Enhancing Durability - Forensic Investigation of Deteriorating Structures

Jonathan G M WOOD
Director
Structural Studies & Design Ltd
Northbridge House,
Chiddingfold,
Surrey GU8 4UU UK
jonathan@ss-design.demon.co.uk

Jonathan Wood has specialised in investigating deterioration and collapses of structures since the 1960s. He has contributed to guidance on investigation, appraisal, remedial works and improved design and construction practice for bridges and heritage concrete. UK member of IABSE WG8 Forensic Engineering.

Summary

Forensic Engineering investigation of premature deterioration and, in extremes cases collapse, of concrete structures shows that the Eurocode theories for 'probability' of failure and 'design life' do not relate to reality for concrete. Design and construction need to be refocused on materials, detailing, site practice and quality control based on lessons from investigation of structures whose inadequate performance has led to premature replacement. These investigations can also provide the basis for predicting and extending the service life of our deteriorating concrete infrastructure.

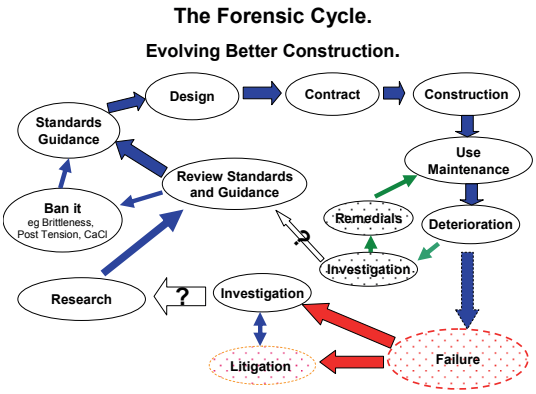
Keywords: Deterioration; collapse; appraisal; design; bridges; heritage; concrete; design life.

1. Introduction

Many C20th concrete structures of all types are decaying, leading to economic disruption and disproportionate costs for remedial works and replacement. National standards and Eurocodes are not fit of purpose for delivering sustainable concrete construction. It is time to radically review and calibrate them, now it is clear that the dominate failure mode is deterioration.

There is a growing body of literature on the forensic investigation of deteriorated concrete structures. IABSE Working Group 8, Forensic Engineering, aims to make detailed information on the performance of structures readily available, so it can be used to improve the construction and maintenance of our infrastructure.

The 'Forensic Cycle' shows how information from failures can improve design, construction and maintenance. This paper gives some UK examples of the application of this approach. Those responsible for standards and guidance for construction and the assessment of our deteriorating infrastructure need to adopt a similar approach.



One of the limitations of current theory is demonstrated by three examples of deteriorating concrete structures, Ynys-y-Gwas, Pipers Row Car Park and de la Concorde, which collapsed suddenly when not subjected to significant live load.

2. Heritage Bridge Structures

Tuckton Bridge 1905 and Montrose Bridge 1930 illustrate the outstanding quality of the best of historic concrete and their localised vulnerability to deterioration.

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3. Car Park Deterioration

Errors in design standards, in the design and in construction and progressive deterioration all contributed to the progressive collapse of Pipers Row MSCP in 1997. The collapse initiated new guidance on UK car park design, appraisal and management using information from investigation reports on 200 deteriorating car parks. Large data sets on developing problems, identified before failures occur, are essential for upgrading standards.

4. De la Concorde - Consequences of neglected maintenance

De la Concorde in 2006 and Pipers Row Car Park in 1997 both had:

- Sudden shear failures of innovative structures when only lightly loaded.
- Construction errors and deterioration which were not identified and made good in an earlier repair contract for which there was no structural appraisal.
- Significant errors in standards used for their shear design.

A lesson from the de la Concorde is the escalation in expenditure and disruption which follows from false economies from inadequate staffing, inspection, appraisal and maintenance of bridges.

5. Initiating Corrosion

The premature development of corrosion is the predominate cause of deterioration in concrete. The presumed linkage in codes between average exposure conditions, specified cover to reinforcement and concrete strength and design life is fundamentally flawed. Localised severe exposure and the realities of poor detailing and as built construction defects need consideration.

6. Alkali Aggregate Reaction (AAR)

Alkali Aggregate Reaction (AAR) became a significant problem in the UK in the 1980s, but there was no information on its effect on structural strength. Guidance on appraisal of AAR was developed based on test programmes and monitoring of over 100 UK structures and parallel international research programmes.

7. Dilemmas in Appraising Deteriorating Structures

Research is needed to determine the current strength and ductility of deteriorating parts of structures, how fast further strength deterioration will occur and how much loss of strength and ductility is acceptable.

8. Conclusions

The growing number of premature failures of concrete structures due to deterioration necessities a critical review of design and construction standards and practice. Current code provisions and site practice have been inadequate to achieve good performance and must be radically revised.

Improvements to current practice and modelling of the deterioration of materials and strength should be based on the detailed investigation of the performance, good and bad, of the range of mature concrete structures.

Significantly improved UK guidance on car park design and on the appraisal of structures with AAR damage are UK examples of applying the Forensic Cycle approach.

The excellent performance of some historic structures demonstrates that the best concrete construction can produce durable and maintainable structures. The extra cost is small.