First Progress Report

EXPERIMENTAL INVESTIGATION OF A PRESTRESSED STEEL BEAM-CONCRETE SLAB BRIDGE UNIT

Initial Creep Test Results

by

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CHAPTER I

INTRODUCTION

1.1 Background

A study is being undertaken at the Fears Structural Engineering Laboratory, University of Oklahoma, under the sponsorship of the Oklahoma Department of Transportation to study the strength and stiffness characteristics of a full-scale pre-cast, prestressed steel beam composite bridge unit. The unit is 55 ft. 0 in. long and 6 ft. 9½ in. wide consisting of two W21x50 steel beams and a 7½ in. thick reinforced concrete slab. The unit weighs approximately 40,500 pounds. The objective of the study is to experimentally investigate the behavior of the unit under various types of loading; sustained load, repeated load and static loading to failure. The research project will take three and one-half years beginning in April 1982 with scheduled completion in December 1985. The project consists of four phases: six months of creep observation under sustained load; six months of repeated loading (one million cycles); two and one-half years of creep observation under sustained dead load; and static test to failure.

The purposes of this first progress report are to document the construction of the unit, to report measured material properties, and to report creep data from the initial 60 days of observation.

1.2 Construction

The unit was fabricated by Robberson Steel Company, Oklahoma City, Oklahoma, using design drawings provided by Grossman and Keith Engineering

Company, Norman, Oklahoma. The concrete was cast with the beams in an upside-down position using a steel form hung from the beams as shown in Figure 1. Once the concrete was poured and finished, an additional steel weight was placed on the beams. After the concrete had cured the weight and the form were removed. The concrete was poured on April 1, 1982 and the forms were removed on April 8, 1982. The unit was moved to the Fears Structural Engineering Laboratory on April 8, 1982 in an upside-down position using a "pole" truck. The unit was turned over upon delivery as shown in Figure 2. The unit was then placed on two W10x49 beams which were set in 16 in. wide and 4 in. high concrete pads poured on an existing conrete slab. The location is outside and subject to weather conditions. Elastomeric bearing pads were placed between the support beams and the unit beams as shown in Figure 3. On April 22, 1982 concrete blocks weighing 33±0.1 pounds each were placed on the unit as shown in Figure 4 to simulate dead load from an asphalt overlay.

The following chapters detail the test unit measured material properties and sustained loading data recorded during the first sixty days.

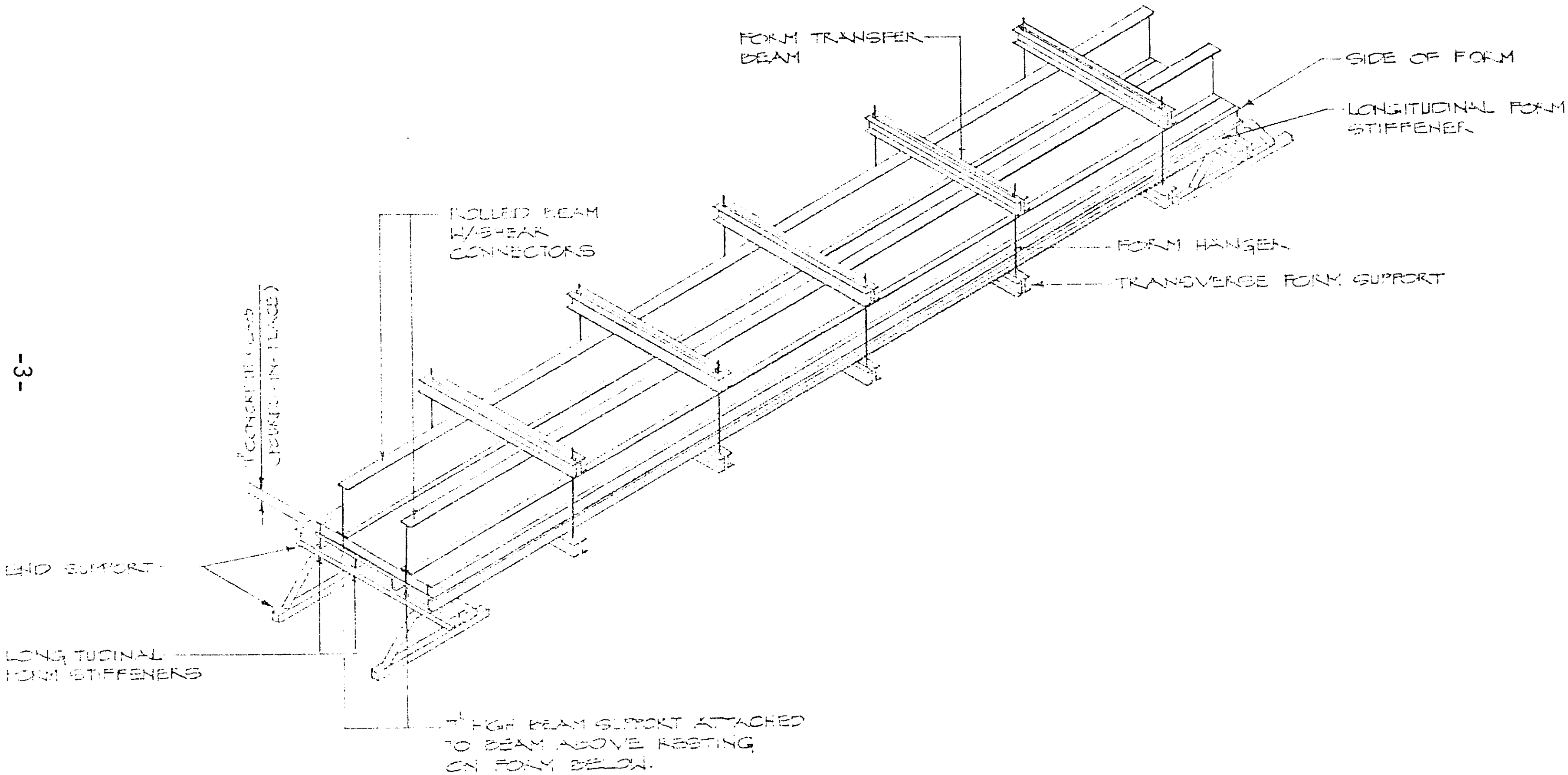


Figure 1. Method of Fabrication

CHAPTER II

TEST SPECIMEN DETAILS

2.1 Specimen

The full scale unit is 55'-0" long and 6'-9" wide and consists of two steel beams (W21x50) and a 7½ in. thick reinforced concrete slab. The concrete slab is reinforced with #4 bars both longitudinally and transversely. The longitudinal bars are spaced at 9 in. at the top and 18 in. at the bottom of the slab as shown in Figure 4. The closer spacing at the top is intended primarily to minimize creep strains in the concrete slab. Both top and bottom transverse reinforcement was placed at variable intervals symmetrically about the mid-span. Starting from the mid-span and going toward each end, the spacings were 5½ in., 11 in. and 16½ in. for each one-sixth of the span length. The intention of this variable spacing is to study the influence of transverse reinforcement on the transverse strength of the concrete slab at a possible later stage.

2.2 Materials

Concrete. An air-entrained concrete with a design strength of 5000 psi was used for the unit. The concrete was obtained from a local ready-mix plant, and was manufactured with Type III portland cement and normal weight aggregate having a maximum size of about 1 inch. The design slump was between 1 and 3 inches.

During the pouring of the concrete, a total of fifty 6x12 in. control cylinders were cast from the two mixing trucks. Slump tests were performed before the cylinders were cast. Water was added at that time and additional mixing was done until the appropriate slump was achieved. Ten cylinders were cast for approximately each half of each truck designated as Series 1A and 1B for the first truck Series 2A and 2B for the second truck. Because of high slump obtained for the second half of the second truck, an additional ten cylinders were cast for that half (Series 2C). The amount of entrapped and entrained air was determined using electron-microscope scanning. The slump, air content, age and strengths of concrete are given in Table 1. The influence of age on the compressive strength of concrete is shown in Figure 5.

Steel. The two steel beams were standard W21x50 sections of A588 steel. Deformed steel bars of Grade 60 steel were used as reinforcement for the concrete slab deck. The stress-strain curves for the reinforcing bars obtained from tension tests of coupons supplied by fabricator are shown in Figure 6.

2.3 Fabrication and Installation

Shear connectors were welded to the W21x50 beams before the beams were placed in the forms. Shear connectors consisted of standard steel studs and short sections of hot-rolled channel. Two studs were welded to the top flange of each beam with variable spacing. The spacing varies from 12 in. at each end to 30 in. at the mid-span as shown in Figure 7. C7x9.8 by 6 in. long channels were welded to the top flange of each beam at 9'-0" intervals. These channels were used as spacers to ensure uniform thickness of the concrete slab deck.

The beam sections were connected together at the ends and third points with a welded diaphragm consisting of 3x3x¼ angles. Details are shown in Figure 8. Center-to-Center spacing of the beams was 3 ft. 9½ in.

Top and bottom slab reinforcement mats were preassembled and tied using standard practices in a specially constructed layout template. All of the longitudinal reinforcing bars were of single length except for those that were strain gaged. The longitudinal bars with strain gages were lap-spliced at the third points with a splice length of 2 ft. 6 in. The reinforcing mats and the beam assembly were then hoisted into well oiled steel forms in the upside-down position. The form work, which was simply supported at the ends, was then hung from the steel beams at 9 ft. 0 in. intervals with hangers as shown in Figure 1. The concrete was then poured and additional weights (approximately 7000 pounds) were placed on the beams at midspan. Shims were used at midspan to limit vertical deflection to 3½ in.

The concrete slab, together with control cylinders, were moist-cured in the formwork for 7 days. The exposed surface of the concrete was covered with web burlap and polythene sheets during the seven-day curing period. On the eighth day after casting, the forms were stripped and the specimen was transferred in the upside-down position from the fabrication shop to the Fears Structural Engineering Laboratory where it was turned over and set on supports (Figure 3).

The 4x8x16 in. solid concrete blocks used to simulate the dead load of the asphalt overlay were obtained from a local manufacturer. The blocks were manufactured from normal weight concrete aggregates and each weighs about 33.0±0.1 pounds.

Table 1
Concrete Properties

Properties	Age (Days)	First Truck		Second Truck		
		First Half (1A)	Second Half (1B)	First Half (2A)	Second Half (2B)	Second Half (2C)
Slump (in)	-	1½	2¼	1 3/4	4¼	4¼
Air Content %	-	5.4	5.4	5.8	5.8	5.8
Entrained Air	-	4.5	4.5	5.0	5.0	5.0
Entrapped Air	-	0.9	0.9	0.8	0.8	0.8
Compressive Strength (Psi)	1	2970	2370	3060	2430	2150
	4	4320	4240	4240	3890	3860
	8	4750	4540	4890	4100	4100
	21	5450	5215	5720	4840	5040
	29	5730	4950	5700	5290	4830

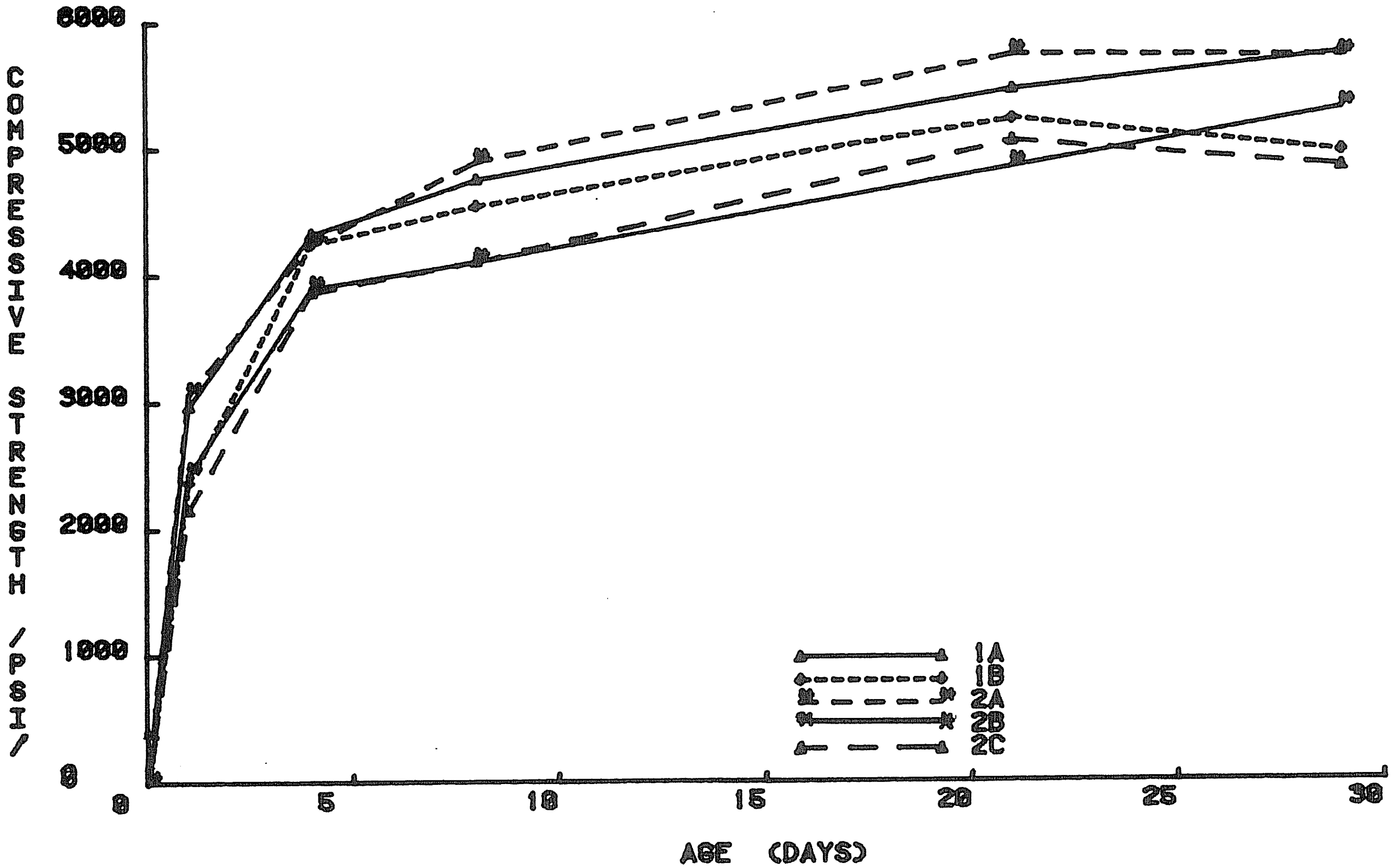


Figure 5. Compressive Strength of Concrete vs. Age

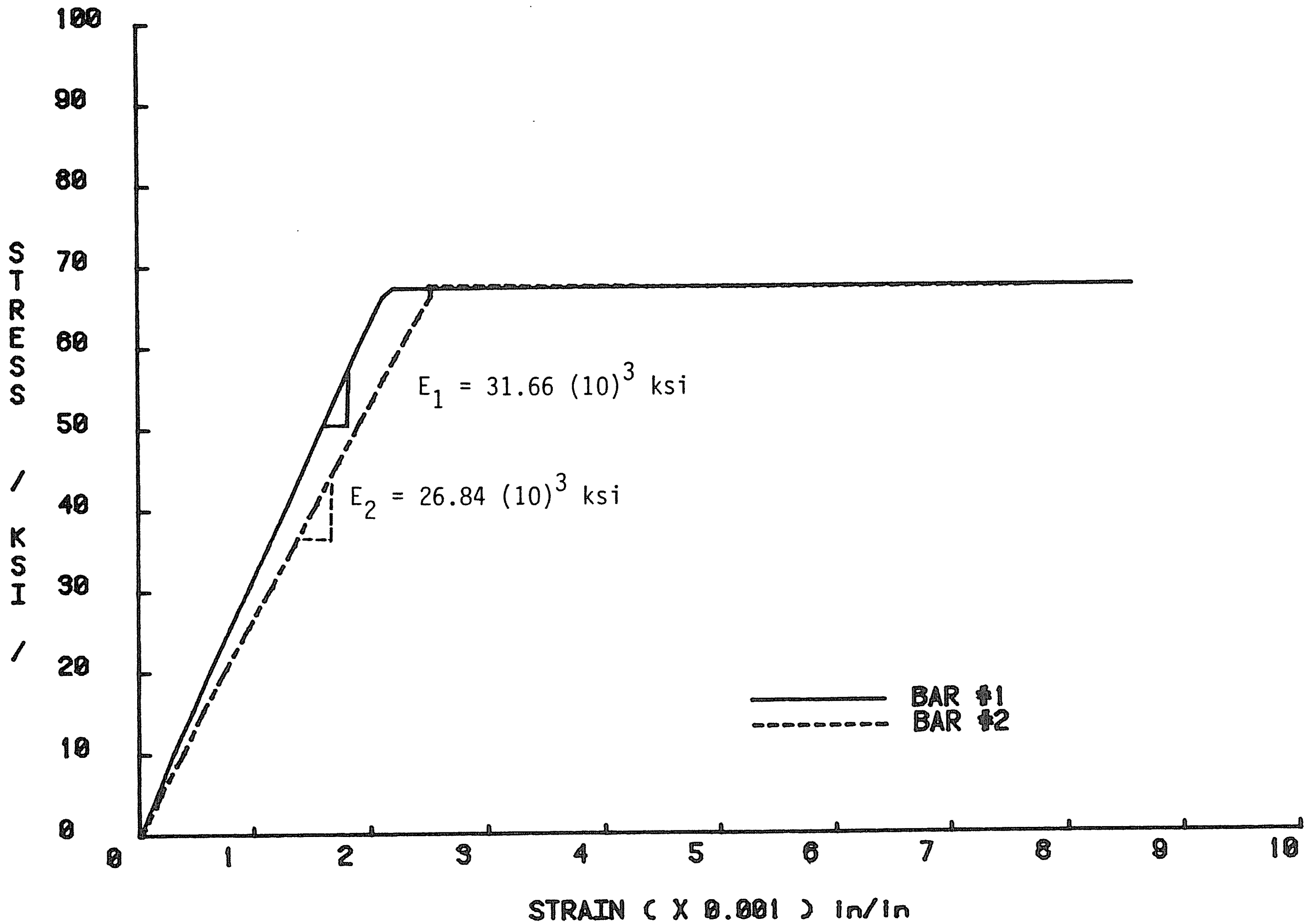


Figure 6. Stress vs. Strain Cruve for Reinforcing Bars

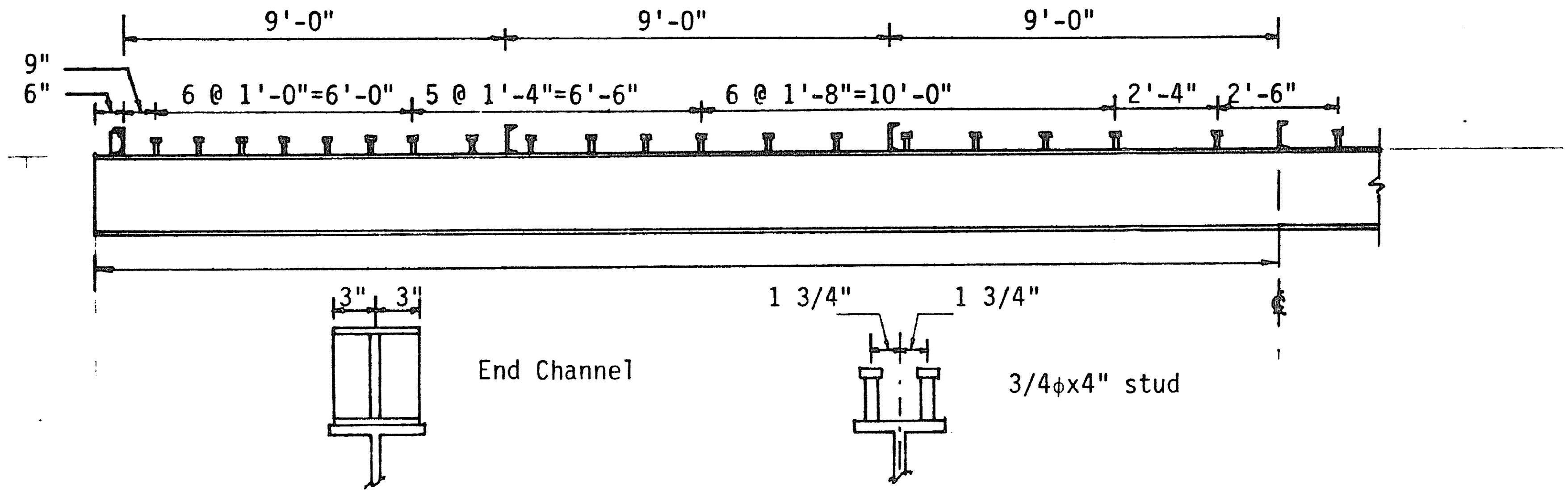


Figure 7. Details of Shear Connectors

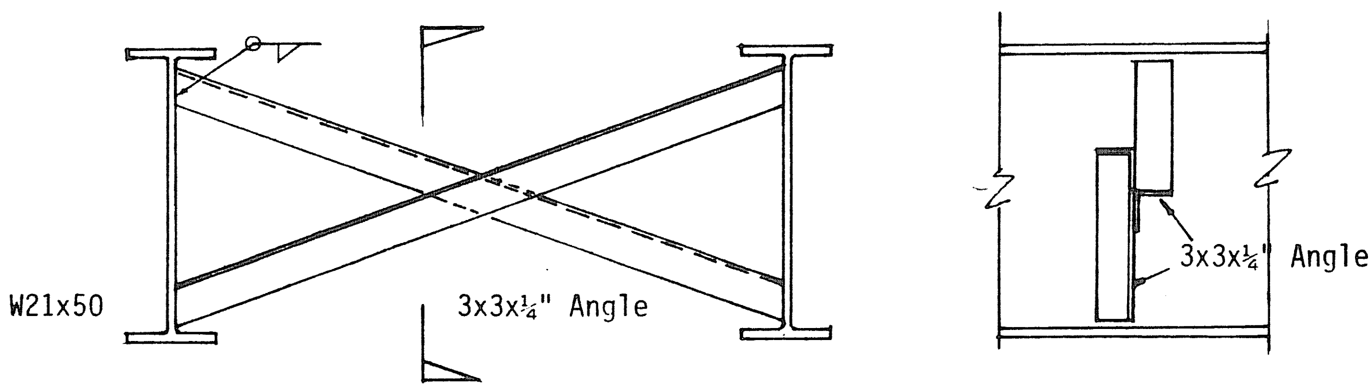


Figure 8. Detail of Diaphragm

CHAPTER III

INSTRUMENTATION AND MEASUREMENTS

3.1 Instrumentation

With the exception of the shear connectors, all components of the bridge unit, reinforcing steel, steel beams and the concrete are fully instrumented. Ten longitudinal reinforcing bars, five top and five bottom were strain gaged longitudinally at the midspan with an electrical resistance strain gage having a gage length of ¼ in. Similar pages were mounted on six transverse reinforcing bars, three top and three bottom. Three gages were placed on the top bars and two on the bottom bars, located as shown in Figure 9. The instrumented transverse bars were located in different spacing regions as discussed previously.

Prior to placing the steel beams in the concrete form, eight ½ in. gage length strain gages were installed on the beam flanges near midspan as shown in Figure 9. The gaged cross-section was 8 in. from midspan to avoid effects induced by a spacer channel located at midspan.

After removal from the forms but prior to turning, two 10 in. gage electrical extensometers were mounted on the top and the bottom surfaced of the concrete and along the longitudinal axis of the unit at midspan. Details are shown in Figure 10.

After the bridge unit was turned over, six concrete strain gages were mounted longitudinally at midspan and on the top surface of the concrete slab. Initially, four strain gages with 2 in. gage length were mounted. These were later replaced with two strain gages with 4 in. gage length as shown in Figure 10.

Once the bridge unit was set in place at the Laboratory, two DCDT deflection transducers were positioned to measure the midspan deflections of the slab near the top flange of each beam as shown in Figure 11. To determine the influence of temperature, a thermometer was attached to the interior portion of each bottom flange. A thermometer was also embedded in the concrete slab.

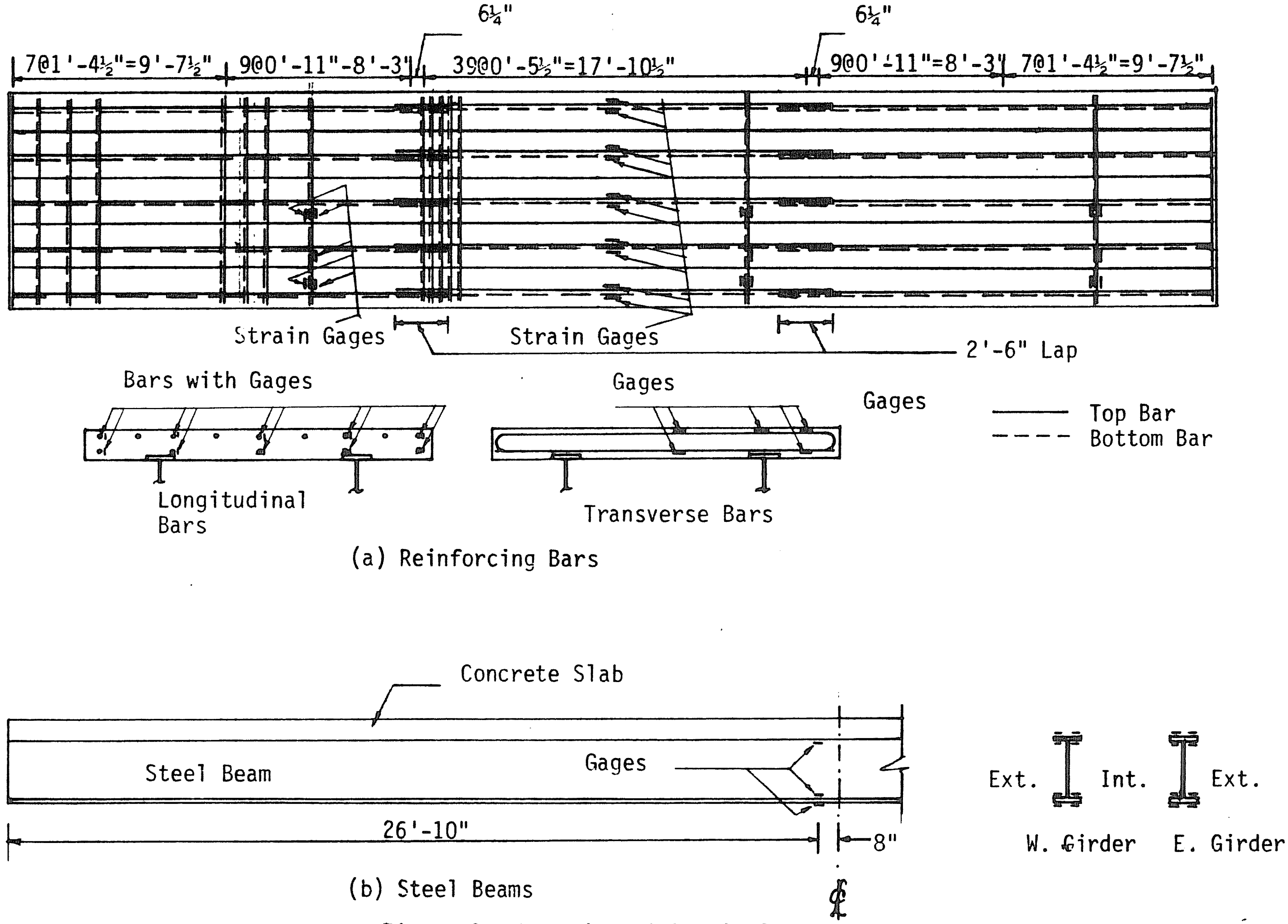
Two switch and balance units and two strain indicator units permanently wired to the strain gages are used to make strain measurements. A d.c. voltage supply and standard voltmeter are used to monitor the deflection transducers. The entire set of measuring instruments is stored in a refrigerator (set at 70^0 F) in a temporary building adjacent to the test unit.

3.2 Measurements

On the seventh day after casting, the additional prestressing weight together with the form hangers were taken off and strain readings were taken. The weight and form hangers were then replaced. This was done to obtain strains due to the spring back effect. The readings are shown in Table 2.

The initial creep test is currently being conducted in the Fears Structural Engineering Laboratory. The unit was brought to the Fears Laboratory on the eighth day of casting, turned over, and set in position. Before the unit was turned over, initial readings were taken for the two extensometers, the six strain gages on the beams, and the ten strain gages on the longitudinal reinforcing bars. After the bridge unit was turned over, readings for the extensometers and the strain gages were again taken to determine the stresses due to the turning over of the unit. Two weeks after the specimen was turned over additional instrumentation of the specimen was completed and additional dead load was applied when the specimen was 21 days old.

Daily readings were taken for the first sixty days of the sustained loading test. Strain data from the nine longitudinal reinforcing bars, strain gages, six beam strain gages, three concrete strain gages, and two extensometers were recorded. In addition, output from the deflection transducers and temperature was recorded at the same time. The weather conditions were also recorded.



(a) Reinforcing Bars

(b) Steel Beams

Figure 9. Location of Strain Gages

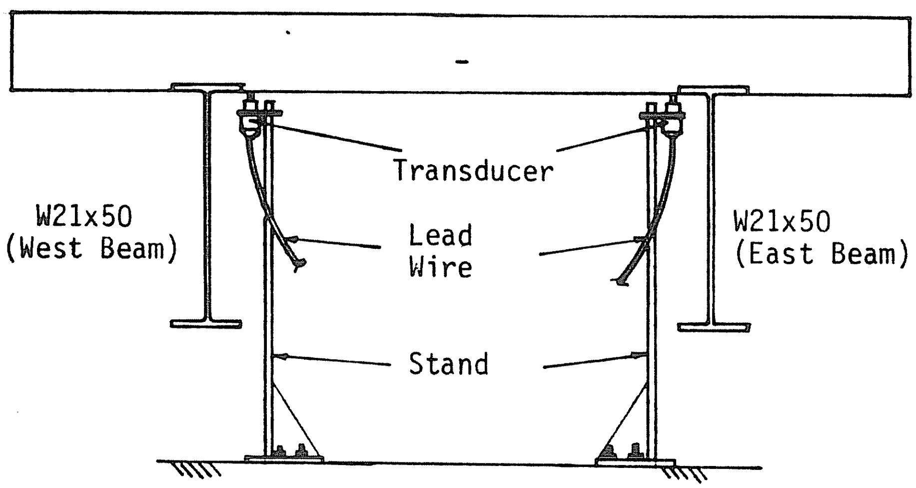
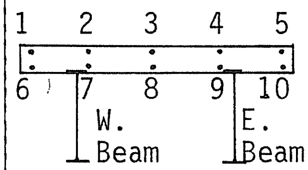
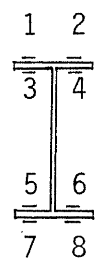


Figure 11. Location of Deflection Transducers

Table 2
Change in Strain Readings When Form Hangers And Additional Prestressing Weight Were Removed

Gage No.	Strain $(10)^{-6}$ in/in		Strain Gage Location
	Longitudinal Reinforcing Bars	West Beam	
1	-	2	
2	-35	1	
3	-25	7	
4	-28	54	Longitudinal Bars
5	-29	136	
6	-	144	
7	-26	135	
8	-1	103	
9	-16	-	
10	-112	-	West Beam

CHAPTER IV

PRELIMINARY CREEP TEST RESULTS

4.1 Test Results

At this time (July 1982) no transverse strains have been measured for either the concrete slab or the transverse reinforcement; only longitudinal strains in the concrete slab, reinforcing bars and steel beams have been measured. Recordings were made on a daily basis between 12 and 3 pm. The results are presented graphically in Figures 12 to 15. Stress data was obtained from strain data using an assumed modulus of elasticity of 29,000 ksi and Hook's law (perfectly elastic material)

Figure 12 depicts the concrete strain variations at midspan along the longitudinal axis of the unit together with changes in temperature. Stress variations in both the top and bottom longitudinal reinforcement are shown in Figure 13. The average deflection of the girders at midspan is illustrated in Figure 14. In Figure 15, the variation in stresses at the top and bottom flanges of the west girder is shown. In Table 3 and Figure 16 changes in the neutral axis position in the steel beam versus time are indicated.

4.2 Discussion

An examination of the results shown in Figures 12 to 15 reveals that all the strain values, and consequently stresses and vertical deflections, are sensitive to changes in temperature. Changes in strain in the steel beams are least affected by temperature variations as shown in Figure 15. Any interpretation of the results will have to take into consideration the variation in temperature.

As expected, strain values in the concrete slab and the reinforcing steel bars increased in a similar manner. The increases in the strain were found to be very rapid during the first few days of observation. Figures 12 and 13 indicate that the strain and stress graphs have not, as yet, asymptotically approached maximum values and creep is still taking place. In Figure 12, it is seen that the strains at the top surface of the concrete slab were significantly more than those at the bottom surface. However, it must be noted that the average temperature has also been increasing since the beginning of the observation period.

Another means of observing the effect of creep is through the measurement of deflection at midspan. Although the deflections results were considerably influenced by temperature as shown in Figure 14, it is also clear that total deflection continues to increase with time, again, indicating creep.

Figure 15 shows that the stresses in the bottom flange of the steel beams increased sharply when the unit was turned over and also when the additional dead load was applied. After the application of the superimposed dead load, the stresses in both the top and bottom flanges continued to gradually increase. Stresses at the top flange increased at a slightly faster rate than those at the bottom flange. This is an indication that the location of the neutral axis is migrating away from the top flange toward the bottom flange. The location of the neutral axis was determined assuming a linear strain distribution within the section. Results of the computations are depicted in Figure 16 and Table 3. Figure 16 shows that the neutral axis moved toward the bottom flange very rapidly during the first week, thereafter the rate of increase reduced considerably.

Table 3 also shows that the strains at the bottom of the interior side of the lower flange were consistently larger than those at the bottom of the exterior side of the lower flange. For the top flange the differences between the strains at the top of the exterior portion of the flange and the strains at the top of the interior portion of the flange were negligible. These differences could be attributed to the fact that the top flange of each beam is continuously braced while the bottom flange is not. The unbraced length of the bottom flange is about 18 ft., the distance between the two interior diaphragms. As a result, the web and the bottom flange of each beam are relatively free to rotate.

Addition of dead load on the slab causes bending of the slab in the direction transverse to the beams. Because of the relatively rigid slab to beam connection, rotation of the slab at the beam location introduces torque into the beams. This torque tends to bend the bottom flanges outward introducing secondary bending stresses in the flanges. The axis of this bending is in the plane of the web and resulting in secondary compressive strains in the exterior part of the bottom flange and tensile strains in the interior part of the bottom flange and decreasing those of the exterior part of the bottom flange.

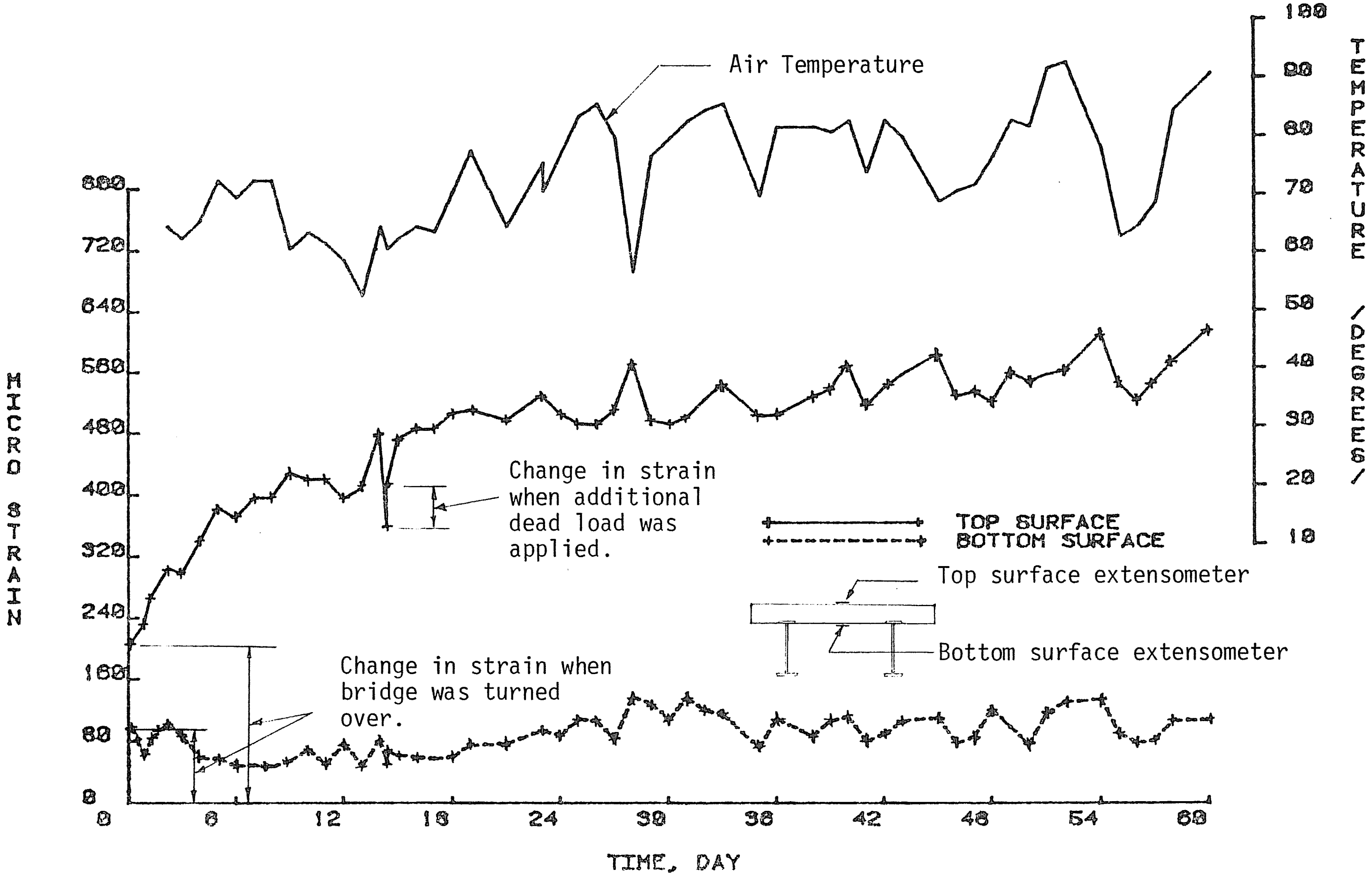


Figure 12. Change in Strain at Concrete Surface vs. Time

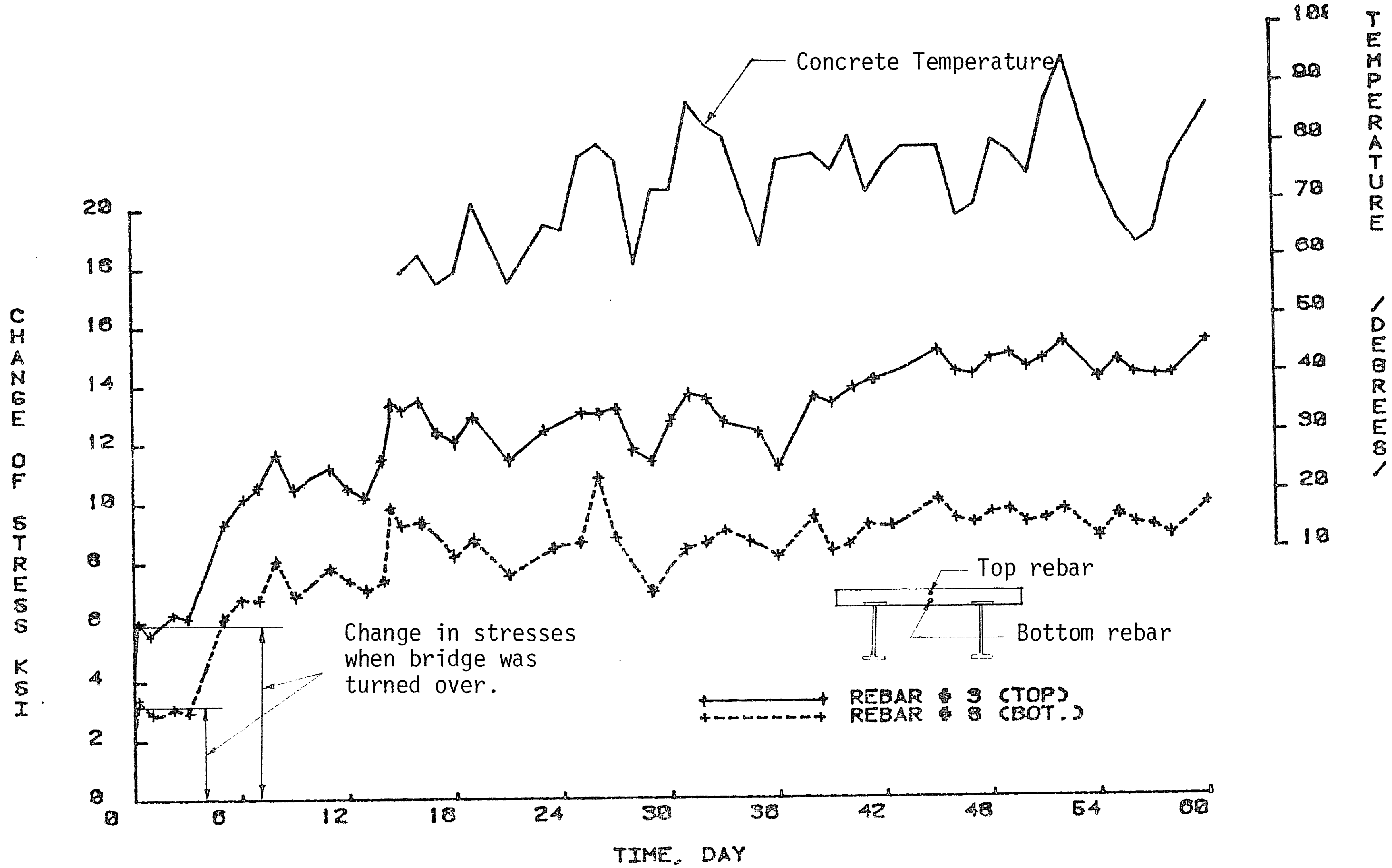


Figure 13. Change in Stress in Longitudinal Reinforcing vs. Time

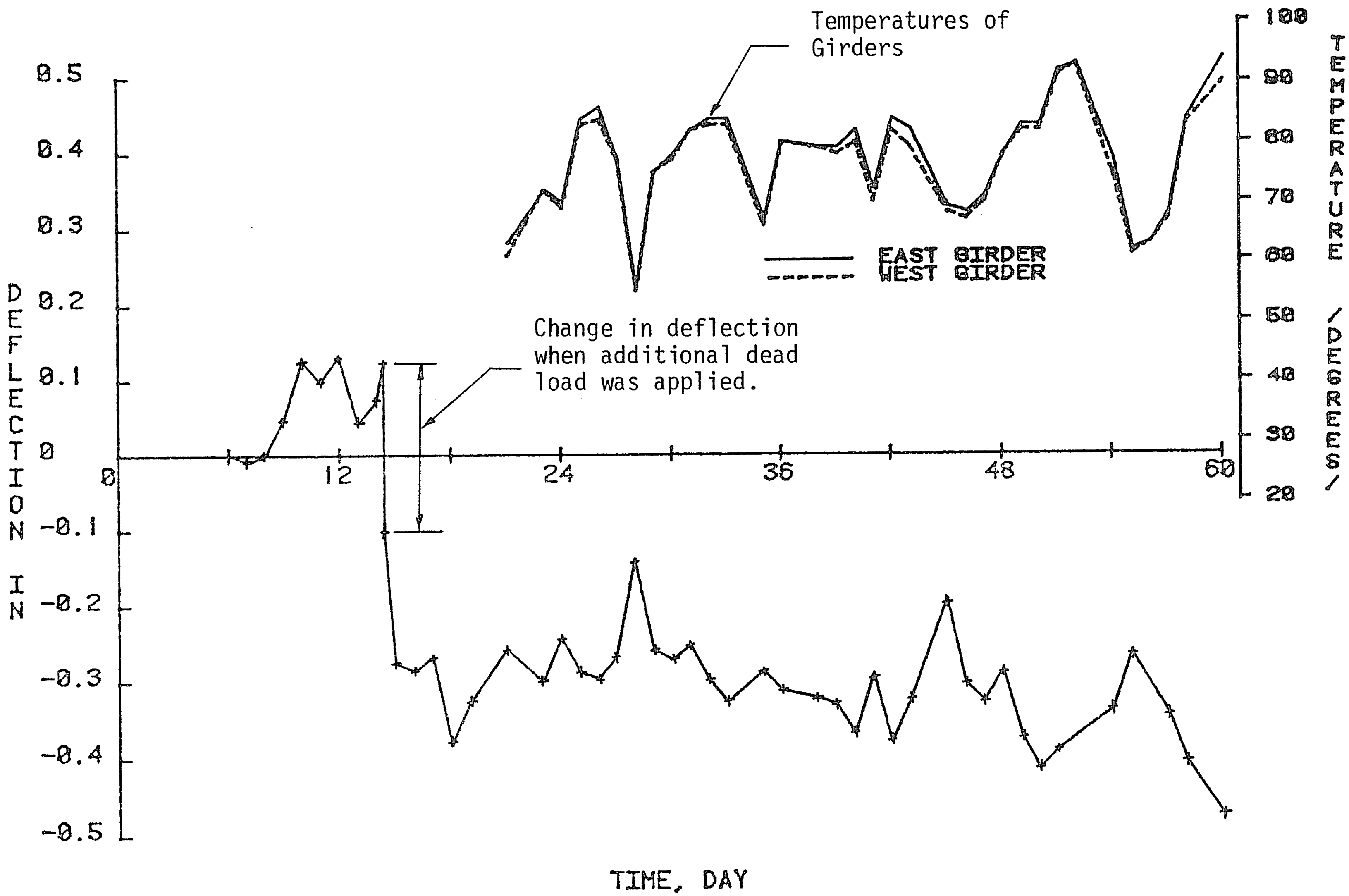


Figure 14. Vertical Deflection vs. Time

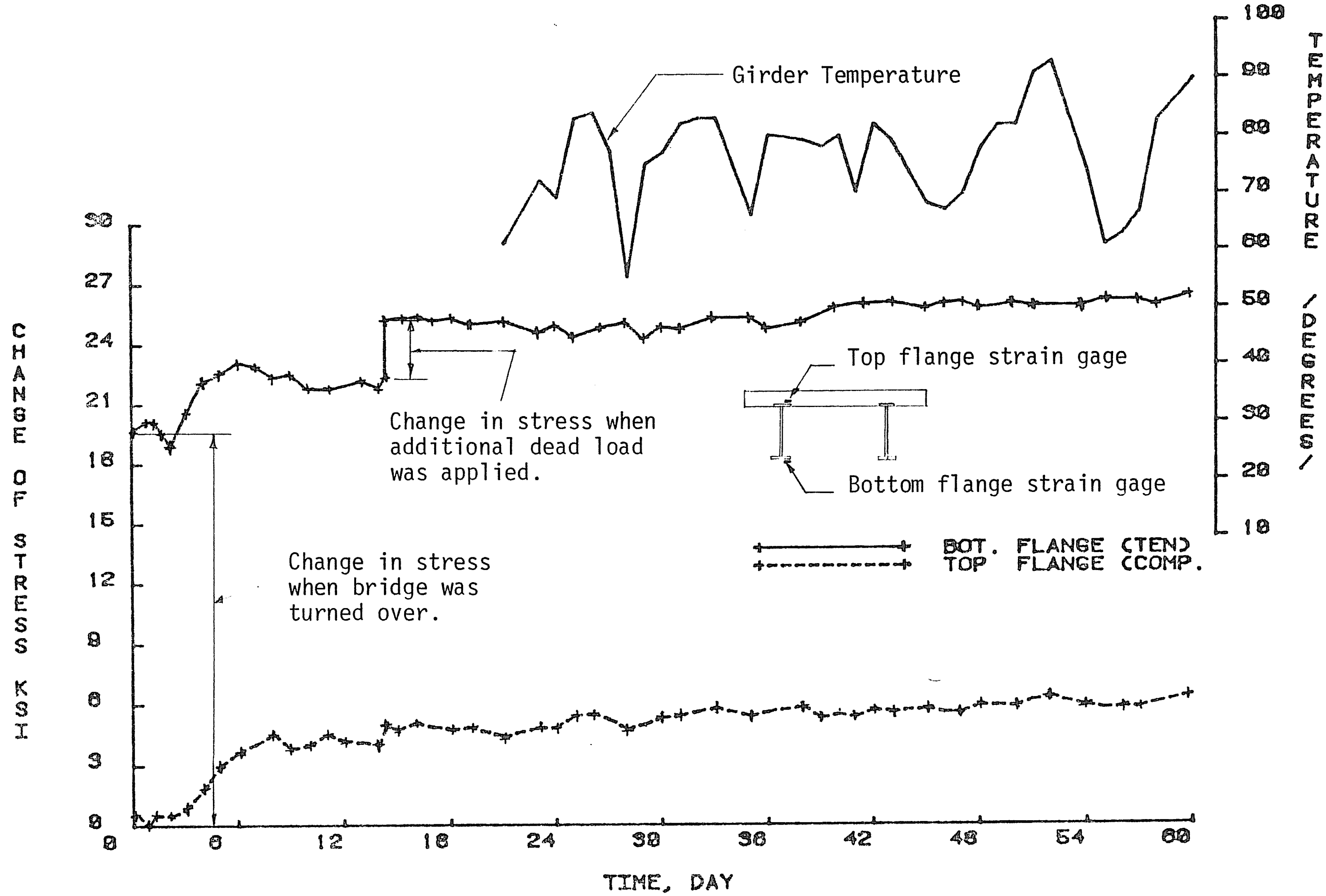


Figure 15. Change in Stress in Steel Beam vs. Time

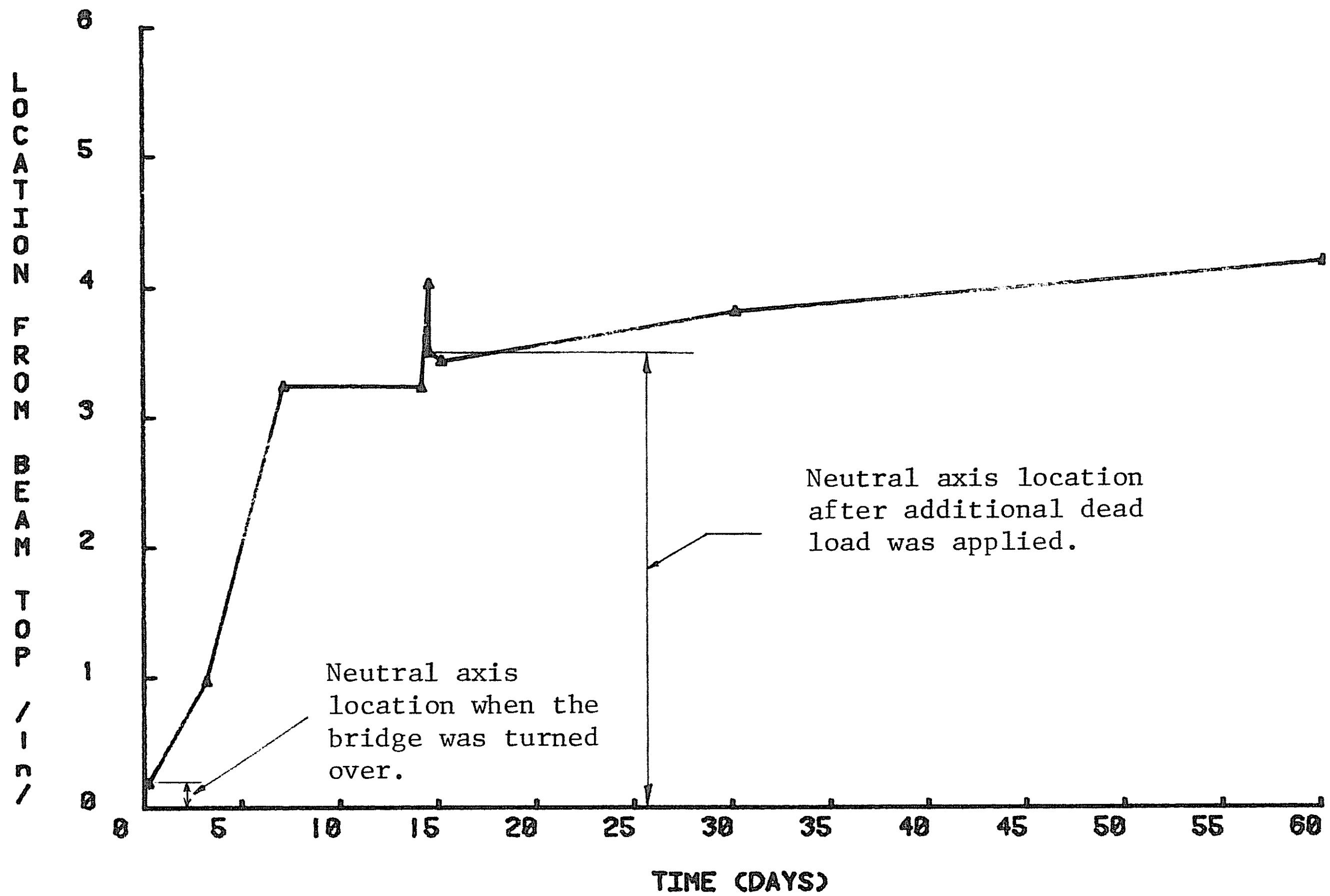


Figure 16. Neutral Axis Location vs. Time

Table 3

Beam Strains and Location of Neutral Axis

Days From Beginning of Observation	W. Beam Strains $(10)^{-6}$ in/in				Average Flange Strain $(10)^{-6}$ in/in		Neutral Axis Location From Top of Beam (in)
	Top of Top Flange		Bottom of Bottom Flange				
	Ext.	Int.	Ext.	Int.	Top	Bottom	
0	-7	-5	626	670	-6	648	0.19
3	-37	-29	649	702	-33	675.5	0.97
7	-140	-140	728	788	-140	758	3.24
14	-146	-137	684	854	-141.5	769	3.23
14.4(1)*	-182	-175	716	769	-178.5	742.5	4.03
14.4(2)*	-174	-166	813	870	-170	841.5	3.50
15	-169	-163	810	873	-166	841.5	3.43
30	-184	-182	778	854	-183	816	3.81
60	-217	-219	816	908	-218	862	4.20

*14.4(1) and 14.4(2), respectively, represent just before and after additional dead load was applied at about mid-night.

CHAPTER V

CONCLUSIONS

Although no firm conclusions can be drawn from the results at this stage of the investigation, it is evident that a) the effects of creep are still taking place at the end of sixty days of measurement and b) that the migration of the neutral axis towards the bottom flange occurred very rapidly during the first week; thereafter the rate of migration reduced considerably.

A second progress report will be proposed at the end of six months of observation.