The New South African Loading Code SANS 10160

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ABSTRACT: Design standards play a key role in the process of structural design and construction. The loading code often plays a leading role in establishing design procedures, such as limit states design, in addition to the specification of *minimum loads*.

This is the case of the present South African Loading Code (SA LC) SABS 0160:1989. Following Eurocode practice of a separate standard to establish *the basis of structural design*, the new SA LC SANS 10160 formally introduces such a head standard for structural design (Part 1) in addition to updated provisions for the scope of loads treated in SABS 0160:1989 (self-weight, imposed, wind, seismic and crane loads). It includes the introduction of new load types from Eurocode (geotechnical, thermal actions and actions during execution). The paper provides an outline of SANS 10160, its relation to the previous SA LC, reference to and compatibility with Eurocode, and the way in which local conditions and practice are taken into account.

1. INTRODUCTION

The current South African Loading Code SABS 0160:1989 (referred to subsequently as SABS 0160 for brevity) introduced a new generation of structural design standards to the country and region. It is used together with various other materials-based standards for the design of concrete (SANS 10100), steel (SANS 10162), timber (SANS 10163) and masonry (SANS 10164) structures.

At the South African National Conference on Loading in 1998 (SA-NCL) the need for an update of the SA LC was identified (Day & Kemp 1999). The SA Institution of Civil Engineering Working Group on the SA Loading Code was launched in 1999. The guiding principles derived from the 1998 conference were to update load provisions whilst maintaining compatibility with materials-based codes and enhancing harmonisation with international practice. The main effort went into a critical review of the various provisions for minimum loads.

The 1998 conference showed the inconsistencies between SABS 0160 and the voluntary version of Eurocode ENV 1991, which inhibited the use of ENV 1997 for geotechnical design in South Africa. In an effort to convert Eurocode into a normative European standard (EN 1990 – EN 1999) it became clear that South African practice for load combinations was consistent with one of the options allowed in EN 1990, as so-called Nationally Determined Parameters.

This Eurocode development removed a critical inconsistency between a major programme for the development of structural design standards in Europe and South African practice. The door was therefore opened, not only for geotechnical design but also for accessing the wealth of information coming from the Eurocode programme in the revision of the SA LC.

Pilot investigations were first performed to consider the application of the Eurocode standards and parts for imposed loads, wind and crane induced actions, with limited consideration of the basis of structural design. At the same time it provided an opportunity to perform an extensive assessment of the characteristics and merit of Eurocode standards, particularly with reference to the scope of SABS 0160. The pilot survey confirmed the advances achieved by the development of Eurocode through its various stages as a draft standard (1980's), voluntary standard (1990's), normative standard (1998+) and now in the process of being implemented as national standard (2005+) by member states. The time scale of development is also indicative of the extensive scope of Eurocode, difficulties with harmonisation amongst the practice of member states, and unification between the ten standards consisting of 58 parts, with vital input to be provided in the national annex for each part by each member state.

The complexity of the Eurocode set of standards and the specific needs for a South African loading code implied the need for a systematic process, based on clearly defined guidelines for the formulation of the SA LC, as opposed to merely 'adopting' the Eurocode.

2. DEVELOPMENT OF SANS 10160

The development of SANS 10160, within the context of the Eurocode, required a proper formulation of a reference base for the process. This was done in the context of the purpose and function of SANS 10160 and provision for local conditions and practice. It required an extensive assessment of the Eurocode in general, with specific attention to the relevant standards and parts. The process can be considered as an optimisation of the scope of SANS 10160 within the wealth of advances captured in the Eurocode.

Attributes of Structural Design Standards

Structural design standards usually develop through an iterative process of updating and improving a current standard, for which substantial experience has been gathered. When a new generation of standards is introduced, however, it is necessary to consider the function of the standard, and consequently the objective with its development. Such requirement applied to the formulation of SANS 10160. The following attributes of a structural design standard have a decisive influence on its formulation: Regulatory function in setting safety requirements by authorities; Statement of acceptable design practice as expressed by the profession; Role and function of the specific standard in relation to other design standards; Scope of application of structures provided for Scope of contents of design procedures included (comprehensive versus selective; standard practice versus advanced procedures).

These attributes are determined by the primary sponsors of the structural design standard, who take responsibility for its development, use and maintenance. Such ownership is traditionally taken by regulatory authorities, industry groups, or the engineering profession.

Responsibility for the South African Loading Code is taken by the engineering profession, with some support given by industry groups for the various materials-based design standards. In contrast, the development of the Eurocode, which is sponsored by the European Union, is an instrument to promote a European-wide construction industry, without trade barriers (CE 2002). These differences in sponsorship and ownership result in important differences in the attributes of the respective standards.

Reference Base for SANS 10160

The principal objective for the development and ultimate use of SANS 10160 is to assist design practitioners in discharging their professional duties, of ensuring public safety; to clients in designing economic structures, and to the profession in providing effective and efficient procedures. The scope of structures is limited to building and similar industrial structures, which form the bulk of general design practice. Provision is not made for advanced structures or specialist design procedures.

This is in stark contrast to the Eurocode, which covers the comprehensive scope of structures for buildings and civil engineering works. It includes the full complement of conventional structural materials. It provides for the wide range of environmental conditions amongst its member countries, and has the objective to maximise harmonisation amongst the diverse traditions of structural engineering and construction practice.

An important feature of the Eurocode is that allowance has to be made for the requirement that safety falls under the national jurisdiction of member states. The formulation and layout is complicated by the need to provide for the Nationally Determined Parameters (NDP), which is captured in a National Annex for each of the fifty-eight Parts of the ten Eurocode Standards EN 1990 to EN 1999!

At the same time such provision for adjustment allows for the formulation of SANS 10160, such as to fully provide for local conditions and practice, whilst maintaining harmonisation and consistency with the Eurocode, which is equivalent to that of member states.

A reference base for the development and formulation of SANS 10160 evolved from the two primary sources (i) the current SA Loading Code SABS 0160 and the directives for its revision expressed at the 1998 conference (ii) the relevant Eurocode standards and parts as they were converted into normative European standards. A constraint is that the institutional framework, design and construction practice and environmental conditions applicable to SABS 0160 have essentially been maintained.

Reference to SABS 0160

The reference base of SABS 0160 is essentially maintained in terms of its role and function in structural design practice as follows:

Scope of structures: Buildings and similar industrial structures; including buildings with crane support structures as an important class. Design verification method: The use of reliability-based partial factor Limit States Design (pfLSD)

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procedures are maintained. Range of loads: Provision for self-weight; imposed loads for floors, roofs and partitions; wind loads; seismic loads and design were maintained from SABS 0160, with updates to incorporate recent development

Scope of procedures: The procedures are primarily directed towards general design practice for standard structures.

Materials-based standards: Consistency with current materials-based standards has to be maintained. The onus is placed on standards still using allowable stress design to make the necessary adaptations.

Reference level of reliability: The present level of reliability is judged to be appropriate due to the absence of any evidence that it is insufficient, (Milford 1988, 1998), and found to be similar to American practice and provides the basis for maintaining consistency with materials-based standards.

A number of deficiencies in SABS 0160 were identified at the 1998 conference, requiring particular attention during the revision process:

Wind loads: The SABS 0160 procedures for wind loads are based on outdated models, which require a substantial revision. Seismic actions and design: The seismic design procedures had no credibility amongst designers in the seismic regions of the area, requiring critical re-evaluation.

Geotechnical design: There is substantial inconsistency between structural and geotechnical design practice in the design of foundations.

Technology base: Although there is an extensive experience base for structural design, constraints on resources limit the systematic capturing of such experience. Similarly research capacity is limited to the investigation of specific topics, rather than the comprehensive development and calibration required for code development.

Eurocode as Technology Base

Reference to the Eurocode was identified not only as remedy to the deficiencies identified in SABS 0160 but also as a potential technology base, for a revised SA Loading Code and beyond. The advantages of using the Eurocode as a technology base for SANS 10160 includes the following:

Advanced standard: Eurocode represents the compilation of a set of standards, which incorporates the most advanced procedures from its member states, supported by extensive research over several decades. The advances include, for example, the introduction of a head standard to define a common reliability-based basis of design, advances in structural fire design, provision for advanced materials such as high performance concrete. International harmonisation: A high degree of harmonisation has been achieved, whilst remaining deficiencies can be clearly identified and assessed.

Comprehensive standards: The scope of application is comprehensive in terms of structures, materials, conditions and relevant procedures. Internal consistency in design is achieved across the range of structures from buildings through bridges, reservoirs, towers, structural steel to geotechnical design; from self-weight to earthquake loads. Range of conditions: Environmental conditions range from the cold Nordic countries to the Mediterranean; institutional conditions range from member states, where design standards are part of the law, to situations similar to that of South Africa.

Principles for Reference to the Eurocode

The principles followed in referencing SANS 10160 to the Eurocode consisted of the following:

Selection of Eurocode Parts: All the Eurocode Parts relevant to the combination of the scope of buildings and SABS 0160:1989 were considered. This implied the extension of the SABS 0160 scope and consideration of nine Parts from EN 1990, EN 1991, EN 1997 & EN 1998. Only the sections and procedures relevant to the scope of SANS 10160 were utilised.

Consistency with the Eurocode: Full consistency with the Eurocode is maintained, providing for incremental extension of SANS 10160 or the introduction of other standards from the Eurocode.

Format, layout and style: SANS 10160 is compiled into the format of SA standards, including a compact layout (as opposed to the elaborate Eurocode formulation to allow for NDP options with a separate National Annex).

Reliability levels: Due to the wide tolerances of reliability allowed by the NDP options, the current reliability levels could be maintained for SANS 10160 whilst achieving consistency with the Eurocode within the restricted scope of application.

Standard level of practice: Advanced procedures from the Eurocode were considered to be beyond the scope of SANS 10160. In a few cases, procedures taken over from the Eurocode were simplified. Sufficient consistency was however maintained to allow for the use of advanced Eurocode procedures locally by specialists (e.g. dynamic effects of wind loads).

Provision for local conditions: The general Eurocode procedures were used for local environmental conditions to determine appropriate representative values for wind, temperatures and seismic ground movement.

3. COMPILATION OF SANS 10160

Steps in the compilation of SANS 10160 consisted broadly in the formulation of each topic, consisting of the basis of design and the selected class of action. In addition to the consideration of the reference material from SABS 0160 and the Eurocode and related background information, other international standards were also consulted. In selected cases calibration exercises were complemented by research projects which ran parallel to the standards development programme.

Layout of SANS 10160

Due to the self-contained nature of the various actions compiled together as the new SA Loading Code SANS 10160, the respective topics are structured as eight independent parts.

The standard can, however, only be used as an integral design standard and is consequently published as a single document.

Reference of SANS 10160 to the Eurocode

The main updates and extensions applied to the respective SANS 10160 Parts, as based on the Eurocode, consist of the following, limiting in every case the sections and procedures to those relevant to buildings:

Part 1 Basis of structural design: A separate Head Standard is introduced to establish the basis of structural design from EN 1990. Procedures for the treatment of accidental design situations, including requirements for structural robustness, are extracted from EN 1991-1-7.

Part 2 Self-weight and imposed loads: Occupancy classes specified and new classes of imposed loads are introduced from EN 1991-1-1. Characteristic values are established from independent surveys.

Part 3 Wind actions: Procedures for the calculation of wind actions and the extensive set of pressure and force coefficients are based on sections relevant to buildings from EN 1991-1-4. Free field wind velocities and profiles, based on terrain roughness are modified from SABS 0160 information.

Part 4 Seismic design and actions: The format of EN 1998-1 and some procedures form other international standards are used to modify SABS 0160 procedures. The map giving ground acceleration across the country is updated.

Part 5 Geo technical basis of design and actions: A new standard is introduced from EN 1997-1, considering also requirements specified in EN 1990 for geotechnical design within the scope of SANS 10160.

Part 6 Actions induced by cranes and machinery: The SABS 0160 procedures for crane induced actions are replaced by that from EN 1991-3; new procedures for actions induced by harmonically rotating machinery are introduced with modifications from EN 1991-3.

Part 7 Thermal actions: Provisions for thermal actions are introduced from EN 1991-1-5, including maps for characteristic maximum and minimum temperatures extracted from the TMH-7:1981 procedures for bridge design.

Part 8 Actions during execution: Procedures for this critical stage in the life of a structure are introduced from EN 1991-6, incorporating only sections relevant to buildings.

The special case of an accidental design situation, which provides for actions on structures exposed to fire, is treated in EN 1991-1-2. Such actions are however not included in SANS 10160.

This important category of action requires the availability of unified provisions for materials-based design procedures, in the Eurocode.

This topic is deemed to satisfy rules in the materials-based standards. Inclusion of provisions for actions due to fire would require co-ordinated development with these standards.

Although there are substantial differences between the Eurocode and SANS 10160 in layout and format, scope of application and procedures.

These differences are directly related to distinctions in institutional, regulatory, environmental and technical conditions of the two regions.

Substantial harmonisation and consistency of SANS 10160 with the Eurocode is being maintained, to the extent that SANS 10160 can be considered as a specific subset of the Eurocode.

SANS 10160 Parts in Relation to the Design Process

The relationship between the respective SANS 10160 Parts and in relation to the materials-based standards is shown schematically in Figure 1. Part 1 applies not only to the actions on buildings, the geotechnical design of foundations and the design for earthquake resistance, but also to the limit states requirements for the materials-based design standards.

Background Report

Since SANS 10160 represents a substantial revision of SABS 0160, proper substantiation of the changes and additions is required. A Background Report has thus been produced to capture the main sources and references; considerations and assessments; decisions and motivations applied in the formulation of SANS 10160 (Retief & Dunaiski 2009). The background information should primarily be considered when SANS 10160 is evaluated for acceptance into design practice by the profession. The Background Report should also serve as the point of departure for its inevitable future revision and updating.

Due to the close link between the Loading Code and the respective materials-based standards for structural design, viz. structural concrete, steel, timber and masonry, the Background Report also serves to validate the use of SANS 10160, with the present materials standards through the demonstration of how consistency between SANS 10160 and SABS 0160, has been maintained. Background on the basis of design also provides important information for the future revision of materials-based design standards or even the introduction of new standards, particularly for related geotechnical design.

4. OUTLINE OF SANS 10160

A brief outline of the main features of SANS 10160 and its various Parts are provided here, as extracted from the Background to SANS 10160 (Retief & Dunaiski 2009).

Part 1 Basis of structural design

Part 1 serves as a general standard to specify procedures for determining actions on structures and structural resistance in accordance with the partial factor limit states design approach. The requirements and procedures are formulated to achieve acceptable levels of safety, serviceability and durability of structures, within the scope of application of SANS 10160.

Procedures for the basis of structural design include: requirements for the specified minimum values for actions on structures presented in SANS 10160-2 to SANS 10160-8; the determination of design values for the effects of combined actions on the structure under a sufficiently severe and varied set of limit states; general requirements for sufficient structural resistance reliability to which the related materials-based design standards should comply.

Part 1 provides a proper reliability framework, which applies not only to actions and their combinations, but also to the resistance as specified by the materials-based standards. The reliability framework consists of extended limit states and associated design situations, reliability classes for buildings, and guidelines for reliability management related

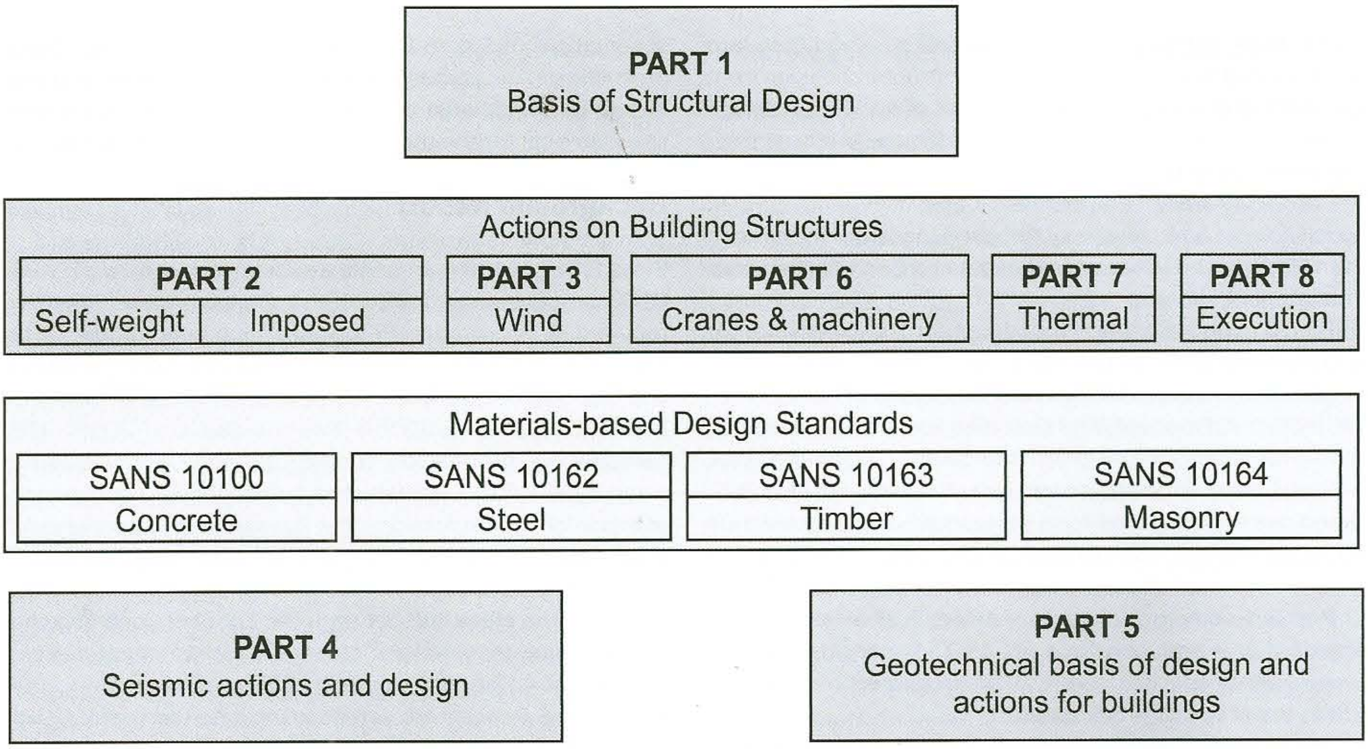

Figure 1 Schematic view of the relationship of SANS 10160 parts and materials-based standards

to quality management. Specific new developments include requirements for the treatment of accidental design situations, design for robustness, the use of design assisted by testing and improved serviceability criteria. International harmonisation is improved through consistency of Part 1 with ISO 2394:1998 and EN 1990. Extensive reliability calibration was implemented, as reported in Retief & Dunaiski (2009), see also Holický & Retief (2005) Holický et al (2007).

Part 2 Self-weight and Imposed Loads

Part 2 presents procedures for the treatment of self-weight and imposed loads on buildings. Procedures for determining self-weight of structural and non-structural materials as permanent loads are given, including recommended values of material densities.

Minimum characteristic values for imposed loads as variable actions are given for loads on floors, as a function of the occupancy and use of the building, for imposed roof loads and horizontal loads on balustrades and partitions.

The specification of actions due to self-weight for buildings from EN 1991-1-1 has generally been maintained in SANS 10160-2, with the main difference being the simplification of the requirements due to the scope of SANS 10160 being limited to buildings.

Extended tables of densities are provided in an informative annex. The most important way in which SANS 10160-2 refers to EN 1991-1-1 for imposed loads on building structures is to follow its layout format, and to introduce a number of imposed load mechanisms, particularly relevant to industrial buildings and processes such as helicopter landing pads on top of buildings. Imposed load values are based on extensive comparisons (Retief & Dunaiski 2009, Retief et al 2001). Provisions for imposed roof loads differentiate between execution and sustained conditions (Retief & de Villiers 2005).

Part 3 Wind Actions

Part 3 covers procedures for the determination of actions on land-based structures due to natural winds. The scope of application is limited to the general type of buildings and industrial structures (in line with the scope of SANS 10160) and is restricted to structures for which wind actions can be treated as quasi-static. For wind sensitive structures the procedures given in EN 1991-1-4 may be used. The calculation of the wind pressure is based on the 10 minute mean wind speed representative of the mature frontal wind experienced in the coastal regions of South Africa. The application of an appropriate gust factor makes provision for thunderstorms and wind climate of the interior of the country. Provision for strong winds generated by thunderstorms (Goliger & Retief 2002) required careful consideration (Goliger 2005). Research on the strong wind climate of South Africa is continued (Kruger et al 2008, 2009). The exponential pressure profiles for wind speed with height are maintained, based on an improved definition of terrain categories. The much more detailed procedures for calculating the wind pressure on building surfaces are based on recent wind tunnel testing.

Part 4 Seismic Actions and General Requirements for Buildings

Part 4 covers earthquake actions on buildings and provides strategies and rules for the design of buildings subject to earthquake actions. Provisions for actions on structures exposed to earthquakes are revised and updated (Wium 2006). The specification of seismic design of standard structures is extended, but procedures are restricted to situations where principles of proper layout and detailing are complied with, requiring the application of advanced procedures for situations beyond the scope of SANS 10160-4.

Part 5 Basis of Geotechnical Design and Actions

Part 5 represents an extension of the scope of SANS 10160 to set out the basis for geotechnical design and gives guidance on the determination of geotechnical actions on buildings and industrial structures, including vertical earth loading, earth pressure, ground water and free water pressure and actions caused by ground movement.

Procedures are given for determining representative values for geotechnical actions. The main advantage achieved by these new Provisions is that (i) consistency between geotechnical and structural engineering practice has been achieved and (ii) that EN 1997 Geotechnical design can be used in local practice. The development of Part 5 was supported by extensive assessment and research (Dithinde 2007; Dithinde et al 2009).

Part 6 Actions Induced by Cranes and Machinery

Part 6 specifies imposed loads associated with overhead travelling bridge cranes on runway beams at the same level; and also actions induced by a limited range of stationary machinery causing harmonic loading.

The standard includes improved provisions for crane induced actions by the introduction of new models based on the mechanics of the movement of the crane and proper specification of the combination of actions (Dymond et al 2006). Partial load factors for crane-induced actions are based on extensive calibration (Dymond 2005).

Part 7 Thermal Actions

Part 7 introduces new procedures that cover principles and rules for calculating thermal actions on buildings, as well as their structural elements.

Its main features are to introduce provisions for thermal actions based on the South African climate, including the classification and representation of actions, the determination of temperatures and temperature gradients in buildings.

Part 8 Actions during Execution

Part 8 introduces new procedures that cover principles and general rules for the determination of actions, which should be taken into account during the execution of buildings.

Its main features are to introduce provisions for actions on structures during execution of the construction works, including actions on the partially completed works and temporary structures.

It consists of procedures for the identification of design situations and representation of actions and their effects on the incomplete structure, considering all activities carried out for the physical completion of the work, including construction, fabrication and erection. The code stipulates the normative requirements of ensuring the safety of the structure during all stages of construction.

The allocation of responsibilities must be determined through contractual agreements between all parties involved.

5. CONCLUSIONS

The introduction of the new SA Loading Code SANS 10160 should have a significant impact on structural engineering practice. Existing procedures and load models have been updated and extended and new procedures have been introduced. The extensive reliability framework provides for wide ranging conditions and performance classes which should lead to structures with improved fitness for purpose. The following general conclusions can be drawn from the process of the development and compilation of SANS 10160 (Retief & Dunaiski 2009).

SABS 0160 as SA Loading Code: The essential properties of SABS 0160 as the South African Loading Code for the design of buildings and similar industrial structures have been maintained. This includes maintaining the present levels of structural performance, although allowance is made to improve its consistency.

An important consequence is that consistency of SANS 10160 with the present materials-based design standards has been maintained.

Specified procedures: Provision for actions that were specified in SABS 0160 were substantially overhauled and updated. Important additions that have been made to SANS 10160 include a number of design situations and actions, the formal treatment of the basis of structural design, and a unified treatment of geotechnical design, and its interface with structural design.

The Eurocode and international harmonisation: the Eurocode was used as reference to SANS 10160, and thereby provided access to an extensive source of information, structural engineering technology and experience.

Most important however, is the extensive scope of structures, conditions, materials and practices across which the Eurocode succeeded in achieving consistency and unification. Much effort was spent to marry the comprehensive nature of the Eurocode with the specific needs of a South African Loading Code.

From a South African perspective, a degree of international harmonisation has been achieved that went well beyond initial expectations. From a Eurocode perspective, SANS 10160 represents one of the first applications of the Eurocode principles beyond its group of Member States.

This opens the door to future cooperation and the use of Parts of Eurocode in situations where there is no equivalent South African code. It also contributes concretely to the extended application of the Eurocode as a reference to other South African structural design standards.

The development of SANS 10160 provided the opportunity to do wide range supporting research, investigations and calibration which provides a solid knowledge base for its future use.

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