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A "Best Practice" Approach to Structural Integrity Assessment

Une "meilleure procédure" pour l'évaluation de l'intégrité structurale

Ein "bestes Verfahren" zur Beurteilung von Gebäuden

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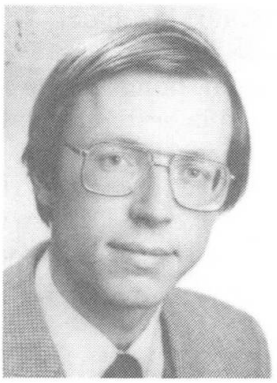

John Maguire obtained his undergraduate and postgraduate degrees at Bristol University, UK. He has been involved with structural integrity assessment projects in the UK and overseas for nearly twenty years. Since 1989 he has been working for Lloyd's Register and currently heads their Civil & Structural Engineering Section.

SUMMARY

This paper briefly describes a number of UK government sponsored projects that have studied structural integrity assessment approaches across a wide range of industries. The aim of these projects has been to define and document "best practice" in complementary technology areas. One of these projects is described.

RÉSUMÉ

Ce document décrit brièvement un certain nombre de projets soutenus par le gouvernement britannique qui ont étudié les méthodes d'évaluation d'intégrité structurale à travers une gamme étendue d'industries. L'objet de ces projets a été de définir et de documenter 'la meilleure procédure' puisée dans des industries diverses. La méthode d'un projet est notamment décrite.

ZUSAMMENFASSUNG

Diese Arbeit gibt eine kurze Beschreibung von Projekten, die untersucht haben, wie in verschiedenen Industriezweigen Strukturintegritätsbeurteilung durchgeführt werden. Der Zweck dieser Projekte ist, die besten Verfahren zu beschreiben und zu dokumentieren. Ein Projekt wird mehr im Detail beschrieben.

1. INTRODUCTION

In the UK there are a variety of sector specific structural integrity assessment (SIA) approaches, for example for buildings and bridges, which are somewhat restricted in scope. Appendix 1 lists some of the major approaches.

In recent years a number of UK government sponsored projects such as the DTA (Dynamic Testing Agency), NAFEMS (National Agency for Finite Element Methods and Standards) and SAFESA (Safe Structural Analysis) have been studying SIA approaches across a wide range of industries (nuclear, defence, offshore, shipping, construction, automotive, aerospace, etc). The aim of these projects has been to define and document "best practice", drawn from a range of industries, in complementary technology areas. The DTA has addressed best practice in dynamic testing, NAFEMS best practice in finite element analysis (FEA) and SAFESA best practice in structural qualification, with particular reference to FEA.

The purpose of the paper is to briefly describe these three projects, and in particular to describe the DTA Primer and Handbooks, produced by the DTA, which provide a modern best practice approach to SIA for a variety of structures. The SIA approach is illustrated by application to a building example.

2. HISTORY AND STATUS OF THE PROJECTS

2.1 History

The chronological development of the three projects is shown in Figure 1. The aims of the three projects are given below.

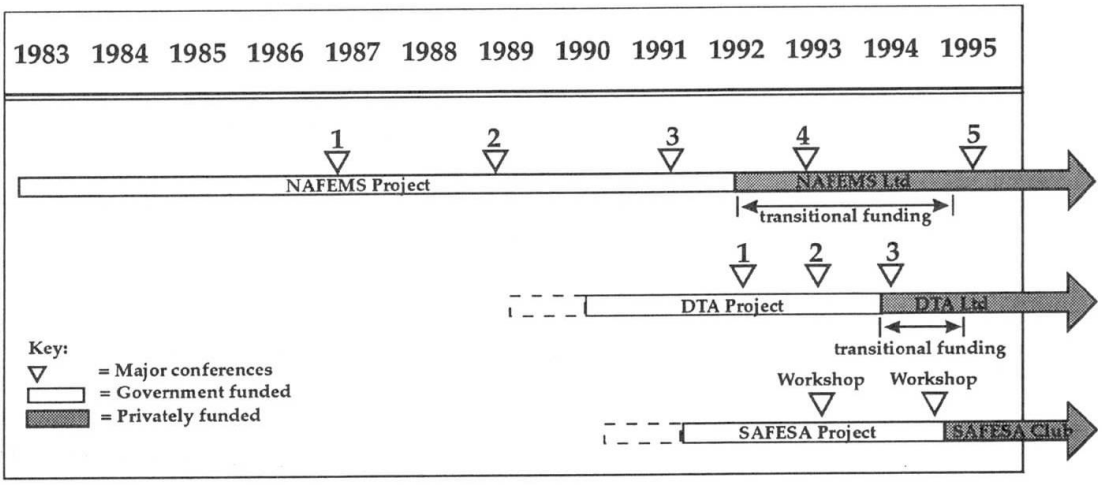

Fig. 1 Chronological development

2.2 NAFEMS Status

NAFEMS (now NAFEMS Ltd) was founded in 1983 as the UK National Agency for Finite Element Methods and Standards. Its aim is to promote the safe and reliable use of finite element analysis and allied technology. NAFEMS is a recognised "centre for quality" of international repute. Membership is open to all companies world-wide. NAFEMS activities include working groups, technology transfer, standards, information services and quality assurance. NAFEMS is owned and operated by the members for their mutual benefit, on a non-profit making basis. For further details see Appendices 2 & 3.

2.3 DTA Status

The Dynamic Testing Agency (DTA) was established in 1990 in order to draw together the many aspects of dynamic testing of structures. Its aim is to encourage best practice in all aspects of "standard" dynamic testing by providing documentation and guidance to supplement that already available. The DTA addresses the need for quality assurance standards in the analysis and measurement of dynamic data and provides practical and authoritative guidance on best practice. The DTA is demand led by industry and is non-bureaucratic. It is non-profit making and is controlled by and acts on behalf of its members. DTA activities include standards, co-ordination/promotion/support for technology, technology transfer, training and accreditation. For further details see Appendices 2 & 3.

2.4 SAFESA Status

SAFESA grew out of the NAFEMS Dynamics Working Group in 1990, leading to a project funded in its own right in 1991. It was organised as a collaborative R&D project, comprising 5 members:

- Assessment Services Limited (lead);
- Lloyd's Register;
- Cranfield University;
- Nuclear Electric plc;
- W S Atkins Science & Technology.

The principal aims were to enable structural qualification to be carried out reliably and accurately (with emphasis on the use of the finite element analysis method). The drivers for the project included:

- the trend to reduce physical testing by finite element analysis;
- the reduction of costs via reduced design cycle time;
- the improvement of quality/added value;
- the improved legal position.

For further details see Appendices 2& 3.

3. THE DTA SIA PRIMER AND HANDBOOKS

At the onset of the DTA programme it was recognized that dynamic testing is only one element in an overall structural integrity assessment process. Accordingly, the DTA commissioned the development of a suite of SIA documentation as follows:

- SIA Primer
- Handbook Volume 9
  - Item 90 - Overview of SIA
  - Item 91 - Detailed Methods for SIA
  - Item 92 - SIA Case Studies
  - Item 93 - SIA Management Procedures
  - Item 94 - Environmental Testing
  - Item 95 - Dynamic Loading
  - Item 96 - Partial Safety Factors

The SIA Primer gives an appreciation of the various facets (test, analysis and experience) to be regarded, and is of interest to project managers and technical managers alike. The SIA Handbooks explore technical subject matter in greater detail giving guidance on procedures, benchmarks, acceptability criteria, relevant codes of practice and databases.

4. EXAMPLE APPLICATION OF SIA PRIMER

4.1 Background

During 1991-93 a number of large panel system (LPS) tower blocks were assessed by Lloyd's Register (LR) for a client. For reasons of client confidentiality the tower blocks will be referred to as blocks A, B, C and D - typical construction is shown in Figure 2 and key details are given in Table 1. The assessment approach adopted by LR was that described in the DTA SIA Primer.

	Block "A"	Block "B"	Block "C"	Block "D"
Number of Stories	9	20	13	20
Height (m)	23.9	50.8	33.2	50.8
Length (m)	21.7	22.6	20.0	21.2
Width (m)	15.7	22.0	15.5	14.4
Underlying soil shear modulus (MN/m^2)	100	100	100	4400
Measured first mode (Hz)	2.72	1.11	1.65	1.11
Estimated mass (kg)	3.25×10^6	9.94×10^6	4.39×10^6	5.08×10^6
Estimated density (kg/m^3)	400	395	428	328

Table 1 - LPS Tower Block Key Data

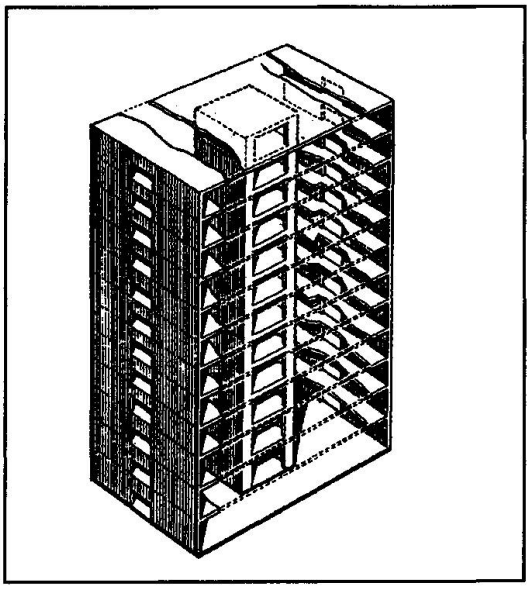

Fig. 2 Exploded Isometric View of Typical Tower Block (with acknowledgements to CIRIA)

4.2 General approach

The DTA SIA Primer assessment approach is summarised in Figure 3. It is a three stage approach, the precise nature of each stage being governed by the required acceptance criteria, level of criticality, etc. The DTA have also published a set of case studies (Handbook Volume 9 - Item 92) which illustrate the application of the SIA Primer to a number of industries. One of these case studies, known as "DTA Handbook Item 92.3", illustrates the approach applied to a tower block very similar to those studied in this paper.

4.3 Detailed approach

In view of the critical nature of the tower blocks assessed, a combined dynamic analysis, test, correlation and updating approach was adopted. The dynamic analysis was carried out via the finite element method. Dynamic testing (experimental modal analysis) was carried out using ambient (wind) vibration. Correlation and updating was carried out using both manual and computer-aided approaches. Stresses in the tower blocks were checked against acceptance criteria agreed in conjunction with the client. Full details cannot be given for client reasons.

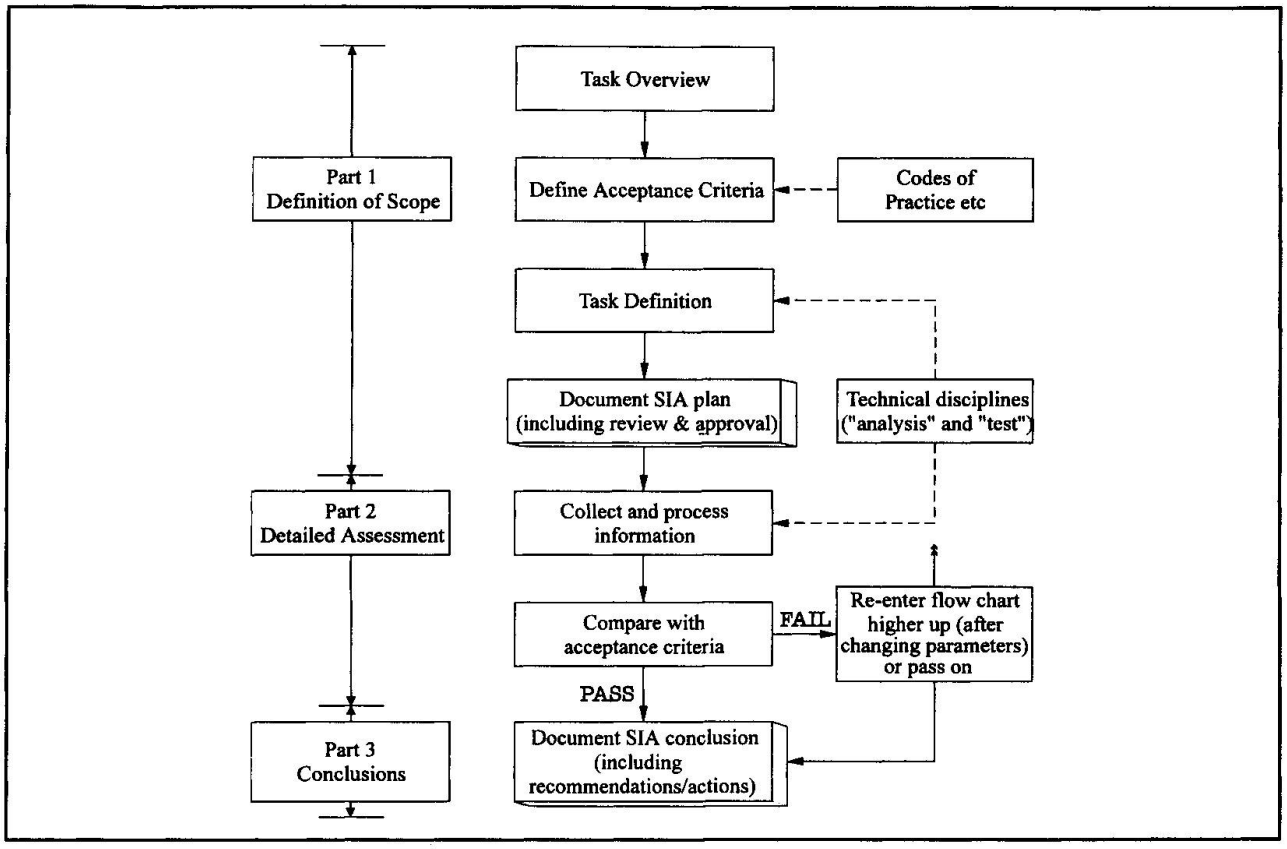

Fig. 3 DTA SIA Primer assessment approach

4.4 Assessment results

The four assessments led to the following conclusions:

a) the LPS blocks met the client acceptance criteria in that the measured and predicted stresses were within acceptable values;
b) the LPS blocks were significantly heavier than "normal" construction;
c) the LPS blocks were significantly stiffer than "normal" construction;
d) in view of (b) and (c) and also the significantly conservative original calculations most of the LPS blocks in fact have a significant margin of safety as regards structural integrity.

5. CONCLUSIONS

This paper has briefly described the DTA, NAFEMS, and SAFESA projects, in particular the DTA SIA Primer and associated handbooks, which provide a modern best practice approach to SIA for a variety of structures.

6. BIBLIOGRAPHY

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APPENDIX 1 - LIST OF MAJOR UK ASSESSMENT APPROACHES (STANDARDS)

1. INSTITUTION OF STRUCTURAL ENGINEERS, Appraisal of Existing Structures, July 1980.
2. INSTITUTION OF STRUCTURAL ENGINEERS, Guide to Surveys and inspections of buildings and similar structures, November 1991.
3. DYNAMIC TESTING AGENCY, Structural Integrity Assessment Primer. Interim Publication dated 1 March 1993. Available from DTA Secretary, c/o College of Aeronautics, Cranfield University, Bedfordshire, MK43 OAL
4. BUILDING RESEARCH ESTABLISHMENT, Structural Appraisal of Existing Buildings for change of use, BRE Digest 366, October 1991.
5. BUILDING RESEARCH ESTABLISHMENT, Structural Appraisal of buildings with long-span roofs, BRE Digest 282, February 1994.
6. BUILDING RESEARCH ESTABLISHMENT, The structural adequacy and durability of large panel system dwellings, BRE Report BR107, 1987.
7. *Appraisal and repair of building structures,* Thomas Telford Ltd, 1992. Edited by R. Holland, B. E. Montgomery-Smith and J. F. A. Moore.
8. *The assessment of highway bridges and structures,* a series of publications by the Department of Transport. Key references are BD 21/93, BA 16/93, BD 44/90, BA 44/90 and BA 34/90.
9. INSTITUTION OF STRUCTURAL ENGINEERS, Appraisal of Sports Grounds, May 1991.
10. BRITISH STANDARD INSTITUTION, Guidance on methods for assessing the acceptability of flaws in fusion welding structures, BSI PD 6493:1991.
11. HMSO, Offshore Installations: Guidance on Design Construction, UK Dept. of Energy, 4th edition, 1990.

APPENDIX 2 - LIST OF PRINCIPAL PUBLICATIONS (AT DEC. 1994)

NAFEMS Details from:	Benchmark Magazine (quarterly), Major Reports, Summary Reports, Guidance Documents, Books, Conference Proceedings (5) NAFEMS Publications Limited, NEL Technology Park, East Kilbride, Glasgow, UK, Tel: +44 (0)3552 72639 - Fax: +44 (0)3552 72749
DTA Details from:	Primers (5), Handbook Volumes (9), Conference Proceedings (3) Dynamic Testing Agency, College of Aeronautics, Cranfield University, Cranfield, Bedford, MK43 0AL, UK Tel: +44 (0)234 751037 - Fax: +44 (0)234 750878
SAFESA Details from:	(draft) Quality Standard, Approach, Best Practice Manual, Examples NAFEMS Publications Limited

APPENDIX 3 - MEMBERSHIP PROFILE

NAFEMS	300 members in 27 different countries, 60% in UK, 20% elsewhere in Europe, 20% outside Europe, members mainly industrial companies and consultants (80%) but also academics (13%) and software vendors (7%)
DTA	40 members in 8 different countries, 80% in UK, 15% elsewhere in Europe, 5% outside Europe, members mainly industrial companies (85%) but also academics/individuals (15%)
SAFESA	5 members (all UK), 4 industrial, 1 academic