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BRIDGE DECK CONDITION SURVEY

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TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

Bridge Deck Condition Survey

by

J. G. Darroch and Howard L. Furr

Introduction

A physical survey of concrete bridge decks made by the Texas Highway Department, THD, collected data which are studied in the basic report.[1] Approximately 36,000 concrete pours forming the decks of 5,282 bridges in the Texas state highway system were inspected in the survey. The sample consisted of essentially all concrete deck bridges 20 feet or more in length controlled at the state level. The survey was concerned primarily with matters pertaining to the decks, but some data on substructures were collected as supplementary information.

The inspection was made by THD personnel comprising individual teams from each THD District. The teams were trained by THD D-18 personnel, and data were recorded in a form designed for subsequent organization by computer.

The decks were rated according to 13 condition variables against 45 structural factors. The condition factors, numbered 50-62, and structural factors, numbered 1-45, are shown in Table 1. Data from 23 of the 25 THD Districts comprised the information studied.

Treatment of Data

Tables were prepared from edited data stored on computer tapes, and the following sets of tables were produced from those data:

1. Frequency tables and relative frequency tables (percentage) of structure variable by condition, 45 x 13 = 585 tables of frequency and 585 tables of percentages.

2. All possible combinations of two condition variables among the 13 conditions, which produced 78 tables.

3. Almost all possible combinations of two among the 45 structural variables; 809 out of a possible 990 tables.

4. Structural variables by Joint Condition, 45 x 4 = 180 tables.

The Chi-square test for independence was made for the various tables under item 1 above, but the frequency distributions were such that the test was not sensitive to changes. There were too many cells of either very low frequencies or of zero frequencies to produce a successful independence test. Because of the insensitive nature of the groupings to the Chi-square test, the tables were visually screened and associations between variables were judged by two reviewers as dependent or not dependent. The independent judgements of the two reviewers were then compared and differences were resolved through additional visual study. The results of that screening are shown in Table 1 in which those pairs of variables judged to be associated are marked.

Table 2, an ordered arrangement of deck condition variables, gives a ratio of the number of times that a condition appeared as significant in Table 1 to the number of possible times that it could have occurred, i.e. 45 times.

Results of the Evaluation of Data

Table 1 shows a great number of pairs of variables which were judged to have some indication of significant associations, but some of those associations are rather weak. A measure of association between variables found by summing the events in each column in Table 1 is shown in Table 2. The latter table shows that the degree and extent of cracking, scaling, and general deck condition occur with greater frequency than the other items of deterioration.

General deck condition, GDC, is the one variable rated in the survey to show the over-all condition of the deck. It combines cracking, scaling and delamination in various degrees of severity in numbered classifications ranging from excellent condition, GDC 10, to deck failure condition, GDC 60. A GDC rating of 30 indicates beginning deterioration by moderate cracking and scaling, and minor delamination. GDC rating 50 indicates a deck with serious cracking and scaling with extensive delamination. Throughout the state, 61 percent of all pours are rated GDC 30 and higher, and 15 percent are rated GDC 50 and higher. Districts with the highest percentages of serious deterioration under this classification are located along an east-west band in the northern portion of the state. The percentage of GDC 30 pours increases with age, but not so with GDC 50.

Two-thirds of the pours have at most minor cracking whereas 27 percent have moderate cracking. Cracks are predominantly transverse with no close association with geographical location. They tend to appear in wheel paths. The degree of cracking increases with support beam type in the order given here: prestressed concrete, reinforced concrete, steel I-beam, and plate girder. There are more cracks in continuous spans than in single spans. Traffic volume and transit mix concrete are not factors in degree of cracking, but mixes using water reducing agents have less extensive cracking.

Scaling, although occurring in serious proportions in isolated cases, does not appear to be a uniformly serious problem on bridge decks throughout the state. The most serious cases

TABLE 1

A LISTING OF DESIGN AND CONDITION PARAMETERS INDICATING THEIR ASSOCIATIONS

Note: X indicates that the association between the parameters is significant.

		Cracking Degree 50	Cracking Type 51	Cracking Spacing 52	Cracking Location 53	Scaling Degree 54	Scaling Depth 55	Scaling Pctg. Area 56	Scaling Location 57	Delamination Degree 58	Delam. Visual Cracks 59	Delam. Pctg. Area 60	Delam. Location 61	General Deck Cond. 62
1.	THD District	X		X		X	X	X	X	X				X
2.	Design Specification	X	X	X		X	X	X	X	X		X		
3.	Design Loading	X			X	X	X	X		X	X	X	X	X
4.	Span Type	X	X	X	X	X	X	X		X		X		X
5.	Structure Type	X		X				X	X					
6.	Main Member Type	X	X	X		X	X	X		X	X	X	X	X
7.	Stringer Spacing	X		X	X	X	X	X						X
8.	Skew Degrees	X												
9.	Type of Crown	X		X		X	X	X	X	X	X	X		X
10.	Type of Deck	X	X	X		X				X			X	X
11.	Continuous or Simple	X	X		X	X	X	X		X	X	X		X
12.	Simple Span Length		X										X	X
13.	Cont. Unit 1st Span Lgth.			X			X		X					
14.	Cont. Unit 2nd Span Lgth.	X	X	X				X						
15.	Cont. Unit Total Lgth.													
16.	Cont. Unit Nmbr. of Spans	X	X	X	X	X	X		X				X	X
17.	Cont. Unsymm. Unit													
18.	Structure Type	X	X		X	X	X	X						X
19.	Slab Thickness	X	X		X	X	X	X		X	X	X	X	X
20.	Traffic Volume/Day	X				X	X		X	X		X		X
21.	Structure Classification	X	X	X	X	X	X	X				X		X
22.	Heaviest Wheel Load	X	X			X	X	X		X	X	X		X
23.	Transit Mix					X								X
24.	Pctg. of Air Entrained	X		X		X	X	X	X			X		X
25.	Type of Admix	X		X		X	X	X	X	X	X	X		X
26.	Type of Cement	X	X	X	X	X	X	X	X	X	X	X	X	X
27.	Source of Cement	X	X	X	X	X	X	X	X		X	X	X	X
28.	Sacks of Cement/C.Y.	X		X	X	X	X	X			X		X	X
29.	Type of Aggregate					X	X	X					X	X
30.	Type of Finish	X		X	X	X			X			X	X	X
31.	Month Slab Placed					X	X							
32.	Year Slab Placed	X	X	X	X	X	X	X	X	X	X	X	X	X
33.	Month Bridge Opened													
34.	Year Bridge Opened	X				X	X	X		X	X	X		X
35.	Type of Overlay	X	X	X		X	X	X	X	X	X	X		X
36.	Month Overlay Applied	X	X			X	X			X	X	X		
37.	Year Overlay Applied	X		X		X	X	X				X		X
38.	Condition of Overlay	X	X	X		X	X	X	X		X	X		X
39.	First Year Salt Applied	X		X		X	X	X		X	X	X		X
40.	Salt Applications/Year	X		X		X	X	X	X	X	X	X		X
41.	Sulfate Stream	X		X	X	X	X	X	X		X		X	X
42.	Condition of Substructure	X				X	X	X		X	X	X		X
43.	Slab Drainage	X	X	X	X	X	X	X	X	X	X	X	X	X
44.	Weather at Pouring	X	X	X	X	X								
45.	Moment Condition	X		X		X					X			X

TABLE 2

CONDITION VARIABLES RANKED WITH RESPECT TO DECREASING FREQUENCY OF SIGNIFICANT ASSOCIATIONS WITH THE 45 STRUCTURAL CHARACTERS

Rank	Condition Variable	Description	Proportion Significant*
1	50	Cracking, degree	37/45
1	54	Scaling, degree	37/45
2	62	General deck condition	34/45
3	55	Scaling, depth	33/45
4	56	Scaling, percent area	30/45
5	52	Cracking, average spacing	28/45
6	60	Delamination, percent area	25/45
7	58	Delamination, degree	21/45
8	51	Cracking type	20/45
9	59	Delamination visible cracking	20/45
10	57	Scaling location	18/45
11	53	Cracking location	17/45
12	61	Delamination location	14/45

*(Number of significant tables)/(Total number of structural characters).

occur in the north and west parts of the state, and in urban areas. Four percent of all pours had some scaling deeper than 3/4 inch. Scaling is, in general, scattered over the deck areas. Salt applications and rapid increases in traffic volume about 1950 were accompanied by increased scaling. Reduced scaling is associated with air entrainment, water reducers, and retarders used in the concrete mixes.

Eighty-one percent of all pours are free of delamination which is found more in heavily traveled bridges with heavy loads. It is generally accompanied by visible cracking and appears to be more of a problem in slabs 5½ to 6½ inches thick. The problem grows more serious with increased salt applications. On a percentage basis, there is more delamination in steel beam bridges, but those bridges tend to be older in Texas than other types. There is a marked decrease in delamination in pours placed in 1959-1960 and the data indicate that significant air entrainment was begun in 1960.

Conclusions

The study shows general trends displayed in the data. It reveals that there are interrelationships between many structural characters and the various measures of deck condition. No one structural character can be singled out as being the prime suspect causing deterioration. Table 3 gives a tabulation in support of the conclusions given here:

1. Sixty-one percent of all pours display some deterioration, GDC 30 and higher; fifteen percent are in serious condition, GDC 50 and higher.

TABLE 3
PERCENTAGE OF CONCRETE POURS OF THE VARIOUS CLASSIFICATIONS OF GENERAL DECK CONDITION

Structural Character	General Deck Condition (62) 10	20	30	31	32	33	40	44	50	GDC Class 30 & Higher	GDC Class 50 & Higher	Percentage of Total Pours
Total Percentage of All Pours	12	27	15	2	9	13	3	4	11	61	15	100
Transit Mix (23) Yes	12	26	14	2	11	15	3	4	8	62	15	61
No	13	30	18	3	8	13	3	5	5	57	7	39
Beam Type: (06)												
Steel I-Beam	6	20	16	3	9	14	3	6	15	74	23	37
Plate Girder	4	20	13	1	11	21	4	12	6	76	14	4
Reinforced Concrete	14	32	15	2	9	12	2	2	11	54	12	47
Prestressed Concrete	33	29	12	3	9	7	4	2	1	38	1	9
Span Type: (04)												
Continuous Steel	6	19	14	3	9	17	4	7	13	75	21	29
Simple Steel	6	24	21	2	7	10	4	6	14	70	20	14
Pan-formed Reinf. Conc.	10	28	11	1	14	17	1	3	14	62	15	19
Reinf. Conc. Beam & Slab	16	32	15	2	7	11	2	2	11	52	13	10
Reinf. Conc. Slab	18	37	18	3	5	8	2	1	6	45	8	16
Prestressed Beam	29	30	13	3	9	7	4	2	2	41	3	9
Crown Type (09)												
Normal	13	30	16	2	7	10	2	3	13	57	17	71
Constant Slope	6	19	4	2	12	21	4	6	7	75	26	25
Traffic: (20)												
0 to 2k/day	15	32	15	2	6	8	2	2	18	53	18	43
2k to 5k	10	30	16	3	8	13	4	4	9	60	12	19
5k to 15k	11	21	15	2	10	20	2	4	8	68	15	22
15k to 30k	8	19	15	2	11	19	3	14	3	73	9	9
Heaviest Wheel Load (22)												
5 kips to 6 kips	14	32	7	8	8	6	1	0	23	54	24	3
7 kips to 8 kips	15	30	14	1	6	8	2	2	20	55	22	16
9 kips to 10 kips	14	31	16	3	7	9	2	2	11	56	16	39
11 kips to 12 kips	9	22	15	2	11	18	4	7	6	69	12	40

2. Decks made of nontransit mix concrete are in a little better condition than decks of transmit mix material.

3. Decks on concrete beams show less deterioration than those supported by steel beams.

4. Decks supported by prestressed beams display the lowest deterioration followed closely in order by slab span decks. Decks on continuous steel girders show the highest percentage of deterioration.

5. The normal crown deck shows much less deterioration than the constant slope crown deck.

6. Bridges with lower traffic density (vehicles per day) display the same GDC 30 deterioration as those with high density traffic. GDC 50 deterioration is greatest with low traffic density, and low traffic density is associated with older bridges.

References

1. Bridge Deck Condition Survey, (Parts I, II, and III)

Part I, Outline of the Project and Findings from the Survey (42 pages), May, 1970.

Part II, Relative Frequency Tables Displaying Associations Between Structural Characters and Deck Conditions (430 pages), April, 1970.

Part III, Computer Tabulations, August, 1970

Volume I—Frequency and Relative Frequency Tabulation of all Combinations of 45 Structural Characters with 13 Condition Variables (948 pages).

Volume II—Frequency and Relative Frequency Tabulations of all Pairwise Combinations of the 45 Structural Characters (1010 pages).

Volume III—Frequency and Relative Frequency Tabulation of all Pairwise Combinations of the 13 Condition Variables (329 pages).

by J. G. Darroch and Howard L. Furr, Texas Transportation Institute, Texas A&M University, College Station, Texas.

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R. L. Lewis, Chairman
Research & Development Committee
Texas Highway Department—File D-8
11th and Brazos
Austin, Texas 78701
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