UNIVERSITY OF SYDNEY

ANALYSIS OF BURIED FLEXIBLE PIPES IN GRANULAR BACKFILL SUBJECTED TO CONSTRUCTION TRAFFIC

By Don A. Cameron

B. Eng, M. Eng (Civil Engineering)

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SUMMARY

This thesis explores the design of flexible pipes, buried in shallow trenches with dry sand backfill. The thesis reports the comprehensive analysis of twenty-two full-scale load tests conducted between 1989 and 1991 on pipe installations, mainly within a laboratory facility, at the University of South Australia. The pipes were highly flexible, spirally-wound, uPVC pipes, ranging in diameter from 300 to 450 mm. Guidelines were required by industry for safe cover heights for these pipes when subjected to construction traffic. The tests were designed by, and conducted under the supervision of, the author, prior to the author undertaking this thesis.

As current design approaches for pipes could not anticipate the large loading settlements and hence, soil plasticity, experienced in these tests, finite element analyses were attempted. Extensive investigations of the materials in the installations were undertaken to permit finite element modelling of the buried pipe installations. In particular, a series of large strain triaxial tests were conducted on the sand backfill in the buried pipe installations, to provide an understanding of the sand behaviour in terms of critical state theory. Subsequently a constitutive model for the soil was developed.

The soil model was validated before implementation in an element of finite element program, AFENA (Carter and Balaam, 1995). Single element modelling of the triaxial tests proved invaluable in obtaining material constants for the soil model. The new element was applied successfully to the analysis of a side-constrained, plate loading test on the sand. The simulation of the buried pipe tests was shown to require three-dimensional finite element analysis to approach the observed pipe-soil behaviour. Non-compliant side boundary conditions were ultimately adjudged chiefly responsible for the difficulty in matching the experimental data. The value of numerical analyses performed in tandem with physical testing was apparent, albeit in hindsight.

The research has identified the prediction of vertical soil pressure above the pipe due to external loading as being the major difficulty for designers. Based on the finite element analyses of the field tests, a preliminary simple expression was developed

for estimation of these pressures, which could be used with currently available design approaches to reasonably predict pipe deflections.

PREFACE

I hereby certify that this thesis contains no material for the award of any other degree or diploma and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by any other person, except where due reference has been made in the text.

Much use has been made of finite element analysis in this thesis. While the author has proposed improvements, these proposals have been refined and implemented by the owners of the finite element analysis suite.

D. A. Cameron,
20th February 2005

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At the University of South Australia, I have received good support from colleagues and technical staff over the period of my candidature. Their patience and understanding have been appreciated. The difficulty of part-time and external candidature for a research undertaking of this size can only be experienced first hand.

Finally to my family and close associates, thank you for your patience and belief, despite perhaps not always understanding what was involved in a thesis of this type, or why it needed to be done.