STRUCTURAL MODELING TECHNIQUES FOR CONCRETE SLAB AND GIRDER BRIDGES

By

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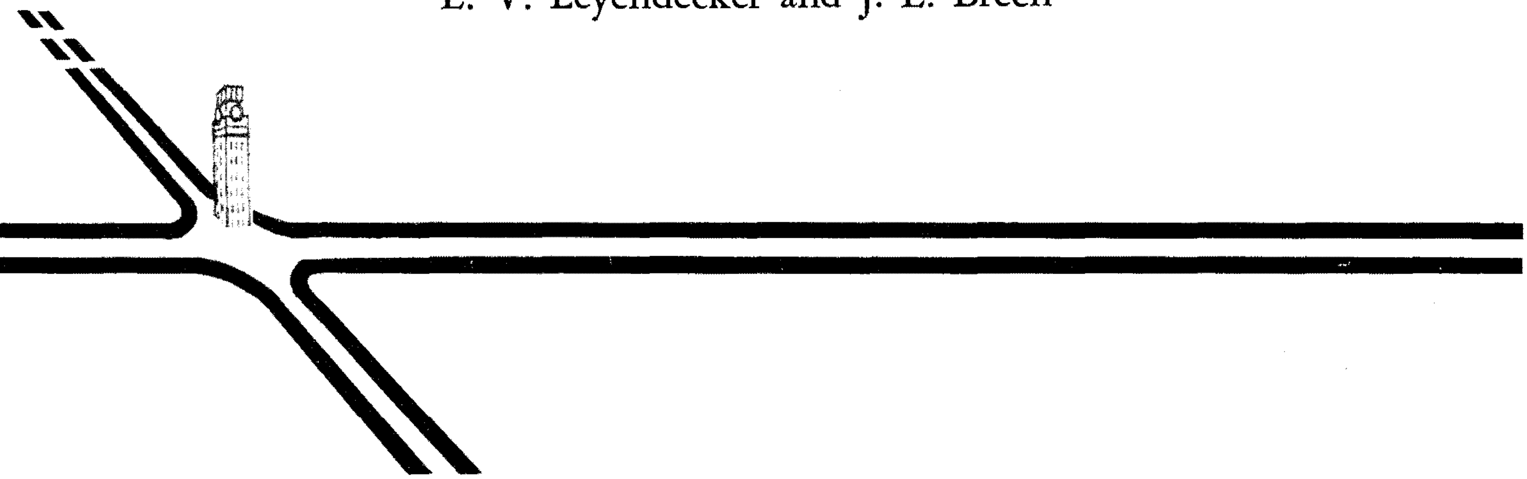

SUMMARY REPORT 94-1 (S)

SUMMARY OF
RESEARCH REPORT 94-1

PROJECT 3-5-66-94

COOPERATIVE HIGHWAY RESEARCH PROGRAM
WITH TEXAS HIGHWAY DEPARTMENT
AND
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SUMMARY REPORT 94-1 (S)

Introduction

Report 94-1 is the first in a series which will summarize a detailed investigation of the behavior of pan-formed concrete slab and girder bridge systems which are widely used by the Texas Highway Department. The report treats the detailed techniques developed for the utilization of reduced scale models in the study and also reports on the degree of correlation between the model tests and full scale prototype testing. Subsequent reports will treat the techniques employed and results obtained in the field testing and the general behavior and recommendations based thereon from the main model test series.

Detailed procedures for fabricating, instrumenting, and loading approximately 1/6-scale reinforced microconcrete "direct models" of a typical pan-formed concrete slab and girder bridge system are presented. The methods rely on achievement of a high degree of material similarity between prototype and model to permit observation of realistic behavior at service load, moderate overload, and ultimate load levels.

The report describes techniques utilized in a reasonably successful study and provides comparisons between model and prototype behavior. The techniques used resulted in models in which the observed load distribution exhibited a high degree of correlation with the prototype field test observations. In addition, the ultimate loads of reduced (statically determinate) sections were in close agreement with accepted ultimate strength theory. Use of similar "direct model" techniques in future investigations is recommended.

Direct Model Technology

The basic goal in the direct modeling process is to obtain a realistic approximation of the behavior of the prototype over a complete spectrum of loads from dead load through service loads until collapse loads. The report outlines the steps taken in order to accomplish this.

(a) The models reflect the "as built" characteristics of the prototype and not the idealizations of an analytical mathematical model.

(b) Materials used must meet similitude requirements so that stress and strain scale factors (S_f, S_ℓ) are equal to unity. This was accomplished by developing realistic microconcretes with stress-strain curves equal to those of the prototype concrete (see Fig. 1).

(c) Fabrication techniques closely approximated details such as spacing, connections, and tolerances.

(d) Boundary conditions matched field conditions and not analytic idealization.

(e) Instrumentation used was sensitive to the range of structural response anticipated.

(f) Loading systems represented prototype loadings and performed accurately over the wide range of loading from service to ultimate load levels.

(g) The entire testing system was continuously checked and verified. Preliminary tests were run with simplified boundary conditions to assess the potential accuracy of the model since techniques inadequate for statically determinate conditions are unwarranted for more complex conditions.

Scale Factor

Detailed studies were made of both fabrication and loading system costs for a number of scale factors. The costs of reusable items such as forms and loading frames were amortized over five models. The results of these studies are shown in Fig. 2. The total combined cost of fabrication and loading indicates a minimum cost at about 1/8 scale. There is very little difference in costs in the range of 1/5 to 1/10 scales when compared to the cost of full-size testing (15 to 17% of prototype). In this study the main reinforcing steel in the prototype was a No. 11 bar; the availability of deformed No. 2 bars was a major consideration in the selection of the scale as $1/S_\epsilon = 2/11 = 1/5.5$.

Reliability

The main objective in the utilization of the direct structural model in this study was to establish the behavioral characteristics of the prototype structure over a wide range of loadings. In order to validate

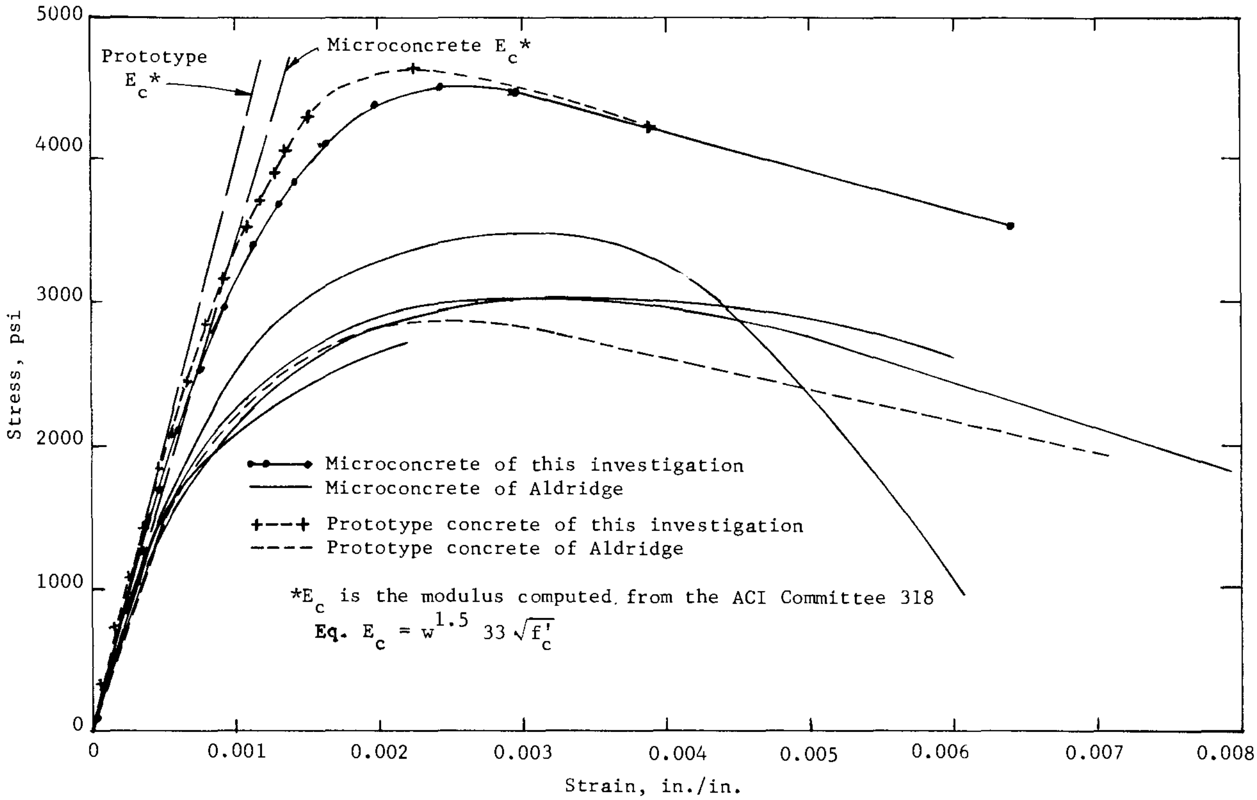

Fig. 1. Stress-Strain Curves for Microconcrete and Prototype Concrete.

this technique for this type of structure, several studies were run to illustrate the credibility and reliability of the techniques utilized.

To assess the general relationship between response characteristics of the model and prototype at service loads levels, a prototype skew span bridge being erected on a Central Texas highway was instrumented and load-tested at service load levels. A corresponding model was constructed and loaded in the same fashion in the laboratory. A typical comparison of the results is presented in Fig. 3 and indicates good agreement between model and prototype.

Since an ultimate load test of the prototype was not feasible, the accuracy of the model technique at ultimate load levels was established by testing two statically determinate models of a reduced section of the bridge and then comparing the test results to accepted ultimate strength theory. Test results indicated excellent agreement.

Conclusions

The overall research project is a study of the behavior of pan-formed concrete slab and girder bridges. The technology used to fabricate, test, and interpret results of the primary research tool used, the direct structural model, has been covered in detail.

Although the objectives of this report were limited in scope, and the investigation was restricted to a

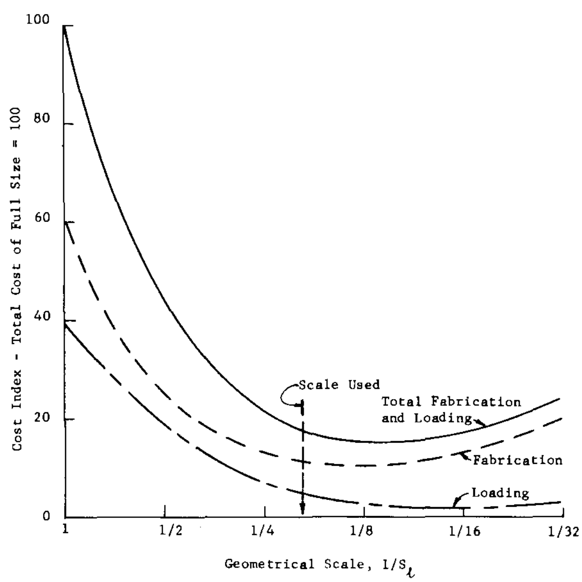

Fig. 2. Estimated Cost Variance with Scale of a Reinforced Concrete Bridge Model.

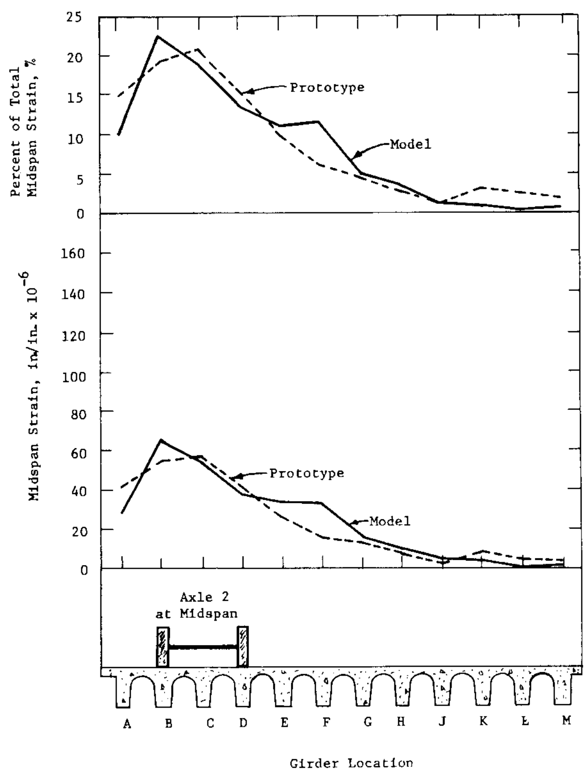

Fig. 3. Strain Data for One Truck on Exterior Girders.

particular bridge system, the following conclusions are warranted:

(1) Fabrication, loading, and instrumentation techniques were developed to realistically model standard Texas Highway Department pan-formed slab and girder bridge spans.

(2) Models of this type may be used to reliably measure load distribution (as indicated by girder longitudinal strain) at service load conditions. This conclusion is based on the comparison of model and prototype midspan strain distributions similar to Fig. 3. The patterns of strain distribution are of similar shape with similar magnitudes of strain. The midspan load distributions based on percent of total midspan strain indicate better agreement than the absolute strain values.

(3) The model sections loaded under statically determinate conditions displayed excellent correlation with predicted ultimate strengths and mode of failure. The ratios of observed to calculated ultimate strength were 0.998 and 0.985. Their modes of failure were flexural, with initial yielding of steel and secondary compression of the concrete. This is the general mode of failure of all specimens in the main investigative series.

Recommendations

Studies indicated that microconcrete is superior to concrete substitutes such as gypsum for use in a structural model of a reinforced concrete structure. Although no comparisons of materials were documented in this report, this conclusion was reached in the early study phase based on literature surveys and discussions. The microconcrete model has been shown to give reliable results at both ultimate load and service load levels. While many of the concrete substitutes give good results at service loads, they generally give less reliable results at ultimate load. This is probably due to the lack of adequate matching of basic failure criteria for concrete. It seems reasonable to assume that if the failure mode of a structure is not known, then it should be modeled with a material with as similar material properties as possible.

Although some concrete substitutes have been recommended because their use may result in faster test times, experience with this program indicates that time required for instrumentation and loading preparations is quite compatible with curing times using Type III cements.

The full text of Research Report 94-1 can be obtained from R. L. Lewis, Chairman, Research and Development Committee, Texas Highway Department, File D-8 Research, 11th and Brazos Streets, Austin, Texas 78701 (512/475-2971).