Compilation of a South African National Standard for the design of Liquid Retaining Structures

Volume I: Compilation of SANS 10100-3

Report to the
WATER RESEARCH COMMISSION

by

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This report forms part of a series of two reports. The other report is *Compilation of a South African National Standard for the design of Liquid Retaining Structures. Volume II: Background to SANS 10100-3* (WRC Report No. 2154/2/15)

EXECUTIVE SUMMARY

WRC project K5/2154/1 had as it main aim the development of the SANS 10100-3 (Draft) Standard into an official SABS TC Draft Standard, ready for public comment and subsequent publication through normal SABS procedures as a National Standard. This was important, because the *de facto* local standard for design of liquid retaining structures, BS 8007, was withdrawn due to the introduction of the Eurocode Standards in the UK.

To achieve this aim, a new SABS Working Group (WG) was formed under SABS TC 98-02 *Design of Concrete Structures.* Suitable WG candidates, providing full representation of experts in design, construction and maintenance of concrete liquid retaining structures, were recruited through a nation-wide series of seminars which highlighted the proposed work. This WG had to critically review the SANS 10100-3 (Draft) originating from previous WRC project K5/1764 and make final decisions on outstanding issues in order to produce a final WG Draft Standard for approval by SABS TC 98-02.

Efficient progress by the WG from day one was facilitated by the availability of SANS 10100-3 (Draft) from the previous WRC project and two input documents produced by the project team, namely the Guideline for the SANS 10100-3 WG (ISI, 2012), highlighting important outstanding issues from SANS 10100-3 (Draft) that needed to be addressed, and the Background to SANS 10100-3 (Barnardo-Viljoen et al., 2014) which highlighted the main references and the way in which they were considered in deriving the provisions of SANS 10100-3 (Draft).

Important to the success of the project in terms of a speedy completion by the WG of SANS 10100-3 (WG Draft) was the administrative- and technical capacity made available through the financial support of the WRC. This allowed compiling all member contributions into the central document and harmonising contributions through liaison with contributors.

The Background to SANS 10100-3 was appropriately updated to reflect the updates and decisions made by the WG in their development of the WG Draft.

Two dissemination seminars presented in August 2013 in Midrand and Stellenbosch were well attended by practitioners and by WG members, totalling 148 attendees. The seminars were presented by UK expert Mr. Robin Atkinson and provided working group members and attendees from general consulting practice with an appreciation of the differences between the old BS 8007 standard and the new EN 1992-3 standard for the design of concrete liquid retaining structures.

The project contributed significantly to capacity building through the involvement of thirteen students, four academics and numerous industry participants. In this regard financial support was aimed at facilitating student training and research and mobility of academics to participate in WG activities.

Finally, SANS 10100-3 (WG Draft) was accepted by TC 98-02 on 18 September 2014. SABS will now drive the process of typesetting the document and circulating it for public comment.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the WRC for funding Project K5/2154/1, which contributed significantly towards the development of useful design documentation that will serve the South African Civil Engineering community well in years to come.

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Dr A Bester, Hatch Goba
Mr A Chemaly, Aurecon
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Mr E Lillie, Knight Piesold
Mr S Naidu, Naidu Consulting
Mr AJ Smith, Joint Structural Division
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Mr H van Dalsen, Aurecon

The WRC project coordinator, Mr Wandile Nomquphu, and his team are much appreciated for their administrative assistance and for his professional advice and constructive discussions throughout the duration of the project.

Finally, the members of the SANS 10100-3 Working Group, listed in Chapter 3.4 of this report, deserves special gratitude, not only from the authors, but from the entire South African Civil Engineering Community, for their valuable contributions towards the creation of SANS 10100-3: *Design of concrete liquid retaining structures.*

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LIST OF ABBREVIATIONS

BS	British Standard
CD	Committee Draft
EN	European Norms
LRS	Liquid Retaining Structures
NWIP	New Work Item Proposal
SA	South Africa
SABS	South African Bureau of Standards
SANS	South African National Standard
TC	Technical Committee
UK	United Kingdom
WG	Working Group
WRC	Water Research Commission
SANS 10100-3 (Draft)	Draft standard for the design of concrete liquid retaining structures, originating from WRC project K5/1764. It is an adapted version of EN 1992-3 (2006) incorporating some information and clauses from BS 8007.
SANS 10100-3 (TC Draft)	Draft standard accepted as SABS Technical Committee Draft by SABS TC98-02 through an official review and voting process. This document is ready for typesetting and distribution for public comment.
SANS 10100-3 (WG Draft)	Draft standard produced by the SANS 10100-3 Working Group.

1 INTRODUCTION AND OBJECTIVES

1.1 Introduction

WRC Project K5/2154/1 is intended to further the development of a South African National Standard for the design of Liquid Retaining Structures (SANS 10100-3), as well as appropriate calibration and harmonisation with related codes, the SANS 10160 *The general procedure and loadings to be adopted in buildings* and the SANS 10100-1 *The structural use of concrete: Design*.

The importance of the class of liquid retaining structures provides sufficient motivation for the development of the proposed standard. A stronger motivation derives from the withdrawal of BS 8007 due to the introduction of the Eurocode Standards in the UK: BS 8007 presently serves as the *de facto* local standard, but there is no equivalent Eurocode Standard that could be considered as is for local use.

The creation of a code of practice for liquid retaining structures will form part of a basis from which the quality, durability and maintenance of liquid retaining infrastructure can be managed in South Africa. It will provide local authorities and water authorities a basis from which systems can be set up in a coordinated manner for the management of durable infrastructure. The establishment of such a code of practice will thus provide one of the building blocks that are necessary to develop effective and innovative water infrastructure management systems.

A previous WRC Project K5-1764 focused on making significant steps towards this ultimate output by developing a Draft Standard for the design of liquid retaining structures for South Arica. The SANS 10100-3 (Draft) document originating from WRC project K5/1764 was developed using EN 1992-3 (2006) (Eurocode) as the principle reference document. Clauses in the code were enhanced by extracts from BS 8007 (1985). Exclusions and changes from EN 1993-3 comprised of a reduction in the scope of the document (excluding silos), defining the temperature range of contained liquids to ambient temperatures (as in BS 8007), and using the concrete crack width criteria from BS 8007.

Also integral to the development of SANS 10100-3 (Draft) was the relationship of this standard with other standards. Members of the project team participated in working groups for the revision of SANS 10160 (2010) and SANS 10100-1 (2000). Evaluations on design codes beyond SANS 10100-3 (Draft) alone formed an integral part of the project.

Various remaining issues that required attention were identified, stemming from the background, development and calibration exercises carried out in the K5-1764 project. It is shown in the K5-1764 report that some degree of harmonisation has been achieved between various proposed design models for the different material parameters and South African (SA) data. Nonetheless, there still is much scope for databases to be extended. Some non-technical issues relating to the formatting of the draft code, such as standard format, diagram quality and other issues affecting the general presentation were also identified.

It was necessary to further the development of SANS 10100-3 *Design of Liquid Retaining Concrete Structures* through the formal process of standards development in accordance with the requirements and procedures of the SABS for the various stages of assessment and approval, including participation by various interested organisations and the engineering profession.

To this purpose WRC Project K5/2154/1 was instrumental.

1.2 Objectives

WRC project K5/2154/1 had as its main aim to develop the SANS 10100-3 (Draft) Standard into an official SABS Draft South African Standard, ready for public comment and subsequent publication through normal SABS procedures as a National Standard.

To achieve this aim, a new SABS Working Group (WG) had to be formed under SABS Technical Committee (TC) 98-02 *Design of Concrete Structures*. Formally, this required the submission to- and approval by SABS of a New Work Item Proposal (NWIP). Suitable candidates for the WG had to be recruited, with the aim of achieving full representation of experts in design, construction and maintenance of concrete liquid retaining structures to critically review the existing draft code and make final decisions on outstanding issues in order to put out a fully operational design code for concrete liquid retaining structures (LRS).

Appropriate input documentation could facilitate efficient progress by the WG from day one. As such it was objectives of the project to produce two useful documents, namely a Guideline for the SANS 10100-3 WG (ISI, 2012), highlighting important outstanding issues from the draft code that needs to be addressed by the WG before a fully operational South African standard for liquid retaining structures (SANS 10100-3) can be established, and the Background to SANS 10100-3 (Barnardo-Viljoen et al., 2014) to highlight the main references as well as the way in which they were considered in deriving the provisions of SANS 10100-3 (Draft)

In typical South African standard developments WG members are academics and industry participants who volunteer their time. This was also the case here. In such developments progress are often hampered by a lack of administrative- and technical capacity in compiling all member contributions into the central document and harmonising contributions through liaison with contributors. As such, the WRC project aimed to provide such coordination service to the WG, to avoid unnecessary delays in progress.

An important aim of the project was to submit the final version of SANS 10100-3 (WG Draft) to SABS TC98-02 for approval and to assist the process until the document is officially voted as SANS 10100-3 (TC Draft), ready for type-setting for distribution for public comment.

The Background to SANS 10100-3 should then be appropriately updated to reflect the updates and decisions made by the WG in their development of the provisions of SANS 10100-3 (WG Draft).

Dissemination seminars were planned to inform the civil engineering fraternity of progress and issues related to the project.

Finally, it was an objective of the project to contribute to capacity building by involving students, academics and industry participants. In this regard financial support was aimed at facilitating student training and research and mobility of academics to participate in WG activities.

To summarise, the objectives of WRC Project K5/2154/1 were to

- Create SANS 10100-3 (TC Draft)
  - Register NWIP with SABS
  - Recruit and appoint a suitable WG
  - Prepare input documentation to facilitate efficient WG progress
    - Guideline for the WG
    - Background to SANS 10100-3 (Draft)
  - Organise WG meetings and compile and coordinate member contributions
  - Submit the final version of SANS 10100-3 (WG Draft) to SABS TC98-02 for approval, assisting up to approval
- Update the Background to SANS 10100-3 to reflect WG decisions and references used in the provisions of SANS 10100-3 (WG Draft)
- Organise suitable dissemination seminars
- Contribute to capacity building in various ways

1.3 Timeline for the development

The development of SANS 10100-3 was foreseen to follow the procedure and steps set out in Table 1.1 below, with the target dates indicated. Some of the work had been completed through the previous WRC Project K5/1764. The current WRC Project K5/2154/1 took responsibility for creating the background documentation, liaising with industry to recruit suitable working group members, handling the logistics of WG meetings and disseminating results to the broader engineering community. The WG and SABS Technical Committee 98-02 respectively will be responsible for the development and acceptance of the technical content of the standard, while SABS will drive the type-setting, public comment process and subsequent publication of the standard.

Table 1.1 Timeline for the development of SANS 10100-3

	Activity	Responsibility	Target Date
	1. PRE-STANDARDISATION PHASE		
1.1	Scoping and background research	WRC K5/1764	Completed
1.2	First Working Draft: SANS 10100-3 (Draft) Design of Concrete Liquid Retaining Structures	WRC K5/1764	Completed
	2. PREPARATION & SETTING UP OF WG		
2.1	Guidelines for the Working Group on SA Standard for Liquid Retaining Structures	WRC K5/2154/1	2012/07/06
2.2	Background report – first revision	WRC K5/2154/1	2012/08/31
2.3	Role players and intended working group members – Phase 1	WRC K5/2154/1	2012/08/31
2.4	Submit New Work Item Proposal (NWIP) to SABS SC 98-02 for approval	WRC K5/2154/1	2012/08/31
2.5	Approval of NWIP	SABS TC98-02	Externally determined
2.6	Appointment of Working Group (WG)	SABS TC98-02	Externally determined
	3. ACTIVITIES OF WG		
3.1	Constituting of WG	WG-Part3	2012/09/30
3.2	First WG Draft	WG-Part3	t.b.d.
3.3	Final WG Draft submitted to SC98-02	WG-Part3	2013/10/31
	4. SABS PUBLICATION OF SANS 10100-3		
4.1	Part 3 voted as Sub-Committee Draft (CD)	SABS TC98-02	2014/04/16
4.2	Editing by SABS	SABS	Externally determined
4.3	Approval of draft by TC98-02	SABS TC98-02	Externally determined
4.4	Publication as Draft South African Standard for comments by SABS	SABS	Externally determined
4.5	Response to public comments	SABS TC98-02 / WG	Externally determined
4.6	Approval by SABS & publication as South African Standard	SABS	Externally determined
	5. IMPLEMENTATION		
5.1	Background document 2nd Draft	WRC K5/2154/1	2014/03/30
5.2	Background document – Final	WRC K5/2154/1	2014/04/30
5.3	Dissemination seminars	WRC K5/2154/1	2014/07/30

2 WORKING GROUP GUIDELINES

2.1 Introduction

This chapter captures the most important content from a document that was created to serve as guideline to the SANS 10100-3 Working Group. The document was intended to steer the Working Group to the pertinent and outstanding issues from the draft code that needed to be reviewed before a fully operational South African standard for liquid retaining structures (SANS 10100-3) could be established. It should be noted that not all issues were attended to due outstanding research needs in several cases. This guideline could therefore also serve future working groups in their consideration of future revisions, in addition to the Background to SANS 10100-3.

More detailed information regarding the use of Eurocodes as references to the code drafting process of South African National Standards (SANS), and an elaborate statement of basis of design requirements for liquid retaining structures (LRS), as well as a detailed assessment of material models is given in the main report (K5-1764, 2010) supporting the development and calibration of the draft SANS 10100-3.

The development of a code for LRS cannot be done in isolation, but consistency with other Working Groups on related standards should be considered, such as the parallel on-going revision of the lead standard for concrete design which will be newly referred to as SANS EN 51992-1-1. As a result, some of the requirements for liquid retaining structures will not be reflected in its own separate standard, but warrant consideration for inclusion in related national standards.

2.2 Initial status

A draft version of the SANS 10100 Part 3 – *Design of Concrete Liquid Retaining Structures* (SANS 10100-3, *draft*) was produced as output from a previous Water Research Commission (WRC) research project titled The Development and Calibration of South Africa's National Standard for Liquid Retaining Structures of which the final report, coded and hereafter referred to as K5-1764: Liquid Retaining Structures, was compiled and submitted in June of 2010. The draft SANS 10100-3 code adapted as main reference its Eurocode counterpart for the design of concrete liquid retaining and containment structures EN 1992-3 (EN 1992-3, 2006). Alternative design procedures, apart from those in the Eurocodes, were also considered for inclusion in the code. A detailed appraisal of this process is given in Section 4 below.

The task of critically reviewing the draft document and making final decisions on outstanding issues to put out a fully operational design code for LRS remains, and consequently formed the primary objective of the WG.

Various remaining issues that required attention were identified, stemming from the background, development and calibration exercises carried out in the K5-1764 project. Some non-technical issues relating to the formatting of the draft code, such as diagram quality and other issues affecting the general presentation were also identified. It was shown in the K5-1764 report that some degree of harmonisation has been achieved between various proposed design models for the different material parameters and South African (SA) data. Nonetheless, there still is much scope for databases to be extended and made more comprehensive and representative of local design practice. No local data was traceable in some instances, such as those regarding the heat of hydration of concrete and the influence of binder composition and curing on stiffness development (E-modulus), thus warranting good judgement on what note or clause to include to that effect in the final version of SANS 10100-3.

WRC project K5/2154/1 provided limited research capacity in support of the concrete code to aid in design, construction, testing, operation and maintenance issues for structural concrete that are specific to LRS; a thread in the fabric of the broader scope of concrete structures. This drive or initiative enabled a critical assessment of local and international design models and methods that were, and should be, compared to representative local data where applicable in order to properly cater for local practice. Where no local data exists, or is limited, future research is implicitly stimulated to bridge the gap and aid in the SA context to provide appropriately for such situations in local practice. The WG therefore had the responsibility to critically review all design provisions related to LRS and their applicability in SA, and where necessary, shed light on areas that require further study. This has double benefits, specifically:

- It will improve the quality and content of the code over time to incorporate scientific and technological advancements in structural engineering related to LRS, which also implies improved understanding of local design situations and requirements.
- It also offered the opportunity for capacity building by stimulating current and future research from which participants, particularly students and young researchers, have and can benefit to become esteemed professionals in the local industry.

2.3 Issues for the WG to consider

Ad hoc judgement based procedures implemented in SANS 10100-3 and other related standards should be based on the most credible and comparable data that is internationally available. This is part of the reason that in the K5-1764 report the revision of SANS 10100-3 has been suggested to take place in five year cycles; not only to better characterise local practice after comparison to extensive local data, but also to bridge knowledge gaps by conducting new research into previously unattended areas. The issues for consideration by the working group, following from the K5-1764 report, could be seen to fall under the general classifications given below. However, it should be understood that this working group had to develop the draft version into a standard suitable for publication, so that some aspects to be considered had to be deferred to future revisions, especially where there were need for further research.

1. *Basis of design* – This is concerned with the methods that establish requirements for safety, durability and serviceability of structures, with due regard given to aspects of reliability. The reference level of reliability, $\beta = 3.0$ for SANS and $\beta = 3.8$ for the Eurocodes, is a key issue in deriving design provisions. β is mainly used in reliability calibration studies to derive suitable partial factors for actions or materials and resistances that achieve consistent and acceptable levels of reliability across various design situations. Use of β in calibration allows for reliability differentiation, in terms of adopting various β-levels to reflect various levels of allowable uncertainty based on principles of risk. For LRS, outstanding basis of design issues include proper calibration of cracking models in the current local design code for concrete structures SANS 10100-1 (SANS 10100-1, 2000) and its European counterpart EN 1992-1-1 (EN 1992-1-1, 2004) to SA requirements as well as the effects of calibrating the ultimate limit state (ULS) and its associated effect on serviceability stress levels. Various other basis of design issues for local consideration as derived from the K5-1764 report are given in Table 2.1 of Section 2.5.

2. *Materials* – An assessment of material property models and their validity for South African materials, production quality, practice, climatic conditions, focusing particularly on liquid retaining structures (LRS) should continue. Cracking, creep, shrinkage, E-modulus, compressive and tensile strength development of concrete and reinforcing steel (both for PC and normal RC), heat of hydration and coefficient of thermal expansivity of concrete, are some of the material properties that should either be newly or continually characterised and calibrated to local data. For the aforementioned aspects, Eurocode methods are compared with, where applicable, either of or any combination of the following:
   a. Test results (local data)
   b. SANS models
   c. BS models
   d. Other internationally recognised models (CEB-FIP, RILEM etc.)

   The outstanding issues pertaining to materials are systematically presented in Table 2.2 of Section 2.5.
   The WG could not attend to all outstanding issues since further research is needed in several cases. The WG was also mandated to identify further research needs and input from such efforts should be used in future revisions of the code.

3. *Detailing* – some locally preferred details were suggested for use in SANS 10100-3, particularly concerning jointing practices as well as the inclusion of water stops. Further, provision is usually made for the seismic load situation through appropriate detailing to achieve sufficient ductility. Research considered in the K5-1764 report suggested that the serviceability limit state governs the design of liquid retaining structures subjected to horizontal seismic excitation. Detailing procedures aimed at providing sufficient ductility in such situations should be scrutinised. Addressing this aspect would constitute a valuable contribution, but is not of such importance that it should withhold or delay publishing of the code.

4. *Construction methods* – The use of precast concrete in the construction of rural liquid retaining structures, due to lack of skilled labour in such areas, should be encouraged. For in-situ casting of concrete, either the labour becomes expensive (too costly) or suffer the risk of shoddy works leading to poor performing structures (in terms of cracking, leakage, storage/retention ability, protection to the environment or stored liquid etc.). Proper design guidelines on how to design and construct using pre-cast elements are therefore essential and should be included in SANS 10100-3. Again, addressing this aspect would constitute a valuable contribution, but is not of such importance that it should withhold or delay publishing of the code.

5. Consideration should be given to producing a design manual, to assist designers on how to apply and benefit from code procedures as well as educate them on the more advanced aspects provided in the code.

6. The WG took cognizance of the parallel development of SANS EN 1992-1-1, particularly the manner in which the clauses are structured and numbered as it affects the same in SANS 10100-3. The content of SANS EN 1992-1-1 was also studied, to ensure correct cross referencing in the final version of SANS 10100-3. This important aspect had to be achieved prior to publication of SANS 10100-3.

7. *Non-technical issues* – The style and format of the new code had to be decided upon: It was decided to use a style similar to EN1992-3, to be consistent with the new SANS EN1992-1-1. Acceptable print quality of the final SANS 10100-3 (diagrams, text, clarity, conciseness, neatness) needs to be ensured.

8. *Research* – The WG was mandated to identify areas within structural concrete specific to LRS that require further study and proper characterisation for SA practice. Some suggested topics for further research were made in the K5-1764 report following some of the characterisation, calibration exercises, and reviews that were conducted therein.

2.4 Adapt or adopt EN 1992-3?

The vast comparison of design models and methods as highlighted in bullet 2 of Section 2.3 was and is warranted as part of the scope of using the Eurocode as reference. The Eurocodes can be viewed as a general set of reference standards which need to be made operational as national standards through the selection of Nationally Determined Parameters (NDPs) in National Annexes. Investigations conducted at a national level are therefore an essential component of validating suggested Eurocode procedures that may vary at a national level, or adopting the appropriate replacement procedures in the event that a more suitable approach is identified, especially after proven mal-performance of the equivalent Eurocode procedure. In this context, the Eurocodes can either be adopted or adapted as a local standard. The former implies that the Eurocode format, layout and style are exactly followed, save for the difference that the NDPs printed in the national code and national annexes must have been substantiated by appropriate investigation or critical judgement.

The latter implies that the general principles and advancements in the Eurocode basis standard are adopted, but the final national code is not restricted to its procedures, even adopting alternative procedures where appropriate, as well as extending or limiting the scope based on a national assessment. The project team responsible for the development and calibration of SANS 10100-3 (Draft) indicated in the K5-1764 report that South Africa should adapt the Eurocode as reference to the development of SANS 10100-3 by limiting the scope and implementing preferred procedures. Using EN 1992-3 as reference for SANS 10100-3 is also in agreement with the previous use of EN 1990 and relevant EN 1991 parts to revise SANS 10160 as well as the use of EN 1992-1-1 to revise SANS 10100-1. BS 8007 is therefore becoming inconsistent with the new national loading and concrete codes, thereby warranting the inception of SANS 10100-3 that is consistent with current developments in structural concrete practice.

The implementation of a South African standard for LRS has therefore been identified to not only entail a review of its companions (EN 1992-3's) applicability in South Africa, but also a review of current local practice and other internationally recognised design and construction methods. The decision to adapt (as opposed to adoption) the Eurocode was based mainly on two facts:

1. SANS 10100-3's counterpart EN 1992-3 is more comprehensive, including the design procedures for silos and its associated particulate solids as well as provisions for tanks containing liquids. SANS 10100-3 will be limited to concrete tanks designed to retain liquids only.

2. BS 8007, which is currently being used in South Africa for the design of liquid retaining structures due to lack of a local standard, provides guidance to designers on testing of structures, details of joints and other considerations which are not part of the Eurocode (BS EN 1992-3) , but which could be included in the case of adaptation.

Though alternative procedures were and are allowed for use in the development of SANS 10100-3, UK NDPs and references served and should serve predominantly as guides where there is lack of local data. This would be in line with the old tradition of adopting British standards prior to their replacement by equivalent Eurocodes.

Figure 2.1 was provided to give a view of how the future SANS documents, currently under review, were proposed to be organised and related as derived from the K5-1764 report. Figure 2.2 gave a similar breakdown for some of the necessary Eurocode parts.

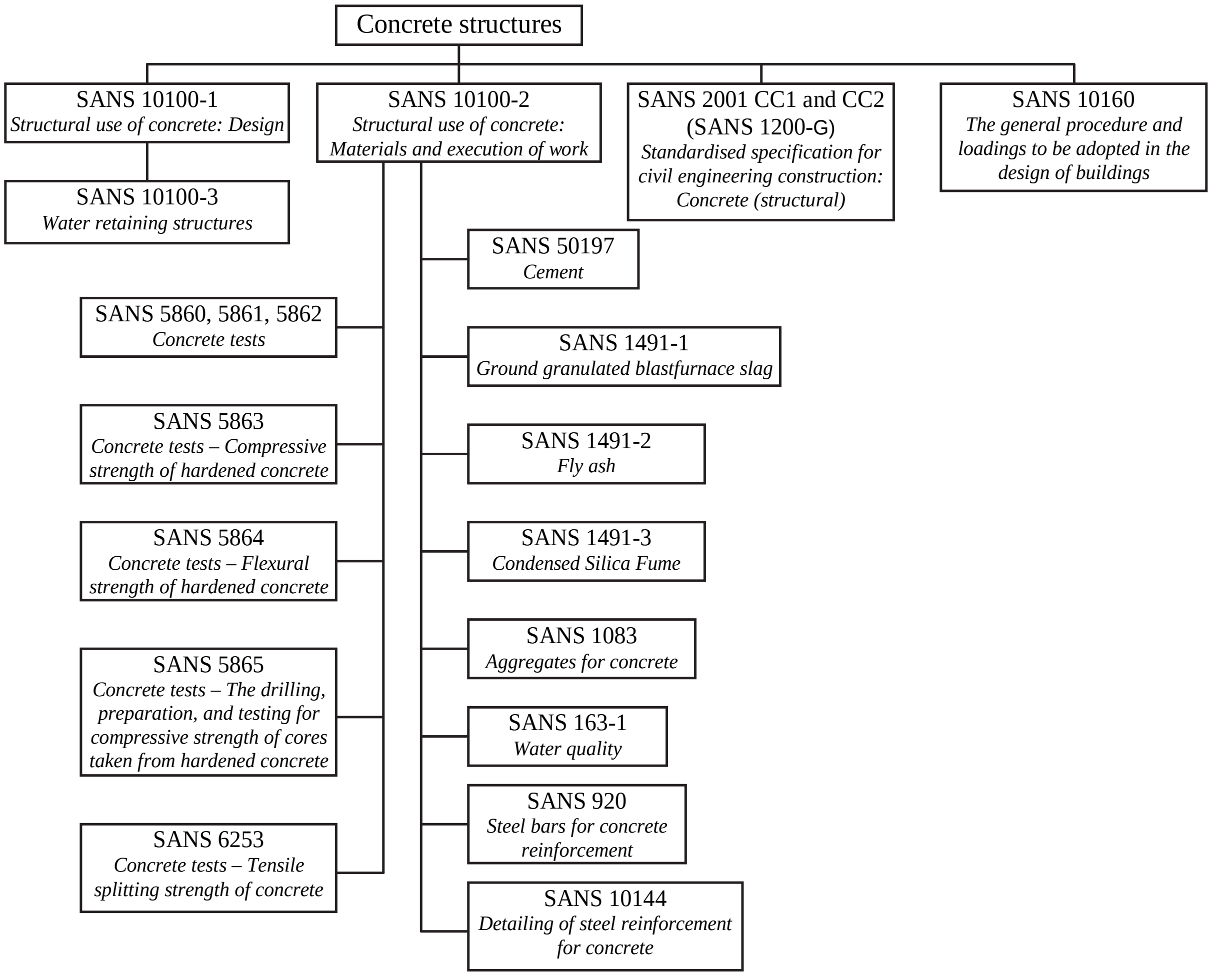

Figure 2.1 Proposed organisational layout for the revised SANS standards (K5-1764 report, 2010)

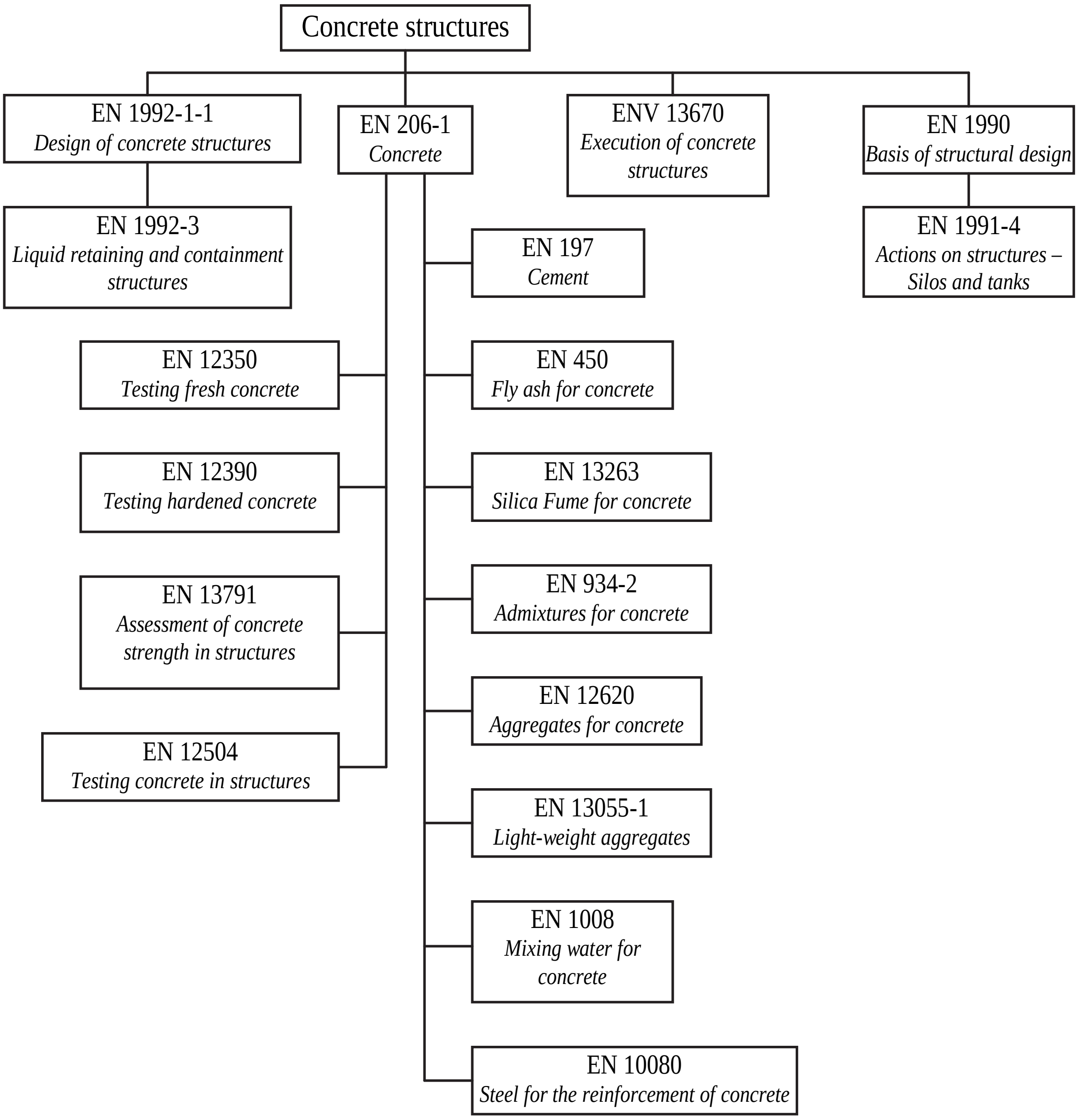

Figure 2.2 Organisational layout of some relevant Eurocode standards (K5-1764 report, 2010)

Other illustrations giving more detailed depictions of how the standards are related, including some British and ISO documents, are given in the K5-1764 report.

2.5 Outstanding issues

In this Section, the general outstanding issues related to the basis of design for the proposed SANS 10100-3 as well as material model characterisation are elaborated upon in Tables 2.1 and 2.2, respectively, with specific outstanding clause by clause issues in Table 2.3, as they stood at the inception of the WG. As a result, the sections following are written in the present tense, as if the development still needs to take place.

General

The following aspects, as derived from the K5-1764 report, need to be addressed for the compilation of a future SA procedure for the design of LRS and should be borne in mind when reviewing Tables 2.1 and 2.2:

- Establish the general principles and procedures on which general basis of design requirements are founded, including the available experience base, technology derived from structural mechanics research or reliability modelling and calibration.
- Scope of the South African standard for LRS: The scope of structures and the contents of procedures relevant to the design of LRS from all the Eurocode parts, with the identification of the parameters that need adjustment.
- Arrangement of these procedures into the South African procedure in a logical format, considering consistency and how it is complemented by the related standards.
- Selection of appropriate qualitative procedures and values for local use, considering local conditions, materials, existing practice and safety standards, through a process of calibration

Although many of these topics have been resolved in principle in SANS 10100-3 (Draft), the proposals therein need to be critically reviewed and outstanding issues need to be resolved as part of the SABS standards development process (K5-1764 report, 2010).

Clause by clause

The previous section presented general basis of design and materials issues that require attention and treatment for LRS in the SA context. Most of the general outstanding issues pertaining to materials warrant inclusion in a national annex in future revisions of SANS 10100-3. This section highlights the clause by clause issues that have been picked up from a detailed review of the design provisions contained in the current draft of SANS 10100-3.

Cracking is central to the performance of LRS, making this a topic that needs to be investigated in some detail, both in terms of the mechanical process and the relevant influencing factors, and in terms of the reliability performance of such structures (K5-1764 report, 2010). At current, the onerous sets of rules given in EN 1992-3 have been omitted for inclusion in the draft version of SANS 10100-3 until such a time that a detailed appraisal of these procedures has been carried out for local South African practice. Stringency or lack thereof in this regard, highly influences or affects the cost of these structures and is thus a critical aspect that should be well defined through proper characterisation and calibration. Identified outstanding clause by clause issues are given in Table 2.3. The code clauses cited in Table 2.3 refer to the relevant design provisions of SANS 10100-3 (Draft) as derived from the K5-1764 report.

Table 2.1 Outstanding basis of design issues for the development of SANS 10100-3

No.	DESCRIPTION	TREATMENT AND SUGGESTED ACTION
1	Selection of appropriate partial factors (and combination factors) for hydraulic loads $\{\gamma_F, \psi\}$	Partial factors given in Annex B of BS EN 1991-4. These values should be validated/calibrated for SA β of 3.0. Adopt UK values?
2	It is assumed that all the other ULS actions (except hydraulic loads) on the structure are treated in accordance with the requirements of SANS 10160	The difference between SANS 10160-1 and EN 1990 and EN 1991 should be scrutinised to ensure that there are no specific situations for LRS that would require adjustment from the SANS 10160 procedures. The working group needs to decide whether to include such provisions in SANS 10100-3 or revise SANS10160.
3	Quasi-permanent action combination: The quasi-permanent combination scheme may provide the appropriate actions for the assessment of cracking	Serviceability loading combinations are given in SANS 10160, Part 1, clause 8.3 and EN 1990 clause 6.5. The SANS procedures differ from EN and must be scrutinised to make adequate provision for cracking for LRS.
4	Reliability for the crack control SLS	Reliability guidelines for the calibration of cracking prediction are given in the K5-1764 report, particularly aimed at reliability differentiation according to severity of leakage class or amount of permitted leakage of contained or retained liquid. Cracking (width and spacing) are main performance indicators for LRS, hence they need to be properly calibrated. The cracking prediction model should be concentrated on, as opposed to combination or partial factors used for actions for verification.
5	Investigation of the effect of stress in serviceability situations due to choices made for ULS	This basically stems around how partial factors calibrated for the ULS affect service stresses, hence careful consideration of this effect on deem-to-satisfy rules as well detailing procedures should be studied.
6	Imposed loads, particularly roof loads	SANS 10160 Part 2 – may need extension for LRS
7	Geotechnical actions	SANS 10160 Part 5 – may need extension for LRS

Table 2.2 Outstanding material model and characterisation issues for the development of SANS 10100-3

No.	MATERIAL PROPERTY	TREATMENT AND SUGGESTED ACTION
1	Compressive strength development	Recommended that information about strength evolution is included for different local binder compositions and cement.
2	Tensile strength	It is proposed that the tensile strength is described in the related concrete standard. Formulations by Collins and Mitchell (1987) and EN 1992-1-1 model compared/considered. Choice of this parameter should be included in revised SANS 10100-1
3	Influence of aggregate type on E-modulus	It is proposed that data on this aspect be included in a NA. Research regarding local characterisation conducted by Alexander and Davis (1989, 1992a and 1992b)
4	Influence of binder composition on E-modulus	This remains to be thoroughly studied in the South African context. What to do in the interim?
5	Influence of curing on E-modulus (also dependent on binder composition)	Ditto
6	E-modulus relation with compressive strength	EN 1992-1-1 and current SABS 100-1 model considered. Decision on preferred model will effect change in related concrete standard i.e. newly revised SANS EN 1992-1-1. Acceptable predictions shown by current SABS models and is recommended to be maintained for use in revised SANS EN 1992-1-1
7	Durability	It is recommended that the durability indicators from SANS 10100-2, SANS 2001 CC1/CC2 be adopted in revised base standards
8	Creep and shrinkage	Different models were compared – GL 2000, CEB-FIP 1990, EN 1992-1-1, ACI 209 1992, BS 8110 1985, RILEM model B3 1995. It is proposed that the EN 1992-1-1 models be accepted as they generally apply, but a note included not to consider curing and loading ages beyond 14 days.
9	Coefficient of thermal expansion	Due to lack of South African data, an informative annexure on the coefficient of thermal expansion of concrete should be added to the final SANS 10100-3, borrowing from Bamforth (2007). Use of this reference is motivated by the fact the same typical rock groups are found in South Africa as in the UK and are extensively used for aggregate for concrete.
10	Heat of hydration	It is recommended to include an informative annex in the revised SANS 10100-1 on heat of hydration and temperature rise based on the UK data (Bamforth, 2007), with clear indication of its origin and that it indicates trends. The local data should be considered in the next revision of SANS 10100-3.

Table 2.3 Outstanding clause by clause issues

Clause	Issue / Title	Action
1.1	Editing	Change *European* to *South African*
1.1	Editing	Give consistent format to referenced SANS documents
2.9.2	Operational safety considerations – Provision for access (Metal ladders)	Consider giving reference to SAISC's Red Book (Steel Designer's handbook). Chapter 12 gives specs on ladders which are mostly governed by the occupational health & safety act, national building regulations and SANS 10400
3.1.11(101)	Heat evolution and temperature development due to hydration	The CIRIA guide has been pointed out to be of value to the consideration of heat evolution and temperature development due to hydration. Consider making reference to this document?
4.4.1.2(105)	Environmental conditions	Consider the strength class in comparison with the exposure class. Give note or explicitly state C30/37 & C 35/40
7.3.1	Cracking – General considerations	All concrete will permit the passage of small quantities of liquids and gases by diffusion. Onerous rules for cracking related to tightness classes given in EN 1992-3 omitted for inclusion in SANS 10100-3 (Draft). Implementation of differentiated levels to be studied and justified for SA context through calibration studies. Nonetheless, some preferences are expressed here that need to be correlated with the crack width requirement. Are they sufficient? Some additional provisions may be required, relating crack widths to tightness classes.
9.1(104)	Editing	Reference in the draft SANS 10100-3 made to A.2 of Annex C which at present does not exist. Either label figures A.1 & A.2 or else A.2 does not exist
Annex K	Annexes	Delete Annex K. Outside scope of SANS 10100-3
Throughout the code	Editing	Change SANS 10100 and/or EN 1992-1-1 to SANS EN 51992-1-1

3 FORMATION OF WORKING GROUP

3.1 Introduction

WRC project K5/2154/1 had as its main aim to develop the draft SANS 10100-3 Standard into an official SABS Draft South African Standard, ready for public comment and subsequent publication through normal SABS procedures as a National Standard.

To achieve this aim, a new SABS Working Group had to be formed, consisting of full representation of experts in design, construction and maintenance of concrete liquid retaining structures to critically review the existing draft code and make final decisions on outstanding issues in order to put out a fully operational design code for concrete liquid retaining structures (LRS). Thus technically capable, experienced and willing individuals from consulting practice, construction firms and client organizations needed to be recruited.

The opportunity arose to present a country wide series of seminars in collaboration with CSSA, which was targeted at professionals actively involved in the design and construction of concrete liquid retaining structures. This allowed a wide audience to be reached. The presentation included some findings from the previous WRC Project K5-1764, contents from the guideline document (Chapter 2), together with background to the draft code, concluding with an invitation to participate. A large number of suitable individuals indicated their interest in becoming involved in the development.

This chapter serves to report on the aims, content and outcome of the seminar series

3.2 Recruitment seminars

The aim of the seminars was to recruit suitable members for the SABS Working Group on a South African Standard for the design of concrete liquid retaining structures. Suitable members would be technically capable, experienced and willing individuals with suitable background in the design, construction and/or maintenance of concrete liquid retaining structures.
Partnering with the Concrete Society of South Africa (CSSA) allowed the recruitment seminars to form part of their larger "Concrete for Fluid Retaining and Excluding Structures" (ConFrex) seminar series, countrywide. The seminars targeted engineers, contractors and clients active in the field of concrete liquid retaining structure design and construction, which made it the perfect platform for recruiting suitable members for the planned Working Group.

The series of four seminars was organized by the Cement and Concrete Society of South Africa (CSSA) and was presented in Johannesburg, Cape Town, Port Elizabeth and Durban respectively, from the 25th to 28th of June 2012. Table 1 summarises the dates and number of attendees per venue. In total, the seminars were presented to 306 attendees.
At each seminar, the presentation on the development of a South African Standard for Liquid Retaining Structures was presented by Dr. C Barnardo-Viljoen.

Table 3.1 Venues, dates and attendance at the four ConFrex seminars

Venue	Date	Number of attendees
Johannesburg	25 June 2012	133
Cape Town	26 June 2012	66
Port Elizabeth	27 June 2012	46
Durban	28 June 2012	61

The presentation aimed to inform the audience of progress made in the previous WRC project and the aims of the present project, including details on outstanding issues that are to be addressed by the new SABS Working Group, concluding with a call for participation. The presentation is included as Appendix A of this report. Specific attention was given to the following:

- A draft version of SANS 10100 Part 3 – Design of Concrete Liquid Retaining Structures (SANS 10100-3 (Draft)) was produced as output from a previous WRC research project K5-1764. The important background, decisions and assumptions on which this draft is based, were presented.
- Various outstanding issues remain to be concluded in order to develop SANS 10100-3 (Draft) into an official SABS Draft South African Standard, ready for public comment and subsequent publication through normal SABS procedures as a National Standard. The content of the guideline document (Section 2) was presented, specifically pointing out the various remaining issues that require attention.
- A new SANS10100-3 Working Group is to be formed, consisting of full representation of experts on the design of concrete liquid retaining structures who will critically review the existing draft code and make final decisions on outstanding issues in order to put out a fully operational design code for concrete liquid retaining structures (LRS).
    - The target dates for the working group to achieve different milestones in the development of the code were presented.

An express call for participation was made, where individuals who considered themselves able and willing to contribute were asked to provide their contact details.

The seminars succeeded in disseminating information on the progress with a South African Standard for the design of concrete liquid retaining structures to a wide and relevant audience from across South Africa. The seminars specifically targeted professionals active in the field of concrete liquid retaining structures and were mostly attended by consultants, contractors, clients and admixture/concrete manufacturers.

From these audiences, many individuals and companies responded to the call for participation in the new SANS Working Group by providing their contact details on a list specifically circulated for this purpose. These individuals thereby declared themselves as suitably experienced and willing or interested to serve on the WG. Table 3.2 provides the number of responses obtained at each seminar. In total, 44 individuals from 34 different companies volunteered their contact details in this way.

Table 3.2 Responses to the call for participation in the new SANS10100-3 WG

Venue	Date	Number of responses
Johannesburg	25 June 2012	26
Cape Town	26 June 2012	11
Port Elizabeth	27 June 2012	1
Durban	28 June 2012	6

3.3 Selection process

Follow-up emails were sent to all individuals and companies that volunteered their contact details as a token of interest to be included in the new SANS10100-3 Working Group. The emails served to

- Inform the individuals of the frequency and location of meetings that is to be expected.
  - Meetings will be held in Stellenbosch and Midrand respectively and will be scheduled as needed. The expectation is that about eight meetings will be necessary to complete the work.
- Highlight the different areas of expertise where contributions will be needed, namely
  - Design of Liquid Retaining Structures (LRS)
  - Concrete mix design for LRS
  - Good construction practice for LRS, including in-situ construction, post-tension- and precast design, and detailing
  - Reliability calibration for load factors and crack width criteria, and
  - Maintenance of reinforced concrete liquid retaining structures
- Explain the different possible levels of involvement in the WG, which can be either
  - Level 1: Full Working Group member: A full member will attend all possible meetings and will take the lead in a certain topic or aspect of the work. This will require review, reformulation and development of the topic.
  - Level 2: Corresponding member (Reader): A reader will serve as reviewer of drafts at various stages and will provide technical and editorial feedback.
  - Level 3: Receiver of information: Minutes of the Working Group meetings will be circulated to these members with an open invitation to attend meetings.
- Obtain confirmation from the individual about their intended level of involvement in the new WG, together with a short CV to detail their relevant expertise.

In response to these emails, a total of 15 individuals confirmed their involvement in the development of the Standard. Table 3 summarises the number of confirmed members per involvement level. These members include representation from consultation firms (9), contractors (2), admixture/concrete manufacturers (2), client organizations (1) and universities (1). Representation from the University of Stellenbosch (3) and the University of KwaZulu-Natal (1) and a number of other experts recruited separately (2) added to this membership number.

Table 3.3 Number of confirmed members of the SANS10100-3 WG, per involvement level

Level of involvement	Number of confirmed members
Level 1: Full member	15
Level 2: Reader	7
Level 3: Corresponding member	5

3.4 Members of the working group

The SANS 10100-3 Working Group consisted of the following members, contributing various areas of expertise as indicated in Table 3.4.

Table 3.4 Members of the SANS10100-3 Working Group

Level 1: Full Members		
Member	**Expertise**	**Contact detail**
Mr. K Bultman	Design	Koos.bultman@telkomsa.net
Mr. B Brouard	Concrete	Brenton@Chrysosa.co.za
Mr. C Koen	Design	Colin.koen@worleyparsons.com
Mr. E Kruger	Cracks, design	erhardk@mwebbiz.co.za
Mr. D Lambert	Post-tension reservoirs	dominicl@freyssinet.co.za
Mr. M Perduh	Design	MilosP@BKS.co.za
Prof. JV Retief	Reliability	jvr@sun.ac.za
Mr. G Theodasiou	Concrete	gary@cnci.org.za
Mrs. C McLeod	Design	Mcleodc@ukzn.ac.za
Mr. D Middleton	Design	davidm@goba.co.za
Mr. W Smith	Design	WSmith@hatch.co.za
Mr. E Mwaka	Construction	Elvis.mwaka@murrob.co.za
Mr. J van Niekerk	Construction	VanniekerkJ@dwa.gov.za
Dr. C Viljoen	Reliability	cbarnardo@sun.ac.za
Prof. JA Wium	Code writing, design	jaw@sun.ac.za

Table 3.4 Members of the SANS10100-3 Working Group, continued

Level 2: Readers / Official Reviewers		
Member	**Expertise**	**Contact detail**
Mr. H Barnard	Design	HeinB@BKS.co.za
Mr H Bosman	Design	Hermanb@BKS.co.za
Mr. P Haambayi	Construction	Patrick.haambayi@hiloadgroup.co.za
Mr. M Martin	Construction, design	Murray.martin@hiloadgroup.co.za
Mr. V Marshall	Design	Vernon.marshall@nucsa.com
Mr. J Meadows	Concrete	Joseph.Meadows@za.afrisam.com
Mr. K Mujaji	Construction, Post-tensioning	kudam@uwp.co.za
Level 3: Receivers of information		
Member	**Expertise**	**Contact detail**
Mr. M Angelucci	N.A.	Matteo.angelucci@uct.ac.za
Mr. F Hein	N.A.	friedrichh@kprsa.co.za
Mr. J Ramatsetse	SABS	jacob.ramatsetse@sabs.co.za
Mr. A Viljoen	N.A.	Andries.Viljoen@rhdhv.com
Mr. G Druce	Design	Gordon.Druce@rhdhv.com

4 WORKING GROUP DRAFT STANDARD

4.1 Input documentation

Significant effort was spent to produce appropriate input documentation to facilitate efficient progress by the Working Group (WG) from day one. These consisted of three documents:

- The SANS 10100-3 (Draft) document originating from WRC project K5/1764 is an adapted version of EN 1992-3 (2006) incorporating some information and clauses from BS 8007. The document could serve as a starting point for the standard's development, should the WG agree with the scope of work and reference material adopted for the creation of this draft.
- Chapter 2 of this report details the content of the Guideline for the SANS 10100-3 WG (ISI, 2012), highlighting important outstanding issues that needs to be addressed by the WG.
- A first revision of the Background to SANS 10100-3 (ISI, 2012) was also created and served to highlight the main references as well as the way in which they were considered in deriving the provisions of SANS 10100-3 (Draft).

These documents were circulated to WG members in preparation for their first meeting.

4.2 Definition of scope

South Africa has limited resources available for standards development. As a result of this, our standards are typically adaptations or adoptions of suitable international standards. In developing a South African standard for the design of concrete liquid retaining structures an important choice had to be made regarding the use of reference material. Two suitable international standards are available for use as reference standards, namely

1. BS 8007:1987 *Code of practice for design of concrete structures for retaining aqueous liquids*
   This standard is currently used by most South African designers as their reference of choice. In addition to the necessary design provisions, it includes useful guidelines on aspects such as joints, concrete mix design and testing of structures. BS 8007 is to be used in conjunction with BS 8110 *Structural use of concrete*. SANS 10100-1 *Structural use of concrete: Design* is for all practical purposes an adoption of BS 8110 and as such the use of BS 8007 is consistent with current South African provisions for design of concrete structures. Unfortunately however, the British Standards Institute has officially withdrawn BS 8007, following the adoption of the Eurocodes. As such, BS 8007 will not be updated with evolvement of best practice and will eventually become outdated.

2. EN 1992-3 *Liquid retaining and containment structures*
   This standard captures not only design provisions for concrete liquid retaining structures under a wide range of operating temperatures, but also for silos containing granular and other materials. EN 1992-3 is to be used in conjunction with EN 1992-1-1 *Structural use of concrete*. In the latest developments related to the revision of SANS 10100-1, it was decided to adopt EN 1992-1-1 as the new South African Standard for the design of concrete structures, here referred to as SANS 51992-1-1. This decision makes it possible to also adopt or adapt EN 1992-3, which can then be used in conjunction with the new SANS 51992-1-1.

After careful consideration, the WG concluded the following:

- The format of the new standard should be to <u>adapt</u> (and not adopt) EN 1992-3. This decision was reached unanimously at the second meeting of the WG, for the following main reasons:
  - The scope of EN 1992-3 is very wide. Sufficient expertise is not available within local practice to warrant adoption as is. Sufficient expertise is also not available within the working group to allow revision of the whole content of EN 1993-3.
  - There is information from BS 8007 which is useful and needs to be retained. This is not possible if EN 1992-3 is adopted as is.
  - It will be too time consuming to develop an entirely new code.
  - The stringent crack width limits of EN 1992-3 will have significant economic implications. Adaptation of this is likely necessary.

    Note: The same conclusion was reached based on investigations carried out as part of WRC project K5/1764.

- EN 1992-3 is not a standalone document, but relies on a concrete design code. The adoption of EN 1992-1-1 as SANS 51992-1-1 *Structural use of concrete*, will allow the use of an adapted version of EN 1992-3.
- Useful information and clauses from BS 8007 will be incorporated in the new SANS 10100-3.
- The draft document originating from WRC project K5/1764 will form the basis of the code to be developed. It is an adapted version of EN 1992-3 (2006) and already incorporates some information and clauses from BS 8007.

4.3 Champions and topics

Work needed to create the new SANS 10100-3 was subdivided into appropriate specialist topics and standard sections, subsequently allocated to suitable champions as set out in Tables 4.1 and 4.2 below. Sections refer to sections in SANS 10100-3 (Draft), which in turn follows the numbering format of SANS 51992-1-1. Specialist topics may be addressed within several sections and Annexes. As such champions of specialist topics were responsible to ensure consistent treatment of the topic throughout the standard. Each champion assessed the scope of work required within his/her topic(s) and sections, reporting back to the WG for comment.

Table 4.1 Specialist topics and associated WG Champions

Specialist topic	**WG Champion**
Loading	Colin Koen
Cracks: Prediction models	Erhard Kruger; Christina McLeod
Concrete specification / Mix design	Gary Theodosiou; Brenton Brouard
Material property models	Milos Perduh
Joints and waterstops	David Middleton; Willem Smith
Detailing	Koos Bultman
Testing and Maintenance of LRS	Jaco van Niekerk
Pre-stressing aspects	Dominic Lambert

Table 4.2 SANS 10100-3 section and associated WG Champion(s)

Section (SANS10100-3 Draft)	**WG Champion**
Section 1: General	Jaco van Niekerk
Section 2: Basis of design	Jaco van Niekerk; Johan Retief
Section 3: Materials	Milos Perduh
Section 4: Durability	Milos Perduh, Gary Theodosiou; Brenton Brouard
Section 5: Structural Analysis	Colin Koen
Section 6: Ultimate limit states	Colin Koen
Section 7: Serviceability limit states	Erhard Kruger; Christina McLeod
Section 8: Detailing provisions	David Middleton; Willem Smith
Section 9: Detailing of members	David Middleton; Willem Smith
Annex A: Basis of design	Colin Koen
Annex B: Actions, partial factors and combinations of actions	Colin Koen
Annex C: Surface zones in concrete members	David Middleton
Annex K: Effect of temperature on the properties of concrete	David Middleton
Annex L: Calculation of strains and stresses in concrete sections subjected to restrained imposed deformations	Erhard Kruger; Christina McLeod
Annex M: Calculation of crack widths due to restraint of imposed deformations	Erhard Kruger; Christina McLeod
Annex N: Provision of movement joints	David Middleton; Willem Smith
Annex P: Cylindrical prestressed concrete structures	Dominic Lambert

4.4 Meetings and process

Several WG meetings were scheduled over the course of the development, as listed in Table 4.3. Meetings were well attended by WG members, which were testament to the team's commitment. Dr. C Viljoen acted as WG coordinator, being responsible during the course of the development for the incorporation of member contributions into the main document, for the circulation of draft versions to members and for liaising with Champions or contributors as and where needed to clarify and finalise clauses or sections.

The first two meetings were mainly devoted to the allocation of topics and sections to suitable Champions from the WG and to conclude on the appropriate reference material and scope of the proposed development. In this regard the draft SANS 10100-3 document originating from WRC project K5/1764 as well as the Guideline- and Background documents developed as part of WRC project K5/2154/1 contributed significantly to focus the efforts of the WG and to allow these important matters to be speedily concluded.

Subsequent meetings were scheduled at longer intervals to allow development work to be completed in between. Champions were responsible for the development of sections and topics in collaboration with other WG members, reverting back to the WG coordinator with developed content. Developed content was incorporated into the SANS 10100-3 WG Draft document and circulated for discussion at the next meeting. On this basis a first WG draft was produced by 5 August 2013, which was discussed in detail at the next WG meeting.

Further adjustments and development was then handled telephonically and per email between the WG coordinator and the relevant Champions, to produce a WG draft fit for distribution and final comment by all full WG members.

Once the WG main members were satisfied with the draft document, it was circulated officially to the WG Readers for comment. The WG Readers made a number of useful comments, which were incorporated into the WG Draft in liaison with the relevant Champion of the section or topic under consideration.

The SANS 10100-3 (WG Draft) was first submitted for review to SABS TC 98-02 on 7 March 2014.

Table 4.3 Important actions of the WG

Action	**Date**
WG Meeting: Definition of scope; Assign Champions	28/11/2012
WG Meeting: Finalise definition of scope; Champion feedback	18/01/2013
WG Meeting: Contributions by members	12/04/2013
WG Meeting: Contributions by members	07/06/2013
Circulate First WG Draft for review to full members	05/08/2013
WG Meeting: Contributions by members	08/08/2013
Circulate WG Draft to all members for review and comment	17/12/2013
Circulate WG Draft to Readers for review and comment	23/01/2014
Submit SANS 10100-3 (WG Draft) to SABS TC 98-02	07/03/2014

5 SABS TC DRAFT STANDARD

5.1 Process

SABS Technical Committee 98-02 *Design of concrete structures* is responsible for the technical review of WG Draft documents stemming from NWIP's submitted under the TC. Its members consist of various academic and industry experts on concrete structures.

Once a WG Draft is submitted to SABS it is distributed to the members of the relevant TC for technical review. TC members are required to formally vote for or against the acceptance of such a WG Draft, by stipulating Accept / Accept with comments / Reject or Abstain. TC members are allowed to submit comments with their vote, which will be referred back to the WG.

The outcome of the TC review and voting process are communicated by SABS to the WG convenor on completion of the vote.

Should the TC vote to "Accept" the WG Draft it implies that the document may be prepared for distribution by SABS as a SABS TC Draft for public comment.

5.2 Outcome and comments

The SANS 10100-3 (WG Draft) was accepted by SABS TC 98-02 through a majority positive vote on 18 September 2014. TC members submitted comments as detailed in Appendix C which were referred back to the WG.

A WG meeting was held on 11 February 2015 to address these comments, with resolutions as documented in the latter part of Appendix C. Adjustments to SANS 10100-3 (WG Draft) were made as per these resolutions. This latest version of SANS 10100-3 (WG Draft) is included in this report as Appendix B.

SABS TC 98-02 officially accepted the amended SANS 10100-3 (WG Draft) as TC Draft Standard at their meeting of 3 March 2015. SABS will now proceed with typesetting the document and distributing it for public comment as SANS 10100-3 (TC Draft). Table 5.1 outlines the process and important dates.

Table 5.1 Important actions of the WG (cont'd)

Action	**Date**
Receive comments from TC 98-02	18/09/2014
WG meeting: Formulate resolutions to TC 98-02 comments	11/02/2015
Submit amended SANS 10100-3 (WG Draft) to SABS TC 98-02	24/02/2015
SANS 10100-3 (WG Draft) accepted as TC Draft	03/03/2015

6 SANS 10100-3 BACKGROUND DOCUMENT

The technical background to the WG draft standard for the design of liquid retaining structures, SANS 10100-3 (WG Draft) *Design of concrete liquid retaining structures*, as compiled by the WG and submitted to SABS TC 98-02, is provided as Volume II of this report. The technical background is compiled as operational material to assist future Working Groups in assessing SANS 10100-3 as input to future revisions of the Standard.

The technical background serves to highlight the main references as well as the way in which they were considered in deriving the current provisions of SANS 10100-3 (WG Draft). It serves to report and record the technical basis for the decisions of the WG and records the critical input, motivations and decisions on which the published standard will be based. It serves the dual purpose of providing the information required for understanding the intentions of the standard and to allow for future systematic review and updating of subsequent editions of the standard.

A specific characteristic of SANS 10100-3 (WG Draft) is that for various reasons it is compiled as a single standard out of a number of reference standards. The point of departure was to base it on the relevant Eurocode Standards; although there is not a single self-contained Eurocode standard for liquid retaining structures. At the same time the standard should also be consistent with other local standards, particularly the general standard for structural concrete and the loading code. The Background Report therefore serves as a road map to referenced and related standards for structural design.

The Background Report concisely compiles information on which SANS 10100-3 (WG Draft) is based, consisting of the primary Eurocode Standard which provides for concrete liquid retaining structures (EN 1992-3:2006), the standard which serves as the *de facto* South African standard for liquid retaining structures (BS 8007), the related general structural concrete standards (EN 1992-1-1:2004; SANS 51992-1-1 (WG draft); nominally also BS 8110); the Eurocode Standard which provides for actions on liquid retaining structures (EN 1991-4:2006), and lastly the South African Loading Code (SANS 10160:2011) with specific reference to the basis of structural design (SANS 10160-1:2011). A general source of background information from which information is abstracted is WRC Project K5-1764 Final Report (2010). The Guidelines for the Working Group (ISI, 2012) which was compiled to motivate the NWIP for a standard on the design of concrete liquid retaining structures and facilitate the launching of a WG, also provides some general background information.

An overview is firstly provided of the relevant scope of the various reference documents and the way in which information from these references have been incorporated in SANS 10100-3 (WG Draft). Secondly, reference is made at a more detailed level of the basis of the various sections and where justified, the specific clauses of SANS 10100-3 (WG Draft) and the corresponding standard or source of information which is invoked in formulating the respective requirements or procedures.

In retrospect, many issues still require proper calibration and characterisation not only on a national, but international platform as well, mostly concerning the establishment of rational design procedures for LRS based on the principles of structural reliability. Further characterisation of material models to local data is warranted, particularly concerning information on the strength evolution of concrete exposed to different curing regimes, the heat evolution of concretes comprising different local binder compositions as well as the coefficient of thermal expansivity in relation to the respective aggregate used locally in South Africa. However, in the interim, sound engineering judgement was used to select appropriate procedures for critical design parameters for incorporation in SANS 10100-3 where no credible or convincing local data is available.

7 KNOWLEDGE DISSEMINATION

7.1 Dissemination to Industry

Knowledge will ultimately be disseminated to the engineering community through the publication of SANS 10100-3 *Design of liquid retaining structures*, which will be supported by the necessary background documentation.

Transfer of the information generated by this project to members of the WG can also be considered to be a direct and effective dissemination of the information. It should be noted that members of the WG represent a selection of leading experts in the field in South Africa.

In addition, two dissemination seminars were held in Johannesburg and in Stellenbosch respectively, as detailed in Section 7.2 below, and reached a large number of civil engineering practitioners.

7.2 Dissemination Seminars

Introduction

The SANS 10100-3 Working Group assigned champions to drive the revision of the different subsections of the standard, as described in Chapter 4. Among other things, decisions pertaining to prediction models and acceptable serviceability limits needed to be taken by the WG. For this reason, the Champions involved in revision of the crack prediction models requested that the input of UK expert Mr. Robin Atkinson (UK) be obtained in comparing BS 8007 with EN 1992-3. Information on the CIRIA C660 document, which contains background information on reservoir design, could also be provided by Mr. Atkinson through his involvement in revising this document.

With the above in mind, a dissemination seminar was organized, to be presented both in Stellenbosch and Midrand. The seminar attracted one CPD point and was open for attendance by practicing engineers.

Content

Currently, most South African designers use BS8007 to design concrete liquid retaining structures. This document has been withdrawn by the British Standards Institute, following the introduction of the Eurocodes. EN1992-3 and CIRIA C660 are now used in Europe for the design of concrete liquid retaining structures. These new design codes and guidance introduce new concepts to the design and reinforcement of the structures and place increased demands on the designer as they require a deeper understanding of the basic principles governing the design.

BS8007, EC2 and CIRIA C660 served as reference documents to SANS 10100 3 (WG Draft) Decisions pertaining to prediction models and acceptable serviceability limits needed to be taken by the WG.

With the above in mind, the seminar aimed to explain:

- How thermal and shrinkage effects control the design
- How flexural and tensile crack equations are derived and used
- How cracks affect the life of the structure
- The differences between BS8007 and EC2 and the implications thereof, pertaining to the
    - Calculation of crack widths, including application to flexure/combined/axial tension.
    - Calculation of minimum reinforcement.
    - Calculation of restraint factors.
    - Implied reinforcement requirements.
- The use of CIRIA C660 for determination of shrinkage, creep and hydration temperatures and how these are used in the EC2 clauses.

Presenters

The seminar was mainly presented by Mr. Robin Atkinson, an international expert in the design of concrete liquid retaining structures and in the development of related design standards, with introductions to the South African context made by members of the SANS10100-3 WG:

- Mr. Robin Atkinson (BSc, CEng, FICE, FIStructE) is an experienced UK design engineer, currently a partner at HAC LLP in Bourne End, Bucks. He specialises in the design of liquid retaining structures and lectures on the design of these structures to the British and Euro codes. He has published several articles on the subject. He is an IStructE "Eurochampion" (representative on the Eurocodes) and is currently the Thames Valley Regional Group representative on IStructE Council and a member of the Engineering Practice committee. He also serves on the CIRIA C660 review committee.
- Mr. Erhard Kruger (PrEng), South African design engineer, member of the working group developing SANS 10100-3: The design of concrete liquid retaining structures.
- Dr. Celeste Viljoen (PrEng), Stellenbosch University, member of the working group developing SANS 10100-3: The design of concrete liquid retaining structures, member of the Joint Committee on Structural Safety and researcher on structural risk and reliability.

Attendance

The seminar was presented in Midrand, Gauteng on Wednesday 28 August 2013 and in Stellenbosch, Western Cape on Thursday 29 August 2013. Table 7.1 reports the type and number of attendees at the two venues. A total of 146 individuals attended.

Table 7.1 Number and type of seminar attendees at the two venues

Type of attendees	Midrand	Stellenbosch
Industry Professionals	94	35
Working group members	9	4
Students	0	4
Total	103	43

A useful set of printed notes and complimentary access to reservoir design software were offered to all attendees.

7.3 Academic Dissemination:

Provision was made for the attendance of one conference during the course of the project by Mr. KK Mensah, a member of the research team, where research findings were published and presented to the broader research community. Mr. Mensah attended the FIB Symposium in Tel Aviv in April 2013, where he presented a paper on the modeling uncertainty and reliability calibration of EN2' VSIM shear design method (Mensah et al., 2013).

Research results generated by students (See Section 8.2) on this project were disseminated to other post-graduate students and staff members in half hour lectures that are regularly scheduled at Stellenbosch University.

7.4 Future dissemination

The publication of SANS 10100-3 will be done by SABS on completion of a call for public comment and subsequent WG response to such comments. It is tentatively planned to organize a dissemination seminar shortly after publication of SANS 10100-3, to provide guidance on its use to the South African Civil Engineering community. Such a seminar should as a minimum requirement be presented in Cape Town and Johannesburg, but preferably also in other large South African centres.

The publication of the Background to SANS 10100-3 as Volume II of this report is also considered important dissemination of decisions taken by the WG.

8 CAPACITY BUILDING

8.1 Introduction

WRC Project K5/2154/1 contributed to capacity building on several fronts, both directly and indirectly. A number of students participated in research related to this project, with several of them being financially supported through bursaries or contributions towards research material. Section 8.2 below details the student involvement in this project. Recruitment- and dissemination seminars were presented as part of the project, as detailed respectively in Chapters 3 and 8 of this report. A summary of attendance for these are provided in Section 8.3 below. Finally, a number or practicing engineers and academic personnel from several universities were active members of the SANS 10100-3 WG. In this regard their involvement in the project contributed to capacity building in Standards development.

8.2 Students

Several post-graduate and final year students were involved in research related to this project. These include 2 PhD students, 3 MSc students and 10 final year students. Their details and research topics are set out in Table 8.1 below. Postgraduate dissertations may be found in electronic format on https://scholar.sun.ac.za/.

Table 8.1 Post-graduate and final year students involved in research related to WRC project K5/2154/1

Student	Race & Gender	Topic	Study leader & University	Year
PhD students				
Mensah, KK	Black, Male	Reliability assessment of structural concrete with special reference to shear resistance.	Dr. C Barnardo-Viljoen & Prof. JV Retief, US	2012-2014
McLeod, C	White, Female	Investigation into cracking in reinforced concrete liquid retaining structures in South Africa.	Dr C Barnardo-Viljoen, US	2013-current
MSc students				
De Witt, CP	White, Male	Reliability based optimisation of crack width limitations for concrete liquid retaining structures in South Africa.	Dr C Barnardo-Viljoen, US	2010-current
McLeod, C	White, Female	Investigation into cracking in reinforced concrete water retaining structures in South Africa.	Prof. JA Wium & Prof. JV Retief, US	2009-2012

Mensah, KK	Black, Male	Reliability assessment of structural concrete with special reference to shear resistance. (Upgraded to PhD, March 2012)	Dr. C Barnardo-Viljoen & Prof. JV Retief, US	2009 - 2011
Final year projects				
Van Wyk, R	White, Male	Self-healing of cracks in water retaining structures.	Dr C Barnardo-Viljoen, US	2012
Ludwick, J	White, Male	Quantification of variability of shear design parameters for South African construction practice.	Dr C Barnardo-Viljoen, US	2012
Morgan, DJ	White, Male	\`n Handleiding vir die gekoordi-neerde ontwerp en konstruksie van beton waterhoudende strukture.	Prof. JA Wium, US	2012
Barnard, R	White, Male	Riglyne vir die ontwerp en konstruksie van voorafvervaardig-de betonelemente.	Prof JA Wium, US	2012
Mostert, LH	White, Male	\`n Ondersoek na die stand van kwaliteit in die Suid-Afrikaanse konstruksiebedryf van geboustruk-ture.	Prof JA Wium, US	2012
Swart, TC	White, Male	Arbeidspraktyke vir die voorafver-vaardiging en in-situ oprigting van betonstrukture.	Prof JA Wium, US	2012
Le Roux, B	White, Male	Self-healing of cracks in water retaining structures.	Dr C Barnardo-Viljoen, US	2013
Kretchmer, M	White, Male	Reliability based optimization of the crack width limit for water retaining structures.	Dr C Barnardo-Viljoen, US	2013
Bester, DC	White, Male	Investigation into the use of prefabrication for the construction of reinforced concrete reservoirs.	Prof JA Wium, US	2013
Harmse, C	White, Male	Prediction of heat of hydration values for South African concretes	Dr C Barnardo-Viljoen, US	2014

8.3 Attendance of CPD courses

Four lectures were presented in June 2012 as part of the CSSA Confrex seminar series, in Midrand, Cape Town, Port Elizabeth and Durban respectively. The seminars specifically targeted professionals active in the field of concrete liquid retaining structures and were mostly attended by consultants, contractors, clients and admixture/concrete manufacturers. In total, the seminar was presented to 306 attendees. The aim of the lectures was to recruit suitable members for the working group on the new SANS10100-3 standard development.

As such, the presentation informed the audience of progress made in the previous WRC project and the aims of the present project, including details on outstanding issues that are to be addressed by the new SABS Working Group, concluding with a call for participation. More details are provided in Chapter 3.

Two dissemination seminars were presented in August 2013 in Midrand and Stellenbosch respectively. The seminars were presented by Mr. Robin Atkinson from the UK with the aim to provide WG members and attendees from general consulting practice with an appreciation of the differences between the old BS 8007 standard and the new EN1992-3 standard for the design of concrete liquid retaining structures. A total of 148 attendees attended the two seminars, which were well received by practice. More details are provided in Chapter 7.

8.4 Staff development

The development of specialization amongst staff members at Stellenbosch University (three members) and University of KwaZulu-Natal (one member) were facilitated through this project. This was achieved through their project related research activities (including student supervision) and participation in standards development committees.

9 CONCLUSIONS

WRC project K5/2154/1 succeeded in its main aim to develop the SANS 10100-3 (Draft) Standard into an official SABS Draft South African Standard, ready for public comment and subsequent publication through normal SABS procedures as a National Standard.

To achieve this aim, a new SABS Working Group (WG) was formed under SABS Technical Committee (TC) 98-02 *Design of Concrete Structures* for which suitable candidates were recruited through presentations at a nation-wide series of seminars which highlighted the proposed work. Full representation of experts in design, construction and maintenance of concrete liquid retaining structures was thus obtained to critically review the SANS 10100-3 (Draft) originating from previous WRC project K5/1764 and make final decisions on outstanding issues in order to produce a final WG Draft Standard for approval by SABS TC 98-02. SANS 10100-1 (TC Draft) was accepted by TC 98-02 on 18 September 2014. SABS will now drive the process of typesetting the document and circulating it for public comment. Comments from TC 98-02 will be addressed by the WG in parallel.

Efficient progress by the WG from day one was facilitated by the availability of SANS 10100-3 (Draft) from the previous WRC project K5/1764 and two input documents produced by the project team, namely the Guideline for the SANS 10100-3 WG (ISI, 2012), highlighting important outstanding issues from SANS 10100-3 (Draft) that needed to be addressed by the WG, and the Background to SANS 10100-3 (Barnardo-Viljoen et al., 2014) which highlighted the main references and the way in which they were considered in deriving the provisions of SANS 10100-3 (Draft)

Important to the success of the project in terms of a speedy completion by the WG of SANS 10100-3 (WG Draft) was the administrative- and technical capacity, made available through the financial support of WRC project K5/2154/1, in compiling all member contributions into the central document and harmonising contributions through liaison with contributors.

The Background to SANS 10100-3 was appropriately updated to reflect the updates and decisions made by the WG in their development of the provisions of SANS 10100-3 (WG Draft).

Two dissemination seminars presented in August 2013 in Midrand and Stellenbosch were well attended by practice and WG members, totalling 148 attendees. The seminars were presented by UK expert Mr. Robin Atkinson and provided working group members and attendees from general consulting practice with an appreciation of the differences between the old BS8007 standard and the new EN1992-3 standard for the design of concrete liquid retaining structures.

Finally, the project contributed significantly to capacity building through the involvement of students, academics and industry participants. In this regard financial support was aimed at facilitating student training and research and mobility of academics to participate in WG activities.

In terms of further future revisions and development of SANS 10100-3 many issues still require proper calibration and characterisation not only on a national, but international platform as well, mostly concerning the establishment of rational design procedures for LRS based on the principles of structural reliability. Further characterisation of material models to local data is warranted, particularly concerning information on the strength evolution of concrete exposed to different curing regimes, the heat evolution of concretes comprising different local binder compositions (including Corex slag) as well as the coefficient of thermal expansivity in relation to the respective aggregate used locally in South Africa. However, in the interim, sound engineering judgement was used to select appropriate procedures for critical design parameters for incorporation in SANS 10100-3 where no credible or convincing local data is available.

10 RECOMMENDATIONS

The Background to SANS 10100-3 (WG Draft) is discussed in Chapter 6 and should be made publicly available. For this reason it is published as Volume II of this report.

As noted in the Conclusions of this report, there is scope for the future revision and updating of SANS 10100-3. In particular, some identified research topics and areas for further study are given in Table 10.1 below. Addressing these research needs is a long term goal which will facilitate future updates and revisions of SANS 10100-3. It is advised that SANS 10100-3 be revised in five year cycles, following its publication as a South African National Standard.

Table 10.1 Some research issues relating to LRS in the SA context

No.	Research title or issue
1	Calibration of hydraulic loads $\{\boldsymbol{\gamma_F}, \boldsymbol{\psi}\}$ for LRS according to SANS requirements
2	Investigate the reliability of the crack control procedure
3	Seismic loading requirements and a study to establish if this is relevant for a region with NGPA = 1.0 to 1.5g. This aspect was partially investigated through an MSc study by Ms. T Fourie.
4	Study of ULS and SLS combination schemes and performance of LRS
5	Investigation of the effect of stress in serviceability situations due to choices made for ULS
6	Splitting tensile tests performed to study the influence of aggregate type, binder type and curing
7	Influence of curing regimes on material properties, with special consideration for the pre-cast industry (heat treatment / steam curing, vs. moist / wet curing)
8	Model reliability studies and calibration to define concrete models for E-modulus, tensile strength and creep and shrinkage prediction models
9	Confirmation of Heat of hydration (T1) values for South African concretes. Including the influence of the use of Corex Slag.

In particular, the crack model and -limits should be reassessed with the next revision of SANS 10100-3. Indications are that significant adjustments and improvements to the current EN 1992-3 crack model and -limits are imminent, which may make it suitable for adoption in SANS 10100-3.

A commentary or user guide for SANS 10100-3 would be useful for practicing engineers.

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APPENDIX A: Recruitment Seminars: Presentation

SA Standard for the design of water retaining structures

Presentation at CSSA ConFrex seminar

Dr C Barnardo-Viljoen

Contents

Creating a SABS Standard for Water Retaining Structures

- Background: SA current practice
- Why is it necessary?
- Our options: BS8007 and EN1992-3
- Work done to date
- The way forward
- A call for participation

Creating a SABS Standard for Water Retaining Structures

Background

- SA does not have its own code for design of these structures.
- SA designers typically use the British Standard BS8007 in conjunction with SANS 10100 (concrete) and SANS 10160 (loading) to design these structures.
- This is creates no inconsistencies in design provisions since SANS 10100 has the BS8110 Standard for design of concrete structures as reference document.
- This was also convenient, since the BS8007 was maintained by the UK in terms of revisions to keep up with new technology and knowledge on material behaviour.

Creating a SABS Standard for Water Retaining Structures

Why is it necessary?

- The British Standard **BS8007 has been officially withdrawn**. The UK now use EN 1992-3 for the design of water retaining structures.
- This implies that the BS8007 **will no longer be maintained** by the UK in terms of revisions to keep up with new technology and knowledge on material behaviour.
  - In the short term this is not a crisis for SA, but in a decade or so it will become an issue as better technology and materials emerge.

Creating a SABS Standard for Water Retaining Structures

Why is it necessary?

- SANS 10100 is currently under revision. The working group has voted to adopt EN1992-1-1 as a SANS Standard.
- SANS 10160 has been revised and is now consistent with its EuroCode counterpart EN1990 and EN1991.
- This implies that the **BS8007 will no longer be consistent** with our latest loading code and concrete standard.

Creating a SABS Standard for Water Retaining Structures

Our options?

Background:

- The European Standards Commission (CEN) allows adoption of its code(s)
  - Such a code will then be named SA EN199_-_
  - The adopting nation must create its own National Annex to make the code operational
- The EuroCodes are not operational without a National Annex, which specifies a host of Nationally Determined Parameters (NDP's), such as target levels of reliability, partial factors, material properties, etc.

Creating a SABS Standard for Water Retaining Structures

Our options?

- Adopt EN1992-3 as is as SANS Standard
  - Create suitable national annex with NDP's to make it operational.
- Use EN1992-3 as a reference standard and adapt to create SANS Standard.
  - Consistent with latest SANS10160
  - Consistent with coming new ~~SANS10100~~ SA EN1991-1-1
- Use BS8007 as a reference standard and adapt to create SANS Standard
  - Ensure consistency with SANS10100 and SANS10160
- A combination of 2 and 3 is proposed
  - Use EN1992-3 as primary reference
  - Enhanced with extracts from BS8007

Creating a SABS Standard for Water Retaining Structures

Our options?

- A combination of EN1992 and BS8007 is proposed
  - Use EN1992-3 as primary reference
  - Enhanced with extracts from BS8007
- EN1992
  - The various Parts cover a very wide scope, including general containment (silos) and liquids with high temperature.
  - This scope is not supported by SA expertise
  - Reduce scope to exclude silos and limit temperature range to ambient
- BS8007
  - Includes guidelines on construction practice (joints, water stops, testing, mix design guidelines, ventilation, access etc.)
  - Less stringent crack width criteria (Question to industry: How often does leakage problems occur? Is this due to inadequate design?)

Creating a SABS Standard for Water Retaining Structures

Work done to date

- Prof. Jan Wium (University of Stellenbosch) started with the creation of a WRS code in 2007 - 2010
  - Three year project funded by the Water Research Commission
  - Compared BS8007 with EN1992-3
  - Preliminary evaluation of consistency with SANS10100 and SANS10160 (the adoption of EN1992-1-1 as concrete code was not known at the time)
  - Identified research needs i.t.o. Material models (cracking, creep, E-modulus)
  - Identified issues central to code writing – to be addressed
  - Created a draft SANS code from EN1992-3

Creating a SABS Standard for Water Retaining Structures

Work done to date

- Comparison: BS8007 vs. EN1992-3
  - Gives similar answers for evaluated items (bending, shear, crack width)
  - EN is less prescriptive (scope for more economic structures)
  - EN does not give element specific guidance, rather general principles
  - EN scope is more extensive (high strength concrete allowed, general containment/silos, wide temperature range).
  - EN specifies crack width limitation according to tightness class of structure.
  - EN crack width calculation more laborious.

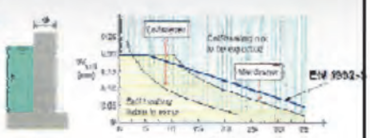
Creating a SABS Standard for Water Retaining Structures

Work done to date

- Comparison of crack limit criteria
  - BS8007: 0.2mm

  vs.

  - EN1992-3:



- Ongoing MSc studies:
  - Reliability assessment of crack width prediction model
  - Economic optimisation of crack width limit

Creating a SABS Standard for Water Retaining Structures

Work done to date

Materials:

- Compared prediction models from SANS with EN and others
- Looked at available data on local materials

In order to

- Identify research needs
- Make recommendations to future working group

Creating a SABS Standard for Water Retaining Structures

Work done to date

Materials:

- Some agreement found between various proposed design models for the different material parameters and SA data.
- Much scope for databases to be extended
  - More comprehensive
  - More representative of local design practice.
- No local data was traceable in some instances
  - Heat of hydration of concrete
  - Influence of binder composition and curing on stiffness development
  - Good judgement needed on what note or clause to include to that effect in the final version of SANS 10100-3.

Creating a SABS Standard for Water Retaining Structures

The way forward

- We have a Draft Standard, based on EN1992-3 but with reduced scope and extracts from BS8007 added
- This must now enter the formal process of conversion to a SABS published standard
  1. Appointment of a working group under SABS Technical Committee 98, subcommittee B.
  2. Working group to evaluate draft and resolve outstanding issues
  3. Support up to the stage of a voted SABS TC98 Committee Draft
  4. Conversion into a Draft South African Standard for public comment
  5. Publication by SABS as a National Standard.
- WRC sponsors a further three year project to drive the completion of pts 1-3
- SABS process will achieve pts 4-5

Creating a SABS Standard for Water Retaining Structures

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- We have a Draft Standard, based on EN1992-3 but with reduced scope and extracts from BS8007 added
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- SABS process will achieve pts 4-5

Creating a SABS Standard for Water Retaining Structures

The way forward

- Issues to resolve:
  - Basis of design issues
  - Materials
  - Detailing
  - Construction methods
  - Design manual
  - SANS 10100 revision
  - Non-technical issues
  - Research

Creating a SABS Standard for Water Retaining Structures

The way forward

- Basis of design issues

No.	DESCRIPTION	TREATMENT AND SUGGESTED ACTION
1	Hydraulic loads: Select appropriate partial γ and combination ψ factors	Partial factors given in Annex B of BS EN 1991-4. Calibrate these for SA β of 3.0. Or adopt UK values?
2	All other ULS actions: Treated in accordance with SANS 10160	SANS 10160-1 vs. EN 1990 and EN 1991 Adjustment from SANS 10160 required for WRS?
3	Quasi-Permanent load combination scheme: Appropriate for the assessment of cracking?	SANS 10160, Part 1, clause 8.3 vs. EN 1990 clause 6.5. SLS loading combinations differ – scrutinise to ensure adequate provision for cracking for WRS.
4	Reliability for the crack control SLS	Calibration of cracking prediction is needed: Allow reliability differentiation according to amount of permitted leakage. Cracking prediction model needs attention.
5	Investigation of the effect of stress in SLS cases due to choices made for ULS	Partial factors calibrated for the ULS: Effect on service stresses, deem-to-satisfy rules and detailing procedures?
6	Imposed loads, particularly roof loads	SANS 10160 Part 2 – may need extension for WRS
7	Geotechnical actions	SANS 10160 Part 5 - may need extension for WRS

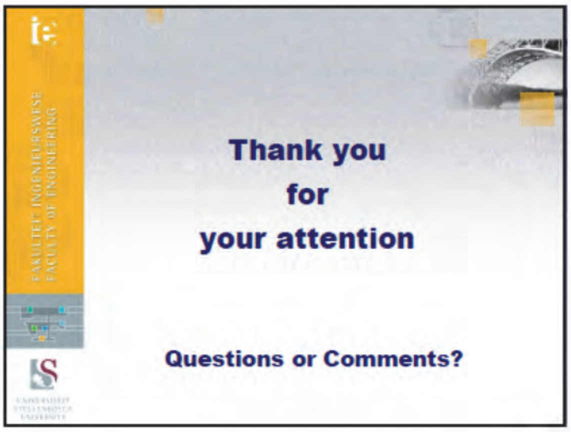
Creating a SABS Standard for Water Retaining Structures

The way forward

- Materials

No.	MATERIAL PROPERTY	TREATMENT AND SUGGESTED ACTION
1	Compressive strength development	**Consider the different prediction models available** EN1992 vs. SANS10100 (& others). Some recommendations available from previous project. **Make decision on what to include in revised SANS10100, new SANS WRS or Annexes.** More research required on some of these properties (Typically to be included in future revisions)
2	Tensile strength	
3	Influence of aggregate type on E-modulus	
4	Influence of binder composition on E-modulus	
5	Influence of curing on E-modulus	
6	E-modulus relation with compressive strength	
7	Durability	
8	Creep and shrinkage	
9	Coefficient of thermal expansion	
10	Heat of hydration	


Creating a SABS Standard for Water Retaining Structures
A call for participation
Appointment of a working group under SABS TC98, subcommittee B.
Working group to include participation of
consultants,
contractors,
governing bodies and
other interested organisations
Please contact
Dr. C Barnardo-Viljoen
021808 4444
cbarnardo@sun.ac.za


Thank you
for
your attention
Questions or Comments?

APPENDIX B: Unedited Working Group Draft of SANS 10100-3

Design of concrete structures

SANS 10100 Part 3 — Design of concrete liquid retaining structures

Foreword

[Standard statement on approval by National Committee SABS SC 98-2/ WG0X is inserted here.

This document was published in 2013.]

[The nine chapters of this document are complemented by seven Informative Annexes. These Annexes have been introduced to provide general information on material and structural behaviour which may be used in the absence of information specifically related to the actual materials used or actual conditions of service.]

Background

SANS 10100 Part 3 provides for the design of water retaining structures as derived and adapted from the equivalent Eurocode Standards and Parts. Reference to Eurocode follows logically from the adoption of Eurocode EN 1992-1-1 as the new South African Standard on the design of concrete structures SANS 51992-1-1, to replace SANS 10100-1.

Two Eurocode Parts are relevant to the scope of SANS 10100-3, namely EN 1991-4 *Actions on structures – Part 4: Silos and tanks* and EN 1992-3 *Design of concrete structures – Part 3: Liquid retaining and containment structures* and. In both cases the bulk of the standards are devoted to the containment of granular materials in silos. The Eurocode procedures on the basis of design, actions and structural design of water retaining structures are therefore adapted into a single self-reliant Standard.

Consistent with Eurocode practice, SANS 10100-3 only provides additional procedures for water retaining structures to supplement the general procedures of SANS 51992-1-1. In this manner the consistency of the Eurocode standards are also transferred to the South African standards. In a similar manner SANS 10160-1 provides the equivalent general basis of design procedures provided for by Eurocode EN 1990; general actions on structures are provided for by SANS 10160-2 to -8, as the equivalent of EN 1991.

Historically BS 8007 served as de facto local standard, together with BS 8110 and SANS 10100-1 as its local equivalent. BS 8007 therefore represents present South African practice in the design of concrete water retaining structures. This function of BS 8007 was particularly important when continuity with existing practice was considered in formulating SANS 10100-3.

0. Introduction

0.1 Link of SANS 10100-3 to SANS 51992-1-1

Design complying with the requirements of SANS 10100-3 is deemed to comply with the requirements of SANS 51992-1-1. In addition, SANS 10100 complements SANS 51992-1-1 for the particular aspects of liquid retaining structures.

In using this document in practice, particular regard should be paid to the underlying assumptions and conditions given in 1.3 of SANS 51992-1-1. Particular attention is drawn to EN 206-1 *Concrete - performance, production, placing and compliance criteria.*

The framework and structure of SANS 10100-3 correspond to SANS 51992-1-1,

Where a particular sub-clause of SANS 51992-1-1 is not mentioned in this SANS 10100-3, that sub-clause of SANS 51992-1-1 applies as far as deemed appropriate in each case.

Some clauses of SANS 51992-1-1 are modified or replaced in SANS 10100-3, in which case the modified versions supersede those in SANS 51992-1-1 for the design of liquid retaining structures.

Where a clause in SANS 51992-1-1 is modified or replaced, the new number is identified by the addition of 100 to the original number. Where a new clause is added, it is identified by a number which follows the last number in the appropriate clause in SANS 51992-1-1 with 100 added to it.

A subject not covered by SANS 51992-1-1 is introduced in SANS 10100-1 by a new sub-clause. The sub-clause number for this follows the most appropriate clause number in SANS 51992-1-1.

The numbering of equations, figures, footnotes and tables in SANS 10100-1 follow the same principles as the clause numbering as described above.

0.2 Additional guidance to SANS 10100-3

It should be noted that any product, such as concrete pipes, which are manufactured and used in accordance with a product standard for a watertight product, will be deemed to satisfy the requirements, including detailing, of this code without further calculation.

There are specific regulations for the surfaces of storage structures which are designed to contain foodstuffs or potable water. These should be referred to as necessary and their provisions are not covered in this code.

Table of Contents

- **Section 1 General**

1.1 Scope

Addition after 1.1.2

1.1.3 Scope of Part 3 of SANS 10100

(101) Part 3 of SANS 10100 covers additional rules to those in SANS 51992-1-1 for the design of structures constructed from plain or lightly reinforced concrete, reinforced concrete or prestressed concrete for the containment of liquids.

(102) Rules are given in this Part for the design of those elements of structure which directly support the stored liquids (i.e. the directly loaded walls of tanks or reservoirs).
Other elements which support these primary elements (for example, the tower structure which supports the tank in a water tower) should be designed according to the provisions of SANS 51992-1-1.

(103) This part does not cover the design of:

— Bins or silos for storage of dry bulk materials

— Structures for the storage of hazardous materials the leakage of which could constitute a major health or safety risk.

— The selection and design of liners or coatings and the consequences of the choice of these on the design of the structure.

— Pressurised vessels.

— Floating structures

— Swimming pools with concrete finishing

— Dams

— Hydraulic tunnels

— Gas tightness

(104) This code is valid for contained non-flammable liquids which are at ambient temperatures or at temperatures up to approximately 75°C and of normal pH (approx. 5.5 to 8.5) such as are found in reservoirs, tanks, swimming pools and industrial storage structures.

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(105) For the selection and design of liners or coatings, reference should be made to appropriate specialist literature.

(106) It is recognised that, while this code is specifically concerned with structures for the containment of liquids, the clauses covering design for liquid tightness may also be relevant to other types of structure where liquid tightness is required.

(107) In clauses relating to leakage and durability, this code mainly covers aqueous liquids. Where other liquids are stored in direct contact with structural concrete, reference should be made to specialist literature.

(108) SANS 10100-3 is intended to be used in conjunction with SANS 51992-1-1 and SANS 10160.

1.2 Normative references

The following normative documents contain provisions that, though referenced in this text, constitute provisions of this Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, users of this Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

SANS 10160-1, *Basis of structural design*
SANS 10160-7 – *Thermal actions*
SANS 51992-1-1, South African National Standard *Design of Concrete Structures – Part 1.1: General rules and rules for buildings*
SANS 10160-5 :*Geotechnical design*

1.6 Symbols

Addition after 1.6

1.7 Special symbols used in Part 3 of SANS 10100

Latin upper case symbols

R_{ax} *Factor defining the degree of external axial restraint provided by elements attached to the element considered;*
R_m *Factor defining the degree of moment restraint provided by elements attached to the element considered;*
T_1 *Estimated temperature fall between the hydration peak and ambient temperature at the time of construction;*
T_2 Fall in temperature due to seasonal variations;

Latin lower case symbols

d Effective depth of section;
f_b Average bond strength between immature concrete and reinforcement
f_{ctx} Tensile strength, however defined
$\mathrm{f_{ct}}$ Direct tensile strength of the immature concrete (usually taken at an age of 3 days)
f_{ckT} Characteristic compressive strength of the concrete modified to take account of temperature;

f_y Characteristic strength of the reinforcement
w_{max} Estimated maximum crack width;
s_{max} Estimated maximum crack spacing;
x Depth of neutral axis form compression face of structural member

Greek symbols

α Coefficient of expansion for mature concrete;
ε_{av} Average strain in the element;
ε_{az} Actual strain at level z;
ε_{iz} Imposed intrinsic strain at level z;
ε_{Tr} Transitional thermal strain;
ε_{Th} Free thermal strain in the concrete;
ε_1 Calculated apparent strain using characteristic loads and normal elastic theory;
ε_2 Stiffening effect of concrete between cracks
ρ_{crit} Critical reinforcement ratio

- **Section 2 Basis of design**

2.1 Requirements

2.1.1 Basic requirements

Addition following (3):

(104) The design situations to be considered should comply with SANS 10160 Parts 1, 3, 5 and 7. In addition, for liquid retaining and containment structures made with concrete, the following special design situations may be relevant:

— Operating conditions implying patterns of discharge and filling;
— Thermal effects caused, for example, by stored materials or ambient temperature;
— Requirements for testing of containment structures for water tightness.

2.1.3 Design working life, durability and quality management

Replacement of (1) with (1) The rules for design working life, durability and quality management are given in SANS 10160-1.

Addition after (1)

(102) The life of a completed structure depends on the durability of its components. A liquid retaining structure should be designed and constructed using good quality materials and workmanship to provide a design life of the structure of at least 50 years unless specified otherwise by the User. Some components of the structure (such as jointing materials) may have a shorter life than the structural concrete and may require renewal during the life of the structure.

(103) In order to ensure the durability criteria are satisfied, the recommendations for the following, as set out in Section 4 of this Standard, needs to be carefully considered:

a) Cover to reinforcement;
b) Concrete grade;
c) Cement content;
d) Water: Binder ratio;
e) Curing of recently cast concrete
f) Permeability considerations.

NOTE Concrete mixes with increased cement content will provide extra protection for the reinforcement, but will also result in higher heat of hydration and require extra reinforcement in accordance with Section 7.

(104) Sufficient measures should be implemented in order to ensure compliance with requirements and specifications as well as workmanship during construction with regards to the following aspects, but not limited thereto:

a) Quality of the concrete in the structure in terms of both constituent materials of batching, mixing, curing, etc.;
b) Quality of the steel reinforcement and prestressing tendons;
c) Good construction practice during execution of the works.

(105) Environmental Influences and Considerations: Exposure conditions are chemical and physical conditions to which the structure is exposed in addition to the mechanical actions. The following exposure conditions should be carefully considered in the design of water retaining structures:

a) The use of the structure;
b) Risk of corrosion or chemical attack;
c) Corrosion induced by carbonation;
d) Corrosion induced by chloride;
e) Corrosion induced by chloride from sea water;
f) Freeze/thaw attack;
g) Chemical attack, including corrosive fumes from sewage;
h) Solutions of acids or sulphate salts; Structures used for storage of such liquids should be lined to prevent leaching of its content into the groundwater.
i) Chloride contained in the concrete;
j) Soft water
k) Alkali aggregate reactions.

The provisions of SANS10100-2 Section 6.2 are relevant in this regard.

(106) Potential physical attack arising during and after construction from any of the following should also be considered during the design of water retaining structures:

a) Temperature change;
b) Abrasion;
c) Possible water penetration.

(107) Specifications: The following items shall be considered for inclusion in the specification for the structure to ensure that the design assumptions for both materials and workmanship are realized during construction:

a) Dimensional tolerances with regards to reinforcement and prestressing tendons;

b) Dimensional tolerances with regards to concrete placement;

c) Positions and details of all construction and movement joints;

d) Method and duration for the curing of concrete

e) The requirements for the test for liquid retention or exclusion, and any period during which autogenous healing is permissible.

2.3 Basic variables

2.3.1 Actions and environmental influences

2.3.1.1 General

Addition after (1):

(102) Special consideration should be given to wave actions during seismic action. Refer to specialist literature, such as Annex A of the New Zealand Standard DZ3106 in this regard. It is expected that in most cases service loads rather than ULS seismic loads will govern the reinforcing design.

(103) Load combinations shall be in accordance with SANS 10160-1 and shall include both the serviceability- and ultimate limit states.

(104) During water tightness test conditions the combination rules and partial factors for the accidental limit state given in SANS10106-1 should be applied. However, accidental actions, such as seismic actions, need not be considered to act during water tightness test conditions.

2.3.1.2 Thermal effects

Addition after (3)

(104) Stresses resulting from restraint of thermal expansion may be ignored if the number of load cycles due to thermal expansion is such that there is no risk of fatigue failure or cyclic plastic failure.

(105) Loads due to thermal gradients caused by the liquid stored shall be taken into account.

2.3.1.3 Differential settlements/movements

Addition after (4)

(105) Allowance shall be made for the effects of any adverse soil pressures on walls.

(106) No relief shall be given for beneficial soil pressure effects on the walls

(107) Settlement loads shall be taken into account where uneven settlement can be expected during the lifetime of the structure.

(108) Site conditions which could give rise to possible ground movement, such as the possibility of geological faults or subsidence due to mining, shall be assessed. In cases where it is not possible to avoid sites where such conditions occur, the following measures should be considered:

a) Dividing the structure into sections to limit the possibility of differential movement;
b) Providing specially designed joints to facilitate movement;
c) Using prestressing techniques to limit possible cracking;
d) Providing for flexibility of service pipework;
e) In areas where mining activities are present, providing for foundations that will reduce horizontal forces from ground movement; and
f) Providing underfloor drainage to limit possible uplift where groundwater is not considered in the design and in situations where leakage occurs.

(109) Alternative measures may also be necessary depending on the predicted degree of subsidence of the founding material.

Addition after 2.3.1.4

2.3.1.5 Liquid induced loads

(101) Loads due to liquids should be calculated after considering:

– a defined range of liquids to be stored in the tank;
– the geometry of the tank;
– the overflow level of the tank;– the maximum possible depth of liquid in the tank.

(102) The characteristic value of pressure *p* should be determined as:

$$p(z) = \gamma z \qquad \text{(A.1)}$$

where:

z is the depth below the liquid surface;
γ is the unit weight of the liquid.

NOTE 1: This is valid for static conditions in all types of tanks, but tanks in which dynamic phenomena may occur are not included.

(103) The densities given in SANS 10160-2 should be used.

(104) During operation, the load due to the contents shall be the weight of the liquid to be stored from maximum design liquid level (over flow level) to empty.

(105) During tightness testing and ultimate limit state, the load due to the contents shall be the weight of the liquid test medium from maximum test liquid level (top of wall level) to empty.

2.3.1.6 Internal pressure loads

(101) During operation, the internal pressure load shall be the load due to the specified minimum and maximum values of the internal pressure.

(102) During tightness testing, the internal pressure load shall be the load due to the specified minimum and maximum values of the test internal pressure.

(103) Where the venting system to a structure may be susceptible to blockage or impediment, a rational analysis shall be used to determine the suction (negative) pressures arising during tank discharge at the peak rate. This analysis shall consider the possible adiabatic nature of the process.

2.3.1.7 Self-weight loads

(101) The self-weight loads on the structure shall be considered as those resulting from the weight of all component parts of the structure and all components permanently attached to the structure.

(102) Numerical values should be taken from SANS 10160-2 Annex A

(103) Covering material on the roofs of structures may be taken as permanent actions but due consideration should be given for additional actions that may be experienced during construction and causing the design action for service conditions to be exceeded.

2.3.1.8 Insulation

(101) The insulation loads shall be those resulting from the self-weight of the insulation.

(102) Numerical values should be taken from SANS 10160-2 Annex A.

2.3.1.9 Imposed loads

(101) The distributed imposed load should be taken from SANS 10160-2.

(102) The concentrated imposed load should be taken from SANS 10160-2.

(103) If client/user requirements give rise to higher loads than specified in SANS101060, the design engineer should ensure adequacy of the design loads.

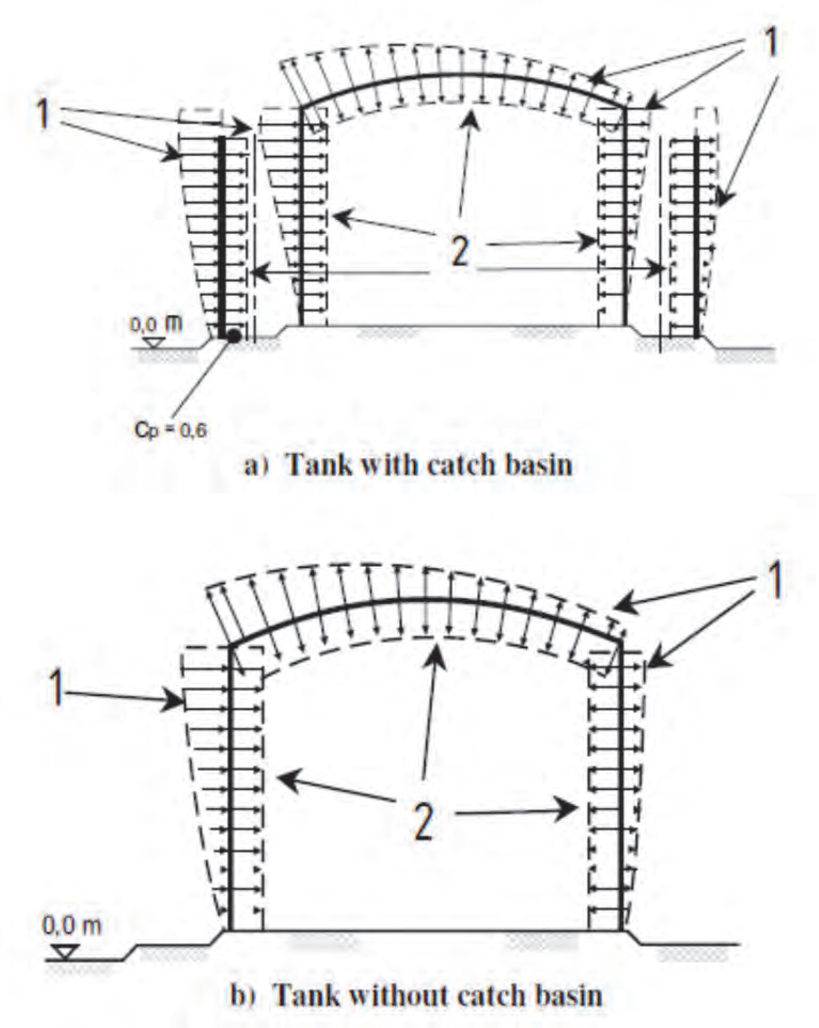
2.3.1.10 Wind

(101) The loads should be taken from SANS 10160 Part 3

(102) In addition, the following pressure coefficients may be used for circular cylindrical tanks, see figure A.1:
a) Internal pressure of open top tanks and open top catch basin: C_p = -0,6.
b) Internal pressure of vented tanks with small openings: C_p = -0,4.
c) Where there is a catch basin, the external pressure on the tank shell may be assumed to reduce linearly with height.

(103) Due to their temporary character, reduced wind loads may be used for erection situations according to SANS 10160 Parts 3 and 8.

(104) Terrain topography (for example hills and cliffs) shall be taken into account as taken from SANS 10160 Part 3.



Key
1. C_p according to SANS 10160 Part 3
2. C_p = 0,4 vented structure only
Figure A.1: Pressure coefficients for wind loading on a circular cylindrical structure

2.3.1.11 Loads resulting from connections

(101) Loads resulting from pipes, valves and other items connected to the structure and loads resulting from settlement of independent item supports relative to the structure's foundation shall be taken into account. Pipework shall be designed to minimize loadings applied to the structure.

2.3.1.12 Flotation

(101) A structure subject to groundwater pressure should be designed to resist flotation. The structure should be verified for the condition of static equilibrium in accordance with SANS 10160-1.

(102) Flotation should be considered as an ultimate limit state EQU failure mode according to SANS10160-1. However, the partial factor for permanent un-favourable load may be reduced to $\gamma_G = 1.1$, except in cases where higher uncertainty is associated to the assessed groundwater level, in which case the SANS10160-1 recommended value of $\gamma_G = 1.2$ should be used. For cases where higher uncertainty is present in the favourable action, such as significant roof gravel loads, the partial factor for favourable action should be assessed by the designer and decreased from 0.9 to a more appropriate value.

(103) The uplift may be reduced by:

(a) Providing effective drainage to prevent a build-up of external water as far as local conditions permit;

(b) Providing pressure relief devices discharging into the vessel (where the entry of external groundwater is acceptable).

2.3.1.13 Seismic loads

(101) Refer to SANS 10160-4 and EN 1998-4 which also sets out the requirements for seismic design.

2.3.1.14 Accidental actions

(101) The loads should include the consequences of events such as external blast, impact, adjacent external fire, explosion, leakage from the inner tank, and overfilling of the inner tank.

NOTE: These loads may be specified by the design engineer in accordance with user requirements for the individual project.

2.3.2 Material and product properties

Addition after 2.3.2.2

2.3.2.3 Properties of concrete with respect to watertightness, mix proportions and workability

(101) Concrete used for water retaining structures should have a low permeability. This is important not only for its direct effect on leakage but also because it is one of the main factors influencing durability, resistance to leaching, chemical attack, erosion, abrasion, frost damage and the protection against corrosion of the embedded reinforcement and prestressing tendons.

(102) If the minimum thicknesses of the member given in 9.11 (102) are used then a lower water-binder ratio may be required and, consideration should be given to a limitation to the maximum aggregate size.

(103) Good concrete practice in terms of mix proportions, aggregates and curing would generally ensure an adequately impermeable concrete. It is also of critical importance to ensure full compaction without segregation which can only be obtained by means of concrete mix with sufficient workability within water content limits. The workability of the concrete should be specified in relation to the equipment and methods of handling and compaction. Further information may be found in Section 4.

(104) In order to ensure compliance with the requirements in terms of water tightness, the design should also be in accordance with Sections 3 and 4 of this code.

2.3.2.4 Surface preparation

(101) Surface preparation should be carefully considered when specified and should include consideration of the following aspects:

a) Contact between the foundation and the structure;
b) Contact between consecutive concrete placements;
c) Rate of concrete placement which could result in additional surface preparation requirements;
d) The use of admixtures in order to enhance bond and effective sealing at interfaces.

(102) Surface preparation should adhere to the provisions in SANS 1200. Further information may be found in informative Annex N.

2.3.2.5 Surface finish

(101) The required exposure conditions for the surfaces of all members should be clearly defined at the onset of the design process and each member designed in accordance with the crack width limits in Section 7 of this standard.

(102) In cases where significant efflorescence or staining of the surface of the structure would be considered to be unacceptable, recommendations for critical aesthetic appearance should also be specified by the designer.

(103) The type of surface finish to be specified for any given member will depend on its position in the structure, its exposure, whether or not it is to receive an applied finish and the properties of the liquid to be retained. It is not possible to ensure that any concrete member will remain uncracked. It is recommended, therefore, that any member that is to be permanently exposed to view is provided with a profile and type of finish that tend to minimize the effects of any surface marking.

Addition after 2.4.2.5

2.4.2.6 Partial factors for actions

(101) The partial factors for actions shall be applied according to SANS 10160-1.

(102) The value of the partial factor for the liquid induced loads during operation (see 2.3.1.5(104)) is g_F = 1,20.

(103) The value of the partial factor for the liquid induced loads during test (see 2.3.1.5(105)) is g_F = 1,00.

(104) For accidental design situations, the value of the partial factor for the variable actions is g_F = 1,00.

Addition after 2.7

2.8 Design situations

2.8.1 General

(101) All structures required to retain liquids should be designed for both the full and empty conditions, and the assumption regarding the arrangement of loading should be such as to cause the most critical effects.

(102) Particular attention should be paid to possible sliding and overturning. Liquid loads should allow for the actual density of the contained liquid as well as possible transient conditions, e.g. suspended or deposited silt or grit where appropriate.

(103) Thermal expansion of a roof should be minimized by single sized coarse aggregate or other long lasting protection against solar radiation. Thermal expansion of a roof results in forces and hence moments being applied to the walls. Where the roof slab is not relied upon to provide lateral restraint to the reservoir wall(s), these forces can be minimized by providing a sliding joint between the top of the wall and the underside of the roof. . This can be either a temporary free sliding joint that is not cast into a fixed or pinned connection until the aggregate or other solar protective material is placed on the roof, or a permanently sliding joint of assessed limiting friction capacity.

(104) Movement of a roof may occur also where there are substantial variations in the temperature of the contained liquid. Where a roof is rigidly connected to a wall, this may lead to additional loading in the wall that should be considered in the design.

2.8.2 Structural design situations (Limit States Design)

2.8.2.1 Ultimate Limit State

(101) For ultimate limit state conditions, liquid levels should be taken to the tops of walls assuming that the liquid outlets are blocked.

(102) Section 6 of this Standard should also be considered.

2.8.2.2 Serviceability Limit State

(101) For serviceability limit state conditions the liquid level should be taken to the actual operating level or the level of the overflow, as appropriate to working conditions.

(102) Allowance should be made for the effects of any adverse soil pressures on walls, according to the compaction and/or surcharge of the soil and the condition of the structure during construction and in service. No relief should be given for beneficial soil pressure effects on the walls of containment structures in the full condition.

(103) Section 7 of this Standard should also be considered.

2.9 Structural considerations

2.9.1 Joints

2.9.1.1 General

(101) Considerations during design for construction and movement joints should be in accordance with Section 9 of this Standard.

2.9.1.2 Construction Joints

(101) Full structural continuity is assumed in design at a construction joint. The positions of construction joints should be specified by the designer and indicated on the drawings.

2.9.1.3 Movement Joints

(101) Structures should be provided with movement joints if effective and economic means cannot otherwise be taken to avoid unacceptable cracking.

(102) The following types of movement joints should be distinguished between during the design of the structure:

- Expansion joint;
- Complete contraction joint;
- Partial contraction joint;
- Hinged joint; and

- Sliding joint.

More information on these can be found in informative Annex N.

(103) Careful consideration should be given to the specification of suitable movement joints where seismic action, including seismic action induced by mining, needs to be provided for. Sliding joints are generally not recommended in this case.

2.9.2 Deflections

(101) The recommendations for span/effective depth ratios given in SANS 51992-1-1 Table 7.4N apply to horizontal members carrying uniformly distributed loads. For a cantilever wall which tapers uniformly away from the support and which is loaded with a triangular pressure, a net reduction factor should be applied to the above ratios if the thickness at the top is less than 0.6 times the thickness at the base. This reduction factor can be assumed to vary linearly between 1,0 and 0,78 where the thickness at the top varies between 0,6 and 0,3 times the thickness at the bottom.

(102) In addition, allowance should be made for the significant additional deflection which occurs at the top of the wall due to rotation, if the pressure distribution under the base is triangular or very asymmetrically trapezoidal. Limits for deflections will normally be those for non-liquid-retaining structures since only in exceptional circumstances will deflections be more critical with regard to freeboard, drainage or redistribution of load. Retaining walls should be backfilled in even layers around the structure, the thickness of the layers being specified by the design engineer. Over compaction adjacent to the wall should be avoided otherwise large differential deflections (and sliding) of the wall may occur.

(103) At least 75% of the liquid load should be considered as permanent when calculating deflections.

2.9.3 Testing of the structure

2.9.3.1 General

(101) Testing for liquid tightness should be in accordance with 2.11.2 and 2.11.3

2.9.3.2 Testing of structures for liquid retention

(101) For a test of liquid retention, the structure should be cleaned and initially filled to the normal maximum level with the specified liquid (usually water) at a uniform rate of not greater than 2 m in 24 h. When first filled, the liquid level should be maintained by the addition of further liquid for a stabilizing period while absorption and autogenous healing take place. The stabilizing period may be 7 days for a maximum design crack width of 0.1 mm or 21 days for 0.2 mm or greater.

After the stabilizing period the level of the liquid surface should be recorded at 24 h intervals for a test period of 7 days. During this 7-day test period the total permissible drop in level, after allowing for evaporation and rainfall, should not exceed 1/500th of the average water depth of the full tank, 10 mm or another specified amount.

(102) Notwithstanding the satisfactory completion of the test, any evidence of seepage of the liquid to the outside faces of the liquid-retaining walls should be assessed against the requirements of the specification. Any necessary remedial treatment of the concrete, cracks, or joints should, where practicable, be carried out from the liquid face. When a remedial lining is applied to inhibit leakage at a crack it should have adequate flexibility and longevity and have no reaction with the stored liquid.

(103) Should the structure not satisfy the 7-day test, then after the completion of the remedial work it should be refilled and if necessary left for a further stabilizing period; a further test of 7 days' duration should then be undertaken in accordance with this clause.

2.9.3.3 Testing of roofs

(101) The roofs of liquid-retaining structures should be watertight and should, where practicable, be tested on completion by flooding the roof with water to a minimum depth of 25 mm for 24 h or longer if so specified. Where it is impracticable, because of roof falls or otherwise, to contain a 25 mm depth of water, the roof should have water applied by a continuous hose or sprinkler system to provide a sheet flow of water over the entire area of the roof for not less than 6 h. In either case the roof should be considered satisfactory if no leaks or damp patches show on the soffit.

(102) Should the structure not satisfy either of these tests, then after the completion of the remedial work it should be retested in accordance with this clause. The roof insulation covering should be completed as soon as possible after satisfactory testing.

2.10 Operational considerations

2.10.1 Statutory safety requirements

(101) The designer should take account of the safety requirements appropriate to the construction and operation of the structure issued by the Health and Safety Act, the National Building Regulations and SANS requirements.

2.10.2 Provision for access

(101) In enclosed structures the provision of access for personnel is required for inspection, cleaning and testing. At least two access hatches should be provided at opposite ends of the structure and at least one in each compartment. The hatches should be of sufficient size to enable personnel wearing breathing apparatus to enter (e.g. a minimum of 600 mm x 900 mm), and it should be possible to lock the hatches in both the open and closed positions. It is preferable to provide a platform under an access hatch. Access ladders and walkways, where provided, should be in accordance with Occupational Health & Safety Act, National Building Regulations and SANS requirements.

2.10.3 Ventilation

(101) Harmful and/or explosive gases may collect in enclosed structures, and provision should be made for adequate ventilation to limit any possible dangerous accumulations to acceptable levels.

2.10.4 Toxic materials

(101) Toxic materials should not be used, except where their toxicity exists only for a short period prior to commissioning and within acceptable limits.

2.10.5 Maintenance, inspection and operation

(101) The completed structure should be inspected regularly. The designer should provide the User with a statement listing the items requiring examination during such maintenance inspections, and stating the recommended frequency of such inspections. The inspection should include examination of the concrete for cracking, leakage, surface deterioration and settlement. Particular attention should be paid to any rust stains that might indicate corrosion of the reinforcement. Any defects should then be corrected. Movement joints should be cleaned and the joint materials replaced if necessary. The designer should also prepare a schedule of precautions to be taken by the user in order to prevent the structure being damaged or the design life shortened during use. The schedule should be included in the commissioning documentation.

- **Section 3 Materials**

3.1 Concrete

3.1.1 General

Additional after (102)

(103) The effect of temperature on the properties of concrete should be taken into consideration in design. Further information may be found in informative Annex O.

(104) The effect of the concrete mix design on the heat of hydration should be considered. Further information may be found in Section 4.

3.1.3 Elastic deformation

Replace (5) by:

(105) Unless more accurate information is available, the linear coefficient of thermal expansion may be taken as equal to 10 x 10^{-6} K^{-1}. It should be noted, however, that

coefficients of thermal expansion of concrete vary considerably depending on the aggregate type and the moisture conditions within the concrete.

3.1.11 Heat evolution and temperature development due to hydration

(101) Where conditions during the construction phase are considered to be significant, the heat evolution characteristics for a particular cement should generally be obtained from tests. The actual heat evolution should be determined taking account of the expected conditions during the early life of the member (e.g. curing, ambient conditions). The maximum temperature rise and the time of occurrence after casting should be established from the mix design, the nature of the formwork, the ambient conditions and the boundary conditions.

3.2 Reinforcing steel

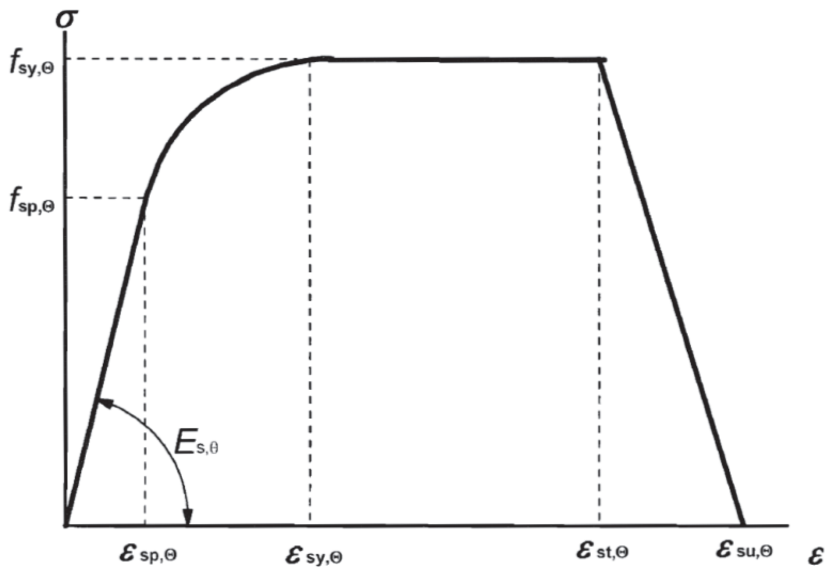
(1)P The strength and deformation properties of reinforcing steel at elevated temperatures shall be obtained from the stress-strain relationships specified in Figure 3.3 and Table 3.2 (a or b). Table 3.2b may only be used if strength at elevated temperatures is tested.

(2) The stress-strain relationships given in Figure 3.3 are defined by three parameters:

- the slope of the linear elastic range $E_{s,\theta}$
- the proportional limit $f_{sp,\theta}$
- the maximum stress level $f_{sy,\theta}$

(3) Values for the parameters in (2) for hot rolled and cold worked reinforcing steel at elevated temperatures are given in Table 3.2. For intermediate values of the temperature, linear interpolation may be used.

(4) The formulation of stress-strain relationships may also be applied for reinforcing steel in compression.



Range	Stress $\sigma(\theta)$	Tangent modulus
$\varepsilon_{sp,\theta}$	$\varepsilon E_{s,\theta}$	$E_{s,\theta}$
$\varepsilon_{sp,\theta} \leq \varepsilon \leq \varepsilon_{sy,\theta}$	$f_{sp,\theta} - c + (b/a)[a^2 - (\varepsilon_{sy,\theta} - \varepsilon)^2]^{0,5}$	$\dfrac{b(\varepsilon_{sy,\theta} - \varepsilon)}{a\left[a^2 - \left(\varepsilon - \varepsilon_{sy,\theta}\right)^2\right]^{0,5}}$
$\varepsilon_{sy,\theta} \leq \varepsilon \leq \varepsilon_{st,\theta}$	$f_{sy,\theta}$	0
$\varepsilon_{st,\theta} \leq \varepsilon \leq \varepsilon_{su,\theta}$	$f_{sy,\theta}[1-(\varepsilon - \varepsilon_{st,\theta})/(\varepsilon_{su,\theta} - \varepsilon_{st,\theta})]$	-
$\varepsilon = \varepsilon_{su,\theta}$	0,00	-
Parameter *)	$\varepsilon_{sp,\theta} = f_{sp,\theta} / E_{s,\theta}$ $\quad \varepsilon_{sy,\theta} = 0,02$ $\quad \varepsilon_{st,\theta} = 0,15$ $\quad \varepsilon_{su,\theta} = 0,20$ Class A reinforcement: $\varepsilon_{st,\theta} = 0,05$ $\quad \varepsilon_{su,\theta} = 0,10$	
Functions	$a^2 = (\varepsilon_{sy,\theta} - \varepsilon_{sp,\theta})(\varepsilon_{sy,\theta} - \varepsilon_{sp,\theta} + c/E_{s,\theta})$ $b^2 = c\,(\varepsilon_{sy,\theta} - \varepsilon_{sp,\theta})\,E_{s,\theta} + c^2$ $c = \dfrac{(f_{sy,\theta} - f_{sp,\theta})^2}{(\varepsilon_{sy,\theta} - \varepsilon_{sp,\theta})E_{s,\theta} - 2(f_{sy,\theta} - f_{sp,\theta})}$	

*) Values for the parameters $\varepsilon_{pt,\theta}$ and $\varepsilon_{pu,\theta}$ for prestressing steel may be taken from Table 3.3. Class A reinforcement is defined in Annex C of EN 1992-1-1.

Figure 3.3: Mathematical model for stress-strain relationships of reinforcing and prestressing steel at elevated temperatures (notations for prestressing steel "p" instead of "s")

Table 3.2a: Class N values for the parameters of the stress-strain relationship of hot rolled and cold worked reinforcing steel at elevated temperatures

Steel Temperature θ [°C]	$f_{sy,\theta} / f_{yk}$		$f_{sp,\theta} / f_{yk}$		$E_{s,\theta} / E_s$	
	hot rolled	cold worked	hot rolled	cold worked	hot rolled	cold worked
1	2	3	4	5	6	7
20	1,00	1,00	1,00	1,00	1,00	1,00
100	1,00	1,00	1,00	0,96	1,00	1,00

5.3 Prestressing steel

(1) The strength and deformation [AC1) properties of prestressing steel at elevated temperatures should be obtained by the same (AC1] mathematical model as that presented in 3.2.3 for reinforcing steel.

(2) Values for the parameters for cold worked (wires and strands) and quenched and tempered (bars) prestressing steel at elevated temperatures are given by $f_{py,\theta} / (\beta f_{pk})$, $f_{pp,\theta} / (\beta f_{pk})$, $E_{p,\theta} / E_{p}$, $\varepsilon_{pt,\theta}$ [-], $\varepsilon_{pu,\theta}$ [-]. The value of β is given by the choice of Class A or Class B.

β is equal to 0,9 (see Table 3.3).

Table 3.3: Values for the parameters of the stress-strain relationship of cold worked (cw) (wires and strands) and quenched and tempered (q & t) (bars) prestressing steel at elevated temperatures

Steel temp. θ [°C]	$f_{py,\theta} / (\beta f_{pk})$			$f_{pp,\theta} / (\beta f_{pk})$		$E_{p,\theta} / E_p$		$\varepsilon_{pt,\theta}$ [-]	$\varepsilon_{pu,\theta}$ [-]
	cw		q & t	cw	q & t	cw	q & t	cw, q&t	cw, q&t
	Class A	Class B							
1	2a	2b	3	4	5	6	7	8	9
20	1,00	1,00	1,00	1,00	1,00	1,00	1,00	0,050	0,100
100	1,00	0,99	0,98	0,68	0,77	0,98	0,76	0,050	0,100

Note: For intermediate values of temperature, linear interpolation may be used.

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- **Section 4 Durability and cover to reinforcement**

4.2 Environmental conditions

Addition after 4.2 (3)

(104) The minimum exposure class for water retaining structures shall be XC2 / XS2.

Addition after 4.4.1.2 (4)

4.4.1.2 (105) The minimum cover values for reinforcement and prestressing tendons in normal weight concrete taking account of the exposure classes and the structural classes is given by $c_{min,dur}$. The Structural Class for concrete water retaining structures is S4 for the indicative concrete strengths given in Annex E of SANS 51992-1-1 and the recommended modifications to the structural class is given in Table 4.3N of SANS 51992-1-1. The values of ***c*,dur** are given in Table 4.4N (reinforcing steel) and Table 4.5N (prestressing steel).

Addition after 4.3 (2)

4.3.1 Concrete mix design for durability, including provision to control heat of hydration

4.3.1.1 General

This section gives methods of specifying, producing and assessing concrete for compliance that will in general ensure that the strength, durability and impermeability will be adequate for liquid-retaining structures. The recommendations in SANS 10100-2 apply, except where these are amended by this code.

4.3.1.2 Materials

4.3.1.2.1 Cements

Only common cements conforming to, SANS 50197-1 – Cement – Part 1: Composition, specifications and conformity criteria for common cements, shall be used.

NOTE. It is illegal to sell common cement in South Africa without a regulatory letter of authority (LOA) number, which indicates compliance with SANS 50197-1 or EN 197-1.

4.3.1.2.2 Portland cement extenders

Only the following Portland cement extenders conforming to SANS 1491,shall be used as an additional extension (normally at the site of concrete mixing) to a common cement:-

- SANS 1491:Part 1 – ground granulated blast furnace slag (GGBS).
- SANS 1491:Part 2 – fly ash (FA).
- SANS 1491:Part 3 – silica fume (SF).

The use of either GGBS or FA, will be primarily to reduce the maximum heat of hydration temperature attained and thereby reduce the risk of thermal cracking.

If used, the role of SF will primarily be that of a concrete durability enhancer. The use of SF will normally be in significantly minor quantities (0-15% cement replacement suggested – percentages on the high end of this scale will require specialist knowledge and admixtures to ensure workability), compared to those of GGBS and FA. In most cases, it will be used in conjunction with either GGBS or FA.

NOTE. Exclusions can be made for other commonly used common cement extenders, not conforming to any current national standard e.g. Corex slag (GGCS). When using GGCS as an additional extension, it is recommended that it is used in conjunction with one or more approved Portland cement extenders i.e. in such a way that both a similar heat of hydration increase and similar maximum heat of hydration temperature are attained, as an equivalent additional GGBS and/or FA extension. Note that the use of GGCS as an extender on its own, in most cases, will not reduce the heat of hydration and may even increase it. Further exclusions may be made for accepted "inert" extenders such as finely ground limestone or similar.

4.3.1.2.3 Aggregates

Aggregates to be used should be submitted for testing, according to critical tests identified in SABS 1083. Ideally the aggregates should comply with the critical tests identified in SABS 1083. It is accepted that in some cases (only practical aggregate available or aggregates sourced from remote, temporary quarries/borrow pits/rivers/etc.), where aggregates do not conform to the limits imposed by critical tests, exceptions can be made where accepted methods may be adopted in order to overcome the shortcomings.

Aggregate absorption should generally not be greater than 3%. In the case of an aggregate exceeding an absorption of 1.5%, the aggregate shall be treated with potable water in such a way that the aggregate absorption is eliminated i.e. saturated surface dry (SSD) state. This is normally effectively achieved, by soaking affected aggregate stockpiles with potable water (ensure that soaked stockpiles are adequately drained).

Coarse aggregates with a low coefficient of thermal expansion are preferred (refer to appropriate chapter on Thermal Properties Of Concrete, found in Fulton's Concrete Technology, various editions).

4.3.1.2.4 Water

Water used in the mixing of concrete should ideally be potable. In remote areas where potable water may not be practically available and water is sourced from rivers or boreholes, it must be submitted for testing, for suitability for use in concrete **(**refer to appropriate chapter on Mixing Water, found in Fulton's Concrete Technology, 9^{th} edition).

4.3.1.2.5 Admixtures

In order to achieve the durability tolerances imposed and mix water limits recommended, the use of appropriate admixtures is recommended. Any admixtures used must conform to an accepted international standard.

Contractors carrying out their own site batching should seek specialist advice from reputable admixture suppliers.

4.3.1.3 Mix proportions

It is imperative that the rate of heat of hydration increase and the maximum heat of hydration temperature attained are controlled, thereby reducing the potential for thermal cracking. In order to achieve this, for the majority of common cements, an extender should be added (normally at the site of concrete mixing). Suggestions are provided in Table 1.

The need to meet the requirements of the South African concrete durability testing specifications and at the same time minimise the heat of hydration factors, should be the determining factors in selecting the type of cement used. Where minimum additional extension is suggested as being zero in Table 1, it has generally been assumed that the heat of hydration factors inherent in these cements, is at a sufficiently low level not to warrant additional extension. Where minimum additional extension is suggested as being greater than zero, the role of the minimum additional extension is to lower the heat of hydration factors inherent in these cements, to a similar level as those cements, where cement extension is suggested as being zero. Where alternative extenders other than GGBS or FA are proposed, refer to comments in 4.3.1.2.2.

It should be noted that due to the geometry of a recently cast concrete element and/or when site conditions dictate, despite the adoption of the precautions suggested in Table 1, concrete temperature monitoring may be warranted in critical locations, in order to establish that:-

- Maximum acceptable hydration temperature is not being exceeded.
- Acceptable hydration temperature differentials between the cooler and hotter locations are being maintained.

Table 4.1:- Minimum additional extender required to control heat of hydration

Range Name	Classification	Clinker content of cement (%)	Minimum additional FA extension (%)	Minimum additional GGBS extension (%)
Portland cement	CEM I 52.5	95-100	45	55
Portland cement	CEM I 42.5	95-100	25	35
Portland cement	CEM II 52.5	80-94	35	45
Portland-slag cement	CEM II A-S	80-94	35	45
Portland-slag cement	CEM II B-S	65-79	25	30
Portland-silica fume cement	CEM II A-D	90-94	45	55
Portland-pozzolana cement	CEM II A-P	80-94	30	40
Portland-pozzolana cement	CEM II B-P	65-79	15	20
Portland-pozzolana cement	CEM II A-Q	80-94	30	40
Portland-pozzolana cement	CEM II B-Q	65-79	15	20
Portland-fly ash cement	CEM II A-V	80-94	30	40
Portland-fly ash cement	CEM II B-V	65-79	15	20
Portland-fly ash cement	CEM II A-W	80-94	30	40
Portland-fly ash cement	CEM II B-W	65-79	15	20
Portland-limestone cement	CEM II A-L	80-94	25	35
Portland-limestone cement	CEM II B-L	65-79	0	0
Portland-limestone cement	CEM II A-LL	80-94	25	35
Portland-limestone cement	CEM II B-LL	65-79	0	0
Portland-composite cement	CEM II A-M	80-94	30	40
Portland-composite cement	CEM II B-M	65-79	15	20
Blastfurnace cement	CEM III A	35-64	0	0
Blastfurnace cement	CEM III B	20-34	0	0
Pozzolanic cement	CEM IV A	65-89	15	20
Pozzolanic cement	CEM IV B	45-64	0	0
Composite cement	CEM V A	40-64	0	0

NOTE. As an example, a minimum additional extension of 20% means that the total cementitious content incorporated in the mix design, should be made up of 80% of the appropriate Range Name cement plus 20% extender e.g. 400 kg total cementitious content = 320 kg (80%) appropriate Range Name cement + 80 kg (20%) extender. Unless an intimate knowledge of the performance of the cement being used is known, the default suggested minimum additional extension should be used.

NOTE**.**

- **w/c ratio** implies water/cement ratio, where cement is common cement.
- **w/b ratio** implies water/binder ratio, where binder can be solely common cement, but more often common cement + approved additional common cement extender (latent hydraulic or pozzolanic).

Mix proportions are performance based, without restrictions imposed on binder contents. Other restrictions and recommendations do however exist and need to be taken into account by the concrete mix designer.

The 28 day characteristic compressive strength for standard water retaining structures, should not be less than C29/35 MPa (cylinder strength/cube strength equivalents). In non-standard water retaining structures such as those incorporating prestressed concrete, this characteristic compressive strength may be appropriately increased. In all cases, the objectives of the mix design will be the following i.e. in conjunction with each other:-

(a) Use a w/b ratio applicable to the common cement being used plus any additional extender addition, which will achieve the stipulated 28 day characteristic compressive strength by an appropriate margin of safety (depending on the sophistication of the concrete manufacturer's controls). It should be noted that the target compressive strength thus achieved, should not exceed the 28 day characteristic compressive strength excessively (typically 3-6 MPa, 8 MPa maximum suggested) i.e. if this is not controlled, it will negate the objective of minimising the effects of heat of hydration. From a durability perspective, a w/b ratio ≤ 0.55 is recommended for safety margin guidance purposes.

(b) A maximum free water content (excluding aggregate absorption water) of 190 litres/m^3 is recommended. Higher free water contents will tend to increase the risk of not meeting the durability testing specifications. Where for whatever reason 190 litres/m^3 free water content is not achievable, suitability of the concrete for use will be decided by its ability to pass durability testing, in conjunction with the heat of hydration factors minimised to acceptable levels – measured against a reference concrete, which conforms to all the recommended objectives. In the case of concrete subject to aggressive water, specialist advice should be sought.

(c) Any mix design submitted (concrete manufactured, cured and evaluated in a laboratory), will undergo the following South African concrete Durability Index (DI) testing specifications:-

– Oxygen Permeability Index (OPI).
– Water Sorptivity.
– Chloride Conductivity. **<u>NOTE</u>: Only to be conducted where necessary i.e. highly aggressive environments.**

Acceptance limits for the abovementioned laboratory evaluations, shall be specified by either the client and/or the design engineer. In cases, where circumstances may dictate that the specification of practical acceptance limits are not possible, it is suggested that the following acceptance limits (which have been successfully used in South Africa) are adopted, as described and tabled below:-

Acceptance limits for Water Sorptivity and Oxygen Permeability at an age of 28 days are tabled below:-

XC2 Exposure Class		
Acceptance category	**Test No./Description, unit**	
	Water Sorptivity, mm/(h)$^{0.5}$	**Oxygen Permeability, log scale**
Concrete manufactured, cured and evaluated in a laboratory	<10.0	>9.6
Full acceptance of in-situ concrete	To be specified by client and/or design engineer	To be specified by client and/or design engineer
Conditional acceptance of in-situ concrete (with remedial measures)	To be specified by client and/or design engineer	To be specified by client and/or design engineer
Rejection	To be specified by client and/or design engineer	To be specified by client and/or design engineer

Acceptance limits for Chloride Conductivity at an age of 28 days are tabled below:-

Environmental Class	70:30 CEM I : FA	50:50 CEM I : ggbs	50:50 CEM I : ggcs	90:10 CEM I : SF
XS 1 (Exposed to airborne salt)	2.50	2.80	3.50	0.80
XS 2a (Permanently submerged in salt water)	2.15	2.30	2.90	0.50
XS 2b, XS 3a (XS 2a + tidal splash + spray zones)	1.10	1.35	1.60	0.35
XS 3B (XS 3a + exposed to abrasion)	0.90	1.05	1.30	0.25

NOTE. **Based on the composition of the cementitious content in a mix design, values should be interpolated.**

Acceptance limits for concrete other than that manufactured, cured and evaluated in a laboratory (under controlled conditions), may either be maintained at those specified for laboratory concrete or reduced to acceptable levels by the client and/or design engineer. It is suggested that the reduced acceptance limits take cognizance of the fact that site conditions by their nature are uncontrolled and variable, but that they are not reduced to levels which do not ensure that acceptable levels of durability are achieved.

It is envisaged that a future national South African standard, will provide guidance on the approach to achieving acceptable levels of durability and that this approach will be adopted in this standard.

It should be noted that in-situ concrete testing may be carried out from either cores taken from in-situ concrete or from test panels cast at the same time as the structure, in close proximity to the structure, compacted and cured in the same manner as the in-situ concrete.

4.3.1.4 Workability

The workability of the concrete should be specified in relation to the equipment and methods of handling and compaction, so that the concrete is placed without segregation, fully compacted, surrounds all reinforcement, tendons and ducts and completely fills the formwork. It is particularly important to ensure that full compaction is obtained in the vicinity of construction and movement joints, embedded water bars, tendon anchorages, pipes, etc.

For standard concrete, it is recommended that a slump between 100 and 120 mm is targeted, whilst for pump mixes, a slump between 120 and 150 mm is recommended. If self-compacting concrete is used, specialist advice should be sought. . Slumps towards the high end of this range should be targeted if extended travelling times are expected, to allow for evaporation during transport and to prevent the need to revive workability at the point of discharge.

Under no circumstances should water be used to revive workability. Where environmental conditions are such and/or concrete transport travel times are significantly extended, workability revival to the design workability, will only be carried out with an approved workability revival admixture. Workability revival admixtures are normally added to the concrete at the point of discharge, immediately prior to discharge. In cases where the aforementioned conditions are experienced, the addition of a retarding admixture at the point of manufacture, may be necessary to prevent setting of the concrete during transport.

4.3.1.5 Protection

The protection and curing measures stipulated in SANS 10100-2 clause 8.2 should be rigorously implemented.

Protection of concrete may essentially be defined as practices carried out to prevent the rate of evaporation from the exposed surface of a plastic concrete from exceeding that of the rate of bleed. Protection is normally effected using one of the following practices:-

- Atomised (high pressure) mist/fog sprayers, spraying water above the entire exposed concrete surface i.e. creating a zone of 100% humidity above the entire exposed surface.
- Evaporation retarding admixtures (obtained from reputable admixture suppliers), applied immediately after compaction and initial striking of the exposed concrete surface has been effected. Normally applied using a mist sprayer.
- Plastic sheeting, applied immediately after compaction and initial striking of the exposed concrete surface has been effected.

Atomised (high pressure) mist/fog sprayers spraying water are arguably the most effective, due to providing the earliest protection possible. Plastic sheeting, in many cases if not properly effected, may serve to increase the rate of evaporation i.e. using sheeting with holes, insufficient overlapping, inadequate anchoring of sheeting around the edges of the exposed surface (formation of wind tunnels during periods of significant wind speeds).
Protection of concrete reduces the potential for plastic shrinkage cracking. Its application becomes essential in cases of:-

- Large exposed surface areas i.e. surface beds, suspended slabs, roofs, etc. and/or
- Significantly extended concretes i.e. extended setting times and thus extended bleeding times.

4.3.1.6 Curing

Curing of concrete may essentially be defined as practices carried out to prevent the further loss of moisture from the concrete once bleed water has ceased to appear on the exposed surface of a plastic concrete. This normally coincides with:-

- The initial set of the concrete having been reached.
- The commencement of final finishing of the exposed concrete surface i.e. power floating, texturing, etc.

Curing in some cases may be a continuation of the methods used to protect the concrete i.e. atomised water mist/fog sprays and/or plastic sheeting. In other cases it is not i.e. curing compounds.
Curing of concrete elements is essential for durability. Accepted curing practice should be implemented for the required length of time. Refer to SANS 10100-2, Table 4 for minimum durations of curing. These curing times are longer for significantly extended cements.
NOTE: Inadequate/insufficient curing may contribute significantly to durability specifications not being met.

4.3.1.6 Blinding Layer

Where walls or floors are founded on the ground, a screeded layer of plain concrete not less than 50 mm thick, should be placed over the ground. In normal circumstances, this concrete should have proportions weaker than that used in the remainder of the structure, but not weaker than C11/15 MPa (cylinder strength/cube strength equivalents). Where aggressive soil or aggressive groundwater is expected, the concrete should not be weaker than C20/25 MPa (cylinder strength/cube strength equivalents) and if necessary, a sulphate-resisting or other special cement should be specified.

- **Section 5 Structural analysis**

Addition after 5.11

5.12 Determination of the effects of temperature

5.12.1 General

(101) Rigorous analyses may be carried out using the provisions of 3.1.4 and Annex B of SANS 51992-1-1 for creep and shrinkage.

(102) In storage structures, high temperature gradients may occur where stored liquid is put into the structure at high or low temperatures, or heating/ cooling takes place. In such circumstances calculation of the resulting temperature gradients and the consequent internal forces and moments will be necessary.

5.13 Calculation of the effects of internal pressure

(101) In the absence of a more rigorous analysis, internal pressure from liquids may be assumed to act at the centre of the retaining members.

- **Section 6 Ultimate limit states**

Addition after 6.2.3 (8)

(109) The choice of strut angle in 6.2.3(2) for shear resistance should take into account the influence of any significant applied tension. Conservatively, $\cot\theta$ may be taken as 1,0.

- **Section 7 Serviceability limit states**

7.3 Cracking

7.3.1 General considerations

Addition after (9).

(110) It is convenient to classify liquid retaining structures in relation to the degree of protection against leakage allowed. Table 7.3.1.1 gives the classification. It should be noted that all concrete will permit the passage of small quantities of liquids and gasses by diffusion.

Table 7.3.1.1 — Classification of tightness and provisions for achieving leakage requirements

Tightness Class	Requirements for leakage	Provisions for achieving leakage requirements
0	Leakage acceptable or leakage of liquids irrelevant	Surface crack widths should be limited to 0.3mm to achieve acceptable durability and appearance.
1	Leakage to be limited to a small amount. Some surface staining or damp patches acceptable	Surface crack widths should be limited to 0.2mm. See note 1 below.
2	Leakage to be minimal. Appearance not to be impaired by staining	Surface crack widths should be limited to 0.1mm. See note 1 below.
3	No leakage permitted	Generally, special measures (e.g. liners or prestressing) will be required to ensure water tightness.

NOTE 1: When determining load effects (by structural analysis or from tables), designers must ensure that the assumed boundary conditions reflect the actual boundary conditions. For example: In circular tanks with a fixed wall-footing connection, wall footing rotation due to the elasticity of the founding material is typically enough to significantly increase the axial tension in the walls (compared to the values obtained for a fully fixed condition). A small increase in tension can result in a significant increase in predicted crack width for the same reinforcement configuration.

(111) **Crack width limit.** For the purpose of defining the serviceability crack width limit state, the maximum design surface crack widths for different tightness classes and crack types are given in Table 7.3.1.1 above. .

(a) **Reinforced concrete.**
(1) The maximum design surface crack widths specified in Table 7.3.1.1 should allow for load effects or restrained temperature and moisture effects.
(2) The maximum design surface crack width for critical aesthetic appearance is 0.1 mm. This value assumes a viewing distance of 1m or less.

(b) **Prestressed concrete.** Refer to Annex P for special recommendations for the design of cylindrical prestressed structures. A statically determinate member nominally subjected to axial pre-stressing should be assumed to have a minimum eccentricity of prestressing of 20 mm or 0.05 times the overall thickness in the plane of bending, whichever is less. For statically indeterminate structures, including cylindrical prestressed structures, this minimum eccentricity recommendation can be ignored.

Replace **7.3.2** with:

7.3.2 Minimum reinforcement areas

(1) **Cracking due to load effects in mature concrete.** Minimum reinforcement areas should be calculated in accordance with 9.6 of SANS 51992-1-1.

(2) **Restrained cracking due to temperature and moisture effects.** The reinforcement should be calculated in accordance with 9.6 of SANS 51992-1-1 and Table N.1. in Annex N of this standard (SANS 10100 Part 3). Except as provided for in option 3 in Table N.1 of Annex N, the amount of reinforcement in each of two directions at right angles within each of surface zone should not be less than 0.35% of the surface zone as defined in figures M.1 and M.2 of Annex M for deformed grade 450 reinforcement and not less than 0.64% for plain grade 250 reinforcement. In wall panels less than 200 mm in thickness, the calculated reinforcement may all be placed in one face. For ground slabs less than 300 mm thick (see Figure M.2 of Annex M), the calculated reinforcement should be placed as near to the upper surface as possible consistent with the nominal cover. Bar spacing should not generally exceed 300 mm or the thickness of section, whichever is the lesser. Where welded fabric only is used, bar spacing should not exceed 1.5 times the thickness of the section.

Replace **7.3.3** with:

7.3.3 Control of cracking without direct calculation

(1) **Cracking due to load effects.** The crack widths for reinforced concrete members under externally applied direct tension or flexure may be deemed to be satisfactory if the steel stress under service conditions does not exceed the appropriate value in Table 7.3.3.1.

Table 7.3.3.1 — Allowable steel stresses in direct or flexural tension for serviceability limit states

Design crack width (mm)	**Allowable stress (MPa)**	
	Plain bars #	**Ribbed bars t**
0.1	85	100
0.2	115	130

Plain grade 250MPa bars complying with section 3 of SANS51992-1-1
t Ribbed grade 450MPa bars complying with section 3 of SANS51992-1-1

(2) **Cracking due to thermal movement and restrained shrinkage.** Cracking may be controlled by the provision of reinforcement and/or joints as given in Table N1 of Annex N.

Option1 (design for full restraint): No contraction joints are provided within the area designed for continuity. Crack widths and spacing are controlled by the reinforcement. Construction joints become part of the crack pattern and have similar crack widths. The minimum reinforcement to be provided is ρ_{crit}.

Option 2 (design for partial restraint): Cracking is controlled by the reinforcement but the joint spacing is such that some of the daily and seasonal movements in the mature structural member are accommodated at the joints. The minimum reinforcement to be provided is ρ_{crit}.

Option 3 (design for freedom of movement): Cracking is controlled by the proximity of the joints, with a moderate amount of reinforcement provided sufficient to transmit movement at any cracked section to the adjacent movement joints. Significant cracking between the adjacent movement joints should not occur. The minimum reinforcement to be provided is 2/3 ρ_{crit}.

The critical reinforcement ratio i.e. minimum ratio of reinforcement to the gross area of the concrete section, defined as the surface zone(s) given in Figures M.1 and M.2 of Annex M., is given by Expression (7.101)

$$\rho_{crit} = f_{ct} / f_y \tag{7.101}$$

Where
f_{ct} is the direct tensile strength of the immature concrete (usually taken at an age of 3 days).
f_y is the characteristic strength of the reinforcement.

Replace **7.3.4** with:

7.3.4 Calculation of crack width

(1) **Cracking due to load effects.**

Provided that the strain in the tension reinforcement is limited to $0.8f_y/E_s$ and the stress in the concrete is limited to $0.45f_{cu,}$ the design surface crack width should not exceed the appropriate value given in 7.3.1 (110) and may be calculated as follows:

(a) *Members in flexure, or combined flexure and axial load where d' < x < d*

The design surface crack width is

$$\mathrm{w} = \frac{3a_{cr}\varepsilon_m}{1+2\left(\frac{a_{cr}-c_{min}}{h-x}\right)} \tag{7.102}$$

The average strain at the level where cracking is being considered is

$$\varepsilon_m = \varepsilon_1 - \varepsilon_2 \tag{7.103}$$

Where
ε_1 is the calculated apparent strain using characteristic loads and normal elastic theory.

ε_2 is the stiffening effect of the concrete between cracks and is calculated using either Expression (7.104) or (7.105).

For a limiting surface crack width of 0.15mm or 0.2 mm:

$$\varepsilon_2 = \frac{b_t(h-x)(a'-x)}{3E_sA_s(d-x)} \tag{7.104}$$

For a limiting surface crack width of 0.1 mm:

$$\varepsilon_2 = \frac{1.5\, b_t(h-x)(a'-x)}{3E_sA_s(d-x)} \tag{7.105}$$

The stiffening effect factors should not be interpolated or extrapolated and apply only to the crack widths stated.

(b) *Symmetrically reinforced members in direct tension, or in combined flexure and axial load (whole section in tension.*

The design surface crack is

$$w = 3a_{cr}\varepsilon_m \tag{7.106}$$

Where
ε_1 is the calculated apparent strain using characteristic loads and normal elastic theory.
ε_2 is the stiffening effect of the concrete between cracks and is calculated using either Expression (7.107) or (7.108).

For a limiting surface crack width of 0.2 mm:

$$\varepsilon_2 = \frac{2b_th}{3E_sA_s} \tag{7.107}$$

For a limiting surface crack width of 0.1 mm:

$$\varepsilon_2 = \frac{b_th}{E_sA_s} \tag{7.108}$$

The stiffening effect factors should not be interpolated or extrapolated and apply only to the crack widths stated.

Where the whole section is in tension, ε_2 should be multiplied by a factor between 0.5 when x = 0 and 1,0 for direct tension.

(2) ***Restrained cracking due to temperature and moisture effects.***

The design crack width in continuous (option 1) and semi-continuous (option 2) construction of thin cross section may be calculated from:

$$w_{max} = s_{max}\,\varepsilon \tag{7.109}$$

Where
w_{max} is the estimated maximum crack width

s_{max} is the estimated maximum crack spacing, obtained from

$$s_{max} = (f_{ct} / f_b)(\varphi / 2\rho) \tag{7.110}$$

f_{ct} is the tensile strength of the concrete, taken at an age of 3 days.

f_b is the average bond strength between immature concrete and reinforcement. f_{ct} / f_b is taken as 1.0 for plain bars and 0.67 for deformed grade 450 reinforcement bars. For square-mesh fabric reinforcement, in which the cross-wires are not smaller than the main wires, f_{ct} / f_b may be taken as 0.8 for plain wires and 0.5 for deformed grade 450 reinforcement wires.

ρ is the ratio of the area of reinforcement to the gross area of concrete provided in a surface zone as defined in Figures M.1 and M.2 of Annex M.

φ is reinforcement bar diameter

ε is effective strain, obtained from

$$\varepsilon = \varepsilon_{cs} + R\,\varepsilon_{te} - (100 \times 10^{-6}) \tag{7.111}$$

ε_{cs} is the estimated shrinkage strain. The shrinkage strain less its associated creep strain is generally less than 100 x 10^{-6} unless high shrinkage aggregates are used.

ε_{te} is the estimated total thermal contraction after peak temperature rise of hydration, obtained from

$$\varepsilon_{te} = \alpha\,(T_1 + T_2) \tag{7.112}$$

T_1 is estimated temperature fall between the hydration peak and mean ambient temperature at the time of construction (see Annex. L). For design purposes, values of T_1 should be taken as ≥ 20°C for walls and ≥ 15°C for slabs.

T_2 is a further fall in temperature due to seasonal variations. If movement joints are provided as in Options 2 and 3 of Table N1 of Annex N, then the subsequent temperature fall T_2 need not be considered, provided that the reinforcement has been reduced by 50% at partial construction joints.

R is a restraint factor. Values for R may be found in Annex L. Otherwise, R of 0.5 may be used generally.

α is the coefficient of expansion for mature concrete

Addition after **7.3.4**

7.3.5 Minimising cracking due to restrained imposed deformations

(101) Where it is desirable to minimise the formation of cracks due to restrained imposed deformations resulting from temperature change or shrinkage, this may be achieved by:

— limiting the temperature rise due to hydration of the cement.
— removing or reducing restraints.
— reducing the shrinkage of the concrete.
— using concrete with a low coefficient of thermal expansion.
— application of prestressing.

- **Section 8 Detailing provisions**

8.10.1 Arrangement of prestressing tendons and ducts

8.10.1.3 Post-tension ducts

Addition after Application Rule (1)

(102) In the case of circular structures with internal prestressing, care needs to be taken to avoid the possibility of local failures due to the tendons breaking out through the inside cover. In general, this will be avoided if the theoretical centroid of the horizontal cables lies in the outer third of the wall. Where the cover provisions make this impossible, this requirement may be relaxed provided the tendon duct remains within the outer half of the wall.

(103) The diameter of a duct within a wall should generally not exceed 0.25 times the wall thickness.

(104) The prestressing force on a wall should be distributed as evenly as possible. Anchorages or buttresses should be so arranged as to reduce the possibilities of uneven force distribution unless specific measures are taken to take the effects into account.

(105) Where structures subjected to elevated temperatures containing vertical unbonded tendons are used, it has been found that the protective grease is liable to run out. To avoid this, it is advisable to avoid the use of unbonded prestressing tendons as vertical prestress. If they are used, means should be provided to enable the presence of protective grease to be checked and renewed if necessary.

8.10.4 Anchorages and couplers for prestressing tendons

Addition after Application Rule (5)

(106) If anchorages are located on the inside of structures, particular care should be taken to protect them against possible corrosion.

Addition after 8.10.5

8.10.6 Cylindrical prestressed concrete structures

Refer to Annex P for information on the design of cylindrical prestressed concrete structures

- **Section 9 Detailing of members and particular rules**

9.1 General

Addition after (3)

(104) ***Reinforcement to control restrained shrinkage and thermal movement cracking.*** Reinforcement referred to in Section 2.3.3 of SANS 51992-1-1 to control cracking arising from restrained shrinkage and thermal movement should be placed in all slabs (floors, walls, roofs) as near to the surface of the concrete as is consistent with the requirement for cover.

(105) Prestressed slabs should be provided with reinforcement in any lateral direction in which there is no significant prestress.

9.6 Reinforced concrete walls

Addition after 9.6.4

9.6.5 Corner connections between walls

(101) Where walls are connected monolithically at a corner and are subjected to moments and shears which tend to open the corner (i.e. the inner faces of the walls

are in tension), care is required in detailing the reinforcement to ensure that the diagonal tension forces are adequately catered for. A strut and tie system as covered in 5.6.4 of SANS 51992-1-1 is an appropriate design approach.

9.6.6 Provision of movement joints

(101) If effective and economic means cannot otherwise be taken to limit cracking, liquid retaining structures should be provided with movement joints. The strategy to be adopted will depend on the conditions of the structure in service and the degree of risk of leakage which is acceptable. It should be noted that the satisfactory performance of joints requires that they are formed correctly. Furthermore, the sealants to joints frequently have a life considerably shorter than the design working life of the structure and therefore in such cases joints should be constructed so that they are inspectable and repairable or renewable. Further information on the provision of movement joints is given in Informative Annex N. It is also necessary to ensure that the sealant material is appropriate for the material or liquid to be retained.

Addition after 9.10.

9.11 Prestressed walls

9.11.1 Minimum area of passive reinforcement and cross-sectional dimensions

(101) Where there is no vertical prestressing (or no inclined prestressing in inclined walls), vertical (or inclined) reinforcement should be provided on the basis of reinforced concrete design.
(102) The thickness of walls forming the sides of reservoirs or tanks should generally not be less than 120 mm for class 0 or t_2 mm for classes 1 or 2. Slip formed walls should not be thinner than 150 mm whatever the class and the holes left by the lifting rods should be filled with a suitable grout.

- **Annex L**
- (informative)
-

- **Calculation of strains and stresses in concrete sections subjected to restrained imposed deformations**

L.1 Assessment of restraint

(101) The restraint factors may be calculated from a knowledge of the stiffnesses of the element considered and the members attached to it. Alternatively, practical axial restraint factors for common situations may be taken from Figure L.1 and Table L.1. In many cases (e.g. a wall cast onto a heavy pre-existing base) it will be clear that no significant curvature could occur and a moment restraint factor of 1,0 will be appropriate.

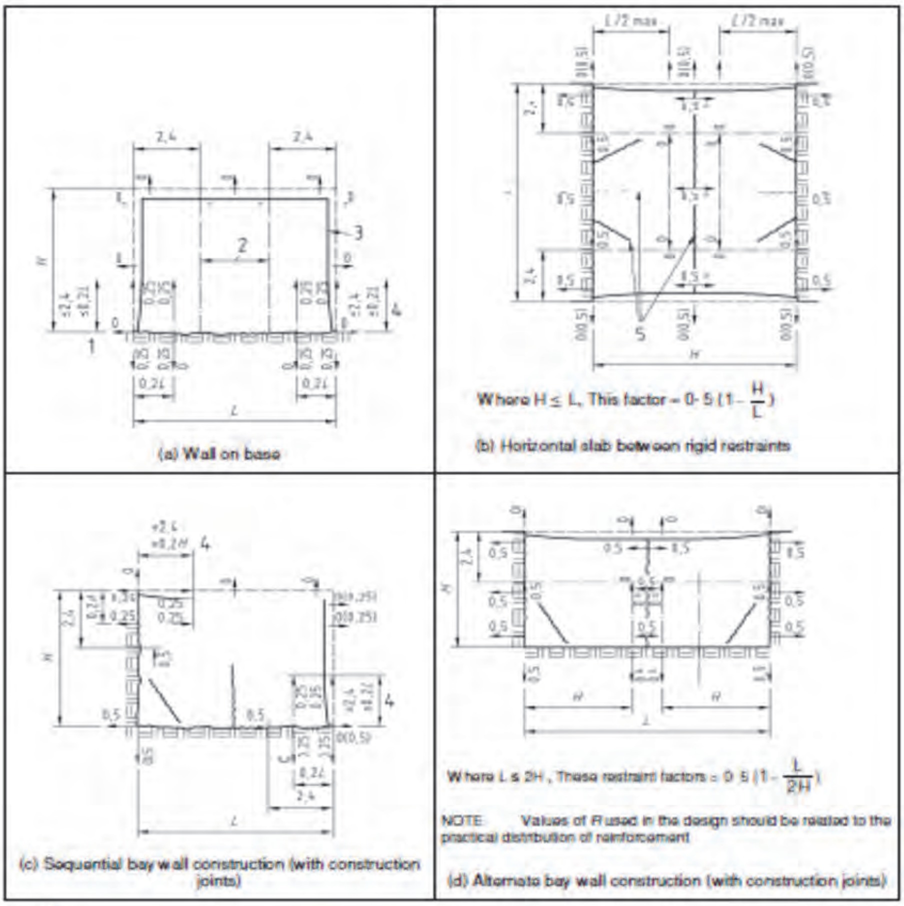

Figure L.1 — Restraint factors for typical situations

Key to Figure L.1
1 Vertical restraint factors
2 Horizontal restraint factor (obtain from table L.1 for this central zone)
3 Expansion or free contraction joints
4 (whichever is the greater)
5 Potential primary cracks

(102) Note that no thermal shrinkage is likely to occur within 2.4m of a free edge since experience has shown that this is the length of wall or floor slab over which the tensile strain capacity of the concrete exceeds the increasing strain contraction, the restraint factor varying between zero at the free edge to a maximum of 0.5 at 2.4m from the free edge. Note that cracking can occur near the ends if stress inducers such as pipes occur within this 2.4m length of wall or slab. However, if not less than 2/3 ρ_{crit}, based on the surface cones (see Annex C), is provided and there are no obvious stress inducers, it may be assumed that the free ends of the members will move inwards without cracking up to where R is 0.5. Where this is only a temporary free edge and a subsequent bay is cast against the edge, the larger restraint factor for the subsequent bay is shown in parentheses in Figure L1 and should be assumed.

(103) The restraint within a wall of floor panel depends not only on the location within the slab but also on the proportions of the slab. Table L1 shows how the restraint factors vary between the opposite edges, one free and one fixed.

Table L.1 — Restraint factors for central zone of walls shown in Figure L.1

Ratio L/H (see Fig L.1)	Restraint factor at base	Restraint factor at top
1	0,5	0
2	0,5	0
3	0,5	0,05
4	0,5	0,3
>8	0,5	0,5

Note: If L < 4.8m, then the values for R may be less than those given in Table L1.

(104) The effective external restraint in ground slabs cast on smooth blinding concrete for the seasonal temperature variation T_2 may be taken as being the design restraint factor R = 0.5 at the mid-length, for 30m lengths and over, and it may be assumed to vary uniformly from 0.5 to zero at the ends.

-

- **L2. Temperature T_1**

(101) T1 is the difference between the peak concrete temperature and the mean ambient temperature.

(102) Recommended values for design purposes for the estimated temperature fall T_1 are given in Figures L.2 to L.4, for wall sections up to 1m thick.

(103) For wall sections thicker than 1m Figure L.5 can be used to obtain the temperature rise per 100 kg/m^3 of binder content. 5°C should be added to the total temperature rise derived from Figure L.5 to obtain T_1.

(104) The values in Figures L.2 to L.5 assume that the concrete placing temperature is 20°C and the mean daily temperature is 15°C. Higher placing temperatures and/or lower ambient temperatures would tend to increase the design values. Figure L.6 gives the recommended adjustment to T_1 (per 100 kg/m^3 of binder content) for placing temperatures that differ significantly from 20°C. It was also assumed that the formwork is left in place until the peak temperature has passed and no allowance has been made for solar heat gain in slabs.

(105) For suspended slabs cast on steel formwork, use the data for walls with steel formwork.

(106) For ground slabs up to 500mm thick the value of T_1 may be obtained by estimating the value for a wall with thickness 1.3 times that of the slab and cast into steel formwork.

(107) While the designer will determine the section thickness, the only information available about the concrete may be the strength grade. To predict T_1, the binder content is required. Table L.2 gives an indication of the binder content likely to be associated to different strength grades and cement types.

NOTE: The values in Table L.2 should not be used for mix design or specification purposes. They are indicative only and are deliberately at the high end of the range that may be expected.

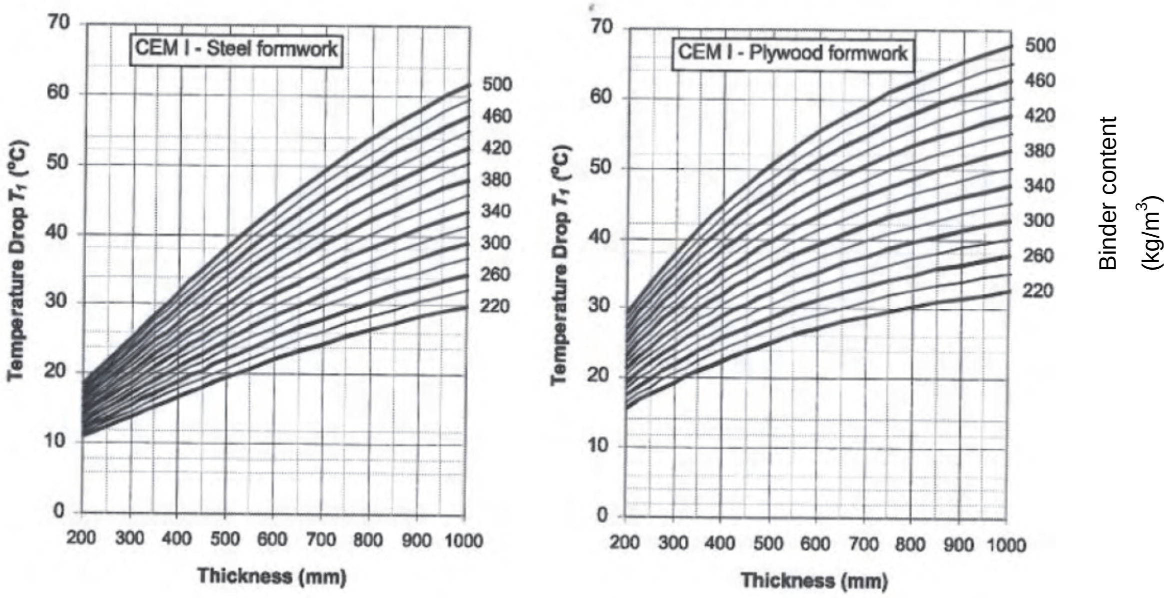

Figure L.2 — T_1 values for CEM I in walls

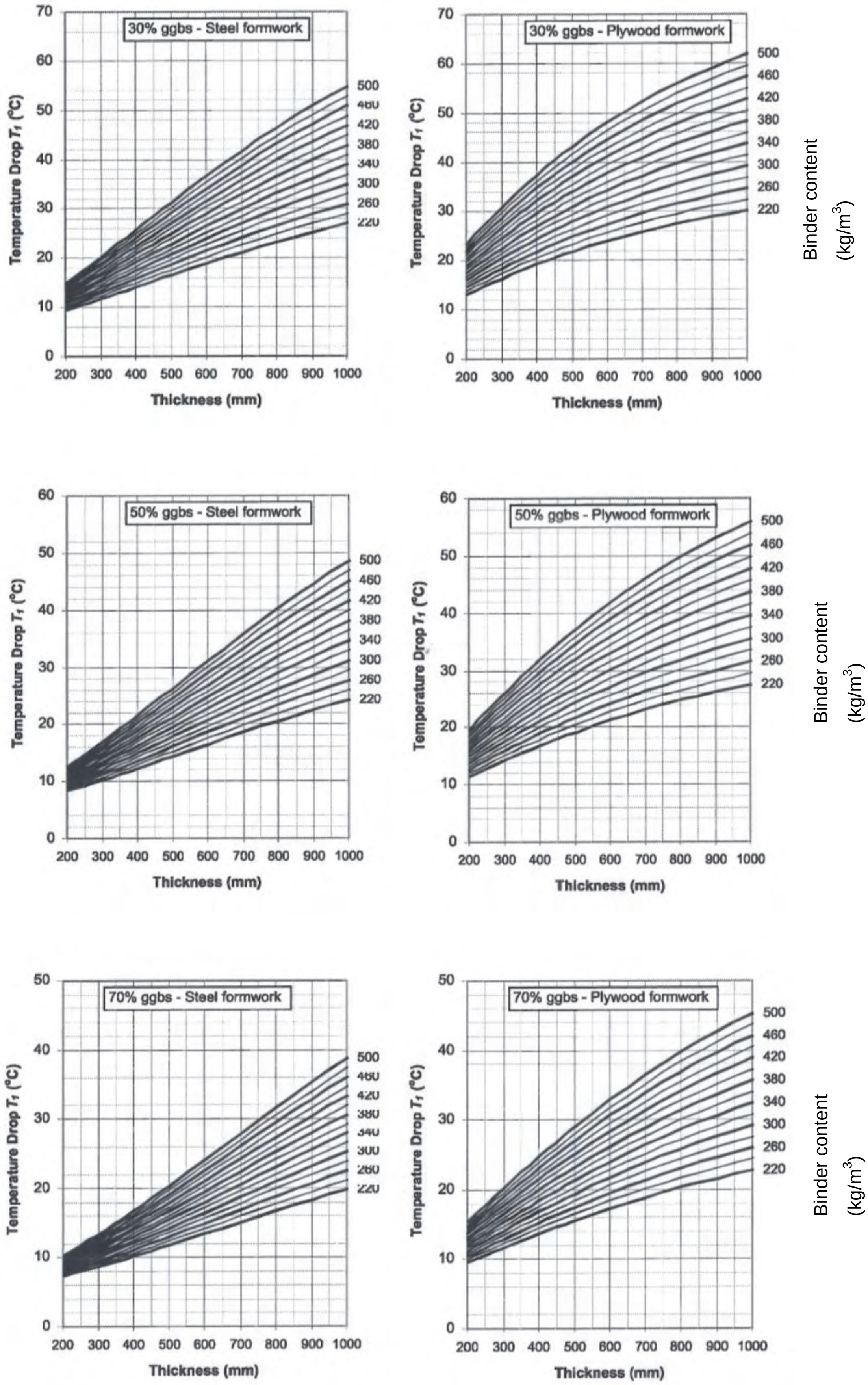

Figure L.3 — T_1 values for walls of concretes containing ggbs

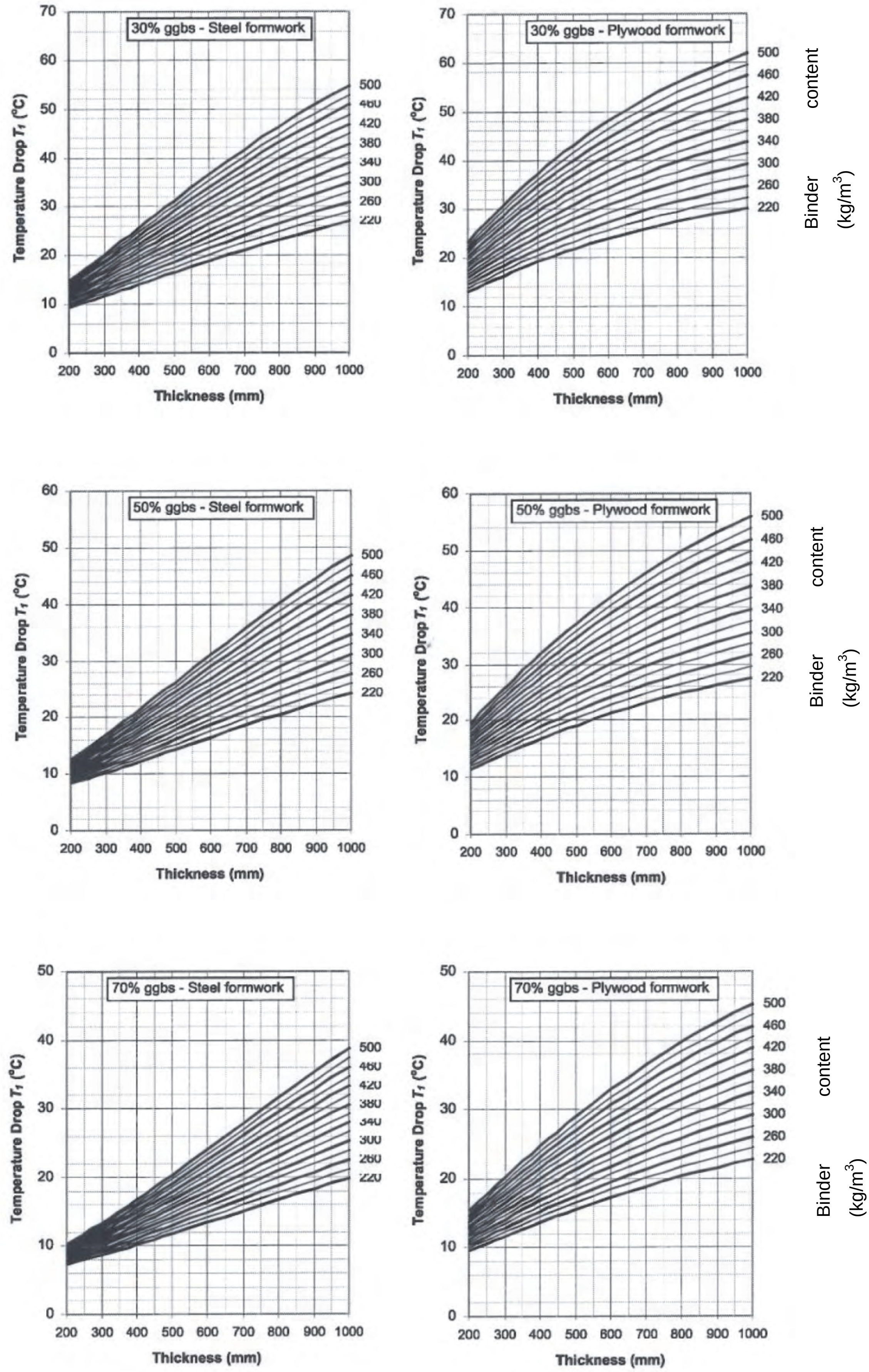

Figure L.4 — T_1 values for walls of concretes containing fly ash

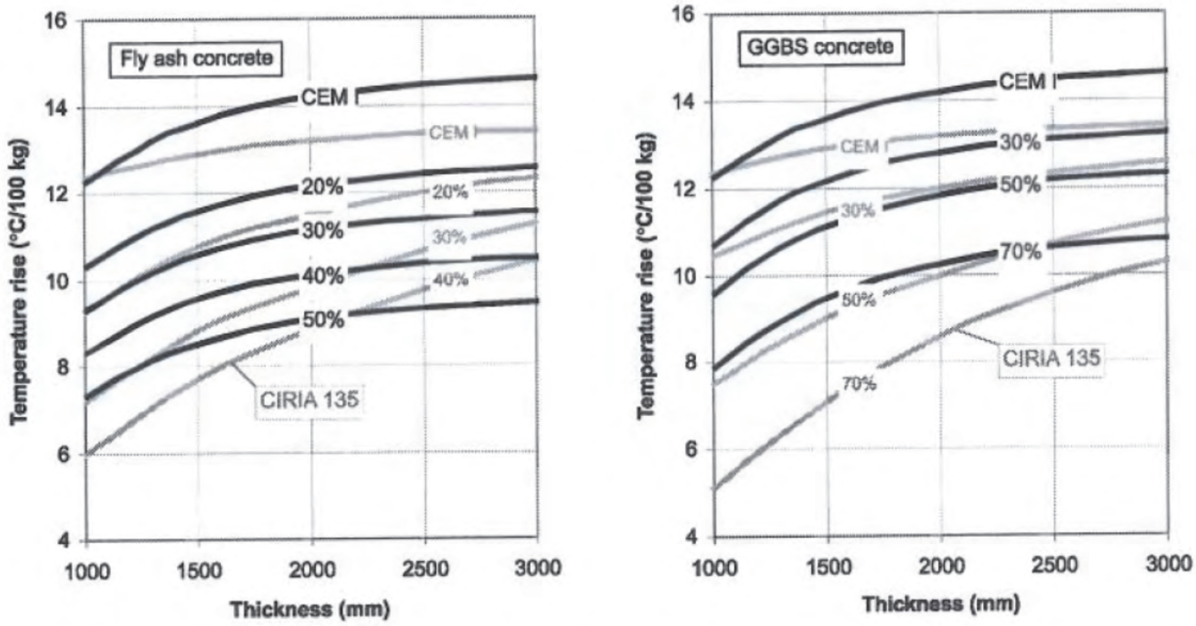

Figure L.5 — Temperature rise per unit weight of binder in massive sections

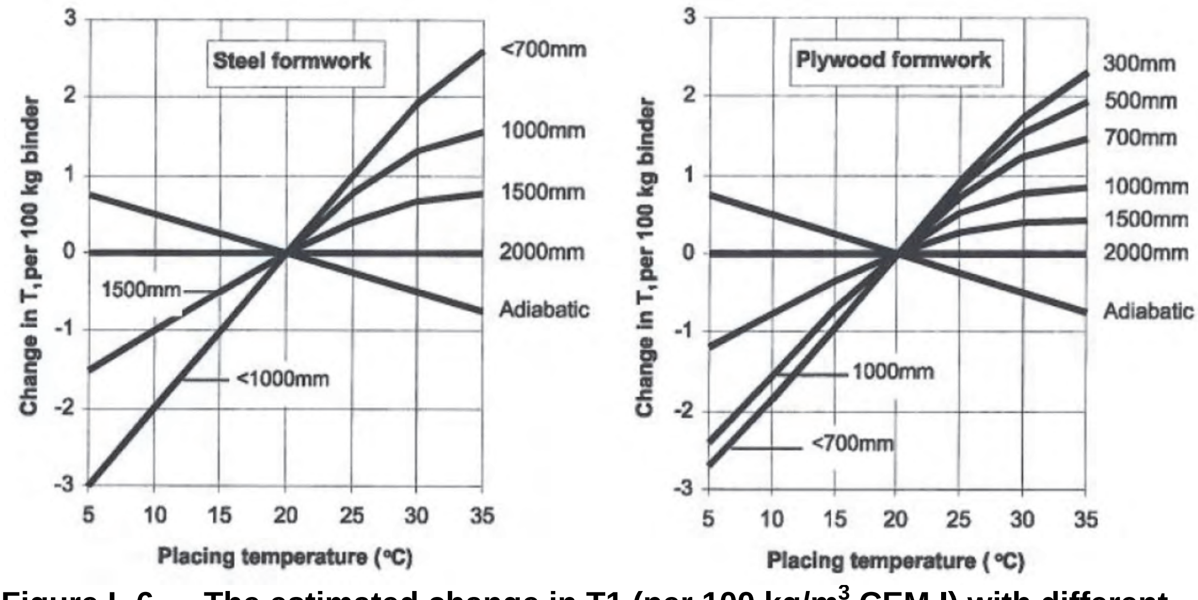

Figure L.6 — The estimated change in T1 (per 100 kg/m^3 CEM I) with different placing temperatures

Strength class	Binder content (kg/m³)										
	Not specified	CEM I	up to 20% fly ash	30% fly ash	40% fly ash	50% fly ash	up to 40% ggbs	50% ggbs	60% ggbs	70% ggbs	80% ggbs
C20/25	275	275	295	300	315	330	275	285	300	325	345
C25/30	300	300	320	325	340	360	300	310	330	355	385
C30/37	340	340	360	365	380	400	340	355	375	410	450
C35/45	380	380	405	410	430	450	380	395	430	480	540
C40/50	410	410	440	445	465	485	410	430	470	530	
C45/55	440	440	470	475	500	525	440	465	515		
C50/60	475	475	505	515	535		475	505			

Table L.2 — Cement contents for different strength classes

NOTE: These values should not be used for mix design or specification purposes. They are indicative only and are deliberately at the high end of the range that may be expected.

NOTE: The shaded values are those which may be necessary without the use of admixtures. However, it is common practice to use water-reducing admixtures for the higher strength classes to enable a reduction in cement content. Values greater than 550 kg/m^3 would not normally be permitted.

- **Annex M**
- (informative)

Surface zones in concrete members

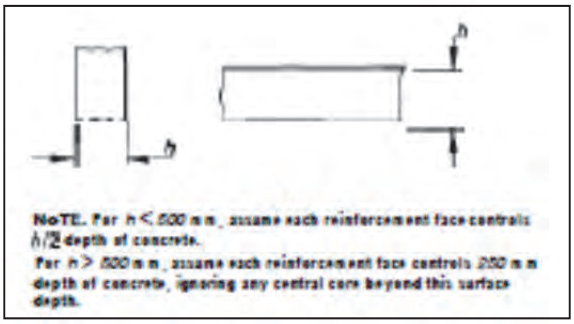

Figure M.1 — Surface zones for walls and suspended slabs

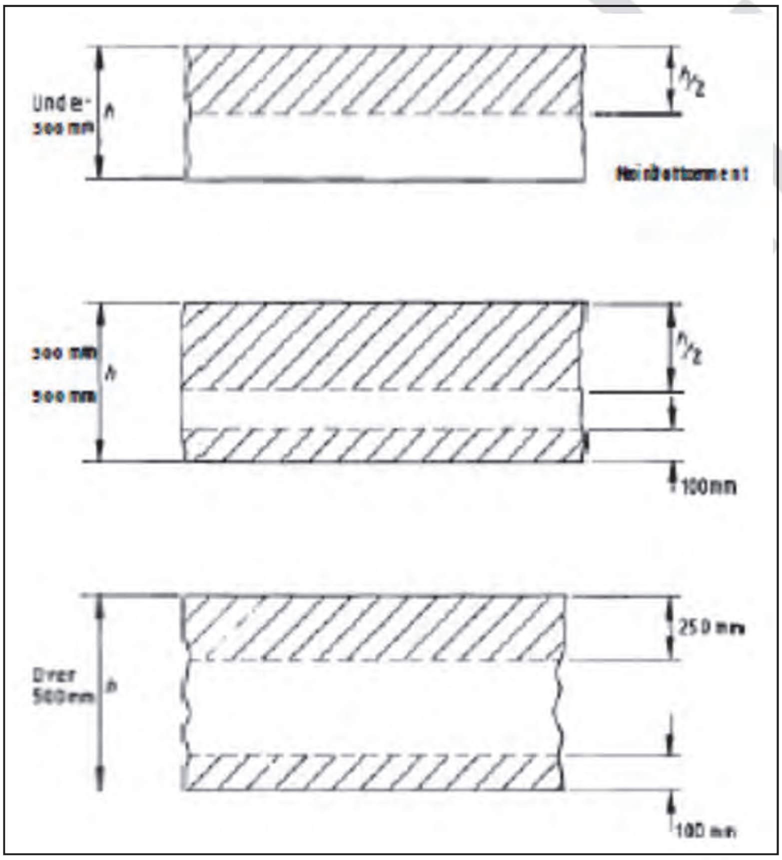

Figure M.2 — Surface zones for ground slabs

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Annex N

(informative)

Provision of movement joints

N.1 General

(101) Joints in liquid-retaining structures are temporary or permanent discontinuities at sections, and may be formed or induced. This section describes the types of joint that may be required and gives recommendations for their design and construction. The types of joint are illustrated in Figure N.1 and Figure N.2 and are intended to be diagrammatic. Jointing materials are considered in N.8 below.

(102) Joints may be used, in conjunction with a corresponding proportion of reinforcement, to control the concrete crack widths arising from shrinkage and thermal changes to within acceptable limits.

(103) The designer should provide the layout of the joints and joint details. If the joint layout is not provided, the contractor should submit a detailed joint layout and placing sequence for approval by the designer before proceeding with construction.

N.2 Movement joints

N.2.1 Need for movement joints

(101) A movement joint is intended to accommodate relative movement between adjoining parts of a structure, special provision being made to maintain the water-tightness of the joint.

(102) All movement joints are a source of weakness, leakages and positions of maintenance. Hence the number of movement joints in a water retaining structure should be minimized or they should be omitted or avoided altogether.

(103) Structures should be provided with movement joints if effective and economic means cannot otherwise be taken to avoid unacceptable cracking. Attention should be paid to the conditions of structures in service. In elevated structures where restraint is small, movement joints may not be required.

(104) The risk of cracking because of overall temperature and shrinkage effects may be reduced by limiting the changes in temperature to which the structure is subjected.
The storage of warm liquids may affect the provision of expansion joints, as may an un-insulated roof slab.

(105) Restraints on free contraction or expansion of the structure should be reduced as far as possible. Every effort should be made to avoid tying the floor slab to any other element of the structure. Restraint from any source, whether internal or external, will increase the potential for random cracking. With long wall bases or slabs founded at or below ground level, restraints can be reduced by the provision of a sliding layer such as 1mm thick uPVC sheeting. This can be provided by founding the structure on a flat and smooth layer of concrete with interposition of some material to break the bond and facilitate movement, provided that friction is not assumed in the design to resist sliding.

(106) Structures on piled foundations should be designed to have a sliding layer between the foundations and the superstructure, or the restraint provided by the piles should be considered in the design.

(107) A sequence of casting slabs that gives temporary free edges in two directions at right angles will help reduce the restraint to free contraction of the immature concrete. In this regard, sequential casting of panels is recommended, rather than alternate panel casting.

N.2.2 Design and detailing of movement joints

N.2.2.1 General.

(101) All movement joints should be designed to accommodate repeated movement of the structure without loss of liquid. The joint should be designed to suit the characteristics of the material available (see N.8 below) and should also provide for the exclusion of grit and debris that would prevent the closing of the joint.

(102) Liquid pressure on the joint should be adequately resisted.

(103) Detailing at places where the joint changes direction or intersects with another joint should be uncomplicated and easily constructible.

N.2.2.2 Expansion/Isolation joint.

(101) This has no restraint to movement and is intended to accommodate either expansion or contraction of the concrete.

(102) At an expansion joint there is complete discontinuity in both reinforcement and concrete.

(103) The practice of using a shear key and a central waterstop in concrete with thickness of less than 300mm is discouraged due to the complexity of the joint.

(104) Central waterstops should be avoided in slabs with thickness less than 250mm.

(105) Isolation joints should be used wherever complete freedom of vertical and horizontal movement is required between adjoining structural elements.

(106) An initial gap should be provided between adjoining parts of the structure to accommodate the expansion of the structure.

(107) Waterstops, joint fillers and joint sealing compounds are essential at these joints to prevent leakage.

(108) Design of the joint so as to incorporate sliding surfaces is not precluded and may sometimes be advantageous.

N.2.2.3 Complete contraction joint.

(101) This also has no restraint to movement, but is intended to accommodate only contraction of the concrete.

(102) At a complete contraction joint there is complete discontinuity in both reinforcement and concrete. Cracking in the adjoining parts of the structure is controlled by the spacing of the joints and the corresponding amount of reinforcement required to transmit movements to the adjacent joints.

(103) A joint may be formed either by:
(a) Using stop ends with no initial gap between the concrete.
(b) Using a crack inducer (or other means) to reduce the depth of the concrete section by at least 25%. In the latter case, the restraint to initial contraction of the concrete exerted by the reduced cross section of the concrete at the joint is small and may be neglected.
(c) Sawcut contraction joints are used to limit random floor slab cracking. The depth of the sawcut should be at least ¼ of the slab depth or a minimum of 25mm whichever is the greater. For fibre reinforced slabs the sawcut depth the depth should be at least $^{1}/_{3}$ of the slab depth.

(104) Waterstops are essential, as are joint sealing compounds, where debris may enter the joints.

(105) Transfer of shear across the joint can be achieved by the use of dowel bars or concrete shear keys with one end of the dowel free to slide. Care should be taken to ensure that dowels positioned at 90° to each other do not “lock in” slab stresses and prevent the slab from shrinking

N.2.2.4 Partial contraction joint.

(101) This provides some restraint, but is intended to accommodate some contraction of the concrete by allowing cracking at the partial contraction joint.

(102) A distinction is made between a complete contraction joint and a partial contraction joint in that, while both types have discontinuity in the concrete, a partial contraction joint has only a proportion (usually 50%) of the reinforcement continuing through the joint.

(103) Waterstops are essential at these joints.

N.2.2.5 Hinged joint.

(101) This allows two structural members to rotate relative to one another with minimal restraint.

(102) A hinged joint is a joint that transmits thrust and shearing force, but permits rotation with minimal restraint. A hinged joint may be formed either by completely separating the two elements, placing one element in a groove in the other, or by crossing the reinforcement at the junction of the two elements, as shown in Figure N 2.2.5. In either case the rotation of one element will not transfer moment to the other.

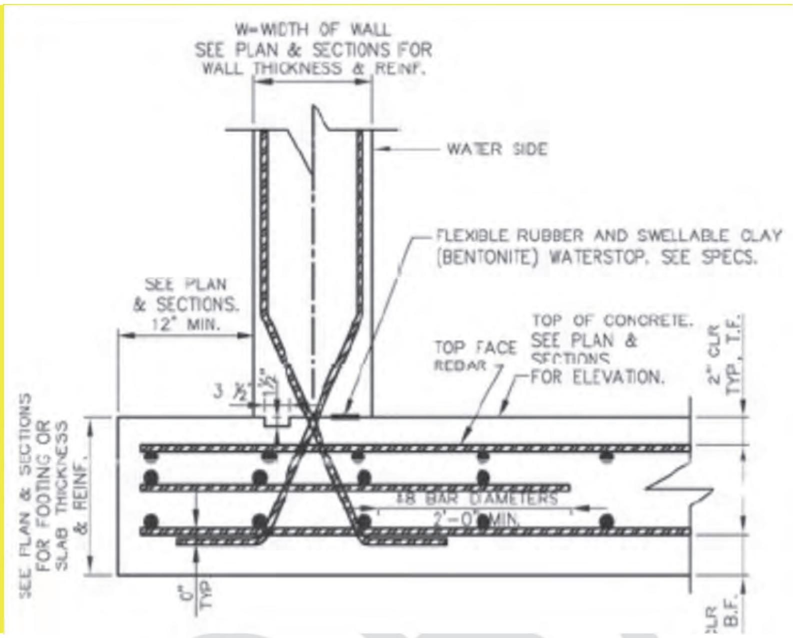


Figure N.1. Typical detail of a hinged joint

N.2.2.6 Sliding joint.

(101) This allows two structural members to slide relative to one another with minimal restraint and are typically be found at the foundation and wall intersection of circular reservoirs, between the wall and roof slab of reservoirs. A sliding joint has complete discontinuity in both reinforcement and concrete and allows relative movement in the plane of the joint. The surface of the concrete on the lower component should be flat and smooth so that movement is not restricted. In order to prevent bonding between the two faces, a separating layer or layers of a suitable material should be provided to allow movement to take place.

(102) Sliding joints are generally constructed with proprietary bearings or bearing strips. The top of the structural element that will receive the sliding bearing should be finished to a smooth horizontal surface.

(103) The sealing of sliding joints between a wall and a foundation should receive particular attention:

(a) Where bandages are used, the horizontal portion of the bandage should be glued to the foundation/floor whereas the vertical portion should be glued to the wall. A corner fillet out of high density foam should be used to avoid acute angles of the bandage.
(b) The joints should be designed to accommodate radial movement of the reservoir wall.
(c) The bandages should be installed after completing the stressing in case of a post-tensioned reservoir.

N.2.2.7 Open joint.

(101) Open joints (gaps) are sometimes used in walkways and are by far the most economical type of movement joint. A reduced chamfer of 10x10 mm should be used at the top of such walkway slabs.

N.2.3 Spacing of movement joints

(101) The provision of movement joints and their spacing are dependent on the design philosophy adopted, i.e. whether to allow for or restrain shrinkage and thermal contraction in walls and slabs:

- At one extreme, the designer may exercise control by providing a substantial amount of reinforcement in the form of small diameter bars at close spacing with no movement joints.
- At the other extreme, the designer may provide closely spaced movement joints in conjunction with a nominal or moderate proportion of reinforcement.

Between these extremes, control may be exercised by varying the reinforcement and joint spacing, an increase in spacing being compensated for by an increase in the proportion of reinforcement required.

Table N.1 — Design options for control of thermal contraction and restrained shrinkage

Option	**Type of construction and method of control**	**Movement joint spacing**	**Steel ratio(see note 2)**	**Comments**
1	Continuous: for full restraint	No joints, but expansion joints at wide spacing may be desirable in walls and roofs that are not protected from solar heat gain or where the contained liquid is subjected to a substantial temperature range	Minimum of ρ_{crit}	Use small size bars at close spacing to avoid high steel ratios well in excess of ρ_{crit}
2	Semi continuous: for partial restraint	a) Complete joints, $\leq 15m$ b) Alternate partial and complete joints (by	Minimum of ρ_{crit}	Use small size bars but less steel than in option 1

		interpolation), $\leq 11.25m$ c) Partial joints, $\leq 7.5m$		
3	Close movement joint spacing: for freedom of movement	a) Complete joints, in metres $\leq 4.8+\frac{\omega_{max}}{\epsilon}$ b) Alternate partial and complete joints, in metres $\leq 0.5s_{max}+2.4+\frac{\omega_{max}}{\epsilon}$ c) Partial joints $\leq s_{max}+\frac{\omega_{max}}{\epsilon}$	$^{2}/_{3}\rho_{crit}$	Restrict the joint spacing for options 3b) and 3c)
NOTE 1 References should be made to Section 7 for the description of the symbols used in this table and for calculating ρ_{crit} , s_{max} and ϵ. NOTE 2 In option 1 and 2 the steel ratio will generally exceed ρ_{crit} to restrict the crack widths to acceptable values. In option 3 the steel ratio of $^{2}/_{3}\rho_{crit}$ will be adequate. NOTE 3 The aspect ratio of slab panels that are unreinforced or reinforced only for crack width control should be a maximum of 1.5 to 1; however, a ratio of 1 to 1 is preferred. L- and T-shaped panels should be avoided.				

N.2.3.1. Horizontal movements

(101) The three main options for the designer are summarized in Table N.1 as follows:

a) *In option 1 (design for full restraint)*
No contraction joints are provided within the area designed for continuity, and crack widths and spacing are controlled by the reinforcement.
Construction joints become part of the crack pattern and have similar crack widths.

b) *In option 2 (design for partial restraint)*
Cracking is controlled by the reinforcement, but the joint spacing is such that some of the daily and seasonal movements in the mature slab or structural member are accommodated at the joints, so reducing the amount of movement to be accommodated at the cracks between the joints.

c) *In option 3 (design for freedom of movement)*
Cracking is controlled by the proximity of the joints, with a moderate amount of reinforcement provided, sufficient to transmit movement at any cracked section to the adjacent movement joints.
Significant cracking between the adjacent movement joints should not occur.

N.2.3.2. Vertical movements in walls

(101) The options given in Table N.1 are considered in terms of horizontal movement, but vertical movement in walls should also be considered. Two cases are as follows:

a) It is possible for horizontal cracks to occur at any free-standing vertical end because of the change in horizontal restraint with respect to height. For bays of any height the vertical strain arising from this warping effect may be taken as approximately half the horizontal strain and the vertical steel ratio should not be less than the critical ratio ρ_{crit}.

b) The vertical restraint exerted on a newly cast panel at a vertical construction joint may be assumed to develop at a depth of 2.4m from the free top surface. Thus design for freedom of movement (option 3) may be used for the vertical reinforcement in the top 2.4m of a lift. Design for partial restraint (option 2) is appropriate for vertical steel below this depth.

(102) The choice of design imposes a discipline on construction. It is desirable to achieve minimum restraint to early thermal contraction of the immature concrete in walls and slabs even though the finished structure may be designed for full continuity.

(103) Cracks arising from thermal contraction in a roof supported on columns may be minimized or even prevented if the roof slab is not tied rigidly to the walls.

N.3 Construction joints

(101) A construction joint is a temporary break in an otherwise continuous structural element. The reinforcement is continuous but the concrete on either sides of the joint is cast on different dates. Hence new concrete is cast against older concrete faces. Measures are taken to achieve subsequent continuity with no provision for further relative movement.

(102) Constructions joints are introduced mainly for two reasons: Firstly for the convenience of construction and secondly to reduce the effects of shrinkage cracks on large elements.

(103) Construction joints are points of structural weakness in concrete members: both shear capacity and flexural capacity at construction joints are normally reduced. Because of this structural weakness the number of construction joints should be reduced to a minimum. However, the design for shrinkage and shrinkage reinforcement usually necessitates construction joints at regular intervals. Because of these contradicting requirements for construction joints, the positions and number of constructions joints should be specified by the design engineer and indicated on the drawings. If there is a need on-site to revise any specified position or to have additional joints the proposed positions should be agreed with the design engineer.

(104) Full structural continuity is assumed in design at a construction joint. Reinforcement is fully continuous across the joint and the concrete is taken to be monolithic.

(105) Cracking in the concrete member arising from all thermal and load effects is controlled by the use of reinforcement.

(106) The designer should specify the following:
(a) The concrete at the joint should be bonded with that subsequently placed against it, without provision for relative movement between the two.
(b) Concrete should not be allowed to run to a feather-edge, and vertical joints should be formed against a stop end.

(107) It is not necessary to incorporate waterstops in properly constructed construction joints. It is difficult to get proper compaction at waterstops and workmanship is usually poor. Waterstops thus reduce the shear and flexural capacity of the concrete section. If concrete at a joint is found to be leaky or porous, the joint should be grouted to make it watertight. Alternatively, incorporating a rope-type expansion waterstop may be a good compromise.

(108) Particular care should be taken when forming the joints:
(a) The surface of the first pour should be roughened to increase the bond strength and to provide aggregate interlock.
(b) With horizontal joints, the joint surface should be roughened, without disturbing the coarse aggregate particles, by spraying the joint surfaces with a fine spray of water and/or brushing with a stiff brush. Alternatively a high pressure water jet may be used to wash out the concrete fines on the surface leaving the exposed aggregate to interlock. This should be done approximately 2h to 5h after the concrete is placed, the exact timing to be experimentally determined on site
(c) Vertical joints can be treated similarly, if the use of a retarder on the stop end is authorized, to enable the joint surface to be treated after the stop end has been removed.
(d) Care should be taken not to disturb reinforcement bars protruding from the first pour surface.

(109) If the joint surface is not roughened until the concrete has hardened, the larger aggregate particles near the surface should be exposed by sandblasting or by applying a scaling hammer or other mechanical device. This should be done at least two days after casting. Powerful hammers should not be used as they may damage or dislodge aggregate particles so reducing, rather than increasing, the capacity of the joint to transfer stresses.

(110) Joint surface preparation should leave larger aggregates exposed and have an amplitude of roughness of between 1.5 and 5 mm.

(111) Before placing fresh concrete, the old concrete should be saturated. Excess water should however be removed from the surface of the joint before the fresh concrete is placed. There is a widespread practice to use cement slurry to wet the old surface before casting fresh concrete. This practice should be discouraged as it serves no purpose.

(112) Care should be taken that the joint surface is clean, free of all loose material and free of laitance immediately before the fresh concrete is placed against it.

(113) Particular care should be taken in the placing of new concrete close to the joint to ensure that it has adequate fines content and is fully compacted and dense.

(114) It will likely be necessary to grout vertical construction joints to ensure water tightness. This grouting should be delayed as long as possible so that shrinkage can take place.

N.4 Temporary open sections

(101) Where structural continuity is required in the final structure (e.g. the wall of a rectangular tank or in floor slabs) the amount of reinforcement required to control early thermal effects (*T1*) may be reduced by the use of temporary open sections or strips.

(102) The width of the open section between adjacent panels should be not greater than 1000 mm.

(103) Properly formed construction joints should be provided at each edge of the temporary open section with the longitudinal reinforcement from each adjacent panel lapping in this area.

(104) Provided that the isolated panels satisfy the criteria for option 3 a) of Table N1, only the effects of *T*2, the temperature fall due to seasonal variations (see Section 7.3.4), need be considered when designing the complete continuous structure.

(105) Sufficient time should be allowed for all the early thermal movement to take place before the open section is in filled.

N.5 Joints in ground slabs

(101) The floor of a structure shall be designed to permit thermal contraction and shrinkage by minimizing restraints to movement. A separating layer of 1.0mm polyethylene should be provided between the floor slab and the blinding concrete, unless there is a subsurface drainage layer. Any downward protrusions below such a slab act as keys and can wholly or partially prevent sliding movement of the slab.

(102) Panels may be cast in single bays or in larger areas with induced joints.

(103) Alternatively, the floor may be designed as fully restrained against shrinkage and thermal contraction and should be cast directly onto the blinding concrete.

(104) Frequently, in large structures, the floor is designed as a series of continuous strips with transverse induced complete contraction joints provided to ensure that cracking occurs in predetermined positions. Longitudinal joints between the strips should form complete contraction joints.

N.6 Joints in walls

(101) Walls may be designed as fully restrained against thermal contraction and shrinkage, or the restraints may be reduced by providing movement joints in accordance with Table N.1.

(102) The joint in this position will be a construction joint, and although it is recommended that wall panels are cast in one lift, any necessary extra horizontal joints will be construction joints.

(103) In walls to circular structures, one of the predominant forces from the liquid pressure is horizontal hoop tension.
(a) Vertical joints in such walls are notorious for being difficult to make watertight and should be avoided.
(b) If vertical joints cannot be avoided, the horizontal reinforcement should be continuous at vertical joints.

N.7 Joints in roofs

(101) Roof slabs are generally designed as flat slabs, in which case all joints should be construction joints so that the slab is structurally monolithic.

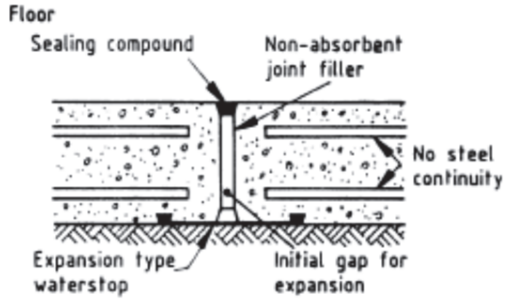
(102) Early thermal effects and subsequent temperature effects should be considered.

(103) Roofs, even those covered by soil, may be subjected to a larger thermal change than the walls and floor, but if the roof is not connected monolithically to the wall the subsequent temperature effects may be disregarded (i.e. reinforcement to control cracking is based only on $T1$, the fall in temperature between the hydration peak and ambient (see Section 7.3.4)).

(104) Where roofs and walls are monolithic, movement joints in roofs should correspond with those in the walls to avoid the possibility of sympathetic cracking.
(105) If, however, provision is made by means of a sliding joint for movement between the roof and walls, correspondence of the joints is less important.

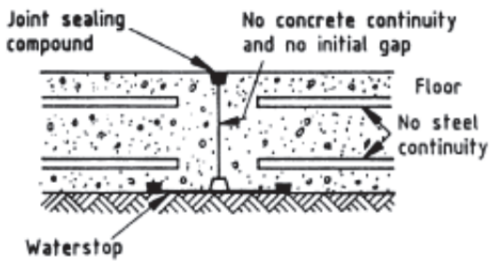
Floor Joints

(a) Expansion Joint

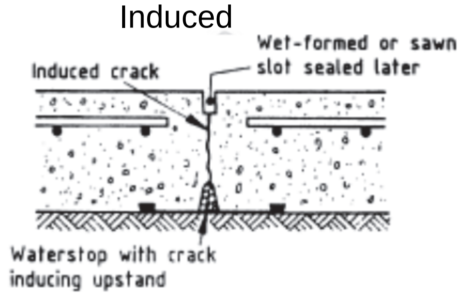


(b) Complete Contraction Joints

Formed

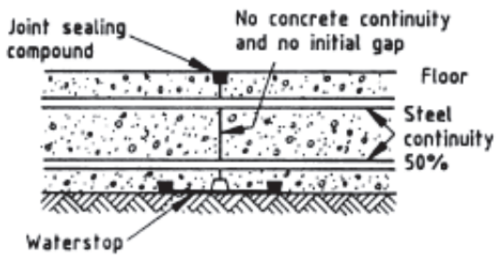


Induced



(c) Partial Contraction Joints

Formed



Induced

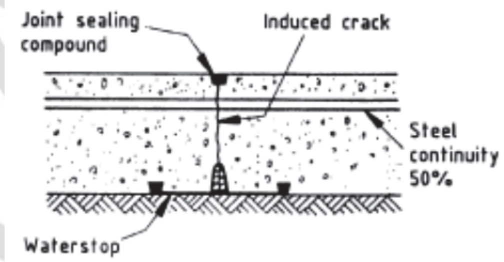
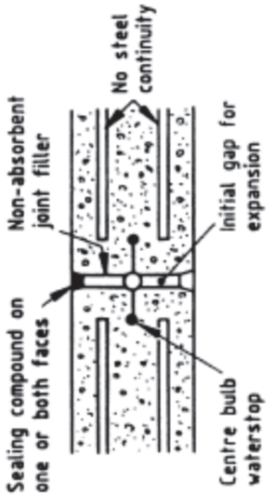
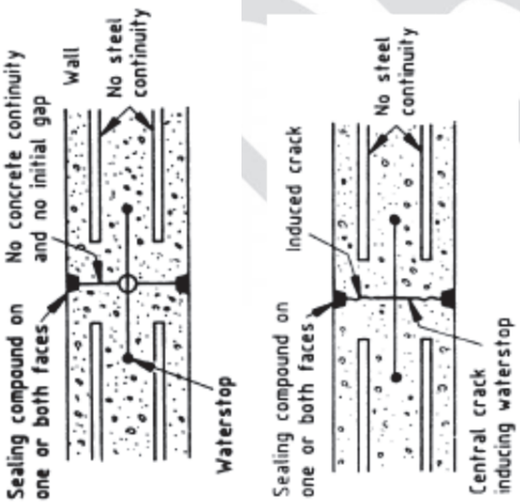


Figure N.2. Floor joints

Wall Joints
(a) Expansion Joint



(b) Complete Contraction Joints
Formed Induced



(c) Partial Construction Joints
Formed Induced

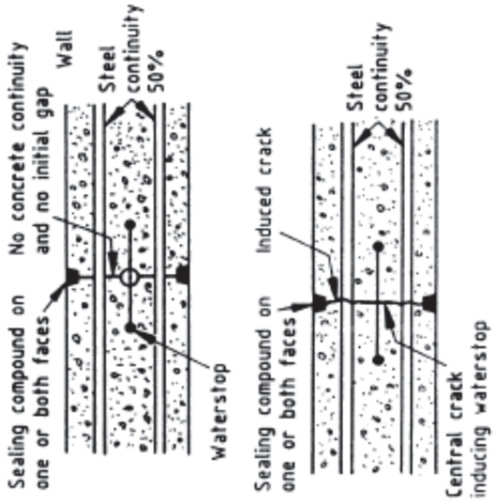


Figure N.3. Wall joints

N.8 Jointing materials

N.8.1 General

(101) The joints described in sections N.1 to N.7 require the use of combinations of jointing materials, which may be classified as:
a) Joint fillers;
b) Waterstops;
c) Joint sealing compounds (including primers where required).
d) Bandages

(102) These materials are inaccessible once the liquid-retaining structure has been commissioned until the structure is taken out of use for maintenance purposes.

(103) The design uses for these materials in joints should take into account their performance characteristics, both individually and in combination, and the restrictions and difficulties of access to them should the joints not perform as designed.

(104) One of the principal problems with joints is obtaining continuously satisfactory adhesion between joint sealing compounds and the concrete surfaces between which they are to provide a liquid-tight seal. Joint sealing compounds cannot be

expected to provide a liquid-tight seal for more than a proportion of the life of the structure, and waterstops should therefore always be provided in movement joints.

(105) When proprietary materials or products are used, the recommendations of the manufacturer should be followed.

(106) Jointing materials should be capable of accommodating repeated movement without permanent distortion or extrusion, and they should not be displaced by fluid pressure. The materials should remain effective over the whole range of temperature and humidities considered. For example, they should not slump unduly in hot weather neither should they become brittle when cold. The materials should be insoluble and durable and not change unduly by evaporation of solvent or plasticizers, nor, in exposed portions, should they be altered by exposure to light. Depending on the application, they may need to be approved for use in contact with chlorinated potable water, non-toxic and taintless and resistant to chemical and biological attack.

(107) Ease of handling and of application or installation of jointing material are important, and the use of jointing materials should not prevent the proper compaction of the concrete next to the joint. Detailing at places where the joint changes direction or intersects another joint should be easily constructable. Sealants, unless otherwise specified in this code, should comply with BS 6213.

N.8.2 Joint fillers

(101) Joint fillers are used in expansion joints as illustrated in section N.1 to N.7. They consist of compressible sheet or strip material fixed to the face of the first-placed concrete and against which the second-placed concrete is cast. They provide the initial separation between the faces of the concrete and compress under the predetermined expansion from each face of the concrete.

(102) It is important that the joint filler accommodates the compression without transferring appreciable load across the expansion joint and recovers so that the joint remains filled when the concrete faces subsequently move apart.

(103) Since the percentage expansion or contraction of the filler is inversely proportional to the initial width of the joint, there is an advantage in using a wide joint.

(104) The usefulness of a joint filler is increased if the material remains in contact with both faces of the joint throughout joint movements. This is important since the joint filler is used as a support to the joint sealing compound which is usually resisting liquid pressure.

(105) Only non-degradable and non-absorbent materials should be used as joint fillers.

N.8.3 Waterstops

(101) Waterstops are preformed strips of durable impermeable material that are wholly or partially embedded in the concrete during construction. They are located

across joints in the structure to provide a permanent liquid-tight seal during the whole range of joint movements.

(102) Waterstops are usually proprietary items with determined performance characteristics in accordance with BS 6213. When specified, waterstops should be appropriate to the required design performance.

(103) The different applications of waterstops are described in sections N.1 to N.7 and illustrated in Figures N.1 and N.2.

(104) It is essential that the concrete placed around the waterstop is well compacted and that the waterstop be fixed and maintained firmly in position until the concrete placing is completed and the concrete has set.

(105) Waterstops may be divided into six categories:

(a) The central-bulb type: The first category is used in walls to form expansion, contraction and partial contraction joints. The central bulb is positioned across the joint, and the main waterstop is set parallel to the water-surface of the concrete wall. There is a solid bulb or wing at each end of this type of waterstop, which is made of rubber or flexible plastics such as PVC. The distance of the waterstop from the nearest exposed concrete face should not be less than half the width of the waterstop.

(b) The second category is similar to the first category but has no central bulb. It is set in a similar manner to category one, but should be used only in contraction, partial contraction and construction joints.

(c) The third category consist of surface types or rearguard of waterstops. These are mainly used on the undersides of concrete slabs, and sometimes on the outer face of walls that are backfilled. These waterstops are set into the surface of the concrete each side of contraction or partial contraction joints that are formed. They are also used with a central crack-inducing tongue for induced contraction joints. To secure good compaction of the concrete against the water-stop it should be fixed to a base of blinding concrete or formwork. The use of a surface waterstop is sometimes specified at construction joints. This type of waterstop is usually formed from rubber or flexible plastics such as PVC.

(d) The fourth category of waterstop is a rigid type. These waterstops are specified when, as in construction joints, no movement is expected at the joint but a positive waterstop is required because of the pressure of the contained liquid, as in a pressure pipeline. These waterstops are usually formed from copper or steel strip.

(e) Expanding Waterstops are bentonite/butyl based and swell when it comes in contact with water. The product is available as caulk grade or self-adhesive strip. These are typically used at construction joints and can be effective to seal joints of limited movement, but should be kept dry until concreting takes place. These products can be used on most sub-strata. On concrete a cover of at least 50mm is required. Expanding waterstops are not to be used in expansion joints

(f) Bandage systems consist of flexible rubber sheeting with a thickness of 1 mm or 2 mm fixed to either side of the joint with epoxy resin adhesive as a positive pressure sealant. This type of water stop has become common practice and can be carried out horizontally, vertically or overhead. It is suitable for sealing irregular sized or high movement joints or where the joint faces are not sufficiently straight to allow the use of a conventional sealant. Flexible joint systems must be protected from mechanical damage and the joint strip must be supported in the joint by foam or sealant backing material. Fixing surfaces should be mechanically cleaned, preferably by blast cleaning followed by vacuuming. The laitance must be removed to establish good adhesion. Concrete should be at least 3 weeks old at the time of application. Particular care should be taken to ensure watertight continuity at all junctions in bandages. Allowance should be made for testing the adhesion of the bandage to the concrete surfaces.

(106) The design of the structure should generally provide for the continuity of the waterstop system across all joints and particularly junctions between floor and wall systems.

(107) The correct procedure for making the running joints on site using heat fused butt welds for PVC, vulcanized or pocketed sleeve joints for rubber and brazed or welded lap joints for copper or steel needs to be adopted. Intersections and special junctions such as those that arise between rubber and PVC should be prefabricated.

(108) Metal waterstops can be lapped instead of welded, provided that the gap between them is 5 mm greater than the specified size of the coarse aggregate. Laps should be at least 100mm.

(109) The gap between a waterstop and the reinforcement bars should be at least twice the specified size of the course aggregate to allow for adequate compaction.

(110) Surface waterstops should be used only in situations where there is sufficient pressure from the outside to ensure that the waterstop remains in position.

(111) Waterstops in the middle of slabs should be avoided since compaction of concrete below such a waterstop is problematic and waterstops are easily displaced during concreting . Waterstops placed in the middle of thin structural elements (thinner than 300 mm) may also pose problems when pouring concrete.

N.8.4 Joint sealing compound

(101) These materials (or sealants) are impermeable ductile materials that are required to provide a liquid-tight seal by adhesion to the concrete throughout the range of joint movements. The sealing performance is obtained by permanent adhesion of the sealing compound to the concrete each side of the joint only and most sealants should be applied in conditions of complete dryness and cleanliness.

(102) There are joint sealing compounds that are produced for application to surfaces that are not dry. The recommendations of the manufacturer should be

followed to ensure that the sealing compounds are applied correctly to adequately prepared surfaces.

(103) It is necessary that the corners of the concrete each side of the joint are accurately cast as detailed with impermeable concrete to avoid water by-passing the sealant through the concrete.

(104) BS 6213:1982 provides guidance on types of constructional sealant and on their selection and correct application, so enabling the specifier to select appropriately from Table 4 of that standard.

(105) Table 4 of BS 6213:1982 lists the main types of sealants and their suitability for the different types of joints in a variety of liquid-retaining structures. Table 4 and sections 6 and 7 of BS 6213:1982 give guidance on the method of application of the sealants. Suitable surface preparation for sealant application is important.

(106) Table 2 of BS 6213:1982 provides an expected service life for the various types, with an indication that 20 years is a reasonable maximum, although in favourable conditions a longer service life may be expected.

(107) In floor joints, the sealing compound is usually applied in a chase formed in the surface of the concrete along the line of the joint. The actual minimum width will depend on the known characteristics of the material. In floor joints of the expansion type, the sealant is supported by the joint filler. In floor joints, retention of the sealant is assisted by gravity, and in many cases sealing can be delayed until just before the structure is put into service, so that the amount of joint opening subsequently to be accommodated is small.

(108) The chase should be neither too narrow nor too deep to hinder complete filling and should be primed before the sealing compound is applied. Here again, a wider joint demands a smaller percentage distortion in the material.

(109) The utilisation of a properly set backing cord is recommended to ensure a filler width to depth ratio of 1.5 to 1.

(110) Vertical joints in walls should be primed where necessary and then sealed on the liquid-face with a sealant that is usually pressured by gun or knife into the preformed chase. The sealants should have non-slumping properties and great extensibility.

(111) The long-term performance of a joint sealing compound depends on its formulation, the workmanship with which it is prepared and applied as well as the circumstances of the structure. It would be unwise to depend on the sealing compound for liquid-tightness in the long term and that should be provided by the waterstop. The sealing compound should maintain stability at the face of the joint and preclude the ingress of any hard objects that could impair joint movements.

- **Annex O**
- (informative)
- **Effect of temperature on the properties of concrete**

O.1 General

(101) This Annex covers the effects on the material properties of concrete of temperatures in the range -25°C to +200°C. Properties covered are: strength and stiffness, creep and transitional thermal strain.

(102) In all cases the changes in properties are strongly dependant on the particular type of concrete used and the Annex should not be considered to provide more than general guidance.

O.2 Material properties at sub-zero temperatures

(101) When concrete is cooled to below zero, its strength and stiffness increase. This increase depends mainly on the moisture content of the concrete: the higher the moisture content, the greater is the increase in strength and stiffness. It should be noted that the enhancement in properties would apply only to structures, which would be permanently below -25°C.

(102) Cooling concrete to -5°C leads to increases in the compressive strength of:

— around 5 MPa for partially dry concrete

— around 30 MPa for saturated concrete.

(103) The expressions given in Table 3.1 for tensile strength may be modified to give the effect of temperature as follows:

$$f_{ctx} = \alpha\, f_{ckT}^{2/3} \qquad [O.1]$$

where:

f_{ctx} = tensile strength, however defined (see Table O.1).
α = a coefficient taking account of the moisture content of the concrete. Values of α are given in Table O.1.

f_{ckT} = the characteristic compressive strength of the concrete modified to take account of temperature according to (102) above.

Table O.1 — Values of α for saturated and dry concrete

Definition of tensile strength (f_{ctx})	Saturated concrete	dry concrete
f_{ctm}	0,47	0,30
$f_{ctk\,0,05}$	0,27	0,21
$f_{ctk\,0,95}$	0,95	0,39

(104) Cooling concrete to -25°C leads to increases in the modulus of elasticity of:

— around 2 000 MPa for partially dry concrete

— around 8 000 MPa for saturated concrete.

(105) Creep at sub-zero temperatures may be taken to be 60% to 80% of the creep at normal temperatures. Below -20°C creep may be assumed to be negligible.

O.3 Material properties at elevated temperatures

(101) Information on the compressive strength and tensile strength of concrete at temperatures above normal may be obtained from 3.2.2 of EN 1992-1-2.

(102) The modulus of elasticity of concrete may be assumed to be unaffected by temperature up to 50°C. For higher temperatures, a linear reduction in modulus of elasticity may be assumed up to a reduction of 20% at a temperature of 200°C.

(103) For concrete heated prior to loading, the creep coefficient may be assumed to increase with increase in temperature above normal (assumed as 20°C) by the appropriate factor from Table O.2

Table O.2 — Creep coefficient multipliers to take account of temperature where the concrete is heated prior to loading

Temperature (°C)	Creep coefficient multiplier
20	1,00
50	1,35
100	1,96
150	2,58
200	3,20
NOTE The values in the table have been deduced from CEB Bulletin 208 and are in good agreement with multipliers calculated on the basis of an activation energy for creep of 8 kJ/mol.	

(104) In cases where the load is present during the heating of the concrete, deformations will occur in excess of those calculated using the creep coefficient multipliers given in (103) above. This excess deformation, the transitional thermal

strain, is an irrecoverable, time-independent strain which occurs in concrete heated while in a stressed condition. The maximum transitional thermal strain may be calculated approximately from the expression:

$$\varepsilon_{Tr} = \kappa\sigma_c\varepsilon_{Th}/f_{cm} \quad [O.2]$$

where:

κ = a constant obtained from tests. The value of κ will be within the range $1{,}8 \leq \kappa \leq 2{,}35$

f_{cm} = the mean compressive strength of the concrete

ε_{Tr} = the transitional thermal strain

ε_{Th} = the free thermal strain in the concrete (= temperature change · the coefficient of expansion)

σ_c = the applied compressive stress

- **Annex P**
- (informative)
- **Cylindrical prestressed concrete structures**

P.1 Cylindrical prestressed concrete structures

(101) The special recommendations for the design of cylindrical concrete structures prestressed vertically and circumferentially are as follows:

(a) The jacking force in the circumferential tendons should not exceed 75% of the characteristic strength.

(b) The principal compressive stress in the concrete should not-exceed $0.33f_{ck,\ cube}$.

(c) The temporary vertical moment induced by the circumferential prestressing operation in the partially stressed condition should also be considered. The maximum value of the flexural stress in the vertical direction from this cause may be assumed to be numerically equal to 0.3 times the circumferential compressive stress. Where the tensile stress would exceed 1,0 N/mm^2, either the vertical prestress should be
increased or the circumferential prestress should be built up in stages, with each stage involving a progressive application of prestress from one end of the cylinder.

(d) When the structure is full there should be at least 1.0N/mm^2 compression in the concrete in the circumferential direction, after allowance for all losses of prestress and on the assumption that the top and bottom edges of the wall are free of all restraint.

(e) The bending moments in the vertical direction should be assessed on the basis of a restraint equal to one-half of that provided by a pinned foot, where the foot of the wall is free to slide. In other cases where sliding at the foot of the wall is prevented, the moments in the vertical direction should be assessed for the actual degree of restraint at the wall foot. The tensile stress arising from vertical moments should not exceed 1.0 N/mm^2.
.
(f) Where the structure is to be emptied and filled at frequent intervals, or perhaps left empty for a prolonged period, the structure should be designed so that there is no vertical residual tension in the concrete at any point when the structure is full or empty.

(g) Placing of prestressing wire outside the walls is strongly discouraged, especially in industrial areas or near the sea, where there is high risk of corrosive penetration of the pneumatic mortar covering. The cables should be placed within the walls and preferably grouted. Non-bonded tendons may be used provided that they and their anchorages are adequately protected against corrosion.

(102) Cylindrical concrete structures which are prestressed circumferentially and reinforced vertically should comply generally with the recommendations of this Annex, except that clause P.1(f) may be relaxed to allow vertical tensile stress not exceeding 1 N/mm2. The design for the vertical reinforcement should be in accordance with Sections two and seven.

- **Annex Q**

- (informative)

- **Guidelines for good construction practices**

Q.1. Scope and introduction

(101) This guideline gives methods of specifying, producing and assessing concrete structures for water retaining purposes.

(102) All concrete structures designed to SANS 51992-1-1 have to meet the design requirements in terms of strength, stability, robustness and serviceability. Water retaining structures (WRS) have to meet additional requirements in terms of durability and water tightness. This section then focuses on construction practices that are required to achieve the additional requirements of durability and water tightness for water retaining structures.

(103) These guidelines are mainly intended for site personnel, but design engineers can also take note of the recommendations regarding construction methods, since constructability of the structure and its various components and details should be considered at design stage.

(104) Those looking for more details should refer to specialist literature.

Q.2. Administration

Q.2.1. Site personnel

(101) All key site personnel from all parties involved should preferably have previous experience in the construction of WRS. The curricula vitae of the Contractor's site personnel should be submitted to the Engineer for approval.

(102) All key site personnel involved in the construction of water retaining structures should be briefed on the design objectives of the Engineer. The differences between general concrete structures and water retaining concrete structures should be highlighted during a construction project brief at the start of the project.

Q.2.2. Construction project brief

(101) A proposed agenda for the construction project brief could be as follows:

(a.) Introduction of key personnel
(b.) Establishing and defining of roles and responsibilities
(c.) Establishing of communication channels
(d.) Introduction to project, including wider background of project and client's objectives
(e.) Introduction to various structures and other elements of the project
(f.) Project program; supply of information
(g.) Concrete for WRS; durability and water tightness
(h.) Concrete mixes, including cement pastes, aggregates, water, admixtures
(i.) Testing of concrete: Cube strength, Slumps, Absorption, Oxygen Permeability.

(j.) Curing method
(k.) Repair of concrete: honeycombing, cracks, construction joints, ferrule holes.
(l.) Testing of other materials and products: Structural steel, coating on structural steel, anchor bolts, compaction of backfill
(m.) Placing and details of reinforcement, stools, clips, concrete spacers, concrete cover to reinforcement
(n.) Site reinforcement for emergency situations; cutting and bending thereof
(o.) Water tightness tests including planning thereof
(p.) Construction sequence, location and details of construction joints; actual forming of construction joints
(q.) Loading of structures; temporary loads or construction loads; age of structure at loading
(r.) Quality control

Q.2.3. Quality Control

(101) Most Contractors have their standard quality control (QC) documentation. It is important that specific aspects pertaining to water retaining structures (WRS) are included in such documentation. The Structural Engineer must approve the Contractor's QC plan.

Q.3. Loadings

Q.3.1. Loadings during construction stage

(101) In most cases a structure is designed for the loadings pertaining to its working life. During construction the actual loadings sometimes exceed the final design loads. Before placing higher loads on a structure it is imperative that the Design Engineers' permission or opinion is obtained. Construction loads are typically temporary in nature. Some examples of construction loads are:

(a.) Excess loading of stone or earth on roof of reservoir
(b.) One-sided loading to a baffle wall
(c.) Backfilling to a partially completed structure
(d.) Any loading at early age, i.e. before concrete is 28 days old

Q.3.2. Permanent loadings

(101) The most important permanent load for a WRS is the load of the water. The design water level for tanks should always be shown on the design drawings. It is of utmost importance that this level is never exceeded, most notably during water tightness testing. The emergency overflow outlets from WRS should therefore always be open and unobstructed.

Q.4. Concrete

Q.4.1. General

(101) Concrete for WRS has to satisfy additional requirements in terms of durability and water tightness. Such additional requirements can be met by changes to the

concrete mix design, special cements to be used, by the inclusion of additives to the mix as well as enhanced placing and compaction techniques.

(102) Refer to Annex K for recommendations on the concrete mix design.

Q.4.2. Compaction

(101) Compaction or vibration of concrete for WRS is identical to ordinary concrete structures. A few improvements can be made:

(a.) After vibration or revibration: This method can be of importance at top of walls. One or two hours after completing a wall section, the top of the wall (say the top 600 mm) can be vibrated again, thus eliminating any voids that may have formed below horizontal reinforcement bars. The exact timing of such revibrating needs to be determined by experimenting.

(b.) Over-compaction: Fresh concrete against existing concrete, i.e. at construction joints, should be well compacted. In a well-designed concrete mix with the right water cement ratio, the risk of over-compaction and segregation is very remote. It should be noted that most WRS show leakages at construction joints that could have been prevented by some extra compaction effort.

(c.) Compaction at recesses and openings: All recesses and openings in WRS should be detailed in such a way that proper compaction is possible. If detailing is incorrect or insufficient, the Contractor should propose alternatives to the Design Engineer. The following points can be noted:

- i.) Box-outs for pipes should be placed with sides at 45 degrees to the horizontal. (See detail)
- ii.) Horizontal recesses should have a 45 degrees slope at bottom. (See detail)
- iii.) Square permanent openings, if unavoidable, should have casting windows at bottom.

Q.4.3. High evaporation concreting

(101) Concreting during times of high evaporation is particularly challenging. High evaporation typically occurs during hot weather, high winds and dry air. It is the combination of the three mentioned factors that result in high evaporation.
Higher temperatures cause water to evaporate from the surface of the concrete at a faster rate and cement hydration occurs more rapidly, resulting in an earlier stiffening of concrete with increased incidences of plastic cracking.

(102) One or more of the following measures should be taken to mitigate the effects of a high evaporation environment:

- a.) Concreting during early morning hours
- b.) Use of mist spray on steel formwork
- c.) Use of site-batching so that concrete is very fresh when placed
- d.) Use of iced-water to concrete mix
- e.) Use of shade netting, possibly combined with other measures

f.) Use of appropriate placement techniques and sequences

Q.4.4. Cold weather concreting

(101) When ambient temperatures are 5°C or lower, the weather is described as "cold".

(102) During cold weather concreting the cement hydration process occurs more slowly or does not occur at all.

(103) Stripping times for formwork are normally increased during winter times. The best method of curing is to use insulated formwork over a sustained period. Water curing methods should not be used during cold weather.

(104) Special measures like heating of aggregate and/or mixing water are seldom done in South Africa.

Q.4.5. Pneumatically applied mortar

(101) The pneumatic application of mortar is a specialist operation and should be carried out only by experienced operators. The designer should agree a full specification with the contractor for materials, mix proportions, mixing, placing, equipment and curing before any work commences.

Q.5. Reinforcement

Q.5.1 Quality control of reinforcement

(101) One of the most vital aspects of overall quality control on site is the quality control of reinforcement.

(102) Quality control of reinforcement on site consists mainly of three parts: checking the quality of the reinforcement, checking the quantity of the reinforcement and checking the placement of the reinforcement.

(a.) Checking the mechanical properties, mostly tensile strength and elongation: All reinforcement must comply with SANS 920: Steel bars for concrete reinforcement, as amended. At the beginning of the project the Contractor should supply mill certificates for the reinforcement. In addition a number of sample bars should be taken for tensile and elongation tests. Such tests should be repeated at the discretion of the Engineer during the construction phase. If deemed necessary, the chemical properties of the steel can be checked as well. Particular care should be taken with imported products.

(b.) The quantity of reinforcement can easily be evaluated by checking the bar diameters and bar spacing. It should be noted that (equal) bar spacing is important since crack widths are influenced by bar spacing.

(c.) The correct placing or positioning of reinforcement is of utmost importance. One of the most important factors in placing of reinforcement is the nominal concrete cover. The following points are of note:

i.) If the nominal concrete cover to reinforcement is less than specified, the long term durability of the structure will be reduced, despite a smaller crack width and an increase in flexural strength for that particular section.

ii.) If the nominal concrete cover to reinforcement is more than specified, the crack width will increase and the flexural strength will decrease.

iii.) From i and ii above it is clear that positive tolerances on cover are as important as negative ones, and that reinforcement should be placed in its designed position.

iv.) Concrete spacers (often called cover blocks or spacer blocks) provide the specified nominal cover between the reinforcement nearest to the surface of the concrete element and the surface itself. Only cementitious, proprietary spacers should be used, preferably the circular variety. The concrete grade should be the same as for the structure. Plastic spacers and spacers made on site should never be used. Concrete spacers should be placed at bar intersections and spaced at not less than 50d, where d is the diameter of the bar that is supported. Concrete spacers should be spaced in staggered rows.

v.) Concrete spacer blocks as mentioned in iv above prevent the reinforcement from getting too close to the surface. They do however not prevent the reinforcement from moving away from that surface. This is of particular importance, but not limited to, walls with one or two sloping surfaces.]

vi.) Ties or clips are used to prevent reinforcement from moving away from wall surfaces. They should be fixed to the inner reinforcement bars, so as not to encroach into the concrete cover. Ties or clips should be spaced at not less than 50d where d is the diameter of the bar that is supported. As for concrete spacers, the ties or clips should be spaced in staggered rows. (The reinforcement in opposite faces of a wall can also be kept separated by using stools or chairs; this is however seldom done in South Africa).

vii.) Stools or chairs (the word “chair” is used in British Codes) are mostly used to support the top reinforcement in slabs and floors. Detailing of stools is adequately covered in SANS 0144. The legs of stools should be detailed long enough to be able to rest on and fixed to two bottom bars. Stools should be placed close to concrete spacers and spaced at not less than 50d, where d is the diameter of the bar that is supported. Stools should be spaced in staggered rows.

viii.) The ends of wire ties should not encroach into the concrete cover.

(103) All stools and clips should be detailed on the bending schedules. The prescribed spacing of stools and clips should be shown on the reinforcement layout drawings. Further information and guidance on the above subject can be found in BS 7973.

(104) It is of relevance to note that in most cases it is the responsibility of the Contractor to review all bending schedules for correctness prior to reinforcement being ordered.

Q.6. Formwork

Q.6.1 Design of formwork

(101) All formwork should be designed in accordance with special requirements for WRS. The design is usually undertaken by a specialist subcontractor and should be approved by the Engineer. The design drawings should show the construction joints, the types of formwork, the wall ties to be used as well as measures taken to prevent leakage.

Q.6.2 Types of formwork

(101) Formwork is usually constructed from steel or timber, each with their own properties, advantages, disadvantages and limitations.

(102) Permanent formwork should be allowed with caution since the concrete surfaces cannot be inspected afterwards.

(103) Casting against soil or rock faces should not be allowed except possibly in cases of edges of foundation slabs.

(104) Timber formwork can more readily be used for smaller elements and can be more readily adapted on site. The number of re-uses of timber forms is probably substantially smaller than that of steel forms.

(105) Timber formwork however has an important design disadvantage for the Structural Engineer: Due to the insulating properties of timber, the heat from the hydrating concrete is retained for a prolonged period causing temperature rises in the concrete. The subsequent temperature drop from peak to ambient temperature is therefore higher, resulting in increased early-age temperature cracking.

(106) The insulating properties of timber formwork can have an advantage when concreting in winter, where some protection to frost attack is provided and concrete will gain strength more rapidly.

(107) Due to its reduced weight, timber formwork can save transportation and crane costs on site.

(108) Steel formwork has the advantage of more re-uses as well as assisting in a more rapid dissipation of heat from the concrete resulting in reduced early temperature cracking.

Q.6.3 Details

(101) Where formwork joins onto existing concrete, it is important to make sure that no leakage from water and/or cement paste takes place. This can be achieved by fixing a foam strip along the formwork edge.

(102) Details of formwork wall ties are of specific importance. A common wall tie has two removable cones at its ends. After stripping the formwork, the cones are removed (leaving the connecting piece behind – cast in) and the holes are then repaired as per specification and the Contractor’s approved method statement.

(103) Wall formwork is often temporarily fixed to foundations or slab by using steel anchors. The positioning and number of such steel anchors should be approved by the Engineer. They should be removed after stripping of the formwork and the holes should be repaired with a proper and approved grout.

(104) Formwork release agents should be approved by the Engineer.

(105) In most WRS the cement contains fly-ash or slagment. It should be noted that stripping times for concrete containing fly-ash or slagment should be increased as per specification.

Q.7. Repair work

Q.7.1 General

(101) Even a well-designed and properly build structure will exhibit some cracking or honeycombing, which in itself is not necessarily a cause for concern.

Q.7.2 Construction joints

(101) It is normal for some slight cracking to occur at construction joints. Such cracking is invariably due to shrinkage. In some cases such cracks are very shallow (say less than 5 mm deep) and can be ignored. If repair is deemed necessary, such repair should be delayed as long as possible.

Q.7.3 Cracks

(101) When cracks appear in a concrete structure it is imperative that the Structural Engineer understands the cause of such cracking since the repair method vary depending on the reasons for cracking.

Q.7.4 Honeycombing

(101) In WRS all honeycombed concrete should be removed and repaired without exception.

(102) Grout specifications and work methods can be obtained from specialist grout suppliers.

(103) Preparation of surfaces to expose aggregates is vital. The so called “feather edging” of new concrete should be prevented by cutting perpendicular into surfaces to a depth of at least 10 mm or to the satisfaction of the Structural Engineer.

Q.7.5 Blow holes

(101) Blow holes, which are caused by slight under vibration, are small spherical or semi spherical voids on the surface of the finished concrete structure, usually a wall. They should be filled up with an appropriate grout as soon as possible after stripping of formwork.

Q.8. Drainage

Q.8..1 General

(101) Various forms of drainage are often provided for in WRS and should only be provided if necessary. Drainage systems below WRS are usually installed to detect leakage of floor slabs. Drainage systems behind walls are typically provided to limit external water pressure on the walls. In all cases both the Design Engineer and the Contractor should fully understand the functions and details of the drainage systems to be installed.

Q.8..2 Subsoil drainage

(101) Subsoil drainage underneath WRS should be installed to detect possible leakage of the floor slabs. The Design Engineer may decide to omit such subsoil drainage if:

(a.) The footprint of the WRS is relatively small
(b.) The floor slab of the WRS is cast in one operation, i.e. without construction joints and/or expansion joints.
(c.) The type of foundation material permits. Foundations on problem soils like dolomite and dispersive soils may require leakage control.

(102) Most leakage through floor slabs will occur through construction joints and expansion joints.

(103) A system of drainage pipes can be provided below all or most construction joints and expansion joints. The drainage pipes should be perforated and laid with the rows of holes at the bottom. The footprint of a medium or large WRS can be subdivided in such a way that leakage from a pipe can be related back to a specific area of the floor slab involved. The portions of the drainage pipes outside the WRS should for obvious reasons not be perforated. All drainage pipes should drain into inspection manholes. The drainage pipes below the WRS should be encased in no-fines concrete.

(104) In order for subsoil drainage to be effective, the slipsheet provided on top the blinding layer should be perforated.

Q.8..3 Wall drainage

(101) Drainage behind the external walls of a WRS can be provided to limit the horizontal water pressure onto the wall, as well as limiting the vertical uplift pressure on the WRS.

(102) The perforated drainage pipes must be placed with the rows of openings to the bottom. The pipes must be placed inside a stone trench. The stone trench should be protected against the ingress of fines by wrapping in geotextile filter cloth.
(103) For WRS with no or low external backfill, the external wall drainage may be omitted at the discretion of the Design Engineer.

Q.9. Joints

(101) Refer to Annex N for guidance on joints.

Q.10. Curing

Q.10.1 General

(101) Proper curing is crucial to ensure concrete with adequate strength and durability. Curing specification, specific site inspections and contractual provision in terms of penalty clauses should be considered to ensure proper curing.

(102) One of the most neglected aspects of concrete construction on site is the curing of concrete. One reason for this neglect could be that the consequences of poor curing are not always immediately visible.

(103) During the hardening process of concrete, sufficient water must be available for the full hydration of cement.

(104) The aim of curing is to prevent moisture loss in fresh concrete or to replace such moisture in cases where losses have occurred or are occurring.

(105) A more complete definition of curing includes the maintaining of both favourable moisture and temperature conditions; During cold weather, the hydration process is slow or does not take place at all, and curing times should be extended depending on temperature conditions.

(106) Moisture loss in concrete can be prevented by curing with water, spraying with a curing compound or by some form of covering.

(107) At start of construction the agreed curing method can be used for a trial period with the option to review depending results.

(108) The period of curing should be at least 7 days after completion of casting.

Q.10.2 Curing with water

(101) Curing with water is fundamentally the most appropriate way to prevent moisture loss. Under hot weather conditions, curing with water should be the only acceptable curing method. The exact temperatures and circumstances should be left to the judgement of the Structural Engineer.

(102) Water curing should not be used during cold weather.

(103) Floor slabs and roofs can be cured by ponding of water or continuously spraying with water, including over weekends and other non-working periods.

(104) Curing water should be of the same quality as the water that is used to produce concrete.

Q.10.3 Curing with liquid curing compounds

(101) Liquid curing compounds can be applied by spraying or brushing and in case of walls, should be applied immediately after striking of formwork. Curing compounds on slabs are usually applied the day after casting.

(102) The curing compound should be approved for potable WRS if and where applicable.

(103) The use of a pigmented type of compound has the advantage that site quality control is made easier.

Q.10.4 Curing by covering

(101) The simplest method of curing is by leaving the formwork in place, but this could prove uneconomical for the Contractor.

(102) Wrapping columns with thin plastic has proved popular and is widely used.

(103) Walls can be covered with plastic sheeting of at least 250 micron thickness. Care should be taken that all edges are properly closed. Large plastic sheeting is susceptible to wind and should be properly fixed.

(104) Slabs can be cured by covering with sand or equivalent moisture retaining materials that must be kept wet continuously.

Q.11. Steelwork, Pipework, Mechanical and Electrical items

(101) This section deals with a number of non-concrete items in WRS.

(102) Crane gantries and related structural steelwork is often used to install mechanical and electrical equipment into position. In corrosive conditions the coating specification and application should receive special attention. In addition, the quality of bolts should be addressed.

(103) Structural steel roofs with cladding are sometimes provided over WRS. The corrosive conditions under these circumstances should be taken into account. For smaller roofs a timber structure could be more appropriate.

(104) All metal pipework leading into or away from concrete structures should be provided with a flexible coupling. HDPE and PVC pipes are assumed to have sufficient flexibility so that flexible couplings can be omitted, except possibly for large diameters.

(105) Access ladders, ventilators, pipework, etc. inside WRS that are subject to alternate wetting and drying should be made out of stainless steel.

(106) Mechanical equipment such as aerators and mixers and electrical equipment such as transformers and distribution boards should be specified well in advance so that appropriate provision can be made for anchors, openings, sleeves etc.

(107) Pipework cast into boxouts at walls and slabs:

(a.) Such pipework is often provided with a puddle flange that should be placed in the centre of the wall.
(b.) The boxout should be angled at 45 degrees to the horizontal to prevent honeycombing.
(c.) The remaining opening between concrete and pipe should be grouted with an approved grout. This grout should preferably have non-swell properties.
(d.) Similar principles apply for grouting of sluice gate frames etc.

Q.12. Testing for water tightness

Q.12.1 Planning for testing

(101) The technical procedure for water tightness testing of WRS is clearly described in clause 2.9.3. The actual planning of water tightness tests is equally important. The water tightness test for each individual structure on a project should be shown on the construction program and should only take place after all ferule holes and pipe items have been grouted, all sluices have been installed, all joints have been sealed and the structure has been cleaned.

(102) For structures that are mostly protruding above groundlevel the external faces of walls can easily be inspected. For structures placed below groundlevel the external backfilling operations should be done after completing the water tightness test.

(103) For certain structures and logistics permitting, the water tightness test can be done in phases. It is sometimes possible to do a test on the floor only and test the walls of a structure at a later stage.

Q.13. Retrospection

(101) At the end of construction activities a meeting should be held between the relevant parties.

(102) The purpose of this meeting should be an honest exchange of views on the relative merits and achievements of the completed construction project, in order to improve the next project. To this end all parties should endeavour to establish both the positive and negative aspects and possible improvements of the project without recriminations.

(103) The construction project brief checklist given in clause Q.2.2 can be used as an agenda for such a meeting.

APPENDIX C: Comments by SABS TC98-02 and resolutions taken

ANNEX
TEMPLATE FOR COMMENTS AND PROJECT LEADER RESPONSE

Refers to document number:	SANS 10100-3	**Date of issue:**	2014-09-18

1	2	3	4	5	6	7
Abbreviated organisa-tion name	**Comment No.**	**Clause No. / Subclause No. Annex etc.** (e.g. 3.1)	**Justification for change**	**Proposed change**	**Response of Standards Writer**	**Resolu-tion taken in a meeting**
The concrete institute	1	Annex K	This clause should be in the main body of the text not the informative annex	It should form part of clause 6	This clause can be changed into a normative annexure as it will still be just as compulsory as the main body of text, otherwise this can be further debated in the meeting.	
The concrete institute	2	Annex K	This clause should be in the main body of the text	Technically modify annexure K into clause 6.2 to 6.2.2.9 (see embedded document) The concrete institute SANS 10100	This can be discussed in the upcoming meeting	
Stellenbosch University	3	4.1.3.9	Editorial	Refer to Figure A.1 in text. Wrong figure number	Shall update immediately	
	4	6.1	Reference is made to SABS 10100-2 which is being revised and will not be available soon.	The wording in the new draft SANS 51992-1-1 The durability of structures is addressed in Section 4 of SANS 51992-1-1 NA reads as follows: *This section of the code can be used to design structures for durability.* *An alternative approach to durability design will be included in the revised version of SANS 10100-2 to be published after 2012. Once this code has been published, either of the two approaches can be followed.* A similar phrasing should be used in SANS 10100-3	Shall cut and paste the relevant clauses accordingly	
	5	4.2.4	Editorial	Use correct subscripts for variables	Shall update immediately	

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1	2	3	4	5	6	7
Abbreviated organisation name	**Comment No.**	**Clause No. / Subclause No. Annex etc.** (e.g. 3.1)	**Justification for change**	**Proposed change**	**Response of Standards Writer**	**Resolution taken in a meeting**
	6	4.3.1	Editorial	Use only one full stop after "the roof"	Shall update immediately	
	7	5.2.2	Referencing	Reference is made to EN 1992-1-2: The user would not have access to this document	This can be discussed in the upcoming meeting to assess whether does this comment necessitates an adoption of this standard	
	8	9.3.2.1	Equation 7.108 has not been taken over correctly from BS 8007.	Use BS 8007 formulation.	This can be discussed in the upcoming meeting	

For complaints or compliments contact us at **Standards.Improve@sabs.co.za**

SABS

MINUTES

Title: SANS 10100-3 Chairperson: Prof Retief

Date of the meeting: 11-02-2015
Venue: Committee room Imbizo, SABS Groenkloof, PTA
Circulation date:

NOTE: THE MINUTES OF THIS MEETING ARE NOT A TRANSCRIPTION OF DISCUSSIONS. ONLY DECISIONS, REPORTS AND UNDERTAKINGS ARE RECORDED

RESOLUTION NUMBER	RESOLUTION / INFORMATION	ACTION
Information 1 (Introduction)	Prof Retief welcomed everybody in the meeting and informed members	
Apologies	Jan Wium Celeste Barnado Perduh Milos Vernon Marshal Bosman Herman David Middleton	
Attendance register	SANS 10100-3 Attendance register 2	
Resolutions for comment 1&2	WG members AGREED that Annex K to be incorporated in the main body of text under clause 6 The contents of clause 6 would be rearranged such that the comments that were submitted by CNCI would form clause 6.2 in the document. Any remaining variations resulting from comments of the working group of the previous draft will be resolved by CV,BB & GD. Celeste will review the CNCI suggested clause and send to Sizakele to include into SANS 10100-3.	
Resolutions of comment 3	The committee draft Renumber according to the sequence set out in the document.	
Resolutions of comment 4	Delete second paragraph of clause 6.1	
Resolutions of comment 5	Editorial corrections shall be done by the convenor	
Resolutions of comment 6	Editorial corrections shall be done by the convenor	

Resolutions of comment 7	Scrap the reference to EN 1992-1-2 and the convenor shall provide appropriate information	
Resolutions of comment 8	The WG AGREED that all equations shall be formatted according to the standardized format for equation including using the decimal comma instead of the decimal point	
Additional resolution	The WG raises the reservations regarding table 1 especially since the limitations on design crack widths where the full section is in tension make design unworkable. It is recommended that table 1 is replaced by the design crack width limitations in BS 8007 clause 2.2.3.3. The WG members AGREED to delete clause 9.1.1 .1 (c)	
Closure	The meeting was adjourned at	