Managing structural engineering risk

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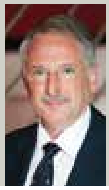

ECSA'S GENERIC APPROACH TO COMPETENCE

ECSA (Engineering Council of South Africa) has in recent years published a competency standard which defines the competence required for registration as a professional engineer (see R-02-PE). In terms of this standard, competence must be demonstrated within *"complex engineering activities"*. ECSA's Guide to the Competency Standards for Registration as a Professional Engineer (R-08-PE) suggests that "competence" is "*the possession of the knowledge, skills and attitudes necessary to perform the activities within the professional category to the standards expected in independent employment or practice*."

Registration is based on education, training and experience at an entry level to a profession. Registration as such confirms that a person is capable of working independently.

The 2013 Rules of Conduct for Registered Persons issued in terms of the Engineering Profession Act, 2000 (Act No 46 of 2000) requires that "*registered persons*:

- *must discharge their duties to their employers, clients, associates and the public with due care, skill and diligence;*
- *may only undertake work which their education, training and experience have rendered them competent to perform and is within the category of their registration;*
- *must, when carrying out work, adhere to norms of the profession."*

This generic approach to all engineering disciplines assesses competence at the entry point to the engineering profession against "*standards expected in independent employment or practice*". It thereafter relies on the integrity of the registered persons (self-regulation) to not take on work which he or she is not competent to perform, and to perform work within the "*norms of the profession*".

PROFESSIONAL REGISTRATION IN A CIVIL ENGINEERING CONTEXT

Civil engineering is a very broad engineering discipline covering the planning, design, construction, maintenance and operation of works comprising:

- structures such as buildings, dams, bridges, roads, railways, runways and pipelines;
- transportation, water supply and treatment, drainage and sewerage systems;
- the result of operations such as dredging, earthworks and geotechnical processes;
- waste disposal; and
- sea defence and coastal protection.

The *Civil Engineering Body of Knowledge for the 21st Century* produced by the American Society of Civil Engineers (ASCE) recognises that there are 24 outcomes which define the knowledge, skills and attitudes necessary to enter the practice of civil engineering at the professional level (see www.asce.org/uploaded-

Files/Leadership_Training_-_New/BOK2E_%28ASCE_2008%29_ebook.pdf). This body of knowledge groups the 24 outcomes down into three areas, namely:

- **Foundational** (mathematics, natural sciences, humanities and social sciences);
- **Technical** (materials science, mechanics, experiments, problem recognition and solving, design, sustainability, contemporary issues and historical perspectives, risk and uncertainty, project management, breadth in civil engineering areas, technical specialisation); and
- **Professional** (communication, public policy, business and public administration, globalisation, leadership, teamwork, attitudes, lifelong learning and professional and ethical responsibility).

According to ASCE, all 24 outcomes are, with the exception of "technical specialisation", fulfilled at least at a comprehension level via formal education in a baccalaureate programme. For 15 outcomes (almost two thirds of the total), experience is needed, in addition to formal education, to enter the practice of civil engineering at the professional level.

Advanced technical knowledge and skills beyond that included in the traditional four-year bachelor's degree are essential to attaining entry into the professional practice of civil engineering. ASCE requires that "technical specialisation" needs to be demonstrated at the levels of cognitive achievement depicted in Table 1.

The outcome "technical specialisation" "*includes all traditionally defined areas of civil engineering practice, but also includes coherent combinations of these traditional areas – i.e. advanced knowledge and skills in the area of general civil engineering are appropriate within the context of advanced specialisation. Civil engineering specialisations in non-traditional, boundary, or such emerging fields as ecological engineering and nanotechnology, are suitable and encouraged.*"

ECSA's generic approach to registration is very similar to that of ASCE. ECSA's standard talks about "*advanced knowledge" and "specialist knowledge" within a "generally recognised or distinctive area of knowledge and expertise developed by an engineering practitioner by virtue of the path of education, training and experience followed*," i.e. a practice area.

Understandably, "technical specialisation" or "specialist / advanced knowledge" is very broad and can involve a broad spectrum of works which require very different applications of knowledge gained at undergraduate level in a number of distinctly different contexts. "Advanced knowledge", i.e. knowledge gained after obtaining a degree but before admission to a profession at a professional level, is understandably narrow. Accordingly, the demonstration of the outcomes necessary to be admitted to a profession merely means that a registered person has demonstrated capability to perform the outcome in a specific aspect of civil engineering practice. It does not mean that the person has mastered the depth and breadth of a practice area.

It is not uncommon that the nature and subject matter of the work undertaken by a person prior to registration to that of post-registration can be very different. As a result, a tacit assumption is made that a professional will be able to achieve the levels of comparative achievement in a different "technical specialisation" and will limit what they do in accordance with the rules of conduct. This may be true in many areas of civil engineering practice. It is not necessarily true in the high-risk practice areas such as structural engineering.

Reliance on competence demonstrated at the point of entry to a profession on a generic basis does not sit well with the principles of quality management as espoused by ISO 9000:2005, *Quality management systems – Fundamentals and vocabulary*. ISO defines competence as "*demonstrated ability to apply knowledge and skills*." In quality management systems competence is linked to specific requirements in a specific context.

SHORTCOMINGS IN THE STRUCTURAL ENGINEERING PRACTICE

There have in recent years been a number of structural failures in South Africa resulting in the collapse of buildings, with loss of life and severe economic loss. Two such collapses have resulted in ECSA's permanent disqualification of two professional engineers from registration due to gross misconduct. These are the only two such instances of disqualification in ECSA's history.

The two collapses leading to the permanent debarring of the professional engineers who were responsible for the structure are as follows:

- On 17 October 1996 the third floor of the Northpark Mall in Pretoria collapsed during construction, killing four people and seriously injuring many more. The Committee of Inquiry, consisting of former Judge President Frikkie Eloff (Chair) and two senior professional engineers, found that one or more of the engineer's deficient construction techniques, and in particular his failure to exercise proper supervision and to maintain records, contributed to the collapse.
- A three-storey building nearing completion collapsed in the Little Falls area of Roodepoort on Thursday 16 October 2008, killing two workers and injuring 14 others. Half of

Table 1: Level of cognitive achievement

Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Define key aspects of advanced technical specialisation appropriate to civil engineering.	**Explain** key concepts and problem-solving processes in a traditional or emerging specialised technical area appropriate to civil engineering.	**Apply** specialised tools, technology, or technologies to **solve** simple problems in a traditional or emerging specialised technical area of civil engineering.	**Analyse** a complex system or process in a traditional or emerging specialised technical area appropriate to civil engineering.	**Design** a complex system or process or **create** new knowledge or technologies in a traditional or emerging advanced specialised technical area appropriate to civil engineering.	**Evaluate** the design of a complex system or process, or **evaluate** the validity of newly created knowledge or technologies in a traditional or emerging advanced specialised technical area appropriate to civil engineering.

the nearly completed office block was destroyed when the top two storeys collapsed onto the bottom storey. Tony Aimer, the chief investigator for the Department of Labour, who was responsible for overseeing the safe collapse of the structure on 13 June 2009, commented, "*The demolisher was breaking away the first portion of the northwest corner adjacent to the existing building, and without warning the whole structure collapsed in not more than three seconds ... This means that the structure was standing on the brink of failure the whole time ...*"

Researchers in a study conducted by the Swiss Federal Institute of Technology in Zurich (www.matscieng.sunysb.edu/disaster/) on 800 cases of structural failure in which people were killed and injured, and where engineers were at fault, classified the causes of failure in order of incidence as follows:

1. Insufficient knowledge (36%)
2. Underestimation of influence (16%)
3. Ignorance, carelessness, negligence (14%)
4. Forgetfulness, error (13%)
5. Relying upon others without sufficient control (9%)
6. Objectively unknown situation (7%)
7. Imprecise definition of responsibilities (1%)
8. Choice of bad quality (1%)
9. Other (3%)

Erling and Watermeyer (www.ioptions.co.za/Files/Doc/RBWnew/P1-6.pdf) found that the causes of the failure in the Roodepoort collapse fell into the above-mentioned categories 1, 2, 3 and 5. The findings of the Eloff enquiry suggest that the faults of the professional engineer fall within similar categories to that which might be ascribed to the professional engineer involved in the Roodepoort collapse.

ECSA used to publish the circumstances surrounding a complaint where a professional engineer was found guilty of a breach of the Rules of Conduct. Currently it does not. ECSA's legal advisor in 2006 confirmed that around 95% of complaints involved structural engineering practice. An analysis of the available information in the public domain at the time found that the number of complaints dealt with by ECSA was an order of magnitude higher than that of the Institution of Structural Engineers (IStructE) (~ 50 times higher). What was of concern was that 95% of the complaints investigated by ECSA related to the practice of structural engineering, and most appeared to relate to technical advice rather than business practices. The IStructE complaints related more to business practices. This meant that the situation is far worse than the figures suggest. Anecdotal evidence suggests that the situation has not improved since 2006.

The late Tony Goldstein contextualised the problem as follows: "*I think the main problem, from the point of view of*

Table 2: Competence levels of structural engineering practice

Level	Designation	Typical characteristic of the practitioner	Risk associated with work done
1	Candidate	Practitioner has a tertiary education qualification in civil engineering and works under supervision and control from an appropriately registered person.	Low
2	Registered professional in civil engineering	Practitioner is registered with the Engineering Council of South Africa as a Professional Engineer or Professional Engineering Technologist or Professional Engineering Technician in the civil engineering discipline.	Low to Medium
3	Structural engineering professional	Practitioner, apart from being registered with the Engineering Council of South Africa as a Professional Engineer or Professional Engineering Technologist in the civil engineering discipline, has developed structural engineering competencies relating to the design of structures and has had his competencies recognised by his or her peers.	Medium to High
4	Structural engineering expert	Practitioner is a structural engineering professional who has developed specialist skills in aspects of structural engineering practice or knowledge in specialised fields of structural engineering.	High

Table 3: Categories of risk

Category of structure	Level of risk	Illustrative nature of structural engineering work
1	Low	Simple structures with low structural safety and serviceability performance requirements where the analysis requires a simple application of design rules or direct interpretation of reference guidelines.
2	Medium	Structures with moderate to challenging structural safety, and serviceability performance requirements where the design approach involves either a process of: ▪ reasoning and calculation based on the application of standards; or ▪ reasoning, calculation and consideration of accepted analytical principles, based on a combination of deductions from available information, research and data, appropriate testing and service experience.
3	High	Structures with challenging structural safety and serviceability performance requirements that require specialist skills, recognised expertise or knowledge beyond that required for category 2 structures.

structural engineers, is that a minimum of three years' experience after graduating is not nearly enough to know what one is competent to design ... An engineer might thus believe that his design is adequate when it is dangerously inadequate." No matter how ethical a professional engineer may be, he is not capable of self-assessing what he does not know. Alternatively, a professional engineer may solve the wrong problem.

THE JSD'S APPROACH TO MANAGING STRUCTURAL ENGINEERING RISK

The Joint Structural Division (JSD) has recently published a *Guide to Good Practice for Structural Engineering* – http://www.jsd.co.za/technicial_articles_guides.php – to address the issues surrounding the practice of structural engineering. According to this Guide, "*structural engineering practitioners, depending on the tertiary education, training and experience, category of registration and recognition by the profession, function at one of four distinct levels as indicated in Table 2. The level of practitioner assuming responsibility for the design of a structure is linked to the category of risk as defined in Table 3.*"

The levels of competence required for structural engineering practitioners and the career path to achieving these levels are shown in Figure 1. It is accepted that, due to the varying nature

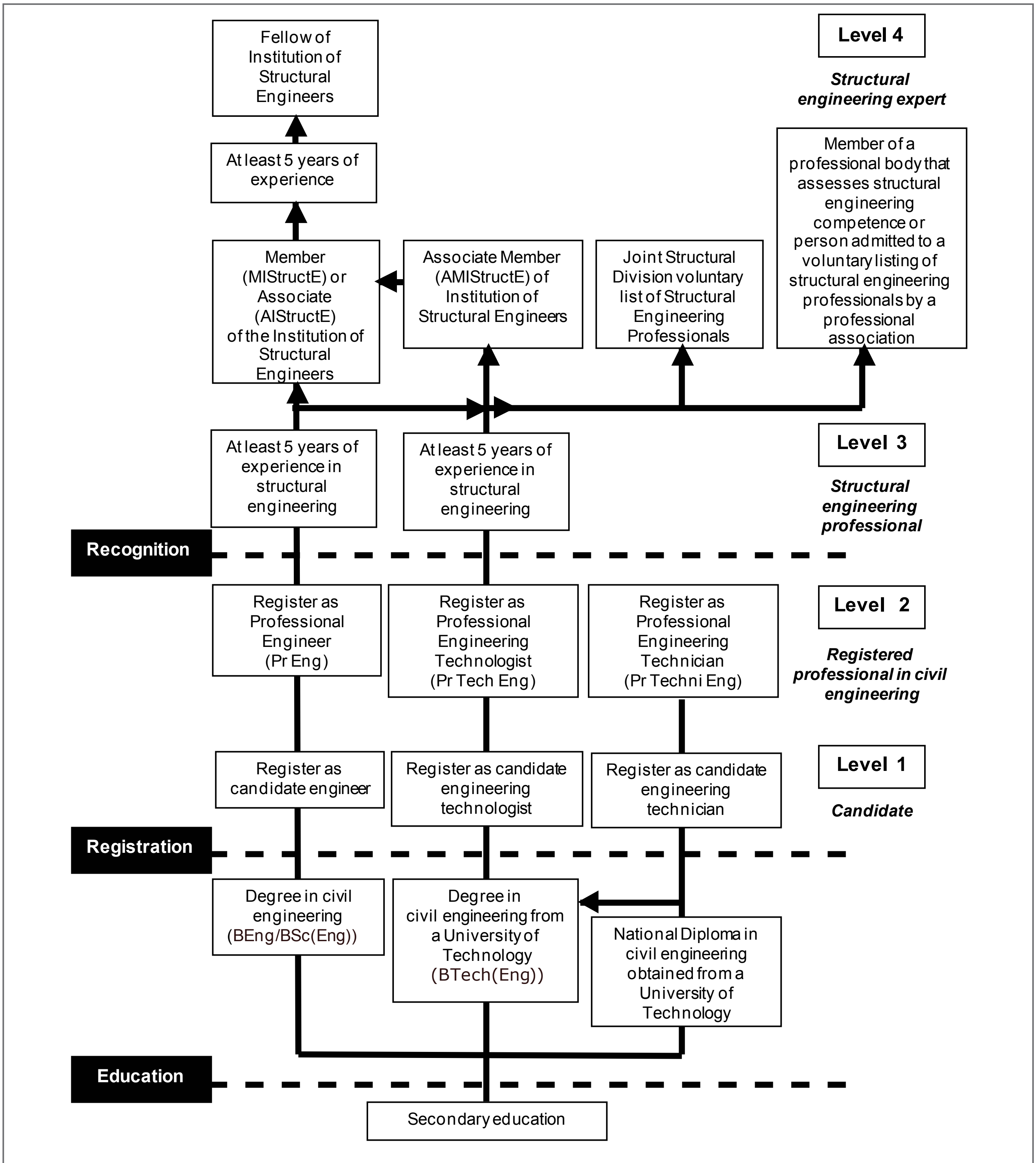

Figure 1: Levels of competence required for structural engineering

of a structural engineering service, rigid boundaries are not applicable, but the experienced structural engineering practitioner would recognise the appropriate competence level required.
It should be noted that:

- membership of IStructE, the world's leading professional body for qualifications and standards in structural engineering, requires the passing of rigorous interviews and/or examinations that test professional competence in structural engineering design; and
- admission to the JSD voluntary list for structural engineering professionals is based on a peer review of competence in structural engineering.

Registration as a professional engineer or engineering technologist is a prerequisite for admission to the JSD voluntary list for structural engineering professionals. Membership of IStructE is not.

The Joint Structural Division has also recently published a *Standard for Structural Engineering Services.* This standard establishes requirements for structural engineers who perform services relating to the determination or confirmation of the structural safety and structural serviceability performance of structures during their working life. This document, as well as the Guide, establishes norms for structural engineering practice.

Clients and employers can make use of the competency levels provided in Figure 1 to procure structural engineering services or appoint personnel, respectively. They can also require that structural engineering services are executed in accordance with the JSD standard and guide. This will enable clients to mitigate their risk exposure. ◻

The late Tony Goldstein contextualised the problem as follows: "I think the main problem, from the point of view of structural engineers, is that a minimum of three years' experience after graduating is not nearly enough to know what one is competent to design … An engineer might thus believe that his design is adequate when it is dangerously inadequate."