Structural Design Standards in the Context of Decisions in Civil Engineering

A South African view as a special case of international development

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Context of Structural Design Standards

• **Structural design** is but one of the steps in the life cycle of Civil Engineering Works
  – need & project identification; prioritizing; budgeting; **concept & detail design**; construction; operation and maintenance; decommissioning

• **Structural design standards** in turn is but one of the instruments of design
  – Serving as a *constraint* to the creative process of design
  – Addressing primarily the design of *structural elements*

⇒ This would be a *minimalist* view of the role and function of structural design standards
The opposite view is taken here:

- **Structural reliability** introduced a common theoretical basis for structural design
  - To establish a common and universal philosophy for the performance of civil engineering works
  - That goes far beyond the design of structural elements
- The full potential of such a development has not yet been realized
- Recent advances in probabilistic approach has the potential of extending such development even further
  - Risk and decision making procedures
  - Methodologies supporting the application of such procedures and extracting appropriate data
In order to develop some ideas on the potential application of SDS to provide a harmonized basis for the performance of the structural aspects of civil engineering works, an outline of a conceptual process of standards development is given:

- **Process of development**
  - *Needs* for improved standard
  - *Advances* in structural modeling and practice
  - *Reliability* based formulation of stipulations
  - *Judgment* based formulation of standard
Development of SDS: Role Players

• Needs for improved standard
  • ➔ Structural engineering industry
• Advances in structural modeling and practice
  • ➔ Research and academic community
• Reliability based formulation of stipulations
  • ➔ Task Groups
• Judgment based formulation of standard
  • ➔ Standards Committee representing
    – Researchers
    – Practitioners
Process of Development

- **Needs** for standard: improved or new
  - Regulatory environment – provide for changes
  - Structural engineering practice – *industry and profession* serving it
    - Need for improved performance
    - Capturing advances in technology

- **Advances** in structural modeling and practice
  - Structural mechanics
  - Reliability modeling
  - Construction practice

- **Reliability** based formulation of stipulations
  - Calibration of structural mechanics design models
  - For homogeneous categories of design parameters

- **Judgment** based formulation of standard
  - Experience based moderation of theoretically based stipulations
Different Approaches

• **Ad hoc approach:**
  – Consider need from present situation

• **Progressive approach:** incremental
  – Assess historical development of SDS and their theoretical basis
  – Identify next step in progressive development

• **Comprehensive approach:** top down
  – Derive principles for SDS development (detached from time)
  • Their role and function in structural engineering practice
  – Apply to development of new standard – next step
  – Consider future objectives for standards development
Example: Application of Reliability

• Incremental:
  – Appropriate stipulations are developed when a situation requiring specific reliability treatment is identified

• Comprehensive:
  – Set of situations
    • { homogeneous reliability ; differentiated reliability levels}
  – Provide internally consistent stipulations

Comments:
• In practice standards development somewhere in-between,
  – Tending towards incremental development, at least for different standards such as for structural types or materials

• Incremental development
  – (May) reach the same end result, much less efficient

• Comprehensive development
  – Extensive input in advance,
  – Better guarantee for a superior result
Progressive Steps of SDS Development

Historic view of SDS development helps to identify possibilities of taking a comprehensive view of the rationality of providing for structural performance in design, in tandem with development of structural mechanics modeling:

- Empirical design rules (safety built into rules)
- Allowable stress design (judgment based factor of safety)
- Limit states design (differentiated performance)
  - Judgment based partial factors
  - Reliability based partial factors normalized to experience
  - Extended pf-LSD \{structural types; design situations; reliability differentiation\}
- Probabilistic design
- Performance based design
- Risk based procedures – design and beyond
  - Basis for LSD \{all levels of structural performance\}
- Decision based procedures – design +
Unification of Structural Design (& SD Standards)

• A unified theory for structural performance provides the basis for
  – Treatment of a diverse set of situations {structural functions; configurations; levels of performance; materials; etc}
  – On a common basis as function {rational parameters}

Reliability based standards unified design of building ("standard") structures [= unified electromagnetic theory as physics analogy]

Risk based standards has the potential to unify diverse structures and performance levels [= grand unified theory (GUT)]

Decision based standards allowing for optimization of conflicting objectives [as idealistic as super symmetry]
Features of Ideal SDS

• Rational theoretical basis for unification: Applicable to comprehensive range of design situations; providing for \{sets of parameters\}
  – Structural types \{complexity; function (buildings; bridges; industrial; infrastructure; etc)\}
  – Structural situations \{actions; materials\}
  – Levels of structural performance \{economy; serviceability; safety; accidental; disaster; post-disaster\}
  – Levels of decision making \{life cycle\}

• Provision for treatment of external conditions and constraints:
  – Societal conditions \{economical; political; regulatory\}
  – Environmental conditions and influence \{on facility; by facility\}

• Professional considerations:
  – Optimization parameters clear for treatment at appropriate levels of complexity
Practical Limitations

- **Models** to be applied
  - Not properly developed
  - Gross error and human reliability arguably in principle not possible to be modeled
- **Data** limited and insufficient
- **Utility** scale not universal, or even appropriately formulated
  - Acceptability criteria can therefore not be established
- **Spatial dependence** of all the principal elements (E) of a high level theory E\{utility; models; data\}
  - Countries and groupings
  - Natural environment
Example: South Africa

- **Social / economic / political features**
  - Socio-economic: extreme range from an
    - advanced economy,
    - strong and fast advancing middle class to
    - utter poverty in large sectors of the nation
  - Policies: ranging from
    - progressive idealistic but unrealistic in some areas
    - very pragmatic management of the economy
    - inadequate and populist approach in some areas

- **Construction and structural engineering**
  - Large differences across different sectors
    - Buildings, industry, mining – very active
    - Infrastructure – huge backlog,
      - policies to catch up but a lack of engineering capacity (and political understanding of the role and function of engineers in the process)
Conclusions

Taking the philosophical view
   Asking (the appropriate) questions [rather than developing the appropriate answers!]
   ➔ Where do we go from here?

• Formulate a high level unifying theory
   – Risk based standards
     • Elements of risk based treatment already incorporated in recently developed standards – arguably more unified provision of accidental actions {fire; earthquake; impact; explosions; unidentified (robustness?)}
     – Rational risk criteria
     – Development of standard for risk assessment

• Appropriate procedures to support such a unifying theory
   – Methodologies demonstrated at this forum hold promise for this purpose