Design of Robust Structures

Introduction

What is “robustness”?
Why is it important?

Limit States

- **Ultimate Limit State - AS5100 Definition:**

The ultimate limit states include the following:

(a) Stability limit state.

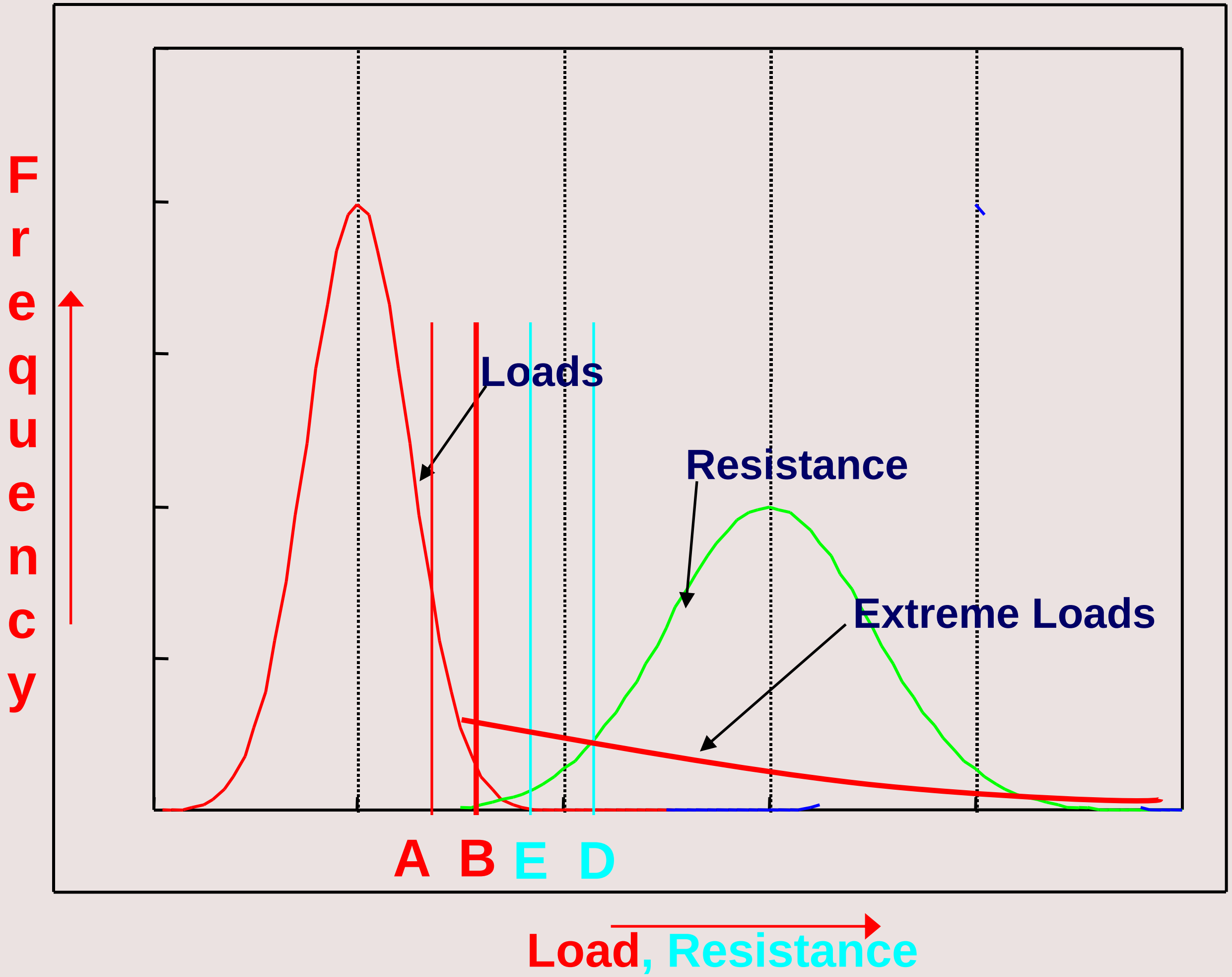
(b) Strength limit state, ... in which the collapse condition is reached at one or more sections of the structure ...

(c) Failure or deformation of any foundation material

(d) Deterioration of strength ... such that the collapse strength of the damaged section is reached...

(e) Brittle fracture failure of one or more sections of the structure ...

Ultimate Limit State Design Philosophy



A: Nominal max. load, T_n

B: Ultimate design load, T_u

D: Nominal long term ultimate resistance, R_p

E: Ultimate long term design resistance, R_d

Design Criterion:

$$R_d > T_u$$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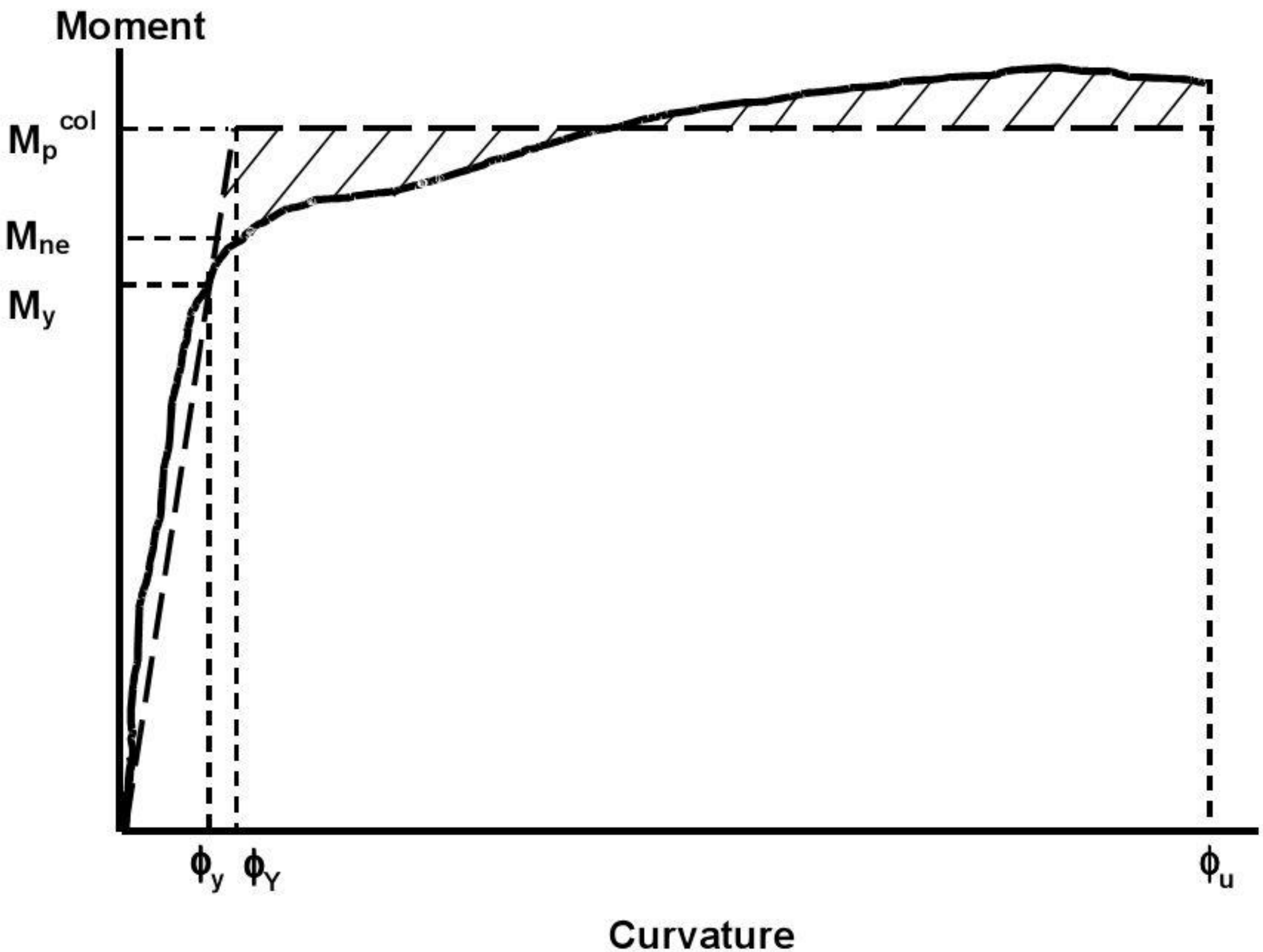

Figure 3.7 Moment Curvature Curve

Ultimate Limit States

- **Strength Limit State:**
  - **The state at which a structure or member reaches its design ultimate strength**
- **Collapse Limit State:**
  - **The state at which a structure or member suffers total collapse.**

ICE Proceedings – Structures and Buildings

Assessment of progressive collapse in multi-storey buildings	Structures & Buildings 160 Issue SB4	197	B. A. Izzuddin et al
Impulsive loading on a concrete structure	Structures & Buildings 160 Issue SB4	231	J. I. Siddiqui MSc et al
Catenary action in steel-framed buildings	Structures & Buildings 160 Issue SB5	247	M. Byfield et al
Disproportionate collapse: a pragmatic approach	Structures & Buildings 160 Issue SB6	317	U. Starossek
Robustness of light steel frames and modular construction	Structures & Buildings 161 Issue SB1	3	P. M. Lawson et al
Assessing and achieving structural safety	Structures & Buildings 161 Issue SB4	219	C. B. Brown et al

Ronan Point Collapse - 1968

Alternative Approaches to Designing for Robustness.

- Starossek
  - Pragmatic design approach
  - Focus on segmentation as an alternative to redundancy

- Izzuddin et al
  - A simplified framework for the progressive collapse assessment of multi-storey buildings
  - Inadequacy of prescriptive tying force requirements that neglect ductility issues
  - Typical composite buildings must rely on bending or compressive arching rather than tensile catenary action for enhanced structural robustness

Definition of “Robustness”

Starossek:

The term ‘robustness’ regularly appears in publications ... it is used differently and there is no common agreement to date on its exact meaning.

‘robustness’ – “insensitivity to local failure”

‘collapse resistance’ – “insensitivity to accidental circumstances”

INADEQUACY OF CURRENT DESIGN METHODS

(current design approach) “fails with regard to the identification and proper treatment of a potential for disproportionate collapse”

1. consideration of local instead of global failure
2. low probability events and unforeseeable incidents are not taken into account
3. probabilistic concept requires specification of an admissible probability of failure

SUGGESTED DESIGN APPROACH

1. design methods as specified in current codes are applied.
2. additional measures are taken with particular regard to collapse resistance.
3. not necessarily based on reliability theory but rather on judgement and decision making
4. Emphasis is put on performance-based methods.
5. Structural analyses are carried out deterministically

DESIGN STRATEGIES

1. Prevent local failure of key elements
    1. specific local resistance
    2. non-structural protective measures
2. Presume local failure
    1. alternative paths
    2. isolation by segmentation
3. Prescriptive design rules

Interactive Design Services

REDUNDANCY VERSUS SEGMENTATION

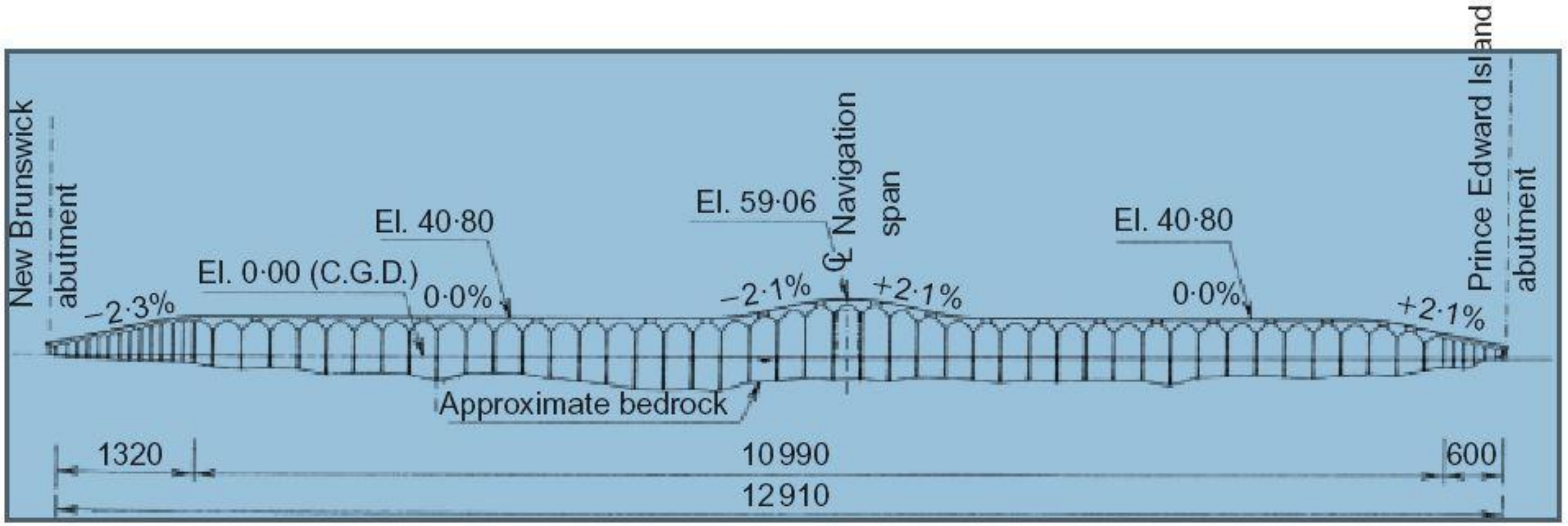

Fig. 1. Confederation Bridge, Canada

REDUNDANCY VERSUS SEGMENTATION

REDUNDANCY VERSUS SEGMENTATION

REDUNDANCY VERSUS SEGMENTATION

CONCLUSION

"For certain structures, segmentation is the more suitable approach to prevent disproportionate collapse—a fact that has found little attention in the structural engineering community so far. If this option has nearly been overlooked, one reason might be that the terms continuity, redundancy and robustness are intuitively equated—a tacit assumption that is justified at best only for particular types of structures."