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Prestressed Concrete Girders

Inv. 80-5

1980 Field Survey of Underdeck Cracking of Bridge Decks Placed on Prestressed Concrete Girders (Built 1976-1980)

INTRODUCTION

Cracking on the underside of concrete bridge decks placed on prestressed concrete girders has been observed on many bridges at very early ages. In some cases where the inspector was aware of the possible problem, cracking was observed when the plywood forms were removed after 10 days of curing. Efflorescence has been observed on bridges which have not yet been open to traffic.

This investigation was organized to study the type of structure described above which was constructed within the past 5 years (1976-1980). The analysis consisted of a field underdeck survey and evaluation in conjunction with a search of construction records for information which may be considered to have a contributory effect to explain early cracking of concrete bridge decks.

SCOPE

Eighty-one bridges which had prestressed concrete girder superstructure design in all or part of the spans were surveyed in October, 1980. All of these bridges were constructed during the period 1976 thru 1980.

Nine of the eighty-one bridge decks were constructed with the Class B-2 concrete and epoxy coated reinforcing steel. Thirty of the bridge decks constructed with Class B-1 concrete either had a waterproofing membrane or a latex or Low Slump concrete overlay. Of the remaining forty-two bridges with Class B-1 concrete decks, twenty-eight had epoxy coated reinforcing steel and fourteen had non-coated reinforcing steel or as commonly referred to as gray steel.

MATHEMATICAL ANALYSIS DESIGN

Organization of the data assembled to interpret the significant feature or features relating to the amount of cracking observed on the underside of the concrete deck was based on an unbalanced block design. For example, from the complete outlay of the data shown in Table 1, the block design for the dependent variable (total cracking observed) on Class B-1 concrete decks analyzed by its relation to type of reinforcing steel (epoxy or gray) and stratified or subdivided by bridge wearing surface (waterproof membrane and latex, low slump, or Class B-1 concrete) would appear as shown in Figure 1. Obviously, from the outset of this particular analysis, the lack of corresponding epoxy steel used with wearing surfaces other than B-1 will severely influence the analysis if a significant difference exists between the wearing surface types. Data shown in these block designs were then analyzed by routine statistical analysis of variance methods.

The data in Table 1 was worked through this type of analysis process to determine significant contributing factors to the cause of cracking in the concrete decks. A multiple step procedure was adopted whereby each suspect independent variable would be considered through similar block design. For each analysis discussed in the succeeding sections, an associated block design will be shown when analysis of variance is used.

CLASS B-1 VS. CLASS B-2 CONCRETE

Information available for analysis of Class B-1 and B-2 concrete decks supported on prestressed concrete girders was limited because Class B-2 concrete is a relatively new design. Nine bridges with Class B-2 concrete were observed ranging in age of 1 to 13 months. Only two of these bridges were open to traffic at the time of observation.

Bridges having Class B-1 concrete decks constructed during the same time period as the Class B-2 concrete deck were selected from these observed for consideration of this relationship. Table 2 is a reduced tabulation of the bridges showing the respective age of construction and age after being open to traffic.

All bridges represented in this analysis are similar in design with the following exceptions. The Class B-1 and B-2 concrete deck thickness was 8 or 8 1/2 inches with the exception of A-3633 at 7 1/2 inches. Additional deck thickness resulted also from application of waterproofing membranes and low slump concrete overlays. Reinforcing steel was all epoxy coated except where a waterproofing membrane or low slump concrete was used. Depth of cover on the top reinforcing bar was 3 inches except where a membrane or low slump concrete was used. Low slump concrete overlayed bridges had a total of 3 1/4 inches of cover total and the waterproofing membrane decks had 2 1/2 inches of concrete cover.

Cracking on the underside of the concrete decks used in this analysis showed similar patterns regardless of type of concrete. Crack counts made in this investigation were based on each crack or portion of a crack observed between any two girders being counted as one crack. Should, however, two or more small portions of crack be oriented such that they would form a continuous crack in the future, these portions were collectively counted as one crack. Cracking under the curb and parapet wall extension was not included in the crack count.

Cracking was generally oriented perpendicular to the girders except near skewed bents. Near the skewed cast in place bent diaphrams both perpendicular and oblique crack patterns were observed. The oblique cracks generally began as perpendicular cracks to either the girders or the cast in place diaphram, then would curve to a random orientation. Bridges with lesser numbers of cracks tend to show cracking to be more concentrated near the bents rather than distributed throughout the spans. End spans normally show lesser amounts of cracking than the intermediate spans.

Analysis of the data followed a procedure, whereby, the characteristics most likely to influence the development of cracks in the underside of the concrete deck were considered first. Total amount of cracking and the maximum air temperature during placement of the concrete, shown in Table 2, regardless of class of concrete was developed using regression methods. Figure 2 shows the data with the linear regression results. No correlation exists within the Class B-1 or the Class B-1 and Class B-2 concretes combined. Some correlation exists for the Class B-2 concrete data, however, is not significant because it only explains 45% of the population and exhibits a coefficient of variation of 11.3% with a correlation coefficient of 0.67. Additional data collected as the Class B-2 concrete construction continues may or may not provide a more significant relationship between cracking and maximum air temperature during pour. Therefore, maximum air temperature during pour does not explain the occurrence of cracking in the Class B-1 and B-2 concrete decks within the 1 to 13 month age group used in this analysis.

Attempts to find relationship between the Class B-1 and Class B-2 concretes within any of the other variables shown in Table 1, all proved non-significant. The main reason for failure in these correlations was the high variability of the number of cracks on the underside of the concrete deck regardless of the variable being considered. For example, approximately half of the bridges in each class of concrete had no observable cracks on the underside of the deck, however, these bridges had corresponding ranges in maximum air temperature during pour of 98 to 70 and 88 to 72 for the Class B-1 and B-2 concretes respectively.

B-1 CONCRETE

Failure to establish correlation between Class B-1 and B-2 concretes gave reason for some concern as to the fact that cracking on the underside of the deck was not new just because of the use of the Class B-2 mix but had always existed on many of the bridges constructed with the Class B-1 mix. Analyzing the Class B-1 concrete decks separately gave an available data base of 72 bridges. Each variable was systematically analyzed to determine if a correlation existed which could explain or predict the probable occurrence of cracking on the decks.

Bridges with the Class B-1 concrete decks included in this analysis were constructed from June 1976 to the date of survey, October 1980. Design was similar for all bridges, however, specific ranges existed such as: deck thickness was 7 1/2 to 8 1/2 inches except where waterproofing membranes or concrete overlays were used, reinforcing steel was either gray or epoxy coated, depth of cover varied from 1 7/8 to 3 inches except where waterproofing membranes or concrete overlays were used, and wearing surface varied from Class B-1 concrete to waterproofing membrane to an overlay of low slump or latex concrete. With this array of information, the analyses followed a procedure, whereby, the characteristics most likely to influence the development of cracks on the underside of the concrete decks were considered first.

Analysis of total cracking observed on the underside of the deck and the maximum air temperature during placement of the concrete, data block diagram shown in Figure 3 stratified with temperature ranges of less than 75°F, 75 to

90°F, and greater 90°F and deck wearing surface type, indicated that temperature was not significant but the type of wearing surface was significant with no effect of interaction. Attempts to determine if temperature could be significant at other levels of temperature by stratification of the data into two temperature cells and two types of wearing surface cells, as shown in Figure 4, proved fruitless for temperatures of 90°F, 85°F, and 80°F. Failure of all these designs was caused by the extremely high variability of cracking observed within each temperature stratification. The significance of the type of wearing surface was the result of the relatively low variability of cracking observed within the type of wearing surface other than the Class B-1 surface.

Figure 3, with the expanded stratification for type of wearing surface, indicates that the two concrete overlay systems are relatively free of cracking. The waterproofing membranes had only three bridges with large amounts of cracking. The Class B-1 wearing surface has several bridges with large amounts of cracking in each of the temperature stratifications. This distribution of bridges having the larger amounts of observed cracking accounts for the non-significance of the temperatures and the significance of the type of wearing surface. Similar distributions of the data was experienced when attempts to analyze other variables such as clear depth of steel in the Class B-1 concrete, skew of the end abutment and bents and total length of deck supported on the prestressed concrete girders were analyzed.

Data blocks for these analyses are shown in Figure 5 with each respective analysis of variance table.

Wearing surface type appears to hold the only significant relationship that could be derived from these efforts. However, explanation as to the cause and effect relationship between the lack of cracking and Class B-1 concrete decks with overlays is not evident within the variables as studied herein. Explanation may be related to the increased deadload or the increased section modulus due to the effective increase in thickness of the deck. The concrete overlays may add significantly to the strength of the deck based on composite design. Additional deadload may retard or decrease the tendency of the prestressed concrete girders to continue to deflect after loading.

SUMMARY

Attempts to find relationship between the cracking observed on the underside of the concrete decks and the construction or design variables included within this investigation all proved non-significant. Wearing surface type appears significant when based on the Class B-1 observations, however, is not readily explanable within the variables studied.

The inability of the data to align itself significantly with respect to any of the variables studied, does not eliminate the possibility that any one variable may be a contributing factor to cracking which was observed. Apparently, factors other than what have been presented here, i.e., quality control of the concrete, construction placement or handling procedures, or the design itself may be of benefit in trying to explain the cracking which appears to occur somewhat sporadically. Should the time be warranted, consideration should also be given to a study of steel girder designs which were constructed during the same time periods to determine if the cracking problem is unique for prestressed girder designs only.

Table 1

Summary of Prestressed Concrete Girder Structures Surveyed Fall 80

Bridge	Number of Cracks (Total)	Number of Cracks Effloresced	Mfg. Date Prestressed Girder	Type of Deck Concrete	Age of Deck (1) (Const.)	Age of Deck (1) (Mo.)	Open To Traffic (Date)	Open To Traffic (Mo.)	Wearing Surface Type	Concrete Deck Thickness (2) (Design) (Inches)	Clear Cover on Steel (Design) (Inches)	Type of Reinforcing Steel-Top	Pier Design Skew-Straight	Width of Deck (Rdwy. Width) (Feet)	Total Length Of Deck (3) (Feet)	Temp. of Concrete Pours Max.	Temp. of Concrete Pours Min.
A-923 EB	0	0	10-78	B-1	8-79	14	Not Open	X	B-1	7 1/2	2	Epoxy	Rt. AH	39.5	793.5	91	40
A-1756 NB	66	66	10-76	B-1	10-77	36	12-77	34	Membrane	8	2 1/2	Gray	Sq.	39.4	901.3	96	42
A-1756 SB	19	10	10-76	B-1	9-77	37	6-78	28	Membrane	8	2 1/2	Gray	Sq.	39.4	901.3	82	41
A-1758 NB	5	4	7-76	B-1	8-77	38	12-77	34	Membrane	8	2 1/2	Gray	Sq.	39.4	1955.4	98	51
A-1758 SB	103	100	7-76	B-1	8-76	50	6-78	28	Membrane	8	2 1/2	Gray	Sq.	39.4	1955.4	89	44
A-2858	21	8	4-78	B-1	10-78	14	8-79	14	B-1	7 1/2	2 1/2	Gray	Lt. AH	28.0	127.2	68	40
A-2896	27	18	6-79	B-1	9-79	13	12-79	10	B-1	8 1/2	3	Epoxy	Lt. AH	44.0	146.0	87	69
A-2906	0	0	9-75	B-1	6-76	52	10-77	36	B-1	7 1/2	1 7/8	Gray	Rt. AH	44.0	572.0	89	33
A-3017	0	0	3-77	B-1	10-77	36	5-79	17	B-1	8	2 1/2	Gray	Lt. AH	44.0	337.0	88	39
A-3085	3	3	12-77	B-1	8-79	14	10-79	12	1 1/2" Latex	7	1 1/2	Gray	Rt. AH	88.3	166.4	88	58
A-3097	27	25	10-78	B-1	7-79	15	9-79	13	B-1	8 1/2	3	Epoxy	Rt. AH	39.4	215.8	84	65
A-3113 EB	0	0	9-79	B-2	5-80	5	Not Open	X	B-2	8 1/2	3	Epoxy	Lt. AH	47.4	234.1	72	35
A-3113 WB	2	1	9-79	B-2	5-80	5	Not Open	X	B-2	8 1/2	3	Epoxy	Lt. AH	47.4	234.1	82	50
A-3208	27	16	7-78	B-1	10-78	24	11-78	23	B-1	8 1/2	3	Epoxy	Lt. AH	76.0	233.1	95	47
A-3217	38	0	11-79	B-2	9-80	1	Not Open	X	B-2	8 1/2	3	Epoxy	Sq.	44.0	1359.2	106	49
A-3259	2	2	2-76	B-1	6-77	40	12-78	22	Membrane	8	1 1/2	Gray	Sq.	86.0	109.1	86	60
A-3269	0	0	7-77	B-1	7-78	27	9-78	25	B-1	7 1/2	2	Epoxy	Sq.	40.0	106.1	86	73
A-3270	28	19	6-77	B-1	9-77	37	9-78	25	B-1	7 1/2	2	Epoxy	Rt. AH	40.0	117.6	78	56
A-3271	68	64	7-77	B-1	9-77	37	8-78	26	B-1	7 1/2	2	Epoxy	Rt. AH	40.0	137.6	79	53
A-3272	52	46	5-77	B-1	9-77	37	8-78	26	B-1	7 1/2	2	Epoxy	Sq.	40.0	124.1	91	63
A-3273	100	92	10-77	B-1	6-78	28	10-78	24	B-1	7 1/2	1 7/8	Epoxy	Sq.	44.0	159.1	90	64
A-3274	258	198	5-77	B-1	6-78	28	10-78	24	B-1	7 1/2	1 7/8	Epoxy	Lt. AH	44.0	522.0	84	34
A-3299	0	0	11-76	B-1	9-77	37	10-77	36	Membrane	7 1/2	2	Gray	Lt. AH	72.0	153.4	88	51
A-3327 NB	0	0	8-79	B-2	10-79	12	Not Open	X	B-2	8 1/2	3	Epoxy	Rt. AH	56.0	181.2	73	44
A-3327 SB	18	17	8-79	B-2	9-79	13	Not Open	X	B-2	8 1/2	3	Epoxy	Rt. AH	56.0	181.2	81	52
A-3358	0	0	1-76	B-1	10-76	48	9-78	25	B-1	7 1/2	1 7/8	Gray	Sq.	44.0	245.1	67	31
A-3361	0	0	1-76	B-1	8-76	50	9-78	25	B-1	7 1/2	1 7/8	Gray	Sq.	44.0	230.8	86	57
A-3400	0	0	7-77	B-1	8-78	26	11-79	11	B-1	8	2 1/2	Epoxy	Rt. AH	39.4	201.0	98	66
A-3406	15	8	3-77	B-1	5-77	41	6-77	42	B-1	7 1/2	1 7/8	Gray	Sq.	44.0	163.1	89	63
A-3412	187	149	6-78	B-1	8-78	26	6-79	16	B-1	8	2 1/2	Gray	Lt. AH	37.3	365.3	93	55
A-3434	0	0	10-76	B-1	6-77	40	8-78	26	Membrane	7 1/2	2	Gray	Rt. AH	39.5	183.4	77	52
A-3470	0	0	11-78	B-1	8-79	14	3-80	7	Membrane	8	2 1/2	Gray	Lt. AH	39.4	261.0	90	70
A-3474	0	0	9-78	B-1	4-79	18	Not Open	X	B-1	8 1/2	3	Epoxy	Rt. AH	39.4	400.4	85	34
A-3475	0	0	7-78	B-1	5-79	17	Not Open	X	Membrane	8	2 1/2	Gray	Rt. AH	39.4	244.9	70	62
A-3496	0	0	8-79	B-1	10-79	12	Not Open	X	2 1/4" Low Slump	8	1	Gray	Lt. AH	39.4	211.1	98	41
A-3498	0	0	5-79	B-1	4-80	6	Not Open	X	2 1/4" Low Slump	8	1	Gray	Rt. AH	34.9	175.2	90	38
A-3500	0	0	7-79	B-1	9-79	13	Not Open	X	2 1/4" Low Slump	8	1	Gray	Lt. AH	39.4	211.3	81	64
A-3516	5	3	3-77	B-1	7-77	39	6-78	28	Membrane	8	2 1/2	Gray	Rt. AH	39.4	211.2	91	71
A-3522	8	0	8-77	B-1	6-78	28	6-79	16	2" Low Slump	6 1/2	1	Gray	Rt. AH	39.4	163.2	82	64
A-3543	0	0	6-78	B-1	9-78	25	Not Open	X	Membrane	8	2 1/2	Gray	Rt. AH	44.0	216.1	72	49
A-3548	0	0	12-77	B-1	4-78	30	9-78	25	B-1	8	2 1/2	Epoxy	Sq.	44.0	133.1	73	45
A-3580	0	0	3-79	B-2	9-79	13	Not Open	X	B-2	8	3	Epoxy	Rt. AH	39.4	168.2	88	64
A-3591	26	25	10-77	B-2	9-79	13	10-79	12	B-2	8 1/2	3	Epoxy	Lt. AH	39.4	220.5	72	51
A-3595	0	0	9-77	B-1	10-77	36	6-80	4	Membrane	8	2 1/2	Gray	Sq.	44.0	231.1	69	51
A-3596	0	0	9-77	B-1	5-78	29	6-80	4	Membrane	8	2 1/2	Gray	Rt. AH	44.0	157.3	87	63
A-3597	0	0	10-77	B-1	11-77	35	6-80	4	Membrane	8	2 1/2	Gray	Sq.	44.0	157.1	60	44
A-3599	0	0	8-78	B-1	10-78	24	6-79	16	B-1	7 1/2	2 1/2	Gray	Lt. AH	28.0	214.4	75	34
A-3613	0	0	11-77	B-1	7-78	27	10-78	24	B-1	7 1/2	2 1/2	Gray	Sq.	34.0	246.1	97	68
A-3618	22	22	10-78	B-1	6-79	16	9-79	13	B-1	8 1/2	3	Epoxy	Sq.	44.0	474.7	86	50
A-3631	1	1	8-77	B-1	5-78	29	7-78	27	B-1	7 1/2	2 1/2	Gray	Rt. AH	28.0	301.6	65	45
A-3632	6	6	7-78	B-1	8-78	26	8-79	14	B-1	8	2 1/2	Gray	Sq.	38.0	725.5	96	61
A-3633	0	0	(5)	B-2	4-80	6	6-80	4	B-2	7 1/2	2 1/2	Epoxy	Sq.	34.0	595.5	79	41
A-3658	0	0	9-78	B-1	4-79	18	9-79	13	B-1	8	3	Gray	Sq.	28.0	211.1	68	38
A-3659	3	3	9-78	B-1	4-79	18	7-79	15	B-1	8 1/2	3	Epoxy	Sq.	44.0	468.4	82	34
A-3663	2	2	12-78	B-1	6-79	16	9-79	13	B-1	8 1/2	3	Epoxy	Lt. AH	40.0	151.3	94	75
A-3670	0	0	5-77	B-1	6-78	28	11-78	23	Membrane	8	2 1/2	Gray	Sq.	38.0	404.7	94	54
A-3671	0	0	8-78	B-1	11-78	23	10-79	12	2" Low Slump	6 1/2	1	Gray	Lt. AH	44.0	151.6	70	46
A-3688	0	0	8-78	B-1	8-78	26	7-79	15	B-1	8	2 1/2	Epoxy	Sq.	44.0	226.1	97	55
A-3711	51	32	4-78	B-1	9-78	25	5-79	17	B-1	8	2 1/2	Gray	Lt. AH	38.0	265.9	90	44
A-3731	0	0	8-78	B-1	11-78	23	9-79	13	Membrane	8	2 1/2	Gray	Sq.	40.0	367.0	74	35
A-3732	0	0	(5)	B-1	8-78	26	11-78	23	Membrane	8	2 1/2	Gray	Sq.	40.0	430.7	94	55
A-3738	0	0	4-78	B-1	6-78	28	10-78	24	Membrane	7 1/2	2 1/2	Gray	Lt. AH	28.0	261.8	86	49
A-3749	229	223	4-79	B-1	8-79	14	11-79	11	B-1	8 1/2	3	Epoxy	Lt. AH	30.5	361.2	97	71
A-3750	185	104	(5)	B-1	4-80	6	8-80	2	B-1	8 1/2	3	Epoxy	Lt. AH	54.5	362.1	72	48
A-3752	393	351	5-79	B-1	9-79	13	11-79	11	B-1	8 1/2	3	Epoxy	Lt. AH	54.5	381.4	87	61
A-3753	255	244	(5)	B-1	7-80	3	8-80	2	B-1	8 1/2	3	Epoxy	Lt. AH	54.5	381.4	92	65
A-3760	83	22	3-79	B-1	7-80	3	Not Open	X	B-1	8 1/2	3	Epoxy	Rt. AH	44.0	511.3	98	34
A-3762	0	0	3-78	B-1	10-78	24	6-79	16	Membrane	8	2 1/2	Gray	Lt. AH	38.0	322.0	92	44
A-3778	0	0	6-79	B-1	5-80	5	9-80	1	B-1	8 1/2	3	Epoxy	Sq.	44.0	622.5	78	24
A-3784	2	1	6-78	B-1	9-78	25	9-79	13	B-1	8 1/2	3	Epoxy	Lt. AH	44.0	205.4	90	71
A-3798	0	0	3-79	B-1	9-79	13	11-79	11	Membrane	8	2 1/2	Gray	Sq.	38.0	486.0	95	39
A-3799	0	0	11-77	B-1	11-78	23	11-79	11	Membrane	8	2 1/2	Gray	Sq.	38.0	334.0	97	36
A-3808	0	0	5-78	B-1	6-79	16	Not Open	X	1 1/2" Latex	7	1 1/2	Gray	Lt. AH	24.8	246.6	90	78
A-3809	0	0	8-78	B-1	4-79	18	Not Open	X	1 1/2" Latex	7	1 1/2	Gray	Lt. AH	24.8	445.4(4)	72	41
A-3810	0	0	8-78	B-1	11-78	23	10-79	12	1 1/2" Latex	6 1/2	1 1/2	Gray	Rt. AH	40.0	198.7	56	39
A-3880	58	33	(5)	B-2	7-80	3	Not Open	X	B-2	8 1/2	3	Epoxy	Rt. AH	44.0	189.8	98	58
A-3889	0	0	5-79	B-1	7-80	3	Not Open	X	B-1	8	3	Epoxy	Lt. AH	34.0	209.1	89	64
A-3890	0	0	8-79	B-1	10-79	12	10-80	0	B-1	8	3	Epoxy	Sq.	34.0	136.1	70	56
A-3912	19	19	5-79	B-1	10-79	12	1-80	9	B-1	8 1/2	3	Epoxy	Lt. AH	48.0	335.1	65	28
A-3926	0	0	8-79	B-1	9-79	13	12-79	10	B-1	8 1/2	3	Epoxy	Sq.	44.0	178.1	72	60
A-3960	0	0	8-78	B-1	10-78	24	6-79	16	B-1	8 1/2	3	Gray	Sq.	38.0	190.1	64	31

(1) Age of concrete deck based on date of survey, October, 1980.
(2) Deck thickness relates to the thickness of the Class B-1 or B-2 concrete before any waterproofing membrane or concrete overlays were added.
(3) Length is for concrete sections only - omitting steel sections.
(4) Length measured on Arc all others on cord.
(5) Date of manufacture not visible on beams.

Table 2

Summary of Data From Class B-1 and B-2 Concrete Decks Supported on Prestressed Concrete Girders

Bridge Number	Age of Deck (Months)	Cracks Total	Cracks W/Efflor.	Temperature (1) Max.	Temperature (1) Min.	Age After Open To Traffic (Months)	Wearing Surface
B-1 Concrete							
A-3753	3	255	244	92	65	2	B-1
A-3760	3	83	22	98	34	Not Open	B-1
A-3889	3	0	0	89	64	Not Open	B-1
A-3778	5	0	0	78	24	1	B-1
A-3498	6	0	0	90	38	Not Open	Low Slump
A-3750	6	185	104	72	48	2	B-1
A-3496	12	0	0	98	41	Not Open	Low Slump
A-3890	12	0	0	70	56	0	B-1
A-3912	12	19	19	65	28	9	B-1
A-2896	13	27	18	87	69	10	B-1
A-3500	13	0	0	81	64	Not Open	Low Slump
A-3752	13	393	351	87	61	11	B-1
A-3798	13	0	0	95	39	11	Membrane
A-3926	13	0	0	72	60	10	B-1
B-2 Concrete							
A-3217	1	38	0	106	49	Not Open	B-2
A-3880	3	58	33	98	58	Not Open	B-2
A-3113 EB	5	0	0	72	35	Not Open	B-2
A-3113 WB	5	2	1	82	50	Not Open	B-2
A-3633	6	0	0	79	41	4	B-2
A-3327 NB	12	0	0	73	44	Not Open	B-2
A-3327 SB	13	18	17	81	52	Not Open	B-2
A-3580	13	0	0	88	64	Not Open	B-2
A-3591	13	26	25	72	51	12	B-2

(1) Maximum, Minimum Temperature range during concrete pours.

Figure 1

Mathematical Data Block Design For Analysis Of Dependent Variable (Total Cracking Observed) Based On Stratification Of Type Of Reinforcing Steel And Deck Wearing Surface Type

Type of Wearing Surface	Type of Reinforcing Steel: Gray	Type of Reinforcing Steel: Epoxy
Class B-1 Concrete	21 0 0 0 0 0 1 0 6 15 0 187 51	0 0 68 0 229 2 27 52 0 185 0 27 100 22 393 0 27 258 3 255 19 0 0 2 83 0 28 0 0
Waterproofing Membrane	66 0 0 0 19 0 0 0 5 0 0 0 103 5 0 2 0 0 0 0 0	
Latex Concrete	3 0 0 0	
Low Slump Concrete	0 0 0 0 8	

Sample Design

Figure 2

Relationship Of Total Number Of Cracks Observed On Underside Of Deck And Maximum Air Temperature During Pour

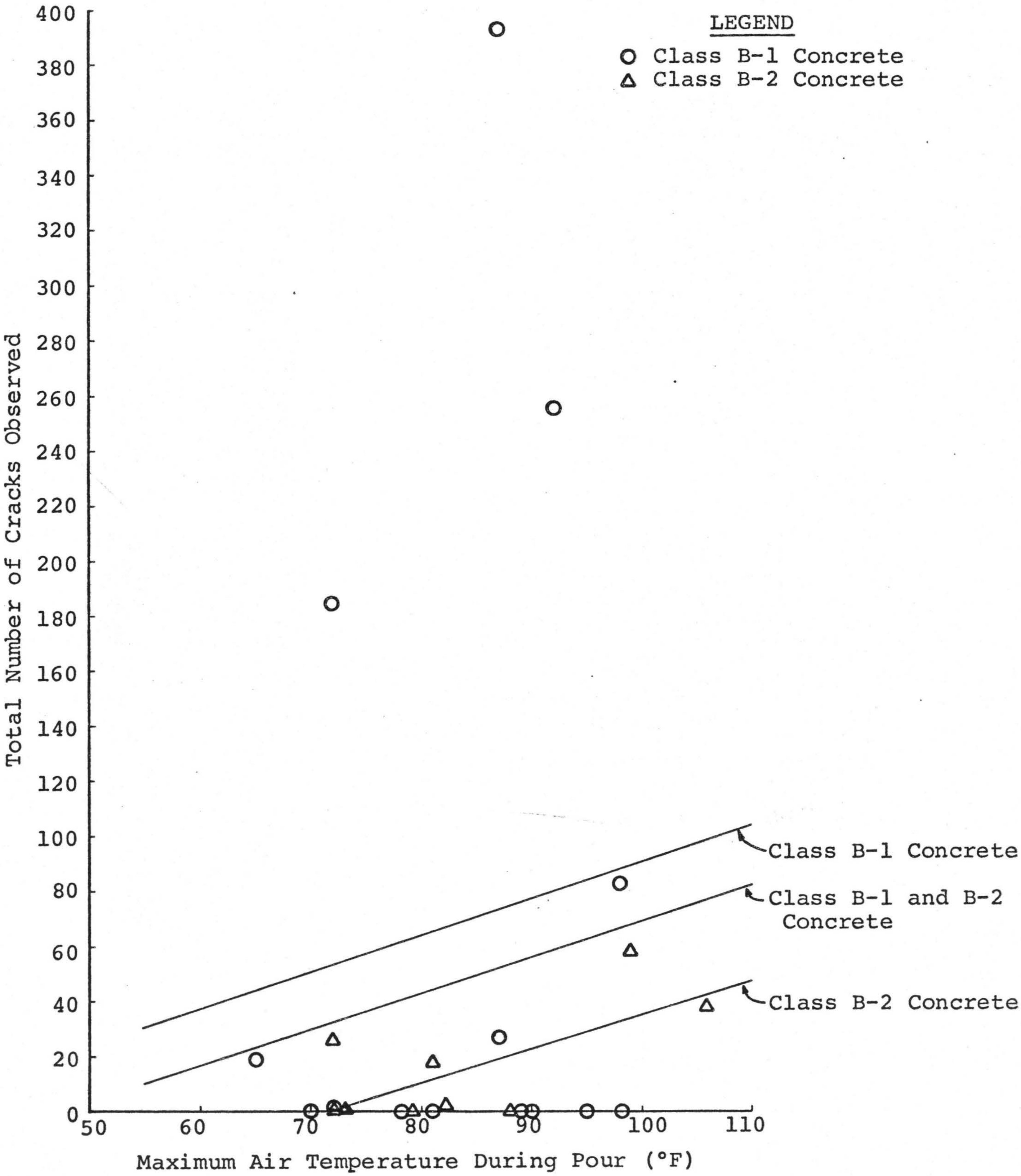

Figure 3

Date Block And Analysis Of Total Cracking
Observed Based On Maximum Air Temperature During
Pour and Deck Wearing Surface Type

Type of Wearing Surface	Maximum Air Temperature During Pour: <75°F	75°-90°F	>90°F
Class B-1 Concrete	21 0 0 19 0 0 1 0 0 185	27 68 0 2 0 100 22 0 0 258 3 27 0 51 0 15 393 28 0 0	0 6 27 2 52 0 0 229 187 255 0 83
Waterproofing Membrane	0 0 0 0	19 0 103 0 2 0 0 0 0	66 0 5 0 5 0 0 0
Latex Concrete	0 0	3 0	
Low Slump Concrete	0	0 0 8	0

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (1)
Temperature	2	8,662.8	4,331.4	0.84	NS
Wearing Surface	1	27,697.0	27,697.0	5.39	.05
T x W Interaction	2	4,011.9	2,006.0	0.39	NS
Within Cells	66	339,087.0	5,137.7	1.00	
Total	71	379,458.7	5,344.5	1.04	

(1) α = Significance with the following terminology:

NS = Not significant at any level
.05 = Significant at 95% level of confidence
.01 = Highly significant at 99% level of confidence

Figure 4

Data Blocks And Analysis Of Total Cracking Observed Based On Temperature Range Breaks Of 90°F, 85°F And 80°F And Deck Wearing Surface Type

A. Air Temperature Break = 90°F:

Air Temperature

Type of Wearing Surface	≤90°F					>90°F	
Class B-1 Concrete	21	0	0	258	3	0	6
	0	19	27	0	51	27	2
	0	0	0	15	393	52	0
	1	0	28	0	0	0	229
	0	27	68	0	2	187	255
	185	0	100	22	0	0	83
Membrane (1)	0	0	0	0		66	0
	0	19	0	0		5	0
	0	103	0	8		5	0
	0	2	0			0	
	0	0	3			0	
	0	0	0			0	

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (2)
Temperature	1	3,580.7	3,580.7	0.71	NS
Wearing Surface	1	33,465.0	33,465.0	6.61	.05
T x W Interaction	1	2,726.2	2,726.2	0.54	NS
Within Cells	68	344,417.0	5,064.9	1.00	
Total	71	384,188.9	5,411.1	1.07	

Figure 4

(Continued)

B. Air Temperature Break = 85°F:

Type of Wearing Surface	Air Temperature ≤85°F	Air Temperature >85°F
Class B-1 Concrete	21 0 0 28 1 0 68 185 27 0 0 258 0 19 0 0 0 3	0 52 0 229 27 100 22 393 0 0 6 255 0 0 2 83 27 15 0 2 0 187 51 0
Membrane (1)	0 0 0 0 0 0 0 19 0 0 0 8	66 0 0 5 0 0 103 0 0 3 5 0 2 0 0 0 0 0

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (2)
Temperature	1	5,041.4	5,041.4	1.00	NS
Wearing Surface	1	28,409.1	28,409.1	5.61	.05
T x W Interaction	1	1,450.2	1,450.2	0.29	NS
Within Cells	68	344,141.1	5,060.9	1.00	
Total	71	379,041.8	5,338.6	1.05	

Figure 4

(Continued)

C. Air Temperature Break = 80°F:

Type of Wearing Surface	Air Temperature: ≤80°F	Air Temperature: >80°F
Class B-1 Concrete	21 1 0 28 0 0 68 185 0 0 0 0 0 19	27 0 0 6 255 258 0 0 2 83 0 27 15 0 2 3 0 187 51 0 0 52 0 229 27 100 22 393
Membrane (1)	0 0 0 0 0 0 0 0 0	19 3 5 0 0 2 0 0 8 0 0 0 66 0 0 5 0 0 103 0 0

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (2)
Temperature	1	9,067.6	9,067.6	1.80	NS
Wearing Surface	1	21,213.2	21,213.2	4.30	.05
T x W Interaction	1	3,185.0	3,185.0	0.64	NS
Within Cells	68	336,949.6	4,955.1	1.00	
Total	71	370,415.4	5,217.1	1.05	

Figure 5

Data Blocks And Analysis Of Total Cracking Observed Based On Clear Depth Of Steel, Skew Of Bents, And Length Of Deck With Deck Wearing Surface Type

A. Clear Depth of Steel in the Class B-1 and B-2 Concrete, regardless of membrane type.

Type of Wearing Surface	Depth of Steel: <2 1/2 Inches	Depth of Steel: $\geq$2 1/2 inches
Class B-1 Concrete	0 100 0 258 0 0 28 0 68 15 52	21 187 1 51 0 0 27 0 6 229 0 0 0 0 185 2 27 0 3 393 0 27 0 2 255 0 0 22 0 83 19
Membrane (1)	3 0 2 8 0 0 0 0 0 0 0 0	66 5 0 19 0 0 5 0 0 103 0 0 0 0 0 0 0 0

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (2)
Depth of Steel	1	567.4	567.4	0.11	NS
Wearing Surface	1	27,569.8	27,569.8	5.34	.05
D x W Interaction	1	220.7	220.7	0.04	NS
Within Cells	68	351,108.2	5,163.4	1.00	
Total	71	379,466.1	5,344.6	1.04	

Figure 5

(Continued)

B. Skew of Bents:

	Skew of Bents		
	Right Ahead	Left Ahead	Square
Class B-1 Concrete	0 0 0 1 27 83 28 68 0	21 0 255 27 2 2 0 51 0 27 229 19 258 185 187 393	0 0 0 52 22 0 100 6 0 0 0 0 0 3 0 15 0
Membrane (1)	0 0 0 0 5 8 0 0 3	0 0 0 0 0 0 0 0 0	66 0 19 0 5 0 103 0 2 0 0 0

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (2)
Skew of Bents	2	22,154.0	11,077.0	2.68	NS
Wearing Surface	1	26,855.5	26,855.5	6.50	.05
S x W Interaction	2	35,498.8	17,749.4	4.29	.05
Within Cells	66	272,819.7	4,133.6	1.00	
Total	71	357,328.0	5,032.8	1.22	

Figure 5

(Continued)

C. Length of Deck supported on Prestressed Girders:

Type of Wearing Surface	Length of Deck: <200 Feet	200 to 500 Feet	>500 Feet
Class B-1 Concrete	21 100 27 15 0 0 28 2 68 0 52 0	0 187 0 393 27 0 3 255 27 0 0 2 0 0 51 0 0 22 229 0 0 1 185 19	0 0 258 6 83 0
Membrane (1)	2 0 0 0 0 8 0 0 0 3	0 0 0 0 0 0 5 0 0 0 0 0 0 0 0 0	66 19 103 5

Analysis of Variance Table:

Source	df	Sums of Squares	Mean Squares	F Ratio	α (2)
Length of Deck	2	13,386.9	6,693.5	1.06	NS
Wearing Surface	1	12,176.1	12.176.1	1.93	NS
L x W Interaction	2	5,309.2	2,654.6	0.42	NS
Within Cells	66	416,100.4	6,304.6	1.00	
Total	71	446,972.6	6,295.4	0.998	