BRIDGE OWNERS FORUM 57

15 May 2018

Assessment of Masonry Arches and Asset Management: A Client View

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- Independent Consultant

- UK Bridges Board
- Bridge Owners Forum
- Deputy Chair, ADEPT Bridges Group

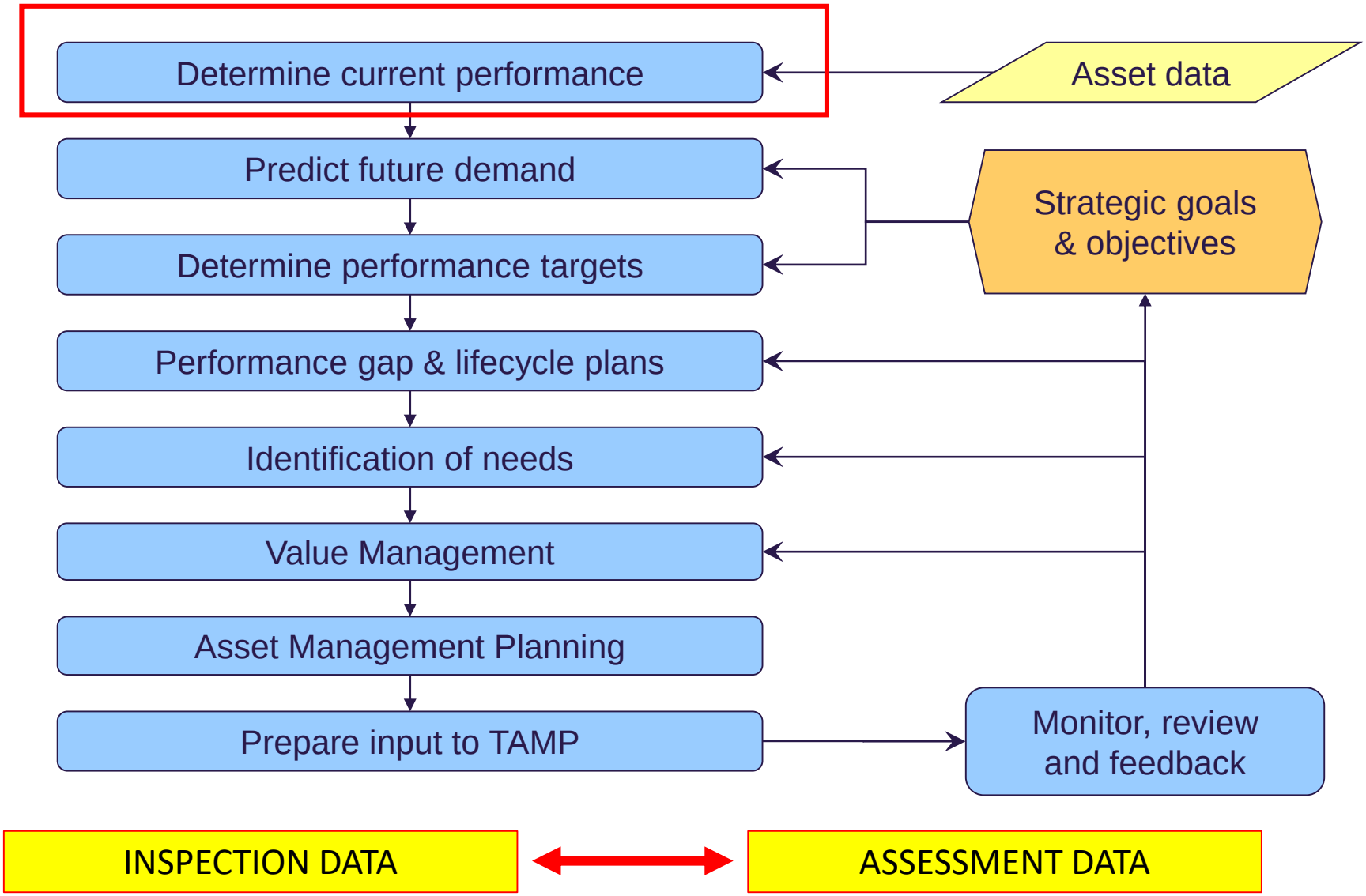
- TRL Guide to repair and strengthening of masonry arch bridges
- CIRIA C656 Steering Group
- University of West of England
- Universities of Sheffield and Salford

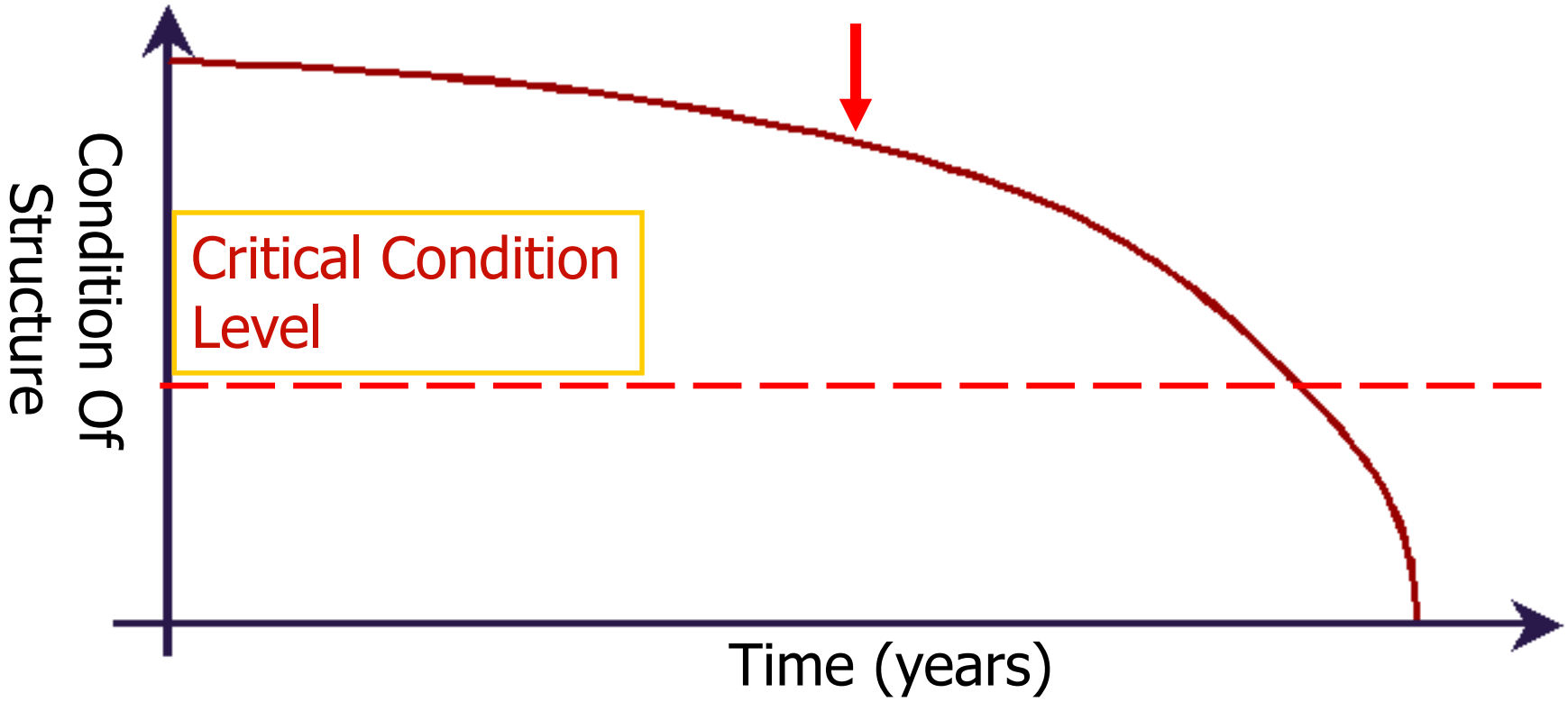
KEY DRIVERS

(for effective assessment of masonry arch bridges)

- Key part of transport infrastructure
- Rarely formally designed
- Historically important
- Need consistent method of inspection
- Need consistent method of assessment
- Manage risks to an acceptable level
- Input to asset management process

Asset Management for Bridges




Condition Of Structure
Critical Condition Level
Time (years)

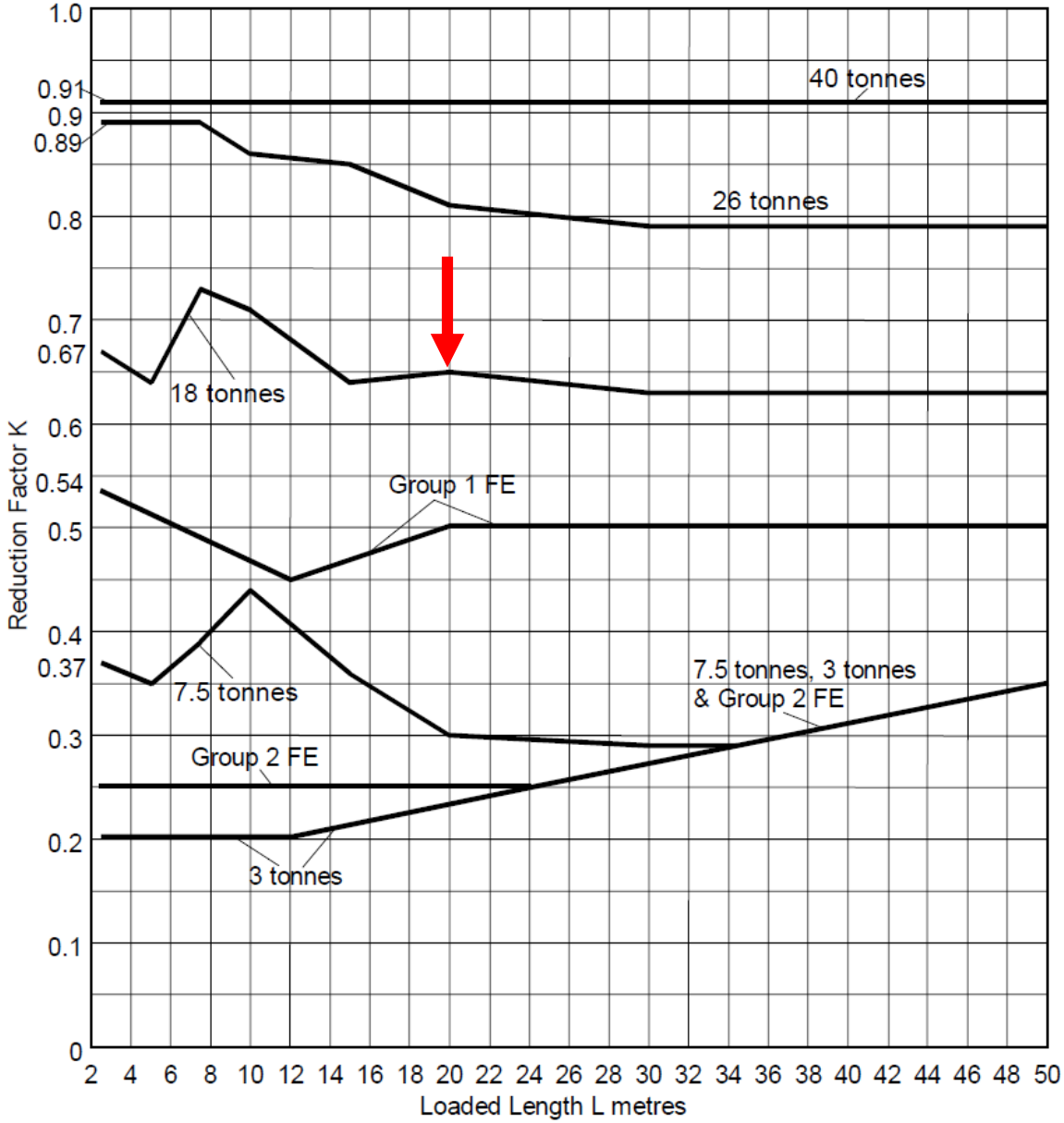


Figure 5.2 K Factors for Heavy Traffic Poor Surface (Hp)

They think its all over ..... !!

BUT IS IT??

Knowledge of assessment adequacy factor is a key input to effective asset management

‘Current bridge assessment codes rely on rigid assumptions and the use of subjective factors to account for variations in arch design and condition. Assessment made by these standards produce results of unknown accuracy.’

P.A.Woolfenden, British Rail Research

Modelling the masonry arch: improving modern bridge assessment using nonlinear finite-element software package (MAFEA)

Bridge Management 2, Thomas Telford 1993

Has anything changed?

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Modelling the masonry arch: improving modern bridge assessment using nonlinear finite-element software package (MAFEA)

Bridge Management 2, Thomas Telford, 1993

‘All arch spans have to be assessed for the capability to carry loads to which they will be subjected. For masonry arches in the UK, the most common and established methods in use are contained in …. BD21/84 with advice note BA16/84 …

These are still, effectively, the current standards for highway structures.

‘These assumptions (of the MEXE method) and factors simplify calculation of an allowable load for the arch, but have unsatisfactory limitations. The analysis assumes that tensile stresses can be supported, which is unconservative. It does not model the structural behaviour of the arch and cannot produce the limit state solution. This means that the engineer cannot find the margin of safety between the allowable axle load and the collapse load of the arch. Variation of load patterns and placement on the arch is not supported. The reliance on factors to take account of arch shape and profile preclude realistic representations of the physical arch geometry (e.g. representation of variable arch barrel thickness). Factors used for material condition are based on visual impressions and can only be subjective in their applications.’

1993.

Has anything changed?

BOF BACKGROUND

- Prompted production of CIRIA C656 (2006)
- BOF17 (January 2006) – retrofitted strengthening special
- BOF24 (January 2008) – discussion on Bill Harvey views
- BOF30 (January 2010) – Salford/Sheffield paper on assessment for CSS
- BOF51 (January 2016) – Matthew Gilbert update on assessment

BOF 30 Sheffield / Salford report for CSS

Chapter 2: Review of comments on the views of Prof. Harvey

- Outcome: consensus view is that existing assessment methods should be reviewed

Chapter 3: Review of current assessment methods

- Outcome: many anomalies identified; the commonly used MEXE method ought to provide conservative predictions and the reasons why this is apparently not the case needs to be investigated.

Chapter 4: Specific notes on the MEXE method

- Outcome: some assumptions made when formulating MEXE may make it unsuitable for short span bridges.

Chapter 5: Relevant experimental research

- Outcome: near-surface strong/stiff layer can transform short-span bridge behaviour, increasing strength and stiffness.

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2010

BOF 51 minute:

‘Professor Gilbert explained that the Highways England Standard BD21 did not take into account recent research and developments. The Standard used an approach where ULS/SLS were combined in a single analysis. This resulted in situations where assessment results could be under or over conservative depending on the parameters’

- Reluctance to use current analysis methods as this can require a Departure from Standards

- Standards are now 30 years old
- Warnings issued over many years
- New research is available

WHAT DO I NEED TO DO AS AN ASSET OWNER?

HOW CAN WE IMPROVE MATTERS AS BOF?

Example One

Method	Barrel Thickness (mm)	Depth of Fill (mm)	Allowable Axle Load (t)
MEXE	205	205	35.0
MEXE	205	600	40.5
RING	205	205	5.5
RING	205	600	14.5*

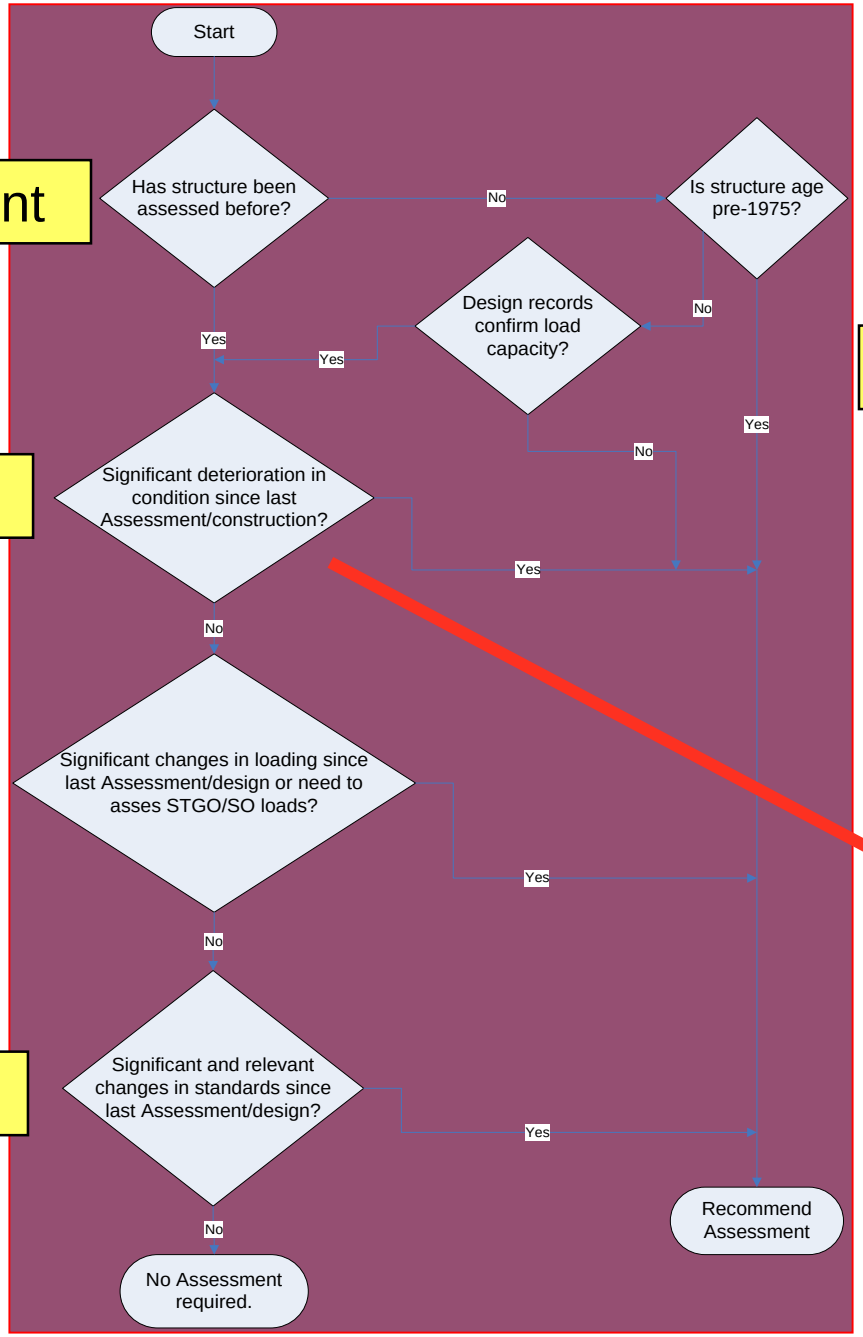
BD101

Previous Assessment

Deterioration

Loading

Standards



Pre-1975

Design Records

Bridge Inspector!

HOW?

Significant!

No need to review all MEXE assessments

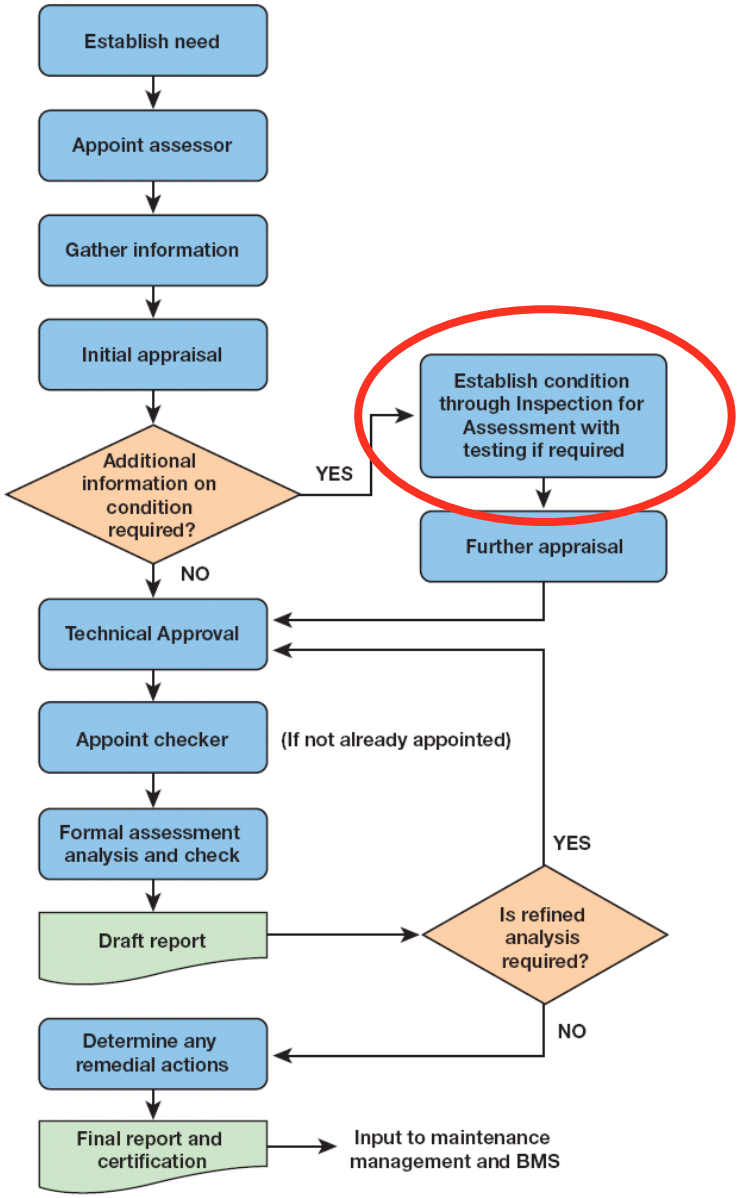


Figure 7.1: Flowchart of the assessment process for a highway structure

ASSESSMENT PROCESS

- Detect change in condition
- Include condition state in assessment

No.	Item		Severity				
			1	2	3	4	5
3	**Masonry, Brickwork and Mass Concrete**						
	Deformation	.1	No evidence of deformation	Minor deformation	Moderate deformation	Major deformation	Collapsed
	Pointing	.2	Pointing sound	Minor depth of pointing deteriorated	Moderate to significant depth of pointing lost…	Pointing in very poor condition…..	Collapsed
	Arch Ring Separation	.3	No arch ring separation	Arch ring cracks difficult to see	Arch ring separation (gap less than 25mm)	Arch ring separation (gap greater than 25mm)	Disintegrated
	Arch Barrel Cracks	.4	No arch barrel cracks	No diagonal cracks, longitudinal cracks greater than 3mm wide	Diagonal cracks, longitudinal cracks greater than 3mm wide	Diagonal cracks, longitudinal cracks breaking barrel into 1m sections or less	Failure due to structural cracks

Supplemented by photos in Inspection Manual part 2

IS THIS ADEQUATE?

Width of Joint	Width Factor (F_w)
Joints with widths up to 6mm	1.0
Joints with widths between 6mm and 12.5mm	0.9
Joints with widths over 12.5mm	0.8

Table 3/3 Width Factor

Condition of Joint	Mortar Factor (F_{mo})
Mortar in good condition	1.0
Loose or friable mortar	0.9

Table 3/4 Mortar Factor

Construction of Joint	Depth Factor (F_d)
Unpointed joints, pointing in poor condition and joints with up to 12.5mm from the edge insufficiently filled	0.9#
Joints with from 12.5mm to one tenth of the thickness of the barrel insufficiently filled	0.8#
Joints insufficiently filled for more than one tenth the thickness of the barrel	At the + engineer's discretion

Table 3/5 Depth Factor

Defects Affecting the Stability and Load Carrying Capacity of the Arch Barrel

3.21 Ranges of condition factors are given below for crack patterns resulting from specific causes. The choice of factor is made from a critical examination of the size, shape and importance of the various defects. The overall figure representing several defects should be based on the relative importance of the worst type of defect present. It will not necessarily be derived by multiplying the factors for several separate defects together:

Plate 4a Elevation

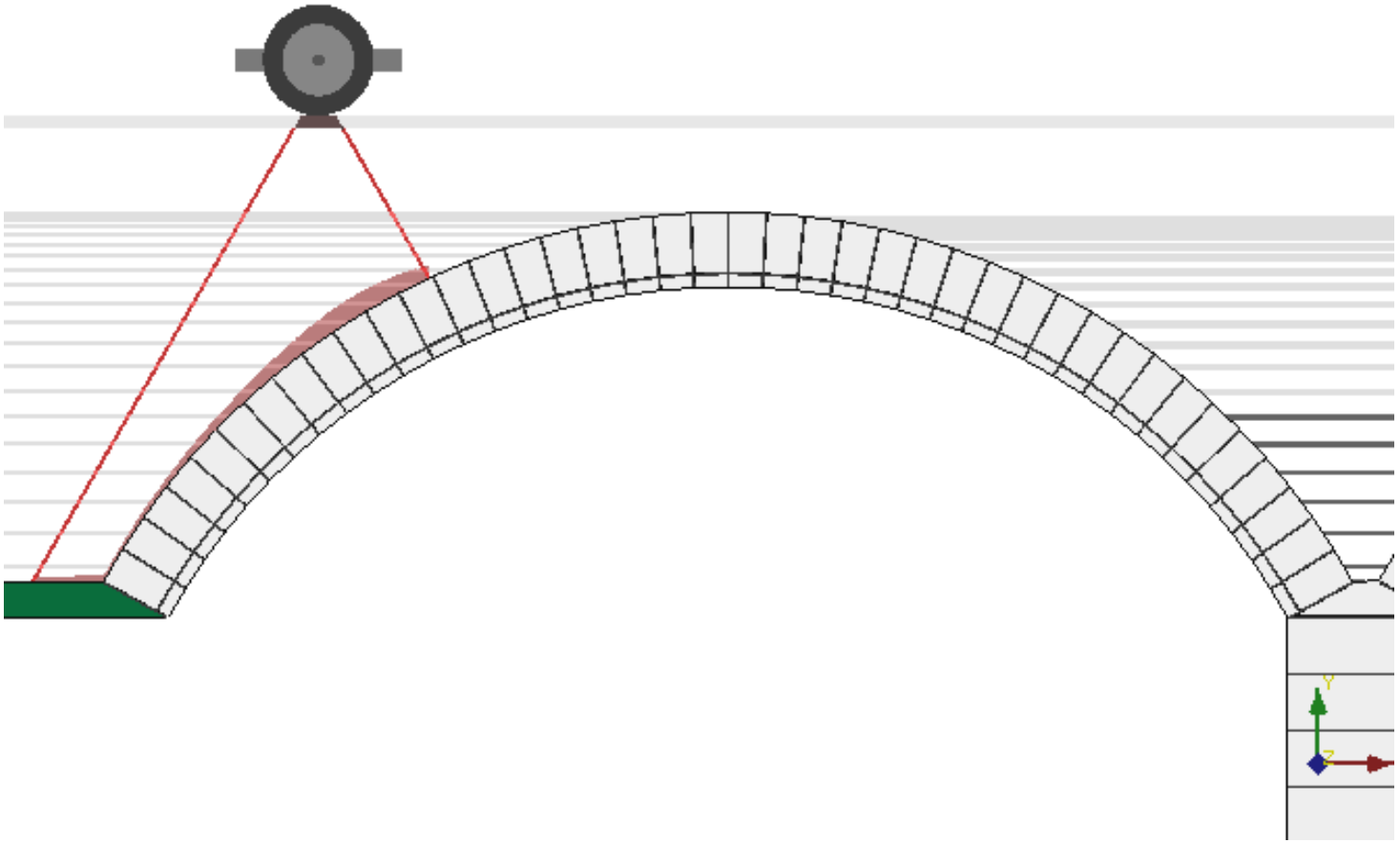
Plate 4b View of Soffit

Plate 4 **The arch shape is good, but there is severe longitudinal cracking towards the outer areas of the arch barrel.**

Suggested Condition Factor: 0.5

Modelling defects

- Ring separation modelled through entering multiple rings at each span



ASSESSMENT ISSUES:

- DIMENSIONS
- BARREL THICKNESS
- DEPTH OF COVER
- MASONRY STRENGTH
- BACKFILL
- EFFECTIVE WIDTH of BARREL

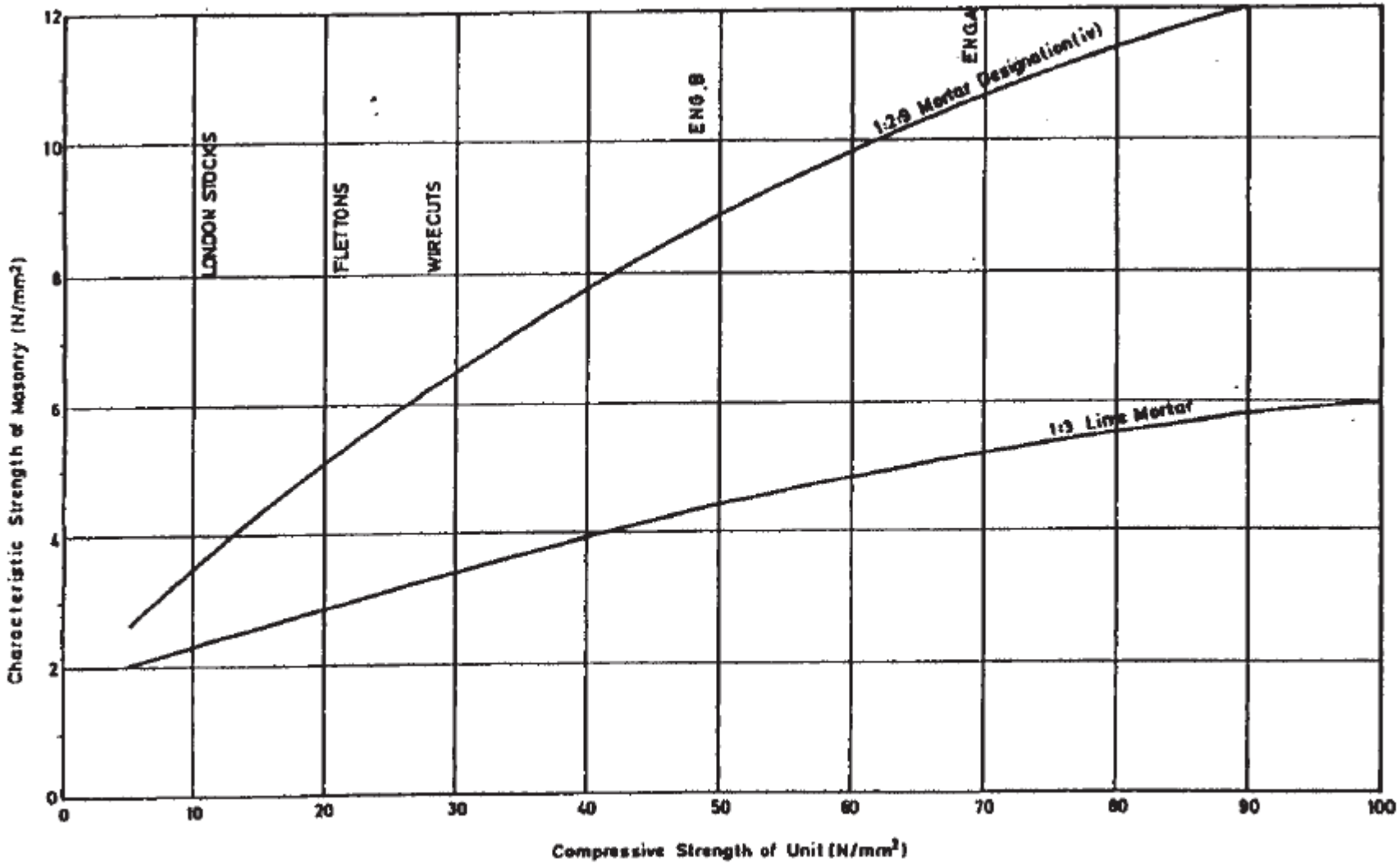


Figure 4.2 Characteristic Strength of Normal Brick Masonry

CIRIA C656 London, 2006

Masonry arch bridges: condition appraisal and remedial treatment

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What to do about it?

- Make Network Rail documents freely available
- Review Highways England standards
- Guidance on impact of condition on assessment
- Publish assessment guidance to assist with departures from standards

Thank you