Viewpoint

Towards a minimum standard for structural engineering work

Ron Watermeyer (F), Joint Structural Division of SAICE and IStructE, outlines the content of a generic standard for use where no registration system exists

Introduction

There are statutory requirements in many jurisdictions for the structural safety of buildings. These in the main relate to the design and the confirmation of design intent during the construction of the buildings. Statutes are commonly framed around the construction of buildings either from a building control or an occupational health and safety perspective.

There is a need to establish minimum standards for individuals who assume responsibility for performing statutory duties relating to the structural performance of structures, particularly in developing countries.

The proposed generic standard, which is set out below, establishes requirements for certifying the adequacy of a structural system or part thereof of an existing or proposed structure, the assumption of overall responsibility for the rational design, rational assessment or inspection (or any combination thereof) of a structure and the independent review of the structural performance of a structure. It is designed to be referenced by regulators and clients alike when assigning specific duties to those who are entrusted with ensuring the structural performance of a structure. It can form the basis of the client's brief for structural engineering related services.

It also establishes the peer recognised competencies of a structural engineer, based on an analysis of the Institution of Structural Engineer's membership examination. Passing the membership examination is accordingly one way of demonstrating competence.

'It establishes competencies of a structural engineer, based on analysis of the Institution's membership exam'

This standard establishes minimum requirements and is particularly suited for application in jurisdictions which do not have in place a registration system for structural engineers and rely on 'competent persons' to assume responsibility for the structural safety of buildings in terms of legislation. For example, the registration system in South Africa only recognises the civil engineering discipline and makes no provision for recognising the structural capabilities of those on its register, while up until very recently, the National Building Regulations required a 'Professional Engineer or other approved competent person' to assume responsibility for the structural safety of buildings where deemed to satisfy rules were not applied or were inappropriate.

The standard facilitates the establishing of specialist lists or a licensing scheme which can be linked to local registration requirements. For example the definition for a structural engineer can be linked to local registration (see listing of structural engineers on the website: www.jsd.co.za).

Comments on the proposed standards should be emailed to: (watermeyer@ssinc.co.za).

Proposed standard for structural engineering work

Scope

This standard establishes:
a) competency criteria for persons to perform work as structural engineers; and
b) norms and standards for structural engineers who undertake structural engineering work.

Definitions

For the purposes of this standard, the following terms and definitions apply:

Actions – an assembly of concentrated or distributed mechanical forces acting on a structure or the cause of deformations imposed on the structure or constrained in it.

Client – the person who make use of the services of a structural engineer.

Inspection – in relation to the construction of the structural system or part thereof means the general inspection at such intervals as may be necessary in accordance with accepted practice to enable the designer to satisfy him or herself that the design is being correctly interpreted and the work is being executed generally in accordance with the designs, appropriate construction techniques and good practice, but shall exclude detailed supervision and day-to-day inspection.

International standard – standard that is adopted by an international standardising / standards organisation.

Load – value of force corresponding to an action.

National standard – standard that is adopted by a national standards body.

Rational assessment – an assessment of the adequacy of the performance of a design for a proposed, or the adequacy of an existing, structural system or part thereof including, as necessary, a process of reasoning, calculation and consideration of accepted analytical principles, based on a combination of deductions from available information, research and data, appropriate testing and service experience.

Rational design – any design involving a process of reasoning and calculation based on the use of an international or national standard or other suitable document.

Structural engineer – a person who has demonstrated to the satisfaction of his or her peers the five outcomes listed in Table 1 through an interview, a written examination, the submission of a portfolio of work or a combination thereof, as required by the peer review group, and whose name appears on a publically available list published by a learned society or registration body.

Structural engineering –

a) the rational design, rational assessment or inspection (or combination thereof) of buildings, walls, bridges, water retaining structures, masts, towers, silos, frameworks, and other similar structures in their construction or alteration to ensure structural safety and structural serviceability performance during their working life;

b) the assessment of the ability of such structures to maintain their structural safety and structural serviceability performance in

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Study Groups

The purpose of the study group scheme is to create opportunities for members of the Institution to exchange ideas and work on deepening and developing their knowledge of structural engineering, thus stimulating a greater interest in and promoting the art and science of structural engineering.

Members who require further information about a Study Group should contact the appropriate Convener. Membership databases are held either by the convener or by Sarah Okoye at the Institution, International Headquarters, 11 Upper Belgrave St., London SW1X 8BH Tel: 020-7234-4535, Fax: 020-7235-4294, Email: sarah.okoye@istructe.org. Members wishing to register their membership of a Study Group should contact either the convener or Sarah Okoye as indicated below.

Arch bridges

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Façade engineering and structural use of glass

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Fire engineering

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Heritage structures

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History of structural engineering

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Management and maintenance of bridges

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Management of structures

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Nuclear standards

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Qualitative analysis of structural behaviour

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Teaching Eurocodes in university

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Register membership with convenor.

Outcome		Assessment criteria
Number	Description	
1	Communicate the environment within which structural engineering is practised	1. Professional bodies associated with structural engineering are described 2. Codes of conduct regulating structural engineering are described 3. Legislation governing structures is described 4. Procurement arrangements for structural engineering works are identified 5. Quality assurance systems are identified
2	Produce viable structural solutions, within the scope of a design brief, taking account of structural stability, durability, aesthetics and cost	1. A brief is appraised in accordance with structural engineering principles and concepts 2. Approximate structural engineering solutions are identified 3. Two different structural designs are developed from a brief and are communicated 4. The implications of changes to design briefs are identified and communicated
3	Determine and document the form and size of principal structural elements from a proposed structure	1. Structural engineering problems are solved using a variety of suitable methods of analysis 2. Structures are appraised for overall stability, resistance to progressive collapse, fire and performance of a structure as a whole 3. Compliance with all relevant criteria for the design of primary structural materials (concrete, steel, masonry timber) is demonstrated by calculation with all assumptions stated 4. General arrangement plans, sections and elevations are prepared for estimating purposes 5. Connection details associated with a given structure are sketched
4	Specify and co-ordinate the use of primary structural materials	1. Properties and behaviour of primary construction materials (concrete, masonry, timber and steel) are defined 2. Testing procedures are defined 3. Storage and handling procedures are described 4. Construction standards are described
5	Communicate construction techniques and sequencing for structural engineering works	1. Basic construction techniques and equipment are identified 2. Construction programmes and construction sequencing are described 3. Site activities and safe working methods pertaining to structures are communicated

Table 1: Outcomes and assessment criteria

the environment in which they are located over their design working life when subject to their intended use in terms of one or more of the following:

i) external and internal environmental agents;
ii) maintenance schedule and specified component design life;
iii) changes in form or properties.

Structural safety performance – the ability of the whole structure and its parts, with an appropriate degree of reliability, to maintain their strength and stability under all actions likely to occur during its construction and design working life.

Structural serviceability performance – the ability of the whole structure and its parts, with an appropriate degree of reliability, to perform within established parameters under all expected actions for normal use in terms of local damage, deformation and vibration.

Structural system – a system of constructional elements and components of a structure which is provided to resist the loads acting upon it and to transfer such loads to the ground upon which such structure is founded.

Structure – organised combination of connected parts designed to provide some measure of rigidity, or a construction works having such an arrangement.

Suitable – capable of fulfilling or having fulfilled the intended function or fit for its intended purpose.

Water retaining structure – means a structure which stores fluids including swimming pools, other than a barrier constructed to retain water in order to raise its level or reduce or prevent flooding.

Requirements

General requirements

Any person may, subject to the provisions of the section on ethics below, perform activities associated with structural engineering provided that their education, training and experience have rendered them competent to perform such activities.

Only structural engineers may:

– certify the adequacy of a structural system or part thereof of an existing or proposed structure in terms of any statutes or in response to a client or employer's request to do so;
– assume overall responsibility for the rational design, rational assessment or inspection (or any combination thereof) of a: building, bridge, reinforced concrete cast *in situ* culvert, water retaining structure that retains more than 250 000 litres of fluid, silo, or tower or mast having a height exceeding 3m.
– perform rational assessments;
– independently review the structural performance of a structure.

Ethics

Structural engineers shall:

– take reasonable care to ensure the quality and safety of all structural engineering work entrusted to them and adopt a balanced, disciplined and comprehensive approach to problem solving;
– observe all applicable legislation and statutes;
– not include anything in the design of the structure necessitating the use of dangerous procedures or materials hazardous to the health and safety of persons, which could be avoided by modifying the design or by substituting materials;
– take into account the hazards relating to any subsequent maintenance of the relevant structure and make provision in the design for that work to be performed in a manner that minimises the associated risk;
– recognise that the lives and safety of the people are dependent upon engineering judgments, decisions and practices incorporated into structures;
– not accept anything in cash or in kind which prejudices independent and impartial judgment and declare to their clients or employers any interest which may influence professional judgment;
– not misrepresent their areas or levels of experience and responsibility;
– not agree to or comply with any instructions requiring dishonest action or the disregard of established norms of safety or levels of risk in design and construction;

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– take reasonable steps to minimise the risk of the loss of life, injury or suffering which may result from their work or the effects of their work and point out the level and significance of risk associated with their work to those affected;
– ensure, where their structural engineering judgment is ignored or rejected, that their clients or employers are informed of the possible consequences;
– report to the appropriate organisation or authority any situation of which they became aware where a structure or structural system places the safety of the public at risk.

Practice

Structural engineers shall take all reasonable steps to:
– understand and define the brief with the client;
– ensure that the client understands the scope and limitations of the service to be provided and not allow the urgency of the work to override the need for written clarification of the brief;
– provide services with the skill and care normally used by professionals providing similar services.

They shall also:
– accept personal responsibility for their work and work performed under their supervision or direction;
– take reasonable steps to ensure that anyone working under their authority is both competent to carry out the assigned tasks and likewise accepts personal responsibility for their work;
– review all structural design concepts to determine that the structural concepts are complete, consistent and in general compliance with any relevant and appropriate or applicable national or international standards;
– ensure that the assumptions made and the level of reliability of rational designs or rational assessments are such that a peer review of the structural system or part thereof would arrive at a similar conclusion;
– ensure that the basic assumptions made in the software used in the analysis and design of structures or parts thereof (such as adequate lateral restraints) are actually fulfilled in reality;
– check their work either using another method or by engaging another structural engineer to do so;
– ensure that the record drawings of the structures for which they are responsible contain information on the following as relevant:
  i) the design standards that were used;
  ii) the loads which the structure was designed to withstand;
  (iii) the key geotechnical parameters used in the design;
  (iv) the basic engineering properties of the construction materials that were used;
  v) the construction standards that are to be used;
– affix their name and any relevant registration number to all construction and record drawings of the structure or part thereof for which they have assumed responsibility and sign such drawings;
– if called upon by an owner of a structure within a period of 10 years after completion of the structure or part thereof, produce documentation, including assumptions made, loads applied, calculations and drawings.

Structural engineers shall ensure that structural calculations are prepared to support all rational designs and, where relevant, rational assessments. Such structural calculations shall be prepared legibly and presentably, be capable of being audited and filed for record purposes. Hard copies of inputs and relevant outputs of any computer analysis shall be filed as well as description of the software used, the design assumptions that are made, the design criteria and the relevant geotechnical information upon which the design is based.

Structural engineers shall ensure that structural drawings are prepared to enable the structure to be constructed. Such drawings shall typically show the locations, sizes, reinforcing, and connections of the structural elements in sufficient scale and detail to enable their fabrication, construction and the connection of the members in a reasonable sequence by a competent constructor familiar with the techniques of construction for the specified materials.

Structural engineers shall ensure that constructors are provided with suitable structural specifications for concrete, reinforcing steel, masonry, structural steel, wood and other materials that are to be used. Such specification shall include requirements for materials, workmanship, fabrication, quality control, tolerances, inspection and testing.

Structural engineers shall where necessary, ensure that the constructor is provided with information for temporary works and erection information to ensure the intent and integrity of the design and its safe construction.

Structural engineers shall ensure that any revisions, updates or new versions of documents issued to constructors for fabrication or construction purposes are identified by a unique number or other form of designation.

Structural engineers shall review any construction or erection method statement relating to the structural system provided by the constructor and promptly communicate in writing to the constructor one of the following:
– acceptance of the statement;
– qualified acceptance of the statement citing the actions that need to be taken to achieve acceptance of the statement; or
– rejection of the statement citing the reasons for such rejection so that a revised statement can be submitted.

Structural engineers, shall in respect of designs which incorporate structural steelwork or structural timber, ensure that any connection detail and drawings prepared by a fabricator are reviewed to ensure that the design has been correctly interpreted and that design intent is met.

Use of structural engineering software

Structural engineers shall only use structural engineering software in the analysis and design of structures or parts thereof that have been independently validated or have been obtained from a software supplier that has in place a quality assurance program and has evidence of software validation that substantiates the veracity of the outputs.

Structural engineers in making use of structural engineering software in the analysis and design of structures, shall ensure that:
– the software is used within the limitations stated by the software developer and the modelling techniques upon which the software is based;
– the applied actions are correctly determined and modelled;
– the dimensions of members and layouts are consistent with the construction drawings;
– parameter settings and selections including member sizes, member properties, connections between members, supports and restraints, appropriately and reliably model the behaviour and expected performance of the structure, the member sizes, properties and connections between members; and
– account is taken of any construction actions, construction techniques or sequences in construction in the modelling of the structure.

Structural engineers shall conduct an independent check of the output of software programs to determine that the structure as modelled is in equilibrium.