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Bridge Assessment and the Management of Substandard Structures

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Agenda

- Background
- Review of the Assessment Programme
- Development of BD79
- Conclusions

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Background

- extensive programme of bridge assessment and strengthening has been undertaken in UK
- work commenced in 1989
- large suite of assessment standards developed based on British Standards
  UK current bridge assessment standards.xls
- many £100M's invested, lessons learned
- robust procedures established for managing substandard structures

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Background

- need for vigilance

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Project Brief

- to review and evaluate the application of BA79 in the management of sub-standard highway structures
- to capture the reasons for assessment failure, to use the findings to inform future policy and practice, investigating:
  - relative incidence of each type of structure failing assessment
  - the critical elements, locations and potential modes of failure
  - reasons for element becoming critical

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Review of Assessment Programme

Methodology → Key Results → Recommendations

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Review of Assessment Programme

Methodology → **Key Results** → **Recommendations**

- **Preliminary data collection and sampling**
- **Technical audit**
- **Participants**
  - Highways Agency (& Managing Agents)
  - Devolved Authorities (& Managing Agents)
- **NB: All reporting on a non-attributable basis**

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Methodology - Challenges

- **Identification of structures**
- **Availability of records**
- **Consistency of data collection**
  - Training of all auditors
  - Cascading of experience
  - Electronic database
- **Over 20 000 items of data relating to 294 structures collected**

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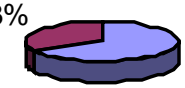
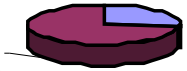
Availability of Records

Original Design Documentation Yes 11% No 89% 	Special Inspections Yes 19% No 81% 	Summary of Load Effects and Corresponding Resistances Yes 33% No 67% 
AIP Yes 53% No 47% 	Test Reports Yes 31% No 69% 	Assessment Report Addenda Yes 12% No 88% 
Assessment and Check Certificates Yes 62% No 38% 	AHS2/i and AHS2/ii forms Yes 20% No 80% 	Identification of Assessment Level Yes 18% No 82% 
Condition Survey / Principal Inspection Yes 72% No 28% 	Assessment Report No 18% Yes 82% 	BA79 Proforma Yes 22% No 78% 

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Review of Assessment Programme

Methodology → **Key Results** → **Recommendations**

- Audit Sample
- Deck Material Types
- Critical Elements
- Critical Failure Modes
- Reasons for Failure

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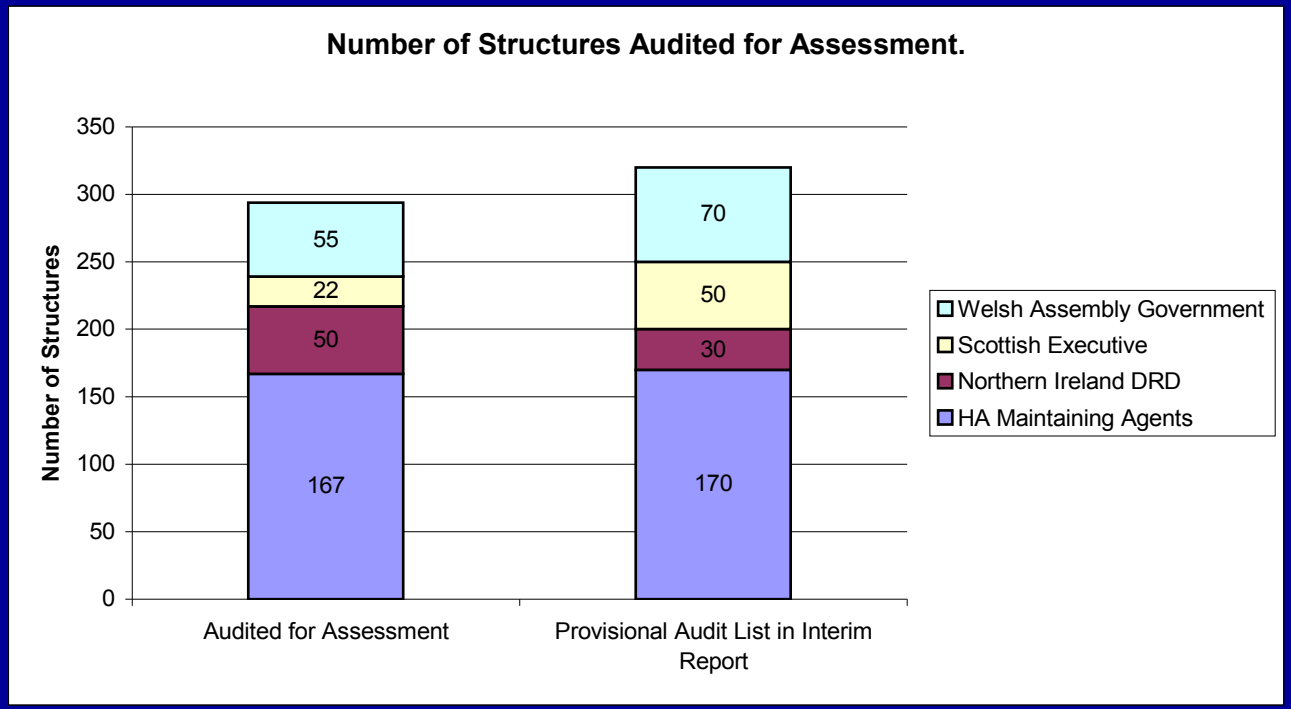
Results – Audit sample

- **294 structures audited**
  - HA 167
  - WAG 55
  - SE 22
  - NI 50



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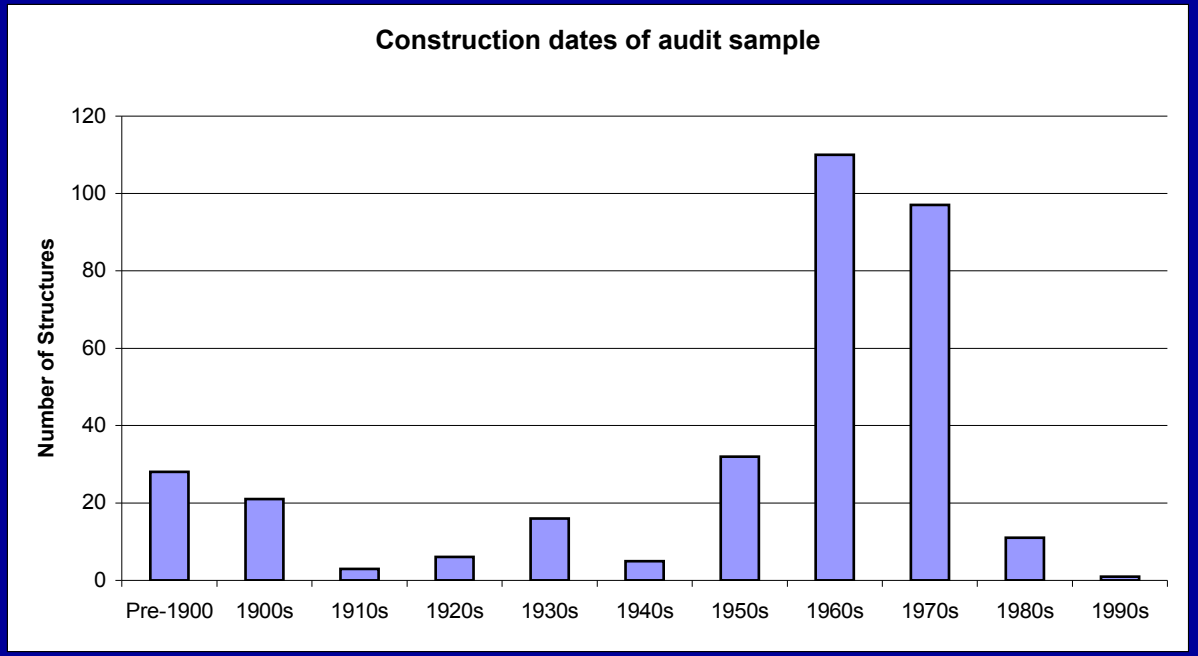
Results – Audit sample

- **Construction dates**
  - from pre 1900 to 1990's
  - majority in 60's and 70's



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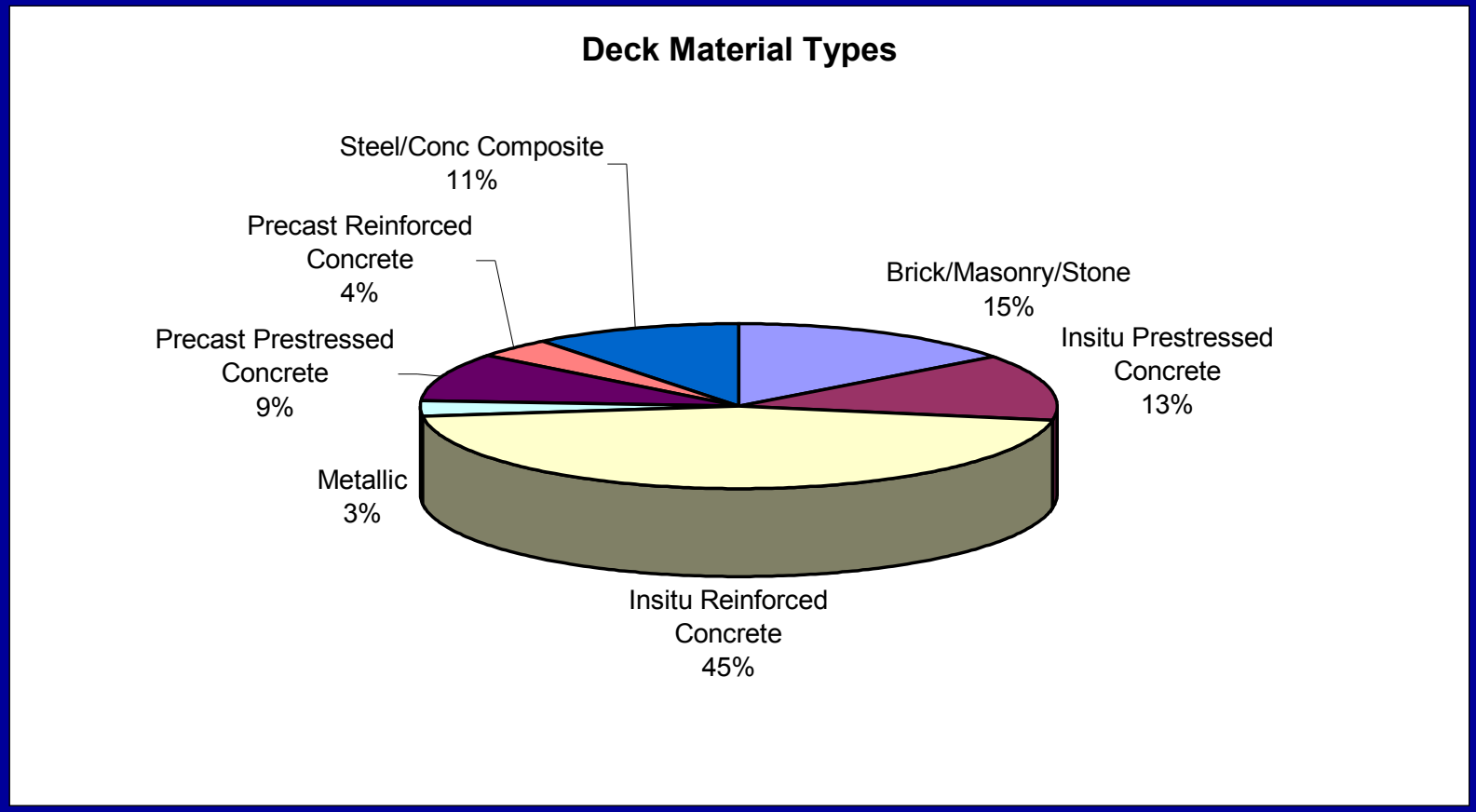
Results – Deck material types



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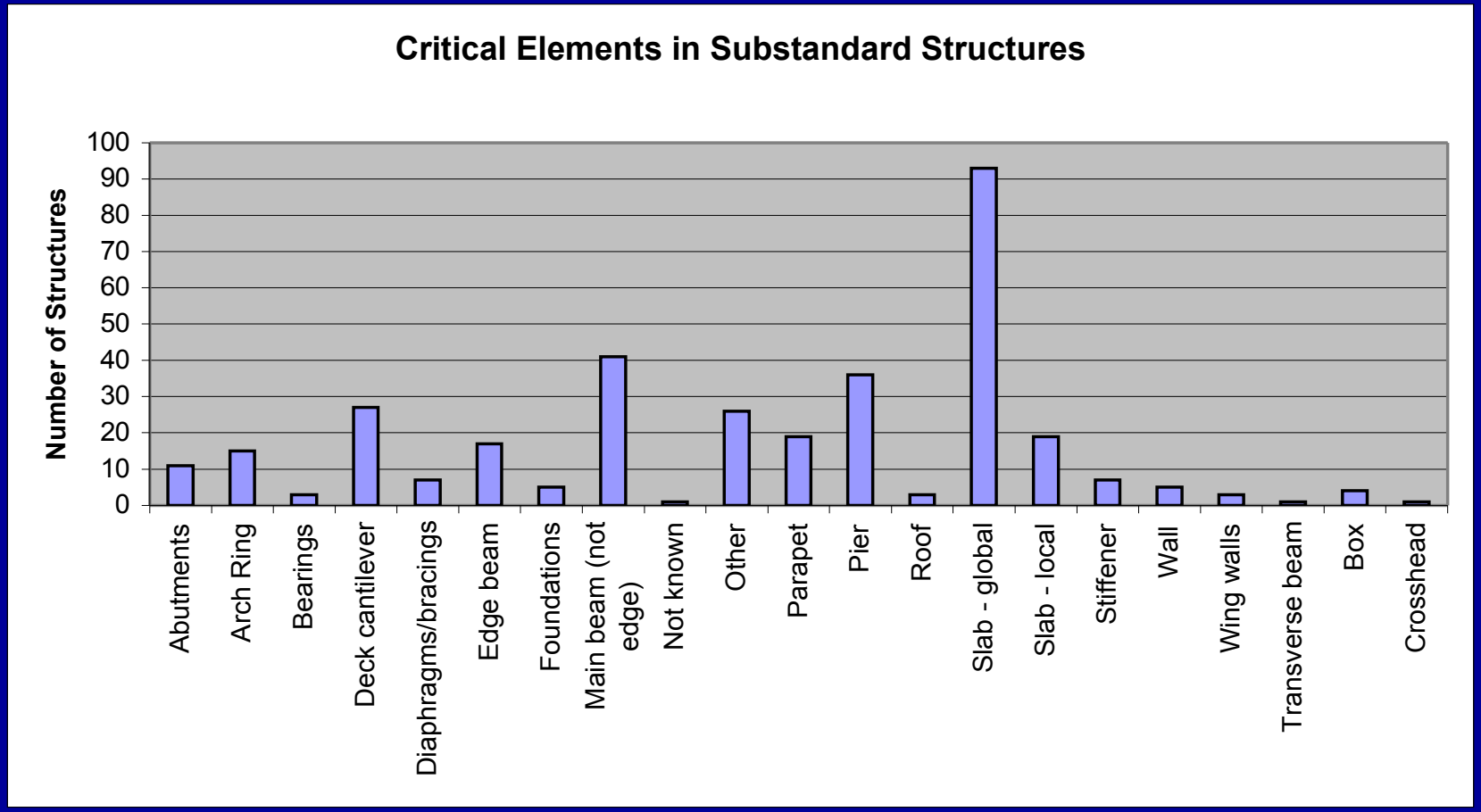
Results – Critical elements



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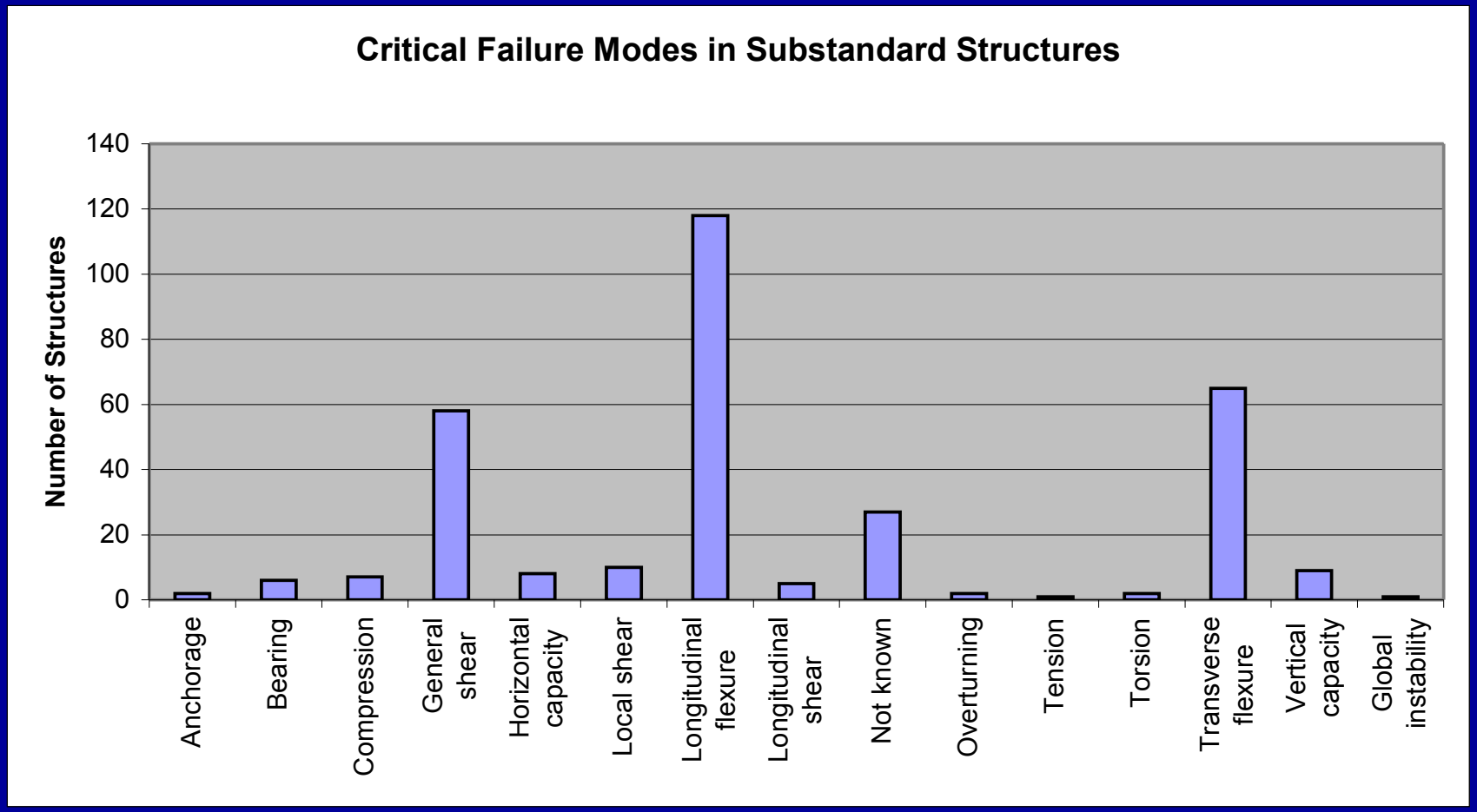
Results – Critical failure modes (all elements)



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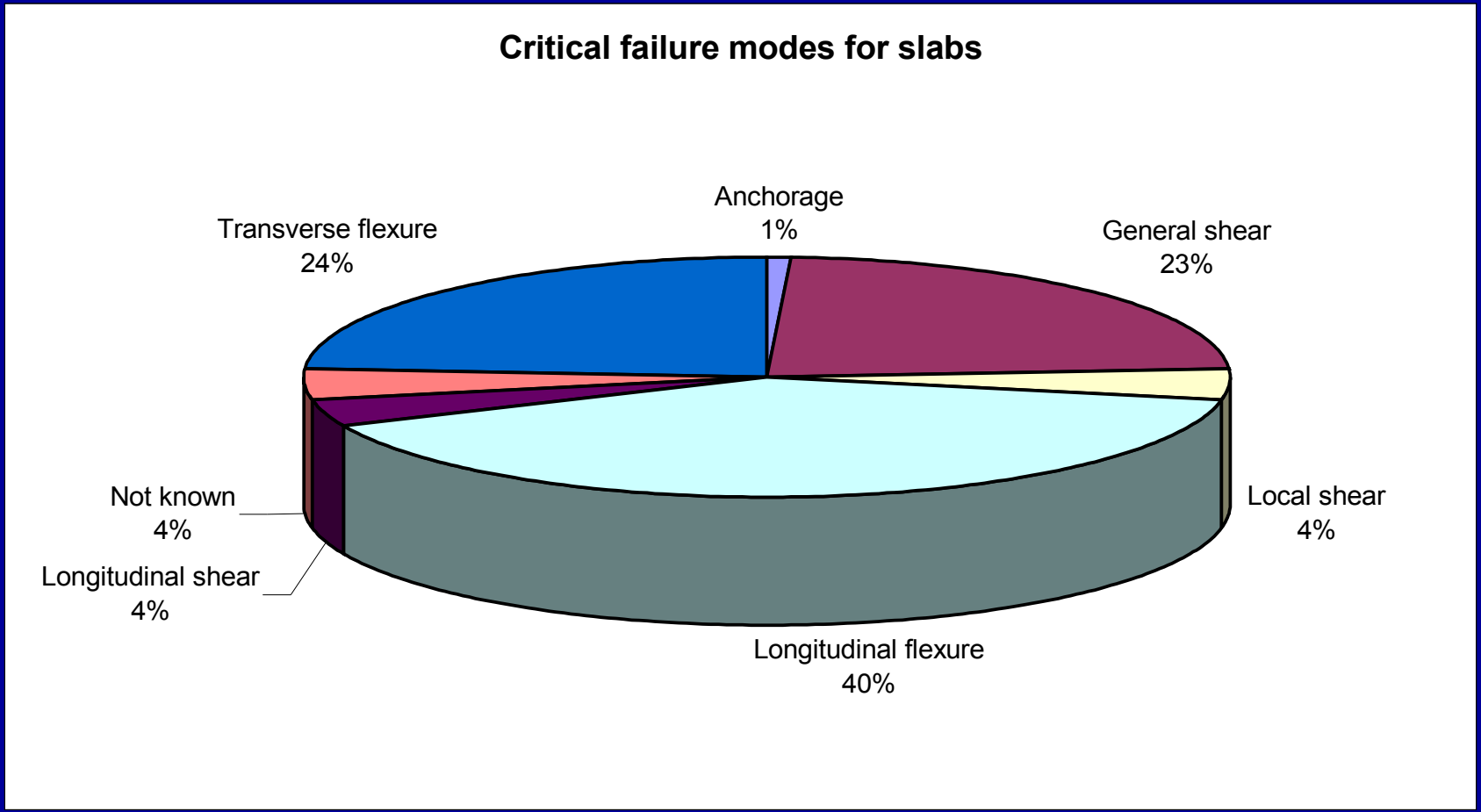
Results – Critical failure modes for slabs



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Results – Reasons for Failure

- **Potential reasons for failure**
  - Increases in loading
  - Updates in standards
  - Inappropriate or too conservative analysis
  - Conservative assumptions due to lack of design data
  - Misinterpretation or inappropriate application of assessment code
  - Reduced capacity due to deterioration/damage
  - Poor original design or construction

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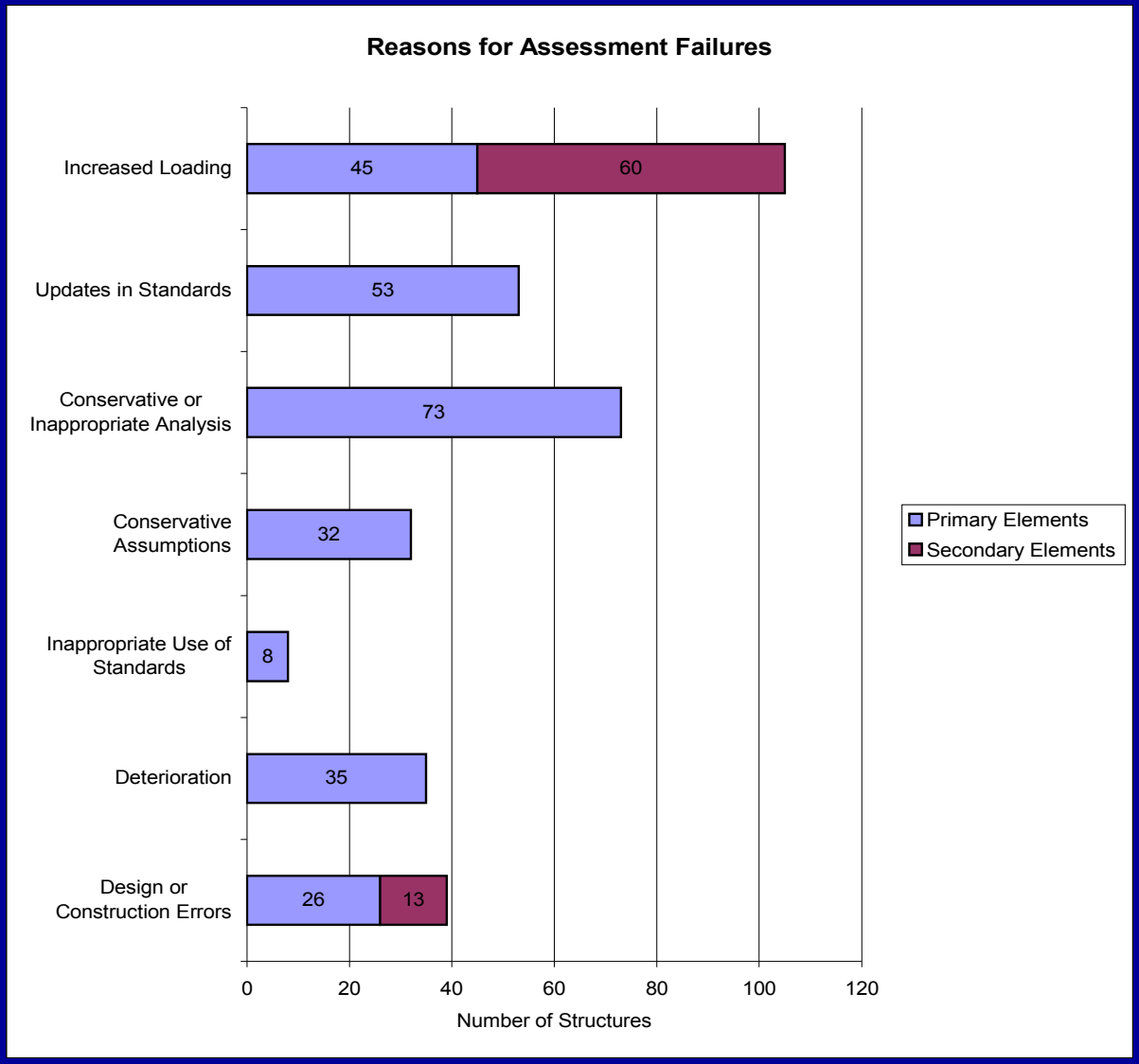
Results – Reasons for Failure



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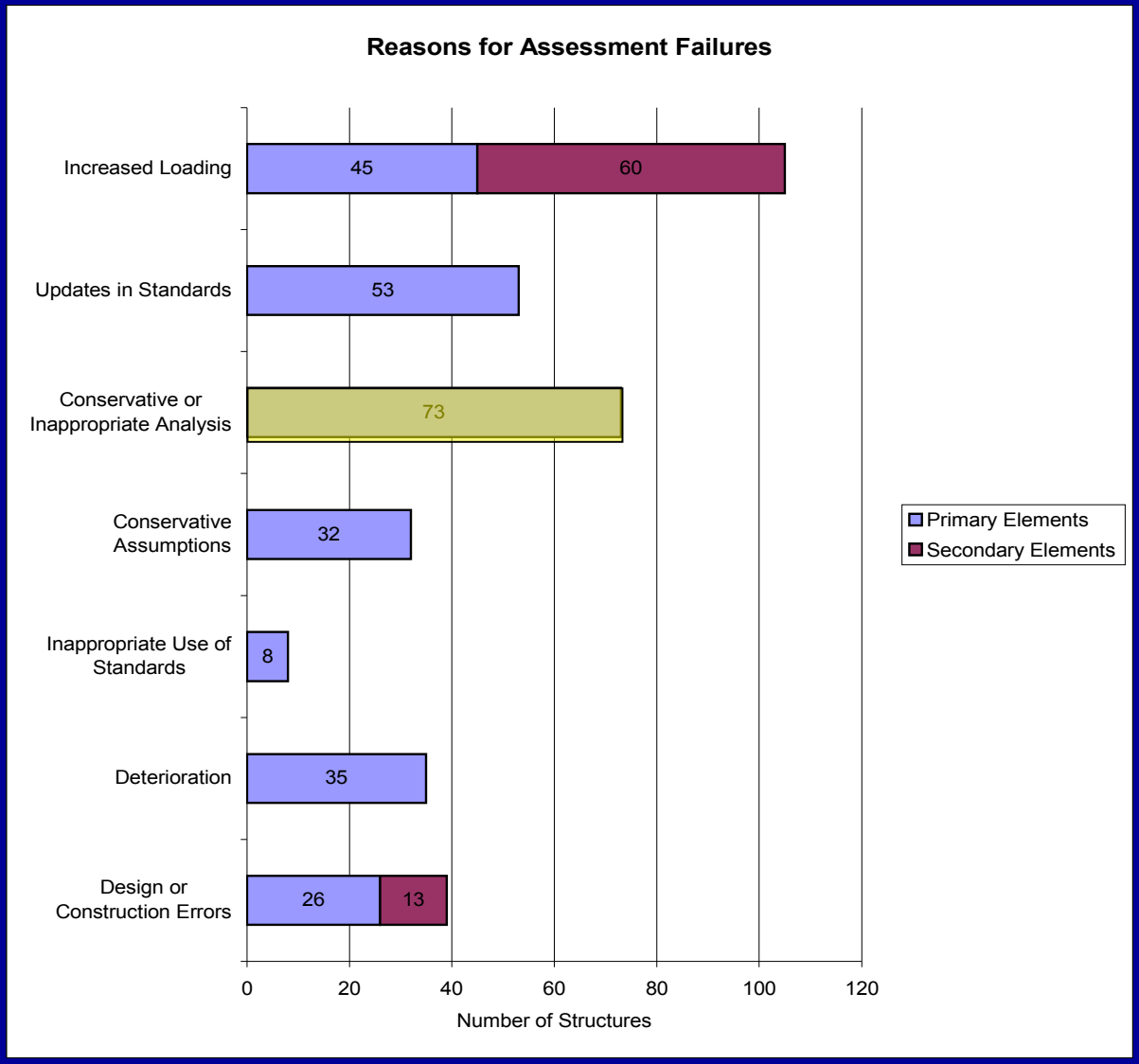
Results – Reasons for Failure



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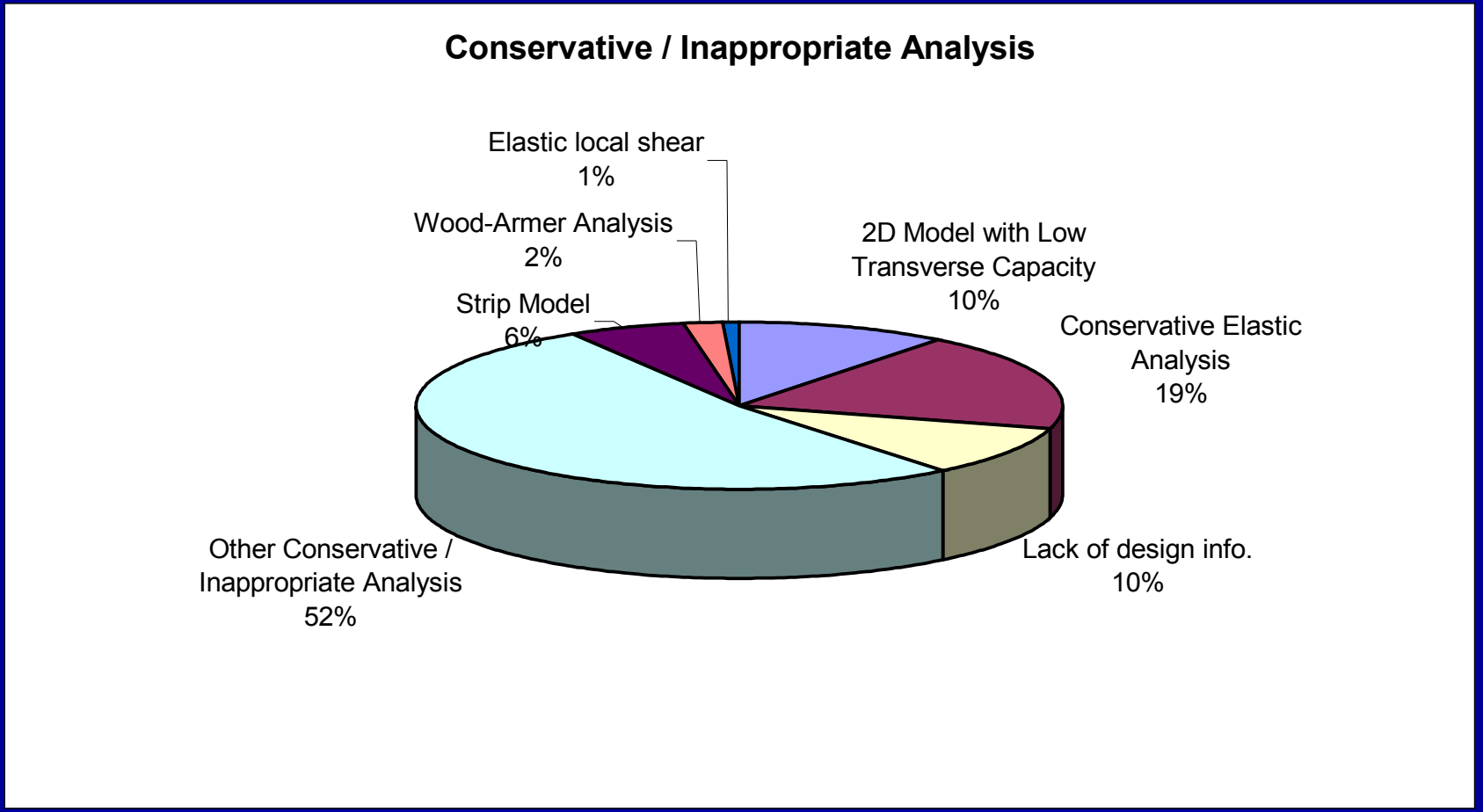

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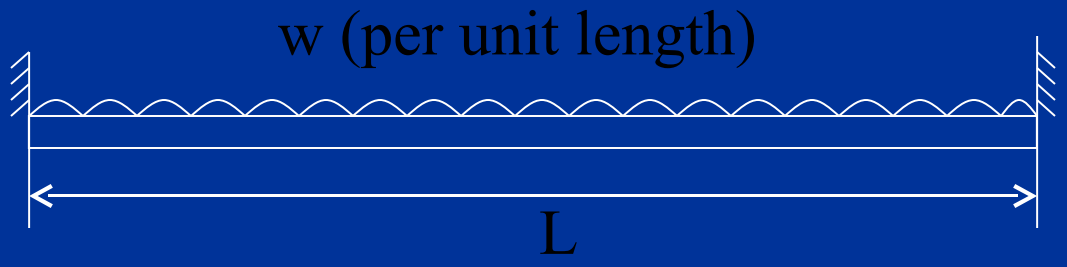
Key challenges

- Realistic assessment is a complex engineering challenge

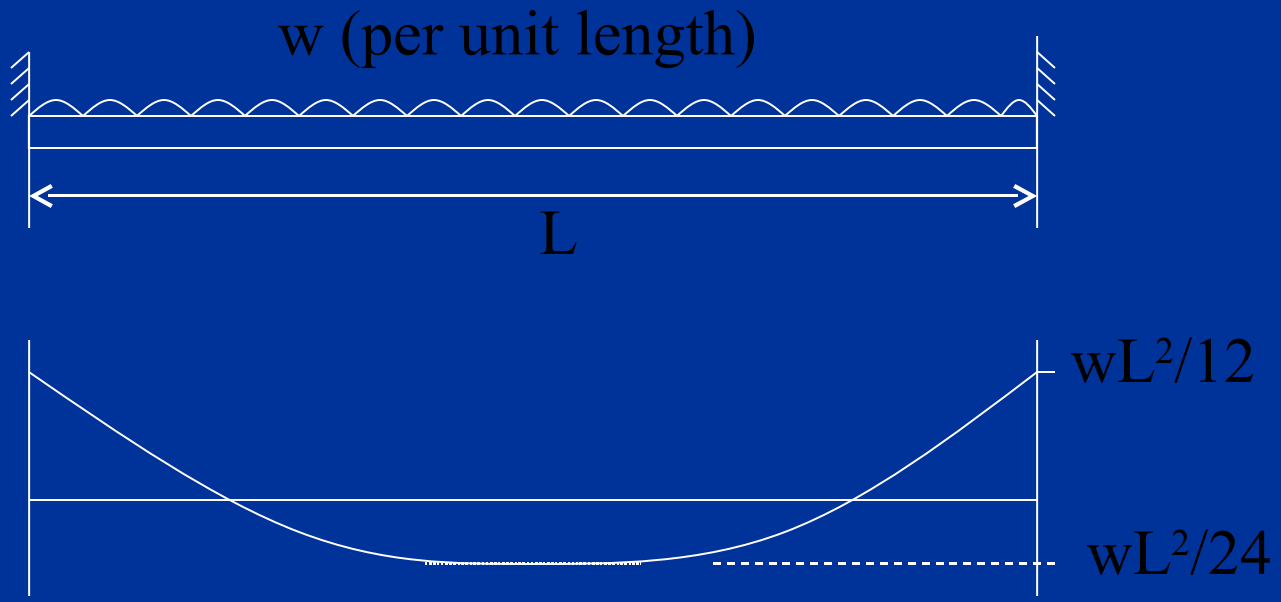
Design Process

- Structures contain reserves of strength not utilised in design
- The cost of conservatism is high (sustainability)

Achieving realistic assessments



Achieving realistic assessments



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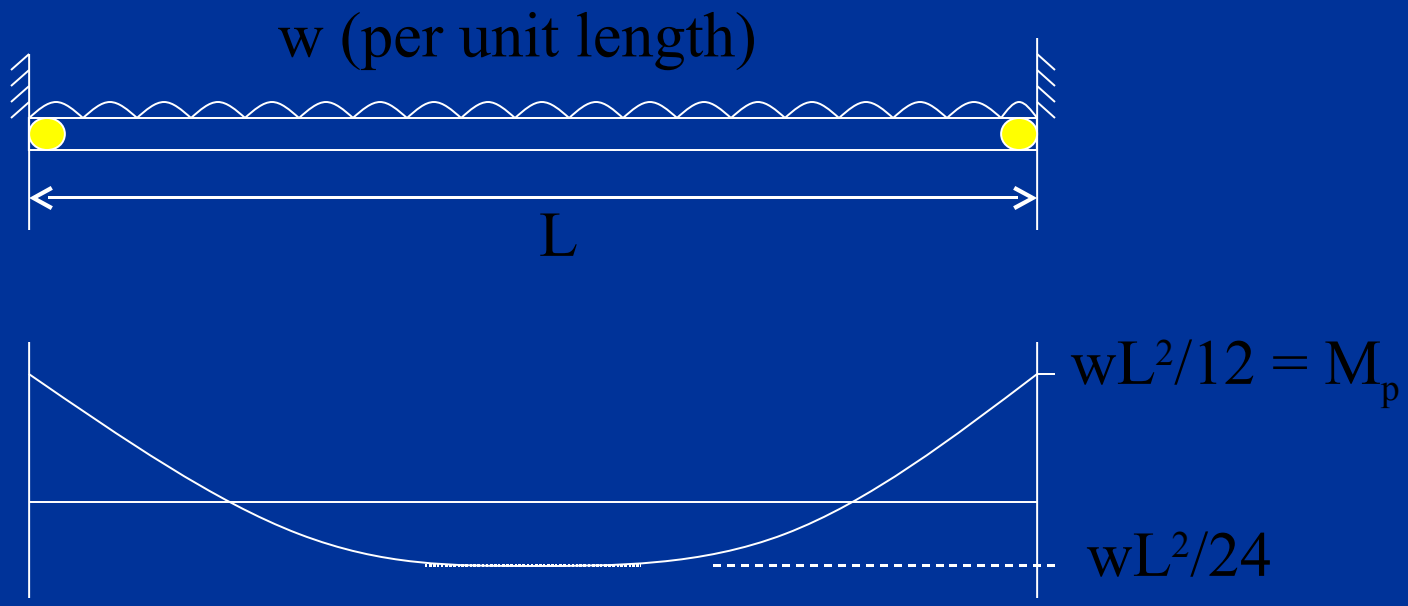
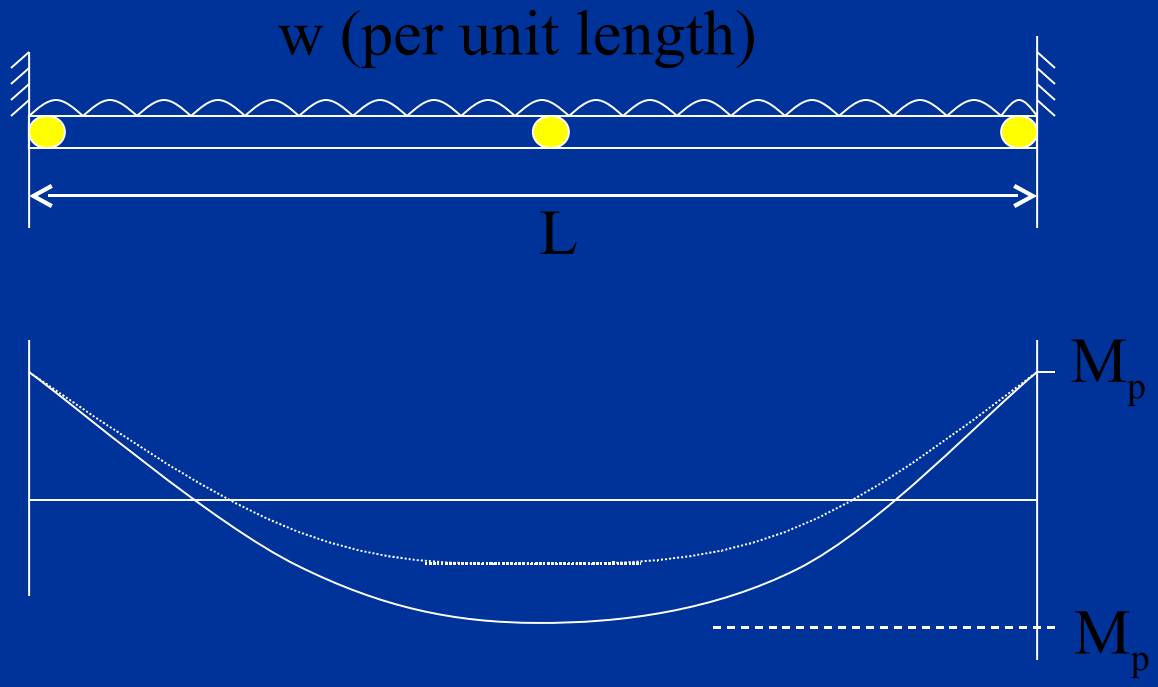


$$w = 12\ M_p / L^2$$

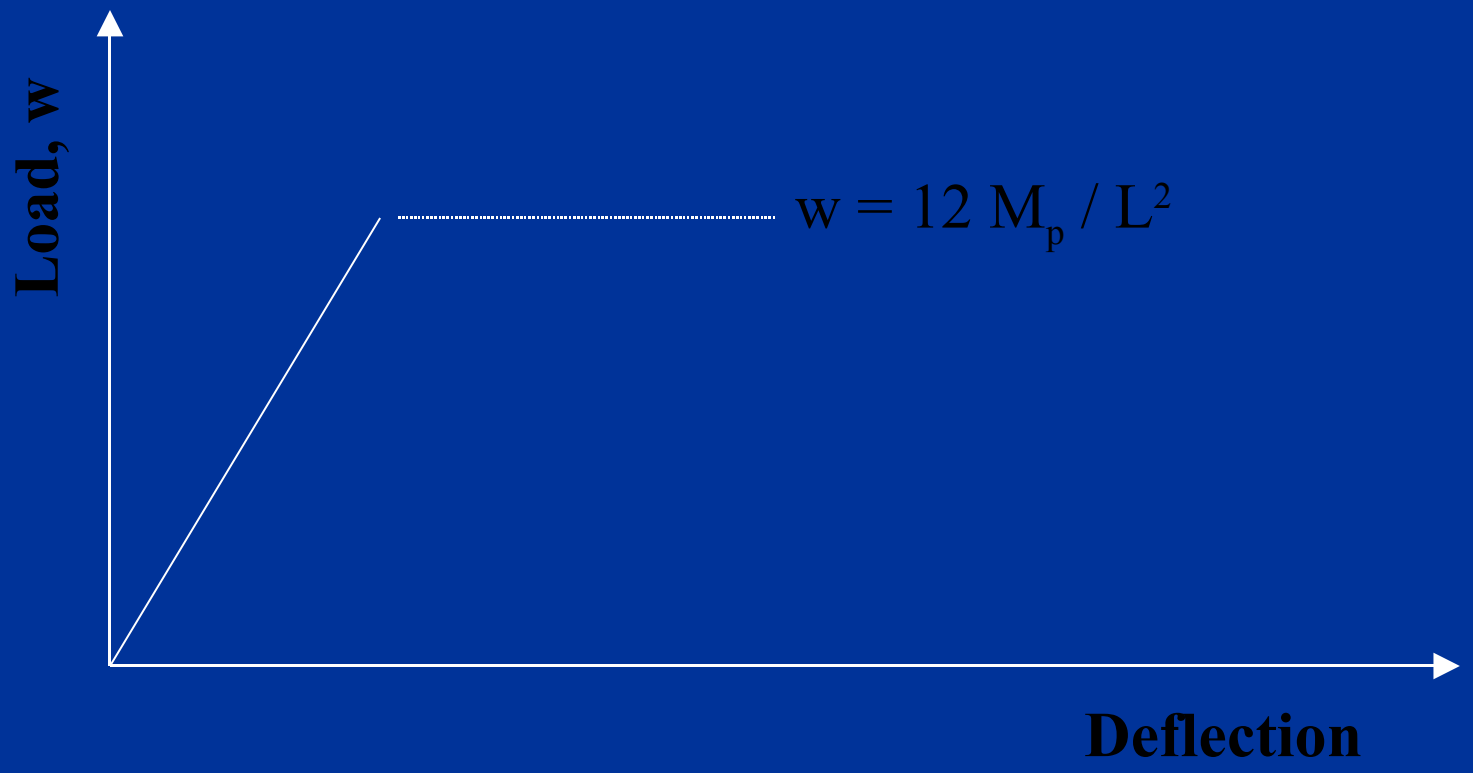
Achieving realistic assessments



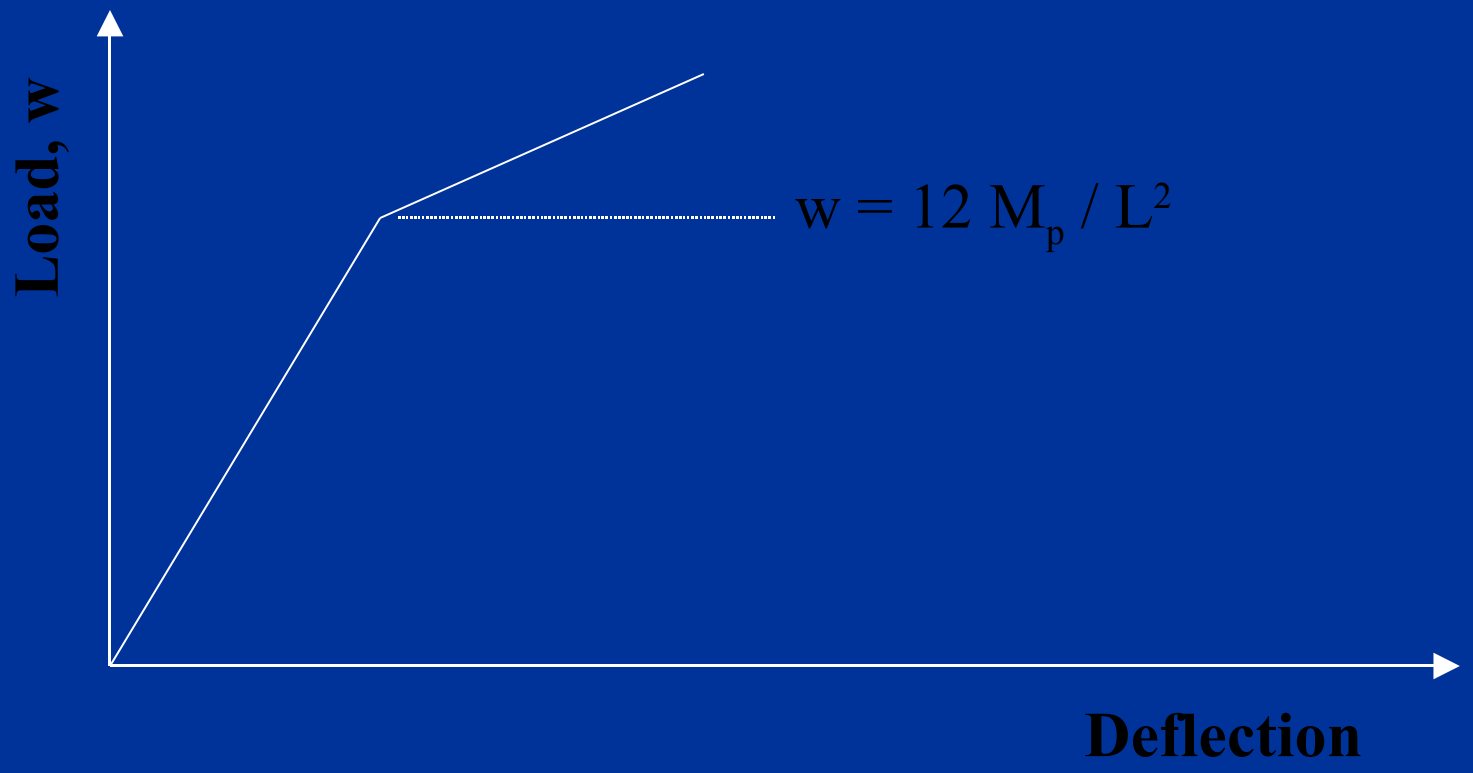
$$w = 16\, M_p / L^2$$

Achieving realistic assessments

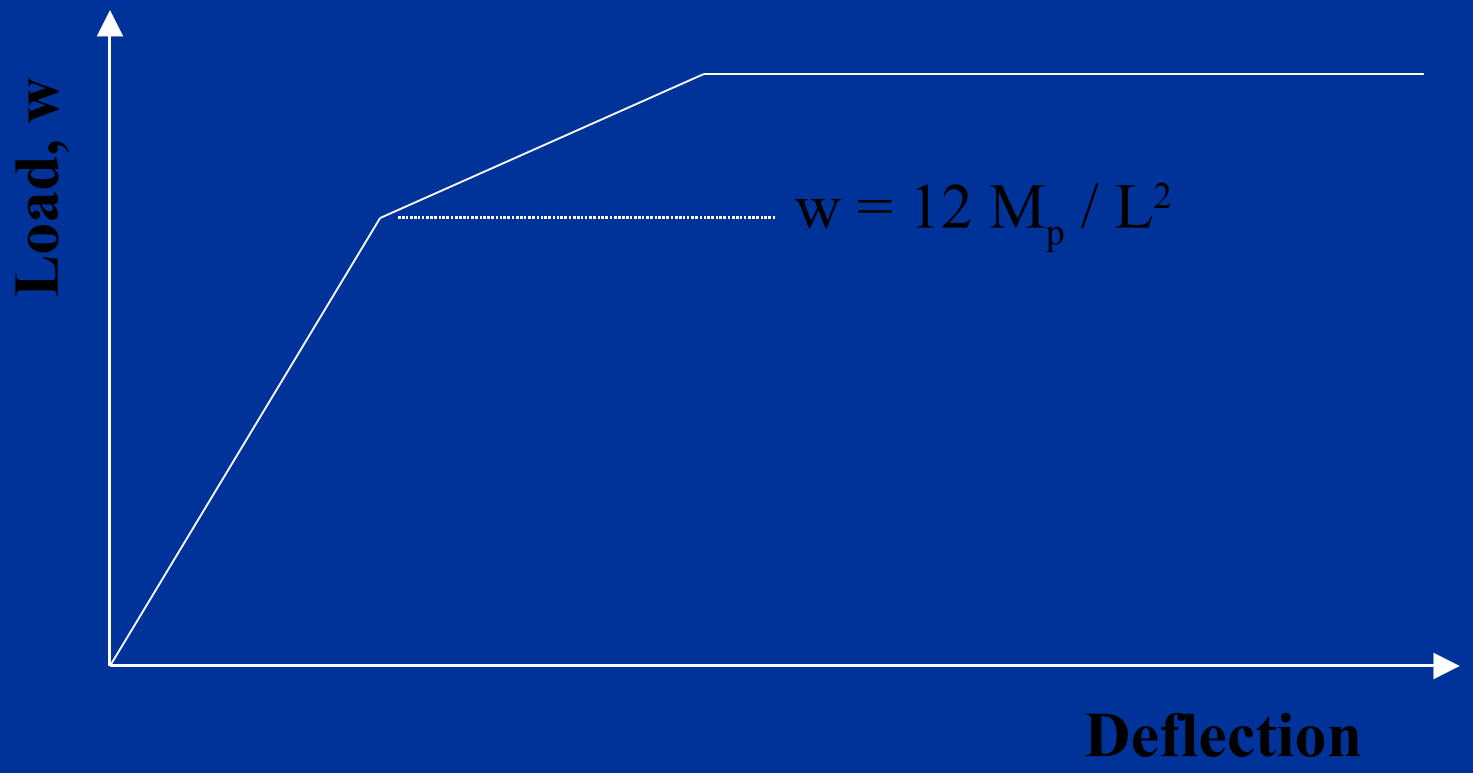
Achieving realistic assessments



Achieving realistic assessments



Achieving realistic assessments



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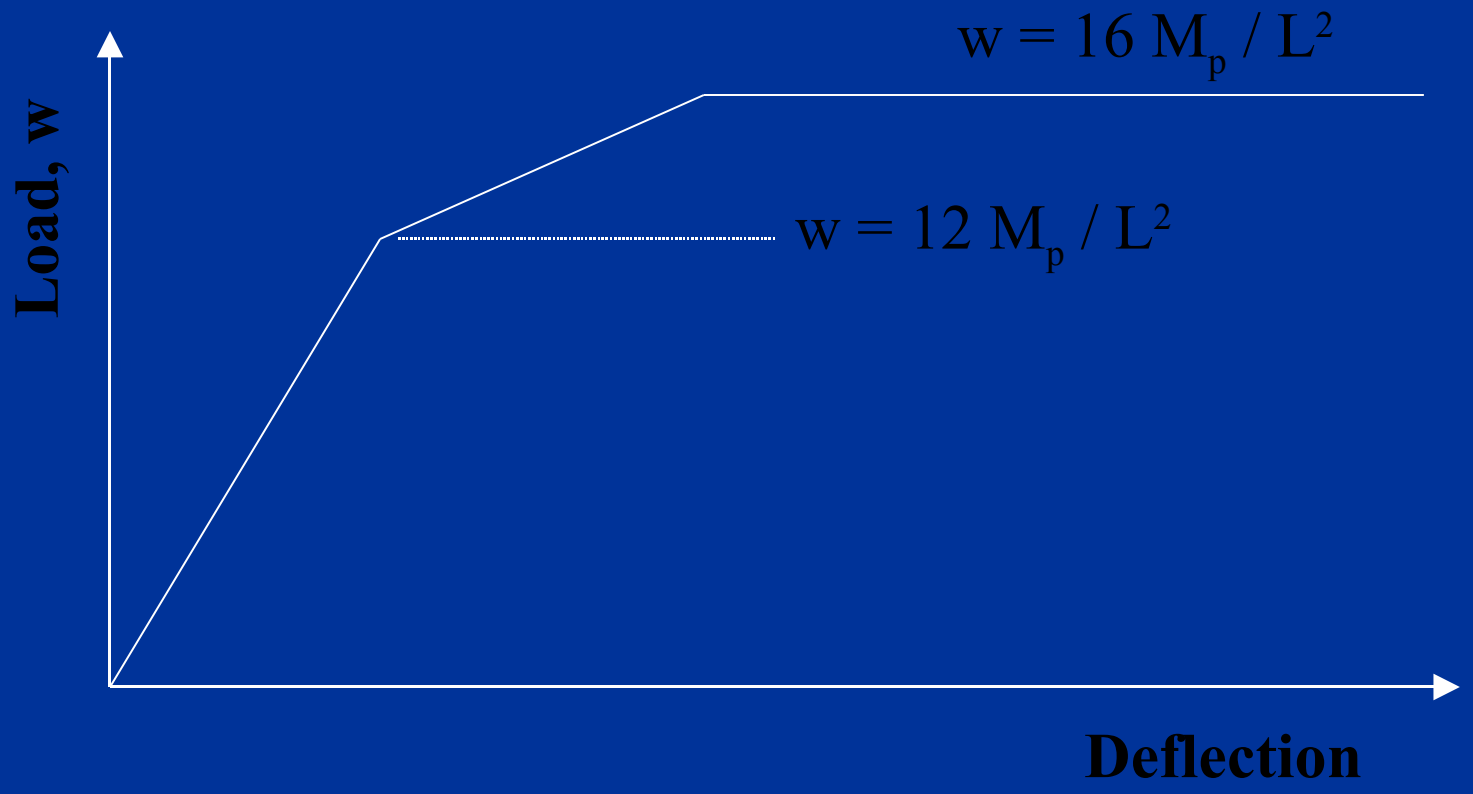

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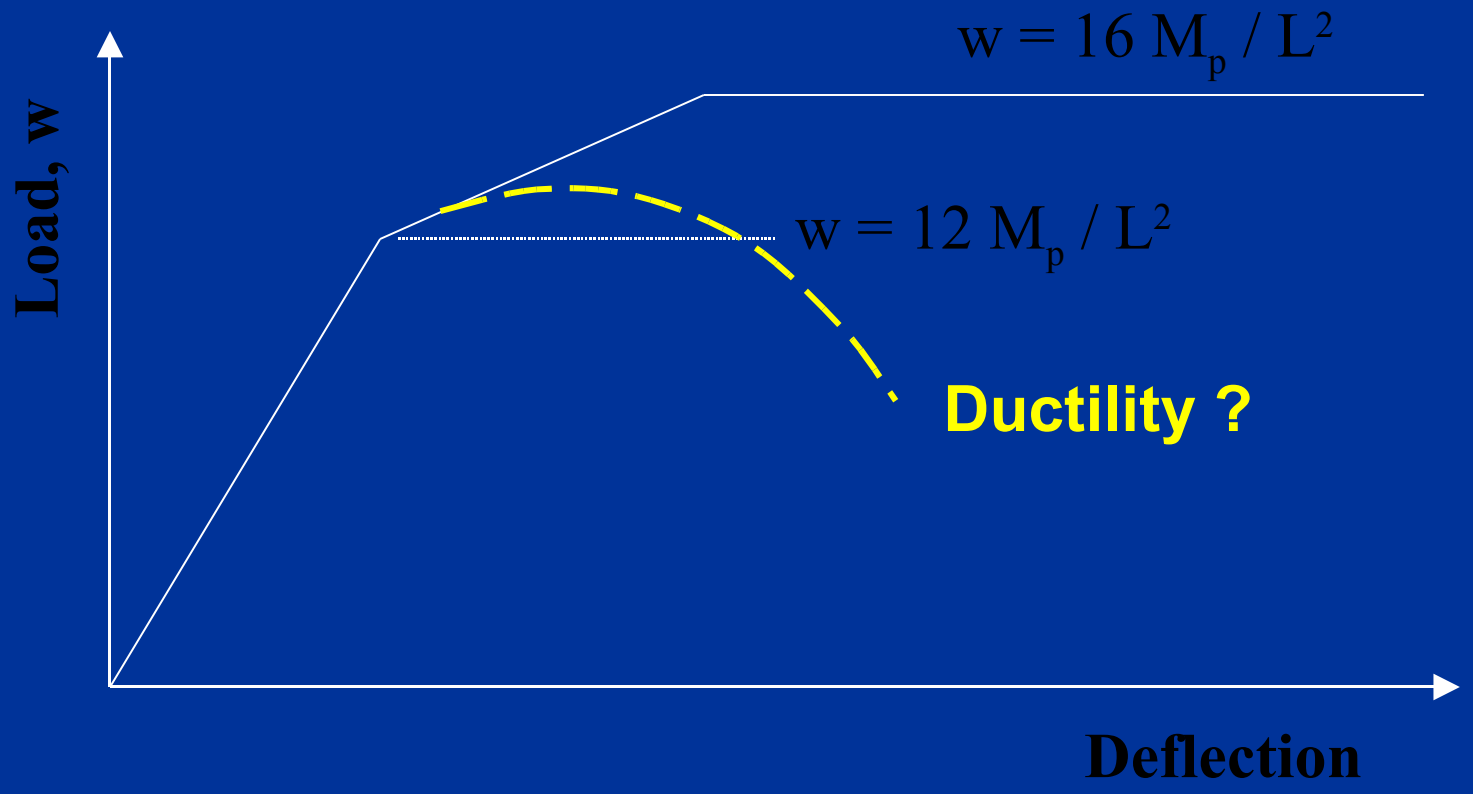

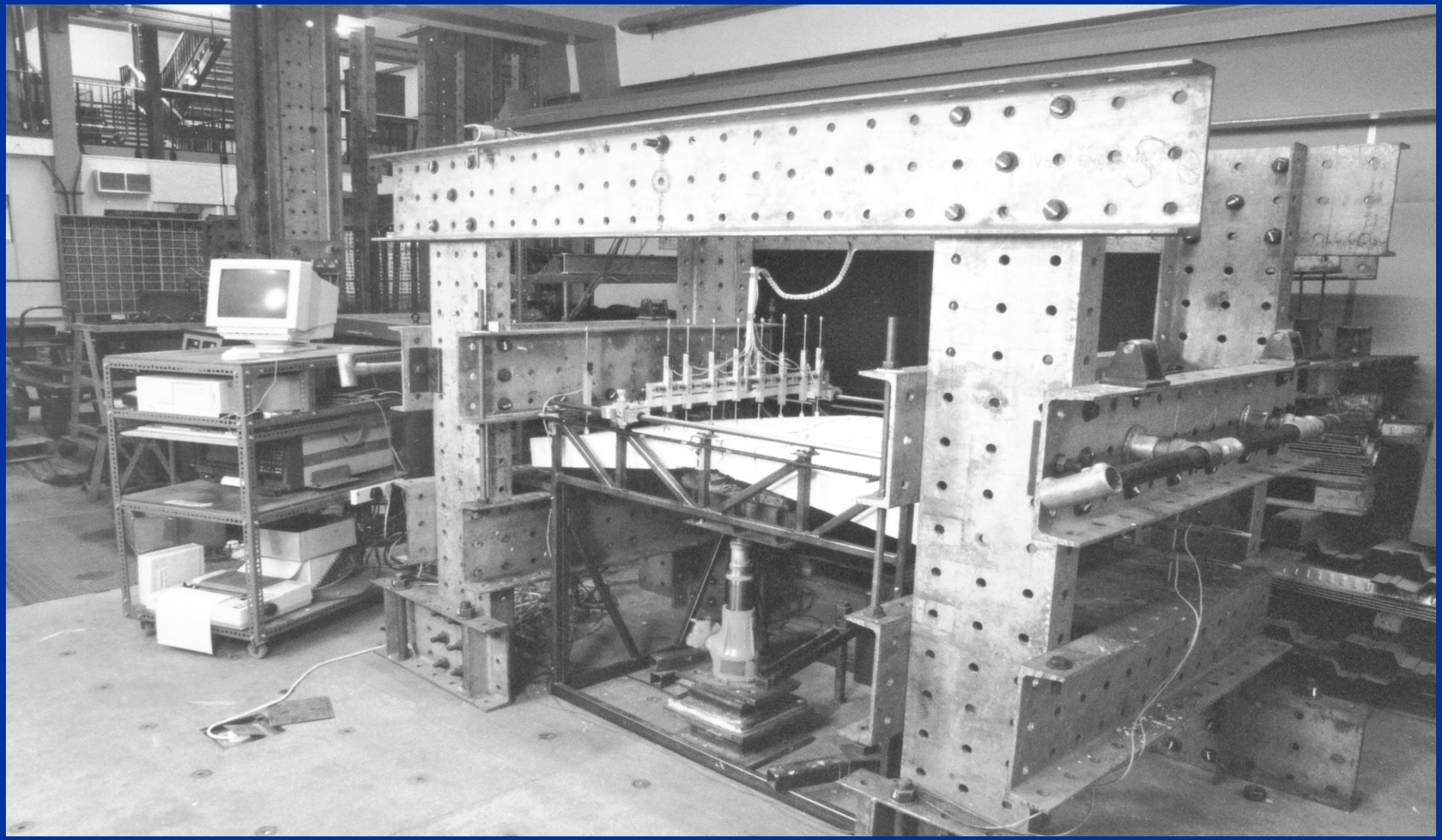

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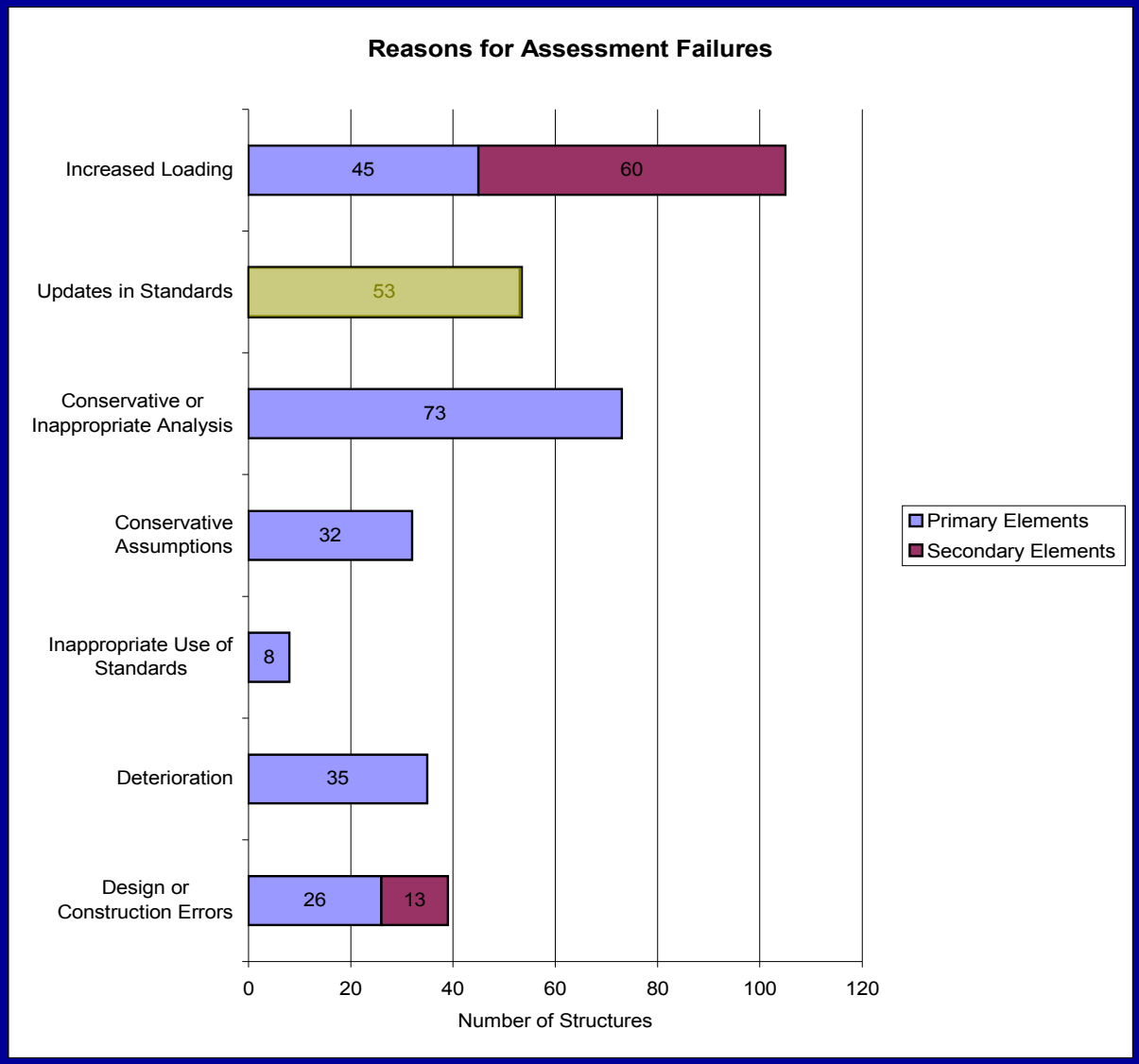
Results – Reasons for Failure



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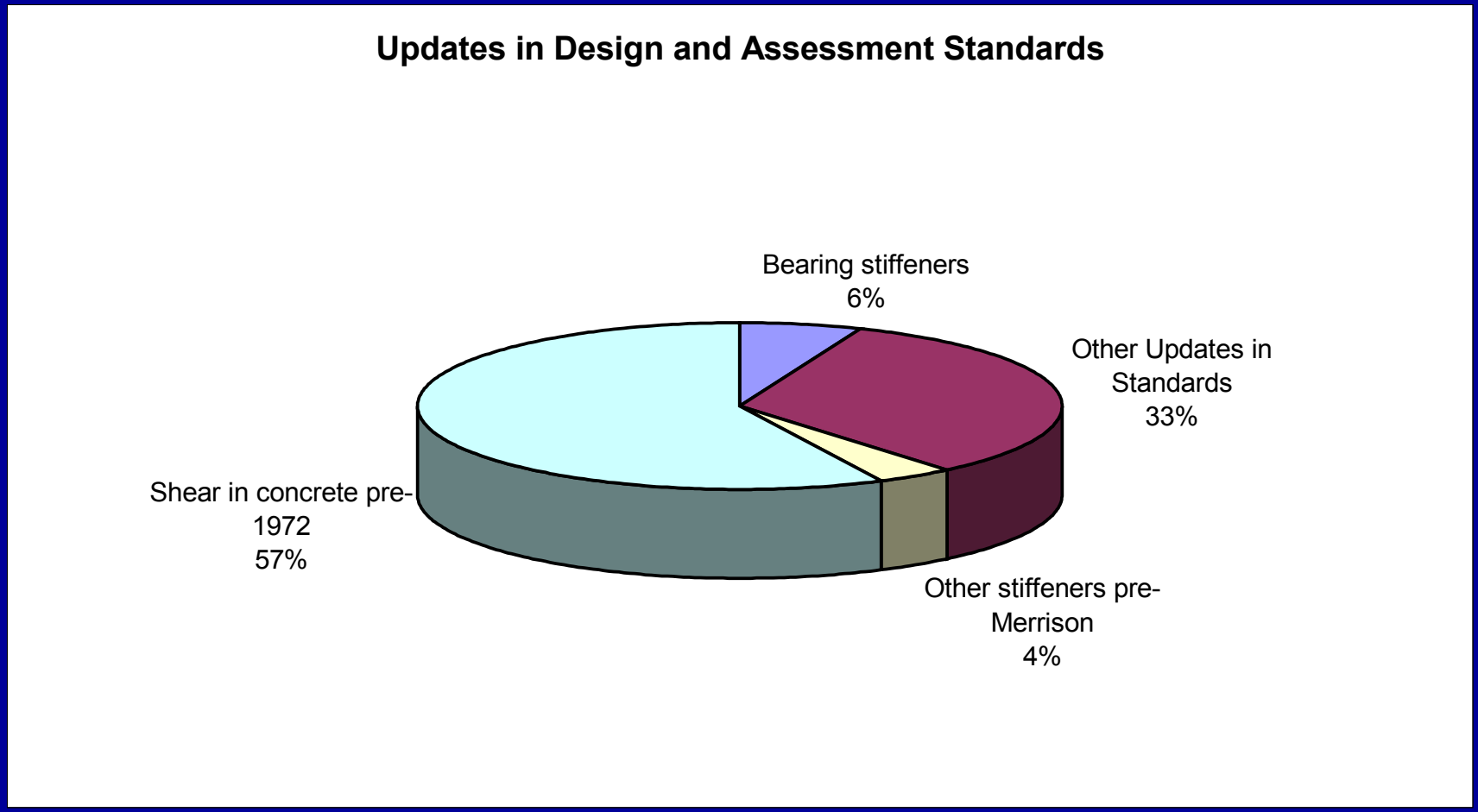

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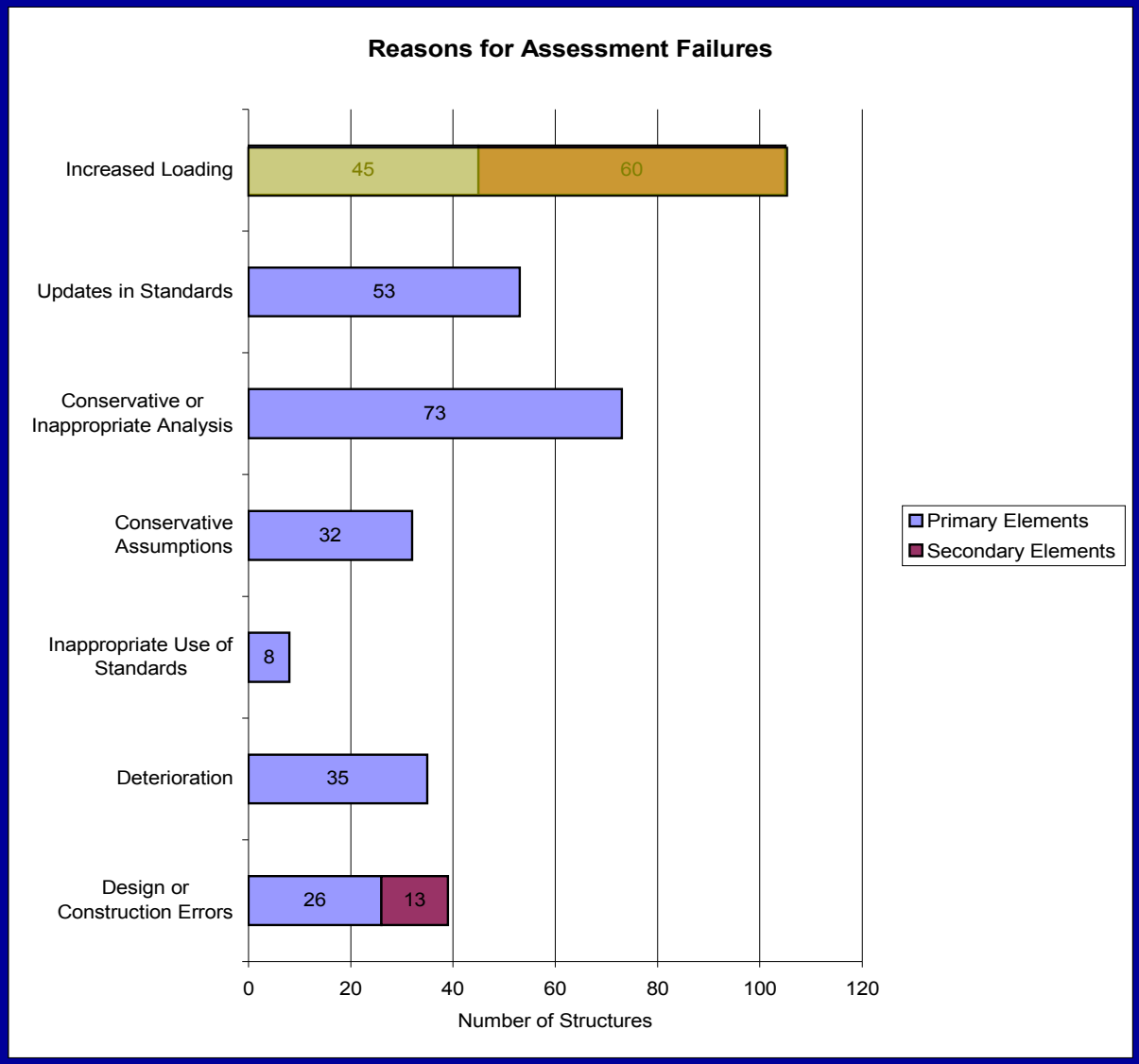

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Review of Assessment Programme

Methodology → **Key Results** → **Recommendations**

- Shear in concrete: the effect of longitudinal reinforcement anchorage – BD44/95 cl 5.3.3 and 5.8.7
- Distribution analysis – BD21/01 cl 6.1
- Clarification of levels of assessment (BA79/98)
- Condition factors – BD21/01 cl 3.18-3.19
- Enhancing the understanding of Assessment Engineers

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- Conclusions

Contents

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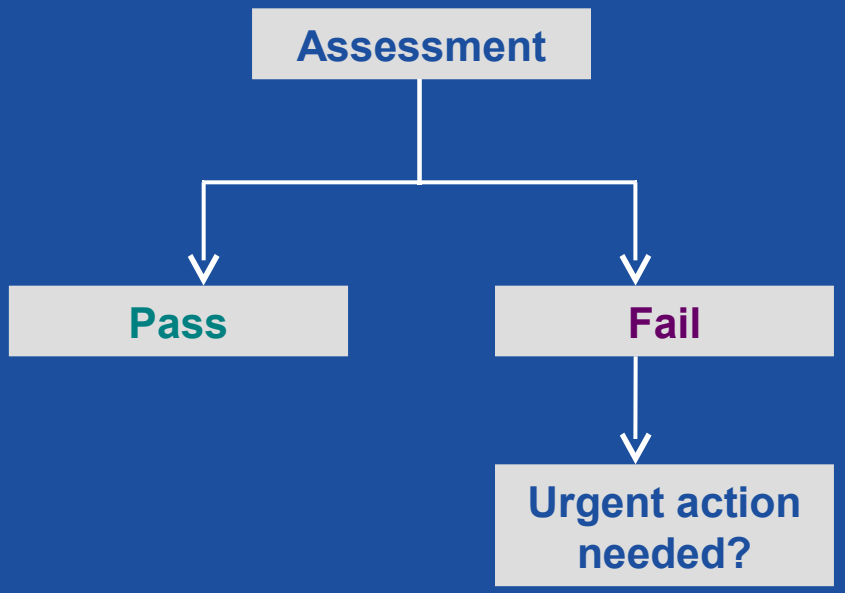
Background

- Appropriate methods are needed for managing “sub-standard” structures
- What is the risk?
- What interim measures should be applied?



Background

- BD21 has some strict requirements for structures that have failed an assessment

BD21 requirements

- Vehicle weight restrictions
- Lane restrictions
- Propping
- Replacement
- Strengthening
- Closure

- Cost and disruption of imposing these measures
- Appropriate for every structure?

Background

- Highways Agency advice note BA79/98
- Allows some sub-standard structures to remain in unrestricted service through use of monitoring
- Departure From Standard

BD21 requirements

("Formal interim measures")

- **Vehicle weight restrictions**
- **Lane restrictions**
- **Propping**
- **Replacement**
- **Strengthening**
- **Closure**

BA79

("Other interim measures")

- **Monitoring**
- **Monitoring with other measures**

Background

- 1998: Highways Agency publishes BA79
- 2002: PB appointed by HA to review the application of BA79
- 2003: PB makes recommendations for improvements to BA79
- 2005: PB commissioned by HA to update BA79
- 2006: New Standard BD79 finalised (to replace BA79/98) (to be published Autumn 2006)

Technical review of the application of BA79/98

- BA79 “a good document” but underused
- Bridge management records often incomplete
- Over a third of sub-standard structures had no evidence of being managed
- Inconsistency of application
- Guidance needed to identify immediate risks
- Monitoring sometimes used inappropriately
- Monitoring specifications not generally used

Recommendations and key areas for development

- Key area of risk lies with the way BA79 is applied, rather than the quality of the document itself
- BA79 should be replaced by a new document
- Structure owners to play a key role in producing document
- Process-based document
- Applicable to wide range of stakeholders

Recommendations and key areas for development

- Document to become a “BD” Standard
- Mandatory requirements in boxed clauses (key processes)
- Guidance in unboxed clauses (recommended approaches)
- Requirements for auditable records to be kept
- Improvements to clarity, usefulness and terminology

Development of new standard BD79

- Technical Project Board (TPB)
- 29 representatives from:

The Highways Agency

Transport Scotland

Welsh Assembly Government

Northern Ireland Roads Service

County Surveyors' Society

Maintaining Agents

Network Rail

Transport for London

British Waterways

Local Authorities

London Underground

- Size and variety of TPB a potential challenge to achieve consensus

Development of new standard BD79

- High level processes

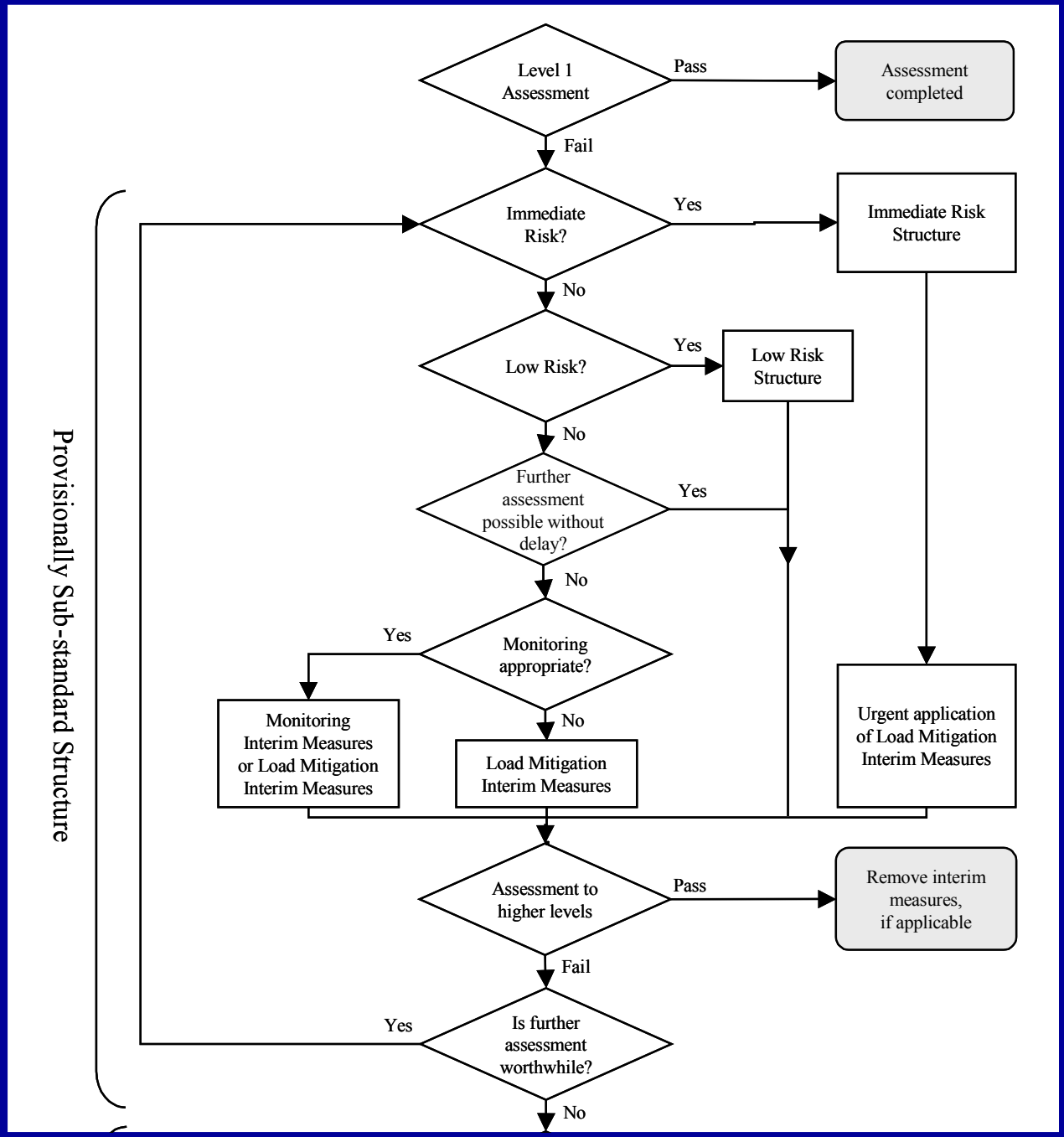
> **"Sub-standard and Provisionally Sub-standard Structures shall be managed by assessing the risks to public safety associated with their continued use and imposing appropriate interim measures when necessary."**

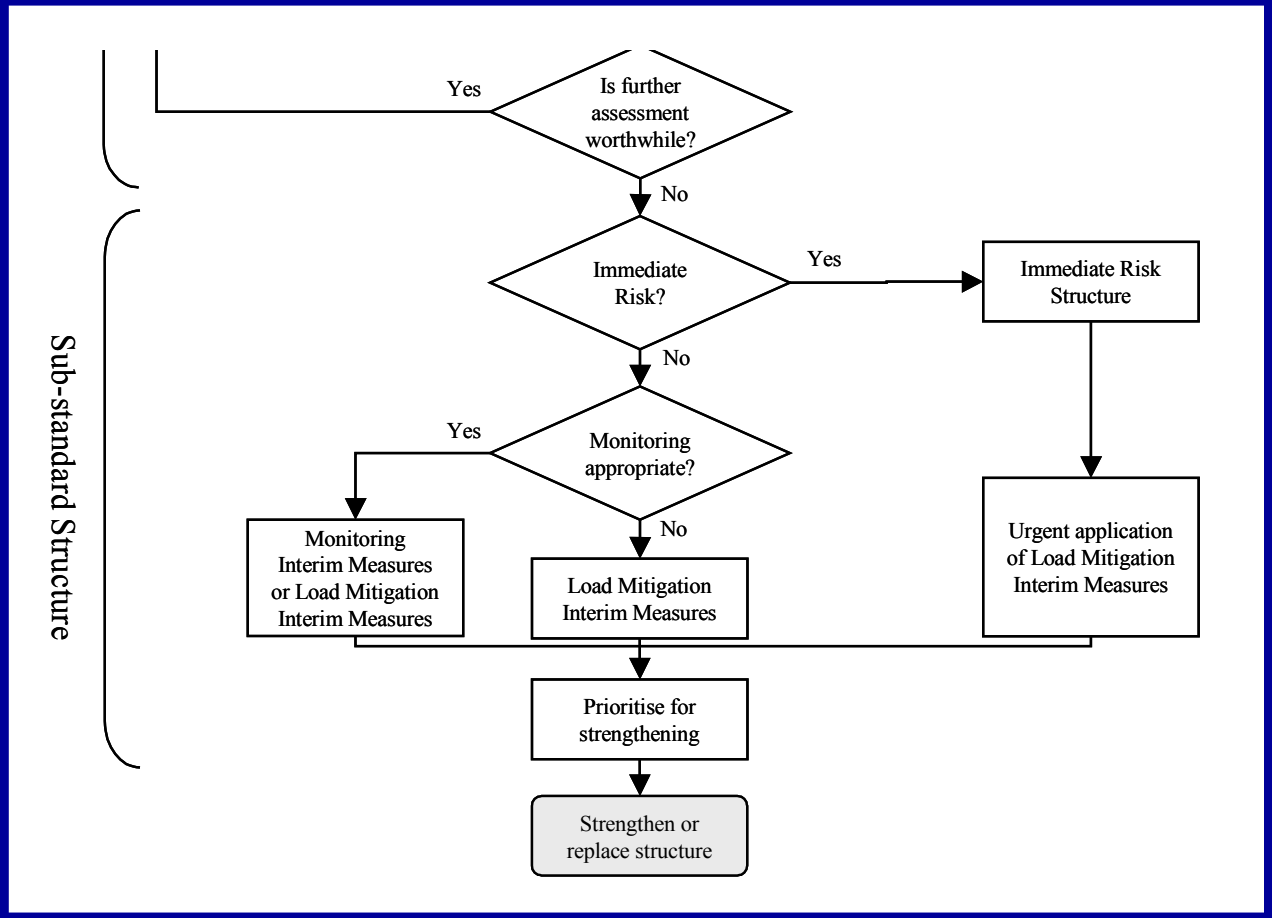
- Recommended approaches
  - Assessment of risks
  - Suitability of interim measures
  - Circumstances where interim measures might be unnecessary
  - Documentation

Development of new standard BD79

- BD79 primary document for management of sub-standard structures
- Management requirements of BD21 moved into BD79
- No longer a need for a Departure from standard
- Terminology updated accordingly

“Formal Interim Measures”	→	Load Mitigation Interim Measures
“Other Interim Measures”	→	Monitoring Interim Measures


Level 1 Assessment
Pass
Assessment completed
Fail
Immediate Risk?
Yes
Immediate Risk Structure
No
Low Risk?
Yes
Low Risk Structure
No
Further assessment possible without delay?
Yes
No
Monitoring appropriate?
Yes
No
Monitoring Interim Measures or Load Mitigation Interim Measures
Load Mitigation Interim Measures
Urgent application of Load Mitigation Interim Measures
Assessment to higher levels
Pass
Remove interim measures, if applicable
Fail
Is further assessment worthwhile?
Yes
No
Provisionally Sub-standard Structure


Sub-standard Structure
Yes
Is further assessment worthwhile?
No
Immediate Risk?
Yes
Immediate Risk Structure
No
Monitoring appropriate?
Yes
No
Monitoring Interim Measures or Load Mitigation Interim Measures
Load Mitigation Interim Measures
Urgent application of Load Mitigation Interim Measures
Prioritise for strengthening
Strengthen or replace structure

Development of new standard BD79

- Parties involved in proposing and approving interim measures

Principal

Technical Approval Authority (TAA)

Highway (or Roads) Authority

Structure Owner

Other relevant parties

Development of new standard BD79

- Requirements for record-keeping
  - Details of all decisions made
  - Evidence of approval and implementation of interim measures
- Mechanism may be electronic or paper based
- Appendices provided in BD79 for documentation of:
  - Summary of management history and current status
  - Feasibility, risks and costs of management options
  - Proposals for interim measures
  - Monitoring specification

Development of new standard BD79

- Immediate Risk Structures
  - Immediate and unacceptable risk to public safety
  - Once identified, must inform TAA and urgently implement Load Mitigation Interim Measures (eg weight restriction)
  - New guidance on identification of Immediate Risk Structures

Consequence of failure

Signs of distress

Condition data

Nature of structural weakness

Possibility of hidden distress

Sensitivity of structure to applied loading

Recent load history

Level of assessment

Past performance under unrestricted loading

- Simple indicative methods provided

Development of new standard BD79

- Low Risk Provisionally Sub-standard Structures
  - Not necessary to impose interim measures during the assessment process
  - Proposal to manage structure in this way based on assessment of risks, with the agreement of TAA and structure owner.
  - Decision must be recorded
  - Arrangements for regular review
  - Indicative methods provided:

Non-carriageway elements failing under accidental loading

Gradual failure predicted

Low consequences

C > K/1.5

Development of new standard BD79

- Three rounds of TPB review carried out
- Electronic tools developed to assist reviewing
- Automated compilation of composite document for HA knowledge management purposes
  - Draft Standard
  - All TPB comments
  - Responses to comments
  - Amendments to Draft
  - Commentary
- Finalised Standard at publication stage
- Publication in Autumn 2006

Conclusions

- New Standard BD79 for management of sub-standard structures
- Addresses the findings of PB's review of the application of BA79
- Intended for a variety of stakeholding organisations
- Process-based, allowing flexibility of approach
- Many new provisions, e.g. requirements for record-keeping

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Conclusions

- Major programme of assessment undertaken
- Comprehensive suite of Standards
- Review of assessment programme highlighted improvement opportunities
- Procedures established for managing substandard structures (BA79 / BD79)
- BD79 updated and improved in response to audit of its application
- Need to remain vigilant and provide funding