SCHOOL OF CIVIL ENGINEERING

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STUDY OF THE SEGMENTAL BOX GIRDER BRIDGE AT TURKEY RUN: SUMMARY REPORT

David W. Floyd
C. D. Sutton

FINAL REPORT

PURDUE UNIVERSITY
INDIANA STATE HIGHWAY COMMISSION

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FINAL REPORT

STUDY OF THE SEGMENTAL BOX GIRDER

BRIDGE AT TURKEY RUN: Summary Report

TO: H. L. Michael, Director October 26, 1982
Joint Highway Research Project Revised: September 26, 1984
Revised: June 1985
File: 7-4-20

FROM: C. D. Sutton, Research Engineer Project: C-36-56T
Joint Highway Research Project

Attached is the Final Report as revised by the principal investigator with completion in September 1984 on the HPR Part II research project titled "Study of the Segmental Box Girder Bridge at Turkey Run". The report was originally drafted by David W. Floyd and revised by Professor Sutton to correct errors found in review of the data reduction procedure.

Major findings of the study important to design of bridges of the studied type were 1) for transverse bending measured responses were significantly less than predicted by an accepted finite element computer program; 2) the temperature gradient in the bridge elements was found to be larger than that for which designed; and 3) long-term deformation was found to be typically small. The report documents these findings.

This report completes all activity on this project.

Sincerely,

C. D. Sutton

C. D. Sutton
Research Engineer

CDS/tb

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FINAL REPORT

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BRIDGE AT TURKEY RUN: Summary Report

By

David W. Floyd
Graduate Instructor in Research

and

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Research Engineer

Joint Highway Research Project

Project No.: C-36-56T

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Prepared as Part of an Investigation

Conducted by

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Engineering Experiment Station
Purdue University

In cooperation with the

Indiana State Highway Commission

and the

U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Purdue University
West Lafayette, Indiana
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HIGHLIGHT SUMMARY

The results of a field study of the precast prestressed segmental box girder bridge at Turkey Run, Indiana are presented in summary form. Experimental data have been collected using an ad-hoc instrumentation system in order to determine certain features of the behavior and performance of the bridge. The study is specifically concerned with transverse bending, bridge temperatures and associated effects, and long term deformations.

Details of a comprehensive load test to determine transverse bending responses are reported, as are the results of these tests.

The results of all phases of the research are discussed and summarized. The principal findings and conclusions drawn from the project are given.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Since precast segmentally-constructed box girder bridges were first introduced on this continent in the early part of the last decade, this type of structural system has become the one of choice for numerous medium and long span applications. This can be attributed to the key characteristics of segmental bridges: relative ease and economy of construction, and excellent esthetic properties. A fairly recent tabulation of North American concrete segmental box girder bridges which have been or are being constructed, designed, or studied has been supplied by the Portland Cement Association (1). Other significant projects, initiated since this list was prepared, are at various stages of completion. The growing appeal of this type of construction is, thus, clearly demonstrated.

This research project evolved out of a perceived need for verification of those criteria which were borrowed and/or adopted from European sources and used as the basis for design of the first American segmental box-girder bridges. The stated objectives of this research, cited in detail later in this chapter, are concerned with some of the specific questions which had been raised regarding the behavior and performance of segmental bridges. Research projects conducted by The Pennsylvania Transportation Institute of Pennsylvania State University

(2,3,4,5,6,7,8), the University of Illinois (9,10), and the Construction Technology Laboratories of the Portland Cement Association (11,12), among others, were developed to meet this same general need.

During 1976 and 1977 a research project entitled "Instrumentation of the Turkey Run Segmental Bridge" was conducted under the auspices of the Joint Highway Research Project of Purdue University and the Indiana Department of Highways. The result of this project, as reported by Holman (13), was the initial design of an instrumentation system to be used on the Turkey Run Bridge. This bridge, located on State Road 47 near the entrance to Turkey Run State Park in Parke County, Indiana, carries two lanes of traffic over Turkey Run Creek (see Figures 1.1 through 1.4). It has two equal continuous spans of 158'-6" and was erected by the now familiar cantilever method. Its cross-section is made up of twin boxes which are connected by a short cast-in-place segment.

The above-cited development project served as the basis for the one which is the subject of this final report. In March of 1977, a proposal was submitted which contained a plan for continuation of the work begun by Holman. The tasks to be accomplished under this project were: completion of the design and installation of the instrumentation, field and laboratory data collection, analysis of these data, and identification of significant findings which have implications for future designs of bridges of this type.

An interim report on this project entitled "Study of the Segmental Box Girder Bridge at Turkey Run: Construction, Instrumentation, and Data Collection", by Wanders, Winslow, and Sutton (14), was submitted in December 1979. This report contains a comprehensive review of the relevant literature, an account of the construction of the bridge, and a detailed description of the instrumentation system and its implementation. Data collection methods for each of the investigative topics were presented, as were those data which had been collected, reduced, and analyzed during the initial phase of the project. Inasmuch as the interim report is complete and self-contained in its own right, only those restatements of material contained therein required for clarity and completeness will be made in this final report.

1.2 OBJECTIVES AND SCOPE

The objective of this study is to collect and document information regarding certain aspects of the actual short-term and long-term behavior of a prototype precast segmentally-constructed box girder bridge, both during construction and under prescribed service conditions. This information will provide a basis for checking certain aspects of current design methodology and for establishing parameters and/or procedures for future designs.

The detailed objectives of the research are as follows:

1. To complete the development and installation of a suitable instrumentation scheme for the segmental bridge at

Turkey Run.

2. To determine through experimental measurements and analysis the transverse bending behavior of representative cross- sections due to prescribed truck loadings.
3. To determine through experimental measurements the daily and seasonal variations in thermal gradients (top and bottom slab temperatures) at representative locations in the bridge.
4. To measure tip deflections simultaneously with thermal gradients during certain stages of the construction process.
5. To measure over a three year period long-term deformations (primarily due to creep) at key locations of the structure.
6. To compare the results obtained from the experimental analysis to the response predicted by currently recommended analytical methodology and design procedures.
7. To evaluate present design methodology and parameters in light of the experimental evidence, and to either verify existing criteria or suggest changes in the following areas:
 - a. Analysis methodology for transverse bending.

- b. Thermal gradients applicable to various stages of construction and service life.
- c. Long-term deformations due to creep and prestress losses.

In order to accomplish these objectives an instrumentation scheme was developed and installed, and a plan for collection of relevant data was implemented. The interim report, entitled "Study of the Segmental Box Girder Bridge at Turkey Run: Construction, Instrumentation, and Data Collection", by Wanders, Winslow, and Sutton (14), contains discussion on the construction of the bridge, a complete description of the instrumentation system, data and analysis pertaining to initial efforts on the transverse bending response study (including results of the preliminary test), and detailed information on the thermal response and long-term deformation studies.

This final report on the project contains summary presentations of the findings in each of the areas stated in the project objectives, including those results which have been obtained since submission of the interim report. The report on the comprehensive tests conducted to study transverse bending response is also given.

Figure 1.1. State Road 47, Parke County, Indiana.

Figure 1.2. Two Span Box Girder.

Figure 1.3. Twin Box Cross-Section.

Figure 1.4. Twin Box Cross-Section.

CHAPTER II

TRANSVERSE BENDING

2.1 GENERAL

Rational design of cross section proportions and transverse reinforcement for box girders involves the use of analytical methods for prediction of stress resultants. The principal thrust of the work on this (transverse bending) part of the project was to collect field data on transverse bending response for comparison to predictions obtained from typical theoretical models.

This chapter is concerned with the experimental study of transverse bending response of the bridge to controlled (static) truck loadings. A summary description of the field testing program is presented, including details of data collection and data reduction procedures. The results - bending stress resultants inferred from the measured strains - are tabulated to facilitate comparison with analytical predictions.

Principal features of the general field testing scheme used for determining transverse behavior of the bridge superstructure were initially developed and reported by Holman (13); subsequent modifications and implementation are discussed by Wanders, Winslow, and Sutton (14) in the interim report on this project.

Key physical properties of the concrete and steel, which were required for the data analysis, were established prior to

conducting the field tests by means of a series of control specimen tests. The results of these were reported in detail in the interim report (14).

2.2 FIELD TESTING SCHEME

A tandem-axle truck, supplied by the Indiana State Highway Commission, was used to produce the truck loadings for the transverse bending tests (see Figure 2.1).

The axle spacings and load proportions for the nominal truck loading originally prescribed for these tests, schematically shown in Figure 2.2, are consistent with those of this truck. Actual loadings used for the tests differed from the nominal loading only in gross weight; relative axle load ratios were preserved for all tests. Gross vehicle weights somewhat larger than the indicated nominal value were used because of the low levels of strain response anticipated.

All analytical solutions were obtained for the nominal truck loading shown in Figure 2.2. Since the structural responses were entirely in the linear-elastic range, the experimental data were scaled by the ratio of the nominal gross weight to the actual (test) gross weight for purposes of comparison with the analytical results.

The pattern of longitudinal and transverse truck positions specified for the tests is shown schematically in Figure 2.3. There were four (instrumented) longitudinal test sections, two

per span, and eight transverse truck positions per longitudinal section. This loading arrangement is identical to the one used for the finite element analysis, with the exception of transverse truck positions 1 and 8. For these two truck positions it was physically impossible to produce the loading used in the finite element solution. The concentrated loads used in the analytical solutions for these two positions were located at the extreme outer edge of the top slab cantilever and over the outside web, i.e. at the nodal load locations of the finite element mesh. Thus, it was not possible to make direct comparisons between test results and analytical solutions for transverse truck positions 1 and 8.

Figures 2.4 through 2.7 show the eight typical transverse positions of the test truck on the bridge deck. Permanent markings locating these positions have been painted on the bridge deck (see Figures 2.8 and 2.9); these markings were utilized in locating the center of the test truck rear axles (see Figure 2.10).

2.3 PRELIMINARY TEST

A preliminary transverse bending test was conducted during the summer of 1979. The purpose of the test was to check out the instrumentation and test procedures, and to obtain preliminary data.

During the test, a truck like the one shown in Figure 2.1 was sequentially placed in all eight transverse positions of

longitudinal position 1 and 2. The tandem axle test truck had a gross weight of 47,900 pounds and a front axle to rear axle load ratio of 0.401.

Strains were measured in the top slab and both webs of segments 24A and 3A (see Figure 2.16 through 2.20). Readings were taken in Segment 24A only when the truck was in longitudinal position 1 and in segment 3A only when the truck was in longitudinal position 2. A digital strain indicator was utilized in measuring the strain levels from the 20 gages that were monitored. Switching was done manually.

Strain readings were taken for the 16 distinct loading cases. Several times during the testing process readings were taken with no load on the structure to provide a basis for correcting the strain data for temperature effects and instrument drift. Several of the truck loading cases which produced the higher strain levels were repeated to provide a check on the first set of readings. The loading arrangements used and gages monitored for this test provided data for most of the regions where relatively high bending tractions (moments) were anticipated.

Evaluation of the results of this test led to the conclusion that the instrumentation was functioning properly and that test procedures used were satisfactory. Moreover, it is believed that the experimentally determined tractions are reasonably reliable. For a complete description of this preliminary testing and the

results obtained therefrom the reader is referred to the interim report (2).

2.4 COMPREHENSIVE TEST

A comprehensive transverse bending test was conducted during the month of August, 1981. The purpose of this test was to determine strain responses for the prescribed truck loadings at key locations in the bridge. The reduced strain data were used to compute bending moment tractions corresponding to the strain response at key locations. In turn, these bending moment tractions were compared with the analytical bending moment values determined by means of the finite element computer program developed by Batla (15) and discussed by Holman (13) and Wanders, Winslow, and Sutton (14).

The loaded tandem axle truck utilized for the test had a gross weight of 52,590 pounds; the ratio of front axle load to rear axle load ratio was .399. This truck was provided by Veedersburg Substation of the Indiana State Highway Maintenance Division. Each axle was weighed independently on a commercial truck scale by test crew personnel (see Figure 2.11).

In conducting the test, the test truck was sequentially placed in all eight transverse positions of longitudinal positions 1 and 2, and the strains in longitudinal sections 1 and 2 were recorded. Next, the truck was placed in all eight transverse positions of longitudinal positions 3 and 4, and strains for longitudinal sections 3 and 4 were measured. As

mentioned above, it was physically impossible to place the wheel loads in the nominal locations for transverse positions 1 and 8. However, readings were taken with the truck located as close to the curb as possible. Figures 2.12 through 2.15 show the test truck in various positions during testing.

Strains in the top and bottom slabs and both webs of bridge segments 24A and 25B (see Figure 2.3) of longitudinal section 1, i.e. Section A, and in segments 24B and 25A of longitudinal section 4, i.e. Section D, (see Figures 2.16 through 2.20) were measured and recorded. Readings were taken for segments 24A and 25B of longitudinal section 1 only when the truck load was applied at longitudinal positions 1 and 2. Readings were taken in segments 24B and 25A of longitudinal section 4 only when the truck load was applied at longitudinal positions 3 and 4. Similarly, strains in the top slab and both webs of bridge segments 2B and 3A of longitudinal section 2, i.e. Section B, and segments 2A and 3B of longitudinal section 3, i.e. section C were recorded. Readings were taken in segments 2B and 3A of longitudinal section 2 only when the truck was placed in longitudinal positions 1 and 2. Readings for segments 2A and 3B of longitudinal section 3 were taken only when the test truck was placed in longitudinal positions 3 and 4.

For each of the load cases it was necessary to record data from forty-eight strain gages. Readings were acquired from forty of the gages by means of a Vishay System 220 (V/E 20A Digital Strain Indicator and four V/E 21 Switch-and-Balance Units);

switching was done manually. Strain data were obtained from the remaining eight gages by means of a Vishay Model 350A Portable Strain Indicator complemented by a Vishay Model SB-1K Switch-and-Balance Unit; this system, too, required manual switching. The system is shown in Figures 2.21 through 2.23. Original plans to use a 100-channel data acquisition system for collection of strain data were discarded when it was found that this system was not sufficiently reliable for the very low signal levels encountered in these tests. Use of the systems cited above resulted in overall improvement in the accuracy and reliability of the data collected.

Strain readings were taken for 32 distinct load cases. At thirty minute intervals during the course of the testing, strain readings were taken with no load on the structure so that the strain data could be corrected during the data reduction process for temperature effects and instrument drift.

As was stated in the interim report (14), it was impossible to detect measurable strains in sections far removed from the loading. Thus, the loading arrangements and sites for strain measurement indicated above were selected in order to provide data for those sites where relatively meaningful transverse bending tractions were expected.

2.5 DATA REDUCTION AND RESULTS

Before the transverse bending test was begun, each strain channel was calibrated to the proper span (gage current) and

balanced to indicate zero output for the no-load condition. The span settings were established at values which accounted for both the gage factors (provided by the gage manufacturer) and desensitization due to the relatively long lengths of the lead wires. Calibration of the data acquisition system in this manner made it possible to read strain responses directly from the digital strain indicators.

The strain readings recorded during the test were corrected for instrument drift and thermal strains. Corrected strain values were obtained by deducting those strains not due to the truck loadings, as established from the no load readings mentioned previously. In addition, transverse sensitivity effects were taken into account where applicable. Thus, the final strain values obtained nominally reflected only effects produced by the applied truck loadings.

The strain values for each instrumented cross-section were plotted to scale in order to check strain linearity with depth. At longitudinal sections 1 and 4 the distributions indicated by the measured strains, with few exceptions, were essentially linear. Less satisfactory overall results were observed at longitudinal sections 2 and 3; however, the significantly less accurate Vishay Model 350A Portable Strain Indicator was used to measure the concrete surface strains at these sections.

Transverse bending tractions indicated by the above-described strain data were calculated for each instrumented

transverse cross section (Moment Station) for each loading condition. In carrying out the bending traction analysis, cross-sections were assumed uncracked. Using the measured strains in the inside and outside layers of steel reinforcement together with the actual dimensions and section properties, the neutral axis was located from strain geometry and surface strains in the concrete were computed. The forces in the steel and concrete were then calculated using the stress-strain relationships and cross-section areas of the materials previously determined from the control-specimen tests. The total axial force in each section was determined as the sum of the individual forces. Bending moments were obtained by summing the moments of the internal forces about the centroid of the cross section.

The resulting transverse bending tractions were scaled by a factor 0.798 to permit direct comparison between experimental tractions and those determined previously by means of the finite element computer code. This scaling factor is simply the ratio of nominal truck loading, used in obtaining the finite element solution, to the applied truck loading. The transverse bending tractions thus inferred from the comprehensive bending test are presented in Tables 2.1 through 2.8. An abridged listing of finite element analysis moment tractions - those used in comparison to the experimental results - is given in Tables 2.9 through 2.16. A comprehensive listing of the moments obtained from the finite element analysis is presented in Appendix A of this report.

Table 2.1. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS
(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	329	-436	---	-145	38	7	-236	312
	2	988	-654	---	-508	-404	22	-180	182
	3	1271	-654	---	-581	111	29	-151	276
	4	166	218	---	-73	148	36	-93	509
	5	52	436	---	0	184	44	-90	160
	6	11	218	---	0	1247	-458	-61	-908
	7	-34	145	---	-73	1027	-516	24	-821
	8	-74	145	---	0	366	-291	27	-509

TRUCK LONGITUDINAL POSITION NO. 1

READING LONGITUDINAL POSITION NO. 1

Table 2.2. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	151	0		130	146	123		31
	2	151	0		268	180	-61		-15
	3	186	0		100	97	-8		8
	4	151	0		230	169	192		38
	5	187	0		138	127	222		-8
	6	152	0		115	-518	54		-61
	7	73	0		23	-19	-46		-184
	8	-1	0		-77	111	77		-153

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 2

Table 2.3. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-37	0	---	0	74	-73	0	0
	2	-73	0	---	0	-72	0	0	0
	3	36	0	---	0	-36	-73	0	0
	4	73	0	---	0	0	-73	27	-73
	5	36	0	---	0	-36	-73	0	0
	6	0	0	---	0	-73	-73	27	0
	7	-37	0	---	0	-37	-73	27	0
	8	-37	0	---	0	37	-145	27	0

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 1

Table 2.4. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

TRANSVERSE POSITION	STATION							
	1	2	3	4	5	6	7	8
	1	187	---		77	112	77	-230
	2	970	---		-230	112	153	-77
	3	1080	---		-230	112	77	0
	4	74	---		0	37	230	230
	5	111	---		0	75	153	77
	6	37	---		77	745	-230	-460
	7	74	---		0	634	77	0
	8	0	---		0	149	77	-77

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 2

Table 2.5. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	187	---		0	0	0		77
	2	709	---		-307	-37	0		77
	3	820	---		-230	37	77		153
	4	74	---		-77	-37	230		383
	5	0	---		230	-74	-77		460
	6	-37	---		-77	782	77		-153
	7	36	---		-77	891	-77		-230
	8	36	---		-77	297	-230		0

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 3

Table 2.6. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-37	0	0	0	0	73	53	73
	2	-37	0	27	0	0	0	53	73
	3	0	0	0	0	0	0	53	0
	4	0	73	0	0	0	0	0	0
	5	36	73	0	0	0	0	27	73
	6	74	73	27	0	0	73	27	73
	7	218	145	27	0	145	0	27	73
	8	146	145	27	0	36	0	27	73

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 4

Table 2.7. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

	STATION							
	1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-74	---		0	37	0	77
	2	-37	---		0	74	77	0
	3	-37	---		77	37	77	77
	4	0	---		77	37	77	0
	5	0	---		77	75	77	77
	6	0	---		0	0	0	0
	7	0	---		0	75	0	0
	8	38	---		0	0	77	230

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 3

Table 2.8. Comprehensive Test Results

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	366	-581	0	73	0	145	27	291
	2	880	-654	53	-363	0	73	27	291
	3	988	-799	80	-436	37	145	27	291
	4	110	145	0	-73	0	145	-27	436
	5	37	581	-27	0	74	218	-53	145
	6	0	363	-27	0	734	-436	27	-436
	7	-37	363	-27	-73	807	-436	27	-436
	8	37	436	-27	-73	330	-291	80	-291

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 4

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 134	-193	-42	+1398	- 70	+ 51	-17	+366
	2	+2202	-950	+57	- 615	- 72	+ 47	-17	+372
	3	+2220	-989	+61	- 682	- 80	+ 56	-19	+419
	4	- 15	+253	- 7	- 21	- 102	+ 72	-29	+717
	5	- 21	+717	-29	+ 73	- 15	- 21	- 7	+253
	6	- 80	+419	-19	+ 56	+2220	- 682	+61	-989
	7	- 72	+372	-17	+ 47	+2202	- 615	+57	-950
	8	- 70	+366	-17	+ 51	- 134	+1398	-42	-193

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 1

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-4	- 3	+5	-5	-8	+4	-3	+20
	2	-3	- 9	+7	-4	-8	+5	-4	+20
	3	-1	-14	+6	-5	-8	+6	-4	+18
	4	-3	- 9	+4	-2	-6	+4	-1	+ 7
	5	-6	+ 7	-1	+4	-3	-2	+4	- 9
	6	-8	+18	-4	+6	-1	-5	+6	-14
	7	-8	+20	-4	+5	-3	-4	+7	- 9
	8	-8	+20	-3	+4	-4	-5	+5	- 3

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 2

Table 2.11. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS
(ft-lbs/ft)

+TENSION ON INSIDE
-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	+1	- 5	0	-1	-2	+1	0	+ 9
	2	+2	- 8	0	-1	-2	+1	0	+ 9
	3	+2	-10	0	-2	-2	+1	0	+ 8
	4	+1	- 7	0	0	0	0	0	+ 2
	5	0	+ 2	0	0	+1	0	0	- 7
	6	-2	+ 8	0	+1	+2	-2	0	-10
	7	-2	+ 9	0	+1	+2	-1	0	- 8
	8	-2	+ 9	0	+1	+1	-1	0	- 5

TRUCK LONGITUDINAL POSITION NO. 2
READING LONGITUDINAL POSITION NO. 1

Table 2.12. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 117	+160	-240	+1109	- 2	+ 1	- 2	+ 12
	2	+2092	-403	+172	- 493	+ 0	0	+ 2	- 9
	3	+2094	-478	+174	- 433	- 2	+ 3	- 2	+ 2
	4	- 47	+365	- 86	+ 84	- 40	+ 60	- 95	+403
	5	- 40	+403	- 95	+ 60	- 47	+ 84	- 86	+365
	6	- 2	+ 2	- 2	+ 3	+2094	- 433	+174	-478
	7	0	- 9	+ 2	0	+2092	- 493	+172	-403
	8	- 2	+ 12	- 2	+ 1	- 117	+1109	-240	+160

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 2

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 132	+190	-245	+1086	- 6	+ 6	- 6	+ 28
	2	+2104	-411	+186	- 535	- 4	+ 6	- 3	+ 9
	3	+2108	-533	+189	- 433	- 7	+ 10	- 9	+ 23
	4	- 51	+325	- 85	+ 113	- 50	+ 75	-101	+434
	5	- 50	+434	-101	+ 75	- 51	+ 113	- 85	+325
	6	- 7	+ 23	- 9	+ 10	+2108	- 433	+189	-533
	7	- 4	+ 9	- 3	+ 6	+2104	- 535	+186	-411
	8	- 6	+ 28	- 6	+ 6	- 132	+1086	-245	+190

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 3

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE
-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	+6	-31	+1	-5	-8	+6	-2	+42
	2	+7	-36	+2	-6	-8	+6	-2	+39
	3	+8	-40	+2	-6	-7	+5	-2	+34
	4	+5	-23	+1	-3	-2	+2	-1	+12
	5	-2	+12	-1	+2	+5	-3	+1	-23
	6	-7	+34	-2	+5	+8	-6	+2	-40
	7	-8	+39	-2	+6	+7	-6	+2	-36
	8	-8	+42	-2	+6	+6	-5	+1	-31

TRUCK LONGITUDINAL POSITION NO. 3

READING LONGITUDINAL POSITION NO. 4

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-4	- 1	+3	-4	-6	+2	-2	+16
	2	-3	- 6	+4	-3	-7	+3	-2	+15
	3	-2	-10	+5	-3	-7	+4	-2	+14
	4	-3	- 6	+3	-1	-5	+3	+6	+ 5
	5	-5	+ 5	+6	+3	-3	-1	+3	- 6
	6	-7	+14	-2	+4	-2	-3	+5	-10
	7	-7	+15	-2	+3	-3	-3	+4	- 6
	8	-6	+16	-2	+2	-4	-4	+3	- 1

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 3

Table 2.16. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 117	- 282	-38	+1384	- 87	+ 64	-20	+ 454
	2	+2218	-1029	+61	- 627	- 87	+ 63	-20	+ 451
	3	+2233	-1053	+64	- 692	- 93	+ 66	-22	+ 485
	4	- 10	+ 225	- 6	- 26	- 108	+ 78	-31	+ 747
	5	- 108	+ 747	-31	- 78	- 10	- 26	- 6	+ 225
	6	- 93	+ 485	-22	+ 66	+2233	- 692	+64	-1053
	7	- 87	+ 451	-20	+ 63	+2218	- 627	+61	-1029
	8	- 87	+ 454	-20	+ 64	- 117	+1384	-38	- 282

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 4

Figure 2.1. Tandem Axle Truck.

Figure 2.2. Test Truck Axle Loads and Spacings.

TRANSVERSE POSITION NO. 1

TRANSVERSE POSITION NO. 2

Figure 2.4. Transverse Positions 1 and 2.

TRANSVERSE POSITION NO. 3

TRANSVERSE POSITION NO. 4

Figure 2.5. Transverse Positions 3 and 4.

TRANSVERSE POSITION NO. 5

TRANSVERSE POSITION NO. 6

Figure 2.6. Transverse Positions 5 and 6.

TRANSVERSE POSITION NO. 7

TRANSVERSE POSITION NO. 8

Figure 2.7. Transverse Positions 7 and 8.

Figure 2.8. Test Locations Painted on Bridge Deck.

Figure 2.9. Test Locations Painted on Bridge Deck.

Figure 2.10. Test Locations Painted on Bridge Deck.

Figure 2.11. Loaded Test Truck.

Figure 2.12. Transverse Position 5.

Figure 2.13. Transverse Position 7.

Figure 2.14. Transverse Position 8 (Front View).

Figure 2.15. Transverse Position 8 (Rear View).

Figure 2.16. Instrumented Sections for Transverse Bending.

Figure 2.17. Section A.

Figure 2.18. Section B.

Figure 2.19. Section C.

Figure 2.20. Section D.

Figure 2.21. Digital Strain Indicators.

2.22. Gages Wired to Gage Blocks.

2.23. Gages Wired to Gage Blocks.

CHAPTER III

SUMMARY AND CONCLUSIONS

3.1 GENERAL

The general objective of this research project is to determine by means of experimental analysis certain aspects of the behavior of a typical precast segmental box girder bridge. The "Turkey Run Bridge", subject bridge for this study, was appropriately instrumented and suitable tests and data collection methods were used to determine the response characteristics of interest. The specific aspects of behavior studied were: transverse bending of representation cross sections, diurnal and seasonal transverse (vertical) temperature variations, and time dependent deformations due to creep and loss of prestress force.

Detailed descriptions of the bridge, its construction, and the instrumentation system have been provided in the interim report (14, Ch. I); this information will be repeated only as required to improve clarity. Herein are provided summaries of the results of the transverse bending tests and comparisons with analytical predictions, a summary of the results and findings of the thermal response studies, and a summary of the results of the investigation of time-dependent deformations due to creep and prestress loss. Finally, concluding comments and recommendations are presented.

3.2 TRANSVERSE BENDING

Various analytical methods have been utilized for purposes of design of segmental box girder bridges. The more frequently used ones are based on linear-elastic theory, with twin-boxes being treated as a single system when the boxes are connected by an elastic linking element, such as a cast-in-place connecting slab. The methods vary considerably in complexity, levels of approximation involved in modeling restraint conditions (boundaries, internal diaphragms), and required computational effort.

Several of these methods were reviewed within the context of this project. Those receiving special attention were the ones originally described by Holman (13, Ch. II): (1) a method which reduces the transverse analysis to two dimensional frame analysis, for which fixed-end moments are calculated using influence surfaces, and (2) a finite element solution. Even though the so-called "influence surfaces" method was studied and evaluated in detail, its use to obtain moments for comparison to experimentally obtained values was finally rejected. This method, as Holman (13) observed, is based on a number of gross approximations, and is very conservative. It might reasonably be used as a rough preliminary design tool, but not as a primary analytical method for design of major bridges. Computer codes based on finite element models are presently being used for this purpose.

The analytical solutions used for comparative purposes in this study were obtained by means of an elastic finite element

method written as a computer code. The assumptions upon which the model is based are those normally employed for linear-elastic theories; the material is assumed to be homogeneous and isotropic, and the effects of cracking are disregarded. This computer program, developed by Batla (15), was used by the Indiana State Highway Commission during the design process. The calculated results given in Chapter II in Tables 2.9 through 2.16 were obtained for the same loading configurations, except as noted earlier, as those used for the load tests.

In interpreting and using the experimental results from the comprehensive test it should be borne in mind that all the bending moments induced by the truck loading were very small, i.e. the induced strain levels in the steel were very low. Moreover, a difference in strain of only one microstrain (1×10^{-6} in/in) is produced between the two steel layers by an internal moment of approximately 40 ft-lbs per ft. for the top slab and one of 80 ft-lbs per ft. for the webs. The largest observed bending moment due to the heavy truck loading used in these tests was 1592 ft-lbs/ft., and most were less than half of this value. Strain measurement resolution for the steel gages was nominally one microstrain and, as has been discussed at length previously, each reading had to be corrected to delete signals due to quantifiable extraneous effects such as zero drift and transverse sensitivity. There are, of course, also indeterminate experimental errors due to deviations from nominal dimensions, inexact positioning of the instrumented reinforcement bars, and differences in materials

properties from average measured values. Thus, it can be seen that sizeable error percentages are to be anticipated, especially for the smaller bending moments.

To facilitate study and comparison, the experimental and analytical results for some key loading cases, reduced in accordance with the procedures described in both the interim report (14, Ch. IV) and Chapter II of this report, are presented in Tables 3.1 through 3.6. These tables have been set up so as to permit ready comparison of nominally symmetrical or nearly symmetrical loading cases on the nominally symmetrical structure. In these tables, where meaningful, experimental moments are compared in percentage terms to the corresponding analytical predictions; average experimental values at nominally symmetrical locations are also given where available and relevant. Percentage comparisons and averages have been omitted when theoretical and/or inferred moments are so small that unavoidable experimental errors have magnitudes of the same order as those of the desired data.

The arrangement of these tables may be illustrated by examining Table 3.1A. For example, the first line in this table contains experimental and theoretical results for: Truck Longitudinal Position 1 (TLP1) - Reading Longitudinal Position 1 (RLP1) - Truck Transverse Position 2 (TTP2) - Moment Station 1 (MS1), in abbreviated form TLP1-RLP1-TTP2-MS1. The next three lines are for: TLP1-RLP1-TTP7-MS5; TLP4-RLP4-TTP2-MS1, and TLP4-RLP4-TTP7-MS5. The four readings are grouped because they represent

nominally identical or nearly identical loading-reading conditions, given the symmetry of the structure and the loading patterns used for the test. Lines 1 and 2 are for nominally identical conditions, as are lines 3 and 4. The conditions for lines 1 and 2 differ from those for lines 3 and 4 only in the relative longitudinal direction of the truck on the bridge. This difference has a minor effect on theoretical predictions, and, presumably, on the induced bending moments. Thus, the data on each of the lines may be evaluated individually, or in pairs (e.g. to check for transverse symmetry of the experimental results), or in groups of four (e.g. to check for longitudinal and transverse symmetry of the experimental results).

Tables 3.1A, 3.1B, 3.2A, 3.2B, and 3.3 present the transverse bending moments in longitudinal sections 1 and 4 due to truck loadings applied, respectively, at those same longitudinal positions. Tables 3.1A and 3.2A give responses at moment stations within the loaded box; Tables 3.1B and 3.2B give responses for the other (not loaded) box. Table 3.3 contains the moments produced in both boxes by loadings applied between the boxes. Tables 3.4A, 3.4B, 3.5A, 3.5B, and 3.6, which are concerned with longitudinal sections 2 and 3, are arranged in the same way.

Both the experimental results and the finite element model predictions indicate that the largest transverse bending responses occurred at a given longitudinal position (section) when the tandem axle loads are placed immediately at that same position. These, then are the responses of central interest for

this test series. We shall first discuss the results for longitudinal sections 1 and 4 (see Figure 2.3), since these locations are representative of cross sections removed from the direct influence of support constraints.

Bending moments induced at moment stations 1 and 5 when wheel loads were placed directly over the gaged locations were the largest observed during the tests. The first four lines in each of Tables 3.1A and 3.2A are concerned with this type of situation. Under these conditions the experimentally determined moments were typically less than half the values predicted by the finite element code. (42% average for loadings 2/7 in Table 3.1A, 48% average for loadings 3/6 in Table 3.2A). At moment stations 2/8 and 4/6 in the loaded boxes, measured responses were also less than the predicted values; at stations 3/7 the moments were quite small, and thus excessively influenced by experimental errors. The overall average "percentage of theoretical predictions" obtained for the sites given in Tables 3.1A and 3.2A was 61%, with a standard deviation of 17%. No single experimental value was larger than the corresponding theoretical value.

Responses in the adjacent, unloaded boxes are given in Tables 3.1B and 3.2B. Except for moment stations 2/8, predicted and measured moments were generally small. A few of the experimentally inferred moments are opposite in sign to the predicted values. This is not surprising, however, when one considers the relative magnitudes of the quantities (strains) being measured and unavoidable experimental errors, which are present under the

most optimum test conditions. The experimental moments at stations 2/8 from the two tables average 61% of the theoretical values. The results clearly suggest that the cast-in-place slab does function effectively in providing continuity between the boxes.

Table 3.3 contains the experimentally inferred moments produced by loads applied in Transverse Loading Positions 4 and 5, i.e. for loads applied between the two boxes. Under these loadings predicted and measured responses are quite small except at moment stations 2/8. The average percentage of theoretical prediction obtained for stations 2/8 was 60%. There were sign reversals and responses larger than the theoretical values observed at some of the other moment stations.

Turning to longitudinal sections 2 and 3 and the bending moments induced by loads applied, respectively, in these two positions, it can be seen that the results, while somewhat more erratic than those for longitudinal sections 1 and 4, follow a similar pattern. Responses directly under wheel loads (lines 1 through 4 of Tables 3.4A and 3.5A) average 40% of the predicted values. Overall percentage of theoretical prediction from Tables 3.5A and 3.6A is 46%, somewhat less than for longitudinal sections 1 and 4. Responses in adjacent boxes predicted by the finite element code are very small, due to the stiffening influence of the adjacent pier section; the measured values, though quite sporadic, more or less confirm this prediction (see Tables 3.4B, 3.5B, and 3.6).

Reference to Tables 2.10, 2.11, 2.14, and 2.15 indicates that the theoretical model predicts very low moments at sections well removed longitudinally from the section where the loading is applied. The experimentally inferred moments given in Tables 2.3, 2.6, and 2.7 are generally small also, thus verifying the predictions. Observed transverse bending moments at longitudinal section 2 produced by loadings applied at longitudinal position 1 - see Table 2.2 - were generally larger than those predicted. No satisfactory means of explaining this has been developed to date.

Certain general conclusions can be drawn from these data and the above discussion. The measured responses at longitudinal sections 1 and 4 due to loads applied at these section suggest that the finite element model is somewhat conservative in predicting moments; measured values at sections with significant moment averaged 61% of the predictions. A similar conclusion, with a lower percentage (40%), can be drawn for sections 2 and 3. Since these moments are of direct interest for design purposes, this would seem to be an important finding. Measured moments occurring directly under wheel loads were also low, being generally about 40% of predicted values. This is probably due to local effects not fully accounted for in the finite element model. The experimental data also provide ample evidence that the cast-in-place slab provides a fully continuous connection between the twin boxes.

3.3 THERMAL RESPONSE

That bridges respond in various significant ways to thermal effects has long been known. Bridges have traditionally been designed to account for internal forces and deformations induced in statically redundant systems by temperature differences and gradients. The nature of within-member temperature distributions and their induced effects did not, however, receive significant study until the 1970's. When the Turkey Run Bridge was designed, the criteria used for design for thermal effects were necessarily arbitrary due to the limited state of knowledge at that time.

This research project was designed to include the collection of selected, but significant, field data on temperature distributions within selected cross-sections of the bridge. To this end, eight temperature sensors, four in each of two of the bridges cross sections, were installed during manufacture of the segments. These sections were located in each span 96'-0" from the central pier, the same sections also instrumented for transverse strains. The sensors used were thermistors; they were placed at the mid-depths of the top and bottom slabs of each segment comprising each section. After the bridge was completed and the project was well under way, twelve additional thermistors were installed, three in each of the webs of two of the segments, to permit better measurement of the nature of transverse (vertical) temperature distributions through the superstructure. Complete descriptions of the instrumentation system were provided in the interim report (14, Ch. V); Figure 3.1 shows the locations of the

thermistors used to measure temperatures.

The studies of bridge response to thermal effects conducted during this project were: a study of thermally-induced tip deflections during construction, measurement of vertical temperature distributions for selected time periods, and a study of thermally-induced strains conducted on the completed bridge.

Tip Deflections During Construction

Because bridge structures built by the cantilever method are built in two directions toward a common joining point, it is imperative that vertical alignment be subject to careful control during construction. As the assembly of the superstructure progresses, deflections due to temperatures must be predicted and appropriate corrections made to account for them. Where possible, grade (deflection) checks are made during weather conditions and at times in the diurnal cycle when transverse temperature gradients are minimal.

To check the simple method then being used for calculating thermally induced tip deflections, both temperatures and deflections were measured during placement of two of the bridges segments. Top and bottom slab temperatures at mid-depth of the slabs were monitored by means of the implanted thermistors. A complete description of this test was presented in the interim report (14, pp. 120-126).

Weather conditions during this test, while ideal for minim-

izing temperature-related deflections and thus control of vertical alignment, led to results which did not facilitate checking the deflection calculation procedure. The maximum observed difference between top and bottom slab temperatures during this test was less than 10°F .

Data from this test and the predicted deflections obtained using the procedure recommended in the PCI-PTI temperature distribution method given in the "Precast Segmental Box Girder Bridge Manual" (16) were also presented in the interim report (14, pp. 120-126). Results of the tests agreed reasonably well with the predictions. However, all deflections were very small, and there was considerable scatter of the data. The prediction method used yielded results which were sufficiently accurate for the temperature and deflection ranges encountered during the test.

Bridge Temperatures

Beginning with the winter of 1979 and extending through September of 1980, bridge temperatures were sampled several times for periods ranging from one to ten days in duration. Readings were taken during every season of the year; more were taken during the spring and summer months when maximum positive gradients were anticipated. For the longer-duration tests, temperatures indicated by all thermistors were read automatically every thirty minutes by a data acquisition system controlled by a digital clock. Unfortunately, it was not feasible to measure top slab

surface temperatures, since the positions of the transducers would have had to be in the bridge's travel lanes.

The purpose of obtaining these data was to observe representative maximum positive and negative temperature differences between top and bottom slabs, and to determine the general nature of transverse (top to bottom of superstructure) temperature distribution.

Figures 3.2 and 3.3 show the diurnal variations of top and bottom slab temperatures on February 27, 1979, the day on which the maximum observed negative temperature difference of -8°F occurred. This difference occurred during mid-morning of a foggy day when the low ambient temperature was 16°F and the high, 49°F .

Figures 3.4 and 3.5 indicate the diurnal variations on June 26, 1979; on this day the maximum observed positive temperature difference of 24°F was observed. High and low ambient temperatures were 86°F and 50°F , respectively. It is on days when ambient temperature ranges are largest that temperature gradients are expected to assume their maximum values. Short of measuring the temperatures daily over several years, it is not possible to determine an average yearly maximum temperature difference. This, of course, was not within the scope of this research. However, it is the opinion of the authors that the maximum observed values given above are probably less than the maximum values for the years during which the measurements were taken.

The additional thermistors required to measure transverse temperature distribution in detail were not installed until early July of 1979. Thus, transverse distribution information is not available for June 26, 1979, when the maximum positive difference was observed. Presented in Figures 3.6A and 3.6B are transverse distributions for July 10, 1979, a day for which the maximum observed temperature difference was 20°F . High ambient temperature for that day was 86°F and low was 62°F . It can be seen that the average temperature of the webs varied slightly over the day and that all web temperatures were close to the average. At the time (6:00 p.m.) when maximum temperature gradient was recorded, the bottom slab was approximately 2°F warmer than the web. The top slab mid-depth temperature, however, underwent a significant variation over the diurnal cycle. The experimental values defining transverse distribution at 6:00 p.m. were consistent with the characteristic shape of the fifth-power curve specified in the New Zealand specification (17), which was developed by Priestley and others. The data collected within the context of this study is insufficient to permit complete quantitative comparisons to that specified distribution; the lack of corresponding surface temperatures and mid-depth slab temperatures directly over the webs is critical in this connection.

Study of the data acquired during the project duration, of which the above plots are representative examples, suggest certain general observations. Minimum temperature gradients generally existed during the early daylight to mid-morning hours;

maximum positive gradients typically occurred during the late afternoon and early evening hours. The observed maximum positive temperature gradient of 24°F is one-third larger than the PCI-PTI value of 18°F . And, as cited above, the shapes of the vertical temperature distributions corresponding to maximum gradients appeared to be quite similar to that of the New Zealand Specification distribution.

Temperature-Induced Strains in the Completed Bridge

Vertical temperature gradients in a statically indeterminate structure such as the subject bridge induce curvatures which result in redistributions of the tractions (stress resultants) of the bridge. The nature and significance of this redistribution has been discussed in detail by Holman (13, Ch. V) and others.

A supplemental test conducted during August, 1979, had as its objective the experimental determination of longitudinal strains corresponding to measured temperature differences between top bottom slabs. Strains were measured by means of a Whittemore gage and the same implants used for the long-term strain measurements. Temperatures were measured using the thermistors described above.

Plots of the measured strains obtained during this eleven hour test are given in Figures 3.7 through 3.12. The corresponding temperature variations are shown in Figures 3.13 and 3.14.

Predictions of strains induced by the temperature differ-

ences, calculated in accordance with the PCI-PTI procedure are also included on the figures. From these plots it appears that the top slab strains were predicted reasonably well; bottom slab strains were significantly larger than the predicted values.

3.4 LONG-TERM DEFORMATIONS

Time-dependent deformations in concrete bridges are caused by the combination of coupled effects due to concrete creep and shrinkage, and relaxation of the post-tensioning steel. In the case of precast segmentally-constructed bridges, the greater part of the total shrinkage deformation occurs after casting and prior to segment erection. Therefore, it is generally assumed that this effect is minimal. Because a continuous segmental box girder bridge is prestressed in a different structural configuration from that which it assumes during its service life, prestress losses and time dependent concrete deformations result in redistribution of dead load moments (18,19). Consequently, internal stresses vary continuously during the service life of the bridge. The Turkey Run Bridge, being a continuous structure erected by the cantilever method, is therefore subject to time dependent redistribution of internal forces and the associated deformations.

In order to measure long-term deformations, strains and deflections have been monitored monthly at key locations on the bridge. The experimental long-term strain and midspan deflection data which were obtained during the course of this research are

presented and discussed below.

Long-Term Strain Measurements

Longitudinal strains have been measured and recorded monthly over a three year period at key sites by measuring changes in dimensions between permanently installed Whittemore strain gage implants. Implant locations are shown in Figure 3.15. Strains were determined by dividing the measured relative movements between each pair of implants by the ten inch gage length of the instrument.

Summary plots of the recorded strains versus time are shown in Figures 3.16 through 3.21. The numerical data are presented in tabular form in Appendix B. At each instrumented location the strain levels shown in the plots were determined as the average of the responses of the three sets of gage implants. Bridge temperatures recorded simultaneously with strain measurements were utilized, in accordance with the procedure discussed in the interim report (14, Ch. V), to calculate temperature-induced strains. These (temperature-induced) strains were subtracted from the measured strains to obtain the long-term strains shown in the figures. The dates when the individual segments were cast and erected and the construction completion date are shown on the time axis.

Variation of longitudinal stresses during construction is due to the sequential erection of segments and the post-tensioning of those segments. Therefore, the long-term creep

strains are referenced from the strain levels existing at the end of construction.

The reduced data indicate a definite influence from seasonal effects. This finding is consistent with the observations of Marshall and Gamble (20), who have discussed possible causes in detail. Of foremost importance in this connection is the dependence of several key materials properties on environmental factors, especially relative humidity.

At the instrumented pier sections, observed long term compressive strains in the top slab increased at a slightly greater rate than in the bottom slab. This would indicate that the prestressing force is dominant over gravity load in inducing creep deformations at these sections. On the other hand, for the midspan cross sections, the two effects appear to be reasonably equal.

Due consideration was given to comparing these experimental results with analytical predictions. Various methods (20,21,22,23,24,25) for predicting long term strains have been proposed that apply to the problem of predicting long term strains for a structure such as this one. However, for all of these methods it was found that the time that would be required to develop or obtain, revise, and implement a suitable computer code to permit comparisons was inconsistent with the original project scope and objectives. Further work of this type, utilizing the experimental data from this research as a basis, is worth

considering. It should be pointed out, however, that accurate predictions of long term strains do require detailed knowledge of both the chronology of construction sequence and the relevant materials properties as determined from numerous control tests. This type of information is only partially available for the Turkey Run Bridge.

Midspan Deflection Measurements

Midspan deflection measurements were recorded on a monthly basis, beginning immediately after completion of construction, at the instrumented sections shown in Figure 3.22. A complete description of the data acquisition process, the instrumentation scheme and data reduction procedures was presented in the interim report (14, pp. 162-167).

Bridge elevations were significantly affected by expansion and contraction of the central pier induced by temperature fluctuations. Thus, midspan deflections were determined with respect to the relative elevations at the abutment and pier sections. Deflection data were corrected by means of the procedure described previously by subtracting those deflections caused by vertical temperature gradients. In an independent study conducted during the summer of 1979, a positive 16°F temperature differential between top and bottom slabs was found to cause a midspan camber of approximately 0.008 ft.; this was of the same order of magnitude as the maximum observed long-term deflection.

Over the 1200 day period following completion of the bridge, 32 sets of deflection data were collected and reduced. The total long-term deflection which occurred during this period was less than 0.005 ft. A more precise statement than this is not possible because the resolution of the elevation measurements from which the deflections were inferred was 0.001 ft., and the corrections used to delete temperature effects are inherently approximate. However, it is possible to conclude that the measured long-term deflections were very small, thus confirming the prediction by the bridge's designers, V.D. Bouvy and V.D. Niet, Consulting Civil Engineers in The Netherlands. They predicted a net camber growth of 0.016 ft. over a period of 27 years. Little additional long-term deflection is anticipated over the life of the structure, since nearly 90 percent of the total time dependent deflection generally occurs during the first year after construction (14, pp. 162-167).

3.5 CONCLUSIONS AND RECOMMENDATIONS

In view of the results of the above-described experiments, studies, and comparisons, the following observations, conclusions, and recommendations are offered:

1. Observed transverse bending moments for both the preliminary and comprehensive tests at cross-sections subject to significant bending by the test loads were significantly less than those predicted by the finite element computer code used for design. Measured values at sections away from the stiffening

influence of the central pier average approximately 60% of the analytical values; thus, the theoretical predictions were quite conservative. The experimental data confirmed that full continuity existed between the twin boxes.

Major bridges such as the subject of this study should be analyzed by the best available computer-based methods. Predictions provided by more detailed computer codes with more degrees of freedom can and should be checked against the experimental evidence presented herein. Design of future bridges for lowered bending moments cannot be recommended solely on the basis of this research. However, further study of transverse bending in segmental box girder bridges would seem warranted, since savings in the cost of transverse reinforcement for a typical bridge could be substantial.

2. The maximum difference in temperature between top and bottom slab mid-depths observed within the several multi-day sampling runs made during all seasons of the year was 24° F. Even though the measurements taken covered representative periods during likely times for maximum differences, there is a significant probability that even larger differences occurred on other days when temperatures were not being measured. The gradient of 18° F given in the PCI-PTI Precast Segmental Box Girder Bridge Manual (16) is obviously well below the measured maximum.

The temperatures measured at several points in the two instrumented cross sections are very useful data. However, this

information alone is insufficient to permit suggestion or confirmation of detailed proposed temperature profiles or design gradients. Clearly the maximum gradient must be raised above the PCI-PTI value. The data does appear to confirm, at the points measured, the general shape of the (fifth-power) temperature distribution now included in New Zealand design regulations.

The half-day study of temperature-induced strains at sites on the completed bridge suggest that curvatures predicted by the approximate PCI-PTI step-gradient method were not unreasonable. This, of course, does not necessarily imply that stress distributions obtained by the method are satisfactory predictions.

3. Useful information on long term strains collected over a three year period has been obtained and documented. Obtaining meaningful comparisons with values calculated by means of a detailed prediction method was not feasible during the active phase of this research due to the lack of a general computer code and some key, time-dependent, materials properties data.

Measured long term mid-span deflections were very small, and less than the predicted value of 0.016 ft. stated by the designers of the bridge.

Table 3.1A Transverse Bending Moments for Transverse
Truck Positions 2 and 7
at Longitudinal Sections 1 and 4

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Theoretical (Prediction)	Moment (ft lbs/ft) Experimental (Inferred)	Average Experimental	Percentage of Theoretical Prediction
1	1	2	1	2202	988	1008	45
1	1	7	5	2202	1027		47
4	4	2	1	2218	880	844	40
4	4	7	5	2218	807		36
1	1	2	2	-950	-654	-738	69
1	1	7	8	-950	-821		86
4	4	2	2	-1029	-654	-545	64
4	4	7	8	-1029	-436		42
1	1	2	3	57		40	
1	1	7	7	57	24		
4	4	2	3	61	53	40	
4	4	7	7	61	27		
1	1	2	4	-615	-508	-512	83
1	1	7	6	-615	-516		84
4	4	2	4	-627	-363	-400	58
4	4	7	6	-627	-436		70

Table 3.1B Transverse Bending Moments for Transverse
Truck Positions 2 and 7
at Longitudinal Sections 1 and 4

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Theoretical (Prediction)	Moment (ft lbs/ft) Experimental (Inferred)	Average Experimental	Percentage of Theoretical Prediction
1	1	2	5	-72	-404		
1	1	7	1	-72	-34		
4	4	2	5	-87	0		
4	4	7	1	-87	-37		
1	1	2	8	372	182	164	49
1	1	7	2	372	145		39
4	4	2	8	451	291	327	65
4	4	7	2	451	363		80
1	1	2	7	-17	-180		
1	1	7	3	-17	---		
4	4	2	7	-20	27		
4	4	7	3	-20	-27		
1	1	2	6	47	22		
1	1	7	4	47	-73		
4	4	2	6	63	73		
4	4	7	4	63	-73

Table 3.2A Transverse Bending Moments for Transverse
Truck Positions 3 and 6
at Longitudinal Sections 1 and 4

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Moment (ft lbs/ft)		Average Experimental	Percentage of Theoretical Prediction
				Theoretical (Prediction)	Experimental (Inferred)		
1	1	3	1	2220	1271	1259	57
1	1	6	5	2220	1247		56
4	4	3	1	2233	988	861	44
4	4	6	5	2233	734		33
1	1	3	2	-989	-654	-781	66
1	1	6	8	-989	-908		92
4	4	3	2	-1053	-799	-618	76
4	4	6	8	-1053	-436		41
1	1	3	3	61	--	--	--
1	1	6	7	61	-61		--
4	4	3	3	64	80	54	
4	4	6	7	64	27		
1	1	3	4	-682	-581	-520	85
1	1	6	6	-682	-458		67
4	4	3	4	-692	-436	-436	63
4	4	6	6	-692	-436		63

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.2B Transverse Bending Moments for Transverse
Truck Positions 3 and 6
at Longitudinal Sections 1 and 4

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Theoretical (Prediction)	Moment (ft lbs/ft) Experimental (Inferred)	Average Experimental	Percentage of Theoretical Prediction
1	1	3	5	-80	111		
1	1	6	1	-80	11		
4	4	3	5	-93	37		
4	4	6	1	-93	0		
1	1	3	8	419	276	247	66
1	1	6	2	419	218		52
4	4	3	8	485	291	327	60
4	4	6	2	485	363		75
1	1	3	7	-19	-151		
1	1	6	3	-19	--		
4	4	3	7	-22	27		
4	4	6	3	-22	-27		
1	1	3	6	56	29		
1	1	6	4	56	0		
4	4	3	6	66	145		
4	4	6	4	66	0

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.3 Transverse Bending Moments for Transverse
Truck Positions 4 and 5
at Longitudinal Sections 1 and 4

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Theoretical (Prediction)	Moment (ft lbs/ft) Experimental (Inferred)	Average Experimental	Percentage of Theoretical Prediction
1	1	4	1	-15	166	175	
1	1	5	5	-15	184		
4	4	4	1	-10	110	92	
4	4	5	5	-10	74		
<hr/>							
1	1	4	2	253	218	189	86
1	1	5	8	253	160		63
4	4	4	2	225	145	145	64
4	4	5	8	225	145		64
<hr/>							
1	1	4	3	-7	--		
1	1	5	7	-7	-90		
4	4	4	3	-6	0		
4	4	5	7	-6	-53		
<hr/>							
1	1	4	4	-21	-73		
1	1	5	6	-21	44		
4	4	4	4	-26	-73		
4	4	5	6	-26	218		
<hr/>

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.3 Transverse Bending Moments for Transverse
Truck Positions 4 and 5
at Longitudinal Sections 1 and 4 (Continued)

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Moment (ft lbs/ft)		Average Experimental	Percentage of Theoretical Prediction
				Theoretical (Prediction)	Experimental (Inferred)		
1	1	4	5	-108	148	100	
1	1	5	1	-108	52		
4	4	4	5	-108	0	37	
4	4	5	1	-108	74		
1	1	4	8	747	509	473	68
1	1	5	2	747	436		58
4	4	4	8	747	436	291	58
4	4	5	2	747	145		19
1	1	4	7	-31	-93		
1	1	5	3	-31	--		
4	4	4	7	-31	-27		
4	4	5	3	-31	-53		
1	1	4	6	78	36	18	
1	1	5	4	78	0		
4	4	4	6	78	145	182	
4	4	5	4	78	218

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.4A Transverse Bending Moments for Transverse
Truck Positions 2 and 7
at Longitudinal Sections 2 and 3

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Moment (ft lbs/ft)		Average	Percentage
				Theoretical (Prediction)	Experimental (Inferred)	Experimental	of Theoretical Prediction
2	2	2	1	2092	970		46
2	2	7	5	2092	634	802	30
3	3	2	1	2104	709		34
3	3	7	5	2104	891	800	42
<hr/>							
2	2	2	2	-403	--	--	--
2	2	7	8	-403	0		0
3	3	2	2	-411	--		--
3	3	7	8	-411	-230		56
<hr/>							
2	2	2	4	-493	-230		47
2	2	7	6	-493	77	-77	--
3	3	2	4	-535	-307		57
3	3	7	6	-535	-77	-192	14
<hr/>

Table 3.4B Transverse Bending Moments for Transverse
Truck Positions 2 and 7
at Longitudinal Sections 2 and 3

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Moment (ft lbs/ft)		Percentage of Theoretical Prediction
				Theoretical (Prediction)	Experimental (Inferred)	Average Experimental
2	2	2	5	0	112	
2	2	7	1	0	74	
3	3	2	5	-4	-37	
3	3	7	1	-4	36	
<hr/>						
2	2	2	8	-9	-77	
2	2	7	2	-9	--	
3	3	2	8	19	77	
3	3	7	2	9	--	
<hr/>						
2	2	2	6	0	153	
2	2	7	4	0	0	
3	3	2	6	6	0	
3	3	7	4	6	-77	
<hr/>

Table 3.5A Transverse Bending Moments for Transverse
Truck Positions 3 and 6
at Longitudinal Sections 2 and 4

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Moment (ft lbs/ft)		Average Experimental	Percentage of Theoretical Prediction
				Theoretical (Prediction)	Experimental (Inferred)		
2	2	3	1	2094	1080	913	52
2	2	6	5	2094	745		36
3	3	3	1	2108	820	801	39
3	3	6	5	2108	782		37
2	2	3	2	-478	--		96
2	2	6	8	-478	-460		
3	3	3	2	-533	--		29
3	3	6	8	-533	-154		
2	2	3	4	-433	-230	-230	53
2	2	6	6	-433	-230		53
3	3	3	4	-433	-230		53
3	3	6	6	-433	77		--

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.58 Transverse Bending Moments for Transverse
Truck Positions 3 and 6
at Longitudinal Sections 2 and 3

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Theoretical (Prediction)	Moment (ft lbs/ft) Experimental (Inferred)	Average Experimental	Percentage of Theoretical Prediction
2	2	3	5	-2	112		
2	2	6	1	-2	37		
3	3	3	5	-7	37		
3	3	6	1	-7	-17		
<hr/>							
2	2	3	8	2	0		
2	2	6	2	2	--		
3	3	3	8	23	153		
3	3	6	2	23	--		
<hr/>							
2	2	3	6	3	77		
2	2	6	4	3	77		
3	3	3	6	10	77		
3	3	6	4	10	-77		
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TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.6 Transverse Bending Moments for Transverse
Truck Positions 4 and 5
at Longitudinal Sections 2 and 3

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Theoretical (Prediction)	Moment (ft lbs/ft) Experimental (Inferred)	Average Experimental	Percentage of Theoretical Prediction
2	2	4	1	-47	74		
2	2	5	5	-47	75		
3	3	4	1	-51	74		
3	3	5	5	-51	-74		
2	2	4	2	365	--		
2	2	5	8	365	77		21
3	3	4	2	325	--		
3	3	5	8	325	460		142
2	2	4	4	84	0	77	
2	2	5	6	84	153		
3	3	4	4	113	-77	-77	
3	3	5	6	113	-77		
2	2	4	5	-40	37		
2	2	5	1	-40	111		
3	3	4	5	-50	-37		
3	3	5	1	-50	0

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Table 3.6 Transverse Bending Moments for Transverse
Truck Positions 4 and 5
at Longitudinal Sections 2 and 3 (Continued)

Truck Longitudinal Position	Reading Longitudinal Position	Truck Transverse Position	Moment Station	Moment (ft lbs/ft)		Average Experimental	Percentage of Theoretical Prediction
				Theoretical (Prediction)	Experimental (Inferred)		
2	2	4	8	403	230		57
2	2	5	2	403	--		
3	3	4	8	434	383		88
3	3	5	2	434	--		
<hr/>							
2	2	4	6	60	230		
2	2	5	4	60	0		
3	3	4	6	75	230		
3	3	5	4	75	230		
<hr/>

TRANSVERSE TRUCK POSITIONS

MOMENT STATION LOCATIONS

Figure 3.1. Temperature Instrumentation

Figure 3.2. Bridge Temperatures.

Figure 3.3. Bridge Temperatures.

Figure 3.4. Bridge Temperatures.

Figure 3.5. Bridge Temperatures.

THERMAL GRADIENTS FOR A REPRESENTATIVE SUMMER DAY

SEGMENT 25B

DAY 191

7/10/79

Figure 3.6A. Bridge Temperatures - Vertical Distributions

THERMAL GRADIENT AT TIME OF MAXIMUM TEMPERATURE DIFFERENTIAL

SEGMENT 25B

DAY 191

7/10/79

6:00 pm

Figure 3.6B. Bridge Temperatures - Vertical Distribution

Figure 3.7. Temperature Induced Strain.

Figure 3.8. Temperature Induced Strain.

Figure 3.9. Temperature Induced Strain.

Figure 3.10. Temperature Induced Strain.

Figure 3.11. Temperature Induced Strain.

Figure 3.12. Temperature Induced Strain.

Figure 3.13. Variation In Bridge Temperatures.

Figure 3.14. Variation In Bridge Temperatures.

Figure 3.15. Whittemore Instrumentation.

Figure 3.16. Long-Term Strain.

Figure 3.17. Long-Term Strain.

Figure 3.18. Long-Term Strain.

Figure 3.19. Long-Term Strain.

Figure 3.20. Long-Term Strain.

Figure 3.21. Long-Term Strain.

Figure 3.22. Deflection Instrumentation.

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APPENDICES

APPENDIX A

FINITE ELEMENT BENDING MOMENTS

Table A1. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 134	-193	-42	+1398	- 70	+ 51	-17	+366
	2	+2202	-950	+57	- 615	- 72	+ 47	-17	+372
	3	+2220	-989	+61	- 682	- 80	+ 56	-19	+419
	4	- 15	+253	- 7	- 21	- 102	+ 72	-29	+717
	5	- 21	+717	-29	+ 73	- 15	- 21	- 7	+253
	6	- 80	+419	-19	+ 56	+2220	- 682	+61	-989
	7	- 72	+372	-17	+ 47	+2202	- 615	+57	-950
	8	- 70	+366	-17	+ 51	- 134	+1398	-42	-193

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 1

Table A2. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-4	- 3	+5	-5	-8	+4	-3	+20
	2	-3	- 9	+7	-4	-8	+5	-4	+20
	3	-1	-14	+6	-5	-8	+6	-4	+18
	4	-3	- 9	+4	-2	-6	+4	-1	+ 7
	5	-6	+ 7	-1	+4	-3	-2	+4	- 9
	6	-8	+18	-4	+6	-1	-5	+6	-14
	7	-8	+20	-4	+5	-3	-4	+7	- 9
	8	-8	+20	-3	+4	-4	-5	+5	- 3

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 2

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-13	+32	-6	+6	+ 2	-7	+9	-24
	2	-12	+29	-5	+5	+ 1	-5	+7	-20
	3	-10	+24	-4	+5	0	-4	+6	-16
	4	- 7	+12	-2	+3	- 3	-1	+2	- 5
	5	- 3	- 5	+2	-1	- 7	+3	-2	+12
	6	0	-16	+6	-4	-10	+5	-4	+24
	7	+ 1	-20	+7	-5	-12	+5	-5	+29
	8	+ 2	-24	+9	-7	-13	+6	-6	+32

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 3

Table A4. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-5	+27	-1	+4	+5	-4	+1	-26
	2	-5	+24	-2	+4	+4	-3	+1	-22
	3	-4	+19	-1	+3	+3	-2	+1	-16
	4	-2	+ 9	0	+1	+1	-1	0	- 6
	5	+1	- 6	0	-1	-2	+1	0	+ 9
	6	+3	-16	+1	-2	-4	+3	-1	+19
	7	+4	-22	+1	-3	-5	+4	-2	+24
	8	+5	-26	+1	-4	-5	+4	-1	+27

TRUCK LONGITUDINAL POSITION NO. 1READING LONGITUDINAL POSITION NO. 4

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	+1	- 5	0	-1	-2	+1	0	+ 9
	2	+2	- 8	0	-1	-2	+1	0	+ 9
	3	+2	-10	0	-2	-2	+1	0	+ 8
	4	+1	- 7	0	0	0	0	0	+ 2
	5	0	+ 2	0	0	+1	0	0	- 7
	6	-2	+ 8	0	+1	+2	-2	0	-10
	7	-2	+ 9	0	+1	+2	-1	0	- 8
	8	-2	+ 9	0	+1	+1	-1	0	- 5

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 1

Table A6. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft—lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

	STATION							
	1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 117	+160	-240	+1109	- 2 + 1	- 2	+ 12
	2	+2092	-403	+172	- 493	+ 0	0	+ 2 - 9
	3	+2094	-478	+174	- 433	- 2 + 3	- 2	+ 2
	4	- 47	+365	- 86	+ 84	- 40	+ 60	- 95 +403
	5	- 40	+403	- 95	+ 60	- 47	+ 84	- 86 +365
	6	- 2	+ 2	- 2	+ 3	+2094	- 433	+174 -478
	7	0	- 9	+ 2	0	+2092	- 493	+172 -403
	8	- 2	+ 12	- 2	+ 1	- 177	+1109	-240 +160

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 2

Table A7. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

TRANSVERSE POSITION	STATION							
	1	2	3	4	5	6	7	8
	1	- 44	+ 58	-105	+487	+ 1	- 3	+ 3
	2	+768	-132	+410	-168	+ 2	- 3	+ 4
	3	+769	-154	+ 60	-166	+ 1	- 2	+ 3
	4	- 20	+165	- 37	+ 21	- 11	+ 18	- 37
	5	- 11	+170	- 37	+ 18	- 20	+ 21	- 37
	6	+ 1	- 9	+ 3	- 2	+769	-166	+ 60
	7	+ 2	- 13	+ 4	- 3	+768	-168	+410
	8	+ 1	- 4	+ 3	- 3	- 44	+487	-105

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 3

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-1	+6	0	+1	+1	-1	0	-5
	2	-1	+6	0	+1	+1	-1	0	-5
	3	-1	+4	0	+1	+1	+1	0	-5
	4	0	+2	0	0	+1	0	0	-3
	5	+1	-3	0	0	0	0	0	+2
	6	+1	-5	0	+1	-1	+1	0	+4
	7	+1	-5	0	-1	-1	+1	0	+6
	8	+1	-5	0	-1	-1	+1	0	+6

TRUCK LONGITUDINAL POSITION NO. 2READING LONGITUDINAL POSITION NO. 4

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-4	+19	-1	+3	+4	-3	+1	-19
	2	-4	+19	-1	+3	+4	-3	+1	-18
	3	-4	+18	-2	+3	+3	-3	+1	-16
	4	-2	+ 9	0	+1	+1	-1	0	- 7
	5	+1	- 7	0	-1	-2	+1	0	+ 9
	6	+3	-16	+1	-3	-4	+3	-2	+18
	7	+4	-18	+1	-3	-4	+3	-1	+19
	8	+4	-19	+1	-3	-4	+3	-1	+19

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 1

Table A10. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS (ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 2	- 3	-14	+64	+ 5	- 8	+ 8	-21
	2	-88	+25	-14	+44	+ 4	- 8	+ 7	-21
	3	-87	+61	-14	+ 7	+ 4	- 8	+ 7	-22
	4	- 5	+42	- 5	-20	+ 6	-10	+ 3	- 4
	5	+ 6	- 4	+ 3	-10	- 5	-20	- 5	+42
	6	+ 4	-22	+ 7	- 8	-87	+ 7	-14	+61
	7	+ 4	-21	+ 7	- 8	-88	+44	-14	+61
	8	+ 5	-21	+ 8	- 8	- 2	+64	-14	- 3

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 2

Table All. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

TRANSVERSE POSITION	STATION							
	1	2	3	4	5	6	7	8
	1	- 132	+190	-245	+1086	- 6	+ 6	- 6 + 28
	2	+2104	-411	+186	- 535	- 4	+ 6	- 3 + 9
	3	+2108	-533	+189	- 433	- 7	+ 10	- 9 + 23
	4	- 51	+325	- 85	+ 113	- 50	+ 75	- 101 +434
	5	- 50	+434	-101	+ 75	- 51	+ 113	- 85 +325
	6	- 7	+ 23	- 9	+ 10	+2108	- 433	+ 189 -533
	7	- 4	+ 9	- 3	+ 6	+2104	- 535	+ 186 -411
	8	- 6	+ 28	- 6	+ 6	- 132	+1086	- 245 +190

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 3

Table A12. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	+6	-31	+1	-5	-8	+6	-2	+42
	2	+7	-36	+2	-6	-8	+6	-2	+39
	3	+8	-40	+2	-6	-7	+5	-2	+34
	4	+5	-23	+1	-3	-2	+2	-1	+12
	5	-2	+12	-1	+2	+5	-3	+1	-23
	6	-7	+34	-2	+5	+8	-6	+2	-40
	7	-8	+39	-2	+6	+7	-6	+2	-36
	8	-8	+42	-2	+6	+6	-5	+1	-31

TRUCK LONGITUDINAL POSITION NO. 3READING LONGITUDINAL POSITION NO. 4

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-4	+22	-1	+3	+4	-3	+1	-21
	2	-4	+19	-1	+3	+3	-3	+1	-17
	3	-3	+15	-1	+2	+3	-2	+1	-14
	4	-1	+ 7	0	+1	0	-1	0	- 4
	5	0	- 4	0	-1	-1	+1	0	- 7
	6	+3	-14	+1	-2	-3	+2	-1	+15
	7	+3	-17	+1	-3	-4	+3	-1	+19
	8	+4	-21	+1	-3	-4	+3	-1	+22

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 1

Table A14. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-11	+29	-6	+7	+ 2	-7	+8	-21
	2	-10	+25	-5	+6	+ 1	-6	+7	-18
	3	- 9	+21	-4	+5	0	-4	+5	-13
	4	- 7	+11	-2	+2	- 3	-1	+2	- 4
	5	- 3	- 4	+2	-1	- 7	+2	-2	+11
	6	0	-13	+5	-4	- 9	+5	-4	+21
	7	+ 1	-18	+7	-6	-10	+6	-5	+25
	8	+ 2	-21	+8	-7	-11	+7	-6	+29

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 2

TRANSVERSE BENDING MOMENTS

(ft-lbs/ft)

+TENSION ON INSIDE
-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	-4	- 1	+3	-4	-6	+2	-2	+16
	2	-3	- 6	+4	-3	-7	+3	-2	+15
	3	-2	-10	+5	-3	-7	+4	-2	+14
	4	-3	- 6	+3	-1	-5	+3	+6	+ 5
	5	-5	+ 5	+6	+3	-3	-1	+3	- 6
	6	-7	+14	-2	+4	-2	-3	+5	-10
	7	-7	+15	-2	+3	-3	-3	+4	- 6
	8	-6	+16	-2	+2	-4	-4	+3	- 1

TRUCK LONGITUDINAL POSITION NO. 4

READING LONGITUDINAL POSITION NO. 3

Table A16. Finite Element Bending Moments.

TRANSVERSE BENDING MOMENTS

(ft—lbs/ft)

+TENSION ON INSIDE

-TENSION ON OUTSIDE

		STATION							
		1	2	3	4	5	6	7	8
TRANSVERSE POSITION	1	- 117	- 282	-38	+1384	- 87	+ 64	-20	+ 454
	2	+2218	-1029	+61	- 627	- 87	+ 63	-20	+ 451
	3	+2233	-1053	+64	- 692	- 93	+ 66	-22	+ 485
	4	- 10	+ 225	- 6	- 26	- 108	+ 78	-31	+ 747
	5	- 108	+ 747	-31	- 78	- 10	- 26	- 6	+ 225
	6	- 93	+ 485	-22	+ 66	+2233	- 692	+64	-1053
	7	- 87	+ 451	-20	+ 63	+2218	- 627	+61	-1029
	8	- 87	+ 454	-20	+ 64	- 117	+1384	-38	- 282

TRUCK LONGITUDINAL POSITION NO. 4READING LONGITUDINAL POSITION NO. 4

APPENDIX B

LONG-TERM STRAIN DATA

Table B2. Strain Data.

TIME (DAYS)	TEMP. SLAB (DEGREES F)	STRAIN CASE B1 (IN/IN)	STRAIN CASE B2 (IN/IN)	STRAIN CASE B3 (IN/IN)	AVERAGE (MICRO- STRAIN)	TEMP. SLAB (DEGREES F)	STRAIN CASE B4 (IN/IN)	STRAIN CASE B5 (IN/IN)	STRAIN CASE B6 (IN/IN)	AVERAGE (MICRO- STRAIN)
0	79	0.00000	0.00000	0.00000	0	79	0.00000	0.00000	0.00000	0
170	72	0.00000	0.00000	0.00000	0	72	0.00000	0.00000	0.00000	0
173	72	0.00032	0.00003	0.00024	21	71	-0.00119	0.00000	-0.00261	-127
183	60	-0.00032	-0.00004	-0.00041	-35	60	-0.00132	0.00050	-0.00301	-161
223	64	-0.00035	-0.00043	-0.00043	-42	63	-0.00173	0.00104	-0.00227	-215
247	75	0.00000	-0.00017	0.00027	2	31	-0.00124	0.00059	-0.00330	-171
255	85	0.00020	0.00023	0.00037	43	31	-0.00084	0.00056	-0.00320	-120
252	80	0.00045	0.00050	0.00055	24	80	-0.00164	0.00036	-0.00336	-218
261	85	0.00000	0.00008	0.00013	7	83	-0.00164	0.00147	-0.00420	-254
263	86	0.00028	0.00028	0.00044	29	85	-0.00203	0.00167	-0.00420	-270
274	84	-0.00019	-0.00032	0.00077	-87	86	-0.00036	0.00147	-0.00420	-257
278	79	-0.00133	-0.00092	-0.00092	-6	20	-0.00036	0.00233	-0.00590	-348
281	76	-0.00159	-0.00130	-0.00039	-126	77	-0.00037	0.00260	-0.00556	-378
291	69	-0.00183	-0.00170	-0.00129	-161	70	-0.00310	0.00222	-0.00501	-421
302	71	-0.00221	-0.00220	-0.00152	-201	71	-0.00401	0.00354	-0.00639	-471
315	80	-0.00181	-0.00165	-0.00120	-153	86	-0.00312	0.00254	-0.00542	-373
334	71	-0.00227	-0.00212	-0.00179	-206	76	-0.00397	0.00350	-0.00606	-451
340	65	-0.00229	-0.00251	-0.00219	-250	66	-0.00407	0.00344	-0.00603	-405
356	57	-0.00212	-0.00287	-0.00257	-335	57	-0.00435	0.00439	-0.00643	-528
391	47	-0.00370	-0.00332	-0.00318	-347	47	-0.00477	0.00459	-0.00751	-552
402	25	-0.00320	-0.00335	-0.00335	-375	28	-0.00520	0.00530	-0.00751	-552
451	23	-0.00432	-0.00405	-0.00378	-423	21	-0.00509	0.00503	-0.00836	-611
485	33	-0.00418	-0.00321	-0.00356	-333	25	-0.00531	0.00520	-0.00836	-633
517	52	-0.00332	-0.00350	-0.00320	-347	49	-0.00471	0.00418	-0.00690	-563
543	57	-0.00328	-0.00308	-0.00320	-306	53	-0.00431	0.00383	-0.00719	-511
580	82	-0.00181	-0.00192	-0.00163	-182	97	-0.00306	0.00323	-0.00547	-372
610	74	-0.00321	-0.00251	-0.00185	-223	63	-0.00374	0.00322	-0.00559	-432
640	73	-0.00279	-0.00257	-0.00210	-243	61	-0.00433	0.00374	-0.00621	-493
655	65	-0.00318	-0.00321	-0.00335	-312	73	-0.00455	0.00352	-0.00613	-529
731	50	-0.00403	-0.00441	-0.00353	-411	46	-0.00572	0.00353	-0.00701	-599
753	33	-0.00494	-0.00533	-0.00453	-537	27	-0.00641	0.00353	-0.00731	-731
783	29	-0.00500	-0.00524	-0.00452	-535	27	-0.00655	0.00373	-0.00731	-731
820	10	-0.00503	-0.00529	-0.00453	-577	6	-0.00746	0.00352	-0.00836	-833
850	34	-0.00480	-0.00502	-0.00450	-534	33	-0.00746	0.00354	-0.00836	-833
900	51	-0.00334	-0.00401	-0.00349	-419	52	-0.00623	0.00234	-0.00730	-633
913	50	-0.00425	-0.00414	-0.00417	-478	50	-0.00553	0.00233	-0.00695	-695
940	74	-0.00405	-0.00409	-0.00353	-389	82	-0.00541	0.00227	-0.00633	-632
953	77	-0.00323	-0.00340	-0.00319	-322	85	-0.00542	0.00233	-0.00633	-645
1000	73	-0.00405	-0.00425	-0.00350	-376	84	-0.00577	0.00233	-0.00633	-650
1023	72	-0.00423	-0.00432	-0.00320	-371	76	-0.00577	0.00233	-0.00633	-650
1051	62	-0.00455	-0.00453	-0.00353	-407	64	-0.00502	0.00235	-0.00633	-678
1089	51	-0.00517	-0.00537	-0.00418	-475	48	-0.00637	0.00265	-0.00765	-704
1118	38	-0.00521	-0.00512	-0.00434	-453	27	-0.00724	0.00265	-0.00765	-833
1202	39	-0.00527	-0.00512	-0.00434	-475	40	-0.00740	0.00265	-0.00765	-833
1242	47	-0.00527	-0.00512	-0.00434	-475	40	-0.00740	0.00265	-0.00765	-833
1333	80	-0.00482	-0.00482	-0.00357	-384	45	-0.00551	0.00265	-0.00765	-833
1353	77	-0.00415	-0.00415	-0.00357	-357	75	-0.00510	0.00265	-0.00765	-833
1437	60	-0.00319	-0.00319	-0.00273	-255	57	-0.00532	0.00265	-0.00765	-833
1462	51	-0.00312	-0.00312	-0.00273	-255	62	-0.00532	0.00265	-0.00765	-833
1521	45	-0.00312	-0.00312	-0.00273	-255	43	-0.00532	0.00265	-0.00765	-833
1543	25	-0.00312	-0.00312	-0.00273	-255	46	-0.00532	0.00265	-0.00765	-833
1583	33	-0.00312	-0.00312	-0.00273	-255	40	-0.00532	0.00265	-0.00765	-833
1633	53	-0.00312	-0.00312	-0.00273	-255	57	-0.00532	0.00265	-0.00765	-833

SEGMENT 20A

Table B3. Strain Data.

TIME (DAYS)	TEMP. (DEGREES F)	SLAB (IN/IN)	STRAIN GAGE A16 (IN/IN)	STRAIN GAGE A17 (IN/IN)	STRAIN GAGE A18 (IN/IN)	AVERAGE (MICRO- STRAIN)	TEMP. TOP SLAB (DEGREES F)	STRAIN GAGE A13 (IN/IN)	STRAIN GAGE A14 (IN/IN)	STRAIN GAGE A15 (IN/IN)	AVERAGE (MICRO- STRAIN)
0	83	0.00000	0.00000	0.00000	0.00000	0	84	0.00000	0.00000	0.00000	0
24	82	0.00000	0.00000	0.00000	0.00000	0	81	0.00000	0.00000	0.00000	0
26	85	0.00045	0.00137	0.00000	0.00000	91	89	0.00098	0.00058	0.00091	85
31	85	0.00010	0.00035	0.00035	0.00035	27	85	0.00038	0.00014	0.00031	22
33	87	0.00014	0.00037	0.00054	0.00054	29	85	0.00005	0.00017	0.00014	22
37	84	0.00029	0.00033	0.00027	0.00027	7	83	0.00015	0.00037	0.00041	-31
101	73	0.00057	0.00030	0.00035	0.00035	-11	89	0.00073	0.00050	0.00078	-31
104	76	0.00034	0.00033	0.00030	0.00030	-31	77	0.00068	0.00107	0.00100	-39
114	69	0.00019	0.00032	0.00033	0.00033	-81	70	0.00035	0.00053	0.00053	-37
125	70	0.00191	0.00153	0.00143	0.00143	-152	70	0.00037	0.00092	0.00104	-34
141	82	0.00227	0.00183	0.00185	0.00185	-174	83	0.00045	0.00063	0.00059	-33
143	81	0.00229	0.00311	0.00355	0.00355	-355	71	0.00167	0.00043	0.00133	-135
157	71	0.00327	0.00337	0.00355	0.00355	-343	76	0.00201	0.00165	0.00163	-169
163	65	0.00443	0.00321	0.00325	0.00325	-355	66	0.00215	0.00221	0.00221	-212
193	57	0.00453	0.00391	0.00401	0.00401	-420	57	0.00224	0.00255	0.00271	-230
207	47	0.00433	0.00442	0.00452	0.00452	-422	47	0.00272	0.00299	0.00298	-230
225	35	0.00574	0.00504	0.00543	0.00543	-527	31	0.00322	0.00359	0.00357	-233
234	23	0.00615	0.00549	0.00593	0.00593	-559	28	0.00359	0.00425	0.00423	-432
238	23	0.00555	0.00532	0.00533	0.00533	-539	29	0.00378	0.00372	0.00337	-232
240	42	0.00515	0.00453	0.00453	0.00453	-475	43	0.00263	0.00301	0.00255	-233
271	57	0.00463	0.00434	0.00413	0.00413	-421	53	0.00234	0.00259	0.00261	-235
403	82	0.00729	0.00729	0.00735	0.00735	-363	87	0.00132	0.00162	0.00161	-113
424	74	0.00450	0.00434	0.00431	0.00431	-393	83	0.00133	0.00227	0.00209	-113
453	73	0.00349	0.00452	0.00415	0.00415	-472	81	0.00224	0.00230	0.00270	-231
518	65	0.00335	0.00505	0.00500	0.00500	-530	73	0.00035	0.00032	0.00030	-233
534	50	0.00339	0.00528	0.00542	0.00542	-619	46	0.00411	0.00453	0.00443	-435
532	33	0.00742	0.00716	0.00694	0.00694	-717	27	0.00423	0.00522	0.00453	-435
611	23	0.00715	0.00697	0.00634	0.00634	-672	27	0.00424	0.00571	0.00527	-527
643	10	0.00932	0.00714	0.00705	0.00705	-740	5	0.00551	0.00632	0.00559	-521
673	34	0.00740	0.00723	0.00694	0.00694	-639	33	0.00444	0.00525	0.00453	-475
703	51	0.00351	0.00376	0.00354	0.00354	-530	52	0.00390	0.00431	0.00402	-433
723	50	0.00707	0.00532	0.00512	0.00512	-650	32	0.00395	0.00482	0.00430	-433
763	74	0.00352	0.00593	0.00592	0.00592	-612	82	0.00361	0.00438	0.00420	-436
791	77	0.00339	0.00573	0.00551	0.00551	-608	85	0.00394	0.00439	0.00437	-433
823	78	0.00566	0.00593	0.00594	0.00594	-622	84	0.00363	0.00453	0.00395	-432
851	72	0.00678	0.00519	0.00524	0.00524	-627	76	0.00403	0.00435	0.00441	-431
834	64	0.00703	0.00555	0.00513	0.00513	-652	64	0.00463	0.00540	0.00473	-434
912	51	0.00207	0.00735	0.00692	0.00692	-741	48	0.00523	0.00507	0.00543	-533
941	29	0.00308	0.00735	0.00723	0.00723	-655	27	0.00655	0.00712	0.00658	-623
933	38	0.00763	0.00735	0.00735	0.00735	-752	40	0.00655	0.00622	0.00576	-591
1025	39	0.00773	0.00735	0.00735	0.00735	-752	40	0.00655	0.00622	0.00576	-591
1065	47	0.00749	0.00715	0.00693	0.00693	-735	40	0.00655	0.00622	0.00576	-591
1112	66	0.00330	0.00632	0.00633	0.00633	-715	45	0.00654	0.00610	0.00516	-534
1153	80	0.00356	0.00584	0.00545	0.00545	-632	45	0.00416	0.00479	0.00453	-433
1181	77	0.00359	0.00529	0.00545	0.00545	-653	75	0.00432	0.00482	0.00438	-433
1230	60	0.00770	0.00714	0.00691	0.00691	-719	50	0.00379	0.00455	0.00399	-431
1256	51	0.00323	0.00734	0.00727	0.00727	-737	52	0.00395	0.00530	0.00516	-537
1291	45	0.00330	0.00639	0.00603	0.00603	-642	48	0.00359	0.00460	0.00573	-532
1347	25	0.00332	0.00639	0.00603	0.00603	-642	46	0.00319	0.00495	0.00633	-531
1381	39	0.00354	0.00634	0.00618	0.00618	-691	22	0.00437	0.00730	0.00707	-713
1411	33	0.00330	0.00632	0.00618	0.00618	-689	40	0.00454	0.00735	0.00730	-635
1446	53	0.00334	0.00673	0.00673	0.00673	-754	37	0.00516	0.00705	0.00654	-635
			0.000754	0.00063	0.00063	-754	57	0.00534	0.00949	0.00951	-635

Table B4. Strain Data.

TIME (DAYS)	TEMP. SLAB (DEGREES F)	STRAIN CASE B7 (IN/IN)	STRAIN CASE B8 (IN/IN)	STRAIN CASE B9 (IN/IN)	AVERAGE (MICRO- STRAIN)	TEMP. SLAB (DEGREES F)	STRAIN CASE B10 (IN/IN)	STRAIN CASE B11 (IN/IN)	STRAIN CASE B12 (IN/IN)	AVERAGE (MICRO- STRAIN)
0	81	0.00000	0.00000	0.00000	0	20	0.00000	0.00000	0.00000	0
185	80	0.00000	0.00000	0.00000	0	80	0.00000	0.00000	0.00000	0
183	83	0.00000	0.00000	0.00000	13	89	0.00000	0.00000	0.00000	0
195	85	0.00012	-0.00004	-0.00035	13	85	-0.00002	-0.00005	-0.00014	62
197	87	0.00025	-0.00018	-0.00095	20	85	-0.00032	-0.00033	-0.00016	7
205	79	0.00035	-0.00095	-0.00021	-33	80	-0.00002	-0.00014	-0.00024	27
213	75	0.00023	-0.00127	-0.00100	-33	77	-0.00074	-0.00097	-0.00030	-12
214	75	0.00063	-0.00121	-0.00053	-65	78	-0.00002	-0.00057	-0.00030	-78
218	69	0.00029	-0.00029	-0.00029	-85	70	-0.00011	-0.00087	-0.00093	-102
222	71	-0.00033	-0.00137	-0.00103	-134	71	-0.00126	-0.00143	-0.00108	-136
226	70	-0.00037	-0.00163	-0.00130	-160	86	-0.00149	-0.00007	-0.00005	5
231	71	-0.00025	-0.00234	-0.00205	-253	76	-0.00156	-0.00145	-0.00143	-149
267	65	-0.00325	-0.00337	-0.00255	-413	65	-0.00205	-0.00195	-0.00193	-200
293	57	-0.00275	-0.00416	-0.00327	-426	57	-0.00237	-0.00234	-0.00243	-239
311	47	-0.00374	-0.00463	-0.00353	-448	57	-0.00276	-0.00292	-0.00308	-235
329	36	-0.00234	-0.00337	-0.00307	-473	33	-0.00226	-0.00359	-0.00353	-354
372	23	-0.00427	-0.00552	-0.00377	-542	21	-0.00408	-0.00412	-0.00433	-419
412	23	-0.00440	-0.00534	-0.00509	-528	25	-0.00379	-0.00372	-0.00358	-330
444	42	-0.00405	-0.00451	-0.00434	-434	49	-0.00235	-0.00302	-0.00317	-201
475	57	-0.00351	-0.00425	-0.00470	-419	59	-0.00272	-0.00274	-0.00281	-276
507	82	-0.00323	-0.00392	-0.00407	-337	97	-0.00135	-0.00165	-0.00185	-152
522	74	-0.00342	-0.00376	-0.00431	-355	88	-0.00105	-0.00221	-0.00243	-213
557	73	-0.00322	-0.00431	-0.00430	-434	81	-0.00235	-0.00234	-0.00305	-329
582	65	-0.00437	-0.00455	-0.00445	-480	73	-0.00207	-0.00343	-0.00376	-329
590	50	-0.00523	-0.00435	-0.00359	-535	46	-0.00416	-0.00442	-0.00427	-422
606	23	-0.00632	-0.00631	-0.00529	-673	27	-0.00495	-0.00531	-0.00516	-514
715	23	-0.00517	-0.00525	-0.00421	-667	27	-0.00495	-0.00539	-0.00555	-511
777	10	-0.00327	-0.00727	-0.00312	-739	6	-0.00323	-0.00333	-0.00355	-473
777	34	-0.00334	-0.00637	-0.00376	-642	33	-0.00453	-0.00483	-0.00476	-473
807	51	-0.00484	-0.00555	-0.00339	-533	52	-0.00475	-0.00412	-0.00413	-400
816	50	-0.00529	-0.00574	-0.00435	-639	50	-0.00427	-0.00481	-0.00468	-432
837	74	-0.00503	-0.00575	-0.00471	-597	82	-0.00357	-0.00423	-0.00406	-335
835	77	-0.00555	-0.00555	-0.00397	-552	85	-0.00355	-0.00420	-0.00413	-335
847	78	-0.00433	-0.00423	-0.00357	-526	84	-0.00350	-0.00352	-0.00393	-370
853	72	-0.00450	-0.00423	-0.00381	-558	76	-0.00407	-0.00443	-0.00442	-434
853	64	-0.00573	-0.00465	-0.00421	-621	54	-0.00477	-0.00499	-0.00512	-435
1016	51	-0.00323	-0.00595	-0.00474	-635	43	-0.00557	-0.00552	-0.00536	-568
1037	23	-0.00705	-0.00723	-0.00526	-775	27	-0.00584	-0.00584	-0.00568	-672
1123	23	-0.00524	-0.00720	-0.00747	-730	40	-0.00577	-0.00522	-0.00507	-593
1169	47	-0.00524	-0.00623	-0.00747	-638	40	-0.00552	-0.00522	-0.00572	-552
1169	65	-0.00517	-0.00527	-0.00403	-643	46	-0.00535	-0.00547	-0.00527	-503
1217	65	-0.00373	-0.00570	-0.00503	-572	78	-0.00439	-0.00430	-0.00456	-423
1217	80	-0.00273	-0.00473	-0.00353	-522	97	-0.00277	-0.00302	-0.00327	-362
1235	77	-0.00315	-0.00575	-0.00503	-574	50	-0.00327	-0.00413	-0.00422	-414
1304	60	-0.00505	-0.00670	-0.00613	-671	62	-0.00527	-0.00542	-0.00527	-542
1350	51	-0.00337	-0.00735	-0.00637	-723	43	-0.00537	-0.00502	-0.00512	-500
1325	45	-0.00740	-0.00690	-0.00643	-795	46	-0.00645	-0.00657	-0.00657	-723
1451	25	-0.00227	-0.00227	-0.00227	-555	22	-0.00715	-0.00733	-0.00722	-723
1425	39	-0.00725	-0.00725	-0.00725	-824	40	-0.00620	-0.00714	-0.00627	-594
1515	33	-0.00323	-0.00323	-0.00323	-724	37	-0.00545	-0.00634	-0.00653	-633
1515	53	-0.00547	-0.00727	-0.00727	-718	57	-0.00577	-0.00537	-0.00555	-593

SECTION 21A

Table B5. Strain Data.

TIME (DAYS)	TEMP. SLAB (DEGREES F)	STRAIN GAGE A10 (IN/IN)	STRAIN GAGE A11 (IN/IN)	STRAIN GAGE A12 (IN/IN)	AVERAGE TEMP. (MICRO- SLAB STRAIN) (DEGREES F)	STRAIN GAGE A7 (IN/IN)	STRAIN GAGE A8 (IN/IN)	STRAIN GAGE A9 (IN/IN)	AVERAGE (MICRO- STRAIN)
0	81	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0
119	22	0.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0
121	65	0.000026	0.000070	0.000020	75	0.000063	0.000055	-0.000071	79
122	83	0.000034	0.000058	0.000043	53	0.000033	0.000035	-0.000035	45
130	87	0.000030	0.000045	0.000042	53	0.000044	0.000040	-0.000017	20
134	84	0.000032	0.000050	0.000035	54	0.000002	0.000055	-0.000015	14
139	79	0.000051	0.000005	0.000013	27	0.000063	-0.000031	-0.000044	-48
141	76	0.000017	0.000023	0.000010	13	0.000104	-0.000076	-0.000079	-85
151	69	0.000045	0.000051	0.000050	-52	0.000098	0.000079	0.000035	-91
153	70	0.000108	0.000119	0.000053	-107	0.000072	0.000083	0.000050	-84
172	80	0.000151	0.000150	0.000135	-145	0.000017	0.000014	0.000029	-20
185	72	0.000227	0.000272	0.000223	-277	0.000131	0.000155	0.000150	-149
194	71	0.000233	0.000232	0.000233	-285	0.000115	0.000133	0.000129	-123
200	55	0.000333	0.000327	0.000330	-319	0.000155	0.000188	0.000206	-190
226	57	0.000345	0.000342	0.000330	-349	0.000218	0.000226	0.000237	-217
244	47	0.000330	0.000333	0.000333	-377	0.000257	0.000347	0.000322	-295
262	35	0.000425	0.000404	0.000403	-416	0.000340	0.000337	0.000375	-320
311	23	0.000472	0.000473	0.000419	-555	0.000357	0.000335	0.000312	-323
345	28	0.000453	0.000429	0.000357	-585	0.000349	0.000325	0.000262	-370
377	42	0.000354	0.000323	0.000310	-624	0.000278	0.000278	0.000231	-320
402	57	0.000271	0.000253	0.000250	-630	0.000203	0.000230	0.000230	-320
440	62	0.000217	0.000232	0.000237	-625	0.000109	0.000140	0.000119	-123
451	74	0.000235	0.000233	0.000230	-622	0.000143	0.000185	0.000170	-137
500	73	0.000317	0.000346	0.000330	-543	0.000207	0.000253	0.000222	-219
555	65	0.000316	0.000433	0.000423	-416	0.000552	0.000523	0.000559	-275
591	50	0.000558	0.000550	0.000515	-520	0.000353	0.000330	0.000343	-332
619	33	0.000533	0.000523	0.000518	-508	0.000430	0.000453	0.000446	-445
628	29	0.000535	0.000619	0.000533	-591	0.000445	0.000457	0.000431	-475
630	10	0.000547	0.000539	0.000530	-572	0.000347	0.000347	0.000374	-353
710	34	0.000535	0.000534	0.000534	-516	0.000405	0.000442	0.000418	-422
740	51	0.000443	0.000500	0.000510	-433	0.000339	0.000354	0.000342	-345
769	50	0.000535	0.000503	0.000514	-571	0.000355	0.000401	0.000406	-391
800	74	0.000455	0.000458	0.000453	-453	0.000301	0.000349	0.000343	-331
823	77	0.000452	0.000453	0.000453	-421	0.000318	0.000359	0.000338	-329
830	78	0.000437	0.000434	0.000433	-420	0.000323	0.000337	0.000338	-329
833	72	0.000475	0.000503	0.000503	-501	0.000320	0.000400	0.000331	-423
891	64	0.000533	0.000533	0.000533	-523	0.000327	0.000455	0.000423	-423
921	51	0.000533	0.000531	0.000531	-512	0.000327	0.000357	0.000351	-423
973	33	0.000533	0.000531	0.000532	-512	0.000327	0.000353	0.000321	-423
1023	38	0.000532	0.000533	0.000532	-514	0.000325	0.000353	0.000321	-423
1032	39	0.000533	0.000533	0.000532	-513	0.000325	0.000353	0.000321	-423
1102	47	0.000533	0.000533	0.000532	-513	0.000325	0.000353	0.000321	-423
1142	65	0.000532	0.000533	0.000532	-513	0.000325	0.000353	0.000321	-423
1190	80	0.000452	0.000452	0.000453	-475	0.000329	0.000370	0.000370	-423
1218	77	0.000447	0.000452	0.000452	-513	0.000329	0.000353	0.000353	-423
1257	60	0.000535	0.000533	0.000533	-520	0.000471	0.000509	0.000493	-423
1333	51	0.000557	0.000532	0.000532	-523	0.000524	0.000524	0.000524	-523
1383	43	0.000717	0.000747	0.000747	-714	0.000534	0.000523	0.000523	-523
1434	25	0.000729	0.000744	0.000744	-711	0.000531	0.000523	0.000523	-523
1419	29	0.000724	0.000724	0.000724	-712	0.000531	0.000523	0.000523	-523
1445	33	0.000555	0.000555	0.000555	-634	0.000523	0.000523	0.000523	-523
1493	53	0.000557	0.000557	0.000553	-634	0.000561	0.000561	0.000561	-523

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