EVALUATION OF EXPERIMENTAL DATA OBTAINED FROM LIGHTWEIGHT AGGREGATE BRIDGE GIRDERS

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INTRODUCTION AND SCOPE

The use of lightweight aggregates in prestressed concrete is becoming more of a reality as our design criteria become more demanding. Bridge girders of greater lengths have been restricted from travel on many of our highways because the weight of the combined girders and transporting vehicle is excessive making hauls of any distance prohibitive. This, along with new safety recommendations, prompted the State of Iowa to investigate the use of lightweight aggregate bridge girders.

Until recently, it was possible to use 67' bridge girders to cross a two lane section of interstate highway, now it is necessary to have at least an 87' span to provide the necessary clear distance on both sides of the roadway. The new safety standards require that any obstruction such as columns or abutments be at least an additional 10' away from the edge of the pavement. This requirement means that the girders will be increased to at least 87' in length on a right angle crossing. If it should develop that a skewed crossing would be necessary, the length of the girders could conceivably be 90-95 feet in length. With these lengths, the deadload (weight of the girder) due to the normal weight concrete would be more than the state law permits. Figure I shows the relationship between the new and old standards.

A series of three projects was started to investigage the possibility of using lightweight aggregate in prestressed concrete.

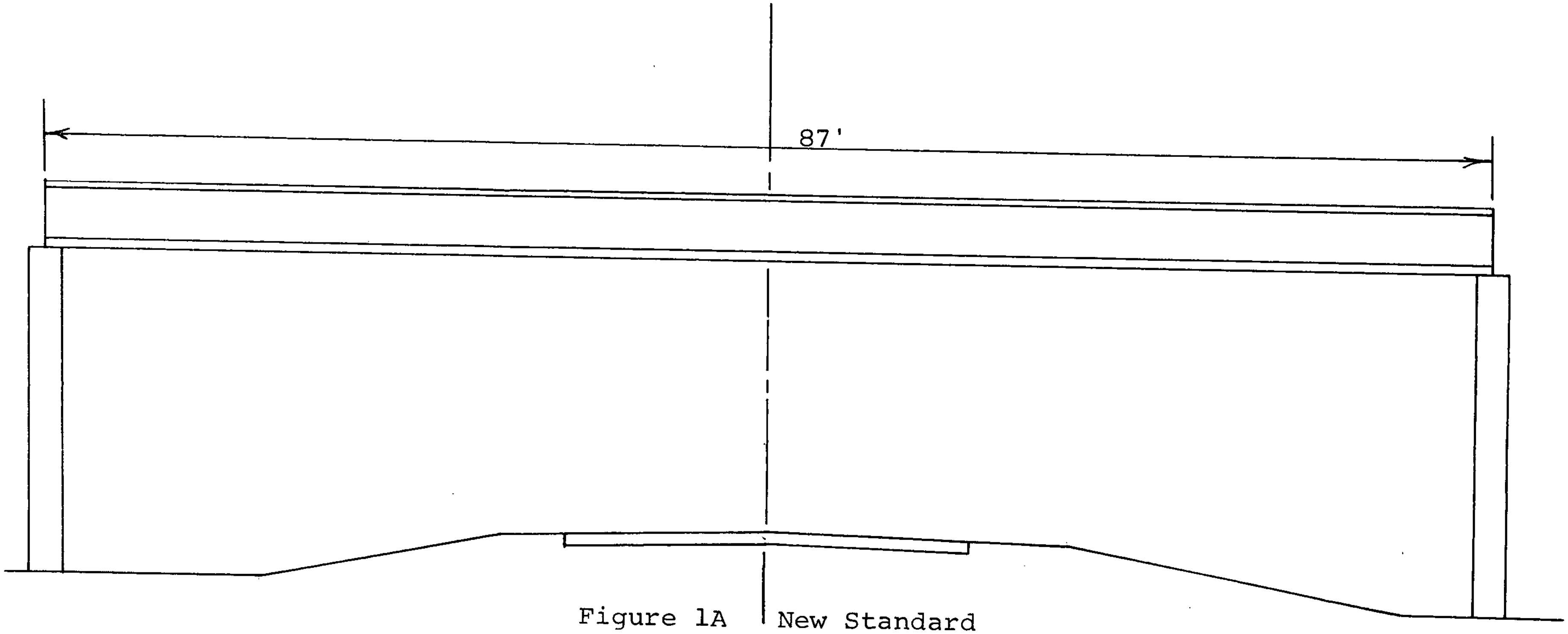


Figure 1A New Standard

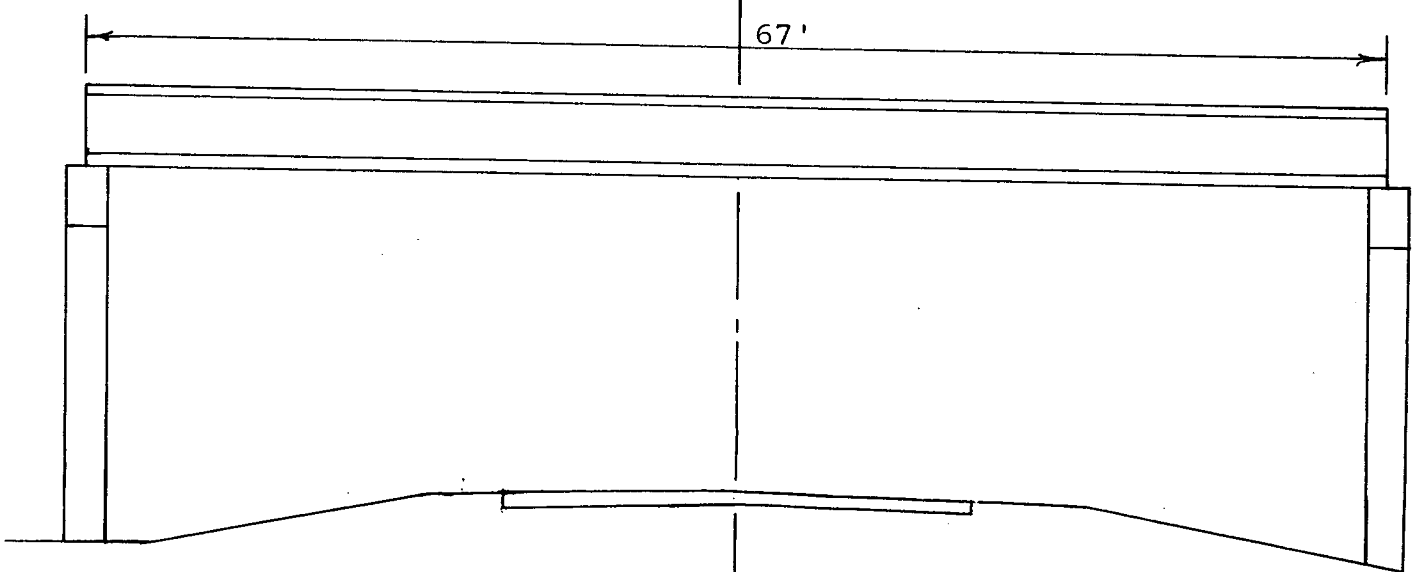


Figure 1B Old Standard

bridge girders. These projects were basically designed to test the feasibility of using lightweight aggregate bridge girders in the State of Iowa. The three projects, which were started at approximately the same time are: "Creep and Shrinkage of Lightweight Aggregate Concretes," "Time Dependent Camber and Deflection of Non-Composite and Composite Lightweight Prestressed Beams," and "Lightweight Aggregate Beams - Field Trial, Hardin County, Iowa."

The first two are under the supervision of the Civil Engineering Department, at the University of Iowa, the third project is the subject of this report.

The object of this project is to study the effect which lightweight aggregate concrete has on the camber of bridge girders when used in a field situation.

EXPERIMENTAL PROCEDURES

The methods which were used to determine camber can best be explained by breaking the experimental procedures into four sections, they are: Concrete Mix, Brass Plates, Girders and Instrumentation.

Concrete Mix

One of the most importantparts of any project involving concrete is the proper mixing and proportioning of the necessary constituents. This project is no exception; Table 1 indicates the concrete quantities, procedures and design criteria for the lightweight aggregate concrete to be used in this particular project.

Brass Plates

To achieve a permanent reference point, 3½" x 2" brass plate was fastened to the bottom flange of the girder. Three plates were fastened to each girder; one at a distance of 22" from each end, the other at the midpoint. In the placement of the plates, temporary ¼" bolts were used to secure the plates to the flange. These ¼" bolts were only temporary because of a tendency for the bolts to cause local cracking of the concrete or to become sheared themselves during the peiod when the concrete is setting. Figure 2 shows the location of the plates. After the plates were set, a ½" SAE-fine-thread bolt was placed in a hole which had been tapped before the setting of the plate, these bolts were used for all future measurements.

TABLE I CONCRETE MIX QUANTITIES FOR LIGHTWEIGHT CONCRETE BRIDGE GIRDERS

DESIGN OBJECTIVES	
Concrete Quantity	$1\frac{1}{2}$ cu. yds.
Concrete Strength @28 days	5000 psi
Unit Weight, Maximum Air-Dry	(117) pcf
Air Entrainment	(5 ± 1) %
MIX INGREDIENTS	
Cement (Type 1)	1058 lbs.
Sand	2093 lbs.
Idealite Aggregate (60% of 3/4" to 5/16" and 40% of 5/16" to #8)	1230 lbs.
Water	52.5 gal.
Darex @7/8 oz. per sack	9.75 oz.
Pozzolith	31.5 oz.

MIXING PROCEDURES

1. Proportion sand and Idealite.
2. Add 26 gallons of water.
3. Mix for approximately two minutes.
4. Proportion the cement.
5. Add six gallons of water.
6. Add Darex AEA in 3 gallons of water.
7. Add Pozzolith with remaining water while adjusting to $2\frac{1}{2}$" slump.

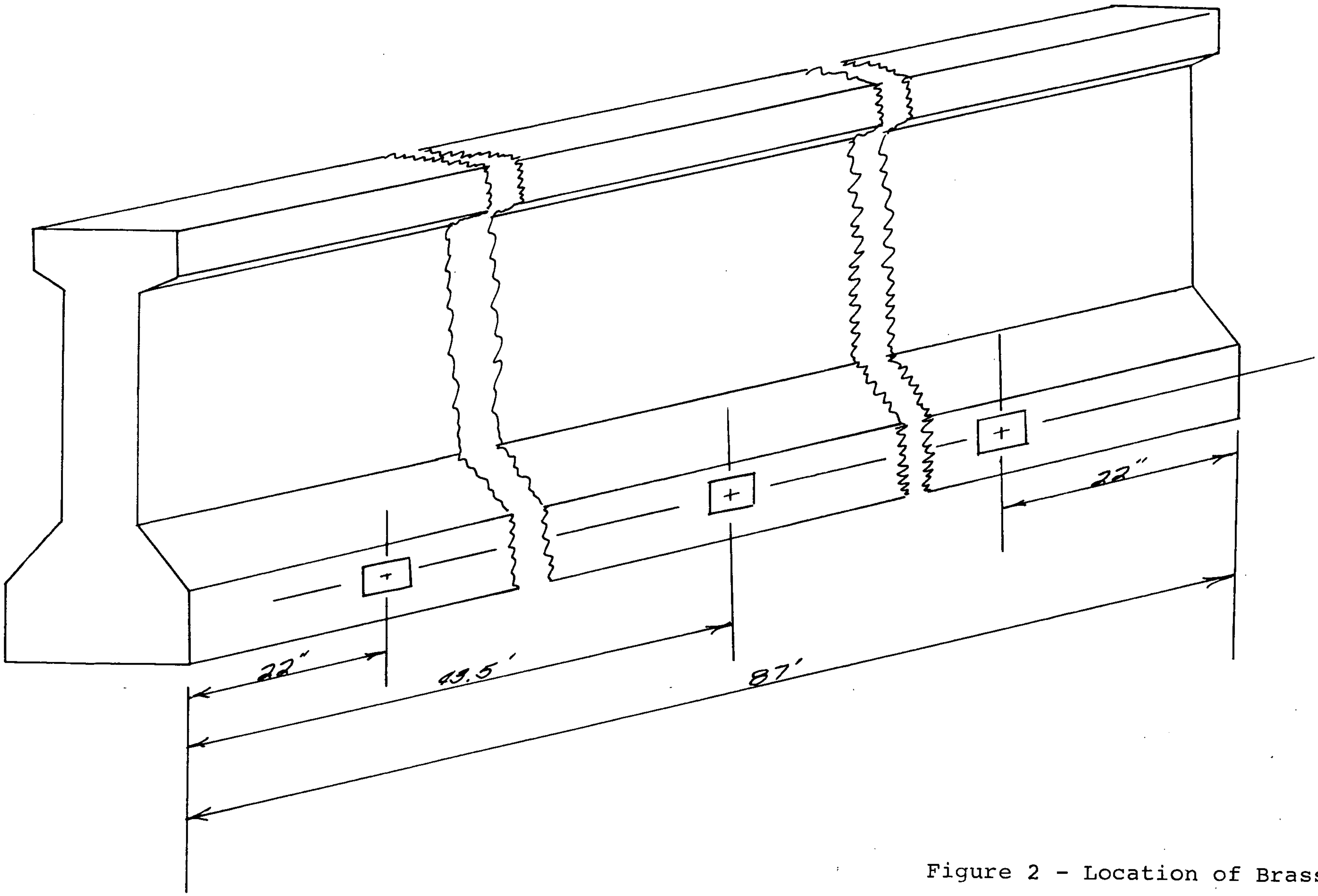


Figure 2 - Location of Brass Plates

Girders

Five pretensioned-prestressed concrete girders were cast in 2 groups; the first group of 3 was cast on April 15, 1968, the second group of 2 was cast on April 19, 1968. Once the girders had been cast, Groups I and II were steamed 40 and 67 hours respectively.

Group I, consisting of girders numbered 152, 153, & 154, was to have been released* on April 16th but the cylinder that was broken on that date had a low strength, the girders therefore were not released until the 17th of April. Table 2 gives the strength and age of the cylinders at the time of testing.

Table 2, Strength and Age of Cylinders for Group I Girders.

Cylinder No.	Age (Hours)	Strength (psi
152A	24	4310
152B	48.5	5160
153A	40.5	4460
153B	48.5	4480
154A	40.5	4420
154B	48.5	4950

Group II, consisting of girders numbered 155 and 156, after being cast on the 19th, were allowed to sit until being released on the 22nd of April. At the time of release these girders exhibited the strengths and ages as shown in Table 3.

Table 3, Strength and Age of Cylinders for Group II Girders

Cylinder No.	Age (Hours)	Strength (psi)
155A	67	5130
155B	-	-
156A	67	4350
156B	67	4350

*released - is defined as the time at which the pretensioned cables are cut and the stress is transferred from the prestressing steel to the concrete.[1]

At the time the girders were released, readings were taken at short intervals to show the development of the camber during this period. Figures 3a-3e show this development. Figure 4 shows the camber development on girder number 155, readings were taken at 15 second intervals to develop this curve.

During the 2 months immediately after casting, the girders were stored out-of-doors. The temperature varied during this period from a low of 30°F on the 24th of April to a high of 89°F on the 7th of June. Camber measurements were taken during the period of 22 April to 7 June at an average of one every 8 days.

On June 10th the girders were moved from their storage position to the bridge site, which is located on County Road "W", over Tipton Creek, one mile west of U.S. #65 and 3 miles north of Hubbard, Iowa. A final set of readings were taken after the girders were set and before any load was applied.

On June 21st the deck was placed on the single span bridge. As the loading progressed camber measurements were taken at 30 minute intervals; it should be noted that even though readings were taken at set time intervals the relationship between time and distance advanced across the bridge is directly proportional.

It is the intention of this department to continue readings every 10-14 days for at least 180-200 days after release.

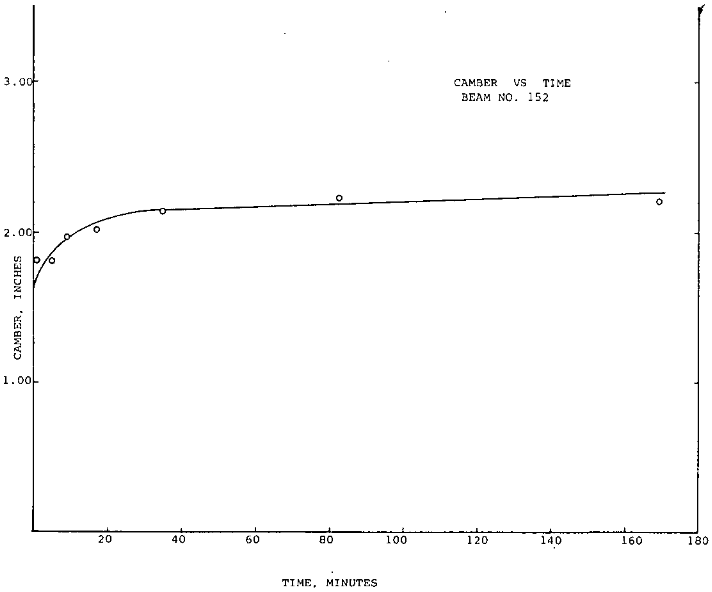


Figure 3a

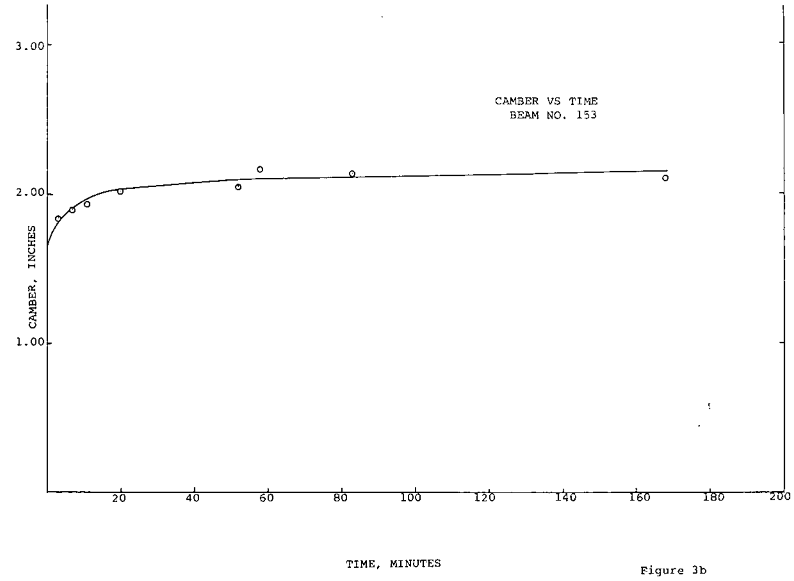


Figure 3b

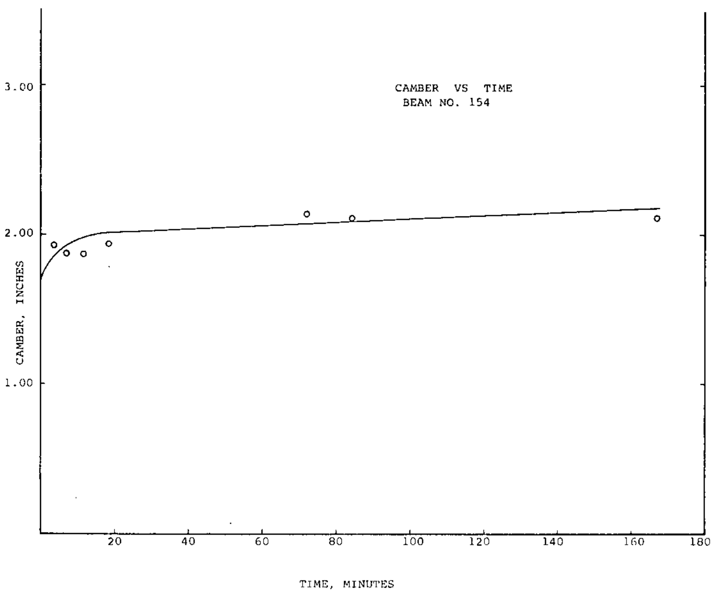


Figure 3c

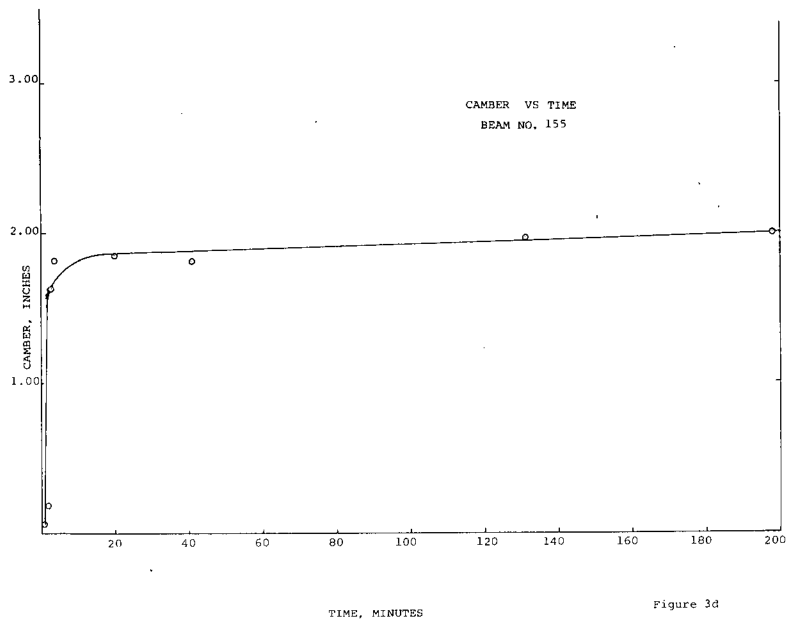


Figure 3d

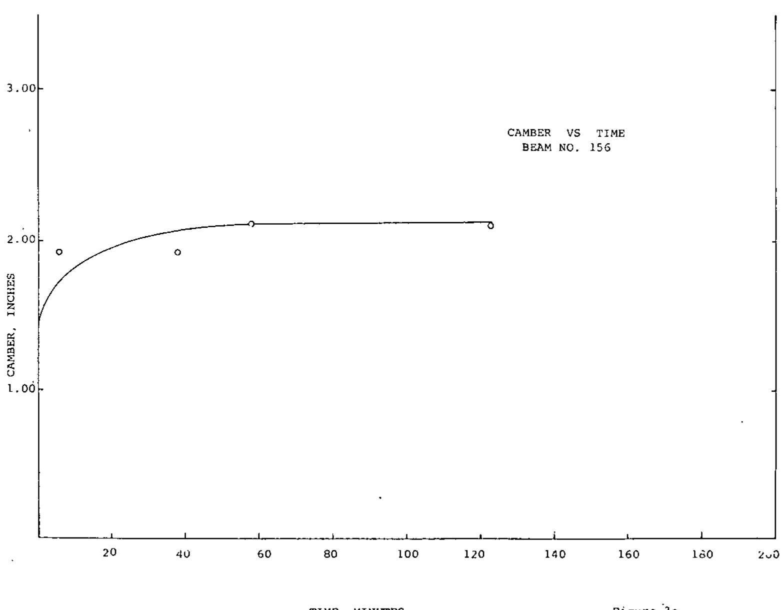
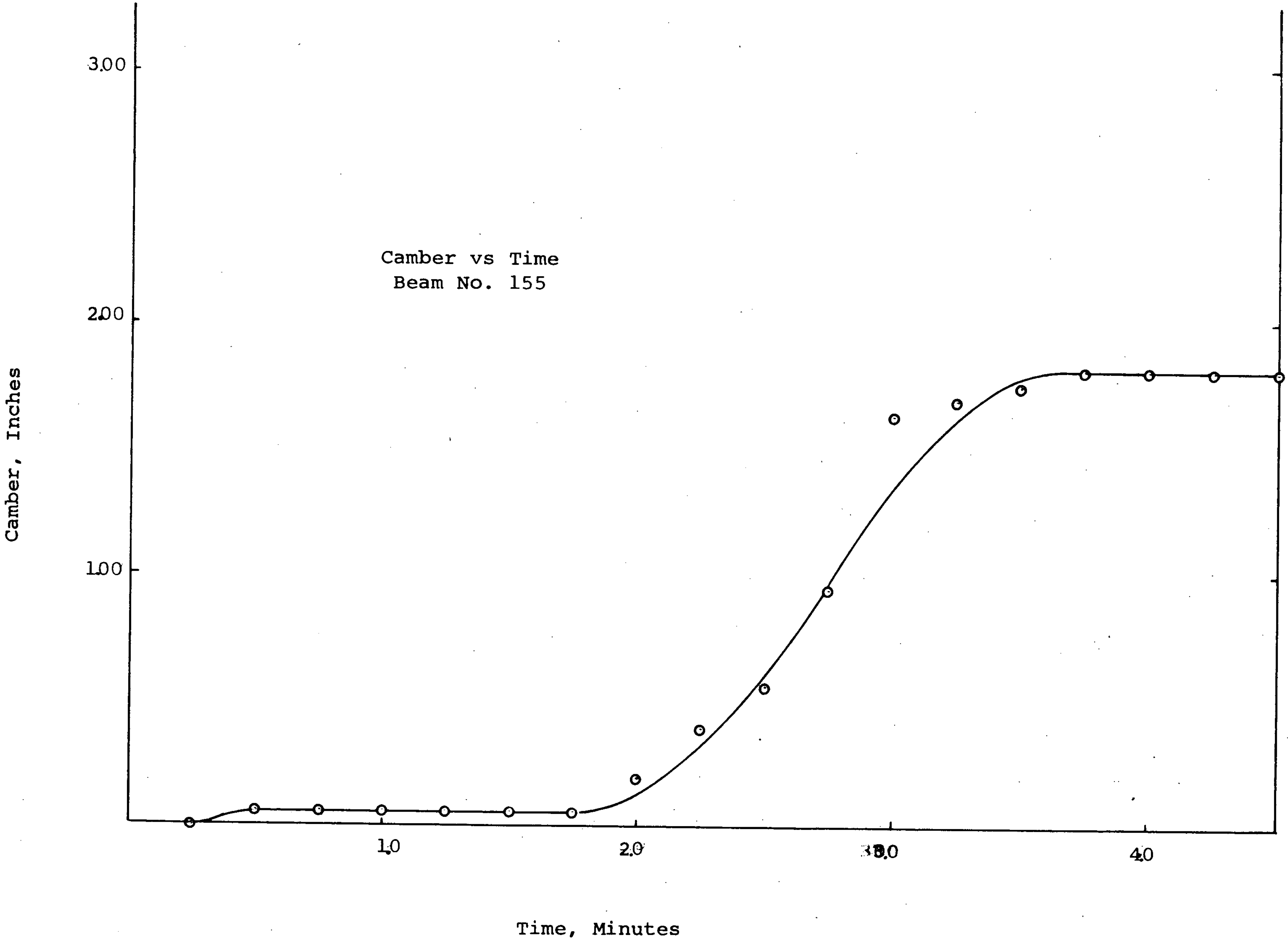


Figure 3e



Camber vs Time
Beam No. 155
3.00
2.00
1.00
Camber, Inches
1.0
2.0
3.0
4.0
Time, Minutes

Figure 4

Instrumentation

The determination of the relative displacement of the center of the girder is the prime objective of this project. During the time the deck was being placed, a method of reading the level rods as shown in figures 5 and 6 was employed. The initial readings were taken and the camber calculated. During the deck pour, a continuous set of readings were made on the level roads with the assistance of a man to steady the rods. Periodic checks were made on the end bolts to determine if any displacement had occurred at these points due to rotation of the ends of the girders.

In the calculation of the camber it is essential the rotation of the ends of the girder be taken into account. The bolts which are used as reference points will displace vertically upward approximately 0.13 inches when 3 1/8 inches of camber is attained. In all field calculations it was necessary to apply a correction factor to the calculated camber to compensate for this displacement.

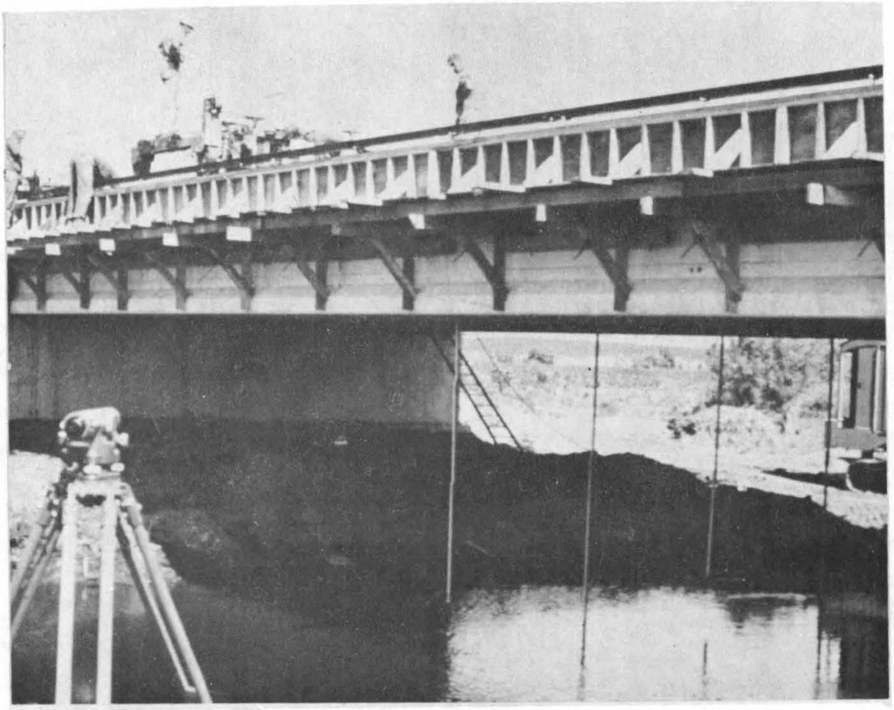


Figure 5, Set-up during deck placement

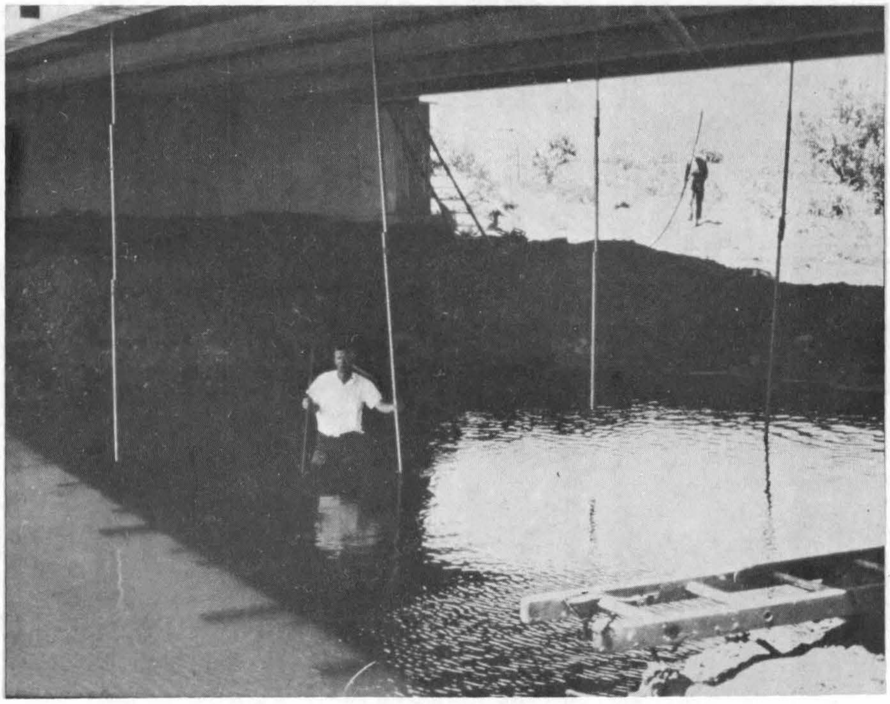


Figure 6, Procedure in reading rods

DISCUSSION OF RESULTS

Laboratory Tests

In addition to the cylinders which were cast at the time the girders were made, another series of cylinders were made to study the strength development pattern of the lightweight concrete. The cylinders were cured exactly as the girders, the first set was cured for 40 hours in steam, the second set 67 hours in steam. Table 4 shows the properties as they were determined. It will be noted that the cylinders which were cured longest developed a

Table 4, Concrete Test Properties

Date Cast	Age (days)	f'_c (psi)	E_c[1] (psi x 10^6)
4/15/68[2]	7	5125	3.10
4/15/68	14	5560	3.23
4/15/68	28	5980	3.35
4/15/68	58	6360	3.46
4/19/68[3]	7	4915	3.04
4/19/68	14	5570	3.23
4/19/68	54	5925	3.34

1. Computed by $E_c = 33\sqrt{w^3 f'_c}$ where w has an average value of 120 lb/ft^3.

2. 40 hours steam cure.

3. 67 hours steam cure.

slightly smaller modulus at approximately 2 months. This fact could have been a contributing factor in the camber development of the girders in group II. This will be discussed in more detail in the next section entitled "Camber Development."

Camber Development

Figures 7a-7c indicate the pattern of camber development which the girders took from the time they were cast until 50 days after the deck was placed. Girders 152, 153 and 154 developed camber at a uniform rate from the time of concrete placement until after the deck was placed. Figures 8 and 9 indicate the trends which the two groups followed in their development. Figures 7d and 7e show how the girders in Group II developed at a rate which is somewhat slower with respect to time than those of Group I. The girders in Group II were cast four days after those in Group I and experienced a total camber which was less than Group I.

Since no cylinders were broken at twenty-eight days for the second set of girders, the use of the strengths at the time the girders were set will be used. The difference between the two groups in strength and modulus at the time the girders were set is almost insignificant. The 350 psi difference in ultimate strength and the 0.12×10^6 psi difference in modulus are not significant to where this data could be used as a basis for explaining the difference in camber between Groups I & II. The difference between the two groups could be attributed to any one of a number of things. It is the feeling of the author that the curing conditions are the prime cause of the low camber in Group II or the high camber in Group I whichever is the case. After

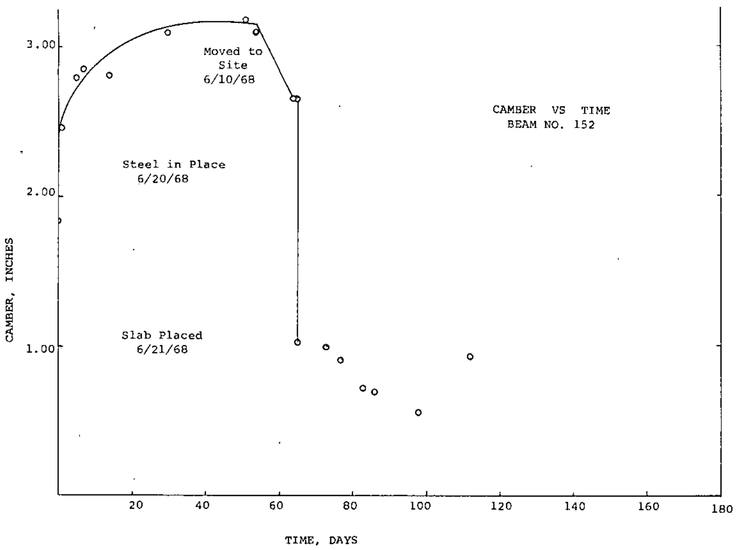


Figure 7a

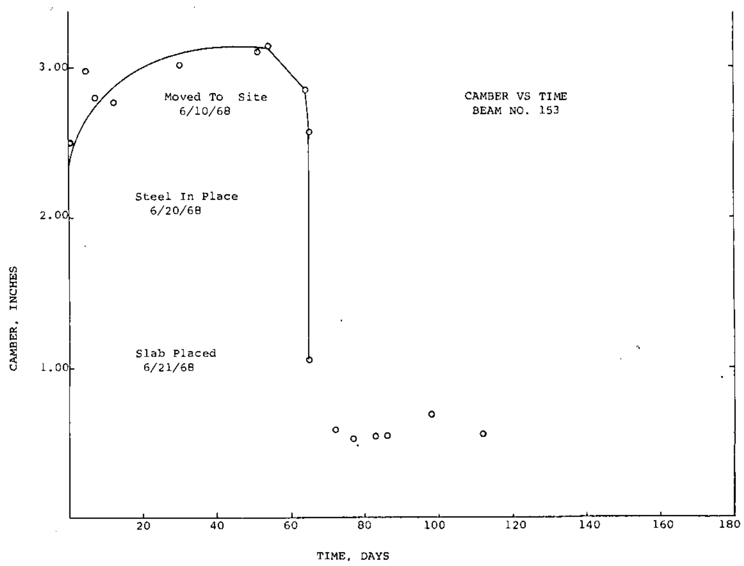


Figure 7b

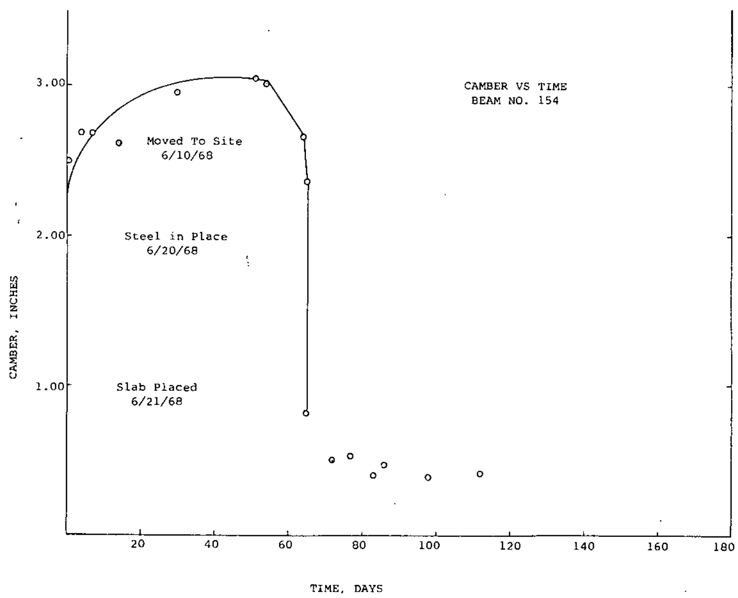


Figure 7c

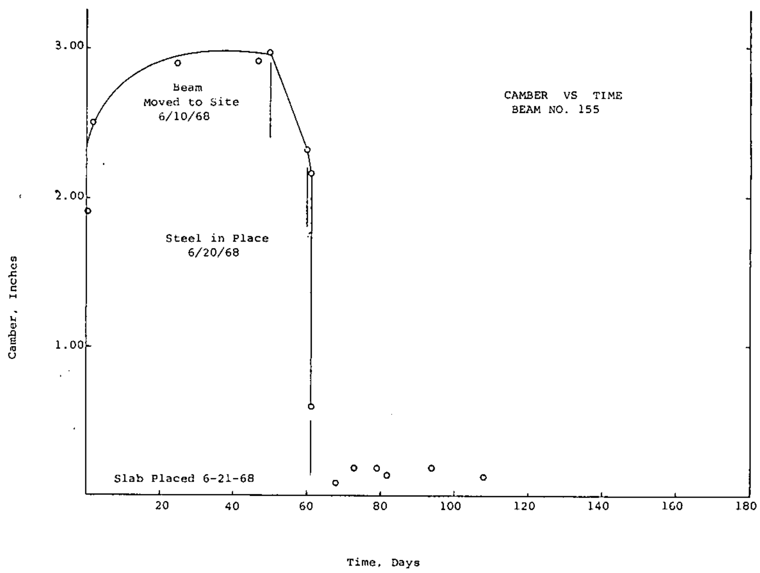


Figure 7d

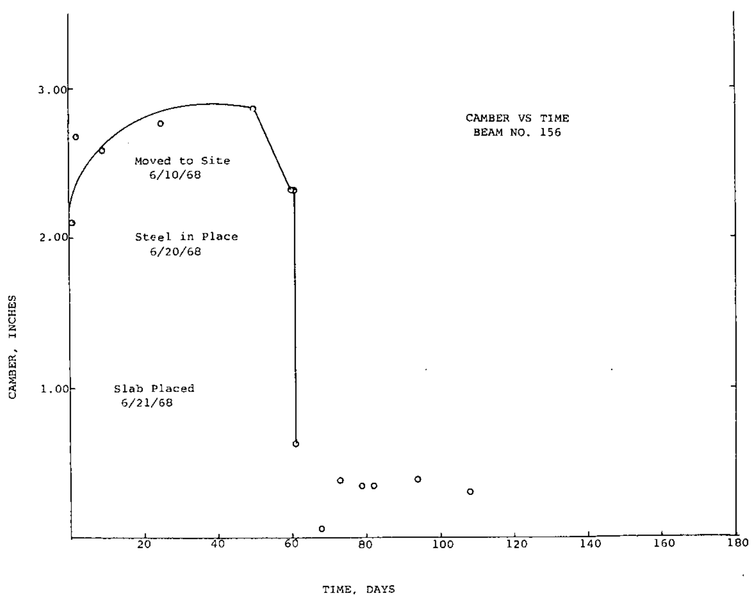


Figure 7e

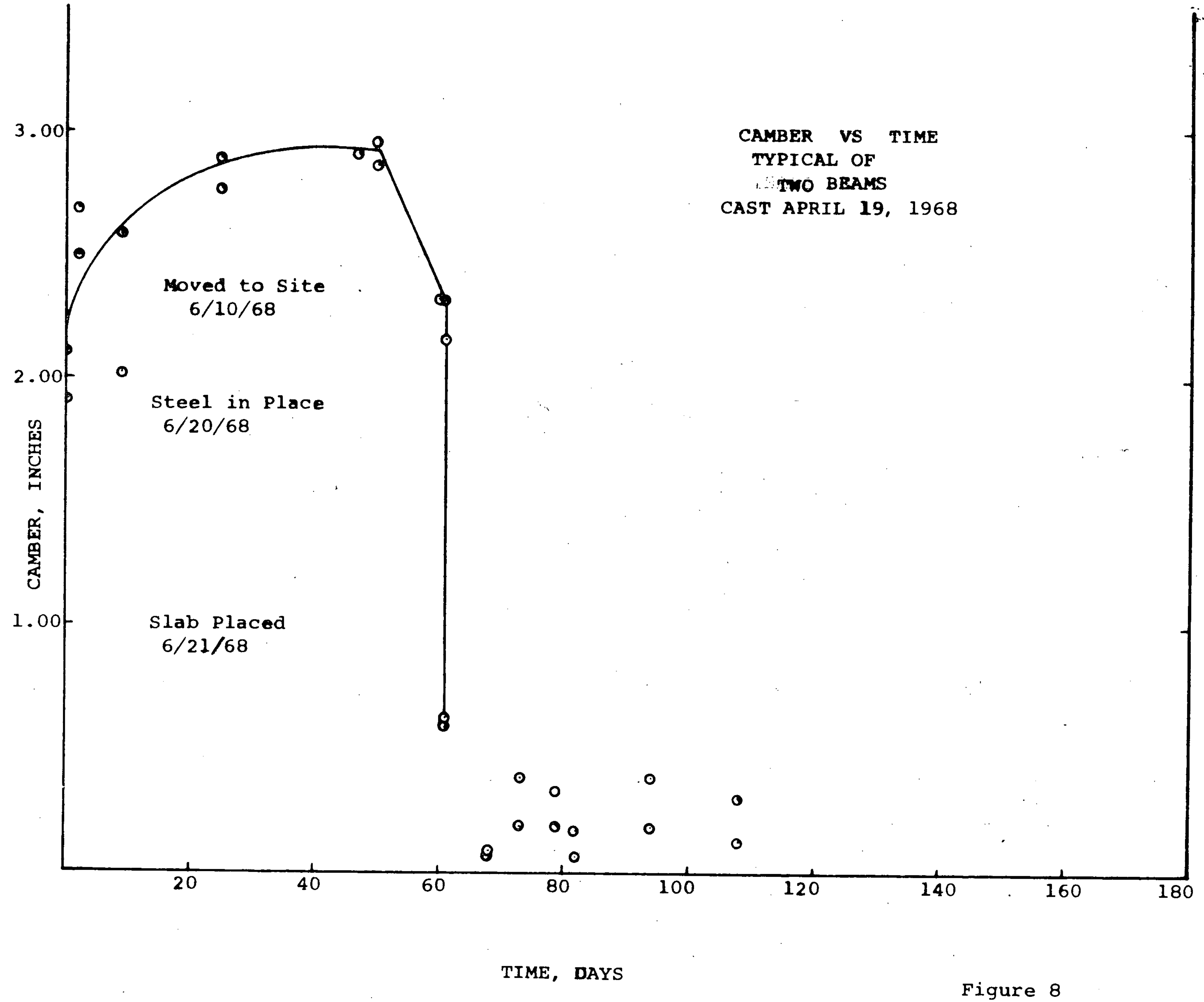

CAMBER VS TIME
TYPICAL OF
TWO BEAMS
CAST APRIL 19, 1968
Moved to Site
6/10/68
Steel in Place
6/20/68
Slab Placed
6/21/68
3.00
2.00
1.00
CAMBER, INCHES
20
40
60
80
100
120
140
160
180
TIME, DAYS

Figure 8

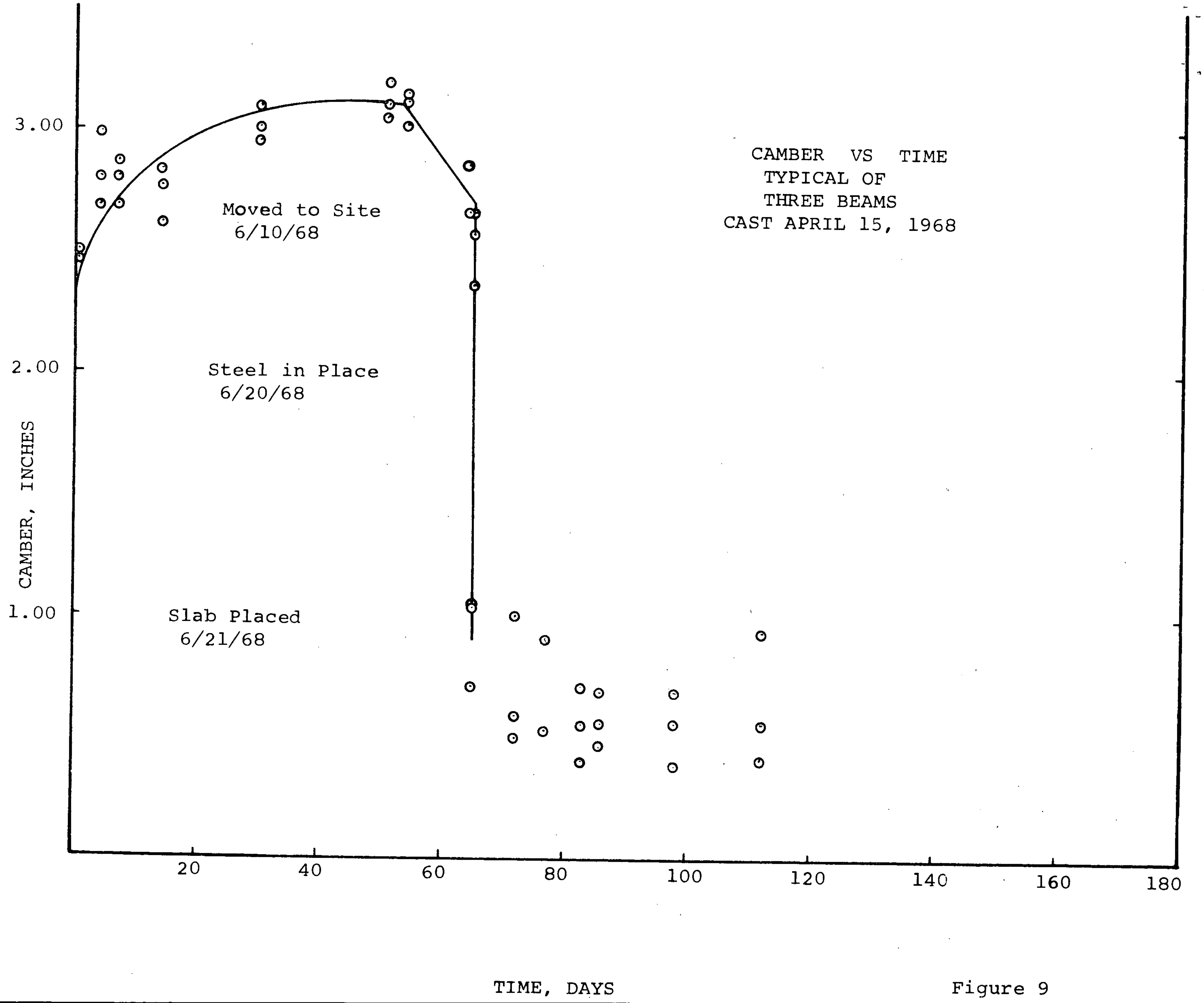

3.00
2.00
1.00
CAMBER, INCHES
20
40
60
80
100
120
140
160
180
TIME, DAYS
Moved to Site
6/10/68
Steel in Place
6/20/68
Slab Placed
6/21/68
CAMBER VS TIME
TYPICAL OF
THREE BEAMS
CAST APRIL 15, 1968

Figure 9

Group I had been cast, the steam was delayed for approximately 8 hours. The pour was completed between 2:30 - 3:00 p.m. and it was 11:00 p.m. before the steam cure was actually started. The gradual increase of steam was started at 7:00 p.m. and took a full 4 hours to raise it to the desired level. Group II had the steam brought up in only 2½ hours.

Once the steam cure had been started the cure was continued for 40 hours on Group I and 67 hours on Group II. The curing conditions will sometimes have an effect on the creep characteristics and could very well change the whole pattern of camber development. These two different curing conditions are possibly the very cause of the camber differences between Groups I and II.

The effect of the deck placement is to rapidly decrease the camber development thus bringing the camber down to some predetermined level. In this case, the camber immediately after the deck was placed had been calculated in design to be almost zero (0.005 inches.)

Figures 10a - 10e show how the camber changed with time as the load was being applied. The deck pour was a reasonably constant affair and the assumption that the distance across the bridge is directly proportional to time is quite accurate. For example, after one half of the total time had elapsed the progression of the deck had reached the midpoint of the bridge. The tendency for the girders to rebound near the end of the pour can

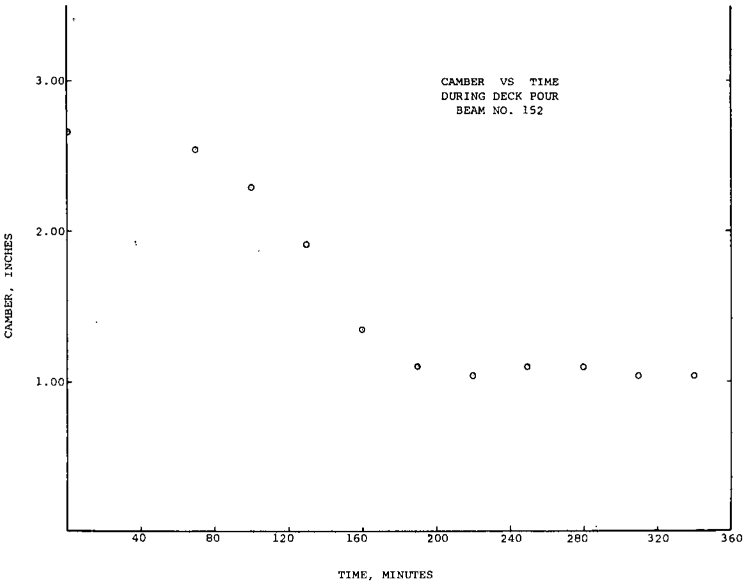


Figure 10a

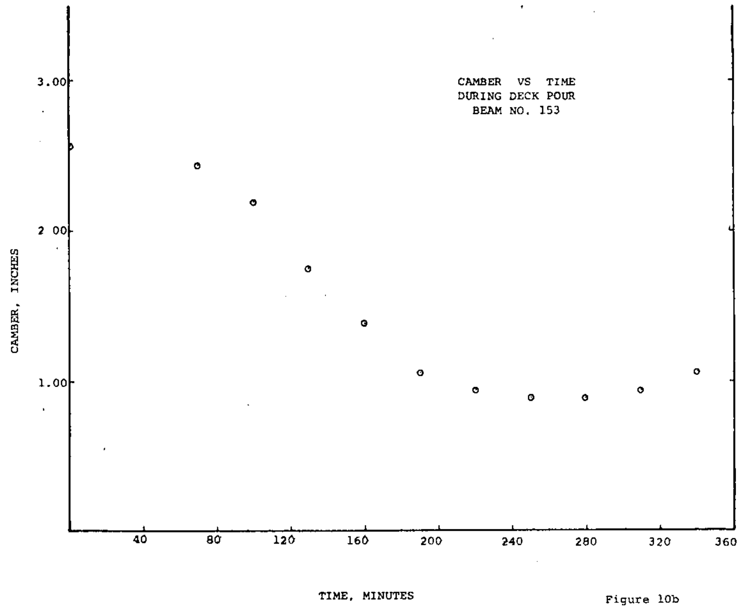


Figure 10b

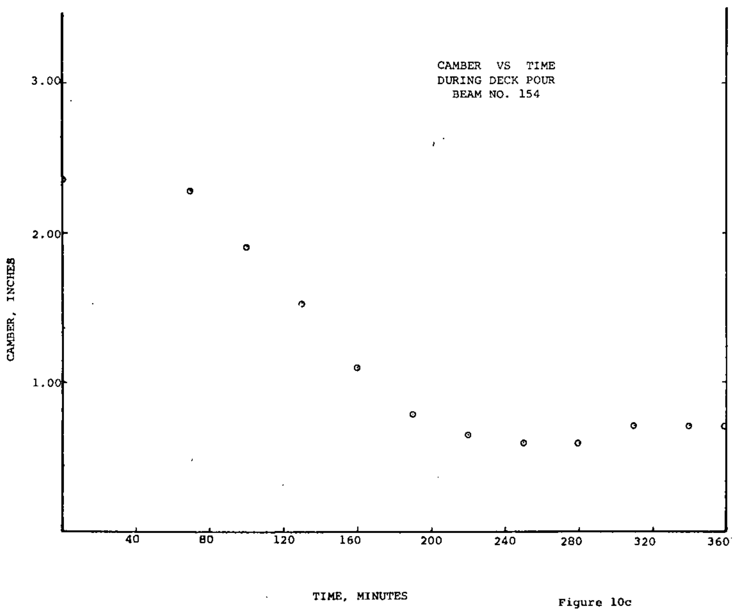


Figure 10c

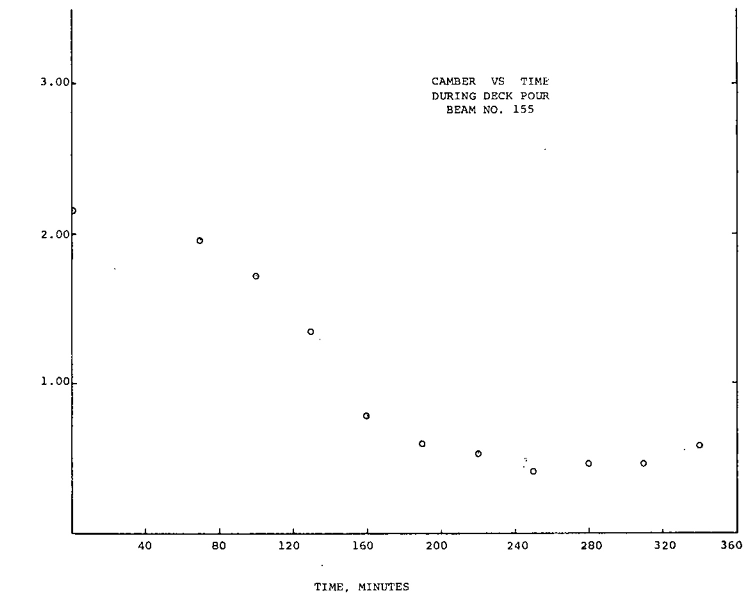


Figure 10d

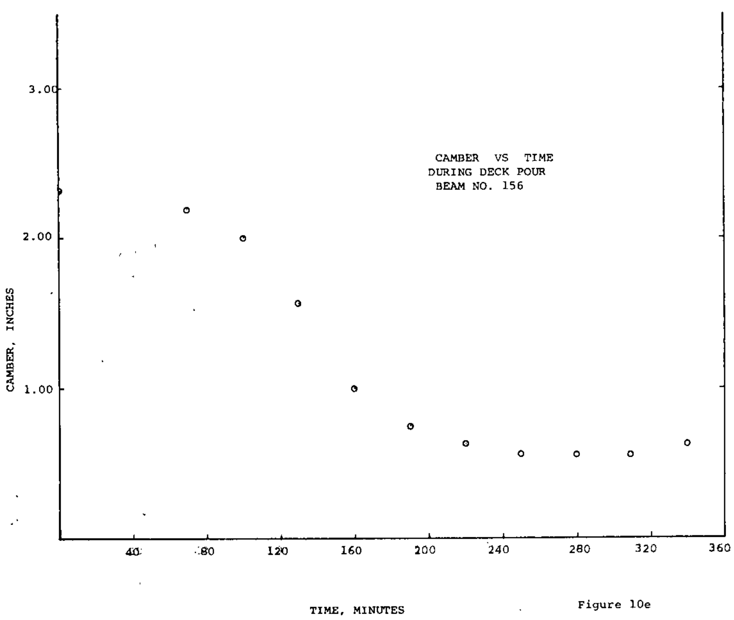


Figure 10e

be attributed to the finish machine moving towards the end of the deck and finally being removed. The reason that a sudden displacement at the outset of the pour was not exhibited can be attributed to the machine being on deck at the time the initial readings were taken.

Conclusions

In looking at the data (and the various plots of camber vs. time) it is evident that the results of our work is quite typical of work done by others[1]. Deflection (inches) vs. time (age-days after release) has indicated that we have data which is quite consistent with what can be normally expected. Our method of determining camber was relatively "crude" when compared to methods available, however we obtained what was expected. This fact is an indication that we were pretty well "in the ballpark" with our data.

Some definite conclusions are available with respect to the current data, these are:

1. The design camber at the time of erection was 3 1/8 inches, this value was attained in the Group I girders, but not in Group II.
2. The procedure for prediction of camber immediately after loading may have to be modified somewhat, the camber after loading was predicted to be nearly zero (0.005 inch), however it was as follows:

Girder No.	Camber (inches)
152	1.05
153	1.05
154	0.70
155	0.60
156	0.65

It should be kept in mind this project reported the work which was carried out on a particular group of girders which were cast at a particular time, placed at a single location, and exposed to identical weather conditions. With this in mind, it is recommended that at least one other set of data be collected on lightweight aggregate bridge girders to give some meaning to this data.

ACKNOWLEDGMENTS

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J.A.Y.

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1. Furr and Sinno, "Creep in Prestressed Lightweight Concrete," Texas Transportation Institute, October, 1967.