinforcement.
- Provision of inspection eyes for vertical reinforced cores.
- Position of control joints.
- Type of control joints.
- Position of special lintels and bond beams.
- Position of roof anchorages.
- Position of services.

### **5.5 Reference standards for design, materials and construction**

#### **5.5.1 Design standards**

- SANS 10164-1:1980, *The structural use of masonry Part 1: Unreinforced masonry walling*
- SANS 10164-2:2008, *The structural use of masonry Part 2: Structural design and requirements for reinforced and prestressed masonry*
- SANS 10249:2012, *Masonry walling*
- SANS 10400-H:2012, *The application of the National Building Regulations Part H: Foundations*
- SANS 10400-K:2015, *The application of the National Building Regulations Part K: Walls*
- SANS 10400-M:2011, *The application of the National Building Regulations Part M: Stairways*
- EN 1996-1-1:2005, *Eurocode 6 - Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures*
- EN 1996-1-2:2005, *Eurocode 6 - Design of masonry structures - Part 1-2: General rules - Structural fire design*
- EB 1996-2:2006, *Eurocode 6 - Design of masonry structures - Part 2: Design considerations, selection of materials and execution of masonry*
- EN 1996-3:2006, *Eurocode 6 - Design of masonry structures - Part 3: Simplified calculation methods for unreinforced masonry structures*

#### **5.5.2 Material standards**

- SANS 28:2010, *Metal ties for cavity walls*
- SANS 190-2:2008, *Expanded metal Part 2: Building products*
- SANS 227:2007, *Burnt clay masonry units*
- SANS 248:2007, *Bituminous damp-proof courses*
- SANS 285:2010, *Calcium silicate masonry units*
- SANS 298:2007, *Mastic asphalt for damp-proof courses and tanking*
- SANS 523:2009, *Limes for use in building*

- SANS 952-1:2011, *Polymer film for damp-proofing and waterproofing in buildings Part 1: Monofilament and co-extruded products*
- SANS 1090:2009, *Aggregates from natural sources - Fine aggregates for plaster and mortar*
- SANS 1215:2008, *Concrete masonry units*
- SANS 1504:2015, *Prestressed concrete lintels*
- SANS 10073:1974, *The safe application of masonry-type facings to buildings*. (Refer to SANS 10400-K (Latest version))
- SANS 50197-1:2013 / EN 197-1:2011, *Cement Part 1: Composition, specifications and conformity criteria for common cements*
- SANS 50413-1:2014 / EN 413-1:2011, *Masonry cement Part 1: Composition, specifications and conformity criteria*
- SANS 50934-3:2012 / EN 934-3:2009, *Admixtures for concrete, mortar and grout Part 3: Admixtures for masonry mortar - Definitions, requirements, conformity and marking and labelling*
- EN 12878:2014, *Pigments for the colouring of building materials based on cement and/or lime - Specifications and methods of test*.

### **5.5.3 Construction standards**

- SANS 1504:2015, *Prestressed concrete lintels*
- SANS 2001-CC2:2007, *Construction works Part CC2: Concrete works (minor works)*
- SANS 2001-CM1:2012, *Construction works Part CM1: Masonry walling*
- SANS 2001-CM2:2011, *Construction works Part CM2: Strip footings, pad footings and slab-on-the-ground foundations for masonry walling*
- SANS 2001-EM1:2007, *Construction works Part EM1: Cement plaster*
- SANS 10145:2013, *Concrete masonry construction*
- SANS 10249:2009 *Masonry walling*
- BS 8215:2013, *Design and Installation of Damp-Proof Courses in Masonry Construction*

## **5.6 Useful publications**

- Concrete Manufacturer's Association, *Concrete Masonry Manual*, Ninth edition, 2011
- Concrete Manufacturer's Association, *Detailing of Concrete Masonry Volume 2 – hollow units 140/190*, fifth edition, 2011
- Concrete Manufacturer's Association, *Detailing of Concrete Masonry Volume 3 – cavity walls 240 to 290*, third edition 2005
- Curtin, W.G, Shaw, G, Beck, J.K and Bray, W.A and Easterbrok, D. *A Structural Masonry Designers' Manual 3rd Edition*, Blackwell Publishing, 2006
- Lane, J.W., Watermeyer, R.B. and De Villiers, P.D. *Masonry materials and design for movement*, SAICE lecture course, Structural Division, Johannesburg, South Africa, 1991.
- Roberts, J.J. *Concrete Masonry Designer's Handbook*, Eyre & Spottiswoode, 1983
- Watermeyer RB, Crofts FS, Lane JW. *The structural use of masonry: SABS 0164 - Parts 1 & 2*. SAICE lecture course, Structural Division, Johannesburg August 1992.
- Watermeyer RB. *Free-standing walls - a design guide*. CMA, Randburg, 1993.

## 6 STRUCTURAL TIMBER DESIGN

### 6.1 Introduction

- There are two applicable design standards:
  - SANS 10163-1:2003, *The structural use of timber Part 1: Limit-states design; and*
  - SANS 10163-2:2001, *The structural use of timber Part 2: Allowable stress design.*

Each one employs a different design philosophy with regards to stress modification factors although based on similar characteristic stress values. Therefore choose a standard and stay with it, or undertake two comparative designs!

- Take particular care when choosing material factors, since they make a significant difference to the resistance stress values and deflection evaluation.
- Note that long term deflection often dictates the appropriate beam size for serviceability requirements.
- Undertake careful research when using timber types not covered in the codes. The degree of drying prior to loading particularly with high stress level hard-woods, can influence the elastic modulus value used for deflection evaluation.
- The tables in each standard are excellent references for design of members and connections.

### 6.2 Application to roof trusses

#### 6.2.1 Roof trusses – design and drawings

All roof layout drawings need to specify the following items:

- Dead and live loadings for top and bottom chords of trusses including special loads e.g. solar panels, suspended services.
- Dead and live loads for bottom chord of truss including special loads such as geyser, water tanks, extraction equipment, air-conditioning equipment.
- Loading generally – are there any cyclical loads, what is the wind exposure condition; what is the snow exposure condition.
- The dimension position and truss mark of all trusses to be shown with relevant truss spacings.
- The relevant batten or purlin size and spacing.
- Bracing details to provide lateral stability to bottom chord – where applicable.
- Bracing details to provide lateral stability to top chord.
- Bracing details to provide lateral stability to internal web members.
- Number of ply of multiple ply girders and method to connect them together.
- Position and type of proprietary truss hangers with statement of tested load capacity.
- Position of special cleats/brackets and manufacturing details/fixing details of such brackets.

#### 6.2.2 Design considerations

- Method of analysis.
- Deflection limits and consequences.
- Support positions.



- Tension perpendicular to the grain.
- Torsion control (girder to girder connections).
- Combined bending and axial stress.
- Bi-axial bending.  
Splices in members are designed so that they can occur anywhere in the chord or if necessary, identify specific positions and plate sizes (only when necessary).
- No splicing of webs, ever.

### **6.2.3 Truss quality**

- Specified sizes and grades of all members.
- Type of treatment (if necessary) against biological attack.
- Sizes and accurate positioning of all connector plates.
- Quality of assembled joint (tight fitting joints between members i.e. to SANS 10243 specifications).

### **6.2.4 Site inspection/assessment of completed structure**

- Holding down details – roof fixing to batten/purlin; purlin to top chord; truss to wall plate; wall plate to super structure.
- Trusses erected straight/within straightness tolerance.
- Trusses erected plumb/within plumbness tolerance.
- Truss spacings comply with (3% tolerance).
- Battens/purlins as per size shown on drawing.
- Battens/purlins at design spacing.
- Top chord bracing fully installed.
- Bottom chord bracing fully installed.
- All bracings required on web members installed including T bracing where necessary.
- Splices to battens/purlins staggered on trusses (no more than 1 in 3 on same truss).
- Battens/purlins fully connected to top chords-especially to each ply of a multiple ply girder.
- All proprietary cleats and truss hangers fixed in position.
- All special brackets fully fixed in position.
- Trusses provided with additional supports which have not been designed for.
- Multiple member girders connected together properly.
- Any trusses cut to allow passage of services etc.
- Any additional members fixed locally per design requirements.
- The erected roof at the design pitch.
- Piggy back/top hat trusses properly connected to the base truss.
- All girder/top chords properly restrained.
- Top chords of truncated trusses properly restrained (in accordance with details provided).
- Additional battens/purlins fixed to the underside of top chords provided where supporting a valley configuration.
- The valley side of a hip-valley girder is properly braced.
- All connections and Nail Plates are as per design size or greater.
- Fire protection requirements complied with (300m<sup>2</sup> on plan between fire breaks).
- The influence of a rational design supported on a “deemed to satisfy” structure should be considered.

- Any trusses that seem to have had unsanctioned modifications.
- All proprietary connectors should have tested structural values available.

## **6.3 Reference standards for design, materials and construction**

### **6.3.1 Design standards**

- SANS 10082:2007, *Timber frame buildings*
- SANS 10163-1:2003, *The structural use of timber Part 1: Limit-states design*
- SANS 10163-2:2001, *The structural use of timber Part 1: Limit-states design*
- SANS 10400-J:2010, *The application of the National Building Regulations Part J: Floors*
- SANS 10400-K:2015, *The application of the National Building Regulations Part K: Walls*
- SANS 10400-L:2011, *The application of the National Building Regulations Part L: Roofs*
- SANS 10407:2015, *Thatched roof construction*

### **6.3.2 Material standards**

- SANS 457-2:2008, *Wooden poles, droppers, guardrail posts and spacer blocks Part 2: Softwood species*
- SANS 457-3:2013, *Wooden poles, droppers, guardrail posts and spacer blocks Part 3: Hardwood species*
- SANS 753:2009, *Pine poles, telephone systems and street lighting*
- SANS 754:2015, *Eucalyptus poles*
- SANS 1460:2015, *Laminated timber (glulam)*
- SANS 1783-1:2013, *Sawn softwood timber Part 1: General requirements*
- SANS 1783-2:2013, *Sawn softwood timber Part 2: Stress-graded structural timber and timber for frame wall construction*
- SANS 1783-4:2012, *Sawn softwood timber Part 4: Brandering and battens*

### **6.3.3 Construction standards**

- SANS10243:2004, *The design manufacture and erection of timber*
- SANS 2001-CT1:2011, *Construction works Part CT1: Structural timberwork (flooring)*
- SANS 2001-CT2:2011, *Construction works Part CT2: Structural timberwork (roofing)*

## **6.4 Useful publications**

- Institute for Timber Construction, Volume 1 and Volume 2 Handbooks : Erection and bracing of timber roofs

