Computational Modelling of ASR/DEF Affected Concrete Bridge Columns

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Summary

The research discussed in this paper included both experimental and computational of ASR/DEF effects on bridge columns. For the experimental research, scaled models of a column were constructed and fractured using stone-splitting wedges. This method was intended to create the worst-case scenario: ASR/DEF cracks propagating through the core of the columns and effectively cleaving each column into four pieces. The finite-element software ATENA was used for the computational modelling and parametric studies. The program excels in modelling the geometry, widths, and propagation of cracks. The computer model was correlated to the experimental results and then used to predict capacities for a variety of deterioration levels. This paper focuses on the computational portion of the research.

Keywords: Alkali-Silica Reaction, Delayed Ettringite Formation, Modelling.

1. Introduction

Durability and repair of major reinforced concrete infrastructure, such as the U.S. Interstate Highway System, are receiving greater emphasis as the age of these structures becomes a critical issue. A research program performed at the University of Texas at Austin addressed the evaluation and remediation options for concrete bridge columns suffering from material degradation. Alkali silica reaction (ASR) and delayed ettringite formation (DEF), both producing concrete expansion, were the causes of concrete degradation considered by this investigation. Although the research evaluated the effects of ASR/DEF on the structural capacity of bridge columns located in San Antonio, Texas (USA), the information learned can be useful throughout the world, as material attack is a global issue.

In San Antonio, Texas an elevated interstate highway was constructed in the mid-1980s. The substructure design featured large single columns supporting the various spines of the wide highway as shown in Figure 1. The massive concrete pours during construction, along with the materials selected at the time, resulted in high fresh-concrete temperatures. As an added complication, the aggregate selected is reactive, although it was not detected by the material tests available at the time of construction. As a result of materials and curing condition, the stage was set for the occurrence of ASR and DEF. The Texas Department of Transportation engaged researchers from the University of Texas at Austin to investigate the cause of the cracking in 2003, when cracking in the substructure became large enough to raise concerns. From petrographic analysis it was discovered that some columns suffered primarily from ASR and others primarily from DEF [2]. Due to the high potential expansions found in laboratory testing, concern was raised as to the reduction of structural capacity of the affected columns. Thus, a structural analysis was undertaken to investigate the lower-bound capacity of the affected columns.

Figure 1: Columns Supporting Elevated Highway [1]

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2. Computational Model

2.1 Background on ATENA

ATENA is a finite-element program developed by Cervenka Consulting to model close approximations to the real behaviour of concrete and reinforced-concrete elements. The software is capable of modelling the non-linear behaviour of concrete using 3D solid elements and of steel reinforcement using non-linear 1D elements. The crack initiation and propagation feature was the prevailing reason for the selection of this program by the project researchers. A research goal was to develop a relationship between structural strength and the premature cracking of the concrete due to ASR and DEF. To that effect, a key computational feature was the ability to model the various levels of pre-existing cracks and then study the propagation of cracking and associated capacities.

2.2 Parametric Studies

Once correlated to the laboratory tests, the model was run for a variety of large pre-cracking widths. By varying the initial crack size, a parametric study of crack width to column capacity is underway. This study was desired to extrapolate the laboratory work to predict the critical crack size for the column, whereupon it would no longer be capable of supporting design loads. As the computational model followed the experimental assumption of through section cracking induced by ASR/DEF, the model predicts a lower-bound capacity.

3. Results of Computational Model

The results of the computational model and parametric study are summarized in the full paper. There is a great deal of reserved capacity for these particular columns, which have as-built concrete strength that is much higher than their design strength. Thus, cracks from deterioration would have to be very wide before the column capacities are reduced to the design load.

4. Conclusions and Acknowledgements

4.1 Conclusions

For the analysis of deteriorated concrete, ATENA proved very useful. The numerical model correlated with experimental results was able to predict capacities for columns with even greater deterioration than has been observed. As such, ATENA is a valuable addition to the structural engineering toolbox through the use of pre-cracking load step to model a deteriorated condition.

Although the researchers used ATENA to generate through section cracks, other users could model shallower cracks by adjusting the depth of the pre-cracking loads. In addition, future researchers could run additional material-property tests in order to refine the base concrete model, which ought to correlate the computer model to the actual structure.

The innovation of a pre-cracking load step in analysis provides a pathway for the future modelling of deteriorated concrete structures. The ability to model deteriorated concrete will come into ever greater demand as infrastructures continue to age and owners desire to implement efficient repair and replacement schedules.

4.2 Acknowledgements

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5. References

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